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Efficacy of Bear Deterrent Spray in Alaska

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Abstract: We present a comprehensive look at a sample of bear spray incidents that occurred in Alaska from 1985—2006. We analyzed 83 bear spray incidents involving brown bears (61 cases, 74%), black bears (20 cases, 24%), and polar bears (2 cases, 2%). Of the 72 cases where persons sprayed bears to defend themselves, 50 (69%) involved brown bears, 20 (28%) black bears, and 2 (3%) polar bears. Red pepper spray stopped bears' undesirable behavior 92% of the time when used on brown bears, 90% for black bears, and 100% for polar bears. Of all persons carrying sprays, 98% were uninjured by bears in close-encounters. All bear-inflicted injuries (n = 3) associated with defensive spraying involved brown bears and were relatively minor (i.e., no hospitalization

required). In 7% (5 of 71) of bear spray incidents, wind was reported to have interfered with spray accuracy, although it reached the bear in all cases. In 14% (10 of 71) of bear spray incidents, users reported the spray having had negative side effects upon themselves, ranging from minor irritation (11%, 8 of 71) to near incapacitation (3%, 2 of 71). Bear spray represents an effective alternative to lethal force and should be considered as an option for personal safety for those recreating and working in bear country.

Key words: Alaska, bear deterrent spray, bear-human interactions, black bears, brown bears, polar bears, *Ursus americanus*, *Ursus arctos*, *Ursus maritimus*

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Throughout North America bear-human conflict periodically results in serious, sometimes fatal, injuries to both bears and humans (Herrero 2002). These conflicts between bears and people include negative interactions that are aggressive, defensive, or nuisance in nature (Gore et al. 2006). A few studies have investigated bear-human conflict in North America (Herrero 1970, Middaugh 1987, Herrero and Higgins 1999, Miller and Tutterow 1999, Herrero and Higgins 2003). Miller and Tutterow (1999) reported that brown bear (*Ursus arctos*; synonymous with "grizzly bear" and hereafter brown bear) attacks resulted in 2.75 injuries and 0.42 deaths per year in Alaska from 1986—1996.

Miller and Chihuly (1987) found that 72% of non-sport brown bear deaths in Alaska were the result of aggressive bear-human interactions. It is likely that some of

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these bear fatalities could have been avoided had non-lethal deterrents been available. On Alaska's Kenai Peninsula, the number of brown bears killed in defense of life or property has increased more than 5-fold in recent years and presently exceeds population sustainability (Suring and Del Frate 2002).

People rely on a variety of deterrents for protection from bears including firearms, red pepper sprays, signal flares, incendiary screamers, and an assortment of noise makers (Herrero 2002). Red pepper spray repellants, hereafter bear spray, were initially developed in the 1960s as a defense against aggressive domestic dogs (Miller 2001). The active ingredients in bear spray, capsaicin and related capsaicinoid compounds, produce a non-lethal, yet debilitating response including coughing, sneezing, broncho-constriction, apnea, retrosternal discomfort, laryngeal paralysis, and temporary blindness (Miller 2001). Miller (1980) tested dog repellent sprays on captive brown bears and found that charging bears were stopped when sprayed in the face. Spraying resulted in swift retreats to the farthest corner of the cage where bears rubbed their eyes and blinked vigorously (Miller 1980). Encouraged by these results, Miller (1980) advocated the development of red pepper spray-based repellents for bear defense.

Initial tests of the improved formulation and packaging proved promising, so research trials were conducted involving captive bears (Hunt 1984). Rogers (1984) reported positive results when red pepper spray was used on free-ranging black bears (*U. americanus*). Importantly, none of these studies reported bears responding aggressively when sprayed.

Herrero and Higgins (1998) analyzed 66 non-experimental incidents in which bear spray was used on both wild brown and black bears and found that in aggressive

encounters with brown bears bear spray ended the bears' unwanted behavior in 94% (15 of 16) of incidents. However, in 6 cases the bear continued to act aggressively; in 3 of these cases the bear attacked the person spraying. In 88% (14 of 16) of the cases the bear(s) eventually left the area after being sprayed. Results regarding black bears were more variable but no humans were injured after spray use.

Some people have been reluctant to rely on bear spray for protection. We believe several reasons contribute to their reluctance. Chief among these is the notion that bear sprays are too weak to dissuade curious or aggressive bears from approaching people. Additionally, some people believe that wind can easily render sprays ineffective and that wind-driven spray may incapacitate the user. We present data from Alaska bear spray incidents that address these concerns. Additionally, we present bear spray incidents involving polar bears (*U. maritimus*), the first reported in the literature. Our goal was to provide data regarding the effectiveness of bear spray over a 20 year period. Given the overall lack of evaluation of the efficacy of bear-human conflict interventions, including bear spray, analysis of bear spray effectiveness is needed (Gore et al. 2006). Insights about bear spray efficacy may contribute to more informed decisions regarding its use and reduce human injury and non-sport loss of bears.

METHODS

We collected bear spray incident records from 1985—2006 from state and federal agencies, newspaper accounts, and anecdotally. We included all Alaska records (31) previously analyzed by Herrero and Higgins (1998) so we could present a comprehensive, updated assessment of bear spray incidents from Alaska. Bear spray incident variables of interest included: date, time, location of incident, number of persons

involved, person's activity prior to interaction, bear species and age-sex class, bear's activity prior to being sprayed, manufacturer of spray used, wind effects, effects on humans, dosage of spray administered, dosage of spray received, distance to bear when sprayed, bear's response to spray, mechanical problems, and whether the bear returned after being sprayed. Whenever records were incomplete (n = 10), we interviewed individuals involved. We regrouped values for the variable distance to bear when sprayed into broader categories to aid analysis (e.g., 0-5 m, ≥6-10 m, ≥11-20 m). Subjectivity of incident records, presence of confounding factors (e.g., multiple manufacturer's products having been used), and small sample sizes limited statistical analyses.

We pooled bear spray incident data by bear species and bear behavior, consistent with Herrero and Higgins (1998). Data included incidents involving black, brown, and polar bears. We labeled bears curious if they were exploring the environment in a non-aggressive manner. We deemed bears aggressive when the encounter included behaviors such as charging, agonistic vocalizations, or persistent following (Herrero and Higgins 1998). In some instances we could not infer the bear's behavior and we classified those as unknown.

We pooled data by behavior of the bear prior to being sprayed into 2 categories, food-motivated and non-food motivated, consistent with Herrero and Higgins (1998). Bears in the first category were perceived to be searching for human food or garbage. If aggressiveness was involved in these incidents it was with respect to acquiring food or garbage. Bears in the second category were acting aggressively and were not attempting to acquire food or garbage.

We defined successful outcomes as bear spray having stopped the undesirable behavior of the bear. A bear that no longer pursues a person, breaks off an attack, abandons attempts to acquire food or garbage, or turns and leaves the area are examples of successful outcomes. We deemed failures spray incidents in which the bear continued its pursuit, persisted in attempts to acquire food or garbage, or showed no change in its undesirable behaviors. A bear not leaving an area after being sprayed, however, was not deemed a failure so long as threatening behaviors, rummaging through trash, or direct risks to people ceased.

To address wind effects on spray, we tested the velocity of bear spray issuing from canisters at the actuator, or nozzle, using a Kestrel wind meter (Nielsen-Kellerman, Inc., Sylvan Lake, MI, USA). We held the meter approximately 5 cm from the actuator and released a 1-second burst of spray. We recorded maximum wind speed attained. We replicated this procedure 5 times to calculate a mean exit velocity for bear spray. We used the *G* test for goodness-of-fit for differences between observed and expected frequencies (Dytham 2003). We selected the *G* test because we were dealing with observed frequencies of various categories and expected proportions for those categories that we did not derive from the data. We set significance at $P = 0.05$.

RESULTS

We analyzed 83 cases involving the use of bear sprays in Alaska (Table 1), of which 72 incidents involved persons spraying menacing bears, and the remainder ($n = 11$) are examples of spray misuse or bear attraction to residues. We address instances of bear spray misuse separately.

From 1985-2006, our sample of bear spray incidents showed that Alaska averaged 3.1 ± 0.7 reported bear spray incidents per year. Of the 83 incidents we examined, brown bears were involved in 61 (74%), black bears in 20 (24%), and polar bears in 2 (2%; G_1 = 96.6, $P < 0.001$). Of the 72 cases where persons defensively sprayed bears, 50 (69%) involved brown bears, 20 (28%) black bears, and 2 (3%) polar bears (G_1 = 73.0, P = 0.000). All instances of spray misuse (n = 11), or of spray residues attracting bears, involved brown bears. In 92% (46 of 50; G_1 = 41.4, $P < 0.001$) of close-range encounters with brown bears, spray stopped undesirable behavior in which the bear was engaged. In 90% (18 of 20; G_1 = 14.7, P = 0.001) of close-range encounters with black bears, spray stopped the bear's undesirable behavior. All bear-inflicted injuries (n = 3) involved brown bears and were relatively minor (i.e., no hospitalization required). During 1985-1995, Herrero and Higgins (1998) found bear spray use in Alaska 94% effective overall (30 of 32 incidents; G_1 = 31.3, $P < 0.001$); we found that in the decade following bear spray efficacy was 90% (36 of 41 cases; G_1 = 33.4, $P < 0.001$).

Bear spray incidents for which time of day was known (65%; 47 of 72) show that none occurred between the hours of 0100 and 0600; 14 (30%) occurred between 0600 hours and 1200 hours; 14 (30%) occurred between 1200 hours and 1800 hours; and 18 (38%) occurred between 1800 hours and 2400 hours; only 1 (2%) occurred between 2400 hours and 0100 hours (Fig. 1).

In 96% (69 of 72) of bear spray incidents the person's activity at the time was reported (Fig. 2). The largest category involved hikers (35%), followed by persons engaged in bear management activities (30%), people at their home or cabin (15%), campers in their tents (9%), people working on various jobs outdoors (4%), sport fishers

(4%), a hunter stalking a wounded bear (1%), and a photographer (1%). Persons injured in bear deterrent spray incidents included 2 hikers and one field biologist.

In 62% (31 of 50) of brown bear incidents bears were either acting curious or searching for food or garbage prior to being sprayed. Of these bears 13% (4 of 31) were acting aggressively (13%; 4 of 31) with respect to obtaining food; 87% (27 of 31) were not acting aggressively. In 77% of incidents (24 of 31) one bear was involved, but in the remaining incidents females with cubs comprised 10% (3 of 31), large males 7% (2 of 31), and a pair of siblings 7% (2 of 31) of bears involved. In 100% (29 of 29; $G_1 = 32.8$, $P < 0.001$) of these incidents, use of bear spray stopped the undesirable behavior of the bears involved. In 17% of incidents (5 of 29; $G_1 = 13.5$, $P = 0.001$) the bear returned after being sprayed.

In 68% (13 of 19) of black bear incidents, bears were either acting curious or were searching for food or garbage. Of these bears, none acted aggressively towards people while in pursuit of human foods. In 77% (10 of 13) of these incidents one bear was involved, but the remaining 23% (3 of 13) involved family groups. In 85% (11 of 13; $G_1 = 6.9$, $P = 0.032$) of these incidents, bear spray stopped the bear's behavior, whereas in 15% (2 of 13) the outcome was unclear due to confounding factors (i.e., bear trapped inside a structure and unable to flee, linkage between spraying and cessation of behavior unclear). In 11% (2 of 19; $G_1 = 13.6$, $P = 0.001$) of incidents the black bear returned to the site following initial spraying.

In both polar bear incidents, sub-adult bears approached humans in a pickup truck there to observe bears feeding on bowhead whale (*Balaena mysticetus*) remains near the village of Kaktovik, Barter Island, Alaska. In both instances (100%) bear spray stopped

187 the bear's approach and turned the bear away. Neither of these bears returned to the
188 truck following spraying.
189 In 36% (18 of 50) of brown bear incidents, brown bears acted aggressively
190 towards people prior to being sprayed. In 86% (12 of 14 for which distance was known)
191 of these incidents, the person was first aware of the bear at <15 m, with a mean estimated
192 distance of 6 m. In the remaining 2 instances, bears were first noticed at 25 m and 50 m,
193 respectively. In 64% (9 of 14) of these close encounters, brown bears charged the
194 person(s) prior to being sprayed. In 85% (12 of 14; $G_1 = 7.9$, $P = 0.019$) of aggressive
195 encounters with brown bears, bear spray stopped the bear's aggressive behavior; in 12%
196 (1 of 14) the person spraying the bear was not injured, but the bear charged through the
197 fog, halting 1 m from the person before moving off. In 12% (1 of 14) of aggressive
198 encounters the bear contacted and slightly injured the person in the interaction (i.e., deep
199 scratches requiring stitches). Of brown bears involved in aggressive interactions
200 unrelated to food procurement, 38% (6 of 16) were single bears, 56% (9 of 16) were
201 females with dependent young, and 6% (1 of 16) were a pair of bears. In 3 instances
202 (21%; 3 of 14) aggressive brown bears returned after being sprayed.
203 In 35% (7 of 20) of incidents involving black bears, bears acted aggressively
204 towards people without an apparent food-related motive. In 4 of these 7 aggressive
205 incidents the bear was apparently surprised at close range (≤15 m). Only in one case (1
206 of 7; 14%) did the black bear charge prior to being sprayed. In 100% (7 of 7) of bear
207 spray incidents involving aggressive black bears, the undesirable behavior was stopped
208 by spraying. No one using bear spray was injured by black bears in any behavioral mode,
209 aggressive, food-seeking, or curious. Of black bears involved in aggressive interactions,

100% (7 of 7) were single bears, one reportedly a sub-adult, the others adults. After being sprayed, 3 bears (43%; 3 of 7) returned, 3 did not return (43%, 3 of 7), and one (14%, 1 of 7) did not leave the general area.

In 7% (5 of 71) of bear spray incidents, wind was reported to have interfered with spray accuracy, although it reached bears in all cases. In 14% (10 of 71) of bear spray incidents, users reported spray having negative side effects upon themselves, ranging from minor irritation (11%, 8 of 71) to near incapacitation (3%, 2 of 71).

On 10 occasions (14%, 10 of 71) the sight and sound associated with spray release were reported as key factors in changing bear behavior. In 67 spray incidents for which distance was reported, the mean distance between user and bear at the time of spraying was 4 m (range 1-15 m). One user commented that he had "squarely hit the bear" at 10 m, though at distances >5 m success was variable. When bears were sprayed at ≤3 m (33 cases), the spray always enveloped the bear, with only one resulting in a failure to deter the attacking bear.

Three persons (<2% of the 175 persons involved in 71 separate incidents) suffered injury by bears that had been sprayed with bear deterrent. One person halted the attacking bear by spraying it at close range in the face, and the other 2 persons were unable to spray a second dose because the initial attack knocked the spray canister from their hands. Nonetheless, only one of the 3 reported that the spray had failed to protect them. No mechanical failures of spray canisters were reported in the 71 cases.

We analyzed 11 incidents of spray misuse that resulted in unintended consequences. In 45% (5 of 11) of incidents persons applied spray to objects they hoped to protect from damage by curious bears; these efforts all failed. In 2 instances (18%)

persons applied sprays as a zonal repellent but reported bears inordinately attracted to these locations (i.e., tent and on river bank. In 2 instances (18%) persons reported bears attracted to spray residues following use of bear spray for practice purposes. Repeated sprays (n = 5) with fully pressurized cans showed mean exit velocities > 112 ± 4 km/hr (70 ± 2 miles/hr).

DISCUSSION

Two decades of bear spray use in Alaska confirm that it is an effective bear deterrent. Findings by Herrero and Higgins (1998) regarding the efficacy of bear spray in Alaska from 1985-1995 were comparable to ours for the following decade, 1996-2006. As there were only 2 incidents involving polar bears these results should be interpreted with caution. However, we located 3 additional polar bear incidents, 2 from Russia and one from northern Canada, which support our findings (Cochran 2000, Ovsyanikov 2004). In Russia and Canada, bear spray successfully protected the user from injury by aggressive polar bears. The only injuries (n = 3) associated with bear spray usage in Alaska were inflicted by brown bears, consistent with findings by Middaugh (1987) and Herrero and Higgins (2003) that brown bears are the most aggressive of all 3 North American bear species.

We found little change in the overall efficacy of bear sprays between the 2 decades of study (94% vs. 90%), in spite of reported improvements by manufacturers (e.g., increased capsaicinoid content, pressure, and dispersal distance). Differences in bear deterrent spray brand formulation (e.g., percentage capsaicin, chemical carrier

composition, and volume), spray duration, and distance exist, but our data were too few for rigorous performance comparisons or analysis.

In 18% of cases we analyzed (13 of 72) both brown and black bears resumed their threatening behavior after having been sprayed the first time. In these instances, repeated spraying eventually deterred bears such that the user could escape the situation. Bear spray diffuses potentially dangerous situations in the short term by providing the user time to move out of harm's way and allowing the bear time to reassess the situation and move on. When food or garbage is involved with bear conflict, bear spray is effective initially, but one can expect bears to continue returning until these attractants are removed or otherwise secured. In surprise encounter situations, bear spray buys time for both the human and bear to go their separate ways.

Consistent with others' findings regarding bear-human conflict, our data show hikers to be the largest group involved in bear spray incidents (Middaugh 1987, Herrero and Higgins Herrero 2003). This activity correlates with the most frequent time of day for bear spray usage, between 0600 hours and 1800 hours (60%, Fig. 1). The increase in bear spray incidents in the evening (38%, 1800 hr to 2400 hr) was largely due to bear management activities.

Wind can influence bear spray's accuracy and distance; however our data show that wind rarely affected the outcome of bear-human interactions involving bear spray, which is likely because many close encounters do not occur in open areas, but rather in dense brush or forests where wind is greatly attenuated (T. Smith, Brigham Young University, unpublished data; S. Herrero, University of Calgary, unpublished data). High exit velocities of spray from cans likely compensates for cross-wind effects and may

account for the low incidence of wind-related effects reported in Alaska. Of the 72 incidents we studied, 4 (6%) involved persons that had to leave the area to alleviate burning eyes and coughing. No one reported being incapacitated by spray although one user said he had to move or would have been overwhelmed.

Importantly, latent bear spray residues have been found to attract brown bears rather than repel them (Smith 1998), which was evident in 7 instances in Alaska where persons applied bear spray to objects with the intention of repelling bears. Unfortunately, bears were attracted to, and subsequently destroyed, the property that had been coated with bear spray, similar to observations reported by Smith (1998). These observations underscore a need to carefully manage spray residues by not indiscriminately dispersing spray.

Because some persons had to spray bears multiple times to drive bears off in 24% (17 of 72) of instances we studied, spray conservation, and total canister volume, may be concerns. We suggest discarding bear spray when contents fall below 90% of the original amount (as determined by weighing), or when the canister is past its expiration date, generally 3–4 years from date of purchase.

MANAGEMENT IMPLICATIONS

Our research shows that bear deterrent spray is an effective tool for defusing bear-human conflict in a non-lethal manner. In Alaska, bear spray was highly effective in dealing with all 3 species of North American bears, although more data on polar bear responses is needed. Persons working and recreating in bear habitat should feel confident that they are safe if carrying bear spray. Although bear spray was 92% effective by our definition

of success, it is important to note that 98% of persons carrying it were uninjured following a close encounter with bears.

In portions of North America where bears are in decline managers may reduce the number of bears killed in defense-of-life by arming employees with bear deterrent sprays in addition to firearms. No bear spray has ever been reported to kill a bear It is our belief that wide spread use of bear spray will promote human safety and bear conservation.

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LIST OF FIGURES

368 Table 1. Bear spray incident data from Alaska, 1985-1995 and 1996-2006. We did not
369 include incidents of misuse (n = 11) with these data.

370

	Decade of study	
	1985-1995[a]	1996-2006[b]
Total no. of incidents	32	40
Black bears (total)	6	14
Single bears	4	13
F with cubs	2	1
Brown bears (total)	26	24
Single bears	21	11
F with cubs	4	9
Large M	0	2
Pair of bears	1	2
Polar bears (total)	0	2
Single bears	0	2
Injuries inflicted	0	3[c]
Successful deterrence[d]	30 (94%)	36 (90%)
Return after spraying[e]	5	8
Mean distance to bear (m)	3.4	4.8
Behavior prior to spraying:		
Aggressive	9	16
Curiosity	23	23

Indeterminable	0	1

[a] Data from Herrero and Higgins (1998)

[b] Data from this study

[c] Minor injuries resulting in outpatient treatment (e.g., scratches and lacerations)

[d] Spray was deemed successful when the undesirable behavior of the bear was stopped.

[e] This refers to the number of incidents in which the bear returned after initial spraying.

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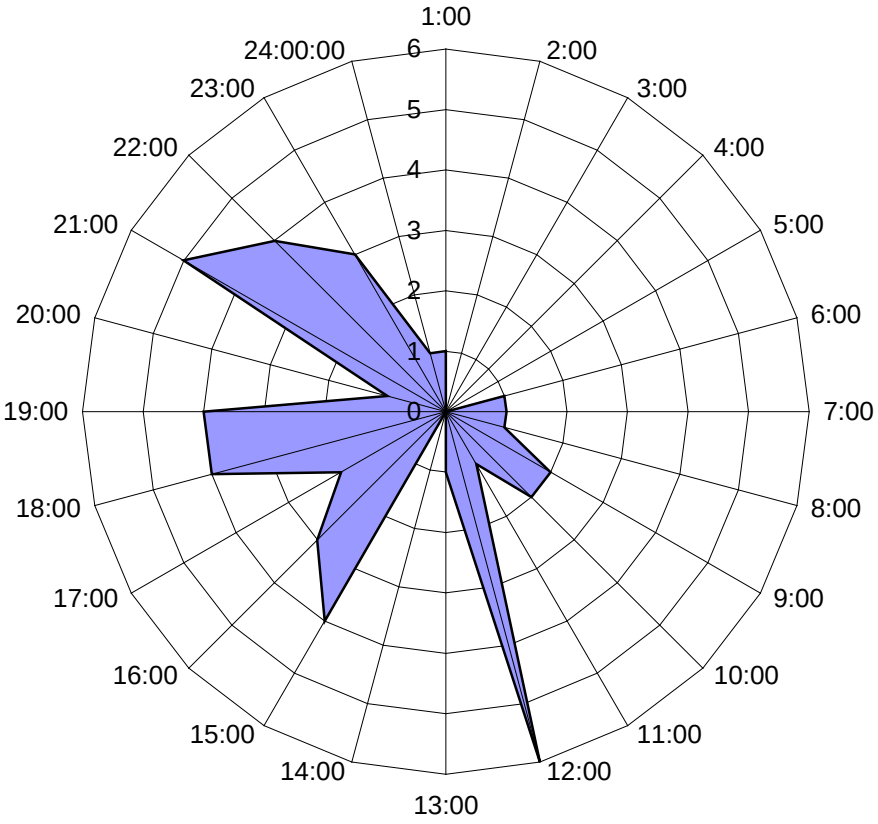
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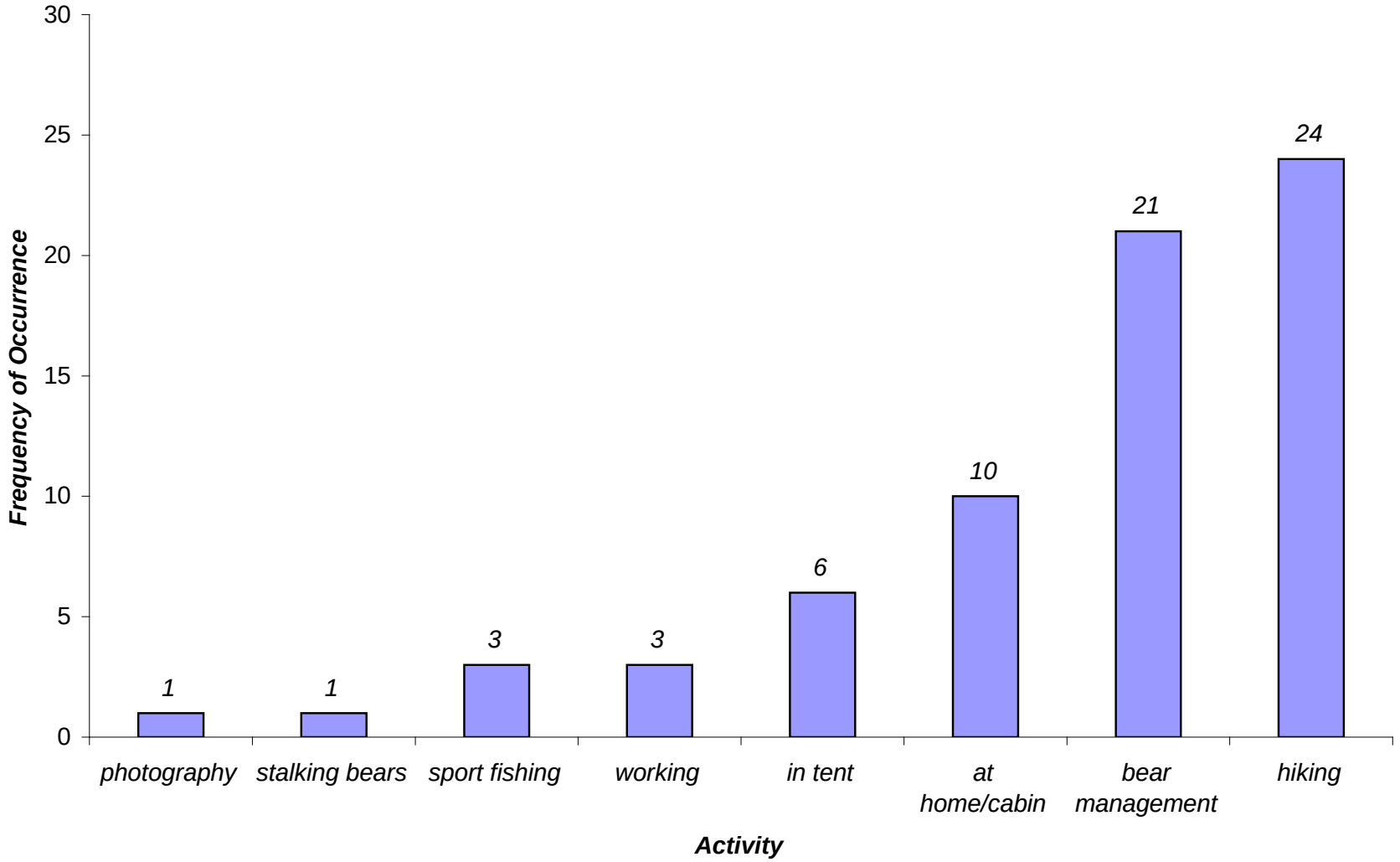
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Frequency of Occurrence
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photography
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working
in tent
at home/cabin
bear management
hiking
Activity