Food habits of American black bears as a metric for direct management of human–bear conflict in Yosemite Valley, Yosemite National Park, California

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Abstract: The management of human–American black bear (*Ursus americanus*) conflict has been of significant concern for Yosemite National Park (YNP) personnel since the 1920s. Park managers implemented the YNP Human–Bear Management Plan in 1975 in an effort to reduce human–bear conflicts, especially in the extensively developed Yosemite Valley (YV). We used scat analysis to estimate annual and seasonal food habits of black bears in YV during 2001–02. We assessed the success of efforts to reduce the availability of anthropogenic foods, including garbage, by examining changes in the diet compared to a study from 1974–78 (Graber 1981). We also quantified consumption of non-native fruit to address its possible contribution to human–bear conflicts. The annual percent volume of human-provided food and garbage in black bear scats in YV decreased from 21% to 6% between 1978 and 2002, indicating YNP efforts have been effective. We found high use of non-native apples by bears throughout YV. Non-native food sources could be contributing to habituation and food conditioning, given their proximity to developed areas of YV. We recommend that YNP managers continue to (1) adapt and improve their management tools to address changing circumstances, (2) quantify the success of new management tools, and (3) reduce the availability of non-native food sources.

Key words: American black bear, California, food habits, habituation, human–bear conflict, non-native vegetation, tourism, *Ursus americanus*, Yosemite National Park, Yosemite Valley

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Yosemite National Park (YNP) in California, USA, has a long history of human–bear conflict dating back to the infancy of tourism in the region in the 1920s. It has long been recognized in YNP and in other areas of high human use that human presence significantly alters the behavior and ecology of American black bears (Hastings et al. 1981, Tate and Pelton 1983, Keay and Webb 1989, Mattson 1990, Keay 1995, Thompson and McCurdy 1995, Beckmann and Berger 2003, Matthews et al. 2006). Human–black bear conflicts are especially pronounced at the interface of wild and developed areas (Beckmann and Berger 2003), such as the Yosemite Valley (YV) region of YNP. These areas offer the greatest opportunities for developing effective management strategies aimed at reducing human–bear conflict and to measure success of these strategies.

The National Park Service initiated the Human–Bear Management Program in YNP in 1975 to address negative human–black bear interactions (National Park Service 1975, 2003a; Thompson and McCurdy 1995). Goals of the program included restoring and maintaining the natural distribution, abundance, and behavior of the black bear population; providing for the safety of visitors and their property; and providing opportunities for visitors to understand, observe, and appreciate black bears in their natural habitat.

Since the program's initiation, YNP managers have employed a number of strategies to reduce the availability of anthropogenic foods to bears (National Park Service 1975, 2003a; Thompson and

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McCurdy 1995). They replaced all outdoor garbage receptacles with bear-resistant models; increased the frequency of garbage pick-up; installed bear-resistant food-storage containers at all front-country campsites and many backcountry trailheads; required the use of bear-resistant food canisters by backpackers; prohibited overnight storage of food in vehicles; implemented a diverse public information and education campaign; and employed additional education and law enforcement staff.

The presence of fruit-producing, non-native vegetation in YV could be a contributing factor to human–bear conflict levels. Several non-native apple orchards and Himalayan blackberry (*Rubus armeniacus* Focke) thickets are close to developed areas throughout YV, serving as a bear attractant and creating potential for human–bear conflict. Some park managers have become increasingly concerned that bears may be attracted to the abundant fruit in these areas of high human density and become habituated to people. Additionally, the location of the apple orchards may be unacceptably close to human-populated areas in YV, where, despite the best efforts, some foods may eventually be available to bears frequenting the area, leading to food-conditioning. Food-conditioned behavior may lead to a loss of fear of humans and aggressive displays, which threaten visitor safety (McArthur Jope 1983, Herrero 2002). Habituated bears are more likely to be involved in human–bear incidents, may exhibit aggressive behavior toward people, and stand a greater chance of being killed by park personnel to protect human safety and property (Gilbert 1989, Mattson et al. 1992).

Our first objective was to determine the success of management efforts to reduce the availability of anthropogenic foods to bears through a quantification of annual and seasonal bear food habits. Graber (1981) quantified bear food habits in YV prior to the implementation of management actions aimed at reducing the consumption of human food by bears. Graber's (1981) results served as a baseline from which to compare our current results and the success of these management actions. Our second objective was to quantify the consumption of non-native vegetation by bears in YV and address its possible contribution to human–bear conflicts.

Study area

Yosemite National Park encompasses approximately 308,000 ha on the west slope of the Sierra Nevada range in central California. Our efforts were conducted in the approximately 1,800 ha of Yosemite Valley, on the western slope of the park at approximately 1,200 m in elevation. Average temperatures in YV range from 12 to 32°C in the summer to −3 to 8°C in the winter; average precipitation is 92 cm/year, 87% of which falls between November and April (National Oceanic and Atmospheric Administration 2003). The vegetation of YV was composed primarily of mixed conifer, with prevalent species being ponderosa pine (*Pinus ponderosa*), incense cedar (*Calocedrus decurrens*), and California black oak (*Quercus kelloggii*) (Barbour and Major 1977).

The floor of YV is heavily affected by human development. Although YV comprises only 3% of YNP's area, 90% of the nearly 3.5 million people who visit YNP annually stop there (Keay and Webb 1989, National Park Service 2003b). Approximately 45% of the YNP's nearly 2,000 campsites and most of the 1,600 lodging units for park visitors and employees are located in YV. Accommodations include 2 major hotels with, combined, 372 rooms in addition to 4 restaurants, 2 swimming pools, tennis courts, 2 horse stables, several grocery stores, a bus system, and a medical and dental clinic. Additionally, 62% of human–bear conflicts documented in the park between 1989 and 2002 occurred in YV (Matthews et al. 2003).

Methods

A total of 500 bear scat samples were collected opportunistically in YV between 20 July and 1 November 2001 and between 29 March and 4 November 2002. Home range estimates of radio-marked bears showed high degrees of overlap and completely encompassed YV (Matthews et al. 2003). Thus, opportunistic scat collection during ground-based telemetry tracking used to develop these home range estimates ensured samples were collected from areas representative of the YV used by bears. A potential bias of the sampling design was possible oversampling in areas where scats were readily observed (i.e., apple orchards) and undersampling where scats were less obvious.

We aged samples based on moisture content of the scat at the time of collection. Seventy-nine of the 162 samples collected in 2001 and 198 of the 338 samples collected in 2002 were judged to be <2 weeks old and were categorized as spring (20 Mar–21 Jun), summer (22 Jun–23 Sep), or fall (24 Sep–22 Dec) for analyses

(Graber 1981). These samples, as well as the 223 samples estimated to be >2 weeks old at time of collection, were used to quantify annual bear food habits in YV.

We employed the same scat analysis methods used by Graber (1981) to facilitate a comparison of findings between the 2 studies. Each of our samples was either oven-dried (2001) or sun-dried (2002), rehydrated in water with a surfactant, and passed through a series of sieves (1 mm and 0.4 mm, H&C Sieving Systems, models 6998 and 7003, Columbia, Maryland, USA) to separate equal-sized particles for identification. Food items were identified macroscopically and with the use of a dissecting microscope (Vanguard, model 1200SH, Kirkland, Washington, USA). Each item was categorized into forage classes: human foods (including garbage and human-intended food); reproductive plant parts (including flowers, fruit, and seeds); herbage (including roots, stems, and leaves); animal matter; and debris (including items inadvertently consumed or collected, such as wood, bark, stones, and pine needles). Food items were keyed to species when possible.

Seasonal and annual black bear food habits were quantified by determining the proportion of the 5 forage classes identified in scat samples. Percent volume of each forage class was measured by water displacement to the nearest 1%. However, volumetric analysis alone tends to overestimate the proportion of herbage eaten and underestimate more easily digested reproductive plant parts and animal foods (Hatler 1972, Poelker and Hartwell 1973, Mealey 1980, Graber 1981, Graber and White 1983). To more accurately assess food habits, we also calculated the percent frequency of occurrence of food items as the percent of total scat samples in which an item comprised >1% of the volume of a sample (Graber 1981, Graber and White 1983). Our study was confined to YV; therefore, we compared our results to the YV-specific results of Graber (1981), which were synthesized into a YNP-wide analysis for Graber and White (1983). Although Graber and White (1983) reported both percent volume and percent frequency of occurrence, Graber (1981) only reported percent volume; therefore, only direct comparisons of volume were possible.

Results

Anthropogenic foods comprised 6% fecal volume and occurred in 22% of bear scats found in YV between 2001 and 2002 (Table 1). Seasonally, anthropogenic foods were more abundant in scats collected during the summer (3% by volume and 20% by frequency of occurrence) than in those collected in the spring or fall (Table 1).

Reproductive plant parts were the most prevalent items in fecal remains of black bears in YV, comprising 51% of fecal volume and present in 83% of all scats annually, and were most prevalent in the summer and fall (Table 1). Reproductive plant parts primarily included apple, *Rubus* spp., manzanita (*Arctostaphylos* spp.), and acorn (*Quercus* spp.). Apples were prevalent in collected fecal samples, comprising an average of 31% fecal volume, and were represented in 57% of all samples. During summer, apples averaged 60% of dietary volume and occurred in 79% of scat samples. We were unable to determine the prevalence of Himalayan blackberries because of macroscopic similarities to native western raspberries (*Rubus leucodermis*). However, berries (including Himalayan blackberries) and fruit (excluding apples) comprised 16% of fecal volume and occurred in 38% of scats collected annually. Other food items in this forage class were blue elderberry (*Sambucus mexicana*), western chokecherries (*Prunus demissa*), coffeeberry (*Rhamnus* spp.), dogwoods (*Cornus* spp.), gooseberries and currents (*Ribes* spp.), thimbleberries (*Rubus* spp.), and Sierra plum (*Prunus subcordata*). Acorns were a prevalent food for bears during fall, comprising an average 31% of fecal volume and present in 54% of scats.

Herbage was the second most prevalent forage class, comprising 29% of fecal volume and present in 44% of all samples annually. Herbage was most prevalent in spring (Table 1) and included graminoids and graminoid-like plants such as sedges and rushes, leaves and stems, and forbs. The most common items in this forage class were graminoids, comprising 25% of total scat volume and present in 38% of all samples (Table 1). Frequently consumed graminoids included *Poa* spp., *Avena* spp., and *Agrostis* spp. Frequently consumed forb species during our study included *Trifolium* spp., *Montia* spp., and *Lupinus* spp. Horsetail (*Equisetum* spp.) was present in 2.2% of all samples. Yampah (*Perideridia* sp.) and an unidentified mushroom were found in at least one sample each. Club moss (*Isoetes* spp.) was present in trace amounts during the spring.

Animal matter comprised 3% of fecal volume, occurred in 35.4% of scats collected annually, and

Table 1. The percent volume (vol) and percent frequency (freq) of occurrence of food items found in black bear scats ($n = 500$) collected in Yosemite Valley, Yosemite National Park, California, 2001 and 2002. Items comprised at least 1% of individual scat volume.

	Spring ($n = 45$)		Summer ($n = 136$)		Fall ($n = 96$)		Annual ($n = 500$)	
Item	% vol	% freq	% vol	% freq	% vol	% freq	% vol	% freq
Reproductive plant parts	2.4	20.0	81.1	97.8	75.7	97.9	51.1	82.8
Acorns	0.0	0.0	0.7	2.8	30.5	54.2	4.3	13.8
Apples	1.6	11.1	59.5	79.1	38.5	57.3	30.8	57.2
Berries and other fruit	<0.1	8.9	20.9	39.7	6.7	27.1	16.0	38.0
Herbage	89.3	97.8	4.3	22.8	6.1	43.8	29.0	44.0
Grasses, sedges, rushes	86.3	95.6	3.6	16.9	4.0	35.4	25.2	37.6
Forbs	3.0	17.8	0.7	9.6	2.1	24.0	3.7	15.2
Animal matter	0.6	26.7	2.0	28.8	4.7	54.1	3.0	35.4
Insects	0.5	17.8	0.8	19.9	2.7	40.6	1.1	28.0
Other animals	<0.1	8.9	1.2	8.9	2.0	13.5	1.8	11.8
Anthropogenic foods	0.7	8.9	3.1	19.9	1.5	14.6	6.4	22.4
Debris	4.8	73.3	6.5	52.2	7.1	52.1	7.7	58.0
Unidentified matter	2.2		2.3		3.7		2.9	

was most prevalent in fall (Table 1). Increasing prevalence of animal matter from spring to summer to fall can be largely attributed to increasing use of insects by bears, as the frequency of occurrence of other animal matter remained relatively low and consistent throughout the year. Insects were present in 17.8% of spring scats and 19.9% of fall scats and comprised 0.5% and 0.8% of total fecal volume, respectively (Table 1). Use of insects nearly doubled in the fall, primarily due to much higher consumption of insects in the fall of 2001. Insects of the families *Vespidae* (wasps), *Apidae* (bees), *Isoptera* (termites), and *Formicidae* (ants), especially carpenter ants (*Campanotus* spp.), were the most represented animal food items. Non-insect animal remains found in scat samples were rodent hair and bones (including one specimen from the *Muridae* family), mule deer (*Odocoileus hemionus*) hair and bones, raccoon (*Procyon lotor*) hair, bird feathers, and fish bones.

Debris and other non-food items comprised 10% of fecal volume and occurred in 58% of scats annually. These items were primarily wood, bark, pine needles, and rocks that were either inadvertently consumed or collected as part of the sample from the substrate upon which the scat was found.

The annual percent volume of human food in bear scats declined from 21% to 6% of fecal volume between 1978 and 2002, respectively (Graber 1981, Table 2). Concurrently, the consumption of herbage increased from 17 to 29% (Table 2). Consumption of reproductive plant parts and animal matter changed little between the two studies (Table 2).

Discussion

The sizable decrease of anthropogenic foods observed in black bear scats in YV between 1974–78 and 2001–02 suggests that National Park Service efforts to reduce the availability of these foods to bears were effective. Presence of anthropogenic foods in scats was highest in the summer months and lowest in the spring after den emergence, consistent with greater numbers of visitors to YNP and overnight visitors to YV during summer (National Park Service 2003b). A correlation between human visitation and bear consumption of anthropogenic foods was also observed in the Sierra Mountains of California (Grenfell and Brody 1983)

Table 2. Percent volume of food items in black bear scat samples collected in Yosemite Valley in Yosemite National Park between 1974 and 1978 (Graber 1981) and between 2001 and 2002 (current study). Items comprised >1% of individual scat volume.

Item	1974–78	2001–02
Anthropogenic foods	21	6
Reproductive plant parts	53	51
Herbage	17	29
Animal matter	2	3
Debris	7	10

and in Great Smoky Mountains National Park (Beeman and Pelton 1980).

Increased use of anthropogenic foods and nuisance behavior has been observed when natural foods are scarce (Rogers 1976, McDonald et al. 1994, Ryan et al. 2007). Thus, differences in natural food availability between the 2 study periods might have affected our results and study comparisons. Graber and White (1983) noted remarkable consistency in black bear feeding patterns during the 5 years of their study, although they noted natural and unpredictable variations in the production of fruits, nuts, and seeds based on anecdotal observations. They also noted temperature and precipitation patterns departing considerably from long-term averages. We did not note such departures from normal temperature and precipitation patterns or evidence of any mast failures during our study. However, these factors could have affected our comparisons. Still, the proportion of fruit in the diet was remarkably similar between the studies, so the trade off appeared to be between anthropogenic foods and vegetation. Additionally, many of the fruits consumed in YV were soft mast, and, unlike hard mast, usually produces a consistent crop from year to year (Graber 1981). The collection of systematic food production data during both studies would have improved data consistency and study comparisons. However, even without these data, we felt these comparisons still have validity and significance for Yosemite managers.

The observed decline in the use of anthropogenic foods by bears was also coupled with a reduction in the incidents of bear–human conflict. Harms (1980) and Keay and Webb (1989) assessed incident numbers for the entire Park between 1974 and 1978, the period during which Graber (1981) and Graber and White (1983) collected their food habits data. Over these 5 years, human–bear incidents averaged 683/year park-wide. Matthews et al. (2003) assessed human–bear incident numbers for the entire park and YV during 2001–02. For these 2 years, annual incident numbers averaged 395 and 263 park-wide and in YV, respectively.

These decreases in human food consumption by bears and human–bear conflicts were the result of management actions that occurred because infusions of funds to the YNP Human–Bear Management program since 1999. In 1999, Congress appropriated $500,000 annually to the YNP Bear–Management Plan with which to fund much-needed staffing and equipment. Funds were used to staff additional bear-related positions, purchase and install food storage lockers, improve public information, and conduct research. An organization with representatives from each park division and park partners was also formed to coordinate the Human–Bear Management Program.

Longer-term and park-wide monitoring is necessary to determine the continued success of the Human–Bear Management Plan. However, the reduction in the amount of anthropogenic foods consumed by bears in YV and in the number of human–bear incidents recorded in 2001–02 suggests that the plan has achieved some levels of success. Devices such as bear-proof garbage cans, dumpsters, recycling cans, and food storage containers, as well as an intensive educational campaign may have contributed to this success. Additionally, YNP employs interpretive rangers to patrol campgrounds each night, law enforcement rangers to enforce food storage regulations, and 24-hour bear management patrols during the busiest summer months to respond to incidents and aversively condition bears in developed areas.

The nearly 500 fruit trees (primarily apple, many located in 3 orchards in YV) are remnants of YNP's agricultural past (Thompson and McCurdy 1995). They are recognized by park managers as a cultural resource that should be preserved as part of YNP's history (Thompson and McCurdy 1995). However, availability of apples in YV coincides with peak human visitation in the summer and bears' hyperphagia period in the fall. Apples offer a reliable and concentrated food source, close to human activity, obtained without a major investment in foraging time. For example, one of the largest parking lots in YV is within the 143-tree Curry Orchard (Thompson and McCurdy 1995).

Not surprisingly, bears have frequented the orchards of YV for decades (Beatty 1943, Thompson and McCurdy 1995). Researchers in other regions documented bears making consistent use of abandoned and maintained orchards more often during years when native bear foods are in short supply (Bennett et al. 1943, Mattson 1990). Similar to the open-pit garbage dumps of the 19th and 20th centuries, park managers view the apple orchards as providing a unique opportunity for YV visitors and employees to view bears foraging. Despite these opportunities being managed by park officials when staffing levels allow, these interactions may lead

orchard-foraging bears to become habituated (Beatty 1943, Thompson and McCurdy 1995). Also, the location of the orchards in YV may be unacceptably close to human-populated areas, where, despite the best efforts, some human foods may eventually be available to bears frequenting the area, leading to food-conditioning (Thompson and McCurdy 1995). As a point of context, Breck et al. (2008) identified 27 of 46 bears in YV as food conditioned based on observational data. Future research efforts should address the suspected connection between the use of YV apple orchards by bears, habituation, and food-conditioning.

Park wildlife managers Thompson and McCurdy (1995) acknowledged the dilemma: should a cultural resource be protected even if it adversely affects a natural resource? In response, park wildlife managers have attempted to reduce the availability of apples to bears in the Curry Orchard since 1998 through an annual apple picking event in late August. The purpose of the event is to remove apples from trees and ground and to provide bear-awareness information to the public and park employees. Unfortunately, despite this effort to remove apples, these orchards continued to provide reliable, exotic food for bears close to the developed areas of YV during peak human visitation.

Himalayan blackberries, another non-native food source, are believed to be consumed in great quantities while seasonally available. Despite our efforts to distinguish their seeds from those of the native raspberry with the use of a seed reference collection, we were not able to draw conclusions on the use of this contentious non-native species. Additional research should address the relative abundance of blackberries in YV and in the diets of YNP bears. This work takes on added significance as blackberries have recently been identified as a high priority species for removal in YNP's Invasive Plant Management Plan (National Park Service 2008).

Management recommendations

Results from this study indicate that current YNP practices have reduced the amount of anthropogenic foods available to bears in YV. YNP managers should continue to adapt and improve their management tools to address changing circumstances. Management efforts should focus on constantly upgrading proactive educational campaigns aimed at visitors and employees alike (Lackey and Ham 2003, Beckmann et al. 2008), strict enforcement of food storage regulations, waste management practices, and continued investigation of bear food habits in YNP.

Non-native apples are abundant in the diet of black bears in YV. These food sources are also located close to human activity. We recommend YNP personnel extend apple removal efforts throughout the summer and fall and to all orchards in YV or consider incrementally removing the orchards altogether. An incremental removal would help to avoid immediate increases in the number of human–bear conflicts resulting from the loss of a well-utilized food, as observed in Yosemite (Beatty 1943) and Yellowstone (Craighead et al. 1974, Knight and Eberhardt 1985, Mattson et al. 1990) National Parks. Under either management strategy, enforcement of food storage regulations and aversive conditioning will be critical management tools following the removal of these food sources, as bears accustomed to foraging on these sources seek out alternate foods.

Finally, we recommend continued vigilance in implementing management strategies, in conjunction with research and monitoring to measure the success of YNP efforts. Continued assessments of the diets and foraging behavior of bears will inform and assure the best management practices aimed at reducing human–black bear conflicts in YNP.

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