ECOLOGY, HABITAT USE, AND CONSERVATION OF ASIATIC BLACK BEARS IN THE MIN MOUNTAINS OF SICHUAN PROVINCE, CHINA

Jewel Andrew Trent

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Michael R. Vaughan
Eric M. Hallerman
Marcella J. Kelly
Dean F. Stauffer
William J. McShea

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ABSTRACT

This project was initiated in an attempt to address the paucity of data on Asiatic black bears (*Ursus thibetanus)* in Mainland China. Field work was carried out from May 2004 – August 2006 within the Tangjiahe National Nature Reserve in northwestern Sichuan Province, China. Initial methodology relied on trapping and GPS radio-collaring bears, but due to extreme difficulty with capturing a sufficient sample size, I expanded the study to include reproduction, feeding analysis from scats and sign, and occupancy modeling from sign surveys. I documented the home ranges of an adult female (100% MCP = 107.5km^2, n=470 locations) and a sub-adult female (100%MCP = 5.9km^2, n=36 locations) Asiatic black bear. I also documented two birthing occasions with a total of four male cubs produced and eight bear den sites. I collected feeding data from 131 scat samples and 200 bear sign transects resulting in 50 identified food items consumed by Asiatic black bears. I also employed the program PRESENCE to analyze occupancy data using both a standard grid repeated sampling technique and an innovative technique of aging bear sign along strip transect surveys to represent repeated bear occupancy over time. Conservation protection patrolling and soft mast were shown to be the most important factors determining the occupancy of an area by Asiatic black bears in Tangjiahe Nature Reserve, Sichuan Province, China.

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GENERAL INTRODUCTION

Asiatic Black Bear

The International Union for Conservation of Nature (IUCN) lists the Asiatic black bear on the red list of threatened species as “vulnerable” and it thus faces a high risk of extinction in the wild (Garshelis and Steinmetz 2008). The Asiatic black bear’s range extends from SE Iran through Afghanistan and Pakistan and eastward along the lower foothills of the Himalayas, China, and Southeast Asia. Populations of Asiatic black bears also can be found in northeastern China, southern Russian Far East, and North and South Korea. Islands in Asia with Asiatic black bears include Japan, Taiwan, and possibly Hainan. The Asiatic black bear currently occupies an extremely patchy and disjointed area throughout its range (Figure 1.1). The actual population status of the Asiatic black bear in Mainland China is mostly unknown.

Study Area

This research was conducted within the Min Mountains of northern Sichuan Province, China, which extend eastward from the edge of the Qinghai-Tibetan plateau along the Sichuan-Gansu Province border (Figure 1.2). The main study site, Tangjiahe National Nature Reserve, lies between east longitudes 104° 36’ - 104° 53’ and north latitudes 32° 32’ - 32° 41’ in Qingchuan County. Tangjiahe has a sub-tropical monsoon climate with an average rainfall of 1,150mm – 1,500mm, mostly occurring from July to September (Seidensticker and Eisenberg 1984, Schaller et al. 1989, Reid et al. 1991). The average temperature in the reserve is 11° C with temperatures reaching 20°C in summer and 1.0 - 1.5° C in winter (Reid et al. 1991). Elevations within the reserve range from 1,150 to over 3,800 meters. The Tangjiahe Nature Reserve contains the entire upper drainage of the Tangjia River (referred to as the Qingchuan River further east).

Tangjiahe was established as a nature reserve in 1978, and then expanded with a buffer area in 1995, for the protection of three rare species of China: the giant panda (*Ailuropoda melanoleuca*), takin (*Budorcus taxicolor*), and golden monkey (*Pygathrix roxellana)*. Prior to the establishment of the reserve, the area experienced extensive logging and replacement planting of forestry valuable trees, such as Chinese fir (*Cunninghamia lanceolata*), up to approximately 2,000 meters with areas above 2,000 meters undergoing some selective logging (Seidensticker and Eisenberg 1984).

The border of the reserve mirrors the high elevation ridgeline that almost entirely encloses the reserve. Tangjiahe is bordered to the north (in Gansu province) by another giant panda reserve, Baishuijiang State Nature Preserve, to the east by the Dongyanggou provincial nature reserve, to the south by farmland and the towns of Qingxi, Sangouxiang, Qiaolouxiang, and to the west by sparsely inhabited mountainous terrain. Tangjiahe encompasses 400 km^2, but a 100 km^2 buffer area is managed by the Qingchuan county government under different rules and habitation levels, thus we considered that 100 km^2 to be "outside the reserve" for purposes of data analysis.

Tangjiahe reserve is divided into 3 protection categories (Figure 1.3):

1. Core – No disturbance or removal of the ecosystem components
2. Experimental – Area of limited development of infrastructure and ecological non-destructive tourism practices
3. Buffer – Area between the main town area and the reserve; moderate to heavy use and impact by villagers tolerated, scattered villages still present

The vegetation of Tangjiahe Nature Reserve, as described by Schaller (1989) and the Tangjiahe Nature Reserve Management Plan developed by the Tangjiahe administration in 2005, is as follows: evergreen broadleaf ~1,000 – 1,700 m, mixed conifer- deciduous broadleaf 1,700 - 2,500 m, sub-alpine conifer 2,500 - 3,200 m. The tree line gives way to either sub-alpine shrub or meadow habitats between 2,500 and 3,200 m. Early-successional (less than 15 years old) forest is present in lower elevation areas disturbed by honey hive keeping, habitation, forest resource use, and road maintenance and expansion activities. Mid-successional (15 - 50 years old) and late-successional (50+ years old) forest are patchily distributed in the higher elevations where they are less accessible to harvest or disturbance.

Dominant tree types within the reserve consist of oak (*Quercus spp.*), walnut (*Juglans spp.*), evergreen oak (*Cyclobalanopsis spp.*), chestnut (*Castanea spp.),* alder (*Alnus spp.)*, birch (*Betula spp.*), hemlock *(Tsuga spp.)*, spruce (*Picea spp.),* fir *(Abies spp.)*, planted conifers

(*Cunninghamia lanceolate, Pinus armandii, and Cryptomeria japonica),* and evergreen laurel (*Lauraceae.).* Major understory components are *Hydrangea spp., Rhododendron spp., Ilex pernyi,* rose (*Rubus spp.), Lindera spp., Litsea spp.,* and at least five species of bamboo (*Poaceae* spp.).

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CHAPTER 1: REPRODUCTIVE AND FEEDING ECOLOGY OF ASIATIC BLACK BEARS IN SICHUAN PROVINCE CHINA

INTRODUCTION

Understanding the reproductive and feeding ecology of an animal is imperative for effective management and conservation decisions. Previous research has demonstrated that food availability and quality can impact aspects of bear productivity (Jonkel and Cowan 1971, Rogers 1976, Eiler et al 1989, Elowe and Dodge 1989, McDonald and Fuller 2001). Based on research by Bunnell and Tait (1981), Pelton (1989), and Rogers (1993) food abundance in the wild is the main factor controlling reproduction in that, during years of abundant food resources bears can reproduce at an earlier age and produce more cubs per litter. Research that leads to an understanding of both the feeding and reproductive ecology of the Asiatic black bear (*Ursus thibetanus*) across more of its geographic range is long overdue. Countries where reproductive or feeding studies have been undertaken include Japan (Nozaki et al. 1983, Horino and Miura 2000, Hashimoto et al 2003, Huygens et al. 2003), Russia (Seryodkin at al. 2003), China (Schaller et al. 1989, Reid et al. 1991, Hwang et al. 2002, Hwang 2003), and India (Schaller 1969, Sathyakumar 2001). Mainland China is thought to have the largest remaining population of Asiatic black bears and yet little in-depth research on reproduction in wild Asiatic black bears has been completed there. Most of the studies throughout the Asiatic black bear's range have focused entirely on feeding ecology or movement and habitat data. In many cases, there were either very few or only male individuals studied (Schaller et al. 1989, Reid et al. 1991).

Collecting reproductive data on black bears is difficult due to their dangerous nature, secluded birthing, solitary existence, low population density, wide ranging behavior, and low reproductive rate (Graber 1981, Pelton 1982, Kolenosky 1990, Schaller 1996). Reproductive research is also expensive relative to research on basic feeding ecology where data in the form of "tree-feeding" and scats are readily obtainable. However, feeding ecology research on Asiatic black bears can still be somewhat challenging due to the remote and rugged terrain and often sparse populations. Overcoming such issues and successfully obtaining a sufficient sample size to fully understand the feeding and reproductive ecology of Asiatic black bears continues to be a substantial obstacle.

Previous Asiatic black bear research carried out in China within the Min Mountains by Schaller (1989) and Reid (1991) and in the Qionglai Mountains by Reid (1991) occurred during and immediately following a time of heavy forest exploitation and human habitation. Nonetheless, those studies provide a solid foundation from which to base further investigation into the ecology of the Asiatic black bear in China. The transition of the Tangjiahe forest from the heavy exploitation of the past to the mature, diverse, and protected forest of today may provide insight into the ecologically adaptive and elastic nature of the Asiatic black bear and its recovery potential throughout China.

The objective with this portion of the research was to gain more insight into the reproductive and feeding ecology of the Asiatic black bear in the Min Mountains of China. Tangjiahe Nature Reserve was chosen as the study area partly because it serves as a good representative example of the Min mountain habitat, elevation, and fauna composition. In addition its protection initiatives, funding, and staff resources were sufficiently robust to see such a study through.

METHODS

Trapping and Handling

We captured bears using modified Aldrich spring-loaded foot snares (Johnson and Pelton 1980), passive triggered foot snares (Reagan et. al. 2002), and homemade barrel traps from late May - July 2004, late September-early November 2004, and then during peak honey hive production in the summers of 2005 and 2006. We also attempted captures and free range darting after credible sightings or evidence of bears at food sources. Bears were sedated with a mixture of ketamine hydrochloride and xylazine hydrochloride (200:80 mg/ml) (White et al. 1996) at a dosage of 1mL per 45.5 kg (100 lbs.) using a blow pipe, jab stick, or dart rifle. We determined the sex of sedated bears, weighed, and measured them and marked each with colored and numbered ear tags. Females were examined to determine reproductive stage (non-reproductive, past reproduction, presently with young). A vestigial premolar was removed (Jonkel 1993) for age determination from cementum annuli analysis (Willey 1974). We attached GPS/VHF collars (Lotek, Newmarket, Ontario, Canada) to bears older than two years and VHF only collars

(Telonics, Mesa, Arizona, USA) to bears one to two years old. Both types of collars were equipped with a leather breakaway spacer (Garshelis and McLaughlin 1998). A tetracycline antibiotic also was administered for possible infections and to act as a permanent biomarker in teeth and bones (Johnson 1964, Garshelis and Visser 1997). Hair samples were taken for DNA identification analysis.

During the winter den season, we located previously radio-collared bears and hired local hunters and former bear poachers to locate new bears in dens for capture purposes. Finding bear dens in the winter and killing adult hibernating bears for their cubs, meat, and body parts (for sale as traditional Chinese medicine) is a traditional method of hunting in the area. The hunters approached either past den areas or "likely" den areas and quietly looked into the den to determine bear occupancy. Once a new bear was located, the area was vacated and no further human disturbance was made in the area. We then returned to all den sites with the appropriate equipment and entered the dens to sedate the adults and collar new bears, collect reproductive data on females, and to replace batteries and/or spacers on previously captured individuals. All individuals (adults and young) captured in dens underwent the same data collection protocol as trap-captured bears.

Reproductive Ecology

All captured females were examined for signs of active or previous reproduction. During summer and early fall trapping periods, bears were assumed to be in estrus if there was visible vulva swelling (Ryan 1997), pink to reddish coloration, and/or discharge. The reproductive stage of the bear also was based on observations of cubs or yearlings, loss of hair around nipples, nipple elongation indicating nursing (Brooks and McRoberts 1997), and/or active lactation. We further assumed any non-lactating adult female (>3 years) was available for reproduction. Teeth extracted from adult females were examined to determine past reproductive events (Coy and Garshelis 1992).

During winter den entries, reproductive and morphological data were recorded on all females and cubs. Bridges et al. (2002) developed a mixed regression model to determine American black bear cub age using hair and ear length. Although this model performed well on American black bears, it was untested on Asiatic black bears; therefore, the mixed regression model was used in conjunction with knowledge gained from handling many known-age American black bear cubs with other previously documented methods such as tooth eruption (Marks and Erikson 1966) and eye-opening dates (Alt 1989) to estimate Asiatic black bear cub ages. We felt that the Asiatic and American black bear's ecological and physiological similarities would lend themselves well to these aging techniques and be fairly accurate when applied to Asiatic black bears in Tangjiahe. Den entrance and emergence of GPS collared bears were estimated from previously obtained GPS locations in early winter and the first location obtained the following spring, respectively. Den locations were determined either by field location during the winter capture period, during post-emergence spring field visits, or by the approximated mid-point of the entrance-emergence GPS locations.

Feeding Ecology

Sign Surveys

We overlaid a 1 km x 1 km grid, consisting of 410 grid squares, onto the entire Tangjiahe nature reserve. From the 410 grids we removed: 70 reserve perimeter and alpine grids, 101 of the 114 grids in the buffer zone that are managed by the local government, and 106 grids comprising prime giant panda (*Ailuropoda melanoleuca*) habitat or known giant panda occupied areas. We excluded giant panda occupied areas at the request of the Chinese government and managers so as not to harass giant pandas during this study. Another exclusion factor for the giant panda occupied areas was the difficulty of differentiating claw marks (our most prevalent sign) between giant pandas and Asiatic black bears. This left a total of 120 possible grids within the core and experimental protection categories and 13 grids in the buffer category in which to perform sign surveys. To spread the survey effort across the reserve and varied habitats, we sampled 10 – 12 grids in each of four main areas comprising a diverse mix of habitat types and human impact levels.

The four main areas were (Figure 1.4):

1. West - A very remote area with the least human impact. Habitat consists largely of old growth (50+ years) deciduous and conifer trees with extensive bamboo present. This is the reserve's primary area of giant panda occupancy. This area had 32 possible survey grids.

2. Central - Main reserve headquarters and hotel area with localized heavy use from eco-tourism and reserve personnel. The habitat is mostly mixed deciduous and planted conifers with moderate amounts of bamboo. This area had 34 possible survey grids.
3. North - Moderate accessibility and impact from tourists and locals. Moderate level of remnant habitat alteration from human habitation and utilization at lower elevations. Low elevation habitat consists of mixed deciduous and evergreen hardwoods. Some extensive areas of giant panda occupancy at higher elevations within old growth conifer and bamboo areas. This area had 29 possible survey grids.
4. South - An easily accessible area with heavy impacts from tourists and villagers. This area is dominated by the reserve buffer zone, which experiences extreme impact from habitation, farming, grazing, firewood collection, hunting, and collecting of wild food and medicinal items. The habitat includes small areas of deciduous and evergreen hardwoods while the remainder is sparsely forested or disturbed areas of shrub/scrub evergreen and deciduous firewood forest. This area had 25 possible survey grids within the core and experimental categories and 13 in the buffer category.

The resulting 42 grids were not randomly selected but were chosen based on accessibility and researcher safety. Within each of 42 grid cells, at least four fixed-width strip transects (100m X 20m) were established (except one grid where only three could be established). Some grids near the research station were visited repeatedly to train personnel; thus some of these grids had more than 4 transects. In total, we established 200 transects. Because of the rough and steep terrain with abrupt cliff edges, we could not establish transects randomly. Rather, our aim was to spread them across the entire grid in an effort to sample the habitat, elevation, and human impact relative to what was available within the grid while ensuring researcher safety. Thus, we first assessed grid habitat and terrain on a GIS map and chose four general transect areas, each with a centrally designated GPS point. We then attempted to place the transect survey starting points as close to the central GPS point as safety allowed in the field. We took GPS coordinates of all starting points and recorded them onto a GIS map.

From the starting point, a tape measure was extended along the natural land contour for the entire 100 meter length. The bearing from the transect starting point along the tape measure was recorded along with the elevation, slope, aspect, habitat type, age of the forest and dominant canopy trees within the transect.

Within each transect the entire area and each individual tree and shrub was inspected for bear sign. Bear sign consists of claw marks (Figure 1.5), feeding platforms (Figure 1.6), body rubbing, bite marks (Figure 1.7), broken stems or branches, feces, ground digging (Figure 1.8), tracks, rock/log disturbance, and dens. If a sign was deemed to be questionable in animal species or age, then a second, and if present, third trained researcher was consulted. If for any reason a sign could not be positively identified as bear sign, it was not recorded.

All recorded sign was aged as fresh (< 3 months), 1 year (3 - 12 months), 1 - 2 years (12 - 24 months), and 2+ years (older than 24 months). We estimated the age of feeding platforms based on: the color and sharpness of the exposed wood (light color and sharp/splintered breaks = 0 – 1 year, darkened wood with dull edges = 1 – 2 years, very worn dark wood with decay visible = 2+ years); the presence or absence of leaves (green, moist leaves = <3 months, brown leaves that are malleable to dry (i.e. breaking into sections in hand) = 0 – 1 year; brown dry (i.e. crush easily into small pieces in hand) leaves still attached = 1 – 2 years, no leaves left on branches = 2+ years); and the overall condition of the platform and tree growth around it (no growth of branches into space above platform = 0 – 1 year, some new growth in area above platform, but area still somewhat open = 1 – 2 years, platform completely closed in by new growth and parts of the platform falling onto the ground = 2+ years). For claw mark aging, we established reference marks on various tree species within the local area with a pocket knife to replicate the climatic conditions affecting natural marks and monitored them through a ~1.5-year period as a visual reference guide. Some indicators mirror those used for the platforms such as the color of the inner wood, and the sharpness and presence of splinter pieces along the edges of the claws, while with claw mark indicators we also looked for the presence of fungus in the marks, the amount of healing growth that had taken place, and in fresh sign the presence of still weeping sap. Scats were aged based on their level of decomposition, moisture content, and actual content. (Food items were backdated to when they would have been available for consumption). No scat was aged older than 1 year as I recorded no evidence that scats were identifiable as such after a year in the field.

Trees or shrubs found with sign were identified to lowest possible taxon and DBH (diameter at breast height) was recorded. Other sign data recorded included digging depth and platform height.

We completed 33 transects in 2004, 119 transects in 2005, and 48 transects in 2006. On transects completed in 2005 and 2006 (n=167) we increased the number of variables collected to include hard mast plant count, soft mast plant count, forest age, and slope. The hard and soft mast plant species counted were determined from previously published Asiatic black bear food lists, local hunter and ranger interviews, and personal observations. We also recorded the average phenological stage (dormant, budding, leafing, flowering, fruiting, ripe fruit, or leaf loss/post fruit) of each food species within each transect.

Scat sampling and analysis

All bear scat samples encountered while in the field were carefully identified, collected with attention to exclude ground debris, placed in a plastic bag, and taken to the field station to be frozen or immediately analyzed. For each scat sample collected we recorded the date, GPS location, estimated age of scat (based on color, moisture content, degradation, and content), and the collector's name on the plastic bag in permanent marker. At the lab, scats were thawed, washed through a 0.5 mm sieve with warm water, and components separated into lowest identifiable taxon. To aid in scat food item identification, we identified, collected, and preserved a reference collection of local flora (tree, shrub, broadleaf and grass plants) whole plants, seeds, flowers, and mammalian hair. I also consulted regularly with the staff botanist at the reserve to ensure proper identification.

Food items were grouped into seven general categories: hard mast, soft mast, bamboo, other vegetation, mammal, bird, and invertebrate. We noted but did not include in the analysis any non-food items (NFI) (i.e. bear hairs, stones, soil, or woody items) identified. We also attempted to determine the proportion of each individual species within each of the seven categories. This was mainly limited to soft mast, mammal, bird, and invertebrates due to the lack of identifiable residual matter from hard mast and vegetation. If there were identifiable items (e.g. an identifiable piece of acorn or shell, grass or broadleaf vegetation pieces), they were so noted.

We determined both the frequency of occurrence as well as the relative volume of each food item. Frequency of occurrence (FO) for each food item is the proportion of all scats collected that contain that particular food item: $\% FO_i = (n_i/N) * 100$, where n_i = the number of scat samples containing item *i* and N is the total number of scat samples collected. We visually estimated relative volume (RV) for each identified item in each scat. We then averaged these individual volumes across all scats collected. The formula for averaging across all scats is $\% RV_i = \sum V_i / N$, where $\sum V_i$ is the sum of the percent volumes for food item *i* across all scats and N is again the total number of scat samples collected. Item amounts recorded as "trace" were considered to be 0 or 0% for all analyses.

We examined both yearly and seasonal variation in food items found in scats. Seasons were determined by local climatic conditions, phenological changes in the vegetation, and data on hibernation periods from collared bears. Seasons were defined as: winter/denning (Dec 1st - April 15th), spring (April 16th – May 31st), summer (June 1st - Aug 15th), and fall (Aug 16th – Nov 30th).

Food Availability Surveys

Food availability surveys were performed in conjunction with the sign strip transect surveys. Within the confines of the strip transect, every tree (>5cm dbh), shrub, bush, and vine that was known or suspected to produce bear food was tallied. For each food item the phenological stage; dormant, budding, leafing, flowering, fruiting, with ripe fruit, or leaf loss/post fruit was recorded. The percent bamboo, fern, and grass/forb ground cover were estimated and categorized (0, < 10%, 10 – 25%, 25 – 50%, 50 – 75%, and 75 – 100%) within each 20m x 20m area and then averaged over the entire transect.

Ground mast surveys were performed centered along the tape measure at the 0 meter, 50 m, and 100 m mark. These mast surveys utilized 1m x 1m square plots marked off on the ground. Within the mast survey area every mast item (including husks and shells) were collected, identified and tallied by type (i.e. acorn, acorn cap, chestnut, chestnut husk, walnut, walnut shell and soft mast species). Pieces of mast and husk/shells were approximately reassembled to equate to one item before being tallied. In our analysis, we used the larger of the two tallies between mast item and mast item shell for that plot. This was done to approximate a generalized available mast index in sampled areas from year to year as well as to provide an index relating to the presence or absence of sign within the transect.

RESULTS

Trapping and Handling

Over the course of the study we tallied 1,700 trap nights (1 trap night = 1 trap being set for 1 night) using a wide array of baits for an overall trap success rate of .006 captures/100 trap nights (Table 1.1). One sub-adult female Asiatic black bear was captured at an apiary in the eastern end of the reserve. One takin (*Budorcas taxicolor)* was captured at a baited trail set and two additional takin captures occurred at blind trail sets. One Tibetan macaque (*Macaca thibetana)* was also captured in a blind trail set. All non-target animals were tranquilized, monitored until they fully recovered, and observed to be unharmed at time of release.

Reproductive Ecology

An adult (11-13 years old in 2004) female (FA1) Asiatic black bear was immobilized and fitted with a GPS radio collar at a rock cave den (2004-1) (Figure 1.9) on March 4, 2004. Results from the tooth analysis revealed that she had her first reproductive event at 3 – 5 years of age followed by reproductive events every two years after that. In FA1's 2004 den we discovered two male cubs. Male cub one (MC1) was 2,350 grams with ears and eyes opened, no noticeable tooth eruption, head hair length of 16 mm and unknown ear length. Male cub two (MC2) was 2,450 grams also with ears and eyes open, no noticeable tooth eruption, head hair length of 18 mm and unknown ear length. The cubs' age was estimated to be 35 - 50 days old with a birth date between 19 January and 3 February 2004. Because the female could not be radio located from a distance, researchers went back to check on her the next day and found both cubs abandoned at the recovery site and dead from exposure. FA1 had moved ~630 meters to a new den (2004-2) to re-den on 17 March until 15 April (Table 1.2).

On approximately 13 December 2004 bear FA1 entered another rock den (2005-1), only ~168 meters from den 1 (2004-1). Multiple unsuccessful attempts to navigate to and enter the den were made during early January 2005. Deep snow and thick ice on the sheer rock faces made the area impassible. FA1 stayed in den #3 (2005-1) until 15 April 2005. We observed the solitary FA1 moving through her home range in early May 2005. Thus, she either was unsuccessful at mating and reproducing during the 2004-2005 den period or no cubs survived to emerge from the den with her.

Bear FA1 entered a rock ledge den (2006-1) on approximately 20 November 2005. This den was located ~500 meters from den #1 (2004-1) and ~425 meters from den #3 (2005-1). On 3 March 2006 we attempted to enter den 2006-1 for data collection and to replace the collar battery. FA1 again abandoned the den and made no movements back towards the den in subsequent days. She moved ~1,630 meters from den 2006-1 to re-den at den 2006-2 on 16 March until 11 April 2006. Den 2006-2 was located ~600 meters from den #2 (2004-2) (the previous post-cub abandonment den location). She had again given birth to two male cubs. Male cub #3 (MC3) weighed 1,800 grams with eyes open, ears not fully open, ear length of 18.4 mm and hair length of 7 mm. Male cub #4 (MC4) weighed 1,600 grams with eyes open, ears not fully open, ear length of 17.1 mm and hair length of 8 mm. The estimated ages of cubs MC3 and MC4 were 25 - 40 days old with birthdates between 23 January and 7 February 2006. Cubs MC3 and MC4 were removed from the den because of reserve management concerns that the female would not return and the cubs would perish. All attempts to relocate the female to re-unite the cubs and mother failed. The cubs were hand-raised until July for attempted re-release in the spring, but ultimately were placed in captive care.

FA1's radio collar battery failed during fall 2006, thus no further reproductive field data were collected for her.

A second bear was captured in a trail set leading to an apiary that had been previously severely damaged by bears. The bear was a female sub-adult (FSA2) and was captured on 30 June 2005. FSA2 weighed 28 kg, was not lactating, showed no sign of being in estrus or of recent mating activity (swollen or red vulva), and her nipples showed no indication of previous suckling. FSA2 was fitted with a standard VHF collar because of her small size and concern for her well-being regarding the heavier GPS collar.

Only a generalized area could be identified as FSA2's den site during winter 2006 because her radio collar locations indicated continuous small movements through her home range. During the attempted approach to the den area to record her reproductive status and to replace her VHF collar with a GPS collar, she was found to be actively traveling and thus eluded recapture. From the lack of any identified prolonged den location and her expansive post-hibernation period movement pattern, we assume FSA2 did not breed, was unsuccessful at giving birth, or unsuccessful at raising cubs to emergence. FSA2's VHF collar prematurely failed during the fall of 2006; therefore no further reproductive data were obtained on her.

One additional bear-occupied den and three suspected occupied dens were located during the study. Two of the dens were rock cavities and the other two were open area dens adjacent to large rock faces. One rock cave and one ground den were approached in an attempt to immobilize denning bears. The ground den was approached on 6 March 2004 and resulted in a solitary bear leaving the area before immobilization could be accomplished. The second ground den was not approached because of the likelihood that the bear would also flee. In a very large (~10 by 20 meters) and deep (~30 meters) rock cave, den searchers reported multiple bears during their search efforts. Unfortunately, after rappelling into the cave in January 2005, I found the den to be empty. There was no sign of a den "bed" or ground indentation to indicate denning use, but claw marks on the rock wall at the entrance to the cave indicated that it was at least entered by bears within the year. The final suspected rock cavity den was not approached during the March 2006 den season because of warming weather and concern over further cub abandonment. This den site was visited during the following summer and determined inactive in recent years.

On 8 July 2004 an adult female with one cub of the year was visually located walking along the main portion of the river within the reserve. This cub could have been FSA2 captured in 2005 since the sighting would fall well within her later established sub-adult home range. No other confirmed mother and cub sightings were reported either inside the reserve or in the surrounding area during the study period.

Other confirmed bear sightings included a photo taken in August 2006 that showed what appeared to be two yearlings (estimated based mostly on size and general appearance) bears of equal size on a high rock outcropping. The observer reported watching them for one to two minutes before they moved off into the forest. No other bear (i.e. mother bear) was seen in the vicinity by the observer. A dead female bear was located in the eastern part of the reserve during late fall 2005 that showed no signs of trauma (broken bones, bullet holes, or attacks from other carnivores), but her organs were too decomposed to allow for the testing of disease or poisoning.

The bear was determined to be between 2 and 3 years old from cementum annuli tooth analysis and thus assumed not to have reached reproductive age. Given her close proximity to actively guarded apiaries (that had suffered bear raids), fresh poaching camps, and her age, she was assumed to have been killed by humans most likely with poison.

Feeding Ecology

Sign Surveys

A total of 200 sign strip survey transects was completed in the Tangjiahe Nature Reserve over the period of this study. In 53.5% (n = 107) of the total surveys at least one bear feeding sign was recorded. Bear feeding sign was detected on 61.9% (n = 70) and 66.1% (n = 37) of the surveys within the experimental and core zones, respectively. However sign surveys within the buffer zone (N = 31) detected zero bear sign. A chi-square test of association detected a significant association ($X^2 = 42.465$, d.f. = 2, $p < .00001$) between the land use zones (core, experimental, and buffer) and the detection of bear feeding sign. However, excluding the buffer zone where zero bear detections were recorded, a chi-squared test of association failed to detect a significant association ($X^2 = 0.27$, d.f. = 1, $p = 0.6$) between the core and experimental protection categories and bear sign detection.

Bear feeding sign was detected in all surveyed habitat types (Table 1.3). A chi-square test of association detected a significant association between the habitat category and bear feeding sign detection ($X^2 = 30.23$, d.f. = 4, $P<0.01$). The calculated expected chi=square value averaged >10, but the conifer habitat had an individual expected value of less than 5, thus I performed a second chi-squared test of association with the conifer habitat data combined into the deciduous/conifer habitat type. The results were similar and resulted in a significant association between habitat and bear feeding sign detection ($X^2 = 25.85$, d.f. = 3, $P<0.01$). Odds ratios indicated that the deciduous/conifer habitat had more detectable sign (odds ratio ≥ 1.55) than deciduous habitat or shrub/disturbed habitat (odds ratio ≥ 12.55) (Table 1.3).

The sign survey results by elevation (Figure 1.10) indicates an avoidance of the lowest elevations (1,000 – 1,199m) surveyed and a relative constant level of use of the mid-range (1,200 – 2,399m). The 2,000 – 2,199m range shows a high percent of use (87.5%) but it also had a relative low number of surveys (n=8).

Bear sign surveys were categorized into three main forest ages based on dbh of trees present and known harvesting history of the area as: 0 - 10 years, 10 - 25 years, and 25 + years. In a chi-square test of association, a significant association was found between the forest age category and bear feeding sign detection ($X^2 = 10.77$, d.f. = 2, $P<0.01$). Odds ratios revealed that the 10 – 25 years old forest had more detectable sign (odds ratios ≥ 1.85) and much more detectable sign (odds ratios ≥ 19.78) than the 25+ years old and 0 – 10 years old forest, respectively.

There was no significant association ($X^2 = 7.53$, d.f. = 7, P = 0.38) between the eight sign survey aspect categories and bear feeding sign detection (Table 1.4).

The feeding sign from all transects resulted in the identification of 32 species of woody plants, seven additional woody plants identified to genus level, one species of vine, and one genus of insect (Table 1.5). In addition, we recorded three conifer tree species with bear sign that we did not consider to represent true feeding events because the trees in question produced no known food source for Asiatic black bears.

Scat Sampling and Analysis

Over the course of this study we collected 131 scat samples. Scats appeared to remain in the environment for a maximum of 10 - 12 months. The largest percentage of scats (38.2%, n = 50) located were identified as 1 - 3 months in age with scats being located in all categories (Table 1.6) from very fresh, 1 - 6 days (n = 17) to very old, 10+ months (n = 10). A disproportionate number of scats (90.8%, n = 119) were from the fall season with very few scats located in either spring (n = 4) or summer season (n = 8).

Identified food items from scats included six of seven broadly assigned categories: mammal, bird, invertebrate, hard mast, soft mast, and other vegetation. No evidence of bamboo as a food item was discovered in the collected scats. We identified only two mammal species, takin and Chinese muntjac (*Muntiacus reevesi*), from reference hairs collected from dead animals. We also found evidence of nine other occurrences of mammal hair and/or bone, but were unable to identify species. We found the remains of pheasant (*Phasianidae spp.)* in five fall scats. Remains of invertebrates were identified to the Order *Coleoptera* (Beetles) (n = 6), the family *Formicidae* (Ants) (n = 2), the family *Apoidea* (Bees) (n = 15), and un-identifiable invertebrates in four other scats.

Analysis of percent frequency of occurrence (FO) and percent relative volume (RV) revealed that hard mast represented the most frequent (FO = 89.32%), as well as the largest volume (RV = 71.82%) food item consumed (Table 1.7). The second most frequently consumed item was vegetation (FO = 29.77%) and the second largest volume item was soft mast with RV = 6.17%. Birds appeared in the fewest scats (FO = 3.82%) and accounted for the least volume in the scats (RV = 0.07%).

Food Availability Surveys – Mast Plots

Four hundred ninety-eight mast-plot ($1m^2$) surveys (three transects had only two mast plots completed) were completed on 167 sign survey transects and analyzed to assess mast availability (Table 1.8) within each transect and across the study area. One hundred forty-nine (29.9%) individual mast plots had no identifiable mast present.

Data from all mast plots performed on a single transect survey were combined for a larger scale analysis of availability and possible correlations to bear sign detection on that survey transect. Of those transects, 89.8% (n = 150) had at least one recorded mast item. Acorns (*Quercus spp.)* and Manchurian walnut (*Juglans mandshurica*) represented the most commonly occurring mast items on the survey transects with 58.1% (n = 97) and 56.9% (n = 95) frequency of occurrence, respectively. Chi-squared tests of association showed no significant association (X^2 = 8.742, d.f. = 5, P-value = 0.1198) between the detection of mast and bear sign detection. Although English walnut (*Juglans regia)* and Chinese chestnut (*Castanea mollissima)* mast was found on a small percent of the total mast surveys performed, 1.2% (n = 2) and 16.2% (n = 27) respectively, the percent of those surveys that also produced bear sign was very high, 100% (n = 2) for *J. regia,* and 77.8% (n = 21) for *C. mollissima*. Whereas sign surveys with Manchurian walnut (*Juglans mandshurica)* mast, 56.9% (n = 95), had the lowest corresponding bear sign detection with 53.7% (n = 65). Only 34 of 167 (20.4%) sign surveys had both fresh sign (sign made within 1 year) and mast detected on at least on survey plot.

We identified 12 species of soft mast from mast survey plots. Within the surveys with sign the most frequently occurring soft mast was spicebush (*Lindera limprichtii),* which was found at 6.30% (n = 22) of the surveys sites.

Food Availability Surveys – Food Production

One hundred sixty-seven food production strip transects were completed in 2005 and 2006 resulting in a total tally of 29,221 mast-producing plants. Chinese Fir (*Taxodiaceae Cunninghamia lanceolata)* trees also were tallied (n = 1,524) due to claw mark sign being recorded on the species, but they were not counted as true mast-producer plants because of the insignificant seed production by the tree. The Chinese White Pine (*Pinus armandii)* was tallied (n = 1,482) as a mast producer, even through there were no recoded instances of bear sign on the trees, because it produced such large and edible pine nuts. The most common tree mast producers recorded were deciduous oaks (n = 4,715), Manchurian walnut (n = 3,261), and *Lauraceae* trees (n = 2,124). The spice bush was the most prevalent (n = 4,244) shrub or bush on the surveys. On average, across all surveys, ground cover consisted of 11 – 25% ferns, 26 – 50% grasses and forbs, and 0% bamboo. The relative selection of the tallied mast producers revealed that Asiatic black bears in Tangjiahe selected for some species of mast relative to their availability (Table 1.9). Bears showed a particular interest in domestic pear trees and English walnuts and, surprisingly, the analysis shows less of a selection for deciduous oaks; only 1.9% of the tallied trees had bear feeding sign.

DISCUSSION

Trapping and Handling

The extremely low capture rate for bears during this study relative to other bear studies coupled with the general lack of interest from bears for any form of bait used indicates a very small population. Yet the historical persecution of bears in the area could also be influencing the bears' behavior to the point of extreme avoidance of anything human or human-scented. I believe the population within Tangjiahe Nature Reserve is quite low and that the remaining population of bears has developed a keen ability to avoid contact with humans due to the likelihood of persecution or death.

There were no known "missed captures" (i.e. bears stepping into or onto a snare that failed to make a capture) of bears at a trap, although on at least one occasion a bear did avoid a trap by walking around a trail set to avoid the baited area altogether. All other sets failed to elicit visitation to the immediate area by a bear. A lone bear was observed walking and feeding in a valley within approximately 60m of a baited trap site with no indication of either detecting or showing interest in the fresh bait. Asiatic black bears in Tangjiahe Nature Reserve, it seems, may have a non-response/negative response reaction to "bait" of the kinds used in this study from the observations detailed above and from the extremely low rate of trap success.

Local bear trappers speculated that it was the scent left by humans frequently visiting trap sites that kept bears away. This is not a new notion as trappers and researchers around the world assume that human scent can lead to trap detection and avoidance if not masked by natural scents. But most bear research and monitoring relies on some kind of bait to at least elicit a visitation by bears in the study area and we documented numerous incidents of bears raiding apiaries that were actively being guarded by villagers. To test the hypothesis that bears in Tangjiahe were actively avoiding traps because of frequent human visitations we placed samples of all available bait types in the field at over 30 bait stations within known active bear use (from bear sign) areas and left them undisturbed for 2 – 6 weeks. Upon returning to the bait stations, we detected no bear visitation to any sites and other than insect use of the honey baits, most of the baits were completely undisturbed by any animals.

If bears and other carnivores are exhibiting an extreme aversion to baits and/or human scents it may be attributed to continual harassment and hunting pressure. Asiatic black bears in the mountains of Sichuan China endure winter den killings, dog chase hunting, poison, and explosive-laden baiting, and an extensive array of wire snares throughout their habitat, as well as heavy forest utilization by humans for food, building supplies, and fuel-wood collection. Since bears actively came into heavily human- utilized areas to raid honey hives during periods of good mast production, we feel the lack of bait visitations indicates a scarcity of bears and carnivores in general within Tangjiahe Nature Reserve. This conclusion is strengthened by a remote camera survey performed with the reserve that tallied > 4500 camera trap nights across the reserve with no Asiatic black bears being captured (Wang et al. 2006).

Reproductive Ecology

Although this study included only two females and two recorded reproductive events, the paucity of reproductive information on Asiatic black bears still makes it extremely valuable data.

The recorded age at primiparity (3-5 years) and birth interval (2 years), for the Tangjiahe Asiatic black bears is comparable to the reported 3-4 years and ~2 years for American black bears in most Eastern United States black bear studies (Clark and Smith 1994, Hellgren and Vaughan 1994, Maddrey 1995, Kasbohm et al. 1996, Freedman et al. 2003, Bridges 2005 and Garrison et.al. 2007). Primiparity is earlier when compared with more western and northern United States black bear studies where first reproduction commonly occurs from 5-8 years (Rogers 1987, Kolenosky 1990, Miller 1994). Given the parallel habitat types, similar forest structure, and similar food resources, it isn't surprising that Sichuan Asiatic black bears mirror the reproduction habits of the Eastern United States.

Although it is common for American black bears to reproduce the year after a complete litter loss, this did not appear to happen in the one occasion of a complete litter loss for Asiatic black bears. In this instance an adult female was observed shortly after den emergence alone. It is possible that she reproduced, but failed to raise cubs to emergence; however, given her apparent excellent body condition it was assumed she did not reproduce.

Studies of American black bears have shown that reproduction can be influenced by age (Alt 1982) and general body condition (Samson and Hout 1995) of the reproducing bear, while Elowe and Dodge (1989) indicated that habitat quality could affect reproduction. Over the duration of the study we documented no substantial change in the habitat quality of the study area such as mast failures or forest fires, and all handling and visual observation events of bears revealed good body conditions. It is possible that an undocumented resource was lacking that caused the missed reproductive opportunity, but it is interesting that during the mating season following the missed event, this female was documented traveling in a nearly straight line for over 15 km in one day to reach an adjacent reserve. She remained within a 10 km area for one month during the breeding season before returning to her original home range and eventually denned within ~500 meters of her old dens to produce two more male cubs. Schaller et al. (1989) believed that very few bears were present in Tangjiahe during their study period (1984 - 1987) and that none resided there year round. It therefore could still be possible that, with their large home ranges, male Asiatic black bears endure a greater risk of poaching and poisoning from villagers and therefore few to no males reside within the reserve. Thus, this long-distance, short-duration journey by the female could have been necessary for her to locate a mate.

Feeding Ecology

The few other studies on Asiatic black bear feeding ecology available in English used opportunistic feeding data collection methods (Wu 1983, Schaller et al. 1989, Hu 1990, Hwang et al. 2002, Huygens et al. 2003), radio-tracked directed searches (Wang 1988, Reid et al. 1991, Huygens and Hayashi 2001, Hwang et al. 2002), survey routes to record feeding platform sign and direct feeding observations (Nozaki et al. 1983), and hunter interviews (Hwang et al. 2002). We employed all of these techniques, but unlike Hwang et al. (2002) felt that hunter and field staff interviews of food items, while providing a very large list of possible bear food items, were not reliable as they may have been based on assumptions and incorrectly identified animals and sign. Performing strip transect surveys for Asiatic black bear feeding ecology seems to be the most thorough, economic, and efficient technique to employ. This study clearly demonstrates that Asiatic black bears not only make very obvious sign within the forest but that also they make a lot of it. This fact leads to the conclusion that, at least for Asiatic black bears, sign abundance does not mean population abundance; it only indicates occupancy.

Sign Surveys

Strip sign surveys for American black bears are rarely used as a means to collect feeding data due to their more ground-based foraging strategy and the subsequent difficulty in identifying a feeding event. While transects have been used to document Andean bear (*Tremarctos ornatus)* feeding ecology (Peyton 1980, Cuesta et.al. 2003), the building of feeding platforms seems to be a much less utilized feeding strategy. Unlike American black and Andean bears, Asiatic black bears utilize a highly arboreal foraging strategy (Wang 1988, Schaller et al.1989, Reid et al. 1991) especially for fruits and hard mast. The prolific climbing and feeding platform construction behavior of the Asiatic black bear provides easily documented feeding events.

The majority of our feeding data was collected from 200 sign survey transects. We recorded 40 fruit producing woody plant species, one fruiting vine, and one insect as food items from transects alone. Employing direct observational and sign survey routes during a study of the feeding ecology of Asiatic black bears in a temperate forest area of Japan, Nozaki et al. (1983) identified 23 individual food items.

Feeding sign within our study area was concentrated within the core and experimental zones while no bear sign was detected within the buffer zone. Even when the buffer zone surveys were performed in areas with hard mast and mature forest we could detect no use by bears. This feeding avoidance by bears likely stems from the persecution bears suffer when they move into human inhabited areas.

Scat Sampling and Analysis

Scat collection and analysis continues to be a common source of feeding ecology data for most large carnivores (Litvaitis 2000). Collection can be performed opportunistically any time while in the field for any research activity and scats are easy and inexpensive to store and analyze. During our research, we collected 131 scats both opportunistically (n = 89) and during thorough searches within strip transects (n = 42). Because fall scats containing hard mast persist longer in the environment and are in areas with little herbaceous cover, they represented a majority (90.8%) of the scats collected. Biased fall or hard mast bear scat collection is common with Asiatic black bear scat surveys in general (Nozaki 1983, Hu 1990, Hashimoto et al. 2003, Hwang 2002, Huygens 2001).

Food items were identified from all available general food types including mammal, bird, invertebrates, vegetation, hard mast, and soft mast. Given the bias toward fall scat collection, it is not surprising that hard mast represented the highest frequency of occurrence and relative volume. Vegetation had the second highest frequency of occurrence and soft mast had the second highest relative volume. Mammalian and avian food items represented the lowest two frequencies of occurrence and relative volumes and likely were derived from scavenging events. Thus, we detected no deviation from the perception of bears as omnivorous generalists that seasonally shift their diets to match available food resources (Beeman and Pelton 1977).

Food Availability Surveys – Mast Plots

We conducted mast availability plot surveys primarily to detect yearly fluctuations and habitat specific differences in the availability of hard and soft mast items available to bears and the effects the availability had on bear use. The year prior to the start of this study, there was cursory evidence that it was a better than average chestnut and deciduous oak mast year.

However, throughout the three-year study we detected no difference in the quantity of either hard or soft mast.

We found that only 20.4% of the sign surveys had both fresh (0 – 3 months old) bear sign and mast detection on the ground available for animals. In Tangjiahe, multiple species like Asiatic black bear, Tibetan macaque (*Macaca thibetana*), golden monkey (*Rhinopithecus roxellanae)*, giant flying squirrel (*Petaurista spp.*), and birds consume the mast before it falls from the plants. These species are usually followed quickly by a multitude of ground feeding animals: hog badger (*Arctonyx collaris*), masked palm civet (*Paguma larvata)*, wild boar (*Sus scrofa)*, forest musk deer (*Moschus berezovskii*), tufted deer (*Elaphodus cephalophus*), Chinese muntjac (*Muntiacus reevesi*), takin, serow (*Naemorhedus sumatraensis*), goral (*Naemorhedus caudatus)*, and porcupine (*Hystrix brachyuran*). A better suited mast survey technique would employ sampling that mimics the selective behavior bears may use such as a count or qualitative assessment of mast while still on the tree or shrub.

Food Availability Surveys – Food Production

The food production surveys clearly demonstrated that Tangjiahe Nature Reserve has not only an abundance of both hard and soft mast-producing plants, but also a great diversity of species. The diversity of food-producing species within Tangjiahe results in a cycle of different species ripening and being available for consumption over a longer period. It also would act as a buffer in the case of a disease outbreak or crop failure within one species. This makes Tangjiahe an ideal location for bears and the multitude of other species that share the food resources.

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Table 1.1 Trapping data for the Tangjiahe Nature Reserve. Table shows the total number of trap days per year, type of trap set, types of bait used, and results of the trapping efforts. In total we had 1 Asiatic black bear capture from 1,700 trap nights (Overall trap success = .006 bear captures / 100 trap nights.

Season and year	# of trap nights	# of trap sites	Types of traps	Types of bait	Trap success (captures/100 trap nights)
Spring 2004	833	28	C,A,P B,T,L,	Meat, Sweets, Lure Scents	0
Fall 2005	759	30	B,T,A, N,X	Meat, Sweets, Lure scents, Corn Dead Takin	0
Summer 2005	79	2	B,A	All at Apiaries	1.27
Fall 2005	29	1	B,T,N	Honey and Fruit	0

Types of traps include; B = Blind trail leg hold snare, T = Baited trail leg hold snare, L = Log cubby with leg hold snare, C = Stick and leaf cubby with leg hold snare, N = Tree notch leg hold snare, A = Apiary non-baited leg hold snare, P = Baited passive in-ground leg hold snare, X = Barrel trap.

Table 1.2 Denning and birthing dates for an adult Asiatic black bear from Tangjiahe Nature Reserve, Sichuan, China. Bear FA1 was originally captured from her den on March 4th, 2004 wherein she was found with two male cubs. We unsuccessfully attempted a den re-capture of FA1 on March 3rd, 2006; she again left two male cubs in the den and did not return.

Den years	Den entrance date	Cub birth date[a]	Research disturbance date	Re-den date	Final emergence date	Total days in den[c]
2003 - 2004	Unknown	19 .Jan- 3 Feb	4 Mar	17 Mar	15 Apr	Unknown
2004 – 2005	13 Dec	None[b]	NA	NA	15 Apr	124
2005 – 2006	19 Nov	23 Jan-7 Feb	3 Mar	16 Mar	11 Apr	132

[a] Estimated dates based on cub developmental stage and morphological measurements compared to known aged American black bear cubs.
[b] Either no cubs born or none survived to emerge from den with mother
[c] Including entrance and emergence dates

Table 1.3 Asiatic black bear sign survey results and odds ratios from May 2004 – Aug 2006 in the Tangjiahe Nature Reserve, Sichuan Province China, by habitat type as recorded in the field. The odds ratio ranking details the relative weight of the odds for each habitat having detectable bear sign.

Habitat type	Total surveys	Number of surveys with feeding sign	Percent of total surveys with feeding sign	Odds Ratios[a]
Deciduous-conifer	48	34	70.8%	1
Deciduous	72	44	61.1%	1.55
Deciduous-evergreen	36	21	58.3%	1.73
Conifer	7	2	28.6%	6.07
Shrub-disturbed	37	6	16.2%	12.55
Total	200	107	53.5%	

[a] Ex. Deciduous/Conifer habitat has 1.55 times the odds of having sign when compared to deciduous habitat and 12.55 times the odds when compared to shrub/disturbed

Table 1.4 Asiatic black bear sign survey results from May 2004 – Aug 2006 in the Tangjiahe Nature Reserve, Sichuan Province, China, by aspect.

Cardinal direction	Degrees	Number of surveys	Percent of total surveys	Percent of surveys with feeding sign
N	337.6 - 22.5	20	10.8%	55.0%
NE	22.6 - 67.5	29	15.6%	58.6%
E	67.6 - 112.5	21	11.3%	71.4%
SE	112.6 - 157.5	27	14.5%	59.3%
S	157.6 - 202.5	31	16.7%	41.9%
SW	202.6 - 247.5	31	16.7%	58.1%
W	247.6 - 292.5	7	3.8%	71.4%
NW	292.6 - 337.5	20	10.8%	75.0%

Table 1.5 Food Items, and their fruiting period (shaded area), of the Asiatic black bear in Tangjiahe Nature Reserve derived from claw mark, feeding platform, or digging sign recorded on survey transects performed from May 2004 – August 2006. This list does not include food items identified from scats.

Species	Spring		Summer		Fall			
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Acer pictum (Shantung maple)						■	■	
Pistacia chinensis (Chinese pistachio)					■	■	■	■
Kalopanax septemlobus (Castor oil tree)						■	■	
Carpinus fangiana (Fang hornbeam)				■	■	■		
Castanea mollissima (Chinese chestnut)					■	■	■	
Cornus controversa (Giant dogwood)				■	■	■		
Cornus macrophylla (Big-leaf dogwood)					■	■	■	
Corylus chinensis (Chinese hazelnut)				■	■	■		
Davidia involucrata (Dove tree)					■	■		
Elaeagnus umbellate (Autumn olive)						■	■	■
Lyonia ovalifolia (Staggerbush)				■	■	■		
Fagus spp. (Beech)					■	■	■	
Ilex spp. (Holly)						■	■	■
Pterocarya macroptera (Wingnut)				■	■			
Juglans regia (English walnut)						■	■	
Lindera limprichtii (Spicebush)				■	■	■		
Lindera megaphylla (Nanmu laurel)						■	■	■
Litsea pungens (Laurel)				■	■	■		
Litsea szechuanica (Sichuan laurel)				■	■	■		
Melia azedarach (Chinaberry-mahogany)							■	■
Broussonetia papyrifera (Paper mulberry)			■	■				

Morus alba (White mulberry)

Aegiros spp. (Cottonwood)

Quercus aliena (Dec.) (Oriental White oak)

Quercus engleriana (Evg.) (Engelmann Oak)

Quercus glauca (Evg.) (Ring cup oak)

Quercus oxydon (Evg.) (Ring cup oak)

Quercus serrata (Dec.) (Konara oak)

Quercus spinosa (Evg.) (Spiny leaf oak) **

Quercus spp. (Deciduous Oak)

Quercus variabilis (Dec.) (Cork bark oak) **

Rhododendron spp.

Rhus chinensis (Chinese sumac)

Rhus punjabensis (Sumac)

Robinia pseudoacacia (False acacia)

Sorbus zahlbruckneri (Mountain ash)

Ailanthus altissima (Tree of heaven)

Tilia spp. (Basswood)

OTHER FOOD ITEMS

Actinidia chinensis deliciosa (Kiwi fruit - vine)

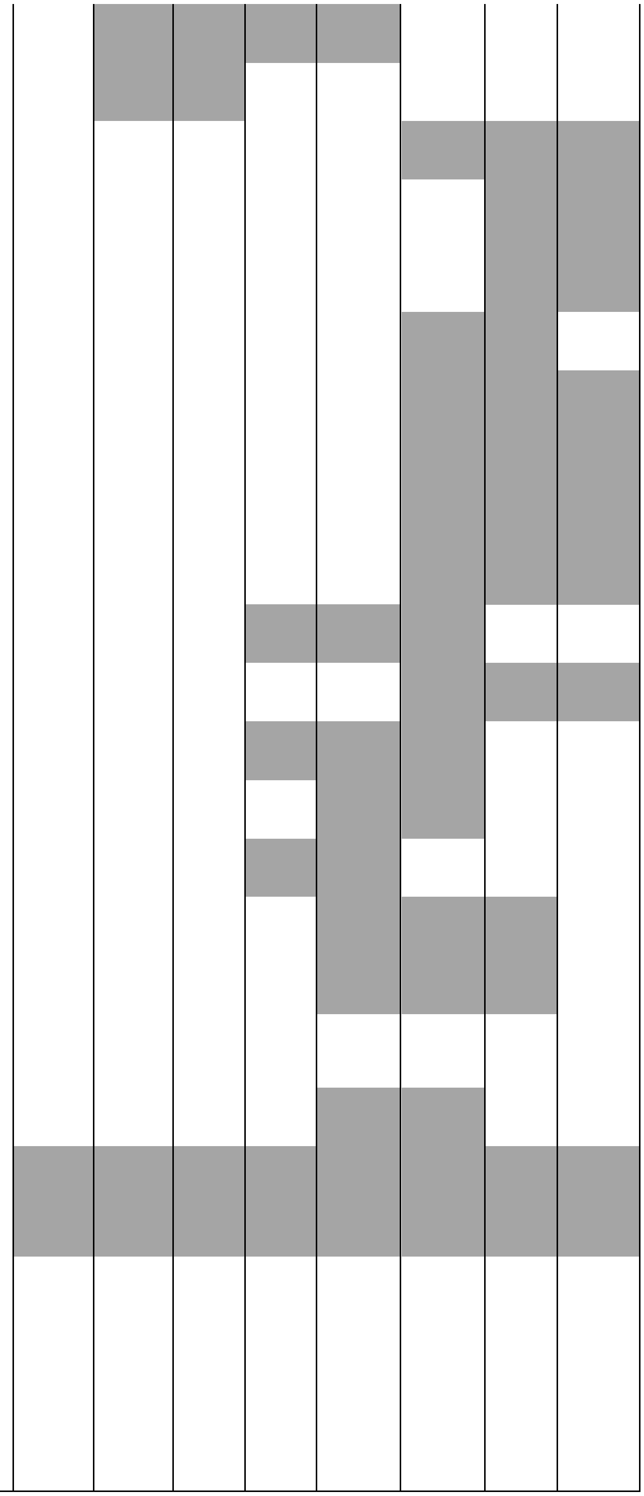
Formicidae spp. (Ant)

NON FOOD MARKED TREE SPECIES

Picea wilsonii (Wilson's spruce)

Cunninghamia lanceolata (Chinese fir)

Tsuga chinensis (Chinese hemlock)



** Only produces mast every two years

Table 1.6 Asiatic black bear scat age and seasonal data from May 2004 – Aug 2006 in Tangjiahe Nature Reserve, Sichuan Province, China. Table shows the breakdown of scats by estimated age and back calculated season when the scat was left.

Age	Spring 4/16 – 5/31 (n = 5, 3.1%)*	Summer 6/1 – 8/15 (n = 8, 6.1%)*	Fall 8/16 – 11/30 (n = 119, 90.8%)*
1 – 7 Days	0	35.3% (n = 6)	64.7% (n = 11)
1 – 4 Weeks	8.6% (n = 4)	0	91.4% (n = 32)
1 – 3 Months	0	0	100.0% (n = 50)
3 – 6 Months	33.3% (n = 1)	66.7% (n = 2)	0
6 – 9 Months	0	0	100.0% (n = 10)
9 – 12 Months	0	0	100.0% (n = 16)

* Percent and sample size derived for each season from total scat samples (n = 131)
Factors resulting in the high frequency of scats from the fall could be both ease of location (under or around feeding areas within relatively reduced herbaceous cover) or based on the general observation that acorn mast dries and is preserved in the environment longer than vegetative, fruit, or meat-based scats.

Table 1.7 Frequency of occurrence and percent relative volume of food items identified from all Asiatic black bear scats (N=131) by season collected from May 2004 – Aug 2006 in Tangjiahe Nature Reserve, Sichuan Province, China.

Category	Item	Occurrence (per season) Spring	Summer	Fall	% FO	% RV
Mammalian					7.63	2.24
	Budorcas taxicolor (Takin)	1	0	2		
	*Cervidae (*Deer spp.)	0	0	1		
	Mammal (Unidentified)	1	2	6		
Avian					3.82	0.07
	Phasianidae (Pheasant spp.)	0	0	5		
Invertebrate					16.79	4.31
	Formicidae (Ant spp.)	0	1	1		
	Coleoptera (Beetle spp.)	3	0	3		
	Apoidea (Bee spp.)	0	1	14		
	Insect (Unidentified)	0	3	1		
Vegetation					29.77	4.40
	Poaceae (Grass spp.)	0	5	25		
	Pteridophyta (Fern spp.)	0	0	10		
	Ilex spp. (Holly leaves)	0	0	1		
	Forbs (Unidentified)	4	3	9		
Hard Mast					89.31	71.82
	Cyclobalanopsis spp. (Evergreen Oaks)	0	0	9		
	Castanea mollissima (Chinese chestnut)	0	0	1		
	Juglans regia (Common Walnut)	0	2	8		
	Fagaceae (Unidentified oak, chestnut, beech)	0	1	111		

Soft Mast					11.45	6.17
	Physalis alkekengi (Chinese lantern plant)	1	0	0		
	Actinidia chinensis deliciosa (Kiwi fruit)	0	2	7		
	Lindera limprichtii (Chinese spicebush)	0	0	8		
	Rubus spp.(berry fruit)	0	0	1		
	Stranvaesia davidiana (drupe fruit tree)	0	0	2		

Table 1.8 Mast food availability plot survey results from May 2004 – Aug 2006 in the Tangjiahe Nature Reserve, Sichuan Province, China.

Mast type	Surveys with mast	% Surveys with mast	Range of abundance*
Oak Acorn	193	38.75%	.5 – 198
Juglans mandshurica (Small Walnut)	173	34.74%	.5 – 20
Juglans regia (Large Walnuts)	5	1.00%	2 – 7
Chestnut	37	7.43%	1 – 25
Hazel Nut	33	6.63%	1 – 52
Beech Nut	8	1.61%	1 – 116
Soft Mast	60	12.05%	1 – 84
No Mast Recorded	149	29.92%	NA

* Reflects the largest number of food items available at the site determined by the largest count of husk, shell/caps, or actual food items.

Table 1.9 Number of mast producing trees/shrubs counted on 167 strip transect surveys conducted on Tangjiahe Nature Reserve, Sichuan Province, China in 2005 and 2006, and the number and percent of those surveys with bear sign.

Mast producing trees/shrubs with sign	Number counted	Number with sign	Percent with sign
Domestic fruit tree	3	3	100.0
English walnut	258	35	13.6
White mulberry	8	1	12.5
Chestnut	660	48	7.3
Dogwood	406	29	7.1
Paper mulberry	122	7	5.7
Nan mu	180	9	5.0
Wild cherry	90	3	3.3
Hazelnut	190	5	2.6
Evergreen oak	1144	28	2.4
Deciduous oak	4715	90	1.9
Basswood	163	2	1.2
Laurel	2124	17	0.8
Spicebush	4244	28	0.7
Sumac	735	5	0.7
Beech	392	2	0.5
Holly	2116	1	0.05
Manchurian walnut	3261	0	0
Armandi Pine	1482	0	0
Autumn Olive	969	0	0

Figure 1.1 Range map of the Asiatic Black Bear

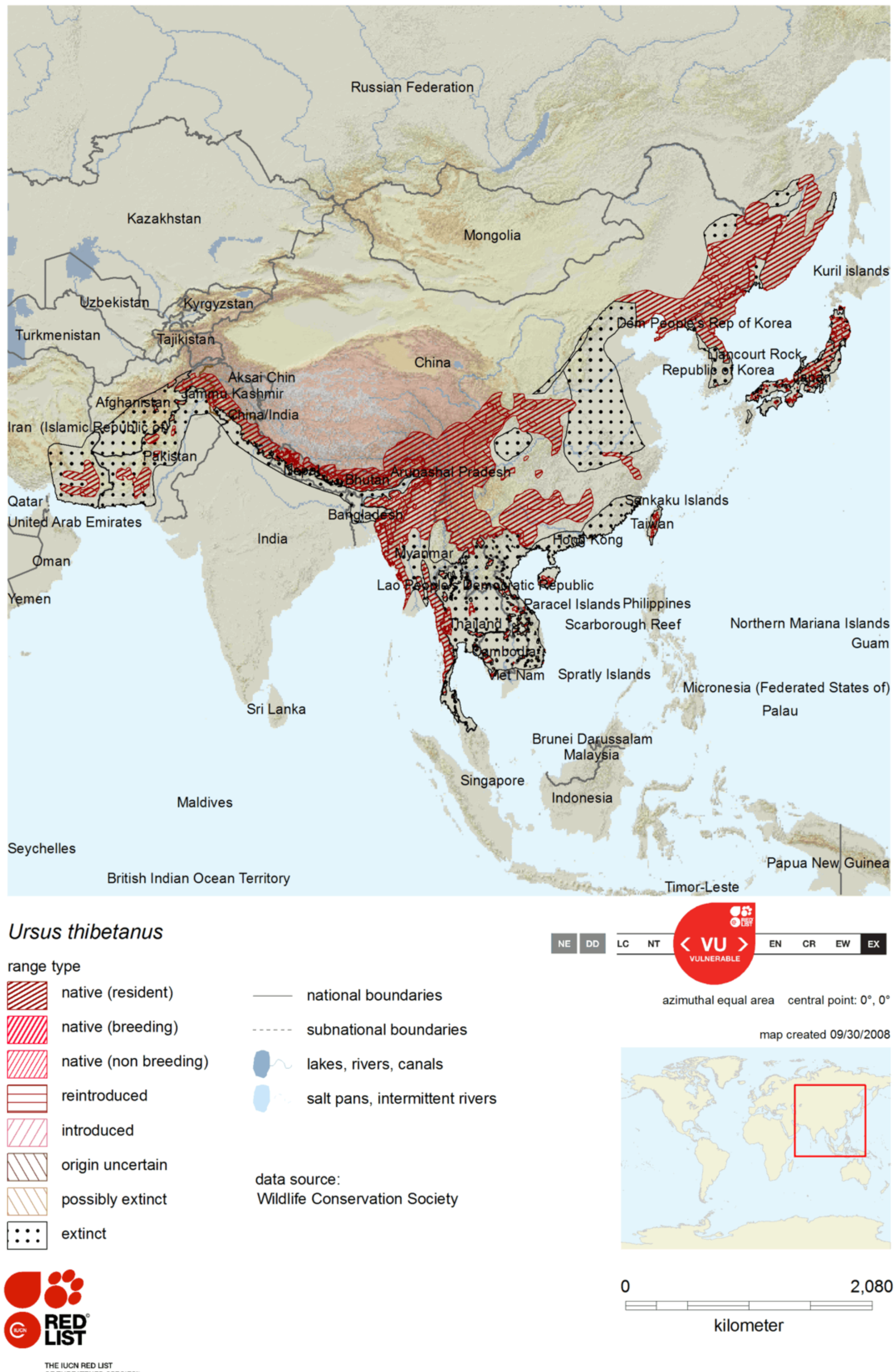


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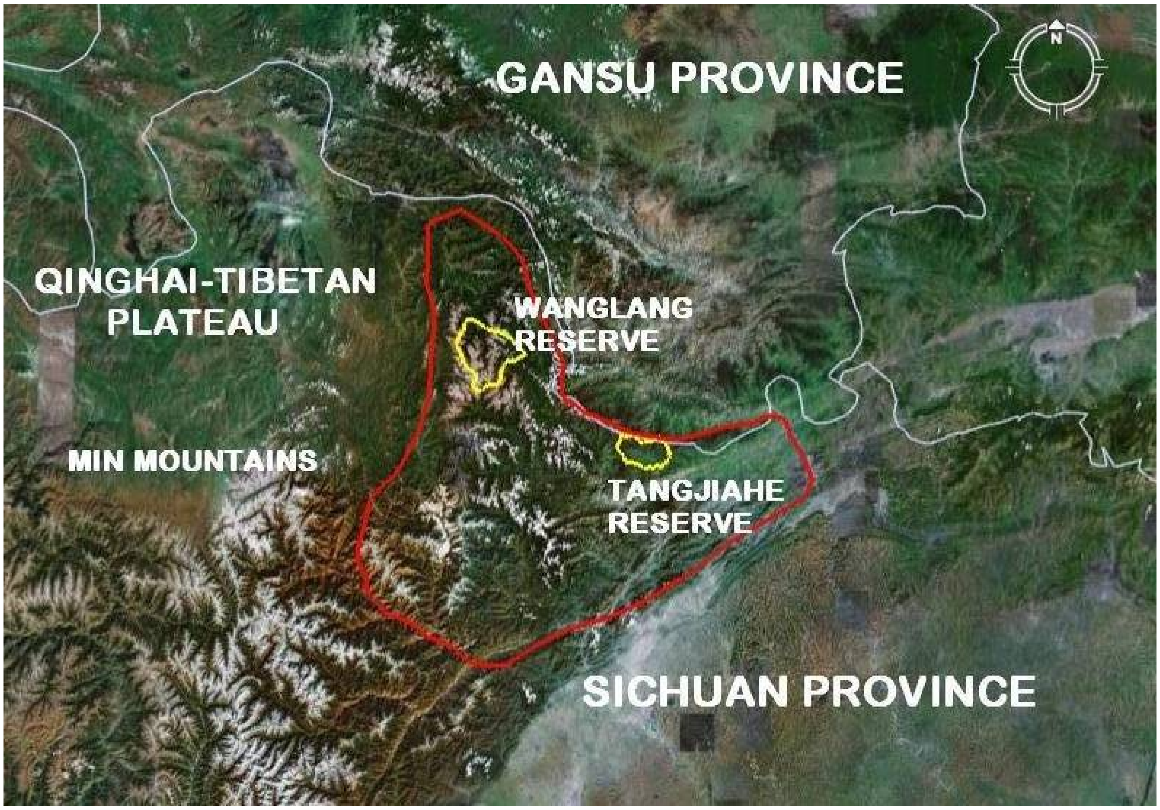
Figure 1.2 General topography map showing the location of the Tangjiahe Nature Reserve (yellow outline) within the Min Mountains (red outline) of Sichuan Province, China.



Google Earth

Figure 1.3 Tangjiahe nature reserve designated protection categories. The buffer area experiences high use from villagers through habitation, farming, grazing, hunting, and collecting. All tourist and reserve infrastructure is limited to the experimental area. The core area reflects most of the giant panda habitat as well as the most well preserved forest.

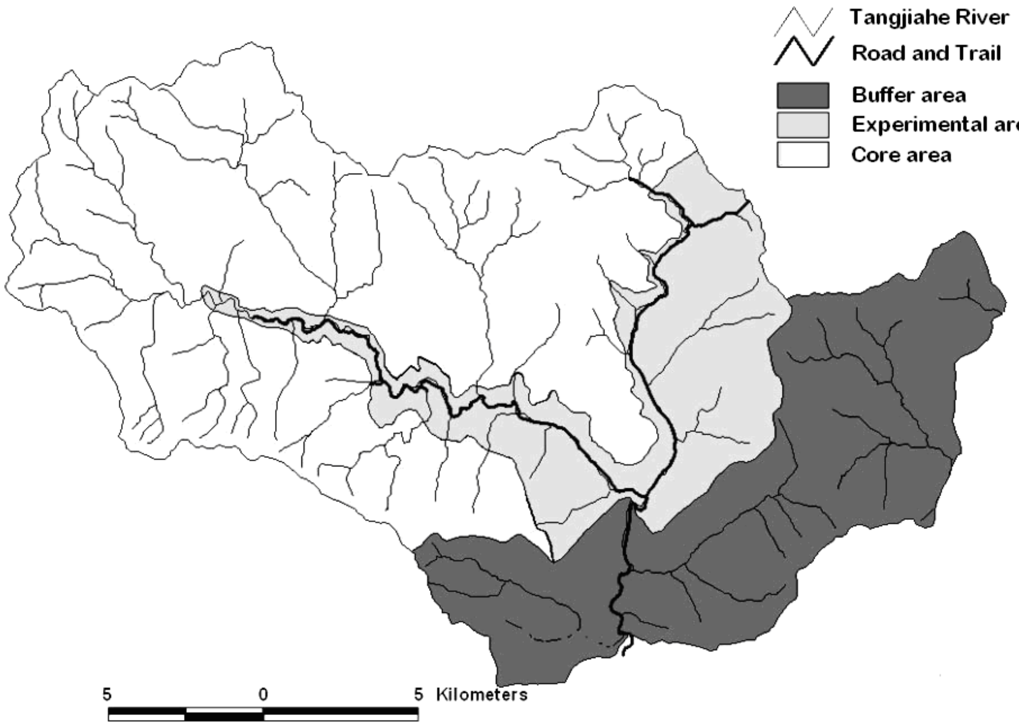


Figure 1.4 Tangjiahe Nature Reserve map with the four main survey areas shown and grids removed from survey consideration highlighted.

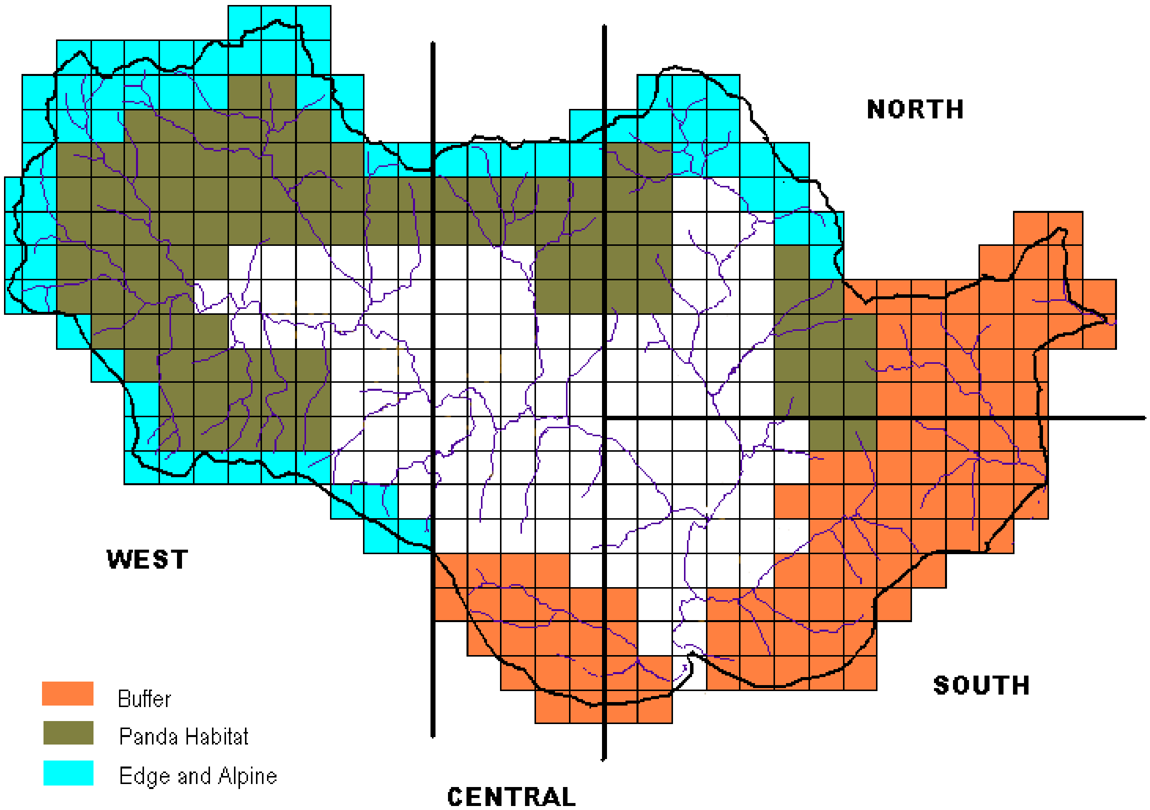


Figure 1.5 Asiatic black bear claw marks. Bear claw marks left on climbed trees were the most common type of sign found. Some marked trees were obvious as in the pictured example whereas claw marks left on rough bark trees were more difficult to identify and required careful and meticulous inspection.

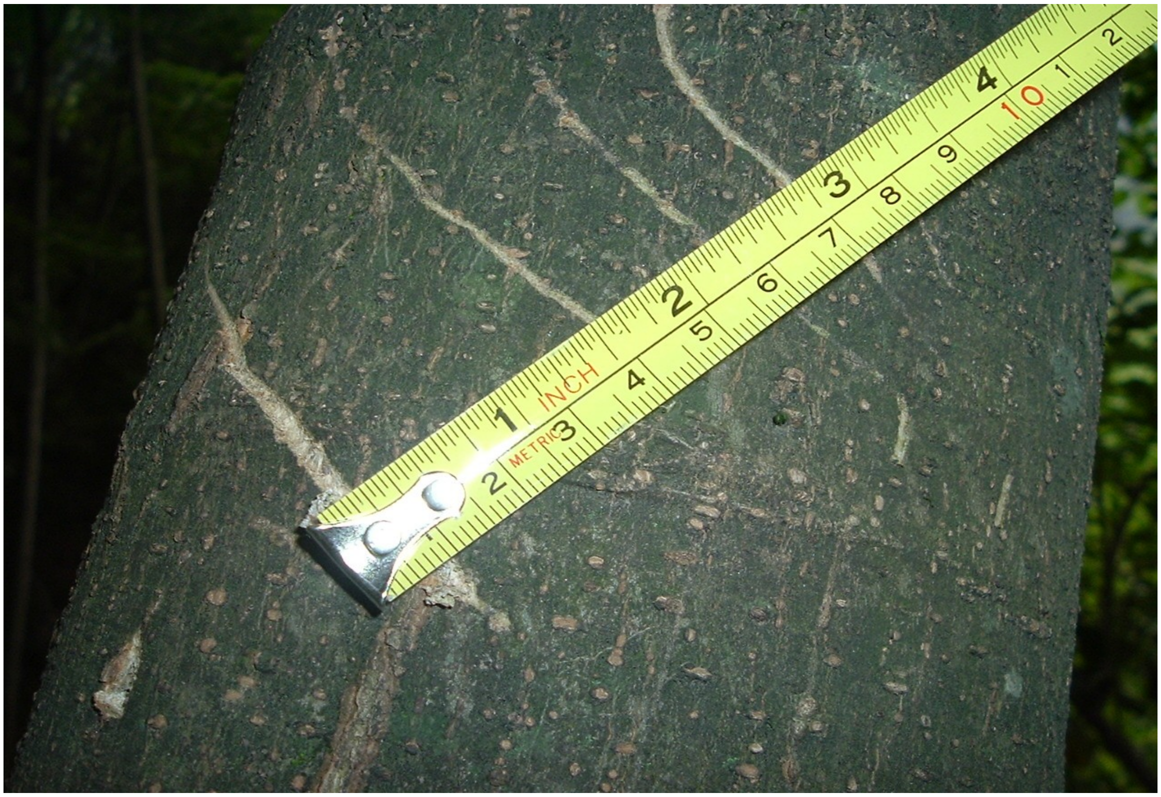


Figure 1.6 Asiatic black bear feeding platform. Feeding platforms are typically large, obvious, bowl-shaped piles of broken or bent branches which the bear will clean of food items and then place under itself while proceeding to another branch.

Figure 1.7 Asiatic black bear biting sign. This sign was made by a bear both using its teeth and claws. The biting is evident directly around the hole in the tree and claw marks can be seen all around. The tree was a wild cherry tree (*Prunus* spp.) that had been climbed and fed from by bears for many years. The inside of the tree was hollow and at the time the photo was taken only had water inside. There was no detectable food source inside, but there may have been wild honey hives or other insects inside the tree in previous years.

Figure 1.8 Asiatic black bear digging sign. This feeding sign was made by a bear in an apparently successful effort to access large ground nesting bees and their larvae approximately 30 cm below grade. The level area of soil is where the bear expanded the original opening to access the inside. We found both claw marks and a bear track in this area of soil.

Figure 1.9. Map detailing AF1's core home range locations (red points) and five known den locations (black points). Note each time the bear ran from her den site she would always go north over the high ridge in the area. The ridge was extremely rugged and impassable by researchers. We did not attempt an approach of the 2005 den and thus the female made no movement from the area. During the 2005 winter den period, the female either did not produce cubs or none survived to den emergence.

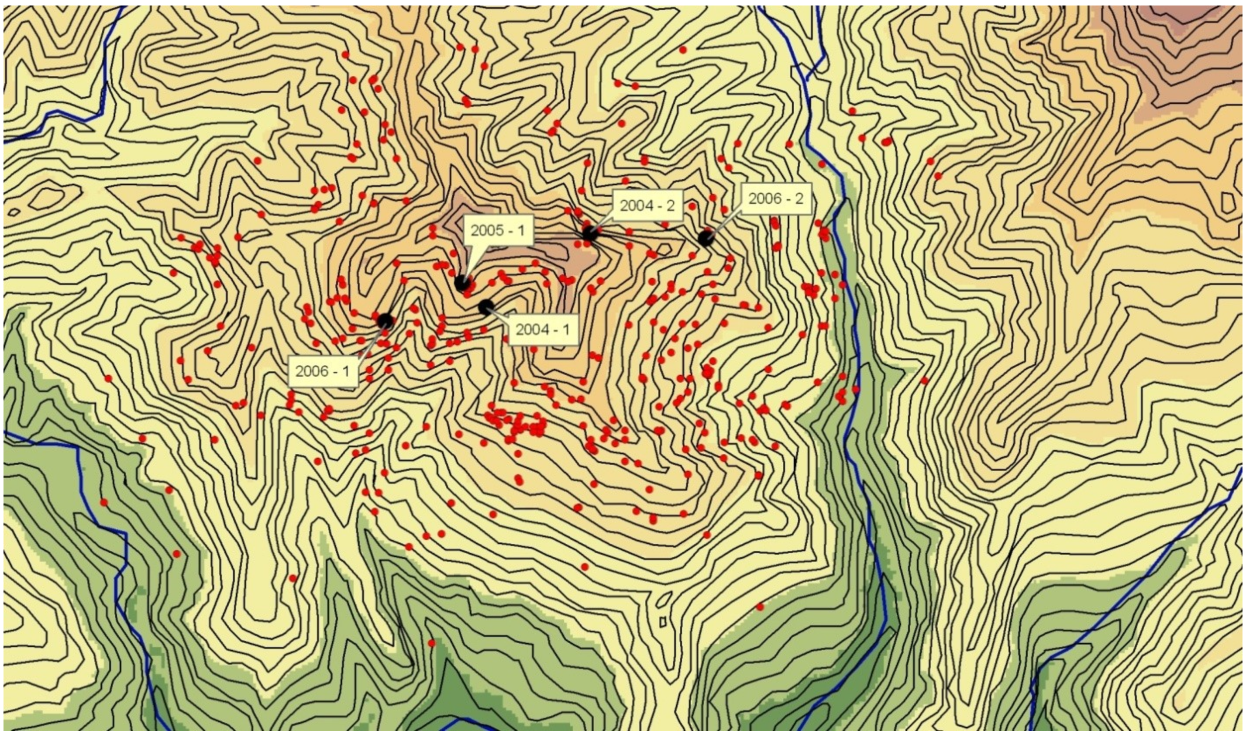
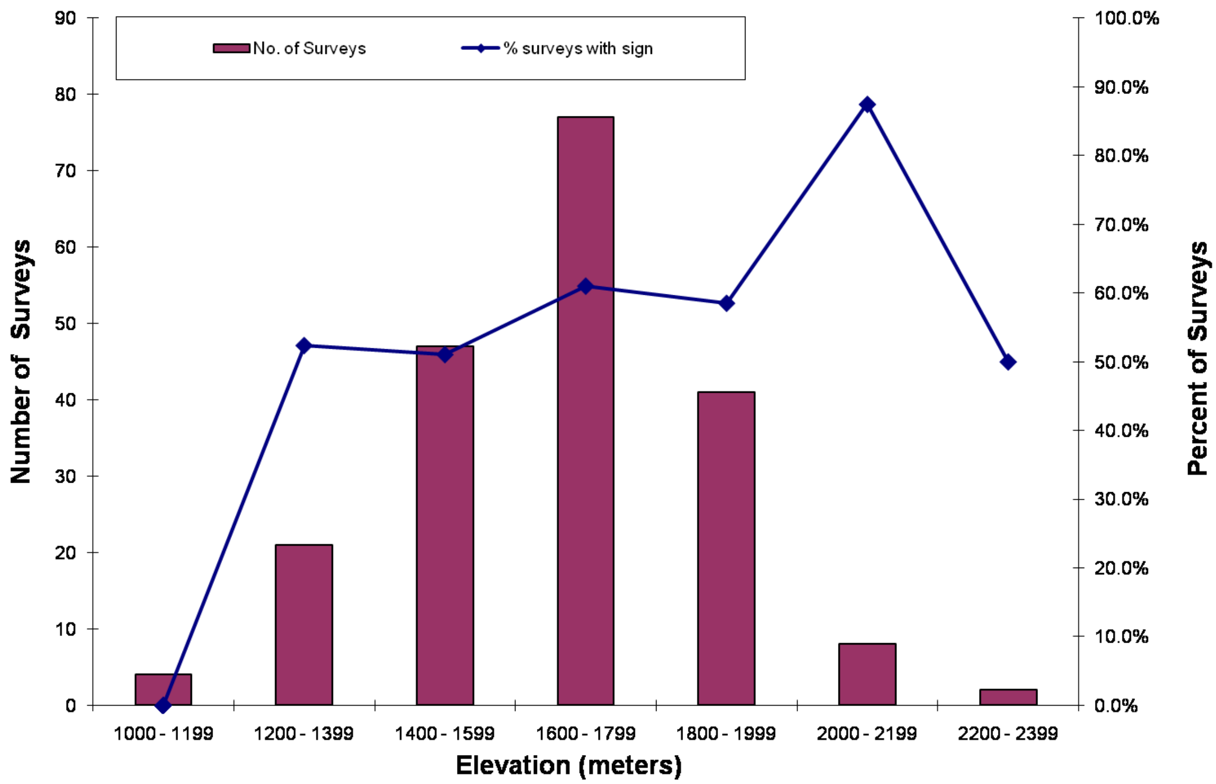


Figure 1.10 Results of transect sign surveys performed from May 2004 – Aug 2006 in Tangjiahe Nature Reserve, Sichuan Province China, by elevation. The graph illustrates the negative impact human development and resource extraction has on Asiatic black bear populations in China. The lowest elevations (1000-1199 meters) with high human development had no detectable bear sign or occupancy while just inside the reserve the next elevation range (1200-1399 meters) had an over 50% success rate of detecting bear sign.



CHAPTER 2: HOME RANGE AND MOVEMENT PATTERNS OF ASIATIC BLACK BEARS IN TANGJIAHE NATURE RESERVE, SICHUAN CHINA

INTRODUCTION

Understanding home range and movement patterns of any animal is critical in providing for their protection. Home range and movement patterns provide insight not only into the habitat and spatial needs of an animal, but also into how the behavioral choices within that range ultimately effect reproduction and survival (Powell et al. 1997). The availability, distribution, and fluctuation of limited resources is believed to exert effects on home range and movement patterns of animals (Jonkel and Cowan 1971, Carpenter and MacMillen 1976, Hixon 1980, Schoener 1981, Young and Ruff 1982, Rogers 1987, Smith and Pelton 1989, and Powell et al. 1997). Spatial use and movement patterns also may highlight affects on animals from environmental and anthropomorphic factors (Jonkel and Cowan 1971, Ayres et al. 1986, Kolenosky 1990). In addition, a number of other factors have been shown to effect bear home ranges such as social behavior and kinship (Jonkel and Cowan 1971, Garshelis and Pelton 1981), age (Reynolds and Beecham 1980, Garshelis and Pelton 1981) and reproductive class (Hellgren and Vaughan 1989).

Burt (1943) defined home range as the area in which animals acquire necessary resources and carry out their biological requirements to live. Kernohan et al. (2001) attempted to clarify and make quantifiable the definition by describing it as a probability of occurrence within a specific time period. In tandem with the evolution of the definition, researchers have also developed an evolving and diverse array of analytical techniques to calculate home range and movement (Harris et al. 1990, White and Garrot 1990, Boulanger and White 1990, Worton 1995).

METHODS

GPS and Telemetry

We monitored bears wearing GPS (Global Positioning Systems) collars from the ground once per week to determine their general location and to monitor the battery life of the GPS signal. The GPS collars were equipped with a specialized signal to warn of impending battery failure. We monitored bears wearing standard VHF collars every three to four days to determine their location and activity status (active or mortality mode). If bears wearing either collar type could not be located on their assigned schedule then two teams would search daily for the bear until located and then return to the normal monitoring protocol.

Data from the GPS collared bears were remotely downloaded using a hand-held unit that connected directly to the UHF frequency in the collar. Data were downloaded approximately every March, July, and November to secure as much data as possible in the event that the collar failed, the collar was dropped, or the animal was poached or lost.

Ground locations were determined by triangulation from a minimum of three locations taken within a one-hour interval. We made every effort to triangulate bears from ridge lines or roadways spaced half a kilometer apart, but the rugged terrain of the study area frequently prevented such optimal locations. A hand-held GPS unit was used to determine the location of the personnel taking the bearing. Collars broadcasting a mortality signal were located the next day to determine if the collar was still in the same area and still on mortality. Collars broadcasting a mortality signal for two consecutive days that did not display substantial movement from one day to the next were physically located to determine cause of death or to retrieve the dropped collar. Bear locations and error ellipses were estimated using azimuths from ground locations entered into program Locate III (Nams 2006). All radio locations were then plotted on a GIS (Geographic Information System) map of the area and analyzed using Home Range Tools for ArcGIS (Rodgers et al. 2007). Any location with an error ellipse greater than 2.5km^2 was removed from analysis.

We captured an adult female (AF1) in her den on March 04, 2004 and programmed her GPS collar to take locations as follows: 08:00 and 20:00 local mean time (LMT) during the winter (denning) period of December 1 – April 15 and every 4 hours (00:00, 04:00, 08:00, 12:00, 16:00, and 20:00) during the remainder of the year. In addition, I attempted to locate the GPS collared bear from the ground once a week. Data were downloaded every 4 – 5 months and entered into a geographic information system (GIS) and mapped.

Due to the large size of Lotek GPS collars and the possible negative effect on the health of animals wearing them, a sub-adult female (SAF1) captured on June 30, 2005 was fitted with a smaller standard VHF collar. The field team attempted to locate the VHF collar twice a week from the ground, but the rugged terrain limited our ability to obtain accurate and time-constrained locations.

Minimum convex polygon (MCP) analysis was performed for the entire length of the study (March 2004 – August 2006), each year, and for each of the three active seasons (spring: April 16 (~den emergence) – 30 June, summer: July 1 – September 15, fall: September 16 – November 31 (~den entrance). Previous Asiatic black bear home range studies mainly have used a minimum convex polygon (MCP) or a derivation thereof for their data analysis (Hazumi and Maruyama 1983 & 1986, Reid et al. 1991, Hwang 2003). Thus, to facilitate comparisons from this study to others I also performed MCP analysis. Acknowledging that fixed-kernel home range analysis (KDE) has proven to be a more realistic estimator of home ranges (Worton 1989, Harris et al. 1990, Powell et al. 1997) and a robust technique for detecting areas of concentrated use (Lawson and Rodgers 1997) I also attempted KDE techniques for home range analysis. Unfortunately, the data from the GPS collar in this study proved to be difficult to analyze with this technique. Thus, I ultimately used the 50% MCP method to determine concentrated or core use areas within an established home range. I used 100%, 95%, and 50% of the location points to obtain the MCP home range estimations. Although the 95% MCP technique has been shown to make home range estimates more precise by eliminating outlier locations and thus presents a more reliable pattern of repeated locations (Powell et al. 1997), we again included the MCP for 100% of the location so that we could compare our results with previous Asiatic black bear results reported in this manner.

RESULTS

The overall minimum convex polygon home ranges of AF1 were 107.5 km^2 (100%), 39.3 km^2 (95%), and 3.5 km^2 for 50% MCP (Table 2.1, Fig. 2.1). The overall MCP home ranges for SAF1 were 5.9 km^2 (100%), 5.8 km^2 (95%), and 2.4 km^2 (50%) (Table 2.1, Fig. 2.2). The maximum and core seasonal MCP ranges for AF1 during the three active seasons were; 8.0 km^2 (100%) and 2.0 km^2 (50%) for spring (Figure 2.3), 49.0 km^2 (100%) and 3.4 km^2 (50%) for summer (Figure 2.4), and 91.7 km^2 (100%) and 1.5 km^2 (50%) for fall (Figure 2.5). Too few location points were available to analyze SAF1's seasonal home ranges. In 2005 the 100% and 95% MCP overall, summer, and fall home ranges of AF1 all included a long distance movement this bear made from her core home range to an adjacent nature reserve in Gansu Province at a straight line distance of approximately 14 km.

AF1's 100% MCP home range size increased 94% from 6.7 km^2 in 2004 to 106.7 km^2 in 2005 (Figure 2.6). Her 50% MCP home range sizes increased 42% between 2004 (2.2 km^2) and 2005 (5.3 km^2) (Figure 2.7).

AF1's 100% MCP seasonal home range sizes increased as the year progressed from 8.0 km^2 in spring, through summer (49.0 km^2) to 91.7 km^2 in fall (Figure 2.8).

SAF1 did not display any detectable dispersal movements during the course of this study. AF1 made one large movement (~14 km) from her established home range to an adjacent nature reserve in 2005. She remained in the distant area from Aug 30, 2005 until September 30, 2005, at which time she returned to her home range where she remained until the end of the study.

DISCUSSION

It is generally accepted that males in all bear species worldwide utilize larger areas than females (Powell et al. 1997, Pelton 1982, Koehler and Pierce 2003), yet for Asiatic black bears only limited data are available to verify this (Toshihiro and Naoki 1983, Hwang 2003).

Three male Asiatic black bears collared in Tangjiahe nature reserve by Schaller (1989) and Reid (1991) had estimated home ranges from 6 km^2 - 36.5 km^2 based on 100% MCP analysis of 2 – 3, 38, and 116 locations. These home ranges would be quite smaller than the single adult female from this study at 107.5km^2 100% MCP, yet the upper range would be comparable to her 95% MCP (39.3 km^2, n=447) and the lower range to her 50% MCP (3.5km^2 n=235). Both Schaller and Reid noted inherent difficulties in documenting a complete home range as the bears were frequently out of receiver range and the authors suspected the bears to be completely outside the reserve where they could not be radio-tracked. Thus, these home ranges are minimal at best for male Asiatic black bears in Tangjiahe Nature Reserve.

In Taiwan, Mei-Hsiu Hwang (2003) recorded 100% MCP home ranges of 27 – 202 km^2 for seven males and 117 km^2 for a single female and then a revised 100% MCP for males of 24.2 – 70.8 km^2 (Hwang et al. 2010) when some locations were further scrutinized for precision. Hwang also encountered difficulties in accurately locating individuals from the ground and with obtaining reliable and consistent GPS or Satellite collar location data. Even though this study followed only two female Asiatic black bears, the GPS collared adult bear provided more data over a longer consistent time period than has been recorded thus far and likely represents a good approximation of an actual home range.

In Japan, the 100% MCP home ranges of Asiatic black bears varied widely from 3.9 – 96.0 km^2 for females and 3.2 – 123 km^2 for males (Hazumi and Maruyama 1986, Izumiyama and Shiraishi 2004). Even with the large amount of variance, the Japanese studies' relatively larger sample sizes (n = 6 and n = 7 respectively) helps clarify Asiatic black bear home range sizes yet does not detail a distinct difference in home range size between females and males.

Because of insufficient research on Asiatic black bears outside of Japan, comparisons with data recorded on the American black bear may be informative. Both species occupy a wide range of habitat types from subtropical to high elevation conifer while sharing a large degree of behavioral and ecological attributes. Compared to a variety of black bear home range studies across North America (Table 2.2), male Asiatic black bears seem to have similar home ranges as the American Black bears whereas the female Asiatic bears seem to have larger home ranges (Table 2.3). The Asiatic black bear also does not seem to exhibit the typical pattern of male home ranges being larger. This seemingly reversed home range size pattern may be more a reflection of the inability to adequately document the entirety of male Asiatic black bear home ranges.

Asiatic black bear home range size does not appear to vary greatly across the vast array of habitat types found within their range, although the estimates do tend to be highly variable. This lack of home range difference across habitats could be a function of the general difficulty in following bears across the rugged and remote areas they tend to inhabit. Long-term studies of Asiatic black bears are extremely difficult to conduct, thus detecting fine scale home range differences from habitat types or climatic regions is greatly hampered.

Study site locations for bear research in Asia tend to be confined to protected areas with minimal fragmentation and higher quality habitat. Regardless of the actual habitat type, these protected areas seem to have ample food and a relatively high level of protection from poaching. Thus, it is unlikely that adult bears captured within such areas would choose to leave the area unless there was a mast failure or if the area had reached its carrying capacity of individual bears. These types of ecological events would be detected only with long-term research projects. In this study area, a clear lack of bear sign detections within the buffer area of the reserve suggested that bears that left the protected area either moved great distances to settle far away or were quickly killed by poachers or villagers.

Excluding the research performed in Japan on Asiatic black bears, there is limited knowledge of Asiatic black bear home range size and movement patterns throughout the bear's range. Female Asiatic black bear home range information is even more incomplete. While this study obtained information on only two female Asiatic black bears, it provides strong data and a good foundation for future research into home range and movement patterns.

This study was conducted in the same ridge and valley area as the Schaller (1989) and Reid (1991) studies, yet there are still difficulties in making home range and movement comparisons. The previous studies captured and radio-tracked male bears only whereas we captured and radio-tracked female bears only. GPS collars allowed this study to accurately document bear locations even when the bear was well outside radio range including forays outside the reserve. Schaller and Reid were limited to locating individuals only where terrain and access made it possible. Also, during the early years of the Schaller and Reid studies the reserve was still being heavily logged and inhabited by both workers and villagers. By the start of this research project, the reserve had been transformed into a giant panda reserve with approximately 300 km^2 of diverse habitat that was well protected and occupied by only a small group of staff members. Regularly scheduled wildlife poaching patrols have been instituted within the giant panda inhabited zones and are instrumental in locating and removing snares in those areas.

Annual Home Range

Overall, the adult female's (AF1) 100% MCP home range (107.5 km^2) from our study fell within the already documented 100% MCP home range of female Asiatic black bears elsewhere in Asia (Hwang 2003, Izumiyama and Shiraishi 2004). AF1's home range was drastically reduced to only 39.3 km^2 when considering only the 95% MCP. The 95% MCP home range is considered a more accurate estimation as it eliminates the outliers of either single long range movements or location errors and the potentially vast areas within those points completely unused by the individual (Powell et al. 1997). In the case of our GPS collar, no significant errors in the locations were recorded. However, it is clear that at least within the study period (~2.5 yrs), AF1 made only one long range movement where she remained for approximately one month. While away from her core range, enough locations were recorded for some of this movement to be included in the 95% MCP analysis. We were unable to perform any habitat or food availability surveys in the area where AF1 spent the one month due to time and permit constraints. We did not document major mast failures within her core range that could explain her movements. When we could not find her during routine ground tracking, we performed an intensive search for her within her core range and located one active poaching camp and new wire snares set for deer along a ridge frequented by AF1. It is only speculation as to what caused the movement, but using Burt's (1943) definition of home range implies the area was "necessary" for the bear's biological requirements. Interestingly, AF1 lost her cubs during the winter of 2003 -2004 and spent 2004 within a very small core home range (6.7 km^2 n = 204). Either she did not produce cubs or they did not survive to emerge from the den during the winter of 2004 – 2005. Although the actual mating season of wild Asiatic black bears is unknown in China it is suspected that it occurs anywhere from mid June to well into fall. Thus AF1's one long range movement in 2005 into Gansu Province could have occurred during this late season mating period. She remained in Gansu Province for one month and then returned to her core fall feeding areas where she denned on 19 November. During winter 2005 – 2006 she successfully produced 2 male cubs.

Knowing nothing of the true biological reasoning for the long-range movement we must interpret the data strictly based on the resulting data points and thus assume a true home range of somewhere between 39.3 km^2 (95% MCP) and 107.5 km^2 (100% MCP).

In 2004, AF1 had a total 100% MCP home range of only 6.7 km^2 (n = 204) while in 2005 it was 106.7 km^2 (n = 164). Thus, her entire home range in 2004 was only slightly larger than her 2005 core home range of 5.3 km^2 (50% MCP). AF1's core home range data results of 3.5 km^2 (50% MCP) clearly defines the area of heavy use and biological importance.

Seasonal Home Range

AF1's 100% MCP seasonal home range increased in size through the three active seasons, likely a result of food availability and denning issues. Bears emerge from dens in Tangjiahe in late spring when food is most scarce. Following emergence, female bears tend to stay close to the den area and consume food items such as insects, grass, and forbs that can be found nearby. In summer, as fruits and berries become available in lower elevations, bears concentrate in these areas. Hard mast, the bears' most important food source, ripens in fall. Since not all hard mast species ripen at the same time or in the same place, bears continually move to find and consume this most important food source. To survive winter denning, bears must enter the dens with large amounts of fat stores, mostly derived from consuming massive amounts of hard mast. During this time bears must also find and prepare den sites. Den sites in Tangjiahe tend to be located at high elevations within a bear's core home range.

The yearling female's (SAF1) overall 100% MCP home range was only 5.9 km^2 (N = 36), well within the wide range of documented female Asiatic black bear home ranges across Asia. In addition, her home range was comparable to AF1's 2004 annual home range of 6.7 km^2 (100% MCP). SAF1 stayed very close to the area where she was trapped and at relatively low elevations along the river drainage and main roadway. I was unable to collect a sufficient number of location data points to examine SAF1's yearly or seasonal movements.

I did not document any dispersal or long range movement by SAF1 due to the limited time her collar was operational. I detected a movement away from her home range eastward into the reserve buffer zone toward the village (Fig 2.9). Her movements and locations are not included in any home range analysis because we could not get accurate locations from the ground due to very rugged terrain and the collar's failing signal. We first found her in the eastern area on July 24, 2006 and then again further south into the buffer zone on August 9, 2006. These eastward movements took SAF1 approximately 1.3 km and 1.7 km straight line distance from the eastern edge of her established home range She seemed to be moving toward the villages and as such we offered a small cash reward for any verifiable sightings of the bear as well as a reimbursement for any crop damage she caused. We offered the reward in an attempt to protect the young female bear and the villagers while also documenting and intervening if any human-bear interactions occurred. On August 11, 2006 SAF1 was back in her established home range, with no known interactions with humans or their crops. Her collar stopped transmitting shortly after this time and thus no more data were collected.

Although long-term studies are costly and difficult to complete, we believe that they are the only way to truly gain insight into the actual home range and movements patterns of such a large, long-lived species like the Asiatic black bear. This research is a small, but important step in the right direction toward a better understanding of the spatial ecology of the Asiatic black bear.

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Table 2.1 Minimum Convex Polygons of two Female Asiatic Black Bears in Tangjiahe Nature Reserve, Sichuan Province, China**:** Home range seasonal and yearly variability over the course of the study.

	% Minimum Convex Polygon		
	100	**95**	**50**
AF1[a] – All Locations	107.5 km^2 n = 470	39.3 km^2 n = 447	3.5 km^2 n = 235
AF1 – 2004 Locations	6.7 km^2 n = 204	5.6 km^2 n = 194	2.2 km^2 n = 102
AF1 – 2005 Locations	106.7 km^2 n = 164	100.6 km^2 n = 156	5.3 km^2 n = 82
AF1 – Spring Locations	8.0 km^2 n = 175	5.8 km^2 n = 167	2.0 km^2 n = 88
AF1 – Summer Locations	49.0 km^2 n = 146	48.9 km^2 n = 139	3.4 km^2 n = 73
AF1 – Fall Locations	91.7 km^2 n = 100	70.3 km^2 n = 95	1.5 km^2 n = 50
SAF1[b] – All Locations	5.9 km^2 n = 36	5.8 km^2 n = 35	2.4 km^2 n = 18

[a] AF1 – Adult female no. 1
[b]SAF1 – Sub-adult female no. 1

Table 2.2 American black bear home ranges from regions across North America. Shown here are male and female home range sizes in km^2 along with the analytical techniques used by various researchers across North America.

Location	Male	Female	Analysis Method	Source
<u>Northern Region</u>				
Alberta Canada	119	20	95% Min. Area	Young and Ruff (1982)
Maine	17	43	100% MCP	Hugie (1982)
Michigan	150	69	100% MCP	Manville (1983)
Wisconsin	71	14	100% MCP	Kohn (1982)
<u>Western Region</u>				
California	22	17	100% MCP	Novick and Stewart (1982)
Idaho	60	12	100% MCP	Reynolds and Beecham (1980)
Washington	5	2	100% MCP	Lindzey and Meslow (1977)
<u>Eastern Region</u>				
Arkansas	90	35	100% MCP	Clark (1991)
Massachusetts	318	28	100% MCP	Elowe (1984)
North Carolina	39	12	100% MCP	Seibert (1989)
Pennsylvania	173	41	95% Jenrich and Turner Index	Alt et al. (1977)
Tennessee	21	8	100% MCP	Garshelis and Pelton (1980)
Virginia	112	27	100% MCP	Hellgren and Vaughan (1989)
West Virginia	204	49	Bivariate normal	Brown (1980)

Southern Region

Florida	170	28	100% MCP	Wooding and Hardisky (1994)
Louisiana	60	4	95% MCP	Weaver (1999)
Mississippi	81	11	95% MCP	White (1996)

Table 2.3 Asiatic black bear home ranges from various countries in Asia. Shown here are 100% MCP for male and female home range sizes in km^2 documented by various researchers, including this study.

Location	Male (N)	Female (N)	Source
China			
NW Sichuan	6 (1)		Schaller et al.(1989)
NW Sichuan	36.5 (1)		Reid et al.(1991)
NW Sichuan	5.1 (1)		Reid et al.(1991)
NW Sichuan		**5.7 – 107.5 (2)**	**This Study**
Japan			
Mid-Western Japan	3.22-28.1 (3)	3.92-12.88 (3)	Hazumi and Maruyama(1986)
Central	33 (1)	20 (1)	Ohsako (1995)
Central	45-123 (3)	33-96 (4)	Izumiyama and Shiraishi (2004)
Taiwan			
Central Mts.	24.2-70.8 (7)	117.1 (1)	Hwang et al. 2010

Figure 2.1 Adult female Asiatic black bear minimum convex polygon (50%, 95%, and 100%) home ranges from Tangjiahe Nature Reserve, Sichuan Province China from 2004 - 2006.

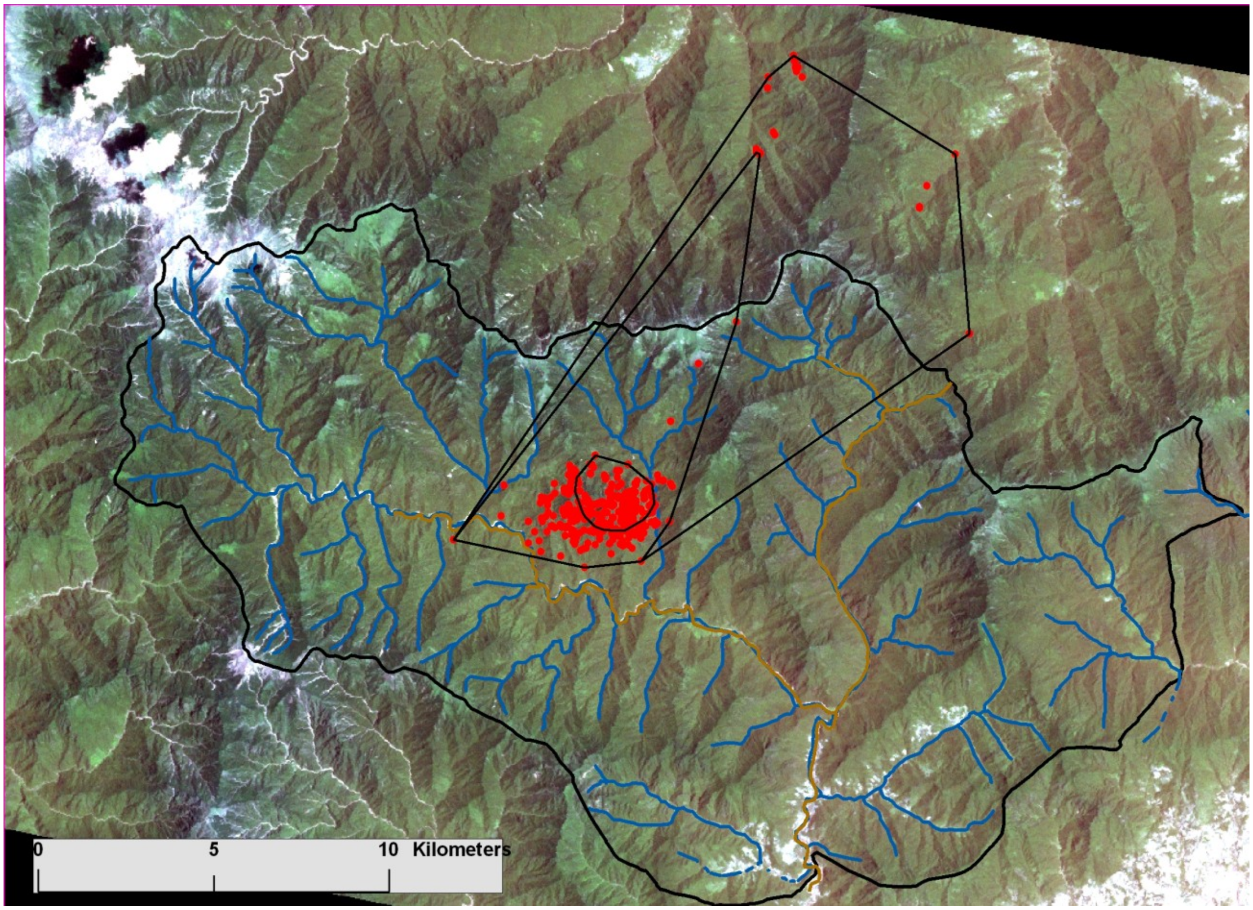


Figure 2.2 Overall sub-adult female Asiatic black bear minimum convex polygon (50%, 95%, and 100%) home range sizes from Tangjiahe Nature Reserve, Sichuan Province China from 2005 – 2006. The black squares are village homes.

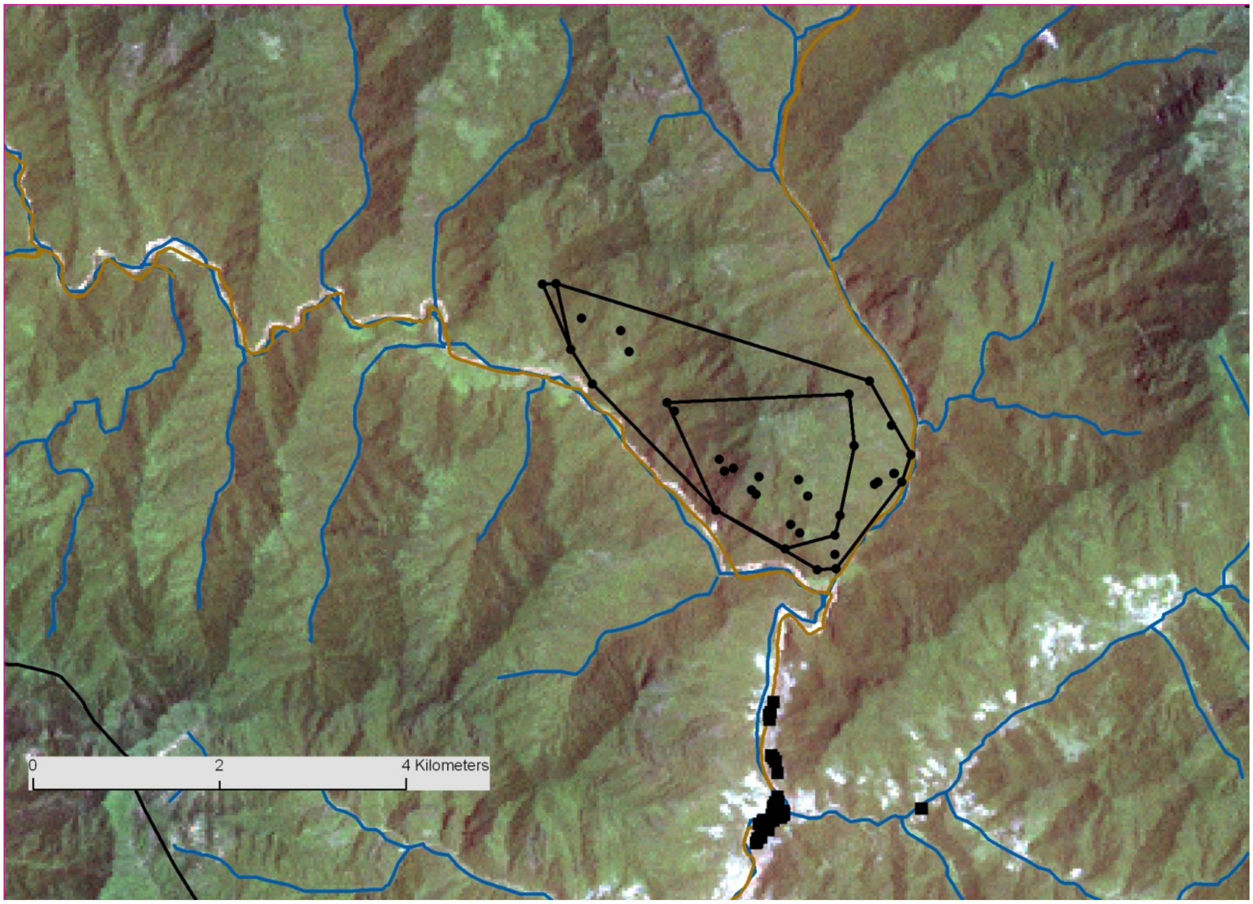


Figure 2.3 Adult female Asiatic black bear spring seasons from 2004 – 2006 minimum convex polygon (50%, 95%, and 100%) home range sizes from Tangjiahe Nature Reserve, Sichuan Province China.

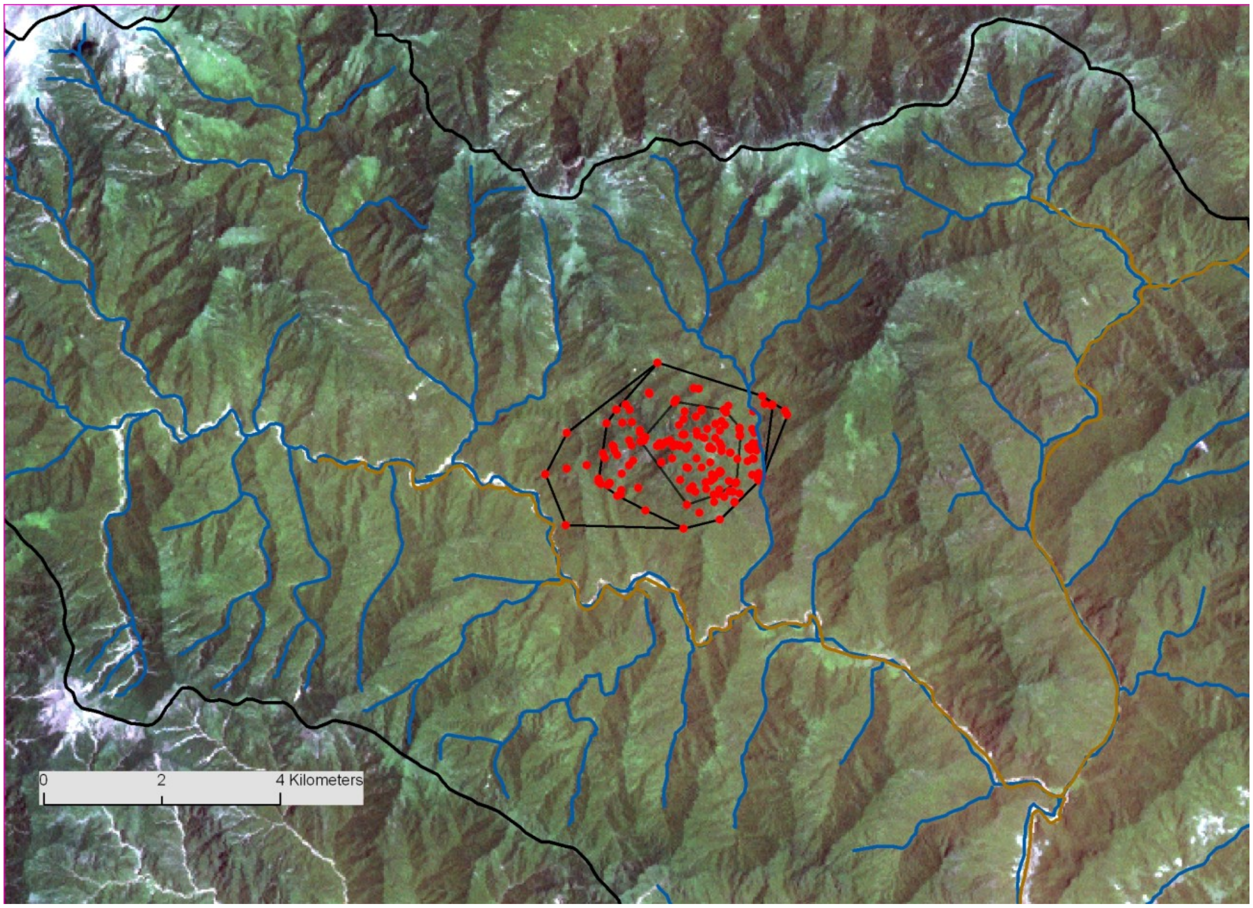


Figure 2.4 Adult female Asiatic black bear summer seasons from 2004 - 2006 minimum convex polygon (50%, 95%, and 100%) home ranges from Tangjiahe Nature Reserve, Sichuan Province China.

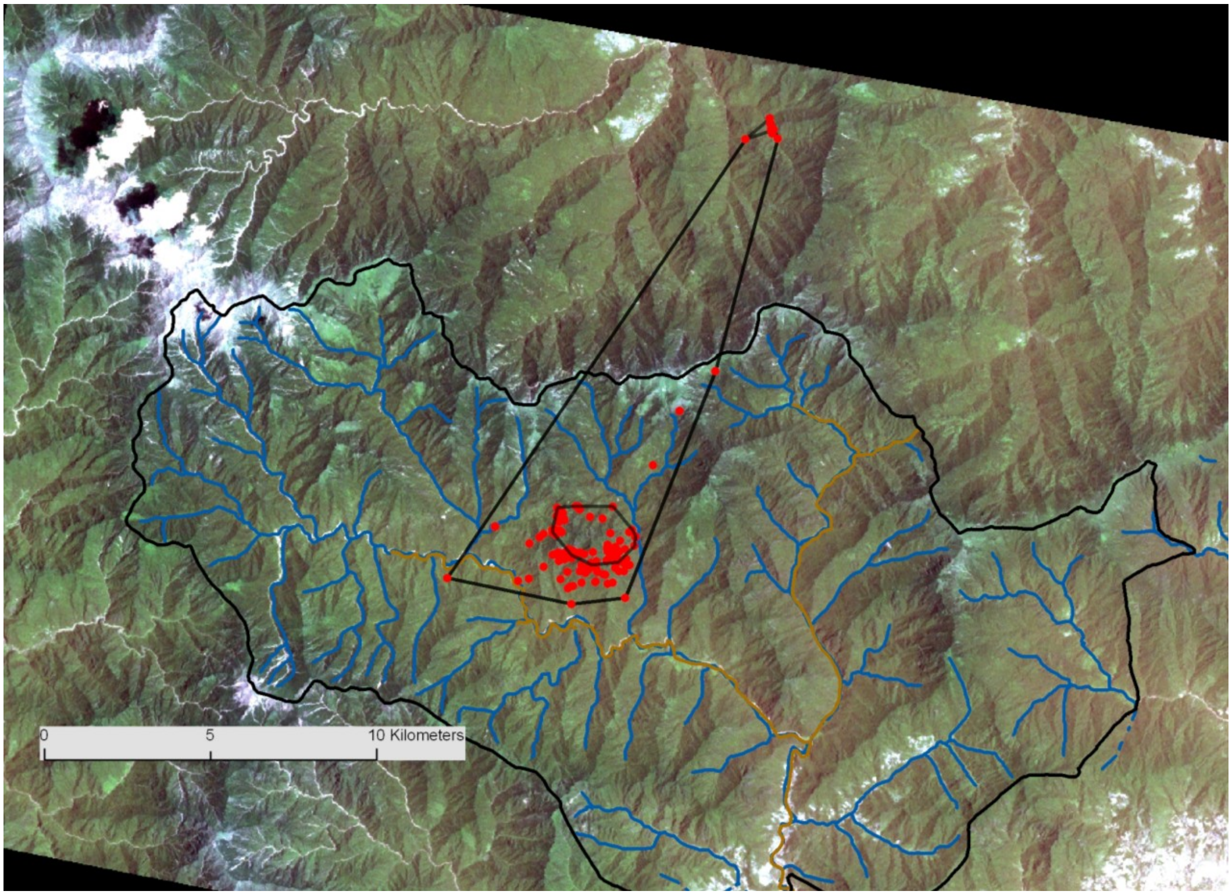


Figure 2.5 Adult female Asiatic black bear fall seasons 2004 – 2006 minimum convex polygon (50%, 95%, and 100%) home ranges from Tangjiahe Nature Reserve, Sichuan Province China.

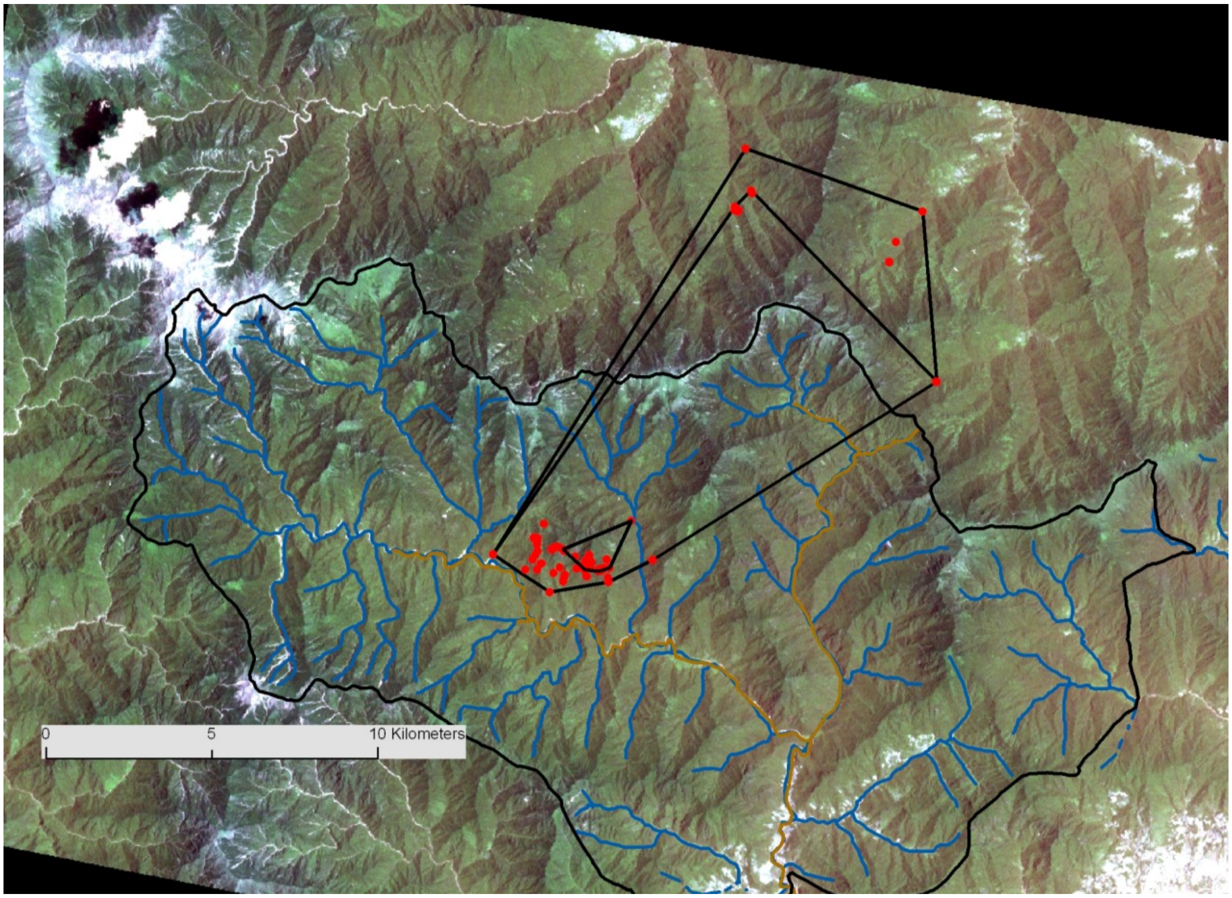


Figure 2.6 Adult female Asiatic black bear 100% minimum convex polygon home range comparisons from 2004 (red circles and border) and 2005 (black triangles and border) from Tangjiahe Nature Reserve, Sichuan Province, China.

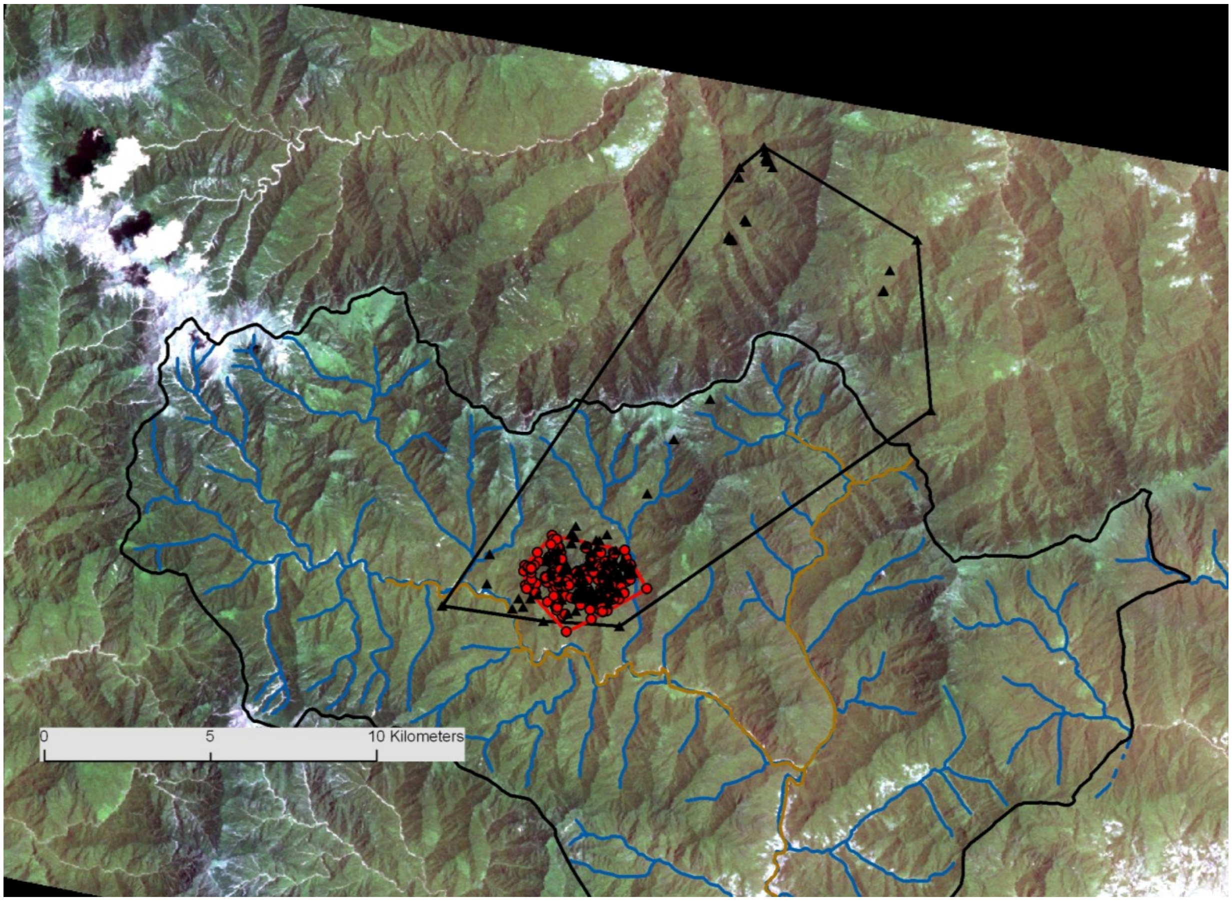


Figure 2.7 Adult female Asiatic black bear 50% minimum convex polygon "core" home range comparisons from 2004 (red circles and border) and 2005 (black triangles and border) from Tangjiahe Nature Reserve, Sichuan Province, China.

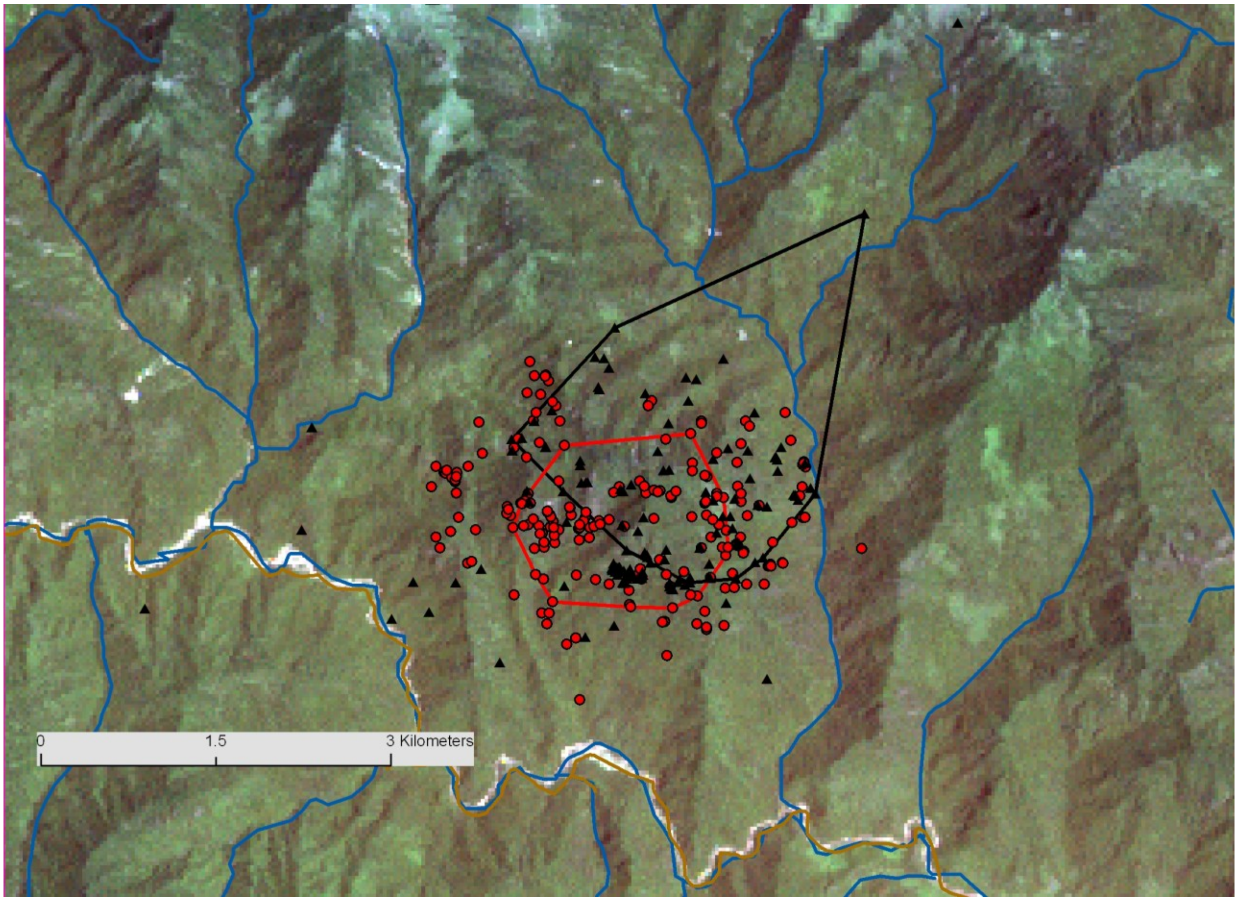


Figure 2.8 Adult Asiatic black bear seasonal; green – spring, red – summer, black – fall, 100% minimum convex polygons from 2004 – 2006 in Tangjiahe Nature Reserve, Sichuan Province, China.

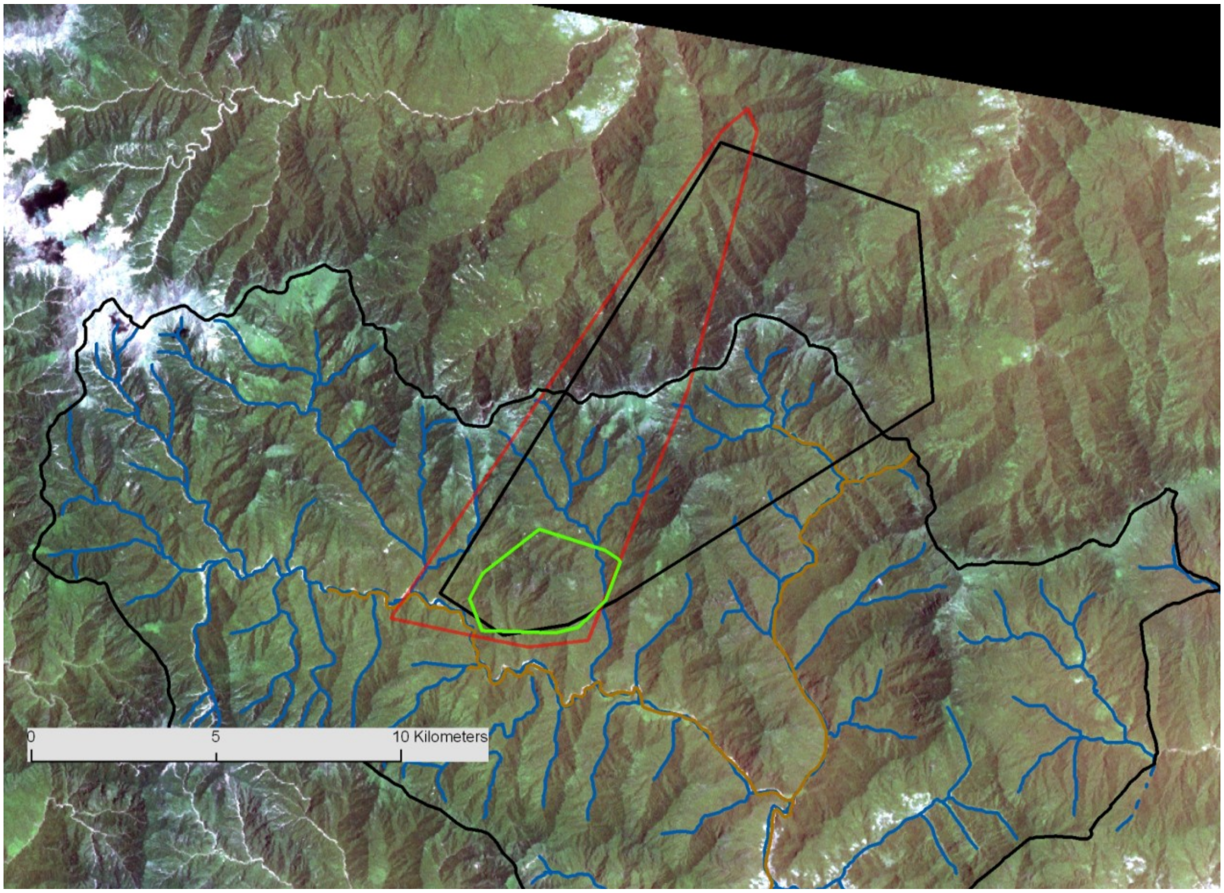
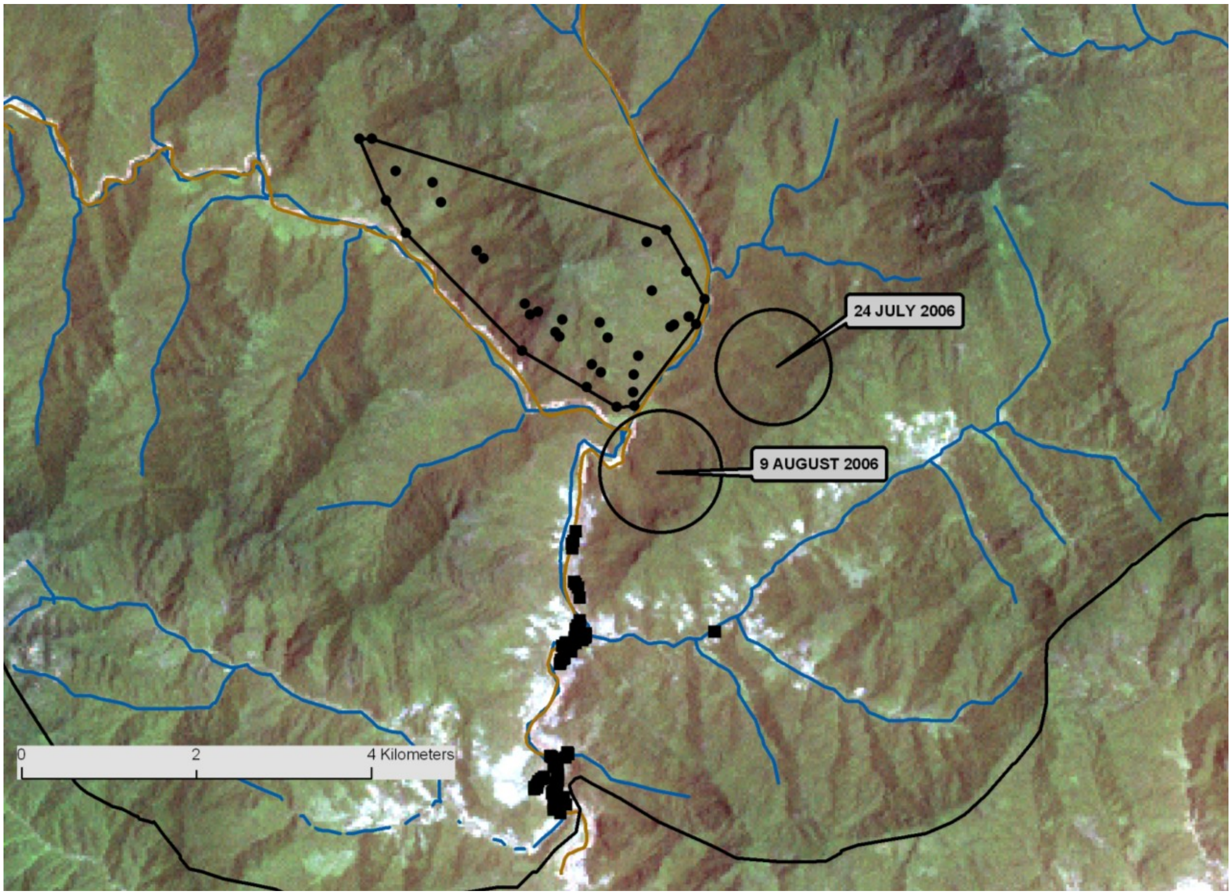


Figure 2.9 Sub-adult female locations (black dots), 100% MCP (black border), and movements (large open circles) recorded from Tangjiahe Nature Reserve, Sichuan Province China from 2005 - 2006. The black squares are known village houses.



*The two dated circles represent approximate locations of the yearling female outside her established home range. Neither location was included in any home range analysis because of poor quality locations. Thus these are only estimates of her actual location.

CHAPTER 3: OCCUPANCY MODELING OF ASIATIC BLACK BEARS IN TANGJIAHE NATURE RESERVE, SICHUAN PROVINCE, CHINA USING SIGN SURVEYS

INTRODUCTION

To effectively protect rare or endangered species, managers require an understanding of the patterns and dynamics of the occurrence of the species. But complete and long-term animal surveys are rarely feasible as a tool for conservation or management. Researchers are increasingly using modeling of species occurrence data, or detection/non-detection data, to advance such conservation initiatives as reserve or protected area planning and management (Cocks and Baird 1989, Araújo and Williams 2000, Williams and Araújo 2000, Polasky and Solow 2001, and Johnson et al. 2004). Occupancy modeling also can be used to address questions of abundance (Royle and Nichols 2003, MacKenzie and Nichols 2004, Royle et al. 2005, and Pearce and Boyce 2006) and colonization and extinction (MacKenzie et al. 2003 and Barbraud et al. 2004). With the development of remote sensing technologies, researchers also can assess the distribution, extent, and availability of natural resources even across vast landscapes and remote areas. Coupling remote sensing resource data with a basic understanding of a species range and biological needs, researchers can utilize modeling techniques to predict species occurrence and change in occupancy over time within any given area. Thus, occurrence modeling has become a powerful tool in the investigation of current ecological systems, aiding in monitoring the effects of changing ecological patterns on biological diversity (Yoccoz et al. 2001).

There are many different approaches to using detection/non-detection data to estimate species presence and site occupancy (MacKenzie et al. 2002, Royal and Nichols 2003, O'connell et al. 2006). Guisan and Zimmerman (2000) reviewed many of the presence-absence or used-unused models while Pearce and Boyce (2006) reviewed models that used only presence data. Thompson (2004) edited an entire volume that detailed an array of techniques developed for and tested on a variety of species that are either rare or elusive. MacKenzie et al.'s (2006) occupancy modeling technique and computer program PRESENCE is one of the more robust methods to analyze occupancy data of all types (MacKenzie et al. 2002, 2003, Royle and Nichols 2003).

One of the main concerns when performing any type of occupancy survey for a species is that the species may go undetected when it is actually present. This not only results in an underestimation of occupancy, but can also have serious consequences on any inferences made about habitat use and the related value of the habitat to the species (Gu and Swihart 2004, MacKenzie 2006). The MacKenzie et al. (2002) basic occupancy modeling methodology addresses the issue of imperfect detection by incorporating the probability of detecting the species into the model. This approach should lead to a much more accurate estimation of occupancy

In China, Asiatic black bears tend to inhabit remote mountain areas and occur in very low density. Trapping and radio-tracking an adequate sample size of bears to accurately predict their distribution and occupancy is extremely difficult. Kendall et al. (1992) demonstrated the utility of using sign surveys to monitor the population trends in grizzly bears in the western United States. Therefore, this study employed sign survey methodologies (MacKenzie and Royle 2005) to examine both Asiatic black bear occupancy and resource use. Previous studies have employed a range of methods to examine the relationship between species occupancy and habitat covariates (Mladenoff et al. 1995, Wiser et al. 1998, Odom et al. 2001and Scott et al. 2002). Asiatic black bears proved to be an ideal species for this kind of research as they leave unique and long lasting detectable sign during their feeding activity. This methodology seems to be one of the few ways to gather a sufficient data set in which to model the Asiatic black bear's population distribution and habitat use in China. This study combined the use of bear sign surveys with occupancy modeling techniques in program PRESENCE as detailed by MacKenzie et.al (2006) to determine habitat use and landscape scale occupancy of the Asiatic black bear in Tangjiahe Nature Reserve Sichuan Province, China.

METHODS

Using the 1 km^2 grids (n = 42) selected according to the method described in greater detail in previous chapters, we established four (except for one grid where only three transects were feasible) fixed-width strip transects (100m X 20m) within each. Transects were placed deliberately within each grid in an attempt to distribute them across the entire grid area while also ensuring we would be able to complete the 100 meter survey. The surveys were located in this manner due to the Tangjiahe's steep, cliff-ridden terrain. Data recorded from starting point of transect included elevation, slope, aspect, habitat type, age of the forest and dominant canopy trees. Each bear sign found was recorded and assigned an estimated age. The sign was aged as fresh (< 3 months), < 1 year (3 months - 12 months), 1 year (12 – 24 months), and 2+ years (older than 24 months) based on color, moisture content, and general degradation. We established reference claw marks on various species of trees with a pocket knife within the local area to replicate the climatic conditions affecting natural marks and monitored them through a ~1.5 year period as a visual reference guide for ageing transect sign.

A hard and soft mast index was determined by tallying each mast producing item within the transect that was mature enough to produce mast. For analysis at the grid level all mast tallies within the grid were averaged. The index was then standardized for inclusion in the model.

Within each transect, every positively identified bear sign was recorded along with type of sign (feeding platforms, claw marks, scats, ground diggings, rock rolling, and other); approximate age of sign; GPS location of sign; and species and diameter at breast height of trees upon which sign was found. The transect data were recorded into program PRESENCE as 1s and 0s denoting detection and non-detection respectively within the grid. Using the detection history data and the general likelihood method described by MacKenzie et al. (2002) detection probability (*p)* and site occupancies (Ψ) were calculated for Asiatic black bears within the study area. We further analyzed the data using each transect as a site and the age of the bear sign (0-1 year old, 1-2 years old, 2+ years old) found as a surrogate for three repeat sampling occasions along that transect. We then analyzed the resulting data of detection/non-detection and associated variables using three different model sets.

The first model employed 42 1 km^2 grids with 4 transect surveys as the "repeat" sampling occasions per grid (except one with only 3). I built a second model based on transect level data, from all 200 transects completed during this study, by utilizing the 3 ages of bear sign along transects as the "repeat" visits. For example, if bear sign was detected along the transect within the <1 year old and 2+ years old categories, then the transect occupancy data would be recorded as being occupied 2 years before and during the present year but not during the time period of 1 – 2 years ago (i.e.101). Using the same sign aging technique, I built a third model based only on the transect data collected during 2005 (n = 119) and 2006 (n = 48) because we collected additional site variables (hard mast index, and soft mast index) during these years and wanted to analyze them within PRESENCE, which does not allow for missing covariates. PRESENCE ranks all models with the same data set according to the Akaike's Information Criterion (AIC) (Akaike 1973). AIC is a numerical ranking tool for model outputs and the lower its value the better the model "fits" the data provided (MacKenzie and Bailey 2004).

Within PRESENCE, covariates can be added into the model to determine the relative importance of that covariate on the detection and/or occupancy of the species of concern. Therefore, we analyzed all variable data collected within each transect to determine their effect on the probability of occupancy by Asiatic black bears (Table 3.1). Based on environmentally important attributes from previous studies (Schaller et. al. 1989, Reid et. al. 1991, and Hwang et. al. 2002) we chose to evaluate conservation category, habitat type, forest age, hard mast, soft mast, elevation, aspect, and slope. The refuge conservation category was considered to be a surrogate for the level of protection Asiatic black bears had within the study site.

The covariate data analyzed for the 42 grid occupancy modeling method included: protection category (core, experimental or buffer), habitat type (deciduous, deciduous-broadleaf evergreen mix, deciduous-conifer mix, shrub/human disturbed, or conifer), elevation, forest age (less than 10 years, 10 – 25 years, or over 25 years), hard mast index (the average number of mature hard mast trees recorded), and soft mast index (the average number of mature soft mast producing vegetation).

The second survey occupancy model, using the three sign ages as "repeat" visits, analyzed the 167 transects performed in 2005 and 2006. This model had the most extensive covariate data collected and included: protection category (core, experimental, or buffer), habitat type (deciduous, deciduous-broadleaf evergreen mix, deciduous-conifer mix, shrub/human disturbed, or conifer), forest age (less than 10 years, 10 – 25 years, and greater than 25 years), slope, elevation, aspect, hard mast index, and soft mast index.

The covariate data collected for the 200 transect occupancy modeling method included: protection category (core, experimental or buffer), habitat type (deciduous, deciduous-broadleaf evergreen mix, deciduous-conifer mix, shrub/human disturbed, or conifer), elevation, and aspect.

Currently, there are two types of models that can be fit to detection/non-detection data within PRESENCE. The first is the single season model detailed by MacKenzie et al. (2002), which assumes the sites are closed to changes in the state of occupancy for the duration of sampling for the species. The second is the multiple season extension (MacKenzie et al. 2003) where occupancy can change from season to season, but not during the surveying period. It is also important to note that the target species may or may not be detected during a survey, but should never be falsely detected when actually absent. To ensure that we did not have false detections, all sign was verified by two staff personnel. If there was any doubt about a sign, it was eliminated in the final data analysis.

The assumptions of MacKenzie's single season model are that all parameters are constant across sites, that the occupancy state of the site does not change over the duration of the survey, and that the sites have closure at the species level. Since the closure assumption is at the species level, some movement of individuals into and out of sites does not significantly affect the model outcome.

Grid Occupancy Modeling

Transect data were recorded in the same manner for all three analysis methods, as a vector of 1s and 0s indicating detection and non-detection respectively. The resulting outcomes can be either that the site was occupied and bears were detected ($\Psi * p$), the site was occupied, but bears were not detected ($\Psi * (1-p)$), or the site was not occupied and bears were not detected ($1 - \Psi$). Covariates can be continuous (using z transformation) or categorical. Categorical covariates are entered as a series of 0s and 1s much like detection data, except a 1 entered within a covariate category indicates the presence of that particular covariate and a 0 indicates its absence. Within the grid method, Asiatic black bear detection probabilities were estimated through multiple sampling occasions (3 - 4 transects) within each grid.

Transect Occupancy Modeling

Within the transect level method, Asiatic black bear detection probabilities were estimated using the age of bear sign found on the transect as a surrogate for 3 repeat sampling occasions. I felt this was a valid methodology since the most common types of bear sign (platforms and claw marks) typically last for many years. We did this to assess the efficacy of using such a historical single survey to discern changes over a 3-year time period in landscape or habitat use by Asiatic black bears. Such a survey would prove to be an important and extremely useful tool for the rapid assessment of the occupancy of bears throughout their range in China. Thus, each sign detected along the survey was considered to be a bear occupancy occurrence for that given year (i.e. within the present year, the previous year, and 2 or more years past). This provided us with a vector of detection / non-detection occurrences for three sampling occasions at the same site just as repeated visits to a site would. During the 2005 and 2006 surveys, we increased the number of recorded variables at each survey to determine any fine scale environmental factors that affected the occupancy of the site. Since occupancy modeling does not allow for missing covariate data, we performed separate analysis on these two data sets.

RESULTS

Grid Occupancy Modeling

The baseline analysis of detection/non-detection data for 42 sites (with 4 sampling occasions and only 1 missing observation) (Table 3.2) yielded a naïve (# sites with sign/total sites samples) occupancy estimate of 0.81. The detection probability was 0.68 (0.042(SE)) and the derived occupancy was 0.82 (0.062(SE)).

Based on the AIC values and the closeness of the ΔAIC's value from all the models run (Table 3.3), the best fitting models (i.e., Delta AIC $\leq$ 2.00) for the grid occupancy all had a constant probability of detection [p(.)] and had the protection category as an important covariate in the equation. The top model was simply constant probability of detection and probability of occupancy being determined by the protection category covariate with the higher protection level producing higher likelihood of occupancy (core; ß = 83.43 0.00(SE), experimental; ß = 44.55 0.74(SE), buffer; ß = -41.11 0.74(SE)) for the grid (Table 3.4). Two other models are also considered top models as their ΔAIC's are very close to the top model's with 0.20 for an additive effect model of protection category and soft mast and 0.25 for an additive model with protection category and elevation

Transect Occupancy Modeling

The analysis of all 167 sites (3 sampling occasions and 0 missing observation) data resulted in a naïve occupancy estimate of 0.60. The detection probability was 0.48 (0.036 SE) and the derived occupancy was 0.70 (0.051 SE).

The resulting AIC values (Table 3.5) indicated only one of the 46 models was clearly the best fitting model (constant probability of detection and occupancy probability derived from an additive model of protection category, soft mast, and slope) (Table 3.4). The results detail a relatively large separation between the top models' ΔAIC (0) and the second best fitting model's ΔAIC (3.28). Nevertheless, the top three models once again had the covariate protection category as a common component as well as soft mast, slope, and aspect in various configurations as common covariates of importance.

The analysis of the 200 transect data (with 3 sampling occasions and 0 missing observation) yielded a naïve occupancy estimate of .57. The detection probability was 0.48 (0.034 SE) and the derived occupancy was 0.66 (0.046 SE).

Based on the AIC values and the closeness of the ΔAIC's value from all the models run, (Table 3.6) the best fitting 4 models for the 200 survey occupancy all had a constant probability of detection [p(.)] and had the protection category covariate in the equation. The top model was again the constant probability of detection with the probability of detection being determined by the protection category covariate for the survey (Table 3.4). Three other models are also considered competing models as their ΔAIC's are very close to the top model's with 0.19 for an additive effect model of use and aspect, 0.71 for an additive model with protection category and habitat, and lastly with 1.48 for an additive effect model with protection category and elevation.

DISCUSSION

Occupancy modeling has become a widely applied technique especially when a species is rare or elusive such as the Asiatic black bear in China. The black bear's rarity may increase and occupancy estimation can be used to examine changes in proportion of area occupied through time, giving us valuable insight into bear conservation in the absence of data on abundance, which is prohibitively difficult to obtain.   .

Even though the naïve occupancy estimates are calculated by means of simple division (# sites with sign / total sites sampled), they serve to illustrate an important difference that will resurface with models that calculate occupancy estimates from both raw data and detection probabilities. The naïve estimates from the 200 and 167 survey level models are fairly comparable at 0.57 and 0.60 respectively. Yet the naïve estimate 0.81 for the grid (n = 42) level model is much higher due to the larger landscape scale of the sampling unit. The issue of scale is present in most types of occupancy or distributional modeling so it warrants caution here as well.

Detection Probabilities

The detection probabilities from the transect level modeling scenarios, 0.70 (0.05 SE) for the 167 surveys and 0.48 (0.03 SE) for the 200 surveys, exhibit a wide margin of difference even though the survey sample size difference (n = 33) is relatively small. This difference could stem from effects exerted on the calculation by the relatively high percentage of surveys with zero sign detected (i.e. a site with no sign in any age class) during the surveys performed the first year (2004) of the study (57.6%, n = 19) when compared to the second and third years (40.1% n = 67). Thus, the most reliable survey level detection probability would be 0.48 (0.034 SE) from the all-inclusive (n = 200) model which should smooth the effects from the time of data collection. The detection probability at the grid level, 0.68 (0.042 SE), is as expected, greater than the 200 survey level probability due to the larger scale of analysis.

Occupancy Estimations

Given the relatively high level of wildlife protection and abundant hard and soft mast within the Tangjiahe Nature Reserve, the 82% occupancy estimation rate from the grid level surveys for Asiatic black bears is not unexpected. Prior to our research, it was widely thought by Chinese university professors, forestry officials, and prior researchers (Schaller et. al. 1989, Reid et. al. 1991) that Tangjiahe was a haven for Asiatic black bears and that they thrived within its borders. In fact, one reason the reserve was chosen for this research was the high likelihood of successfully collecting an adequate sample size to be able to employ occupancy modeling techniques. While an 82% occupancy rate for a large carnivore would be impressive in most any protected area, it is an amazing feat in mainland China, where the demand for land access and natural resources is fast outpacing the supply. However, an 80% Asiatic black bear occupancy rate across the entire Tangjiahe Nature Reserve is possible when considering that bears can travel large distances, leave sign that lasts for years, and the relative small size of Tangjiahe Nature Reserve (~300 km^2). Outside the protected borders of the reserve the occupancy rate would be far less and likely less stable over time.

The transect level occupancy estimations, 47.7% and 66.1% for the 167 transect level model and the 200 transect level model respectively, were considerably less than the 82% from the grid level surveys. This difference is likely due to both the scale difference and survey methodology between the grid level (1km^2) and the transect level (200m^2) analysis. The grid surveys employed 4 independent surveys performed across the $1km^2$ area and would have detected sign left within the four transects over the past three years. Whereas the transect level survey relied on a bear leaving detectable sign within a particular small patch of habitat during the past three years. On a landscape scale (i.e. the entire reserve) the resulting 82% occupancy estimate from the grid surveys is likely the most accurate representation of the area of the reserve occupied by bears at some time over a relatively short time period (1 – 2 years). The bears tracked during this study showed a fairly small core occupied area of 2.4 km^2 and 3.5 km^2 for the sub-adult female and adult female respectively that would result in an intense use of the area and abundant sign. Yet the adult female also exhibited long distance movement patterns wherein exist possibilities for the deposition of sign over a much larger area (107.5 km^2). An occupancy rate of 82% is certainly plausible especially with such abundant and detectable bear signs (claw marks and feeding platforms) being made by each individual bear.

Although landscape level occupancy was best determined from the grid surveys the transect survey analysis provided valuable insight into the ecological basis for the selective use of some habitats and resources within a Asiatic black bears home range in Tangjiahe Nature Reserve.

The large discrepancy in occupancy rates between the grid level and the survey level analysis illustrates the need for caution when attempting to apply a sign survey methodology within very large grid cells. Since it takes only one detected sign within a grid for the entire grid to be labeled “occupied,” it becomes apparent that the presumed occupied area could very well be overestimated greatly. Due to the longevity (5+ years for large feeding platforms) of some types of Asiatic black bear sign, there is also the possibility of identifying a grid as occupied that in reality has not been occupied for many years. Therefore careful consideration should be given to choosing a grid size that can be surveyed sufficiently across the entire area while providing biologically significant data without inflating the occupancy area too greatly.

An even greater cautionary approach would need to be taken if resulting occupancy estimations were to be used by extension of the hypothesis that occupancy is closely linked with abundance (Holt et al. 2002) in an attempt to ascertain bear abundance for fear the results may present a false impression of the actual bear abundance and population trends. In an attempt to coarsely map the distribution of Asiatic black bears throughout Sichuan Province, Liu et al. (2009) employed a $15km^2$ grid sign survey method. In most cases the authors were led directly to bear sign by villagers, after which the researchers marked the entire grid occupied. They recognized and reported the high likelihood of occupancy area overestimation due to scale issues.

I believe the key to developing an accurate moderate scale Asiatic black bear distribution map lies in the use of a more appropriate grid size such as 4-5 km^2 (the approximate core area of the female bears recorded in this study). There must be some independent repetition of the surveys within the grid and appropriate covariate data should be recorded at all transects.

Occupancy Estimations with Covariates

By adding covariates into the models, we were able to fine tune our understanding of the landscape and resource selection processes of the Asiatic black bears within the study area. Since the 42 grids had the least amount of input data to work with statistically, we analyzed only six covariates for that model (Table 3.1). Given that the protection category covariate was present in all three top models (i.e. $\Delta AIC < 2.0$), this points to the importance of the level of protection for wildlife since occupancy increased with better protection. The protection category represents levels of protection afforded a particular zone within the study area (Fig. 3.1). The protection level extends from the core areas of intense patrolling and zero legal resource extraction to the buffer area where there is no patrolling and intensive resource extraction.

While most researchers likely would incorporate this type of covariate simply as the distance to the villages, Figure 3.2 suggests that the causes of the negative impact on bear occupancy within the study area are a combination of accessibility, including known trails and connections along ridgelines, and the lack of enforcement patrols. In the southern region of the study area, Figure 3.2 clearly illustrates an extreme negative impact on bear occupancy from the proximity of villages and the extensive trail system emanating from the village as well as all associated resource degradation issues such as poaching, poisoning, firewood and other resource collection, and livestock grazing (Tangjiahe National Nature Reserve Management Plan 2005) that take place within the buffer protection category. The buffer zone is dominated by farmland, shrub/scrub, and ~10 year coppice forest harvested for firewood (Fig 3.3) or mushroom production (Fig 3.4). There are also natural alpine oak forests at the higher elevation within the buffer zone. Our surveys within other shrub/scrub and alpine oak forest within protected zones successfully documented bear sign, and it is assumed that even though inferior to deciduous oaks and chestnuts, alpine oak acorns should suffice as a food source for bears. Therefore, there should be detectable sign of bear use within the buffer area given the presence of bears. Yet we recoded no bear sign within any of the habitats or elevations within the buffer zone. There is also a complete lack of enforcement patrolling anywhere in the buffer zone.

Within the reserve, Figure 3.2 also shows a depressed bear occupancy rate along the west road and in a radiating pattern from the tourist hotel area. While the tourist area impact is most likely due to human activities such as loud noises, walking trails, extensive apiaries, firewood, food, and medicinal herb collection, the north road displays no such depressed occupancy. Both the west and north road are heavily traveled by tourists and both have extensive apiary sites, yet only the north road has an established conservation patrol route, which seems to be having an impact in protecting bears along the route. The low occupancy rates should serve as advanced warning of the increasing encroachment on the bear population in the southern region and along the west road within the reserve.

When examining the four covariates used for the 200 surveys level model, it is again obvious that the best fitting model has a constant probability of detection and the probability of occupancy determined by the protection category. In fact, the top three all have the protection category as a main factor in determining the probability of occupancy and the top model had protection as the only determining covariate with a constant probability of detection.

We were able to analyze a large host of covariates (Table 3.1) with the 167 surveys level model, yet the results were overwhelmingly that the protection category again played a primary role in determining occupancy. Protection category again showed up in all three top models. The best fit model (Protection category + Soft Mast + Slope) was an additive one that incorporated what were two of the most important factors affecting the Asiatic black bear in Tangjiahe Nature Reserve: adequate protection and the availability of soft mast. In a heavily dominated hard mast-producing forest like Tangjiahe, spring and summer soft mast food resources are very important to bear occupancy, just as the model illustrates. The slope covariate in the top model is more likely a result of our own slope limitations when trying to perform field surveys. Bears in the rugged mountains of Tangjiahe are not likely limited or affected by the steepness of the terrain.

One objective of this research in the Tangjiahe Nature Reserve on Asiatic black bears was to develop and test methods to aid in the conservation of large carnivores. This study has shown that simple, low cost research methodologies can produce a rich array of ecological data on Asiatic black bears. By joining those data collection methodologies with the growing field of occupancy modeling, results can be used and applied in a far greater capacity. This study has provided the basic framework to a greater understanding of the landscape and ecological needs of the Asiatic black bear; and, by pairing those data with occupancy modeling, a powerful tool has been developed for the conservation of the Asiatic black bear in China and throughout its range.

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Table 3.1. Listing of environmental variables recorded from 2004 – 2006 and analyzed in the Tangjiahe Nature Reserve, Sichuan Province, China using three occupancy models. Due to additional variables being recorded during the second and third years of the study and since the analysis does not allow for missing values for covariates, survey level models had to be run separately. Variable data is entered either as a vector of 1s and 0s (1 indicating that particular variable was present in the survey and 0 indicating it was absent) or as standardized numerical data.

Covariates Analyzed	Model 1 Grids (n = 42)	Model 2 Transects (n = 167)	Model 3 Transects (n = 200)
Protection Category	X	X	X
Habitat	X	X	X
Avg. Elevation	X	X	X
Forest Age	X	X	
[a]Hard Mast Index	X	X	
[b]Soft Mast Index	X	X	
Slope		X	
Aspect		X	X

[a] Hard mast index is the average number of mature hard mast producing trees recorded on the survey.
[b] Soft mast index is the average number of mature soft mast producing vegetation recorded on the survey.

Table 3.2 Asiatic black bear sign detection (1) or non-detection (0) results for 42 1km^2 grids within the Tangjiahe Nature Reserve, Sichuan Province, China. Note that a (-) indicates a survey was not done.

Conservation Category*	Survey 1	Survey 2	Survey 3	Survey 4
B	0	0	0	0
B	0	0	0	-
B	0	0	0	0
B	0	0	0	0
B	0	0	0	0
B	0	0	0	0
B	0	0	0	0
E	0	0	0	0
E	1	1	1	1
E	1	1	0	1
E	0	0	1	0
E	1	0	1	1
E	1	1	0	0
E	1	0	1	0
E	1	0	1	1
E	1	0	1	1
E	0	0	0	1
E	1	0	0	1
E	1	1	0	1
E	0	1	0	1
E	1	1	0	0
E	1	0	1	1
E	1	1	1	0
E	1	1	1	0
E	1	1	0	1
E	0	0	1	1
E	1	0	1	1
E	1	1	1	0
E	1	1	1	1
E	0	1	1	1
E	1	1	1	1
C	1	1	1	0
C	0	1	1	0
C	1	1	1	1
C	1	1	1	1
C	1	0	0	1
C	1	1	0	0
C	1	1	1	0
C	1	1	0	1
C	0	1	1	1
C	1	1	0	1
C	1	0	0	1

* B = buffer, E = experimental, C = core

Table 3.3 Results from PRESENCE, ranking occupancy models for 42 grids surveyed for bear sign 3 – 4 times within a 1 km^2 area in Tangjiahe Nature Reserve, Sichuan Province, China from 2004 – 2006.

Model	AIC	ΔAIC	AIC Wgt.	Model Likelihood	No. Par	-2*LogLike
p(.)psi(PC)	185.55	0.00	0.2957	1.0000	4	177.55
p(.)psi(PC + Smast)	185.75	0.20	0.2676	0.9048	5	175.75
p(.)psi(PC + Elevation)	185.80	0.25	0.2610	0.8825	5	175.80
p(.)psi(PC + Hmast)	187.55	2.00	0.1088	0.3679	5	177.55
p(.)psi(ForAge)	191.18	5.63	0.0177	0.0599	4	183.18
p(.)psi(Forage + Elevation)	191.39	5.84	0.0160	0.0539	5	181.39
p(.)psi(ForAge + Smast)	191.80	6.25	0.0130	0.0439	5	181.80
p(.)psi(Habitat + PC)	192.03	6.48	0.0116	0.0392	8	176.03
p(.)psi(Forage + Hmast)	192.98	7.43	0.0072	0.0244	5	182.98
p(.)psi(Habitat + ForAge)	197.14	11.59	0.0009	0.0030	8	181.14
p(.)psi(Habitat)	200.48	14.93	0.0002	0.0006	6	188.48
p(.)psi(Habitat + Elevation)	200.81	15.26	0.0001	0.0005	7	186.81
p(.)psi(Habitat + Hmast)	202.31	16.76	0.0001	0.0002	7	188.31
p(.)psi(Habitat + Smast)	202.35	16.80	0.0001	0.0002	7	188.35
p(.)psi(Elevation)	203.50	17.95	0.0000	0.0001	3	197.50
p(.)psi(Elevation + Hmast)	204.20	18.65	0.0000	0.0001	4	196.20
p(.)psi(Elevation + Smast)	204.43	18.88	0.0000	0.0001	4	196.43
p(.)psi(Hmast)	215.55	30.00	0.0000	0.0000	3	209.55
1 group, Survey-specific p	216.85	31.30	0.0000	0.0000	5	206.85
2 groups, Constant p	217.71	32.16	0.0000	0.0000	4	209.71
2 groups, Survey-specific p	224.26	38.71	0.0000	0.0000	10	204.26

p = probability of detection; p(.) = constant probability of detection; psi = probability of occupancy; PC = Protection category; Smast = Soft mast index; Hmast = Hard mast index; ForAge = Forest age.

Table 3.4 Coefficient and standard error estimates from the top 4 occupancy models derived from sign surveys performed in Tangjiahe Nature Reserve, Sichuan Province, China 2004 – 2006.

Model	Parameter	Estimate (SE)
42 grids sites:		
1. p(.)Ψ(PC)	Ψ(Core)	83.43 (±0.000)
ΔAIC = 0.00	Ψ(Experimental)	44.55 (±0.737)
	Ψ(Buffer)	-41.12 (±0.737)
2. p(.)Ψ(PC + Smast)	Ψ(Core)	174.40 (±0.000)
ΔAIC = 0.20	Ψ(Experimental)	84.35 (±0.823)
	Ψ(Soft Mast)	-1.53 (±1.347)
	Ψ(Buffer)	-80.06 (±0.823)
3. p(.)Ψ(PC + Elevation)	Ψ(Core)	81.01 (±0.000)
ΔAIC = 0.25	Ψ(Experimental)	47.47 (±0.845)
	Ψ(Elevation)	2.26 (±1.079)
	Ψ(Buffer)	-42.65 (±0.845)
4. p(.)Ψ(PC + Hmast)	Ψ(Core)	138.67 (±0.000)
ΔAIC = 2.00	Ψ(Experimental)	67.32 (±0.737)
	Ψ(Hard Mast)	0.01 (±0.893)
	Ψ(Buffer)	-63.89 (±0.737)
167 transect sites:		
1. p(.)Ψ(PC + SMast + Slope)	Ψ(Core)	59.47 (±2.022)
ΔAIC = 0.00	Ψ(Experimental)	59.14 (±2.942)
	Ψ(Soft Mast)	0.89 (±2.839)
	Ψ(Slope)	-0.87 (±2.074)
	Ψ(Buffer)	-57.81 (±3.570)
2. p(.)Ψ(PC + SMast +Aspect)	Ψ(Core)	38.76 (±2.105)
ΔAIC = 3.28	Ψ(Experimental)	38.41 (±2.977)
	Ψ(Soft Mast)	0.72 (±2.964)
	Ψ(Aspect)	0.48 (±3.420)
	Ψ(Buffer)	-37.15 (±3.663)
3. p(.)Ψ(PC + Slope + Aspect)	Ψ(Core)	42.93 (±1.777)
ΔAIC = 3.65	Ψ(Experimental)	42.74 (±2.891)
	Ψ(Aspect)	0.52 (±3.349)
	Ψ(Slope)	-0.87 (±1.850)
	Ψ(Buffer)	-41.36 (±3.394)

4. p(.)Ψ(PC + SMast)	Ψ(Core)	37.99	(±2.155)
ΔAIC = 4.07	Ψ(Experimental)	37.68	(±2.996)
	Ψ(Soft Mast)	0.72	(±3.027)
	Ψ(Buffer)	-36.39	(±3.691)

200 transect sites:

1. p(.)Ψ(PC)	Ψ(Core)	1.44	(±0.516)
ΔAIC = 0.00	Ψ(Experimental)	1.39	(±0.379)
	Ψ(Buffer)	0.00	(±3162)
2. p(.)Ψ(PC + Aspect)	Ψ(Core)	32.66	(±2.260)
ΔAIC = 0.19	Ψ(Experimental)	32.63	(±3.371)
	Ψ(Aspect)	0.34	(±3.904)
	Ψ(Buffer)	-31.35	(±4.059)
3. p(.)Ψ(PC + Habitat)	Ψ(Core)	26.48	(±2.126)
ΔAIC = 0.71	Ψ(Experimental)	26.23	(±3.267)
	Ψ(Dec/Conifer)	2.89	(±1.323)
	Ψ(Dec/Evergreen)	2.14	(±1.634)
	Ψ(Deciduous)	1.92	(±2.719)
	Ψ(Shurb/Disturbed)	1.43	(±1.459)
	Ψ(Buffer)	-27.04	(±3.898)
4. p(.)Ψ(PC + Elevation)	Ψ(Core)	36.30	(±2.334)
ΔAIC = 1.48	Ψ(Experimental)	36.03	(±3.358)
	Ψ(Elevation)	-0.22	(±4.030)
	Ψ(Buffer)	-34.81	(±4.089)

p(.) = constant probability of detection; Ψ = probability of occupancy; PC = protection category; Smast = soft mast index, HMast = hard mast index

Table 3.5 Results from PRESENCE, ranking occupancy models from 167 bear sign surveys performed in the Tangjiahe Nature Reserve Sichuan Province, China from 2005 – 2006. The aged sign left from the previous two years served as the repeat visits to the sites.

Model	AIC	ΔAIC	AIC Wt.	Model Likelihood	No. Par.	-2logLike
p(.)psi(PC + SMast + Slope)	573.98	0.00	0.5682	1.0000	6	561.98
p(.)psi(PC + SMast + Aspect)	577.26	3.28	0.1102	0.1940	6	565.26
p(.)psi(PC + Slope + Aspect)	577.63	3.65	0.0916	0.1612	6	565.63
p(.)psi(PC + SMast)	578.05	4.07	0.0743	0.1307	5	568.05
p(.)psi(PC + Slope)	578.75	4.77	0.0523	0.0921	5	568.75
p(.)psi(PC + Elevation +SMast)	579.80	5.82	0.0310	0.0545	6	567.80
p(.)psi(PC + Aspect)	580.19	6.21	0.0255	0.0448	5	570.19
p(.)psi(PC)	581.01	7.03	0.0169	0.0297	4	573.01
p(.)psi(PC + Elevation)	582.13	8.15	0.0097	0.0170	5	572.13
p(.)psi(Habitat + PC)	582.74	8.76	0.0071	0.0125	8	566.74
p(.)psi(PC + HMast)	582.77	8.79	0.0070	0.0123	5	572.77
p(.)psi(PC + Elevation + HMast)	583.95	9.97	0.0039	0.0068	6	571.95
p(.)psi(PC + ForAge)	584.92	10.94	0.0024	0.0042	6	572.92
p(.)psi(Habitat + SMast)	598.78	24.80	0.0000	0.0000	7	584.78
p(.)psi(Habitat + Slope)	600.88	26.90	0.0000	0.0000	7	586.88
p(.)psi(ForAge + SMast)	601.74	27.76	0.0000	0.0000	5	591.74
p(.)psi(Slope + ForAge)	603.30	29.32	0.0000	0.0000	5	593.30
p(.)psi(Habitat)	603.50	29.52	0.0000	0.0000	6	591.50
p(.)psi(Slope + SMast)	604.07	30.09	0.0000	0.0000	4	596.07

p = probability of detection; p(.) = constant probability of detection; psi = probability of occupancy; PC = protection category; Smast = Soft mast index; Hmast = Hard mast index; ForAge = Forest age.

Table 3.6 Results from PRESENCE, ranking occupancy models from 200 bear sign surveys performed in the Tangjiahe Nature Reserve Sichuan Province, China from 2004 – 2006. The aged sign left from the previous two years serves as the repeated visits to the sites.

Model	**AIC**	**ΔAIC**	**AIC Wgt.**	**Model Likelihood**	**No. Par**	**-2*LogLike**
p(.)psi(PC)	664.70	0.00	0.3239	1.0000	4	656.70
p(.)psi(PC + Aspect)	664.89	0.19	0.2945	0.9094	5	654.89
p(.)psi(PC + Habitat)	665.41	0.71	0.2271	0.7012	8	649.41
p(.)psi(PC + Elevation)	666.18	1.48	0.1545	0.4771	5	656.18
p(.)psi(Habitat)	698.33	33.63	0.0000	0.0000	6	686.33
p(.)psi(Habitat + Aspect)	699.45	34.75	0.0000	0.0000	7	685.45
p(.)psi(Habitat + Elevation)	700.22	35.52	0.0000	0.0000	7	686.22
2 groups, Constant P	716.51	51.81	0.0000	0.0000	4	708.51
p(.)psi(Elevation)	717.24	52.54	0.0000	0.0000	3	711.24
p(.)psi(Aspect)	718.24	54.17	0.0000	0.0000	3	712.87
1 group, Constant P	720.78	56.08	0.0000	0.0000	2	716.78
2 groups, Survey-specific P	722.80	58.10	0.0000	0.0000	8	706.80
1 group, Survey-specific P	723.63	58.93	0.0000	0.0000	4	715.63

p = probability of detection; p(.) = constant probability of detection; psi = probability of occupancy; PC = protection category

Figure 3.1 Designated protection category boundaries of Tangjiahe Nature Reserve, Sichuan Province, China, 2007. The buffer area (dark gray) have little to no protection patrols and thus experience very high exploitation by villagers from habitation, farming, grazing, firewood cutting, hunting, and food and herb collecting. All tourist activities and reserve infrastructure are limited to the experimental area (light gray) where patrols are minimal and mainly along the roadways. Within the core area (white), it is illegal to remove, destroy or disturb any natural resource while having the most intensive patrolling regime. The core area contains all of the known giant panda habitat as well as the most well-preserved forest areas in Tangjiahe.

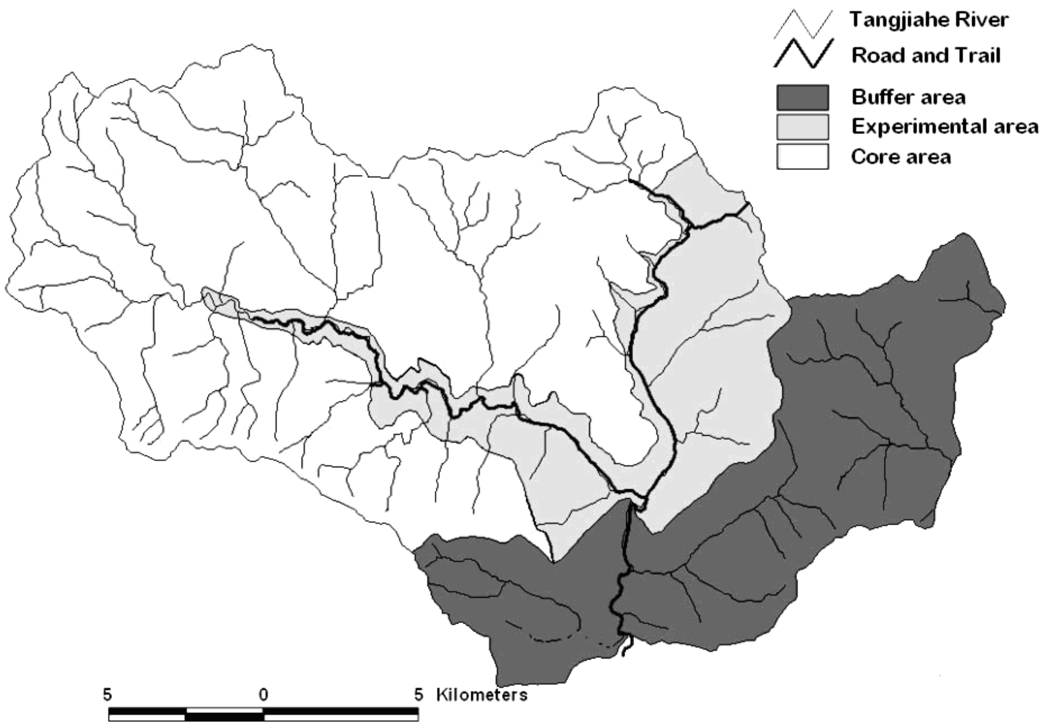

Figure 3.2 Tangjiahe Nature Reserve in Sichuan Province, China with 42 grid level occupancy survey results detailed. We completed 4 sign survey transects within each colored 1 km^2 grid. The color gradient represents the % of transects within that grid that had at least one Asiatic black bear sign detected. Note that the grids with no detections (red) are all within the Qinxi village buffer use area and along the lower entrance road. There are no regular patrols in this area and farming, firewood, herbs, and food harvesting are also allowed. In theory there is no hunting allowed in the buffer area, but in fact a vast network of wildlife kill snares are set throughout the area.

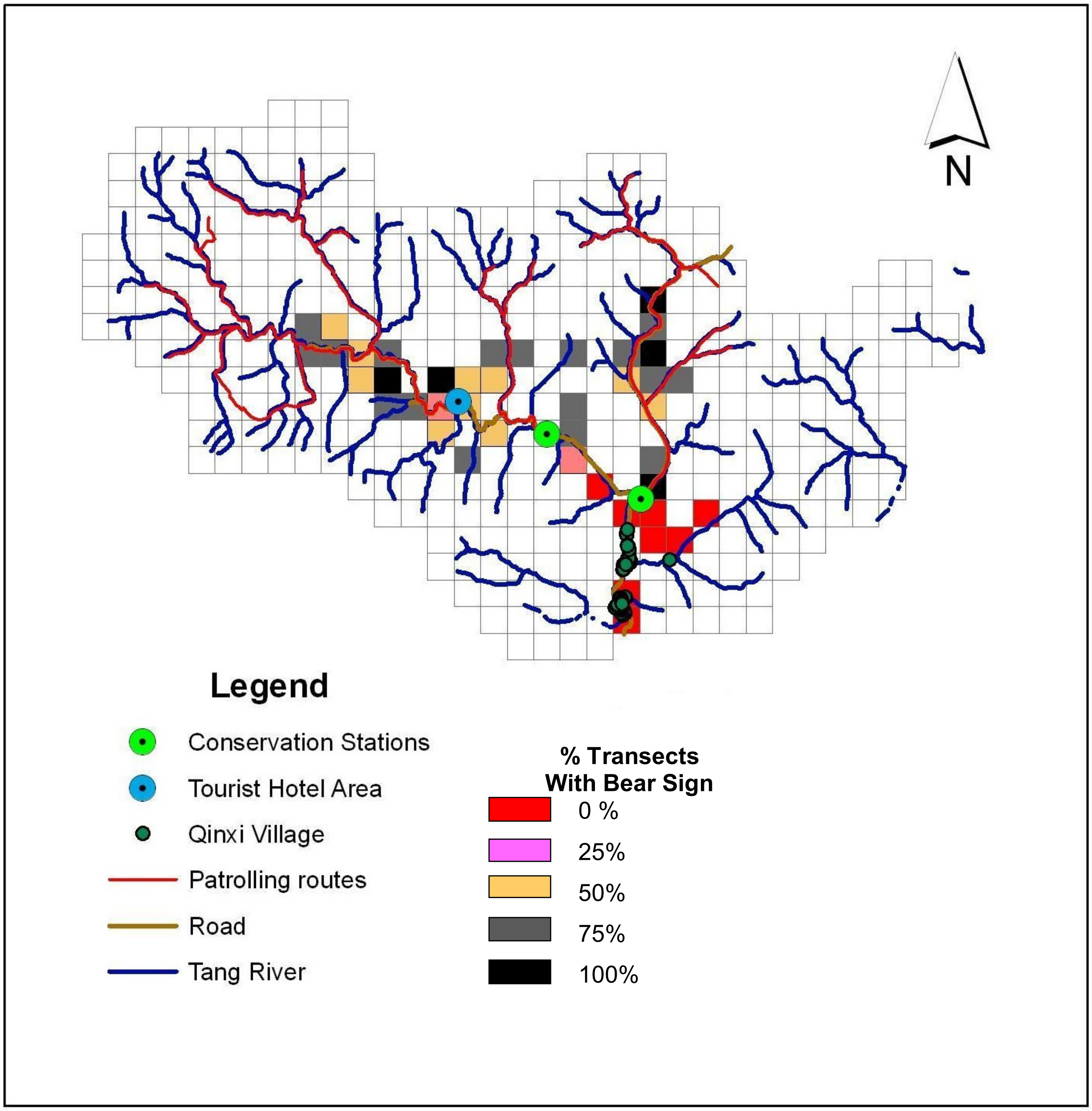

Figure 3.3 Harwood firewood collected from the buffer zone of Tangjiahe Nature Reserve, Sichuan Province, China. The forest in the buffer zone is a mixed deciduous forest dominated by oak tree species yet the trees never reach maturity. The hardwood forest is kept in a near-perpetual 10-year old coppice rotational harvest for firewood. Thus, the area does not produce a sufficient hard mast crop to sustain most species of wildlife, especially bears.

Figure 3.4 Mushroom production in the buffer zone of Tangjiahe Nature Reserve. The harvested hardwood trees are left to dry on the ground as seen in Figure 3.3. Any tree that begins to sprout edible mushrooms is separated from the firewood and placed into these mushroom lean-tos to provide an important local food source for the villagers.