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Efficacy of bear spray as a deterrent against polar bears

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Abstract

Although there have been few attempts to systematically analyze information on the use of deterrents on polar bears (*Ursus maritimus*), understanding their effectiveness in mitigating human-polar bear conflicts is critical to ensuring both human safety and polar bear conservation. To fill this knowledge gap, we analyzed 19 incidents involving the use of bear spray on free-ranging polar bears from 1986 to 2019 in Canada, Russia, and the United States to evaluate the effectiveness of bear spray as a polar bear deterrent. We found that bear spray was an effective deterrent in close-range encounters with polar bears, stopping undesirable behavior in 18 of 19 incidents. Bear spray effectively deterred both curious and aggressive polar bears, including polar bears attempting to attack people. The mean distance between user and bear at the time of spraying was 2 m (min–max = 0.2–10.0 m, mode = 1 m), though bears were usually first seen at greater distances. Bear spray was successfully deployed against polar bears in all 4 seasons. Wind affected spray performance in 1 of 19 of incidents. In 8 of 14 bear spray incidents, other deterrents were used without success before bear spray was used effectively to deter polar bears. No humans or polar bears were killed or injured in any of the incidents in which bear spray was used. We also analyzed 54 polar bear attacks and attempted attacks on humans where bear spray was not carried. The data suggest that in 93% of those incidents, the

use of bear spray might have saved the lives of both the people and bears involved if it had been available and used. Our analysis improves our understanding of the effectiveness of bear spray for polar bear conflict mitigation.

KEYWORDS

attacks, bear spray, climate change, conflicts, conservation, deterrents, human-bear conflicts, polar bear, *Ursus maritimus*

Observed declines in sea ice extent and duration in the Arctic (Maslanik et al. 2011, Stroeve et al. 2014, Stern and Laidre 2016) are predicted to continue (Thackeray and Hall 2019, Peng et al. 2020). Reduced temporal and spatial availability of sea ice has impacted seasonal distributions for many species (Post et al. 2013) and has resulted in increased use of terrestrial habitats for some marine mammals (Jay et al. 2012, Rode et al. 2015). Impacts of reduced sea ice on polar bears (*Ursus maritimus*) are well documented (Wiig et al. 2008, Stirling and Derocher 2012, Lunn et al. 2016, Laidre et al. 2020), and have resulted in an increased number of days spent on land for some subpopulations (Rode et al. 2015, Atwood et al. 2016, Heemskerk et al. 2020). As a result, polar bears are more likely to come into close proximity to humans, resulting in a higher probability for negative human-bear interactions (Dyck 2006, Towns et al. 2009, Wilder et al. 2017). Conflicts between wildlife and humans can jeopardize human safety, increase wildlife mortality, and ultimately hinder local support for long-term conservation efforts (Naughton-Treves et al. 2003). Therefore, developing tools and strategies to reduce human-bear conflicts is imperative for effective polar bear conservation in the face of a changing climate.

Wildlife managers have long sought effective deterrent tools and techniques for use against bears (Wooldridge 1980, Wooldridge and Belton 1980, Stenhouse and Cattet 1984, Herrero 2002, Interagency Grizzly Bear Committee 2008). A bear deterrent is an aversive agent administered to bears to cause pain, avoidance, or irritation (Hopkins et al. 2010). The working assumption has been that deterrents used for brown (*U. arctos*) and black bears (*U. americanus*) also work for polar bears. However, Smith et al. (2008) and Wilder et al. (2017) demonstrated differences between the 3 species that suggested the need for species-specific evaluation of deterrent effectiveness. Unlike brown and black bears, few recent attempts have been made to systematically collect, analyze, and interpret available information on effective deterrents specifically for polar bears, although substantial work was conducted in the early 1980s in Churchill, Manitoba (Wooldridge 1980, Wooldridge and Belton 1980, Miller 1983, Stenhouse and Cattet 1984, Miller 1987).

A notable achievement in the development of effective bear deterrents was the advent of bear spray. Initially, Miller (1980) tested sprays developed to repel dogs on captive brown bears and found that all charging bears (n = 4) were stopped when sprayed in the face. Subsequent studies identified both pepper spray and a capsaicin solution as effective deterrents on both captive and non-captive brown and black bears, with both formulations deterring bears without causing aggressive responses (Hunt 1984, Rogers 1984). Bear repellent spray (hereafter bear spray) became commercially available in 1986. Since then, 2 studies have investigated its effectiveness on brown and black bears. Herrero and Higgins (1998) analyzed 66 cases of field use of bear spray and found that bear spray ended undesirable bear behavior in 94% (15 of 16) of incidents involving brown bears, although in 6 incidents the bear continued to act aggressively and in 3 incidents the bear attacked the person spraying. In 100% (4 of 4) of encounters with aggressive or possibly predacious black bears, and in 73% (19 of 26) of cases associated with curiosity, bear spray stopped the behavior that the bear was displaying immediately prior to being sprayed. In 62% (8 of 13) of the incidents where the black bear received a substantial dose to the face, it either did not leave the area or left the area and returned. No humans were injured by black bears after

spray use (Herrero and Higgins 1998). Smith et al. (2008) analyzed 83 bear spray incidents and reported that 92% (46 of 50) and 90% (18 of 20) of both brown and black bears ceased their undesirable behavior after being sprayed, and that 3 people who used bear spray were injured by bears. Both studies noted that wind affected the efficacy of spray in a small proportion (≤7%) of incidents, while Herrero and Higgins (1998) also reported that 3% (2 of 66) of incidents involved mechanical failure of spray canisters. Smith et al. (2008) were also the first to evaluate bear spray use on polar bears ($n = 2$) and found it to be effective in both incidents in which it was used.

Despite bear spray's demonstrated utility in deterring brown and black bears, many do not believe that it can effectively deter polar bears (Wilder et al. 2017, A. Kochnev, Russian Academy of Sciences, personal communication). Questions remain regarding whether the chemical components of spray are strong enough to deter polar bears, the proximity required to successfully use bear spray against a polar bear, and whether spray can be used effectively in the cold and windy conditions prevalent in the Arctic. In fact, some polar bear management authorities have banned bear spray from their jurisdictions for some combination of these concerns, including both Norway and Greenland (Wilder et al. 2017).

To address the outstanding questions related to bear spray use on polar bears, a systematic evaluation of its efficacy was needed. We analyzed data from records of bear spray use against polar bears throughout the Arctic to determine its effectiveness as a deterrent under Arctic field conditions to address the concerns described above. Our goal is to provide an objective appraisal of bear spray's effectiveness in mitigating human-polar bear conflicts to contribute to both human safety and polar bear conservation.

METHODS

Our study area included the circumpolar range of polar bears across the Arctic including Greenland, Norway, Russia, Canada, and the United States. As part of a broader study of human-polar bear interactions, we compiled data on field use of bear spray as a deterrent against free-ranging polar bears from 1986 to 2019 from government records, literature, biologists' field notes, and media accounts and entered them into the Polar Bear-Human Interaction Management System (PBHIMS) database, following the methods described in Wilder et al. (2017). The PBHIMS data are maintained independently by the agency in each polar bear range state (Greenland, Norway, Russia, Canada, and the United States) tasked with collecting the relevant data. Accordingly, requests for access should be directed to the contacts listed at https://polarbearagreement.org/index.php/working-groups/human-polar-bear-conflict/pb-conflict#PB-injured. The PBHIMS database was designed to document, quantify, and help evaluate human-bear interactions and other information relevant to management, including the efficacy of various deterrent techniques for polar bears. When possible, we directly contacted individuals who had used bear spray as a polar bear deterrent to verify details about the incident. We included 2 polar bear records previously analyzed by Smith et al. (2008).

We used summary statistics to characterize the overall effectiveness of bear spray use, incidents in which bear spray was used to prevent an attempted attack, human encounter group size, the frequency and severity of bear spray affecting the user, whether the bear left the area or returned after being sprayed, the amount of spray required to deter a bear, bear behavior before being sprayed, use and effectiveness of other nonlethal deterrents, distance bear was first seen before an incident, the mean distance between user and bear at the time of spraying, season in which the incident occurred, and the effect of wind on spray. To reflect weather conditions in the Arctic, we defined seasons as fall (September–October), winter (November–February), spring (March–May), and summer (June–August). Attractant types were categorized as natural (e.g., whale carcasses), anthropogenic (human food or garbage), or human (a person was apparently considered potential prey in a predatory incident). We defined encounter group size as the number of people that initially encountered the bear(s) but we note this may be different than the total number of people in the group. For example, if the lead 2 hikers in a group of 5 strung out

over several hundred yards of a trail encounter a bear, we considered the total group size as 5, but the encounter group size is 2.

We followed Smith et al. (2008) and defined a successful outcome as bear spray stopping the undesirable behavior of the bear. A bear ceasing pursuit of a person, breaking off an attack, abandoning attempts to acquire food or garbage, or leaving the area are examples of successful outcomes. Conversely, we deemed spray incidents to be failures when the bear showed no change in its undesirable behaviors. An incident in which a bear did not leave an area after being sprayed was not deemed a failure if its undesirable behaviors or direct threats to people ceased (Smith et al. 2008).

A bear attack refers to intentional contact by a bear resulting in human injury (Smith et al. 2005, Hopkins et al. 2010). We defined an attempted attack as an incident in which all factors indicate the bear was intent on attacking the person but was unsuccessful, usually due to mitigating actions taken by the person(s) involved. If the bear was reported to have charged a person(s), we carefully considered whether this was an attempted attack, based on the complete details of the incident. To identify predatory events, we used behavioral components such as stalking and rushing the victim (Herrero and Higgins 2003), absence of both vocalizing and stress behaviors by the attacking bear (Fleck and Herrero 1988, Herrero et al. 2011), and prolonged aggressive interactions despite sustained attempts to drive the bear off. We defined a predatory investigation as an incident where all indications were that the bear was intent on preying on the people involved (i.e., the bear was probing and testing to discover information about the people involved, in conjunction with exhibiting some predatory behavioral components as described above), but the bear did not attempt an attack, usually due to the successful actions of the person(s) involved.

To better understand why bear spray was a success or failure, we identified bear behavior leading up to the incident as either curious or aggressive. We considered a bear to be curious if it was simply exploring its environs in a nonthreatening manner, and aggressive if displaying behaviors such as predatory investigation, stalking, charging, defending cubs, or persistent following (Herrero and Higgins 1998, Smith et al. 2008). We noted any aspects of bear or human behavior that may have influenced causation and outcome.

When enough information was available in the narrative descriptions and pictures provided by those involved to estimate the characteristics of the bears involved, we classified independent bears from 3 to 4 years of age as subadults and bears older than 4 years as adults, we assigned a body condition score from 1 (skinny) to 5 (obese) using the body condition (fatness) index developed for polar bears (Stirling et al. 2008), and we determined the sex of the bear(s) involved. When possible, we assigned a probable cause (i.e., the main factor that initially brought bears and humans into conflict) to each incident after considering all the information available. The completeness of the information reported here varied by period, data source, and region. Details for some variables of interest were not always available for each incident. In those cases, we report the number of incidents for which we had adequate data. We acknowledge that additional incidents likely occurred that we are unaware of due to incomplete reporting.

We also took the opportunity to examine attacks and attempted attacks by polar bears throughout the Arctic since 1986 to evaluate if bear spray could have been used if it had been carried. To determine this, we queried PBHIMS as follows: Bear code = polar bear; Year = 1986 to 2019; Bear attack = yes, attacked or yes, attempted attack; Bear spray possible = yes or likely. The latter was determined based on if (1) the bear was first sighted at an adequate distance (i.e., the person(s) involved had time to prepare for defensive action), or (2) other deterrents were used and failed. We considered bear spray use to have been possible for incidents that qualified in at least one of these categories. Once we determined if bear spray could have been used in an incident, we noted any alternate nonlethal deterrents that were used unsuccessfully (i.e., did not end the interaction). We also evaluated the results that using bear spray could have had on the outcome of the incident if it had been available and used (i.e., saved human or bear lives and/or prevented injury). We acknowledge that our analysis was subjective in nature, however, it may provide insights into scenarios where bear spray could be a practical deterrent.

RESULTS

We analyzed 19 incidents from 1986 to 2019 involving the use of bear spray against non-captive polar bears: 10 occurred in Canada, 6 in Russia, and 3 in the United States. We contacted individuals involved in 10 of those incidents. In 18 of 19 incidents with polar bears in which it was used, bear spray stopped the undesirable behavior of the bear (Table 1). Wind reportedly interfered with spray accuracy in only 1 of 19 bear spray incidents, when a crosswind (approximately 93 km/hour) prevented the spray from reaching a curious bear rummaging through gear on a beach. On average, bears involved in bear spray incidents were first seen at 252 m, however, distances were highly variable, ranging from 0.3 m to 2,200 m (mode = 35 m). The mean distance between user and bear at the time of spraying was 2 m (min–max = 0.2–10.0 m, mode = 1 m). Based on 14 incidents where season or month was known, bear spray was successfully used in all seasons (3 in summer, 8 in fall, 1 in winter, and 2 in spring). No humans or bears were killed or injured in the 19 incidents we evaluated.

Polar bears attempted to attack people in 5 of 19 incidents, however, bear spray was successful in stopping all attempted attacks (Table 1). In 14 of 16 of incidents where information was available, the bear left the area after being sprayed. In 3 incidents bears were observed running away for >500 m after being sprayed. In 2 of 16 of incidents for which it was reported, the polar bear returned after being sprayed. In 6 of 11 of incidents, the person(s) had to spray the bear multiple times to deter it; in 5 incidents 2 bursts of spray were required, and in one incident 2 full cans were required to deter the bear. In 8 of 14 incidents, other deterrents were used without success before effectively using bear spray (Table 1). In 5 of 14 bear spray incidents multiple deterrents (up to 7) were used multiple times without success, including gun shots in the air, banger rounds, cracker shells, rubber bullets, noise from a boat motor, chasing the bear with an ATV, a bear rattle, yelling, a Critter Gitter® (heat and motion activated animal repeller that emits loud

TABLE 1 Data from incidents where bear spray was used against non-captive polar bears (*Ursus maritimus*) in Canada, Russia, and the United States, 1986–2019.

	n	Total records
Bear spray successfully deterred bear[a]	18	19
Bear attempted to attack person	5	19
Spray ended attempted attack	5	5
Spray affected user	7	13
Impact of spray on user was minor[b]	7	7
Bear left area after spraying	14	16
Return after spraying	2	16
Bear spray dose		
One burst	5	11
Two bursts	5	11
More than one can	1	11
Other nonlethal deterrents failed before bear spray use	8	14
Bear behavior before being sprayed		
Aggressive	8	15
Curious	7	15

[a]An incident in which spray stopped the undesirable behavior of the bear (Smith et al. 2008).

[b]Minor incidents were resolved without medical attention.

noise and flashing light when tripped; AMTEK, Poway, CA, USA), setting a dog loose to chase the bear, and hitting the bear with a wooden stick.

Body condition of bears involved in bear spray incidents were skinny (1 of 13), thin (2 of 13), or average (10 of 13). There were no bears reported to be in above average body condition (i.e., fat or obese). In 11 of 14 bear spray incidents only one bear was involved, and 3 of 14 involved females with cubs. Adult bears accounted for 10 of 13 incidents, whereas subadults accounted for 3 of 13. Female bears were involved in 6 of 11 bear spray incidents, male bears in 5 of 11.

We categorized bear behavior before being sprayed as curious for 7 of 15 incidents and aggressive for 8 of 15 incidents (Table 1). Bears displayed predatory behavior in 5 of 15 bear spray incidents. Of the other aggressive incidents, one was attributed to the bear being chased by a dog, one to food conditioned behavior, and one to a female defending cubs. Additionally, we found attractants were present in 11 of 13 incidents. In 5 of 11 cases, a human was the putative attractant (i.e., predatory investigations). The encounter group size for bear spray incidents was one (6 of 13), 2 (5 of 13), or 3 (2 of 13) people. Bear spray was reported to affect the user in 7 of 13 incidents, however all affected users reported that the effects were minimal (i.e., slight irritation; Table 1).

We evaluated 103 polar bear attacks and attempted attacks that occurred from 1986 to present to determine if bear spray could have been used if it had been carried. Of those records, 54 provided enough detail to subjectively classify whether bear spray could have been used. Based on the information available in 93% (50 of 54) of the attacks and attempted attacks that we examined, the primary person involved may have had enough time to deploy bear spray if it had been carried in an easily accessible location. A total of 37 bears were killed in those 50 attacks and attempted attacks. Attacks comprised 17 of 50 incidents analyzed, which resulted in 6 human deaths and 15 human injuries.

In 58% (29 of 50) of attacks or attempted attacks where bear spray use was possible, multiple deterrents were used unsuccessfully. Unsuccessful deterrents used ranged from yelling to shooting the bear with a .22 caliber rifle. The encounter group size involved was as follows: one (38%, 16 of 42), 2 (43%, 18 of 42), or 3 or more (19%, 8 of 42) people. The body condition of the bears involved were reported as skinny (26%, 9 of 34), thin (26%, 9 of 34), or average (47%, 16 of 34). There were no bears reported to be in above average body condition (i.e., fat or obese).

DISCUSSION

Our data indicated that bear spray successfully deterred polar bears in the Arctic environment, and that the chemical components of bear spray are strong enough to effectively deter both aggressive and curious polar bears of every age, sex, and reproductive class. Despite concerns to the contrary (Wilder et al. 2017), our data show that spray stopped attempted attacks by polar bears every time. No humans or bears were killed or injured in any of the incidents in which bear spray was used to deter polar bears. Further, the cold and windy conditions prevalent in the Arctic did not unduly affect bear spray performance. Our findings are similar to previous work that found spray to be 92% effective at ending brown and black bears' undesirable behavior and preventing bears from causing human injury 98% of the time (Smith et al. 2008). In most bear spray incidents, bears left the area after being sprayed. In the 2 incidents where bears returned after being sprayed, they were thin and the probable cause of the incidents were ascribed to predatory behavior, suggesting the bears were highly food-motivated. The bears were ultimately deterred by the peoples' preparedness and well-executed deterrent actions.

Although there are numerous nonlethal deterrents available for use against polar bears, our results suggest that few may be as dependably effective as bear spray in close range encounters with polar bears. In over half of bear spray incidents, other deterrents were used without success before the bear was successfully deterred with bear spray, and in 5 of 14 bear spray incidents multiple deterrents (up to 7) were used several times without success. In the end, bear spray was the only deterrent that was effective in ending the bear's undesirable behavior. Further,

bear spray worked in all incidents against polar bears exhibiting aggressive behavior. Our data show that even small encounter group sizes of 1 or 2 people can successfully deter polar bears with spray.

Attractants did not play a prominent role in the bear spray incidents we analyzed, but we found that the person involved were themselves the presumed attractant in 5 of 11 of the incidents examined. None of the bears in our study that were sprayed were in above average body condition (i.e., fat or obese), however, a few were either thin or skinny. Nutritionally stressed polar bears pose a greater threat to people than bears in above-average body condition (Wilder et al. 2017) and are thought to be more aggressive (Voorhees et al. 2014). Polar bears in poor body condition may be more motivated and harder to deter in general. For example, in all 3 of the incidents where bear spray was used successfully against skinny and thin bears, they were exhibiting predatory behavior. This reinforces the findings in Wilder et al. (2017) that polar bears in above-average body condition generally do not pose a great threat to people. In that context, a fed bear is a risk-averse bear, or a bear that is likely not interested in preying on people. Although our data do indicate that spray is effective against predatory polar bears in poor body condition, some extremely food-motivated/predatory polar bears may react differently. Some polar bears in poor body condition may be stopped by nothing short of lethal force.

We found that the mean distance between user and polar bear at the time of spraying was 2 m, including polar bears attempting to attack people. The proximity to polar bears at the time of spraying was congruent with the findings of both Herrero and Higgins (1998) and Smith et al. (2008) that most bears were sprayed at distances ≤6 m to the bear, and success was greatest at ≤3 m. For many, the proximity to polar bears required to use bear spray is reason enough to resist using it, in that they would rather opt for tools that allow a bear to be deterred or killed at a greater distance. Although we advocate using other deterrence tools at further distances if time and circumstances allow, many of the incidents reported in our study were surprise encounters, with some not seeing the bear until it was within very close proximity. In dangerous close-range encounters such as these, having a deterrent that can be deployed from a hip or chest holster and that does not require time to precisely aim can allow for very quick response times when every second counts. Sometimes just the sight and sound of deploying a blast of bear spray is enough to deter bears (Herrero and Higgins 1998, Smith et al. 2008). None of the bears sprayed in this study contacted the person(s) involved despite their proximity.

Our results demonstrate that Arctic conditions did not inordinately affect bear spray performance. Bear spray was successfully deployed against polar bears in all 4 seasons. Despite common beliefs to the contrary, wind only affected spray performance in 1 of 19 of incidents, similar to findings by Herrero and Higgins (1998) and Smith et al. (2008) who reported that wind only affected spray performance in 6% and 7% of bear spray incidents, respectively. The only failure of bear spray to deter a polar bear was due to wind (approximately 93 km/hour crosswind) preventing the plume from reaching the bear.

Smith et al. (2020) found that under headwinds and crosswinds of >10 m/s (~22 mph), bear spray can still reach 2 m directly in front of the person deploying it. Furthermore, laboratory tests demonstrate that tailwinds improve spray performance with respect to speed and distance, which could increase the probability of the plume reaching the bear (Smith et al. 2020). Although our sample is limited to a single case for winter use, Smith et al. (2020) demonstrated that bear spray has a range of >4 m even at temperatures as low as −23°C, though the plume was narrow, concentrated, and not well aerosolized at that temperature. Although wind and temperature are factors in spray performance, given the protection it affords even under high wind and extreme cold scenarios, there is no reason to not carry it because of those concerns. In winter, we recommend carrying bear spray inside a coat to allow the user's body heat to keep the canister warm. Given that most incidents we analyzed, as well as defense-of-life kills (Stenhouse et al. 1988, Dyck 2006, Wilder et al. 2017), occur during more temperate months, temperature may not be an important factor affecting the outcome of many reported polar bear spray incidents.

Another concern that prevents some from using bear spray is the potential for negative effects on the user. In contrast to Smith et al. (2008), who found that bear spray users reported negative effects of the spray in only 14% of bear spray incidents, we found that spray had a negative effect on the user in 54% (7 of 13) of incidents.

However, all affected users reported that the effects were minimal (i.e., slight irritation) and that all polar bears were deterred without injuring people. The physiological effects of bear spray on bears and people have been reviewed in Rogers (1984), Herrero and Higgins (1998), and Miller (2001). Although there is a risk of users being negatively affected by bear spray when it is used, the potential benefits of avoiding injury or death from a bear attack far outweigh any temporary discomfort that may be caused by bear spray.

In the attacks and attempted attacks we examined where the use of bear spray may have been possible if it had been carried, we found that if used with 95% effectiveness as described in our results above, bear spray may have prevented injury or death to both the people and bears involved in 93% of those incidents. In other words, the bear was first sighted at an adequate distance (i.e., the person(s) involved had time to prepare for defensive action), or other deterrents were used and failed. It should be noted, however, that because 52% of the bears involved in those incidents were in poor body condition (i.e., skinny or thin) and likely highly food-motivated, they may have been more difficult to deter, as discussed above. Based on our results, it is reasonable to assume that bear spray would have been successful in some proportion of the 54 attacks and attempted attacks that met one of our 2 criteria.

Herrero et al. (2011) found that bear spray was not carried or used for defense by the victim during any of the fatal black bear attacks they reported, nor was bear spray available for other party members to deter the attacking bear. Wilder et al. (2017) reported similar findings, in that bear spray was in the possession of the victim or bystanders in only 1 of 36 polar bear attacks since 1986 (when bear spray became available in some regions). However, the spray was not used in that incident because the victim was attacked, reportedly without warning, and dragged from their tent in the middle of the night (Wilder et al. 2017).

In addition to preventing an attack, bear spray also provides users with a valuable tool to de-escalate bear encounters that start out at a relatively low level (e.g., bears testing and probing people, a curious bear) before they escalate into an attack or a situation that reinforces undesirable bear behavior, such as food conditioning (Mazur 2010). For example, in 7 of 15 incidents we examined in which the bear's behavior leading up to the incident was known, the bear was demonstrating curious behavior. In all but one case, bear spray use caused the bear to leave the area. Bears later returned in 2 incidents. Further, bear spray gives many people a reason to stand their ground and not run and this fact alone may decrease the chance of injury in most cases (Herrero 2002). However, carrying bear spray is not a substitute for adhering to proper bear avoidance safety techniques.

We recognize that bear spray is unavailable in many remote Arctic communities due to restrictions on transporting it via air. In Russia, commercially available pepper sprays are not appropriate for use on bears due to their low concentrations of the active capsicum ingredient (A. Kochnev, personal communication). Sprays manufactured in Canada or the United States that are adequate for use against polar bears can cost as much as $200 USD in Russia. As a result, many in Russia cannot afford or may mistrust bear spray for polar bear deterrence and prefer instead to solve conflict situations with a firearm (A. Kochnev, personal communication). To ensure its utility, we recommend that people only purchase bear spray that is registered by the U.S. Environmental Protection Agency or by Health Canada.

Although many deterrent tools can be highly effective if used correctly in specific situations, they often require some level of training and practice to maintain proficiency. This is true of firearms, especially under high stress scenarios (Shelton 1994, Smith 2004, Gookin and Reed 2009, Smith et al. 2012, Wilder et al. 2017). For example, in 25% of polar bear attacks where a firearm was in possession, it was mishandled due to inexperience or the stress of the incident, which contributed to further human injury or death (Wilder et al. 2017). This is particularly relevant in jurisdictions that allow or even require visitors to carry firearms with few checks on user proficiency.

Bear spray requires little training or specialized skills, which makes it the ideal deterrence tool for individuals that are not proficient in firearm use. Although there may be situations where bear spray is not the most appropriate tool (e.g., a skinny polar bear making persistent attempts to attack a human), our data suggest that it is a highly reliable and effective option for personal safety that should be included in the toolbox of deterrents available to those who live, work, or recreate in the Arctic.

MANAGEMENT IMPLICATIONS

Our work represents a step towards improving our understanding of the efficacy of bear spray against polar bears. We hope our findings will help inform management authorities on human-polar bear conflicts and the deterrence tools they authorize for use, particularly in jurisdictions where bear spray is currently prohibited. We encourage all who live, work, or recreate in polar bear habitat to carry bear spray in an easily accessible manner and to be familiar with how to use it. We also recommend that parties carry multiple cans of spray, as our results indicate that polar bears often need to be sprayed more than once to make them cease their undesirable behavior. Continued collection and analysis of range-wide data on polar bear conflicts will help bear managers and policy makers increase human safety and ensure the conservation of polar bears for future generations. Although bear spray cannot be substituted for a firearm or other nonlethal deterrent tools in every situation, our results demonstrate that it can be a valuable tool in close-range encounters with polar bears.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

ETHICS STATEMENT

No ethical information provided.

DATA AVAILABILITY STATEMENT

Author elects to not share data.

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