Accepted Manuscript - URSUS

16 June 2020

Maximilian Allen

maxallen@illinois.edu

Running Title: Food caching by bears

Title: Food caching by bears: a literature review and new observations for Asiatic and American black bears

Authors: Maximilian L. Allen[1]*, Heiko U. Wittmer[2], Akino Ingaki[3], Koji Yamazaki[4], Shinsuke Koike[5, 6]

Affiliations:

[1] *Illinois Natural History Survey, University of Illinois, 1816 S. Oak Street, Champaign, IL 61820, U.S.A.*

[2] *School of Biological Sciences, Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand*

[3] *Graduate School of Agriculture, Tokyo University of Agriculture and Technology, Fuchu, Tokyo, Japan.*

[4] *Department of Forest Science, Tokyo University of Agriculture, Setagaya, Tokyo, Japan*

[5] *Institute of Global Innovation Research, Tokyo University of Agriculture and Technology, Fuchu, Japan*

[6] *Institute of Agriculture, Tokyo University of Agriculture and Technology, Fuchu, Japan*

**Corresponding Author:* maxallen@illinois.edu

Abstract

Food caching is a common behavior for many mammals, but less is known about the prevalence and importance of food caching for some species. Here we report the first documented caching events by Asiatic black bears (*Ursus thibetanus*, n = 5) and three additional caching events by American black bears (*U. americanus*). We also performed a systematic literature review on caching by bears as a reference point for future investigations. Caching was most frequently reported for brown bears (*U. arctos*), and most caching by bears occurred with large prey. Caching is most likely used to protect large carcasses from spoiling or detection by scavengers, allowing bears to consume more of the carcass. The lack of published studies on caching by bears may be due to the behavior being infrequently used and difficult to record. We encourage an increase, but also consistency, in future reporting, including specific descriptions of caching behavior.

Keywords: cannibalism, food caching, foraging strategies, scavenging, *Ursus americanus*, *Ursus thibetanus*

Introduction

Food caching, or storing food for later consumption, is a behavior that preserves surplus food (MacDonald 1976, Smith and Reichmann 1984). Caching often occurs during times of resource abundance to extend the pulse of food, while also limiting detection of food by competitors. Caching has been observed in many taxonomic groups; in mammals well known examples include many species of rodents caching nuts or seeds (Smith and Reichmann 1984) and Arctic foxes (*Vulpes lagopus*) caching excess eggs during a limited waterfowl breeding season for later consumption (Careau et al. 2007). Many large carnivores cache the remainder of ungulate or other large kills that are too large to consume in a single feeding bout, either in a tree (e.g., leopards [*Panthera pardus*]; Balme et al. 2017) or covered with soil or other debris for later consumption (e.g.; pumas [*Puma concolor*]; Hornocker 1970). Although caching of food has been observed in many carnivores, there is variation among species in how and why caching is used.

Bears are carnivores that have evolved to consume large amounts of food quickly during periods of food abundance and most bear species hibernate during seasons of food scarcity. For example, bears are well-known to exploit pulses of food, such as neonatal ungulates (Bull et al. 2001, Bertram and Vivion 2002), patches of ripening berries or insects (Bull et al. 2001), and spawning fish (Barker and Derocher 2009). The general feeding strategy of bears is to consume as much food as possible in a patch, but there are times, such as with large prey, that food needs to be stored for consumption over multiple days. Although it is rare for most bear species, with the exception of polar bears (*Ursus maritimus*) and brown bears (*U. arctos*) in some areas, to regularly kill large prey, many bear species exploit the carcasses of adult ungulates or other large prey they find or usurp from other carnivores (e.g., Cristescu et al. 2014, Elbroch et al. 2015). The carcasses of large prey often need to be consumed over a period of multiple days, and caching these carcasses could help preserve them and limit losses to other scavengers.

Although caching is a common behavior for brown bears, less is known about caching by other bear species. The absence of systematic investigations into caching behavior in many bear species results in confusion about its prevalence and importance. For example, Craighead and Craighead (1972) have

been cited by multiple authors as evidence of caching by American black bears (*U. americanus*), despite there being no mention of caching behavior reported anywhere in the manuscript. Similarly, Svoboda et al. (2011) cite evidence of caching by American black bears, but both studies cited (Elgmork 1982, Bertram and Vivion 2002) detail caching by brown bears rather than American black bears. On the other hand, the absence of caching observed during mortality-site investigations of livestock has sometimes been used to assign cause of mortality to American black bears (Bertram and Vivion 2002). Here we report multiple instances of caching of ungulates by both American black bears and Asiatic black bears (*U. thibetanus*). Because of uncertainty regarding the prevalence of caching behavior by most bear species, we also performed a systematic literature review as a reference point for future investigations.

Materials and Methods

Study Areas and Field Methods

We studied Asiatic black bears with GPS collars in the Ashio-Nikko Mountains of central Honshu Island, Japan. The study area has a wet and cool-temperate climate. Between 2006 to 2017, annual precipitation averaged 2236 mm and the annual mean temperature was 7.2 °C (Japan Meteorological Agency 2018). Up to 1600 m a.s.l., the natural vegetation of this area is dominated by deciduous broad-leaved forest composed of *Quercus crispula*, *Q. serrata*, *Acer* spp., and *Fagus crenata* (Furusaka et al. 2019). We have captured and fitted bears with GPS collars in the area since 2003 and on average monitored 10 bears fitted with GPS collars each year. We randomly visited GPS locations clusters of collared bears after they had left to determine food items or record environmental conditions associated with resting sites (Furusaka et al. 2019).

We also studied Asiatic black bears and other scavengers in Nikko National Park, central Japan. Precipitation averaged 1631 mm per year and the mean annual temperature was 7.7 °C. Forest types included deciduous broadleaved forests, conifer plantation forests, and patches of mixed forests, with an understory of bamboo grasses in each forest type (Inagaki et al. 2020). In this study, we deployed video camera traps on 49 sika deer (*Cervus nippon*) carcasses to document scavenging activity. We obtained

fresh deer carcasses from culled nuisance animals or animals killed through vehicle collisions from June to November in 2016, 2017, and 2019, and secured each carcass to a tree with a wire rope. We monitored the carcasses using Ltl Acorn 6210 camera traps (Green Bay, Wisconsin, USA) (Inagaki et al. 2020). We programed cameras to record either 30 s videos at each trigger with a 30 s refractory period or 30 s videos at each trigger with a 1 s refractory period.

We studied American black bears and other scavengers in the Mendocino National Forest, California, USA. Climate in the Mendocino National Forest is considered Mediterranean with hot and dry summers and generally mild and wet winters. The mean annual rainfall was 1320 mm and average daily temperatures ranged from -1 °C to 24 °C (Allen et al. 2015b). The area is primarily forested with conifers mixed with some deciduous trees, but also contained chaparral and open grassland habitats. We deployed video camera traps on 100 Columbian black-tailed deer (*Odocoileus hemionus columbianus*) carcasses to document scavenger activity. We obtained fresh deer carcasses from animals killed through vehicle collisions from January 2010 to November 2012 (Allen et al. 2015a) and secured each carcass to a tree with a wire rope. We monitored the carcasses using Bushnell ScoutCam camera traps (Overland Park, KS), and programed the camera traps to record 60 s videos at each trigger with a 1 s refractory period.

Literature Review

On 8 February 2020 we performed a systematic literature search on Web of Science to find peer-reviewed documentation of caching among bears. We searched Web of Science for the term “cach*” matched with the search term “ursus” and “bear” in English and Japanese. We then read each entry and removed duplicate and mismatched publications, as well as those not from peer-reviewed journals and studies involving captive animals. The systematic search using Web of Science resulted in few relevant studies (n = 5). We thus augmented our systematic review of the literature using snowball sampling by searching the references of papers that we reviewed for additional articles (n = 11).

Results

Asiatic black bear observations

We documented caching by Asiatic black bears on 5 occasions.

1. On 23 October 2006, a 10-year-old female Asiatic black bear initiated a cluster of GPS points (elevation 1,210 m). On 26 October the bear left the area after staying 3 days at the location (Table 1), and we investigated the location. We found a mostly consumed juvenile (3-year-old) Asiatic black bear carcass cached with leaves under a Japanese oak (*Quercus mongolica*) (Figure 1a).

2. On 6 August 2013, a 9-year-old male Asiatic black bear initiated a cluster of GPS points (elevation 1,270 m) along Chuzenji-Lake shore line in Nikko area, and stayed at the same location for 3 days. When investigating the location, we found a mostly consumed sika deer carcass cached with soil and rocks under root of fallen birch tree (*Betula platyphylla*).

3. On 7 November 2017, we set out an adult sika deer carcass at an elevation 660 m in a conifer plantation forest under a Japanese cedar (*Cryptomeria japonica*). A raccoon dog (*Nyctereutes procyonoides*) discovered the carcass first on 20 November at 23:08. An Asian black bear discovered the carcass on 21 November at 0:05, while it was snowing. The bear began to scavenge the carcass and began to cache the carcass with fallen leaves at 0:21(Video 1) for 5 minutes. The bear was present at the site for at least 2:07 and fed for total of 55 seconds for 16 videos over the next day, but we did not document caching behavior after the initial visit. Another Asiatic black bear, red fox (*Vulpes vulpes*), Japanese marten (*Martes melampus*), wild boar (*Sus scrofa*), and mountain hawk-eagle (*Nisaetus nipalensis*) were also documented scavenging at the carcass (Table 1).

4. On 14 July 2019, a 10-year-old female Asiatic black bear initiated a cluster of GPS points where she stayed for 14 hours. When we investigated the cluster, we found a cached sika deer carcass buried by grass in a riparian forest with vegetation dominated by *Clethra barbinervis*. The carcass remains included the broken skull and foot bones.

5. On 9 August 2019 we set out an adult sika deer carcass at an elevation 650 m, in a conifer plantation forest (*Cryptomeria japonica* and *Chamaecyparis obtusa*). On August 11, we visited the site

and found that the deer carcass was moved 20 m up a slope and was cached with undergrowth in an open area dotted with *Morus australis* between the conifer plantation forests (Figure 1b). Based on camera footage, at least 4 bears (2 solitary bears, and a mother with a cub) visited the carcass until the carcass was completely consumed on 13 August, but other scavenger species were not recorded (Table 1).

American black bear observations

We documented caching by American black bears on 3 occasions.

1. On 11 November 2011, we set out a field-dressed black-tailed deer carcass at an elevation of 1,254 m, under a blue oak (*Quercus douglasii*) with a canopy cover of 76%. A gray fox (*Urocyon cinereoargenteus*) discovered the carcass initially on 13 November at 21:39, and made 4 short visits, before an American black bear discovered the carcass on 14 November at 22:55. During the initial visit of 13 minutes, the bear sniffed around the carcass, but did not fed. It returned less than half an hour later at 23:46 and fed for 2 minutes. The bear returned again on 15 November at 0:14, for a visit of 15 minutes where it investigated the bait and fed, before caching the carcass with leaves. The bear returned half an hour later and finished caching the carcass entirely with leaves. We assume that the same bear returned for multiple visits over the course of 6 days, and a female with cubs also fed on the carcass for a few minutes.

2. On 28 March 2012, we set out a field-dressed black-tailed deer carcass in a Douglas fir (*Pseudotsuga menziesii*) stand at an elevation of 974 m with a canopy cover of 99%. A gray fox discovered the carcass initially on 1 April at 22:02, and a ringtail (*Bassariscus astutus*) discovered the carcass on 4 April at 22:06. Both species made multiple short visits to the carcasses, before an American black bear discovered the carcass on 6 April at 18:36. During its twelfth visit on 8 April, the bear cached the carcass with needles and duff (Video 2), and subsequently made 3 more short visits to the carcass over the next 3 days. The carcass was subsequently visited by common ravens (*Corvus corvax*) and woodrats (*Neotoma* sp.) (Table 1).

3. On 24 September 2012, we set out a field-dressed black-tailed deer carcass in at an elevation of 1,428 m, under a ponderosa pine (*Pinus ponderosa*) with a canopy cover of 89%. An American black bear discovered the carcass on 24 September and made multiple visits that night until a female bear and her cub showed up at 22:38. The original bear initially won a contest over the carcass, but the female initiated another contest and usurped the carcass from the original bear. The usurping female then fed for 51 minutes, during which she cached the carcass with pine needles and litter. The female and her cub fed in an alternating pattern with what we assume was the original bear until the carcass was completely consumed on 29 September, but did not cache the carcass again.

Literature Review

Most of the published studies of caching by bears had small sample sizes (Table 2). Most reports were for brown bears, with 2 studies each for polar bears and American black bears and our observations. Most studies reported caching based on observations during field investigations of clusters of bear activity or depredations. However, 1 study used direct observations of predation and subsequent caching (Dean et al. 1986) and 1 study used a mix of field investigations and direct observations over 45 years (Stirling et al. 2019, and we also used camera trapping at experimental ungulate carcasses. The prey items that were reported cached were almost always large prey (e.g., ungulates, marine mammals, or other large-bodied mammals;), with the exception of fish (n = 1). Most studies had small sample sizes, and caching material was most often reported as vegetation and leaf litter or soil, but polar bears always cached with snow (Table 2).

Discussion

We documented 8 instances of black bears (Asiatic n = 5, American n = 3) caching large animal carcasses. These are the first documented caching events by Asiatic black bears, and only the third study to unequivocally document caching by American black bears. The prior published literature on caching by bears was most frequently (75%) about brown bears, and caching may be less frequent for other bear

species. For example, Stirling et al. (2019) were only able to document 19 instances of caching by polar bears across 45 years of extensive field research and observations. Although the lack of published studies on caching in most bear species may be because they are less often reported or of less interest to researchers. But it is most likely due to the behavior being infrequently used and difficult to record (Stirling et al. 2019). Understanding the frequency of the behavior will help understand whether it plays an important part in their feeding ecology.

An important aspect of caching behavior for bears is that it is most often used, or at least reported, for large prey. For example, 7 of our cases were caching of ungulates, and the other case was caching of a bear. Similarly, in the prior literature, most cached prey were ungulates, marine mammals, or bears; the exception being the caching of multiple migrating broad whitefish (*Coregonus nasus*) by brown bears (Barker and Derocher 1989). Two other reviewed studies documented brown bears caching multiple individuals at the same site, including ungulates (Cristescu et al. 2014), and domestic sheep (*Ovis aries*; Elgmork 1982), but the caching of multiple individuals has not been reported for other bear species. Caching of smaller prey may just not be documented or reported as often as large prey, but it appears to occur less frequently than with large prey. This may be because caching is not needed, due to smaller prey being consumed more quickly, or the difficulty of locating small prey compared to large prey during field investigations.

Caching by bears being primarily for large food items (ungulates, livestock, and other large prey) likely indicates that the proximate mechanism for caching is the preservation of food. Large prey take longer for bears to consume, whereas the energetic costs of returning to small prey that is cached can decrease the net energetic gain for bears. But large prey are also prone to competition from scavengers and decomposers (e.g., Allen et al. 2015a). Covering food may decrease the rot and consumption of large prey by decomposers, as well as detection by scavengers. In most of the observations we documented for black bears, they stayed in the vicinity of the large animal carcass for multiple days, often staying until the carcass was completely consumed. The effects of caching by bears for scavenger deterrence were more equivocal. In Japan, 1 cached carcass we monitored with a camera trap was visited by 5 other

scavengers, whereas the other was visited by other Asiatic black bears (Table 1). Similarly, in the USA, 2 cached carcasses were visited by other bears, whereas the other was visited by 4 other scavenger species (Table 1). In 1 instance, a pair of American black bears had 2 direct encounters where they fought over the carcass.

Although there was a strong pattern of bears caching large food items, other patterns were less clear. There was little seasonal or geographic pattern, suggesting that caching occurs in most seasons and across the geographic range of the bear species for which caching has been reported. Most reports were based on field investigations of clusters of activity for collared bears, with 2 studies also using direct observations, but most of our observations (5 out 8) were made using video camera traps. The use of field investigations and camera trapping are important, because otherwise caching events would most likely only be encountered by chance. Camera traps are useful for documenting behaviors that are difficult to document (e.g., Allen et al. 2019), and could be used for detailed studies of caching behavior in the future. It seems that most caching was covering or burying carcasses in vegetation or soil without excavating a hole or depression, but it is difficult to be sure in some accounts from the prior literature.

Our Web of Science search performed poorly, missing approximately 2/3 of the records in the peer-reviewed literature that we were eventually able to find. Past studies may also have used other terms for caching, such as covering, which could lead to records being missed. For example, there were vague or potentially conflicting terms in the reports, including ‘bury’ vs. ‘cover’ vs. ‘excavate’ vs. ‘burial mound (in Japanese)’. We encourage future studies to use the term ‘cache’ to describe when bears cover their food with vegetation, soil, or other material, and include specific descriptions of caching behavior.

Acknowledgements

We thank the Illinois Natural History Survey, and the University of Illinois for their support. We thank Y Sugimoto and the members of Asian Black Bear Research Group who helped with fieldwork, especially S. Haneo and C. Kozakai. We also thank Dr. Y. Sato and Dr. K. Kobayashi for providing information. We

thank N. Selva, B. McLellan, and two anonymous reviewers for comments that greatly improved the quality of the manuscript.

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Table 1. Summary of our common variables across the seven instances we documented food caching by American and Asiatic black bears.

American Black Bear					
Date	Sex & Age	Habitat	Food Cached	Duration of Visit	Other Scavengers
14 November 2011	Adult	Hardwood-Conifer Forest	Scavenged black-tailed deer	1 day	Gray fox, American black bear
28 March 2012	Unknown	Douglas Fir Forest	Scavenged black-tailed deer	6 days	Gray fox, ringtail, common raven, woodrat sp.
24 September 2012	Adult Female	Hardwood-Conifer Forest	Scavenged black-tailed deer	5 days	American black bear

Asiatic Black Bear					
Date	Sex & Age	Habitat	Food Cached	Duration of Visit	Other Scavengers
23 October 2006	10-year-old Female	Oak Forest	3-year-old black bear	3 days	Unknown
6 August 2013	9-year-old-Male	Oak Forest	Sika deer	3 days	Unknown
21 November 2017	Adult	Conifer Plantation	Scavenged sika deer	1 day	Asiatic black bear, Japanese marten, mountain hawk-eagle, raccoon dog, red fox, wild boar
14 July 2019	10-year-old Female	Riparian Forest	Sika deer	1 day	Unknown
11 August 2019	Unknown	Conifer Plantation	Scavenged sika deer	5 days	4 total bears

Table 2. The results of our review of peer-reviewed literature on caching by bears. We report the bear species, location, caching events, type of food cached, and cache material.

Bear Species	Location	Caching Events	Food Cached	Cache Material	Study
American black bear	Coahuila, Mexico	Not Reported	Cattle (*Bos taurus*)	Not reported	Doan-Crider et al. 2017
American black bear	Michigan, USA	1	White-tailed deer (*Odocoileus virginianus*)	Vegetation and litter	Svoboda et al. 2012
American black bear	Mendocino National Forest, California, USA	3	Columbian black-tailed deer	Vegetation and litter	This Study
Asiatic Black Bear	Ashio-Nikko Mountains, Japan	3	Sika deer, Asiatic black bear	Vegetation, soil and litter	This Study
Asiatic Black Bear	Nikko National Park, Japan	2	Sika deer	Vegetation and litter	This Study
Brown Bear	Alberta, Canada	85	Ungulates	Not reported	Cristescu et al. 2014
Brown Bear	Northwest Territories, Canada	Not Reported	Broad whitefish	Vegetation and litter	Barker and Derocher 1989
Brown Bear	Hokkaido, Japan	1	Female adult brown bear	Soil and debris	Kadosaki 1983
Brown Bear	Hokkaido, Japan	2	Sika deer	Soil, litter, and snow	Kadosaki and Inukai 2000
Brown Bear	Hokkaido, Japan	Not Reported	Sika deer	Soil and vegetation	Okada and Yamanaka 2001
Brown Bear	Hedmark, Norway	2	Moose (*Alces alces*)	Vegetation and litter	Mysterud 1973
Brown Bear	Hedmark, Norway	5	None	Vegetation and litter	Mysterud 1980
Brown Bear	Vassfaret, Norway	16	Sheep	Vegetation and litter	Elgmork 1982
Brown Bear	Lapland Reserve, Russia	Not Reported	Moose, Reindeer (*Rangifer tarandus*), Cattle	Snow, or vegetation and litter	Semenov-Tian-Shanskii 1972
Brown Bear	Cantabrian Mountains, Spain	Not Reported	Livestock	Not reported	Clevenger et al. 1994
Brown Bear	Denali National Park, Alaska, USA	1	Brown bear	Sand and Gravel	Dean et al. 1986
Brown Bear	Yukon Flats, Alaska, USA	Not Reported	Moose	Soil	Bertram and Vivion 2002
Polar bear	Svalbard, Norway	2	White-beaked Dolphin (*Lagenorhynchus albirostris*)	Snow	Aars et al. 2015

Polar bear	Norway, Greenland, and Canada	19	Bearded seal (*Erignathus barbatus*), ringed seal (*Pusa hispida*), harp seal (*Pagophilus groenlandicus*),beluga (*Delphinapterus leucas*), polar bear	Snow	Stirling et al. 2019

Figure 1. Documentation of caching by Asiatic black bears, including (a) the cache pile of a cannibalized Asiatic black bear and (b) the caching a sika deer with vegetation.

(a)

(b)

Video 1 Thumbnail. An Asiatic black bear caching a Sika deer carcass during a snowstorm.

Video 2 Thumbnail. An American black bear caching a black-tailed deer carcass in Mendocino National Forest.