Review of Human-Polar Bear Conflict Reduction Measures

Research Report

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(photo: Sybille Klenzendorf)

Preface

This report is the result of the research for my BSc thesis for my major in Wildlife Management at Van Hall Larenstein, University of Applied Sciences in Leeuwarden. I have been able to conduct this research thanks to the opportunity WWF Netherlands gave me.

During this project I increased my knowledge about human-wildlife conflicts, polar bears and the Arctic. But not only has this opportunity given me more insight in the topic, it has provided me with many more valuable lessons which I can take with me in my next steps.

I would like to thank my supervisor at WWF Netherlands, Femke Hilderink-Koopmans, for giving me this chance to work for WWF on this project. It was tremendous to have her support, as well as having her as my colleague for the last six months.

Of course, my supervisors from VHL, Berend van Wijk and Gabriëlle van Dinteren, have to be mentioned here as well. Without their critical, caring, humorous and wise advice I could not have done this. I think I could not have asked for better supervisors!

I would also like to thank Theo Meyer, who has been my independent reviewer and showed interest in me and my project during this whole experience. Furthermore I would like to thank all the people that took the time to share their knowledge and experience with me, amongst which Gert Polet, Brandon Laforest, Jouke Prop, Sybille Klenzendorf, Pete Ewins, Maarten Loonen, Geoff York, Ivan Mizin, Jeff Marley, Andy McMullen and James Mayer.

And of course a big thanks is due to all the other wonderful people at WWF who made this project as valuable as it was for me!

I have enjoyed every step of the way!

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Abstract

This report provides an overview of a literature study focused the conflict between polar bears (*Ursus maritimus*) and humans and gives an overview of measures that could reduce or avoid human-polar bear conflict (HPBC). The goal of this study is to provide an insight into which measures are most successful in avoiding and/or reducing HPBC in the Arctic Range States. This is done by getting insight in 1) which measures to avoid and/or reduce HPBC are currently used and/or which have been studied, 2) under which preconditions these measures work optimally to avoid or reduce HPBC incidents, 3) how successful these different measures are, and 4) what the advantages and disadvantages of the application of these different HPBC reduction measures are.

Data were collected through a literature study and additional information was gained through interviews with experts. Measures found were subdivided in four categories, based on their usefulness in different phases of conflict, namely proactive measures, reactive measures, human body language and polar bear patrol groups. Potential users of HPBC reduction measures were divided into three groups based on their background, attitudes and experience with polar bears. Besides a technical overview of each measure, insight was given in the socio-political aspects of HPBC as this plays an important role in the success of reducing HPBC.

Due to the different circumstances of each encounter between polar bear and man, each situation has to be evaluated differently and response needs to be chosen depending on the circumstances. General preconditions such as increasing distance when encountering polar bears, having respect for polar bears, and avoiding polar bears to be attracted to humans and human property always have to be implemented. For each measure the preconditions have to be followed for the measure to work properly. Also, the user needs to be aware of the limitations and training is advisable for the user to be able to use the proper measures to its full potential. Main restriction of the measures is the accessibility of the measures to the general public, as not all measures are easily accessible due to socio-political aspects.

The measures food and waste management, electric fences, chasing away polar bears with vehicles, dogs as deterrents, hand-held flares and bear spray seemed to show most potential in being an effective conflict reduction measure. Gaps in knowledge have been found for several measures and further testing of potentially useful measures is advisable.

To reduce HPBC, integrated management is important. The different attitudes and backgrounds of the three group types should be taken into account when setting up strategies. Additionally, education is recommended to create understanding and acceptance among people involved in HPBC.

Samenvatting

Dit verslag geeft een overzicht van een literatuurstudie gericht op het conflict tussen de ijsbeer (*Ursus maritimus*) en de mens en geeft een overzicht van de middelen die mens-ijsbeerconflict (*Human-Polar Bear Conflict*, HPBC) zouden kunnen verminderen of vermijden. Het doel van deze studie is het geven van inzicht in welke middelen het meest succesvol zijn in het voorkomen en/of verminderen van HPBC in de Arctische gebieden. De studie geeft inzicht in 1) welke middelen om HPBC te voorkomen of verminderen momenteel gebruikt worden en/of zijn bestudeerd, 2) onder welke omstandigheden en voorwaarden deze middelen optimaal werken om HPBC te voorkomen of verminderen, 3) hoe succesvol deze verschillende middelen zijn, en 4) wat de voor- en nadelen zijn van het toepassen van deze verschillende HPBC-verminderingsmiddelen.

Gegevens zijn verzameld door middel van een literatuurstudie en aanvullende informatie is verkregen door middel van interviews met experts. De gevonden middelen zijn onderverdeeld in vier subgroepen, gebaseerd op hun bruikbaarheid in verschillende fases van conflict, namelijk proactieve middelen, reactieve middelen, menselijke lichaamstaal en ijsbeerpatrouillegroepen. Potentiele gebruikers van HPBC verminderingsmiddelen zijn onderverdeeld in drie groepen, gebaseerd op hun achtergrond, attitudes en ervaring met ijsbern. Naast een technisch overzicht van elke maatregel is er inzicht gegeven in het sociale-politieke aspect van HPBC, daar dit een belangrijke rol speelt bij het succes in het terugdringen van HPBC.

Door de omstandigheden en de context van elke ontmoeting tussen ijsbeer en mens verschillend zijn, moet elke situatie anders beoordeeld worden en de reactie worden afgestemd op de omstandigheden. Algemene voorwaarden, zoals het vergroten van de afstand bij het tegenkomen van ijsberen, respect hebben voor ijsberen en vermijden dat ijsberen worden aangetrokken door mensen en hun bezittingen moeten altijd opgevolgd worden. Voor elke maatregel moeten de voorwaarden opgevolgd worden om de maatregel naar behoren te laten functioneren. Daarnaast moet de gebruiker zich bewust zijn van de beperkingen en is het aan te raden te trainen met het de werking van de juiste maatregel om het zo effectief mogelijk te kunnen gebruiken. De belangrijkste beperkingen van de maatregelen zijn de beschikbaarheid voor het algemene publiek, aangezien niet alle middelen even makkelijk toegankelijk zijn door sociale en politieke aspecten.

De maatregelen voedsel- en afvalmanagement, elektrische hekken, het wegjagen van ijsberen met voertuigen, honden als verjagers, fakkels en berenspray lijken de meeste potentie te bezitten om conflict effectief te voorkomen. Echter, een gebrek aan kennis is geconstateerd bij een aantal middelen en verder onderzoek naar potentieel bruikbare middelen is aan te raden.

Om HPBC te doen afnemen is geintegreerde management belangrijk. De verschillende attitudes en achtergronden van de drie verschillende groeptypes behoren overwogen te worden bij het opzetten van strategiën. Daarbij komt dat voorlichting aanbevolend wordt om begrip en acceptatie te creëren bij de mensen die betrokken zijn bij HPBC.

Contents

List of Abbreviations

ACIA	Arctic Climate Impact Assessment
AECO	Association of Arctic Expedition Cruise Operators
AHDR	Arctic Human Development Report
ASCM	Arctic Species & Communications Meeting
BPC	Bear Proof Container
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
ESA	Endangered Species Act
GBSS	Get Bear Smart Society
HWC	Human-Wildlife Conflict
HBC	Human-Bear Conflict
HPBC	Human-Polar Bear Conflict
IUCN	International Union for the Conservation of Nature
IUCN/SSC	IUCN Species Survival Commission
MMPA	Marine Mammal Protection Act
ORD	Overt Reaction Distance
PBHIMS	Polar Bear-Human Information Management System
PBSG	Polar Bear Specialist Group
USFWS	United States Fish and Wildlife Service
WWF	World Wide Fund for Nature

Glossary

Attack	The intentional contact by a bear resulting in human injury (Smith et al., 2005).
Attractant management	Taking measures or precautions to prevent polar bears feeling attracted to approach human property.
Aversive conditioning (AC)	A learning process in which deterrents are used in a continual and consistent manner to reduce the frequency of undesirable behaviour on the part of a bear (Hopkins et al., 2010). (Appendix III)
Deterrent	A non-lethal aversive method that makes use of the polar bears' auditory, visual, olfactory and/or tactile senses, causing a polar bear avoidance, irritation or pain (Hopkins et al., 2010), with the intention to actively prevent polar bears from approaching or coming too close to humans or human property, or to leave the site of conflict and divert the polar bear elsewhere.
Diversionary feeding	Moving or placing of food sources such as marine carcasses away from human property and settlements to reduce HBC (Dutton et al., 2011).
Early detection measures	Devices or measures to detect approaching polar bears to humans or human property and alert people of the presence of the polar bear and increase safety around human property.
Encounter/Interaction	A person and a bear are mutually aware of one another. Bear may react to this by leaving the area, with seeming indifference or by approaching the person (Smith et al., 2005).
Food-conditioned	Bears with a previous positive experience of foraging on human food or waste (Mazur, 2010).
Habituation	The loss of avoidance behaviour after repeated exposure to a stimulus or the lack of a negative stimulus (Mazur, 2010). Habituated bears do not show overt reactions to nearby presence of people (Herrero et al., 2005).
Human property	A resource that is of importance and in need for humans and is in their possession.

Human-Bear Conflict	When a human-bear encounter results in 1) exhibiting stress-related or curious behaviour on the part of the bear which causes a person to take defensive action, 2) physical contact with the person, 3) exhibited predatory behaviour, or 4) the bear being intentionally harmed or killed by a person (Hopkins et al., 2010).
Human-Wildlife Conflict	When competition over resources or unintentional encounters affect humans, as well as all cases in which interactions between humans and wildlife lead to negative impact on both sides through fear, injuries, death, loss of property or livelihoods (Koopmans & Polet, 2015).
Incident	Interaction between a bear and a person that involves HBC, in which the bear 1) acts aggressively, or 2) when a bear obtains anthropogenic food, 3) damages human property, 4) kills pets or 5) when bears are affected negatively by human activities (Hopkins et al., 2010; Smith et al., 2005; Wilder et al., 2007). Incidents are a subset of human-bear interactions and have an outcome ranging from benign to injury (Smith et al., 2005).
Nutritional stress	Stress to polar bears that is caused by suffering a lack of proper nutrition for a prolonged period of time.
Overt reaction distance (ORD)	Distance at which a bear overtly reacts to a person. It describes the behaviour of a bear that can be observed, keeping in mind that unobserved internal reactions may occur without overt response (Herrero et al., 2005).
Personal defence measures	Portable measures or tools that can be carried and handled by a person for protection against an approaching or attacking polar bears as a last resort. The intention is to deter, defend or even (preferably not) kill a polar bear when it is approaching or attacking a person or human property.
Preconditions	The conditions that need to be established for a measure to work optimally in relation to a certain situation to reduce or avoid HPBC.
Proactive measures	Measures which aim to proceed against the cause of possible conflict between humans and polar bear
Problem bear	A bear which is involved in repeated incidents (Hopkins et al., 2010).
Reactive measures	Measures responding to HPBC when the conflict occurs
Sighting	When a person sees a bear, but the bear is apparently unaware of the person (Smith et al., 2005) or the bear is aware of the presence but allows people to observe it (at a distance) (Hopkins et al., 2010).

1. Introduction

1.1. The Arctic

The Arctic is divided over eight Arctic States (Canada, United States (Alaska), Russia, Finland, Sweden, Norway, Iceland and Denmark (Greenland)) which have Arctic territory. Additionally, it consists of large areas of no-mans-land (/sea-ice) which belong to no single state and international waters (ACIA, 2004; Pers com. Polet, 2016). According to the Arctic Human Development Report (AHDR), the area is inhabited by approximately four million people (Larsen & Fondahl, 2015).

1.2. Polar Bear Biology

The polar bear is a predator at the top of the food chain living in the Arctic. It has only humans as its (natural) enemy, apart from occasional cannibalistic predation by adult males (Stirling, 2011). This makes the polar bear fearless and curious by nature (York et al., 2014). In a surrounding of ice and white, everything else that is different, will get their attention (Smith, 2016; pers com. Prop, May 4, 2016). Polar bears are described as intelligent animals (NPBGTP, 2013) that learn things quickly (Stirling, 2011). When encountering humans, polar bears will usually move away (GBSS, 2010).

Polar bears are well-equipped predators of ice-dependent seals (Ovsyanikov, 3rd IBPCWS, 2009). Their main food sources are ringed seal (*Pusa hispida*) and bearded seal (*Erignathus barbatus*) (Derocher et al., 2004), with the ringed seal being its primary prey (Stirling & Derocher, 2012). Polar bears have a well-developed sense of smell and can detect a food source many kilometres away (PBSP, 2005). They can detect seal breathing holes or seal pups under a meter of snow over a distance of a kilometre (Stirling, 2011). Their eye sight is comparable to humans' (GBSS, 2010; Stirling, 2011) however, they are not visually orientated like humans (GBSS, 2010). The hearing of a polar bear can be compared to that of dogs, with the frequency range exceeding that of humans (GBSS, 2010).

Polar bears' success rate in hunting is relatively low (Stirling, 2011). Polar bears have two main types of hunting: stalking, where the polar bear lowers its head, walks slowly and steadily in as straight a line as possible towards its prey, sometimes in a semi-crouched position to get closer. The second is still-hunting; where the polar bear is lying, sitting or standing motionless beside a breathing hole, waiting for a seal to surface to breathe (Stirling, 2011).

Polar bears are described as solitary and relatively unsocial. Breeding pairs and family groups do occur (Stirling, 2011). Polar bears live at low densities. However when sea ice has melted they can be found in higher densities on land (IUCN Red List, 2015) separating according to sex and age (Stirling, 2011).

Polar bears are a K-selected species and have high adult survival rates. As they reach sexual maturity late in life and produce small litters with high maternal investment they have a low reproductive rate (Derocher et al., 2004). The annual survival rate of yearlings can be as high as 70-75% (Demaster & Stirling, n.d.). Once they have survived their first year polar bears usually reach old age and die a natural death (Pers com. Polet, July 8, 2016). Female polar bears mature at 4 to 5 years. Mating occurs in April and early May, however implantation only occurs in autumn. Polar bears have a gestation period reaching from 195 to 265 days (Derocher et al., 2004), with the period of actual

gestation following implantation to birthing being approximately 60 days. Pregnant females will retreat to dens in the beginning of winter and begin the process of gestation (NWF, 2016). Denning usually occurs on land where they will give birth to the cubs around December or January. Cubs leave the maternity den around April, simultaneously with the maximum availability and accessibility of prey (Stirling, 2011). Females fast while staying in the den and loose up to half of their body weight (NWF, 2016).

The primary habitat of polar bears is the annual sea ice of the continental shelf. Polar bears prefer shallow ice-covered waters where prey is most abundant (IUCN Red List, 2015; Stirling & Derocher, 2012). Polar bears move over thousands of kilometres on sea ice and along coastlines in search of food and mates (Parks et al., 2006). In the Arctic areas where the sea ice melts completely in summer, polar bears move to shore and spend several months on land. There they wait until freeze-up in autumn and mainly live off the fat reserves that they build up in winter time. The periods of polar bears spending time on land increases as the sea ice breaks up earlier each year due to climate change (Stirling & Derocher, 2012).

Polar bears range the circumpolar Arctic waters that are covered in ice. They occur in Canada, Greenland (Denmark), Norway, Russia, Alaska (United States) and occasionally Iceland, with the coast of Newfoundland, Canada being the southern extent of their home range. Numbers concerning polar bear populations are based on estimations; the current population size is approximately 26,000 (95% CI = 22,000-31,000). The current population trend is unknown (IUCN Red List, 2015). As of 2008, the polar bear is listed as “vulnerable” on the IUCN Red List and “threatened” under the US Endangered Species Act (ESA).

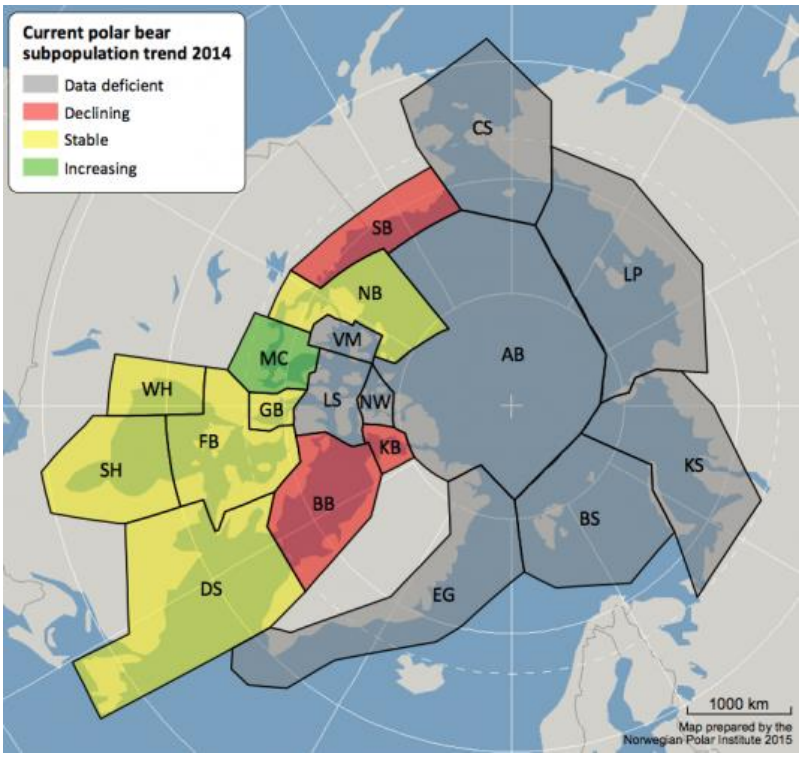

Figure 1 Polar bear range map in the Arctic by the Norwegian Polar Institute showing the status of the 19 polar bear subpopulations according to the latest IUCN Polar Bear Specialist Group report (PBI, 2015)

1.3. People in the Arctic

People have inhabited the Arctic for at least 20,000 years (Larsen & Fondahl, 2015). The people that occupy and inhabit the Arctic, and that can come into contact with polar bears, can roughly be divided into three groups, namely 1) indigenous people, hunters and herders living that have a vast experience living with polar bears in close proximity, 2) long-term settlers and city residents from elsewhere and 3) newly settled and temporary residents (see chapter 3.1.) (ACIA, 2004; pers com. Polet, July 8, 2016).

1.4. Human-Polar Bear Conflict

Encounters between humans and polar bears are a natural consequence of two species living together and sharing the same habitat. An encounter is considered to be a situation in which a person and a polar bear are mutually aware of one another (Smith et al., 2005). This does not necessarily have to be a negative or dangerous experience, for instance in the case of bear viewing. Polar bears often show avoidance behaviour before people are even aware of the polar bear's presence (BBC News, 2011; IUCN/SSC PBSG, 2009b). The distance at which a polar bear visibly responds to the presence of a human is the so called overt reaction distance (ORD). There are three categories which influence the ORD of a bear, namely 1) individual bear-related factors, 2) environment-related factors, and 3) human-related factors (Figure 2).

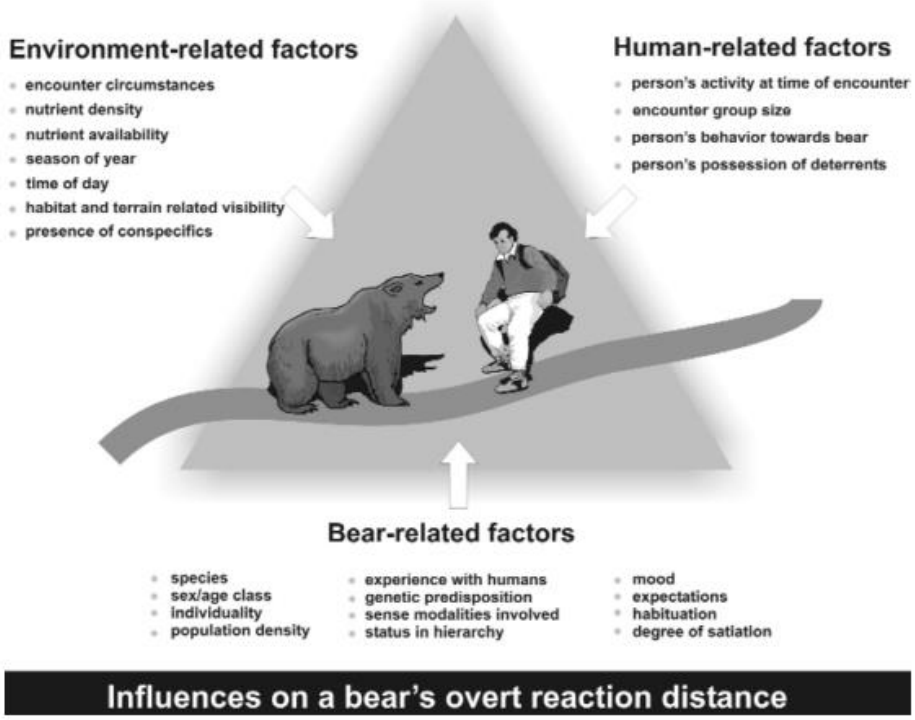

Figure 2 Influences on a bear's overt reaction distance (ORD) (Herrero et al., 2005)

An encounter turns into conflict when the polar bear comes too close to humans or human property and could pose a threat to human safety or property. Where that exact turnover point lies depends on a polar bear's ORD, human personal safety level, the encounter's circumstances and a person's knowledge of and experience with polar bears. For a visiting tourist this turnover might be significantly sooner than that of an Inuit who has lived with polar bears his entire life. Literature shows several definitions of human-wildlife conflict (HWC) and human-bear conflict (HBC) (Hopkins et al., 2010; Vongraven et al, 2012; Wilder et al., 2007). In this study, HWC, and more specifically human-polar bear conflict (HPBC), are defined as the situation in which wildlife and humans suffer from the interaction with each other in the form of injuries, death, loss of property or fear. In addition, competition over resources and unintentional encounters affecting humans negatively, are also defined as HWC (Koopmans & Polet, 2015).

An indicator for the threshold distance for an encounter to change into actual HPBC is the distance between person and polar bear, where the person still has the opportunity to deter the approaching polar bear and prevent conflict. It is difficult to set this threshold as no specific rules can be found in literature to define the different phases in HPBC and a polar bear could have different motives when approaching a human. The approach can be of investigative, defensive or aggressive nature. It is important to keep in mind that a polar bear should be avoided when it is sighted as all encounters with polar bears could potentially be dangerous (Pers com, Mizin, 2016). In this study three phases will be distinguished, namely the avoidance phase, deterring phase and conflict phase:

- ➔ **Avoidance phase**: A polar bear is at a distance of >1 km and is passive or moving away. People observing a polar bear at this distance should come together, observe the polar bear and its behaviour and prepare to withdraw, leave or get into the safety of a building. When a polar bear is at a distance of >1 km but approaching slowly, people should prepare to withdraw, leave the area or get into the safety of a building. (PolarQuest, 2015)
- ➔ **Deterring phase**: The AECO and Loonen reckon the threshold to start deterring an approaching polar bear is when they reach a distance of 100 meters on land (Pers com. Loonen, May 11, 2016; PolarQuest, 2015).
- ➔ **Conflict phase**: The polar bear keeps approaching to within a distance of 50-30 meters on land and thus comes in such proximity that it becomes a direct threat to human safety with a high chance of a physical encounter. (Pers com. Loonen, May 11, 2016; pers com. Mizin, 2016, PolarQuest, 2015).

The maximum distance for sightings of polar bears either on land or on ice from a zodiac is set at 30 meters by the Association of Arctic Expedition Cruise Operators (AECO) to minimize risks (AECO, 2014). For more information on motivation and recognizing polar bear behaviour in conflict situations see appendix I: Type of approach of a polar bear.

Through climate change, sea ice is diminishing and breaks up early in spring. This results in a decline of the natural habitat of the polar bear (Molnar et al., 2010) and their main prey; ringed (*Pusa hispida*) and bearded seals (*Erignathus barbatus*) (Derocher et al., 2004). As a result polar bears are more nutritionally stressed and are forced to spend more time on shore looking for alternative food sources (Molnar et al., 2010).

Reduced sea ice cover makes the Arctic more accessible to people and a variety of activities such as tourism (Hall & Saarinen, 2010), industry such as fishery and oil and gas extraction (ACIA, 2004; Davies & Rockwell, 1986; Krauss et al., 2005), scientific research and shipping (Aksenov et al., 2016; Stephenson et a, 2013). The loss of sea ice habitat and an increase in human presence results in an increased risk of human-polar bear encounters and conflict (Vongraven et al,. 2012; York et al., 2014). In addition inappropriate waste management and food storage causes polar bears to be attracted to human settlements (York et al., 2014). Furthermore the limitations in capacity, limitations in access to avoidance and deterrent equipment and lack of knowledge plays a role in increasing interactions between people and polar bears (Pers com. Polet, July 8, 2016; Koopmans & Klenzendorf, 2014) and officially recorded incidents in governmental records of the US Fish and Wildlife Service (USFWS) and other Range States show an increasing trend in human-polar bear conflict (HPBC) over the years.

HPBC often results in loss of property, injuries and occasionally the loss of human life. Such was the case in 2011 when a British school boy was killed during a school camping trip in Svalbard, Norway (BBC News, 2011). In 1990 a man was killed by a polar bear in Point Lay, Alaska, US (The Seattle Times, 1990). Most often the control measures taken after such incidents results in the death of the polar bear (Vongraven et al., 2012) as the animal will be killed in case human casualty is caused (Aarden, 2004). This was also the case in Churchill, Canada where two bears were shot after attacking a man and a woman (CBC News, 2013). In Svalbard, Norway in 2015 a man camping was attacked by a polar bear and a fellow camper shot the bear with a revolver (Reilly, 2015). In Hudson Bay, Canada a polar bear was killed out of precaution to avoid the risk of the polar bear returning to the place of conflict (CBC News, 2014). Proper usage of HPBC reduction measures can prevent HPBC from resulting in death of people and polar bears and could possibly have prevented these fatal conflicts (Kennedy, 2012; Orange, 2012; pers com. Koopmans WWF NL, Laforest WWF Canada, 10 February, 2016).

Without proper conflict management HPBC could be an additional stressor on polar bear populations (Koopmans & Polet, 2015; York et al., 2014) and affect the conservation of the polar bear (Towns et al., 2009). Good management of HPBC is also important to prevent humans from developing aversion and negative attitudes towards the polar bear, which could erode support. It is important to encourage coexistence with polar bears and willingness of people to cooperate in conserving the polar bear in the future when populations may be decreasing.

Through this study insight will be gained in the different available HPBC avoidance and reduction measures and the conditions that contribute to the success or failure of these measures. This will lead to better choice and use of available measures and reduces the number and severity of HPBC in the future.

The main question in this research is:

Which measures are most successful in avoiding and/or reducing human-polar bear conflict?

Secundary questions are defined as:

1. Which measures to avoid and/or reduce HPBC are currently used and/or which measures have been studied?
2. What are the preconditions under which these measures work optimally to avoid or reduce HPBC incidents?
3. How successful are these different HPBC reduction measures?
4. What are the advantages and disadvantages of these HPBC reduction measures?

2. Material and Methods

This study makes a distinction between different forms of conflict reduction measures based on different phases of HPBC (figure 4).

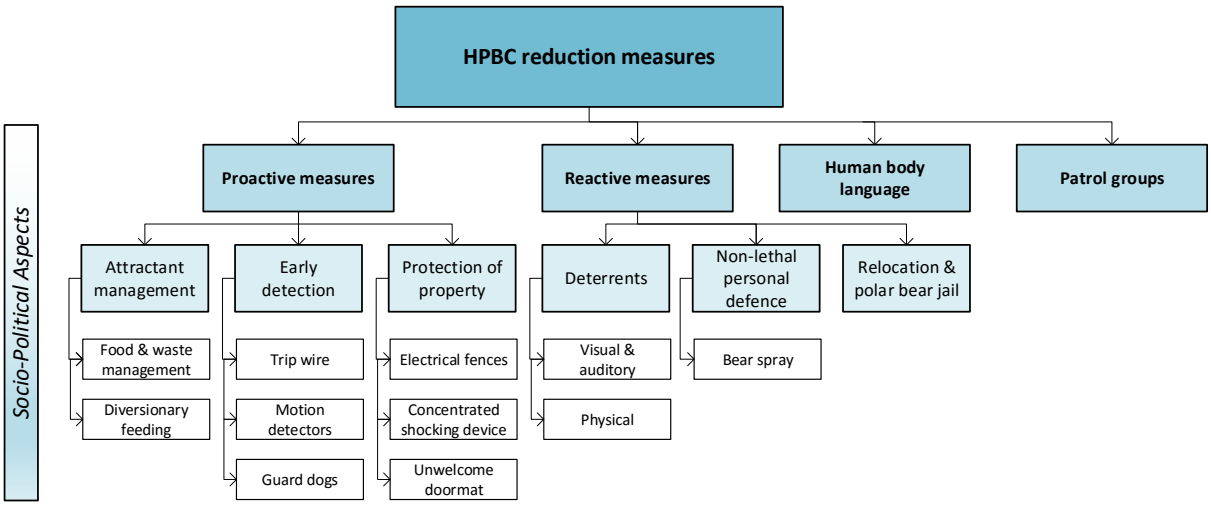

Figure 4 Overview of the subdivision and categorising of HPBC reduction measures.

A subdivision is made of measures which aim to proceed against the cause of possible conflict between humans and polar bears, the so called proactive measures. These are categorised into attractant management (e.g. waste management and food storage), early detection devices (e.g. trip wires) and protection of property (e.g. through electric or strong fences).

And a subdivision is made of measures responding to HPBC when the conflict is about to take place, or is taking place, the so called reactive measures. These measures are further categorised into deterrents (e.g. visual & auditory (flare guns) and physical (rubber bullets)) and personal defence measures (e.g. bear spray). Furthermore this study discusses patrol groups (that apply a range of measures) and human body language. (Appendix IV: Overview of HPBC Reduction Measures)

A deterrent is defined as successful when the polar bear changes the unwanted behaviour without causing any severe physical injuries to the polar bear and provides people with a chance to get into safety. Based on the conducted literature study of this research, the successfulness of a deterrent is interpreted into 3 categories:

1. Highly successful: the polar bear is deterred within the first attempt of using the deterrent
2. Moderate successful: polar bear is deterred within 2-4 attempts
3. Not successful: More than 5 attempts are necessary or the outcome of the deterrent is too unreliable

A precondition in this study of a deterrent is that it should be non-lethal to polar bears and humans.

Through a desktop study literature and secondary data was collected and analysed. When defining the research problem and creating the background of this study a list of key words relevant for this study was set up and could be used as search terms. Search terms and key words used (all in English) were a combination of *human, polar bear, bear,* Ursus*, encounter, conflict, harassment, interaction, reduction, avoidance, measure (e.g. bear spray, rubber bullets, electric fence, light), tool, deterrent, repellent, attractant, waste, problem bear, nuisance behaviour, nutritional stress, aggression, attack, habituation* and *food-conditioned*.

Data collecting was done by using scientific reports and reports and working documents available through WWF Netherlands. Scientific reports were collected through search machines such as Google Scholar, Science Direct, Scopus, WUR library and WWF Workspaces Directory, using both WUR and WWF access portal to scientific literature. All data available on the topic that could be found was used, creating an opportunistic approach. Where literature on polar bears was lacking on a specific measure, available literature on other human-bear conflict was used, such as the brown bear (*Ursus arctos*), Grizzly bear (*Ursus arctos*), American black bear (*Ursus americanus*) and Asian black bear (*Ursus thibetanus*). Therefore when spoken about "bears" in this report bear species in general are meant. When particularly spoken of polar bears or other bear species these species will be named accordingly.

All articles and reports were uploaded into Mendeley Reference Manager to organise and annotate the available information. When information was lacking on a specific measure additional information was obtained through interviews. Interviewees were selected based on their knowledge on HPBC, bear species or experience in the field. The list of interviewees can be found in appendix II.

A form of open interviews was used with the topics discussed known beforehand and asked in more detail when necessary. Interviewees were contacted by email to make an appointment for conducting the interview. This email had a short introduction to explain what the interview would be about, what questions the interviewee could expect and the purpose of the interview. The interviews were conducted over Skype and were audio recorded. Information obtained from the interviews was processed by categorising the information in an overview, based on the different topics and measures. Findings were compared with literature and further categorising was done according to the subdivision of measures as seen in figure 4.

As a results a description was given of the different measures and the context in what conflict situation it should be used. Per measure most important preconditions and main advantages and disadvantages are presented in results along with an overview of the situation description (e.g. optimal usage range and user group). For further reading, additional information, background and explanation see appendices V-IX.

Table 1 shows the descriptions of the different criteria necessary to evaluate the preconditions, advantages and disadvantages and restrictions of the different HPBC reduction measures. Not for all measures it was possible to describe all criteria, only those found in literature or obtained by interviews are presented in the results and appendices.

Table 1 Criteria for preconditions and description of HPBC reduction measures (based on own interpretations resulting from the literature study).

Criteria	Description
Design	The set up and manner of implementing the measures relevant for the successfulness of the measure
Environment	The environmental conditions, such as climate and landscape, which might affect the successfulness of the measure.
Training	Training and education necessary for proper implementation and successfulness of the measure
Distance	The range necessary for the measure to function effectively
Maintenance	Maintenance required to keep the measure functioning successfully 1. High: maintenance on daily basis 2. Moderate: On weekly basis or after using of measure 3. Low: Less than once a week
Responsibility	The stakeholders (government, organisations, communities, people) responsible for proper implementation and successfulness of the measure
Accessibility	Whether the measure is accessible for everyone to use in the situation of HPBC and people that need access to the measure in order for it to function successfully
Legal restrictions	Possible legal restrictions
Costs	Estimated costs of purchase 1. High: > $1000 USD 2. Moderate: $300 - $1000 USD 3. Low: < $250 USD
Successfulness	1. Highly successful: the polar bear is deterred within the first attempt of using the deterrent 2. Moderate successful: polar bear is deterred within 2-4 attempts 3. Not successful: More than 5 attempts are necessary or the outcome of the deterrent is too unreliable
Safety	Safety requirements and risks for both humans and polar bears 1. High: No direct contact between humans and polar bear and polar bear and/or human have a low chance of getting physically injured 2. Moderate: Chance of injury of either polar bear or human or both when used improperly or at a close distance. 3. Low: High risk of injury of either polar bear or human or both or when measure asks for close proximity to the polar bear to be applied
Interaction phase	1. Avoidance phase: a polar bear is at distance of > 1 km 2. Deterring phase: polar bear approaches within a distance of 100m 3. Conflict phase: polar bear approaches within a distance of 50-30m
Aversive conditioning (AC)	Resulting in a short-term or permanent behaviour change of nuisance behaviour of the polar bears after exposing the polar bear to the measure
Human behaviour	Required human behaviour to improve effectiveness of the measure
Polar bear related factors	Factors of influence on polar bear behaviour, and polar bear behaviour of influence of effectiveness of the measure
Combination with other measures	Other measures that have proven to improve effectiveness of the measure
Applicable group type	If measure is applicable for Indigenous People (IP), (Semi) Permanent Settlers (SPS) or Newly Settled and Temporary Residents (NSTR)
Other	Other conditions important for the successfulness of the measure

3. Results

3.1. Potential users of measures

Indigenous People (IP)

Indigenous people make up approximately 10% of the total population living in the Arctic and are divided over more than 40 ethnic groups. Indigenous communities have small widely scattered settlements and developed a specific connection to the land they inhabit. Its natural resources are important for the culture of the indigenous people as well as their survival. (Arctic Centre, 2016)

Major aspects considered by indigenous people regarding HPBC and polar bear wellbeing are:

1. Impact of polar bears on indigenous people

Indigenous people have a vast experience living with polar bears in close proximity. As well as seals and whales, hunting of polar bears helps to provide food and clothes to communities and contributes to the traditional economy as selling polar bear products provides money for life expenses and equipment for harvesting. Furthermore polar bear hunting contributes to the cultural identity of indigenous communities and helps form a bond with their environment. Polar bear hunters often fulfil a role model in their community as hunting polar bears is highly respected. In Canada another source of income provided by the hunting of polar bears is that of selling licences for sports hunting. (IUCN/SSC PBSG, 2009a; York et al., 2014)

2. The impact of human presence on polar bears

As indigenous communities have been living with polar bears for thousands of years, sharing the same area, conflict is a natural consequence. Indigenous people have been injured or even killed by polar bears and vice versa as long as they have been living side by side with each other. (York et al., 2014) In most communities any polar bear causing conflict was shot. With current hunting quota (MSUCL, 2016; PBI, 2016) this is no longer possible and communities need to find different solutions to deal with this conflict. In some areas shooting a problem polar bear is still doable when the quota are not met with hunting only, or when conflict polar bears are simply hunted within quota. However in the future with increasing conflicts and more “problem” bears, this would exceed the quota. And the challenge is to manage conflict in non-lethal ways. (Pers com. Koopmans, August 8, 2016)

3. Other challenges faced concerning HPBC
    - The area to be monitored and guarded is often extensive,
    - Communities located near the coast are often located along seasonal travel routes of the polar bear,
    - Around communities a large number and many different types of polar bear attractants are present (incl. traditionally stored and dried meat and fish),
    - The level of human activity is high and activities are often unpredictable (NPBGTP, 2013)
    - Communities often lack funding and resources for proper deterrent management. (Pers com. Koopmans, August 8, 2016)

(Semi) Permanent Settlers (SPS)

In the 1950s and 1960s immigrants moved to the Arctic because of the discovery of vast natural resources and in prospect of new opportunities. (ACIA, 2004; Arctic Centre, 2016a) Therefore this next group includes long-term settlers from elsewhere and other long term based settlers such as military station workers, meteorological/weather station workers, extractive companies and industrial development companies (ACIA, 2004; pers com. Mizin, June 13, 2016).

These groups often have more resources available to implement strict waste and food management protocols and therefore would expect to have significantly less problems than communities (NPBGTP, 2013). However experience shows that this is not always the case as they do not always manage their food and waste strictly even though they have the means (Pers com. Polet, July 8, 2016). As most people carry radios or are near a vehicle or locations where they can be contacted, movement and activities of people can be directed and people can be early warned when a polar bear has been sighted. Instructions can be communicated quickly. This makes deterrent actions better controllable. As many people do not have experience with polar bears in the past, this group should be intensively trained on how to respond when encountering a polar bear and requires the assistance of bear guards. (NPBGTP, 2013)

Major aspects considered by (semi) permanent settlement regarding HPBC and polar bear wellbeing are:

1. The impact of polar bears on (semi) permanent settlers:
    - Injury or death from an attack
    - Property damage
    - Work stoppages (from short delays when a polar bear is present in an area to extended closures around a den site)
2. Impact of human presence on polar bears:
    - Possibility of den disturbance by industrial operations, leading to den abandonment and possible cub mortality
    - Possible polar bear mortality from access to improperly stored toxic substance such as antifreeze, or from an oil spill
    - Harassment of polar bears by aircrafts, water crafts or vehicles.
    - Polar bears becoming food-conditioned by consuming human food and waste, or getting habituated around people, work sides or camps (Exxon, 2009)
3. Other challenges faced concerning HPBC
    - The area to be monitored and guarded is often extensive,
    - The level of human activity is high, activities are however often scheduled and routine
    - There is a large turnover in personnel that do not have experience with polar bear behaviour (NPBGTP, 2013)

Newly Settled and Temporary Residents (NSTR)

There are a lot of temporary newcomers in the Arctic. Numbers have grown from about 1 million in the early 1990s to more than 1.5 million in 2006 and 2007 (UNEP, 2007). This group consists of scientists, land-based tourists, expedition cruise based tourists and adventure tourists (sometimes semi-scientific) (Pers com. Polet, July 8, 2016). Scientists and tourists often do not use sturdy constructed buildings and are often based in camps (Pers com. Mizin, June 13, 2016). Tourists either stay overnight on board of a ship, in communities or in remote camps in polar bear territory. Researchers often stay in (tented) camps. Most incidents happen when new comers are camping on land, not picking the safest place to set up their camp (Pers com. Polet, July 8, 2016). Camps must be well managed to avoid HPBC. (NPBGTP, 2013) Cruise based tourism is often well-arranged as they are based on board of the ship and stay out of reach of polar bears (PolarQuest, 2015).

Majority of tourist and scientific activity is occurring in summer months. Polar bears on land are trying to conserve energy in these periods and suffer in some cases from nutritional stress. As tourists are not familiar with polar bear behaviour their safety is often dependent on people with experience such as bear guards, tour guides and sometimes patrol groups, who are responsible for the protection of tourists. (NPBGTP, 2013) Major aspects considered by newly settled and temporary residents regarding HPBC and polar bear wellbeing are:

1. The impact of polar bears on newly settled and temporary residents
    - Injury or death from an attack
    - Property damage
2. Impact of human presence on polar bears
    - Possibility of disturbance by bear viewing and human presence
    - Harassment of polar bears by vehicles
    - Polar bears becoming food-conditioned by consuming human food and waste, or getting habituated around people and camps
3. Other challenges faced concerning HPBC
    - Establishing the safest place to put up a camp or temporary residence
    - Responsibilities of both tourists and guards/researchers must be clear and must have the same understanding,
    - Situations should be evaluated by guards, and tourists should be warned in time to ensure safety,
    - Ensuring the presence of tourists/researchers should not have a negative effect on polar bears. (NPBGTP, 2013)

Concluding

For all groups knowledge of polar bear behaviour is necessary to recognize when human presence causes a polar bear to become stressed and this knowledge along with gained skills in using measures should be applied constantly to prevent or reduce HPBC (NPBGTP, 2013b). It is important to have reduction measures that not only will be effective, but also acceptable and accessible to the public or focus group (Cotton, 2008; pers com. Mizin, June 13, 2016).

3.2. Measures in general

The most appropriate response to avoid conflict when encountering a bear is to increase the distance between the bear and the person (Brown & Conover, 2008; GBSS, 2010; PolarQuest, 2015). Purpose of conflict reduction measures could be deterring polar bears without killing them, aversive conditioning (AC) (Appendix III) and providing human safety (Stirling, 2011). A deterrent should only be used when an unavoidable conflict with a bear has occurred or is about to occur (Stenhouse, 1984). If proactive measures have not been taken with caution, no deterrent will solve the underlying problem. Therefore effort must be made to avoid attracting bears to human property. (GBSS, 2010; Stenhouse, 1984) It is important to prevent polar bears to feel comfortable around human property to avoid habituation and an increasing chance of HPBC (Ovsyanikov, 3rd IBPCW, 2009). Measures should be chosen carefully to avoid people being given a false sense of security. If a polar bear should be deterred in a non-emergency situation, the least intense method for the polar bear should be used first .The choice of measure also depends on the level of experience and expertise of a person with the different measures. (GBSS, 2010) The conditions during the conflict determine the success of the outcome of HPBC (Wooldridge, 1983). There will be no guarantee that when attacked by a bear a person will avoid injury or death, however the response of the attacked person and selecting the right course of action adjusted to the circumstances can reduce this risk (Brown & Conover, 2008). No non-lethal deterrent works 100%, regardless of previous success (Stenhouse, 1983), therefore a combination of measures should be used (Treves & Karanth, 2016) Adapted management of HBC concerns both proactive and reactive conflict reduction measures to increase effectiveness and should change over time according to previous failures and success and research findings (Hopkins et al., 2010).

The previous experience of bears with human property and attractants will affect its response (Dalle-Molle & Van Horn 1989; Gillin et al. 1992; Shideler & Perham, n.d.). Naïve polar bears with no previous experience with human property are easiest to deter, while habituated polar bears are more difficult to deter, food-conditioned polar bears being the hardest to deter. (Gillin et al., 1992; Shideler & Perham, n.d.) The physical condition of a bear influences the success of conditioning experiments as bears experiencing nutritional stress could have a higher motivation to get to the attractant (Gillin et al., 1997). Furthermore effectiveness depends on the character of the individual bear and opportunity for repeated occasions (Gillin et al., 1992).

3.3. Proactive measures

The implementation of preventive, proactive conflict reduction measures aims at avoiding HPBC and nuisance behaviour of polar bears. Experience showed that it has reduced the amount of nuisance behaviour of bears obtaining human food and damaging property, the amount of human injury and removals and translocation of bears (Hopkins et al., 2010).

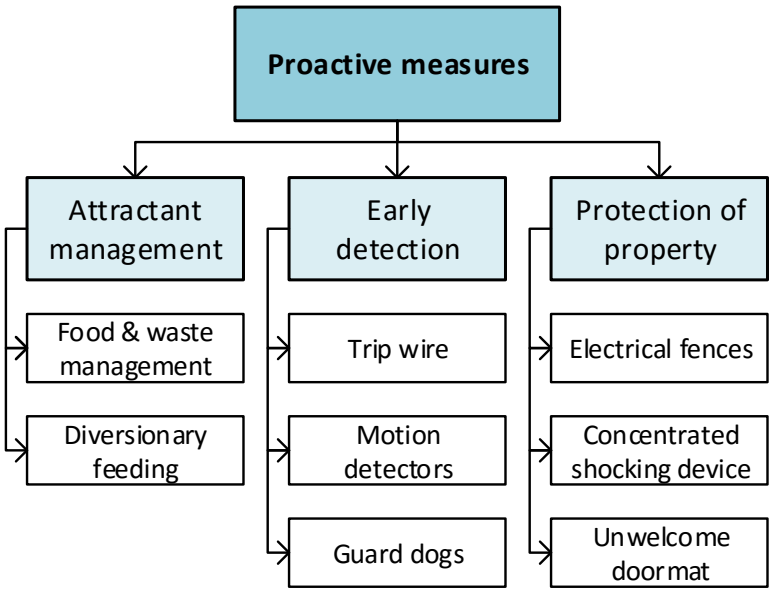

Figure 5 Overview of the subdivision and categorising of proactive measures to prevent HPBC

3.3.1. Attractant management

The aim of attractant management is to manage attractants to polar bears in such a way that it prevents polar bears from approaching humans and human property. For background on the role of attractants in HPBC: Appendix V.

Food and waste management

The aim of appropriate (i.e. polar bear proof) food storage and waste management is to avoid polar bears from being attracted to humans and human property by food, waste and sewer odours. A polar bear proof physical barrier needs to be placed between the animal and the attractant, as it is essential that when a polar bear does come close to human property, food and waste should not be accessible. This prevents polar bears from being rewarded. Physical barriers such as electric fencing could be a measure to keep polar bears away from human food and waste (Sowka, 3rd IBPCW, 2009), however to avoid polar bears to become attracted and hang around proper waste management is required inside the fence as well. Smells must be reduced through coverage and avian scavengers should be prevented from picking up waste and food and dropping it in the area (Marley, 3rd IBPCW, 2009). Adequate waste management and food storage facilities must be readily available, together with an enforcement program to ensure proper usage of the facilities (Mazur, 2010). Conflicting interest groups could be an obstacle for a range wide action plan and voluntary compliance will not be widespread and possible everywhere due to lack of appropriate storage facilities. There will be need for a generalized policy and it will only work when a whole community cooperates storing food in a polar bear proof way, possibly with police enforcement and giving fines. (Peine, 2001) It may be beneficial to establish an agency policy on storage and management of food and waste attractants (Spencer et al., 2007).

It is impossible to clean up everything and to have absolutely no attractants. There will always be attractants for bears at human settlements. Therefore another important focus point to minimize HPBC is trying to keep polar bears out and away of human property by using food and waste management in combination with other proactive measures. (Pers com. Klenzendorf, May 4, 2016)

Options for better food and waste management are:

- Trash compacters to reduce waste volume (Stirling, 2011)
- Incinerators to burn waste to reduce volume as unburned waste attracts bears (Sowka, 2013b)
- Bear proof garbage containers/dumpsters, solid waste dumpsters/container to manage odours and secure unnatural food sources and attractants for bears (Sowka, 2013b) and for storage of food harvested by indigenous people (mainly Inuit and coastal people)(Pers com. Ewins, August 9, 2016).
- Land fill is another option (Stirling, 2011), but as with landfill the attractants are just buried polar bears are still attracted to landfill sites, the problem still remains (Pers com. McMullen, June 21, 2016). Unless fully effective big or electrified fences with big locked gates are installed (Pers com. Ewins, August 9, 2016)

Items that could be used for food and waste storage are:

- Steel storage drums with a bolt-type lock
- Plastic storage containers with screw-on lid
- Trailers
- Fright containers
- Buildings
- Freezers (Sowka, 2013b)

Table 2 Preconditions of food and waste management

	Preconditions
Design	**General** • Food and waste should be stored inside buildings when possible (Exxon,2009; Pers com. Klenzendorf, May 4, 2016) • Food and non-food waste should be disposed and kept separately • Food and non-food waste should be incinerated daily when possible or otherwise stored temporary in enclosed containers • Storage of food and waste should be kept short term (Exxon, 2009) • Human property and settlements need to be kept as clean as possible and prevent attractive smell as much as possible (Stirling, 2011) **Food** • Scrap metal and other non-bear proof containers should be kept free of food waste (Exxon, 2009) • Food items should not be stored in tents and cooking, dishwashing and eating should be done at a distance of at least 90m (100yd) from sleeping areas (Sowka, 2013). • Food should not be left in parked vehicles • Only permitted in vehicles in containers that minimize odours, and only for short periods when unable to use permanent facilities. (Exxon, 2009) **Waste** • To minimize solid waste that requires off-site transport and disposal, settlements could have a small batch process waste incinerator • Non-burnable waste should be stored in enclosed BRCs and periodically removed and disposed outside of polar bear territory (Exxon, 2009) **Sewage and wastewater** • Should be a waste water treatment plan • Sewage sludge should be regularly incinerated (Exxon, 2009)
Responsibility	• Rules should be implemented at both governmental and community levels (Pers com. Mizin, June 13, 2016). • Whole community is responsible and has to contribute as infrequently rewarding a polar bear will renew the nuisance attractive behaviour (Stenhouse, 1983) • Should expand to all areas where polar bears range to reduce HPBC in a wider range (Gunther et al., 2004) • Enforcement (formal or peer-pressure) program necessary to ensure proper usage of the facilities (Spencer et al., 2007) • Should be an inspecting team responsible for patrolling and keeping waste and food management lived up to in the whole area/town to ensure no waste is lying around and everything is stored away properly. (Pers com. Klenzendorf, May 4, 2016)
Human behaviour	• Need of a public education program • Public awareness of the problem and the level of conflict should be increased, thus making it a human responsibility and the need for a collective action plan to solve the problem (Peine, 2001). • Implementing penalties/fines for improper food storage and waste management once BPC are available. (MacHutchon & Wellwood, 2002)

Bear proof containers (BPC)

There are different types of BPCs available for food management. However no literature mentions that these containers are smell proof and air tight to minimize attraction of polar bears. Experience shows that what may well be sufficiently proof to a black bear, is not always the case for polar bears which are much larger and stronger. Therefore containers should be specified to the bear species (Pers com. Ewins, August 9, 2016) and BPCs should be used in combination with other measures to reduce conflicts.

Table 3 Preconditions for Bear-Proof Containers (BPCs)

	Preconditions
Design	• Lids and doors must be completely enclosed/secured to reduce odours • Latches on lids must be bear-proof • When not stored inside a building it should be anchored to the ground to prevent tipping over • Hinges and latches must be strong enough to prevent being opened by claws • Should be strong enough to prevent from being crushed and chewed or opened by claws • Should be of corrosion resistant material to prevent rust and ensure long product life (Sowka, 2013b)

Table 4 Advantages and disadvantages of bear proof containers

Advantage	**Disadvantage**
• Often weather proof • Can be shipped almost anywhere • Could work well in remote places and camp grounds (Sowka, 2013b)	• In practice not all products are equally bear-resistant (Sowka, 3rd IBPCW, 2009) • Due to costs not all proper waste management systems and good food storage is available to local communities (Pers com. Klenzendorf, May 4, 2016; Sowka, 3rd IBPCW, 2009) • When not implemented by an entire community polar bears will still come into the village and cause problems (Pers com. Polet, July 8, 2016) • Sometimes hard to meet cultural needs of communities, who have their traditional ways of storing and drying meet. (Pers com. Koopmans, July 8, 2016)

Table 5 Overview of important facets of influence on determining BPC as an appropriate measure

Interaction phase	**Applicable group**	**Success**	**Maintenance**	**Costs**	**Safety**	**AC**
Avoidance	• IP • SPS • NSTR	Low - High	High	Moderate - High	High	Short term

Incinerators

Using an incinerator is better than land fill as an incinerator gets rid of the waste. With land fill the problem of attractants remains. Incinerators should be developed for large communities, they are available for communities of less than 30 people but are very expensive ($6000 USD). On 10 to15 man camp sites, incinerators could be used, while using a hot fire and burning waste could be sufficient on smaller campsites. (Pers com. McMullen, June 21, 2016) (Further reading: ADFG, 2016)

Table 6 Preconditions for incinerators

	Preconditions
Design	• Food waste should go immediately in the incinerator and should not be stored outside. (Pers com. McMullen, June 21, 2016) • Entire community has to comply (Pers com. Polet, July 8, 2016)
Legal restrictions	• Burning regulations: might have strict air quality standards and might not be legal to burn waste all year round (Sowka, 2013b)

Table 7 Advantages and disadvantages of incinerators

Advantage	Disadvantage
• Through burning actually gets rid of the waste	• Very good waste management systems with recycling and incinerators such as is done in Churchill are very expensive (Pers com. Klenzendorf, May 4, 2016) • Elimination of polar bears feeling attracted will be a long and slow process and when infrequently rewarded by (accidently) getting access to the attractant, it can renew the nuisance behaviour and motivation of the polar bear (Stenhouse, 1983). • When burning other materials than non-toxic materials it has a polluting impact on the environment (ADFG, 2016)

Table 8 Overview of important facets of influence on determining incinerators as an appropriate measure

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Avoidance	• IP • SPS	Low - High	High	High	High	Short term

Diversionary feeding

Diversionary feeding is the moving or placing of food sources such as marine carcasses away from human property and settlements to reduce HPBC (Dutton et al., 2011). Distributing in a remote area draws bears away from human settlement and property (Madel, PBDFW, 2011). There are different opinions on the definition of diversionary feeding. Some only consider it as relocation of washed up marine mammal carcasses, in which case it is a way of dealing with carcasses of marine mammals (which is food to the locals). The carcasses of whale or seal are moved away and not butchered in front of the village. Polar bears can then quietly feed on the carcass. Others would also include actively provided food to move polar bears away. The later could result in food-conditioning in bears. (Adams, PBDFW, 2011) Another discussion point is whether diversionary feeding is a method to avoid HPBC by attracting polar bears elsewhere or whether it is a form of waste management. The risk of feeding animals for the purpose of avoiding conflict is that once feeding is stopped, polar bears will continue to come back in search of food. Thus diversionary feeding might be better when initiated as a form of waste management (Pers com. Polet, July 8, 2016).

A concern would be that diversionary feeding could possibly result in exceeded carrying capacity in an area due to expanding populations (Dutton et al., 2011). It could attract more polar bears to a specific region and thus possibly create a growth in polar bear presence in that area. However random distribution might prevent this and also depends on the frequency and amount of diversionary feeding. Bears that are too food-conditioned and get too dependent on the provided food sources might get in trouble maintaining their body size and physical condition on their own (Shideler, PBDFW, 2011). When just relocating natural food sources such as washed up whales, no additional amounts of food are provided to the polar bears and randomising the location could prevent them from becoming conditioned to a specific food area. However since Inuit communities traditionally harvest whales remains that will be improperly disposed will become an additional food source nevertheless. This is seen in Barrow, Cross Island and on Barter Island, Alaska where unused portions of whale carcasses provide an additional food source to polar bears in a period when otherwise they would be fasting (Dutton et al., 2011).

Developing specific guidelines to standardize carcass placement methods and requirements could minimize potential problems. Monitoring of the feeding areas can provide information on carcass use, consumer species specifics and rate of consumption. (Madel, PBDFW, 2011)

Table 9 Preconditions of diversionary feeding

	Preconditions
Design	• Only existing, natural food sources to polar bears should be used (Dutton et al., 2011) • Location should be chosen where natural food sources will occur at another time of the year (Dutton et al., 2011). • Migration route of polar bears should be kept in mind to avoid movement through human settlement to get to the feeding area (Sims-Kayotuk & Burns, PBDFW, 2011)
Distance	• Minimum of 8 km (5 miles) away from human property (Pers com. Klenzendorf, May 4, 2016)
Responsibility	• Need of dedicated people to be successful (Pers com. Klenzendorf, May 4, 2016) • Villages located in an area in close proximity should all take the same responsibility as the problem only shifts to another village if not all villages cooperate (Pers com. Klenzendorf, May 4, 2016).
Polar bear related factors	• Distribution should be random to prevent conditioning to a specific area or humans (Dutton et al., 2011; Madel; PBDFW, 2011). • Should be done in consideration with environment and polar related factors as it could influence the behavioural characteristics, demographics and physiological requirements (Shideler, PBDFW, 2011).

Table 10 Advantages and disadvantages of diversionary feeding

Advantage	Disadvantage
• When done properly it shifts the location but not the amount or source of food available (Madel, PBDFW, 2011). • Food sources provided are of traditional diet and nutrition for the bears (Madel; PBDFW, 2011). • Effective in preventing new bears in becoming food-conditioned (Shideler, PBDFW, 2011) • Possibility of meeting mates (Adams, PBDFW, 2011)	• Attracting unwanted wildlife with the risk of spreading diseases (Adams, PBDFW, 2011; Dutton et al., 2011) • Educating people and changing their habits might be challenging. (York, PBDFW, 2011) • Risk of conditioning of polar bears to a specific area (Adams, PBDFW, 2011) • Less effective on already food-conditioned polar bears (Shideler, PBDFW, 2011) • An increase in polar bear numbers could lead to an increase in problem bears, especially when diversional food source will be removed or is inadequate (Dutton et al., 2011). • Providing food sources to a polar bear in a period where it would normally be fasting could result into a higher metabolic rate and loosing of fat reserves if the necessary energy nutritional requirements that come with an increased metabolic rate cannot be met (Dutton et al., 2011).

Table 11 Overview of important facets of influence on determining the use of diversionary feeding as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Avoidance	• IP	Moderate - High	Low	Moderate - High	High	Long term

3.3.2. Early detection measures

Undetected polar bears can be a threat to the safety of people and their property. Weather and climate conditions can make it difficult to visibly detect polar bears when they approach villages or other settlements. Early detection measures can help detect the presence of a polar bear and alert people quickly, which thereby increases safety around human property. The earlier a polar bear is detected, the more time there is to evaluate the situation and to determine an appropriate response. (NPBGTP, 2013b) Early detection can be done by trip wire systems, motion detectors or guard dogs.

Trip Wire

A trip wire fence sets off an alarm when the wire or connection is broken by people or wildlife (NPBGTP, 2013c; Wooldridge, 1983) that apply 7kg of pressure on the system (Pers com. Marley, 2016). The system is easy and fast to set up and break down, which is good when travelling around a lot. It is very accessible as it can be sent by mail (Pers com. Marley, June 16, 2016).

Literature shows divers opinions on the effectiveness of trip wire mechanisms, ranging from reliable and effective, to unreliable. The system is sensitive to other trespassers and could set off "false" alarm (Pers com. Prop, May 4, 2016). Failure of trip wire systems is possible and could be a result of a human fault in set up of the system or mechanical failures. Therefore the system and control unit should always be tested (Margo Supplies Ltd, n.d.a.) and reset after each intrusion (Stenhouse, 1983). Protection is increased with the number of wire strands used; minimum of 2 strands of wire is required (NPBGTP, 2013c, pers com. Marley, 2016). The system does not alter the behaviour of approaching polar bear, so should be combined with deterrents.

Table 12 Preconditions of trip wire systems

	Preconditions
Design	• Device should surround the whole settlement (mainly used for tourist- or science camps). • Poles should be strong enough to support the pressure that a polar bear applies on the system (Pers com. Marley, June 16, 2016). • Wires should be tensioned • Height of wire approximately 20 and 40 cm • 12-volt power supply (NPBGTP, 2013c) • Alarm controller (Margo Supplies Ltd, n.d.a)
Distance	• System should be placed at least 5m (16ft) from all sides of the settlement to give people enough time to respond to an intruding polar bear. (NPBGTP, 2013c)
Responsibility	• Set up of guidelines and appointing a person responsible could increase reliability

Table 13 Advantages and disadvantages of trip wire systems

Advantage	Disadvantage
• Simple set up (GBSS, 2010; Stenhouse, 1983) • 12 volt battery provides 50 hours of continuous operation. When not activates battery life is up to 2 years (Pers com. Marley, August 28, 2016) • Practical for relatively small mobile field camps (Stenhouse, 1983) • Portable (Stenhouse, 1983) • Alarm may scare off the approaching bear (NPBGTP, 2013c)	• System can fail when not properly set up (GBSS, 2010) • Difficult to keep the wires tight and repair breaks when the fence is too large (NPBGTP, 2013c). • Frozen ground makes it difficult to properly set up posts (Pers com. Marley, June 16, 2016)

Table 14 Overview of important facets of influence on determining the use of trip wire systems as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Conflict (50-30m)	• IP • SPS • NSTR	Low	High	Low	High	Short term

Motion detectors

Motion detectors use passive infrared sensors to detect body heat and motion along a line of sight of up to maximum 24m (80ft) in front of the detector unit, creating an invisible fence around a site. An alarm goes off and/or a light switches on when the sensor of the detection unit detects heat or movement within its sensing beam. (NPBGTP, 2013c) It is a cold weather system suitable to operate at -30°C, however excessive rain and snow can be a problem interfering with the sensor. It is easily accessible for all groups and relatively cheap (Pers com. Marley, 2016). It might be of better use for small permanent camps, and unsuitable for large settlements as the system reacts on all motions, not just that of polar bears and restricts movement of people. (NPBGTP, 2013c, Pers com. Polet, July 8, 2016) An example of such a device is the Critter gitter which works on batteries and has a built in strobe light and siren. The system does not always alter the behaviour of approaching polar bear, so should be combined with deterrents as habituation quickly occurs. (Pers com. Marley, June 16, 2016)

Table 15 Preconditions of motion detectors

	Preconditions
Design	• Device should be placed clear of obstructions and surrounding the whole camp. • For a totally enclosed site and 360° detection 3 devices should be used as the device is limited in seeing only one direction • Powered by 9V lithium battery (Pers com. Marley, June 16, 2016)
Accessibility	• Readily available from most electronic stores (NPBGTP, 2013c) • No restrictions on accessibility, can be send in mail as is very small of size (Pers com. Marley, June 16, 2016)

Table 16 Advantages and disadvantages of motion detectors

Advantage	Disadvantage
• Easy to use/install (GBSS, 2010; NPBGTP, 2013c) • Automatically resets itself (NPBGTP, 2013c) • Operational in darkness and reduced visibility (Stenhouse, 1983) • Lithium battery provides up to 200 activations (Pers com. Marley, August 28, 2016) • Alarm and/or switching on a light might already deter the approaching polar bear (NPBGTP, 2013c)	• Not for large camps (NPBGTP, 2013c) • Activated not only by polar bears, but also humans and other wildlife (Pers com. Polet, July 8, 2016) • Could be falsely activated by wind due to temperature differences in the wind. (Pers com. Marley, June 16, 2016) or snow (NPBGTP, 2013c) • Dirt, snow and ice could cover the sensor, preventing it to work properly (NPBGTP, 2013c)

Table 17 Overview of important facets of influence on determining the use of motion detectors as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Conflict (50 – 30m)	• IP • NSTR	Low	Moderate	Low	High	Short term

Guard dogs

With their sharp sense of smell, dogs can detect approaching polar bears that cannot be detected visibly by people and thus increase safety in an area with restricted view (NPBGTP, 2013). The distance that dogs can detect polar bears under optimal conditions is not known, however dogs have been seen detecting seal meat under a meter of snow at a distance of 1km (Stirling, 2011). In good weather conditions dogs seem to be a good early detection device, however when weather conditions are bad, e.g. when there are strong winds that go upwind (opposite direction of travel direction of the polar bear) the scent of the polar bear is carried away from the dogs and dogs could fail to detect an approaching polar bear. Inuit have good experience with letting the lead dog run free around the rest of the dogs that are tied up in a camp. The lead dog can fend off or detect polar bears better by being able to circle the rest of the dogs. (Pers com. Klenzendorf, May 4, 2016)
Dogs can warn people and draw an approaching polar bear's attention away from people or property. However dogs could also attract polar bears and provoke aggression and increase conflict. (Ovsyanikov. 3rd IPBCW, 2013) Dog food could also be an attractant to polar bears. (NPBGTP, 2013b)

Unfortunately information is lacking on the full potential of this measure, such as in what conditions dogs prove to be efficient detectors of polar bears, what breed of dog is advisable and what are the conditions the dogs need to be kept in (on a chain or let run loose) to have the highest detection possibilities.

Table 18 Preconditions of guard dogs

	Preconditions
Design	• Dogs must be well trained (GBSS, 2010; Gillin et al,. 1997; McMullen, 2000; NPBGTP, 2013b). • Dog breed and individual dog must be suitable detecting and deterring bears (Gillin et al., 1999)
Training	• To avoid guard dogs obeying to only one handler training should be done in a team. (NPBGTP, 2013b).

Table 19 Advantages and disadvantages of guard dogs

Advantage	Disadvantage
• When well trained a guard dog could also be an effective deterrent measure (GBSS, 2010; Gillin, 1999; NPBGTP, 2013) • Accessible for local communities, especially when they are already used to keeping dogs (Pers com. Klenzendorf, May 4, 2016)	• Even experienced dogs could fail in detecting, sleeping through an approaching polar bear and sound alarm too late (NPBGTP, 2013b). • Dogs and dog food could be an attractant in themselves (NPBGTP, 2013b) • Training requires a lot of time and investment. (NPBGTP, 2013b). • When lack of proper training, dogs could possibly be a hazard by barking and provoke aggression of the polar bear (NPBGTP, 2013b)

Table 20 Overview of important facets of influence on determining the use of guard dogs as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Avoidance & Deterrent	• IP	-	High	Moderate - High	Low	Short term

3.3.3. Protection of property

Electrical fences

In order to be functional, electric fences should be site specific and designed accordingly (Muruthi, 2005; Stenhouse, 1984). Literature on the use of electric fences to keep out bears shows different rates of success (Morrison, 3rd IBPCW, 2009; Stilling, 2011; Wilson et al., 2005). Major limiting factors of wider use of electric fencing are costs, environmental factors, types of fencing and the species the fence is designed to deter (Muruthi, 2005). Problems affecting the effectiveness of electric fences are insufficient grounding, incorrect spacing between the lines, incorrect number of lines and slack lines, incorrect fence height and weak and improperly buried corner posts (Huygens & Hayashi, 1999). Furthermore the required levels of maintenance are a major limiting factor (Honda, 2007; Muruthi, 2005) especially maintenance relating to keeping electric fences snow free (Pers com. Koopmans, July 8, 2016).

The electric circuit of a fence starts with a positive electric flow from the energizer through positive wires. When a polar bear touches the wires it becomes a bridge and the flow goes back to the negative terminal, creating a circuit. (McMullen, 2000; Pers com. Marley, June 16, 2016) Design factors such as the position of the fence and the number and spacing of the wires determine whether an animal receives the right shock (McKillop & Sibly, 1988).

The biggest problem with electric fencing is the grounding. In the Arctic, electric fences are usually set up on sea ice or frozen ground with permafrost. The grounding of the energizer and the polar bear is complicated as both do not ground well on ice. Normally ground rods can be used for grounding. They need to be dug in or put in a trench and buried. Ideally ground rod or plate is placed in humid soil. When it is not possible to get the rods in the ground properly or when the fence has to be moved often, ground plates could be used. Also when using a portable fence, ground plates are often used. (pers com. Marley, June 16, 2016)

Electric fences can be portable or used in a permanent settling. A permanent fence will remain in place longer than a portable electric fence and will require different construction materials. The general components of both types of fences are the same: wires, posts, energizer, grounding system and insulators. Both types of fences could be just as effective. The difference between these two types of fencing is the type of fence posts used and the extent to which the posts are fixed into the ground. Portable fences are cheaper to install but the posts do not hold up as well as permanent fence posts. (Sowka, 2013a)

Several sources discuss the preconditions of setting up electric fences in order to be effective in keeping polar bears out. Opinions and results vary (see appendix VII: electrical fences) Most important preconditions that seem to have the best results are described in table 21 and are based on field experience of Marley from Margo Supplies (pers com. Marley, June 16, 2016).

(Further reading: Margo Supplies ltd., n.d.a.; Sowka, 2013a)

Table 21 Preconditions of electric fences to work accordingly (Source: Pers com. Marley, June 16, 2016, unless mentioned otherwise)

	Preconditions
Design	• Energizer needs to be grounded. When available, electricity poles could be used for grounding • Polar bear needs to be grounded. In order for the electric shock to be effective they should stand on green vegetation, humid soil, or a ground plate • Ground rod need to have mass (solid) and surface area • Alternating positive-negative wiring should be used to increase effectivity of the shock • As fur is an insulator, wires have to be round and tight to separate the hair of the polar bear to be able to touch the skin. Flat high visibility tape fails to do so. However this tape could be used on top to give a polar bear a shock on the nose when sniffing the fence. • Preferable 12 ½ gage high tensile wire should be used, as this wire is strong and it takes around 1800 pounds to break it. However it is difficult to get the wire tight without proper tools • Stranded galvanised wire is a good alternative. It is easy to work with and strong. It has less resistance than solid wire, because it is stranded. It carries the current better. It has a breaking strength of approximately 360-455kg (800-1000lb). It keeps it quality when moved and has good results in keeping polar bears out. • Poly-wire is suitable for light weight portable fences, when up for only a few nights and moved again • Corner post have to be absolutely rigid as direction or wires change at a corner and it has to uphold a lot of strength from tensioned wires (90kg (200lb) per wire x 8 strands = 725kg (1600lb) (Pers com. Marley, June 16, 2016) and a polar bear may first apply considerable force to the fence before the conductors reach the skin and a shock can be provided (Gasvoda, 1999). • Fiberglass posts are most exclusively used in the arctic as they are 1. Logistically attractive: less expensive to ship, they are not as bulky 2. Practical in size and light in weight 3. Durable and difficult to break 4. Flexible: line posts bend in the direction of force applied when pushed against but comes back. 5. Applicable in any type of ground, using the right tools • Diagonal post are important to keep the fence rigid and prevents the fence from moving inward • Line post can have smaller diameter as they function to keep the line height properly in between the corner posts. • 8 strands of wire (4 negative, 4 positive) with 20cm in between each wire • Metal ground clamps should be used • In general an output of 80watt or 110amp/hour is necessary • Choice of energizer is important. Energizer output has to be directly proportional. Size of the fence does not matter but energizer should match the size of the fence. A fence extending 500-700m the energizer should be bigger or should be split up in segments. • Stronger energizer unit is necessary as dealing with human safety is a serious business • Shock needs to be greater when grounding conditions are poor. • When more power has to put out, more power intake is necessary. • 5.000V is the minimum voltage to shock a heavily furred coat animal. There is no code for optimal voltage for polar bears. The more voltage the better and should always go for as much voltage as possible. Could go up to 10.000V. This is still safe for human contact. **Power supply:** • When available alternating current power input is preferable over batteries as it pulls more current • Otherwise Solar Magnum 12 Fence energizer is a good option

	• When choosing batteries frost proof batteries are necessary, such as the AGM gel cell • Batteries should not be put directly on the cold ground, as this will drain the battery. • Energizer should be in comparison to the fence overall length of charged wires and site conditions to provide sufficient power supply (6-8 weeks) (Pers com. Marley, June 16, 2016) • Power should always be on in order to work successfully (Pers com. Prop, May 4, 2016)
Distance	• When using the right materials and maintenance size of an area should not matter (Pers com. Prop, May 4, 2016)

There is a difference between keeping polar bears out of an area and trying to kick them out, as is the case with polar bears that are already food-conditioned. Food-conditioned polar bears will respond to 5000V, but higher voltage would be more effective. The same is the case with poor grounding. Aim is to get out more voltage when possible. It depends on ground conditions and size of the fence if it is possible or not to get a higher output. There are no hard numbers available in literature on preconditions for voltage. (Pers com. Marley, June 16, 2016)

Prices of electric fences depend on the size of the fence. Energizers are the most expensive part. A larger fence is needs a bigger energizer. A bigger fence is relatively cheaper per meter. (Pers com. Marley, June 16, 2016) Costs of electric fencing would need to be weighted out against the risk of conflict, depredation and the size of the fence needed (Wilson et al., 2005). Although fencing of small areas with relatively expensive electric fences is economically unattractive, by finding effective methods to reduce levels of bear depredation it can improve the attitude towards bears and bear conservation by communities (Huygens & Hayashi, 1999). To reduce costs and support communities, partnerships with other NGO's to provide electric fencing and assistance with installation could be considered (Gunther et al., 2004) There are no restrictions getting fences to remote areas. It could however be difficult and expensive. (Pers com. Marley, June 16, 2016)

When used simultaneously with other AC methods it is hard to see the efficiency of the electric fence itself and bias could occur. Using simultaneously with other deterrents and measures however it could be highly successful (Huygens & Hayashi, 1999). McMullen reckons the most effective method of reducing HBPC kills in outpost camps is using electric fencing in combination with rubber bullets and dogs (McMullen, 2000).

Table 22 Advantages and disadvantages of electrical fences

Advantage	Disadvantage
• Easy accessible to people (Pers com. Marley, June 16, 2016; pers com. Prop, May 4, 2016) • Relatively easy to build up (Pers com. Marley, June 16, 2016) • Portable fences are easy and fast set up (Gasvoda, 1999) • When used with proper food storage and minimization of attractants (food odours) highly successful (Davies & Rockwell, 1986). • When installed and maintained properly electric fencing is a successful, long term safety measure. (Pers com. Marley, June 16, 2016; McMullen, 2000) • Polar bears respect the fence when they have not been successful to breach though the fence (pers com. Klenzendorf, May 4, 2016)	• Difficult the get the poles into the ground when ground is frozen (Pers com. Prop, May 4, 2016). • Snow drift and storms can cause snow to touch the bottom wire and prevent proper grounding and causing voltage leak, decreasing the electric shock below the required voltage (pers com. Klenzendorf, May 4, 2016) • Maintenance is very labour intensive. In bad weather conditions needs to be checked at least twice a day (Pers com. Klenzendorf, May 4, 2016). • Due to high maintenance and costs, often not accessible to local communities • Might shift problem elsewhere to place with no electric fencing • Wet vegetation and snow can cause the electric current to ground and decrease the electric shock below the required 5000V (Gasvoda, 1999). • Lack of light in winter makes solar power unfeasible (Pers com. Polet, July 8, 2016)

Table 23 Overview of important facets of influence on determining the use of electrical fences as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Used to avoid conflict	• IP • SPS • NSTR	Moderate - High	High	High	Moderate	Short term

Concentrated shocking device

A concentrated shocking device is a portable and adaptable system that potentially can be used in a variety of situations to deter bears from accessing concentrated food or waste sources. Activation of the device occurs when a bear triggers the contact plate, providing an electrical shock. An example of a concentrated shocking device is the Nuisance Bear Controller (NBC) that has been tested on black bears and seems very reliable and has long battery life. (Breck et al., 2006) A similar system could be used to electrify containers and dumpsters, or as an electrified mat on the ground.

A concentrated shocking device in combination with BPCs and dumpsters (see paragraph 3.3.1. Bear proof containers) could provide an extra AC stimulus for a polar bear to teach them to avoid containers (Sowka, 2013a). It could be a useful system to protect resources that are remote or difficult to access. The device is relatively cheap, however could become cost prohibitive when many units are needed to protect resources (Breck et al., 2006).

Testing on polar bears has not been done and would be advisable to indicate the effectiveness of this device on changing the behaviour of polar bears. As well as testing on how the Arctic environment could be of influence on the effectiveness as batteries could be affected by low Arctic temperatures and snow cover might prevent the device from functioning properly. Snow cover and wind could move the trigger plate, activate the device causing the battery to drain (Breck et al., 2006)

Table 24 Preconditions of concentrated shocking devices

	Preconditions
Design	• Energizer of 110-120 volt A.C. or a 12-volt battery necessary to power each unit • Emitted shock should be 10,000-13,000V (Breck et al., 2006)

Table 25 Advantages and disadvantages of concentrated shocking devices

Advantage	Disadvantage
• Batteries are not continuously drained due to activation only when trigger plate is moved • Long battery life: two 6-volt lantern batteries to power each unit, which lasted the duration of 4,5 months despite weekly testing of each system. • Useful for protecting resources that are remote or difficult to access on a frequent basis due to low maintenance • Reliable in the field (Breck et al., 2006)	• Wind could move the trigger plate, activate the device causing the battery to drain (Breck et al., 2006) • Battery could be affected by low Arctic temperatures (Breck et al., 2006)

Table 26 Overview of important facets of influence on determining the use concentrated shocking devices as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Avoidance	• IP • SPS	-	Low - Moderate	Moderate - High	High	Short term

Unwelcome doormats

Placing unwelcome mats in front of doors and windows could provide protection of polar bears entering buildings. Non-electrical unwelcome mats could easily and inexpensively be made by applying nails or screws into boards. The sharp ends of the nails extending from the boards prevent bears to step or stand in front of doors and windows. (CDW, n.d.)

In Svalbard a similar idea has been tested with spikes around window sills. This seems to work well to prevent polar bears demolishing windows with frames. (Pers com. Polet, 2016) The idea of using nails in unwelcome mats has not been tested on polar bears yet and optimal conditions are not known. It could be an option to put unwelcome mats in front of human property when property is deserted (CDW, n.d.). However due to chance of severe injuries for both humans and polar bears (especially when covered by snow) this measure is not recommendable (Pers com. Polet, 2016)

Table 27 Preconditions of unwelcome doormats

	Preconditions
Design	• Nails or screw have to extend approximately 1,25-2,5 cm (½-1 inch) from the board (tested on black bears) • Distance between nails approximately 5 cm (2”) • Mat should be large enough to prevent a bear from leaning in and reaching for the object that is supposed to be protected.
Safety	• Nails should not be spaced too far apart or too long as it could severely injure a polar bear or human. (CDW, n.d.)

Table 28 Advantages and disadvantages of unwelcome doormats

Advantage	Disadvantage
• Relatively cheap and easy accessible • Not affected by weather conditions on short term (CDW, n.d.)	• Not tested on polar bears yet • Could severely injure polar bears or people, especially when covered with snow (Pers com. Polet, July 8, 2016)

Table 29 Overview of important facets of influence on determining the use of unwelcome doormats as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Conflict	• IP	-	Low	Low	Low	-

3.4. Reactive measures

Although proactive prevention measures are the best option to prevent conflict, reactive approaches will be necessary when conflict does occur (Muruthi, 2005) and a polar bear comes within the deterrents and conflict phase. Deterrent measures that use scaring and repelling techniques are in many cases sufficient in repelling polar bears. When a polar bear continues its approach and despite using deterring techniques personal defence measures can be used in the actual conflict phase. In extreme cases when deterrents fail repeatedly and a particular polar bear causes repetitive problems, complete removal of the problem bear by capture and relocation could be an option.

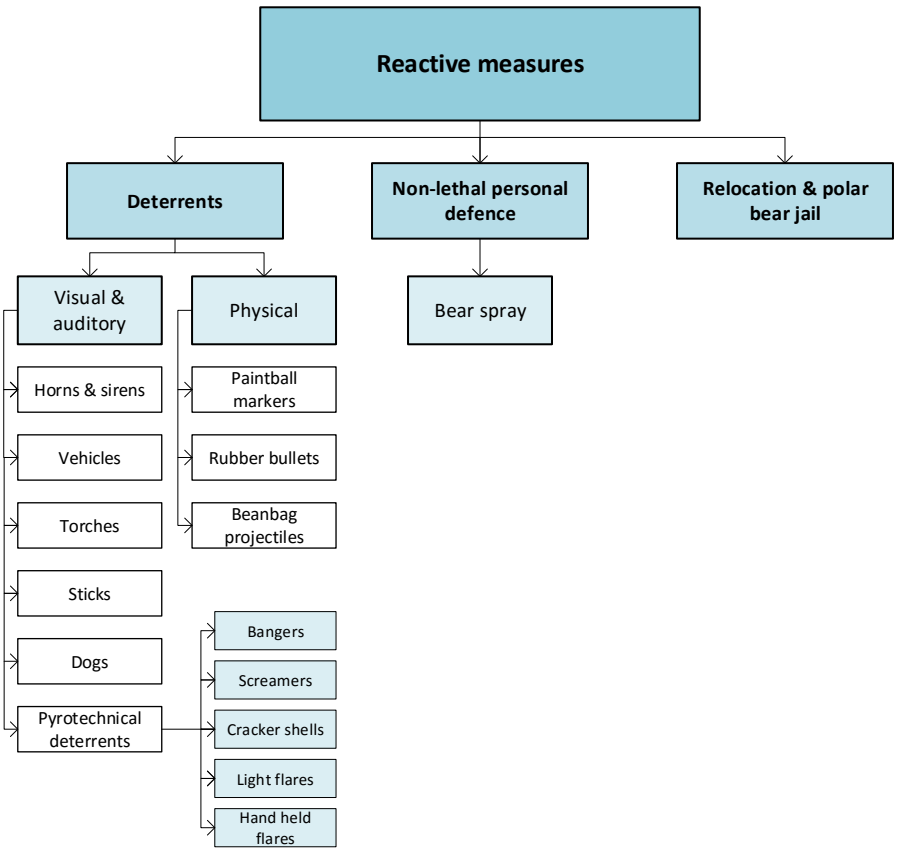

Figure 6 Overview of the subdivision and categorising of reactive measures

3.4.1. Deterrents

Deterrent efforts benefit from good early detection measures, giving a person more time to respond in a proper way and expends the choice of possible measures that can be used (Exxon, 2009). Overuse of deterrent measures can decrease their effectiveness (Exxon, 2009) and habituation can occur (Exxon, 2009; GSBS, 2010; Wooldridge, 1985). Not all deterrents are effective in every situation as for example all deterrents are less effective on food-conditioned bears (NPBGTP, 2013c). Each deterrent measure has different preconditions and limitations. Appropriate use of deterrent measures could increase human and polar bear safety, reducing the need to kill problem polar bears. (NPBGTP, 2013b)

Deterrents can be grouped into two categories of aversive stimuli:

1. **Noise and visual deterrents** providing loud and unpleasant sound, causing unease or annoyance along with visual intimidation, causing the bear to move away (GSBS, 2010; NPBGTP, 2013b). Noise and visual deterrents include horns and sirens, vehicles/mobile equipment, torches, sticks, dogs and pyrotechnical devices.
2. **Physical deterrents**; causing short term pain, but no injury (NPBGTP, 2013b). The intention of these measures is to create discomfort or pain in order for the bear to learn to associate this with the situation, and avoid that in the future (GBSS, 2010). Physical deterrents that cause negative tactile sensations include rubber bullets, bean bags, and paintball markers.

When used correctly all mentioned deterrents are non-lethal (NPBGTP, 2013b). General conditions to increase the effectiveness of deterrent measures can be found in appendix IX.

Noise and visual deterrents

Horns and sirens

Horns and sirens are used to produce a loud noise and deter polar bears at a close range. Vehicle mounted horns can be used as well as portable hand-held air horns. Horns and sirens can additionally be used to alert people for approaching polar bears. (NPBGTP, 2013b)

These noise deterrent devices should produce a noise in range of 110-120 decibels. Before using the device the polar bear should be made aware of human presence, to avoid surprising the polar bears and provoke a charge or attack (NPBGTP, 2013b). Multiple sources state that horns and sirens are not as effective on their own and need to be used in combination with other deterrents (NPBGTP, 2013b), especially to scare off a nutritionally stressed or human-food and waste conditioned polar bear (NPBGTP, 2013c).

A limiting factor of air horns are shipping restrictions. An air horn pressurised using a pump can be emptied for transport and recharged on location, avoiding dangerous goods shipping restrictions (NPBGTP, 2013b). After usage the canister can immediately be recharged using the air pump for multiple uses (NPBGTP, 2013b).

Table 30 Preconditions of horns and sirens

	Preconditions
Design	• Sound should be in range of 110-120 decibels
Distance	• Sound should be initiated when bear is within an approximate distance of 100m (Wooldridge, 1985)
Accessibility	• Readily available in northern communities and industrial installations
Legal restrictions	• Alaska: Shipping restrictions when not pressurised by using a pump
Human behaviour	• Before using the device the polar bear should be made aware of human presence, to avoid surprising the polar bears and provoke a charge or attack (NPBGTP, 2013b).
Combination measures	• Needs to be used in combination with other deterrents as noise deterrents are not reliable enough on its own and habituation quickly occurs (NPBGTP, 2013b).

Table 31 Advantages and disadvantages of horns and sirens

Advantage	Disadvantage
• Quite easily accessible for all group types • Easy to apply, no training needed • Not dangerous for people	• Not effective on its own • Compressed air horns may not work properly in cold temperatures • Effectiveness decreases with distance • Does not work on strong motivated bears • Habituation quickly occurs (NPBGTP, 2013b) • Could cause direct hearing damage when exposed next to human ear (Dangerous Decibels, 2016)

Table 32 Overview of important facets of influence on determining the use of horns and sirens as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Deterrent & Conflict	• IP • SPS • NSTR	Low	Moderate	Low	High (Low when used in close proximity)	Short term

Vehicles/mobile equipment

When used appropriately vehicles can be a good tool to deter polar bears without harming them (NPBGTP, 2013b) as was the case in Churchill, Canada when chasing a polar bear away with a truck prevented a woman from being killed (CTV Winnipeg, 2015).

Deterring with a vehicle can be done by making movements towards the polar bear, using sounding of horns or sirens, revving the engine and turning on lights or chasing the polar bear using a slow speed (NPBGTP, 2013b). Often just revving an engine is enough to have a polar bear retreat. (Exxon, 2009; GBSS, 2010; NPBGTP, 2013b) Vehicles of use as deterrent are trucks, all-terrain vehicles, snowmobiles, helicopters, boats or other heavy equipment (Exxon, 2009; NPBGTP, 2013b).

This measure is most effective when it involves naïve or relatively naïve polar bears (Stirling, 2011). Mazur experienced that chasing black bears away with machines was not as effective on food-conditioned black bears as on non-food conditioned bears, but it was nearly as effective as using rubber slugs or pepper spray (Mazur, 2010). Habituation might be a problem occurring using this method as animals could quickly learn that these machines do not pose a real threat to them and start ignoring them (Muruthi, 2005). Polar bears should always be deterred when approaching a vehicle and not be allowed to approach vehicles unchallenged. This teaches them that they cannot approach a vehicle or humans without consequences and to avoid habituation (NPBGTP, 2013b). Unfortunately this approach is not consistent as tourist operations intent to attract polar bears up close to their vehicles. For local communities that have a snow mobile or ATV available it is an effective measure when used consistently (pers. Com Klenzendorf, 2016).

Table 33 Preconditions of vehicles or mobile equipment as deterrents

	Preconditions
Design	• When approaching a vehicle polar bears should always be deterred and not be allowed to approach vehicles unchallenged (NPBGTP, 2013b)
Distance	Ground vehicle: • Approaching close enough to motivate the polar bear to move in the desired direction Helicopter: • When pushing to change the direction of the polar bear: 20m (65ft) height, 100m (110yards) in length • When non-controlling trailing of a polar bear at a distance: 30m (100ft) height, 300m (330 yards) length (NPBGTP, 2013b)
Accessibility	• Accessible to anyone that is allowed to operate a vehicle
Legal restrictions	• Licence for operating vehicle • Legal restrictions on chasing and disturbing of wildlife
Polar bear related factors	• No chasing for more than 10 minutes or 3 kilometres to avoid overheating, leading to injury or death. Especially when a polar bear is in bad physical condition. (NPBGTP, 2013b) • Polar bear should get enough space once it moves in the right direction (NPBGTP, 2013b).

Table 34 Advantages and disadvantages of vehicles and mobile equipment as deterrents

Advantage	Disadvantage
• Immediate retreat (Mazur, 2010) • Can approach a polar bear closer and safer than on foot (NPBGTP, 2013b). • Vehicles can use additional horns and lights (NPBGTP, 2013b). • Snowmobiles and ATVs are able to go off-road to deter polar bears (NPBGTP, 2013b).	• Trucks and some other vehicles are restricted to roads (NPBGTP, 2013b). • Rough terrain, lack of snow cover and thin or broken ice may restrict usage of off-road vehicles (NPBGTP, 2013b). • Can only be used for short periods due to risk of overheating of a polar bear (NPBGTP, 2013b)

Table 35 Overview of important facets of influence on determining the use of vehicles or mobile equipment as deterrents as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Deterrent (100m)	• IP • SPS	High	Low	Low	High	Short term

Torches

In Churchill, Canada a resident showed that the light of his cell phone distracted an approaching polar bear enough for him to get into safety without suffering any severe injuries (CBC News, 2013). Polar bears seem to react to light. Unfortunately not enough testing has been done to provide advice on using lights as deterrents. However the use of torches when hold in a person's hand and pointed at an approaching polar bear seems to work effectively to deter polar bears as they are not keen on fire. Torches could easily be made of sticks with burnable material on top. Torches are easily accessible and cheap to use. It could be a good solution for remote local communities. Experience in the past has showed the usage of torches works well. (Pers com. York, May 20, 2016) Further testing of use of torches to deter polar bears is advisable.

Table 36 Preconditions of torches as deterrents

	Preconditions
Design	• Further specific information on preconditions for the use of torches are unknown

Table 37 Advantages and disadvantages of torches

Advantage	Disadvantage
• No shipping restrictions as not considered as fire arm • Easily accessible (Pers com. York, May 20, 2016)	• Chance of burning • Might ask for close proximity to the polar bear (Pers com. York, May 20, 2016)

Table 38 Overview of important facets of influence on determining the use of torches as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Deterrent (100m) & Conflict (50-30m)	• IP	High	Moderate	Low	Moderate to Low	-

Sticks

The use of sticks seems to be an effective reduction measure of Mr. Nikita Ovsyanikov, who used this method on Wrangle Island for many years. If an encounter does happen and the polar bear comes too close, sticks can be used by striking the ground. When not successful the sticks can be waved in front of the face of the polar bear as if to strike the bear. Actually striking the polar bear should be avoided as this might invoke a defensive reaction. The idea behind this is that the sticks resemble the tusks of a walrus. Polar bears have been observed actively avoiding being struck by a walrus' tusks to avoid fatal injuries.

Besides few sites in Russia this technique has not been tried out. It is a difficult measure to practice when unexperienced as it requires a lot of confidence of the person handling the sticks and knowledge of polar bear behaviour and the effects of human body language. Risk of safety is high, especially when people are not trained well and experienced in using this measure (Pers com. Mizin, June 13, 2016) It could be considered as an option for remote communities where availability of other measures is low. However unless more knowledge about preconditions and proper training using this measure is accessible, it is not advisable to use this measure as a deterrent due to risk of human safety.

Table 39 Preconditions of sticks as deterrents

	Preconditions
Design	• Specific information on preconditions for the use of sticks are unknown

Table 40 Advantages and disadvantages of sticks as deterrents

Advantage	**Disadvantage**
• Low costs and easily accessible	• Not safe or usable for inexperienced people as it was tested only by Nikita Ovsyanikov on Wrangel Island, who spend many years in polar bear territory and learned to read their behavior very well (Pers com. Mizin, June 13, 2016)

Table 41 Overview of important facets of influence on determining the use of sticks as an appropriate measure.

Interaction phase	**Applicable group**	**Success**	**Maintenance**	**Costs**	**Safety**	**AC**
Deterrent & Conflict	• IP	-	Low	Low	Low	-

Dogs as deterrents

One step further to having guard dogs detecting approaching polar bears and warning people is having dogs that could deter a polar bear as well. The dogs used to deter bears should be comfortable around bears, not show any fear and be well trained and obey it's handler. Dog breeds suggested suitable for this task are Karelian bear dogs and Greenland huskies. Personality of the dog is also very important. (Hunt, 2003; Thing, 1990) By letting their lead dogs run loose, Inuit people have good experiences with deterring polar bears (Pers com. Klenzendorf, May 4, 2016).

A barking dog could cause an approaching, curious polar bear to be more cautious, stop or be deterred. In combination with pyrotechnical or physical deterrents, more determined polar bears could be deterred. When dogs and handlers are well trained and the dogs are very responsive to commands they could deter polar bears from areas with human activity. (GBSS, 2010; NPBGTP, 2013)

More knowledge on what dog breeds are best to use, how to train these dogs and under which conditions the dogs should be kept is still required to properly implement this measure. It is advisable to gain further insight from experienced dog trainers and users and experiment with Karelian Bear Dogs as there are some positive results using these dogs on other bear species (Pers com. Klenzendorf, May 4, 2016).

Table 42 Preconditions using of dogs as deterrents

	Preconditions
Design	• Dogs must be well trained (GBSS, 2010; Gillin et al,. 1997; McMullen, 2000; NPBGTP, 2013b)
Training	• To avoid guard dogs obeying to only one handler training should be done in a team (NPBGTP, 2013b)

Table 43 Advantages and disadvantages of using dogs as deterrents

Advantage	Disadvantage
• Well trained dogs could be a good early detection measure to detect and deter an approaching polar bear (NPBGTP, 2013b). • Keeping dogs is less intensive than keeping an electric fence working optimally • Better acceptable measure for local people than other measures (Pers com. Klenzendorf, May 4, 2016)	• When not trained well dogs could provoke an aggressive response (McMullen, 2000; NPBGTP, 2013b). • Dogs and dog food could be an attractant (NPBGTP, 2013b). • Well trained guard dogs are often responsive to one master (NPBGTP, 2013b). • Risk of losing dogs to a polar bear (Pers com. Klenzendorf, May 4, 2016)

Table 44 Overview of important facets of influence on determining the use of doge as deterrents as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Deterrent (100m) & Conflict (50-30m)	• IP	Low to High	High	High	Low (for dogs) High (for humans)	Short term

Pyrotechnical deterrents

Pyrotechnical deterrents rely on an explosion and when fired they send a loud bang, whistle or scream toward an approaching polar bear, or just a bright light in case of flare guns. The projectiles are fired from a specialized pistol type launcher or 12-gauge shotgun. For more background on the different types of firearms see appendix X: VIII-I. Most commonly used projectiles are bangers and screamers and occasional cracker shells (NPBGTP, 2013b). General preconditions of bangers, screamers and cracker shells can be found in table 45 with the general advantages and disadvantages in table 46, followed by projectile specifics described separately for each projectile type.

Pyrotechnical deterrents could be a useful first measure to deter an approaching polar bear for a short while, enough to get into safety. When the light or explosion is unpredictable to the polar bear causing a shock effect and if fired immediately preceding conflict with humans or human property, pyrotechnical deterrents could be effective. It would need to be modified regularly to avoid habituation. (Treves & Karanth, 2016)

Table 45 Preconditions of pyrotechnical deterrents

	Preconditions
Design	• Should not be shot directly at a polar bear (NPBGTP, 2013b). • Should be fired in such a way that they explode between the shooter and the polar bear as explosion behind the bear could cause it to drive it towards the shooter (GSBS, 2010).
Training	• Shooters must know the optimal range to prevent injury to the bear (Hunt, 2003) • Training is required to be able to handle measures (Pers com. Klenzendorf, May 4, 2016)
Legal restrictions	• Alaska: Licence for possession necessary. (Pers com. Klenzendorf, May 4, 2016) • Norway: Obligatory to carry (in Svalbard, when in the field) • Russia: Allowed (Pers com. Polet, 2016)
Human behaviour	• Before using the device the polar bear should be made aware of human presence, to avoid surprising the polar bears and provoke a charge or attack (NPBGTP, 2013c).

Table 46 Advantages and disadvantages of pyrotechnical deterrents

Advantage	**Disadvantage**

• Effective at longer distances than noise makers (NPBGTP, 2013b).
• Deterrent does not have to explode right next to the polar bear to be effective (NPBGTP, 2013b).
	• Wind can be an obstruction and change direction of projectile (NPBGTP, 2013b)
	  ○ Head wind: reduces range
	  ○ Tail wind: may increase range
	  ○ Side wind: may blow off course
	• Detrimental effects on performance of cardboard projectiles by humidity and moisture (NPBGTP, 2013b)
	• High safety risk when improperly used (GSBS, 2010; Hunt, 2003; Shideler & Perham, n.d.)
	• Habituation can occur after repeated use (Morrison, 3rd IBPCW, 2009; NPBGTP, 2013b).

Table 47 Overview of important facets of influence on determining pyrotechnical deterrents as an appropriate measure.

Interaction phase	**Applicable group**	**Success**	**Maintenance**	**Costs**	**Safety**	**AC**
Deterrent (100m)	• IP • SPS • NSTR (Scientists & Tour guides)	Low to High	Moderate	Low	Moderate	Short term

Bangers

After firing, bangers travel approximately 20-30 meters (depending on type and brand of cartridges) and explode with a loud bang of 115-160dB. The noise the banger creates is greater than the range of the projectile as the noise will be heard from the point of exploding out in all directions, resulting in an effective range that is double the distance. (NPBGTP, 2013b) Most common and effective is the 15mm cartridge fired from .22 calibre single or multiple launcher. (GSBS, 2010; Sowka, 2013b) (Further reading: Margo Supplies ltd, n.d.d.)

Table 48 Preconditions of using bangers as deterrents

	Preconditions
Design	• Fired in angle of 45° from ground level for optimum sound effect • The less distance to the point of explosion, the louder the noise (NPBGTP, 2013b)
Distance	• Height range is approximately 40m (131ft) (Sowka, 2013b)

Table 49 Advantages and disadvantages of bangers

Advantage	Disadvantage
• Flight pattern is consistent (Hunt, 2003)	• Slow to reload when used in a single shot (Hunt, 2003)

Screamers

When fired, screamers make continuous high-pitched screeching noises of approximately 115dB. This unusual alarming noise is likely what makes screamers effective (NPBGTP, 2013b). Projectiles may emit a bright light or explode with a loud bang at the end of the flight (GSBS, 2010).

Table 50 Preconditions of using screamers as deterrents

	Preconditions
Design	• Fired in angle of 45° from ground level (NPBGTP, 2013b)
Distance	• Approximately 75-100m (250-300ft) before exploding

Table 51 Advantages and disadvantages of screamers

Advantage	Disadvantage
• Flare component provides a light source to make the approaching polar bear visible at night (NPBGTP, 2013b). • Safer firing through low accuracy (Shideler & Perham, n.d.)	• Inconsistent flight pattern (NPBGTP, 2013b; GBSS, 2010) • Compensation for unpredictable flight path by aiming well off the side of the polar bear (NPBGTP, 2013b) • Risk of possible backdrop (GBSS, 2010)

Cracker shells and whistle crackers

Crackers shells and whistle crackers are 12-gauge shotgun loads. Whistle crackers emit a loud screeching noise during flight. Both projectile types explode with a loud bang. (GSBS, 2010)

Table 52 Preconditions of using cracker shells as deterrents

	Preconditions
Design	• Require low velocity (GSBS, 2010)
Environment	• Wind direction is important (Shideler & Perham, n.d.)
Distance	• Approximately 100m (GSBS, 2010)

Table 53 Advantages and disadvantages of cracker shells

Advantage	Disadvantage
• Flight pattern is consistent (GSBS, 2010) • Safer firing through low accuracy (Shideler & Perham, n.d.)	• Compensation for unpredictable flight path by aiming well off the side of the polar bear (NPBGTP, 2013b) • Risk of possible backdrop (GBSS, 2010)

Light flares

Opinions in literature and experiences in the field on the effectiveness of light flares are diverse. Stenhouse (1984) states that a light flare should not be used on its own, but only in combination with other deterrent measures. Mayer (2016) reckons it to be an effective first attempt to deter an approaching polar bear and that it gives enough time for a person to get into safety. As was the case in Torngat, Canada where the use of a flare gun saved the life of a man being attacked by a polar bear while camping (Abrahamson, 2015)

Flares produce a bright coloured flash that lasts approximately 3-4 seconds (Margo Supplies ltd, n.d.c.). There are however different brands and types of flares available with different illuminating patterns, flight pattern and burning time. It is therefore necessary to get familiar with the light flares purchased. (Further reading: Margo Supplies ltd, n.d.g.)

Table 54 Preconditions of using light flares as deterrents

	Preconditions
Design	• Fired from specialized pistol type launcher or 12-gauge shotgun (GBSS, 2010) • Fired at 45° angle towards approaching polar bear to ensure the shell detonates between the bear and the researcher (Stenhouse, 1984)
Distance	• Projects at 45m • Flight height: approximate 30-40m (Sowka, 2013b) • Effective range: 15-90m (50-300ft) (NPBGTP, 2013b).
Training	• Shooter needs to be trained how to use the projectiles and the fire arm
Legal restrictions	• Must be shipped by courier or truck transport • Cannot be delivered to a box number • Purchaser requires an End Use Certificate/Wildlife Control Statement (Margo Supplies ltd, n.d.c.)

Table 55 Advantages and disadvantages of light flares

Advantage	**Disadvantage**
• Flare component provides a light source to make the approaching polar bear visible at night (NPBGTP, 2013b; Stenhouse, 1983). • Waterproof (Smith, 2016b) • Reliable distance (Stenhouse, 1983) • Effective at longer distances than noise makers (NPBGTP, 2013b).	• Dangerous around fuels and flammable materials (PBGTP, 2013b) • When under stress of being attacked it is difficult to fire accordingly • Response polar bear is unpredictable (Ovsyanikov, 3rd IBHCWS, 2009; Stenhouse, 1983) • Habituation can occur by multiple use (NPBGTP, 2013b).

Table 56 Overview of important facets of influence on determining the use of light flares as an appropriate measure.

Interaction phase	**Applicable group**	**Success**	**Maintenance**	**Costs**	**Safety**	**AC**
Deterrent (100m)	• IP • SPS • NSTR (Scientists & tour guides)	Low to High	Moderate	Low	High	Short term

Hand held flares

There is little information in literature available on the effectivity of hand held flares. Experience in the field indicates that hand held flares work well as polar bears are not keen on fire and the flare produces a bright coloured light with a light output of 700 candlepower. Hand held signal flares have a match strike ignitor and burning time is approximately 3 minutes. Because they are not considered fire arms, shipping restrictions do not apply and hand held flares are easily accessible. (West Marine, n.d.)

Further testing on effects on polar bears is advisable. When testing results are positive it could be a good deterrent option and possibly also personal defence measure for everyone entering polar bear territory.

Table 57 Preconditions of hand held flares as deterrents

	Preconditions
Design	• Specific information on preconditions for the use of hand held flares are unknown

Table 58 Advantages and disadvantages of hand held flares

Advantage	Disadvantage
• Easy to use • Reliable • Waterproof • Compact: easy to carry (West Marine, n.d.)	• One time use only • Expiry date of 3 years (West Marine, n.d.)

Table 59 Overview of important facets of influence on determining the use of hand held flares as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Deterrent (100m) & Conflict (50-30m)	• IP • SPS • NSTR	-	Low	Low	Moderate	Short term

Physical deterrents

Paintball markers

The use of a paintball gun has proven to work effectively on coyotes, wolves, black bears and humans (Nelson, 2016), unfortunately little is known about use on polar bears. Few cases that are known on deterring polar bears with paint ball markers have worked very well (Pers com. York, May 20, 2016). Bursting strength of the balls causing physical impact might not be high enough to deliver an effective stimulus to deter a polar bear (Nelson, 2016; Pers com. Klenzendorf, May 4, 2016), but as the balls are released in a continuous stream, Marley suggests this creates a more annoying "mosquito" effect that might be what is effective on (polar) bears (Pers com. Marley, June 16, 2016).

Paintball projectiles are available in two types: paint projectiles and biodegradable non-paint projectiles. Using the actual paint projectiles has the additional advantage of marking nuisance bears. (Pers com. York, May 20, 2016) However caution needs to be taken with using red paint balls as they might be mistaken for blood (Pers com. Marley, June 16, 2016). If a certain individual keeps on coming back regularly in the area this is easily recognized by the paint marks on its coat and possible further actions can be taken (Pers com. York, May 20, 2016). Marley suggests the best success might be reached with powder or chalk balls fired from a paintball gun as he has good results using this method on other bear species. The balls can be shot on the ground next to a bear to direct it away. When they hit the ground they designate in a puff of smoke, along with popping sounds, creating a visual and audio stimulation. The balls are released fast from the gun thus it is not necessary to hit a bear itself but the chalk balls can be used to direct the bears away. This seems to work well on other bear species; however the response of polar bears is not known. (Pers com. Marley, June 16, 2016)

Due to lack of knowledge on and experience of effectiveness on polar bears, this method requires further testing.

There are types of balls available combined with pepper liquid that sticks on the animal when hit, however not much testing on wildlife has been done (Pers com. York, May 20, 2016). Further knowledge to be gained is what type of paintball projectiles are best to use on polar bears (e.g. paintballs, non-paintballs, powder balls), how best to release the balls to the polar bear (e.g. hitting it on its body, or shoot in front on the ground to direct it away) and whether it is operational in Arctic conditions. When proved to be an effective deterrent, paintball markers might be a good general deterrent measure as they are inexpensive and because they are not considered firearms, they are more accessible than other physical deterrents to the general public. (Pers com. Marley, June 16, 2016)

Table 60 Preconditions of using paintball markers as deterrents

	Preconditions
Design	• Projectiles can be used with any standard .68 calibre paintball gun • Projectiles can be released in a continuous stream (GSBS, 2010)
Environment	• Operating temperature up to -34°C
Training	• Should learn to get to know the distance and flight pattern of balls
Distance	• Accurate on target up to 30m (100ft) (Nelson, 2016)

Table 61 Advantages and disadvantages of paintball parkers as deterrents

Advantage	Disadvantage
• Useful to deter a bear in a certain direction due to continuous release of balls (GSBS, 2010) • Projectiles are biodegradable and environmentally safe (Nelson, 2016). • Presents a softer public image than fire arms (GSBS, 2010) • Accessible to general public (Pers com Marey, 2016)	• Convincing (local) people to consider new deterrent options might be challenging (pers com. Mizin, June 13, 2016) • Paintballs itself can degradate through cold when it freezes (Pers com. Marley, June 16, 2016)

Table 62 Overview of important facets of influence on determining the use of paintball markers as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Deterrent (100m)	• IP • SPS • NSTR	-	-	Low	High	-

Rubber bullets

Rubber bullets are meant to be non-lethal and designed to inflict pain, creating an unpleasant experience to a polar bear, but not to cause penetration or severe injury (GBSS, 2010; Stirling, 2011). The minimum striking distance and impact of the projectile will vary depending on the distance towards the polar bear, its size, and its physical condition (NPBGTP, 2013c; GSBS, 2010). When used at a distance less than 25-30m or on small bears, rubber bullets could cause severe injury or penetration (Margo Supplies Ltd, n.d.), and should therefore never be used on cubs (GSBS, 2010). It is important to test the optimal range of new impact projectiles beforehand (GSBS, 2010).

Due to several injury cases of bears when shot with fin-stabilized rubber bullets and plastic bullets now only Fiocchi rubber batons or Margo Supplies ltd "Strike Two" rubber batons are recommended by the Alaskan Department of Fish and Game (ADFG) grizzly bear project office. (NPBGTP, 2013; Shideler, n.d) Rubber bullets harden over time as well as when they are stored or used below temperatures of 1°C, this could be a problem in the Arctic.

It would be advisable to use rubber bullets to deter polar bears before they have approached humans or human property, within 30-60m (preferred shooting distance). One should aim at the animals' backside/hip, rump or shoulder to prevent vital organs to be hit by the bullet. When applied properly, the polar bear will learn that approaching people is rather more painful than rewarding. (Margo Supplies ltd, n.d.; NPBTP, 2013c; Shideler & Perham, n.d.; Stirling, 2011)

Table 63 Preconditions of using rubber bullets as deterrents

	Preconditions
Design	• 12 gauge rubber slug shotgun with a muzzle velocity of 220m/sec. • Or a 38mm riot control gun • Chambers longer than 2 ¾ inches • Cylinder bore/improved cylinder (Shideler & Perham, n.d.). • No autoloaders (Shideler, n.d.)
Environment	• Temperatures above 0°C (Temperatures below 0°C only applies for Fiocchi batons)
Training	• Requires intensive training before fair degree of accuracy can be assured (Stenhouse, 1983) • The optimal range of new projectiles should be tested before use (GBSS, 2010).
Distance	• Minimum distance to prevent severe injury: 25-30m (Margo Supplies Ltd, n.d.) • Ideal distance: 30-60m (Mazur, 2010; Stirling, 2011) • Effective range: max 75m from target bear (Margo Supplies Ltd, n.d.)
Accessibility	• Only people completing firearm safety training and in possession of a valid firearm licence (NPBGTP, 2013c).
Legal restrictions	• Local laws should be checked for regulations. • Suppliers have shipping restrictions, cannot ship via air (MidwayUSA, 2016)
Human behaviour	• Before using the device the polar bear should be made aware of human presence (NPBGTP, 2013c).
Polar bear related	• Should be hit in backside/hip, rump or shoulders (Margo Supplies ltd, n.d.; NPBTP, 2013c; Shideler & Perham, n.d.; Stirling, 2011)

Table 64 Advantages and disadvantages of rubber bullets as deterrents

Advantage	Disadvantage
• Often immediate retreat of the bear (Mazur, 2010) • No sign of aggression of the (polar) bear towards humans while struck (Gillin et al., 1992; Shideler & Perham, n.d.; Stenhouse, 1983) • Fiocchi batons remain safe at temperatures -0°C (NPBGTP, 2013) • If properly used it will not injure the bear (Shideler & Perham, n.d.).	• Not legally available to the general public (Stirling, 2011) • Wrong type of bullet hardens over time and becomes lethal (GBSS, 2010). • -0°C can cause rubber projectiles to be less pliable (NPBGTP, 2013c) • Cold air and wind decreases effective range of the projectile. (NPBGTP, 2013c) • Cross wind can blow it off course. (NPBGTP, 2013c) • Risk of serious injury, penetration or lethal when misplaced shots of too close distance (NPBGTP, 2013c) • Inaccuracy (Stenhouse, 1983; Shideler, n.d.) • No lasting aversive conditioning effect (Gillin et al., 1997; Stirling, 2011) • Habituation can occur (Exxon, 2009) • Less effective on food-conditioned bears (Gillin et al., 1997 • Difficult to hit on safest hitting locations when approached by polar bear

Table 65 Overview of important facets of influence on determining the use of rubber bullets as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Conflict (50-30m)	• IP • SPS • NSTR (Scientists & Tour Guides)	Moderate-High	Moderate	Low	Moderate	Short term

Bean bag projectiles

Bean bag projectiles are 12-gauge shotgun shells consisting round or square-shaped fabric bags filled with #9 lead shot. To improve accuracy and range some bean bag projectiles have stabilizing tails attached. (NPBGTP, 2013c) Effective and operational range varies between load types, bag shape and manufacturer.

Impact of the projectile depends on the size of the polar bear and physical condition (NPBGTP, 2013c). Bean bags are of good use on smaller and younger bears (GBSS, 2010). Due to impact surface of 1-2 square inches, risk of penetration of the hide is significantly reduced (NPBGTP, 2013c). Physical impact might not be large enough for polar bears to move away (Pers com. Klenzendorf, May 4, 2016). However, York has good experiences with bean bags as projectiles and finds them just as effective but safer than rubber bullets. (Pers com. York, May 20, 2016) Because the sensation of the bean bag projectile is thump rather than stinging as is the case with rubber bullets, it might actually impress a bear more (Shideler, n.d.).

Table 66 Preconditions of using bean bag projectiles as deterrents

	Preconditions
Design	• Muzzle velocity of approximately 90m/sec (300ft/sec). • Cylinder bore/improved cylinder (Shideler, n.d.) • No autoloaders (Shideler, n.d.)
Distance	• 9-27m (30-90ft) GBSS, 2010; NPBGTP, 2013c)
Accuracy	• 30-45 cm (1-1,5ft) of point of aim (Shideler, n.d.)
Responsibility	• Person carrying license should be present at all times to use the fire arm in case conflict occurs.
Accessibility	• Only people completing firearm safety training and in possession of a valid firearm licence (NPBGTP, 2013c).
Human behaviour	• Before using the device the polar bear should be made aware of human presence (NPBGTP, 2013c).
Polar bear related	• Should be hit in backside/hip, rump or shoulders (Margo Supplies Ltd, n.d.; NPBGTP, 2013; Shideler & Perham, n.d.; Stirling, 2011)

Table 67 Advantages and disadvantages of bean bag projectiles as deterrents

Advantage	Disadvantage
• Less likely to injure bear than other projectiles (Shideler, n.d.) • Can be used on small and smaller bears (GBSS, 2010) • Can be coated with dye to mark polar bears (NPBGTP, 2013c).	• At close range still chance of serious injury exists when shot in the chest of stomach area • Wind may reduce effective range and influence flight course.

Table 68 Overview of important facets of influence on determining the use of bean bag projectiles as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Conflict (50-30m)	• IP • SPS • NSTR (Scientists & Tour Guides)	Moderate - High	Moderate	Low	Moderate	Short term

3.4.2. Non-lethal personal defence

When deterrents have failed and a polar bear keeps approaching a person, personal defence measures can be used as a last resort to protect oneself. Many people carry firearms for this purpose. In some areas carrying firearms is even obligatory (e.g. Svalbard, Norway). Non-lethal measures would not by definition replace fire arms completely, as in many circumstances firearms should still be carried (e.g. tour operators responsible for a group of tourists).

Bear Spray

Multiple sources show that the use of bear spray has stopped unwanted behaviour of bears (Herrero & Higgins, 1998; Hunt, 1985; IGBC, 2008; Smith et al., 2012).The active ingredient in bear spray is 1% to 2% Capsaicin and related Capsaicinoids which affect the bears eyes, nose, mouth, throat and lungs (IGBC, 2008). The spray expands in a cloud and reaches the bear at a distance, giving the bear time to respond to the effect and divert its charge (CWI, 2009). All other types of deterrents should be used first. Bear spray is a last resort personal defence measure. Bear spray should only be used when charged by a polar bear or when a polar bear continuous approaching despite the use of other deterrent measures. Non-threatening bears should not be sprayed. (CWI, 2009)

The formation of the cloud and sound of the spray when discharged from the canister have been seen to work as a deterrent on its own, independent of the cloud actually reaching the bear. It also prevents that the sprayer needs to spray directly at the charging bear (Herrero & Higgins, 1998). Effectiveness depends on the level of agitation and motivation of the bear. If it attacks from a close range it might take some time for the bear to feel the effect of the spray, possibly already attacking the person. The bear stops the attack and runs off as soon as the bear feels the effect of the spray (CWI, 2009).

Herrero & Higgins found bear spray effective 100% (N=20) and that the bears left the area (90%, N=20) after using the spray (Herrero & Higgins, 1998). The use of bear spray also stopped polar bears approaching in two cases in Kaktovik, Alaska, US (Smith et al., 2006). The repelled bears do seem to return to the area in time (Herrero & Higgins, 1998), however bear spray does give a person enough time to get into safety. The effectiveness of bear spray seems to be quite reliable over the years (Smith et al., 2012).

Bear spray could be an effective tool when each person present in the habitat of a (polar) bear carries a can of bear spray and has it quickly accessible. It should also be present in all areas of human settlement (IGBC, 2008). Culturally and politically (as bear spray is prohibited in Svalbard, Norway) it might be a challenge getting people to carry bear spray instead of a firearm (Smith, 2016).

Due to wind the spray might not reach the polar bear to be effective or could blow back towards the person spraying. However data shows that wind rarely affected the outcome of HBC as the high exit velocity of spray from the canister likely compensates for cross-wind effects (Smith et al., 2008). Bear spray has not been sufficiently tested on polar bears but does show potential and further testing on polar bears under Arctic circumstances is advisable.

Table 75 Preconditions of using bear spray as a personal defence measure

	Preconditions
Design	• Minimum net contents of bear spray should be 7.9 ounces or 225 grams. (CWI, 2009) • Spray should be in a shotgun-cloud pattern (CWI, 2009) • The canister should state that it is for use on bears only (CWI, 2009) • Suggested duration of spraying is 6 seconds (CWI, 2009; IGBC, 2008) • Continued spraying if the polar bear is close (CWI, 2009)
Environment	• Spraying should be adjusted to wind circumstances • Possible re-spraying necessary (CWI, 2009; IBGC, 2008)
Training	• Practice in using the spray to get familiar with dispersal pattern of the spray (Herrero & Higgins, 1998) • Test if the propellant works by brief spraying (Herrero & Higgins, 1998).
Distance	• Distance towards the bear at least 7,5m (25ft). • Spray when charging bear is within distance of 18m (60ft) (CWI, 2009; IBGC, 2008).
Responsibility	• Each person present in the habitat of a (polar) bear should carry a can of bear spray and have it quickly accessible. It should also be present in sleeping areas, cooking areas and toilet areas of a camp (IGBC, 2011)
Accessibility	• Range State dependent
Legal restrictions	• Not supported by authorities on Svalbard, Norway (WWF-Norway, 2013)
Human behaviour	• Non-threatening bear should not be sprayed. (CWI, 2009)
Combination with other measures	• All other types of deterrents should be used first. Bear spray is a last resort personal defence measure.

Table 76 Advantages and disadvantages of using bear spray as a personal defence measure

Advantage	Disadvantage

• Immediate retreat of the bear (Mazur, 2010)
• No aggressive response of the bears towards humans when sprayed (Smith et al., 2008)
• Injuries to humans could be avoided in all cases (Herrero & Higgins, 1998)
	• Not legal in all 5 Range States
	• Mechanical malfunction is possible.
	• Canister can empty during spraying if used multiple times (Herrero & Higgins, 1998)
	• Effectivity of spray could be reduced by
	  ○ Low temperatures
	  ○ Heavy rain or snow
	  ○ Moderate or high wind
	(CWI, 2009; Herrero & Higgins, 1998; Smith et al. 2012)
	• Bear spray residues may work as an attractant (Mazur, 2010; Smith, 1998).

Table 77 Overview of important facets of influence on determining the use of bear spray as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Conflict (50 – 30m)	• IP • SPS • NSTR	High	Low	Low	Low	Short term

3.4.3. Relocation and polar bear jail

Relocation means that problem animals are captured, removed from the site of conflict and released in another area. (Gunther et al., 2010)

Counterarguments for relocation are that it is quite common for a relocated animal to return to the side of capture and conflict happens again (Muruthi, 2005; Treves & Karanth, 2016). Other animals could immigrate in the area that has come available and take over empty territories making the problem continue (Gillin et al., 1997; Muruthi, 2005).Wilder reckons that removal of bears from an area allows young males to occupy available niches, taking the place of the removed bears (Wilder, 3rd IBPCW, 2009). The problem animal could also cause the same problem at the relocated area. Brady experienced that the effect of long-distance translocations showed poor success and reckons that unless attractants are controlled, translocation of nuisance bears will not work (Brady, 3rd IPBCW, 2009).

In Manitoba, Canada relocation in combination with using a polar bear jail seems to have positive results.

Table 69 Preconditions of relocation

	Preconditions
Design	• Removing and moving should be done "north" towards natural migration route, towards new ice rather than away from it. (Stirling, 2011)
Distance	• At least 10-20km and northward (Stirling, 2011)

Table 70 Advantages and disadvantages of relocation

Advantage	Disadvantage
• Removal of the problem bear from the area results in immediate solution of conflict	• Many polar bears return to the area of capture (Hopkins et al., 2010; Stirling, 2011). • Extremely expensive • Reliant on very specialised equipment and skill of handlers (Pers com. Polet, July 8, 2016)

Table 71 Overview of important facets of influence on determining the use of relocation as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Deterrent & Conflict	• IP	-	-	High	Moderate	Short term

Polar bear jail

Since 1996, polar bears that enter the dump close to Churchill, or the selected zone around the dump, are captured and put in jail for 30 days. When entering this zone the bears are first chased away. When attempts of deterring fail or when the polar bear is not present at the time of deterring, a live trap is set up. After being trapped the bear is relocated to the Polar Bear Holding Facility (or polar bear jail). (Manitoba, n.d.) The polar bear jail could be part of relocation of polar bears but also be effective in itself. The program of 30 days of time-out for polar bears is meant to keep them from harming people and people from harming the nuisance polar bears. After the period of 30 days the polar bears are released. If they do return, they will be captured again and taken 40miles north. Even though this is rare, if polar bears would return from the north, they are captured and kept in jail until the new ice develops. Polar bears will not be fed in jail. (Hedman, 3rd IPBCW, 2009)

Since the dump was closed in 2005 the number of nuisance polar bears has decreased. (Hedman, 3rd IPBCW, 2009) Overall it has been one of the most successful programmes undertaken in polar bear conservation anywhere in the world (Stirling, 2011). The programme is wider than just a jail facility as it can be used in developing public awareness, controlling attractants and nuisance polar bears and as AC (GOM, n.d.). (For further reading: Manitoba, n.d.)

Table 72 Preconditions of using a polar bear jail

	Preconditions
Design	• Due to lack of resources specific information on preconditions for the use of polar bear jail could not be collected during this study
Distance	• Need to be moved at least 10-20km and northward even then still bears can return (Stirling, 2011)

Table 73 Advantages and disadvantages of polar bear jails

Advantage	Disadvantage
• It succeeds in preventing polar bears from spending much time around human settlement where they might be killed (Stirling, 2011)	• Polar bears could still return (Hedman, 3rd IPBCW, 2009; Stirling, 2011) • Program is expensive and therefore not easily applied in small communities with limited resources (Derocher et al., 2013) • Cost of temporary holding will increase when the ice-free period extends beyond the fasting capacity of captive bears. (Derocher et al., 2013)

Table 74 Overview of important facets of influence on determining the of polar bear jails as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Deterrent & Conflict	• IP	High	-	High	Moderate	Short term

3.5. Human body language

Many sources note that human behaviour and body language can increase the effectiveness of conflict reduction measures. Correct behaviour can be a proactive prevention of conflict. Furthermore it is also often a precondition of other measures (Pers com Polet, August 8, 2016) as by maintaining and displaying confidence while using conflict reduction measures, they are more likely to be successful in deterring polar bears and keeping the situation manageable (Gilbert; Ovsyanikov, 3rd IHPCW, 2009). In return, measures can help to boost a person's confidence and decrease the risk of conflict (Gilbert, 3rd IBPCW, 2009). Using the natural intendancy of polar bears to avoid humans, humans can be an effective deterrent themselves (NPBGTP, 2013c).

The human voice is already a good bear deterrent and should be used first before the bear comes into responding distance to use other deterrents (Pers com. McMullen, June 21, 2016). By waving hands slowly in the air and talking in a low voice, people can communicate their presence to the polar bear, often being enough to cause a curious polar bear to move off (NPBGTP, 2013b, pers com McMullen). In addition clapping in hands could be used and seems to work well scaring a curious polar bear off (Pers com. Mayer, July 7, 2016; Pers com. McMullen, June 21, 2016)

When a polar bear considers a person to be a threat, one can show the polar bear he is not by speaking in a calm voice and slowly backing off while holding hands below shoulder height, to prevent from provoking a defensive attack. When a polar bear approaches, one can speak in a loud voice, holding hands high and showing a confident or aggressive body posture, to communicate not being an easy prey. (NPBGTP, 2013b)

Along with using the human body language it is important to have a good understanding of polar bear behaviour. Human voice and body language are good devises and diverse, however it depends on the situation how you should use them and interpreting and understanding polar bear behaviour is essential, along with respect for the polar bear. (Pers com. McMullen, June 21, 2016) Everyone working and living in polar bear country should be aware of polar bear behaviour and how body language can influence this. The human body language should not be an option to consider, but should be one of the basics a person should learn when working or living in the Arctic. (Pers com. Koopmans, July 8, 2016)

Table 78 Preconditions of using human body language as an additional measure to deter polar bears.

	Preconditions
Design	• Requires full understanding of polar bear behaviour (NPBGTP, 2013b).
Environment	• Weather conditions need to be good and sight clear to be effective (NPBGTP, 2013b)
Training	• Gaining skills and confidence requires training, time and experience (NPBGTP, 2013b).
Distance	• Within a distance of 30m (NPBGTP, 2013b) • Voice should be used before polar bear enters deterrent phase (100m) • With increasing distance between humans and polar bears the deterrent effect of vocalization and human body language decreases (NPBGTP, 2013b).
Safety	• Must be sure to have quick access to safety (NPBGTP, 2013b). • Person should always be armed or backed up with an extra deterrent tool (NPBGTP, 2013b).
Combination with other measures	• Using other objects to make noise increases the effective range (NPBGTP, 2013b)

Table 79 Advantages and disadvantages of using human body language as an additional measure to deter polar bears.

Advantage	Disadvantage
• Vocalisation and human body gestures and postures are diverse and can be changed responding to the situation, making it a useful measure (NPBGTP, 2013b).	• Not everyone is confident dealing with polar bears at a close range (NPBGTP, 2013b). • Possibly not effective enough to scare off a nutritionally stressed polar bear or human-food and waste conditioned polar bear • Less effective when distance increases (NPBGTP, 2013c)

Table 80 Overview of important facets of influence on determining using human body language as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
Deterrent & Conflict	• IP • SPS • NSTR	Low to High	Low	Low	Low - Moderate	-

3.6. Polar Bear Patrol Groups

Polar bear patrol groups are established by hiring local residents to monitor and deter approaching polar bears (NSB, 2016). Polar bear patrol groups seem to be very efficient (USFWS, 2010). Communities can contact their local patrol group when an approaching polar bear has been detected or actually encountered one. The patrol groups are then responsible for deterring the polar bear and ensuring safety. (Pers com. Mizin, June 13, 2016) Patrol groups can reduce the number of polar bears visiting villages in search of food by applying deterrents (Dutton, et al., 2011) and work with the community to reduce attractants (Pers com Koopmans, August 8, 2016). The extra benefit of having patrol groups is to have dedicated people that are trained and know what to do when polar bears approach. They are often also involved in monitoring activities in peak season and on the look-out for polar bears, providing early detection and thus a good safety system for the community. (Pers com. Koopmans, July 8, 2016) Patrol groups can use all measures described in earlier chapters and are trained to apply various tools.

The mission of patrol groups is to initiate large-scale education regarding polar bear safety and deterring polar bears from villages. Tasks and goals of patrol groups concerning HPBC among others are:

- Educating local people and visitors how to prevent conflicts and respond when encountering a polar bear
- Restricting visitors from approaching polar bears to prevent conflict
- Moving marine mammal carcasses away from villages to minimize HPBC (York, PBDFW, 2011)
- Daily patrols in polar bear peak season (September-December), especially at night (WWF CA, 2016)
- Monitoring of polar bear activities (York, PBDFW, 2011)
- Deterring polar bears to avoid conflict using different types of measures
- Improving management of attractants (food and waste)
- Protecting local people from polar bears (e.g. by guiding children to school) (Hughes, 2016)

Even though patrol groups are often started at the initiative of local communities (Pers com. Koopmans, August 8, 2016), a challenge setting up patrol groups is having local people understand the importance and need of such patrol groups as for them it is much easier to shoot that one problem bear than perceiving it (Pers com. Klenzendorf, May 4, 2016). Another challenge to establish and keep patrol groups active is funding (USFWS, 2010).

Table 81 Preconditions of polar bear patrol groups

	Preconditions
Design	• Patrol groups should be able to be easily contacted by local communities when a polar bear approaches human property. (WWF CA, 2016) • Patrol groups should have snow machines and fuel available for patrol and deterring polar bears. (Ewins, 2016) • Should have a range of deterrent measures available: - Cracker shells - Rubber bullets - Bean bags - Flares - Live rounds - Sticks - Bear spray (Ewins, 2016; WWF CA, 2016) • Additionally live traps to catch persistent polar bears that need to be captured and transported away from communities (Ewins, 2016; WWF CA, 2016)
Training	• Approximately 3 day training courses (Pers com. Mizin, June 13, 2016)
Maintenance	• Patrols should be daily and especially during the night (Pers com. Mizin, June 13, 2016)
Responsibility	• Local authorities should have the responsibility setting up patrol groups. • Recruitment of patrol groups could consist of local people and representatives of local authorities such as police. (Pers com. Mizin, June 13, 2016)
Accessibility	• In remote settlements with lack of routine law enforcement it could be a solution for residents to protect themselves against polar bears (Hughes, 2016)

Table 82 Advantages and disadvantages of polar bear patrol groups

Advantage	Disadvantage
• Through education and establishing safer conditions by the patrol groups, local people are taking greater responsibility for their own safety (WWF, 2013).	• Sometimes difficult to get local people to understand the problem and having them feel responsible to cooperate. (Pers com. Klenzendorf, May 4, 2016).

Table 83 Overview of important facets of influence on determining polar bear patrols as an appropriate measure.

Interaction phase	Applicable group	Success	Maintenance	Costs	Safety	AC
• Avoidance • Deterrent • Conflict	• IP • SPS	High	-	High	Low - Moderate	Short term

3.7. Socio-Political Aspects of HPBC Measures

All measures mentioned in this report have the potential to be effective in avoiding or reducing HPBC. But without understanding when and why an encounter turns into conflict, what factors play a role in HPBC for the different group types and what drives people and polar bears together, chances are slim these measures will be effective. Putting all these factors together gives an indication of which steps need to be taken in the case of HPBC and what to base the choice of HPBC measures on (table 84).

Table 84 Overview of factors contributing to the choice and availability for HPBC reduction measures for different group types (+++=Large influence, ++=Moderate influence, += Little influence, -=not of influence)

		Type of Group		
Factor	Indicators	Indigenous People	(Semi) Permanent Settlers	Newly Settled and Temporary Residents
Attitude	Utilitarian/Naturalistic	+++	-	-
	Ecologistic/Neutralistic	-	+++	-
	Humanistic/Naturalistic	-	+	+++
Knowledge of polar bear behaviour		+++	+	+(+)
Law and Legislation	Level of empowerment	+++	+	-
	Hunting quota	+++	-	+
	Firearms allowed	++	++	+(+)
	Shipping restrictions	++	+	++
Measures available	Financing available/Wealth	+	+++	++
	Area	+++	++	+
	(Semi)permanent settlement	+++	+++	+
	Mobile	++	+	+++
	Season	+	++	+++
	Snow	+++	+++	+
Attractants	Food and Waste	+++	+	+
	Smell	+++	+	++
	Movement	+++	+++	+
	Interesting new materials	+	++	+++
	Distance to polar bears	++	+++	+

First of all the motivation of the polar bear is plays a role. It is important to understand what triggers the polar bear to approach humans or human property. Important factors could be physiological (the polar bear is hungry) or ethological (when curiosity plays a role). Furthermore the previous experience of polar bears with humans is important.

Regarding humans it is important to make a differentiation between different group types. Between the three different groups knowledge of and attitudes towards polar bears varies, as well as the legal restrictions that apply to them, the level of attractiveness for the polar bear and what array of measures is available.

Attitudes

People have different motivations and respond differently when encountering polar bears (Brown & Conover, 2008). People of the three group types involved in HPBC have different attitudes. These attitudes towards polar bears depend on several factors, including differences in people's perceptions and experiences (Brown & Conover, 2008). Indigenous people who live with polar bears their entire lives and who potentially suffer damage to food and property through HPBC, see polar bears differently than tourists or scientists, who enter polar bear territory because they want to encounter polar bears, not avoid them (Pers com. McMullen, June 21, 2016). In general, five attitudes can be distinguished among the three groups; humanistic, with a primary interest in and strong affection for individual animals, ecologistic, with a primary concern for the environment as a system, neutralistic (primary orientation a passive avoidance of animals due to indifference and lack of interest), utilitarian, with the primary concern for the practical and material value of animals and naturalistic, with a primary interest in and affection for wildlife and the outdoors.(Kellert, 1980)

Knowledge of polar bear behaviour

A person's knowledge of polar bear behaviour and experience with polar bears will influence the outcome of an encounter between polar bears and humans. Newcomers in the Arctic cannot interpret the behaviour of polar bears as well as indigenous people or polar bear specialists can. Also, a person who is scared of polar bears will be less tolerant to them and is likely to define a situation as threatening more quickly (Dickman, 2010).

Law & legislation

Politics set rules for what is and is not allowed in certain Range States and provide a first selection of measures that are accessible. These rules and restrictions are the same for all interest groups throughout a certain area or Range State. Examples of these regulations could be the right to bear firearms, the right to possess bear spray, hunting quota and whaling rights.

Attractants

The level of attractiveness to a polar bear depends on food and waste management among the different group types, as well as the type and amount of smell coming from these people and their settlement, the level of movement and how much new and interesting things these groups provide to the polar bear.

Array of measures available

Not all measures are available and accessible to all three group types. Factors that influence the array of measures available are finances available, whether the area is extensive, if the human settlement is (semi)permanent or temporary, if people are mobile, what season it is and whether weather conditions or snow are of influence.

For the different groups different factors are important and of influence on HPBC and the choice of HPBC reduction measures.

Indigenous people
The attitude towards polar bears of indigenous people is utilitarian and naturalistic. Indigenous people live in a permanent type of settlement, around which is a lot of movement and attractants are present such as (whale) meat and waste. Some communities have dogs, which could be an additional attractant to polar bears. This results in a high chance of encountering polar bears and potential HPBC. Indigenous people are restricted in their array of available HPBC reduction measures as legislation and often financing are a limiting factor. However indigenous people do have an understanding of polar bear behaviour and have experience in dealing with polar bears, therefore they have the best knowledge and experience to deal with HPBC.

(Semi) permanent settlers
This group has a (semi) permanent settlement with a large turnover in personnel, who often do not have knowledge of polar bear behaviour or any experience with polar bears. Therefore the chance of an encounter turning into HPBC is high. However, the attitude of this group is ecologistic and neutralistic. Attractants are reduced due to regulations for food and waste management and the availability of resources to implement these regulations. Due to greater financial resources available, this group has access to a large array of measures.

Newly settled and temporary residents
Tour operator and scientist often do have experience with polar bears and knowledge of polar bear behaviour. Tourists do not have this knowledge and are relatively ignorant when it comes to polar bear behaviour. They often carry different smells with them than indigenous people and (semi)permanent settlers do and are at unexpected places in polar bear territory. They have a humanistic and naturalistic attitude, they come to polar bear territory in a season when polar bears come ashore and intentionally look for an encounter with polar bears. This creates a potential problem situation. Because money is available a greater array of measures is available to this group. However, legal restrictions make these measures available to tour guides and scientist, but limits them for tourists.

This shows that HPBC is a complex matter and is not just a simple choice of the right tool. To further reduce HPBC law and legislation and education could be good additional tools. For policy makers, focus lies with making measures available to the general public and having the right legislation and implementation for indigenous people.

Education
Sometimes, different perceptions of cultural traditions have to be overcome and people's way of thinking has to be changed in order to reduce conflict situations (Cotton, 2008; Herrero, 3rd IBPCW, 2009; York, PBDFW, 2011). As most HPBC reduction measures provide only a short-term physical solution to avoid or reduce HPBC, education is important to manage HPBC in the long term, creating long-term understanding and acceptance concerning social factors (Distefano, 2005). Beckmann et al. (2004) suggest that education might be more effective to reduce conflict between humans and black bears than deterrent techniques. Therefore education is an essential part for different parties entering polar bear territory to help reduce HPBC (Elliott & Kube, 2008).

Education on ways to minimize HPBC is most important. This can be done by education on the use of measures and on polar bear biology, habitat and behaviour (Stenhouse, 1983). Not only could education help people gain technical skills and experience to help deal with HPBC, but over time education also results in behaviour change and contributes to reducing HPBC. Education promotes commitment to and understanding of polar bear conservation (Distefano, 2005).

Education is also important as increased HPBC challenges people's acceptance of polar bears, especially that of indigenous people. To conserve the polar bear, support and tolerance of those people is necessary (York et al., 2014) as it will be too late to only start establishing this when polar bear populations start decreasing and conservation really starts to be an issue.

Marley reckons that locals have the potential to communicate this to other local communities. If a few communities are willing to try and use different measures, they could function as a role model and spread their success to other communities (Pers com. Marley, June 16, 2016).

4. Discussion

This research is based on findings in literature and on interviews with experienced professionals. Therefore, this study gives an indication of what measures are available, their effectiveness, preconditions, advantages and disadvantages, and where knowledge gaps are.

The overview of measures is based on findings made using an opportunistic search approach. As a consequence of this approach, information that is available elsewhere might be missing. The interviews add valuable missing information, as Brown & Conover (2008) for instance found that the answer for what is effective for human wildlife conflict was sometimes unavailable in the scientific literature.

Not much literature was available on research and experiences in Russia, Norway, and Greenland, making it difficult to have a range wide overview on the situation of HPBC and available measures throughout the whole of the five polar bear Range States. The Range States that literature was available on is therefore used to set an example. Due to comparable geographical context, measures are expected to be applicable in the other Range States as well.

Integrated HPBC management

When choosing the right measures for HPBC reduction, it is important to take into account the motivation of the polar bear, the type of people involved and socio-political aspects, as these all affect the outcome of HPBC and the successfulness of the measure. For example, if someone's perception of a deterred bear is one that will not show nuisance behaviour again, a deterrent measure will most likely always fail, as most measures only have a short term AC effect (Beckmann et al., 2004).

Madden reckons that any measure or management option is more likely to succeed if it is incorporated into a full arsenal of strategies that have the flexibility to change as conflict conditions change themselves. As HPBC is often complex, Madden finds that solutions need to be complex and multifaceted too, as a single measure or tool can rarely address the full arsenal of aspects of a conflict scenario (Madden, 2004). Even though this study does show that there is a large arsenal of aspects involved in the choice of HPBC reduction measures, it is more important to have a measure that works and is accessible to the different groups of people, preferring a rather more simple solution. As the background and opinions of different stakeholders and group types differ, strategies to reduce HPBC should be managed differently for the different groups, trying to balance the rights and socio-political aspects of people that are affected by the situation (Conover, 2002).

Sharing knowledge

An way to gain insight in the underlying causes and patterns of HPBC and to help reduce HPBC is sharing knowledge. This can be done by keeping records of all encounters and conflicts with polar bears throughout the Arctic and making this data base accessible to all stakeholders involved. The choice of measures implemented is often based on the outcomes of past experiences of the implementer, rather than on data collected to answer a specific management-related problem. Even though implementations based on previous experience often does result in fewer incidents, the successfulness and full potential of each measure remains unclear as they are not evaluated (Hopkins et al, 2010).

Local managers and stakeholders may lack knowledge or other measures, and fail to look further than their local situation, culture or experience when looking for an effective solution to reduce conflict. Expertise and knowledge often exist with dedicated people that are committed to specific projects, but lack time, energy and resources to share their expertise with others that suffer from similar problems. When understanding similarities between different HPBC situations, stakeholders can gain knowledge and create an integrated vision (Madden, 2004).

Dyck reckons that keeping records of HPBC with a detailed description of the cause and situation can benefit understanding of underlying specific circumstances and help reduce HPBC in the future (Dyck, 2006). Furthermore, such data can provide information on the level of habituation of bears to humans (MacHutson & Wellwood, 2002) and identification of possible areas in need of management solutions (Baruch-Mordo et al. 2007; MacHutson & Wellwood, 2002) where targeted management could be applied (Baruch-Mordo et al., 2007). Access to a combined database is an option to achieve these goals. Such a database does exist and the Polar Bear-Human Information Management System (PBHIMS) has been established. Range States use this system to record their data on HPBC. However the PBHIMS database is not yet shared and accessible between countries as there is no data sharing agreement between the Arctic Range States (Pers com. F. Koopmans, February 1, 2016), therefore the data base does not make use of its full potential to reduce HPBC in an integrated manner.

Bear spray and firearms

As seen in this study, opinions differ strongly on the usefulness of bear spray. Discussion is ongoing about its effectiveness and whether or not carrying firearms is a better and safer option (Cramer, 2007; USFWS, n.d.). However, people have also been injured or even killed by bears while unsuccessful in defending themselves with firearms (U.S. Fish and Wildlife Service 2003). Debate is ongoing whether people who use firearms to defend themselves are actually more likely to be injured or killed than ones using bear spray (U.S. Fish and Wildlife Service 2003, Smith et al. 2005), and whether wounding a bear with an unsuccessful shot would provoke a more serious attack (U.S. Fish and Wildlife Service 2003). The person handling the firearm should be skilled and able to shoot under extreme pressure when charged by an animal in order for firearms to be successful. This makes firearms unsuitable for the general public to use (Brown & Conover, 2008). Bear spray could be an option for people that are not allowed to carry firearms and are restricted to only a limited array of defensive measures (e.g. tourists and local people).

Polar bear health and safety

Another point of discussion is that of the safety of polar bears during the deterrent action. Rubber bullets for example are not safe at close range or when hitting the polar bear in the wrong place of the body. York reckons that avoiding HPBC by injuring a polar bear with a rubber bullet might be better than having to shoot and kill a polar bear in defence (Pers com. York, May 20, 2016). Mayer, however, argues that polar bear health should be considered when using rubber bullets. He notes that possible injury could affect the polar bears´ ability to survive in the wild and could cause suffering and a slow death. He therefore prefers not to use rubber bullets (Pers com. Mayer, July 7, 2016).

When an encounter does turn into conflict, and a polar bear injures or kills a human, this often results in the death of the polar bear too (Aarden, 2004). Killing a polar bear should be kept as a last resort or back-up (see chapter 1.4 Human-Polar Bear Conflict). The intention of any deterrent should not be to injure a polar bear, but if the choice is between lethal control and just injury, deterrents are the best option (Pers com. York, May 20, 2016).

Other measures

The following management measures have not been discussed in this research, as there was little information available. However, they do show potential in avoiding or reducing HPBC.

- Polar bears seem to respond to recorded sounds of aggressive bears. Wooldridge and Belton reckon this may be an effective tool in repelling nuisance polar bears. However, this is only effective when polar bears have had an encounter with aggressive polar bears in the past (Wooldridge & Belton, 1980).
- Data on testing different types of noise and sound as deterrents on polar bears is outdated or involves old equipment. New equipment might have different effects on polar bears and renewed testing could offer new and different results. McMullen reckons there is need to further research on deterrents in general as well, as most research on deterrents was carried out over 20 years ago (Pers com. McMullen, June 21, 2016).
- Gillin et al. (1997) reckon that high pressure $C0_2$ canisters used in fire extinguishers might be an effective repellent as they also cause an impressive visual display.
- Herrero et al. (2005) suggest that where brown bears require access to critical habitats, the best management practice might be to exclude humans from that area altogether. However, more research is needed to conclude whether this option would be applicable to polar bears as well.
- Testing is done with innovative tools such as lasers to detect or deter polar bears, however besides personal communication, further details cannot be found on these measures and their effectiveness.
- The most commonly used early detection method is to have people on the outlook (e.g. in the case of science camps) (Pers com. Koopmans, July 8, 2016). This option is not covered in this research as it is difficult to find proper references.

5. Conclusion

General conditions

Each conflict situation is different and the effectiveness of measures depends on previous experiences a polar bear has with humans, the motivation of the polar bear and its character. The fact that a measure has worked before does not mean it will do so again in the next conflict situation. A measure should fit its user. It is important that the user knows how the measure works and feels comfortable using it. Even the best measure is not effective when not used properly.

There are three different groups of people in the Arctic that all require a different approach and have access to different arrays of measures. The choice of measures depends on the phase the polar bear is in, the type of person using it and the accessibility of the measures to these people (e.g. depending on resources available, legal restrictions).

A measure will not keep polar bears away from human property and only has the effect of AC when the attractant is still in the area. It is therefore important to look at the underlying causes and remove those in order to really reduce HPBC. Besides food and waste management, no other measure itself really takes in consideration possible cause of the problem and motivation of the polar bear and therefore will only result in temporary avoidance of polar bears from humans and human property, and thus prevention of HPBC. Literature shows that no measure seemed to have a long-term AC effect on polar bears and with all measures polar bears would return to the area after a period of time. The most realistic outcome of most deterrent measures is therefore to buy time to get to safety. Various measures should be combined to prevent habituation and increase the AC effects.

General conditions when using HPBC reduction measures that have been identified during this research:

- Each situation needs to be interpreted differently and measures adjusted to the situation. Therefore knowledge of polar bear behaviour and measures is essential.
- Most important is to avoid conflict by increasing the distance (if possible) when encountering a polar bear in the encounter phase.
- When a polar bear comes within the deterrent phase, the polar bear should be alerted of humans present.
- It is important to have the polar bear understand that the negative stimulus it receives from the measure is linked to its unwanted behaviour.
- Proactive and reactive measures should be used together and changed regularly to avoid habituation of polar bears to the measure. Over time different measures should be implemented as HPBC is a changing process.
- Ideal HPBC reduction measures work at the first attempt, are cost effective, safe for both human and polar bear and easily accessible to the potential user.

Proactive measures

Proactive measures that seem most successful or have the highest potential in being effective HPBC reduction measures are electric fences and food and waste management. When properly installed and used in combination, these measures are good tools to prevent polar bears from feeling attracted to and reaching human property and increase human safety. Electric fences are easily accessible, however cost and maintenance are an important limiting factor. An electric fence does not have a direct reducing influence on HPBC and combining it with reactive measures is advisable to teach polar bears to stay away from human property.

Reactive measures

Vehicles/mobile equipment

Using vehicles to chase away polar bears is the most successful reactive measure. It does not require any additional costs or maintenance when vehicles are already available. However it is important for drivers of the vehicles to know how to chase a polar bear away without harming or causing unnecessary stress to the polar bear (see Chapter 3.4.1Vehicles & Appendix IX-III). Knowledge of polar bear behaviour is important. For the measure to be effective, chasing away polar bears with vehicles should be done in a consistent manner.

Torches

Other reactive measures with good potential are torches, as they are cheap and easily accessible. It is a simple measure, but based on some experience in the field it seems to have the potential to be an effective measure that can be used to scare off polar bears even in remote places. Specific preconditions for the use of torches are still unknown.

Dogs as deterrents

Opinion and experiences with using dogs as deterrents differ. It seems like this measure definitely has potential to be an effective polar bear deterrent as indigenous people have positive experiences with using dogs as such. However more knowledge is necessary on what dog breeds are best to use, how to train the dogs and under which conditions the dogs should be kept for properly implementing this measure.

Hand-held flares

Hand-held flares are relatively cheap, easy to use and accessible to all types of people, making them a good option as an available deterrent for everyone entering polar bear country. Unfortunately, little information is available on using hand-held flares in the field.

Bear spray

Bear spray seems to work effectively as a deterrent on other bear species but it has not been properly tested on polar bears yet. A major limiting factor for the use of bear spray on polar bears is that possession is not allowed in all Range States.

Table 85 Group types and their potential and accessible proactive and reactive HPBC reduction measures in different interaction phases

		Potential User (Type of Group)			
Interaction Phase	Measure	Indigenous People	(Semi) Permanent Settlers	Newly Settled and Temporary Residents	
				Tour Guides & Scientists	Tourists
	Proactive				
Avoidance >1 km	**Attractant management**				
	Food &waste management	+	+	+	+
	Bear Proof Containers	+	+	+	+
	Incinerators	+	+		
	Diversionary feeding	+			
	Early detection				
	Guard dogs	+			
	Protection of property				
	Concentrated shocking device	+	+		
Deterrent 100m	**Early detection**				
	Guard dogs	+			
Conflict 50-30m	**Early detection**				
	Trip wire	+	+	+	+
	Motion detectors	+	+		
	Protection of property				
	Electrical fences	+	+	+	+
	Unwelcome doormats	+			
	Reactive				
Deterrent 100m	**Deterrents**				
	Horns & sirens	+	+	+	
	Vehicles	+	+		
	Torches	+			
	Sticks	+			
	Dogs as deterrents	+			
	Pyrotechnical deterrents	+	+	+	
	Light flares	+	+	+	
	Hand held flares	+	+	+	+
	Paintball markers	+	+	+	
	Rubber bullets	+	+	+	
	Bean bag projectiles	+	+	+	
Conflict 50-30m	**Deterrents**				
	Horns & sirens	+	+	+	
	Vehicles	+	+		
	Torches	+			
	Sticks	+			
	Dogs as deterrents	+			
	Hand held flares	+	+	+	+
	Non-lethal personal defence				
	Bear spray	+	+	+	+

Socio-political aspects of HPBC

It is important to also realize that there is a social aspect to the measures suggested in this research. The measures discussed in this report offer a technical option to people to protect themselves against HPBC. However, people and their backgrounds should be taken into consideration as they are the ones encountering polar bears. It is important that they can see the benefit from sharing a habitat with wildlife and have a positive or neutral attitude towards polar bears. Measures need to help achieve that by giving people something they can rely on and increasing their sense of safety. By taking in account peoples' backgrounds and attitudes and by providing education, more acceptance for the use of measures to reduce HPBC can be created and management options are made more acceptable to (local) people.

Recommendations

Further testing

This research shows potential successful HPBC reduction measures, however further testing is required (table 86).

Table 86 Potentially successful HPBC reduction measures that require further testing and/or research and information that is still missing

Measure	Missing Information
Proactive measure	
Diversionary feeding	• The effect of diversionary feeding on polar bear populations
Guard dogs	• Dog breeds best suitable • Specific training • Circumstances dogs should be kept in
Concentrated shocking device	• Effectiveness on polar bears • Effectiveness under Arctic circumstances
Reactive measures	
Torches	• Specific information on preconditions for the use of torches are unknown such as: - Length of torches/sticks - Distance to polar bear - Human body language and use of voice - Motions made with torches
Sticks	• Specific information on preconditions for the use of sticks are unknown such as: - Length of sticks - Material of sticks - Distance to polar bear - Human body language and use of voice - Motions made with sticks
Dogs as deterrents	• Dog breeds best suitable • Specific training • Circumstances dogs should be kept
Hand held flares	• Successfulness in deterring polar bears: - Distance to polar bear - Human body language and use of voice - Motions made with flares
Paintball markers	• Successfulness in deterring polar bears - Type of projectiles most effective - Manner of firing (physical impact to the polar bear or on the ground) - Effectiveness under Arctic circumstances
Rubber bullets	• Effectiveness on polar bears
Bean bag projectiles	• Effectiveness on polar bears
Bear spray	• Effectiveness on polar bears • Effectiveness under Arctic circumstances

Proactive measures

Proactive measures that require more research are diversionary feeding and guard dogs. Also, concentrated shocking devices need further testing.

Reactive measures

Dogs as deterrents

It is advisable to gain further insight from experienced dog trainers and users and experiment with Karelian Bear Dogs, as these dogs show success in deterring other bear species.

Hand-held flares

Further testing on the effect of hand-held flares on polar bears is advisable. In case test results are positive, hand-held flares could be a good deterrent option and possibly also a personal defence measure for anyone in polar bear territory, as it is easily accessible to the general public.

Bear spray

Further testing on the effect on polar bears and usage of the spray under Arctic conditions is advisable. Once proven to be effective on polar bears and in Arctic circumstances, regulations might be reconsidered making it accessible to the general public as an effective last resort personal defence measure and making its usage more generally acceptable.

Other reactive measures that require further testing are torches, paintball markers, rubber bullets and bean bag projectiles.

For further testing, local communities in conflict areas could be invited to assist. They would be provided with an array of measures that could deter polar bears in different phases, using the least intensive option first. In other areas, stakeholders could experiment using a combination of measures to see if those achieve better results than using a single measure on its own.

Integrated HPBC management

When involving communities in decision making and giving them responsibility, they are likely to be more tolerant of wildlife and possible damage (CPW, n.d.). To help create more understanding, more knowledge exchange between stakeholder groups and regions is recommendable. Additionally, conducting further interviews with indigenous people and people in the field could provide further insight and new findings on HPBC and what seem like realistic solutions. Additional interviews and set up of research in Russia, Greenland and Norway is advisable were information is lacking.

An idea for involving and educating local people is to organise workshops to share knowledge and experience. Furthermore, knowledge should be shared among the Range States and an agreement is necessary to create a clear understanding of who is responsible for implementing measures and management. As HPBC reduction should be part of integrated management in order to be successful and reach its full potential throughout the Arctic, sharing knowledge is essential and highly recommended. The shared data base PBHIMS has the potential to establish this. And thus an information sharing agreement between the Range States is necessary.

Besides a shared data base different stakeholders should be motivated to share knowledge to establish an integrated vision. This could be done by organising workshops and create opportunities for stakeholders to come together and share experience.

As this research provides mainly a technical approach to HPBC reduction measures, further research on the socio-political aspect of HPBC is highly recommended, as this is an important factor in reducing HPBC.

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References

Appendices

Appendix I: Types of polar bear approaches

Recognizing the motivation of polar bears and knowing how to respond can influence the outcome of an encounter (SBCS, 2005; USFWS, 2010). A wrong choice of measures might stop the behaviour of the polar bear for an instant, but if ineffective, polar bears will most likely find ways to avoid the negative stimulus in the future and eventually creating more severe damage (Van Daele, 3rd IBPCW, 2009). However, Brown & Conover reckon that many victims of HBC are not able to identify the underlying intention of the attacking bear (Brown & Conover, 2008). Intensions of bears can easily be misinterpreted and people with lack of knowledge on polar bear behaviour can misjudge the situation. Misinterpreting a situation might influence a person's response to an approaching polar bear regardless of the intension of that polar bear (Clark, 2003) Fear could be exacerbated when not knowing how to respond when being threatened or attacked (Brown & Conover, 2008). This not only leads to a dangerous situation for people, but also to polar bears as they could get shot when approaching out of curiosity while people believe they are under attack (Pers com Koopmans 2016).

Three main types of approaching behaviour of polar bears have been identified (SBCS, 2005):

1. Investigative approach: Approach out of curiosity to see what a person or human property is, the polar bear is:
    - Slowly moving
    - Stopping frequently to sniff the air
    - Moving around its head to catch scents
    - Holding its head high with ears forward
    - Circling around downwind (SBCS, 2005)
    - Could stand up (Bureau of Land Management, n.d.)

    In this situation people should make sure the polar bear is aware of humans present. People should stay together, upright and moving a little. Avoid moving towards or away from the polar bear. Monitor and assess the behaviour of the polar bear.

Continuing approach of a polar bear that seems defensive or aggressive and is in need of deterring are:

2. Aggressive/predatory approach with the intention of attack. The polar bear:
    - Does not vocalize or gives much warning
    - Shows no sign of fear or stress
    - Stays intensely focused on object considered to be prey
    - Holds its ears are erected
    - Opens its mouth (SBCS, 2005)
    - Sneaks or crawls up on the object considered to be prey
    - Approaches in a straight line at constant speed without exhibiting curious or threatened behaviour (Bureau of Land Management, n.d.)

3. Defensive approach when a polar bears feels threatened with the intent to scare a person by acting aggressively. The bear:
    - May huff
    - Snaps jaws together
    - Stares directly at person or object of threat

- Lowers its head below shoulder level
- Presses its ears back
- Sways from side to side (Bureau of Land Management, n.d.)
- Takes a run forward and stops short of contact, so called “bluff charge” (SBCS, 2005)

In these situations it is important for people to stay calm and stay together. If the polar bear approaches within 100m signal shots should be fired, if necessary multiple shot should be fired until the polar bear retreats. Avoid hitting the polar bear.

If the polar bear comes within 50-30m preparation should be made to shoot physical deterrent rounds at the polar bear. Make sure to have a loaded lethal rifle ready as back up. An attack may occur suddenly and quickly. Staying calm is necessary to be able to take good aim at the polar bear.

After a deterrent or conflict situation the area should be left. Important is to stay calm and vigilant and stay together as a group.

Appendix II: List of Interviewees

10 February 2016	Brandon Laforest WWF Canada
04 May 2016	Jouke Prop, ecologist University Groningen
04 May 2016	Sybille Klenzendorf, WWF US
09 May 2016	Peter Ewins, WWF Canada, leader HPBC work in Arviat, Canada
11 May 2016	Maarten Loonen, researcher Netherlands Arctic Station Spitsbergen
20 May 2016	Geoff York, Polar Bear International
13 June 2016	Ivan Mizin, WWF Russia, leader Barents Sea programme
16 June 2016	Jeff Marley, Marley Supplies ltd
21 June 2016	Andy McMullen, Bear Wise
07 July 2016	Jim Mayer, Expedition Leader Oceanwide Expeditions

Appendix III: Aversive conditioning (AC)

Aversive conditioning (AC) can be defined as a learning process in which deterrents are used in a continual and consistent manner to reduce the frequency of undesirable behaviour of a bear (Hopkins et al., 2010). AC is successful when a bear learns to associate humans and human property with a negative stimulus and avoids them in the future. Ideally, this change in unwanted behaviour is permanent. However, bears may return to a site later on and differentiation should be made between short-term and long-term behavioural change. (Mazur, 2010) Beckmann et al. concluded that most common non-lethal deterrents used on black bears were not successful in altering nuisance bear behaviour over a period of time extending one month (Beckmann et al., 2004). The most successful long-term efforts to deter a polar bear involve using a combination of measures (NPBGTP, 2013b).

Ideal AC methods are cost effective, allow for multiple usage, are safe for both human and bear and make a strong connection between an aversive stimulus and the presence of humans (Mazur, 2010). To ensure association with humans, shouting at the bear before applying the measure is appropriate (Mazur, 2010). AC is most effective on non-food-conditioned bears, as they have not learned to associate humans with the reward of food yet. The effectiveness on food-conditioned bears is related to how soon the bear receives its first AC after obtaining human food. Food-conditioned bears can be chased out of an area for a little while but the effect is often short-termed. AC will not be effective when the attractant remains in the area. (Mazur, 2010)

Appendix IV: Overview of HPBC reduction measures

Proactive measures

- Attractant management
    - Food & waste management
    - Diversionary feeding
- Early detection measures
    - Trip Wire
    - Motion detectors
    - Guard dogs
- Protection of property
    - Electrical fences
    - Concentrated shocking device
    - Unwelcome doormat

Reactive measures

- Deterrents
    - Visual & auditory deterrents
        - Horns and sirens
        - Vehicles
        - Torches
        - Sticks
        - Dogs
        - Pyrotechnical deterrents
            - Bangers
            - Screamers
            - Cracker shells
            - Light flares
            - Hand held flares
    - Physical deterrents
        - Paint ball markers
        - Rubber bullets
        - Bean bag projectiles
- Non-lethal personal defence
    - Bear Spray
- Relocation & polar bear jail

Human body language

Patrol groups

Appendix V: Role of attractants

Most incidents of HPBC involve attractants, as was the case in 92% (N=304) of the incidents between 1965 and 1985 researched by Herrero & Fleck (Clark, 2003; Herrero & Fleck, 1990). In 40% (N=20) of injurious cases the attractant involved was garbage, animal carcasses, live animals and/or food. Smith et al found that out of 72 incidents with black, brown and polar bears between 1986 and 2006, 32 cases were caused by human food and waste as attractants (Smith et al., 2012). Spencer et al noted that 69% (N=48) of professionals working with bears in the wild state that waste and food attractants are the most common cause of HBC (Spencer et al., 2007). Food can be defined as "any food or other material attractive to bears such as human, livestock and pet foods, garbage and household waste, livestock carrion, game meat in the possession of man, other edibles, and other edibles and/or garbage which is allowed to accumulate, or the residue thereof" (Peine, 2001). Also, non-food items can serve as attractants to polar bears (see table 84).

Polar bears are opportunistic foragers (Herrero & Fleck, 1990) and are attracted to food and associated odours, waste and items with a strong smell (table 84). All of these items can contribute to problems with polar bears when not disposed properly (Exxon, 2009). Furthermore the curious nature of polar bears plays a role (Smith, 2016; Pers com. Prop, May 4, 2016).

Table 87 List of common polar bear attractants

Category	Items/products
Personal care products	• Lotions • Deodorants • Scented soap • Sun screen lotion • Etc. (Sowka, 2013)
Food related items	• Cooking oil • Containers and packages used for food and drinks (Herrero & Fleck, 1990; Stenhouse, 1983) • Dog food (McMullen, 2000)
Industry & household products	• Petroleum products • Motor oil • Waxes • Anti-freeze (GBSS, n.d.; Sowka, 2013b) • Bio diesel • Vegetable-based fuels • Lubricants (GBSS, n.d.) • Paint • Snow mobile seats (Sowka, 2013b)
Waste related items	• Sewage • Waste water (Exxon, 2009)
Other	• Menstrual blood/odours (Cushing, 1983) • Dogs (McMullen, 2000)

When bears get a positive reinforcement and become conditioned to human food, they become persistent and learn to associate human stimuli with obtaining food, resulting in bears also being attracted to clean camps and human settlement, lose fear and becoming more aggressive and bolder (Breck et al., 2006; Herrero et al., 2005; Hopkins et al., 2010; Stenhouse, 1983). Once a bear has successfully obtained food at a certain site, it usually comes back to check for more food regularly (Gunther et al., 2004). Obtaining human food and waste is also a learning process. Stirling describes

how females tagged as cubs on a waste dump were seen later as an adult bringing their cubs to a waste dump. But most importantly, the majority of polar bears do not come to the dump and thus seem to get sufficient food elsewhere. Males that were seen to come to the dump as sub-adults have stopped coming since being healthy adults. Females do not seem to come to the dump when they are pregnant, but do seem to bring their cubs there and return more frequently over the years. (Stirling, 2011) It seems that if there are adequate food sources, shifting to dump sites or stored food is less common (pers com. Polet, July 8, 2016).

To prevent polar bears from developing bad habits and incidents like these to happen, storing food, waste and carcasses should be done with care (Exxon, 2009; Herrero & Fleck, 1990). The priority measure to minimize bear-human interactions is obtained through controlling bear access to human food (MacHutchon & Wellwood, 2002). Proactively dealing with HBC by reducing food conditioning in bears increases safety for both humans and bears and reduces costs at the long term compared with dealing with food-conditioned bears (MacHutchon & Wellwood, 2002). An additional problem is carcass dump sites that have attracted polar bears and therefore consequently come into conflict with hunting camps (Hedman, 3rd IBPCW, 2009).

Additionally for other deterrents to work properly, care should be taken into other preventative measures and strategies to keep polar bears from being rewarded by obtaining food and waste rewards (Exxon, 2009). Reduction measures will not be working optimally or be a successful management strategy if human food and waste remains in the area (Mazur, 2010).

Appendix VI: Attractant management

I: Waste and food management

Securing waste and food and enforcing a feeding ban on polar bears are good measures to reduce HPBC and is according to Exxon relatively easy to achieve even at remote settlements when financial capacity is available (Exxon, 2009). In a community with traditional food this will be more difficult (Pers com. Koopmans August 8, 2016). According to Dalle-Molle and Van Horn, bear proof food canisters designed especially for hikers have successfully reduced the frequency of HBC with other bear species (MacHutchon & Wellwood, 2002). Implementing bear-resistant waste and food containers has decreased the number of incidents in rural and remote communities, as black bears were to a lesser extent attracted to food and waste (Cotton, 2008; Madison, 2008). Literature shows multiple cases of implementing bear-proof dumpsters, containers and food storage canisters that have resulted in a decrease of HBC (Beckmann et al., 2004; Cotton, 2008; Madison, 2008; Peine, 2001) and a number of cases in which HBC could have been prevented or reduced by more efficient handling of storage of food and waste management (Stenhouse, 1983).

A big communal fridge seems to work well in Arviat. People store their food there and have a smaller fridge at home. This form of food management seems to work properly, it is however expensive to purchase such freezers. This communal fridge does not store dog food so that still remains an attractant. More freezer space is necessary but resources are limited. The freezer should run on solar power to prevent it from becoming too expensive. (Pers com. Klenzendorf, May 4, 2016)

To reduce polar bear attraction, waste transfer and recycling centres should be bear-resistant too (Sowka, 2013). For further reading and possibilities see Sowka, 2013b.

Table 88 Additional information BPC

	Preconditions

Design	There are several designs for waste and food management that are bear proof:
	• Steel drums with locking lids (MacHutchon&Wellwood, 2002)
	• Aluminium boxes for storing food when transporting on small rafts
	• Ocean fright containers (Sowka, 3rd IBPCW, 2009)
	• Food storage containers: all made of .9090 (3/32) thick aluminium (Sowka, 2013)
	• Bear-Resistant Containers (BRCs)
	  ○ Polycarts
	  ○ Fully-automated dumpsters
	  ○ Trash bag receptacles
	  ○ Automated roll-offs
	  ○ Grease traps
	  ○ Backpacking containers (Sowka, 3rd IBPCW, 2009)

Maintenance	• All products require monitoring and maintenance (Sowka, 3rd IBPCW, 2009) • Regular checks are necessary (Exxon, 2009)
Costs	• Cost range from $500-$2000 (Spencer et al., 2007) • Could require substantial equipment changes for waste collection agencies (Spencer et al., 2007) • Implementation of penalties and fines brings additional costs for regulation and enforcement. (MacHutchon&Wellwood, 2002) • As BPC and waste management implementation measures are costly, an option could be to address funds from outside (Spencer et al., 2007)
AC	• Long term process but results in short-term behaviour change of polar bears
Human	• According to Keay&Webb people are motivated to follow rules and guidelines when

behaviour		potential financial consequence are present (MacHutchon&Wellwood, 2002)
Combination	•	Electric fencing (Pers com. Klenzendorf, May 4, 2016; Sowka, 3rd IBPCW, 2009)

Table 89 Additional disadvantages BPC

	Disadvantage
Design	• Hinges and latches of boxes are often not bear proof (MacHutchon & Wellwood, 2002)
Costs	• Lack of agency funds and personnel limits the ability to make BPC readily available (Spencer et al., 2007)
Polar bear related factors	• Bear proof testing in captivity with other bear species does not guarantee field effectiveness of the product when encountering polar bears, only relative bear resistance (Sowka, 3rd IBPCW, 2009)

II: Diversionary feeding

Before 1992 the remains of whale carcasses were pushed in the ocean for wildlife to consume. Ocean currents and winds brought the bones back to land, creating more problems with polar bears. Depositing remains as far away from communities as possible seems like the best solution. (Adams, PBDFW, 2011)

Diversionary feeding programs seem to have been successful in reducing conflict with brown bears in Montana, U.S. and Lake Louise area, Alberta, Canada. However the latter had different measures implemented at the same time, not certain how the individual measures had their effect. (Madel, PBDFW, 2011; Morrison, PBDFW, 2011) The use of diversionary feeding measures could be a successful tactic to reduce HWC. However when diversionary feeding is provided when natural food sources are lacking, an increase of wildlife numbers is possible and could result into more conflict. (Muruthi, 2005)

Factors that may affect polar bear behaviour during an encounter and are of importance for human and polar bear safety need to be considered before a diversionary feeding program. These factors include:

- Environmental factors: season, time of day, nutrient availability, presence of con-species
- Polar bear related factors: species, sex-age class, degree of habituation to humans
- Human related factors: previous experience with humans, human response during encounters (Dutton et al., 2011)

When choosing diversionary feeding as a measure, the goal needs to be clear to take the right actions for it to be successful (Dutton et al., 2011).

Table 90 Additional information diversionary feeding

	Preconditions
Design	• Distributing in a remote area draws bears away from human settlement and property (Madel; PBDFW, 2011). • Providing in multiple smaller areas could be considered over a large amount of food in a certain area to prevent a large number of polar bears to feed in one location and minimize disease transmission (Dutton et al., 2011).
Distance	• As far away from communities as possible, the further the better. However for practical reasons area should still be accessible by road (Dutton et al., 2011)
Responsibility	• Local people that are directly affected should be involved and given the opportunity to be involved in management decisions (Dutton et al., 2011). • Need dedicated people to be successful (Pers com. Klenzendorf, May 4, 2016)
Accessibility	• Heavy equipment/big vehicles/boats are necessary to be able to move the carcasses. (Pers com. Klenzendorf, May 4, 2016). This makes it not accessible for everyone.
Costs	• Funding and fuel available is of influence on the distance and the number of that carcasses could be moved (York, PBDFW, 2011).
Safety	• Diversionary feeding areas could be flagged to warn people of (polar) bear activity (Madel; PBDFW, 2011). • Keeps polar bears at a safe distance away from people
AC	• It is a long term initiative once implemented and should not be stopped abruptly (Dutton et al., 2011)
Human behaviour	• People should be made aware on how to behave around polar bears to make it successful (York, PBDFW, 2011). • People should stay away from sites where carcasses are placed to avoid HPBC.
Combination measures	Seems successful on brown bears in combination with: • Electric fencing • Food and waste management (Morrison, PBDFW, 2011) Food and waste management should be applied and all attractants should be minimized to prevent polar bears from approaching human property. (Dutton et al., 2011; Hannah, 3rd IPBCW, 2009; Shideler, PBDFW, 2011).

Table 91 Additional disadvantages of diversionary feeding

	Disadvantage
Responsibility	• Difficult to determine who should be held responsible for the job (pers com. Klenzendorf, May 4, 2016)
Other	• Risk of attracting other bear species when present in the area. Creating conflict between bear species, out competition of polar bears and possibly increase HBC (Dutton et al., 2011).
Polar bear relates factors	• Polar bear numbers might increase at feeding sites or polar bears show up earlier in the season. Consequences to this should be considered (Dutton et al., 2011).

Appendix VII: Early detection measures

I: Trip wire

Opinions on the effectiveness of trip wire mechanisms are divers. Tests on single, double, and triple trip-wire fences had a 93% (N=161) success rate for detecting approaching bears (Wooldridge, 1983). Stenhouse states a 100% (N=50) success (Stenhouse, 1983). Thing reckons you should not rely on just a trip wire system as it is not 100% reliable (Thing, 1990). Several sources mention failure and unreliability of trip wire detection systems (Kennedy, 2012; PBS, 2015; pers com. Prop, May 4, 2016), this could be the result of a human fault in setup of the trip wire system (GBSS, 2005; Kennedy, 2012), but also mechanical failure (pers com. Prop, May 4, 2016).

Table 92 Additional information trip wire systems

	Preconditions
Design	• Wires 10-12”above ground and the next 10-12”above that. This way Arctic fox can still go underneath the wire without activating it. (Pers com. Marley, 2016) Wire height at 20, 40 and 46cm when using a triple-wire fence (Wooldridge, 1983) • Support posts of fiberglass are advisable, but any convenient wire support can be used (NPBGTP, 2013c). • 11/16”posts are advisable (Margo Supplies ltd, n.d.a) • Spikes of 12”can be used to make holes for posts (Margo Supplies ltd, n.d.a) • Posts set up approximately 4 -10m apart • Light gauge wire (NPBGTP, 2013c) • Wire should be run between posts using wire hangers (Margo Supplies ltd, n.d.a) • Wires should be tensioned and can be supported using electrical house hold staples (Wooldridge, 1983) • Alarm controller or siren, placed 150cm (5ft) above ground to project sound (Margo Supplies ltd, n.d.a) • Power supply should be protected by cover (Margo Supplies ltd, n.d.a)
Environment	• Must be protected from weather and severe temperatures (Margo Supplies Ltd, n.d.a)
Maintenance	• Should be manually reset after every breaking of the wire strands (Stenhouse, 1983)
Responsibility	• Set up of guidelines and appointing a person responsible could increase reliability
Accessibility	• Accessible to anyone over mail (Pers com. Marley, 2016)
Costs	• $160-300 CAD (Margo supplies ltd, n.d.a)
Polar bear related	• Does not alter the behaviour. The alarm could startle naïve polar bears; however that is not its primary function. (NPBGTP, 2013)

Table 93 Additional advantages and disadvantages of trip wire systems

	Advantage	Disadvantage
Design	• Small, portable and inexpensive (Stenhouse, 1983) • Not require large number of materials (jerry cans, tent poles could serve as corner posts) (Stenhouse, 1983) • The triple-wire microswitch system provided too many obstacles for bears to enter undetected; this system detected all entries and required no maintenance over the study period. (Wooldridge, 1983)	• Mechanical failures can occur (Pers com. Prop, May 4, 2016)
Environment	• Proved to be very strong and reliable despite cold weather conditions. (Wooldridge, 1983)	• Must be protected from weather and severe temperatures (Margo Supplies ltd, n.d.a) • Rocky grounds makes stability of the system difficult (Pers com. Koopmans, 2016)
Distance		• Limitations to size of area enclosed by system (Stenhouse, 1983)
Maintenance		• Requires reconnection and repair after each entry (Wooldridge, 1983)
Polar bear related factors	• The alarm may already startle or scare off the bear, preventing further action to take place (NPBGTP, 2013)	

II: Motion detectors

The detection system tested by Wooldridge in 1983 detected 100% (N=13) of approaching polar bears, but was too sensitive to stray electrical inputs. Testing of a modified system in the second season detected 63% (N=41) of approaching polar bears. Refined versions of these devices could offer significant improvements in safety for people working in polar bear inhibited areas (Woodridge, 1983). Stenhouse tested the system to be 100% successful in detecting approaching bears (N=187) (Stenhouse, 1983).

Table 94 Additional information motion detectors

	Preconditions
Design	• Require high performance 9-volt lithium batteries as these work better in cold than standard alkaline batteries and get more activations (up to 200 activations) (Pers com. Marley, June 16, 2016)
Environment	• Not adversely affected by snow, rain, fog during study period (Stenhouse, 1983) • Cold weather system operating at -40°C (Stenhouse, 1983)
Training	• Practice with properly setting up the system
Distance	• It should be placed at least 5m (16ft) from all sides of the camp to give people enough time to respond to an intruding polar bear. (NPBGTP, 2013c)
Maintenance	• Sensor should be kept clean (NPBGTP, 2013c) • Daily check on power supply (Stenhouse, 1983) • Daily testing necessary to ensure operational status. (Stenhouse, 1983)
Responsibility	• Set up of guidelines and appointing a person responsible could increase reliability
Costs	Critter Gitter (Margo Supplies Ltd, n.d.d) • Device: $87.50 CAD • Strobe/Siren Enhancer: $60 CAD • 9V High Performance Lithium Battery: $15.25 CAD
Polar bear related	• Polar bears could invest the systems and damage them (Stenhouse, 1983) • Needs chain link fence to protect from curious bears (Stenhouse, 1983)

Table 95 Additional advantages and disadvantages of motion detectors

	Advantage	Disadvantage
Design		• The system is extremely sensitive to stray electrical input. The sensitivity of the device rises exponentially with increases in antenna length, resulting in extra or irregular counts. (Wooldridge, 1983) • System can fail when not properly set up (GBSS, 2005)
Environment	• Operational in darkness and reduced visibility, therefore useful in northern latitudes in (Stenhouse, 1983)	• Moving branches or snow might trigger the alarm (NPBGTP, 2013c) • Impractical for use on uneven ground (NPBGTP, 2013c) Effective range is reduced if the terrain is irregular (Stenhouse, 1983)
Maintenance	• Relatively simple to maintain and operated with basic knowledge of electronics (Stenhouse, 1983)	

III: Guard dogs

Inuit have depended on dogs for hunting polar bears and protection for centuries (GBSS, 2010; NPBGTP, 2013; Stirling, 2011). Dogs trained specially for detecting and deterring polar bears are still used nowadays, however less common (NPBGTP, 2013).

Table 96 Additional information guard dogs

	Preconditions
Maintenance	• Dogs are high in maintenance and require daily care year round (GBSS, 2010; NPBGTP, 2013b).
Costs	• Costs depend on if the dogs still need to be trained or are contracted over a season or several years (GBSS, 2010) • Further costs are food, daily care and veterinary care
Safety	• Risk for dogs to be killed by polar bear

Table 97 Additional disadvantages of guard dogs

	Disadvantage
Design	• (Barking) dogs could possibly aggravate the approaching polar bear and provoke an aggressive response (McMullen, 2000; NPBGTP, 2013b). • Well trained guard dogs are often responsive to one master (NPBGTP, 2013b).
Training	• When lack of proper training, dogs could possibly be a hazard (NPBGTP, 2013b)

Appendix VIII: Protection of property

I: Electrical fences

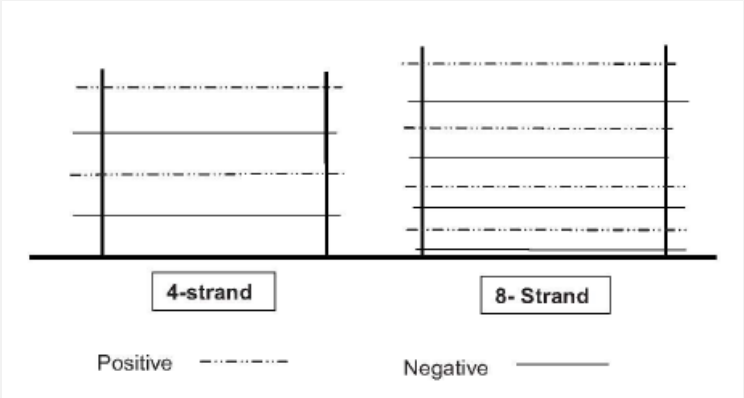
An effective method to control HWC is the use of physical barriers to exclude wild animals (Muruthi, 2005). Since the 1930s electric fencing has been used to keep bears away from attractants and human property (Marley, 3rd IBPCW, 2009). Design of electric fences has been developed mainly through trial and error, trying to use as little material and keeping the costs as low as possible (McKillop & Sibly, 1988). A study of McMullen showed that of 31 attempts of polar beas trying to penetrate an electric fence, 30 polar bears failed to do so (success rate of 97%), with the acception of a small cub. This does not support earlier reseach done by Wooldridge (1983) and Stenhouse (1981) that find electric fencing unsuccessful (McMullen, 2000). Sowka states that when properly used and operated correctly electric fencing can be an effective tool deterring bears from attractants (Sowka, 3rd IBPCW, 2009), as does Marley of Margo Supplies ltd, who reviewed mechanical principles that must be applied correctly for electric fences to be effective (Marley, 3rd IBPCW, 2009).

Different studies have experimented with different voltages, not all being successful. A sufficient power is necessary to reliably deliver an electric shock through the average 6cm of (dry) fur depth of a polar bear (Wooldridge, 1983). The impact the electrical shock has on polar bears depends on the part of the body which the polar bear makes contact with the electric fence, and thus determines the reaction (McKillop & Sibly, 1988). Most often this is the nose, head, ears, back, neck, chest or shoulder, with the nose being the most sensitive part. (McKillop & Sibly, 1988; Wooldridge, 1983) Effectiveness could be improved by using barbed wired fencing, penetrating deeper into the polar bear fur and additionally acting as a physical barrier (McKillop & Sibly, 1988; Wooldridge, 1983).

To take into account bear behaviour and to prevent bears from learning to avoid a shock and going under the fence, a strip of wire could be placed on the surface of the ground on the outside of the fence, or an electric trip wire could be installed (Huygens & Hayashi, 1999; McKillop & Sibly, 1988).

A problem could be the gates of the fences as people tend to leave them open (Marley, 3rd IBPCW, 2009). However problems could be reduced with patrolling staff during “daytime” hours and closing gates at night-time hours (Sowka, 3rd IBPCW, 2009) or stepping over the fence (pers com. Prop, May 4, 2016).

Table 98 Additional information electric fences

	Preconditions
Design	• The fence line is critical for setting up an electric fence. Important to use earth moving equipment to maintain a layer of material in which to place posts, if not possible an alternative is drilling and grouting holes. (Marley, 3rd IBPCW, 2009) • Ground contact needs to be made (Davies & Rockwell, 1986; McMullen, 2000, pers com. Prop, May 4, 2016). When making the bottom wire negative it does not have to touch the ground (Marley, 3rd IBPCW, 2009). The bottom wire should be at a sufficiently low level to prevent bears from crawling under the fence (Marley, 3rd IBPCW, 2009). Gasvoda reckons not more than 2inches from the ground (Gasvoda, 1999). In addition for higher success electrified mats could be used at gates and dips (Obbard, 3rd IBPCW, 2009) • Rods should be driven in the earth as deep as possible and ideally located in a wet spot. Gasvoda reckons using a metal rod 0,6 cm or longer. (Gasvoda, 1999) McMullen used 3-5/8"x 10'ground rods with electrical ground clamps between the charger and the fence (McMullen, 2000). • A 4-wire fence is recommended by both Wooldridge and Huygens & Hayashi. A 4-wire fence should be set up starting from 23-30cm above the ground with intervals of 23-30 cm. (Davies & Rockwell, 1986; Huygens & Hayashi, 1999; Wooldridge, 1983) Prop has good experience with a 5 wire fence, 20cm in between the wires. (Pers com. Prop, May 4, 2016). Gasvoda reckons a minimum height of 1,2m as the bear should not be able to walk of jump over the fence. He reckons 7 wires of smooith metal fence wire (16-gauge minimum) or Polywire (interwoven polyethylene with at least 6 strands of stainless steel wire), spaced 15-25cm apart. (Gasvoda, 1999) McMullen used 8-strands of 12,5 gauge smooth galvanised wire supported by fiberglass posts with the first positive wire above ground level was at 20 cm (McMullen, 2000).  Figure 7 Comparison of 4-strand and 8-strand electric fence wire spacing. With the 8-strand wire fence having the first positive wire 20 cm above the ground (McMullen, 2000). • According to Gasvoda a ground wire return fence should be used; using alternating hot and ground fence wires. Top two wires connect to the fence controller's hot terminal. Third wire down connects to the fence controller's ground terminal. Next wire connects to the hot terminal, etc. Bottom wire must be a grounded wire and may touch the earth. Ground terminal connects to an earth ground (fig 8). All fence wires connected to the hot terminal of the fence must be supported using suitable electric insulators. (Gasvoda, 1999)

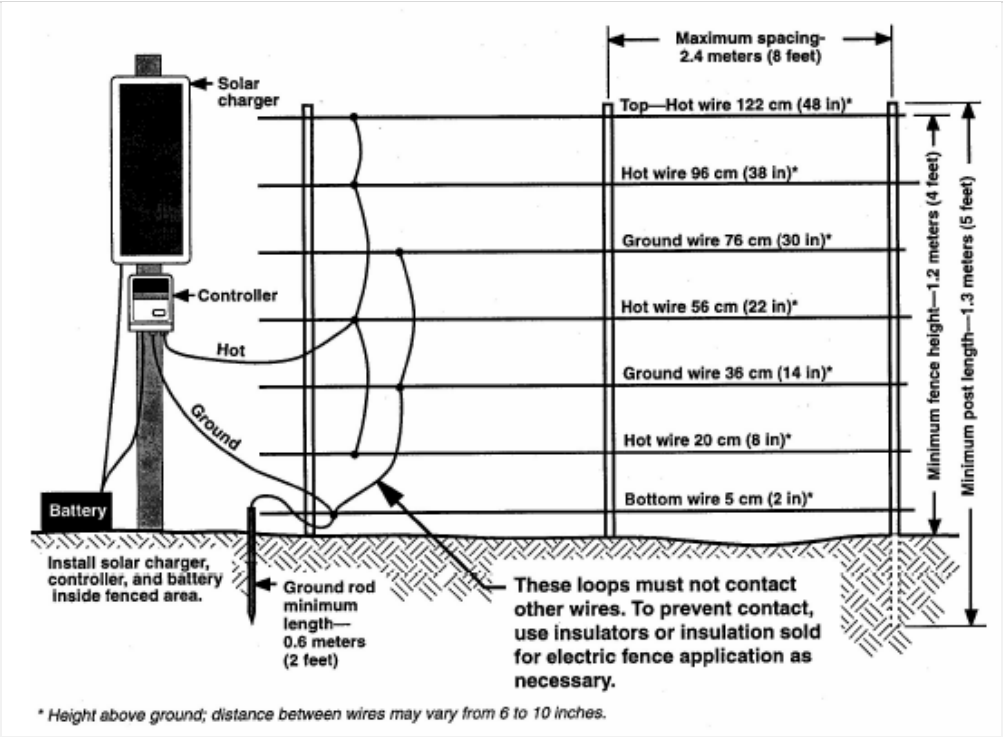


Figure 8 Construction details of an electric fence (Gasvoda, 1999)

- Huygens & Hayashi reckon Gallagher turbo wire (electro plastic wire) and using a trip wire 30 cm in front of the main fence, 30 cm above the ground, to function as a warning for the bears and preventing them from going under the fence. The trip wire was made of single line electro plastic tape. The wires are interwoven plastic lines with thin steel wires.

- The lines could be a single length of line wrapped continuously around the field at successive heights and with the exception of the ground wire being positively charged (Huygens & Hayashi, 1999). Huygens & Hayashi used Gallagher Power Fence Systems and energizers and Marley reckons two hundred/stand is ideal (Marley, 3rd IBPCW, 2009). Proper bracing of tight wiring is essential and at every direction change the wire needs to be braced. Proper tension indicator is the twitching of the wire when electricity pulse through it. (Marley, 3rd IBPCW, 2009) McMullen reckons approximately 250 lbs tension to ensure the wire will part the hair of the polar bear to make contact with the skin to deliver the shock. Wires should be alternating positive and negative. (McMullen, 2000)

- Wooldridge used ground wires. Davies & Rockwell used a chain link fence on the ground outside the fence serving as a ground mat, connected to the ground pole of the fence unit. This caused adequate delivery of charged pulses (Davies & Rockwell, 1986). To ground the system negative connections have to be metal to metal. The soil conditions determine the number of ground rods necessary and the ground clamps need to be used. Poor grounding would require a higher power output. (Marley, 3rd IBPCW, 2009) McMullen attached a ground plate to each corner post (McMullen, 2000).

- The pole post should be set approximately 2-3m apart for main fence (pers com. Prop, May 4, 2016), 3-5m (Davies & Rockwell, 1986; Huygens & Hayashi, 1999) and 7m (Wooldridge, 1983). Metal corner poles could be used to ensure grounding (Pers com. Prop, May 4, 2016). Additional posts could be of fiberglass (McMullen, 2000)
  Corner posts should be sturdy enough to not deflect excessively under tension. Fiberglass (or plastic posts for portable fences) may be used, but must be adequately braced. (Gasvoda, 1999) The posts of permanent fencing are often large-diameter treated wooden posts to prevent them from demolition quickly and wire strands will be

	used. To ensure a sufficient flow of electricity throughout the whole length of the fence a stronger energizer is required. (Sowka, 2013a) • The fence could be powered by an energizer of 110-120 volt A.C. (McMullen, 2000; Sowka, 2013) or a 12 volt battery (Davies & Rockwell, 1986; McMullen, 2000; pers com. Prop, May 4, 2016), emitting 40 pulses/min of direct current with a peak output of 8000 volts (Davies & Rockwell, 1986). Huygens & Hayashi used B160 Gallagher energizer to achieve a peak output of 6500-8000V using the same 12V battery or electrical house outlet (Huygens & Hayashi, 1999). Prop has good experience with the Gallagher B28 or B300 for a 7000V output on a 12V battery. Power should be on at all times (Pers com. Prop, May 4, 2016) • Gallagher Models for electric fence controllers and fence testers are recommended (Gasvoda, 1999).
Environment	• The soil conditions determine the number of ground rods necessary and the ground clamps need to be used. • Dry gravel beach ridges need special measures to ensure grounded contact of the animal with the fence (Davies & Rockwell, 1986) as well as frozen, dry-snow covered ground (Wooldridge, 1983). • Application of electric fences is less successful on snow as this does not ground well (Stirling, 2011). • Saturated ground or wet tundra ground at which the polar bear has to stand in water is preferable, assuring grounded contact with the fence. (Davies & Rockwell, 1986) • Insulators have to be frost protected. Hoar-frost on insulators causes leakage of the fence voltage. (Wooldridge, 1983) • Snow needs to be removed from the fence to maintain proper grounding (Stirling, 2011). • Vegetation and snow, should be prevented to make contact with any hot wires, even in windy conditions (Gasvoda, 1999)
Distance	• Prop successfully protected an area of 20x20m (Pers com. Prop, May 4, 2016) • Davies & Rockwell used a fence with a perimeter of 300m around the station, Wooldridge set the fence at a distance of 10m away from the base and the average surface protected with electric fencing of Asian Black bears was 0,75ha with a 100% (N=23) success rate (Huygens & Hayashi, 1999). • Set up of a portable fence should not be closer than 1m from the item protecting (Gasvoda, 1999)
Maintenance	• When properly installed routine inspection and maintenance is necessary to keep the fence working at full capacity. • New isolators should be used every season for optimal safety • Fence should be cleaned regularly to prevent rust and more regularly with more wind (Pers com. Prop, May 4, 2016). • Damaged material must be prepared immediately. (NPBGTP, 2013[e]) • Daily check of voltage and batteries, tightness of the lines and if fences are properly grounded. (Huygens & Hayashi, 1999; Pers com. Prop, May 4, 2016). • Removing snow, debris and other obstacles from touching the fence, avoiding shorting out the fence (Huygens & Hayashi, 1999; NPBGTP, 2013[e]). • An alarm to warn when battery is low, a wire is broken or when grounded contact is maintained for 1 or more pulses might be useful (Davies & Rockwell, 1986) • An electric fence tester with a displaying range of 600-5000 volts must be available to test if minimum requirements are met. Fence voltage should be tested as far as possible from the fence controller. Hot wires as well as ground wires should be tested. Each should test a minimum of 5000 volts. (Gasvoda, 1999) • Testing can be done using a short circuit with a double insulated hook up wire (Pers com. Marley, June 16, 2016).
Responsibility	• One person responsible for daily routine of checking and maintenance of the fence (Pers com. Prop, May 4, 2016).

	• Dedicated person necessary for responsibility to do maintenance as it is a labour intensive task (pers com. Klenzendorf, May 4, 2016)
Accessibility	• Due to high maintenance and costs often not accessible to local communities (pers com. Klenzendorf, May 4, 2016) • Supplies are easily accessible and available through importers. For researchers it is no problem to transport electric fencing equipment to Svalbard. However transport is expensive (Pers com. Prop, May 4, 2016)
Costs	• Costs of electric fences are dependent on size and components and are site specific. When considering costs of fencing, human injury and damage of property should be taken into account if no protection would be used. Property damage can be significant. (NPBGTP, 2013[e]) • To give an indication of prices: Starting point is around $15 CAD per meter. A 6-strand fence of 12x12m with 1 gate entrance, with a solar magnum 12 Fence energizer costs around $900 CAD (Pers com. Marley, June 16, 2016) • Shipping and transport costs of supplies should be taking into account as it is often expensive (Pers com. Prop, May 4, 2016). Shipping an electric fence to Norway from Canada could be 100.000 CAD (Pers com. Marley, June 16, 2016) • (Monthly) payment for person taking up maintenance should be considered (Pers com. Klenzendorf, May 4, 2016)
Safety	• No severe injury for polar bears • Chance of an electrical shock for humans when stepping over the fence (Pers com. Prop, May 4, 2016). • Not harmful for people (Pers com. Marley, 2016) • All power units should pass safety standards, batteries do not necessarily have to pass these standards (Marley, 3rd IBPCW, 2009).
AC	• Fences should be powered the whole time as it only results in short term behaviour change of polar bears (Pers com. Prop, May 4, 2016).
Polar bear related factors	• Under dry-air conditions the fur of a polar bear is a good electrical insulator (Wooldridge, 1983). • Nutritional stress can contribute to the successfulness of the electric fence. When tested in summer when polar bears have larger fat reserve they might not be as motivated as when more nutritionally stressed in winter (Davies & Rockwell, 1986). • For food-conditioned bears a higher power unit is necessary, a lower power unit is sufficient for non-food-conditioned bears (Marley, 3rd IBPCW, 2009)
Combination measures	• Food and waste management to keep work effectively on bears (Davies & Rockwell, 1986; Marley, 3rd IBPCW, 2009). • Dogs (McMullen, 2000). • Noise deterrents: Usage could be combined with an air horn as a second repellent and warn residents (Davies & Rockwell, 1986) • Rubber bullets (McMullen, 2000)

Table 99 Additional advantages and disadvantages of electrical fences

	Advantage	Disadvantage
Environment	• Even though creating the worst case scenario with the soil frozen and ground covered in snow McMullen had a 26 out of 27 success rate deterring polar bears (with the exception being a cub) (McMullen, 2000).	
Responsibility		• When no dedicated person taking responsibility system fails to be fully functional (Pers com. Klenzendorf, May 4, 2016).
Costs		• Electric fences are labour intensive and expensive in capital and time (Huygens & Hayashi, 1999) (Treves & Karanth, 2016) • The primary limiting factor in constructing electric fences at conflict sites for grizzly bears have been shortage on funding and personnel (Gunther et al., 2004).
Polar bear related factors		• When not designed properly bears could use outside braces as ladders (Marley, 3rd IBPCW, 2009) • Once a polar bear has been successful entering the fence, it will break through the fence again, even if power is on. In that case relocation of the fence is required (pers com. Klenzendorf, May 4, 2016)
Combination with other measures		• Should be used in combination with good food storage. If attractants are still available electric fences will not keep out polar bears (Stenhouse, 1983)

For further reading: Sowka, 2013a, Living with Predators Resource Guide. Living with Wildlife Foundation.

II: Concentrated shocking device

Table 100 Additional information concentrated shocking devices

	Preconditions
Costs	• Approximate $300 per unit at Ralph E. Arnold, 710 Broadway Street, Superior, Wisconsin 54880 USA (Breck et al., 2006; Sowka, 2013) • Costs depend on the amount of units necessary to protect resources (Breck et al., 2006)
Maintenance	• Weekly testing of the system advisable • Maintenance is said to be minimal (breck et al., 2006), however environmental conditions such as snow might influence and increase maintenance
Safety	• Not harmful but gives powerful shock for humans (Breck et al., 2006)

Table 101 Additional disadvantages of concentrated shocking devices

	Disadvantage
Costs	• It could become cost prohibitive in cases when many units are needed to protect resources (Breck et al., 2006)

III: Unwelcome doormats

Table 102 Additional information unwelcome doormats

	Preconditions
Costs	• Basic materials are cheap and easily accessible in remote places
Maintenance	• Should be kept free of snow to increase safety
Safety	• Could severely injure a polar bear or human (Pers com. Polet, July 8, 2016)

Appendix IX: General conditions to increase effectiveness of deterrents measures

- Give people the option to choose between different effective deterrents (Clark et al., 2003).
- Always be prepared for an encounter, as this will decrease the likelihood of an actual conflict (GBSS, 2010).
- Deter bears before they show nuisance behaviour (Shideler & Perham, n.d.) and before their behaviour becomes a major management concern (Domjan, 1996).
- Choose the deterrent measures carefully. Knowledge of the limitations and the capabilities is necessary. Deterrent measures should not give a false sense of security (NPBGTP, 2013).
- To avoid habituation, the stimuli should be intense enough for the bear to respond during its first encounter with the applied measure (Domjan, 1996).
- Measures should be modified regularly to avoid habituation (Treves & Karanth, 2016).
- The punishment should be within a couple of seconds of displaying the unwanted behaviour (GBRS, 2010, Mazur, 2010)
- An approaching bear should be deterred every time it approaches (NPBGTP, 2013).
- Conditioning the bear should be done consistently and according to the same standards (GBSS, 2010; Mazur, 2010; NPBGTP, 2013)
- Inconsistency will create an intermittent reward system, which reinforces the behaviour rather than deterring it (Homstol, 3rd IBPCW, 2009).
- Measures that have a bigger surprise effect seem more effective (Homstol, 3rd IBPCW, 2009).
- Attractant management will increase the effectiveness of deterrents (GBSS, 2010; Mazur, 2010)
- Training and practice are required to use measures appropriately (GBSS, 2010; Stenhouse, 1983)
- Knowledge of polar bear behaviour is required (Stenhouse, 1983)
- Measures should be acceptable to the public (Cotton, 2008) and politically tolerated (Pers com. Koopmans, July 8, 2016)

Appendix X: Deterrents

I: Visual & Auditory

I: Noise deterrents

For a noise to be an effective repellent the bear would have to learn to associate the noise deterrent to the unwanted behaviour (GSBS, 2010). The noise would have to be unpredictable and immediately triggered by the behaviour (Treves & Karanth, 2016).

Response of a bear is often inconsequent. Responses could lead from no response, to bears returning after an hour. (Woodridge, 1983) Greatest success is achieved when used on a naïve bear that is not used to human presence (Stirling, 2011). A bear that is familiar with human presence and activity and repeatedly returns to the same place or that has been exposed to repellents before is less likely to respond as desired (GSBS, 2010; Wooldridge, 1985). Even though a noise stimulus might be irritating, it does not necessarily have to result in a strong repellent response after frequent exposure, as animals learn that they pose no real threat and learn to ignore them (Muruthi, 2005; Wooldridge, 1985). Several sources in literature show loud noises alone are less successful in deterring polar bears (Exxon, 2009; Morrison, 3rd IBPCW, 2009; Stirling, 2011; Wooldridge, 1985). To avoid habituation to one sound, types of noise deterrents should be varied and modified regularly (GSBS, 2010; Treves & Karanth, 2016). When used in combination with dominance techniques (see chapter 3.5 human body language), association of the noise deterrent with humans can be made (GSBS, 2010). Stenhouse and Gillin et al suggest the noise repellents are more effective when used in combination with visual display, such as a flair component (Gillin et al., 1997; Stenhouse, 1985).

Table 103 Additional information noise deterrents

	Preconditions
Design	• Sound should come from a point source (Wooldridge, 1983). • Frequency of the sound should be in range of 100-600 Hz (Wooldridge, 1983). • The noise should be unexpected for a polar bear (Stirling, 2011). • Timing and presentation of the sound is important for it to be effective (Wooldridge, 1985)
Distance	• Sound should be initiated when bear is within an approximate distance of 100m (Wooldridge, 1985)
Safety	• When correctly used it does not cause harm or injury to the bear (GSBS, 2010) • It requires no actual contact between bear and equipment (Wooldridge & Belton, 1980)

II: Horns and Sirens

Table 104 Additional information horns and sirens

	Preconditions
Maintenance	• Recharged or replaced after every usage (NPBGTP, 2013).
Costs	• Air horn with pump $6 USD (Amazon, 2016a)
Safety	• When correctly used it does not cause harm or injury to the bear (GSBS, 2010) • It requires no actual contact between bear and equipment (Wooldridge & Belton, 1980) • Decibel levels of 125 are painful to humans (NPBGTP, 2013b) • When used in close proximity (within 30m) to the polar bear could become a dangerous

	situation to humans
AC	• Habituation quickly occurs (NPBGTP, 2013b)
Other	• Sounds used for deterring bears and alert people should differ from other emergency sounds as the safety procedure is different from other causalities (NPBGTP, 2013b).

III: Vehicles/mobile equipment

Table 105 Additional information vehicles as deterrents

	Preconditions
Design	• When using snowmobiles and ATVs deterring should be done in pairs (NPBGTP, 2013b).
Distance	• The bear should be given space once it moves in the right direction, however staying close enough to a polar bear to anticipate quickly when it changes direction or behaviour (NPBGTP, 2013b).
Maintenance	• Requires normal vehicle maintenance
Legal restrictions	• Polar bears should only be chased by a vehicle for protection of people and human property, as unnecessary disturbance or harassment is unlawful (NPBGTP, 2013b). • Nunavut: (Nunavut Wildlife Act) Chasing of a wild animal is only allowed for reasons of human and bear safety (NPBGTP, 2013b).
Costs	• When vehicles are present it is a low cost solution
Safety	• Vehicles with cabs provide safe shelter when deterring a polar bear (NPBGTP, 2013b). • When correctly used it does not cause harm or injury to the polar bear • It requires no actual contact between polar bear and equipment
AC	• Bears only stay away during the first hour after chasing (Mazur, 2010)
Combination with other measures	• Noise deterrents: Vehicle horns • Visual deterrents: Lights (NPBGTP, 2013b)

Table 106 Additional advantages and disadvantages vehicles as deterrents

	Advantage	**Disadvantage**
Design	• The vehicle can herd polar bears away from a side (NPBGTP, 2013b). • Often sight of a vehicle or sound of revving engine can be enough to deter a polar bear (NPBGTP, 2013b).	
Environment		• In rough terrain only experienced drivers should operate the vehicles (NPBGTP, 2013b).
Legal restrictions		• Land use permits or company policy might not allow off-road use of snowmobiles or ATVs (NPBGTP, 2013b).
Safety	• Provides a quick escape to people if necessary (NPBGTP, 2013b).	• Snowmobiles and ATVs have no protected cab exposing the driver (NPBGTP, 2013b)
Polar bear related factors		• When polar bears are not challenged habituation of vehicles occurs (NPBGTP, 2013b)

IV: Torches

Table 107 Additional information using torches as deterrents

	Preconditions
Maintenance	• Replaced after every usage
Costs	• Sticks with burnable materials, often already available in settlements
Safety	• It requires no actual contact between polar bear and equipment, however sometime close proximity of the polar bear could be the case • When used in close proximity (within 30m) to the polar bear could become a dangerous situation to humans
AC	• Unknown
In combination with other measures	• Strong human body language

V: Sticks

Table 108 Additional information using sticks as deterrents

	Preconditions
Maintenance	• Unknown
Costs	• Material is often readily available in settlements
Safety	• It requires no actual contact between polar bear and equipment, however sometime close proximity of the polar bear could be the case • When used in close proximity (within 30m) to the bear could become a dangerous situation to humans
AC	• Unknown
Combination measures	• Strong human body language

VI: Dogs as deterrents

Some dog breeds have been recognised to be able to assist in bear deterrence (GBSS, 2010). In Russia Laika dogs are used to detect, deter and protect humans from brown bears (Gillin et al,. 1997). Another dog breed used for deterring bear are Karelian bear dogs, who were considered very trainable (GBSS, 2010; Hunt, 2003; Ovsyanikov, 3rd IBPCW, 2009) Thing recommends Greenland huskies (Thing, 1990).

Ovsyanikov observed that during polar bear encounters dogs can be useful as well as hazardous. Dogs can alert people for approaching polar bears and may draw the attention away from the people. However dogs could also provoke aggression of a polar bear and increase conflict. (Ovsyanikov. 3rd IPBCW, 2013) Gillin et al noticed that individual brown bears responded differently to attacking dogs, varying from retreating behaviour to attacking in defence. He noticed that brown and black bears react similar to dogs as to humans, having no fear for dogs if they are also not afraid of humans. Some breeds of dogs seem to provoke an attack on humans by bears and are not suitable for bear deterrence. (Gillin et al,. 1997) Hunt states that personality of the dog is more important that the dog breed. The dogs used to deter bears should be comfortable around bears, not showing any fear and well trained and obeying to the handler (Hunt, 2003).

Klenzendorf knows of Inuit people letting their lead dog loose to deter approaching polar bear. This method seems successful as sometimes polar bear tracks are found in the snow the next morning, but no attacks or damage has occurred during the night. The Inuit people are willing to take the risk of losing their lead dog, as keeping out polar bears using dogs is less labour intensive for them than maintenance of an electric fence for example. (Pers com. Klenzendorf, May 4, 2016)

Table 109 Additional information using dogs as deterrents

	Preconditions
Design	• Dogs must be on a lease or chained as a loose dog might aggravate a polar bear (NPBGTP, 2013b). However Inuit people have good experience with letting the lead dog run loose (pers com. Klenzendorf, May 4, 2016). • The use of more than one dog has a higher success rate at deterring brown and black bears (Gillin et al,. 1997).
Training	• Requires a lot of time and investment (Pers com. Klenzendorf, May 4, 2016; NPBGTP, 2013b) • Dogs require professional training • Also the handler needs to be trained to properly train and handle the dogs. • Handler should acquire guidance from a bear deterring expert (GBSS, 2010)
Maintenance	• Dogs are high in maintenance and require daily care year round (GBSS, 2010; NPBGTP, 2013b).
Costs	• Costs depend on if the dogs still need to be trained or are contracted over a season or several years (GBSS, 2010) • Occasional loss of dogs is expensive • Training of dogs is expensive (Pers com. Klenzendorf, May 4, 2016)
Safety	• No close contact between polar bears and humans • Using dogs provide a safety net and back up when dealing with nuisance bears (Hunt, 2003; GBSS, 2010) • Risk of losing dogs to polar bears in conflict (Pers com. Klenzendorf, May 4, 2016)
AC	• The effectiveness of dogs as deterrents is unsure. Black bears that are deterred by dogs do not return significantly later to an area than bears deterred with other measures and the amount of days before returning varied majorly (range: 5-641 days) (Beckmann et al., 2004).

Human behaviour	• Using guard dogs is also a matter or modifying human behaviour towards polar bears (Treves & Karanth, 2016).
Combination measures	• Combining other deterrent measures may be more effective in modifying the behaviour of nuisance bears. The deterrent measure should not affect the dog (possibly the use of bear spray might affect the dogs) (Gillin et al,. 1997).

Table 110 Additional advantages and disadvantages of using dogs as deterrents

	Advantage	Disadvantage
Design		• Not all dogs are suitable for detecting and deterring bears (Gillin et al., 1999)
Training		• When lack of proper training, dogs could possibly be a hazard (NPBGTP, 2013b)
Human behaviour	• Dogs can be used as ambassadors when educating people (Hunt, 2003)	

VII: Pyrotechnical deterrents

i: Different types of fire arms

Pistol type launchers

Pistol type launchers are incapable of firing bullets. They contain muzzles or muzzle cup adaptor to hold 15 mm deterrent cartridges. Functioning capabilities of .380 calibre (9mm) and .22 calibre (6mm) launchers are very similar. Pistol type launchers can be a single or a multiple shot model. Multiple shot models are designed for rapid firing. Each launcher is preloaded with primers, which ignite the cartridge when struck and help push the cartridge out of the launcher.

There are two types of launchers: Revolver or Clip launcher

- Revolver: Double action trigger mechanism
- Clip launcher: Flat magazine holding up to 10 primers

Both types are easy to use (NPBGTP, 2013b), for comparison see table 108.

Table 111 Pistol type launchers compared (NPBGTP, 2013)

Pistol Type Launcher Comparison		
	Launcher Type	
	Revolver	Clip
Cleaning	Swing out chambered cylinder makes cleaning easy; all critical components are visible.	The more complicated firing mechanism makes cleaning difficult and some disassembly is required.
Capacity	Five to seven shots.	Six to ten shots.
Reloading	Slow to reload using loose primers.	Faster to reload using spare preloaded clips.
Determining if loaded.	Swing out cylinder makes it easy to check if loaded.	An unloaded clip launcher looks identical to a loaded one. Determination requires that the clip be fully ejected.

Table 112 Preconditions pistol type launchers

	Preconditions
Training	• Practice is required to learn how to operate the device in a safe manner.
Costs	• Clip Launcher: $60-150 CAD • Revolver: $150-200 CAD • Semi-automatic launcher: $300 CAD (Margo Supplies ltd, n.d.g)
Legal restrictions	• Launchers and revolvers itself do not have shipping restrictions, the cartridges do • Primers and deterrent cartridges must be shipped under dangerous goods
Accessibility	• Advanced planning is necessary to get primers and cartridges to remote sites. (NPBGTP, 2013b)
Safety	• Clip launcher: When not cleaned properly risk of backward flash and damaging the launcher and injuring shooter (NPBGTP, 2013b)
Availability for group type	• Indigenous people • (Semi) Permanent Settlers • Newly Settled and Temporary Residents: Scientists and tour guides

Table 113 Additional advantages and disadvantages pistol type launchers

	Advantage	Disadvantage
Design	• Fast and easy use • Reliable when properly maintained • Can be preloaded with primers • Deterrent cartridges can be quickly inserted in muzzle cup of a pre-loaded pistol when needed for rapid firing. • Can fire signal flares (NPBGTP, 2013b)	
Environment		• Cold fingers make reloading difficult (NPBGTP, 2013b)
Safety	• Can be safely carried (NPBGTP, 2013b)	

12 Gauge Shotgun

There are two types of 12-gauge shotguns advisable for bear management purposes:

- 12-gauge pump action
- Single or double barrel break-action (NPBGTP, 2013c)

12-gauge shotguns are versatile deterrent launchers as they can be used to launch cracker shells, physical deterrent rounds (rubber bullets) and killing rounds (NPBGTP, 2013c).

Table 114 Preconditions 12 Gauge Shotgun

	Preconditions
Design	For bear deterrence shotguns must have: • 3"chamber • Smooth bore barrel • Open or cylinder choke; no narrowing of the barrel at the muzzle • Front and rear sights when used for firing rubber slugs or bean bags (NPBGTP, 2013c) Double-barrel Break-Action Shotgun is recommended for polar bear deterrence. (NPBGTP, 2013c)
Environment	• Firearms need to be kept outside the heated part of buildings/tents to prevent condensation and freezing of moving parts. (GBSS, 2005) • During cold weather oil needs to be removed from firearms
Training	• Firearm safety training should be completed (NPBGTP, 2013c)
Maintenance	• Due to the slow muzzle velocity and the possibility of the over-powder wad being stuck in the barrel of the gun, the barrel needs to be checked after each shot to prevent blockage (Margo Supplies ltd., n.d.i). • Routine cleaning to ensure safe operation and reliability
Responsibility	• Person carrying license should be present at all times to use the fire arm in case conflict occurs.
Accessibility	• Not widely accessible to public as firearm safety training and valid firearm licence is required to handle a 12-gauge shotgun (NPBGTP, 2013c).
Costs	• Starting price Double-barrel Break-Action Shotgun approximately $500 USD (Stoeger Industries, 2016)
Legal limitations	• Valid firearm licence is required (NPBGTP, 2013c) • Federal, state and local laws need to be followed in order to purchase a fire arm (ATF, n.d.)
Safety	• Risk to safety: projectiles can easily be mixed up and the wrong projectile could be used under the wrong circumstances, possibly leading to severe injury or death of the polar bear (NPBGTP, 2013c).

Table 115 Additional advantages and disadvantages 12 Gauge Shotgun

	Advantage	Disadvantage
Design	**Double-barrel Break-Action Shotgun:** • Reloading is simple • Safest of all action types **12-gauge pump action:** • Reloading is simple • Muzzle can stay fixed on the target while reloading • Easy to operate from the shoulder • Fast manually operated action (NPBGTP, 2013c)	**Double-barrel Break-Action Shotgun:** • Must be backed up by a person with a loaded lethal firearm (NPBGTP, 2013c) **12-gauge pump action:** • Difficult to check for potential obstructions in the barrel due to alignment of the barrel and the action (NPBGTP, 2013c)
Environment	• System should work well under low light conditions (NPBGTP, 2013c)	• Cold fingers make reloading difficult (NPBGTP, 2013b)
Maintenance	Double-barrelled Break-Action Shotgun: • Easy to clean (NPBGTP, 2013c)	**12-gauge pump action:** • More difficult to clean (NPBGTP, 2013c)
Human behaviour		• Having a firearm present could give false sense of security and people may become less observant and cautious concerning polar bear behaviour and the circumstances (NPBGTP, 2013c).

ii: Bangers

Table 116 Additional information Bangers

	Preconditions
Design	Available in two sizes: • 15 mm fused projectiles that explode with a loud bang (GSBS, 2010; Sowka, 2013) for specialized launchers • 12-gauge fired from 12-gauge shotgun (NPBGTP, 2013b) →12-gauge cartridges should be used in un-choked barrels only (GBSS, 2010) • When firing it provokes an initial noise at the muzzle followed by louder noise when projectile explodes (NPBGTP, 2013b; Sowka, 2013). • Fired in angle of 45° from ground level for optimum sound effect (Fig. 9) (NPBGTP, 2013b). • When exploding at range of 38m the noise is heard from the point of exploding out in all directions, sounding as hard at the positon of the shooter at 38m distance as at the position of the polar bear, 38m on the other side of the explosion. Resulting in an effective range of approximately 76m (250 ft) (fig. 10). (NPBGTP, 2013b) • Blanks can be used as they deliver extremely load sound by themselves (Hunt, 2003)
Training	• Shooters must know the optimal range to prevent injury to the bear (Hunt, 2003) • Alaska: Training required to be able to handle measures (Pers com. Klenzendorf, May 4, 2016)
Distance	• Travels 30-40m before exploding (Hunt, 2003; Sowka, 2013) • Height range is approximately 40m (Sowka, 2013)
Maintenance	• Barrels should be checked after every shot to prevent blockage • Cleaning is necessary (GBSS, 2010)
Costs	• $27 CAD/50 cartridges (Margo Supplies ltd, n.d.c)
Legal restrictions	• Alaska: need licence to have pyrotechnical measures. These permits are difficult to get as polar bears are an endangered species (Pers com. Klenzendorf, May 4, 2016)
Safety	• Should not be shot directly at a polar bear (fig. 10) (NPBGTP, 2013b). • Should not be shot from inside a vehicle as risk of backdrop can occur (NPBGTP, 2013b) when cartridges hit an obstruction (Hunt, 2003) • When shot from too close can cause injury or death (Hunt, 2003) • Improper use could cause injury to shooter, bystanders, polar bear or damage to property (GSBS, 2010)
Combination measures	• Increased chance of successful deterring a polar bear and possible avoidance of habituation when used in combination with physical deterrents (rubber bullets). (NPBGTP, 2013b).

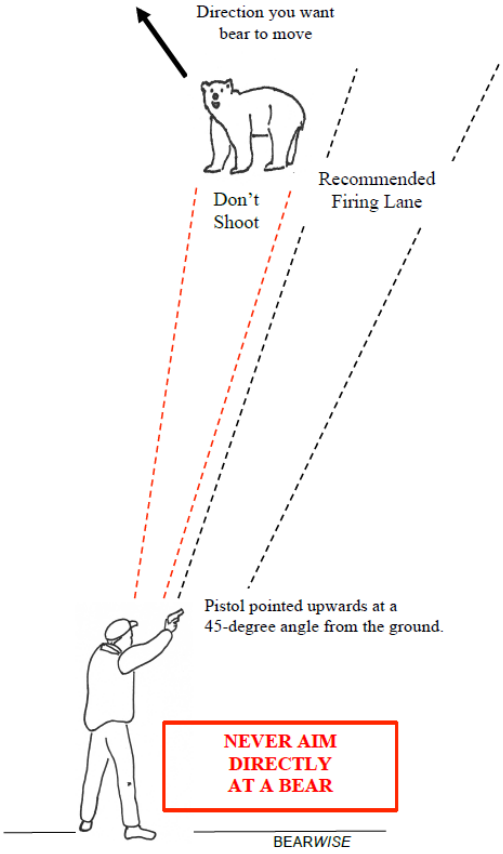


Figure 9 Shooting instructions for firing pyrotechnical deterrents at a polar bear (NPBGTP, 2013)

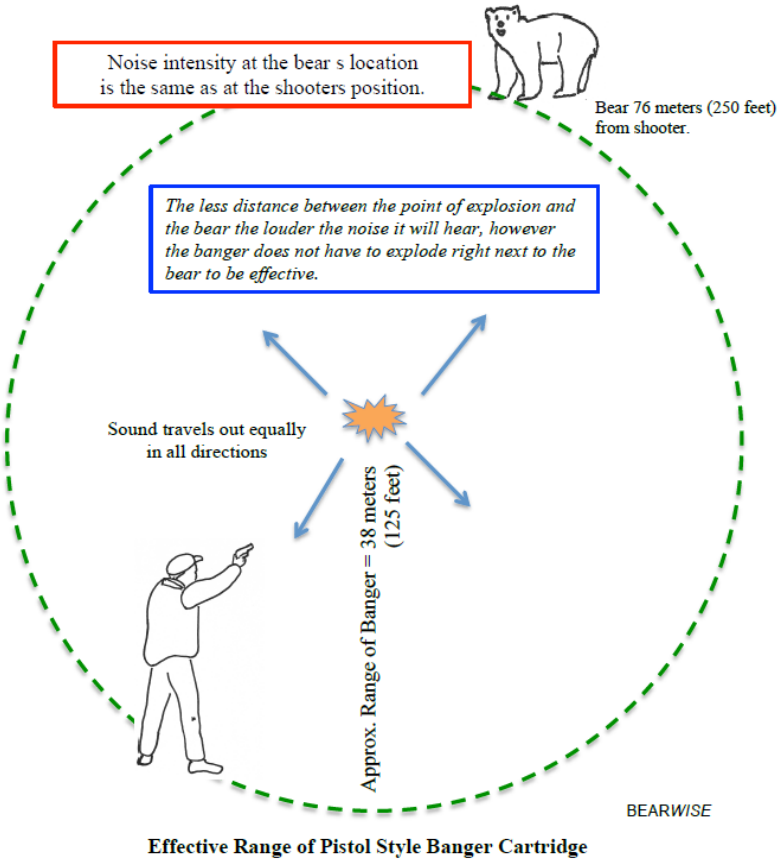


Figure 10 Effective range of pistol style banger cartridge (NPBGTP, 2013)

Table 117 Additional advantages and disadvantages bangers

	Advantage	Disadvantage
Design	• The banger does not have to explode right next to the polar bear to be effective (NPBGTP, 2013b) • Pattern is consistent (Hunt, 2003) • Multiple shot launchers can be preloaded (Hunt, 2003)	• Dangerous around fuels and flammable materials. When risk of fire bangers should not be used (NPBGTP, 2013b) • Slow to reload when used in a single shot (Hunt, 2003)
Environment		• Single shot revolver is difficult to use in low light conditions (Hunt, 2003)
Safety	• Blanks have no risk of backlash or injury to the bear (Hunt, 2003)	

iii: Screamers

Table 118 Additional information screamers

	Preconditions
Design	Available in two sizes: • 15 mm fired from specialized launchers • 12-gauge fired from 12-gauge shotgun (NPBGTP, 2013b) →12-gauge cartridges should be used in un-choked barrels only (GBSS, 2010)
Environment	• Light-emitting screamer provides a visual display, important at night.
Training	• Should learn to get to know the distance and unpredictable flight pattern • Shooters must know the optimal range to prevent injury or cause death to the bear (Hunt, 2003) • Alaska: Training required to be able to handle measures (Pers com. Klenzendorf, May 4, 2016)
Distance	• Approximately 75-100 m (250-300ft) before exploding
Maintenance	• Barrels should be checked after every shot to prevent blockage • Cleaning is necessary (GBSS, 2010)
Costs	• $27 CAD/50 cartridges (Margo Supplies LTD, n.d.c)
Legal restrictions	• Alaska: need licence to have pyrotechnical measures. These permits are difficult to get as polar bears are an endangered species (Pers com. Klenzendorf, May 4, 2016)
Safety	• Should not be shot from inside a vehicle as risk of backdrop can occur (NPBGTP, 2013b) when cartridges hit an obstruction (Hunt, 2003) • When shot from too close can cause injury or death (Hunt, 2003) • Improper use could cause injury to shooter, bystanders, polar bear or damage to property (GSBS, 2010) • Fired in angle of 45° from ground level to reduce possible risk of starting a fire under dry conditions (NPBGTP, 2013b)
Combination measures	• Increased chance of successful deterring a polar bear and possible avoidance of habituation when used in combination with physical deterrents (rubber bullets). (NPBGTP, 2013b).

Table 119 Additional advantages and disadvantages screamers

	Advantage	Disadvantage
Design	• Because of low accuracy the gun does not necessarily have to be shouldered to aim, but also firing from the hip would service, which is safer (Shideler& Perham, n.d.).	• Dangerous around fuels and flammable materials. When risk of fires screamers should not be used (NPBGTP, 2013b) • Difficult to predict the course of the screamer through a varying looping flight path (NPBGTP, 2013b) • Due to low velocity over-powder wad may stick in the barrel of the shotgun (GSBS, 2010; Shideler & Perham, n.d.)
Environment		• Single shot revolver is difficult to use in low light conditions (Hunt, 2003)
Distance		• When shot from too close can cause severe injury or death (Hunt, 2003; Shideler & Perham, n.d.)
Polar bear related factors	• Reduced risk of charge or attack towards shooter even when screamer travels beyond the polar bear (NPBGTP, 2013b)	

iv: Cracker shells

Table 120 Additional information cracker shells

	Preconditions
Design	• Crackers and whistle crackers are 12-gauge shotgun loads • 12-gauge cartridges should be used in un-choked barrels only (GSBS, 2010)
Environment	• As the loads are light, shooting against the wind will decrease the range, shooting with the wind will increase the range (Shideler & Perham, n.d.)
Training	• Shooters must know the optimal range to prevent injury to the bear (Hunt, 2003) • Alaska: Training required to be able to handle measures (Pers com. Klenzendorf, May 4, 2016)
Distance	• Approximate 100m (GSBS, 2010)
Maintenance	• Barrels should be checked after every shot to prevent blockage • Cleaning is necessary (GBSS, 2010)
Costs	• $27 CAD/50 cartridges (Margo Supplies LTD, n.d.c)
Legal restrictions	• Alaska: need licence to have pyrotechnical measures. These permits are difficult to get as polar bears are an endangered species (Pers com. Klenzendorf, May 4, 2016)
Safety	• Should not be shot from inside a vehicle as risk of backdrop can occur (NPBGTP, 2013b) when cartridges hit an obstruction (Hunt, 2003) • When shot from too close can cause injury or death (Hunt, 2003) • Improper use could cause injury to shooter, bystanders, polar bear or damage to property (GSBS, 2010)
Combination measures	• Increased chance of successful deterring a polar bear and possible avoidance of habituation when used in combination with physical deterrents (rubber bullets). (NPBGTP, 2013b).

Table 121 Additional advantages and disadvantages cracker shells

	Advantage	Disadvantage
Design	• Because of low accuracy the gun does not necessarily have to be shouldered to aim, but also firing from the hip would service, which is safer (Shideler & Perham, n.d.)	• Not as accurate (Shideler & Perham, n.d.)
Distance		• At too close range can cause penetration of the skin and explode internally (GSBS, 2010; Shideler & Perham, n.d.)

Table 122 Comparison of characteristics of bangers, screamers and cracker shells based on findings in literature

	Projectile type		
Characteristic	**Bangers**	**Screamers**	**Cracker shells**
Flight pattern	Consistent/ predictable	Inconsistent/ not predictable	Consistent/ predictable
Does not have to explode right next to the polar bear	+	+	+
Reloading	Slow	-	-
Flare component	-	+	-
Accuracy	-	low	low
Exploding behind polar bear is risk	+	+	+
Aim offside of the polar bear	+	+	+
Risk of back drop	-	+	+

v: Light flares

Stenhouse observed that 77% (N=75) of polar bears were successfully deterred by firing flares and did not approach again until fieldworkers finished their work. 18,6% approached again after initially moving away 5-25m. 4% (3 bears) gave no response to the measure. (Stenhouse, 1983) Ovsyanikov has observed that polar bears become confused and aggressive when flares are wielded as a deterrent (Ovsyanikov, 3rd IPBCW, 2009). In another study 36% (N=16) of the polar bears continued their approach, therefore one should not rely solely on flares as effective deterrents (Stenhouse, 1984) but used in combination with other deterrent measures.

Table 123 Additional information Light flares

	Preconditions
Design	• 12 gauge cartridges should be used in un-choked barrels only
Distance	Depending on brand and manufacture effective distance may vary: • 120m (Stenhouse, 1983) • Projects at 45m, flight height approximate 30-40m (Sowka, 2013) • Effective range of 15-90m (50-300 ft) (NPBGTP, 2013b). • Illuminating distance a night: 15m (Stenhouse, 1983)
Maintenance	• Barrels should be checked after every shot to prevent blockage (GBSS, 2010)
Costs	• $7 CAD/ 10 cartridges (Margo Supplies LTD, n.d.c)
Safety	• No close contact between polar bears and humans

vi: Hand held flares

Table 124 Additional information hand held flares

	Preconditions
Maintenance	• Do not require specific maintenance • Expiry date should be checked annually
Costs	• $35 USD for four flares (West Marine, n.d.a)
Safety	• Build in protective handle (West Marine, n.d.b) • Chance of burning • Might ask for close proximity to the polar bear • Should not be used 42 months after manufacture date

II: Physical deterrents

I: Paint ball markers

Table 125 Additional information paintball markers

	Preconditions
Design	• Shelf life of 7 years (Nelson, 2016) • 15mm blank paintball gun (Pers com. Marley, June 16, 2016)
Training	• Should become confident to handle the paint ball gun
Distance	• Projectiles will break on animals within 18m (20yd) (Nelson, 2016)
Accessibility	• Accessible to general public as it is not considered a fire arm • Anyone can order it online
Costs	US: • Nelson Deter-it starter package: $275-300 USD • Projectiles 400 pieces $75 (Nelson, 2016) Canada: • Paintball gun: $175-185 CAD • Projectiles: $110 CAD/400 rounds (Margo Supplies ltd, n.d.f)
Legal restrictions	Legal in all five Range States, however each county might has its own restrictions concerning muzzle velocity and precautions
Safety	• When used properly paintball markers are very safe and do not lead to major injuries (Spyder, 2016) • No close contact between polar bears and humans

Table 126 Additional advantages and disadvantages paintball markers

	Advantage	Disadvantage
Design		• Bursting strength and physical impact might not be high enough to deliver an effective stimulus to deter a polar bear (Nelson, 2016; Pers com. Klenzendorf, May 4, 2016)
Costs	• Less expensive than other physical deterrents on the market (Nelson, 2016)	
Human behaviour		• Might not be a nice image for tourists to have polar bears with paint on their coats and could be sensitive with local people (Pers com. Koopmans, July 8, 2016)

II: Rubber bullets

Originally rubber bullets were developed for human crowd control (NPBGTP, 2013). In the 1980's rubber bullets were used for the first time to deter wild grizzly bears that caused problems (GSBS, 2010). Rubber bullets could be a potential ideal AC method. They can create a strong connection between humans and the aversive stimulus, allow for multiple trials, are safe when used properly and cost-effective, and seem to be slightly more effective than chasing a bear away (Mazur, 2010). Fieldwork proved that rubber bullets were quite successful deterring polar bears (Stirling, 2011). Even though successful in 98% (N=100) in the cases used on black bears, rubber bullets were not superior in keeping food-conditioned bears away for more than an hour over other measures (Mazur, 2010).

Rubber "Slugs" include many different projectiles with different potential for harm (3rd IBPCW, 2009). The torpedo finned stabilized rubber rocket and the hourglass shaped rubber bullet are the two most common designs of rubber projectiles.
At the moment Shideler (ADFG) and Perham (USFWS) only recommend "Strike two" rubber bullets of Margo Supplies as other brands of "rubber" or plastic bullets cannot provide enough safety for the bears. Several recent cases of bear injury or death were caused by use of other brands or when shot with fin-stabilized rubber bullets (Shideler & Perham, n.d.). Fiocchi rubber bullets are also approved by the Alaskan Department of Fish and Game (ADFG) grizzly bear project office as they are proven to be a safer and more predictable. It remains pliable and retains mushrooming qualities (NPBGTP, 2013c).

Peine states that physical AC applied to nuisance black bears by scientists resulted into a deterrence of 43% (N=14) with bears not coming back to the conflict site (Peine, 2001). Shooting 38mm rubber batons with riot gun was 99,2% (N=123) successful in deterring polar bears (Stenhouse, 1984) and 100% (N=27) successful in deterring grizzly bears at a distance of 40-60 meter (Gillin et al., 1997). However rubber bullets do not seem effective when shot from a pistol (Gillin et al., 1997; Stenhouse, 1983; Stirling, 2011). Stirling suggests that making a loud noise simultaneously as giving the negative stimulus of the rubber bullet could be quite effective for a short period of time (Stirling, 2011).

Individual slugs should be checked for product specifications as not all slugs are suitable for usage. Types of slugs range from rubber to hard plastic. Hard plastic slugs should not be used on bears as they have a higher probability of penetration of the skin.

Using rubber bullets as AC techniques has little effect on bears that have been habituated to humans and human food for most of their lives (Gillin et al., 1997), or when using rubber bullets that are too light or the wrong brand (such as the Bear Deterrent Cartridge rubber bullets (AAI Corporation, Hunt Valley, MD 21030)) (Gillin et al., 1997). Using 12 gauge plastic slugs on polar bears had not such a high success rate; 55% (N=25) of the bears walked away when hit and 45% continued their approach (Stenhouse, 1983).

Table 127 Additional information rubber bullets

	Preconditions
Design	• 12 gauge shells should not be used in larger gauge guns and guns with chambers shorter than 2¾ inches to avoid danger. • To prevent wads to get stuck in the barrel use of cylinder bore or improved cylinder chokes are advisable (Shideler & Perham, n.d.). • Auto loading shotguns require manual operation at low gas pressure (Shideler, n.d.)
Training	• Testing should be done when using modified firearm (GBSS, 2010).
Range	Range depends on types of projectiles (Shideler & Perham, n.d.). • Margo Supplies "Strike Two" rubber bullets: 18-46 meters (60-135ft) (NPBGTP, 2013c)
Accuracy	• Accuracy only within 30-45 cm of point of aim (Shideler & Perham, n.d.). • Accuracy will decline dramatically extending 46 meters (Shideler & Perham, n.d.).
Maintenance	• Due to the slow muzzle velocity and the possibility of the over-powder wad being stuck in the barrel of the gun, the barrel needs to be checked after each shot to prevent blockage (NPBGTP, 2013c). • During cold weather oil needs to be removed from firearms (NPBGTP, 2013c).
Responsibility	• Person carrying license should be present at all times to use the fire arm in case conflict occurs. • A support person is necessary and in possession of a loaded fire arm shooter (NPBGTP, 2013; Shideler & Perham, n.d)
Accessibility	• Due to legal restrictions and acquire skills not available for all group types. • Thumper gun and 12 gauge shotgun systems are available for use by state and federal agency personnel (Gillin et al., 1994) • Canada: Highly restricted weapon as it could fire tear gas. It is not available to the general public. Only provided to wildlife officers (Pers com. Marley, June 16, 2016)
Costs	• An estimation for the costs of fire arms, ammunition and training based on black bears in Sequoia National Park is roughly US$400 per year (Mazur, 2010) • Fiocchi 12ga rubber slugs: $40 USD/ 25 pieces (Ballistic Products Inc., 2016) • "Strike Two" Rubber Slugs: $4,50 CAD per round (Margo Supplies ltd, n.d.i)
Legal restrictions	• Local laws should be checked for regulations. • Suppliers have shipping restrictions, cannot ship via air (MidwayUSA, 2016)
Safety	• Rubber bullets should not be used on cubs. (GBSS, 2010) • Safest hitting locations are large muscle areas: backside/hip, rump or shoulders (fig. 11) (Margo Supplies Ltd, n.db.; NPBGTP, 2013; Shideler & Perham, n.d.; Stirling, 2011) • Head, ribs or flanks should be avoided (Shideler & Perham, n.d.), however, this could be difficult when approaching polar bear is coming towards the shooter. • Misplaced shots could cause severe injury and even (lingering) death bears or bystander (Shideler & Perham, n.d.; Stenhouse, 1983; NPBGTP, 2013) • A hit from a rubber bullet on the stomach or chest of a polar bear at close range can cause death (NPBGTP, 2013c). • Sick or thin bear is more susceptible to injury (NPBGTP, 2013c).

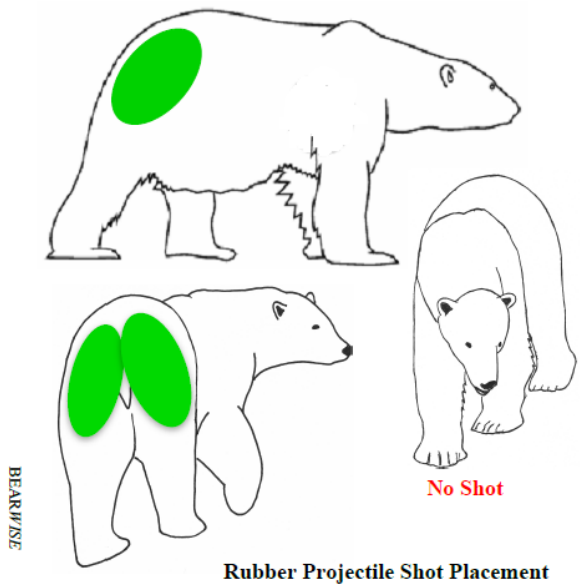


Figure 11 Rubber projectile shot placement areas on polar bears (NPBGTP, 2013).

AC	• Short period: Bears will return to the site ranging from after 1 hour (Mazur, 2010) up to 2-4 hours (Stenhouse, 1983). They sometimes return a few times (Stirling, 2011). • Generalization of the negative experience with rubber bullets on grizzly bears seem to fail and at each encounter the bear has to be struck again. However the bears could be send away again by hitting them again. (Gillin et al., 1992) • Experience showed that polar bears learn quickly and learn to come back when humans are away/asleep (Stirling, 2011)
Human behaviour	• When person shouts before firing the bear might learn to associate the painful impact with human shouting, learning it to avoid people who shout at it (Shideler & Perham, n.d.).
Combination with other measures	• Food and waste management • Early detection devices • Loud noises/noise deterrents • Pyrotechnical deterrents • When possible it is advisable to have two shotguns available: one ready for repelling the bear with a rubber bullet deterrent and one with lethal rounds for emergencies or have backup from another shooter (NPBGTP, 2013; Shideler & Perham, n.d). • If only one shotgun is available it is advisable to load it with the rubber bullets directly into the chamber and keep lethal rounds as backup in the magazine (Shideler & Perham, n.d.).

Table 128 Additional advantages and disadvantages rubber bullets

	Advantage	Disadvantage
Design	• Shotgun can be used again for other rounds of deterring or defence (Shideler & Perham, n.d.). • An extra effect through the noise the gun produces when firing the bullets (Stirling, 2011)	• Need for a special gun to fire the slugs/bullets (Stenhouse, 1983) • Single shot capability (Stenhouse, 1983) • Rubber bullets of Marge Supplies "Strike two" will not work in auto-loading shot guns, only pump or break actions and thus shotgun must have a cylinder bore or improved cylinder choke (Shideler & Perham, n.d.).
Polar bear related factors		• It is not a long term solution for grizzly bears and only temporarily altering nuisance behaviour (Gillin et al., 1992) • Possibly does not work on bears that have low nutritional body condition. The motivation to not be repelled seems bigger when starving (Shideler & Perham, n.d.; Stirling, 2011)

III: Bean bag projectiles

Table 129 Additional information bean bag projectiles

	Preconditions
Design	• To prevent wads to get stuck in the barrel use of cylinder bore or improved cylinder chokes are advisable (Shideler & Perham, n.d.). • Should not be used in semi-automatic shotguns (NPBGTP, 2013c). • Auto loading shotguns require manual operation at low gas pressure (Shideler, n.d.)
Training	• Requires intensive training before fair degree of accuracy can be assured (Stenhouse, 1983) • The optimal range of new projectiles should be tested before use, especially when using modified firearm (GBSS, 2010).
Maintenance	• After each round of shots the barrel should be inspected due to low powder loads (NPBGTP, 2013c)
Responsibility	• Person carrying license should be present at all times to use the fire arm in case conflict occurs. • A support person is necessary and in possession of a loaded fire arm (NPBGTP, 2013; Shideler & Perham, n.d)
Accessibility	• Due to legal restrictions and acquire skills not available for all group types.
Costs	• $10 CAD per round (Margo Supplies ltd, n.d.i)
Legal restrictions	• Local laws should be checked for regulations.
Safety	• Due to impact surface of 1-2 square inches risk of penetration of the hide is significantly reduced (NPBGTP, 2013c). • Little risk of penetration at close range (NPBGTP, 2013c). • At close range still chance of serious injury exists when shot in the chest of stomach area at close range (NPBGTP, 2013c). • Safest hitting locations are large muscle areas: backside/hip, rump or shoulders (fig. 11) (NPBGTP, 2013c)
Combination measures	• Food and waste management • Early detection devices • Loud noises/noise deterrents • Pyrotechnical deterrents • When possible it is advisable to have two shotguns available: one ready for repelling the bear with a bean bag deterrent and one with lethal rounds for emergencies or have backup from another shooter (NPBGTP, 2013; Shideler & Perham, n.d). • If only one shotgun is available it is advisable to load it with the bean bags directly into the chamber and keep lethal rounds as backup in the magazine (Shideler & Perham, n.d.).

Table 130 Deterrent range chart of different polar bear deterrent projectiles (NPBGTP, 2013d)

DETERRENT RANGE CHART SUMMARY TABLE				
Launcher Type	**Deterrent**	**Maximum Projectile Range (Meters)**	**Effective or Operational Range (Meters)**	**Reminder**
Pistol	Banger	38	40 to 80	Bear must be beyond projectile range before firing banger; noise effective beyond point of explosion
	Screamer	90	10 to 100	Fired at a bear less than 10 meters away the results are unpredictable
12-Guage Shotgun	Shell Cracker	80	80 to 160	Bear must be beyond projectile range before firing shell cracker; noise effective beyond point of explosion
	Rubber Projectile	40	25 to 35	Under 25 meters risk of penetration
	Beanbag Projectile	27	10 to 22	Under 10 meters risk of serious injury

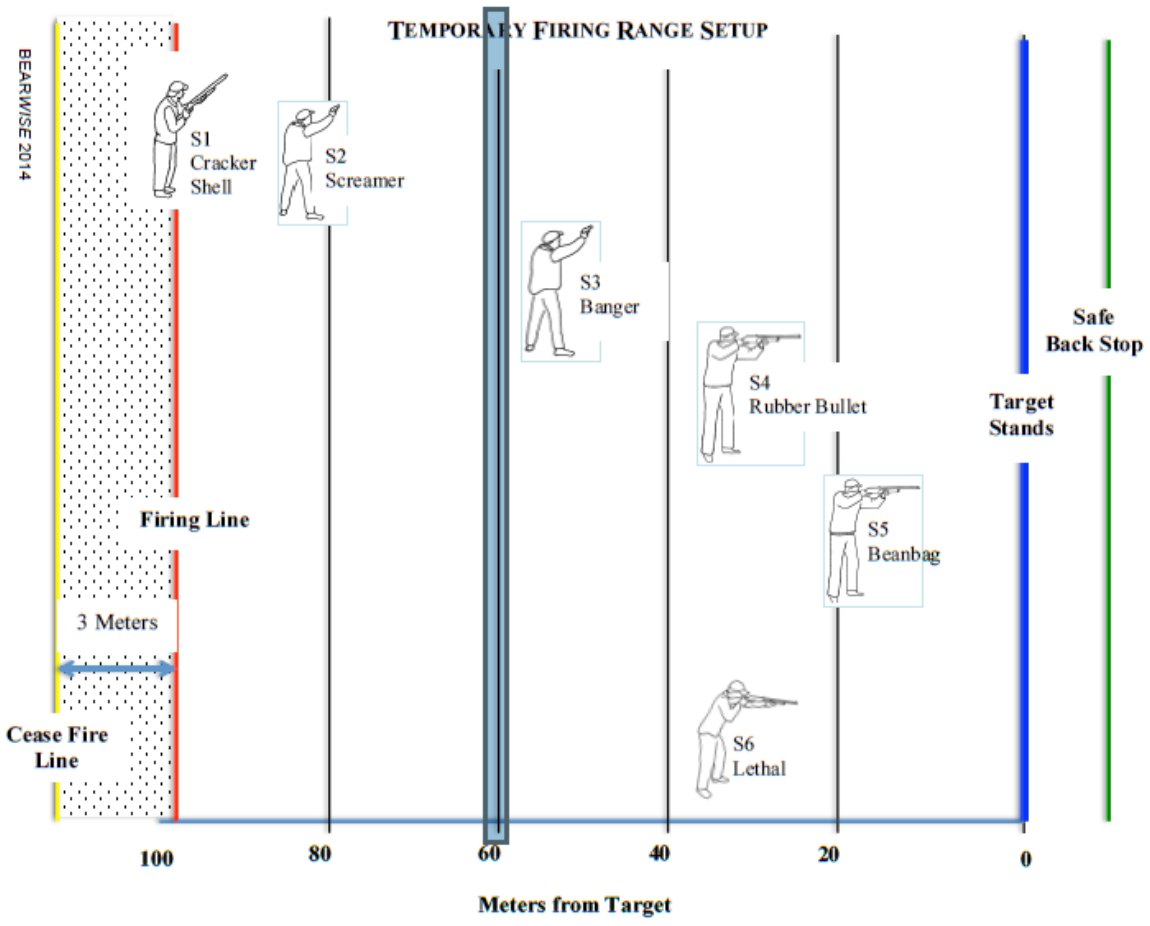


Figure 12 Distance of shooter to target polar bear of different deterrent projectiles (NPBGTP, 2013).

Appendix XI: Personal defence

I: Bear Spray

Hunt was one of the first testing pepper spray for dogs on grizzly bears. She found a nearly 100% success rate in repelling both captive and free ranging bears without aggressive responses. However, the commercially available spray used required to have to come up close to the bear to spray it in the eyes. (Hunt, 1985; IGBC, 2008)

Smith et al collected data from all available sources on the use of bear spray in Alaska from the period of 1985-2006 (n=83). This resulted in 72 records of bear spray use on free ranging brown, black and polar bears in Alaska. (Smith et al, 2012) They defined that successful use of bear spray is when undesirable behaviour stopped. In 69 out of 72 of the incidents when bear spray was used there were no injuries and in only 3 cases slight injuries occurred. 86% (N=unknown) of aggressive encounters with brown bears, bear spray has stopped the bear's aggressive behaviour. With aggressive black bears 100% (N=7) of undesirable behaviour was stopped by spraying. No one using bears spray was injured by black bear in any instance. (Smith et al., 2012) Smith et al also noticed that in 10 out of 72 cases the sight and sound of bear spray already affected the bears were noted to be the key factors in changing the behaviour of the bear(Smith et al., 2008), as did Herrero & Higgins in 38% (N=8) of the cases (Herrero & Higgins, 1998).

Although uncertain to say how HBC would have ended when bear spray was not available (Herrero & Higgins, 1998; Smith et al., 2012), the use of bear spray seems to have prevented injury in most researched conflicts (Herrero & Higgins, 1998). Smith et al also concluded that bear spray is an effective bear deterrent tool in a wide variety of situations (Smith et al., 2012).

Even though not seriously tested on polar bears, Smith believes there is no reason to think bear spray should be less effective on polar bears than it is on other bears. With bear spray being effective in 98% (N=unknown) of all bear cases he has studied, Smith states bear spray shows promise on polar bears (Smith, 2016). Ousland reports that they have safely deterred a visiting polar bear with human pepper spray (Borge Ousland, 2015a). They have pepper spray with them as a last resort facing a polar bear and they seem to find it extremely effective. In another encounter with hungry polar bears, a mother and a cub were detected by trip wire and deterred by flares, however they returned being hungry. The use of pepper spray and firing gun in the air, plus shouting at them made them take off. (Borge Ousland, 2015b) In combination with other measures bear spray seems to work successfully in deterring polar bears.

Because bear spray is easily accessible in countries where bear spray is allowed, it is good choice for use by general public on large carnivores (Brown & Conover, 2008).

Table 131 Additional information using bear spray as a personal defence measure

	Preconditions
Design	• The active ingredients are derived from Oleoresin of Capsicum (CWI, 2009; IGBC, 2011). It disperses a fine atomized expanding cloud that the bear must pass through. When entering the cloud the active ingredients will irritate the bear's eyes, nose, mouth, throat, and lungs (CWI, 2009; IGBC, 2011) • If the bear is close, the spray should be directed at the front of the bear and continues spraying until the bear diverts its charge is advisable. (CWI, 2009) • A canister of 230 g empties in about 7,2 seconds or 10 blasts. (Margo Supplies ltd, n.d.e) Mechanical malfunction is possible: • In one out of 66 the spray released a stream like shot instead of a cloud • 1 out of 66 the canister lost pressure • Canister can empty during spraying if used multiple times (Herrero & Higgins, 1998)
Environment	Environmental conditions that could have effect on bear spray delivery and effectivity: • **Wind** With wind present the direction and distance of the spray can be affected (in 5 of 72 cases reported) (CWI, 2009; Smith et al., 2012). In that case spraying should be adjusted and possible re-spraying is necessary (CWI, 2009; IBGC, 2011). However data shows that wind rarely affected the outcome of HBC as the high exit velocity of spray from the canister likely compensates for cross-wind effects (Smith et al., 2008). • **Temperature** Low temperature could affect the spray (CWI, 2009). The canisters should not be stored in temperatures lower than 0°C (Margo Supplies LTD, n.d.e) However this has not been adequately tested in the Arctic yet. • **Precipitation** Heavy rain or snow could disperse the spray. (Only recorded in 1 of 66 cases) (Herrero & Higgins, 1998) • **Vegetation** Thick vegetation could obstruct the spray cloud (1 out of 66) (Herrero & Higgins, 1998) However injuries could be avoided in all cases mentioned above (Herrero & Higgins, 1998)

Training	• Practice in using the spray:
	  ○ Removing the canister from the holster
	  ○ Removing safety clip
	  ○ Practice until action becomes a quick, automatic reflex (CWI, 2009)
	  ○ Get familiar with dispersal pattern of the spray (Herrero & Higgins, 1998)
	• Familiarize with what to do in case of mechanic failure or malfunction of the bear spray canister or if it does not have the required effect (Herrero & Higgins, 1998)

Distance	• A bear should be sighted at an adequate distance to be able to respond properly. The mean distance of a bear first seen in cases where bear spray has been successful is 24m (78ft) (range= 5 to 250m, n=6). Mean distance of when bear spray was used on polar bears: 2m (range=0,5 to 10m, n=6) (Wilder USFWS, 2013 ppt) • Distance towards the bear should be at least 7,5m (25ft) for the cloud to reach the bear. A charging bear should be sprayed when it is within distance of 18m (60ft). The bear will meet the cloud at 7,5m (25ft) and will be affected by it, diverting its charge and retreat. (CWI, 2009; IBGC, 2011) • If approached by a bear from a distance of 9m (30ft) or closer, continuous spraying is advisable at the front of the bear until it moves away. The bear may not immediately respond to the effects of the spray as the bear will be too close for the spray to work properly. However reports show the use of spray in these situations had lessened the severity and length of the attack (CWI, 2009). • Herrero & Higgins have found that best results were from spraying from 3 meters (Herrero & Higgins, 1998)

Maintenance	• Spray should be tested once a year (IGBC, 2011) • Spray should be replaced after usage
Accessibility	• Alaska: bear spray is widely distributed, even over Amazon.com. However logistically it might be difficult to get the canisters to remote places/villages due to logistical restrictions (Pers com. Klenzendorf, May 4, 2016). • Canada: Can be ordered online (Margo Supplies ltd, (n.d.d) • Russia: No experience with bear spray, accessibility is unknown (pers com. Mizin, June 13, 2016) • Greenland: Unknown • Norway: prohibited (WWF-Norway, 2013)
Costs	• $35-50 CAD (Margo Supplies ltd, n.d.d) • $30 USD (Amazon, 2016)
Legal restrictions	• Alaska: shipping restrictions (Pers com. Klenzendorf, May 4, 2016) Spray should be registered by the EPA (CWI, 2009; IGBC, 2011) • Canada: shipping restrictions (Margo Supplies ltd, n.d.d.) • Russia: unknown • Greenland: prohibited, bear spray use for patrols has been approved (Pers com. Klenzendorf, May 4, 2016). • Norway: Not supported by authorities on Svalbard, Norway (WWF-Norway, 2013)
Safety	• Injuries to humans could be avoided in all cases of use of bear spray (Herrero & Higgins, 1998) • People could be affected by their own bear spray, however in most cases when people are affected by their own bear spray, they are able to continue functioning (CWI, 2009). • Asks for close proximity to the bear
AC	• The repelled bears do seem to return to the area in time (Herrero & Higgins, 1998), however bear spray does give a person enough time to get into safety. • The bear will only stay away for a short period and might return within an hour (Mazur, 2010).
Human behaviour	• With a firm tone of voice telling the bear to stop and go away and standing ground by strong body language could increase the successfulness of the bear spray (CWI, 2009). • When helping another person that is being attacked the spray should be aimed directly at the head of the bear and continuing spraying when the bear separates from the person to encourage it to leave (CWI, 2009). Caution should be obtained that the bear does not redirect its charge on the person helping. • Non-threatening bears should not be sprayed. If not certain of the bear's intention a short burst could be dispersed towards the bear to monitor its reaction. (CWI, 2009)
Polar bear related factors	• The effectiveness depends on the level of agitation and motivation of the bear (CWI, 2009). • Polar bears in Barents Sea are more aggressive. Bear spray might possibly not be effective on those polar bears. (pers com. Mizin, June 13, 2016)
Availability for group type	• Should be available for all group types, but due to shipping and legal restrictions not available in certain countries or places.

Table 132 Additional advantages and disadvantages of using bear spray as a personal defence measure

	Advantage	Disadvantage
Design		• Sometimes multiple spraying is necessary (24% (N=72) of the cases investigated by Smith et al, 2012). • Bear spray has an expiry date, generally 3-4 years from date of purchase (Smith et al., 2008)
Environment	• If a person is standing upwind of the bear, it could have a positive effect on delivering the spray to the bear (Herrero & Higgins, 1998)	• If the course of the wind is in the wrong direction the spray cannot reach the bear (Wilder, USFWS, 2013 ppt)
Training	• Using bear spray does not require the training or experience as needed to shoot accurately at a charging bear with a rifle or a shotgun (Herrero & Higgins, 1998).	
Distance		• Bear spray might not give enough time for a bear to be distracted by the sound, cloud or irritants of the spray when a bear is charging from a close distance (CWI, 2009).
Human Behaviour	• The fact that a person is carrying bear spray when living, working or temporarily staying in (polar) bear habitat could increase confidence and sense of safety (Smith et al., 2008)	• Carrying bear spray should not be a substitute for the normal precautions when present in (polar) bear habitat (Herrero & Higgins, 1998) • Culturally it is challenge getting people to carry bear spray instead of a firearm (Smith, 2016)

Appendix XII: Relocation & Polar Bear Jail

I: Polar bear jail

Table 133 Additional information of relocation

	Preconditions
Maintenance	• Unknown
Costs	• Specific costs are unknown
Safety	• Lack of information on safety risks • Could cause stress to polar bear • Risk of people getting hurt during capture and release of animal

II: Polar bear jail

Table 134 Additional information of polar bear jail

	Preconditions
Maintenance	• Unknown
Costs	• Specific costs are unknown
Safety	• Lack of information on safety risks • Could cause stress to polar bear • Risk of people getting hurt during capture and release of animal

Appendix XIII: Polar bear patrol groups

There are several patrol groups active in the Arctic. Russia has the Umky Patrol group active in Vankarem, Chukotka and surrounding area and Yamal region. (USFWS, 2010; Nunatsiaq online, 2016), U.S. has patrol groups among others active in Kaktovik and Wales, Alaska, (Hughes, 2016; USFWS, 2010) Canada in Aviat, Nunavut (WWF CA, 2016) and Greenland is experimenting with polar bear patrol groups in Ittoqqortoormiit (WWF, 2016).

Since the introduction of Patrol groups in Aviat in 2010, the number of polar bears killed due to HPBC has reduced from an average of eight per year to one per year, even though the frequency of human and polar bear encounters have increased (WWF CA, 2016). 4 bears were shot in the village of Kaktovik, Alaska during the period of August and September 2009 when the patrol group was not active, indicating the importance and effectiveness of the patrol group (USFWS, 2010).

The Umky Patrol group in Russia has reported around 200 polar bears around the village of Vankarem, Chukotka in 2009 (USFWS, 2010), of which they prevented all conflict between humans and polar bears (Nikiforov & Boltunov, 2007). Since the establishment of the Umky Patrol in 2006 no additional human injuries or fatalities have occurred. (York, PBDFW, 2011)

In September and October most effort of the Umky Patrol Group, and other polar bear patrol groups, is focussed on minimizing disturbance and protection walrus haul-outs and moving carcases away from villages. In November and December main polar bear activity occurs and patrols of human areas are more severe and additional focus lies on education. Education is also a year-round task. (York, PBDFW, 2011)
Other tasks of the patrols is improving lighting in villages to keep people safe walking through the village in the dark, suggesting demolition of dilapidated buildings to prevent them from being used as shelter by polar bears and conserving communal buildings or safety for people. (WWF, 2013) Other tasks of patrol groups are establishing protected areas and anti-poaching work (York, PBDFW, 2011). New patrol groups are being established based on experience of already functioning groups. Aaskan communities have invited Russian patrol groups to share knowledge and Greenlandic people have been to Canadian patrol groups. (Pers com. Koopmans, August 8, 2016)

Table 135 Additional information polar bear patrol groups

	Preconditions
Costs	• Costs that needs to be considered are: - Purchase and maintenance snow machines - Fuel - Travel budget for additional training and outreach (York, 2009) • $400.000 CAD annually in 2011 in Canada
AC	Polar bear patrols should be established for long term to be effective.
Safety	• Trained staff with experience • Requires occasional close proximity to polar bears • Safety also depends on type op measure used

Table 136 Additional advantages and disadvantages of polar bear patrol groups

	Advantage	Disadvantage
Costs	• Oil companies in East Alaska help financing the polar bear patrol projects	• Funding to keep patrol groups active has been a problem in recent years (USFWS, 2010). No finances available in the west side of Alaska • NGOs and supporting organisations cannot keep supporting forever, people need to take own responsibility and co-financing (Pers com. Klenzendorf, May 4, 2016).
Human behaviour		• Not all local communities want the help or involvement of an NGO to establish patrol groups