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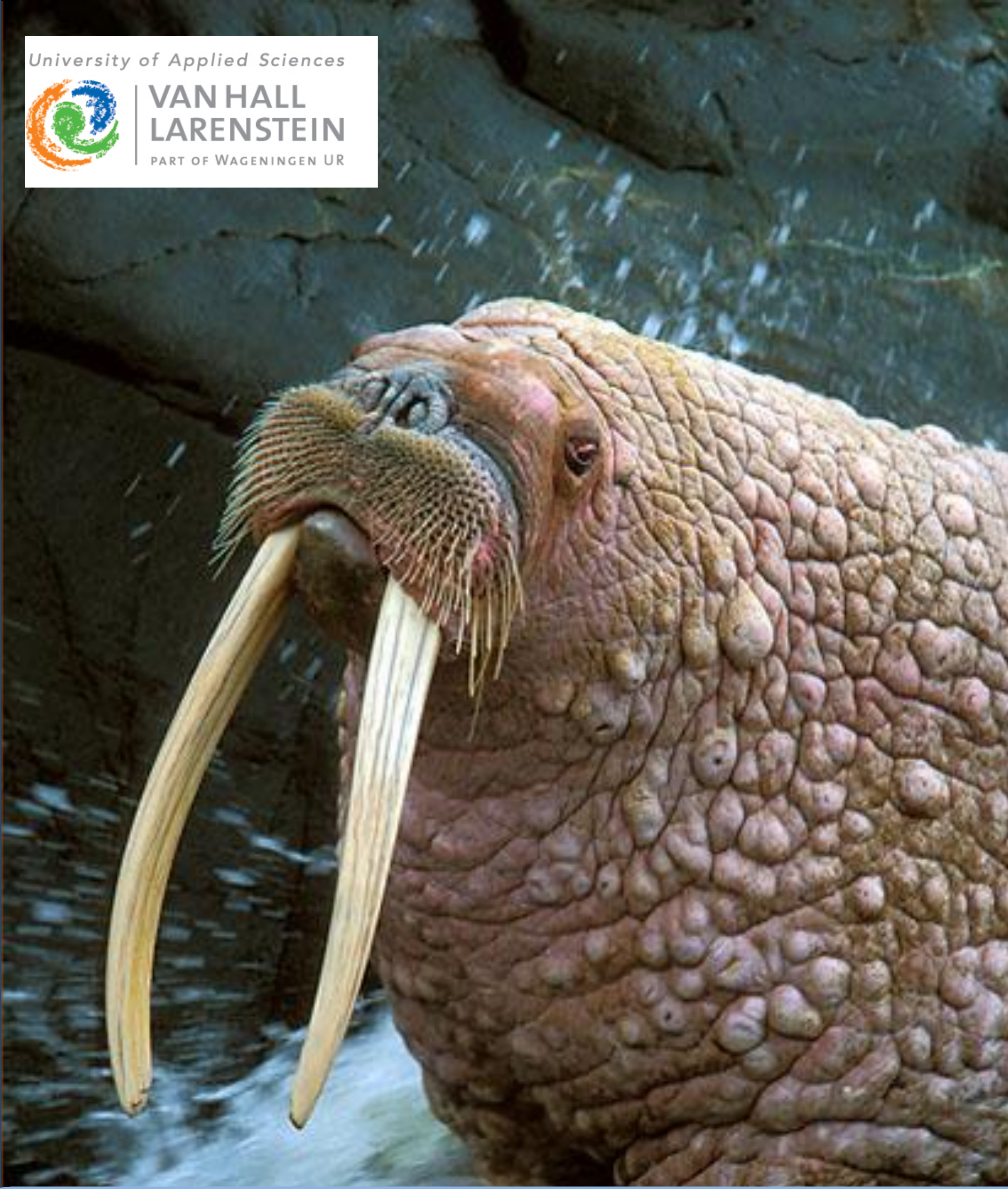

The circumpolar walrus population in a changing world

Joël Kasser and Jeadiz Wiedmer 2011-2012

The circumpolar walrus population in a changing world

An assessment of the Circumpolar walrus populations, aiming to combine worldwide information regarding biology, distribution and possible threats, related to the effects of climate change and economic development.

A BSc thesis assignment commissioned by WWF-Netherlands

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Preface

This report, named 'Circumpolar walrus populations in a changing world' is the end product of our final thesis for our major in Wildlife Management, as a part of the Animal Management BSc studies at University of Applied Sciences 'Van Hall Larenstein' in Leeuwarden.

During this thesis project we have searched and bundled the available knowledge on walrus into a scientific report. The specific subjects treated in this report are the characteristics of the species, its distribution, the changes and economical development in its habitat, possible threats summarized in a threat assessment, and recommendations for current and future conservation. All these subjects were researched, mapped and bundled into a report for the WWF-Netherlands, aiming to provide a report on which they can base their walrus conservation statement.

We would like to thank Gert Polet, Advisor Protected Area Networks & Species Conservation at WWF-Netherlands, for giving us this chance to join this special project and for his support and sense of humour during the research. A big thanks also goes to Arjen Strijkstra and Theo Meijer who as supervisors, have given us helpful feedback during the entire research period. We would also like to thank Ignas Dummer, who we are grateful for helping us out with all GIS related issues. Furthermore we thank all who have shared their time, knowledge and expertise with us in any way, amongst which M. Frost, N. Walker, J. MacCracken, C. Christman, D. Losey, J. Boer, R. Bentum, R. Roelofs and F. Perreau.

We are grateful for this great opportunity and have enjoyed it every step of the way.

Joël Kasser and Jeadiz Wiedmer

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ABBREVIATION	DEFENITION
ABT	Arctic Biodiversity Trends
ACIA	Arctic Climate Impact Assessment
AMAP	Arctic Monitoring and Assessment Programme (Arctic Council working group)
AMSA	Arctic Marine Shipping Assessment
AWPPA	Arctic Waters Pollution Prevention Act
MMPA	Marine Mammal Protection Act (United States of America)
CAFF	Circumpolar Arctic Fauna & Flora (Arctic Council working group)
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DD	Data deficient
DFO	Fisheries and Oceans Canada
EEZ	Exclusive Economic Zone
ESA	Endangered Species Act
GIS	Geographical Information System
HS	High Seas
IMO	International Maritime Organisation
ITIS	Integrated Taxonomic Information System
IUCN	International Union for Conservation of Nature
JSTOR	Journal Storage
LOS	Law Of the Sea
MMC	Marine Mammal Council (Russian Federation)
MMS	Minerals Management Service (United States of America)
MPA	Marine Protected Area
NAMMCO	The North Atlantic Marine Mammal Commission
NOAA	National Oceanic and Atmospheric Administration (United States of America)
NOW	The North Water
NSIDC	National Snow and Ice Data Centre
OGA	Oil and Gas Assessment
PAH	Polycyclic aromatic hydrocarbon
PAME	Protection of the Arctic Marine Environment (Arctic Council working group)
UNCLOS	United Nations Convention on Law of the Sea
UNEP	United Nations Environment Programme
USGS	United States Geological Survey
WWF	World Wide Fund for Nature

Samenvatting

Deze literatuurstudie over de circumpolaire walrus populaties, is gericht op alle sub-soorten van de walrus, de Pacific walrus (*Odobenus rosmarus divergens*), de Atlantische walrus (*Odobenus rosmarus rosmarus*) en de Laptev walrus (*Odobenus rosmarus laptevi*). Het hoofddoel van dit onderzoek was 1) inzicht krijgen in de biologie, het gedrag, de habitat voorkeur en distributie van de soort, 2) het vaststellen van de verschillende factoren die de walrus bedreigen (waaronder klimaatverandering en daarmee samenhangende economische ontwikkeling), en 3) het vaststellen van de kritieke gebieden binnen hun verspreidingsgebied. De walrus distributie informatie is ontleend aan literatuur. Alle sub-soorten gebruiken zowel zee-ijs als op land gelegen gebieden als haul-out locaties. Walrussen voeden zich voornamelijk met verschillende soorten mossels die voorkomen tot 100 meter diepte in de kusstroken van de Arctische oceaan.

De Pacifische walrus wordt het meest bedreigd door klimaatsverandering vanwege hun migratie patroon, waarbij de vrouwtjes en kalveren in de zomer het zee-ijs volgen naar het noorden. Nu het zee-ijs zich zomers terug trekt tot ver buiten het continentaal plat, wordt de afstand tussen de zee-ijs haul-outs en hun foerageer gebied te groot.

De jacht op walrussen vormt voor alle sub-soorten een potentiële bedreiging maar vooral voor de Atlantische walrus. De jachtcijfers lijken in alle landen, behalve in Noorwegen (Svalbard), bovenmatig. Over de Laptev walrus is weinig bekend, wat het lastig maakt om uitspraken te doen over deze sub-soort.

Doordat het zee-ijs zich steeds verder terugtrekt wordt de Noordpool, met naar schatting 22 procent van 's werelds potentiële olie en gas reserves, steeds toegankelijker. Dit zal de economische ontwikkeling in het gebied laten toenemen. Olie en gasproductie zal menselijke activiteit in het gebied verhogen en het risico van vervuiling vergroten. Scheepsvaart zal toenmen, ook door het toegankelijker worden van transarctische transportroutes. Deze ontwikkelingen brengen risico's voor verstoring van walrussen op haul-outs met zich mee, waarbij dieren direct en indirect gedood kunnen worden.

De sub-soorten hebben allemaal poteniële olie- en gasgebieden in hun verspreidingsgebied en krijgen te maken met de risico's van de economische ontwikkeling. Rekening houdend met alle bedreigingen is het een aanbeveling om meer onderzoek te doen naar alle walrus sub-soorten, maar met name de Laptev walrus, om gaten in de beschikbare informatie te vullen, zodat wetenschappers en overheden populatie aantallen weten en daarmee jacht quota's kunnen bepalen, om de populatie in stand te houden.

Het is denkbaar dat de walrus weinig problemen zal hebben met de effecten van economische ontwikkeling mits door de scheepvaart en andere menselijke acitiviteiten voldoende afstand wordt bewaard, en elke mate van vervuiling wordt tegengegaan. Hoewel walrussen zeezoogdieren zijn, lijkt bescherming van op land gelegen haul-outs tegen verstoring en jacht de belangrijkste beschermingmaatregel.

Summary
This literature study on the circumpolar walrus population is focused on all sub-species populations; Pacific walrus *(Odobenus rosmarus divergens)*, Atlantic walrus *(Odobenus rosmarus rosmarus)* and Laptev walrus *(Odobenus rosmarus laptevi)*. The main goal of this research was 1) to gain an insight in the biology, behaviour, habitat preference and distribution of the species, 2) to determine which threats the walrus faces (including climate change and associated economic development) and 3) the determining of critical areas within their habitat. The walrus distribution data is derived from literature. All sub-species use sea-ice platforms as well as coastal areas as haul-out locations. Walruses feed mainly on different species of mussels and clams that occur up to a 100 meters depth in the coastal areas of the Arctic Ocean.

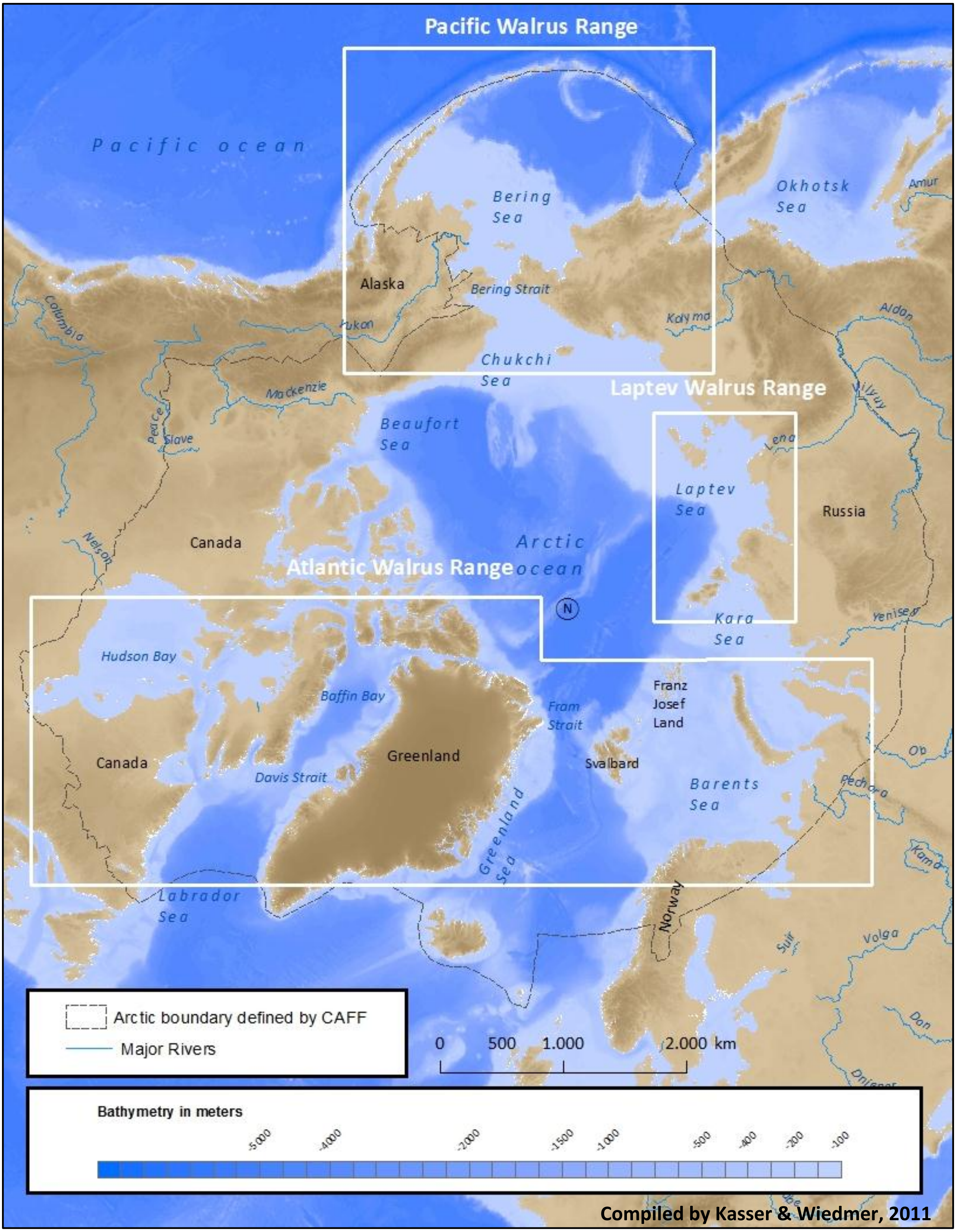
Due to their migration pattern the Pacific walrus is most vulnerable to climate change. Females and calves follow the sea-ice North, but nowadays distances between foraging grounds on the continental shelf and sea-ice haul-outs become too great when sea-ice retreats far beyond the continental shelf during summer.

Although harvesting is a potential threat to all sub-species, at present, it seems to affect Atlantic walrus most. Harvest numbers in all its range countries except Norway (Svalbard) are above sustainable yield levels. The biggest threat for the Laptev walrus is the chronic lack of information, making it difficult to make any statements about them.

With sea-ice retreating further and the Arctic containing 22 percent of the worlds undiscovered oil and gas reserves, economic development will increase In the future. Oil and gas developments have the potential to increase human activity in these areas as well as the potential for oil spills and pollution. Shipping will increase, also on international trading routes, which will become more and longer accessible due to the ice retreat. Human activities have the potential to disturb walruses that are hauled out. Stampedes that occur as a result of disturbance cause deaths among the walrus leaving the haul-outs.

All sub-species are equally sensitive to economic developments and all have potential oil and gas areas within their habitat. Taking all threats into account we recommend doing more research on all walrus sub-species to be able to give more accurate population estimates and to clear up the doubt and fill the information gap concerning the Laptev walrus. This will enable scientists and governments to set more reliable and sustainable harvesting quota. This way, populations can be preserved.

It is conceivable that walruses are able to cope with increased economic developments and human activities when a disturbance perimeter is observed around haul-outs to prevent stampeding and associated deaths. With all activities involving oil, oil extraction and transportation a preventive approach should be maintained, so any degree of pollution can be mitigated. Although walrus are considered marine mammals protecting them on land when hauled-out, against disturbance and harvesting, seems most important.



Map 1 Overview of the Arctic region including bathymetry & walrus sub-species range
References used to compile this map: ESRI, 2008, 2010; Olsen and Dinerstein, 2010; Blijleven and van Dijk, 2011; CAFF, 2009

1. Introduction

This research aims to provide an overview of the current status of the three walrus sub-species found in the Arctic: the Atlantic walrus *(Odobenus rosmarus rosmarus),* the Pacific walrus *(Odobenus rosmarus divergens)* and the Laptev walrus *(Odobenus rosmarus laptevi)*[79]. In this report the focus will be on walrus distribution and habitat preference, combined with the impact of climate change and the potential effects of increasing economic development in the Arctic. Possible effects on walruses and their habitat are determined, ultimately aiding the issuing of a conservation statement on walruses and their habitat.

1.1 The arctic

The Arctic region contains large areas of tundra and permafrost, large rivers systems and the Arctic Ocean. The Arctic Ocean is the smallest of the world's five oceans and is in part permanently covered with ice [133]. The Arctic is an area with high nature values. It contains much of the world's remaining untouched and continuous wilderness. (CAFF 2002) and therefore represents a natural heritage of global significance (CAFF 1996).

The borders of the Arctic can be defined according to different criteria. An important geographical definition is the Arctic circle, the latitudinal line at 66° North, above which at least one day a year the sun does not set [2, 125, 133]. A climatological definition of the Arctic is the 10°C July isotherm, indicating the area where the average temperature of the warmest month is below 10°C [125, 133, 143]. Ecological borders are determined by the distribution of animal and plant communities. The tree-line is a good example, marking the boundary between taiga and Arctic tundra [143].

The area considered as Arctic in the scope of this research is the area that is defined as Arctic by the member states of the Circumpolar Arctic Fauna & Flora (CAFF) working group of the Arctic Council, based on a combination of climatic and bio-geographical data [23]. The CAFF members are Canada, Finland, Norway, Russia, Sweden, Alaska (USA), Greenland (Denmark) and Iceland [20].

Arctic conditions are characterized by sea ice, ice sheets, glaciers, and permafrost [113]. The most important kind of ice considered in the scope of this research on a marine species is sea-ice. Sea-ice is formed when surface water in autumn is cooled below -1.8°C [38]. The resulting ice crystals rise to the surface and undergo a characteristic formation process from grease ice to super pancakes before they freeze together forming a closed ice-cover [84, 133].

The Arctic marine area is relatively shallow with broad continental shelves. These shelves extend 100 - 200 kilometres from the United States and Canada, and more than 1,000 kilometres from the Russian Federation [125]. Depths on the shelves average between 100 - 200 meters, but are variable, especially where landmasses and islands are approached [2]. The continental shelves are characterised by a high biological productivity. The Bering Sea, Chukchi Sea and Barents Sea are among the largest and most productive shelf habitats in the world, harbouring a high benthic biomass [133].

1.2 Climate change

Over the last several million years, Polar Regions have undergone major, natural changes in climate, with corresponding transformations of habitats.

Many scientists relate current changes in the Arctic to climatological changes caused by a human induced rise of CO2 concentrations in the atmosphere. Current changes in the global climate, and especially in the Arctic, occur faster and more extreme[133] than the long term global measurements [112].

Since the 1970s, the global surface temperature has increased with ≈ 0,2°C per decade [75] while in the Arctic the increase of air temperature is almost double the global average. [1, 4, 129]

This is caused by different feedback mechanisms, of which the loss of albedo is one of the most important processes.

White surfaces have a high albedo as they reflect incoming shortwave solar energy back into space. Dark surfaces such as water bodies and landmasses absorb shortwave solar energy which is transformed into heat energy and cannot escape from the atmosphere. Therefore a heating Arctic results in diminishing snow and ice cover which in turn results in a reduction in albedo and hence a further heating of the Arctic [117, 133]. [78]

Warming of surface temperatures corresponds with the warming of water temperatures [119], the decline in average sea-ice thickness and changes in the Arctic ice cover [31, 32, 112]. Satellite data between 1979 and 2000 show that the perennial sea ice cover in the Arctic, with an average thickness of about 3 to 4 meters, has declined [131] with 9 percent each decade in the Arctic [31]. In September 2007, sea ice extent reached its lowest extent of 4.13 milion km^2, deveiating greatly from the 1979 to 2010 average of 6.52 million km^2 [112]. A comparison between the maximum ice extent of March 1979 and the minimum ice extent of September 2007 is displayed on map 2. Average ice extent in the summer of 2011 was measured to be second lowest in history [112].

When speculating about when the Arctic ocean will be ice free, different models show different estimates varying from 2015 [2] to 2050. The Intergovernmental Panel on Climate Change (IPCC) illustrated a decline of Arctic sea ice extent, measured over a period from 1953 to 2006, but observations have demostrated an even faster decline than the IPCC has shown [131].

As a response to climate change induced sea-ice decline, ice-associated marine mammals are already affected, showing distribution shifts, compromised body condition and decreases in abudance and reproductive succes [93], lowering their chances of survival. Walruses are adapted to the climatological conditions of the Arctic and can cope with severe fluctuations in temperature and other harsh weather conditions. [1, 97] The utilization of a habitat niche related to low temperature, forces walruses to adapt to the rising temperatures [133]. Considering that walruses are a K-species with a slow growth and a low fecundity [92, 101, 134], they will need a long time to adapt to the warming of their habitat. This gives scientists reason to consider walruses as vulnerable to climatological change [101].

Data on recent variations and trends in precipitation are limited [1] but it is assumed that precipitation in the Arctic has increased [145]. As an effect, increasing river run-off into the Arctic ocean [1, 7, 84] may cause freshening of the Arctic Ocean and can stimulate upwelling of nutrient rich water [99]. Together with the earlier seasonal melting of sea ice, nutrient composition can experience extreme shifts in all layers of the seawater, potentially resulting into an earlier but shorter spring bloom of phytoplankton [99]. This will lead to a disruption in the foodchain, forcing all communities in it, to adapt [119] and could affect the benthic communities which the walrus uses as its main food source.

Walruses depend on benthic ecosystems for their main foodsupply [41]. Shifts in the Arctic ecosystems caused by climate change may also lead to increased competition, and crowding, when seasonal migrant pinnipeds and Cetaceans encroach into more Northern latitudes, and thus into walrus habitat, where these species may also stay for longer periods of time [102]. Secondly, an increase in predation on walrus by Polar bears (*Ursus maritimus*) and Killer whales (*Orcinus orca)* may occur [48, 102, 121].

Rapid climatic changes in the Arctic, with diminishing sea-ice as its main result, will progressively open the area to new economic activities, such as transit shipping and oil & gas development [2]. The larger the extent of these activities, the larger the likelyhood that the areas in which these activites take place, will overlap with important walrus habitat, adding human disturbance to the other natural effects of climate change in walrus habitat.

1.3 Research goal and questions

The goals of this research are to collect and bundle the current knowledge that is now spread over literature and expertise in different countries, with a focus on walrus distribution and the economic development in their Arctic habitat. Potential threats are assessed and based on that, recommendations for short-term and mid-term conservation priorities are suggested. The ultimate aim is to provide a thorough research report that can be used as a basis for a conservation statement.

The main research questions are about: the biology, behaviour and the (seasonal) distribution of the walrus populations in the Arctic and the possible threats to these populations related to the climate change invoked economic developments, in order to identify critical geographical areas and to suggest conservation priorities (including location of Marine Protected Areas) and other necessary interventions.

Related to the subjects stated in the main question above several sub-questions on biology, distribution, threats and conservation are formulated.

Biology and distribution

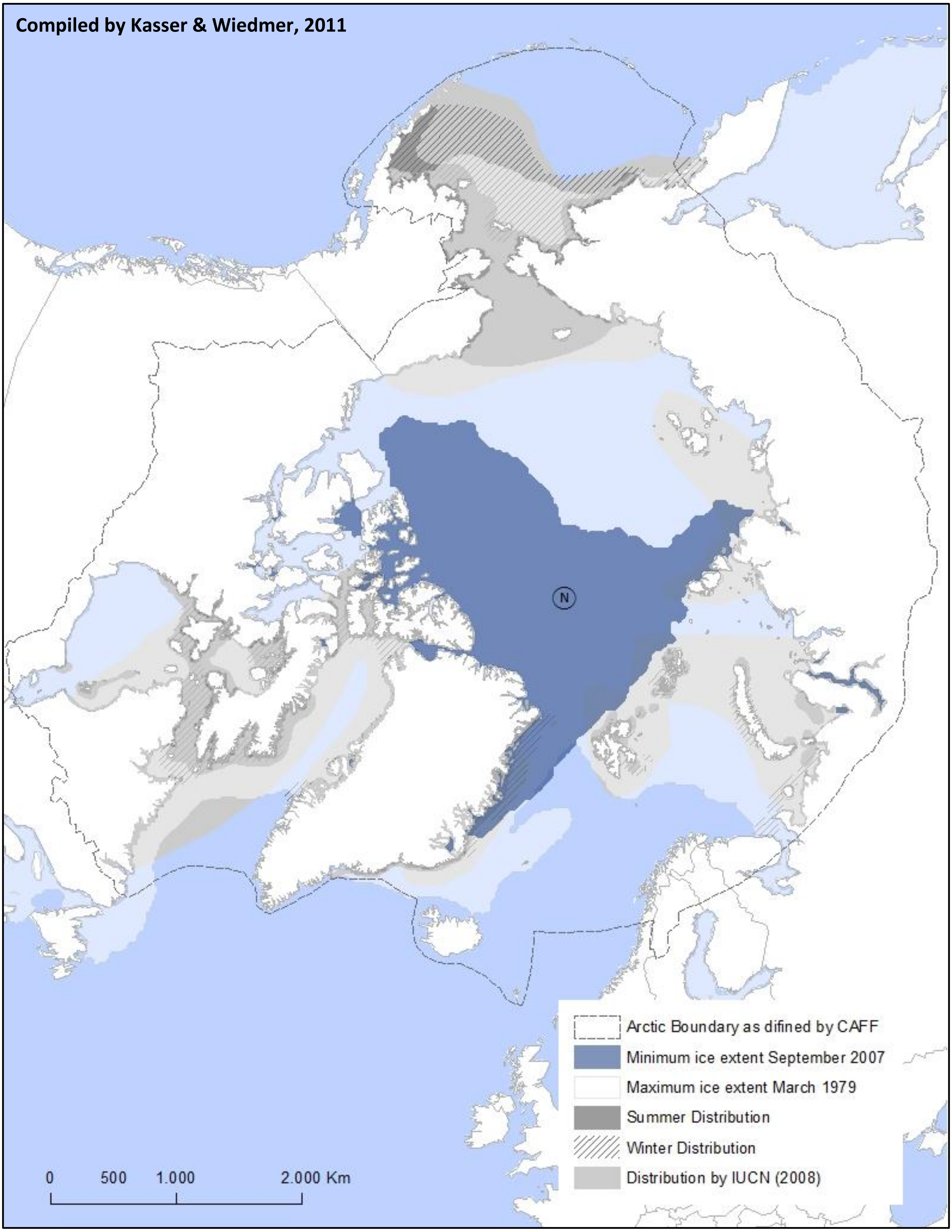
1. What is the general biology of the walrus?
2. What is the distribution of the global walrus population?
3. What is the (seasonal) distribution of the three sub-species of walrus populations?
4. What are the population trends of each sub-species over the past decennia?
5. Where are critical habitats and migration routes of walrus populations situated?
6. What are key habitat factors essential for walrus survival and can they explain current distribution?
7. What could be future seasonal distributions of walrus populations taken in account the effects of climate change?

Threats

1. What are immediate and longer-term threats to the walrus populations caused by economic developments?
2. Which threats can shipping and oil and gas extraction in the Arctic pose on walrus?
3. Where are these development projects planned?

Conservation

1. What current law and legislation is applied on walrus and their habitat?
2. Do walrus distribution and specifically their key habitats overlap with (future) developing areas?
3. What economic activities require which regulation or safeguards to ensure walrus continued survival?
4. What are the immediate and mid- and long-term conservation interventions required to safeguard the walrus populations?
5. Can current and future geographical areas be identified that are critical for walrus continued survival?



Map 2 Maximum sea-ice extent March 1979 compared to minimum sea-ice extent September 2007
References used to compile this map: CAFF, 2009; ESRI, 2008; Fetterer *et al,* 2009; Olson & Dinerstein, 2010

2. Research methods

To execute this research, dedicated to the circumpolar walrus populations in their Arctic environment, two main methods have been used. Data collection to develop the written part of the study and data collection to create the GIS maps.

Data collection

The main part of the data used for this research is collected through the search machines Web of Science, Google Scholar, Science Direct and JSTOR. The collected data consisted of research articles, books and status reports.

All data has been collected in an Endnote X5 citation database. Through the use of an online Endnote database, both researchers could share data with each other on different work locations.

GIS maps

The data used to create the GIS maps are gathered through reports and experts. The maps are created with ArcGIS 10. Additional data on the maps, consisting of metadata on all layers and flowcharts can be found in appendix I, II and III.

Feedback and verification

During the research period, several experts in the field have contributed to the research by reviewing certain parts or in some cases, the whole report. Feedback, links or other interesting input to the research has been communicated by e-mail.

3. The Walrus

In this chapter the general biology of the species will be outlined as well as the difference between sub-species. Currently three sub-species of walruses are distinguished: the Atlantic walrus *(Odobenus rosmarus rosmarus),* the Pacific walrus *(Odobenus rosmarus divergens)* and the Laptev walrus *(Odobenus rosmarus laptevi)* [41, 79, 83, 97]. The sub-species status of the Laptev walrus is still under debate, as some regard the walrus of the Laptev Sea as the most western, isolated, population of Pacific walrus [96]. In this report the Laptev walrus will be treated as a separate sub-species.

3.1 Species characteristics

Walruses are the largest and most gregarious of all Arctic, ice-breeding pinnipeds (fin-footed mammals). Males are mostly longer and heavier than females. Adult male Pacific walruses reach about 3.6 m in length and weigh between 880-1,557 kg; adult females reach about 3 m and weigh between 580-1,039 kg. Adult Atlantic walrus are slightly shorter and lighter in comparison. New-borns are 1-1.4 m and weigh 33-85 kg [42]. Older males have many tubercles on the neck and chest, giving them a warty appearance [85]. Adult walruses have a short coarse pelt that reduces with age, especially in older males [110].

Walrus colouration varies with age and activity. They possess the ability to regulate blood flow to the skin, known as peripheral vasoconstriction and vasodilatation. When a walrus spends long periods of time in cold water, blood flow to the skin is restricted causing the walrus colouration to fade to pale greyish-white. When they leave the water this process reverses giving them a pink to reddish-brown appearance. Walrus calves are darker in colouration, with a greyish fur [83, 85].

The upper canine teeth of the walrus develop into tusks that grown throughout life in both sexes, a unique feature among Pinnipeds. The tusks of male walruses can reach a length of more than 100 cm and are longer and thicker than tusks of female walruses, that reach lengths of about 80 cm [110]. Walruses use their tusks as weapons during intra-specific aggression and as "pick-axe" when hauling-out on the ice. Hence its Latin name *Odobenus,* which means tooth-walker.

Established difference among subspecies

Research has shown that Atlantic and Pacific walruses are genetically and morphologically distinct [34]. This is most probably a result of range fragmentation and separation during pre-historic periods of glacial maxima [76].

Pacific walruses are on average larger than Atlantic walruses [41, 85]. Differing features among the two subspecies are mainly found in their tusks, skulls and tubercles presence [41]. Pacific walrus of both sexes generally have longer, thicker and more curving tusks than similar size and age Atlantic walrus, although there is some overlap in length and size. Pacific walruses have wider skulls than Atlantic walruses, resulting in slightly wider heads and muzzles. Adult Pacific walruses regularly have more prominent tubercles on the neck chest and shoulders. [83]

Fay (1981) describes the Laptev walrus as intermediate in size between the Atlantic and Pacific walrus with skull morphology similar to the Pacific walrus.

Although the walrus population in the Laptev Sea is geographically isolated they appear to be most closely related to Pacific walruses. Mitochondrial DNA and morphometric data analyses suggest that the taxon *Odobenus rosmarus laptevi* should be abandoned and the Laptev walrus should be recognized as the most western population of the Pacific walrus. [96]

3.2 Ecology and behaviour

The walrus is only found in the Arctic, where its distribution is limited to the Arctic oceans adjoining seas [110]. Its range is especially influenced by the availability of foraging grounds in shallow water and the thickness of sea-ice [85].

Walruses are social and gregarious animals. They travel and haul-out on ice or land in densely packed groups. On both haul-out platforms walruses tend to lie in close physical contact with each other during all seasons. Young animals often lie on top of adults to prevent oppression [42]. Group size can range from a few individuals, up to several thousands of animals [56, 83, 85]. Walruses are very wary animals and easily disturbed. Disturbance can cause walruses to flee their haul-out site. Such a stampede can lead to injuries and mortality, especially among calves and young [41]. Walruses haul-out to rest and prefer to do this within close distance to their feeding grounds. When available, sea-ice provides preferable conditions [142].

Walruses mate in January and February in broken sea-ice habitat. Breeding bulls follow herds of females and compete for access to groups of females hauled out on the sea-ice. It is believed that walruses are polygynous and that the males establish small aquatic territories where they vocalize and display adjacent to resting females, hauled-out on the ice. Individual females leave the resting herd to join a male in the water where copulation takes place. [45, 83, 85, 128]

With the lowest rate of reproduction in any of the pinniped species [41], walrus are considered to be a K-species [47, 134]. Although male walruses reach puberty at 6-7 years of age they are unlikely to successfully compete for females until they reach full body size at 15 years of age or older [41, 45]. Female walruses reach sexual maturity at 4-7 years of age [41, 54]. Walruses give birth to a single calf and under normal conditions the calf remains with its mother and is suckled for at least 1-2 years, sometimes longer, if the mother does not conceive and gives birth again [41, 85]. This behaviour results in much lower rates of mortality among calves than in other pinniped species [27, 47].

When calves are old enough to survive alone, young females tend to remain with groups of adult females, while young males gradually separate from the females and begin to associate with groups of other males. The social status of an individual walrus appears to be based on a combination of body size, tusk size and aggressiveness. Because individuals do not necessarily live in fixed groups they have to reconfirm their social status in each new aggregation. [41] A walrus may reach an age of 30 or 40 years. [86] This means that one female can produce a maximum of eleven young in her entire life span.

Established difference among subspecies
A behavioural difference between walrus sub-species is that in Pacific walrus the sexes and age classes live separately for most of the year. Females and calves move with the pack-ice while males rest on terrestrial haul-outs, this happens especially during summer moult. Atlantic walruses also moult in summer and during that time males and females haul-out on both land and ice, sometimes even in mixed groups. [85]

3.3 Foraging

The walrus's primary food source are benthic invertebrates [11, 13, 35, 41, 83, 85, 110, 127]. Most commonly eaten benthic organisms are bivalves and snails, but small crustaceans, worms and star fish are also taken. Even seals, fish and other vertebrates are reported occasionally [41, 127]
When searching for food walruses search the bottom sediment with their muzzles and use their sensitive vibrissae to locate prey items. Walruses use their fore-flippers, muzzles and jets of water to extract prey buried up to 32 cm [41, 85, 87, 95, 114]. They swallow invertebrates, without shells, whole and remove the soft parts of molluscs and clams from their shells by suction, creating low pressure in the mouth cavity with their tongue. After the shells are emptied they are discarded [41].

Although walruses are capable of diving to depths of more than 250 m [12], they usually forage in waters of less than 100 meters deep [11, 12, 43, 85, 92, 110]. The preference for shallower water is presumably because of the heightened benthic productivity and thus greater food availability. [26, 43, 61, 62, 80]

Walruses make foraging trips from land or sea-ice haul-outs ranging from a few hours up to several days [11, 80, 122, 142]. Distances travelled to feeding grounds differ between populations and can range from 2-140 km [10, 60]. These trips are more frequent but shorter in duration and distance when walruses use sea-ice haul-outs as a starting point compared to terrestrial haul-outs [142]. This suggests that sea-ice haul-outs bring them closer to their food source and feeding depth [41]. In appendix XIII , XIV, XV and XVI maps can be found that depict terrestrial haul-out sites in comparison to the 100 meter depth line indicating the walrus's feeding limit per sub-species.

Main food items taken by walrus
The global walrus population seems to depend mainly on a small number of circumpolar bivalve species. Throughout their range *Serripes groenlandicus, Mya truncata, Hiatella rugosa, Hiatella arctica* and *Astarte borealis* are considered to be main prey items in the walrus's diet [7, 8, 45, 50] varying depths but within the preferred walrus feeding distance of 0-100 meters [8, 39] although it is known that some species also occur at greater depths [39].

Established difference among subspecies
There are no significant differences in feeding strategy, prey handling and main food item preference among sub-species. There is however, local differentiation in supplementary food items.

The diet of the Pacific walrus for example also includes lesser, but significant proportions, of local bivalves like *Clinocardium spp*., Penis worms or Priapulida, polychaetes worms, snails, molting brachyuran crabs, and holothurians or sea cucumbers. [45] A map displaying benthic biomass in Pacific walrus habitat in comparison to known terrestrial haul-out sites is included in Appendix XVII.

The diet of the Atlantic walrus is supplemented by worms like *Priapulus caudatus,* isopods like *Saduria entomon* and *Saduria sabini*, the shrimp *Sclerocrangon boreas* and the Barents Sea crab *Hyas araneus var. hoeki.* [8]. No specific benthic biomass data was available for the habitat of the Atlantic walrus.

3.4 Population status

Due to different survey techniques, gaps in surveys, survey stops in the past and several areas on which no data are available, precise numbers and sub-species population trends are largely unknown.

The population estimates that are available have a low precision. The main reasons for this are the characteristics of walrus behaviour and the harsh environment in which they live [56].

Global Population
The global walrus population is currently registered under IUCN as: Data Deficient (DD) and the global population trend is unknown. [97]

The Pacific walrus
In the past, Pacific walruses have been harvested commercially on a large-scale. It is believed that these intensive harvests reduced the population to 50.000 – 100.000 animals in the mid-1950s. After this period the Pacific walrus population slowly recovered from its depleted state, despite continued harvest by indigenous people on a limited scale. [44]

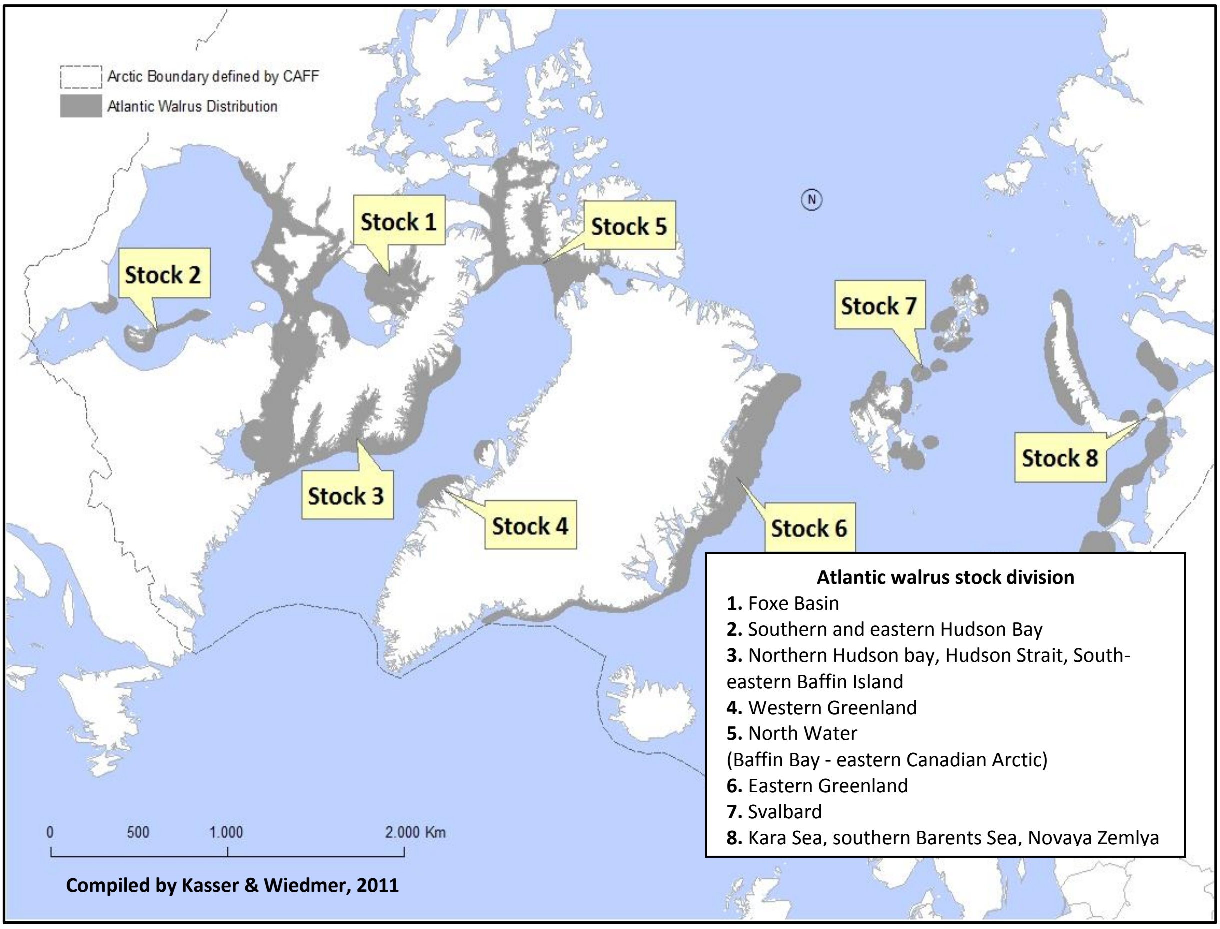
During the 1960's and 1970's harvest regulations, that limited the take of females, were put in place [47]. Between 1975 and 1990, aerial surveys were carried out by the United States and Russia at five-year intervals. These produced population estimates ranged from 201,039 to 290,000 [57].

In 2006, American and Russian scientist and researchers collaborated to conduct a substantial Pacific walrus survey. They surveyed walrus haul-outs on Bering Sea Pack-ice using thermal imaging systems and satellite transmitters to account for walruses in the water [130]. The number of walruses within the surveyed area was estimated at 129,000 (with a 95% confidence interval of 55,000 to 507,000 individuals).

Table 1 shows the estimated population trend of the Pacific walrus population from 1975 – 2006. When looking at these numbers it appears that, after a short period of increase, the Pacific walrus population has declined substantially in recent decades. Two things have to be born in mind though. First is, that due to differences in methods and techniques, estimates across past years cannot be compared reliably and the second is that the estimate based on the 2006 data has a large confidence interval that in fact includes all previous estimates.

Table 1 Estimates of Pacific walrus population size 1975 - 2006

Year	Estimated Population Size	Reference
1975	214,687	(Udevitz *et al.* 2001)
1980	250,000-290,000	(Johnson *et al.* 1982, Fay *et al.* 1997)
1985	242,366	(Udevitz *et al.* 2001)
1990	201,039	(Gilbert *et al.* 1992, Fay *et al.* 1997)
2006	129,000 (55,000-507,000)	(Speckman *et al.* 2010)



Map 3 Atlantic walrus stock division
References used to compile this map: Born *et al.,* 1995; CAFF, 2009; ESRI, 2008; Gavrilo, 2011; IUCN, 2009; Norwegian Polar Institute, 1995; Olson & Dinerstein, 2010

The Atlantic walrus
To estimate the population size of the Atlantic walrus population, Born *et. al.* (1995) divided the entire population in eight different stocks, displayed above on map 3.

These stocks are based on distribution, history of exploitation and the existence of independent management regimes. To be able to provide a description that is as accurate as possible, we have adopted the same stock division for this report.

The Atlantic walrus has been harvested commercially on large-scale in the past and all stocks, with the exception of Svalbard, are still harvested by indigenous people at present.

Although harvest numbers are much lower today then during the days of the industrial harvests, it is still believed that all stocks for which data are available, are harvested above their maximum sustainable yield. [9] More detailed information on harvesting can be found in paragraph 5.5

Stock 1. Foxe Basin
The Atlantic walrus population in Foxe basin was estimated to be 5,500 individuals in 1989, based on systematic visual strip transect surveys that were flown over central Foxe Basin. These surveys did not cover the entire north of northern Foxe Basin however, nor was there any correction for animals that were submerged an thus out of view. [9] This stock is still harvested by local communities.

Stock 2. Southern and eastern Hudson Bay
Based on the limited information that is available on this particular stock the size of

this population is estimated at approximately 500 individuals. [9, 123] This stock is still harvested by local communities.

Stock 3. Northern Hudson Bay, Hudson Strait, south-eastern Baffin Island and northern Labrador
The total size of the Northern Hudson Bay population, including the area around Southampton and coastal islands, western Hudson Strait and south-eastern Foxe basin, is estimated at about 4,000 individuals. To this, another 2,000 individuals can be added occurring in Unagava Bay, eastern Hudson Strait and along eastern Baffin Island. Coming to an estimated total of 6,000 individuals in this stock. [9] This stock is still harvested by local communities.

Stock 4. Western Greenland
The walrus population in western Greenland is thought to be in steady decline. The total number of individuals is estimated at 1,000. [149] This stock is still harvested by local communities.

Stock 5. North Water (Baffin Bay - eastern Canadian Arctic)
Born *et al*. (1995), estimated that this particular population contained around 3,000 individuals. Included in this estimation were 300 - 600 individuals in Jones Sound and along eastern Ellesmere Island and 1,000 individuals in the Lancaster Sound area.

Combining these data would mean that this population could be between 2,700 and 3,000 individuals. However, all these numbers were educated guesses because the data were insufficient for an up-to-date assessment. [9]

Since then, late summer surveys of the coastal waters of Jones Sound and northern Lancaster Sound over 4 consecutive years (1998-2001), produced an average count of about 350 walruses [37]. This would mean that the entire stock could number between 1750 -2250 individuals at present. This stock is still harvested by local communities.

Stock 6. Eastern Greenland
The walrus population in Eastern Greenland has been increasing slowly. The total number of individuals is estimated at 1,000. [12, 149] This stock is still harvested by local communities.

Stock 7. Svalbard and Franz Joseph Land
At Svalbard the walrus population is estimated at 2,629 individuals (with 95% confidence limits of 2,318 to 2,998 individuals) [98]. Their numbers have increased slowly in the period of 1993 to 2006 [98]. On Svalbard no harvesting is allowed.

Stock 8. Kara Sea, Southern Barents Sea and Novaya Zemlya
In the 1995 assessment by Born *et al.* this stock was estimated to number 500 individuals or less. Based on very rough estimates, the population was recently estimated to be around 2000 individuals [8]. This stock is still harvested by local communities.

Nova Scotia, Newfoundland, Gulf of St Lawrence
In the past there was a population inhabiting this area that was believed to have numbered in the tens of thousands. It was extirpated by commercial hunting and there has been not been any evidence of the population's re-establishment for the past 200 years. [9]

As can be deduced from the data discussed above, changes in the abundance of Atlantic walruses in the various stock regions, during the past years, are very unclear. Most estimates are very imprecise and often based on incomplete surveys. Although no quantitative population trends can be determined trough lack of data, table 2 provides an overview of the estimated population numbers and assumed stock status.

Table 2 Current estimated Atlantic walrus population size and stock status

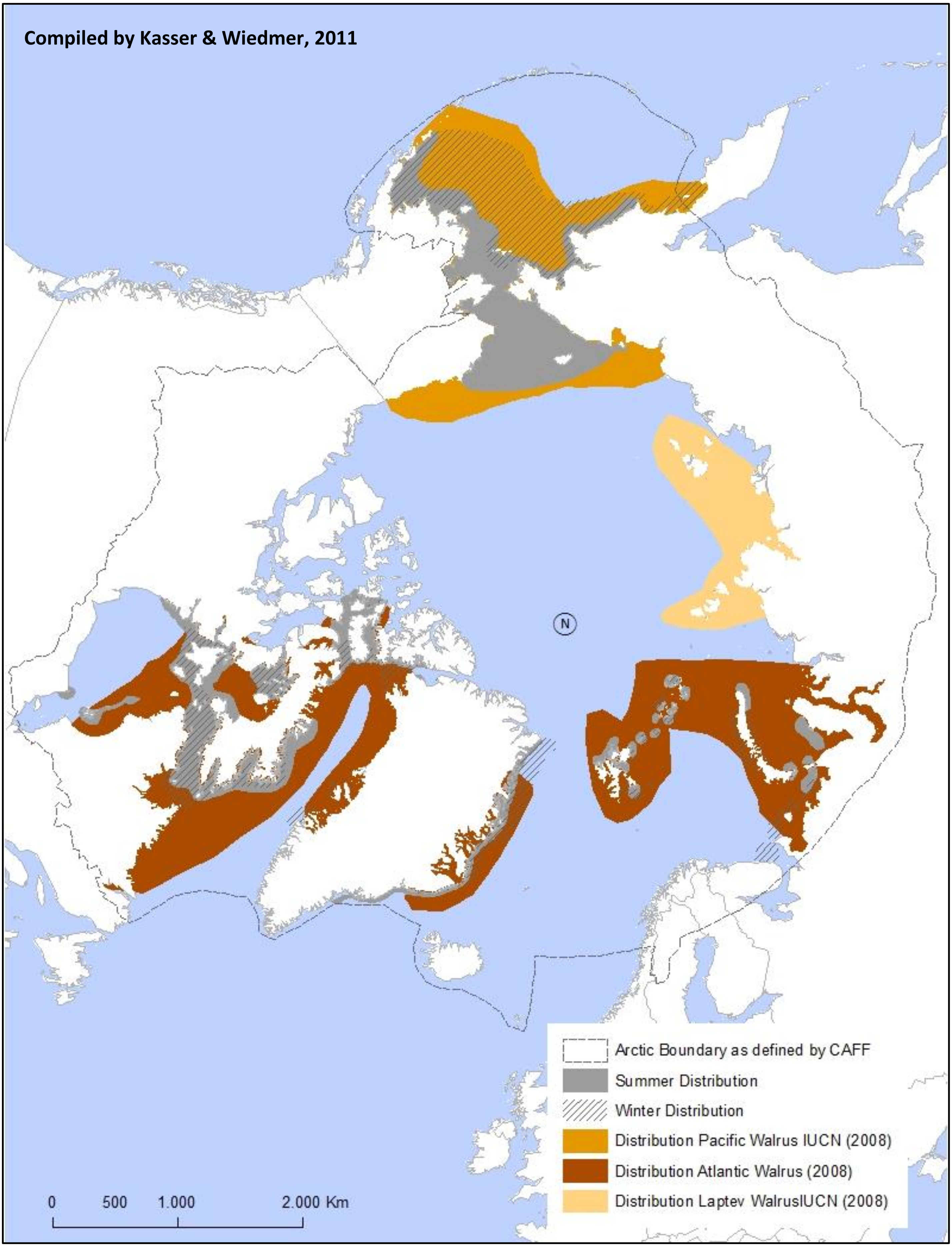
Stock and Area	Estimated population size	Reference	Stock status
1. Foxe Basin	5500	Born *et al*., 1995	Stable (?)
2. S. and E. Hudson bay	500 (?)	Richard and Campbell, 1988, Born *et al*., 1995	Unknown
3. N. Hudson bay, Hudson Strait, S.E. Baffin Island N. Labrador	6000	Born *et al*., 1995	Unknown
4. Western Greenland	(1000) - 3240	Witting and Born, 2005 Grønlands Naturinstitut, 2009	Declining
5. North Water (Baffin Bay - Eastern Canadian Arctic)	(1750) - 3000	Born *et al.,* 1995 DFO 2000,	Declining (?)
6. Eastern Greenland	(1000) - 1429	Witting and Born, 2005 Born *et al*., 2005 Grønlands Naturinstitut, 2009	Increasing
7. Svalbard and Franz Joseph Land	2300 - 3000	Lydersen *et al*., 2008	Increasing
8. Kara Sea, Southern Barents Sea Novaya Zemlya.	500 – (2000)	Born *et al*., 1995 Boltunov, 2010	Increasing/ Unknown

? Insufficient data

Based on the data in the table above it can be deducted that the total Atlantic walrus population numbers 24,669 individuals at best and 18,550 individuals in a worst-case scenario.

The Laptev walrus

The number of Laptev walruses populating the Laptev Sea region North of Siberia has been estimated at 4,000 - 5,000 animals in the past [41]. Recent population estimates are unavailable.



Map 4 Global walrus distribution
References used to compile this map: Born *et al.,* 1995; CAFF, 2009; ESRI, 2008; Gavrilo, 2011; IUCN, 2009; Norwegian Polar Institute, 1995; Olson & Dinerstein, 2010; Smith, 2010

4. Distribution

4.1 Global population

Walruses have a discontinuous circumpolar distribution [42, 83, 97]. This is most probably a result of range fragmentation during periods of pre-historic glacial maxima [76]. Three sub-species originated from this, the Pacific walrus, the Atlantic walrus and the Laptev walrus. Their ranges are shown on map 4.

4.2 The Pacific walrus

Habitat selection

The distribution of Pacific walrus varies in different seasons and is mainly dependant on sea ice extent.

Winter habitat

During winter, Pacific walruses aggregate on the Bering Sea sea-ice. This happens in areas where leads, polynyas and thin ice allow access to water [41, 45]. Winter also marks the beginning of the breeding season. Where breeding aggregations form exactly, depends on distribution, extent and annual variations in the Bering Sea sea-ice. Usually they form south of Nunivak Island, southwest of St. Lawrence Island and south of the Chukotka Peninsula [19, 41, 130, 105]

Spring Habitat

In spring, when the sea-ice in the Bering Sea starts to retreat, a big part of the population, especially females and calves, migrate North through the Bering Strait, destined for the summer feeding areas over the continental shelf in the Chukchi Sea. Most adult males, up to several thousands, remain in the Bering Sea and start to form coastal haul-outs in the Gulf of Anadyr and in Bristol Bay during the ice-free season [52].

Summer Habitat

Distribution in the summer season is as well dependant on the extent and distribution of sea-ice and thus varies annually. When there is plenty of broken sea-ice available, Pacific walrus females and calves are mostly found in aggregations on the sea-ice in the Chukchi Sea while males are found further South on terrestrial haul-outs. Group size at haul-outs range from less than ten to several thousands of individuals and are spread-out over the shallow continental shelf or along coastal areas [56, 122]. These aggregations can be found off the north-western coast of Alaska all the way up to Point Barrow and in Russian waters as far west as Wrangel Island and along the Chukotkan coast [6, 41]. [57]

When the sea-ice reaches its minimum extent in September, and retreats far beyond the feeding grounds on the continental shelf, into the Arctic ocean, large numbers of Pacific walrus females and calves relocate to coastal haul-out areas. This often happens on Wrangel Island, sites along the northern coast of Chukotka peninsula [6, 41, 116]. [90 88] and recently their numbers are also increasing along the Alaskan coast [49]

Fall habitat

Pacific walruses that spend the summer season in the Chukchi Sea start migrating South in September and October, ahead of the forming sea-ice. During this migration large groups haul-out to rest and await the start of ice formation on points along the Chukotkan and Alaskan coasts in the Bering Strait region. When Ice has formed they will migrate further South toward the Breeding grounds [46]. Male Pacific walruses, that summered in the Bering Sea, also start migrate and move northward toward the winter breeding areas around November [81].

Migration routes

As can be deducted from the text above Pacific walrus know two main migrations. One occurring in spring, during which the females and calves migrate North through the Bering Strait and into the Chukchi Sea, while most males migrate toward terrestrial haul-out areas in the Bering Sea. The second migration occurs in fall, during which females migrate South toward the breeding grounds in the Bering Sea and males North toward the breeding grounds.

A detailed sub-species distribution map including haul-out locations, approximate migration routes and approximate mating areas can be found in Appendix IV.

4.3 The Atlantic walrus

Habitat selection

The distribution of Atlantic walrus varies slightly in different seasons and is mainly dependant on sea ice extent. However most walruses appear to stay the same area year round [9]. The Atlantic walrus distribution, however, is less straightforward then that of the Pacific walrus. Atlantic walruses are divided over different stocks occurring in different areas, which cause differences in migration patterns as well.
Therefore seasonal distribution will be shortly discussed per stock, although it has to be noted that the information available is limited and observation moments for different stocks are often spread out over time, making observations and comparisons between them possibly unreliable.

Stock 1. Foxe Basin

In northern Foxe Basin, walruses are present year-round and widely distributed. Their seasonal movements appear to be local, anticipating changing ice conditions. During winter they prefer the floe edges along polynyas to aggregate. While during summer terrestrial haul-outs are found on islands and around the basin coast. [9]

Stock 2. Southern and eastern Hudson Bay

In Hudson Bay, walruses are present year round as well. During summer they tend to haul-out on Ottawa Island, Sleeper Island and Bakers Dozen Island in the East and Southeast of the Bay. One haul-out area is situated on the southern mainland of Cape Henrietta Maria. During winter exact distribution in the Bay is unknown. [9]

Stock 3. Northern Hudson Bay, Hudson Strait, Southeastern Baffin Island and Northern Labrador

Although walruses are present in these areas year round, they seem to be scarce in western Hudson Bay. During summer they use terrestrial haul-outs in the region if ice is no longer available. The extent of their range to the North of Baffin Island is poorly understood but is thought to diminish during winter. [9]

Stock 4. Western Greenland

In Central West Greenland, the coastal waters were the most important areas for walruses historically. During fall and winter females and calves hauled-out on various points along the coast and coastal islands, while males where present either at those haul-outs or in off shore areas. During late spring, early summer the walruses retreated from the coastal regions to the eastern edge of the Davis Strait sea-ice. [9]

Today walruses no longer haul-out along the coast and coastal Islands of Western Greenland. They still seem to occupy their winter range but only from the sea-ice. When the sea-ice retreats scientists believe that one part of the population migrates North toward the North Water stock and one part migrates west across the Davis Strait to Baffin Island (Canada) to return in fall. [9]

In the North-West of Greenland walrus numbers appear to be small. Some occur in the coastal area but there is limited space to overwinter. Other walruses seen in the area appear to be northbound migrants, only passing through. [9]

Stock 5. North Water (Baffin Bay - eastern Canadian Arctic)

The North Water (NOW), situated in northern Baffin Bay, is the largest recurring polynya. Here walrus are present year round. During spring/summer migrants from the southwest coast of Greenland join them although not in great numbers. During summer resident walruses concentrate along the Canadian coasts and in the sounds surrounding Devon Island. Most terrestrial haul-outs are based on Devon Island itself or other nearby coastal areas adjacent to the sounds. Local migrations occur in this area and there are individuals that move further up North depending on ice cover. [9]

During winter walruses concentrate in the NOW itself, in the connected polynyas and in leads and holes in the ice of adjacent areas. During winter females and sub-adults are generally occurring further north than adult males in the NOW. [9]

Stock 6. Eastern Greenland
Walruses are present along the coast of eastern Greenland year round. During summer they occur as far South as Tassilaq and stray individuals even further. During winter they migrate up along the coast to winter in the small polynyas formed at the entrances of various sounds and one large polynya at the far northern tip of eastern Greenland. [9]

Stock 7. Svalbard and Franz Joseph Land
Walruses are present on Svalbard and Franz Joseph Land year round. During summer the walruses on both archipelagos are present at terrestrial haul-outs while during winter they make use of polynyas that form at the edges or between the islands at both archipelagos or in the sea-ice. The individuals present on Svalbard are predominantly males whereas the individuals present on Franz Joseph Land are predominantly females. Telemetry studies have confirmed that there are migrations between the populations although it is mainly the male walrus that migrates. [9, 51]

Stock 8. Kara Sea, Southern Barents Sea and Novaya Zemlya.
Walruses are present in the western Russian Arctic throughout the year but their dispersal varies with the seasons. During summer they are predominantly present at the far North and far South of Novaya Zemlya, in the Pechora Sea surrounding the Kara gate and at the West coast of Yamal Peninsula. During winter the populations on Novaya Zemlya seem to migrate to the East and West coasts of the island while the populations at Yamal Peninsula and in the Pechora Sea region appear to migrate East into the Barents Sea.

Mixing of all populations named above is to be expected but has not been confirmed scientifically. [9]

Migration routes
In comparison with the Pacific walrus, migrations of the Atlantic walrus stocks appear to be more localized. The relatively longer migrations occur between southeastern Baffin Island and the West coast of Greenland, between the West coast of Greenland and the NOW and between Svalbard and Franz Joseph Land. Migrations are, however, similarly depending on the seasons. In some stocks males and females are living separately most of the year but for other stocks this is unclear.

A detailed sub-species distribution map, including haul-out locations and approximate migration routes can be found in Appendix V.

4.4 The Laptev walrus

Habitat selection
There is little known about the Laptev walrus but, because of its small range, it is assumed that it uses its habitat in similar ways as the Atlantic sub-species, making use of ice free areas during winter and terrestrial haul-outs during summer. Because this is an isolated population it can also be assumed that migrations are local and seasonal.

Terrestrial haul-out sites on coastal Islands and along the coast of the Laptev Sea area are known from historic records [55].

An estimated sub-species distribution map, including haul-out locations can be found in Appendix VI.

4.5 Critical habitats

Although there are some differences between sub-species, in general walruses are animals that use extremely variable habitats, which makes it difficult to pinpoint specific critical habitats for them. In this research, a critical habitat is defined as a habitat that is used by walruses for one or more of their key behaviours; resting, foraging, breeding and migrating.

Because the exact place where most of these key behaviours occur, have a close association with sea-ice; pinpointing or predicting the reoccurrence of these critical habitats on a yearly basis poses a challenge. Data available was not accurate enough to be mapped.

The characteristics of these critical habitats however, are described in the following paragraph.

Pacific walrus

Pacific walrus breeding behaviour, is closely associated with the broken sea-ice [45, 83] and as an exception on data availability the approximate breeding areas of the Pacific walrus are known. Usually breeding aggregations form south of Nunivak Island, southwest of St. Lawrence Island and south of the Chukotka Peninsula, see appendix IV. [19, 41, 104, 129]

Migration behaviour is closely related to the retreating and expanding ice edge in the different seasons. Most important is the migration behaviour of females and calves which follow the retreating sea-ice North [52], this route includes the relatively narrow passage of the Bering strait which also knows a high shipping pressure and can therefore be marked as a critical area as well.

When resting, males mostly use land based haul-outs [52], while females, until recently, only rested on the northerly sea-ice edges with their calves [52, 101]. Since the sea-ice extent is retreating to far beyond the continental shelf (see chapter 5), this characteristic is changing, forcing females and calves to use terrestrial haul-outs [49].

All haul-outs can be labelled as critical habitat for resting, especially those that have come into existence during recent years and include the presence of newborns. Haul-outs are the category of critical habitats that can be pinpointed but haul-out locations remain variable on a yearly basis.

Critical habitat areas for foraging are the areas on the continental shelves with a high benthic productivity. Both males and females need these areas, with a depth between 0- 100 meters, to forage. However, records on benthic biomass are few and therefore these areas a hard to pinpoint. For Pacific walrus habitat we have been able to model benthic biomass by approach, results are shown in appendix XVII.

Atlantic walrus

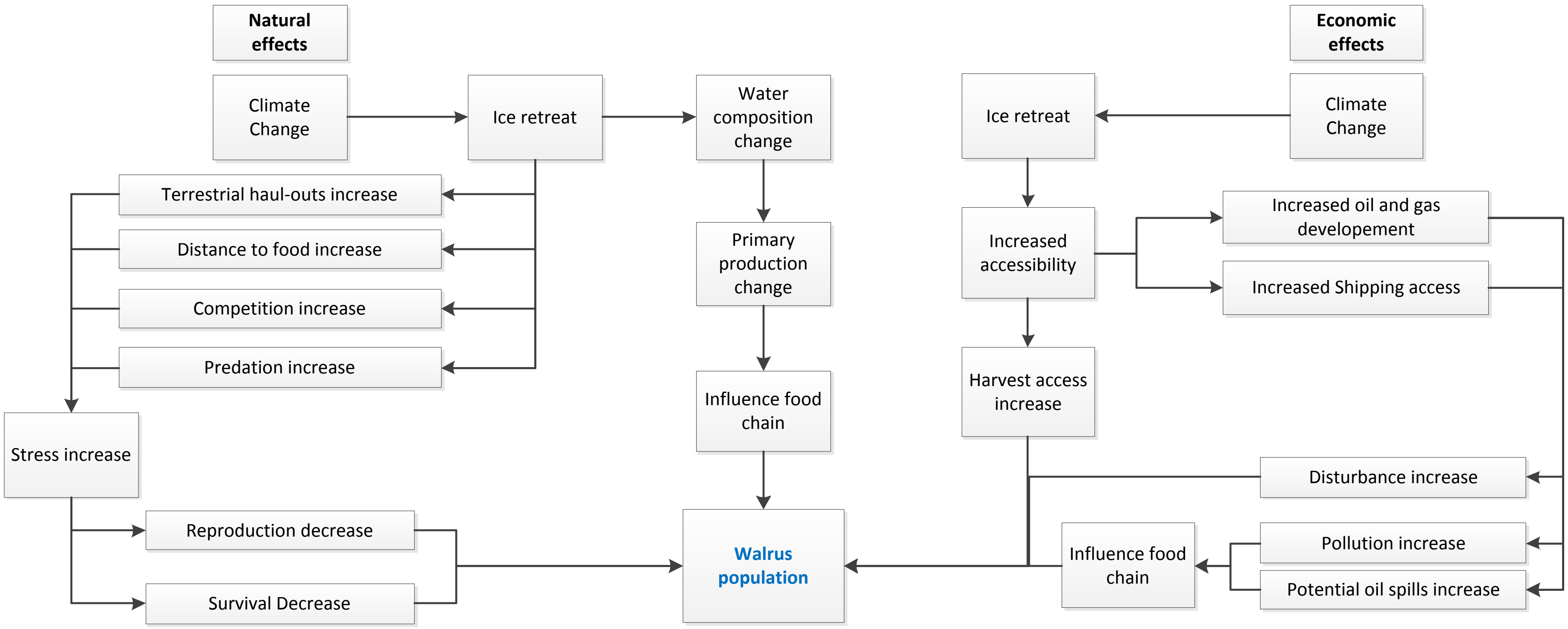
The critical habitats for the Atlantic walrus have overlapping characteristics. Demands for foraging and resting platforms for example are known to be similar.

Mating behaviour is similar as well but in contrary to the Pacific walrus approximate mating locations are unknown.

A behaviour that is substantially different from the Pacific walrus is migration behaviour. Only a few of the 8 Atlantic walrus stocks are known to migrate and these migration routes are short compared to the Pacific walrus, see appendix V.

Another important difference is that Atlantic walruses seem to move toward leads and polynya in the sea ice instead of following the sea ice. Most stocks live in areas that freeze up in winter, making them dependant on these leads and polynyas for forage access. This gives us reason to mark them as critical habitat.

Figure 2 Conceptual model A: Potential threats and their expected relation to the walrus population



Kasser & Wiedmer, 2011

5. Potential threats

This chapter describes the different threats that walruses are facing, starting with climate change as the driving force behind all other changes, followed by oil and gas, shipping, noise disturbance and hunting. Followed by an assessment of these threats, potential areas of concern and involved stakeholders.

5.1 Climate change effects

Although scientists are discussing its causes, most of them agree that changes in climate are taking place in the Arctic at present time. Temperature rise in the Arctic is already more than 2°C and warming is taking place at twice the rate of the global average [1, 4, 129], which results in the decline of sea ice extent, thickness, cover and seasonal persistence. [4, 93, 100]

These combined changes in the Arctic can pose threats to many marine mammals [7], including walrus [93]. Because walrus distribution is restricted to a narrow ecological niche [93, 106], meaning that they depend on shallow water (≤100 m) over rich continental shelves for foraging [43 11 74 12 92], access to open water in the vicinity of rich feeding areas and haul-out platforms (ice and/or land) near feeding areas [41], walrus are seen as vulnerable to climate change.

Primary productivity change

There is a strong connection between sea ice and primary production in the Arctic [5, 94, 133]. Due to the strong interactions between for example, the water of the Pacific ocean, the Bering Sea, the Chucki Sea and the Arctic Ocean [101] and due to sunlight which is entering the photic zone, 0-100 meters, for longer periods of time, seasonal plankton bloom occur annually under the influence of the abundance in nutrients and light [119].

The lifecycle of bivalves, the walrus' main food source [7, 14, 93, 94] is closely related to the plankton blooms and depend on them for their food supply [63, 119].

When sea ice extent is reduced, the water column will warm earlier during the year and also nutrients, captured in the ice, will be freed sooner. These events will speed up the annual blooms and thereby forcing all trophic levels of the food chain to adapt and to shift their annual period of food abundance, up earlier in the year. Benthic invertebrates are part of this food chain and thereby the above changes are likely to effect the walrus, with changes in their food abundance [61].

Another change in nutrient composition is the extra river run off, which as a result of a higher amount of precipitation, will increase upwelling of nutrient rich water and is assumed to have a positive influence on primary productivity [99, 133].

Although a higher primary productivity will have a positive effect on walrus in the beginning, on the long run, when ice composition will change, eventually a stagnation in primary productivity is assumed to arise [63], thereby possibly disrupting behavioural patterns of all organisms that are depending on the annual plankton blooms. Hence, decline of sea ice might be positive at the start, looking at the feeding grounds, but is assumed to be negative on the longer term.

Interspecific competition

As a result of a warmer Arctic, decrease in sea-ice extent and a (temporarily) higher amount of primary productivity, the Arctic will provide new ecological niches for species that previously could not live here [93].

New seasonal migrants, like Harp seals (*Pagohilus groenlandicus)*, Hooded seals (*Cystophora cristata),* Humpback whales (*Megaptera novaeangliae)* and Killer whales (*Orcinus orca)*, are observed to migrate into higher latitudes, staying there for longer periods of time.

This development could increase crowding in the Arctic, where the living conditions until recently, could only be endured by a select group of highly specialised marine mammals [102]. A change in habitat accesibility is likely to result in an increase of the number of species in the Arctic, some of which, like the Grey Whale (*Eschrichtius robustus*), are direct competitors for food [102, 108] and others might regard walrus as their prey.

Warming waters and an increase of immigrants might also increase the risk of diseases [92, 93].

Change in distribution

The effects of declining sea-ice can especially be seen in the annual migration of Pacific walrus, in which, mostly females and calves [101], follow the retreating sea-ice northwards in spring and summer.

The further sea-ice retreats, the further the Pacific walruses have to follow the ice northwards to be able to stay in reach of the relative safety of their sea-ice haul-outs. During the past years it has been observed that sea ice retreats further and further North, resulting in growing distances between foraging grounds in shallow water and resting platforms on the sea-ice. [121]. This puts females at risk of exhaustion. Calves left alone have been observed and this event is said to increase the chance of trampling injuries without the protection of their mothers, possibly also increasing the change of predation [49].

When sea-ice retreats too far North, females and calves have to leave the sea-ice haul-outs and swim back to the main land to form coastal haul-outs. This forced migration can leave both females and calves in a weakened state and may be the cause of the increased mortality among the Pacific walruses that arrived on Wrangel Island in 2007 [116]. It is thought that, when forced to migrate to the main land, mothers abandon their calves if they are not strong enough to survive the long swim. This is assumed to be the reason for the observation of abandoned calves swimming alone in deep waters, far off shore [146].

In appendix XVIII and XIX two maps can be found among which a comparison is made between retreating sea-ice in Pacific walrus habitat, from winter maxima to summer minima, during 1979 the historic maximum and 2007 the historic minimum. A dept line of 100 meters is added to indicate the walrus's maximum feeding depth.

When more walruses aggregate on terrestrial haul-outs, chances of human-walrus conflicts [52] and predation by polar bears are likely to increase.

Predation on walrus

The changes in seasonal ice cover and extent can create new possibilities for species originating from more southerly regions.

Killer whales (*Orcinus orca)*, for example, have the tendency to avoid areas with extensive sea-ice cover. This is believed to be because of ice entrapment risks and due to the damage sea-ice can cause to their dorsal fin.[48].

Walrus and Killer whale habitat overlap partially, but the retreating sea-ice might cause Killer whales to follow their prey species to higher latitudes making them a more common occurrence in those areas [48, 102]. This will lead to an increased risk of Killer whale predation on walrus, adding to the total of increasing stress of other factors influencing the walrus population.

Predation of Polar bear on walrus, is presently taking place occasionally [24, 36, 94]. The Polar bears main prey species are seal species, which they hunt on the sea ice. However, due to changes in sea- ice extent and seasonal duration, hunting efficiency of the Polar bears on seals, is declining [36, 121].

Increase of more land based haul-outs for walrus and an increase of polar bears on land, due to declining sea ice, will increase interaction between polar bears and walrus which makes it likely that the number of polar bears adapting to walrus as a food source will increase [24].

All changes described above are likely to have a cumulative, negative effect on walrus populations.

5.2 Oil & Gas

Oil and Gas Development

Extensive oil and gas development and extraction in the Arctic started in the 1920s and are already a well established and important part of the region's economy [113].

Because of the declining sea-ice extent, Arctic accessibility is increasing. Enhancing the attractiveness of the region for new oil and gas developments. According to the United States Geological Survey (USGS) the Arctic is holding 22 percent of the worlds, technically recoverable, undiscovered oil and gas reserves [144].

The Arctic accounts for about 13 percent of the undiscovered oil, 30 percent of the undiscovered natural gas, and 20 percent of the undiscovered natural gas liquids in the world and about 84 percent of the estimated resources are expected to occur offshore [144].

The construction of new facilities and infrastructure for development and transportation will most likely extend into wilderness areas during the next two decades. [113]

Oil and gas activities will probably pose the most significant challenge of balancing resource development and environmental protection in the Arctic in the near future. With the potential for oil spills as the biggest environmental threat the oil and gas industry can pose. [113] Other factors of concern associated with oil and gas developments are: visual and noise disturbance during exploration phase (seismic) and disturbance associated with the transportation of products (shipping).

Walruses spend the winter near and on the southern borders of the sea-ice. They are dependant on the marginal ice zone, the ice edges, leads and polynyas during wintering and migrations. In spring, when ice retreats, Pacific walruses migrate northwards with the ice. Prior or during these migrations female Pacific walruses give birth to their young, enlarging the danger a potential oil spill could cause during this period. Further adding to the above, the environmental persistence of the hydrocarbons, slow recovery and highly seasonal ecosystems could make walrus populations extra vulnerable to oil spills and disturbance. [113]

Walruses are more sensitive to noise than seals and tend to leave haul-outs when a seismic source is still far away. Meaning that seismic activities can disturb walruses over a very large area. Because of this low tolerance it does mean that they are probably less likely to suffer physical damage by staying to close to a seismic source. [58]

In the Oil and Gas Assessment (OGA) of 2007 is stated that, although production methods and technology have advanced considerably and regulations have become stricter, tanker spills and other accidents are likely to occur. Thus it is unlikely that pollution can be reduced to zero. [113]

When an oil spill occurs, the Arctic’s low temperatures cause hydrocarbons to persist longer in the environment. This can directly affect plants and animals, which have a longer time window for the uptake of pollutants. Marine oil spills are harder to contain in ice covered areas then in other marine areas and have the potential to spread for hundreds if not thousands of kilometres. [113]

If an oil spill occurs in the Arctic, responding to it is a major challenge especially in areas in which ice is present. [113] Many areas along the Arctic coast are vulnerable to oil spills and do not have spill response equipment or manpower nearby. Another concern is that the equipment to clean up oil spills stored in Arctic depots is designed for use in non-ice-covered waters and its applicability under typical Arctic conditions is unknown. For all reasons named above spill prevention should be first priority for all oil and gas activities [113]

Although coverage by oil is not as big a threat for walrus as for other marine species, because walrus do not rely on pelage for insulation, an oil spill can still affect walruses through their food chain when they ingest benthic invertebrates that have taken up hydrocarbons from the water after the spill. [2]

During the aftermath of an oil spill chronic seepage, a constant leaking of oil into the environment can occur. This can keep petroleum hydrocarbon levels elevated in benthic invertebrates when they take up chemicals from the water during feeding. [113]

After the Exxon Valdez oil spill sediments in protected areas, including oiled mussel beds retained contamination for years. The recovery period was estimated, by repeated sampling, to require up to 30 years [118]

Polycyclic aromatic hydrocarbons (PAHs), chemicals found in crude oil, do accumulate in walrus blubber and internal organs. It is likely that walruses ingest chemical compounds through their food because of the low chemical clearance efficiency of invertebrate animals [113], the walrus primary food source.

Walrus populations are most vulnerable to the effects of oil spills at terrestrial haul-outs, particularly in the northern parts of their range where more ice is present. [89, 101]

For the Pacific walrus these areas would be at Wrangel Island, haul-out areas along the northern coast of Chukotka and along the northern coast of Alaska. Here the haul-outs are dominated by females, calves and juveniles [42, 89]. Displacement from these crucial areas would likely result in severe negative impacts on the population.

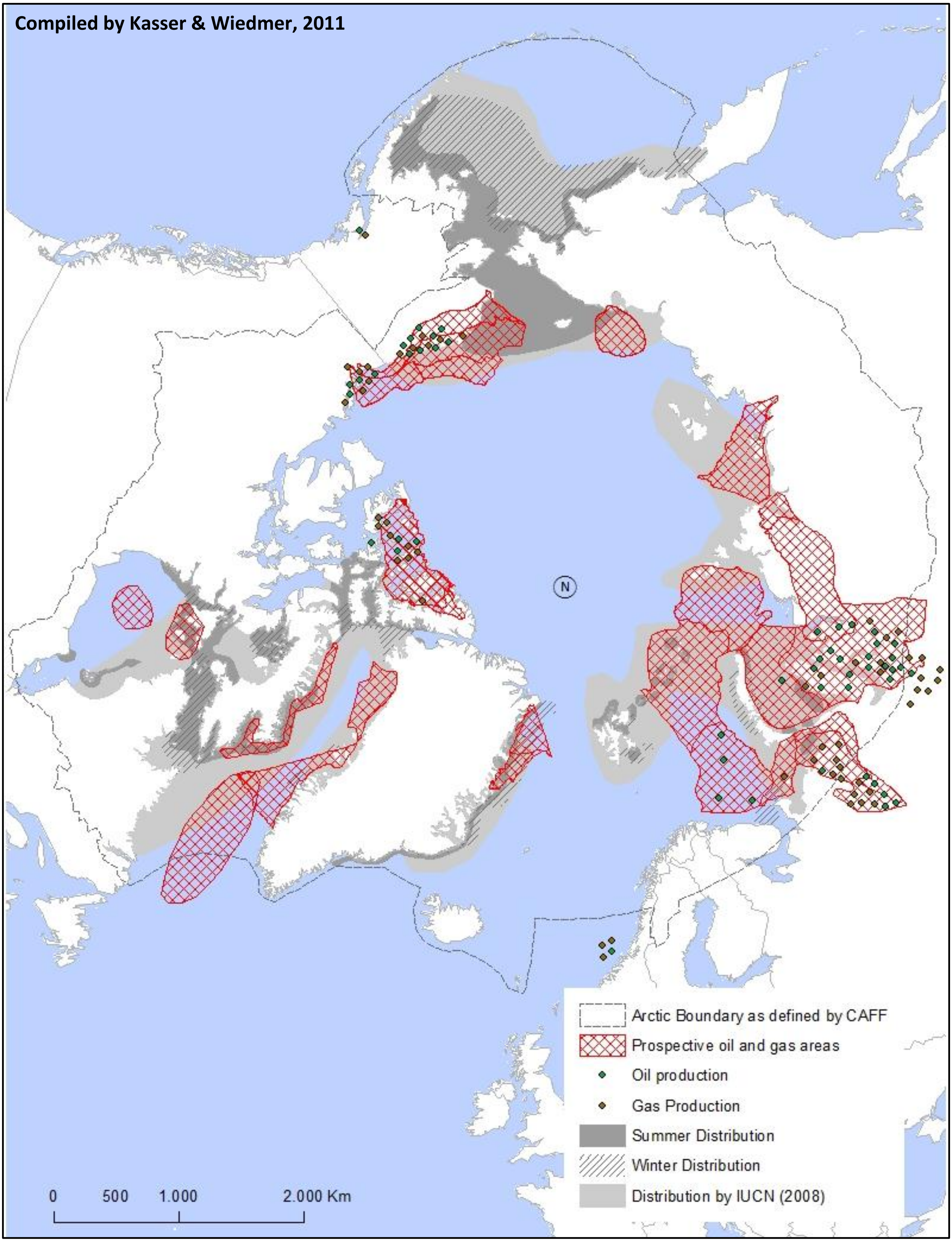
For Atlantic walrus the biggest impact areas are unclear because no research has been done on this subject. However during winter periods they are restricted to systems of leads and polynyas and congregate around these areas. This could be a more vulnerable period for them. Currently there is little oil and gas development in the Atlantic walrus direct habitat but a spill elsewhere could still influence the populations in the vicinity.

The migration patterns and aggregation sites should be taken into account when aiming to reduce or avoid environmental impacts of oil and gas activities. A small spill in an area where many animals aggregated, for example during resting, breeding, feeding, calving or migrating, can have a bigger impact on a population then when it is dispersed. [113]

Another important part of the oil and gas production and extraction process is transportation. People and materials have to be transported into the area and extracted resources have to be transported out of the area. This causes an increase in shipping and disturbance possibilities, both bringing with them their own risks. More information on these subjects can be found in paragraph 5.3 and 5.4.

Oil and gas are finite resources and when oil and gas activities come to an end the final steps in environmental protection are appropriate decommissioning and remediation. But how this needs to be done and to which level, however, is often unclear. [113]

The spread of prospective oil and gas areas throughout the Arctic and their overlap with walrus habitat is depicted on map 5. Detailed maps depicting prospective oil and gas areas and sub-species distribution can be found in Appendix VII for the Pacific walrus, appendix VIII for the Atlantic walrus and appendix IX for the Laptev walrus.



Map 5 Current oil and gas wells & prospective oil and gas areas in the Arctic
References used to compile this map: Bird *et al*., 2008; Blijleven & van Dijk, 2010; Born *et al.,* 1995; CAFF, 2009; ESRI, 2008; Gavrilo, 2011; IUCN, 2009; Norwegian Polar Institute, 1995; Olson & Dinerstein, 2010; Smith, 2010; USGS, 2008

5.3 Shipping

Reduction of sea-ice extent and thickness in the Arctic region is very likely to increase marine transport and access to resources, which eventually has marine transport as a consequence, even further as it has advanced today.

Climate Model Simulations indicate a continuing retreat of sea-ice and the possibility of a sea-ice free Arctic in summer for as early as 2015. This indicates the possibilities for longer seasonal navigation periods and thus an increase in time and frequency of shipping in the Arctic, which in turn could bring an increased probability for accidents.

Shipping accidents can have severe consequences due to the sensitivity of the Arctic environment, remoteness of the area, difficulties in conducting clean-up operations in the harsh environmental conditions, unsuitability of clean up equipment and lack of man power.[2]

During 2004, the survey year of the Arctic Marine Shipping Assessment (AMSA), there were approximately 6.000 individual vessels operating in the Arctic region. Many of these make multiple voyages. About 1.600 of the total number of vessels were fishing vessels. Tourism, which at present accounts for a small amount of voyages, is noted to be an increasing shipping purpose in the Arctic. [2]

Although there is a great number of fishing vessels present in the Arctic, interactions between them and Pacific walrus in American waters are considered insignificant. The estimated annual mortality due to interaction is an average 2.66 walrus in all of Alaska's commercial fisheries combined [148].

Although interactions between fisheries and walruses themselves are few, bottom trawling has a great potential to disturb the benthic habitats of their primary food source. The impacts of trawl disturbance on Arctic benthic ecosystems have only been evaluated by few studies, but these studies do confirm disturbance effects and can diminish the possibility of other species finding feeding grounds. [21]

Most shipping in the Arctic today is of destinational nature, this includes moving natural resources out of the arctic, resupplying Arctic-communities and marine tourism. Other shipping purposes are mostly local. Regions that are experiencing high shipping pressure in the Arctic are the northwest of Russia, the ice free waters off the Greenlandic coast and the Bering Strait region of the U.S. Arctic. [2]

Bulk transport of oil gas and different kinds of ore account form a significant portion of Arctic shipping. Many of the areas where these natural resources are mined have only a limited time window for transport, which means a high increase in shipping activity during the ice-free summer/autumn season. Many vessels operating during this season are not ice-strengthened. [2]

The AMSA identifies Arctic natural resource development (hydrocarbons, hard-minerals and fisheries) and regional trade as the key-drivers of future shipping development. For regions that can become potentially crowded, like the highly productive and denser populated Bering Strait region. Formally established vessel routing measures are suggested. Due to a lack of large ports and critical infrastructure, trans-Arctic shipping will still be limited in the near future. [2]

The most direct and significant threat shipping can pose to the Arctic marine environment, and thus walruses, is the release of oil through accidental discharge. This risk is enlarged by the gaps that exist in hydrographic data for significant portions of the primary shipping routes, but necessary to support save ship navigation and to prevent accidents. Another concern is that, except for limited areas, there is a lack of emergency response capacity for pollution mitigation and salvaging. [2]

Other impacts shipping could have are the loss of hazardous cargo, strikes, introduction of exotic species to the ecosystem, disruption of migratory patterns, noise disturbance (in the air and underwater) and visual disturbance. [2]

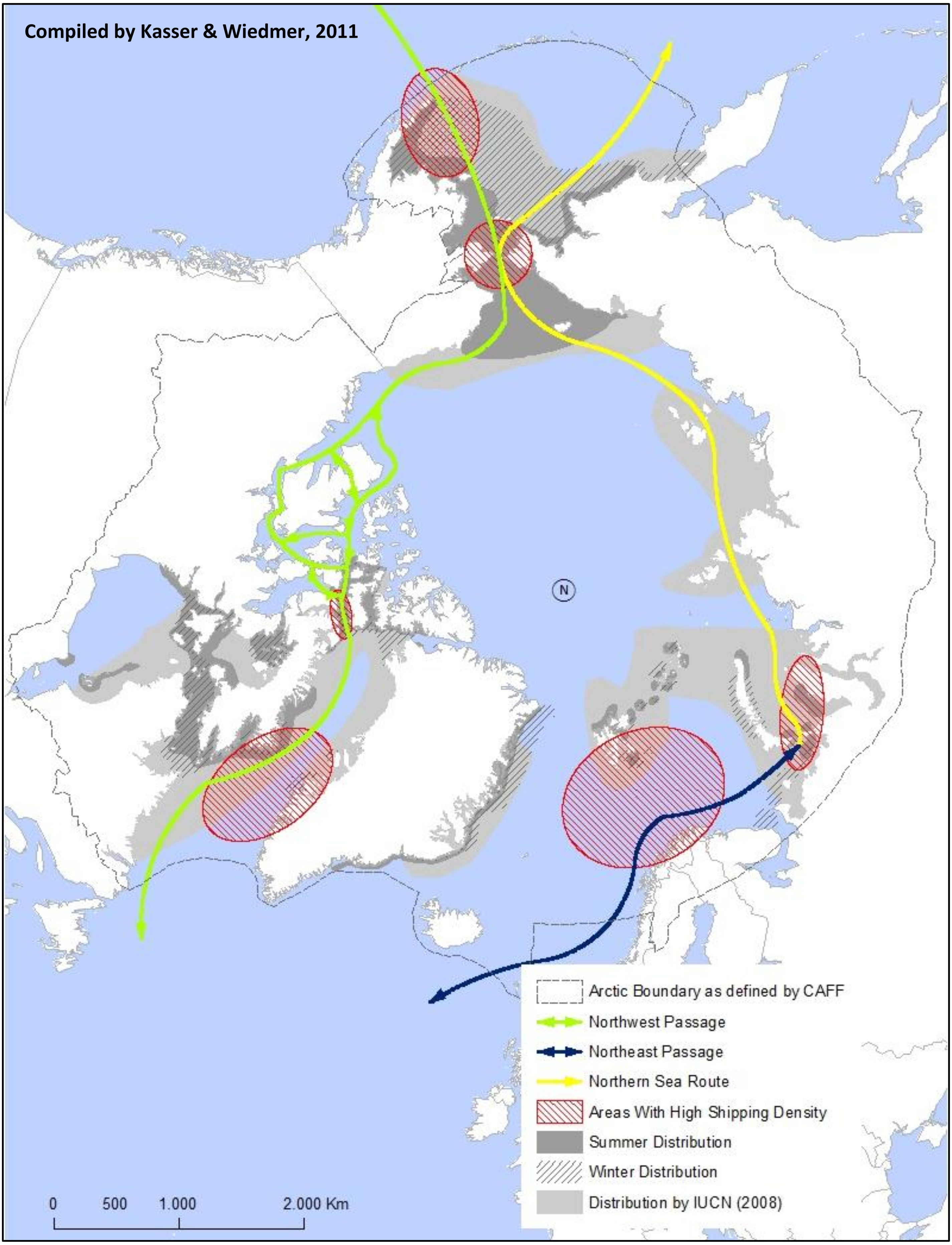
The migration corridors used by marine mammals, including walrus, correspond broadly with the main shipping routes into and out of the Arctic. During spring migration however, there is limited overlap. All shipping activity will typically occur later in spring than the animal migrations. There are more opportunities for interaction between ships and migrating species during fall migrations, as both are leaving the Arctic ahead of the formation of the sea-ice. [2]

Increased shipping along the coasts could cause stampeding at walrus haul-outs [147, 148]. These events are known for their lethal consequences. Stampedes often result in the deaths of about a hundred adult walruses and calves. [42, 46] This can already be caused by the incidental presence of ships.

In the AMSA is pointed out that activities like fishery and shipping are primarily taking place in the relatively shallow coastal seas of the Arctic shelves [2]. This is also identified as important/primary walrus habitat [42, 110].

Despite the hazards of shipping to the Arctic environment uniformity in law and legislation is lacking in the region. This means that there are possibilities to dump pollutants, including oil, in Arctic waters to a certain extent. Ballast water and fouling pose another shipping related risk. A ships ballast water and hull can contain pathogens and life forms that are exotic to the region. Although the International Maritime Organisation (IMO) is preparing a convention on the management and control of ballast water, momentarily only Norway subscribed to this convention. Different paints and coatings can be chosen to prevent fouling. Regrettably some paints used are toxic and do peel off, contaminating the environment. [2]

The main shipping routes across the Arctic, the approximate areas with high shipping density and their overlap with walrus habitat are depicted on the maps VII, VIII and IX. Detailed maps depicting the main shipping routes and sub-species distribution can be found in Appendix VI for the Pacific walrus, appendix VII for the Atlantic walrus and appendix VIII for the Laptev walrus.



Map 6 Main Arctic Shipping routes & approximate areas of high shipping density
References used to compile this map: AMSA, 2009; Born *et al.,* 1995; CAFF, 2009; ESRI, 2008; Gavrilo, 2011; IUCN, 2009; Norwegian Polar Institute, 1995; Olson & Dinerstein, 2010; Smith, 2010

5.4 Noise disturbance

There are several different sources of noise that can influence walruses. Disturbing presences can be flying aircrafts, passing ships and boats and icebreaking activities but, despite the source of the noise, they often have the same consequences. [124]

Aircraft

Reactions of walrus to low flying aircrafts seem quite variable [45] and responses can vary with range, flight pattern, aircraft type, age, sex and group size. Small herds for example seem to be more easily alarmed than larger ones. Adult females, calves and immature walruses are also more likely to abandon their haul-out site during disturbance than adult males. [124]

Walruses have been observed to raise their heads when approached by a small helicopter (Bell 206) at a distance of 2,5 km and flee to the water at a distance of 1.3 km [126]. When approached by a medium sized aircraft (Dehavilland otter) a fleeing response was observed at a distance of <1 Km at an altitude between 305 - 455 meters (1000 - 1500 feet) [126].

Severe disturbance may result in mass stampedes towards the water at a walrus haul-out site [139]. This can result in the crushing of calves and the abortion of foetuses [42]. The deaths of 102 individuals of all sex and age classes were reported at Wrangel Island after an over flight at an altitude of 800 meters.

Despite of the widely observed fleeing behaviour, some walruses seem to become more tolerant of aircraft noise as they are exposed to it repeatedly, for example when occupying haul-out sites close to airstrips. [124]

Boats and Ships

Walruses do not seem to be disturbed by the sound of outboard engines at distances greater than 400 meters [42]. Hauled-out walruses seem to become more tolerant of passing outboard motorboats when they have not been hunted from boats that year [124].

While using ice haul-outs, reactions to passing ships include waking up, head raising and abandoning the haul-out. In 20% of the cases this happens when a ship passes at a distance of 230-460 meters [15-17]. Females with calves appear to be more wary than adult males. When in open water, walruses seem less responsive to ships and usually show little reaction except if the ship is about to run over them [45].

Icebreakers

Walruses appear to react earlier to approaching ice-breakers than to regular ships. Walruses on ice haul-outs became alert at a distance greater than 2 kilometres [45]. About 60% of resting walruses will leave the haul-out when an icebreaker passes at 230-460 meters compared to regular shipping activities. [15-17]. The probability of a fleeing behaviour sharply increases with diminishing distance. Again females with calves appear to be more wary than adult males.

Other noises

There is no scientific evidence that walruses are sensitive to other noise disturbance, originating from, for example, offshore drilling for oil and gas or seismic exploration.

5.5 Harvesting

Walrus harvesting has been an important component in the economy and culture of native communities for over thousands of years [2, 18, 53]. Indigenous people have been using walrus meat as a food source for both humans and sledge dogs for example in a dish called Suassa, a stew with potatoes and rice. Walrus hides are used as strong and durable material for equipment, walrus blubber to produce good quality oil and ivory from walrus tusks for tools, weapons and handicraft [9]. Artifacts from walrus are traded between communities [40].

Before Europeans discovered the northern latitudes and commercial harvesting by foreign hunters started to reduce the numbers of both Atlantic and Pacific walruses [44, 133], [107], population numbers are estimated to have numbered in the hundreds of thousands [9]. Numbers did not vary extremely because of the sustainable harvesting practiced by the indigenous communities for thousands of years [2]. Walrus numbers declined [44] after commercial exploitation for their oil, tusk ivory and hides proceeded on a enormous scale, without any monitoring to ensure sustainability [9].

Altering ways of hunting, changing from hunting with sledge dogs to motorized vessels which increased efficiency tremendously is believed to have contributed to the decline of populations as well [40, 101, 133]. Nowadays the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recognized harvesting as the most immediate cause for mortality among Atlantic walruses [33].

Nowadays native communities still (partially) depend on walrus harvesting [104] which for example can be seen in Alaska and Chukotka where the Pacific walrus is an important part of subsistence for native hunters.

Around the 1960s, due to a decline in sledge dog teams, the need to obtain large amounts of walrus meat declined [9], but variables around native communities change often. For example in Russia where, because of a momentarily unfavorable economy, many native communities become more depending on natural resources again, resulting in a rise in harvests by indigenous communities once more [101].

Population numbers are provided in table 1 for the Pacific walrus and table 2. for the Atlantic walrus, give reason to assume that harvesting poses a threat to the survival of walrus as a species [77]. Due to the importance of walrus hunting for indigenous communities, also the native culture and economy will be experiencing the effects of declining walrus numbers.

In paragraph 5.5.1 and 5.5.2 the data found [9, 67, 71, 150] on the numbers of walruses harvested in both the Atlantic and the Pacific walrus are summarized, and where possible, an overview is provided of current walrus harvest data in different ranges, together with the sustainable yield estimates. Note that for the harvesting numbers of the Atlantic walrus, the same stock division is used as in chapter 3. Harvesting numbers of Laptev walruses are unknown.

5.5.1 Atlantic walrus

Harvest numbers

Harvesting of walrus has had a great influence on the declining population [9], which for example can be seen in Greenland. In the early years of the 20th century, walrus occurred abundantly along the Greenlandic western and eastern coasts, but when in 1911 the hunt at the West coast intensified, haul-out sites where almost all abandoned 20 years later.

When referring to stocks in the text below, the following division is used;

1. West Greenland and North Water stock
2. East Greenland stock
3. South and Eastern Hudson Bay stock
4. Foxe Basin stock
5. North Hudson Bay, Hudson Strait, S.E. Baffin Island and Northern Labrador
6. Kara Sea, Southern Barents Sea Novaya Zemlya.
7. Svalbard

Greenland

From 1997 until 1999, the numbers of walrus harvested in Greenland, are estimated to be 725 for stock 1 and 34 for stock 2 [150]. Harvesting numbers from the years 2000 to 2004 are estimated to be 1399 for stock 1 and 135 for stock 2. When analyzing these two numbers, one should keep in mind that the harvesting numbers from October, November and December of 2004 are not included in these numbers, resulting in incomplete data for 2004 [150].

For the years 2005 to 2009 a different source has been used. In the governmental booklets, 'Greenland in figures ', hunting figures for walrus are published for the years 2003 to 2009 [67, 68].

'Greenland in figures' shows that 284 walruses were hunted in 2003, 194 in 2004, 253 in 2005, 145 in 2006, 133 in 2007, 103 in 2008 and 127 in 2009 (only including harvesting numbers up to September 2009). [67, 68]

These figures are not divided in different stocks and are therefore impossible to analyze in the same way as it is done for the harvesting data summarized above, but it is noticeable that the numbers of harvested walruses are declining slowly.

The sustainable yield per year determined for the Greenlandic walrus stocks is 50 (2% of the total) for stock 1 and 40 (4% of the total) for stock 2. Walruses that are lost during hunting are included in these sustainable levels. When the total of the sustainable yield of 90 walruses per year is compared to the harvest data given above, one can see that although there has been a decline, harvesting numbers are still above the sustainable yield.

Canada
Data on walrus harvesting in Canada is presented by Born (1995). Based on this report the following estimates are made. In stock 3, 250 walruses have been harvested every 5 years, from 1995 to 1999, from 2000 to 2004 and from 2005 to 2009. In stock 4, 1500 walruses have been harvested every 5 years, from 1995 to 1999, from 2000 to 2004 and from 2005 to 2009. In stock 5, 1650 walruses have been harvested every 5 years, from 1995 to 1999, from 2000 to 2004 and from 2005 to 2009. [9] Born (1995) noted that not all data are fully reliable and that actual harvested numbers could be smaller or larger.

The annual sustainable yield determined for the Canadian Atlantic walrus stocks are 10 -25 individuals for stock 3, 110-275 for stock 4 and 120 - 300 for stock 5 [9].

Russia
Harvesting data and the annual sustainable yield for the Atlantic walrus stock in Russia are unknown [9].

Norway
On Svalbard walrus harvesting is banned [132], so there is no (legal) harvest. Illegal harvest is unknown but because of well-enforced laws it is believed to be insignificant on Svalbard.

Data on Atlantic walrus harvesting is often poorly documented and thereby probably unreliable [9], except for the stocks on Svalbard and in Greenland.

Born (1995) states that there is a possibility that the same population of walruses is hunted off Central West Greenland and the North Hudson bay, Hudson Strait, South East Baffin Island and Northern Labrador [9].

Harvesting regulations
Greenland
In Greenland a license for fishing and harvesting can be obtained if one meets certain requirements, written down in Act No. 20 of 27 November 2003. Some examples of these requirement are that the license keeper most have permanent connection to Greenland, is depending on harvesting for a living and a license keeper must always carry his or her license when hunting. [69]
Approximately 2,000 people in Greenland have such a license [120].

In 2006 the home rule No.20 was developed for the protection and harvesting of walrus in Greenland [70]. Females and pups are protected throughout Greenland, except in Qaanaaq, this management area allows the hunt on females and juveniles. In western Greenland south of 66°N, al harvesting is prohibited and between 66°N and 70°30'N, harvesting is only allowed from 01-03 until 30-04. In west Greenland north of 70°30'N and in east Greenland south of the National Park, harvesting is allowed from 01-10-30-06. [71]

The government of Greenland has determined annual walrus harvesting quotas, based on biological advise from the Greenland Institute of Natural Resources [59]. Quotas for 2009 and 2011 can be found on the governmental website of Greenland, but because there are no harvesting figures available from 2011, a comparison between quota and harvesting figures can only be made for the year 2009.

Harvesting quota for 2009 were 113 walruses from stock 1, West Greenland & North Water and 23 from stock 2, East Greenland, making a total quota of 136 animals of the Greenlandic stocks [73]. According to the hunting figures derived from the Greenlandic government, only 127 walruses have been harvested, but taking into account that only walrus harvests up to September have been reported [68], it cannot be said with certainty that the total of harvested walruses in 2009 is within the sustainable yield.

To retain sustainable walrus management, harvesting quotas have currently been reduced with 30% to compensate the loss of wounded walrus that are lost during the harvests and not reported. Quota can be increased again, when reporting of these losses will improve. [72]

Canada
Walruses in Canadian waters have been hunted commercially until 1928 [29]. Canadian marine mammal regulations, in force until October 2011, state that walrus can be hunted with a license for which a fee of 5,00 Canadian dollars has to be paid. No hunting is allowed without that license, but exceptions are made for people subject to the Aboriginal Communal Fishing Licenses Regulations. This regulation states that Inuit or Indians are allowed to hunt four walruses a year [25, 29, 107] without a license but only for food or social and ceremonial purposes. The settlements Coral Harbour, Sanikiluaq, Arctic Bay and Clyde River have specific harvesting quota, which means that for those settlements the above regulation is only valid, until this quota has been reached.[25]

A general rule in Canada for someone that kills or wounds a walrus is that he/she should make a reasonable effort to retrieve the animal without delay and does not abandon or discard it. It is not allowed to waste any edible part of the animal. [25].

Russia
No data on legal walrus harvesting in Russia is found.

Norway
On Svalbard, harvesting walrus is illegal and therefore there is no harvesting record [132].

5.5.2 Pacific walrus

Harvesting numbers
The known number of annual walrus harvests differs each year. A mean harvest mortality level is estimated to be 5,458 walruses a year, based on harvest data from Alaska and Chukotka from the years 2001 to 2005, when added together, it is estimated that 27,290 walruses are harvested every five years [101]. It is not possible to state that in the five years prior and past 2001 to 2005, the same estimation of harvested walrus can be made. Harvest numbers are influenced by changes in, for example climate, economic development of settlements and harvesting techniques.

Harvesting regulations
Russia
Harvesting marine mammals, among which are walrus, is funded by the Government of the Chukotkan Autonomous Okrug. In 2003 the hunting force counted 75 hunters who were officially employed [103], but it should be noted that interviews with hunters revealed that the amount of walrus harvested by these 75 hunters, does not include a substantial amount of harvested pinnipeds, whose products are used for food in the community and as dog food [104].

Alaska
Alaskan residents, who are at least one fourth native, are allowed to hunt walrus. [140] Along the Alaskan coast, in Barrow walrus are harvested from June to September. In

Wainright, it is allowed to hunt walrus at local haul-outs from August to September.

In Point Lay, when ice conditions are favorable, the local residents hunt walrus from June to August along the whole length of Kasegaluk Lagoon, south of Icy Cape and offshore as far as 20 miles. The harvest in Point Hope is concentrated from May to July from the southern shore from Point Hope to Akoviknak Lagoon. [101]

Losses to harvesting

As traditional harvesting techniques changed into harvesting from motorized vessels, using rifles, losses have increased. A significant number of walruses are wounded but cannot be secured by the hunter and die later and/or sink after they have died [66, 104]. For this reason the actual losses due to harvesting are estimated to be 25 to 33 % higher than the reported kills [150], or even higher as suggested by NAMMCO [106]. Because official harvesting statistics do not include these extra losses, they can be regarded as incomplete [150].

5.6 Threat assessment

The threat assessment is based on a review of all information included in the potential threat chapter. It may be used as an instrument to determine what threats should receive immediate attention according to the data that were found during this research.

Table 3 Threat assessment of the occurrence, persistence and urgency of all major threats influencing the global walrus population and their mitigation possibilities.

Threats	Occurrence	Persistence	Urgency		Mitigation		Final Ranking
5.1 Climate change							1
5.5 Harvesting							2
5.3 Shipping							3
5.2 Oil spills							4
5.2 Oil & gas development							5
5.4 Disturbance							6
5.1 Competition							7
5.1 Predation							8

Legend

Threat level

Low High

Mitigation possibilities

Low Medium High

Assessment explanation
All of the assessed threats in table 3 are derived from the topics in this chapter. They were ranked on their occurrence rate, persistence and the need to react to them within a short time span (urgency). These three categories are considered along with the mitigation possibilities for each threat to come to a final ranking on overall importance.

Ranking explanation

1. Climate change
Climate change is the threat that is affecting the entire Arctic region including walruses and their habitat. Its occurrence can be considered high because the effects of climate change are widespread in walrus habitat. When analysed further it appears to be a main and central event, working as a catalyst for all other threats walruses face, including the opening up of the Arctic region, fuelling economic activities in the region. This increases human activity and the impact of other threats that coincide with it. Although this threat demands urgent attention, climate change and associated natural threats and changes are hardest to mitigate.

2. Harvesting
Harvesting is considered to be the most important human related threat to the global walrus population. The reason for this is that harvesting is occurring through the walrus's entire range and it will be persistent because local communities still depend on it. Adding to

this is the fact that harvesting numbers, when known, can be considered to be above sustainable yield levels in all walrus populations, except the population on Svalbard (where hunting is banned). An urgent response to the harvesting pressure is favourable to prevent population depletion. Mitigation measures can be in place relatively fast and can consists of adjustments in law and legislation, setting of (lower) harvesting quotas, upgrading protective status and harvest control throughout the different walrus ranges.

3. Shipping
Currently shipping is occurring throughout the Arctic at varying levels. But, due to the opening of the region by climate change, it will be a persistent and increasing threat in the entire Arctic. Because there are gaps in laws, legislation and navigational data this threat needs urgent attention. If this urgency is received effects of accidents, collisions, dumping of chemical wastes and disturbing hauled-out walrus populations can probably be mitigated.

4. Oil spills
The occurrence rates of oil spills is relatively low. Although these are usually local events they do have the potential to spread over vast distances in a marine environment. If ice is present in these environments the effects of an oil spill can persist for decades, able to influence walrus trough effects on their primary food source. If an oil spill occurs in the Arctic, it is expected that response equipment will be unsuitable and man power insufficient to react adequately. Therefore it is favourable that this problem receives urgent attention to prevent severe consequences in the future.

5. Oil and gas development
Due to the opening up of the region this threat will increase in occurrence, although only in prospective areas. As long as production is possible and there is a demand for oil and gas, this will be a persistent threat in the Arctic for the oncoming years. The presence of oil and gas facilities itself appear no real threat to walruses, provided that activities are not taking place on or near haul-out sites. The potential occurrence of an oil spill, as a consequence of oil and gas activities, is a serious threat to the walrus population, and therefore regulations should be in place before developments are started and a preventive approach should be followed during the entire process of production.

6. Disturbance
Next to direct approach by humans, walruses are mostly disturbed by the sounds of human activities. Ships and aircraft have a high disturbance potential if they come close to haul-out areas. Because shipping will increase in the near future the potential for disturbance will also increase. Mitigation is relatively ease however when disturbance free perimeters are set around haul-out areas.

7. Competition
Increasing competition as a result of climate change, is seen as a threat that is going to occur in future. Since the effects of climate change will probably be persistent increased competition is not a threat that is mitigated easily.

8. Predation
Like competition, increased predation on walrus populations by Polar bears and Killer whales may also occur as a result of climate change. Although these effects will probably be persistent in the future, increased predation is not a threat that is mitigated easily.

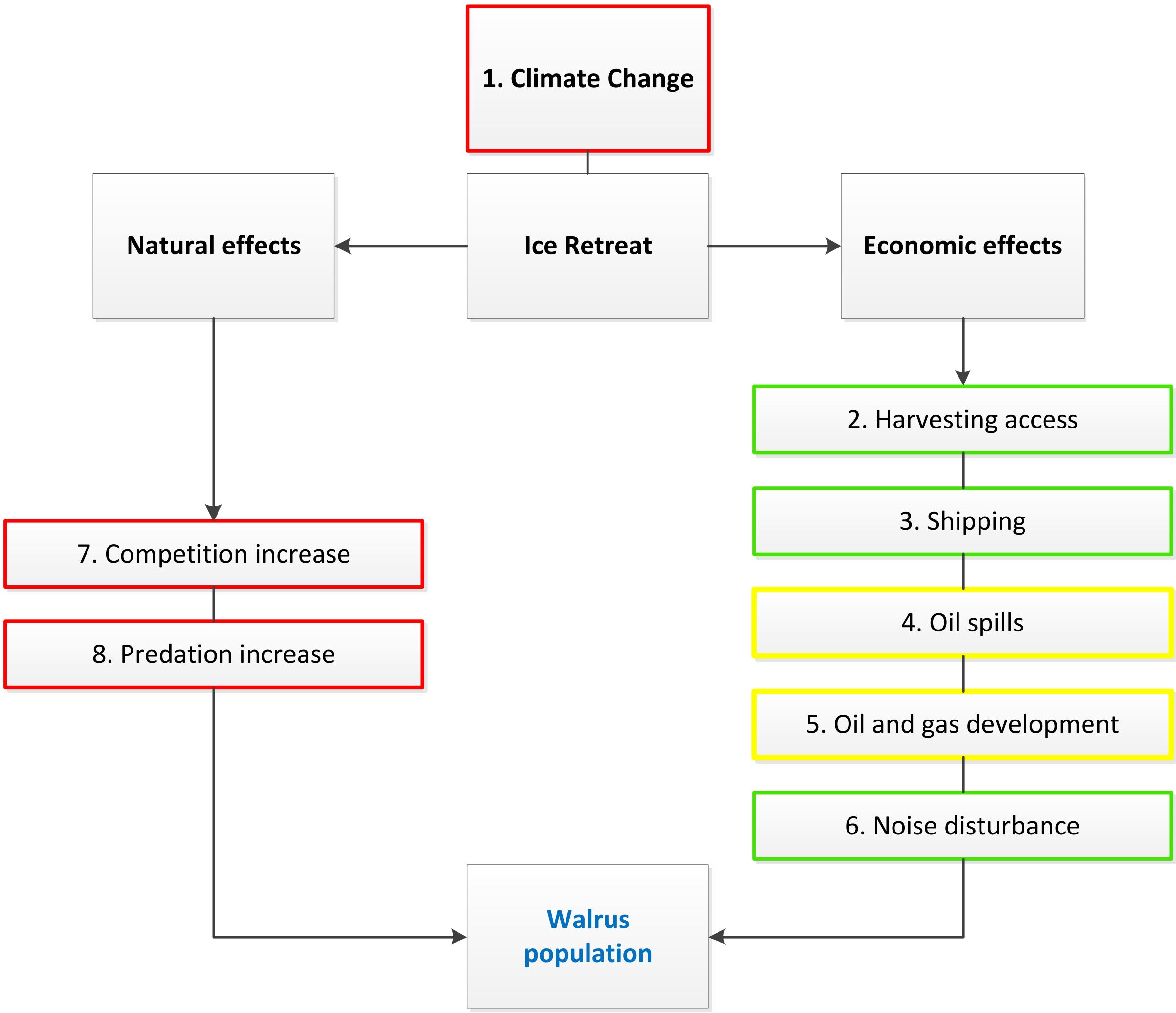
Assessment conclusion
The most important conclusion that can be drawn from the assessment is that climate change is the most important threat to walruses and their habitat at present. When analysed further it appears to be an overarching event working as a catalyst for all other activities threatening walrus populations.

This enables us to divide the current threats walrus face into natural, and human induced or economic threats.

Threats that are associated with climate change and natural changes are hardest if not impossible to mitigate. Mitigation does, however, have a high potential when applied on the human induced threats such as harvesting, shipping and disturbance. Oil and gas related activities prove to be the known factor in the assessment. Although they are not the biggest threats per se, accidents cannot be ruled out and their effects can be very persistent in the Arctic environment and are hard to mitigate.

Another important conclusion is that walrus populations are not necessarily threatened by each problem separately but by the accumulation of threats.

Figure 2 Conceptual model B: Assessed threats and their relation to the walrus population



In the conceptual model displayed above all potential threats that were assessed in the threat assessment of paragraph 5.6 and their relation to the walrus population are presented. The numbers are corresponding with the assessments final ranking column and the colours are corresponding with the level of mitigation possible.

Red - Low Yellow - Medium **Green** - High

5.7 Potential areas of concern

To determine potential areas of concern in the changing habitat of the global walrus population, we have compared their distribution and known terrestrial haul-out locations to potential prospective oil and gas areas and main shipping routes.

The distribution of oil and gas deposits that are of interest in the scope of this research are visualized on map 5. Large potential oil and gas areas are situated throughout the Arctic and indicate significant off shore oil and gas resources.

The potentially profitable areas are spread along the entire Arctic coastline, mostly within the Exclusive Economic Zones (EEZ) of several nations. EEZs are the areas up to 200 nautical miles from the coast in which the bordering state has sovereign rights over all economic resources of the sea, seabed and subsoil as regulated under the United Nations Convention of the law of the sea (UNCLOS).

The approximate main shipping routes are displayed on map 6 and indicate the Arctic's main shipping infrastructure. Exact shipping lanes are subjected to changes in natural conditions, such as sea-ice extent, and can therefore vary considerably over time. (Note: Attempts to map detailed shipping routes and local shipping has proved to be undesirable, causing difficulties with map clarity and readability.)

Because the main threat shipping can pose to walruses is disturbance, a buffer range was set surrounding each terrestrial haul-out, indicating disturbance potential by human activities. For readability purposes buffer distance does not match the real perimeter distance.

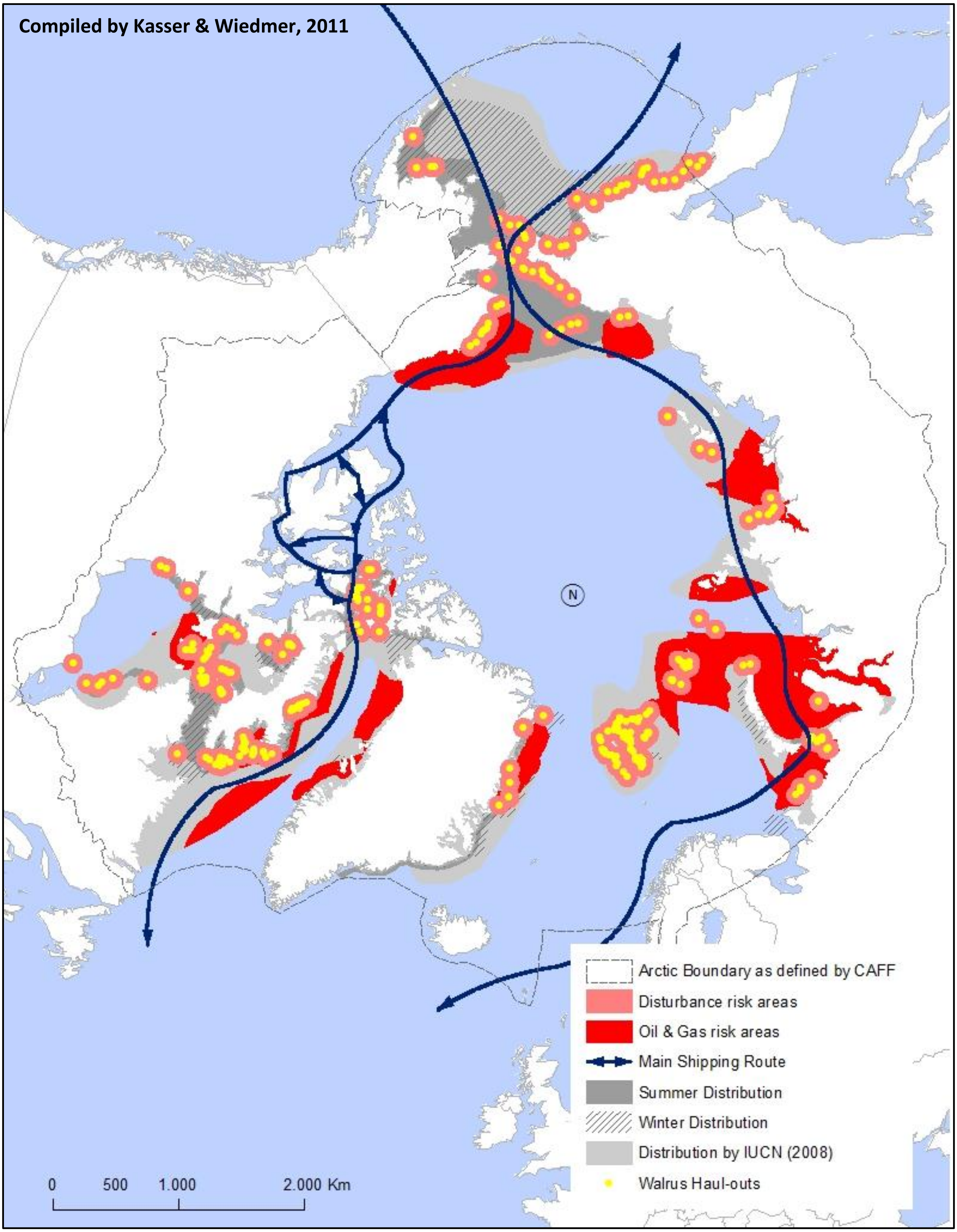
The areas of concern arising from this analysis are displayed on map 7. Overlap with the sub-species specific distribution for Pacific walrus, Atlantic walrus and Laptev walrus habitat are displayed in Appendixes X, XI and XII.

5.8 Stakeholders

The Arctic, being surrounded by land, is an area of interests for all bordering nations, which are also members of the Arctic Council [91]. The nations that are within the Arctic boundary, the Russian Federation, the United States of America (Alaska), Canada, Greenland (Denmark), Iceland, Norway, Sweden and Finland have differing economic interests in industries such as the (upcoming) oil and gas industry and commercial fisheries.

The main Law applicable for all Arctic countries except the U.S.A., is the LOS Convention (LOS) [137] and the two implementation agreements, of Part XI the Deep-Sea Mining [136] agreement and the Fish Stocks Agreement [135], which will be discussed in more detail in chapter six.

Other stakeholders interested in the Arctic marine areas are oil and gas companies, shipping companies, commercial hunters, indigenous hunters and nature conservation organisations. The Arctic is essentially one connected area in which two opposing interests collide: the (growing) economic interests and nature conservation interests. Taking into account that the native communities are, even nowadays, still (partly) depending on the Arctic's natural resources and considering the many communities and populations depending on this ecosystem, a growing group of people understand the necessity of safeguarding the Arctic and its natural values.



Map 7 Potential areas of concern
References used to compile this map: AMSA, 2009; Bird *et al*., 2008; Blijleven & van Dijk, 2010; Born *et al.,* 1995; CAFF, 2009; ESRI, 2008; Gavrilo, 2011; IUCN, 2009; Norwegian Polar Institute, 1995; Olson & Dinerstein, 2010; Smith, 2010; USGS, 2008

6. Legislation

This chapter starts with general law and legislation, after which a separation is made between Pacific and Atlantic walrus and the according law and legislation in the different countries where these subspecies exist, specialized on the available subjects that are not yet described in the chapter 5.5.

6.1 Arctic legislation

Currently there is no universally accepted definition for the spatial scope of the marine Arctic [91]. The main covering (non-governmental) organization is the Arctic Council, of which all eight Arctic States are a member. [91]

The main Arctic legislation is the United Nations Convention on Law of the Sea (UNCLOS) [137], to which only the U.S.A. is not ratified. UNCLOS establishes the right and responsibilities of nations in their use of the world's oceans and seas, among which the countries surrounding the Arctic Ocean.

Another lawful convention in the ocean is the Convention for the Protection of the marine Environment of the North-East Atlantic (OSPAR) [115]. The OSPAR is an international cooperation on environmental protection of the northeast Atlantic seas.

The Arctic Ocean is organized in different zones. The first zone is the Internal Waters (IW), in which the Nation has full power in the same way as on land. The second zone is the Territorial Waters (TW) (12 nautical miles), in which the Nation has full power, but vessels have the right of passage when no harm is meant. After the TW zone, the Contiguous Zone (CZ) (12-24 nautical miles) is in force, saying that the Nation can enforce laws in 4 specific areas: pollution, taxation, customs and immigration. The next and the last zone is the Exclusive Economic Zone (EEZ) (200 nautical mile) in which Nations have sole exploration rights on living, dead and inanimate objects. The Nation has exploration rights but not on fisheries. Everything beyond the EEZ is covered by the High Seas (HS), in which there is free passage. [137]

Coastal states have the authority to adopt laws and regulations applicable to foreign ships transiting through the territorial sea [2].

Another important regulation is the Arctic Waters Pollution Prevention Act (AWPPA) which includes special ship construction equipment and crewing requirements and near zero oil pollution discharge standards

The LOS Convention established a framework with the goal to decrease the risk of international conflicts and through that create stability and peace among the international communities. For the attending countries, the LOS Convention recognizes the sovereignty, consisting of sovereign rights, freedoms, jurisdiction and obligations within a number of maritime zones. [91].

The Exclusive Economic Zone (EEZ) is the basic applicable law, effectual on an area that extends 200 nautical mile (370,4 km) from the coastline and gives these countries the right of exploitation of available resources, the right of fishing and the right of scientific research.

For an overview of instruments and tools in the Arctic regulation system see appendix XX. For a list on involved parties in the Arctic regulation system, see appendix XXI. During this research some gaps in the regulatory system were discovered. For an extensive analysis on this theme, it is advisable to read the report of Koivurova and Molenaar (2009).

6.2 Pacific walrus

Alaska

Since the Marine Mammal Protection Act, administered by the U.S. Fish and Wildlife Service was applied in the United states in 1972, buying or selling non-fossil walrus ivory became illegal after December the 21st. The MMPA also states that taking walruses, which includes harass, hunt, capture, kill, collect, or an attempt to the above, is illegal. An exception to this regulation is the Alaska

Native Claims Settlement Act, which says that everyone who is at least one fourth Alaska Native (Indians, Aleuts or Inuit) and who lives in Alaska, inhabiting the coast of the North Pacific Ocean or the Arctic Ocean, are allowed to harvest walrus for subsistence purposes, creation and sale of Native handicraft or clothing, as long as harvest is not wasteful. [140] [109] Other exceptions can be made through permitting actions for harvesting for commercial fishing, other non-fishing activities like scientific research and for public display at licensed institutions [109]. Taking walrus for ivory only, is illegal in every situation [140].

In 2009 a petition to protect the Pacific walrus under the Endangered Species Act, including a 60 day public comment period, was announced [141] by the Centre for Biological Diversity, but this has been rejected by the U.S. Fish and Wildlife Service. Another petition, of 12 months, has been announced in February 2011. Based on findings from this petition, the Pacific walrus might be added to the candidate species list of the Endangered Species Act (ESA). [138] Listed on this Act means the state shall take measures to preserve the habitat of this species [3].

Russia

In Russia, as part of a Soviet inheritance, no such regulation as the Alaska Native Claims Settlement Act exists. The Soviet government integrated native labor into a wider format of economic development, which included reindeer herding and sea-mammal harvesting for example, and were seen as a part of the agricultural sector. [101]

A possible change in the future can be expected since some Native leaders and activists are forming non-governmental organizations to support indigenous concerns and initiatives. Examples that have been formed already are the Association of Native Minorities of Chukotka and a marine mammal-hunters association. Organizations like these intend to restore traditional practices for resource use and introduce conservation regimes. A few of these organizations have been recruiting native people to inventory and manage Bowhead whales and Polar bear, but also walrus populations. [101]

6.3 Atlantic walrus

Greenland

In Greenland, four categories for hunting purposes are determined, these are the category residents, the category visitors, the category researchers, museums and educational institutions and the category for commercial export. In all four categories the walrus is enlisted on the CITES III list, meaning that walrus products can only be exported or imported if a CITES license is obtained. [64]

All EU countries temporarily ban the import of walrus products from Greenland under the EU law. Exporting walrus products to EU countries thereby requires an import permit from the receiving country. Tourists may take home walrus products as personal belongings, if one is in possession of a CITES export permit from the Ministry of Domestic Affairs, Nature and the Environment. Although, if one travels with more than one walrus skull or tooth, a special application to this department must be sent, to inform them of the purpose of exporting these walrus products. Another restriction is that the specimens that are taken home are legally obtained. [65]

The three present stocks of Atlantic walrus in Greenland are admitted separately on the Greenland red list. The northeast stock is listed as Near Threatened, the West Greenland stock as Moderate Endangered and the northern underwater stock as Critically Endangered.

Canada

In Canada, the Atlantic walrus are managed by Fisheries and Oceans Canada (DFO) under the authority of The Fisheries Act and the Marine Mammal Regulations [29].

In Canada the walruses are listed on one of the appendices [28], that is
Appendix III, Listed in 16-11-1975 [30 28]

Russia
On the eastern coast of Russia, walruses are fully protected from harvesting [107].

Norway
The walrus stock on Svalbard has been protected since the 1950's [107]

7. Conservation

In the past twenty years the extent of Arctic areas that have a form of protected status has doubled. At present there are 1,127 protected areas covering 3.5 million km^2. Although coastal habitats are included in 40% of the existing protected areas it is not clear to which extent the adjacent marine environments are included in the protective measures. [21].

Compared to terrestrial protected areas, marine protected areas are far fewer, see map 8. Under pressure of climate change and increasing human activities there is an urgent need for the identification, designation and protection of biologically important marine areas. [21]

With recent findings showing that the Arctic sea-ice is disappearing more rapidly than even the most pessimistic models showed [111], the oceanography and productivity of Arctic marine ecosystems will face some fundamental alterations in the future. Several population levels will be affected by these changes, including het benthic communities. Understanding these changes and there consequences however is only in its pioneering stages [1].

Although marine protected areas (MPAs) will potentially be of importance to walrus and have the potential to protect their primary food source against bottom trawling, protected coastal areas might play a bigger part in future walrus protection, if they include areas where terrestrial haul-out sites occur. The use of land based haul-out sites is normal but has been increasing in the recent past. Large aggregations of walruses, common in Russian territories, first appeared on the Alaskan side of the Chukchi Sea in 2007. In late August and September 2007, hundreds to thousands of individuals hauled-out on the Alaskan shores for the first time and are now an annual feature. [49] This is assumed to be and effect of disappearing sea-ice through climate change. [82].

A good example of on-going protection anticipating recent changes is the formation of a new coastal protected area in Russia on Cape Kozhevnikov during 2010. This area now protects one of the biggest coastal haul-outs in the world and was established in cooperation with the indigenous population. During recent years, when walruses started to appear at the site, the people of the village of Ryrkaipiy, situated next to the cape, have already been protecting the walruses by cleaning the coast and guarding the animals on their own initiative. [151].

Currently a number of terrestrial haul-outs are already within protected areas, for example on Svalbard, Franz Josef land, East Greenland, Kotelny Island, New Siberia, Wrangel Island and parts of the Alaskan coast and the Chukotka peninsula, see map 8.

In several areas in Alaska protective parameters have already been established around islands that are used by walruses to haul-out. This protects them from human disturbance in the surrounding areas [147].

7.2 Future conservation

In the Arctic Biodiversity Trends report (ABT) the authors recognize the urgent need to develop a circumpolar protected areas strategy for the Arctic. They state that this strategy should build on the on-going national initiatives, like marine protected area planning and existing national parks, to permit effective conservation planning in a global context [21].

During the 1990s the need for the development of a Circumpolar Protected Area Network was already recognized and a gap analysis was performed to identify the most poorly covered areas at that time. These were marine areas, coastal areas, fjords and forests [22].

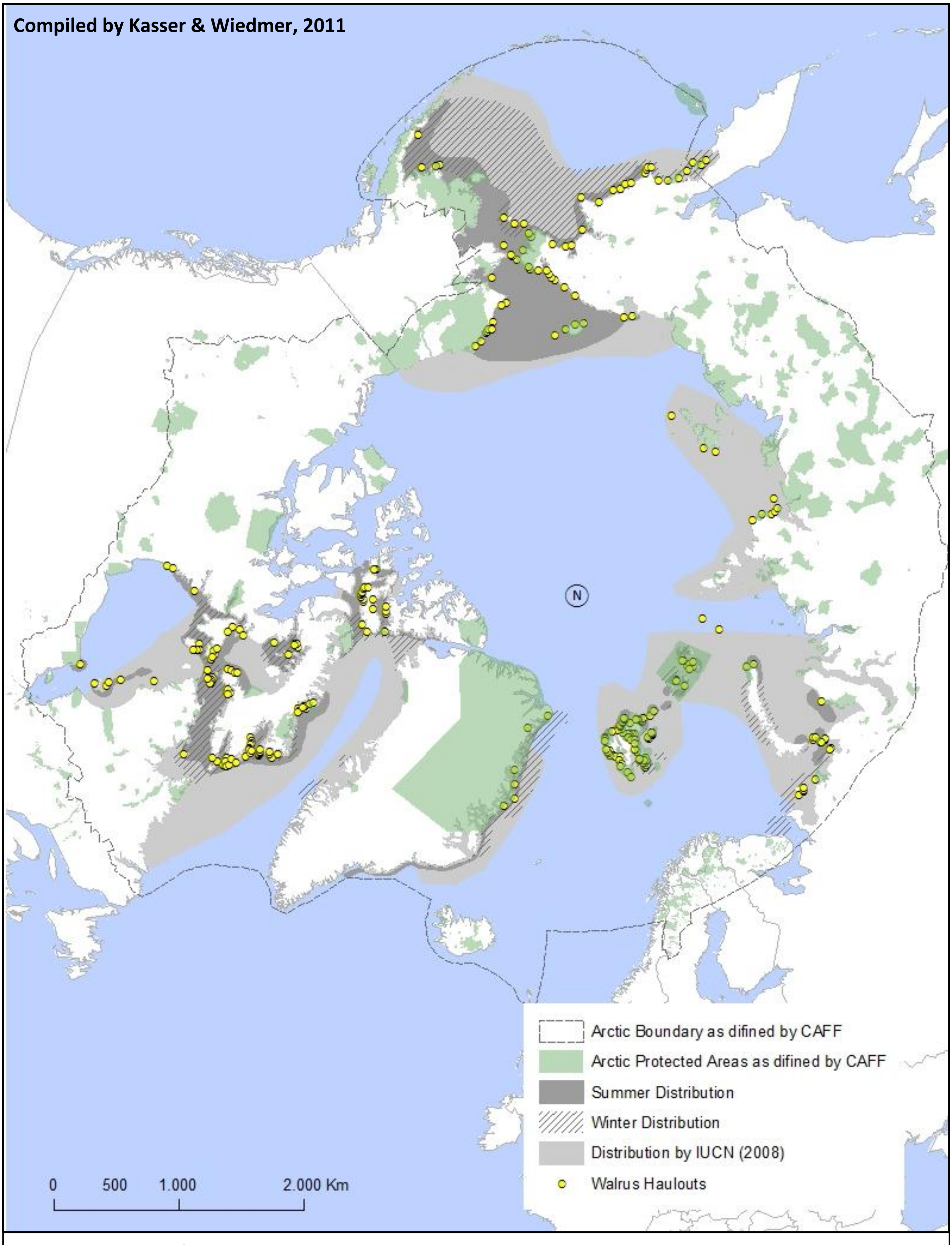
Three of these four areas are in some way connected to the walrus' lifecycle or their prey. Perhaps this is the moment to use the information that is gathered in the past to extent the circumpolar protected area network and enhance the representation of poorly represented areas.

Contributing to the complexity of designating marine protected areas is the absence of a universally accepted definition for the spatial extent of the marine Arctic and Arctic Ocean. [91]

7.3 Absence of a regulatory system

The terrestrial territories of the Arctic are managed according to the law and legislation of the countries they belong to, as are their EEZ. The overall marine Arctic however, is missing coverage by coordinating and cooperating bodies, or a single overarching body, to ensure integrated and responsible marine management and compliance with international rules, standards, regulations and conventions [91].

In their report 'International Governance and Regulation of the Marine Arctic' Koivurova and Molenaar give an overview of regulations applicable in Arctic waters and identifies legislative gaps. The findings in this report underline the need for a regulatory body in the marine Arctic and states that the competence and capacity of the parties operating within the current system is minimal [91].



Map 8 Arctic protected areas

References used to compile this map: Born *et al.,* 1995; CAFF, 2009; ESRI, 2008; Gavrilo, 2011; IUCN, 2009; Norwegian Polar Institute, 1995; Olson & Dinerstein, 2010; Smith, 2010; USFWS, Undated

8. Discussion

8.1 Discussion of the results

The accuracy of walrus population estimates and actual distribution patterns are questionable for all sub-species over at least a part of their range. Data available at present is mostly generally outdated, based on rough estimates, old survey techniques and incomparable methods.

Recent, reliable and comparable data on walrus distribution and population numbers can be invaluable to base a sound conservation statement for all sub-species on. In Russia a new technique based on satellite imagery, has yielded promising results during pilot studies in the Barents Sea and will be used to survey the global walrus populations in 2012, which can lead to more accurate estimates [152].

When walrus numbers can be estimated with more precision through the use of the new technique described above, it will probably be possible to calculate sustainable yield levels more accurately and set harvesting quota that will ensure more sustainable exploitation by indigenous people.

Although harvesting is a serious threat there has to be a certain balance between harvesting regulations and the subsistence lifestyle of the local people. Many do still depend to a certain extent of walrus harvests and probably have to be compensated in some way.

Setting quota and regulations for harvesting is a measure that will bring along another problem, namely, how to enforce and monitor them. Today governments and other organisation have to rely mostly on the honesty of hunters for their official harvesting numbers. Interviews however have proven that opinions on what is official harvest differ among hunters and governments.

Another fact that should probably be taken into account when setting harvesting quota is the relatively high struck and lost factor of walrus harvests. This is now a grey zone of animals that eventually die but are not registered.

Survey results might also help scientists and conservationists to determine which areas, for example terrestrial haul-out locations, are used by walrus frequently and could therefore qualify for protection.

Because walrus are a seasonal species it might also be worth considering temporal protective measures for terrestrial haul-out sites, only applicable if walrus are actually present in the areas.

Walrus dependence on sea-ice is debatable. Apart from the fact that sea-ice use differs per sub-species, Pacific walrus, which have a strong sea-ice connection, have proven to be able to shift from sea-ice haul-outs to terrestrial haul-outs when sea ice retreats too far North.

On the other hand, there are consequences to this forced habitat shift and behavioural adaptation that might compromise Pacific walrus survival. The long migration journey to the coastal haul-out sites seems to seriously weaken the adult walrus and it is also thought to be the cause of females abandoning their young. Weakened walrus might also be more susceptible to disease.

Apart from that, the increased amount of walrus haul-outs in a relatively small coastal area can also effect and maybe even deplete the feeding areas in the close vicinity. When using coastal-areas to haul-out instead of sea-ice the potential for human wildlife conflict is also likely to increase, bringing us back to the importance of protective measures.

The effects that diminishing sea-ice can have on mating and calving, which both take place on the sea-ice, are unknown but have the potential to influence the walrus population.

Hauled-out walrus are easily disturbed; this can lead to stampeding which inevitably leads to walrus deaths by oppression. A protective perimeter around walrus haul-outs can potentially prevent these unnecessary deaths and heightened stress levels. Applying these protective measures to all human activities in the Arctic, like oil and gas exploration and exploitation, shipping, fishing and harvesting could be beneficial to the walrus population.

When these rules are in place however, they might be hard to enforce and will probably largely rely on the honesty and willingness of individuals to cooperate and participated in walrus protection.

Protective rules and/or areas for the bivalves and benthic invertebrates walrus rely on might also be necessary in the future to prevent depletion by overfishing when the northern regions in the Arctic open up to the trawling industry.

Another consequence of human industrial presence in the Arctic is the possibility of oil spills. These potential, local events have the ability in influencing large marine areas. Walrus are probably mostly impacted when their food chain in contaminated. Recovery of benthic invertebrates after an oil spill can take up to thirty years and the effect on the local walrus populations can only be speculated. It is likely that there will be a negative influence however.

Next to human induced threats there is also the overarching problem of climate change which has the ability to effect the entire global walrus population. At first effects might be positive, as melting sea-ice increases primary productivity. Effects on the longer-term can be of opposing nature because primary production will probably stagnate when there is no sea-ice left. This, combined with the potential of inter-specific competition with for example the Gray Whale can have negative effects on walrus populations.

The question remains if walruses will be able to adapt fast enough to their changing environment. It might be a disadvantage that they have a k-species survival strategy and are therefore slow to reproduce, which probably makes them also slow to adapt to changes in their habitat.
Walrus conservation can be straightforward but is complicated by the lack of generally accepted definitions for areas in their habitat and sound rules and regulations for the area. An option to straighten this out might be to establish coordinating and cooperating bodies, or a single overarching body, to ensure integrated and responsible marine management and compliance with international rules, standards, regulations and conventions.

Looking at conservation effort and resource investments it is also important that issues surrounding the sub-species status of the Laptev walrus are resolved. Recent research suggests that the Laptev walrus population is the most western Pacific walrus population, if this is confirmed it might be important knowledge to conservationist because the Pacific walrus seems to be most vulnerable to climate change. Resolving this issue will probably also prevent mismanagement and the wasting of resources and manpower.

8.2 Discussion of the research methods

Since it is a literature-based research, the great challenge was to gather all the available information. Although a lot of information was found online, in books and provided by experts, there was a limitation because of some gaps in access to all possible databases and therefore some useful data might have been missed.

When interpreting the maps in this report, it should be taken into account that some information might be lacking due to the fact that not all information was available during the research period and one should keep in mind that most of the maps are edited by hand using ArcGIS 10 due to a lack of GPS data.

The information found and used in this report is often grouped. The amount of available information on some subjects, areas or species were significantly higher than others, for example the difference in available information on the Laptev walrus, compared to the other two sub-species.

9. Conclusion and recommendations

9.1 Conclusion

Recent, reliable and comparable data on walrus distribution and population trends for all sub-species is lacking. Despite this we can conclude that walrus distribution is season dependant but, according to the literature, the amount of variation and distance of migration movements appears to vary significantly per sub-species.

After analysing the differences in habitat and behavioural ecology, the Pacific walrus appears to be most vulnerable to sea-ice loss. This conclusion is based on the disturbed migration behaviour of Pacific walrus females and calves, which have to leave the relative safety of their sea-ice haul-outs to undertake a weakening journey toward terrestrial haul-outs in time of severe sea-ice loss. This journey is assumed to compromise the survival of both adult females and calves. Atlantic walruses, which migrate locally and use coastal haul-outs more commonly, seem to suffer less in sea-ice free periods.

It is difficult to determine critical habitats due to the close consistency with sea-ice extent critical habitats also vary annually. The only critical habitats with a low variation factor are (terrestrial) haul-outs. Although these are not all occupied on a yearly basis, there is some certainty when pinpointing these locations, which makes it helpful when determining conservation measures.

The most prominent threat to walrus and their habitat is climate change. It is also the hardest to mitigate, especially on the short term. Next to this, it catalyses all other potential threats that walrus face. As climate change progresses it opens up the region for economic development. Human activities like oil and gas exploration and extraction are increasing and the Arctic shipping season is prolonged and intensified. All these developments can pose threats to walrus populations but do also qualify for mitigation measures, which can reduce their severity.

Another threat that has a profound influence on the global walrus population is harvesting. Harvesting numbers, when known, are believed to be around or above sustainable yield levels in all walrus populations, except the population on Svalbard, which is fully protected. Adjusting regulations concerning walrus harvesting and better enforcement of these regulations could prevent stock depletion and can give them a chance to recover.

Disturbance is a threat that can potentially cause substantial, unnecessary walrus deaths. Mitigation is relatively easy though and can be achieved by defining protective perimeters around terrestrial haul-out sites. By doing so, most stampeding and associated deaths can be prevented.

If strict regulations and guidelines are drawn up for the oil, gas and shipping industries, the potential threats these activities can pose can be restricted to a minimum. Accidents, however, cannot be ruled out entirely and for this reason a precautionary approach in the Arctic region is favourable. Oil spills, especially in marine environments, can spread over vast distances and have the potential to contaminate the walrus's primary food source: benthic invertebrates, which have a low hydrocarbon clearing. When contaminated, mussel beds can take thirty years to recover.

The key factors in walrus habitat will probably prevent future population shifts. Walruses are likely to stick to their current habitats because of the high benthic productivity within 0 -100 meters depth and haul-out sites in close vicinity of these high productive areas, which are their most important habitat demands.

Currently the Arctic is missing a circumpolar protected areas strategy. Although there are a reasonable amount of terrestrial protected areas, a gap analysis in the past has identified marine areas, coastal areas, fjords and forests as most poorly covered at present. Three of these four areas are in some way connected to the walrus's lifecycle or their main prey species. The increased use of terrestrial haul-outs by walrus emphasizes the importance of coastal protected areas.

The overall marine Arctic is missing coverage by coordinating and cooperating bodies, or a single overarching body, to ensure integrated and responsible marine management and regulation enforcement.

9.2 Recommendations

- **New data and data sharing:** to preserve the Circumpolar walrus population, it is highly recommended to gain new and up to date data on 1). Walrus numbers, 2). behavioural adaptation and 3). terrestrial haul-out locations and its demands and 4). the Laptev walrus, with regard to their numbers, haul-outs and genetics to make sure whether this is a sub-species or a part of the Pacific walrus population.
  It is advisable to create an international database, so that a general approach can be developed by all responsible states, concerning the walrus. When data are abundant and usable, this can result in new conservation regulations.

- **Drilling platform locations:** drilling platforms should not be built or operated on or in the vicinity of walrus haul-outs. To meet this recommendation, drilling platform locations should be explored and assessed to determine whether or not it may be an important walrus location. Research is advisable to determine a minimum distance, between walrus haul-outs and drilling platform locations.

- **Drilling platforms and the disturbance effects:** since there are no data available, it is recommendable to research the possible disturbance effects of drilling in the vicinity of walrus haul-outs.

- **Oil spill prevention:** it is important to formulate a protocol to mitigate oil spills and a protocol specifying cleaning actions in the Arctic. Researching into better cleaning methods, materials and strategies should also be performed.

- **Shipping regulations:** general regulations for shipping in the Arctic must be developed and a strategy to enforce them must be determined and executed. Special attention should be paid to narrow passages like the Bering Strait and the Kara gate.

- **Navigational routes:** navigational data gaps concerning the main shipping routes that are used in the Arctic, should be filled in, to reduce the risk of accidents and possible oil spills as a possible consequence.

- **Distance to haul-outs:** it is highly recommendable to determine a fixed perimeter around haul-outs which humans executing any activities should keep as a minimum distance, to prevent disturbance in any form which will lower the chance of stampeding and thereby unnecessary deaths.

- **Mussel fishing regulation:** when the Arctic will become more accessible, the accessibility to mussel beds will also increase for fishing fleets. Since this is the main food source of the walrus, it is important to determine quotas and regulations for this part of the fishing industry.

- **Harvesting quotas:** harvesting of walrus is currently not managed by an overall applied regulation and thereby determination of a general conservation regulation is not possible. Because of the spread distribution of walrus over different countries, the best way to prevent stock depletion due to overharvesting is determining general harvesting regulations and the enforcement of these regulations.
  To determine these harvesting quotas in each country, it is advisable to discuss and share data on population numbers, to determine the sustainable yield and based on this, the harvesting quotas of each Arctic State.

- **Local walrus management:** the more the climate will change, the more walruses will make use of terrestrial haul-outs. To prevent conflicts between walrus and humans in any way, it is highly advisable to involve the local communities in walrus management, by education, information and responsibilities.

- **Protected haul-out areas:** it is advisable to make an up to date assessment of the currently occupied haul-outs and compare them to presently designated, coastal protection areas. For haul-outs that are not located in these coastal protection areas, a protocol should be developed to assign these locations as new costal protection areas. It is recommendable to combine the protected haul-outs into a protected area network around the coastal zones.

- **Conservation strategy:** developing an Arctic wide protection strategy is advisable. Extra attention should be paid to the areas that are underrepresented according to the gaps analysis discussed in chapter 7, seeing three out of four under represented areas are connected to either walrus or their food source.

- **Regulatory body:** it is highly advisable to establish a regulatory body between the Arctic States, to fill in the currently existing regulatory gaps and manage the area as a separated body from the surrounding nations.

References

1 **ACIA.** (2005) 'Arctic Climate Impact Assessment ',Cambridge: Cambridge University Press.
2 **AMSA.** (2009) 'Arctic Marine Shipping Assessment '.
3 **Animallaw.** (2011)'West's Alaska Statutes Annotated, Endangered Species. 'http://www.animallaw.info/statutes/stusak16_20_195.htm>.
4 **O.A. Anisimov, D.G Vaughan, T.V. Callaghan, C Furgal, H Marchant, T.D. Prowse, H. Vilhjálmsson, and J.E. Walsh.** (2007) 'Polar Regions (Arctic and Antarctic)', in *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*,Cambridge: IPCC, pp. 653-85 ch. 15.
5 **S.E Belikov, and Yu. A Gorbunov.** (2010) 'Predictable Changes of Climate and Sea Ice Cover of the Eurasian Shelf and Their Potential Influence on Arctic Marine Mammal Species', *Marine Mammals of the Holarctic 2010*, 58!
6 **S. Belikova, A. Boltunov, and Y. Gorbunov.** (1996) 'Distribution and Migration of Polar Bears, Pacific Walruses and Gray Whales Depending on Ice Conditions in the Russian Arctic ', *Polar Biology,* 9, 263-74.
7 **B. A. Bluhm, and R. Gradinger.** (2008) 'Regional Variability in Food Availability for Arctic Marine Mammals', *Ecological Applications,* 18, S77-S96.
8 **A.N. Boltunov, S.E. Belikov, Y.U. A. Gorbunov, D.T. Menis, and V.S. Semenova.** (2010) 'The Atlantic Walrus of the Southeasten Barents Sea and Adjacent Regions: Review of the Present-Day Status',Moscow: WWF-Russia, Marine Mammals Council.
9 **E. W. Born, I. Gjertz, and R.R. Reeves.** (1995) 'Population Assesment of Atlantic Walrus',Oslo.
10 **E. W. Born, and L. Ø Knutsen.** (1997) 'Haul-out and Diving Activity of Male Atlantic Walruses (Odobenus Rosmarus Rosmarus) in Ne Greenland', *Journal of Zoology,* 243, 381-96.
11 **E. W. Born, S. Rysgaard, G. Ehlmé, M. Sejr, M. Acquarone, and N. Levermann.** (2003) 'Underwater Observations of Foraging Free-Living Atlantic Walruses (Odobenus Rosmarus Rosmarus) and Estimates of Their Food Consumption', *Polar Biology,* 26, 348-57.
12 **E.W. Born, M. Acquarone, L.O. Knutsen, and Toudal L.** (2005) 'Homing Behaviour in an Atlantic Walrus (Odobenus Rosmarus Rosmarus)', *Aquatic Mammals,* 31, 23-33.
13 **D. Bowen, and D.B. Siniff. J.E. Reynolds and S.A. Rommel.** (1999) 'Distribution, Population Biology, and Feeding Ecology of Marine Mammals', in *Biology of Marine Mammals*,Washington, DC: Smithsonian Institution Press, pp. Pages 423-84.
14 **O.W. Brude, V.B. Moe, L.H. Hansson, L.H. Larsen, S.M. Lovas, J. Thomassen, and Ø Wiig.** (1998) 'Northern Sea Route Dynamic Environmental Atlas',Norway: Norsk Polarinstitutt
15 **J.J. Brueggeman, R.A. Grotefendt, M.A. Smultea, G.A. Green, R.A. Rowlett, C.C. Swanson, D.P. Volsen, C.E. Bowlby, C.I. Malme, R Mlawski, and J. J. Burns.** (1992), '1991 Marine Mammal Monitoring Program (Walrus and Polar Bear) Crackerjack and Diamond Prospects Chukchi Sea', in *As Cited In: Marine Mammals and Noise* San Diego, CA: Academic Press.
16 **J.J. Brueggeman, C.I. Malme, R.A. Grotefendt, D.P. Volsen, J. J. Burns, D.G. Chapman, D.K. Ljungblad, and G.A. Green.** (1990), 'Shell Western E & P Inc. 1989 Walrus Monitoring Program: The Klondike, Burger, and Popcorn Prospects in the Chukchi Sea.', in *As Cited In: Marine Mammals and Noise* San Diego, CA: Academic Press.
17 **J.J. Brueggeman, D.P. Volsen, R.A. Grotefendt, G.A. Green, J. J. Burns, and D.K. Ljungblad.** (1991), 'Shell Western E & P Inc. 1990 Walrus Monitoring Program/the Popcorn, Burger, and Crackerjack Prospects in the Chukchi Sea', in *As Cited In: Marine Mammals and Noise* San Diego, CA: Academic Press.
18 **D. M. Burn.** (1998) 'Estimation of Hunter Compliance with the Marine Mammal Marking, Tagging, and Reporting Program for Walrus', *Wildlife Society Bulletin,* 26, 68-74.

19 **D. M. Burn, M. S. Udevitz, S. G. Speckman, and R. B. Benter.** (2009) 'An Improved Procedure for Detection and Enumeration of Walrus Signatures in Airborne Thermal Imagery', *International Journal of Applied Earth Observation and Geoinformation* 11, 324-33.

20 **CAFF.** (2011)http://www.caff.is/> [Accessed 11-10 2011].

21 **CAFF.** (2010) 'Arctic Biodiversity Trends 2010 - Selected Indicators of Change',Akureyri, Iceland: CAFF International Secretariat.

22 **CAFF.** (1996) 'Circumpolar Protected Area Network (Cpan) - Strategy and Action Plan, Caff Habitat Conservation Report No. 6. ',Trondheim, Norway: Direcorate for Nature Management. .

23 **CAFF.** (1994) 'The State of Protected Areas in the Circumpolar Arctic 1994', in *CAFF Habitat Conservation Report No. 1.*,Trondheim, Norway: Directorate for Nature Managment, p. 151.

24 **W. Calvert, and I. Stirling.** (1990) 'Interactions between Polar Bears and Overwintering Walruses in the Central Canadian High Arctic', *Bears: Their Biology and Management,* 8, 351-56.

25 **Canada.** (2011) 'Marine Mammal Regulations',Canada: Minister of Justice.

26 **A. G. Jr. Carey.** (1991) 'Ecology of North American Arctic Continental Shelf Benthos: A Review', *Continental Shelf Research,* 11, 865-83.

27 **S. J. Chivers.** (1999) 'Biological Indices for Monitoring Population Status of Walrus Evaluated with an Individual-Based Model', *Marine Mammal Survey and Assessment Methods*, 239-47.

28 **CITES.** (2011) 'Appendices I, Ii, Iii Valid from 27 April 2011', CITES.

29 **CITES.** (2003) 'Cites World Official Newsletter of the Parties, Convention on International Trade in Endangered Species of Wild Fauna and Flora (Cites)', 5-6.

30 **CITES.** (2011)'Convention on International Trade in Endangered Species of Wild Fauna and Flora'http://www.cites.org/> [Accessed 22-11-2011 2011].

31 **J.C. Comiso.** (2002) 'A Rapidly Declining Arctic Perennial Ice Cover', *Geophysical Research Letters,* 29.

32 **J.C. Comiso.** (2003) 'Warming Trends in the Arctic from Clear Sky Satellite Observations', *Journal of Climate* 16, 3498 - 510.

33 **COSEWIC.** (2006) 'Cosewic Assesment and Update Status Report on the Atlantic Walrus Odobenus Rosmarus Rosmarus'.

34 **M. A. Cronin, S. Hills, E. W. Born, and J. C. Patton.** (1994) 'Mitochondrial DNA Variation in Atlantic and Pacific Walruses', *Canadian Journal of Zoology,* 72, 1035-43.

35 **L. A. Dehn, G. G. Sheffield, E. H. Follmann, L. K. Duffy, D. L. Thomas, and T. M. O'Hara.** (2007) 'Feeding Ecology of Phocid Seals and Some Walrus in the Alaskan and Canadian Arctic as Determined by Stomach Contents and Stable Isotope Analysis', *Polar Biology,* 30, 167-81.

36 **A.E. Derocher, N.J. Lunn, and I. Stirling.** (2004) 'Polar Bears in a Warming Climate', *Integrative & Comparative Biology,* 44, 163-76.

37 **DFO.** (2000) 'Atlantic Walrus Dfo Science Stock Status Report E5-21'.

38 **H. Eicken.** (1992) 'The Role of Sea Ice in Structuring Antarctic Ecosystems', *Polar Biology,* 12, 3-13.

39 **EOL.** (2011)'Encyclopedia of Life'http://eol.org/> [Accessed 9 November 2011].

40 **J.A. Fall, M. Chythlook, J. Schichnes, and R. Sinnott.** (1991) 'Walrus Hunting at Togiak Bristol Bay, Southwest Alaska' Alaska Departement of Fish and Game. Juneau, Alaska.

41 **F. H. Fay.** (1982) 'Ecology and Biology of the Pacific Walrus, Odobenus Rosmarus Divergens Illiger ', *North American Fauna,* 74.

42 **S. H. Ridgway and R Harrison** (1981) 'Walrus Odobenus Rosmarus (Linneaus, 1758)', in *Handbook of marine mammals*Academic Press, pp. 1-23.

43 **F. H. Fay, and J. J. Burns.** (1988) 'Maximal Feeding Depth of Walruses ', *Arctic,* 41, 239-40.

44 **F. H. Fay, L. L. Eberhardt, B. P. Kelly, J. J. Burns, and L. T. Quakenbush.** (1997) 'Status of the Pacific Walrus Population, 1950-1989', *Marine Mammal Science,* 13, 537-65.

45 **F. H. Fay, and G. A. Fedoseev.** U.S.A. Department of Commerce (1984) 'Soviet-American Cooperative Research on Marine Mammals.', NOAA p. Vanaf pagina 89 staat iets wat voor ons sowieso interessant kan zijn.
46 **F. H. Fay, and B. P. Kelly.** (1980) 'Mass Natural Mortality of Walruses (Odobenus Rosrnarus) at St. Lawrence Island, Bering Sea, Autumn 1978', *ARCTIC,* 33, 228-45.
47 **F. H. Fay, B. P. Kelly, and J. L. Sease.** (1989) 'Managing the Exploitation of Pacific Walruses, a Tragedy of Delayed Response and Poor Communication1', *Marine Mammal Science,* 5, 1-16.
48 **S. H. Ferguson, L. Dueck, L. L. Loseto, and S. P. Luque.** (2010) 'Bowhead Whale Balaena Mysticetus Seasonal Selection of Sea Ice', *MARINE ECOLOGY PROGRESS SERIES,* 411, 285-97.
49 **A. S. Fischbach, D.H. Monson, and C. V. Jay.** (2009) 'Enumeration of Pacific Walrus Carcasses on Beaches of the Chukchi Sea in Alaska Following a Mortality Event', in *U.S. Geological Survey Open-File Report 2009- 1291*, p. 10.
50 **K. I. Fisher, and R. E. A. Stewart.** (1997) 'Summer Foods of Atlantic Walrus, Odobenus Rosmarus Rosmarus, in Northern Foxe Basin, Northwest Territories', *Canadian Journal of Zoology-Revue Canadienne The Zoologie,* 75, 1166-75.
51 **C Freitas, Kit. M. Kovacs, Rolf A. Ims, Michael A. Fedak, and C. Lydersen.** (2009) 'Deep into the Ice: Over-Wintering and Habitat Seletion in Male Atlantic Walruses', *MARINE ECOLOGY PROGRESS SERIES,* 375, 247-61.
52 **J Garlich-Miller, J.G MacCracken, J Snyder, R Meehan, M Myers, J.M Wilder, E Lance, and A Matz.** (2011) 'Status Review of the Pacific Walrus (Odobenus Rosmarus Divergens)',Alaska: U.S. Fish and Wildlife Service.
53 **J. L. Garlich-Miller, and D. M. Burn.** (1999) 'Estimating the Harvest of Pacific Walrus, Odobenus Rosmarus Divergens, in Alaska', *Fishery Bulletin,* 97, 1043-46.
54 **J. L. Garlich-Miller, L. T. Quakenbush, and J. F. Bromaghin.** (2006) 'Trends in Age Structure and Productivity of Pacific Walruses Harvested in the Bering Strait Region of Alaska, 1952-2002', *Marine Mammal Science,* 22, 880-96.
55 **M.V. Gavrillo.** (2011),Russia: Arctic & Antarctic Research Institute, St. Petersburg.
56 **J. R. Gilbert.** (1999) 'Review of Previous Pacific Walrus Surveys to Develop Improved Survey Designs', *Marine Mammal Survey and Assessment Methods*, 75-84.
57 **J.R. Gilbert, G. A. Fedoseev, D. J. Seagars, E. Razlivalov, and A. Lachugin.** (1992) 'Aerial Cencus of Pacific Walrus, 1990'.
58 **GINR.** (2011) 'Advice on Consequences of Seismic Activities on Marine Mammals' Climate and the Environment Ministry of Infrastructure, Greenland.
59 **GINR.** (2006) 'Advice on Sustainable Catch of Walrus' Greenland Institue of Natural Resources.
60 **I. Gjertz, D. Griffiths, B.A. Krafft, C. Lydersen, and Ø. Wiig.** (2001) 'Diving and Haul-out Patterns of Walruses Odobenus Rosmarus on Svalbards.', *Polar Biology,* 24, 314-19.
61 **J. M. Grebmeier, L. W. Cooper, H. M. Feder, and B. I. Sirenko.** (2006) 'Ecosystem Dynamics of the Pacific-Influenced Northern Bering and Chukchi Seas in the Amerasian Arctic', *Progress In Oceanography,* 71, 331-61.
62 **J. M. Grebmeier, J. E. Overland, S. E. Moore, E. V. Farley, E. C. Carmack, L. W. Cooper, K. E. Frey, J. H. Helle, F. A. McLaughlin, and S. L. McNutt.** (2006) 'A Major Ecosystem Shift in the Northern Bering Sea', *Science,* 311, 1461-64.
63 **J. M. Grebmeier, Jr. W.O. Smith, and R.J. Conover.** (1995), 'Biological Processes on Arctic Continental Shelves: Ice-Ocean-Biotic Interactions', in *Coastal and Estuarine Studies, Arctic Oceanography: Marginal Ice Zones and Continental Shelves* USA: American Geophysical Union.
64 **Greenland.** (2011) 'Cites - Convention on International Trade in Endangered Species of Wild Flora and Fauna', Science and Environment Department of Internal Affairs, Greenland.
65 **Greenland**. (2010) 'Cites Export Rules in Greenland', Nature and the Environment Department of Interior, Greenland.

66 **Greenland**. (2011) 'Faktaark, Hvalros', Ministry for Hunting Greenland Government, Fisheries and Agriculture, Greenland.

67 **Greenland**. (2009) 'Greenland in Figures 2009',Greenland Greenland Home Rule Government, p. 13.

68 **Greenland**. (2011) 'Greenland in Figures 2011',Greenland: Greenland Home Rule Government.

69 **Greenland**. (2003) 'Home Rule Order No. 20 of 27 November 2003 on Commercial Hunting Evidence.', Departement of fisheries, Greenland: Nanoq.

70 **Greenland**. (2006) 'Home Rule Order No. 20 of 27 October 2006 on the Protection and Hunting of Walrus', in *No. 20*, Greenland Home Rule, Greenland.

71 **Greenland**. (2009) 'Hunting Information and Huntingdata',Greenland.

72 **Greenland**. (2011) 'Hunting Information and Huntingdata 2011',Greenland.

73 **Greenland**. (2011) 'Marine Animal Quotas', Hunting and Agriculture Ministry of Fisheries, Greenland.

74 **C. Haas.** (2004) 'Late-Summer Sea Ice Thickness Variability in the Arctic Transpolar Drift 1991 - 2001 Derived from Ground-Based Electromagnetic Sounding', *Geophys. Res. Lett.,* 31, L09402.

75 **J. Hansen, M. Sato, R. Ruedy, K. Lo, D. W. Lea, and M. Medina-Elizade.** (2006) 'Global Temperature Change', *Proceedings of the National Academy of Sciences,* 103, 14288-93.

76 **C. R. Harington.** (2008) 'The Evolution of Arctic Marine Mammals', *Ecological Applications,* 18, S23-S40.

77 **H.P. Huntington.** (2009) 'A Preliminary Assessment of Threats to Arctic Marine Mammals and Their Conservation in the Coming Decades', *Marine Policy,* 33, 77-82.

78 **Climate Institute.** (2011) 'Albedo',Internet Climate Institute

79 **ITIS.** (2011)'Integrated Taxonomic Information System'http://www.itis.gov/> [Accessed 11-10 2011].

80 **C. V. Jay, S. D. Farley, and G. W. Garner.** (2001) 'Summer Diving Behaviour of Male Walruses in Bristol Bay, Alaska ', *Marine Mammal Science,* 17, 617-31.

81 **C. V. Jay, and S. Hills.** (2005) 'Movements of Walruses Radio-Tagged in Bristol Bay, Alaska', *Arctic,* 58, 192–202.

82 **C.V. Jay, and A.S. Fischbach.** (2008) 'Pacific Walrus Response to Arctic Sea-Ice Losses.', U.S. Department of the Interior US Geological Susrvey Alsaka Science Center. Anchorage Alaska, p. 4.

83 **T.A. Jefferson, M.A. Webber, and R.L. Pitman.** (2008), 'Marine Mammals of the World, a Comprehensive Guide to Their Identification ', Academic Press, p. 378.

84 **M.J. Kaiser, M.J. Attril, S Jennings, D.N. Thomas, D.K.A. Barnes, A.S. Brierley, N.V.C. Polunin, D.G. Raffaelli, and P.J. le B. Williams.** (2005), *Marine Ecology, Processes, Systems and Impacts*Oxford: Oxford university press.

85 **R. A. Kastelein. W.F. Perrin, B. Wursig, and J.G.M. Thewissen** (2002) 'Walrus (Odobenus Rosmarus)', in *Encyclopedia of marine mammals*,San Dego, California: Academic Press, pp. Pages 1212-17.

86 **R. A. Kastelein, P. Mosterd, B. van Santen, M. Hagedoorn, and D. the Haan.** (2002) 'Underwater Audiogram of a Pacific Walrus (Odobenus Rosmarus Divergens) Measured with Narrow-Band Frequency-Modulated Signals', *Journal of the Acoustical Society of America,* 112, 2173-82.

87 **R.A. Kastelein, S. Stevens, and P. Mosterd.** (1990) 'The Tactile Sensitivity of the Mystacial Vibrissae of a Pacific Walrus (Odobenus Rosmarus Divergens), Part 2: Masking.', *Aquatic Mammals,* 16, 78–87.

88 **V.I. Kavry, A.N. Boltunov, and V.V. Nikiforov.** (2008) 'New Coastal Haulouts of Walruses (Odobenus Rosmarus) - Response to the Climate Changes. ', in *International Conference of Marine Mammals of the Holarctic V, October 14-18, 2008.*,Odessa, Ukraine.

89 **A. A. Kochnev.** (2004) 'Warming of Eastern Arctic and Present Status of the Pacific Walrus (Odobenus Rosmarus Divergens) Population', in *Marine Mammals of the Holarctic*,Moscow, Russia: Marine Mammals Commision.

90 **A. A. Kochnev, N.V. Kryukova, A.A. Pereverzev, and D.I. Ivanov.** (2008) 'Coast-Al Haulouts of the Pacific Walruses (Odobenus Rosmarus Divergens) in Anadyr Gulf (Bering Sea), 2007', in *International Conference of Marine Mammals of the Holarctic, October 14-18, 2008*,Odessa, Ukraine.

91 **T. Koivurova, and E.J. Molenaar.** (2009) 'International Governance Andregulation of the Marine Arctic, Overview and Gap Analysis', WWF.

92 **K. M. Kovacs, and C. Lydersen.** (2008) 'Climate Change Impacts on Seals and Whales in the North Atlantic Arctic and Adjacent Shelf Seas', *Science Progress,* 92, 117–50.

93 **K. M. Kovacs, C. Lydersen, J. E. Overland, and S. E. Moore.** (2011) 'Impacts of Changing Sea-Ice Conditions on Arctic Marine Mammals', *Marine Biodiversity,* 41, 181-94.

94 **K. L. Laidre, I. Stirling, L. F. Lowry, Ø. Wiig, M. P. Heide-Jørgensen, and S. H. Ferguson.** (2008) 'Quantifying the Sensitivity of Arctic Marine Mammals to Climate-Induced Habitat Change', *Ecological Applications,* 18, S97-S125.

95 **N. Levermann, A. Galatius, G. Ehlme, S. Rysgaard, and E. Born.** (2003) 'Feeding Behaviour of Free-Ranging Walruses with Notes on Apparent Dextrality of Flipper Use', *BMC Ecology,* 3, 9.

96 **C. Lindqvist, L. Bachmann, L. W. Andersen, E. W. Born, U. Arnason, K. M. Kovacs, C. Lydersen, A. V. Abramov, and Ø. Wiig.** (2009) 'The Laptev Sea Walrus Odobenus Rosmarus Laptevi: An Enigma Revisited', *Zoologica Scripta,* 38, 113-27.

97 **L. F. Lowry, K. M. Kovacs, and V. Burkanov.** (2008)' Iucn Red List of Threatened Species, Odobenus Rosmarus'http://www.iucnredlist.org/apps/redlist/details/15106/0> [Accessed 22 September 2011].

98 **C. Lydersen, J. Aars, and K. M. Kovacs.** (2008) 'Estimating the Number of Walruses in Svalbard from Aerial Surveys and Behavioural Data from Satellite Telemetry', *Arctic,* 61, 119-28.

99 **K.H. Mann, and J.R.N. Lazier.** (2006), *Dynamics of Marine Ecosystems*BLACKWELL PUBLISHING.

100 **J. A. Maslanik, C. Fowler, J. Stroeve, S. Drobot, J. Zwally, D. Yi, and W. Emery.** (2007) 'A Younger, Thinner Arctic Ice Cover: Increased Potential for Rapid, Extensive Sea-Ice Loss', *Geophys. Res. Lett.,* 34, L24501.

101 **MMS.** (2007) 'Chukchi Sea Planning Area Oil and Gas Lease Sale 193 and Seismic Surveying Activities in the Chukchi Sea Final Environmental Impact Statement', U.S. department of the interior Mineral Management Service Alaska OCS Region. p. 631.

102 **S. E. Moore, and Henry P. Huntington.** (2008) 'Arctic Marine Mammals and Climate Change: Impacts and Resilience', *Ecological Applications,* 18, S157-S65.

103 **N.I Mymrin, and V.N. Bogacheva. Belkovich V.M.** (2004) 'The Marine Mammal Hunting Output of Chukotka. Provideniya District', in *Marine Mammals of the Holarctic*,Moscow, pp. 414 -15.

104 **N.I Mymrin, and R.N. Mymrin. Dr. Belkovich V.M.** (2004) 'The Harvest of Marine Mammals on Chukotka. Provideniya Region', in *Marine Mammals of the Holarctic*,Moscow, pp. 412 -13.

105 **N.I Mymrin, G.P. Smirnov, A.S. Gaevsky, and V.E. Kovalenko.** (1990) 'Seasonal Distribution and Abundance of Walruses in the Gulf of Anadyr of the Bering Sea. ', *Zoological Journal* 3, 105-13.

106 **NAMMCO.** (2004) 'Report of the Nammco Workshop on Hunting Methods for Seals and Walrus',Denmark.

107 **NAMMCO**. (n.d.) 'Status of Marine Mammals in the North Atlantic, the Atlantic Walrus',Norway.

108 **C. H. Nelson, R. L. Phillips, J.Jr. McRea, J.H. Jr. Barber, M. W. McLaughlin, and J. L. Chin.** (1994) 'Gray Whale and Pacific Walrus Benthic Feeding Grounds and Sea Floor Interaction in the Chucki Sea '.

109 **NOAA.** (2011) 'Office of Protected Resources and the Marine Mammal Protection Act'. U.S. Department of Commerce.

110 **R.M. Nowak.** (2003), *Walker's Marine Mammals of the World*Baltimore, Maryland: The Johns Hopkins University Press.

111 **NSIDC**. (2011)'Arctic Sea Ice News and Analysis', National Snow and Ice Data Center (NSIDC), < [Accessed 05-12-2011 2011].

112 **NSIDC.** (2011) 'Summer 2011: Arctic Sea Ice near Record Lows', in *Arctic Sea Ice News & Analysis.*NSIDC.

113 **OGA.** (2007) 'Arctic Oil and Gas Assesment ', Arctic Monitoring and Assessment Programme (AMAP).

114 **J.S. Oliver, P.N. Slattery, E. F. O'Connor, and L. F. Lowry.** (1983) 'Walrus, Odobenus Rosmarus, Feeding in the Bering Sea, a Benthic Perspective ', *Fishery Bulletin* 81, 501 -12.

115 **OSPAR.** (2012)'Ospar Commission, Protecting and Conserving the Nort-East Atlantic and Its Resources'http://www.ospar.org/welcome.asp?menu=0> [Accessed 16-01-2012 2012].

116 **N.G. Ovsyanikov, I.E. Menyushina, and A.V. Bezrukov.** (2007) 'Unusual Pacific Walrus Mortality at Wrangel Island in 2007.', *Marine Mammals of the Holarctic*, 413-16.

117 **D.K. Perovich, B. Light, H. Eicken, K.F. Jones, and K. Runciman, S.V. Nghiem.** (2007) 'Increasing Solar Heating of the Arctic Ocean and Adjacent Seas, 1979-2005, Attribution and Role in the Ice-Albedo Feedback', *Geophys. Res. Lett.,* 34.

118 **C. H. Peterson, S. D. Rice, J. W. Short, D. Esler, J. L. Bodkin, B. E. Ballachey, and D. B. Irons.** (2003) 'Long-Term Ecosystem Response to the Exxon Valdez Oil Spill', *Science,* 302, 2082-86.

119 **P. R. Pinet.** (2009), *Invitation to Oceanography* 5th ednCanada & United Kingdom: Jones and Bartlett Publishers.

120 **B. Poppel.** (2005) 'Er Det Grønlandske Fangererhverv Truet? (Are the Greenlandic Hunting Profession under Threat?)'.

121 **C. Pungowiyi.** (n.d.) 'Native Obersvations of Change in the Marine Environment of the Bering Strait Region', in *How have changes in Arctic environment over the past 50 years affected the Alaska Native Community?*,Kotzebue, USA: NOAA.

122 **G. C. Ray, J. McCormick-Ray, P. Berg, and H. E. Epstein.** (2006) 'Pacific Walrus: Benthic Bioturbator of Beringia', *Journal of Experimental Marine Biology and Ecology,* 330, 403-19.

123 **P. R. Richard, and R. R. Campbell.** (1988) 'Status of the Atlantic Walrus, Odobenus-Rosmarus-Rosmarus, in Canada', *Canadian Field-Naturalist,* 102, 337-50.

124 **W.J. Richardson, Jr. C.R. Greene, C.I. Malme, and D.H. Thomson.** (1995), *Marine Mammals and Noise*California: Academic Press

125 **R. Sale.** (2006), *A Complete Guide to Arctic Wildlife*Londen: A&C Black Pubilshers Ltd., p. 464.

126 **R. E. Salter.** (1979) 'Site Utilization, Activity Budgets, and Disturbance Responses of Atlantic Walruses During Terrestrial Haul-Out', *Canadian Journal of Zoology,* 57, 1169-80.

127 **G. Sheffield, and J. M. Grebmeier.** (2009) 'Pacific Walrus (Odobenus Rosmarus Divergens): Differential Prey Digestion and Diet', *Marine Mammal Science,* 25, 761-77.

128 **B. Sjare, and I. Stirling.** (1996) 'The Breeding Behaviour of Atlantic Walruses, Odobenus Rosmarus Rosmarus, in the Canadian High Arctic', *Canadian Journal of Zoology,* 74, 897-911.

129 **M Sommerkorn, N Hamilton, H Main, J Eamer, T Kurvits, K. I Johnsen, and Loring P. A.** (2008) 'Arctic Climate Impact Science an Update since Acia',Oslo, Norway.: WWF.

130 **S. G. Speckman, V. I. Chernook, D. M. Burn, M. S. Udevitz, A. A. Kochnev, A. Vasilev, C. V. Jay, A. Lisovsky, A. S. Fischbach, and R. B. Benter.** (2010) 'Results and Evaluation of a Survey to Estimate Pacific Walrus Population Size, 2006', *Marine Mammal Science,* 27, 514-53.

131 **J. Stroeve, M. M. Holland, W. Meier, T. Scambos, and M. Serreze.** (2007) 'Arctic Sea Ice Decline: Faster Than Forecast', *Geophys. Res. Lett.,* 34, L09501.

132 **Governor of Svalbard.** (2011)'Species Management', Governor of Svalbard, <http://www.sysselmannen.no/hovedEnkel.aspx?m=45283> [Accessed 09-11-2011 2011].

133 **D.N. Thomas, G.E. Fogg, P. Convey, C.H. Fritsen, J.-M. Gili, R. Gradinger, J. Laybourn-Parry, K. Reid, and D.W.H. Walton.** (2008), *The Biology of Polar Regions*. *The Biology of Habitat Series* 2th ednOxford: Oxford University Press.

134 **C.R. Townsend, M. Begon, and J.L. Harper.** (2008), *Essentials of Ecology*Oxford: Blackwell Publishing.

135 **U.N.** (1995) 'Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratiory Fish Stocks', United nations, New York.

136 **U.N.** (1994) 'Agreement Relating to the Implementation of Part Xi of the United Nations Convention on the Law of the Sea of 10 December 1982', United nations.

137 **U.N.** (1982) 'United Nations Convention on the Law of the Sea of 10 December 1982'. Division for Ocean Affairs and the Law of the Sea.

138 **U.S.A**. (2011) '12-Month Finding on a Petition to List the Pacific Walrus as Endangered or Threatened', Departement of the Interior Fish and Wildlife Service.

139 **U.S.** (2008) 'Help Minimize the Disturbance of Walruses Along the Chukchi Sea Coast',Alaska.

140 **U.S.** (2007) 'Hunting and Use of Walrus by Alaska Natives, Fact Sheet', U.S. Department of the Interior Fish and Wildlife Service.

141 **U.S.** (2009) 'Protection of Pacific Walrus under the Endangered Species Act May Be Warranted, U.S. Fish and Wildlife Service Finds', U.S. Fish & Wildlife Service.

142 **M. S. Udevitz, C. V. Jay, A. S. Fischbach, and J. L. Garlich-Miller.** (2009) 'Modeling Haul-out Behaviour of Walruses in Bering Sea Ice', *Canadian Journal of Zoology,* 87, 1111-28.

143 **UNEP.** (1997)'Global Environment Outlook 1'http://www.unep.org/geo/geo1/ch/toc.htm> [Accessed 11-10 2011].

144 **USGS.** (2008)'90 Billion Barrels of Oil and 1,670 Trillion Cubic Feet of Natural Gas Assessed in the Arctic ', U.S. Geological Survey <2011].

145 **J.E. Walsh.** (2008) 'Climate of the Arctic Marine Environment', *Ecological Applications,* 18, S3 - S22.

146 **WHOI.** (2006) 'Walrus Calves Stranded by Melting Sea Ice', *Marine Pollution Bulletin,* 52, 604-04.

147 **B. Wilson, and D. Evans.** (2009) 'Establishing a Protection Zone around a Walrus Haulout on Hagemeister Island in Northern Bristol Bay – a Discussion Paper', North Pacific Fishery Management Council. p. 23.

148 **B. Wilson, and D. Evans.** (2009) 'Groundfish Trawl Fishery, Pacific Walrus, and Local Fishery Interactions in Northern Bristol Bay – a Discussion Paper', North Pacific Fishery Management Council. p. 142.

149 **L. Witting, and E. W. Born.** (2005) 'An Assessment of Greenland Walrus Populations', *Ices Journal of Marine Science,* 62, 266-84.

150 **WWF.** (2005) 'The Big Four, a Wwf Update on Greenland's Efforts with Regard to Species Conservation and Nature Protection',Denmark WWF Denmark, pp. 27-40.

151 **WWF, and MMC.** (2010) 'Informational Report on the Project "the New Pacific Walrus Rookery"'.

152 **WWF, and MMC.** (2011)'Space Technologies Helps to Conserve Walruses'http://walrus.2mn.org/event_arch/events21.html>2011].

References used to compile the maps

- **AMSA** (2009) Arctic Marine Shipping Assessment
- **Bird, K.J., Charpentier, R.R., Gautier, D.L., Houseknecht, D.W., Klett, T.R., Pitman, J.K., Moore, T.E., Schenk, C.J., Tennyson, M.E., Wandrey, C.J.** (2008) *Circum-Arctic Resource Appraisal: Estimates of Undiscovered Oil and Gas North of the Arctic Circle* U.S. Geological Survey, Central Energy Resources Team, Denver Colorado.
- **Blijleven en van Dijk** (2011) Bathymetry of Arctic waters, personal data exchange
- **Blijleven en van Dijk** (2011) Bathymetry of Arctic Land, personal data exchange
- **Blijleven en van Dijk** (2011) Potential prospective oil and gas areas in the Arctic, personal data exchange
- **Blijleven en van Dijk** (2011) Operating oil platforms, personal data exchange
- **Blijleven en van Dijk** (2011) Operating Gas platforms, personal data exchange
- Born, E. W., Gjertz, I. & Reeves, R. R. 1995. Population Assesment of Atlantic Walrus. Oslo.
- **CAFF** (2009) CAFF Boundary, Conservation of Arctic Flora & Fauna, Arctic Council Working Group, October 2009.
- **ESRI** (2008), *Country Boundaries (generalized)* ESRI Data & Maps 9.3.
- **ESRI** (2010) World Major Rivers available at: http://www.arcgis.com/
- **Fetterer, F., Knowles, K., Meier, W., and Savoie, M.** (2002 updated 2010) Sea Ice Index, Boulder, Colorado USA: National Snow and Ice Data Center, Digital Media.
- **M.V. Gavrilo** (2011),Russia: Arctic & Antarctic Research Institute, St. Petersburg.
- **IUCN** (2009) Digital Distribution Maps of The IUCN Red List of Threatened Species, IUCN Red List of Threatened Species. Version 2009.1
- **Norwegian polar Institute** (1995) Available on: http://zope.data.npolar.no/svalbard/metaSearch/select_index_html7_script?metadata_id=543 / http://eivind.npolar.no/Geocortex/Essentials/Web/viewer.aspx?Site=svbk_v01_no. Accessed on 18 November 2011
- **Olson, D. M. and E. Dinerstein**. The Global 200: Priority ecoregions for global conservation. (PDF file) Annals of the Missouri Botanical Garden 89:125-126USGS (2008) Maps showing geology, oil and gas fields, and geologic provinces of the Arctic, U.S. Geological Survey, Central Energy Resources Team.
- **Smith** (2010) Audubon Alaska, http://ak.audubon.org/special-reports-and-publications, accessed on 20th October 2011.
- **USWFS** (undated) Protected areas in the Arctic as recognized by CAFF