RELIABILITY, ACCURACY, AND TRACKING TECHNIQUES OF INUIT HUNTERS IN ESTIMATING POLAR BEAR CHARACTERISTICS FROM TRACKS

By

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Abstract

Inuit estimates of polar bear characteristics from tracks could complement ongoing capture-mark-recapture methods to frequently monitor polar bear populations in response to climate-induced habitat changes. Before the inclusion of these Inuit track estimates, they need to be evaluated for reliability and accuracy. Building on previous work, which showed increased reliability among active Inuit hunters, this thesis research reports i) reliability in estimates of sex, age, size, and age of track of a larger number of tracks by a larger number of Inuit hunters; ii) preliminary accuracy assessments of sex and size estimates; iii) semi-structured interviews with Inuit hunters regarding their polar bear tracking experience and techniques; and iv) potential relations between Inuit hunting experience and reliability and accuracy in diagnosing tracks. The Inuit hunters were reliable and consistent as a group in making estimates of sex ($\alpha=0.74$ and mean corrected item-total correlation=0.45), age ($\alpha=0.81$ and mean corrected item-total correlation=0.63), and size ($\alpha=0.91$ and mean corrected item-total correlation=0.73), as well as age of track estimates with the exclusion of a single participant ($\alpha=0.85$ and mean corrected item-total correlation=0.63). Preliminary accuracy assessments suggest Inuit hunters are generally accurate in their estimates of sex (mean 65.28% agreement with genetic sex estimates) and potentially size from tracks, warranting further efforts to determine accuracy in these estimates as well as age and age of track. Semi-structured, open-ended interviews with each hunter revealed they use similar tracking techniques, which may explain their high agreement in making estimates. In addition, Inuit tracking experience and the use of particular tracking methods may correlate with individual reliability and accuracy in track diagnoses. These results suggest the information that Inuit hunters provide may inform any tracking-based polar bear survey.
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Table of Contents

Abstract ii
Acknowledgements iii
Table of Contents v
List of Tables vii
List of Figures ix

Chapter 1: Introduction and Literature Review

General Introduction 1

1) Role of Traditional Ecological Knowledge Provided by Inuit Hunters 5

2) Reliability and Accuracy in Footprint Observations 7

3) Using Tracks to Estimate Population Activity 10

4) Qualitative Methods of Documenting Information from Inuit Hunters 13

Research Goals and Hypotheses 15

Chapter 2: Materials and Methods

Participant Recruitment and Track Sampling Area 16

Reliability Assessment of Sex, Age, Size, and Age of Track Estimates 17

Accuracy Assessment of Sex and Size Estimates 18

Comparisons of Inuit sex estimates with genetic and previous CMR sex estimates 18

Comparisons of hunter size estimates with stride length 20

Semi-Structured Interviews for Hunting and Tracking Techniques and Experience 21
Comparing Participant Background and Hunting Experience with Reliability and Accuracy in Diagnosing Tracks

Chapter 3: Results

Track Data Collection

Reliability of Sex, Age, Size and Age of Track Estimates

Comparisons of Sex and Size Estimates with External Validity Criteria

Semi-Structured Interviews for Participant Background, Hunting Experience and Techniques

Participant background

Making estimates of polar bear sex, age, size and age of track from tracks

Techniques for identifying sex

Techniques for identifying age

Techniques for identifying size

Techniques for identifying age of track

Comparisons of Participant Background and Hunting Experience with Track Estimates and Ability to Diagnose Tracks

Chapter 4: Discussion

Summary

Reliability of Inuit Hunters in Making Estimates of Polar Bear Characteristics from Tracks (Objective I)

Preliminary Accuracy Assessments of Inuit Estimates of Polar Bear Sex and Size
from Tracks (Objective II)

Similarity of Inuit Methods in Diagnosing Sex, Age, Size, and Age of Track from Track Observations (Objective III)

Inuit Hunting and Tracking Experience as Indicators of Reliability and Accuracy in Diagnosing Tracks (Objective IV)

Participant Observations and Contextual Details to Interviews

Conclusions and Further Research

**Literature Cited**

**Appendix I: Preliminary Reliability Assessments (2007 and 2008)**

**Appendix II: Forms for Participants**

**Appendix III: Guideline for Discussion Topics**

**Appendix IV: Sample Interview Transcription**

**Appendix V: Preliminary Analysis of Estimates**

**Appendix VI: Additional Analyses Excluding Participant 5**

**Appendix VII: Details of Accuracy Assessments of Sex Estimates from Tracks**
List of Tables

Table 1. Cronbach’s alpha (α) for sex, age, size, and age of track estimates provided by the group of 9 hunters. 28

Table 2. Mean corrected item-total correlations (r) and individual participant corrected item-total r for estimates of sex, age, size, and age of track. 29

Table 3a. 2x2 Chi-square tests comparing sex ratios of estimates (across 78 tracks) provided by each participant with an expected 1:1 male to female ratio in a population. 36

Table 3b. 2x2 Chi-square tests comparing sex ratios of estimates provided by each participant with the reported sex ratio of 167 females to 117 males reported in the last CMR survey of this region completed in 1998-2000 (Taylor et al. 2006). 37

Table 4. Pearson correlation coefficients (r) between estimates of size and mean stride length measurements across 9 tracks for all 9 participants. 38

Table 5. Summary of participant background. 40

Table 6. Summary of criteria used by different hunters to diagnose sex, age, size and age of track from polar bear tracks. 46

Table 7. Pair-wise Spearman’s rank correlation coefficients (ρ) between participant background and tracking experience and criteria measures for reliability and accuracy. 50

Table 8. Summary of methods of track diagnoses by the group of 9 hunters. 65

Table 9. Summary of reliability, consistency, and accuracy assessments of sex, age, size, and age of track estimates provided by Inuit hunters based on in situ track observations. 66
**List of Figures and Illustrations**

**Figure 1.** Track locations in M’Clintock Channel, Nunavut, Canada from 2007 to 2009. 25

**Figure 2.** Chi-square analysis comparing sex estimates across the 9 hunters. 30

**Figure 3.** One-way ANOVA and post-hoc Tukey-Kramer HSD test comparing age estimates across the 9 hunters. 30

**Figure 4.** One-way ANOVA and post-hoc Tukey-Kramer HSD test comparing size estimates across the 9 hunters. 31

**Figure 5a.** One-way ANOVA and post-hoc Tukey-Kramer HSD test comparing age of track estimates across the 9 hunters. 32

**Figure 5b.** One-way ANOVA and post-hoc Tukey-Kramer HSD test comparing age of track estimates across the hunters with the exclusion of participant 5. 33

**Figure 6.** Linear regression analyses of coefficients of variation for age, size, and age of track diagnoses made by 9 hunters across 78 tracks (diagnosed in order). 33

**Figure 7.** A depicted example of hypothetical differences in walking pattern and footprint orientation used to distinguish a) male and b) female tracks. 47

**Figure 8.** An example of differences in heel shape used to diagnose an a) male and b) female footprint. 48
Chapter 1: Introduction and Literature Review

General Introduction

Although likely negative, range-wide responses of polar bear (*Ursus maritimus*) to changes in sea ice conditions precipitated by climate change are subject to debate (Stirling and Derocher 1993; Aars *et al.* 2006; Freeman and Wenzel 2006; Dyck *et al.* 2007; Stirling *et al.* 2008). These uncertainties can potentially impact contemporary estimates of numbers, sizes and dynamics of polar bear populations (Dowsley 2007), which directly inform harvest quotas of Canadian polar bears by resident Inuit. Further, there are competing perspectives between scientific and Inuit communities on the current status of some polar bear populations (Clark *et al.* 2008; Dowsley 2009). Given these conflicts, polar bear management may benefit from more immediate estimates of polar bear activity, informed by local Inuit, as a complement to current scientific methods that largely determine these contemporary estimates.

At present, polar bears are monitored based on the 1973 Agreement on the Conservation of Polar Bears between Canada, Denmark (Greenland), Norway, Soviet Union and United States (Aars *et al.* 2006; Freeman and Wenzel 2006; Stirling and Parkinson 2006) to protect habitats, denning and feeding sites, female bears, cubs, and denning bears using “sound conservation practices based on the best available scientific data” (The Government of Canada *et al.* 1973). Accordingly, polar bears throughout their range are parsed into 22 discrete management units defined by a combination of genetic analyses (Paetku *et al.* 1999), bear movements of all age and sex classes (Stirling *et al.* 2004) using satellite radio collars (Taylor *et al.* 2001), and partially by physical features of sea ice landscapes (Ferguson *et al.* 1998a). The dynamics and status of Canadian populations within these units are mainly estimated through aerial capture-mark-recapture (CMR) surveys that occur after female adults emerge from their terrestrial dens in the
spring (Taylor et al. 2006; Taylor et al. 2008). Population viability analyses of these CMR data
(Taylor et al. 2005; Taylor et al. 2006) are then used to estimate total allowable harvests (Stirling
and Parkinson 2006). In Nunavut, these quotas are divided among communities hunting the same
population through Memoranda of Understanding that are sanctioned by regional wildlife
organizations and the Nunavut Minister of Environment, as co-management according to the
Nunavut Land Claims Agreement (Agreement 1993; Dowsley 2009). Permits or “tags” are then
distributed to each community, which are then obtained by hunters through a lottery system. In
Canada, polar bear harvest quotas are set at a 2:1 male to female ratio under the assumption that
males are expendable with respect to females that are either suckling or pregnant to maximize
the sustainable yield of polar bears while satisfying the demand for hunting by Inuit communities
(Freeman and Wenzel 2006; Taylor et al. 2008; Dowsley 2009).

While precise at the time of collection, the expected time between CMR surveys of
twelve to fifteen years (Government of Nunavut 2005; Taylor et al. 2006; Dowsley and Wenzel
2008) may be too great to monitor the impacts of expected rapid changes in sea ice on polar bear
dynamics. CMR surveys are expensive (Dowsley 2009), require large sample sizes for
sufficiently small confidence intervals (Derocher et al. 2004) and may have low probabilities of
detection with low density polar bear populations (Hayward et al. 2002). In addition, these
aircraft-assisted CMR methods generally exclude local communities who may inform these
studies, operating in difficult terrain including impassable sea ice, mountains, and open ocean
that may not be accessible to local people (Dowsley 2009). More importantly, these methods
concern local communities because tranquilization may lead to increased aggression and
wariness of polar bears towards humans (Tyrell 2006; Clark et al. 2008; Shannon and Freeman
2009), reduce the quality of polar bear meat for consumption (Tyrell 2006; Clark et al. 2008;
Shannon and Freeman 2009), and may result in handling mortality associated with stressed bears (Derocher et al. 2004). Female bears may also suffer additionally through handling and displacement from their feeding sites, leading to lowered body mass for maternity denning (Derocher et al. 2004; Stirling and Parkinson 2006) and decreased cub survival (Dyck et al. 2007). Moreover, CMR may be inadequate if bears move to unexpected areas and are inaccessible for capture (Stirling and Parkinson 2006). The lack of accurate information on population size and sustainable harvest rates can result in erratic harvest quotas and negative population effects (Taylor et al. 2006; Dowsley 2009). Indeed, polar bear management may benefit from a more frequent, inexpensive, and less-invasive community-based polar bear survey as a complement to ongoing CMR methods.

Inuit communities are committed to protect the polar bear because polar bear hunting is valued socially and economically through native-guided sport hunts and sustenance. Polar bear meat may be consumed with an economic value over $800 for an average of 140kg of edible meat per bear (Freeman and Wenzel 2006; Tyrell 2006), while hides can be valued over $300 per metre based on nose-to-tail length (Freeman and Wenzel 2006; Tyrell 2006). As licensed guides for visiting hunters, Inuit hunters develop skills associated with field knowledge, traveling, and survival, which in turn provides social satisfaction through word-of-mouth reports within their communities (Freeman and Wenzel 2006). In addition, financial returns, gratuities, and gifts are often provided by each visiting trophy hunter to the community (Freeman and Wenzel 2006; Tyrell 2007; Tyrell 2009). A recent listing of the polar bear as “threatened” under the U.S. Endangered Species Act has banned the import of hunt products (Clark et al. 2008; Tyrell 2009) suggesting scientific and conservation communities will continue to pressure Canada to reduce
hunt quotas (Clark et al. 2008). Local communities who take part in many polar bear sport hunts may begrudge these efforts, as is already apparent in some communities (Tyrell 2009).

Given the value of polar bears to Inuit communities, Inuit may be eager to participate in any polar bear monitoring program. As a policy requirement, especially in northern Canada (Agreement 1993; GNWT 1993), information provided by local harvesters – whether presented orally or in writing – should be considered and integrated into environmental assessment and resource management (Stephenson 1996; Usher 2000). However, Canada’s polar bear management has been criticized for lacking thorough integration of the economic, cultural, and symbolic values of harvesting communities (Clark et al. 2008; Dowsley 2009). Wildlife management systems have introduced a concept of Inuit traditional knowledge alongside science, shifting distribution of power that is not entirely favored by scientists and non-aboriginal managers (Clark et al. 2008). Although a laudable goal, it has been proven quite difficult to integrate the two world views using existing methods. For instance, Inuit hunters continually report polar bear sightings that conflict with data from scientific studies (Tyrell 2006; Dowsley 2007; Dowsley and Wenzel 2008). These disputes may be due in part to the lack of Inuit hunters who document actual numbers of bears, locations of sightings, or age and sex classes of bears (Stirling and Parkinson 2006), which may also explain international criticisms against changes in quotas using non-scientific information (Aars et al. 2006). Any information Inuit hunters provide toward a polar bear activity survey should thus include methods of documentation that are mutually comprehensible and appropriate according to both Inuit and scientific communities.

With appropriate documentation, data provided by Inuit hunters in collaborative studies with scientific researchers may assist in the management and conservation of polar bears. The information provided by Inuit hunters may include when and where polar bears are likely to be at
certain times of the year, along with sex, age and size diagnoses from bear tracks. Before their inclusion into any polar bear activity survey, Inuit hunter estimates should be evaluated for reliability (agreement of estimates among the individual hunters) and accuracy (the extent to which estimates are close to the true values). Qualitative methods of documenting and assessing how these estimates are determined may provide a better understanding of the knowledge provided by Inuit hunters. In addition, identifying any relevant background information that is shared by reliable and accurate hunters may provide subsequent recruitment criteria for Inuit hunter participation in track-based polar bear surveys. Below I discuss 4 topics relevant to this study: 1) role of traditional ecological knowledge provided by Inuit hunters; 2) reliability and accuracy in footprint observations; 3) using tracks to estimate population activity; and 4) qualitative methods of documenting information from Inuit hunters.

1) Role of Traditional Ecological Knowledge Provided by Inuit Hunters

Traditional ecological knowledge (TEK) provided by Inuit, often translated as Inuit Quajimajatuqangit in Nunavut (Dowsley 2009), can inform polar bear monitoring programs. TEK is the current ecological information gained through an individual’s lifetime that has been passed on from previous generations (Wenzel 1999; Usher 2000; Dowsley 2009). TEK varies with gender, experience, and age of practitioners (Usher 2000) and may integrate information over larger temporal and geographical scales (Usher 2000; Dowsley 2009) than scientific methods. It is dynamic and enhanced through continuity of tradition (Usher 2000), for example hunting polar bear.

The information that Inuit gather through personal, uninstrumented experience regarding polar bear hunting success rates, population dynamics, and habitat preferences extends back several generations (Freeman and Wenzel 2006) and can be specific and recalled with detail
(Usher 2000). By comparing this current information with past observations, Inuit may provide data with implications for changes in polar bear activity in response to environmental changes. For example, Inuit residents in Gjoa Haven, Taloyoak, and Kugaaruk have identified earlier sea ice break-up, later sea ice freeze-up, and changes in snow accumulation that may reduce polar bear habitat quality (Keith 2009). Inuit elders and hunters from various communities in the Western Hudson Bay region have located specific geographical areas associated with recent increases or decreases in polar bear abundance (Nirlungayuk and Lee 2009). Inuit elders and hunters in Salliq have recently observed polar bears expanding their diets to include food sources other than seal, and indicated skinnier and more aggressive bears, possibly linked to CMR methods (Shannon and Freeman 2009). While local Inuit elders can provide an invaluable temporal scope with respect to the location and timing of polar bear responses to ecological events (Stevenson 1996), active hunters can potentially determine characteristics of harvested populations from their expert knowledge of bear morphology and behavior from track observation (Freeman and Wenzel 2006). More specifically, sex and age estimates of hunted bears provided by hunters can yield information on long-term population trends (Derocher et al. 2004; Taylor et al. 2006) and useful tissue samples are frequently collected by hunters (Freeman and Wenzel 2006).

Inuit hunters will likely be the first to notice major changes in polar bear population dynamics (Derocher et al. 2004). This has been demonstrated in the past through accurate hunter reports of changing population conditions and sizes within their hunting areas (Freeman and Wenzel 2006). For example, local Inuit hunters have previously noted that an abundance estimate of 900 polar bears in M’Clintock Channel (determined in a CMR survey of this region in the 1980s) was too high, and a subsequent CMR survey of this region in 2001 conducted in
collaboration with local hunters reported an estimate of 284 bears, suggesting this population had been severely overharvested (Aars et al. 2006; Taylor et al. 2006; Dowsley 2009). In this manner, Inuit hunters may provide more immediate estimates of changes in population activity, which are potentially accurate, where CMR survey data may be lacking. Inuit hunters from M’Clintock Channel in particular may inform any polar bear activity survey of this region because these hunters maintain high hunting success in all the years that they hunt polar bear (Taylor et al. 2006). However, as noted above, the ability to translate qualitative information provided by hunters into management responses has been difficult (Dowsley 2009) and the integration of TEK with scientific methods requires internal consistency and validation through multiple data types (Usher 2000).

2) Reliability and Accuracy in Footprint Observations

Reliability can refer to whether the same set of participants or raters can provide similar answers to similar questions (Santos 1999), for example whether Inuit hunters provide the same sex, age, and size diagnoses from the same in situ track observations. In this manner, reliability is a measure of internal consistency (Cortina 1993; Yu 2001; Golafshani 2003) and equivalence (Yu 2001) of observations or estimates. By most conventions, measures of reliability are limited to agreement among participants (Shrout and Fleiss 1979). Agreement is also a precondition for accuracy (Peterson 1994; Gliem and Gliem 2003), which refers to the correlation of observations to an external validity criterion.

Reliability of a group of hunters can be measured using statistics such as Cronbach’s alpha (α; Cortina 1993; Peterson 1994; Santos 1999; Yu 2001; Gliem and Gliem 2003), which has described reliability of health-related quality-of-life questionnaires reported by patients (Aaronson et al. 1993; Varni et al. 1999; Varni et al. 2007; Leese et al. 2008; Bekelman et al.)
and quality-of-management questionnaires reported by laborers and managers in manufacturing facilities (Flynn et al. 1994). Thus, $\alpha$ may be used to report reliability of ratings or estimates provided by Inuit hunters from a series of questions, for example sex, age, and size of a polar bear from tracks being observed. $\alpha$ is dependent on the number of hunters in the group, variance of individual hunters, variance among the hunters, and average inter-hunter correlations of estimates (Peterson 1994; Clark and Watson 1995; Gliem and Gliem 2003). Compared to other statistics used to measure reliability, $\alpha$ is mathematically equivalent to the mean of all possible split-half correlations of ratings between observers (Cortina 1993; Yu 2001; Gliem and Gliem 2003) and can be determined for both dichotomous variables (Santos 1999; Yu 2001) such as sex, and continuous variables (Cortina 1993) such as age and size.

While $\alpha$ may provide an estimate of agreement among hunters as a group, corrected item-total Pearson product-moment correlations ($r$) of estimates for each hunter may be a more straightforward measure of internal consistency (Gliem and Gliem 2003) to identify which individual hunters are most correlated with the group. Mean corrected item-total $r$ for a group of hunters may also indicate consistency in a set of estimated parameters. A corrected item-total $r$ is the correlation of a particular hunter’s estimates with the total or summed estimates given by the other hunters; “corrected” by excluding the particular hunter from the total or summed estimates (Gliem and Gliem 2003). A value of 0.7 for $\alpha$ (Cortina 1993; Santos, 1999; Yu 2001) and a moderate mean corrected item-total $r$ ranging from 0.40 to 0.50 has been suggested to indicate reliability in developing a scale for measurement (Clark and Watson 1995; Streiner 2006) – in this case, a group of hunters diagnosing tracks. Should hunter estimates of sex, age and size from tracks appear reliable - have high $\alpha$ as a group and high corrected item-total $r$ - subsequent efforts in determining accuracy of these estimates will be warranted.
While high $\alpha$ and $r$ may suggest Inuit hunters are reliable in their polar bear track diagnoses, the incorporation of these data into a useful polar bear activity survey requires an estimate of accuracy in diagnoses of sex, age, and size. Some reliability assessments of questionnaires have been extended to accuracy by comparing responses with external validity criteria using correlations (Flynn et al. 1994; Varni et al. 1999; Varni et al. 2007) or inter-correlations between responses of known relationships (Aaronson et al. 1993; Bekelman et al. 2010). Accuracy of sex diagnoses from tracks can be determined by comparisons with sex ratios from a previous CMR survey in 1998-2000 (Taylor et al. 2006), or with data from genetic sexing of hair and faecal samples associated with some tracks (Carmichael et al. 2005, Van Coeverden de Groot et al. 2008). Hair samples can be collected noninvasively from bear sampling stations that consist of barbed wire baited with seal meat, which have been erected in M’Clintock Channel from 2006 to 2008 (Van Coeverden de Groot et al. 2008), while hair and faeces can be collected along tracks on an ad hoc basis. True age of a polar bear leaving tracks can be determined by genotyping a bear that was previously captured in a CMR survey of this region (Taylor et al. 2006), as these captured bears were aged from teeth (Calvert and Ramsay 1998). True size can be potentially assessed through measures of gait length that are calibrated by known comparisons with gait data collected from captive (zoo) animals where size is known. However, the relation between polar bear size and gait has not been described in the literature. In addition, the ability of hunters to distinguish between bears of similar age and sex (identity) awaits the optimization of a multivariate analysis of digital images of footprints observed by hunters (Alibhai et al. 2008).
3) Using Tracks to Estimate Population Activity

Tracks, a set a footprints made by the same individual (Smallwood and Fitzhugh 1995; Grigione et al. 1999; Jewell et al. 2001; Alibhai et al. 2008), are often used by indigenous peoples while hunting, identifying species, and interpreting animal behaviour (Stander et al. 1997; Jewell et al. 2001). Tracking-based sexing and identification are attractive because they can be repeatable, objective, and accurate (Smallwood and Fitzhugh 1995; Stander et al. 1997; Gusset and Burgener 2005), are noninvasive and inexpensive to collect (Kendall et al. 1992; Smallwood and Fitzhugh 1995; Beier and Cunningham 1996; Stander 1998; Grigione et al. 1999; Jewell et al. 2001; Hayward et al. 2002; Silveira et al. 2003; Melville and Bothma 2006; Houser et al. 2009; Balme et al. 2009), and available when CMR or direct visualization of animals is difficult (Beier and Cunningham 1996; Jewell et al. 2001). Tracks can detect large changes in population activity over large areas (Balme et al. 2009) and time (Kendall et al. 1992; Hayward et al. 2002; Melville and Bothma 2006; Balme et al. 2009), with high power in detecting decreases in abundance (Beier and Cunningham 1996); these properties suggest tracks would be useful for monitoring polar bear population changes.

Tracks can be used with data from other noninvasive methods to identify the presence of individuals (Balme et al. 2009) and other species (Crooks et al. 2008). Using tracks alone, individual identification can be inferred from multivariate analyses of footprint images, as in black (Diceros bicornis) (Jewell et al. 2001) and white (Ceratotherium simum) (Alibhai et al. 2008) rhinos, cougars (Puma concolor) (Lewinson et al. 2001), mountain lions (Felis concolor) (Grigione et al. 1999), tigers (Panthera tigris) (Karanth et al. 2003), and fishers (Martes pennanti) (Herzog et al. 2007), but these analyses will likely require independent estimates of population parameters to be applied to management (Herzog et al. 2007). Track counts can be
compared to CMR data to determine relationships between track density and population density, which has been determined in cheetahs (*Acinonyx jubatus*) (Houser et al. 2009). Further, track counts can be supplemented with estimates of group size, sex, and age compositions in addition to CMR data to determine population compositions, as in leopards (*Panthera pardus*) (Stander 1998). In this regard, tracks can identify a minimum number of known individuals.

Though identifying presence or absence of tracks alone appears highly reliable (Kendall et al. 1992; Beier and Cunningham 1996) and is useful in estimating population abundance, estimating additional polar bear population parameters from tracks will be extremely useful. Multiple sets of tracks can potentially indicate demographic or behavioral activity, such as births, disappearance of young, maturity, and maternity (Jewell et al. 2001); data that are also collected in polar bear CMR surveys to estimate reproductive parameters from standing age distributions (Taylor et al. 2006). While polar bear sex and age distributions can indicate population status (Derocher et al. 2004; Stirling and Parkinson 2006) and recruitment rates (Taylor et al. 2006; Taylor et al. 2008), body size can indicate health conditions (Derocher et al. 2004; Stirling and Parkinson 2006). More specifically, sex ratios need to be monitored because they are indicative of polar bear hunting success by hunters (Derocher et al. 2004; Taylor et al. 2006; Taylor et al. 2008) – recall hunting quotas are based on a 2:1 male to female ratio. Polar bear cub, subadult, and adult age classes (Taylor et al. 2006) should also be monitored because these classes differ in vulnerability to hunting and survivorship to projected changes in sea ice conditions (Stirling and Parkinson 2006) and are expected to respond differently to changes in sea ice conditions (Derocher et al. 2004). Straight-line body length can suggest overall body mass in females leading to inferences for cub survival and reproductive success (Stirling and Parkinson 2006), as well as hunter selectivity, as hunters often select larger bears. In addition to sex, age, and size,
“age of track” estimates from tracks that are encountered may be useful because the ability to detect tracks is limited by track degradation over time (Jewell et al. 2001; Hayward et al. 2002; Silveira et al. 2003; Alibhai et al. 2008). In particular, variance in track dimensions identified in the snow can be caused by snow condition, wind, presence of ice, and snow melt (Hayward et al. 2002), thus affecting the ability to estimate population parameters and potentially confidence in these diagnoses.

The interpretation of polar bear sex, age, and size along with age of track from tracks alone requires trained personnel (Silveira et al. 2003) or experienced local trackers (Stander 1998; Alibhai et al. 2008). Population studies including local trackers who make these estimates from tracks alone, while assessing these estimates for reliability and accuracy, appear to be lacking. Sex and age classes (Smallwood and Fitzhugh 1995) or social grouping and location (Houser et al. 2009) of mammals using heel dimensions have been estimated in addition to track counts but these data were identified by non-local researchers and required independent estimates of population parameters. Local trackers have led caracal (Caracal caracal) track data collection while providing estimates of age of track but sampling areas were limited to national parks and reliability of these estimates were not reported (Melville and Bothma 2006). Reliability of multiple observers of transects within quadrats of tracks has been determined but are limited to calculations of error in species identification or group error in relation to a single observer (Smallwood and Fitzhugh 1995). One study assessed reliability and accuracy in hunter estimates of sex, age, and behavior from leopard, wild dog (Lycaon pictus) and lion (Panthera leo) tracks but direct observation was required to evaluate accuracy and analyses were limited to consensus information after discussion among the local trackers (Stander et al. 1997). With regards to most animals in general and specifically polar bears, individual and group reliability
and accuracy in local hunter estimates of sex, age, size and age of track from tracks have yet to be assessed.

4) Qualitative Methods of Documenting Information from Inuit Hunters

The knowledge that Inuit hunters provide relies on cultural context to operate, from which it cannot be separated (Stevenson 1996; Wenzel 1999; Usher 2000; Clark et al. 2008). Hence, communities are often reluctant to share their knowledge because of possible misinterpretation (Stevenson 1996; Wenzel 1999; Usher 2000). Conservation biology is dominated by quantitative perspectives and cultural biases that require expert knowledge read to be described in Western scientific terms (Huntington 2000; Fazey et al. 2006; Clark et al. 2008; Dowsley 2009), which may explain the general lack of appropriate procedures for integrating Inuit TEK in Canada’s polar bear management system (Usher 2000; Dowsley 2009). On the other hand, qualitative methods can capture the breadth of knowledge formation (Talja 1999), leading to a better understanding of TEK provided by Inuit hunters. In this respect, qualitative researchers can actively reflect on the data that is being collected and view the information provided from the perspective of the participants as a group of people (Baxter and Eyles 1997; Huntington 1998). The richest and most detailed TEK is shared while hunters are engaging in the sustenance activity in question (Stevenson 1996), for example tracking. Hence, qualitative information gathered through participant observation while Inuit hunters observe polar bear tracks may be a useful way to document and describe their knowledge.

Recording and transcribing semi-structured, open-ended interviews, on a face-to-face basis (Burnard 1991; Baxter and Eyles 1997; Huntington 1998; Huntington 2000) can identify the actual mechanisms and processes through which the knowledge is acquired and applied (Huntington 1998; Maxwell 2004). Using these qualitative methods to document Inuit hunter
tracking experience and the methods they use to identify tracks can provide additional information on how they make polar bear estimates from tracks as a group. Interviews have been effective in documenting TEK from Arctic communities regarding changes in polar bear populations (Tyrell 2006; Dowsley 2007; Dowsley and Wenzel 2008; Dowsley 2009; Nirlungayak and Lee 2009; Shannon and Freeman 2009; Tyrell 2009) as well as population activity in marine birds (Gilchrist et al. 2005; Mallory et al. 2006), bowhead (Balaena mysticetus) (Huntington 2000; Noongwook et al. 2007) and beluga (Delphinapterus leucas) (Huntington 1998; Mymrin 1999) whales, and caribou (Rangifer tarandus) (Ferguson and Messier 1997; Ferguson et al. 1998b). In these studies, the similarities between TEK and scientific data were descriptive however the qualitative nature of the TEK data was maintained, minimizing loss of information. One study used semi-structured interviews to document Inuit methods of hunting seals (Phoca hispada) in addition to TEK of seal population activity (Furgal et al. 2002) but individual differences in hunting methods reported by Inuit participants and the resulting differences on hunting success were not explored. It is difficult to integrate qualitative and quantitative data, given the different processes through which these methods operate (Talja 1999) without inflicting a quantitative or qualitative bias. However, it may be useful to integrate quantitative and qualitative data using statistical correlations by coding and categorizing qualitative information, while minimizing any information that may be lost.

In comparison to quantitative statistics such as $\alpha$ and $r$, qualitative data are less dependent on predetermined methods of their collection (Huntington 2000; Maxwell 2004). Furthermore, small sample sizes of participants are acceptable given the larger scope of information that can be gathered to identify specific situations and mechanisms of knowledge formation, versus the abundant random samples required for conventional quantitative methods to generalize.
conclusions (Maxwell 2004; Flyvbjerg 2006). However, when this type of data is collected, its validity can be influenced by hunters’ ability to recall past information (Talja 1999) as well as hunter relationships with the researcher (Baxter and Eyles 1997). In this regard, reliability and accuracy in these qualitative methods is established through trustworthiness, honesty, and neutrality of the interviewer (Rapley 2001; Golafshani 2003).

Research Goals and Hypotheses

Previous reliability assessments of 3 hunters and 3 elders in 2007 and 3 hunters and 4 non-Inuit in 2008 suggested Inuit hunters were more reliable observers of polar bear tracks (Appendix I). However, these data were based on a small sample size of 3 hunters each year observing only 19 tracks in 2007 and 27 tracks in 2008. Building on this work, the goals and objectives of my thesis research are to determine:

I) an estimate of reliability from larger sample of hunter estimates of sex, age, and size along with age of track by assessing a) group agreement, b) differences in individual estimates, and c) changes in agreement over time.

II) accuracy in hunter estimates of a) sex by comparisons with genetic sex estimates from associated tissue and b) size by comparisons with gait measurements from tracks.

III) the cues and methods that hunters use to diagnose sex, age, size and age of track from tracks.

IV) criteria for hunting background and tracking experience that contribute to high reliability and accuracy of hunters.
Chapter 2: Materials and Methods

Participant Recruitment and Track Sampling Area

Nine Inuit hunters were given instructions and randomly assigned a number (participant 1 to 9) before data collection that corresponded to the order in which they provided their track diagnoses. Data were collected from five hunters from the community of Gjoa Haven (participants 1, 3, 5, 8 and 9), two hunters from Taloyoak (2 and 4), and two hunters from the Cambridge Bay (6 and 7). Participants 8 and 9 were elders, and all data provided by them were translated by participant 1. For this reason, all data collected from 8 and 9 took place after 1. While 1 and 3 participated in a similar project in previous years, all others were contacted through the Gjoa Haven Hunters and Trappers Organization for their familiarity with the hunters. The participants were contacted directly (5, 8 and 9) or referred to by hunters that participated in similar projects over previous years (in 2007 and 2008) but were not available for this field season (2, 4, 6, and 7).

Track locating and data collection was led by participant 1 on a snowmobile, followed by 2 to 9. Tracks were encountered in M’Clintock Channel from 11 – 15 May 2009 between and around Cape Sydney (69° 50.66 N, 97° 39.15 W) and Gateshead Island (70° 34.74 N, 100° 13.52 W). For each set of polar bear tracks observed, each participant was asked to give an estimate of sex, age in years, and nose-to-tail size in feet along with an estimated age of the track in days. If multiple tracks were encountered at the same location, participants were asked to estimate how many different individuals were associated with the tracks and to provide diagnoses for each individual while specifying which track they were observing. All sex estimates were coded as 1 for “male” and 2 for “female” for reliability and accuracy calculations. “I don’t know” was included as an optional response to minimize random guessing (Yu, 2001) and missing data were
excluded from all analyses. Participants were also given the option to designate a particular track being observed as belonging to an individual whose tracks had already been diagnosed. Sex, age, and size estimates were recalled for these instances while a new age of track estimate was provided. All estimates were given by each participant without discussion among the other participants and recorded in the same order at all polar bear tracks observed.

**Reliability Assessment of Sex, Age, Size, and Age of Track Estimates**

Reliability was assessed by computing group agreement in estimates, comparing individual differences in estimates, and determining changes in group variability in estimates over time across the tracks that were diagnosed by all participants. Reliability in estimating number of individual bears across tracks was not assessed, as it was unclear whether all participants understood that re-calling previously observed tracks was an option. In assessing group agreement, Cronbach’s alpha (α; Peterson, 1994; Yu, 2001; Gliem and Gliem, 2003) of the group of hunters was calculated using SPSS (SPSS; SPSS Inc.) for sex, age, size, and age of track estimates provided by the hunters across tracks. For each α analysis, the estimate-by-participant matrix was transposed into a participant-by-estimate matrix (MacLennan, 1993). To make inferences on individual consistency, corrected item-total Pearson correlation coefficients ($r$) for each participant were calculated for sex, age, size and age of track estimates. Mean corrected item-total $r$ for each of the four variables were also determined for the group by $z_r$-transforming corrected-item-total $r$ values for each participant, computing the arithmetic mean, and back-transforming mean $z_r$ values back into mean $r$ values. These transformations were necessary given the skewed sampling distribution of $r$ (Silver and Dunlap 1987).

Consistent differences in estimates of sex, age, size, and age of track among the participants was tested using JMP Statistical Discovery Software Version 9.0 (SAS). A chi-
square ($\chi^2$) analysis was conducted for sex estimates and a one-way analysis of variance (ANOVA) for age, size, and age of track estimates. A post-hoc Tukey-Kramer HSD test was conducted for age, size, and age of track estimates to determine significant differences between participant pairs.

To determine if group variability decreased over time, mean and standard deviation in age, size, and age of track estimates were calculated for each track, which was used as a proxy for time. All tracks were diagnosed and numbered in the order that data collection took place. To compare variability independent of the mean, coefficients of variation were calculated for age, size and age of track at each track. The relation between track and coefficients of variation in age, size, and age of track estimates were tested using linear regression.

**Accuracy Assessment of Sex and Size Estimates**

**Comparisons of Inuit sex estimates with expected, genetic and previous CMR sex estimates.** To determine genetic sex estimates, hair samples were collected along tracks that were observed at bear sampling stations erected between Cape Sydney and Gateshead Island, and along diagnosed tracks (encountered as outlined above) on an *ad hoc* basis in the same area from 11 – 15 May 2009. These samples were supplemented with samples previously collected in the same area from 1 – 14 May 2008, and around Cape Sydney from 2 – 18 May 2007 (Figure 1). Hair samples collected in 2009 were associated with estimates from participants 1 to 9, while supplementary samples collected in 2008 were associated with tracks diagnosed by participant 3, one additional hunter from Gjoa Haven (participant A) and one additional hunter from Taloyoak (participant B). Supplementary samples collected in 2007 were associated with tracks diagnosed by participants 1, 2, B, and two additional hunters from Gjoa Haven (participants C and D). All hair samples were stored frozen in collection tubes or zip lock bags before DNA extraction.
Hair samples were screened for the presence of sex-determining region-Y (SRY), the testis determining factor in males (Carmichael et al. 2005), as well as ZFX as an internal nuclear polymerase chain reaction (PCR) positive control (Taberlet 1993; Pagès et al. 2009). Samples were supplemented with 8 hair samples of known males as well as negative controls. To isolate genomic DNA from hair samples, the DNeasy Blood and Tissue Kit (QIAGEN, Valencia, USA; cat# 69506) was used in accordance with the manufacturer’s instructions. Conditions for PCR amplification of SRY were as follows: 1.0µL of template DNA, 1.0µL of 10X QIAGEN PCR buffer (Tris-HCl pH 8.7, KCl, (NH₄)SO₄, 1.5mM MgCl₂), 0.1µL of 10mM dNTPs, 0.1µL of 10µM forward primer, 0.1µL of 10µM reverse primer, 0.5µL of 1.0µM fluorescent M13 Forward (M13F) universal primer (Sequence: 5’-CACGACGTTGTAAAGCAGC-3’) (LI-COR Inc. M13F-700IRD cat#4200-20, M13F-800IRD cat#4000-20B), 0.15 µL of 0.5U Taq DNA polymerase, and 8.55µL of distilled water to a final reaction volume of 11.5µL. The same conditions were applied for PCR amplification of ZFX except for 0.05µL (instead of 0.15µL) of 0.5U Taq DNA polymerase and 8.65µL (instead of 8.55µL) of distilled water. Cycling parameters for PCR of SRY included a denaturing cycle of three minutes at 94°C followed by 35 cycles of 94°C for 15 seconds, annealing temperature of 65°C for 30 seconds, 72°C for 30 seconds and a final 7 minute extension at 72°C. Cycling parameters for PCR of ZFX were the same except for an annealing temperature of 55°C. PCR products were electrophoresed on a LI-COR 4200 Global IR² System™ (LI-COR Inc., Lincoln NB, USA). The resulting electrophoregrams were analyzed using Gene ImagIR™ 4.05 (Scanalytics Inc.) and ZFX and SRY amplicons were sized using 50-350bp size standard ladder (LI-COR cat#829-05343/4). The two sexing PCRs (for ZFX and SRY) for each sample were attempted 4 times. The amplicons of the two PCRs for each sample were combined prior to running on the LI-COR and all samples
showing the presence of the ZFX gene only were female, while samples that had both the upper ZFX and lower SRY bands were male. In 13 cases, there was some disagreement between replicate assays and the presence of SRY in at least three of the assays was designated male. All 8 samples belonging to known males were validated. On average 91.04% of the samples amplified for at least the ZFX gene. The lack of a ZFX band indicated that the PCR failed. For multiple hair samples at tracks, genetic sex estimates were determined by consensus based on majority rule.

Hierarchical $\chi^2$ analysis was conducted to determine if sex ratios of estimates provided by each of the 9 hunters (2009) differed significantly from an expected 1:1 male to female population ratio as well as heterogeneity among estimated sex ratios. 2x2 $\chi^2$ tests were conducted to determine if the sex ratio reported in the last CMR survey of this region completed in 1998-2000 (167 adult females to 117 adult males; Taylor et al. 2006) and sex ratios determined from genetically sexing hair samples (2007 to 2009) differed significantly from 1:1.

To test whether sex ratios of estimates from the Inuit hunters, last CMR survey (Taylor et al. 2006), and genetic analysis of hair samples were equivalent, 2x2 $\chi^2$ tests were conducted to compare sex ratios of estimates provided by each of the 9 hunters with the CMR sex ratio (Taylor et al. 2006) and the sex ratio of genetic sex estimates with the CMR sex ratio (Taylor et al. 2006). Sex diagnoses provided by participants 1 and 3, who participated in all three years, were also compared with genetic sex estimates by means of 2x2 $\chi^2$ tests. In addition, percent agreement between sex estimates (n=72) provided by Inuit hunters and the associated genetic sex estimates at tracks from 2007-2009 was calculated. To determine if the sex estimates were accurate more often than expected by chance, a binomial test was computed to determine whether percent agreement was significantly different from a random guess frequency of 50%.
Comparisons of hunter size estimates with stride length. In the absence of data comparing stride length and body length in polar bears, it is a useful first step to compare hunter estimates of size directly with gait measurements under the assumption that gait measurements are correlated with true body size (Heglund et al. 1974). Left-hind to left-hind measurements of stride were taken along tracks observed in 2009 as an indicator of true bear size. Gait measurements in feet were recorded by participants 4, 5, and 6, by random assignment, after they provided their estimates at tracks on flat terrain. Individual participant estimates of polar bear size were compared with mean gait measurements at associated tracks by calculating Pearson’s correlation coefficients for each participant using JMP Statistical Discovery Software (SAS) and a one-way analysis of covariance (ANCOVA) was conducted to determine whether correlations were significantly different among participants.

**Semi-Structured Interviews for Hunting and Tracking Techniques and Experience**

Permission to conduct interviews was obtained by the Nunavut Research Institute, Queen’s University General Research Ethics Board, and Gjoa Haven Hunters and Trappers Organization as well as individual consent by each participant through purpose (Appendix IIa) and consent forms (Appendix IIb) provided to them in English and Inuktitut. These forms detail the study’s objectives and methods, specify where raw data will be stored, and whether the participants will be acknowledged for their participation. Semi-structured interviews took place according to participant availability and convenience, ranging from 5 to 12 minutes depending on the detail of information provided by the participant and my ability to comprehend this information. Participants 1 to 4 were interviewed in the afternoon at camp in Cape Sydney before track observations began: 4 was interviewed on May 4th; 2 on May 5th; 1 and 3 on May 10th. Participants 5 to 8 were interviewed at camp on Gateshead Island around midnight: 5 on May
12th; 6 and 7 on May 13th; 8 on May 14th. Participant 9 was interviewed in the afternoon on May 12th on the sea ice around Gateshead Island during track observations. Each participant was interviewed in his tent without any other participant present except when translation was required.

Questions were posed in a conversation-like manner using simple language to ensure a mutual understanding of information that was being gathered (Huntington 2000; Usher 2000). Interview questions followed a guideline (Huntington 1998; Huntington 2000) however more questions were added to this guideline as the interview process progressed (Appendix III).

Interviews began with ice-breaker questions (ie. name, age, community) that were directive in order to simplify comparisons between hunters regarding their background and hunting experience (Huntington 2000). To ensure neutrality, subsequent questions regarding tracking methods were generalized so that they did not encourage the conversation in a leading way, and follow-up questions were posed as a reaction to allow hunters to produce their own understanding and thoughts (Huntington 1998; Huntington 2000; Rapley 2001) or to clarify information being provided (Huntington 2000). All interviews were audio-taped with a digital recorder and transcribed using Windows Media Player and Microsoft Word (Appendix IV) with the exception of participant 5. During his interview, the battery in the recorder malfunctioned and his responses were recorded by hand and recollection to the best of my ability.

Nonverbal cues and verbal styles were also documented, as detailed information on context can justify the interpretations made by the researcher (Baxter and Eyles 1997; Huntington 2000) and quotations can reveal how knowledge is expressed in a participant’s own words that were chosen to describe his experiences (Baxter and Eyles 1997; Rapley 2001). Accordingly, personal comments regarding my feelings, experiences and reflections during each
interview were noted and recorded in a journal following each interview. Additional information that was provided to me by the participants that I felt was relevant was also recorded. All participants appeared to be more comfortable answering similar questions posed casually through conversation outside of the interview when they were not being recorded; I recorded these data by hand as it was provided to me. All transcribed interviews and relevant data pertaining to tracking methods were then grouped based on what I recognized and interpreted as similar (Burnard 1991), and quotations and participants that I felt best represented these similarities were reported and or summarized.

Comparing Participant Background and Hunting Experience with Reliability and Accuracy in Diagnosing Tracks

To make inferences on the effect of participant background on potential biases in track diagnoses and ability to diagnose tracks, pair-wise Spearman’s rank correlation coefficients (ρ) were calculated between coded participant background criteria and criteria representing reliability and accuracy of track diagnoses using JMP Statistical Discovery Software (SAS). Corrected item-total correlations (for each of sex, age, size and age of track), percent agreement of sex diagnoses with genetic sex estimates and r for size estimates with gait measurements (n=9) were compared with participant background to initially describe relationships between participant background and reliability or accuracy of estimates from tracks. Five criteria were chosen to represent participant background and tracking experience using data collected from interviews: age, education, frequency of guiding polar bear hunts, preference for hunting alone or with a group, and the ability to make estimates of sex, age, size, and age of track by observing few footprints. Raw data on age and education were included in these analyses while data on frequency of guiding, preferences for hunting alone, and the ability to diagnose tracks from
observing few footprints were coded into categories. Frequency of guiding polar bear hunts was coded into three categories: 1 for “never guided”, 2 for “sometimes”, and 3 for “often”. Preferences for hunting alone were coded as “1” and preferences for hunting with a group were coded as “2”. The ability to diagnose tracks from observing few footprints were divided into three categories: 1 for “whole track”, 2 for “sometimes whole track, sometimes single footprint”, and 3 for “single footprint”. Data on age, education, preference for hunting alone or with a group, and the ability to make estimates by observing fewer footprints was not available for participant 5 due to the missing audio recording of this interview and my inability to recall this information.
Chapter 3: Results

Track Data Collection

A total of 99 tracks were encountered in M’Clintock Channel (Figure 1). 12 Tracks between Cape Sydney and Gateshead Island were observed by all participants except 2 and 3 on May 11th; these encounters were marked with orange flagging tag and observed by 2 and 3 on May 12th. 14 Tracks were observed by participants 1 and 9 on May 12th North of Gateshead Island. 25 Tracks were observed on May 13th North of Gateshead Island by all participants, 17 on May 14th South of Gateshead Island by all participants, and 31 on May 15th between Gateshead Island and Cape Sydney by all participants. Of the total 99 tracks observed, 78 were diagnosed with sex, age, size, and age of track by all 9 participants. There were no reports of “I don’t know”.

Figure 1. Track locations in M’Clintock Channel, Nunavut, Canada from 2007 to 2009. 19 Tracks were diagnosed by 3 hunters and 3 elders in 2007 and 27 tracks were diagnosed by 3 hunters and 4 non-Inuit in 2008. In 2009 (this study), a total of 99 tracks were encountered between Cape Sydney and Gateshead Island. Of these 99 tracks, 78 were diagnosed with sex, age, size, and age of track by all 9 participants.
Reliability of Sex, Age, Size and Age of Track Estimates

Preliminary data analysis based on box plots revealed outlying data points that appeared to highly skew the distribution of age of track estimates (Appendix Va). Since these outliers were generally associated with participant 5, all reliability assessments were made with and without participant 5 to examine his effect on group reliability. Based on Cronbach’s alpha, the group of 9 participants was reliable in making estimates of sex, age, and size and not reliable in making estimates of age of track (Table 1). However, with the exclusion of participant 5, estimates of age of track were reliable, while there was little change in reliability in estimates of sex, age, and size. Based on corrected-item total correlations, the group of 9 participants was consistent in making estimates of all four variables (Table 2). With the exclusion of participant 5, there was little overall change in consistency in estimates of sex, age, and size, however correlations of each participant with the group in estimates of age of track were generally higher.

In comparing individual estimates, ratios of sex estimates differed significantly across participants ($\chi^2=20.20$, df=8, $P=0.0096$; Figure 2). Mean individual estimates of age were also significantly different (one-way ANOVA, df=8, $r^2=0.40$, $F=58.95$, $P<<0.05$) with a post-hoc Tukey-Kramer HSD test indicating participants 3, 4, and 8 differed the most in estimates of age (Figure 3). Participant 3 made mean age estimates that appeared to be higher and more variable than the rest of the group, while participants 4 and 8 made mean age estimates that appeared to be lower than the rest of the group. Participants also differed significantly in estimates of size (Figure 4; one-way ANOVA, df=8, $r^2=0.15$, $F=15.60$, $P<<0.05$) and age of track with (Figure 5; one-way ANOVA, df=8, $r^2=0.07$, $F=6.45$, $P<<0.05$) and without participant 5 (Figure 6; one-way ANOVA, df=7, $r^2=0.07$, $F=6.37$, $P<<0.05$). Post-hoc Tukey-Kramer HSD tests indicated participants 4 and 8 differed the most in mean estimates of size (Figure 4), which appeared to be
lower than the rest of the group, and participant 5 differed the most in mean estimates of age of track (Figure 5) which appeared to be higher than the rest of the group. With the exclusion of participant 5, however, a post-hoc Tukey-Kramer HSD test revealed participant 9 differed the most in mean estimates of age of track (Figure 6), which appeared to be lower than the rest of the group.

Group mean estimates of age, size and age of track appeared to vary across tracks diagnosed in order by all participants (Appendix Vb). Relationships between coefficients of variation in age (Figure 6; $r^2=1.19\times10^{-5}$, df=76, $P=0.98$), size ($r^2=0.0025$, df=76, $P=0.66$) and age of track estimates with ($r^2=0.037$, df=76, $P=0.09$) and without participant 5 (Appendix VI; $r^2=0.0037$, df=76, $P=0.59$) and the sequence in which tracks were observed over the study were not significant, although in all cases the variation among observers appeared to decline with experience.
Table 1. Cronbach’s alpha ($\alpha$) for sex, age, size, and age of track estimates provided by the group of 9 hunters. The group of 9 hunters was reliable ($\alpha > 0.7$; Cortina 1993; Santos, 1999; Yu 2001) in making estimates of sex, age, and size and not reliable ($\alpha < 0.7$) in making estimates of age of track. With the exclusion of participant 5, the group of 8 hunters was reliable in making estimates of age of track ($\alpha = 0.85$) however there was little change in reliability for the other variables. Cronbach’s alpha with the exclusion of participant 5 is indicated in brackets.

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\alpha$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>0.74 (0.77)</td>
</tr>
<tr>
<td>Age</td>
<td>0.81 (0.79)</td>
</tr>
<tr>
<td>Size</td>
<td>0.91 (0.92)</td>
</tr>
<tr>
<td>Age of track</td>
<td>0.35 (0.85)</td>
</tr>
</tbody>
</table>


Table 2. Mean corrected item-total correlations ($r$) and individual participant corrected item-total $r$ for estimates of sex, age, size, and age of track. The group of 9 hunters was consistent (previously suggested mean corrected item-total $r > 0.40$; Gliem and Gliem 2003) in making estimates of all four variables. Participant 9 was most correlated with the rest of the group in making estimates of sex, while participant 5 was least correlated. Participant 7 was most correlated with the rest of the group in making estimates of age, while participant 4 was the least correlated. Participant 2 was the most correlated with the rest of the group in making estimates of size, while participant 5 was the least correlated. Participant 7 was the most correlated with the rest of the group in making estimates of age of track, while participant 8 was the least correlated; this pattern remained with the exclusion of participant 5. There was little overall change in individual and mean corrected item-total $r$ for sex, age, and size with the exclusion of participant 5, however the group of 8 hunters was more consistent in making estimates of age of track (mean corrected item-total $r = 0.63$) with his exclusion. Corrected item-total $r$ for age of track estimates excluding participant 5 are shown in brackets.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Corrected item-total Pearson product-moment correlation coefficient ($r$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sex</td>
</tr>
<tr>
<td>1</td>
<td>0.37 (0.35)</td>
</tr>
<tr>
<td>2</td>
<td>0.60 (0.60)</td>
</tr>
<tr>
<td>3</td>
<td>0.62 (0.65)</td>
</tr>
<tr>
<td>4</td>
<td>0.41 (0.44)</td>
</tr>
<tr>
<td>5</td>
<td>0.11</td>
</tr>
<tr>
<td>6</td>
<td>0.62 (0.61)</td>
</tr>
<tr>
<td>7</td>
<td>0.33 (0.35)</td>
</tr>
<tr>
<td>8</td>
<td>0.16 (0.19)</td>
</tr>
<tr>
<td>9</td>
<td>0.64 (0.62)</td>
</tr>
<tr>
<td>Mean</td>
<td>0.45 (0.49)</td>
</tr>
</tbody>
</table>
Figure 2. Chi-square analysis comparing sex estimates across the 9 hunters. Proportions of sex estimates varied significantly across participants ($\chi^2=20.20$, df=8, $P=0.0096$).

Figure 3. One-way ANOVA and post-hoc Tukey-Kramer HSD test comparing age estimates across the 9 hunters. Mean estimates of age were significantly different across the 9 hunters (one-way ANOVA, df=8, $r^2=0.40$, $F=58.95$, $P<<0.05$). A post-hoc Tukey-Kramer HSD test revealed participants 3, 4 and 8 made estimates with the most significant differences with the other participants ($P<<0.05$). Participants that are not denoted with the same letter are significantly different.
Figure 4. One-way ANOVA and post-hoc Tukey-Kramer HSD test comparing size estimates across the 9 hunters. Mean estimates of size were significantly different across the 9 hunters (one-way ANOVA, df=8, r²=0.15, F=15.60, P<<0.05). A post-hoc Tukey-Kramer HSD test revealed participants 4 and 8 made estimates of size with the most significant differences with the other participants (P<0.05). Participants that are not denoted with the same letter are significantly different.
Figure 5a. One-way ANOVA and post-hoc Tukey-Kramer HSD test comparing age of track estimates across the 9 hunters. Mean estimates of age of track were significantly different across the 9 hunters (one-way ANOVA, df=8, \( r^2=0.07, F=6.45, P<<0.05 \)). A post-hoc Tukey-Kramer HSD test revealed participant 5 made age of track estimates that were significantly different with the other participants (\( P<<0.05 \)). Participants that are not denoted with the same letter are significantly different.
Figure 5b. One-way ANOVA and post-hoc Tukey-Kramer HSD test comparing age of track estimates across the hunters with the exclusion of participant 5. Mean estimates of age of track were significantly different across the 8 hunters (one-way ANOVA, df=8, $r^2=0.07$, F=6.37, P<<0.05). A post-hoc Tukey-Kramer HSD test revealed participant 9 made estimates of age of track with the most significant differences with the rest of the group (P<0.05). Participants that are not denoted with the same letter are significantly different.

Figure 6. Linear regression analyses of coefficients of variation for age, size, and age of track diagnoses made by 9 hunters across 78 tracks (diagnosed in order). Relationships between track and coefficients of variation in a) age ($r^2=0.016$, df=76, P=0.27), b) size ($r^2=0.0032$, df=76, P=0.62) and c) age of track ($r^2=0.037$, df=76, P=0.09) estimates were not significant. With the exclusion of participant 5, the relationship between track and coefficients of variation in age of track estimates were still not significant (Appendix IV; $r^2=0.0037$, df=76, P=0.59).
Comparisons of Sex and Size Estimates with External Validity Criteria

A total of 22 hair samples were associated with 7 tracks diagnosed with sex in 2009, while 8 hair samples were associated with 2 tracks diagnosed with sex in 2008 and 23 hair samples were associated with 10 tracks diagnosed with sex in 2007 (Appendix VII). 11 Tracks diagnosed with sex were associated with multiple hair samples. Sex estimates were made by some or all of the participants who participated that year. All hair samples associated with hunter estimates of sex were collected at bear sampling stations except for 5 samples in 2007 that were collected along 2 tracks.

At a coarser level, heterogeneity among proportions of sex ratios across participants was significant ($\chi^2=21.27$, df=8, $P=0.0065$). Sex ratios of estimates from tracks provided by participants 2, 3, 4, and 6 differed significantly from an expected 1:1 male to female ratio, while sex ratios of estimates provided by participants 1, 5, 7, 8 and 9 were not significantly different from this 1:1 ratio (Table 3a). The sex ratio reported in the last CMR of this region (117 males to 167 females; Taylor et al. 2006) was significantly different from 1:1 ($\chi^2=4.44$, df=1, $P=0.04$) however the sex ratio of genetic sex estimates (11 males to 8 females) was not significantly different ($\chi^2=0.47$, df=1, $P=0.49$).

The sex ratios of individual estimates provided by all 9 participants (2009) were significantly different from the CMR sex ratio (Taylor et al. 2006) (Table 3b), however the sex ratio of genetic sex estimates was not significantly different from the CMR sex ratio (Taylor et al. 2006; $\chi^2=2.04$, df=1, $P=0.15$). The sex ratio of diagnoses provided by participants 1 (9 males to 3 females) and 3 (11 males to 2 females), who diagnosed tracks from 2007-2009, was not significantly different from the sex ratio of genetic sex estimates for the tracks compared ($\chi^2=0.94$, df=1, $P=0.33$ and $\chi^2=2.57$, df=1, n=13, $P=0.11$ respectively). Participants from
2007-2009 made individual estimates of sex that showed a mean agreement of 65.28% with associated genetic sex estimates (Appendix VIIb), which was significantly different from the random guess frequency of 50% (n=72, P=0.013).

In assessing accuracy of size estimates, a total of 9 sets of 6 left-hind to left-hind measurements of stride length were associated with tracks diagnosed with size by participants 1 to 9. Overall correlations were not significantly different across participants (one-way ANCOVA, df=8, F=0.46, P=0.88). Participants 1 (r=0.67, n=9, P=0.050), 2 (r=0.78, n=9, P=0.014) and 7 (r=0.69, n=9, P=0.038) provided size estimates that showed the highest correlations with mean stride length, which were significant (Table 4). All other participant estimates of size, except participant 8 (r=0.01, n=9, P=0.98), appeared to be associated with mean stride length however these relations were not significant.
Table 3a. 2x2 Chi-square tests comparing sex ratios of estimates (across 78 tracks) provided by each participant with an expected 1:1 male to female ratio in a population. Significance is indicated in bold.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Sex ratio (M:F)</th>
<th>$\chi^2$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>49:29</td>
<td>2.61</td>
<td>0.11</td>
</tr>
<tr>
<td>2</td>
<td>56:22</td>
<td>7.78</td>
<td><strong>0.0053</strong></td>
</tr>
<tr>
<td>3</td>
<td>53:25</td>
<td>5.19</td>
<td><strong>0.020</strong></td>
</tr>
<tr>
<td>4</td>
<td>65:13</td>
<td>19.50</td>
<td><strong>0.00010</strong></td>
</tr>
<tr>
<td>5</td>
<td>43:35</td>
<td>0.41</td>
<td>0.52</td>
</tr>
<tr>
<td>6</td>
<td>57:21</td>
<td>8.78</td>
<td><strong>0.0031</strong></td>
</tr>
<tr>
<td>7</td>
<td>48:30</td>
<td>2.11</td>
<td>0.15</td>
</tr>
<tr>
<td>8</td>
<td>47:31</td>
<td>1.66</td>
<td>0.20</td>
</tr>
<tr>
<td>9</td>
<td>49:29</td>
<td>2.61</td>
<td>0.11</td>
</tr>
</tbody>
</table>
Table 3b. 2x2 Chi-square tests comparing sex ratios of estimates (across 78 tracks) provided by each participant with the reported sex ratio of 167 females to 117 males reported in the last CMR survey of this region completed in 1998-2000 (Taylor et al. 2006).

<table>
<thead>
<tr>
<th>Participant</th>
<th>Sex ratio (M:F)</th>
<th>$\chi^2$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>49:29</td>
<td>11.52</td>
<td>0.0007</td>
</tr>
<tr>
<td>2</td>
<td>56:22</td>
<td>22.96</td>
<td>0.0001</td>
</tr>
<tr>
<td>3</td>
<td>53:25</td>
<td>17.58</td>
<td>0.0001</td>
</tr>
<tr>
<td>4</td>
<td>65:13</td>
<td>43.46</td>
<td>0.0001</td>
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<tr>
<td>5</td>
<td>43:35</td>
<td>4.82</td>
<td>0.0282</td>
</tr>
<tr>
<td>6</td>
<td>57:21</td>
<td>24.91</td>
<td>0.0001</td>
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<tr>
<td>7</td>
<td>48:30</td>
<td>10.21</td>
<td>0.0014</td>
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<tr>
<td>8</td>
<td>47:31</td>
<td>8.97</td>
<td>0.0027</td>
</tr>
<tr>
<td>9</td>
<td>49:29</td>
<td>11.52</td>
<td>0.0007</td>
</tr>
</tbody>
</table>
Table 4. Pearson correlation coefficients (r) between estimates of size and mean stride length measurements across 9 tracks for all 9 participants. Participants 1, 2, and 7 made estimates of size with the highest correlations with mean stride length, which were significant (indicated in bold). All other participant estimates of size did not show significant correlations with mean stride length. Correlations must be regarded with caution as only 9 tracks observed by all 9 hunters were associated with gait measurements.

<table>
<thead>
<tr>
<th>Participant</th>
<th>r</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.67</td>
<td>0.05</td>
</tr>
<tr>
<td>2</td>
<td>0.78</td>
<td>0.01</td>
</tr>
<tr>
<td>3</td>
<td>0.54</td>
<td>0.13</td>
</tr>
<tr>
<td>4</td>
<td>0.63</td>
<td>0.07</td>
</tr>
<tr>
<td>5</td>
<td>0.65</td>
<td>0.06</td>
</tr>
<tr>
<td>6</td>
<td>0.31</td>
<td>0.41</td>
</tr>
<tr>
<td>7</td>
<td>0.69</td>
<td>0.04</td>
</tr>
<tr>
<td>8</td>
<td>0.01</td>
<td>0.98</td>
</tr>
<tr>
<td>9</td>
<td>0.56</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Semi-Structured Interviews for Participant Background, Hunting Experience and Techniques

Participant background. The participants varied in their age, level of education, place of birth, and whether or not they had ever served as a professional guide for polar bear hunts (Table 5). Participants 1 and 3 are well-known professional hunters and guides in Gjoa Haven according to non-participant community members and researchers. Participants 2 and 3 both informed me that they are certified Canadian Rangers as part of the Canadian Forces Reserve (Canada 2010), and their occupation as professional hunters has been recognized by other researchers. Participant 7 informed me of his previous participation on polar bear denning surveys with other researchers and his professional occupation as a guide for polar bear hunts.
The participants also varied in who they learned their hunting and tracking skills from, whether they preferred to make estimates of bear characteristics based on a single footprint or a track, and their reasons for hunting. Participants 1 and 7 indicated that they hunt for monetary income through guiding. All participants except participant 5 mentioned that they hunt for food or food for the family. All participants also indicated that they participate on polar bear hunts with similar frequency except participant 5, who rarely participates, and participant 8, who does not participate annually. It is assumed that all participants interpreted the questions regarding these hunting trips as being restricted to polar bear.

In addition, the participants varied in whether they preferred to hunt alone or with a group. Participants 1 to 4 generally preferred to hunt alone. Participant 1 and 3 appeared to be very confident about hunting alone:

- “I learn it from the hunters first eh?.. I go after that, when I learn like I got enough learning eh?..And I just, I go hunt all by myself…I like to go all by myself now” (Participant 1, May 10\textsuperscript{th})
- “Most of the time, maybe when I go out, most of the time by myself or my boys [sons]” (Participant 3, May 10\textsuperscript{th})

Participant 7 indicated that he can hunt alone but also prefers to “have somebody around” (Participant 7, May 13\textsuperscript{th}). In contrast, participants 6 to 9 generally prefer to hunt in groups. Participants 8 and 9 indicated that they used to hunt alone but hunt in groups as well:

- “…Yeah he go with other hunters too” (Participant 1 translating for participant 8, May 14\textsuperscript{th})
- “He used to go hunt by himself but now is uh, he is old now, he go…He go hunt, and he go far, and then he go with somebody else” (Participant 1 translating for participant 9, May 12\textsuperscript{th})
Table 5. Summary of participant background. Participants varied in their age, level of education, place of birth, frequency in guiding hunts, who they learned how to hunt from, and their reasons for hunting. Data for participant 5 was based on notes recorded in my journal during the interview and my recollection. Variables denoted with an asterisk (*) were included in subsequent comparisons between participant background and reliability and accuracy in estimates.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age</th>
<th>Highest education level</th>
<th>Place of birth</th>
<th>Frequency in guiding hunts</th>
<th>Able to hunt alone</th>
<th>Who hunters learned how to hunt from</th>
<th>Reasons for hunting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>63</td>
<td>Grade 5</td>
<td>Mainland</td>
<td>Often</td>
<td>Yes</td>
<td>Hunters</td>
<td>Food, Fur, Money</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>Grade 6</td>
<td>Community</td>
<td>Occasional</td>
<td>Yes</td>
<td>Elders, Father, Brother, Grandfather</td>
<td>Food</td>
</tr>
<tr>
<td>3</td>
<td>51</td>
<td>Grade 5</td>
<td>Community</td>
<td>Often</td>
<td>Yes</td>
<td>Elders, Father, Grandfather, Uncle</td>
<td>Food, Enjoyment</td>
</tr>
<tr>
<td>4</td>
<td>32</td>
<td>Grade 7</td>
<td>City</td>
<td>Infrequent</td>
<td>Yes</td>
<td>Elders</td>
<td>Food</td>
</tr>
<tr>
<td>5</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
<td>Never</td>
<td>No data</td>
<td>Hunters</td>
<td>No data</td>
</tr>
<tr>
<td>6</td>
<td>23</td>
<td>Grade 9</td>
<td>City</td>
<td>Never</td>
<td>No</td>
<td>Participant 7</td>
<td>Food, Enjoyment</td>
</tr>
<tr>
<td>7</td>
<td>35</td>
<td>Grade 9</td>
<td>Community</td>
<td>Often</td>
<td>Yes</td>
<td>Elders, Hunters, Father</td>
<td>Food, Fur, Money, Enjoyment</td>
</tr>
</tbody>
</table>
Table 5 cont’d.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Never attended school</th>
<th>Mainland</th>
<th>Infrequent</th>
<th>No</th>
<th>Hunters</th>
<th>Food</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>71</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Father</td>
<td>Food</td>
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<tr>
<td>9</td>
<td>67</td>
<td>Never attended school</td>
<td></td>
<td>Infrequent</td>
<td>No</td>
<td>Hunters</td>
<td>Food</td>
</tr>
</tbody>
</table>

*Variables compared with criteria for biases in estimates and ability to diagnose tracks.*
Making estimates of polar bear sex, age, size and age of track from tracks. The group of participants indicated that they use cues in making estimates of sex, age, size, and age of track from tracks, which appear to be common among the participants (Table 6).

Techniques for identifying sex. Estimates of sex are generally determined by observing the footprint orientation, size, and shape. Regarding footprint orientation, the participants indicated that male footprints appear to be more oriented toward the center than female footprints (Figure 7):

- “The heel, and they’re a bit turned. I don’t know how to say, they’re turned…they’re more turned than females. That’s what I know.” (Participant 4)
- “Sometimes, by their walking too? And the way that it’s moving- a little bit different from a female and a male.” (Participant 1, May 10th)
- “Well it’s the way they walk.” (Participant 7, May 13th)

Participant 2 indicated after his interview that footprints of adult males are “turned in” because their [shoulder] muscles are more developed, while young males and female footprints are less “turned in”. The participants also indicated that “males’ footprints are larger than females’” (Participant 2, May 5th), and often used hand motions or simple diagrams in the snow to describe differences in male and female heel shape (Figure 8):

- “The female palms are a little more curved.” (Participant 6, May 14th)
- “The female is a lot more rounded. And the male is a lot straighter.” (Participant 7, May 13th)
- “Those females is uh, long printing.. and uh narrow..and kind of long…and those uh, males are kind of round and wide…And uh males are round and uh, wider and those uh, what you call this (heel of hand)...yeah pad is wider and bigger” (Participant 1 translating for participant 8, May 14th)
- “And the female track and male track is different. And he said it’s a different – those toes are narrow – and males are wider” (Participant 1 translating for participant 9, May 12th)

Participant 1 indicated that the presence of accompanying tracks can be used to identify sex as well as age:

- “…Female only by herself is about uh, 5, 6 years old. Something like that…and a young male too. Same thing.” (Participant 1, May 10th)
In addition, participants 1 and 2 indicated that they often verify the sex of bears after they are hunted, while participants 8 and 9 often verify the sex of bears from other hunters after they hunt them.

**Techniques for identifying age.** Age estimates are generally dependent on footprint size, footprint shape, or sex of the bear. All participants except participant 5 indicated that footprint or track size differed with the age of bears, where larger tracks were usually associated with older bears:

- “When they make 2 foot that means uh, old male. If you put your 2 foot like that, and when you test the same size, then that’s a, old...But theyre’ll always be small small small...but that’s a- a young male eh?” (Participant 1, May 10th)
- “You can kind of tell from how big the track is...um, I guess...like, how, maybe the weight of the bear” (Participant 3, May 10th)
- “By the size of the track” (Participants 6 and 7, May 13th)
- “In some cases they are, there are some bigger bears that are not so old.” (Participant 7, May 13th)
- “Small ones are small track, uh younger...and those uh, smaller cubs are way way small...Those uh, males, uh big ones.” (Participant 1 translating for participant 8, May 14th)

Participant 3 indicated that he infers weight of the bear from depth of tracks in the snow, from which he identifies age of the bear.

- “…By the tracks...you can kind of tell from how big the track is...maybe the weight of the bear...depends on the snow I guess. How deep it is…” (Participant 3, May 10th)

Some participants mentioned footprint shape as a cue to identify age:

- “Grown up, grown up bears are um, tracks or footprints are more round.” (Participant 2, May 5th)
In addition, participants indicated that young males and female bears leave similar tracks in the snow:

- “And uh, young males’, um prints are little bit – almost same size as a female but they’re more narrower” (Participant 2, May 5th)

Techniques of identifying size. All participants indicated that they diagnosed estimates of size by examining the size of the footprint, except participant 5:

- “I know it like footprinting, and uh, that’s the one I know and could know, not this one, this too small” (Participant 1 using my feet as an example, May 10th)
- “The big one is say, about 4 length to 9 feet, and females say, they go up to 8 feet, bigger ones, biggest female, 8 feet some of them.” (Participant 2, May 5th)

Techniques for identifying age of track. Participants indicated that estimates of age of track are made by observing weather and snow conditions or the hardness and softness of a footprint:

- “Depends on how the weather is. Maybe it was a blizzard that day, or the weather was nice, and just kind of tell from the weather, like it was snowing, it’s covered little bit, you can kind of tell how many days or how long it’s been there.” (Participant 3, May 10th)
- “I don’t know, depending on the weather conditions, they change. They change from blowing snow sometimes. Hard to tell…I can only know by uh, what the weather is I guess? I mean, well if it storms, they tend to look old…” (Participant 4, May 4th)
- “From the snow blowing in.” (Participant 6, May 13th)
- “Well usually pay attention to the weather, and you know, wind and stuff. If the tracks are too covered than it’s a little older track… and then the snow dragging on top, then you’ll know – you know it’s fresh.” (Participant 7, May 13th)

Footprints that were soft to touch are generally identified as fresh, whereas harder tracks are identified as old:

- “He said he know when the track, and he could touch it with a finger, when it soft he know it’s a fresh. When it hard it’s a today or last night or something like that. When it’s snowing, after snow, what day when it’s snowing, when they on top of the snow, fresh snow, and he know it really fresh. I already tell you all that. He said when they printing
down and track, and he touch it with the finger he know by hard or soft, and when it soft it really fresh…and uh, when he saw a bear, and it’s gonna be hard from yesterday or last night. When they tracking it, when it laying down first or after overnight it could be fresh track.” (Participant 1 translating for participant 9, May 1\textsuperscript{2}th)

- Participant 5 touches snow and “see days come by, weather, know[s] when snow was there last and make[s] [him] think of when track was there”
- “On a nice day, you can tell it’s not too long ago. Even when there’s drifting snow you can test it with your hand, see if the footprints are hard or soft. Harder means longer and um, soft means just a few hours ago or something.” (Participant 2, May 5\textsuperscript{th})
- “He know it from the weather…every day every night they change…uh, when they really fresh and uh, uh track is soft…And uh, from yesterday it’s uh, could be hard…Older is a harder.” (Participant 8, May 14\textsuperscript{th})
Table 6. Summary of criteria used by different hunters to diagnose sex, age, size and age of track from polar bear tracks. OF = orientation of footprints, FS = footprint size, FSh = footprint shape, AT = accompanying tracks, ES = estimated sex, SD = snow depth, W = weather conditions and Sn = snow conditions. Method refers to whether hunters diagnosed 1-2 footprints (S) or looked at number of footprints (a track, M), data which were subsequently included in comparisons between tracking experience and reliability and accuracy. Participants 1 and 3 identified cues that were not mentioned by the other participants, indicated by an asterisk (*). Data for participant 5 was based on notes recorded in my journal during the interview and my recollection.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hunter 1</th>
<th>Hunter 2</th>
<th>Hunter 3</th>
<th>Hunter 4</th>
<th>Hunter 5</th>
<th>Hunter 6</th>
<th>Hunter 7</th>
<th>Hunter 8</th>
<th>Hunter 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>OF, AT*</td>
<td>OF, FS</td>
<td>No data</td>
<td>OF, FS, FSh</td>
<td>No data</td>
<td>OF, FSh</td>
<td>OF, FSh</td>
<td>OF, FSh</td>
<td>FS, FSh</td>
</tr>
<tr>
<td>Age</td>
<td>FS, ES, AT*</td>
<td>FS, FSh, SD*</td>
<td>FS, ES</td>
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<td>FS</td>
<td>FS</td>
<td>FS</td>
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<td>FS</td>
</tr>
<tr>
<td>Size</td>
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<td>FS</td>
<td>FS</td>
<td>FS</td>
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<td>FS</td>
</tr>
<tr>
<td>Age of track</td>
<td>W, Sn</td>
<td>W, Sn</td>
<td>W, Sn</td>
<td>W</td>
<td>W, Sn</td>
<td>Sn</td>
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<td>M</td>
<td>M</td>
<td>S</td>
<td>S, M</td>
</tr>
</tbody>
</table>

*Cues not mentioned by other participants.*
Figure 8. A depicted example of hypothetical differences in walking pattern and footprint orientation used to distinguish a) male and b) female tracks. Left feet are shown in grey and right feet are shown in black. Travel direction is upward, where the uppermost point of each triangle represents the front of each foot. Male tracks are oriented toward the center, while female tracks are oriented in a straight line.
Figure 9. An example of differences in heel shape used to diagnose an a) male and b) female footprint. Male footprints are wider and rounder while female footprints are longer and narrower.

**Comparisons of Participant Background and Hunting Experience with Track Estimates and Ability to Diagnose Tracks**

Comparisons between participant background (age, education, categorized frequency of guiding polar bear hunts, categorized preference for hunting alone or with a group, and categorized ability to make estimates of by observing few footprints) with reliability (corrected item-total $r$ for sex, age, size, and age of track) and accuracy (percent agreement of sex estimates with genetic sex estimates and $r$ of size estimates with gait measurements) in diagnosing tracks must be interpreted with caution due to small numbers of categories within each of the qualitative criteria and the limited sample size of hunters. Education was correlated with corrected item-total correlations in age of track estimates (Table 7; $\rho=0.74$, $n=8$, $P=0.04$).

Interestingly, the ability to diagnose tracks by observing few footprints correlated with percent agreement of sex diagnoses and genetic sex estimates ($\rho=0.86$, $n=8$, $P=0.01$) and number of accompanying hunters preferred with each hunt correlated negatively with correlations between size estimates and mean gait measurements ($\rho=-0.73$, $n=8$, $P=0.04$). Frequency in guiding polar
bear hunts also appeared to correlate with corrected item-total $r$ for age and size estimates as well as $r$ between size estimates and mean stride length, however these relationships were not significant.
Table 7. Pair-wise Spearman’s rank correlation coefficients (ρ) between participant background and tracking experience and criteria measures for reliability (corrected item-total correlation coefficients (r) for sex, age, size, and age of track estimates across 78 tracks diagnosed by all 9 participants) and accuracy (percent agreement of sex diagnoses with genetic sex estimates and correlation coefficients for size estimates and mean stride length measurements from 9 tracks). Age and education was based on raw data, while frequency of guiding was coded into three categories (1 = never guided, 2 = sometimes, 3 = often), frequency of accompanying hunters preferred was coded into two categories (1 = prefer to hunt alone, 2 = prefer to hunt in a group), and the ability to diagnose tracks from few footprints was coded into three categories (1 = whole track, 2 = sometimes whole track, sometimes single footprint, 3 = single footprint). P-values are indicated in brackets. Significance is indicated in bold. Correlations must be regarded with caution as data were only available for 9 participants for frequency of guiding and reliability and accuracy criteria, and 8 participants (excluding participant 5, indicated by an asterisk (*)) for participant age, education, frequency of accompanying hunters preferred, and ability to diagnose tracks based on few footprints.

<table>
<thead>
<tr>
<th></th>
<th>Frequency of Guiding</th>
<th>Age</th>
<th>Education</th>
<th>Frequency of accompanying hunters preferred</th>
<th>Ability to diagnose tracks from few footprints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item-total r (sex)</td>
<td>0.06</td>
<td>-0.12</td>
<td>-0.11</td>
<td>0.17</td>
<td>-0.19</td>
</tr>
<tr>
<td></td>
<td>(0.89)</td>
<td>(0.78)</td>
<td>(0.80)</td>
<td>(0.69)</td>
<td>(0.65)</td>
</tr>
<tr>
<td>Item-total r (age)</td>
<td>0.45</td>
<td>0.48</td>
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<td>0.06</td>
</tr>
<tr>
<td></td>
<td>(0.23)</td>
<td>(0.23)</td>
<td>(0.54)</td>
<td>(0.69)</td>
<td>(0.88)</td>
</tr>
<tr>
<td>Item-total r (size)</td>
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<td>-0.17</td>
<td>-0.28</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>(0.17)</td>
<td>(0.46)</td>
<td>(0.69)</td>
<td>(0.50)</td>
<td>(0.44)</td>
</tr>
<tr>
<td>Item-total r (age of track)</td>
<td>0.15</td>
<td>-0.60</td>
<td><strong>0.74</strong></td>
<td>-0.17</td>
<td>-0.38</td>
</tr>
<tr>
<td></td>
<td>(0.70)</td>
<td>(0.12)</td>
<td><strong>(0.04)</strong></td>
<td>(0.69)</td>
<td>(0.36)</td>
</tr>
<tr>
<td>Percent agreement (sex diagnoses with genetic sex estimates)</td>
<td>0.13</td>
<td>0.66</td>
<td>-0.52</td>
<td>-0.23</td>
<td><strong>0.86</strong></td>
</tr>
<tr>
<td></td>
<td>(0.73)</td>
<td>(0.07)</td>
<td>(0.19)</td>
<td>(0.59)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>r (size estimates and mean stride length)</td>
<td>0.50</td>
<td>-0.24</td>
<td>0.35</td>
<td><strong>-0.73</strong></td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>(0.17)</td>
<td>(0.57)</td>
<td>(0.39)</td>
<td><strong>(0.04)</strong></td>
<td>(0.88)</td>
</tr>
</tbody>
</table>

* Data available only for 8 hunters (participants 1, 2, 3, 4, 6, 7, 8 and 9).
Chapter 4: Discussion

Summary

As a group, the 9 hunters were reliable and consistent in providing estimates of sex, age, and size based on in situ track observations (Objective Ia). Although the group was consistent in making age of track estimates, the group was not reliable in these diagnoses. However, when a single participant (participant 5) was excluded, the group became both consistent and reliable. Estimates differed significantly for all four variables (Objective Ib), however overall group variability in estimates of age, size, and age of track did not decrease with track diagnoses over time (Objective Ic). Although the 9 hunters varied in whether the sex ratios they estimated differed significantly from an expected 1:1 population ratio, the sex ratios of estimates by all 9 hunters differed significantly from the sex ratio reported in the last CMR survey of this region (Taylor et al. 2006) (Objective IIa). On the other hand, hunter diagnoses of sex from 2007-2009 tracks agreed on average 65.28% with the associated genetic sex estimates. Specific to the 9 hunters forming part of my study, size estimates from tracks appeared to correlate with mean stride length measurements, however significance was only observed for 3 hunters (Objective IIb). Small sample size precluded any meaningful conclusions for accuracy assessments for size. Individual interviews with each hunter revealed that they varied in their background and hunting experience but used similar cues in identifying polar bear sex, age, size and age of track from tracks (Objective III). Differences in individual hunting and tracking experience may explain the observed differences in estimates as well as reliability and accuracy of diagnoses by this group however these comparisons must be regarded with caution due to small sample size (Objective IV). The implications of these results are discussed below.
Reliability of Inuit Hunters in Making Estimates of Polar Bear Characteristics from Tracks

(Objective I)

The generally high reliability ($\alpha > 0.7$; Cortina 1993; Santos, 1999; Yu 2001) and consistency (mean corrected item-total $r > 0.40$; Clark and Watson 1995; Streiner 2006) coupled with no change in group variability over time in making estimates of polar bear characteristics from tracks suggest Inuit hunters can play a role in future polar bear activity surveys. Specifically, $\alpha$ for sex, age, and size estimates provided by the group of hunters exceeded 0.8, which is a suggested target in developing a reliable scale for measurement (Gliem and Gliem 2003). Coupled with mean corrected item-total correlation coefficients exceeding 0.4 (Gliem and Gliem 2003), these data indicate that the group of hunters is reliable in diagnosing tracks for these characteristics. It is expected that a group of hunters with shared knowledge and experience in tracking would make estimates from tracks that are in high agreement. These initial data suggest that active hunters from any Arctic community will provide reliable sex, age, size, and age of track diagnoses from tracks, which contributes to making a tracking-based component of any noninvasive survey of polar bears practical.

It must be noted that only with the exclusion of one participant (participant 5) did the group become reliable in age of track estimates; reliability was unacceptably low ($\alpha < 0.7$; Cortina 1993; Santos, 1999; Yu 2001) with his inclusion. While group sex, age, and size estimates were still reliable, estimates of these variables provided by participant 5 were generally less correlated with the rest of the group than estimates provided by the rest of the participants. In some cases, low reliability can result from random guessing (Yu 2001) and individual participants must be re-examined or removed in order to increase reliability (Peterson 1994; Santos 1999). On the other hand, including variation in track estimates can increase reliability (Clark and Watson
1995) and interviews with hunters of varying experience may allow for new themes to emerge (Fazey et al. 2006) and a broader understanding (Baxter and Eyles 1997) of Inuit knowledge of polar bear tracks. Introducing this variability through discussion among participants can allow the group to identify and resolve any differences in their estimates and tracking methods, as well as clarify instances where personal hunting experiences may not be relevant (Fazey et al. 2006). Although this research was limited to reliability assessment of individual Inuit estimates without discussion among the group, previous studies allowing hunters to discuss their track observations indicate that collective information can be highly accurate (Stander et al. 1997).

It is possible that participant 5 may have been accurate and that polar bear tracks in the snow may still be detectable after the long periods (Amstrup et al. 2006) reported by him, however personal observations and his limited ability to provide answers during his interview suggest he is not as experienced in hunting and tracking as the other hunters. Participant 5 provided irrelevant information throughout his interview and it was unclear whether the information that he provided was restricted to polar bear hunting and tracking. Multiple follow-up questions did not offer clarification (Huntington 2000), which led me to abandon most of the topics. Contacting this participant to gather missing information might validate these interpretations (Huntington 1998; Furgal et al. 2002; Noongwook et al. 2007), but such an exchange would occur out of context, leading to potential misrepresentation (Stevenson 1996; Wenzel 1999; Usher 2000). Unfortunately, the lack of audio recording and data from the interview with participant 5 limits a thorough report of his background and experience. Similar observations from future interviews with Inuit hunters may identify the less experienced participants who will decrease group reliability and potentially accuracy in diagnosing specific track variables and detailed documentations of these data will be necessary.
Preliminary Accuracy Assessments of Inuit Estimates of Polar Bear Sex and Size from Tracks

(Objective II)

The sex ratios estimated by all 9 hunters differed significantly from the CMR sex ratio (Taylor et al. 2006), which may be explained by i) the general inaccuracy of Inuit sex diagnoses, ii) the small geographical range of tracks diagnosed by the hunters compared to the range covered in the CMR survey (Taylor et al. 2006), or iii) change in the M’Clintock Channel polar bear population over the last 6 to 9 years as a moratorium was placed on harvesting this population since 2001 (Aars et al. 2006). However, it is probable that the small range of this study and potential for the M’Clintock Channel population surveyed in 1998-2000 to be different from the contemporary population together explain the different sex ratios reported by these Inuit hunters compared to that reported in the CMR. My data suggest that Inuit are not only reliable ($\alpha=0.74$) and consistent (mean corrected item-total $r=0.45$) in sex diagnoses, but also on average more accurate (mean accuracy of 65.28%) than by random chance in diagnosing sex. This estimate of accuracy must be regarded as initial data from individuals that provided a small sample of sex diagnoses with associated genetic estimates (Appendix VII). A larger sample size can improve this initial accuracy assessment.

The sampling effort required for a valid estimate of accuracy of Inuit hunters is warranted given the high reliability and suggestive accuracy based on small samples reported here. It is important to note that the majority of track-tissue pairs available for accuracy assessments are associated with sampling stations that collect hair snags from bears. A larger sample of tracks with associated tissue samples from both sampling stations and tracks encountered *ad hoc* on the sea ice will be required to ensure accurate diagnoses. Tracks with obviously different probabilities of accurate evaluation should be excluded – for example, excluding tracks
belonging to females and their associated cubs and large tracks belonging to adult males to ensure accurate identification of sub-adult males and females. Further PCR optimization of the polar bear SRY gene will minimize the misclassification of males owing to the purported amplification of an SRY which may be the amplification of SRY-related autosomal genes (Taberlet et al. 1993). Genetic sexing of polar bear hair samples is still relatively recent (Pagès et al. 2009), and optimizing genetic sexing techniques using faecal and blood samples collected on an ad hoc basis will increase the number of samples of tissue associated with track diagnoses, which will allow a thorough evaluation of accuracy in Inuit sex estimates (Van Coeverden de Groot et al. 2008).

As with accuracy assessments of sex diagnoses, preliminary comparisons based on small samples of Inuit hunter size diagnoses with external estimates of size suggest some of the hunters (3 of 9) may be accurate. These assessments were based on the assumption that stride length is correlated with true body size in polar bears; this relationship has yet to be confirmed. Studies comparing body weight and stride length in mammals (Heglund et al. 1974) are broad, with small sample sizes within various taxa. Studies using polar bear gait measurements are also based on small sample sizes and appear to be limited to measuring stride frequency as an indicator of metabolic rate (Best et al. 1981) or comparisons of limb length measurements to body mass (Garland and Janis 1993). More recently, track measurements have been used to infer body length in paleontological studies of carnivores, but are limited to distinguishing species versus individuals (Anton et al. 2004). Relationships between stride length and body mass have been determined in African herbivores (Cuming and Cuming 2003), but similar data are lacking for polar bear. A larger sample of polar bear gait measurements could be calibrated with zoo animals or “rogue” bears in Churchill detained in a holding facility (Tyrell 2006; Tyrell 2009) to
determine the measurements that best predict polar bear size. However, gait measurements may be influenced by animal behavior and terrain in addition to body size. Efforts to determine this index are ongoing, and will be required for an independent estimate of size for further accuracy assessments of hunter estimates.

As with efforts to determine accuracy in sex and size estimates provided by Inuit hunters, the efforts required to genotype tissue associated with tracks from bears that were captured and aged in the previous CMR survey (Taylor et al. 2006; Calvert and Ramsay 1998) to determine accuracy in age are warranted, given the high reliability in Inuit estimates of age reported here. In addition, the ability of Inuit to distinguish bears of similar age and sex (identity) awaits the optimization of multivariate analyses of digital images of polar bear tracks (Jewell et al. 2001; Alibhai et al. 2008). While it is possible that Inuit may be reliable and accurate in reporting multiple tracks belonging to the same individuals in this study, the ability of Inuit hunters to discriminate individuals is required for a valid estimate of population activity, as overestimates of abundance can occur if the same track is sampled more than once (Hayward et al. 2002; Silveira et al. 2003).

While estimates that Inuit hunters provide at tracks appear to have properties suggesting they will inform polar bear surveys, there are a number of limitations concerning the design of a survey based exclusively on Inuit track diagnoses. First, previous work suggest data collected from tracks require high population densities of individuals (Smallwood and Fitzhugh, 1995), accurate track identification, and minimal variance in individual travel distances (Stephens et al., 2006). Second, computer simulations (Beier and Cunningham 1996; Kendall et al. 2002) and comparisons of tracking methods with other noninvasive methods (Gompper et al. 2006; Silveira et al. 2006) indicate that the power of tracks in detecting population activity is dependent on
sampling period, transect length, number of tracks sampled, pooling of track data, reliability of track data, and repeatability of surveys (Kendall et al. 1992; Smallwood and Fitzhugh 1995; Beier and Cunningham 1996; Hayward et al. 2002; Gompper et al. 2006). Third, sampling procedures can be restricted by the physical geography of the survey area (Gompper et al. 2006; Houser et al. 2009) as well as weather and snow conditions affecting the ability to detect tracks (Jewell et al. 2001; Hayward et al. 2002; Silveira et al. 2003; Alibhai et al. 2008). Fourth, current survey methods based solely on tracks require animals to be mobile, being sampled in order to be counted (Becker et al., 1998) with the failure to detect tracks not necessarily indicating absence (Gese 2001; Crooks et al. 2008). These concerns aside, my results indicate that in contrast to most previous tracking studies, Inuit diagnoses of tracks have the potential to provide more than simply presence or absence of individual polar bears in an area. The challenge lies in integrating these data with other information that can be used to provide precise and valid estimates of polar bear activity, in a more focused area, that can be executed by a snowmobile.

**Similarity of Inuit Methods in Diagnosing Sex, Age, Size, and Age of Track from Track Observations (Objective III)**

All 9 hunters in this study indicated that they acquired their skills by following similar sources of experience (elders, other hunters, and family members) and as discussed below many of these shared skills reflect categorical differences in bears being reported in scientific studies. Several of the hunters indicated that they observe footprint size and orientation to distinguish between male and female bears, where male tracks are oriented toward the center of gait due to larger shoulder muscles. The hunters also indicated that footprint size and estimated sex contributes to estimates of bear age, where younger male and older female bears leave similar tracks. This corresponds with studies reporting similarities between young male and female body
size due to the extended growth period in males, which achieve their full body length approximately 2 years after females, which achieve their maximum length at sexual maturity (Derocher and Wiig 2002), as well as reports of mature males having greater body length and body mass than similarly aged females (Derocher and Wiig 2002; Derocher et al. 2005). Footprint shape is also a common cue that the hunters use to identify sex and age of bear and the wider versus narrower footprints that hunters associate with males versus females (or young males) respectively correspond with reported average widths of 22cm in adult males and 16cm in females (Amstrup et al. 2006). However, these observations are opposite to general track observations of footprint shape by communities in the Western Hudson Bay Region, where Inuit have reported wider footprints in female bears versus male bears (Nirlungayak and Lee 2009). In addition to methods of identifying sex, age, and size, all participants indicated that observing snow or weather conditions can help determine age of track. Time since snow has been previously recorded for tracking studies in snow to determine age of track (Hayward et al. 2002; Amstrup et al. 2006), where track degradation or age of track increases with recent snow fall, wind, ice overflow, and melt-out (Hayward et al. 2002).

Further to the above techniques, some hunters identified methods in their track diagnoses that were not mentioned by any of the other hunters. Participant 1 discussed using the presence of accompanying tracks to estimate sex and age of bear, which has previously been noted to as an indicator of maturity, births, and disappearance of young (Jewell et al. 2001). Participant 3 indicated that he estimates polar bear age by observing snow depth to infer body weight, which appears to corroborate reported correlations between body mass and age in polar bears (Derocher et al. 2005). These particular tracking techniques are worth noting due to participant 1 and 3’s higher tracking and guiding experience as reported by other participants and community
members, and capacity to participate in any polar bear survey due to previous experience in diagnosing polar bear characteristics and collecting tissue samples from tracks. These few, context-rich cases can identify particular characteristics that might be generalized to a larger group (Maxwell 2004; Flyvbjerg 2006) such as particular methods in diagnosing tracks adopted by more experienced Inuit hunters.

**Inuit Hunting and Tracking Experience as Indicators of Reliability and Accuracy in Diagnosing Tracks (Objective IV)**

Preliminary statistical comparisons between coded interviews and estimates from tracks must be regarded with caution due to small sample sizes, however qualitative interpretations suggest background and tracking experience of Inuit hunters may correlate with individual reliability and accuracy. The high agreement of hunters in making estimates may be explained by their shared methods of tracking, while individual differences in sex, age, size, and age of track estimates may correspond to individual differences in hunting and tracking experience. Based on qualitative comparisons, the wider range in age estimates provided by participant 3 may accurately reflect the true range in polar bear age over 20 year-old in females (Ramsay and Stirling 2009), reflecting his active hunting and professional guiding experience. On the other hand, significantly different age and size estimates by participants 4 and 8 may reflect their less frequent participation on polar bear hunts. Participant 4 revealed to me on the last day of field data collection that he was unsure of how to make age estimates, which may explain his differences compared to the rest of the group. It is not uncommon that information provided outside of the interview or within another context will be different (Rapley 2001; Fazey et al. 2006). The methods of identifying age and size that participant 4 described during his interview were likely shared information that he had previously acquired from elders in his community.
from who he had learned how to hunt, which he did not know how to use. This information was not likely affected by interactions with the other participants because participant 4 was the first participant to be interviewed. Alternatively, participant 8, an elder, made significantly different estimates of age and size which may be explained by his general lack of active hunting.

Participants 1 and 3, who observed and diagnosed tracks in all three years, made estimates that are in agreement with genetic estimates, which may be explained by their experience in hunting, guiding and participation in polar bear track and tissue sample collection. Three hunters showed significant correlations between size estimates and stride length measurements, comprising participant 1; participant 2, a certified Canadian Ranger who occasionally guides (Canada 2010); and participant 7, a professional guide who has participated in multiple polar bear denning surveys. The participants who made size estimates with little or no correlation with stride length comprised a young hunter (participant 6) and an elder (participant 8). The participants who measured stride length along tracks (participants 4, 5, and 6) did not appear to have an advantage in making more correlated size estimates. Inuit who have similar levels of expertise to the hunters that show the highest agreement in their sex and size estimates with external validity criteria may provide accurate noninvasive estimates of sex and size from tracks.

**Participant Observations and Contextual Details to Interviews**

Various observations and the context established during interview and track data collection from the Inuit hunters augmented my interpretation of these data. Based on my observations, the hunters varied in thoroughness of track observation and the time required to diagnose tracks (Table 8), which may reflect their tracking experience or enthusiasm to observe tracks. In particular, participant 1 always provided estimates of size including inches along with
feet as units, demonstrating his attention to detail. Participants 2, 3, 6, 7 and 9 usually walked around and thoroughly observed the encounter area before providing their estimates, while participants 4, 5 and 8 appeared less enthusiastic about observing the area and only approached tracks when they were called upon. The lack of thorough observations may explain the differences in age and size estimates by participants 4 and 8, and age of track estimates by participant 5. Participants 1, 2, 6 and 9 generally observed and diagnosed tracks quickly while participants 4 and 5 usually required more time to observe tracks before making their diagnosis; the longer time required in making diagnoses may again reflect their inexperience or additional time required to interpret tracks methods that they were unfamiliar with. Because participant 1 led the group in locating tracks, he may have had more time to observe tracks prior to providing his estimates. Participants 3, 7 and 8 varied in the time they needed to observe and diagnose tracks, which may be explained by the general variability associated with track detectability (Hayward et al. 2002). Participants 6 and 7 always provided an estimate of size first, and usually diagnosed age and size with the same numerical value; this may reflect their value of size of hunted bears, given the higher economic value associated with larger bears (Freeman and Wenzel 2006; Tyrell 2006). Participants 5 and 9 often touched tracks before making their age of track diagnoses, suggesting they were identifying snow conditions.

Observations of Inuit hunters and their relationships provide context to my interpretations of their hunting experience and ability to diagnose tracks. Participants 3 and 4 often indicated that they felt participant 5 and the elders (participants 8 and 9) lacked hunting and tracking experience altogether. Participants 5 was contacted based on availability; participants who are contacted based on convenience may not necessarily be informative (Baxter and Eyles 1997), while participants based on referral are likely key informants (Huntington 2000; Usher 2000). In
this regard, the accuracy of estimates by participants 1 and 3 seem to reflect their recognition as experienced hunters within the community, and these two participants were contacted based on referral and participation in data collection in previous years. There may have been some rivalry between these more experienced hunters, as each often inquired about the information that was given by the other. In addition, participant 1 requested that the information he provided to me be kept confidential from the other participants. Participant 1 also translated data collected from his brothers, participants 8 and 9, but the nature of their social relationships is unknown. On the other hand, positive and strong relationships were evident between participants 2 and 4 and participants 7 and 6, who were uncles and nephews respectively. Participants 2 and 4, 7 and 6, and 8 and 9 spent a lot of time in their relationship pairs during tea breaks, in between observing tracks, and at camp. Participant 6 also revealed to me outside of his interview that he often accompanied his uncle (participant 7) on hunting trips, where he acquired his hunting experience. While criticisms among the hunters may indicate competition for social recognition or additional information regarding hunting experience, the positive relationships that were observed may reinforce sharing of knowledge in tracking.

In addition to my interpretations of tracking experience of the hunters, various alternative factors could have affected their ability to provide honest answers. An interviewer can affect how respondents react and the information provided by them (Baxter and Eyles 1997; Rapley 2001), thus my personal level of comfort and experience with the participants during these interviews may have affected the participants’ openness to discuss topics with me. I was more comfortable with interviews after familiarizing myself with the interview process, and I felt the participants who had spent more time with me prior to their interview were likely more open to providing answers. Participants 1 and 3 seemed more comfortable being interviewed likely due
to their familiarity with the study because they had participated with me in fieldwork and track observations in 2008. However, participants 1 and 3 differed in the amount of detail that they provided; participant 1 was very elaborative while participant 3 provided very simple answers to questions throughout his interview with very little elaboration. In addition, their continual participation in fieldwork combined with their reputations as hunters in their community may have suggested to the other participants that the “best hunters” would participate on forthcoming projects, which may have motivated other hunters to provide similar answers to questions. It was reinforced to the best of my ability that any information regarding estimates at tracks or information provided during interviews was not to be discussed among the participants.

Participant 4, who was the first participant I interviewed, was nervous and requested that video-recording be omitted; I was also nervous because I was still unfamiliar with conducting interviews. This discomfort was evident through confusion expressed by participant 4 in understanding some of the questions:

“Yeah…that’s right it would, I don’t know…that again, I can’t – I can’t understand that again.”

(Participant 4, May 4th)

Participant 2, who I interviewed following participant 1, later notified me of participant 4’s potential frustrations with the interview, as he referred to the interview as having “stupid questions”. However, the interview with participant 2 was more at ease likely due to our heightened expectations from the interview process.

Participants 5 to 9, having spent more time with me prior to their interviews were also more comfortable discussing interview topics. Mutually, I was more at ease during these
interviews and I was able to recall most questions without reliance on a guideline. However, these interviews took place during or after long days of track data collection which may have affected enthusiasm and ability to provide honest answers. Interviews that discuss topics at an inappropriate time or setting could elicit different or inaccurate responses to questions (Baxter and Eyles 1997). These participants might have been more enthusiastic in providing answers if the interviews were conducted in the morning or prior to observing tracks, but it was expensive to maintain participation by all hunters for multiple days and the need to collect sufficient track data limited the available time for interviews during these days. Nevertheless, these participants appeared to comprehend the interview questions and the type of information I intended to gather through these questions, and it is likely that having diagnosed tracks provided a better contextual understanding of the interviews.

Despite the differences in willingness to discuss topics among the Inuit hunters, it was evident that polar bear hunting was important to all of the hunters, which reflects the high social value of polar bear hunting to Inuit communities (Freeman and Wenzel 2006; Tyrell 2006). Participant 7 expressed enthusiasm and enjoyment in hunting, and participated on hunting trips with every chance that he had. Participant 9 – although translation was required – often smiled and seemed very excited to share his experiences. Participant 1 was very enthusiastic and elaborative in discussing his first polar bear hunt which I interpreted as a sense of pride; such pride in their first polar bear hunts have also been observed among Inuit in other communities (Shannon and Freeman 2009). Each participant also indicated their reasons for hunting polar bear were primarily for sustenance and meat distribution to their families and community members, which strengthens social ties among the community (Freeman and Wenzel 2006). It is likely that the value of the polar bear, evident among these participants, will not only encourage Inuit
hunter participation in providing information on polar bear population activity, but motivate younger hunters to learn the skills required to make these estimates as well.

Table 8. Summary of methods of track diagnoses by the group of 9 hunters. The 9 participants varied in their observation and time before diagnosing tracks.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Thorough observation of area around track</th>
<th>Time required to make diagnoses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Likely</td>
<td>Little</td>
</tr>
<tr>
<td>2</td>
<td>Often</td>
<td>Little</td>
</tr>
<tr>
<td>3</td>
<td>Sometimes</td>
<td>Vary</td>
</tr>
<tr>
<td>4</td>
<td>Rare</td>
<td>A lot</td>
</tr>
<tr>
<td>5</td>
<td>Rare</td>
<td>A lot</td>
</tr>
<tr>
<td>6</td>
<td>Sometimes</td>
<td>Little</td>
</tr>
<tr>
<td>7</td>
<td>Sometimes</td>
<td>Vary</td>
</tr>
<tr>
<td>8</td>
<td>Rare</td>
<td>Vary</td>
</tr>
<tr>
<td>9</td>
<td>Often</td>
<td>Little</td>
</tr>
</tbody>
</table>

Conclusions and Further Research

Building on previous work, these data suggest Inuit hunters are reliable and consistent in providing estimates of polar bear sex, age, and size along with age of track from in situ tracks, which is likely explained by their shared knowledge in hunting and tracking polar bears (Table 9). In this work, I also attempted to characterize accuracy in sex and size diagnoses; I found sex to be accurately diagnosed on average 62.7% of the time and 3 of 9 participants made estimates
of size that were significantly correlated with stride length. The ability of Inuit hunters to
distinguish between individual polar bears needs to be determined prior to the design of any
Inuit-based polar bear survey using tracks. Preliminary comparisons between track diagnoses and
interviews with each hunter reported here warrant a larger investigation of differences among
Inuit hunters that may reflect regional differences in reliability or accuracy in diagnosing tracks.
Once completed, the challenge will be to integrate diagnoses with varying reliability and
accuracy components into a meaningful and valid component of a tracking-based polar bear
activity survey.

Table 9. Summary of reliability, consistency, and accuracy assessments of sex, age, size,
and age of track estimates provided by Inuit hunters based on in situ track observations. 19
Tracks were diagnosed by 3 participants in 2007; 27 tracks by 3 participants in 2008; and
78 tracks by 9 participants in 2009. Only 9 tracks were diagnosed with size in 2007 (*).
Reliability and consistency with the exclusion of a single participant in 2009 (participant 5)
are indicated in brackets. Accuracy assessments of age, size, and age of track are not yet
complete.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Reliability (mean inter-participant $r$)</th>
<th>Reliability ($\alpha$)</th>
<th>Consistency (mean corrected-item total $r$)</th>
<th>Accuracy (mean %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>0.70</td>
<td>0.55</td>
<td>0.74 (0.77)</td>
<td>0.45 (0.49)</td>
</tr>
<tr>
<td>Age</td>
<td>0.78</td>
<td>0.77</td>
<td>0.81 (0.79)</td>
<td>0.63 (0.63)</td>
</tr>
<tr>
<td>Size</td>
<td>0.52*</td>
<td>0.77</td>
<td>0.91 (0.92)</td>
<td>0.73 (0.74)</td>
</tr>
<tr>
<td>Size</td>
<td>0.63</td>
<td>0.84</td>
<td>0.35 (0.85)</td>
<td>0.47 (0.63)</td>
</tr>
</tbody>
</table>

* Only 9 tracks were diagnosed with size estimates by all participants in 2007.
Although my initial findings are discussed here I have placed a more conservative category of not complete.
**Literature Cited**


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Van Coeverden de Groot P.J., C. Harris, P. Wong and P.T. Boag. 2008. The role of local hunters in i) the genetic studies of polar bear mating, movement and dispersal ii) a genetic estimate of the minimum number of polar bears known alive in M’Clintock Channel, iii) a polar bear activity survey, and iv) potential polar bear population health survey 5244-07-01. Kingston: Department of Biology, Queen’s University.


Appendix Ia. Cronbach’s alpha (α) for sex, age, size, and age of track estimates diagnosed by 3 Inuit hunters and 3 Inuit elders in 2007 and 3 Inuit hunters and 4 non-Inuit in 2008. Both groups were generally reliable (α > 0.7) in estimating sex, age, and age of track from polar bear tracks with the exception of age of track estimates in 2008. Reliability in 2007 estimates of size should be regarded with caution as only 9 tracks were diagnosed with size by all participants.

<table>
<thead>
<tr>
<th>Variable</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>0.88</td>
<td>0.73</td>
</tr>
<tr>
<td>Age</td>
<td>0.90</td>
<td>0.92</td>
</tr>
<tr>
<td>Size(^1)</td>
<td>0.48</td>
<td>0.93</td>
</tr>
<tr>
<td>Age of track</td>
<td>0.88</td>
<td>0.58</td>
</tr>
</tbody>
</table>

\(^1\) Only 9 tracks were diagnosed with size estimates by all participants in 2007.

Appendix Ib. Mean inter-participant Pearson correlation coefficient (\(r\)) for hunter, elder, and non-Inuit groups in 2007 and 2008. Hunter mean inter-participant \(r\) for estimates of sex, age, size, and age of track were larger than the corresponding estimates for elder (2007) and non-Inuit (2008) groups. Small sample size precluded a significance test of these findings.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean inter-participant Pearson correlation coefficient ((r))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hunters</td>
</tr>
<tr>
<td></td>
<td>2007</td>
</tr>
<tr>
<td>Sex</td>
<td>0.70</td>
</tr>
<tr>
<td>Age</td>
<td>0.78</td>
</tr>
<tr>
<td>Size(^1)</td>
<td>0.52</td>
</tr>
<tr>
<td>Age of track</td>
<td>0.63</td>
</tr>
</tbody>
</table>

\(^1\) Only 9 tracks were diagnosed with size estimates by all participants in 2007.
Appendix IIa. Letter of Information for Inuit Participants

This study is being conducted by Pamela Wong and is sponsored by the Queen’s Department of Biology and Department of Psychology.

This study is being conducted to determine reliability and accuracy in your estimates of polar bear characteristics based on footprints in the snow. We will be travelling a 20km quadrant from Cape Sydney to Gateshead Island to Prince of Wales Island to Cape Sydney. At each set of footprints we come across on the sea ice you will be asked to give an estimate of sex of bear (male or female), age of bear (in years), length (size) of bear (in feet) and age of the footprints (in days) without any prior discussion with other participants. In addition, you will be asked questions regarding your tracking experience and related background information throughout this trip to provide more insight into our results.

There are no known physical, psychological, economic, or social risks associated with this study. Your participation in this procedure is completely voluntary and you may withdraw from this study at any time. You will be funded for your participation in this study.

The only information we will be recording about you are the estimates and information that you provide. This information will be audio-taped and/or video-taped. The only individuals who will have access to this information are researchers with scholarly interests in cognition at Queen’s University. Your confidentiality will be protected by means of concealing your names and identities and the information in the form of raw data will be kept safe in a locker in our lab.

If you would like further information about the study, or have additional questions or concerns, please feel free to contact any of the listed researchers.

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Appendix IIa cont’d.

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You may also contact the Chair of the Queen's University General Research Ethics Board, Dr. Steve Leighton, (613) 533-6081, email: chair.GREB@queensu.ca.

Appendix IIb. Consent Form for Inuit Participants

I, __________________________________ have volunteered to participate in the study titled, “Reliability assessment of Inuit estimates of polar bear sex, age, and size along with age of track based on in situ track observation”.

I consent to the above information and understand what is required for participation in the study. I have read the letter of information and have had all questions regarding it answered to my satisfaction. I am aware of the aims of this research project and the nature and extent of my involvement in the same and have consented to the use of a tape-recorder and/or video-recorder to record my interview. I am aware that this data, in summary form, will be published and included in a Masters thesis project. I understand that my participation in the study is completely voluntary and that I am free to withdraw at any time. I am assured that the researcher shall protect the confidentiality of my identity by not using my name or any other identifying information in the research and keeping the raw data safely in a locker within a lab.

Should I have further questions I understand that I can contact any of the following individuals: Pamela Wong, Peter van Coeverden de Groot, Dr. Peter Boag, Dr. Cynthia Fekken or Dr. Howard Smith, or the Chair of the General Research Ethics Board, Dr. Steve Leighton, (613) 533-6081, email: chair.GREB@queensu.ca.

Signature: ______________________________

Date: ______________________________
Appendix III. A guideline of discussion topics regarding participant background, polar bear hunting and tracking experience, and methods of diagnosing polar bear characteristics from track observation. Some topics were discussed outside of interviews during track data collection. Common topics that were discussed and added as the interview process progressed are indicated by an asterisk (*).

<table>
<thead>
<tr>
<th>Topics regarding participant background</th>
<th>Topics regarding polar bear hunting and tracking experience</th>
<th>Topics regarding methods of identifying polar bear tracks</th>
</tr>
</thead>
<tbody>
<tr>
<td>- What is your name?</td>
<td>- How often do you guide hunts?</td>
<td>- How do you tell sex of a bear from footprints?</td>
</tr>
<tr>
<td>- How old are you?</td>
<td>- Have you ever guided a hunt?</td>
<td>- How do you tell age of a bear from footprints?</td>
</tr>
<tr>
<td>- What is your highest level of education?</td>
<td>- How often do you participate on hunts?</td>
<td>- How do you tell size of a bear from footprints?</td>
</tr>
<tr>
<td>- Where are you from?</td>
<td>- How old were you when you hunted your first polar bear?*</td>
<td>- How do you tell how long ago a bear left a footprint?</td>
</tr>
<tr>
<td>- Where were you born?</td>
<td>- How big was your first bear?*</td>
<td>- Can you estimate sex, age, size, and age of track from</td>
</tr>
<tr>
<td></td>
<td>- How did you learn how to hunt?</td>
<td>one footprint or a series of tracks?*</td>
</tr>
<tr>
<td></td>
<td>- Who taught you how to hunt?*</td>
<td>- Why do you hunt?</td>
</tr>
<tr>
<td></td>
<td>- What were the basic things that you learned in your</td>
<td>- How do you tell how many bears left tracks?*</td>
</tr>
<tr>
<td></td>
<td>first hunt?</td>
<td>- How do you know tracks belong to the same bear?*</td>
</tr>
<tr>
<td></td>
<td>- Do you prefer to hunt alone or with a group?</td>
<td>- How do you know a male is tracking a female?*</td>
</tr>
</tbody>
</table>

*Topics that were added as interview process with participants progressed.
Appendix IV: A sample interview transcription with an Inuit participant. Topics discussed by the participant are indicated in bold. Additional relevant notes provided by the participant outside of the interview were recorded in a journal and added below the transcription.

- So what is your name?
  - XXXXXXXX
  - And how old are you?
  - 32
  - What’s your highest level of education? So.. school
  - Grade 7.. grade 7
  - And what community are you from?
  - Taloyoak
  - And where were you born?
  - Yellowknife?
  - And when did you go to Taloyoak?
  - Um…I don’t know
  - OK. Um, in terms of polar bears, how often do you guide hunts?
  - Oh, no, not very often, no..
  - So-
  - I’ve guided before
  - Um…do you have a rough estimate of how many? How many in a year maybe?
  - There was just that one time
  - Just once?
  - Just that one time
  - And how many have you participated in?
  - Just one.
  - Just one?
  - Just one.
  - Um.. so how many bears have you actually hunted, if ever?
  - Myself alone?
  - Yeah
  - Oh, I lost count, I don’t know how many bears I’ve even caught.
  - Hah.. do you have a rough estimate maybe, in a year?
  - Oh a year you’re only aloud one
  - Oh yeah?
  - Yeah, one tag per household.
  - Ok.. do you have a rough estimate how old you were when you hunted your first polar bear?
  - I was 12
  - And, um, how did you learn how to hunt?
  - Just by watching these.. elders
  - So the elders would take you on a hunt -
  - Ya
  - and teach you?
  - Yes
Appendix IV cont’d.

- What were the basics that they taught you, your first time?
- *Oh, pretty much everything.. uh, how to track them down, what kind of ice conditions you have to go through.. a lot of things they taught.*
- Did you go out with them multiple times, or was it like a training kind a thing
- *Both, I’d say both*
- .. until you were comfortable enough to go out on your own I guess?
- *Yes*
- Do you prefer to hunt alone, or with a group of people?
- *Alone.*
- So you prefer to hunt alone?
- *Yes.*
- And.. when you see a set of tracks, how do you know that it belongs to a polar bear and not any other animal?
- *What do you mean?*
- When you see a set of footprints, how do you know it belongs to a polar bear and not any other animal?
- *Oh.. I don’t know, there’s no other track like it I guess, haha*
- Haha yeah, I guess it’s pretty unique. Um, how do you tell sex of a bear from tracks? What are the main things you look for?
- *Um.. the heel, and they’re a bit turned.. I don’t know how to say, they’re turned.*
- The orientation of their-
- *They’re more turned than females..that’s what I know*
- So, would you prefer to look at just one footprint or a set of footprints to determine the sex?
- *Probably uh.. a bunch of footprints.. yeah*
- I guess, if someone were to give you just a picture of footprint, it would be kind of hard to tell?
- *No, it could be easy to tell*
- Yeah? the sex of the bear? .. and how do you tell how old the bear is?
- *The size of it I guess.*
- Do you look at the way that it walks or just.. I guess-
- *No I never really noticed about that.. walks..*
- And how do you tell the size of the bear from, I guess, a set of footprints?
- *How do you tell the size of the bear from footprints…I didn’t, I didn’t get that question*
- Oh, um, I guess if you’re trying to estimate or guess how big a bear was in terms of length from nose to tail, would you be able to tell that from footprints?
- *Yeah.. I’d, I’d say so..otherwise, how else?*
- How would you tell how big it was? What would you look for, I guess?
- *Just the size of the track I guess..*
- The size of the footprint itself?
- *Yeah*
Appendix IV cont’d.

- And.. when you see a set of footprints, how do you know how old, or how long ago, the bear was there?
- I don’t know, depending on the weather conditions, they change.. they change from blowing snow sometimes.. hard to tell.. uh..
- I guess, what are the main differences between, like, a track or a fresh footprint?
- Mmhmm
- And an old one, that was a couple days old?
- What are the difference?
- Yeah
- I don’t even get that question
- Hah, like..if we were to come across a set of footprints..
- Yes
- How would you know that that was, say for example, 3 days ago instead of just now? Or can you tell that difference?
- I can only know by uh.. what the weather I guess? I mean, well if it storms, they tend to look old but, how do you say that.. I’m even having a hard time trying to (count/tell) that, actually..
- OK that’s fine. And, what are your main reasons for hunting?
- To eat
- To eat?
- The traditional food
- OK.. and how do you tell differences between bears? Like, individuals, if you can?
- Can you say it in other words?
- Um, if you saw a cluster of tracks or footprints, I guess, can you tell if there’re one or two bears there, or would it look just like one bear for you?
- Yeah. that’s right it would, I don’t know..that again, I can’t – I can’t understand that again
- Um, if you saw a set of footprints, like if you came up to a set of footprints here and drove around for a bit, and came across a set of footprints that looked similar, would you be able to tell if it was the same bear? Or just 2 bears that looked alike?
- Yeah the, the first one there

Additional comments (not taped)
- male feet turned in
- females more straight
- males see hind pad
- females short and narrow
- cannot tell front from back
- verify sex after each kill and look at feet; eat feet too
- not sure how to tell age of bear
Appendix Va. Preliminary exploratory analysis using box plots to examine distribution of data. Age of track estimates provided by participant 5 appear to highly skew the distribution of age of track estimates.
Appendix Vb. Mean estimates of age, size, and age of track across 78 tracks diagnosed, in order that they appear, by all 9 participants. Vertical bars represent standard deviation from means.
Appendix VI. Linear regressions of coefficients of variation for age of track diagnoses made by all hunters excluding participant 5 across 78 tracks. Relationships between track and coefficients of variation in age of track estimates were not significant ($r^2=0.0037$, df=76, $P=0.59$).
Appendix VIIa. Details of collected hair samples. Sample refers to the number assigned to the sample during this study, Trap refers to the number assigned to the associated bear sampling station at which the sample was collected, and Track refers to the number assigned to the associated track observed by the Participants. N/A refers to samples that were not collected at sampling stations and ND refers to “no data”.

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Appendix VIIb. Percent agreement between individual participant estimates of sex and associated genetic sex estimates at tracks from 2007-2009. Participants 2, 4, 5, 6, 7, 8, and 9 diagnosed tracks in 2009; participant A diagnosed tracks in 2008; and participants C and D diagnosed tracks in 2007. Participants 1 and 3 diagnosed tracks in all three years, while participant B diagnosed tracks in 2007 and 2008. While participants C and D made sex estimates that were in highest agreement with genetic sex estimates, participant A made sex estimates that were in lowest agreement.

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