Dorset Use of Caribou Bones at Mingo Lake (LdFa-1): A Faunal Analysis and Application of 3D Technology for the Recovery of Bone Tool Blanks

By

Holly Krause

A thesis

presented to the University of Waterloo

in fulfillment of the

thesis requirement for the degree of

Masters of Arts

in

Public Issues Anthropology

Waterloo, Ontario, Canada, 2018

Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

The faunal remains from the Dorset culture component at the LdFa-1 site, located at Mingo Lake on Baffin Island, showcase extensive cutting on some caribou bones in the form of the groove and splinter technique. These bones are known from other Dorset sites to have been cut for tools and reflect the assemblage of cut bones from Mingo Lake. These cut bones were scanned and evaluated against the comparative collection, and digitally overlaid to extract the blank that the Dorset were seeking for their tools. This blank could be 3D printed and physically compared to tools for a clearer understanding of the shape the Dorset were seeking for their tools, and which elements could provide that for them.

Acknowledgements

I want to thank my supervisor Dr. Park first for the guidance and support he gave to complete this thesis in the limited time that we had. His help with Blender and the 3D printing was key to making this a successful project.

I also extend my thanks to my committee members, Dr. Watts and Dr. Stenton, for their willingness to listen and provide insight on the project.

This thesis wouldn’t have been possible without the support of my cohort as well, they provided mental and moral support for which I am extremely grateful.

I’m also thankful for my parents and their understanding and help to make the move from Alberta to Ontario.

The move and thesis also would not have been as easy without the monetary support granted through the family of Iris Yuzdepski in the form of scholarships.

Table of Contents

List of Figures

List of Tables

Chapter 1

Zooarchaeology, Conservation, and Caribou in the Arctic

1.1 Introduction

Faunal remains from archaeological contexts are often interpreted solely to understand the subsistence strategies of past human societies. These remains can, however, also provide valuable information to paleoecologists and biologists, and can inform conservation efforts today by providing data regarding what animal species were extant in the past, and the environment in which they lived at that time. Nonetheless, the contemporary usefulness of archaeological finds is often overlooked in these efforts as they are considered by some to be too influenced by 'culture' to be indicative of a past animal species' ecological characteristics, but new literature suggests that integrating archaeological materials with paleoecology and historical ecology can help establish a baseline for ecological projections and aid in conservation efforts (Lyman, 2017; Rick and Lockwood 2012).

A species for which such baseline ecological information would be valuable is caribou, the species whose use more than 1000 years ago in southern Baffin Island is explored in Chapter 2. Caribou (*Rangifer tarandus*) have been a meaningful resource for people living in the Arctic for thousands of years (Gordon 2005). In contemporary and past populations, caribou have been an important source of food, their skins used for clothing, tents, and sleeping bags, their sinew for sewing, and their bones and antlers have been made into tools and utensils (Burch 1972; Stenton 1991). Caribou today are still considered significant to Inuit populations, being ranked one of the top five dietary sources in the Inuvialuit Settlement Region and all three of Nunavut's subregions (Kenny, et al. 2018). Caribou populations have always dramatically fluctuated on their own (Gordon 2005; Gunn, Russell and Eamer 2010; Stenton 1991), but additional factors are now affecting the species with the result that this key staple of Northern Canadian's diet and cultural history now has populations that are considered endangered, threatened, or as of special concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2018). This has led to a hunting ban on some herds, threatening the passing of local knowledge between generations, and creating concerns about the health status of those who will have to find an alternative source of the micronutrients presently provided by caribou meat consumption (Kenny, et al. 2018).

The declines in specific caribou populations are still being studied for exact causes and ways to manage or conserve them. As many caribou populations are migratory, they cross local, provincial, or federal boundaries as they move from their calving grounds to their wintering grounds and back. Management issues in Canada are also present with the sharing or fragmentation of responsibilities between public and Indigenous governments and organizations (Festa-Bianchet, et al. 2011; Gunn, Russell and Greig 2014; Kenny, et al. 2018). Multiple factors need to be considered when examining the management of contemporary caribou populations, including climate change, hunting, and Arctic development for resource extraction. Without a baseline of where caribou were present at various points in the past, and their movements across the Arctic, it will not be possible to create a thorough understanding of how they are affected by current developments. Since caribou populations are impacted by food availability and predators, understanding the effects of climate on them is essential to whether they can be properly protected in their current environment. Humans are not solely predators of the caribou; they also restrict movement, affect caribou through new developments on calving grounds, and cause further stress by their own transportation systems involving either new roadways or low flying aircraft. These issues need further study to understand the decline of some caribou populations and how to mitigate these effects through conservation efforts. In addition to these issues, archaeological faunal material should be consulted to understand past species as archaeological sites predate historical accounts, and can thus provide a longer timeline of ecological changes.

1.2 Factors Connected to Caribou Population Fluctuations

1.2.1 Climate Change

The Arctic climate has fluctuated in the past (Gordon 2005) but is facing more change due to global warming (Mallory, Campbell and Boyce 2018). The Arctic Oscillation (AO), North Atlantic Oscillation and the Pacific Decadal Oscillation are all broad climate patterns which can affect the population trajectories of some barren ground caribou herds (Mallory, Campbell and Boyce 2018). Specifically, in Northern Canada, the AO is an influence on summer temperatures and growing seasons for grazing plants (Mallory, Campbell and Boyce 2018). Little study, however, has shown how global trends of climate change will affect the environmental baseline (Mallory, Campbell and Boyce 2018). Since the AO has been negative for the last twenty years, the trend has been for caribou populations to decrease. The Inuit in the region adapted to the climate changes by adjusting their hunting calendars, using alternative modes of transport, and harvesting different species (Pearce, et al. 2015). Traditional ecological knowledge (TEK) is passed down from elders to the youth as a way to contribute to adaptive capacity, including the ability to be flexible, avoid hazards, and knowing how to be prepared for emergency situations (Pearce, et al. 2015). However, this knowledge is transmitted through observation and apprenticeship, and such transmission is now in danger of being unsuccessful as new technologies are introduced, and hunting restrictions are placed on herds. Inuit voices on climate change in the media are often voiced in terms of this ecological knowledge and the discussion that climate change is disproportionally affecting the Arctic (Stoddart and Smith 2016).

Warmer summers or warming earlier in the year can also pose threats to caribou populations, even as they provide additional grazing options. Warm temperatures may affect ice cover of lakes which are often crossed by caribou in their migrations in the spring and fall. Caribou in Northern Quebec prefer to cross ice instead of detouring around lakes and have adjusted their migration timing to coincide with these changes (Leblond, St-Laurent and Cote 2016). The re-scheduling of these movements may also be due to the growing season of their dietary plants as they begin to grow earlier in the year, causing concern of trophic mismatch, where dietary needs will not be met in sync with the breeding season (Post and Forchhammer 2008). Successful reproduction depends on producing offspring at the time of year when the resources are highest, which means changes in growing seasons may affect the mortality of calves (Post and Forchhammer 2008). Longer and warmer summers may provide more food for the caribou; however, they can also introduce more flies which harass caribou, or change the composition of plants available to those that block out caribou food sources (Mallory, Campbell and Boyce 2018). Caribou are host to the parasitic warble and bot flies which can affect body condition, bothering caribou enough to interrupt their grazing patterns (Klein 1999). The absence or low occurrence of these flies in the high Arctic may change if the summer season lengthens or become warmer, but there are few studies done to monitor the spread of these parasitic flies (Klein 1999).

Winter conditions are also of concern to the survival of caribou in the Arctic. While reports on snow and ice conditions point to winter starvation being a factor in caribou declines, Tyler (2010) determined that only one case of winter snow and icing led to a population crash. The rest of the population declines were likely an amalgamation of climatic, political, sociological and economic factors (Tyler 2010). Lichen is considered a dominant source of winter foraging for some herds and overgrazing or even burning with slow regrowth could be a detriment to winter survival (Jandt, et al. 2008). With warmer weather melting permafrost and burning of ground cover providing more nutrients to the soil, the environment may become better suited for vascular plants instead of lichen (Jandt, et al. 2008).

1.2.2 Arctic Development

Climate change not only affects the caribou through environmental changes, but also affects the way humans see the Arctic in terms of development potential. The Arctic is seen by many as a frontier with potential for offshore oil and gas drilling as well as new shipping routes due to climate change (Stoddart and Smith 2016). Diamond mines are also an economic resource in the Arctic, causing concerns about caribou reactions and range impacts (Gunn, Russell and Eamer 2010). Abandoned mines are a concern to caribou health as they may have specific contaminants affecting the area around them (Gunn, Russell and Eamer 2010). Not only do the mines deter caribou from the region, but the additional camps and air traffic can also disrupt caribou habitation patterns (Gunn, Russell and Eamer 2010). Understanding the impact of development on caribou herds calls for a bottom-up approach so the specific needs of each can be addressed (Gunn, Russell and Greig 2014).

Negative impacts for caribou to such development include running from passing aircraft, especially during and shortly after calving season, as well as in the winter. (Wolfe, Griffith and Gray Wolfe 2000). The introduction of elevated roads or development can provide a barrier to sight which can cause caribou to avoid the areas (Wolfe, Griffith and Gray Wolfe 2000). Caribou can become ‘habituated’ to human activity unless hunting is involved, in which case they are warier of humans approaching, especially if they are on foot (Stankowich 2008). Frequent interactions with humans may have the opposite approach as well, making them less likely to react when being hunted, so understanding how they will react is more a sum of effects and not quite as predictable (Stankowich 2008). If there are large settlements nearby that provide food, caribou may see them as a refuge which could attract predators to the area (Stankowich 2008).

Current suggestions for mitigation efforts include planning for caribou crossings and reactions prior to development approval. Minimizing activity during caribou calving season is highly suggested for mitigation plans, especially with low level flights which cause high stress on caribou populations (Wolfe, Griffith and Gray Wolfe 2000).

1.2.3 Caribou Hunting

Once a species is listed as extirpated, endangered, or threatened by the Species at Risk Act (2002) "no person shall kill, harm, harass, capture or take an individual of the wildlife species." This makes mitigation issues problematic where caribou are, and have long been, considered a dietary staple (Kenny, et al. 2018). The introduction of the snow-mobile, winter roads, and quick communication have likely increased the hunting of caribou due to ease of access (Gunn, Russell and Eamer 2010). The advantages of rifles and binoculars have also increased individual hunting (Birket-Smith 1976). Inuit hunters in Canada can harvest as many animals as they want from the herds unless there is a conservation issue, while resident hunters are limited and commercial hunting is declining or has been stopped where herds are threatened (Gunn, Russell and Eamer 2010).

In the past, caribou populations were likely more affected by environmental changes than overhunting by humans. Early paleo-eskimos belonging to the Arctic Small Tool tradition, and the later Thule people, would have used a bow and arrows to hunt land mammals, while harpoons may have been the most common weapon in the Dorset time (Milne, Park and Stenton 2013). Thus, the increase in transportation routes and advancements in projectile technology would allow for the possibility of over-hunting today, as it is easier to kill the animals in single encounters and transport them long distances (Gunn, Russell and Eamer 2010). This has led to restrictions on hunting as a mitigation effort.

1.3 The Contribution of Archaeology

The issue of caribou conservation thus requires knowledge of biology, animal behaviour, ecology, and how climate change is affecting both the movements of humans and the animals. These subjects cannot be studied without knowing about the past environment, about how animals have adapted over time to the unique climate in the Arctic, and about the knowledge and insights of those who have lived there for many generations. Changes recorded today need the baseline provided through archaeological research for a comprehensive understanding of what issues are the culprit of a species decline so proper mitigation efforts can be applied. Since the Arctic is considered an untapped resource for development, it provides an opportunity to ensure proper mitigation efforts are in place before projects start, so that individual developments can reduce their impact on the environment. Residents who have lived in the area for a long time will have a better understanding of fluctuations in caribou populations and should be consulted for their knowledge even if some may consider it ‘unscientific’. This extends further to the archaeological record in the area, as caribou faunal data from archaeological sites provides a prehistoric baseline on abundance, health, and demography of caribou populations at various points in the past. Caribou remains from these sites can be used to calculate the sex and age ratios of the kills, allowing researchers to infer herd health, and with radiocarbon dating can provide a timeframe of the caribou presence in the area.

Caribou have already been extirpated from between 40 percent to 60 percent of their historic ranges in different provinces (Festa-Bianchet, et al. 2011), making their decline in numbers further north a real concern. Many predators rely on caribou, and while human health and nutrition has been studied (Kenny, et al. 2018), the decline in caribou populations could affect wolf, fox, and bear populations as well. More research will be needed to understand caribou populations that have not been yet been examined, and a better understanding of climate change will be needed to include in mitigation efforts, especially as the ecological baseline may change with the rise in global temperature. Archaeological data helps establish the timeline of ecological change for caribou across the Arctic, as caribou remains can be found at sites spanning the last 4000 years. There will be no single plan that can conserve and protect all caribou herds from the threat of extinction, but collaborative efforts between provinces and territories, locals, and the federal government can no doubt reduce the impact of human harassment on caribou and keep the species from further decline.

Archaeological material from the Arctic suggests where caribou were present in the past and how they were relied upon by those living at the time. Conservation efforts today can use this archaeological faunal data to aid in their evaluation of population densities, and past habitat extent to plan for protected areas and aid in mitigation efforts. As archaeological sites provide information on the ecology of the area, biology of the species present, and how humans have interacted with caribou in the past, they are valuable resources of data for conservation efforts.

The faunal data from an archaeological site on Baffin Island, Nunavut is described in the rest of this thesis. The presence of abundant caribou remains at the site demonstrates their importance to the people of the Dorset Culture a thousand years ago as a reliable resource for food, clothing, and tools. This archaeological site thus establishes both the people and animals in the region, and documents their interactions at that time. These kinds of data may someday be valuable in establishing an environmental baseline for caribou in this part of the Arctic.

1.4 Journal for Publication

I will aim to submit chapter two of this thesis to the *Canadian Journal of Archaeology*. This journal is published by the Canadian Archaeological Association, which focuses on Canadian archaeology and disseminates it to the public. As a member of the CAA for several years, submitting an article to this journal would be a good first publication for me. The site of LdFa-1 where the studied fauna is from, is located by Mingo Lake in Northern Canada on Baffin Island, making it a site area that the CAA would be interested in publishing. By examining faunal remains through digital technology, this thesis is an attempt to understand the pieces missing from the archaeological record. With previous articles written about the site published here, it would add to the knowledge already presented and build on the understanding of the Dorset use of the site.

Chapter 2

Application of 3D Scanning on Faunal Remains from Mingo Lake

2.1 Introduction

Archaeologists stereotypically focus on the grand finds of what was present in the past. The study of pyramids, statues, ceramics, and projectile points is often the picture or ‘face’ of a past culture. This goes far back in the history of the discipline, to when antiquarians searched for curious items to put on display in museums (Trigger 2006). But there are of course many pieces missing from the archaeological record, including those that represent the steps between the raw material and the final artifact. These intermediary pieces are not grand and, because they existed only temporarily, they do not survive in the archaeological record and so cannot be put on display. Their presence, however, can be inferred from what is left behind, and this knowledge tells us a lot about the past and about the people who interacted with the environment around them. Thus, archaeologists have good reason to be interested in these intermediary pieces, and new technology may be able to help us to explore them through digital experiments recreating modified material.

Bones are often considered primarily as evidence of food procurement, with studies done to calculate things such as nutritional content, marrow content, and the elements which are most likely to be transported from the kill site to the camp site (Reitz and Wing 2008). However, bone has also been used as a material for tools. Bone tools have been studied with the *châine opératoire* approach to understand the interaction of social behavior and the environment (Gravina, Rabett and Seetah 2012). Finished tools are studied to understand their use, and the styles are often compared to determine a typology, as first developed by Montelius, which archaeologists use to differentiate between cultural groups (Trigger 2006). In the case of bone tools, the bones found at archaeological sites which have been purposely cut are considered debitage, and thus represent cultural choice. They were selected with a tool already in mind, and some quality of the element chosen makes it an ideal candidate for that tool. Since bone tools are the end products of further working, and debitage of tool creation is likely small and too fragile to survive, the shape of the original blank removed from bones is not easy to conceive as a whole unless it can be reproduced in experimental archaeology. 3D technology may be able to replace the need for an experienced replicator in the process of finding bone blanks as technology becomes more advanced, and 3D programs become cheaper. While this would not replace the replication of use-wear patterns to provide an understanding of bone working, it could be easier to view the blanks without needing to acquire certain bones for reproduction – something which may be helpful for those studying the bones of extinct or endangered species. With 3D printing, these blanks which were once missing from the archaeological record can be reproduced and allow us to determine what tool types may have been created from them.

This research project explores how 3D scanning and printing of cut bones can aid in the understanding of modified caribou remains at a site in Arctic Canada. The faunal remains from Area 1 at LdFa-1 by Mingo Lake on Baffin Island provide an opportunity to examine the use of caribou within the Dorset culture, and study the bones which were cut for tools. Certain bones from the site were extensively modified after the butchering process, making them an ideal candidate for 3D scanning to determine the missing portions, and thus infer which bone tools were created from them. Comparisons of the 3D printed bone blanks and virtual models to the shapes of known tools make it possible to envisage which bones the Dorset sought for specific tools.

2.2 Background

2.2.1 Dorset Cultural History

The Dorset people are recognized to have lived in the Eastern Arctic from around 2500 B.P. (Appelt, Damkjar and Friesen 2016; Ryan 2016). They come from the line of people who migrated east across the Arctic around 5,000 years ago and disappeared before the Thule moved into the Eastern Arctic, though there is no agreed upon reason yet as to why they died out (R. W. Park 2016). The defining aspects of the Dorset occupation of the Eastern Arctic revolve around the cooling of the region, and technologies such as ice crampons, sled runners, snow knives, soapstone vessels for burning blubber, burin-like tools instead of burins, a ground-slate industry, the absence of the bow and arrow and drilling holes in tools, along with carvings of animals and people (Appelt, Damkjar and Friesen 2016; Ryan 2016).

Taylor (1968) proposed that the Dorset culture had an ample sea-mammal economy due to their presence at coastal sites and the dominance of seal and walrus bones in the faunal remains. The Dorset sea-mammal industry has since been further documented, but the call for interior sites to be surveyed and excavated has been raised with the intention of finding more evidence of them moving inland for caribou hunting (Howse 2008; LeMoine 2005; Milne, Park and Stenton 2013; Taylor 1968). Some sites like Payne Lake, Mingo Lake, Nunguvik, and Saatut contain a large amount of caribou bone and bone tools indicating that caribou hunting was still prominent, and the Dorset were most likely travelling inland to hunt them (Mary-Rousselière 1984; Milne, Park and Stenton 2013; Taylor 1968). Low numbers of caribou could possibly be due to hunting pressure in certain areas of the Arctic, but caribou population fluctuations are known to be connected to seasonal weather oscillations (Mallory, Campbell and Boyce 2018). The complicated ecological interactions that influence caribou populations make it difficult to point to a single reason why some Dorset occupations did not have as many caribou bones present as the Pre-Dorset before them, or the Thule after them.

Hunting caribou would have been easier for the Pre-Dorset and Thule with the bow and arrow, but the Dorset could have exploited the landscape and knowledge of caribou movements instead. The presence of caribou drive lanes in the Arctic implies that hunters were capable of encouraging caribou to move into specific areas where they could be easily killed (Brink 2005). The knowledge of how caribou move and react would counteract unpredictability and allow communal hunting of the animals when they may otherwise not be considered reliant (Burch 1972). Thus the documenting and understanding of inukshuk placements and hunting blinds is crucial to understanding how caribou were hunted, as some may have been erected to attract caribou through their curious nature, while others may have been placed at certain points to frighten caribou into drive lanes (Brink 2005). While caribou may be easy to kill because of their curious nature (Burch 1972), most archaeological sites contain more than one animal which means a distinct plan for directing where herds would go once spooked so they could be readily dispatched; this was often to a body of water where they could be lanced from a boat (Birket-Smith 1976; Brink 2005).

Caribou are not just a source of food, they also provide skins for clothing, sinew as thread, and antler as well as bones for tools (Gordon 2005; Stenton 1991) so it is unlikely that this economic value would be ignored if they were present in the area. The animals were most likely hunted and butchered by men within the Dorset community, while sewing of the skins was done by women, but in times of large production need, the work could have been shared (LeMoine 2003). Caribou skins are best for clothing in the autumn as winter hairs are too thick and heavy, and in the spring and summer they are thin and often have holes from warble fly larvae which were laid under the skin (Burch 1972). Antler can easily be scavenged when shed by the caribou, but they are ideal for working when gathered freshly shed, as the longer they are exposed to the elements, the more weathering and deformation due to caribou gnawing the undergo (LeMoine 2005). As caribou have been hunted by groups before and after the Dorset occupation of the Arctic, it is likely that the Dorset also hunted caribou using hunting blinds and pounds, and herded them toward bodies of water or into tight areas where they could easily be killed (Gordon 2005).

2.2.2 LdFa-1

Figure 1. Google map of Baffin Island and Mingo Lake

The site of LdFa-1 lies at the edge of Mingo Lake in the Southern part of Baffin Island (Park 2008). LdFa-1 was first identified by Stenton in 1991, but initial testing of the site was done in 2004 by Milne to investigate ASTt and Dorset use of Baffin Island (Milne, Park and Stenton 2012). Further excavations at the site were carried out in 2007 and 2008 (Milne, Park and Stenton 2012). LdFa-1 was revisited in 2014 for a geophysical survey and additional small test units were excavated (Landry, et al. 2015). The 2008 excavation divided the site into five named areas (Park 2008). Area 1 is unique in the fact that it contained only Dorset style tools, lacking the Pre-Dorset component that the other areas contained, and was strictly a bone bed with no structural features present (Milne, Park and Stenton 2012; Park 2008). The Dorset who created Area 1 are inferred to have been travelling inland for chert and possibly for social gatherings, as well as for hunting caribou and stopped at Mingo Lake for these resources (Milne, Park and Stenton 2013).While it is unclear yet whether the height of the lake was a factor in why Pre-Dorset groups did not use this part of the site, or if other factors were involved (Park 2008), Area 1 provides an opportunity to study just the Dorset occupation and their connection with the faunal remains present.

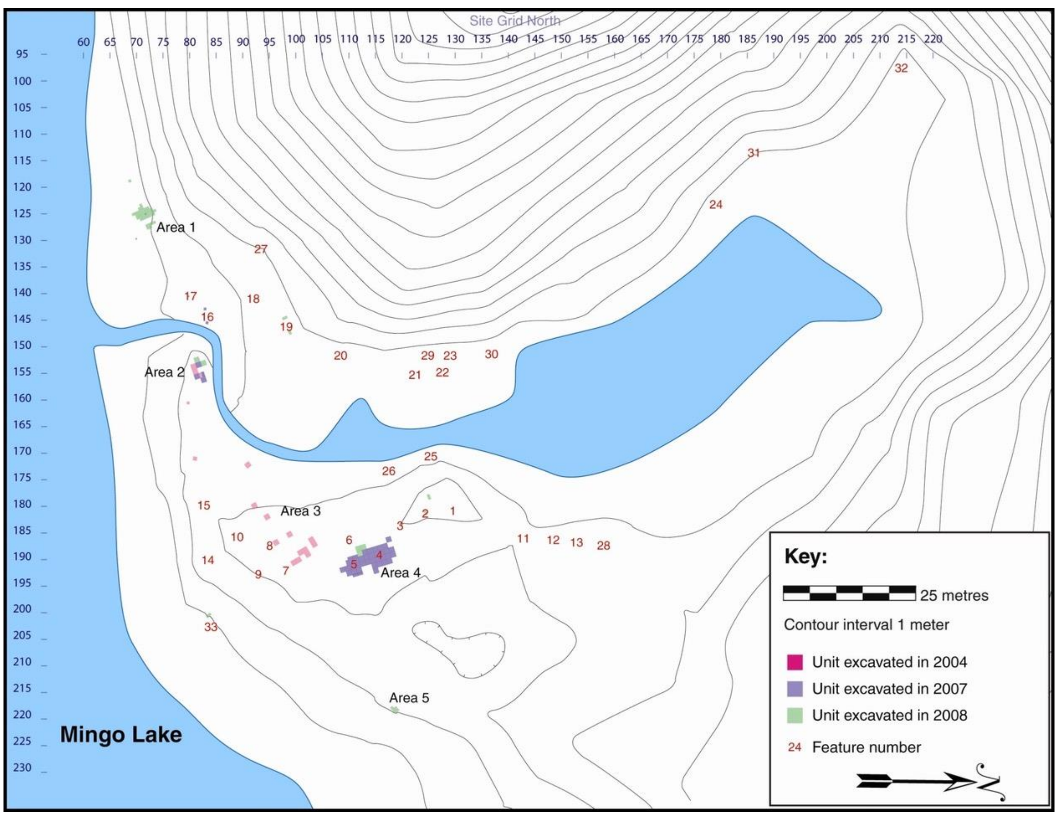

Figure 2. Map of Mingo Lake excavations

Bone tools from LdFa-1 Area 1 recovered during the 2008 field season include needle fragments, burin-like tool handles, one harpoon foreshaft and a miniature harpoon head (Park

2008). Caribou are the main animal present in the faunal remains of LdFa-1, even in the Dorset component (Milne, Park and Stenton 2013). Area 1 of LdFa-1 has bone and antler showcasing the 'groove and splinter' technique, and with the presence of burin-like tools and handles, indicates that pieces of bone and antler were taken either as blanks for tools, or tools were being made at the site (Park, Milne and Stenton 2017). The presence of small fragments of bone at the site may indicate further tool making as well, as debitage would be created when shaping the bones into their final form. The presence of broken needles suggests these items were probably already made and had been brought in from outside, and the fact that they break easily would indicate that more blanks to create new needles would be needed.

2.2.3 3D Technology

3D scanning and printing is being adopted widely in zooarchaeological studies, with the ability to create and share 3D models as a virtual comparative collection being the main drive behind it (Betts, et al. 2011; Niven, et al 2009). These models may help with the accurate recording of attributes as the images are static, with reference points marked and measurements generated by the computer. For veterinary practices, scans and 3D prints of animal bones have been made with measurements of the originally scanned bones, the 3D image, and the printed replica compared for accuracy (Li, et al. 2018). The printed models were highly rated by students who used them in their study as they were durable, had no odor, and resembled the real bone accurately (Li, et al. 2018). 3D replications or 'artifictions' are considered better than just being seen on the computer as they can printed to scale (Manzano, et al. 2015), although the quality of scanner and printer will affect the accuracy of the final printed version (Thomas, et al. 2016). Some virtual zooarchaeological sites are already set up; for example, the Virtual Zooarchaeology of the Arctic project, or VZAP, allows visitors to view different skeletons of Arctic animals collected for reference (Betts, et al. 2011). The Idaho Museum of Natural History has also set up a website available to the public featuring 3D models of various animal bones and fossils, as well as artifacts and plants which was built up around the VZAP project (Idaho Virtualization Lab 2013).

For those who cannot afford to plastinate their specimens, and for those bones that are harder to obtain, the use of virtual models and 3D printing is an alternative option. In addition to serving as models for teaching purposes, printed bones are useful to those who are studying extinct species and may not have a comparative collection because of their rarity. The sharing of virtual models also allows for consistent comparison between labs as the model does not change once it is digitally created.

2.3 Research Problem

The choice to use bone for tools instead of stone or metal reflects some cultural aspect, either the 'age' of technological knowledge, available resources, or a social preference (Choyke 2013). The shaping of bones into tools was done by the Dorset with burin-like tools made of stone, so the material for stone tools must either be poor for the tool purposes, not as easily available, or does not suit a cultural ideology of tool material. 3D scanning and recreating the bone blanks will allow us to look through the finished artifact types to explore what tools could have been created from the blanks.

2.4 LdFa-1: Area 1 Faunal Analysis

The faunal assemblage from the 2008 field season was taken to the University of Waterloo for analysis. From May to August of 2018, the Area 1 bones were examined by the author and the following variables were identified: element, side, age, breakage pattern, presence of burning, and presence of cut-marks. When considering age, bones without the fused epiphyses that were also small were considered juvenile/infant; bones without the fused epiphyses that were larger or were fusing with the epiphyseal line very prominent were considered sub-adult. Breakage patterns were either spiral fracture or angular fracture or else they were considered indeterminate or unbroken. These attributes were entered into a FileMaker Pro database on the laboratory Macintosh computer. A comparative collection was available for most caribou and hare bones, some dog, seal, various species of bird bones, and a few fox bones. An earlier faunal analysis of a sample from the site identified 97.8 percent as caribou (Milne, Park and Stenton 2013), so this species was the focus of this study. The database set up for Area 1 was split into caribou and non-caribou for identification, as only the caribou bones were relevant for this project. While most rib fragments and unidentified broken bone were likely caribou, they were entered under the non-caribou category as they were not independently or confidently identifiable to species. When presented with bones that did not look like something in the comparative collection, the online Idaho Virtual Museum was consulted, though it was not considered a conclusive identification. In total, 13,527 bones and bone fragments were counted, with 4,933 confidently identified as caribou. This is only a 36.5 percent caribou representation; however, on removing the 8,008 bones unidentifiable to taxon, most of them fragments under five centimetres, the percentage of caribou among the bones identifiable to taxon climbed to 89.4. The 586 bones that were identified as non-caribou were set aside for future research.

Most bones from Mingo Lake have been broken, exhibiting a spiral fracture, either to remove marrow, or through other taphonomic processes. Some bones also show evidence of gnawing by rodents, while some antlers were gnawed by caribou. A few bones have punctures where they were most likely gnawed on by a carnivore. As there are also rodent and possibly

Arctic fox bones present at the site, and wolves presently in the area, gnawing is not an unexpected occurrence. All the long bones have been extensively reduced, most likely for marrow extraction as bone marrow is considered highly nutritious and often eaten during the butchering phase (Binford 1981). While some of these pieces were recognizable to element due to their shape or the presence of nutrient foramen, it is unclear how many long bones could be reconstructed from the fragments, and many were unidentified to the element.

Caribou Element	Axial	Left	Right	Side indeterminate	Grand Total
Alveolar ridge (Mandibular or maxillary ind)				3	3
Antler				78	78
Astragalus (Talus)		7	7	1	15
Atlas vertebra	6				6
Axis vertebra	5				5
Calcaneus		24	28	2	54
Caudal vertebra	1				1
Cervical vertebra	47				47
Cranium	45	55	67	176	343
Cuneiform (Ulnar carpal bone)		9	10		19
Cuneiform mediale (1st tarsal)		1	3	2	6
Distal fibula (Ungulates)		18	18		36
Distal phalange ind		5	10	1	16
Epiphysis ind				3	3
Femur		37	44	21	102
Flat bone ind (Ribs, scapulae, pelvis, cranium, etc)				59	59
Fused 2nd & 3rd tarsal		7	10		17
Humerus		34	28	5	67
Hyoid				14	14
Innominate		53	44	10	107
Long bone ind				1510	1510
Lumbar vertebra	61				61
Lunate (Intermediate carpal bone)		11	10		21
Magnum (3rd carpal bone)		7	7		14
Mandible		62	71	30	163
Metacarpal (Front cannon bone)		34	39	39	112
Metacarpal of paradigit (Accessory metacarpal)		2	3	4	9
Metapodial ind				25	25
Metapodial of paradigit (Accessory metapodial)		1		3	4
Metatarsal (Hind cannon bone)		51	46	110	207
Naviculo-cuboid (Fused central & 4th tarsal)		11	9		20
Patella		1	2		3
Phalange ind		103	132	20	255
Pisiform (Accessory carpal bone)		12	5		17
Radius		27	44	21	92

Radius & Ulna fused		14	25	9	48
Rib		135	121	251	507
Sacrum	7				7
Scaphoid (Radial carpal bone)		10	8		18
Scapula		12	22	14	48
Sesamoid		3	3	86	92
Sternum	25				25
Thoracic vertebra	131				131
Tibia		87	75	15	177
Tooth, deciduous		10	6	14	30
Tooth, permanent		38	24	80	142
Tooth, permanent/deciduous ind		1	1	80	82
Ulna		36	38	12	86
Unciform (4th carpal bone)		9	8	1	18
Vertebra ind	11				11
Grand Total	**339**	**927**	**968**	**2699**	**4933**

Table 1. Count of caribou elements from LdFa-1 Area 1

These data can be used to infer the number of caribou that were butchered by the Dorset by calculating the minimum number of individuals (MNI) for further analysis. These numbers can be affected by site-formation processes, recovery techniques, and lab practices as damage to the bones reduces the ability to identify them (Reitz and Wing 2008). The bones from LdFa-1 were well preserved, as even hyoid bones were retrieved from the site. Water screening was done on some sediment brought back to the lab which led to the recovery of very small bones that were missed during the excavation; these were mostly fragments with only a few identifiable small animal bones such as mandibles or long bones.

2.4.1 MNI

The MNI is the smallest number of individuals or animals necessary to account for the elements present (Reitz and Wing 2008). There are always some issues when considering the MNI, as more animals may be present than a final calculation shows. When considering elements with pairs, left and right elements are considered to belong to the same animal, though this may not be the case. A paired limb may have been taken to a different area or site for further processing, or be missing due to scavenging from carnivores. The sex and age can also be considered for calculating MNI, as the presence of an adult bone and a juvenile bone of the same element means there are at least two animals present even if they may be of opposite sides of a paired element. The same goes for the sex of the animal, if the sex can be determined; it allows further distinction between bones that can change the MNI. If there are male lefts and female rights, they are from different animals and the MNI should reflect this instead of counting the paired sides as one animal. The epiphysial fusion rates differ between the proximal and distal ends of some long bones, making it harder to fully determine age differences if dealing with broken bones containing one epiphysis; this could lead to a miscount if one portion of bone is considered adult and the other as a subadult (Reitz and Wing 2008). The MNI is therefore not an absolute count of the animals present but nevertheless provides some useful information on abundance.

At LdFa-1, the lateral malleolus or distal fibula is the most frequently occurring bone from this site, giving an MNI of 18, with both sides represented in equal measure. While some fragmentary portions such as the radius and radius/ulna would suggest a higher count, the portions could likely match with each other as they are broken. The tarsals and carpals are the only bones that are consistently complete from the site, with two fetal/infant ulna also found mostly complete. The carpals and tarsals give an MNI between 8 and 12. There are at least two fetal/infant caribou carcasses, as the two ulnae are both right, and other bones such as the carpals/tarsals and distal phalanges have at least two fetal/infant caribou proportions. No attempt has been made to differentiate between sub-adult and adult caribou in the population for the MNI as the epiphyseal rate of different elements could indicate a difference in count. The comparative collection bones were from a young animal as not all the epiphyses were fused on it, so carpals/tarsals were judged based on size; those that were markedly smaller were estimated to be from a younger animal. As previously mentioned, the MNI is not an absolute representation of the full number of individuals present, and at LdFa-1 only a portion of Area 1 was excavated with the extent of the bone bed currently unknown. The likelihood of there being more caribou killed at Mingo Lake is high, especially if they needed more skins for clothing as Stenton (1991) indicates that on average at least seven skins were needed for adult clothing, and three for a child. Balicki (1970) suggested that a family of four would need around 30 skins, for clothing and sleeping skins, based on ethnographic research of the Netsilik. The skins provided by 18 caribou could provide for the clothing of a family of three or four, although two small caribou would not provide as much skin as the larger animals. Further excavations would be needed to understand the complete abundance of caribou at LdFa-1.

2.4.2 Cut Marks

It is important to remember that identifying cut bones in a faunal assemblage is subjective as Binford (1981) discussed misinterpretations of animal modifications as human made, and a study by Dominguez-Rodrigo, et al. (2017) has shown that different archaeologists do not interpret cut marks in the same way. After giving the same bones to a variety of analysts, Dominguez-Rodrigo, et al. concluded that while the intentionality of marks was often agreed upon, the cultural interpretation later is very different. Bone surface modifications make up a large portion of faunal analysis regarding butchering patterns and carnivore scavenging, so knowing the differences and which category to attribute them to is important (Thompson, et al. 2017). For LdFa-1, bones with possible cut-marks were identified as a separate category from those which had clear cut-marks. The cut-marks were not further separated between those which had butchering cuts and those which were modified, but comments were made on particularly unusual cuts or if there was a pattern to them. While the distinction between butchering and groove and splinter cuts could be seen in the lab when choosing bones for 3D scanning, it is not as clear in the tables as to which were further modified past the butchering stage.

2.5 Methods

A total of 511 bones displaying cut-marks or potential cut-marks were set aside for further analysis. The most cut bones were the ribs, radius/ulna, and metatarsals, while around 50 antler portions also showcased cut-marks. Only bones with deep grooving showing that they had been selectively cut after butchering and disarticulation were chosen for further study. It was previously determined that the radius/ulnae were of interest due to cutting (Conlon 2013), and that antler would most likely show cuts, so these were given careful consideration in the general analysis. It became clear that some ribs were cut and split longitudinally when examined, which fit with Mary-Rousselière's (1984) report that the Dorset were cutting the concave portion away for needle manufacture. Not every split rib showed cut marks so only the ones that did were set aside for further analysis. The only other bones showcasing clear cuts were metatarsals and metacarpals, some of which were warped.

A selection of cut radius/ulnae, ribs, and metatarsals were then 3D scanned, with an attempt to capture all portions of the bones for a complete representation of what the Dorset were cutting away. Two distal portions of the radius chosen to be scanned had the distal epiphysis of the ulna fused, with the diaphysis cut along the ulna fusion line, and some of the anterior portion was missing. Some proximal portions of the radius were scanned, usually with the ulna fused but showcasing a deep cut along the posterior leading down to the radius. Proximal portions of the ulna were also scanned, some with the semilunar notch present and the posterior portion cut, and others with just the three articular facets below the notch present and the posterior cut away. In total, 19 radius, ulna, or radius/ulna were scanned. As most ribs showcased the same cuts of the concave portion, a representative few were chosen for scanning. One metatarsal was chosen for scanning as it was the most complete specimen while the others were small proximal portions or diaphyseal fragments. A comparative collection radius/ulna, metatarsal, and rib were also scanned so their shape could be used as a virtual comparative.

The 3D scanner used was a Next Engine, set at 26” away from the object being scanned. The Next Engine scanner is recommended for use by archaeologists and museums as it is affordable and simple to operate (Kuzminsky and Gardiner 2012). It has an attachable turntable platform which is easier to control than those which require moving the artifact yourself. The scanner projects lasers that slowly move across the object to generate data points (Kuzminsky and Gardiner 2012). Data points create polygons, polygons create a mesh, and the full model is considered a point cloud and all these layers can be used to view the 3D model (Kuzminsky and Gardiner 2012). The bones from LdFa-1 were scanned twice, once upright, and once flipped 90° to capture the ends that were not in view during the first scan. Ten scans were taken as the table turned the full 360° with the colour setting adjusted to pick up medium colours for the archaeological bones, while the comparative collection bones were scanned to pick up light colours. Using the Scan Studio program, these models were trimmed and aligned using identifiable markers and fused together into one mesh file. This file was then input into MeshLab to be cleaned up and compressed.

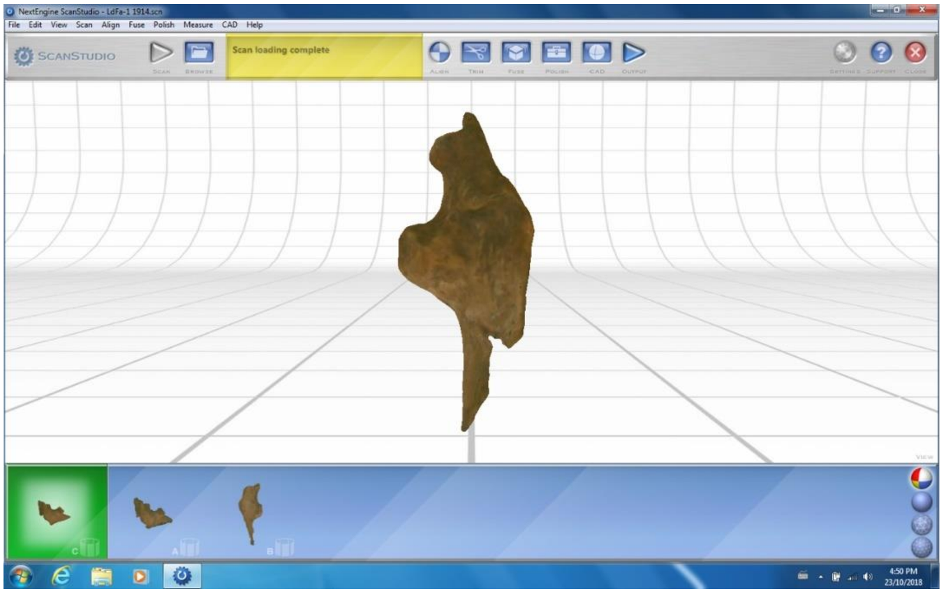

Figure 3. Scan Studio image of an ulna fragment

Once cleaned up, the files were then input into Blender to compare with each other and were overlaid onto the comparative collection scan. The comparative collection model was duplicated multiple times and flipped to have a representation of the opposite side as well. The overlay allows for a visualization of what portion of the bone is present, but the portion of the comparative collection which is not coloured by the overlay would be the portion of bone cut away. A plane was created along the cut marks to virtually draw a line where the Dorset would have cut the bone. The Boolean feature was then used to separate the model and extract the portion that the Dorset were removing, creating a visual representation of the blank they were seeking. This step between the raw material selection and final tool product was therefore successfully reproduced, simulating the Dorset actions and imitating the tool blank normally missing from the archaeological record.

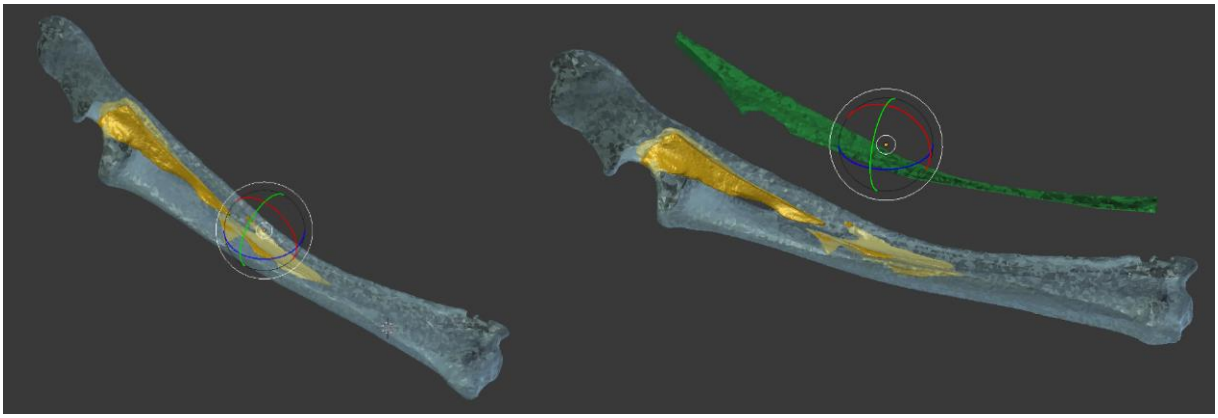

Figure 4. Radius/ulna scans in Blender program

Some of the scans were also 3D printed using a Lulzbot Mini 3D printer to see how well the cut marks were captured and to use as illustrative pieces. Once the image of what was cut away was created, it was saved as its own file. These portions are not meant to represent a tool but are the blanks which the Dorset would have then modified further and shaped for their various purposes. As lithic tools made from flakes are separated from a core and then further shaped to their various tools, so too would bones be worked. Having a physical portrayal of the missing portion was also helpful for identifying potential tools as it provided a concrete shape for comparison.

2.6 Discussion

Once the digital and 3D printed copy of the bone blanks were retrieved, they yielded further insight into the sorts of tools that could have been made and the process of making them. One insight is that these bones would have been modified before the marrow could be retrieved from them, so, to avoid the loss of this important food source, these blanks would have been produced promptly, during or soon after the butchering process.

2.6.1 Metatarsals and Metacarpals

At least 11 (three percent) of the 344 identified metacarpal or metatarsal fragments from the Mingo Lake Area 1 faunal assemblage were cut longitudinally to remove the anterior portion. Metatarsal and metacarpal negatives were discussed by Mary-Rousselière (1984), who suggested the tool that Rowley (1940, 192 and fig 1f) had found and described as a metacarpal instrument could also be seen from the bones left behind at archaeological sites. The tool described is one with percussion scars on the edges, and often has a sharpened tip (Mary-Rousselière 1984). It is also suggested by Mary- Rousselière that an artifact Taylor (1968, 55 and fig 23m) described and pictured from the Tyara site is in fact one of these metacarpal instruments. While these instruments are most likely what were being made, the blanks removed from LdFa-1 are what can be inferred and not the complete tool itself. More possibilities for tools from these portions could be overlooked if Mary-Rousselière's inferences are considered conclusive explanations for these particular blanks. Lanceheads, handles for burin-like tools, and possibly even harpoon heads if carved from bone could be other possibilities for the metapodial blanks as they are long and sturdy pieces of bone. Metapodials are common bones chosen for tool manufacture among a variety of cultures, so their use within the Dorset tool-kit is not atypical.

2.6.2 Ribs

At least 30 (six percent) of the 507 ribs or rib fragments from LdFa-1 had their concave portions cut away. If the proximal portion of the rib was present, it was cut on the neck before being sliced down the shaft. The blank extracted would have been flat and slightly curved depending on which rib was cut. The length and the age of the animal the ribs were taken from will also affect the size of the blank removed. Mary-Rousselière (1984) suggested these were used for needles, because incompletely cut blanks and manufacturing waste were discovered at the Nunguvik and Saatut sites. While most bone needles have been inferred to be made from bird bones (Wells, Renouf and Rast 2014), the ‘curved’ nature of Dorset needles is said to come from the fact that they were made from these convex portions of the ribs (Mary-Rousselière 1984). The shape retrieved from the cut bones at LdFa-1 would suggest that thin tools were made from the rib portion, which could certainly be needles with further working, and the curve of one of the needles found at Mingo Lake precisely matches the curve of a rib. There are 13 ribs per side in a caribou, so not all ribs would need to be cut for blanks, especially if more than one animal has been killed. There would be more than enough material to make multiple needles where a bird would provide a limited amount to work with. The rib portions would be light and easy to carry to a camp where they could be later worked into needles when needed.

2.6.3 Radius and Ulna

Thirteen radii, 34 radius/ulna, and 36 ulnae portions out of 226 showcase cut-marks. Fifty-four (24 percent of the total) were specifically noted for their cuts indicating blank removal.

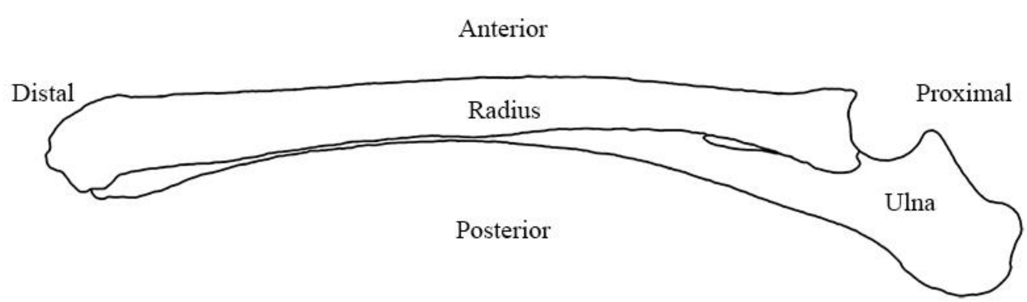

Figure 5. Lateral view of radius/ulna

Cuts around the distal portion of the bones where the ulna fuses to the radius are seen along with cuts lengthwise up the radius, often along the point where the ulna has fused. The ulna is often cut up the posterior to the proximal portion just below the olecranon. This pattern of cutting has been suggested by Mary-Rousselière (1984) to have been done to produce an awl, punch, or retoucher, as, like those artifact types, the portion that was removed has one end usually with a 90-degree angle and the other usually a blunt tip. However, the removed portion from the LdFa-1 examples was much longer than what Mary-Rousselière described, so the type of tool created from them was clearly different than his suggestions.

It is of course possible that a short portion of the ulna was used, from the proximal portion down to the fusion to the radius, and that the radius was separately cut for other purposes, but the line of grooving follows the ulna down to the distal portion of both bones, though the distal epiphysis of the ulna is left behind fused to the radius. This would be a lot of seemingly unnecessary work to carefully remove the long, thin, and slightly curved portion of the ulna intact if it was then to be broken down and used as an awl. If awls were what was being sought, the proximal portion of the ulna would be a more likely candidate, as it would taper to a point and provide a natural handle. Yet these portions are the ones left behind at LdFa-1 with their posterior edge cut away, so they were not what the Dorset wanted. The fact that so many of the radius/ulna elements from Mingo lake have been cut means that these blanks were highly sought after, yet, after comparing the reconstructed shape of the blank that was removed to known Dorset tools from archaeological reports (Mary-Rousselière 2002, Maxwell 1973, Maxwell 1985, McGhee 1981), it is difficult to determine what implement they would have been used for. The closest tools in shape to these portions are gull hooks (Mary-Rousselière 2002, 185; McGhee 1981, 91), but they are much smaller and identified in the reports as being made from ivory instead of bone. If this is a possible misidentification of material, the long radius/ulna blank may have been taken for these tools.

2.6.4 Antler

The antler pieces from Mingo Lake were the most frequently worked, with 64 percent of the 78 pieces showcasing cut-marks or potential cut-marks. This is not an unexpected result from the site as antler is used widely for Dorset harpoons and boxes, even when caribou bones are not dominant at Dorset sites (LeMoine 2005). While antlers can be scavenged from the landscape, LdFa-1 shows that caribou which have been actively hunted also provide antler which was extensively cut. This ensures that the antler would have been fresh as well, though some gnawed antler was also present at the site. This gnawed antler implies that caribou were in the area already, having shed the antler in a previous season, and the Dorset may have used this as an indication of where to find the animals when they needed to hunt.

2.6.5 Implications

It is significant that none of these blanks were found at LdFa-1. The portions of ribs and ulna could easily have been carried away for further processing or traded with groups living in areas where caribou bone was not as available. Multiple needles could have been made from one rib, so they wouldn't need to harvest all of them. Metacarpal/metatarsal tools were larger and could possibly last longer, or they were not needed as much from this site. Almost every radius and ulna from Area 1 had had a blank removed, so there was something about the shape or thickness of the ulna that was sought by the Dorset at Mingo Lake. None of the tool types Mary-Rousselière (1984) described as a reason to take the radius/ulna portions have been found at LdFa-1, so it is just the shape of the missing portion that can be used to postulate what it was taken for.

Harpoon heads from the Dorset component at Philip's Garden were dominantly from antler (Wells, Renouf and Rast 2014). Wells, Renouf and Rast (2014) also consider barbed points to be likely made from caribou bone, making these another possible tool to consider from the Mingo Lake blanks. They used a caribou radius for their experiment, though the portion they used does not seem to match with the modifications of the radii from Mingo Lake. It is possible that a different portion of the radius that was broken when removing the ulna was then used, but it was not seen in the blanks that would have been extracted. Needles could also be made from different bones, as the reproduction done by Rast in the 2014 study showed a needle could be made from a goose ulna, though it would require care to take the blank from the core without snapping it. Their study was done with a focus on the striations produced by the tools used during the creation, and not on whether the tools could be made from different bones, so while they could prove goose ulnae were suitable for needle manufacture, the curve in some Dorset needles and blanks found by Mary-Rousselière would make caribou ribs a bone to practice further reproductions on.

The cut bones from Mingo Lake are most comparable to Mary-Rousselière's (1984) findings and description of Dorset tools from the Nunguvik and Saatut sites. Yet even his description of the caribou ulna tool use was vague and included multiple possibilities. He may not have even noticed that such long pieces were removed as he focused on the proximal ulna pieces for his postulations. While there are certainly many proximal ulnae found at Mingo Lake with the same cuts, the fact that it fuses to the radius and cuts were found along the ulna fusion line, down to the distal radius portion, indicates the full length was being sought, and not just proximal pieces.

2.7 Conclusion

Artifacts are often the focus of archaeological research as they are the visible representation of a past culture. The missing portions of bones cut for tools are not easy to envisage as they disappear in the creation process of tool production. But unlike lithics, the original shape of bones used for tool procurement is known and reveals the template that people had in mind for their tools. Not every anatomical element is cut up and shaped for tool use, so there is a reason certain bones are chosen over others. By using 3D scanning and software, and overlaying the cut bones with a comparative collection full bone, we can determine the shape and size of the missing piece, and 3D print it for further study. At LdFa-1, the shape of the radius and ulna is most likely what was sought after, as well as the shape of the metapodials and ribs since so many have been taken from the site. Since the Dorset definitely had access to sea mammal bones, the fact that they also sought and modified certain caribou bones indicates that these bones had shapes or other characteristics that they needed or wanted. Since many caribou metapodial tools have been found on multiple Dorset sites, it stands to reason that caribou were hunted, and that the shapes of their bones were sought for specific purposes. While this thesis cannot definitively prove what tools were being made, it does reveal a specific shape that the Dorset chose for further tool manufacture. The technique of retrieving this shape digitally can also be used by other researchers if they are not able to find the blanks on site, or if they do not have an experienced replicator, or extra bones to experiment on. Further research may even attempt to 3D scan tools of unknown bone to match against the shape and thickness of these blanks in a 3D program. The use of 3D technology on LdFa-1's faunal assemblage has demonstrated that the specific tools manufactured by the Dorset from nearly a quarter of the caribou radius/ulnae present at the site are not presently identifiable among Dorset archaeological assemblages. Clearly it was an important artifact type for the Dorset as they produced so many of them. This requires further research.

References

Appelt, Martin, Eric Damkjar, and T. Max Friesen. 2016. "Late Dorset." Chap. 33 in *The Oxford Handbook of the Prehistoric Arctic,* edited by T. Max Friesen and Owen K. Mason, 783-806. New York: Oxford University Press.

Balicki, Asen. 1970. *The Netsilik Eskimo.* Garden City: The Natural History Press.

Betts, Matthew W., Herbert D. G. Maschner, Corey D. Schou, Robert Schlader, Jonathan Holmes, Nicholas Clement, and Michael Smuin. 2011. "Virtual Zooarchaeology: Building a Web-based Reference Collection of Northern Vertebrates for Archaeofaunal Research and Education." *Journal of Archaeological Science* 38: 755-762.

Binford, Lewis R. 1981. *Bones Ancient Men and Modern Myths.* New York: Academic Press Inc.

Birket-Smith, Kaj. 1976. *The Caribou Eskimos : Material and Social Lifef and Their Cultural Position.* New York: AMS Press.

Brink, Jack. 2005. "Caribou Drive Lanes on Southern Victoria Island, Nunavut, Canada." *Arctic Anthropology* 42: 1-28.

Burch, Ernest S. Jr. 1972. "The Caribou/Wild Reindeer as a Human Resource." *American Antiquity* 37: 339-368.

Choyke, Alice M. 2013. "Hidden Agendas: Ancient Raw Material Choice for Worked Osseous Objects in Central Europe and Beyond." Chap. 1 in *From These Bare Bones: Raw Materials and the Study of Worked Osseous Objects,* edited by Alice Choyke and Sonia O'Connor, 1-11. Oxford: Oxbow Books.

Conlon, Amanda. 2013. *The Ancient Arctic: Dorset Bone Tools at Mingo Lake.* Honours Essay, Department of Anthropology, University of Waterloo.

COSEWIC. 2018. *Species at Risk Special Registry.* September 19. http://www.registrelep-sararegistry.gc.ca/sar/index/default_e.cfm?stype=species&lng=e&index=1&common=caribou&scientific=&population=&taxid=0&locid=0&desid=0&schid=0&desid2=0&.

Festa-Bianchet, M., J.C. Ray, S. Boutin, S.D. Côté, and A. Gunn. 2011. "Conservation of caribou (Rangifer tarandus) in." *Canadian Journal of Zoology* 89: 419-434.

Gordon, Bryan C. 2005. "8000 years of caribou and human seasonal migration in the Canadian Barrenlands." *Rangifer* (Special Issue 16): 155-162.

Gravina, Brad, Ryan J. Rabett, and Krish Seetah. 2012. "Combining Stones and Bones, Defining Form and Function, Inferring Lives and Roles." In *Bones for Tools - Tools for Bones,* edited by Krish Seetah and Brad Gravina, 1-10. Cambridge: McDonald Institute for Archaeological Research.

Gunn, A., D. Russell, and J. Eamer. 2010. *Northern caribou population trends in Canada.* Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Thematic Report No. 10., Ottawa: Canadian Councils of Resource Ministers.

Gunn, Anne, Don Russell, and Lorne Greig. 2014. "Insights into integrating cumulative effects and collaborative comanagement for migratory tundra caribou herds in the Northwest Territories, Canada." *Ecology and Society* 19 (4).

Idaho Virtualization Lab. 2013. *Idaho Virtual Museum.* Vers. 1.4.0. Accessed 2018. https://virtual.imnh.iri.isu.edu/.

Jandt, Randi, Kyle Joly, C. Randy Meyers, and Charles Racine. 2008. "Slow Recovery of Lichen on Burned Caribou Winter Range in Alaska Tundra: Potential Influences of Climate Warming and Other Disturbance Factors." *Arctic, Antarctic, and Alpine Research* 40: 89-95.

Kenny, Tiff-Annie, Myriam Fillion, Sarah Simpkin, Sonia D. Wesche, and Hing Man Chan. 2018. "Caribou (Rangifer tarandus) and Inuit Nutrition Security." *EcoHealth* 1-18.

Klein, David R. 1999. "The Roles of Climate and Insularity in Establishment and Persistence of Rangifer tarandus Populations in the High Arctic." *Ecological Bulletins* 47: 96-104.

Kuzminsky, Susan C., and Megan S. Gardiner. 2012. "Three-Dimensional Laser Scanning: Potential Uses for Museum Conservation and Scientific Research." *Journal of Archaeological Science* 39: 2744-2751.

Landry, DB, IJ Ferguson, SB Milne, and RW Park. 2015. "Combined Geophysical Approach in a Complex Arctic Archaeological Environment: A Case Study from the LdFa-1 Site, Southern Baffin Island, Nunavut." *Archaeological Prospection* 22: 157-170.

Leblond, Mathieu, Martin-Hugues St-Laurent, and Steeve D. Cote. 2016. "Caribou, Water, and Ice - Fine-Scale Movements of a Migratory Arctic Ungulate in the Context of Climate Change." *Movement Ecology* 4: 1-12.

LeMoine, Genevieve. 2005. "Understanding Dorset From a Different Perspective: Worked Antler, Bone, and Ivory." In *Contributions to the Study of the Dorset Palaeo-Eskimos*, edited by Patricia D. Sutherland, 133-145. Gatineau: Canadian Museum of Civilization Corporation.

LeMoine, Genevieve. 2003. "Woman of the House: Gender, Architecture, and Ideology in Dorset Prehistory." *Arctic Anthropology* 40 (1): 121-138.

Li, Fangzheng, Chunying Liu, Xuexiong Song, Yanjun Huan, Shansong Gao, and Zhongling Jiang. 2018. "Production of Accurate Skeletal Models of Domestic Animals Using Three-Dimensional Scanning and Printing Technology." *Anatomical Sciences Education* 11: 73-80.

Lyman, Lee R. 2017. "Paleoenvironmental Reconstruction from Faunal Remains: Ecological Basics and Analytical Assumptions." *Journal of Archaeological Research* 25 (4): 315-371.

Mallory, Conor D., Mitch W. Campbell, and Mark S. Boyce. 2018. "Climate influences body condition and synchrony of barren-ground caribou abundance in Northern Canada." *Polar Biology* 41: 855-864.

Manzano, Bruce L., Bernard K. Means, Christopher T. Begley, and Mariana Zechini. 2015. "Using Digitial 3D Scanning to Create "Artifictions" of the Passenger Pigeon and Harelip Sucker, Two Extinct Species in Eastern North America: The Future Examines the Past." *Ethnobiology Letters* 232-241.

Mary-Rousselière, Guy. 2002. *Nunguvik et Saatut.* Hull: Musée canadien des civilisations.

Mary-Rousselière, Guy. 1984. "Une remarquable industrie dorsétienne de l'os de caribou dans le nord de Baffin." *Études/Inuit/Studies* 8 (2): 41-59.

Maxwell, Moreau S. 1973. *Archaeology of the Lake Harbour District, Baffin Island.* Ottawa: Archaeological Survey of Canada.

—. 1985. *Prehistory of the Eastern Arctic.* Orlando: Academic Press Inc.

McGhee, Robert. 1981. *The Dorset Occupations in the Vicinity of Port Refuge, High Arctic Canada.* Ottawa: Archaeology Survey of Canada.

Milne, Brook, Robert Park, and Douglas Stenton. 2013. "For Caribou, Chert, and Company: Assessing Mobility as Evidence for Cultural Continuity among the Palaeo-Eskimos of Baffin Island, Arctic Canada." Chap. 5 in *Mobility, Transition and Change in Prehistory and Classical Antiquity:* , edited by Paul R. Preston, 49-61. Oxford: Archaeopress.

Milne, S. Brooke, Robert W. Park, and Douglas R. Stenton. 2012. "Dorset Culture Land Use Strategies and the Case of Inland Southern Baffin Island." *Canadian Journal of Archaeology* 267-288.

Milne, S. Brooke, Robert W. Park, and Douglas R. Stenton. 2013. "For Caribou, Chert, and Company: Assessing Mobility as Evidence for Cultural Continuity among the Palaeo-Eskimos of Baffin Island, Arctic Canada." Chap. 5 in *Mobility, Transition and Change in Prehistory and Classical Antiquit*, edited by Paul R. Preston and Katia Schörle, 49-61. Oxford: Archaeopress.

Niven, Laura, Theresa E. Steele, Hannes Finke, Tim Gernat, and Jean-Jacques Hublin. 2009. "Virtual Skeletons: Using a Structured Light Scanner to Create a 3D Faunal Comparative Collection." *Journal of Archaeological Science* 36: 2018-2023.

Park, Robert W. 2016. "The Dorset-Thule Transition." In *The Oxford Handbook of the Prehistoric Arctic*, edited by T. Max Friesen and Owen K. Mason, 807-826. Oxford: Oxford University Press.

Park, Robert W. 2008. "Archaeological Excavations at the LdFa-1 site, Mingo Lake, Baffin Island, Summer 2008." work conducted under Nunavut Territory Archaeologist Permit No. 08-029, Department of Anthropology, University of Waterloo, Waterloo.

Park, Robert W., S. Brooke Milne, and Douglas R. Stenton. 2017. "Burin and Spall Use at an Inland Arctic Small Tool Tradition Site, Southern Baffin Island, Nunavut." *Canadian Journal of Archaeology* 41: 63-78.

Pearce, Tristan, James Ford, Ashlee Cunsolo Willox, and Barry Smit. 2015. "Inuit Traditional Ecological Knowledge (TEK), Subsistance Hunting and Adaptation to Climate Change in the Canadian Arctic." *Arctic* 68 (2): 233-245.

Post, Eric, and Mads C. Forchhammer. 2008. "Climate Change Reduces Reproductive Success of an Arctic Herbivore through Trophic Mismatch." *Philosophical Transactions of the Royal Society B* 363: 2369-2375.

Reitz, Elizabeth, and Elizabeth Wing. 2008. *Zooarchaeology*. 2nd. Cambridge: Cambridge University Press.

Rick, Torben C., and Rowan Lockwood. 2012. "Integrating Paleobiology, Archeology, and History to Inform Biological Conservation." *Society for Conservation Biology* 45-54.

Rowley, Graham. 1940. "The Dorset Culture of the Eastern Arctic." *American Antiquity* 490-499.

Ryan, Karen. 2016. "The "Dorset Problem" Revisited: The Transitional and Early and Middle Dorset Periods in the Eastern Arctic." In *The Oxford Handbook of the Prehsitoric Arctic*, edited by T. Max Friesen and Owen K. Mason, 761-782. New York: Oxford University Press.

Species at Risk Act, Statutes of Canada 2002, c.9. https://laws-lois.justice.gc.ca/eng/acts/s-15.3/FullText.html

Stankowich, Theodore. 2008. "Ungulate flight responses to human disturbance: A review and meta-analysis." *Biological Conservation* 141: 2159-2173.

Stenton, Douglas R. 1991. "Caribou Population Dynamics and Thule Culture Adaptations on Southern Baffin Island,N.W.T." *Arctic Anthropology* 28 (2): 15-43.

Stoddart, Mark C.J., and Jillian Smith. 2016. "The Endangered Arctic, the Arctic as Resource Frontier: Canadian News Media Narratives of Climate Change and the North." *Canadian Sociological Association* 53 (3): 316-336.

Taylor, William E. 1968. "The Arnapik and Tyara Sites: An Archaeological Study of Dorset Culture Origins." *Memoirs of the Society for American Archaeology* 22: 1-129.

Thomas, Daniel B., Jessica D. Hiscox, Blair J. Dixon, and Johan Potgieter. 2016. "3D Scanning and Printing Skeletal Tissues For Anatomy Education." *Journal of Anatomy* 229: 473-481.

Thompson, Jessica C., J. Tyler Faith, Naomi Cleghorn, and Jamie Hodgkins. 2017. "Identifying the Accumulator: Making the Most of Bone Surface Modification Data." *Journal of Archaeological Science* 85: 105-113.

Trigger, Bruce. 2006. *A History of Archaeological Thought.* New York: Cambridge University Press.

Tyler, N.J.C. 2010. "Climate, snow, ice, crashes, and declines in populations of reindeer and caribou (Rangifer tarandus L.)." *Ecological Monographs* 80: 197-219.

Wells, Patricia J., M. A. Renouf, and Tim Rast. 2014. "Dorset Culture Bone and Antler Tool Tool Reproductions Using Replica Lithics: Report on the Identification of Some Possible Manufacture Traces on Osseous Tools from Philip's Garden, Newfoundland." *Canadian Journal of Archaeology* 38: 394-423.

Wolfe, Scott A., Brad Griffith, and Carrie A. Gray Wolfe. 2000. "Response of Reindeer and Caribou to Human Activities." *Polar Research* 63-74.

Appendix

Pictures of Cut Radii

Pictures of Cut Ulnae

Picture of Cut Radius/Ulna

Pictures of Ribs

Picture of Metatarsal

Non-caribou elements

Sum of Quantity	Axial	Left	Right	Side indeterminate	Grand Total
Axis vertebra	1				1
Calcaneus			1		1
Cervical vertebra	5				5
Compact bone ind (Podials, sesamoids, patellae, etc)				2	2
Cranium	11	2	2	24	39
Epiphysis ind				3	3
Femur		8	4	10	22
Flat bone ind (Ribs, scapulae, pelvis, cranium, etc)				41	41
Humerus		3	2	9	14
Indeterminate (ie, completely unidentifiable)				8008	8008
Innominate		2		5	7
Long bone ind				97	97
Lumbar vertebra	4				4
Mandible		11	10	4	25
Metacarpal (Front cannon bone)				2	2
Metapodial ind				2	2
Metatarsal (Hind cannon bone)				1	1
Phalange ind				5	5
Radius				2	2
Rib		21	21	201	243
Scapula			2	2	4
Thoracic vertebra	6				6
Tibia		3	2	7	12
Tooth, deciduous				1	1
Tooth, permanent				5	5
Tooth, permanent/deciduous ind				32	32
Ulna				3	3
Vertebra ind	7				7
Grand Total	**34**	**50**	**44**	**8466**	**8594**

Bones with cut-marks

Sum of Quantity	Cut marks present	Possible cut marks	Grand Total
Antler	47	3	50
Astragalus (Talus)	1		1
Atlas vertebra	1		1
Axis vertebra	2		2
Calcaneus	2		2
Cervical vertebra	2		2
Cranium	19	3	22
Femur	6	3	9
Flat bone ind (Ribs, scapulae, pelvis, cranium, etc)	4		4
Humerus	5	1	6
Hyoid	3		3
Indeterminate (ie, completely unidentifiable)	33	3	36
Innominate	9	1	10
Long bone ind	52	2	54
Lumbar vertebra	2	1	3
Lunate (Intermediate carpal bone)	1		1
Mandible	20	3	23
Metacarpal (Front cannon bone)	14	1	15
Metacarpal of paradigit (Accessory metacarpal)	1		1
Metatarsal (Hind cannon bone)	25	3	28
Patella	1		1
Phalange ind	3		3
Radius	13	4	17
Radius & Ulna fused	33	2	35
Rib	91	18	109
Scapula	7	1	8
Sesamoid		1	1
Sternum	3		3
Thoracic vertebra	8		8
Tibia	9	5	14
Tooth, permanent	1		1
Ulna	36	2	38
Grand Total	454	57	511