TEMPORAL AND SPATIAL VARIATIONS IN THE LONG-TERM FLUCTUATIONS OF WILDLIFE POPULATIONS IN GREENLAND

NERI Technical Report no. 808 2011

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Charlotte M. Moshøj
Mads C. Forchhammer
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Data sheet

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Authors: Charlotte M. Moshøj, Mads C. Forchhammer and Peter Aastrup
Department: Department of Arctic Environment

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Abstract: Long term data on wildlife population fluctuations in Greenland are presented in this report. Climatic variability and other environmental and societal changes may be causal factors behind these fluctuations. The data provides a historical account for the spatio-temporal dynamics of wildlife in Greenland, and exemplify the potential future use and significance of these data.

Keywords: wildlife fluctuations, spatio-temporal dynamics, climatic variability, NAO, environmental effects, time-series, hunting statistics, historical accounts, Greenland, Arctic fox, seals, caribou, traditional hunting, The Colonial Accounts

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Contents

Summary

Populations of fish, birds and mammals in Greenland display distinct fluctuations, which may vary considerably over time and space. Climatic variability may be one causal factor greatly affecting the abundance of arctic animals. Indeed, climate change impacts raise the questions of speed and magnitude of change in species and, thus, the abilities and opportunities for Greenland's indigenous communities to harvest and process animals for food. Other environmental changes, such as rapid social and cultural shifts may also affect the utilisation of natural resources, and in turn their impact on wildlife populations. The data presented in this report date back more than 100 years and consist of accounts of skins and other products purchased from Greenlandic hunters by the Royal Greenland Trade Department (Den Kongelige Grønlandske Handel, KGH). These hunting records represent a unique time series for retrospective description and analyses of annual and decadal fluctuations in relation to long-term climatic data, environmental factors and temporal variations in social and demographic parameters in the existing society. In this report we provide a historical account for the spatio-temporal dynamics of wildlife in Greenland, a description of data sources, and exemplify the potential use and significance of this data.

Resume

Grønlandske bestande af fugle, fisk og pattedyr udviser varierende fluktuationer i tid og rum. Ændringer i klima kan være en forklarende faktor, der påvirker forekomst såvel som udbredelsen af arktiske dyr. Effekten afhænger af dels hastigheden og dels omfanget af klimaændringer. Ændringer i socio-økonomiske forhold i den grønlandske befolkning forventes også at påvirke udnyttelsen af de naturlige vildtressourcer bl.a. gennem ændringer i fangstmetoder.

Denne rapport er en samlet præsentation af skind og fangstdata registreret af den Kongelige Grønlandske Handel (KGH). Disse informationer rækker for flere arter over 100 år tilbage i tiden og fangststatistikkerne repræsenterer derfor en unik tidsserie der kan anvendes til retrospektiv beskrivelse af svingninger i relation til klima og andre miljømæssige faktorer. Her præsenterer vi en samlet historisk oversigt af langtidsændringerne i fangst fra hele Vestgrønland, en detaljeret beskrivelse af datakilder, og endelig eksemplificerer vi dette store datasæts anvendelse fremover.

Eqikkaaneq

Kalaallit Nunaanni timmissat, aalisakkat miluumasullu piffissap ingerlanerani najugannaamminilu allannguuteqartarput. Silap allanngornera issittup uumasuisa amerlassusiinut siammarsimassusiinullu sunniuteqarsinnaavoq. Qanoq sunniuteqartigineranut apeqqutaasarput allanngornerup sukkassusia annertussusialu. Aammattaaq inuiaqatigiit kalaallit inuuniarnerminni atukkamikkut allannguuteqarnerat aamma uumasunik nujuartanik atueriaatsimik allanngortitsinissaa naatsorsuutigineqarpoq, tassa ilaatigut piniarnermi periaatsit allanngornerannik pissuteqartumik.

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1 Introduction

This report is the result of a pilot project study funded by the Environmental Protection Agency, the Danish Ministry of the Environment. The aim of the study is to establish a database of trading/hunting statistics of harvested species from western Greenland. This database will provide the foundation for more detailed analyses of the long-term dynamics of natural resources in relation to environmental variability including climate and human utilisation. Here, we provide a historical account for the spatio-temporal dynamics of wildlife in Greenland, a description of sources of data, and exemplify the potential of the data by providing a descriptive presentation of selected data. All data collected are available at http://www2.dmu.dk/pub/FR808_Data_CD.zip.

In arctic regions where a severe climate with high seasonal and annual variability and simplistic ecosystems prevail, species of fish, birds and mammals display distinct population fluctuations of varying temporal and spatial scale. In Greenland, historical records, archaeological findings and oral accounts passed on from Inuit elders all document that the presence of wildlife species and their population sizes have undergone pronounced fluctuations throughout recordable historical time (H.C. Petersen, pers. com.; Vibe 1967, Meldgaard 1985). The most detailed accounts are found for the species that were harvested or had economical value. These data on harvestable species such as caribou *Rangifer tarandus*, ringed real *Pusa hispada*, arctic fox *Alopex lagopus* may further be used to highlight fluctuations in the given animal populations (e.g., Stenseth et al. 1999, Forchhammer and Asferg 2000).

As the climate changes, the Arctic's indigenous people are facing special challenges (ACIA 2005), and their abilities to harvest wildlife and food resources are already being tested. It has been proven that climatic variability and weather events often greatly affect the abundance of arctic animals (Forchhammer and Boertmann 1993, Forchhammer et al. 2002, Post and Forchhammer 2002, 2004) and, thus, the abilities and opportunities to harvest and process animals for food. Arctic people have long experience in adapting to the changing conditions here. However, climate change impacts raise the questions of speed and magnitude of change, as compared to how fast people can learn and adapt. The rate and extent of current and projected climate change in the arctic therefore gives cause for alarm (ACIA 2005, IPCC 2007).

The effect of climate change on arctic communities should be viewed together with other environmental changes, such as rapid social and cultural change and globalisation processes. Arctic communities have experienced, and are experiencing, stress from a number of different forces that threaten to restrict harvesting activities and to restrict the mobility that Inuit once possessed, and thereby constrain their adaptive responses to a changing resource base (ACIA 2005).

The data presented in this report consist of accounts of skins and other products purchased from Greenlandic hunters by the Royal Greenland Trade Department (Den Kongelige Grønlandske Handel, KGH) and are based on figures extracted from various historical and newer sources. Commencing in 1792, data on varying harvested and traded species from West Greenland colonies were recorded annually in the trade departments account books. Dating back more than 200 years, these hunting records therefore represent a unique time series for retrospective modelling of annual and decadal fluctuations in relation to long-term climatic data, environmental factors and temporal variations in social and demographic parameters in the existing society.

Because of the recent development of new methods of analysis, however, it has become relevant to re-analyse the data aiming at predicting the effects of climate change on animal populations in and around Greenland. Two measures have been taken to achieve this. First, a PhD project, partly funded by the Danish Natural Research Council, has been implemented and will use the data presented here as a platform for more extensive analyses. Secondly a 4-year project focusing on land-based ecosystems and natural resources was recently successfully funded as a part of the new Greenland Climate Research Centre at the Greenland Institute of Natural Resources, Nuuk. The data presented here will constitute a significant part of the data platform for the analyses to be carried out.

Figure 1.1. Seal skins, bound on a frame (innerfik) to dry. (Photo: Carsten Egevang).

2 Historical background

2.1 Marine and terrestrial wildlife

In Greenland, historical records, archaeological findings and oral accounts passed on from Inuit elders all document that the presence of wildlife species and their population sizes have undergone pronounced fluctuations throughout recordable historical time (Vibe 1967, Meldgaard 1985, H.C. Petersen, pers. com.). Although the records and accounts reveal fluctuations for a wide range of species, the most detailed accounts are found for the species which were harvested or had other economical value, for example ringed seal, cod, and caribou.

For thousands of years the ringed seal has been very important game for the indigenous people in the areas north of the Arctic Circle. The species dependency on the availability of coastal ice influence the seasonal distribution, but diversified hunting methods enabled Inuit hunters to utilize the ringed seal for fresh meat and furs during all seasons. During ice covered periods they used netting under the ice and hunting of seals on coastal ice, while hunting from vessels took place in the ice free periods. Due to the species dependency of available ice, a regional variation in distribution can be documented in the historical catch statistics from the West Greenland coast (Vibe 1967).

Most ringed seals are caught in areas where high densities of the Baffin Bay pack ice reach the Greenland coast. In spring, when the ice starts to retreat towards Canada and northwards along the Greenland coast, the ringed seal catches stay high in the areas that have ice (Vibe 1967, Rosing-

Figure 2.1. Ringed Seal. (Photo: Carsten Egevang).

Asvid 2006). While hunting statistics of ringed seals from western Greenland municipalities give a good indication of these seasonal changes in distribution and abundance, they may also indicate changes in significant environmental and biological factors. From the historical catch statistics and observations of Inuit hunters it has been accounted how the total annual catch of ringed seals during the last century fluctuated from 15-20000, to a high record of 120000 for all of Greenland. These periods of low and high catch rates coincide with periods of respectively warmer and colder climate. While ringed seal catches rise in the central areas of west Greenland in periods of colder climate and increased stagnation of the Baffin Bay ice, there has been observed a general northward shift of ringed seal catches during mild periods (Vibe 1967).

Similarly, terrestrial species have undergone large fluctuations in abundance and distribution. In West Greenland, fluctuations of caribou have been recorded through the last 250 years with drastic population decreases and increases exceeding 90% of the population, and for some populations ending in extinction (Vibe 1967, Meldgaard 1985). These fluctuations with large amplitudes seem to be across the spatially distinct populations in West Greenland, while several populations in Thule, Inglefield Land and Northeast Greenland experienced a synchronous decline in 1895 and 1915 that was out of step with the other populations and ultimately resulted in the extinction of the Northeast Greenland population (Meldgaard 1985).

Other terrestrial species have exhibited similar multi-annual fluctuations. Braestrup (1941) documented that the Greenland populations of arctic fox and ptarmigan *Lagopus mutus* have been subject to considerable annual quantitative fluctuations. Part of this work was based on the records

Figure 2.2. Caribou in West Greenland. (Photo: Carsten Egevang).

and accounts of hunting bags recorded by the Royal Greenland trade department. Vibe (1967) utilized further accounts of these hunting records, to demonstrate that numerous Greenlandic populations of sea and land mammals as well as sea birds had been subject to great quantitative fluctuations and geographical shifts. Vibe (1967) recognized that climate influenced the ecology and distribution of these populations, and recognized that the variation in frequency, quantity and time of arrival of the East Greenland ice in the Davis Strait, along with the relative strengths of the Canadian, The East Greenland and the Irminger current were influencing factors. Indeed, recent studies on caribou and muskox populations in Greenland corroborates that external forcing of climate synchronizes the dynamics of isolated populations (Post and Forchhammer 2002).

2.2 Greenland's climate

The climate of Greenland and the Arctic display dramatic changes. During the last 50 years temperature increases of 2-3°C have occurred throughout the Arctic (Chapman and Walsh 2003), and projections for future arctic climate predict temperature increases of 5-7°C by the end of the 21st century (Kattsov et al. 2005). Indeed, pronounced climate changes are also expected for Greenland during the next 100 years with temperature increases of up to 6-8°C in Northeast Greenland following the expected retreat and reduction in the Polar Sea Ice (Storis) (Rysgaard et al. 2003). In contrast, temperatures are only expected to increase 2-5°C in West Greenland. Similarly, precipitation in Greenland, in particular winter precipitation, has been predicted to increase 20-30% (minus evaporation) in the forthcoming 100 years (Kattsov et al. 2005).

It is also well-established that the Arctic during the past 3 decades has experienced considerable and rather dramatic changes in the cryosphere. For example, associated with the behaviour of large-scale ocean-atmosphere fluctuations such as the Arctic Oscillation (AO) or the North Atlantic Oscillation (NAO), the thickness and the extent of arctic sea ice have been reduced over the last 30 years, indicating 20% acceleration in the rate of the decrease of sea ice in the Northern Hemisphere (Cavalieri et al. 2003). Concomitantly, the terrestrial snow cover in the Northern Hemisphere has been reduced by 10% and with the expected temperature increase of 5-7°C further significant reduction in snow cover is expected (Walsh et al. 2005). Coinciding with the measured increase in ground temperature in the Arctic, a significant degradation of permafrost has been observed. This is expected to continue with up to further 10-20% degradation during the 21st century resulting in a displacement of the southern range of permafrost hundreds of kilometres northward (Walsh et al. 2005).

Evidently, such changes in the climate and the cryosphere will impose tremendous constraint on the terrestrial, limnic and marine environment of the Arctic with significant consequences for the structure, function and feedback of arctic ecosystems (Callaghan et al. 2005, Wrona et al. 2005, Post et al. 2009).

2.3 Climatic impact on wildlife

2.3.1 Terrestrial mammals

Braestrup (1941) demonstrated that the Greenland populations of arctic fox and ptarmigan are subject to considerable annual quantitative fluctuations. Vibe (1967) took the analysis a step further, and related the fluctuations in arctic fox populations to differing climatic periods and geographic regions. The quantitative fluctuations at differing geographic locations ran independent courses, and a rise in one area corresponded to a drop in another region. Vibe (1967) distinguished between three different climatic periods, related to the average advance of drift ice into Davis Strait during the months of May-August. In the drift ice stagnation stage (approx. 1810-1860), the East Greenland ice did not advance far north into Davis Strait and the climate of north-western Greenland was relatively cold, dry and stable providing favourable winter climate for the caribou in central and northern West Greenland, as well as for muskox populations in Northeast Greenland (Vibe 1967). In the drift ice pulsation stage (1860-1910), the ice of the Arctic Ocean drifted into the Atlantic in exceeding amounts and the climate became unstable and wet. The wet winters were unfavourable to the caribou in West Greenland, and to inland populations of arctic fox (Vibe 1967). During the drift ice-melting stage (1910-1960), the east Greenland ice decreased in Davis Strait, the arctic fox population increased and culminated in Northeast Greenland and coastal west Greenland. During the same period the caribou population of west Greenland had ample summer grazing, while winter pastures were often covered by snow and ice (Vibe 1967). Thicker snow cover and more frequent periods of thaw in winter lead to formation of ice crusts in the snow, rendering foraging increasingly difficult as reported for the muskoxen in Northeast Greenland (Forchhammer and Boertmann 1993).

Figure 2.3. The arctic fox. (Photo: Carsten Egevang).

The spatio-temporal dynamics of both caribou and muskox populations in Greenland (Forchhammer et al. 2002, Post and Forchhammer 2002) have been coupled to regional changes in winter precipitation which again were coupled to fluctuations in the NAO. Similarly, the effects of the NAO increased the synchrony of fluctuations of all caribou and muskox populations (Post and Forchhammer 2002).

2.3.2 Marine mammals

In a warmer Arctic, pinnipeds and polar bears are directly affected by changes in the availability of suitable ice-associated habitat (Post et al. 2009). Seals may be particularly vulnerable to changes in the extent or concentration of arctic ice because they depend on pack-ice habitat for pupping, foraging, moulting, and resting (DeMaster and Davis 1995). For example, ringed seals require snow cover to construct subnivean birth lairs on the fast ice. This species depends on the stability of ice for successful rearing of young (Burns et al. 1981). Hooded seal (*Cystopora cristata*) like Polar bear and Narwhal are among the species expected to be the most sensitive arctic marine mammal species in relation to climate induced habitat changes, primarily due to their reliance on sea ice (Laidre et al 2008)..

The Harp seal *Pagophilus groenlandicus*, inhabits the drift ice belt from Newfoundland to Svalbard and the White sea. Their preferred area of residence may be shifted with drift ice borders as harp seals follow the advancing drift ice, moving north in summer and south in winter. In Greenland, the bearded seal *Erignathus barbatus* is found on all coasts and prefers relatively shallow water with thin, shifting ice and leads kept open by strong currents (Burns 1981, Burns et al. 1981, Kingsley and Stirling 1991).

The annual distribution of walruses *Odobenus rosmarus* is strongly coupled with the extent and concentration of ice (Vibe 1967, Born et al. 1997). Walruses overwinter in areas of the pack ice where the ice is thin enough that they can break it with their heads to maintain breathing holes (Stirling et al. 1981), yet thick enough to support their weight (Burns et al. 1981). In this season, walruses are highly clumped in regions in and adjacent to polynyas and ice divergence.

Polar bears require ice as a solid substrate on which to hunt for ringed seals (Stirling and Derocher 1993, Stirling et al. 1993). The distributions of polar bears are probably a function of the distribution of ice conditions that allow them to travel and hunt most efficiently (Burns et al. 1981). Significant differences in usage patterns of sea ice habitat have been shown by bears of different sexes and age classes (Stirling et al. 1993). For example, in the spring, females with cubs of the year show a strong preference for fast ice with snow drifts, whereas adult males, lone adult females, and females with two-year old cubs occur more frequently in floe-edge habitat, where the highest densities of ringed seals are found. Consequently, changes in the extent and type of ice cover are also expected to affect the distributions and foraging success of polar bears.

The onset of decline in the production of ringed seals, and consequently of polar bears, has been linked with the severity of ice conditions. In 1974 and 1975, a major decline of ringed and bearded seals in the eastern

Beaufort Sea followed a winter of heavily compacted sea ice, which lacked the usual formation of leads parallel to the coast (Stirling et al., 1977). Similarly, a decline in ringed seal density in the south-eastern Beaufort Sea from 1982 to 1985 was coincident with heavy ice conditions and less open water, particularly in late summer of 1985 (Harwood and Stirling, 1992).

Since polar bear densities are closely linked to that of mature ringed seals, a milder climate and a resulting decline in its main prey species, poses a severe threat to the polar bear, which may be incapable of adapting rapidly to declining habitat and prey. Sufficient fat reserves may not be acquired before the ice-free period, resulting in declining body condition and lowered reproductive rates and decreased survival rates of adults and newborn cubs. Although the causative mechanisms were unclear, Harwood and Stirling (1992) suggested that a reduction in regional productivity may have contributed to the poorer nutritional condition of ringed seals and bearded seals.

The benefits of ice to arctic cetaceans may relate more to the linkage between prey availability and ice rather than to their direct needs of ice habitat per se. Vibe (1967) found that in periods where little drift ice advanced into the Davis Strait, the populations of sea mammals concentrate at central West Greenland. When the East Greenland current and the East Greenland Ice advanced farther north into the Davis Strait, the sea mammals decreased in central west Greenland and in the "drift ice melting stage" where the east Greenland ice decreases in Davis Strait, the populations of sea mammals increased in Northern West Greenland and East Greenland.

The narwhal *Monodon monoceros* is a strictly arctic species (Vibe, 1967), whereas the beluga is an arctic and sub arctic species rarely found south of 45°N (Reeves, 1990). Both species are strongly associated with ice (Burns et al., 1981), and are known to forage at ice edges and ice cracks (Bradstreet, 1982; Finley and Gibb, 1982; Crawford and Jorgenson, 1990). Historical distributions of narwhal have been linked to sea, ice, wind and current conditions along the Greenland coast (Vibe 1967).

2.4 Traditional hunting and fishing

Since the first wave of immigration via Thule around 4-5000 years ago, the Inuit's in Greenland have been dependent on nature's resources in the form of fish, birds, land mammals and marine mammals. Hunting and fishing have therefore always been a question of survival in a country in which the summer is short and the climate unsuitable for effective farming.

The traditional subsistence economy of the Inuit was well adapted to the natural dynamics of their resource base, hunting a broad range of living resources and thus not as vulnerable to the decline of a single species as the modern exploitation of wildlife resources (Meldgaard 1995).

Seal hunting was the main source of income in Greenland around 1900, but during summer, when hunting opportunities were less ample, many turned to fishing as their main source of income and stable food source.

An overview of the use of raw goods pr person in southern Greenland in 1855 establishes a yearly intake of 440 kg meat and blubber and 400 kg of fish. Commercial fishing had been under development as early on as the 1770s when shark-liver was traded for the production of whale oil, a production that continued until 1962 (Smidt 1983), but fishing was still practiced from kayaks by the end of the 19th century), and the main fishing tool, a hand-held jig was time consuming to utilize and catches therefore mainly sustained own resource needs Rask (1993).

In the late 1800-early 1900 it was estimated that there were 250 kayaks per 1000 inhabitants (Rask 1993). Consecutively the interest for fishing was on the rise and in 1903 the Royal Greenland Trade Department (Kongelige Grønlandske Handel, KGH), was authorized to manage the trade of Arctic char and Greenland halibut for salting and export. Greenland halibut was mainly fished at Ilulissat, where the Faroe Napoleon Andreason was posted by KGH to investigate the potential for commercial fishing off the west coast. Fishing Greenland halibut on the fishing banks off the coast of Ilulissat using longlines, a technique traditional on the Faroe Islands but untried in Greenland was the only success, and the new technology survived after the end of the fishing trials and was further developed by the fishermen to comply to local conditions (Smidt 1983).

The invasion of cod into the southern districts in 1917 must be regarded as the onset of the cod-period which in the following years changed the Greenlandic trade and employment orientation (Smidt 1983, Lyck & Taagholt 1987). The decline in hunting is for a large part ascribable to changed migration routes and distribution of marine mammals. But the decline in hunting may also have been reinforced by the increased possibility and success of cod fishing (Smidt 1983).

Historically, whales have been part of the Inuit traditional catch in Greenland (Caulfield 1993). Hunting took place from small skin covered boats (ummiaq) and aimed at the bowhead whale, as well as humpback whales *Megaptera novaeangliae*. At the beginning of the 1600s, the introduction of bigger and stronger ships made it possible for European whale hunters to go to Svalbard and eastern Greenland for the much sought-after whales.

The whalers were especially interested in the bowhead whale and the right whale *Eubalaena glacialis*. These whales were slow moving, and just one Bowhead whale would provide 20-30 tons of oil.

As whale numbers fell, the whalers moved westward in their search. Here they encountered the Inuit and traded with them. The whalers bartered clothing, textiles, pottery and earthenware goods, brass kettles, tin ware, beads and sewing needles and knives for blubber, teeth and skins. A shirt "cost" the staggering sum of 1.5 barrels of blubber or two fox skins. Whale oil was used primarily for lighting and as a lubricant, but it was also utilized in the clothing industry for tanning leather, in rope making and for the manufacture of soap products, ship tar, varnish and paint. In addition, the glycerine content from the oil was used for manufacturing cosmetics and explosives. The baleen, also known as whalebone, was used for ribs in corsets, parasols, fans, lamp shades and riding whips.

Soon after the colonization of Greenland (1721) the Greenland Trade Department (KGH) began hunting bowhead whales from smaller vessels, using methods similar to traditional Eskimo whale hunting. Modern catcher boat whaling for other whale species was introduced in Greenland in the 1920´s.

The onset of catcher boat whaling ended the more traditional whale boat hunting. Up until 1953 the whales were landed at different settlements along the coast, and the flensing was done by local people. Between 1954 and 1958 the whales were processed at a land station, from where the meat was distributed. Fin whales, humpback and sperm whales composed most of the catches.

The onset of use of smaller motorized vessels had a large impact on the hunting efficiency of walrus and beluga. Herding flocks of beluga into narrow fjords and bays and utilizing nets was a long practiced method, but the implementation of motorized vessels in the hunt made a huge difference in efficiency and catch numbers as the herd could be driven much farther and with higher success rates than when utilizing kayaks. At the same time the success of the hunters with motorized vessels was obtained at the cost of the traditional kayak hunters, making their future unpredictable. Another species that was affected by hunting from motorized vessels was the walrus. With the traditional skin boats the hunters had no opportunity to hunt in the ice off the west coast, due to the distance from the shore, but the motorized vessels gave opportunity to utilize this resource in contrast to previously, where walrus were only hunted at the haul-out sites on land.

In the 1930s a large number of private vessels as well as a few owned by KGH initiated an uncontrolled hunt of walruses off West Greenland (Born et al 1994), where many of the walrus drowned before they were salvaged and where only the most prized parts of the salvaged carcasses were utilized, and large amounts of meat was left behind. This led to a conservational debate, which was unresolved due to the novelty of hunting at sea and the difficulties involved in regulating the foreign hunting vessels and their catches. During the 1940s, some fjords became restricted for kayak hunters only, and hunting techniques were developed where the motorized vessels towed kayaks to the hunting areas, where walrus and seals then were hunted traditionally using harpoons, thereby decreasing the risk of drowning and loss of the catch. The largest catch was recorded in 1940-41, where 300 walrus were caught by a single fishing vessel, and after that catches declined, although the uncontrolled hunting continued for some years (Rask 1993).

3 The data

Accounts of skins and other products purchased from Greenlandic hunters are based on figures extracted from various historical and newer sources. Appendix 1 gives an overview of the distribution of data in space and time by species or item. The sources are reviewed below.

Skin data is the preferred commodity chosen to be included in the analysis, when there are several items given for the same species. One skin could be used for several commodities like sealskin leggings or boot soles or clothing. These commodities were registered in the database in individual categories to reduce the risk of counting the same individual more than once.

3.1 Sources

3.1.1 The Colonial Accounts (Koloniregnskaberne)

In Greenland the term colony has been used synonymously with mission and trade stations. Altogether there are 14 colonies (Amdrup et al., 1921a, b) included in the accounts and data goes back to 1793 for most colonies. The colonial accounts are kept in the Royal Danish archives and each account book documents trade of commodities with the KGH during one year for each colony. The account year runs April 1st- meaning that, for example, skins registered 1792-1793 may be caught in 1792, but registered and shipped in 1793.

Furthermore the whole and partial skins were for some species (polar bear, caribou, arctic fox) classified into several qualities. Only whole skins, of any quality were included in the database. Arctic foxes were accounted for in the white and blue morph separately. For some species (e.g., walrus and narwhal), other commodities such as tusks were registered, or i.e. jawbones or baleen of whales. These commodities were then registered as single catches. Dried seal skins were categorised as 1. adult (sort side) 2. ordinary, 3. boat skins 4. water skins 5. dinghy skins or as finished products, i.e seal boot-soles. Salted or raw sealskins are categorised as spotted, high quality, ordinary or low quality. In addition there are sealskin coats, trousers and for seabirds, the weight in pounds of collected feathers was registered and utilized as an indicator of the bird populations. The down collected from nests registered as from either eider or as seabird feathers, which consists mainly of feathers from Brünnichs guillemot *Uria lomvia*, along with feathers of common eider *Somateria mollissima*, king eider *S. spectabilis* and cormorant *Phalacrocorax carbo carbo*.

Figure 3.1. Skins purchased/traded from Greenlandic hunters by KGH were registered since 1793.

Photo: Manniche, Arner Ludvig Valdemar.

Copyright: Arktisk Institut

(The Arctic institute),

Figure 3.2. Clothing prepared from animal hides was also accounted for in the trading logbooks.

Photo: Jette Bang.

Copyright: Jette Bang Phot.

The development in hunting tools and the degree of use in the population is reflected in the accounts of ammunition sales in the West Greenland colonies. These accounts also included the sales of sable blades, rifles, shotguns, lead shots and spare parts. Within each category of ammunition the individual categories (i.e. shotguns with differing barrel sizes and, shots of varying pellet size and wide and narrow sable blades) were summed as these categorizations were irrelevant, and only the total number traded was included.

3.1.2 Accounts from Royal Greenland Trading Company (Meddelelser fra Direktoratet for den Kongelige Grønlandske Handel)

The accounts from the Royal Greenland Trading Company (1882-1908) include goods that are received in trade or otherwise acquired, and goods that are traded from Denmark in exchange for the Greenlandic goods. The accounts distinguish between goods traded in from Greenlanders, or from the colonists. Furthermore the Danish goods traded in return for the local products could be acquired by trade, as a part of a due salary, or credited for later pay off. Years with meagre hunting or bad weather conditions would lead to a rise in the amount of goods bought on credit.

3.1.3 The Accounts and Declarations regarding the colonies in Greenland (Beretninger og Kundgørelser vedrørende kolonierne i Grønland)

The accounts and declarations regarding the Colonies in Greenland cover the period 1909-1937. Data on traded hides of seals, whales, polar bear, arctic fox as well as some data on whaling and fisheries from this time period are found here. From 1909-1912 the accounts bore the title "Accounts and declarations regarding the colonies in Greenland" (*Beretninger og kundgørelser vedrørende kolonierne I Grønland*), while they were renamed to "Accounts and declarations regarding the administration of Greenland ", during the period 1913-1927 (*Beretninger og kundgørelser vedrørende styrelsen af Grønland)* and finally in 1933 they were titled" "Accounts and declarations regarding the Greenland administration" (*Beretninger og kundgørelser vedrørende Grønlands styrelse).*

3.1.4 Schematic Reports from The Royal Archives (Skematiske indberetninger, Rigsarkivet)

The Schematic reports are another archive kept in the Royal Archives, and it runs from 1861. Each book is a report on an individual topic, as for example the accounts of vessels in North Greenland, where the individual vessels in each colony, their repairs their dimensions and their purpose is reported on.

3.1.5 The hunting statistics based on the Greenlanders list of game

The hunting statistics based on the Greenlanders list of game (Sammendrag af Grønlands fangstlister) cover the period 1954-1983. By 1975 there was a general decrease in numbers of hunters reporting catches. To compensate for this development, the catch numbers reported for 1975-1983 include estimates for catches not reported. The estimates of "not reported catches" were based on local knowledge on individual hunters and there "normal" catches (Ministeriet for Grønland 1976). Hence catch figures since 1975 are less reliable.

3.1.6 Official catch statistics (Officielle fangststatistikker)

Official catch statistics cover the period 1983-2007 (http://www.stat.gl/).

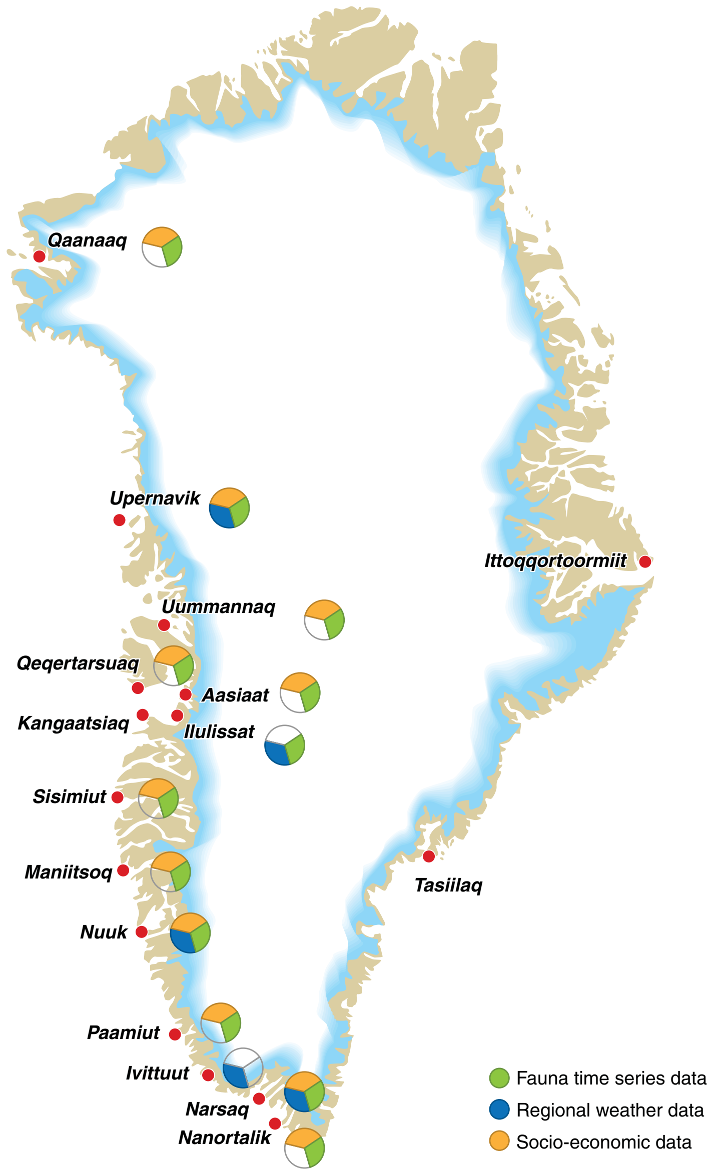
3.1.7 Climate data

Regional weather data on temperature, precipitation and sea ice are directly accessible from annual and scientific reports at the Danish Meteorological Institute and go back to 1860 (www.dmi.dk). Annual winter indices of the North Atlantic Oscillation can be accessed at the National Center for Atmospheric Research, Climate Analysis Section, USA (www.cgd.ucar.edu/~jhurrell/indices.html).

3.2 Examples of long-term data and their potential applicability

The variety of data collected by this project is considerable. Due to the unexpected time-consuming work in merging the huge amount of data available at the Royal Archives (Rigsarkivet) into coherent data files, we focused on the earlier periods embracing the years 1792-1984. All these have been merged into several Microsoft Excel worksheets (*.xls) and Microsoft Access (*.mdb) databases and can be found on the website with supportive file descriptions (See appendix for details).

Figure 3.3. Map of Greenland showing the geographical origin of the earlier data accessed in this project.



Overall, the earlier data embrace time series of an average of 59 years, ranging 12-173 years (Table 6.1). Geographically, the earlier data cover South and West Greenland (Figure 3.3).

Later data on catch statistics (1983-2007) can be readily accessed through files from the Greenland Institute of Natural Resources. These are planned to be merged with the earlier data presented here as a continuation of this project, currently financed as a PhD study at the Roskilde University and Aarhus University.

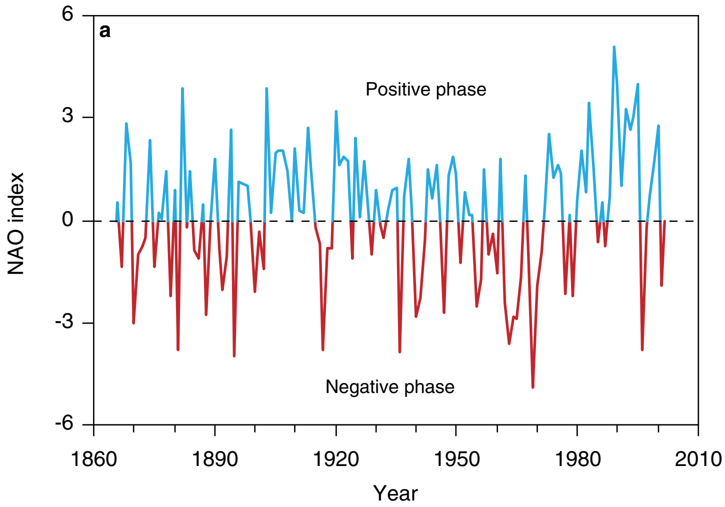
Regional weather data on temperature, precipitation and sea-ice cover is readily accessible from the Danish Meteorological Institute as dat- and txt-files. Annual winter indices of the North Atlantic Oscillation (NAO; Hurrell 1995) are available on National Center for Atmospheric Research, Climate Analysis Section website (www.cgd.ucar.edu/~jhurrell/indices.html).

Below, we give selective presentation of some of the best time series collected and their potential applicability, which is currently being examined in the abovementioned PhD study.

3.2.1 Climate: the NAO

The NAO is a large-scale atmospheric oscillation in atmospheric mass along a meridional gradient in the North Atlantic with action centres over the Azores and Iceland. The NAO index is defined as the annual winter (December–March) deviance from the average difference in sea level pressure (SLP) measured at Lisbon (Portugal) and Stykkisholmur (Iceland). SLP measurements at Ponta Delgada (Azorerne) may also be used instead of those at Lisbon. The NAO index display large inter-annual variations but may in general be described as being in a positive phase or in a negative phase (Figure 3.4a). Spectral decomposition of the NAO time series suggests multi-annual fluctuations of 2–3 year (1/0.128) and 7–8 year (1/0.435) periods (Figure 3.4b) (Forchhammer and Post 2004).

The NAO is one of the most influential large-scale climate systems in the Northern Hemisphere, including Greenland (Forchhammer 2001). Interestingly, the coupling between the NAO and regional weather conditions divides Greenland into west and east with respect to long-term changes in climate (Figure 3.5). Hence, it is obvious to study the relations between NAO, local weather conditions and wildlife and to integrate human utilization of natural resources in Greenland into these analyses.



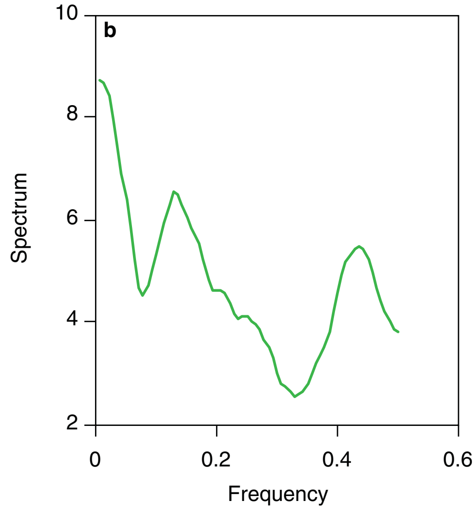
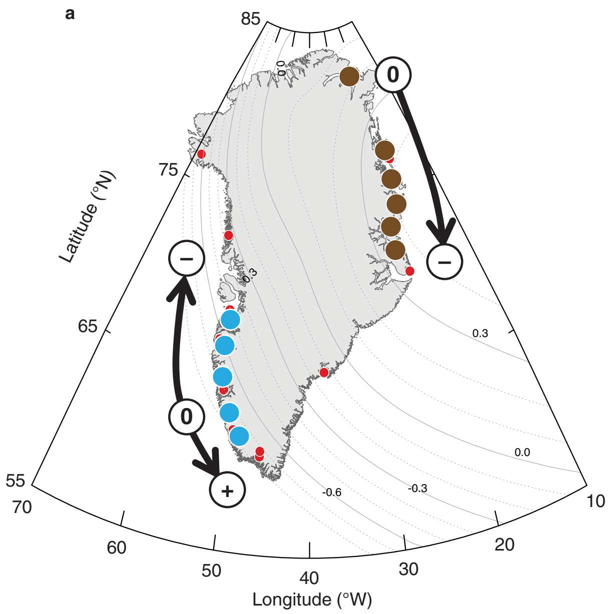
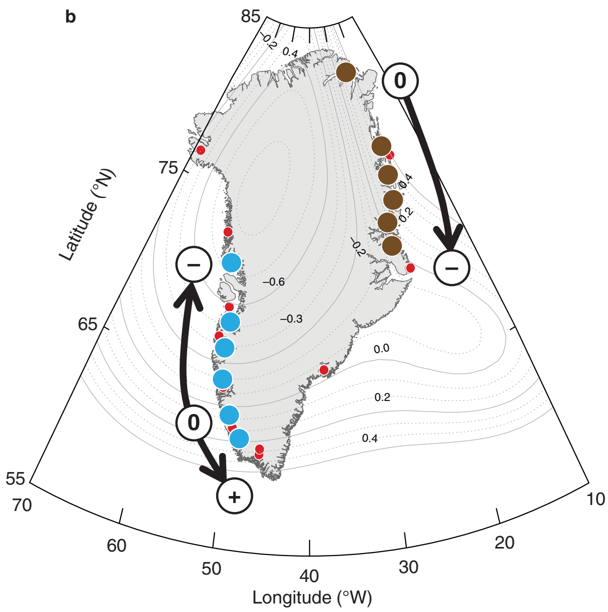


Figure 3.4. (**a**) The NAO time series. (**b**) Smoothed periodogram (Venables and Ripley 1999) of the NAO time series.

Figure 3.5. Correlative relationships between the NAO, local weather conditions and caribou and muskox populations in Greenland. The contours (interval 0.1) denote correlation between the NAO winter index and average winter (December– March) (**a**) temperature and (**b**) precipitation, respectively, from 12 weather stations 1967– 1995 (Post and Forchhammer 2002). Arrows indicate the geographical direction increasing (0 -> +) and decreasing (0 -> -) effects of the NAO across caribou (blue circles) and muskox (brown circles) populations. From Forchhammer and Post (2004).



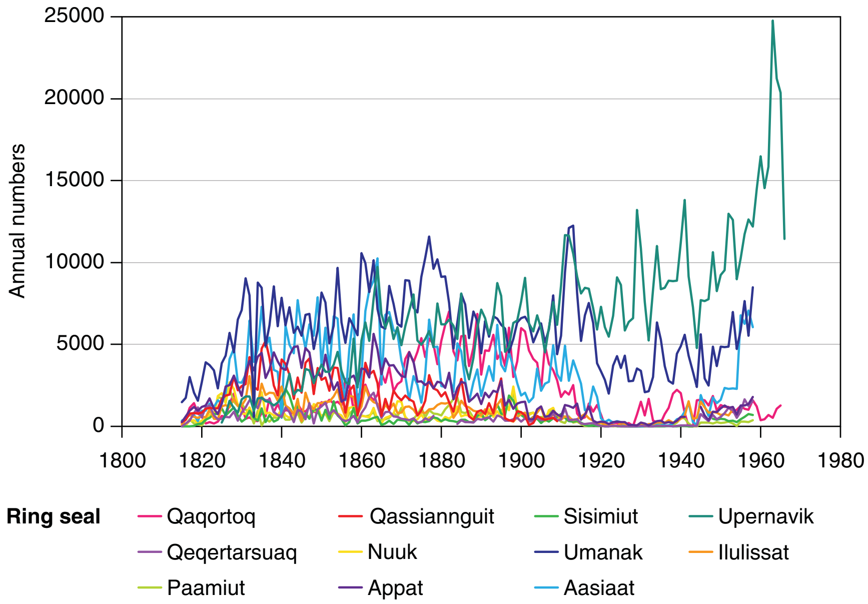


3.2.2 Wildlife long-term dynamics: ringed seal, arctic fox and caribou

The long-term annual skin-trade and hunting records of the ringed seal, arctic fox and caribou in Greenland (Figure 3.6-3.8) provide excellent examples of the significant length of the earlier time series of the wildlife in Greenland.

Two aspects are important here. First, there is a considerable spatial variation across populations, which probably reflect differences in local environmental conditions, including climate conditions. Also the development trend varies across populations. This is in particular obvious for the ring seal dynamics, where some populations have increased (Upernavik) and others have decreased (Qeqertarsuaq) over the period 1900-1950 (Figure 3.6).

Figure 3.6. Annual numbers of ring seal skin traded in 11 communities in West Greenland.

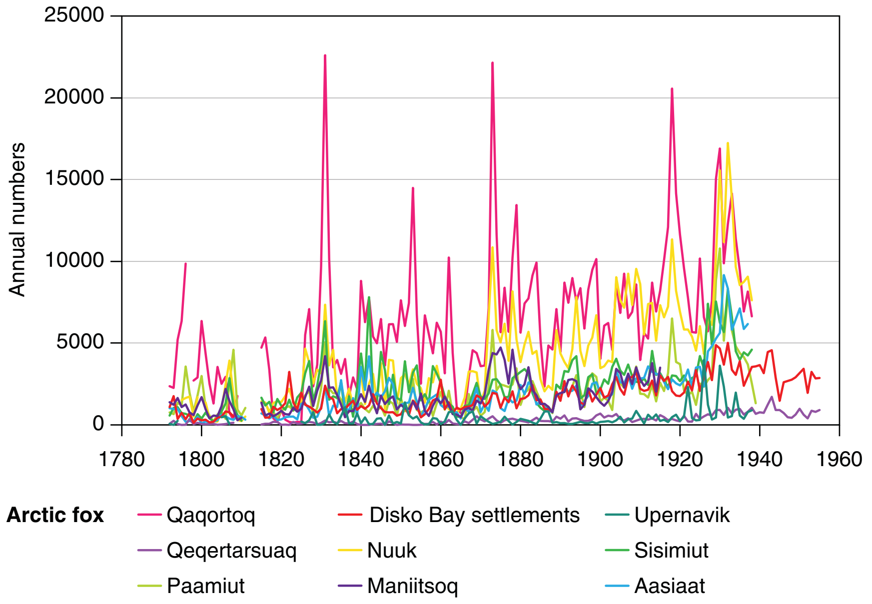


Second, the degree of synchrony across populations changes over time. For example, the degree of synchrony in ringed seal populations remained more or less constant over an entire century (1792-1902), whereas the first five decades of the 1900ies display considerable changes in synchrony across the 11 populations of ring seal (Figure 3.9). The observed decrease in synchrony during the latter period indicates external forcing of populations, such as climate or hunting regulations.

Likewise, changes in synchrony were observed for the caribou time series but not for the arctic fox time series, suggesting relative differences in the influence of environmental conditions between marine and terrestrial wildlife species but, equally important, also between terrestrial species alone.

Hence, differentiating in time as well as space becomes important when the dynamics of wildlife have to be evaluated in the lieu of changes in climate and human utilisation. This perspective is investigated further in the aforementioned PhD study.

Figure 3.7. Annual numbers of arctic fox furs traded in nine communities in Greenland.



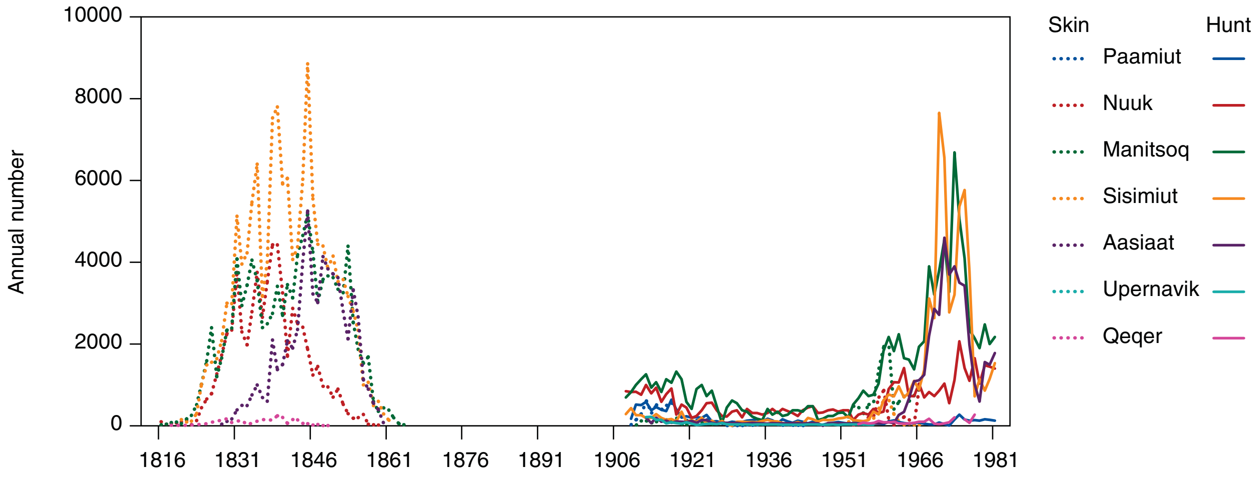


Figure 3.8. Fluctuations in caribou populations expressed the annual number of skin traded and yearly catch data from 7 colonies from West Greenland.

3.2.3 Index of hunting efficiency

The efficiency by which human societies affect natural resources may be expressed in many ways and several sustainable yield strategies rely on the number of vessels or man-hours, depending on the species in question (Begon et al. 2007).

However, the relative effect may depend on the machinery or equipment used by fishermen/hunters, such as the change in acquisition rates of rifles and shotguns (Figure 3.10). From the mid-1800 to the beginning of the 1900, the number of rifles and shotguns sold or traded to Greenland hunters remained relative constant. Through the early and mid 1900 the acquisition of rifles and shotguns increased dramatically (Figure 3.10).

Integrating such measures into the multivariate analyses of human utilisation of wildlife populations in Greenland will provide not only a measure of utilisation but, equally important, a detailed description of the specific mechanisms that may be central to human-wildlife interactions. This is pursued further in the PhD study which has been initiated to develop the analytical framework for huge database provide by this project.

Figure 3.3. Degree of synchrony of ring seal traded across the 11 communities given in figure 3.4. Synchrony was calculated as the inverse coefficient of variation (1/CV) (Sokal and Rohlf 1995).

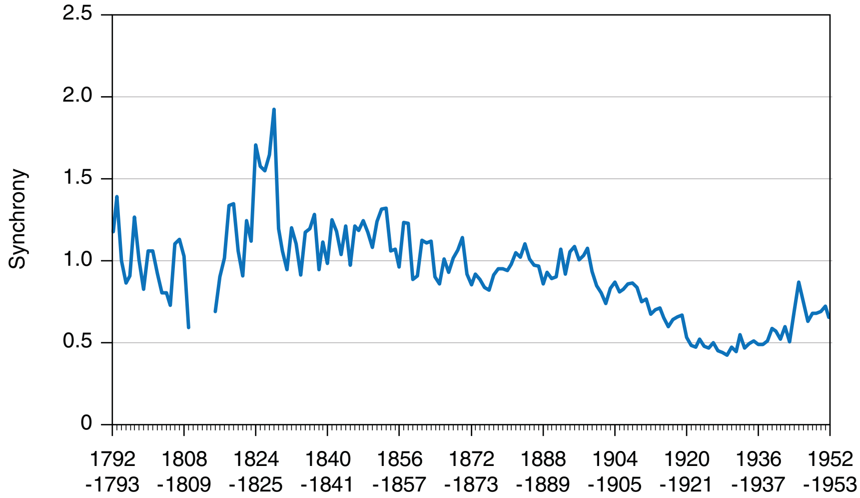
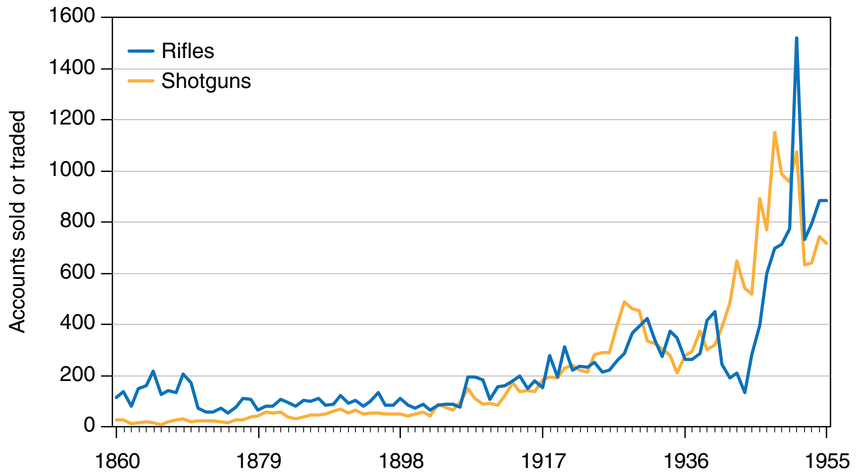


Figure 3.9. Accounts of Rifles/ shotguns sold or traded to Greenlandic hunters.



4 Conclusion/discussion

Climate may affect populations either directly or indirectly through trophic interactions or delayed effects, altering seasonal distribution, geographic ranges, patterns of migration, nutritional status, and reproductive success (Post et al. 2009, Meltofte et al. 2008). Delayed effects of climate have proven to be important in both marine and terrestrial ecosystems. Individuals born in a specific year may be larger or smaller than the average, depending on the climatic conditions in the year of birth (Post et al. 1997). Such cohort effects have been reported in both ungulate and cod populations (Forchhammer et al. 2001, Stenseth et al. 2002).

For some species, hunting or biological/environmental factors other than climate may determine population fluctuations, and within individual populations, intrinsic and extrinsic processes due to, for example, density dependence and a stochastic environment may interact in complex ways (Forchhammer 2001, Begon et al., 2005). Spatial scale must also be taken into account, as the arctic climate varies strongly between regions, and may affect populations of the same species differently (Post et al. 2009).

One of the central challenges of predicting population responses to future climate change rises from the scarcity of long term studies with timescales of sufficient length to compare responses of populations to climatic variability before and after the onset of the recent warming trend (Post & Forchhammer 2004). Another challenge is linking sociological variables to the climatic indices and population trends. Utilizing historical data to discover retrospective patterns in population fluctuations and links to environmental and socioeconomic variables can uncover trends and synergistic interactions that may be used to model dynamics for specific Greenlandic animal populations according to plausible future scenarios.

The earlier data collated and presented above in a historical context are one of the central sources of early data on natural resources in Greenland to be used in a recently initiated PhD, funded by FNU, Roskilde University and National Environmental Research Institute, Aarhus University. This PhD study will integrate the data presented here with more recent data at the Greenland Institute of Natural Resources and will be a component in the newly established Greenland Climate Research Centre (GCRC; http://www.natur.gl/index.php?id=700&L=3). Specifically, the PhD study will focus on the statistical descriptions of long-term data of natural resources and how these interact with spatio-temporal changes in hunting-procedures and climate.

5 References

Aagaard, K. and Carmack, E.C. (1994) *The Arctic Ocean and climate: A perspective*. In: Johannessen, O.M., Muench, RD. and Overland, J.E., eds. The Polar oceans and their role in shaping the global environment. The Nansen Centennial Volume, Geophysical Monograph Series 85. Washington, D.C.: American Geophysical Union. 5–20.

ACIA (2005) Arctic Climate Impact Assessment. Cambridge University Press. Cambridge

Amdrup, G.C., Bobé, L., Jensen, A.S. and Steensby, H.P. (1921) Grønland i tohundredeåret for Hans Egedes landing. Bind 1. Meddelelser om Grønland LX. 567 pp.

Amdrup, G.C., Bobé, L., Jensen, A.S. and Steensby, H.P. (1921) Grønland i tohundredeåret for Hans Egedes landing. Bind 2. Meddelelser om Grønland LXI. 795 pp.

Begon, M., Townsend, C.R. and Harper, J.L. (2005) Ecology. From individuals to ecosystems. Blackwell Science Oxford. Oxford.

Born, Erik W., Heide-Jørgensen, M.P. and Davis, R.A. (1994) The Atlantic walrus (*Odobenus rosmarus rosmarus*) in West Greenland. Monographs on Greenland. Meddelelser om Grønland, vol. 294. Serie: Bioscience, vol. 40.

Born, E.W., Dietz, R., Heide-Jørgensen, M.P. and Knutsen, L.Ø. (1997) Historical and present distribution, abundance and exploitation of Atlantic walruses (*Odobenus rosmarus rosmarus L.*) in eastern Greenland. *Bioscience* 46.

Bradstreet M.S.W. (1982) Occurrence, Habitat Use, and Behaviour of Seabirds, Marine Mammals, and Arctic Cod at the Pond Inlet Ice Edge. *Arctic* 35, 28-40.

Bræstrup. F.W. (1941) A study on the arctic fox in Greenland. Meddelser om Grønland 131, 1-101.

Burns, J.J. (1981) Bearded seal *Erignathus barbatus Erxleben*, 1777. In:: Ridgway, S.H. and Harrison, R.J. (eds). Handbook of marine mammals, vol. 2. Seals. Academic Press, London, pp 145–170.

Burns, J.J., Shapiro, L.H. and Fay, F.H. (1981) Ice as marine mammal habitat in the Bering Sea. In: Hood, D.W., and Calder, J.A., eds. The eastern Bering Sea Shelf: Oceanography and Resources. Vol. 2. Seattle: University of Washington Press. 781–797.

Callaghan, T.V. et al. (2005) Arctic Tundra and Polar Desert Ecosystems. In: Arctic Climate Impact Assessment (Eds: Symon, C., Arris, L. and Heal, B.), pp. 243-352. Cambridge: Cambridge University Press.

Cavalieri, D.J. et al. (2003) 30-year satellite record reveals contrasting Arctic and Antarctic decadal sea ice variability. Geophysical Research Letters 30, 1970.

Chapman, W.L. & Walsh, J.E. (2003) Observed climate change in the Arctic. Updated from Chapman and Walsh 1993. Recent variations of sea ice and air temperatures in high latitudes. Bulletin of the American Meteorological Society 74(1): 33-47.

Crawford, R. and Jorgenson, J. (1990) Density distribution of fish in the presence of whales at the Admiralty Inlet land fast ice edge. Arctic 43, 215–222.

Caulfield, R.A. (1993) Aboriginal Subsistence Whaling in Greenland: The Case of Qeqertarsuaq Municipality in West Greenland. Arctic 46 (2): 144-1558

DeMaster, D.P. and Davis, R. (1995) Workshop on the use of ice-associated seals in the Bering and Chukchi Seas as indicators of environmental change. Report of the Workshop on Ice-Associated Seals held 29–31 March 1994 at the National Marine Mammal Laboratory, NOAA, Seattle. 10 p.

Dietz, R., Heide-Jørgensen, M.P., Richard, P.R. and Acquarone, M. (2001) Summer and fall movements of narwhals (*Monodon monoceros*) from northeastern Baffin Island towards northern Davis Strait. Arctic 54:244–261.

Finley, K.J. and Gibb, E.J. (1982) Summer diet of the narwhal (*Monodon monoceros*) in Pond Inlet, northern Baffin Island. Canadian Journal of Zoology 60:3353– 3363.

Forchhammer, M.C. (2001) Terrestrial ecological responses to climate in the Northern Hemisphere. In: Climate Change Research (eds. Jørgensen, A.M.K., Fenger, J., Halsnæs, K.). GEC Gad, Copenhagen. pp. 219-234.

Forchhammer, M.C. and Post, E. (2004) Using large-scale climate indices in climate change ecology studies. Popul Ecol 46, 1–12.

Forchhammer, M. and Boertmann D. (1993) The muskoxen *Ovibos moschatus* in north and northeast Greenland: population trends and the influence of abiotic parameters on population dynamics. Ecography 16: 299-308.

Forchhammer, M.C. and Asferg, T. (2000) Invading parasites cause a structural shift in red fox dynamics. Proc. R. Soc. Lond. B 267, 779-786.

Forchhammer, M.C., Clutton-Brock, T., Lindström, J. and Albon, S.. (2001) Climate and population density induce long-term cohort variation in a northern ungulate. Journal of Animal Ecology 70, 721–729.

Forchhammer, M.C., Post, E., Stenseth, N.C. and Boertmann, D.M. (2002) Long-term responses in arctic ungulate dynamics to changes in climatic and trophic processes. Popul Ecol 44, 113–120.

Hamilton, L., Lyster, P. and Otterstad, O. (2000) Social change, ecology and climate in 20th-century Greenland. Climatic Change 47, 193-211.

Hurrell J. (1995) Decadal trends in the North Atlantic Oscillation: regional temperatures and precipitation. Science 269:676–679.

IPCC (2007) Climate Change 2007: The physical science basis. Summary for policymakers. Contribution of working group I to the fourth assessment report. The Intergovernmental Panel on Climate Change.

Laidre, K.L., Stirling, I., Lowry, L., Wiig, Ø., Heide-Jørgensen, M.P. and Ferguson, S. Quantifying The Sensitivity Of Arctic Marine Mammals To Climate-Induced Habitat Change. Ecological Applications, 18(2) Supplement, 2008, pp. S97–S125.

Kattsov, V.M. et al. (2005) Future Climate Change: Modelling and Scenarios for the Arctic. In Symon, C., Arris, L. & Heal, B. (Eds). Arctic Climate Impact Assessment pp. 99-150. Cambridge: Cambridge University Press.

Kingsley, M.C.S. and Stirling, I. (1991) Haul-out behaviour of ringed and bearded seals in relation to defence against surface predators. Canadian Journal of Zoology 69, 1857 – 1861.

Lyck, L. and Taagholt, J. (1987) Greenland – Its Economy and Resources, Arctic 40, 50–59.

McBean, G. (2005) Arctic climate: Past and Present. In: Arctic Climate impact Assesment (eds. C. Symon, L. Arris, and C. Grabhorn) pp. 21-61. Cambridge University Press, Cambridge.

McGhee, R. (1984) Thule prehistory of Canada. In: Damas, D., ed. Handbook of North American Indians. Vol. 5 Arctic. Washington, D.C.: Smithsonian Institution. pp 369–376.

Meldgaard, M. (1986) The Greenland caribou: Zoogeography, taxonomy, and population dynamics. Bioscience 20.

Meltofte, H, Christensen, T.R., Elberling, B., Forchhammer, M.C. and Rasch, M. (2008) High-Arctic ecosystem dynamics in a changing climate. Academic Press. London.

Ministeriet for Grønland (1976) Sammendrag af Grønlands Fangstlister m.v. Ministeriet for Grønland 76 pp.

Moore, S.E. and Reeves, R.R. (1993) Distribution and movement. In:: Burns, J.J., Montague, J.J. and Cowles, C.J., eds. The bowhead whale. Special Publication Number 2. Lawrence, Kansas: Society for Marine Mammalogy. 313– 386.

Post, E. and Forchhammer, M.C. (2002) Synchronization of animal population dynamics by large-scale climate. Nature 420, 168-171.

Post, E. and Forchhammer, M.C. (2004) Spatial synchrony of local populations has increased in association with the recent Northern Hemisphere climate trend. PNAS 101, 9286-9290.

Post, E. Forchhammer, M.C., Bret-Harte, S., Callaghan, T.V., Christensen, T.R., Elberling, B., Fox, A.D., Gilg, O., Hik, D.S., Høye, T.T. et al. (2009) Ecological dynamics across the Arctic associated with recent climate change. Science 325, 1355-1358.

Rask, S. (1993) De første erhvervsmotorbåde. Om fangstens betydning for udviklingen i industrifiskeriet. Grønland 41 (3), 100– 118.

Reeves, R.R. (1990) An overview of the distribution, exploitation and conservation status of belugas, worldwide. In: Prescott, J. and Gauquelin, M., eds. Proceedings for the International Forum for the Future of the Beluga. Quebec: University of Quebec Press. 47–58.

Rosing-Asvid, A. (2006) The influence of climate variability on polar bear (*Ursus maritimus*) and ringed seal (*Pusa hispida*) population dynamics.. Can J Zool 84, 357–364.

Rysgaard, S. et al. (2003) Physical conditions, carbon transport, and climate change impacts in a north-east Greenland Fjord. Arctic, Antarctic and Alpine Research 35(3): 301-312.

Smidt, E.L.B (1983) Om overgangen fra fangst til fiskeri i Vestgrønland. Tidsskriftet Grønland 1983 (4): 125-144.

Sokal, R.R. and Rohlf, F.J. (1995) Biometry. W.H. Freeman and Company. New York

Stenseth, N.C., Chan, K.-S., Tong, H., Boonstra, R., Boutin, S., Krebs, C.J., Post, E., O'Donoghue, M., Yoccoz, N.G., Forchhammer, M.C. and Hurrell, J.W. (1999) Common Dynamic Structure of Canada Lynx Populations Within Three Climatic Regions Science 285, 1071-1073.

Stenseth, N.C., Mysterud, A., Ottersen, G., Hurrell, J.W., Chan, K.-S., and Lima, M. (2002) Ecological Effects of Climate Fluctuations. Science 297, 1292-1296.

Stirling, I. and Derocher, A.E. (1993) Possible impacts of climatic warming on polar bears. Arctic 46:240–245.

Stirling, I., Andriashek, D. and Calvert, W. (1993) Habitat preferences of polar bears in the western Canadian Arctic in late winter and spring. Polar Record 29:13–24.

Venables, W.N. and Ripley, B.D. (1999) Modern Applied Statistics with s-Plus. Springer Verlag, New York.

Vibe, C. (1967). Arctic animals in relation to climatic fluctuations. Meddelelser om Grønland 70, 1–227.

Walsh, J.E. et al. (2005) Crysphere and Hydrology. In: Symon, C., Arris, L. & Heal, B. (Eds.) Arctic Climate Impact Assessment, pp. 183-242. Cambridge: Cambridge University Press.

Wrona, F.J. et al. (2005) Freshwater ecosystems and fisheries. In: Symon, C., Arris, L. & Heal, B. (Eds.) Arctic Climate Impact Assessment, pp. 353-453. Cambridge: Cambridge University Press.

6 Appendix

6.1 Tables

Table 6.1. A general overview of the data collected by this project and included in the Access/excel files on http://www2.dmu.dk/pub/FR808_Data_CD.zip. Further detailed information can be found there enclosed with this report. *R.A (Royal Archives) ** A.I (Arctic Institute).

Specimen	Location	N (years)	Periods of min. 10 yrs.	Time series	Sources
Arctic Fox skin	Qaqortoq	173	6	(1792-1793)-(1847-1848), (1852-1853)-(1870-1871), (1872-1873)-(1892-1893), (1882-1883)-(1906-1907), (1908-1909)-(1935-1936),	1792-1893 the Colonial Accounts (R.A) 1882-1907 Accounts from the Royal Greenland trading Company (R.A) 1908-1936Account regarding Greenland
	Upernavik	133	5	(1825-1826)-(1838-1839). (1841-1842)-(1864-1865), (1866-1867)-(1889-1890), (1882-1833)-(1906-1907), (1908-1909)-(1935-1936),	1825-1890 the Colonial Accounts (R.A) 1882-1907 Accounts from the Royal Greenland trading Company (R.A) 1908-1936 The Accounts and declarations regarding Greenland
	Ilulissat	47	2	(1792-1793)-(1807-1808), (1820-1821)-(1832-1833),	1792-1833 the Colonial Accounts (R.A)
	Sisimiut	71	2	(1882-1883)-(1906-1907), (1908-1909)-(1935-1936)	1882-1907 Accounts from the Royal Greenland trading Company (R.A) 1908-1936 The Accounts and declarations regarding Greenland
	Manitsoq	118	2	(1792-1793)-(1810-1811), (1815-1816)-(1915-1916)	1792-1882 the Colonial Accounts 1882-1908 Accounts from the Royal Greenland Trading Company 1909-1916 The Accounts and declarations regarding Greenland
	Qeqertarsuaq	157	2	(1792-1793)-(1809-1810), (1815-1816)-(1955-1956)	1792-1882 the Colonial Accounts 1882-1908 Accounts from the Royal Greenland Trading Company 1909-1956 The Accounts and declarations regarding Greenland
Seal skin	Qaqortoq	34	2	(1882-1883)-(1906-1907), (1908-1909)-(1918-1919)	1882-1907 Accounts From the Royal Greenland trading Company 1908-1919 The Accounts and declarations regarding Greenland
	Upernavik	46	2	(1882-1883)-(1906-1907), (1908-1909)-(1930-1931)	1882-1907 Accounts From the Royal Greenland trading Company 1908-1919The Accounts and declarations regarding Greenland
	Sisimiut	24	1	(1882-1883)-(1906-1907)	1882-1907 Accounts From the Royal Greenland trading Company 1908-1919 The Accounts and declarations regarding Greenland

Polar Bear Skin	Qaqortoq	149	5	(1793-1794)-(1843-1844), (1850-1851)-(1866-1867), (1871-1872)-(1898-1899), (1882-1883)-(1906-1907), (1908-1909)-(1935-1936)	1792-1899 The Colonial Accounts (R.A) 1882-1907 Accounts from the Royal Greenland Trading Company (R.A) 1907-1936The Accounts and declarations regarding Greenland
	Upernavik	133	3	(1826-1827)-(1889-1890), (1882-1883)-(1905-1906), (1908-1909)-(1935-1936)	1826-1890 The Colonial Accounts (R.A) 1882-1906 Accounts from the Royal Greenland Trading Company (R.A 1908-1936 The Accounts and declarations regarding Greenland
	Sisimiut	54	1	(1882-1883),(1935-1936)	1882-1907 Accounts from the Royal Greenland Trading Company (R.A 1908-1936T he Accounts and declarations regarding Greenland
Eider Feathers	Qaqortoq	119	2	(1792-1793)-(1898-1899), (1887-1888)-(1899-1900)	1792-1899 The Colonial Accounts (R.A) 1887-1900 Accounts from the Royal Greenland Trading Company (R.A)
	Upernavik	122	3	(1805-1806)-(1889-1890), (1882-1883)-(1896-1897), (1908-1909)-(1929-1930)	1805-1890 The Colonial Accounts (R.A) 1882-1908 Accounts from the Royal Greenland trading Company (R.A) 1909-1930 The Accounts and declarations regarding Greenland
	Ilulissat	18	1	(1792-1793)-(1809-1810)	The Colonial Accounts (R.A)
	Sisimiut	52	3	(1882-1883)-(1906-1907), (1908-1909)-(1924-1925), (1926-1927)-(1935-1936)	1882-1908 Accounts from the Royal Greenland trading Company (R.A) 1909-1936 The Accounts and declarations regarding Greenland
Bird Feathers	Qaqortoq	36	2	(1849-1850)-(1898-1899), (1882-1883)-(1906-1907), (1908-1909)-(1935-1936)	1849-1899 The Colonial Accounts (R.A) 1882-1908 Accounts from the Royal Greenland trading Company (R.A) 1909-1936 The Accounts and declarations regarding Greenland
	Upernavik	49	2	(1868-1869)-(1888-1889), (1908-1909)-(1935-1936)	(1868-1889) The Colonial Accounts (R.A) 1909-1936 The Accounts and declarations regarding Greenland
	Ilulissat	16	1	(1874-1875)-(1899-1900)	1874-1900 Accounts from the Royal Greenland trading Company (R.A)
	Sisimiut	48	3	(1882-1883)-(1893-1894), (1895-1896)-(1906-1907), (1908-1909)-(1931-1932)	1882-1907 Accounts from the Royal Greenland trading Company (R.A) 1908-1932 The Accounts and declarations regarding Greenland
Blubber and Liver	Qaqortoq	25	1	(1882-1883)-(1906-1907)	1882-1907 Accounts from the Royal Greenland trading Company (R.A)
	Upernavik	25	1	(1882-1883)-(1906-1907)	1882-1907 Accounts from the Royal Greenland trading Company (R.A)
	Sisimiut	25	1	(1882-1883)-(1906-1907)	1882-1907 Accounts from the Royal Greenland trading Company (R.A)
Liver	Qaqortoq	28	1	(1908-1909)-(1935-1936)	1908-1936 The Accounts and declarations regarding Greenland
	Upernavik	28	1	(1908-1909)-(1935-1936)	1908-1932 The Accounts and declarations regarding Greenland
	Sisimiut	28	1	(1908-1909)-(1935-1936)	1908-1936 The Accounts and declarations regarding Greenland
Bird skin blankets	Qaqortoq	28	1	(1908-1909)-(1935-1936)	1908-1936 The Accounts and declarations regarding Greenland
	Sisimiut	23	1	(1908-1909)-(1930-1931)	1908-1936 The Accounts and declarations regarding Greenland

Salmon	Sisimiut	28	1	(1908-1909)-(1935-1936)	1908-1936 The Accounts and declarations regarding Greenland
Halibut	Qaqortoq	15	1	(1916-1917)-(1930-1931)	1916-1931The Accounts and declarations regarding Greenland
Cod and Salted Cod	Sisimiut	12	1	(1913-1914)-(1924-1925)	1913-1925 The Accounts and declarations regarding Greenland
Narwhale-tooth	Upernavik	69	3	(1826-1827)-(1844-1845), (1858-1859)-(1889-1890), (1912-1913)-(1929-1930)	1826-1890 The Colonial Accounts (R.A) 1912-1930-Account regarding Greenland
Caribou antler	Qaqortoq	73	1	(1818-1819)-(1890-1891)	The Colonial Accounts (R.A)
Caribou skin	Manitsoq	122	2	(1816-1817)-(1865-1866), (1910-1911)-(1983-1984)	1816-1865 The Colonial accounts (R.A) 1910-1983 The Accounts and declarations regarding Greenland & hunting statistics
	Sisimiut	57	2	(1820-1821)-(1862-1863), (1952-1953)-(1967-1968)	1820-1863 The Colonial accounts (R.A) 1952-1968 Hunting statistics
	Frederikshåb	64	2	(1909-1910)-(1944-1945), (1954-1955)-(1983-1984)	1909-1945 The Accounts and declarations regarding Greenland
	Kangatsiaq	29	1	(1954-1955)-(1983-1984)	Hunting statistics
	Umanak	29	1	(1954-1955)-(1983-1984)	Hunting statistics
	Nuuk	55	2	(1816-1817)-(1859-1860), (1953-1954)-(1965-1966)	1816-1860 The Colonial Accounts 1953-1966 Hunting statistics
	Aasiaat	32	1	(1828-1860)	The Colonial Accounts (R.A)
	Upernavik	30	1	(1829-1830)-(1859-1860)	The Colonial Accounts (R.A)
Baleen	Ilulissat	31	1	(1793-1794)-(1823-1824)	The Colonial Accounts (R.A)
Walrustusk	Upernavik	33	1	(1856-1857)-(1888-1889)	The Colonial Accounts (R.A)
Rifles	All of West Greenland	167	1	(1792-1959)	Christian Vibes notes (A.I)
Shotguns	All of West Greenland	167	1	(1792-1959)	Christian Vibes notes (A.I)
Lead (pounds)	All of West Greenland	167	1	(1792-1959)	Christian Vibes notes (A.I)
Shots (pounds)	All of West Greenland	167	1	(1792-1959)	Christian Vibes notes (A.I)

7 Description of data

7.1 File 1) Access file: Handels Regnskab

This file contains data from the Royal Archives (Rigsarkivet). All figures are from the colonial accounts ("Koloniregnskaberne") which were initiated in 1793.

The database contains 12 tables:

1. Skins/hides (Skind)
2. Skins/hides – new categories (Skind, nye kategorier)
3. Other seal products (Andre sælprodukter)
4. Capelin (Angmassat)
5. Down and feathers (Dun og fjer)
6. Whale baleens (Hvalbarder)
7. Whale products (Hvalprodukter)
8. Walrus tusks (Hvalrostænder)
9. Narwhal tusks (Narhvalstand)
10. Caribou antlers (Rensdyrtakker)
11. Blubber and liver (Spæk og lever)
12. Weapons and ammunition (Våben og ammunition)

Data originate from three settlements along the west coast: Qaqortoq/Julianehåb, Ilulissat (Jakobshavn), and Upernavik.

Description of the tables: The table "Skind" (hides) and "Skind nye kategorier" (hides new categories) contain the main part of the data, namely the hides of the hunted game that were purchased by the Royal Greenland Trading Company from the Greenlandic hunters, There is also a column depicting the game hunted by colonialists, which was registered separately from the Greenlanders hunt. In the table "SKIND" the data is registered as registered in the colonial accounts. Thereafter we have attempted through literature study and the archival data to subdivide the categories into species (i.e. boatskin, was most often *Cystophora cristata* (hooded seal)). In the table "Hides new categories" we have attempted to simplify the table by only labelling with a species or category. In some categories (i.e "ordinaire or gemene") the sources indicate that this could be a mix of hides from different species, and I have therefore exempted closer categorisation. To compare between the tables, choose a year, geographic location from one table and compare with data in the other table

The other tables in the database cover other products from the hunted game, as i.e. caribou antlers, narwhale tusks, whale baleen, and other products from whales as well as down and feathers from birds. For some species, there are therefore several products that can serve as indicator for the quantity of game hunted on a yearly basis.

7.2 File 2) Access fil: Indhandlede

This is as file 1 data from the purchase of skins/hide by the Royal Greenland Trading Company, but from a different source, the "Reports from the colonies regarding the conditions in Greenland". These can be found at the Royal Archives, start in 1882 and run to about 1936. The data is of the same type as in file 1, but in cruder categories, the seals are i.e. not defined by species, and the data is therefore less detailed.

The remaining data are from Christian Vibes original data found in the archives at the Arctic Institute. They are in Excel, and are more detailed for all species as all colonies along the west coast are represented.

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National Environmental Research Institute
Frederiksborgvej 399
PO Box 358
DK-4000 Roskilde
Denmark
Tel: +45 4630 1200
Fax: +45 4630 1114

Management
Department of Arctic Environment
Department of Atmospheric Environment
Department of Environmental Chemistry and Microbiology
Department of Marine Ecology
Department of Policy Analysis

National Environmental Research Institute
Vejlsøvej 25
PO Box 314
DK-8600 Silkeborg
Denmark
Tel: +45 8920 1400
Fax: +45 8920 1414

Department of Freshwater Ecology
Department of Terrestrial Ecology

National Environmental Research Institute
Grenåvej 14, Kalø
DK-8410 Rønde
Denmark
Tel: +45 8920 1700
Fax: +45 8920 1514

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TEMPORAL AND SPATIAL VARIATIONS IN THE LONG-TERM FLUCTUATIONS OF WILDLIFE POPULATIONS IN GREENLAND

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