Vulnerability of coastal species in Svalbard to selected stressors

Sustainable Arctic Resource Management

Joost Lahr, Judith Klostermann, Rob Smidt

WAGENINGEN UNIVERSITY & RESEARCH

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The objective of this project was to use the vulnerability mapping method to assess vulnerability of Arctic species to environmental stressors. The coastal environment of Svalbard served as a study case. The method of creating vulnerability maps combined three kinds of information: information on species, on stressors and geographical information. The result is a list of ranks of 22 characteristic Svalbard bird and mammal species with regard to vulnerability to oil pollution. Brünnich's guillemot was judged as the most vulnerable of the selected species. We created a series of maps of the distribution of species that are vulnerable to oil. Finally, we compared a map of (touristic) boat landing sites to maps showing the distribution of a few species. The sites where most of these species occur are also visited by tourists. The exercises described in this study showed that a species vulnerability analysis for oil pollution and Svalbard marine birds and mammals can be used with the current level of information and that there is sufficient data on the distribution of these species in Svalbard to create species vulnerability maps.

Keywords: Svalbard, environmental stress, oil pollution, ecological vulnerability, sea birds, marine mammals, maps

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Photo cover: Walrus site on Edgeøya, Spitsbergen, 2015. Photo Judith Klostermann, Wageningen Environmental Research

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Preface

The work described in this report was financed by the Dutch Ministry of Agriculture, Nature and Food Quality as part of its programme System Earth Management (KB-24) and the Sustainable Arctic Resource Management project (KB-24-002-018) included in this.

We would like to thank our colleagues from Wageningen Marine Research (WMR) and Wageningen Economic Research (WECR) for their input and advice during the project: Martine van den Heuvel (WMR), who also reviewed the report, Hans Verdaat (WMR) and Wouter Jan Strietman (WECR).

Summary

Tourism in the Arctic is increasing. Nature is an important factor for tourists who want to visit this area, but at the same time species can be under stress because of human activities and pollution. The objective of our project is to use the vulnerability mapping method to assess vulnerability of Arctic species to environmental stressors. Because of time constraints, the aim is to prove the concept rather than deliver a full analysis and set of maps. The coastal environment of Svalbard served as a study case.

Svalbard (or Spitsbergen) is an archipelago situated between Greenland and Norway. Its total area is 61,022 km2. Svalbard has about 2650 inhabitants. Of the human impacts on biodiversity, land-use changes, pollution, climate change, alien species and harvesting are generally regarded as the greatest threats. Another likely stressor for wildlife is the tourism and recreation sector. From 1999 to 2013 the number of guest nights in Longyearbyen increased from 43,000 to 107,000, of which 60% was from tourists. About 30 cruise ships with thousands of passengers visit Longyearbyen and Ny Ålesund every year.

It was decided to select oil pollution as an example stressor. This is one of the pollutants relevant for cruise ships. In addition, we studied the effects of disturbance by touristic visits on large mammals and birds in Svalbard. For both stressors sufficient data are available to create maps.

The method of creating vulnerability maps combines three kinds of information: information on species, on stressors and geographical information. The overall reasoning is that species vulnerability is defined by exposure, sensitivity and recovery potential at the population level. The classification is based on expert judgement. Based on this classification, habitats can be divided into five classes from not vulnerable to highly vulnerable. Based on a habitat map the vulnerability can be visualized on a map.

From a list of animals that occur at Svalbard and in the surrounding seas we selected 22 marine mammals and birds with varying life styles and body characteristics as demonstration species for a simple vulnerability analysis of oil pollution. The result of this exercise is a list with ranks of 22 characteristic Svalbard bird and mammal species. Brünnich’s guillemot was judged as the most vulnerable of the selected species for oil. It is a swimming sea bird that is easily exposed to floating oil that causes its feathers to smother.

We created a series of maps of the distribution of species that are vulnerable to oil (Brünnich’s guillemot, King eider, Ivory gull, Ringed seal and Walrus). Vulnerability maps for oil pollution can be used for oil spill preparedness and contingency planning, i.e., to choose where to place your oil spill combat capacity and equipment in the most strategic way.

Finally, we compared a map of (touristic) boat landing sites to maps with the distribution of a few species favoured by visitors: seabird colonies, Polar bears and Walrus. The sites where most of these species occur are also visited by tourists. The maps indicate that there is a potential for disturbance by tourist visits at natural sites with vulnerable species. The authorities of Svalbard and policy makers can use these types of maps to regulate visits by tourists on cruise ships and landing with smaller boats.

The exercises described in this study have shown that a species vulnerability analysis for oil pollution and Svalbard marine birds and mammals can be used with the current level of information and that there is sufficient data on the distribution of these species in Svalbard to create species vulnerability maps. Vulnerability analysis of species and mapping of vulnerability and risk may also be applied to stressors other than oil pollution and disturbance by tourism.

1 Introduction

1.1 Problem definition

Tourism in the Arctic is increasing. Nature is an important aspect of this destination, but at the same time species can be under stress because of human activities and pollution. Hagen et al., (2012) discussed the management of the impact of tourism on vegetation, fauna and cultural heritage in Svalbard and called for a method that is more specific per location and more evidence-based. This would make regulation less value-based and more acceptable to stakeholders.

In this project we used a method to quantify the vulnerability of species to stressors and to visualize it on a map. Methods have been developed in the Netherlands for guidance in policy decisions as well as in actual crisis situations. For example, sea birds are vulnerable to floating oil from an oil spill, but when oil dispersants are used to avoid exposure of birds, the oil may have a larger impact on fish eggs and larvae (De Lange et al., 2013). If it is clear which species or group of species has priority at a location, a strategy can be developed, for instance to determine whether a dispersant can be used or not. Vulnerability analysis (prior to contamination) or risk analysis (post contamination) can be used to make maps of areas vulnerable to the effects of stressors, such as pollutants, marine plastics, noise and disturbance by tourists.

1.2 Objectives

The objective of our project was to use the vulnerability mapping method to assess vulnerability of Arctic species to environmental stressors. Because of time constraints, the aim was to prove the concept rather than to deliver a full analysis and set of maps.

Risk maps and vulnerability maps can be used:
- in the planning phase to design and plan protective measures,
- during a crisis to identify the most vulnerable areas, and
- after a crisis to assess the damage.

The results of the vulnerability analysis and the maps can be used by Svalbard authorities to reiterate the planned activities that may cause pollution and disturbance (like tourism, mining) and mitigate the effects of such disturbances. The methods developed may be extended and applied to other areas in the Arctic. For example, they could be used to develop oil vulnerability maps for areas where offshore developments are taking place or are planned, or for areas particularly sensitive to oil pollution.

Wageningen Environmental Research (WENR) has gained experience in both vulnerability analysis, (de Lange et al., 2006, 2009, 2010) and in vulnerability and risk mapping (Lahr & Kooistra, 2010; Lahr et al., 2010). Wageningen Marine Research (WMR) is working on the effects of oil pollution, marine plastics and invasive species. The results of our project may lead to the identification of new stressors and species to investigate.

1.3 Approach

Based on the ecological traits of Arctic species and on the characteristics of contaminants present in Arctic areas, the vulnerability of species to two selected stressors (oil pollution and disturbance by tourism) was assessed.

The study included:
- A brief analysis of human activities and potential stressors in Svalbard (mining, living, tourism, hunting).
- Identification of environmental stressors typical for Svalbard and their significance for species in Svalbard (in collaboration with Wageningen Marine Research).
- Selection of Svalbard coastal species vulnerable to the selected stressors (in collaboration with Wageningen Marine Research).
- Collection of relevant ecological data from the literature and expert judgement suitable to assess vulnerability.
- Calculation and ranking of the species according to their vulnerability to oil. Creation of maps for a few vulnerable species.

1.4 Target audience

The target audience consisted of the different Arctic governments (Table 1) and tour operators who want to conduct activities in Arctic nature with zero to minimal damage. Another target group were scientists carrying out ecological and ecotoxicological research in the Arctic who want to assess the spatial connections between animal species, pollutants and human activities.

Table 1 *Arctic governments in Europe involved in Arctic strategies and policies.*

Country	Government	Website
Finland	Prime Minister's Office	https://vnk.fi/en/contact
Sweden	Ministry of Foreign Affairs	https://www.government.se/country-and-regional-strategies/2011/10/swedens-strategy-for-the-arctic-region/
Norway	Ministry of Foreign Affairs	https://www.regjeringen.no/globalassets/upload/ud/vedlegg/strategien.pdf
Svalbard	Governor of Svalbard	https://www.sysselmannen.no/en/
Greenland / Denmark	Government of Greenland	https://naalakkersuisut.gl/en/Naalakkersuisut/Departments/Udenrigsanliggende/Kongerigets-Arktiske-Strategi
Iceland	Ministry of Foreign Affairs	https://www.government.is/topics/foreign-affairs/arctic-region/
European Union	European Union External Action Service	https://eeas.europa.eu/arctic-policy/eu-arctic-policy_en
Arctic Council		https://arctic-council.org/index.php/en/

1.5 Study area

The coastal environment of Svalbard served as a study case. Svalbard is a group of islands situated between Norway and the North Pole. It encompasses a large number of unique Arctic habitats and species not found on the Norwegian or European mainland. Ecological and ecotoxicological research at Svalbard and elsewhere in the Arctic yields important data that may be used for further analysis and risk assessment. Arctic tour operators are organized in AECO, the Association of Arctic Expedition Cruise Operators (https://www.aeco.no/).

2 Svalbard and its environment

2.1 General characteristics

Svalbard (or Spitsbergen) is an archipelago situated between Greenland and Norway. Its total area is 61,022 km^2, which is comparable to the sizes of European countries Latvia (64,589 km^2) and Croatia (56,594 km^2). Svalbard's main settlement, Longyearbyen, is 1,310 km south of the North Pole. The monthly mean temperature in July is 5.9 ºC and the monthly mean temperature in February is -16.2 ºC (www.met.no). The west coast is slightly warmer than the east coast due to the Atlantic gulf stream running north along the west coast.

About 60% of the land is covered with glaciers and most bare areas consist of bedrock (covered in snow about nine months of the year). Svalbard has little soil, and if there is soil it is mainly permafrost which partly thaws in the summer. In most places there are few nutrients for plant growth. Beneath bird colonies on cliffs more vegetation is found. Svalbard nature has a slow recovery time because of the cold, dry climate and the short growing season.

2.2 Human activities and resulting stress

Svalbard has about 2650 inhabitants and the population density is low with only 0.04 inhabitants per km^2 (Statistics Norway, 2017). Figure 1 shows the human activities in Svalbard as percentages of employment. Coal mining used to be the main economic resource until 1980, but due to low oil prices this industry is in decline. Jobs went down from 400 in 2008 to about 200 in 2015. The tourism industry, however, has grown from about 300 workers in 2008 to 480 in 2015.

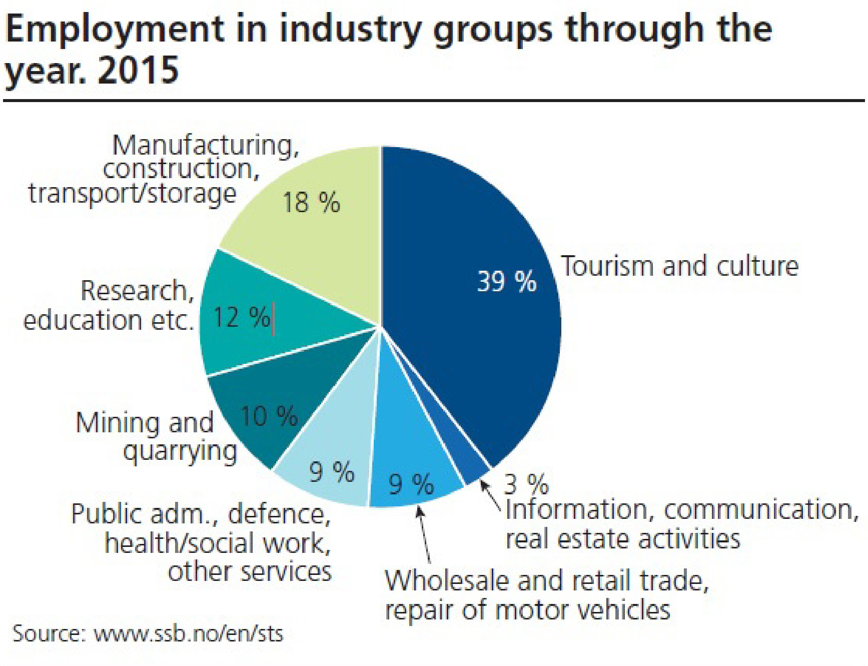

Figure 1 *Employment in Svalbard, based on 1650 FTEs in Longyearbyen, Ny-Ålesund and Svea. Activities in Barentsburg and Pyramiden are not included. (Figure from Statistics Norway, 2017).*

Most activities take place on only 2% of the land surface of Svalbard. Of the human impacts on biodiversity, land-use changes, pollution, climate change, alien species and harvesting are generally regarded as the greatest threats (Kålås et al., 2010). In Statistics Norway (2017) the following impacts on nature and animals were mentioned:

- Hunting and fishing (Arctic fox, reindeer, ringed seal),
- Environmental toxins (PCBs, organic bromide and fluoride compounds) (polar bear),
- Climate change: mild rainy weather followed by ice formation (reindeer), reduction of sea ice (polar bear).

Coal mining in Svalbard started at the beginning of the 20th century. Presently, Store Norske Spitsbergen Kulkompani, a subsidiary of the Norwegian Ministry of Trade and Industry, operates Mine 7 in Longyearbyen (Figure 2). Since 2007, there has not been any significant mining by the Russian state-owned Arktikugol in Barentsburg. Both from present and past mining, coal dust and emissions from the energy plant have spread over the islands.

Due to the use of coal for local heating, more than 75 tonnes of CO_2 equivalents are produced per capita in Svalbard as compared to 7 tonnes per capita on the Norwegian mainland (Statistics Norway, 2017). A significant impact is the airport of Svalbard, but this is not included in the CO_2 production mentioned above. Many inhabitants commute over the weekend between Svalbard and Norway.

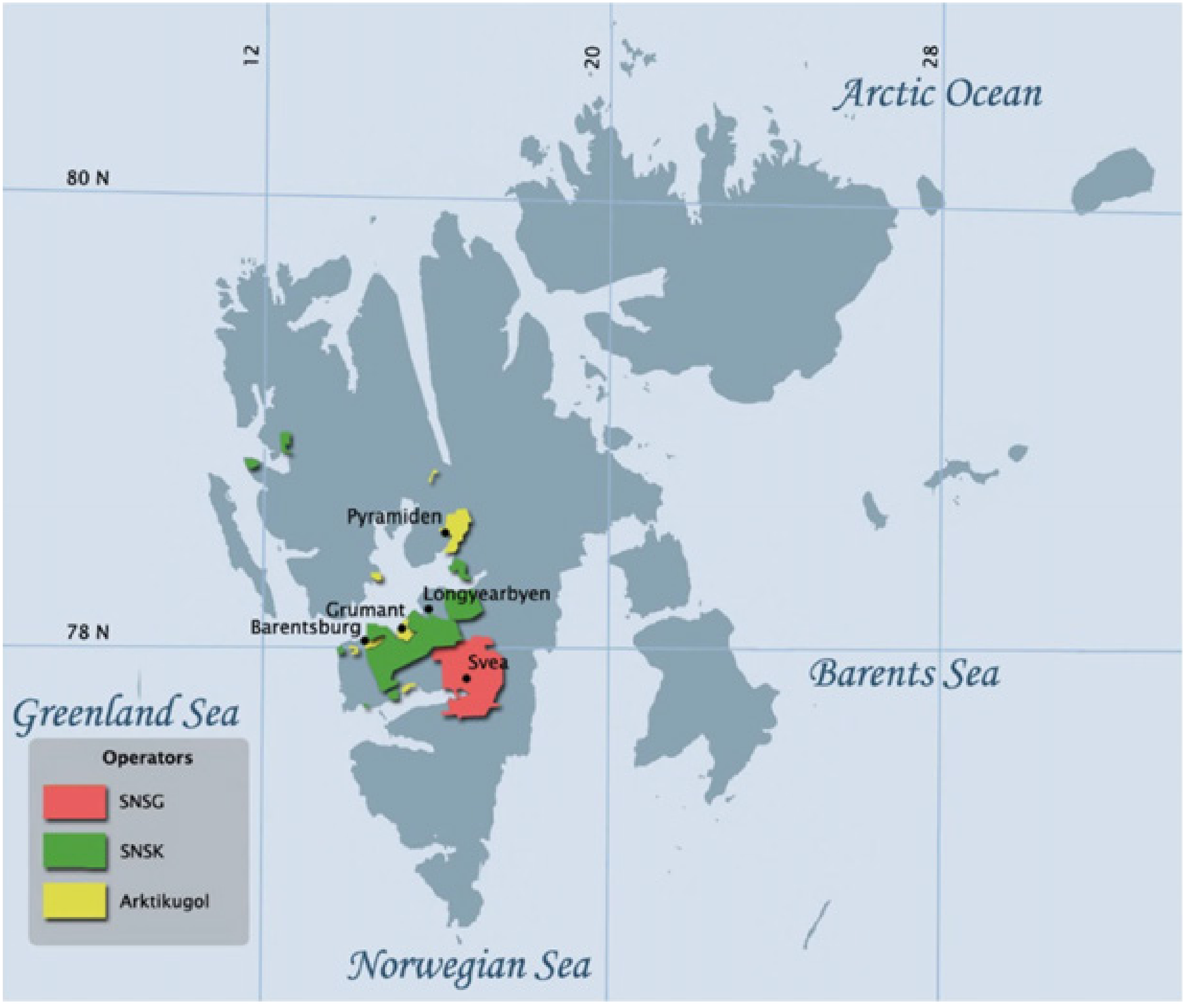

Figure 2 *Coal mine property claims in Svalbard. Store Norske Spitsbergen Kulkompani AS (SNSK) owns the Store Norske Spitsbergen Grubekompani AS (SNSG).*
https://arcticecon.wordpress.com/2012/04/03/coal-mining-in-svalbard-store-norske-arktikugol-norway/

Another likely stressor for wildlife is the tourism and recreation sector. Many of the 2650 people living in Svalbard are enthusiastic users of the natural environment. Snowmobile regulations are less strict than in Norway so some people specifically go to Svalbard to enjoy this activity. Tourism is a growing sector. Svalbard is one of the top destinations for tourists. From 1999 to 2013 the number of guest nights in Longyearbyen increased from 43,000 to 107,000, of which 60% was from tourists and the remainder from research conferences and business trips (Statistics Norway, 2017). It rose to a total of 130,000 guest nights in 2015 (Statistics Norway, 2017). About 30 cruise ships with thousands of passengers visit Longyearbyen and Ny-Ålesund every year (Figure 3).

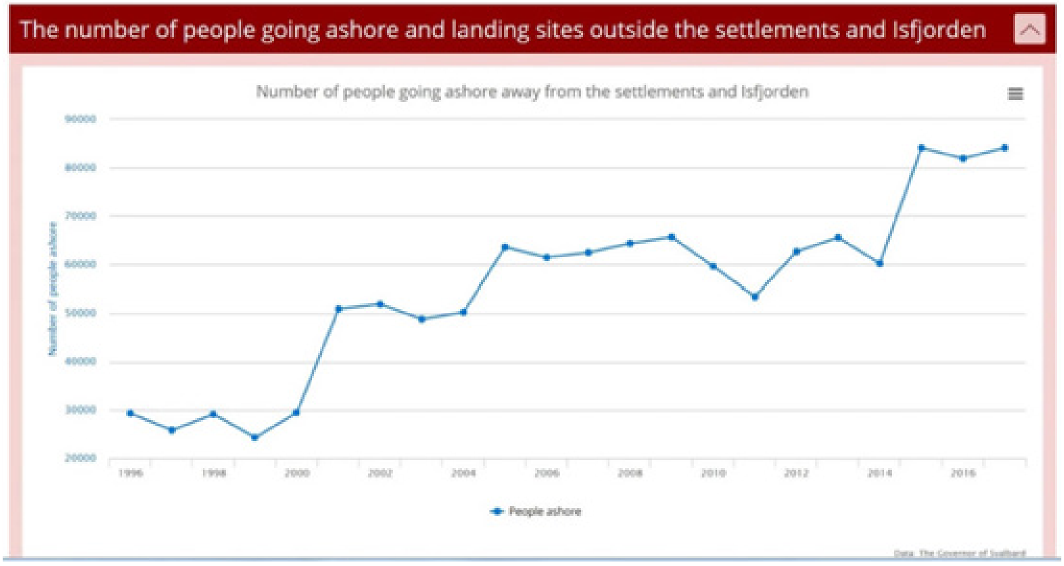

Figure 3 *Growth of tourists visiting the shores of Svalbard from 1996-2017 (http://www.mosj.no/en/influence/traffic/cruise-tourism.html).*

Tourism causes vegetation damage, disturbance of wildlife, littering and water pollution (Wray et al., 2010). Figure 4 shows where tourists go ashore. Vulnerable and protected species at these landing sites may be impacted by the tourist visits.

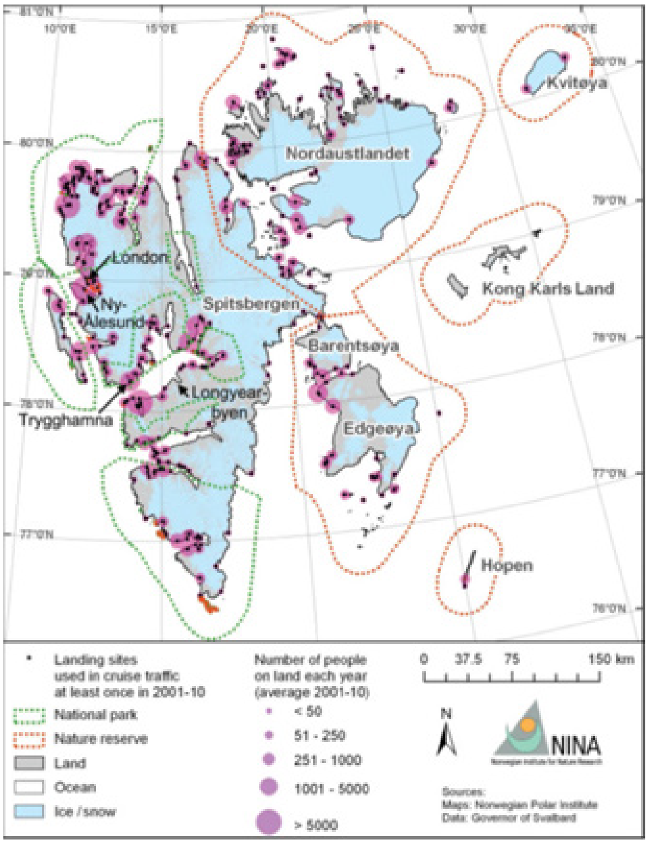

Figure 4 *Landing sites for cruise tourism in Svalbard (Hagen et al., 2012).*

Hunting, trapping and fishing are also activities acting as stressors for wildlife. Hunting, trapping and fishing is allowed for Arctic fox, reindeer, sea mammals, Arctic char and several bird species (Sysselmannen, 2018). The size of the reindeer population is estimated to be around 10,000 animals and seems to be growing, but it varies from year to year due to weather influences. In 2006, 296 hunting permits were issued, and 178 reindeer were shot (https://www.spitsbergen-svalbard.com/spitsbergen-information/fauna/svalbard-reindeer.html). It is not allowed to hunt polar bears on Svalbard since 1973.

In the wider Arctic, human activities include mining, oil and gas exploration, fisheries, shipping and military activities (Nymand Larsen & Fondahl, 2014). Even when these activities do not take place in or near Svalbard, their effects can reach the waters and coast of Svalbard due to currents and atmospheric transport. Most notably, waste can be found on Svalbard beaches (https://weblog.wur.eu/coastsea/category/arctic-marine-litter-expedition/).

Climate change is also having a significant impact on Svalbard. The glaciers are retreating and changed weather patterns are resulting in rain and ice on the land instead of snow (Statistics Norway, 2017).

The stressors described above are summarized in Table 2.

Table 2 *Potential stressors for species in Svalbard (based on Kålås et al., 2010).*

Activity	Stressors	Significance for species of Svalbard
Industry, mining and energy production	Land use changes Traffic Pollution	Eight Red List species of vascular plants in Mimerdalen and five in Colesdalen Organic pollutants found in glaucous gulls and ivory gulls High levels of pollutants in Svalbard polar bears
Land use for housing, research and public services	Land use changes Traffic	Disturbance of animals Trampling of 15 Red List plants in Longyearbyen and Ny-Ålesund
Tourism	Visitor traffic, going ashore	Disturbance of animals, more frequent conflict with polar bears Trampling of plants
	Oil spills and pollution	Polar bears can be poisoned by oil on their coat Fouling of resting places for walruses and harbour seals, particularly in the pupping season
	Introduction of alien species of plants and mosses	Introduction of grasses is limited to settlements
Hunting, trapping and fishing	Direct harvesting	Is thought to have little significance for the Red List species.
Climate change	Glaciers retreat, highly productive glacier fronts will be lost	Marine mammals and sea birds lose feeding grounds, especially polar bears and ringed seals Walrus may lose sea ice for resting
	New terrestrial habitats	Plants, grazers and predators may increase on newly available land with higher production
	Warmer climate	New thermophilic species such as sharks Vascular plants are more thermophilic, whereas bryophytes and lichens decline

2.3 Regulations for species protection

Because of the international **Svalbard Treaty** of 1920 (Sysselmannen, 2019a), Svalbard has a special status. The Svalbard Treaty provides sovereignty for Norway in the archipelago. However, citizens and companies from all treaty nations enjoy the same right of access to and residence in Svalbard as Norwegians. As a consequence, the Norwegian Immigration Act does not apply. This does not mean that anyone can become a resident of Svalbard: acquiring work and housing is difficult and according to regulations the Governor of Svalbard can reject persons without sufficient means to support themselves (Sysselmannen, 2019b).

In 1925, the **Svalbard Act** was passed (Norwegian Polar Board, 2015). According to the Svalbard Act, Svalbard is established as a free economic zone, and a demilitarized zone. Based on this act, several protected animal species were listed, and two first plant protection areas were established in 1932. In 1973, three large national parks, two large nature reserves and fifteen bird sanctuaries were established. Based on an evaluation of nature protection so far, a new protection plan was initiated in 1998 and a new protection act was passed in 2003. The territorial border around Svalbard was expanded from four nautical miles to 12 nautical miles. In 2005, an additional national park was established in the inner fjord of Wijdefjorden. The current protected areas cover 65% of Svalbard's land area.

The purpose of the **Svalbard Environmental Protection Act** of 2001 is 'to preserve a virtually untouched environment in Svalbard with respect to continuous areas of wilderness, landscape, flora, fauna and cultural heritage.' According to the Act all enterprises in Svalbard have to avoid unnecessary damage or disturbance to the natural environment. The Act also regulates the establishment of protected areas in Svalbard that help to maintain marine and terrestrial ecosystems. The Act distinguishes between national parks, nature reserves and protected biotopes of which national parks are the largest in size. For each protected area, specific rules can be established with respect to the human activities that are allowed. Annex 1 provides an overview of the protected areas in Svalbard.

All animal and plant species of Svalbard have a protected status (Government of Norway, 2019). Some exceptions apply for fungi, single-celled organisms, invertebrates, eggs and down. Small rodents are considered invasive species and are not protected. Permits can be issued for fishing, hunting and trapping by the Governor. Only permanent residents in Svalbard may hunt, trap or fish for specific species (Table 3). For hunting and fishing a licence is needed and a fee has to be paid. Animals may be killed in the case of immediate danger to a person’s life. However, situations in which this occurs must be avoided.

Table 3 *Hunting species in Svalbard (Regulations relating to harvesting of the fauna on Svalbard. Regulation Date: 2002-06-24 Ministry of the Environment, Norway).*

Species	Hunting season
Arctic fox (*Alopex lagopus*)	1 November–15 March
Svalbard reindeer (*Rangifer tarandus platyrhynchus*)	15 August–20 September
Svalbard ptarmigan (*Lagopus mutus hyperboreus*)	10 September–23 December
Pink-footed goose (*Anser brachyrhynchus*)	20 August–31 October
Fulmar (*Fulmarus glacialis*)	21 September–31 October
Black guillemot (*Cepphus grylle*)	1 September–31 October
Ringed seal (*Phocus hispida*)	1 February–20 March and 20 May–30 November
Bearded seal (*Erignathus barbatus*)	1 February–27 April and 5 June–30 November

Activities that impact the environment all require permission from the Governor: land use, transport, and economic activities. The Act also restricts or prohibits pollution with toxic substances, waste and waste water.

Legal basis and other regulations for the areas:

1) FOR-2014-04-04-377 regulations concerning establishment of bird sanctuaries and major conservation areas in Svalbard
2) FOR-2002-08-16-903 regulations concerning protection of Bjørnøya Nature Reserve in Svalbard
3) FOR-2000-05-03-526 regulations concerning area protection and regulation of access to Virgohamna in Svalbard
4) FOR-2009-09-23-1220 regulations concerning prohibition of access in the vicinity of automatically protected cultural remains at Midterhuken, Bellsund
5) FOR-1983-06-03-1029 regulations concerning protection of Moffen Nature Reserve in Svalbard
6) FOR-2003-09-26-1185 regulations concerning protection of Hopen Nature Reserve in Svalbard
7) LOV-2001-06-15-79 The Svalbard Environmental Act

The Governor of Svalbard employs six full time field inspectors who monitor the activities of tour operators (Van Bets, 2017). They cannot be everywhere, but they also use information from inhabitants, for example about littering, and they focus on tour operators who are less serious about complying with the regulations. The opinion in Svalbard is that this generally results in good compliance. The tourism sector organization AECO complements government regulation with more operational and detailed self-regulation (Van Bets, 2017). AECO provides, for example, guidance on how to avoid disturbance of animals. Nearly all tour operators active in Svalbard are a member of AECO. Compliance with AECO regulations is a matter of trust, and the number of tour operators is increasing.

Norway has an oil pollution contingency plan that also includes Svalbard (Norwegian Coastal Administration, 2015).

2.4 Environmental stressors

Potential environmental stressors in the Arctic region, which we could use for testing our method are:

- oil pollution (Van den Heuvel-Greve et al., 2016b)
- invasive species (Ware et al., 2013; Van den Heuvel-Greve et al., 2017)
- disturbance by tourism and human presence for other reasons
- marine plastics (fieldwork by Strietman, Wageningen Economic Research, in May/June 2017)
- coal mining: dust, metal pollution (Hg)
- persistent organic pollutants (from atmospheric transport) (See Table 4)
- landfills

We estimated the significance of these stressors for Svalbard as follows. The first three stressors were expected to increase due to the increase of tourism and traffic towards and around Svalbard. Marine plastics are an increasing problem worldwide, including Svalbard (see Table 4). Impacts of coal mining were expected to decline due to reduced activity in this sector, although coal mining for use in Svalbard itself is likely to continue. The relevance of persistent organic pollutants differs per substance (see Table 4), and for some more attention is warranted. The impact of landfills was estimated to be low in Svalbard due to its small population.

Table 4 *Pollutants in the Arctic (AMAP, 2017).*

Substance type	Level of concern	Decline (-), stable (0), increase (+)
Per- and polyfluoroalkyl substances	Ubiquitous presence in Arctic biota. Reductions in the emission in Europe and North America, but possibly continuing emissions in Asia (including India and Russia)	0
Brominated flame retardants	Low concentrations in biota, close to detection limits. Sometimes decrease, sometimes increase	0
Chlorinated flame retardants	Low concentrations in biota, more research is needed	0
Organophosphate-based flame retardants and plasticizers	Widely present, a lack of knowledge on temporal trends. Low levels detected in many Arctic species	0
Phthalates	Environmental concentrations are highest near populated areas of the Arctic, insufficient data to establish a trend	0
Short-chain chlorinated paraffins	Are found in a wide range of Arctic media, including top predators; increases in concentrations since the 1990s	+
Siloxanes	Increasing emissions, exposure of aquatic organisms primarily from local sources such as human settlements, leading to high concentrations in biota	+
Pharmaceuticals and personal care products	Surprisingly high rates of release of selected pharmaceuticals into the Arctic environment, more research is needed on consequences for local food	+
Polychlorinated naphthalenes	Decreasing trends, with considerable inter-annual variability. Lack of data	-
Hexachlorobutadiene	Concentrations are measurable in a range of species, was recently regulated, more data needed	0
Current use pesticides	Concentrations are declining although somewhat higher in Svalbard than in other Arctic regions, more research needed.	-
Pentachlorophenol (PCP) and pentachloroanisole (PCA)	Widely present in Arctic air, low concentrations found in Arctic species	0
Organotins	Regulated in the mid-2000s. Concentrations in biota very low 'but research is outdated'#	-
Polyaromatic hydrocarbons	Emissions are expected to decline	-
'New' unintentionally generated PCBs	Monitoring programmes for POPs in Arctic biota do not currently include these compounds yet	0
Halogenated natural products	Halocarbon concentrations in marine surface waters appear to have changed little over the past decades. No information about presence in Arctic biota	0
Plastics	Plastics are ubiquitous in all oceans. Increasing reports of Arctic biota exposed to plastic debris	+

The low presence of organotins in biota was confirmed in 2016 (Van den Heuvel et al., 2016a).

It was decided to select oil pollution as an example stressor. This is one of the pollutants that is relevant for the cruise ship industry. In addition, we studied the effects of disturbance by touristic visits on large mammals and birds in Svalbard. For both stressors sufficient data are available to create maps.

2.5 Plant and animal species

Svalbard has three Arctic bioclimatic zones: the middle Arctic tundra zone, the northern Arctic tundra zone and the Arctic polar desert zone (Kålås et al., 2010). Important sea habitats are the polar front and the marginal ice zone. The middle Arctic tundra zone has the mildest climate and is found in inner fjord areas of the island Spitsbergen. This is the most species-rich zone in Svalbard.

In Svalbard the following numbers of species have been recorded on land and in the marine environment (Kålås et al., 2010):

- 165 species of indigenous vascular plants
- 370 species of bryophytes / mosses
- 700 species of fungi
- 750 species of terrestrial and freshwater algae
- 764 species of lichens, 12 of which are endemic
- 1050 species of terrestrial and aquatic invertebrates, 230 of which are insects and 59 are springtails
- 1 species of freshwater fish (Arctic char)
- 203 species of birds
- 3 species of mammals on land: the Svalbard reindeer (an endemic subspecies), arctic fox and southern vole (an introduced species)
- 1300-1400 species of marine invertebrates
- more than 250 species of algae
- 60 species of marine fish
- 19 species of marine mammals (polar bear, walrus, 5 true seals and 12 whales)

For the Svalbard area, only vascular plants, springtails, freshwater fish, birds and mammals have been assessed for the Red List. All these species were assessed based on five criteria:

1. Severe reduction in population size
2. Limited geographical range in combination with fragmentation or decline
3. A small declining population and small subpopulations
4. Very small or geographically very restricted population
5. Quantitative analysis

Based on these criteria, they were divided into categories of less or more concern (see Figure 5).

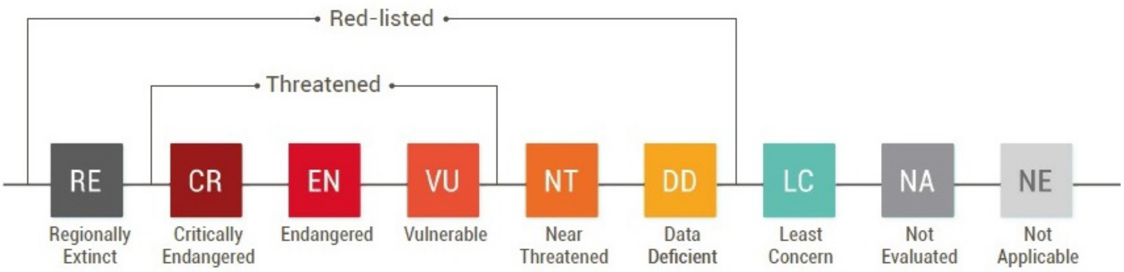

Figure 5 *Categories of Red Listed species (Henriksen & Hilmo, 2015).*

In total, 71 Svalbard species are on the Red List (Kålås et al., 2010):

- 50 vascular plants
- 18 birds
- 3 mammals: polar bear, walrus and harbour seal

3 Vulnerability analysis & mapping

3.1 General approach

The method of creating vulnerability maps combines three kinds of information: information on species, on stressors and geographical information.

- The information on species comprises the characteristics that determine the potential effects and resilience of a population. Other characteristics may be added, such as if it appears on a Red List. It also comprises behavioural information throughout the year, such as migration, feeding and breeding.
- The information on stressors lists types of stressors, their effect on species and, if possible, ecotoxicological information of substances.
- For species as well as stressors, it is important to know where and when they occur and if they coincide. Ecological inventories and habitat maps with different levels of detail are needed to visualize the presence of species.

The method can, in a way, start from any of these three inputs. For example, a vulnerability analysis can be made for one species of interest against a list of stressors, and this can be visualized on a map of areas where this species can be present. The method can also start from a specific stressor, like an oil spill, to assess which species are most vulnerable and which locations need special care. The method can also address a specific area for which a new policy is made, to assess where vulnerable species are present.

The analysis can only be carried out for species for which sufficient (autecological and geographical) data are available. When species are selected for analysing an area, data availability is an important criterion (De Lange et al., 2013). The advantage of the method is that it can be based on literature, while the disadvantage is that it provides a best guess that may overlook unexpected toxic effects like eggshell thinning by DDT (De Lange et al., 2009).

3.2 The species - vulnerability matrix

Regarding the species, the method starts with a selection of characteristics that cut through the complexity of species-stressor interactions. The method was developed to overcome the relative lack of toxicological data for many animal species higher in the food web (De Lange et al., 2009). The overall reasoning is that species vulnerability is defined by exposure, sensitivity and recovery potential at the population level (Lahr et al., 2007).

De Lange et al., (2009) use a longer list of traits in a semi-quantitative analysis to obtain an ordinal classification of species from most to least vulnerable for a range of test substances, i.e. copper, zinc, cadmium, DDT, Chlorpyrifos and Ivermectin. In this analysis, the Bullhead, Common Tern and Slow worm appear as very vulnerable to the investigated substances.

For the three main aspects, the following characteristics are regarded by De Lange et al., (2009) as important (but the characteristics may vary from one stressor to another):

Exposure:

- Habitat preference
- Mobility (swim, fly, root, etc.)
- Migration behaviour (seasonal)
- Contact route (skin, food, etc.)

Sensitivity:
- Contamination, coverage of feathers/fur
- Toxicity (for example, with the Species Sensitivity Distribution; Klok et al., 2012)
- Bioaccumulation
- Indirect effects:
  – warming
  – transparency of medium
  – lack of oxygen
  – acidification / basification

Recovery potential:
- Reproduction (r-strategist: fast reproduction; K-strategist: slow reproduction)
- Mobility / dispersion
- Patchiness of habitat occupation
- Territoriality
- Presence of other stress factors

A similar approach was, for example, used to assess species vulnerability to oil in a Dutch estuary (Lahr et al., 2007). This showed that the most vulnerable species were sea birds with swimming behaviour and/or shellfish-eating behaviour; plants on salt marshes; and invertebrates. This kind of assessment can provide focus for further analysis.

3.3 Habitat vulnerability

Species may or may not be present in the area at a certain point in time. Sometimes essential inventories / datasets for this are lacking. In such cases it is also possible to assess vulnerability of entire habitats or biotopes. Important characteristics for such an assessment are (De Lange et al., 2010):
- biodiversity and biomass (classification in poor, average and rich);
- chemical recovery (classification in slow, average and fast)
- ecological recovery (classification in slow, average and fast)

The classification is based on expert judgement. Based on this classification, habitats can be divided into five classes from not vulnerable to highly vulnerable. Habitat vulnerability can be further visualized on a habitat map.

3.4 From vulnerability to maps

The vulnerability of bird and mammal species may be used to create vulnerability maps. Vulnerability maps "display the parts of a geographical area and certain features in it that are more or less vulnerable to a particular kind of stress that is often not (yet) being exercised" (Lahr & Kooistra, 2010). When environmental concentrations (exposure) of a chemical stressor are also mapped, the combination of exposure and vulnerability maps yields 'true' risk maps on which the (relative) probability of an adverse effect is quantified and displayed (e.g., Lahr et al., 2010; Pistocchi et al., 2010).

Making vulnerability maps requires a number of steps in which the complexity is reduced to one map, providing a quick insight into where the most vulnerable locations for species or habitats are.

The first visualization step is the acquisition of maps with ecological information, such as habitat maps, vegetation maps, results of surveys of birds, fish, sea mammals, plants, etc. Densities of animals must be related to grid cells (or polygons) on a map. Known ecological hotspots can also be visualized, such as mussel and oyster beds, resting places for sea mammals, spawning areas for fish, etc. Depending on the species, maps may be needed for each season of the year (for example, two-monthly maps).

In a second step the ecological information is translated into a vulnerability classification for each different aspect; this may be done separately for the vulnerability of habitats, hotspots and separate species.

In the third and final step all information is combined by adopting the highest class for any of the intermediate maps for a location. The final map shows a classification of an area in classes from not vulnerable to very vulnerable. An example for oil spills in the Dutch Oosterschelde basin is provided in Figure 6. Six seasonal maps may be needed to cover a year.

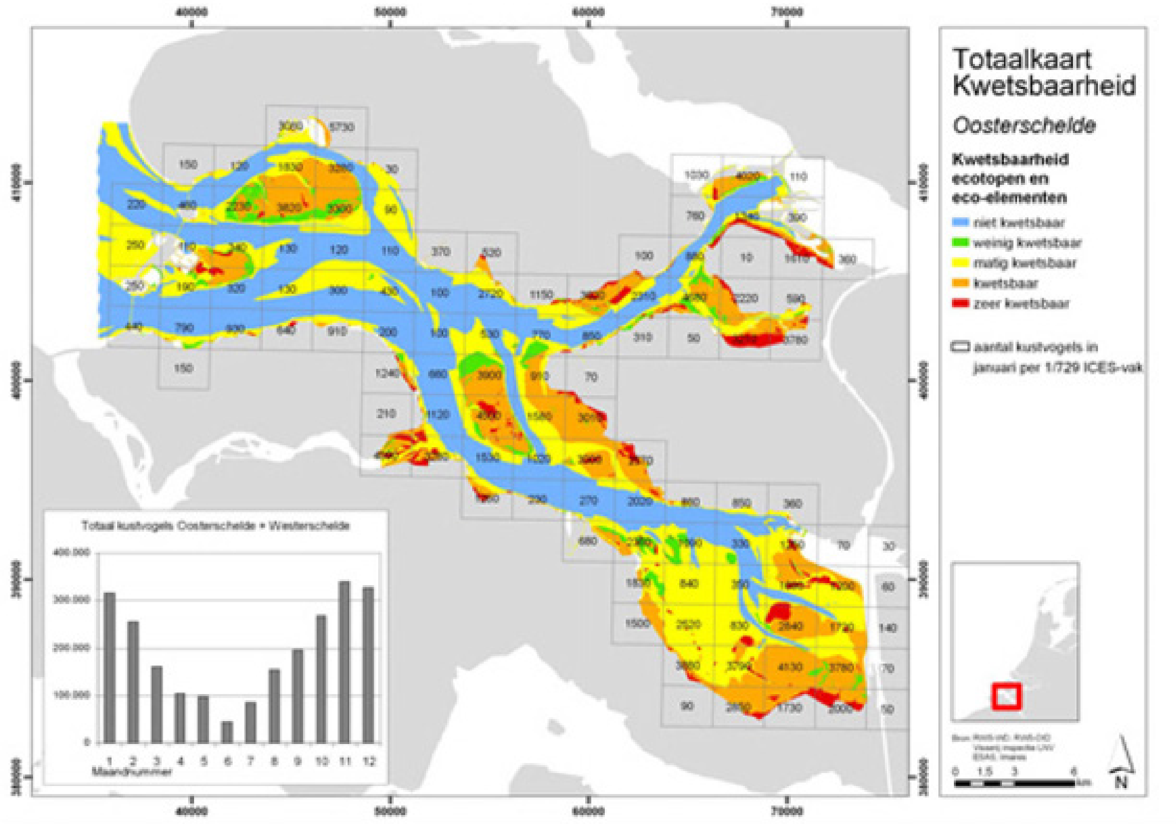

Figure 6 *Vulnerability map of the Oosterschelde basin for oil spills, ranging from not vulnerable (blue) to highly vulnerable (red) (Lahr et al., 2007).*

4 Vulnerability of Svalbard birds and mammals to oil

In this chapter vulnerability is applied to one potential Svalbard stressor, i.e., oil pollution and its effects on marine bird and mammal species.

4.1 Stressor

It is hypothetically assumed that a large oil slick is floating at sea and reaches the Svalbard coast where it also washes ashore. The oil in question is a heavy crude oil such as REBCO oil. For this particular analysis we assumed that the oil only causes smothering of fur or feathers and that affected animals perish from hypothermia as a consequence (in reality oil may also cause other effects such as toxicity through food uptake or inhalation, clogging of the respiratory tract and various injuries and ulcerations).

4.2 Selection of species

Annex 2 contains a list with a number of typical species of birds and mammals that occur at Svalbard and in the surrounding seas. From this list of Svalbard 'ambassador' species we chose 22 marine mammals and birds with varying life styles and body characteristics as demonstration species for a simple vulnerability analysis of oil pollution (see Table 5).

4.3 Methods

Vulnerability is considered to be the result of four factors that differ per species:
- Exposure
- Sensitivity
- Recovery potential
- Red List status

Two types of exposure factors were applied. The first factor is based on behaviour and is derived from the classification proposed by Offringa & Lahr (2007) with some modifications. These exposure factors are chosen on the basis of the dominant behaviour of the species, e.g. a bird that spends most of its time swimming at the water surface and diving (e.g., the Eider) is considered to be more exposed to a floating oil slick than a bird that flies most of its time (e.g., Fulmar). The second exposure factor is based on the environment where the animals occur, i.e., if the species spends most of its time at sea where it is exposed continuously to oil or if it also occurs on land or ice, thus being only partly exposed. The individual exposure factors range from 0 to 1, a value of 1 meaning that the species is considered maximally exposed. The two separate exposure factors were averaged to one overall exposure factor.

Smothering reduces the isolation capacity of fur and feathers of animals and causes hypothermia, especially in colder regions. Sensitivity of birds and mammals to oil is therefore classified according to the presence of fur or feathers and protection of the species against cold (presence of blubber) on a scale from 0 to 1 with a value of 1 being extremely sensitive.

Once populations of species are affected, recovery may occur through dispersal/migration that leads to recolonization, followed by reproduction. Mobility of the selected species was classified on the basis of expert judgement on a scale from 0 to 1 according to De Lange et al., (2006), a value of 1 being equal to entirely immobile. The reproductive capacity was scaled in a similar way (De Lange et al., 2006, used a more complex method to asses reproduction based on quantitative species data and using weight factors). The overall recovery factor (0-1) is calculated according to De Lange et al., (2006) as two third of the mobility factor plus one third of the reproduction factor. The reason is that recolonization is considered essential as a first step. It needs to occur before recovery through reproduction can take place.

The fourth factor considered is the Red List status of the species. The population of a species that is rare, threatened or in decline can be considered more vulnerable to stressors than a population of a more common species that is flourishing. The Red List qualification for Svalbard by the Norwegian government was retrieved from the internet (https://artsdatabanken.no/Rodliste) and the status of each species is classified on a scale from 0 (no status) to 1 (regionally extinct).

The species traits and the various factors used in the oil vulnerability analysis are presented in Annex 3.

Finally, the four factors are averaged, each of the four factors having an equal weight. This yields one single Species Vulnerability Index (SVI) with a value between 0 (not vulnerable at all) and 1 (extremely vulnerable).

4.4 Results

The result of this exercise (see Annex 4) is a ranking of 22 characteristic Svalbard bird and mammal species in the order as shown in Table 5. Brünnich’s guillemot was judged as the most vulnerable of the selected species with the method as applied. It is a swimming sea bird that is easily exposed to floating oil that causes its feathers to smother. Its Red List status is ‘Near Threatened’ (NT). The Purple sandpiper on the other hand was judged to be the least vulnerable of the 22 selected Svalbard species. The main reasons for this is that it spends no time at the sea surface and its Red List status is ‘Least Critical’ (LC).

Table 5 *Ranking of Svalbard birds and mammals in decreasing order of vulnerability to oil (1= extremely vulnerable, 0= invulnerable).*

Species	SVI	Species	SVI
Brünnich’s guillemot	0.62	Ivory gull	0.49
Polar bear	0.59	Fulmar	0.48
King eider	0.59	Blue whale	0.44
Puffin	0.57	Glaucous gull	0.44
Little auk	0.57	Arctic tern	0.39
Black guillemot	0.57	Minke whale	0.34
Kittiwake	0.55	Humpback whale	0.34
Eider	0.54	Grey phalarope	0.34
Red-throated diver	0.54	Beluga	0.39
Walrus	0.53	White-beaked dolphin	0.27
Ringed seal	0.53	Purple sandpiper	0.16

4.5 Discussion

The outcome of the ranking exercise is mainly based on expert judgement and can therefore be considered somewhat subjective. However, such methods are often used for oil vulnerability/sensitivity classifications (for a short review of some existing methods, see Offringa & Lahr, 2007).

The results of this ranking for Svalbard can be used to protect species in the Svalbard environment in various ways. The occurrence of the ‘ambassador’ species of Svalbard can be mapped and such maps with concentrations of vulnerable sea life indicate the areas of Svalbard most vulnerable to oil pollution (see Chapter 5). This information, in turn, may be used for contingency planning, i.e., to identify places where the Svalbard authorities want to locate vessels and materials used to combat oil spills. Combat strategies may include dispersion (which leads to less exposure of animals swimming at the surface, but more exposure of pelagic species such as fish and plankton), containment and different ways of cleaning up (at sea or on the coast). Vulnerability maps may help when choosing between the different options available.

It is also possible to use habitat classification as a first step for oil vulnerability mapping and add information on (concentrations of) vulnerable species such as bird colonies, haul-out areas, feeding areas, etc. to such maps (see for example Lahr et al., 2007).

5 Creating vulnerability and risk maps

In this chapter we present some examples of maps showing the distribution of species that are vulnerable to oil and to disturbance by tourists. Such maps can be used and/or combined to create overall maps of vulnerability and risks of environmental stressors at Svalbard.

On its website (https://geodata.npolar.no/) the Norwegian Polar Institute provides various base maps and thematic maps for Svalbard, including the distribution of species, protected areas and some human activities and cultural/archaeological heritage sites. In the following sections we use some of these maps to discuss the possibilities of using them to create vulnerability or risk maps for oil pollution and disturbance by tourism.

5.1 Vulnerability to oil pollution

In Figures 7 to 10 a few examples are shown of the distribution of species vulnerable to oil (based on Table 5). Species information was obtained from the website of the Norwegian Polar Institute (http://www.npolar.no/en/species/) and other sources.

Brünnich's guillemot is a fish-eating species of auk that breeds in large colonies on cliffs. It was identified as the species most vulnerable to oil among the 22 selected 'ambassador' species (Chapter 4, Table 5) and it is also placed on the Red List for Svalbard (status: Near Threatened). Figure 7 shows where its colonies occur with a classification of the colony size. Most colonies are situated on the coasts of Svalbard facing westwards.

Another vulnerable species, the King eider, is a species of marine duck. It sometimes breeds on the shore of shallow bay areas, but mainly in inland tundra areas with small ponds. It feeds on sediment-dwelling invertebrates. During the winter it remains at sea. Its breeding distribution in Svalbard is shown in Figure 8. It does not breed in colonies. It occurs at fewer sites than e.g. Brünnich's guillemot and its numbers are much lower. Its Red List status is also 'Near Threatened' (NT). Its vulnerability to oil is relatively high (Table 5).

Another characteristic Svalbard species with a different life style is the Ivory gull. It breeds in small colonies on the Arctic coast and on cliffs, but also inland (Figure 9). It feeds between sea ice floats on small fish and invertebrates, and sometimes inland on rodents, bird eggs and chicks. It is also known as a scavenger of corpses of marine mammals killed by larger predators. Its Red List status is 'Vulnerable' (VU). The vulnerability of the species to oil was lower than that of the most vulnerable Svalbard species such as Brünnich's guillemot and King eider (Table 5).

The Ringed seal is common and it reproduces on the land-fast ice in all of the fjords of Svalbard, but also in nearby pack ice of the Barents Sea (Figure 10). It feeds on crustaceans and fish and spends the winter on and around the sea ice. It is the preferred food of polar bears. Its Red List status is 'Vulnerable' (VU). Its vulnerability to oil was estimated as intermediate compared to the other species evaluated, like the walrus (Table 5). The species may be hunted at Svalbard outside the breeding season.

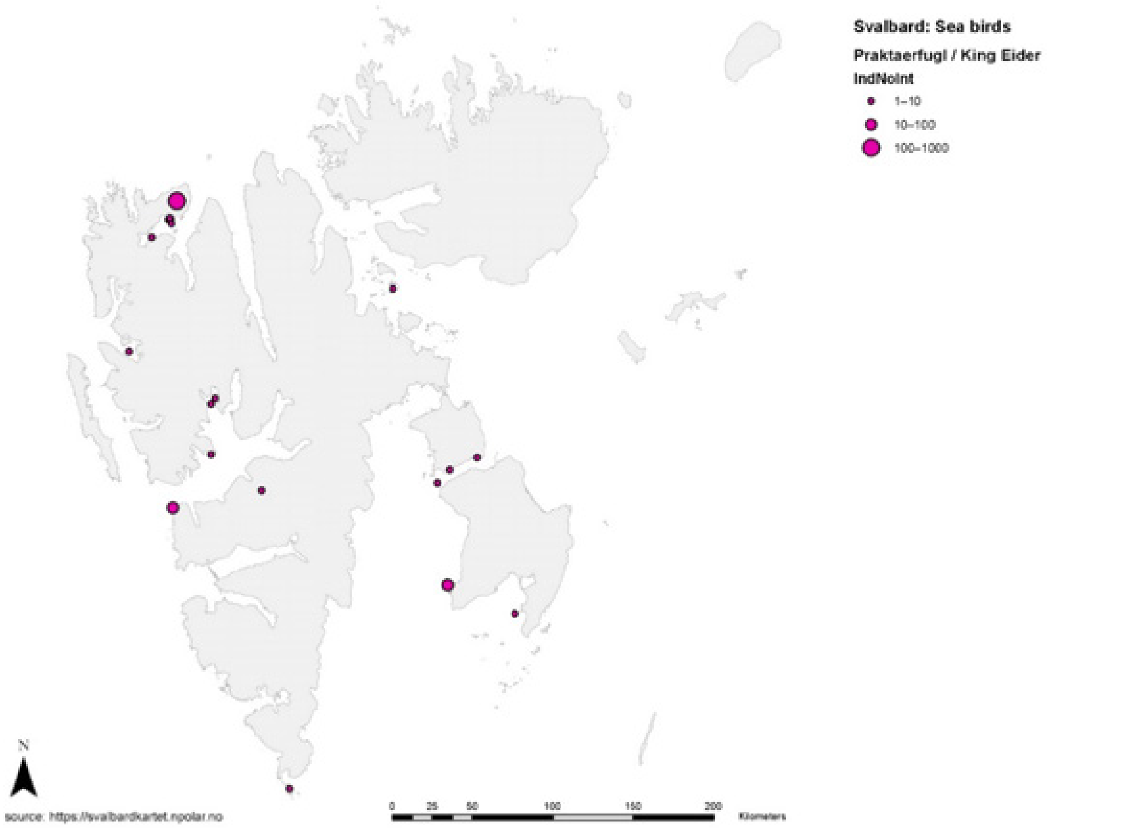

Figure 7 *Occurrence of Brünnich's guillemot in Svalbard. Maps produced with data publicly available from the Norwegian Polar Institute (https://data.npolar.no/dataset/fd4fd3aa-7249-53c9-9846-6e28c5a42587), published in 2008.*

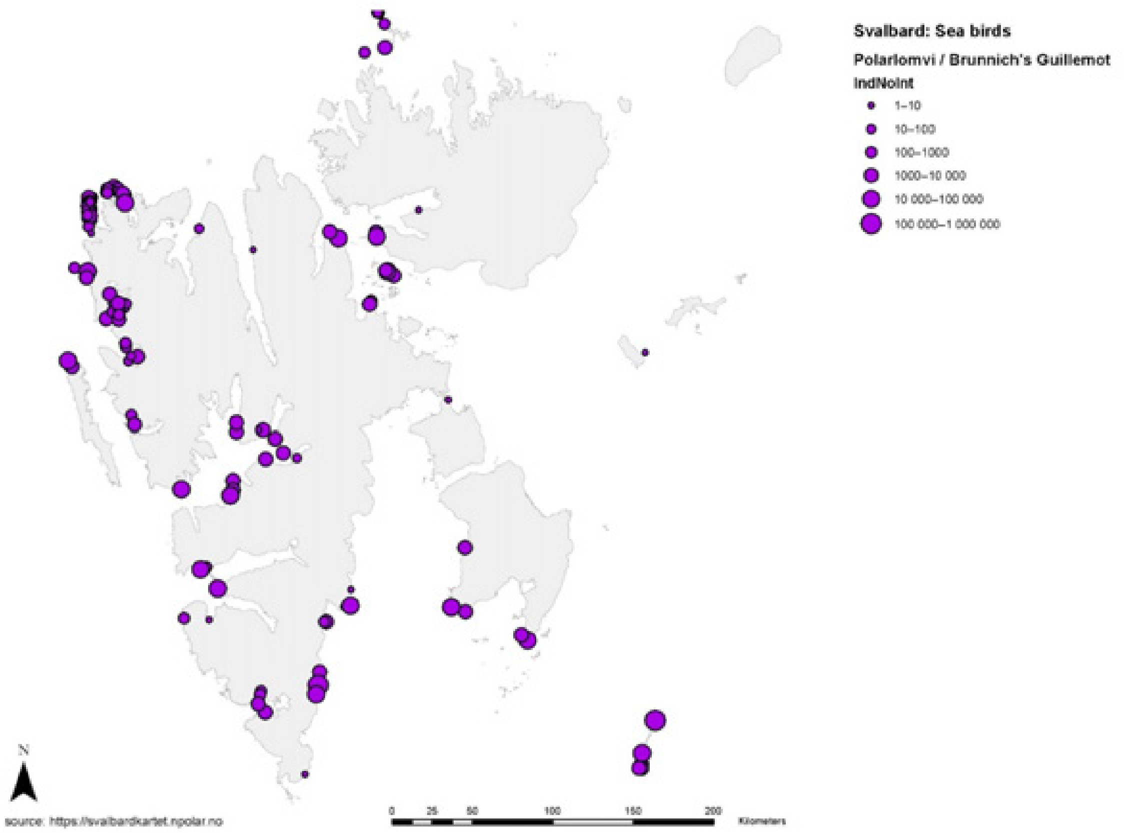

Figure 8 *Occurrence of King eider in Svalbard. Maps produced with data publicly available from the Norwegian Polar Institute (https://data.npolar.no/dataset/fd4fd3aa-7249-53c9-9846-6e28c5a42587), published in 2008.*

Figure 9 *Occurrence of Ivory gull in Svalbard. Maps produced with data publicly available from the Norwegian Polar Institute (https://data.npolar.no/dataset/fd4fd3aa-7249-53c9-9846-6e28c5a42587), published in 2008.*

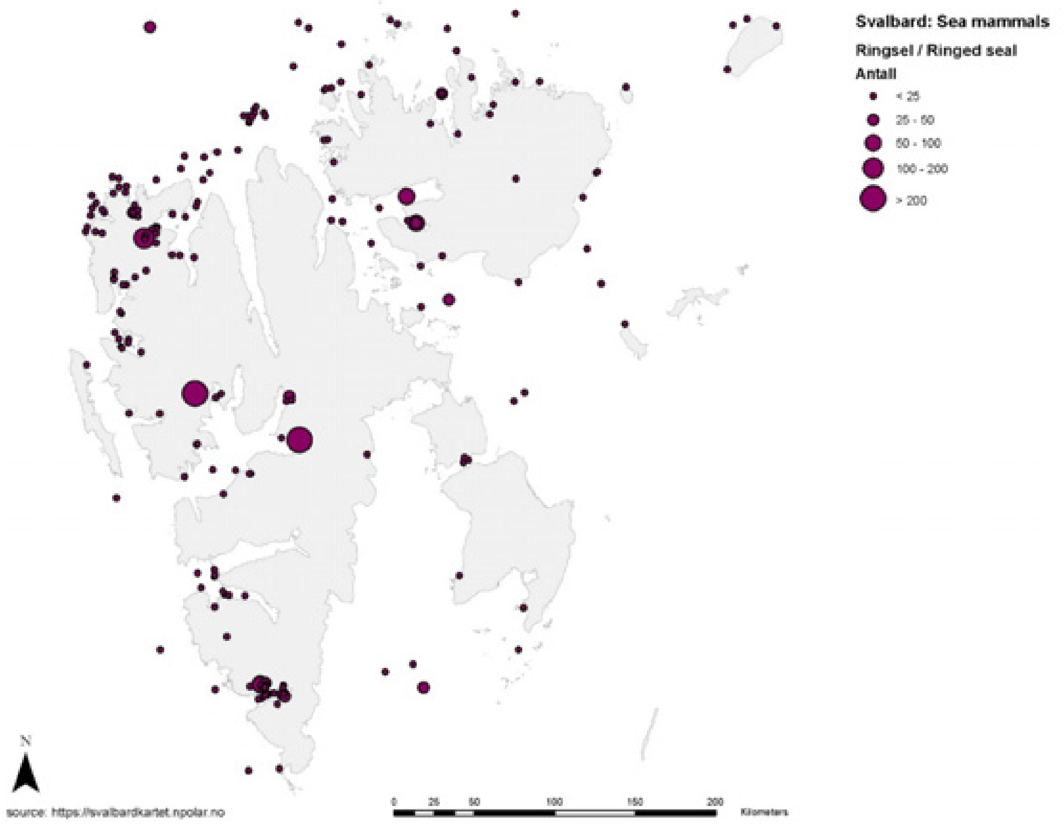

Figure 10 *Occurrence of Ringed seal in Svalbard. Maps produced with data publicly available from the Norwegian Polar Institute (https://svalbardkartet.npolar.no/Html5Svb/index.html?viewer=Svalbardkartet&viewer=Svalbardkartet). Data from 1998 and 2000 to 2009.*

The maps of the individual species may be used to create an overall vulnerability map for oil pollution. There are multiple methods to do this. One approach is the combination of the data on the relevant individual species per area or per site. For seabird colonies, for example, the overall vulnerability can be calculated by multiplying the number of individuals present per species with the value of its Species Vulnerability Index (SVI) (Table 5), followed by summation per species and division by the total number of birds present in the colony. This yields a weighted SVI per site (colony). However, depending on the desired protection goal, it is also possible to base the vulnerability score of a site/area on the most vulnerable species present and not on the combination of species.

The occurrence of vulnerable Arctic species strongly depends on the time of year. Vulnerability maps are therefore always restricted to a certain season. For colony breeding birds and mammals the reproduction period, often in summer, is usually considered critical and therefore mapped. However, autumn and winter may also see concentrations of marine birds and mammals in the open sea or in inlets, for example during moult.

A system of oil spill vulnerability mapping for Svalbard is presented on the website of the Norwegian Polar Institute. It is called PRIMOS and is described in a short paper in Norwegian (NPI, 2012). Bird species and sites are classified in three categories of vulnerability to oil: 1-3 (3 being most vulnerable). The criteria used are Red List status, size of colonies and species vulnerability. PRIMOS also includes localities for the anadromous fish Arctic char, haul-out sites for Walrus and Harbour seal, benthos and cultural heritage sites. Figure 11 shows results of PRIMOS for Svalbard.

Based on these results, the most vulnerable sites for oil pollution in Svalbard are on the north-western part of the archipelago (red colour).

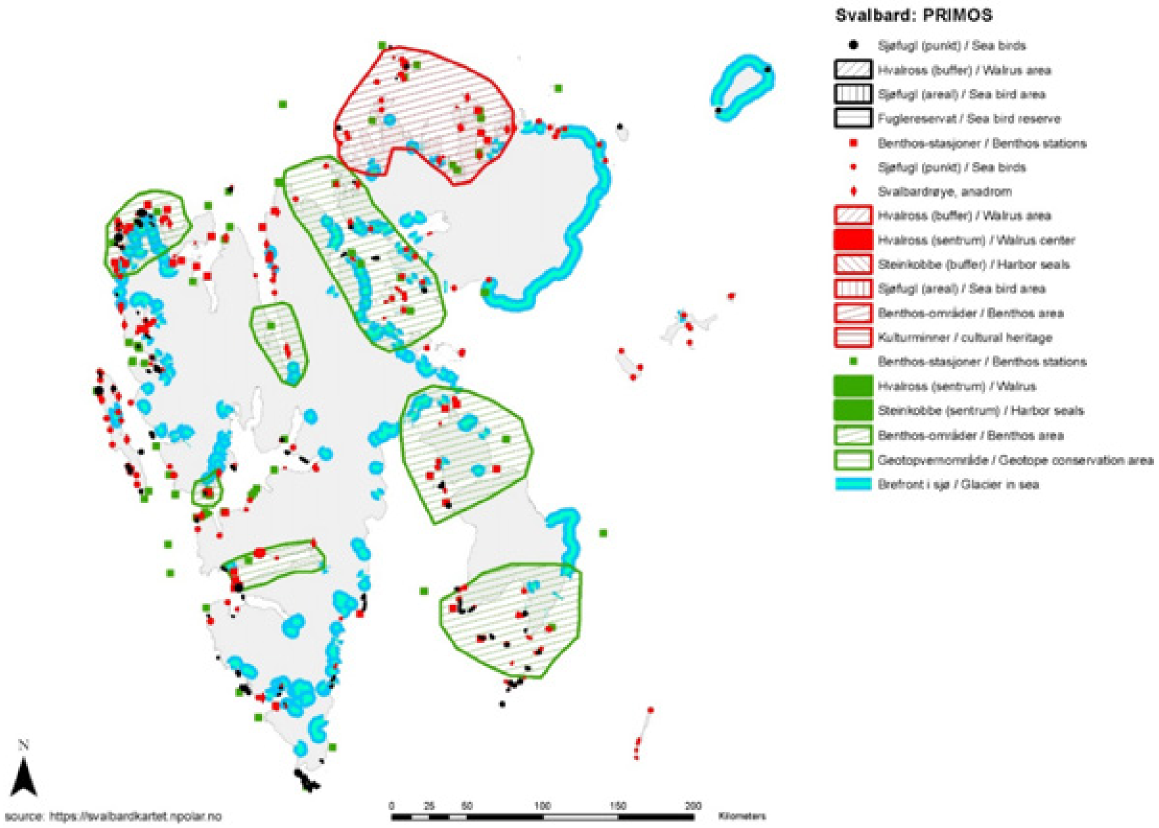

Figure 11 *Results of the PRIMOS tool for prioritizing areas for oil pollution in Svalbard (black= most vulnerable, red= intermediate vulnerability, green= least vulnerable). Maps produced with data publicly available from the Norwegian Polar Institute (https://svalbardkartet.npolar.no/Html5Svb/index.html?viewer=Svalbardkartet&viewer=Svalbardkartet). Bird data from 2011 and mammal data from 2000 to 2009.*

5.2 Risk of disturbance by tourism

The website of the Norwegian Polar institute provides a map of (touristic) boat landing sites. We compared the location of these sites to maps with the distribution of a few relevant areas for species: presence of seabird colonies (Figure 12), occurrence of Polar bears (Figure 13) and occurrence/haul out sites of Walruses (Figure 14).

The maps often show an overlap between sites where most of these species occur and tourist landings. Figure 14 even suggests that the largest Walrus sites are especially targeted by the tourists. Boat landings also partially overlap with the places where Red listed vascular plants occur in Svalbard (Kålås et al., 2010). The highest number of tourist landings is on the western and northern coasts of Spitsbergen and Nordauslandet. Disturbance occurs to a lesser extent on the eastern coasts of Spitsbergen, Nordauslandet and Edgeøya, and the smaller islands in the eastern part of the Svalbard archipelago, such as Kvitøya, Kong Karls Land and Hopen.

The maps indicate that there is an actual potential for disturbance by tourist visits at nature sites that host vulnerable species. The authorities of Svalbard and policy makers can use these types of maps to further regulate visits by tourists on cruise ships and landing with smaller boats.

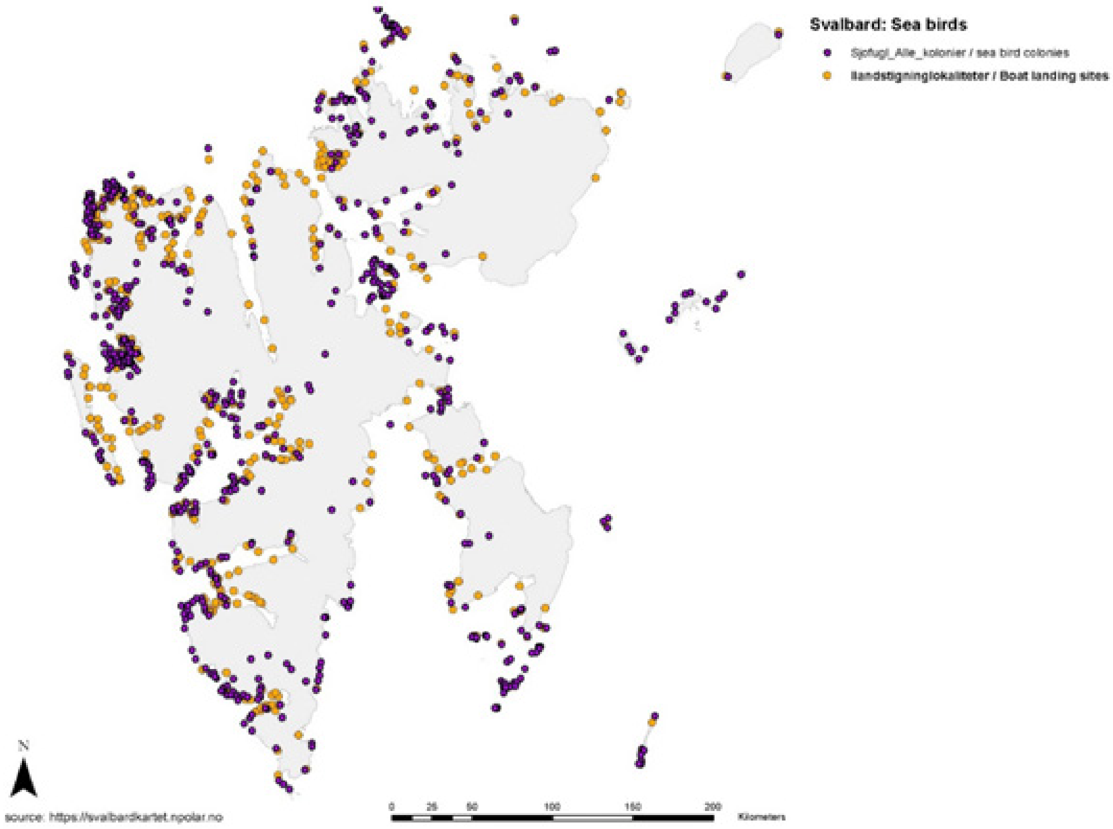

Figure 12 *Presence of seabird colonies in Svalbard compared to the location of tourist boat landing sites. Maps produced with data publicly available from the Norwegian Polar Institute (https://data.npolar.no/dataset/fd4fd3aa-7249-53c9-9846-6e28c5a42587), published in 2008.*

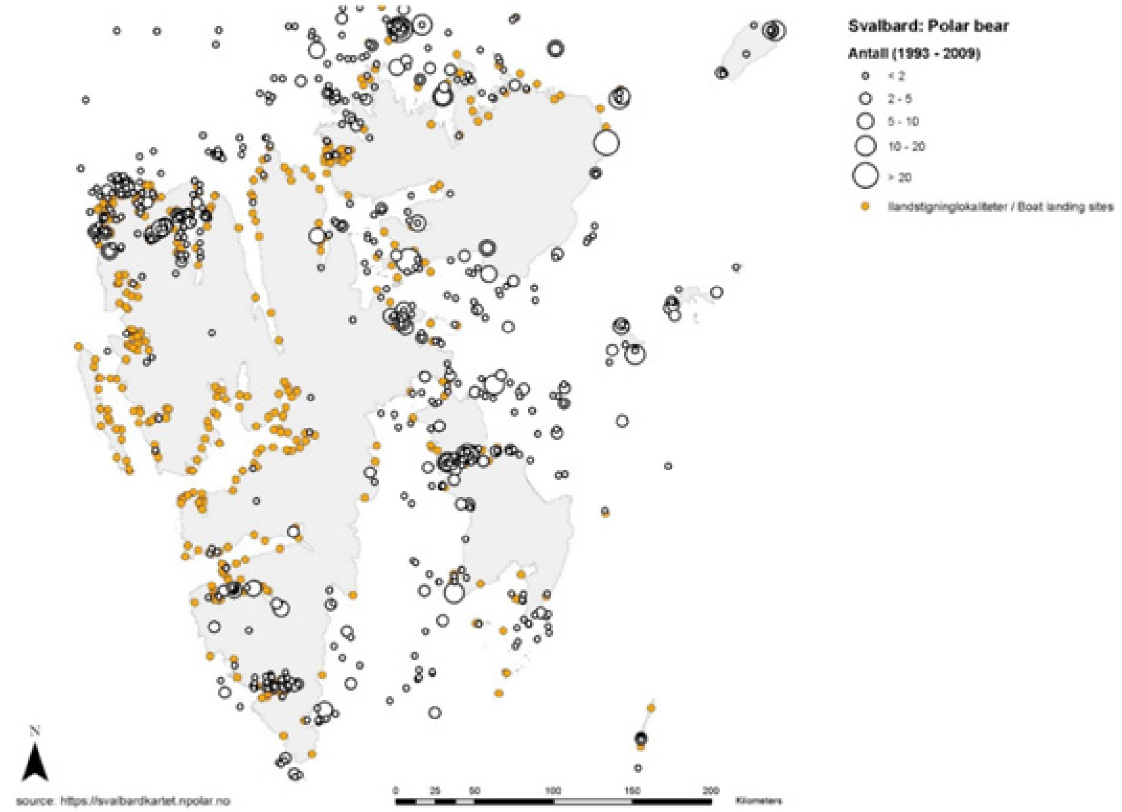

Figure 13 *Occurrence of Polar bears in Svalbard compared to the location of tourist boat landing sites. Maps produced with data publicly available from the Norwegian Polar Institute (https://svalbardkartet.npolar.no/Html5Svb/index.html?viewer=Svalbardkartet&viewer=Svalbardkartet). Data from 1993, 1995 and 1998, and from 2000 to 2009.*

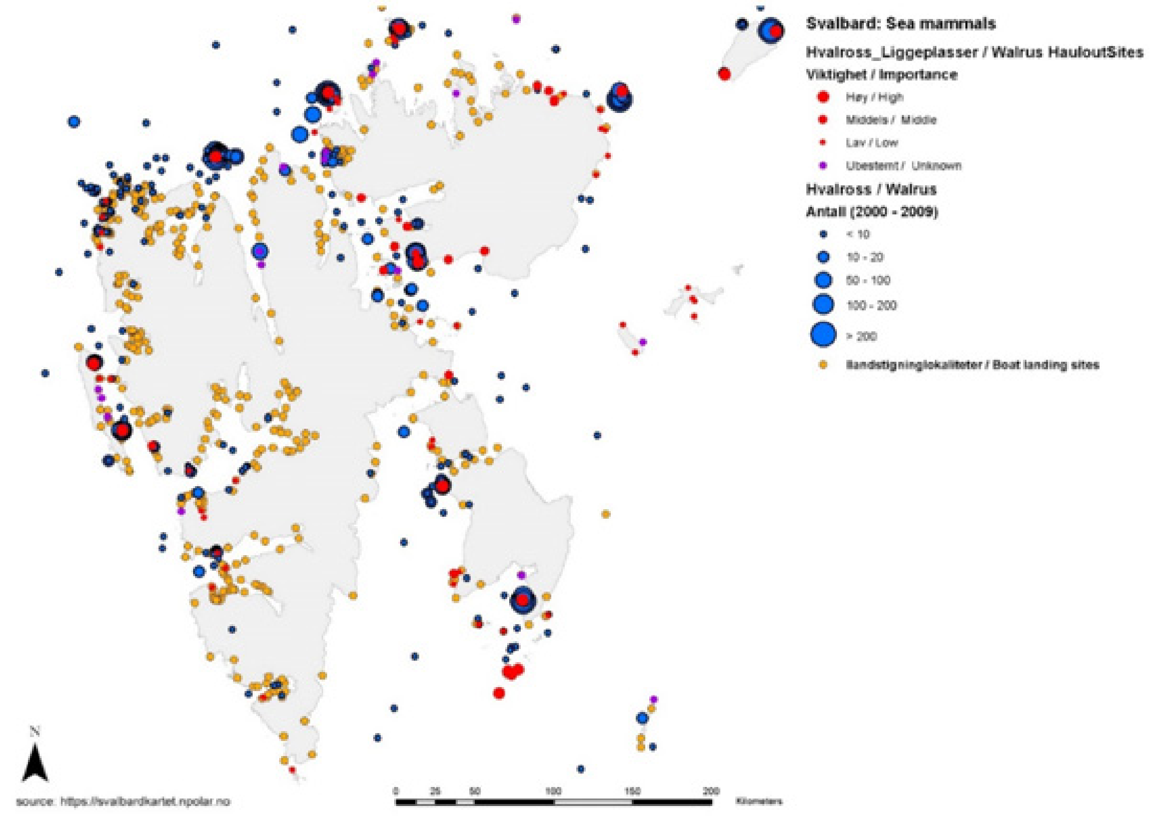

Figure 14 *Occurrence of Walrus and haul out sites in Svalbard compared to the location of tourist boat landing sites. Maps produced with data publicly available from the Norwegian Polar Institute (https://svalbardkartet.npolar.no/Html5Svb/index.html?viewer=Svalbardkartet&viewer=Svalbardkartet). Data from 2000 to 2009.*

6 Conclusions and recommendations

6.1 Proof of concept

The exercise described in Chapter 4 has shown that a species vulnerability analysis for floating heavy crude oil pollution and Svalbard marine birds and mammals can be performed with the current level of information in order to establish a ranking based on expert judgement. There is also sufficient data on the distribution of these species in Svalbard to create species-specific vulnerability maps (see Chapter 5).

The methodology developed here as a proof of concept for oil vulnerability of species does not result in a classification, but in a continuous scale (the Species Vulnerability Index). It could therefore be used as a complementary method to the existing PRIMOS system by providing more distinction between species and sites.

Vulnerability analysis of species as described in Chapter 4 and mapping of vulnerability and risk as shown in Chapter 5 may also be applied to stressors other than oil pollution and disturbance by tourism. An overview of the most relevant stressors for natural species in Svalbard was given in §2.4. The list includes climate change, mining activities on land (metal pollution), landfills, disturbance by traffic (including snowmobiles), persistent organic pollutants (POPs) in the marine environment, invasive species and plastic pollution in the coastal system. For all these stressors the (relative) vulnerability of species can be assessed when there is sufficient quantitative or semi-quantitative information about the particular traits that make these species more or less vulnerable to the stressor. Risk maps can be produced when sufficient spatial information is gathered on the true or potential exposure of species to the stressor.

6.2 Recommendations

The method developed in this report can be extended in the future by:

- Applying it to other relevant Svalbard species,
- Mapping vulnerable areas based on habitats (instead of only species),
- Collecting more relevant geographical information in Svalbard for mapping purposes,
- Collecting information on land use by inhabitants and tourists, and mapping the main attractions such as archaeological sites,
- Extending the method to other types of stressors such as climate change, plastics, POPs, tourism, mining, etc. (see also Chapter 2),
- Assessing regulations regarding the protection of nature and reduction of stressors, including compliance reports.

Arctic governments, international cruise companies and local tour operators (represented by AECO), who want to prevent pollution and disturbance, can use this method to negotiate profitable and responsible tourism in Svalbard. According to the Svalbard Environmental Protection Act, the Governor of Svalbard (Sysselmannen) is the environmental protection authority (supervised by the Norwegian Ministry of Environment). The Governor is the representative of the Norwegian national government and is also responsible for immigration, police, environmental and nature enforcement, including regulation of tourism. The second government in Svalbard is the Longyearbyen Local Council which welcomes tourism businesses. The future of tourists in Svalbard depends largely on the quality of nature. More knowledge about the vulnerability of this nature and a more objective approach to nature regulation is therefore in the interest of the entire Svalbard community.

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Annex 1 Protected areas of Svalbard

Source: http://cruise-handbook.npolar.no/en/svalbard/protected-areas.html

Park	Total Area km² (land and marine)	Wildlife	Human activities
Nordvest-Spitsbergen National Park	9 914	Bird cliffs, nesting sites for ducks and geese. The bird sanctuaries Guissezholmen, Skorpa and Moseøya. Moffen Nature Reserve with walruses	Areas of historical interest from the whaling era, expeditions to the North Pole and the trapping periods. Most visited tourist localities.
Forlandet National Park	4 647	Bird cliffs, small population of Svalbard reindeer, harbour seals, haul-out sites for walrus	Cultural remains from the whaling time, from overwintering trapping and from periods of mineral exploitation. Traffic within the park is modest
Sør-Spitsbergen National Park	13 286	Vegetated strandflats dominate the west coast. Nesting localities for seabirds, ducks and geese The bird sanctuaries Sørkapp, Dunøyane, Isøyane and Olsholmen, with considerable nesting populations of eiders and geese, are located within the park. A fair population of Svalbard reindeer. Hornsund is an important area for polar bears.	Cultural remains from whaling in the 17th and 18th centuries, overwintering trapping, mining, tourism (Giæverhuset), research and World War II. A Polish research station is located in Hornsund. The national park is often visited in the summer by cruise ships.
Nordenskiöld Land National Park	1 362	Lush vegetation in Svalbard's largest valley, Reindalen. Nesting and moulting areas for eiders, waders and geese and several bird cliffs. A large Svalbard reindeer population.	Cultural remains from whaling times (homestead sites, tryworks and graves), remains from Russian overwintering trapping and cultural remains tied to mineral exploitation. There is substantial snowmobile traffic in the park in winter, but very low traffic in summer.
Sassen-Bünsow Land National Park	1 230	Large areas of continuous vegetation and several vulnerable plant species. A great population of Svalbard reindeer. Several large bird cliffs and important wetlands for waders. Pink-footed geese nest in the valleys. The fjords are important birthing and moulting grounds for ringed seals, attracting polar bears in the wintertime.	Cultural remains relate to overwintering trapping and mineral exploitation and mining. Traffic in the park is clearly greatest during the snowmobile season in late winter and spring. There is some traffic from cruise ships and private boats in summer.
Nordre Isfjorden National Park	2 957	Species-rich vegetation. Several bird cliffs and nesting grounds for eiders, waders and geese. A number of the fjords are important birthing and moulting grounds for ringed seals. Polar bears move regularly in the area during winter and spring.	Cultural remains from Russian and Norwegian overwintering trapping. Cultural remains of the whaling area and several important industrial remains. The trapping station at Kapp Wijk is still in use.
Indre Wijdefjorden National Park	1 128	Arctic steppe vegetation and several very rare plant species. Some of the species grow only in this location in Svalbard. Svalbard reindeer, Arctic fox and common birds inhabit the park.	Cultural remains related to Norwegian and Russian overwintering trapping. The trapping station at Austfjordneset is still in use. Traffic in this area is mostly confined to residents travelling by snowmobiles during winter.

Park	Total Area km² (land and marine)	Wildlife	Human activities
Nordaust-Svalbard Nature Reserve	55 551	A large and continuous, and to the extent possible an untouched natural environment Bird cliffs. Svalbard's greatest haul-out sites for walrus. A Svalbard reindeer population Kong Karls Land is the key area for the reproductive part of the Svalbard polar bear population. A large number of polar bears spend the summer within the reserve. Lakes and rivers with Arctic char.	Commercial fishery for shrimp north in Hinlopenstretet. Traffic is more or less restricted to the summertime, and an increasing number of landing sites is being used by expedition cruise ships. In Kong Karls Land traffic is prohibited year-round.
Søraust-Svalbard Nature Reserve	21 873	Large vegetated strandflats. Large populations of Svalbard reindeer and Arctic fox. Important year-round habitats for polar bears. Haul-out sites for several hundred walruses. Important nesting area for brent geese. A great number of eiders nest there too.	Cultural remains related to research and whaling, and also Norwegian and Russian overwintering trapping. Traffic in this area is increasing, but limited to the summertime.
Bjørnøya Nature Reserve	2983	Greatest bird cliff in the Barents Sea on the southern tip of the island. Important migration area for Svalbard's geese. In winter, polar bears migrate south to Bjørnøya with the drift ice. The island has a number of rivers with Arctic char.	Cultural remains related to trapping, research and industrial remains from mineral exploitation. Time-restricted traffic prohibition due to nesting birds.
Ossian Sars Nature Reserve	12	Svalbard's most species rich locality for vascular plants. A bird cliff and Arctic fox localities. This reserve is	
Hopen Nature Reserve	3 254	denning, migration and feeding ground for polar bears. bird cliffs with Brünnich's guillemots and kittiwakes.	Cultural remains from Norwegian overwintering trapping, slaughter sites for walrus and cairns erected by Thor Iversen in 1924.
Moffen Nature Reserve	9	Haul-out site for walrus. Nesting ground for eiders and Arctic terns. Sabine's gulls and brent geese are also observed nesting here.	Traffic is prohibited on the island itself and in a 300 m zone around the island from 15 May to 15 September.
Festningen Geotope Protection Area	17	Occurrences of fossil tracks of prehistoric reptiles and other interesting geological phenomena.	The area is often used in research and education.

Annex 2 Typical Svalbard mammals and birds

Habitat	*Species*
Mammals coast	Walrus (*Odobenus rosmarus*)
	Polar bear (*Ursus maritimus*)
	Ringed seal (*Phoca hispida*)
	Bearded seal (*Erignathus barbatus*)
	Harbour seal (*Phoca vitulina*)
	Bowhead whale (*Balaena mysticetus*)
	White whale/Beluga (*Delphinapterus leucas*)
	Narwhal (*Monodon monoceros*)
	Other marine mammals that can be seen near Svalbard are: blue whales, fin whales, humpback whales, minke whales, sperm whales, northern bottlenose whales, killer whales, pilot whales and white-beaked dolphins
Mammals land	Svalbard reindeer (*Rangifer tarandus platyrhynchus*)
	Arctic fox (*Vulpes lagopus*)
Birds coast	Glaucous gull (*Larus hyperboreus*)
	Black-legged kittiwake (*Rissa tridactyla*)
	Ivory gull (*Pagophila eburnea*)
	Arctic tern (*Sterna paradisaea*)
	Northern fulmar (*Fulmarus glacialis*)
	Arctic skua (*Stercocarius parasiticus*)
	Great skua (*Stercorarius skua*)
	Common eider (*Somateria mollissima*)
	King eider (*Somateria spectabilis*)
	Common guillemot (*Uria aalge*)
	Brünnich's guillemot (*Uria lomvia*)
	Black guillemot (*Cepphus grylle*)
	Little auk (*Alle alle*)
	Atlantic puffin (*Fratercula arctica*)
	Purple sandpiper (*Calidris maritima*)
	Grey phalarope (*Phalaropes fulicarius*)
	Other waders that can be seen in Svalbard are: Ringed plover, sanderling, dunlin and ruddy turnstone
Birds land	Brent goose (*Branta bernicla*)
	Pink-footed goose (*Anser brachyrhynchus*)
	Barnacle goose (*Branta leucopsis*)
	Snow bunting (*Plectrophenax nivalis*)
	Red-throated diver (*Gavia stellata*)
	Svalbard rock ptarmigan (*Lagopus muta hyperborea*)

Annex 3 Classification of species traits

- Exposure factor = 1/2 x behaviour factor + 1/2 x time spent in/on sea
- Recovery factor = 2/3 x mobility factor + 1/3 x reproduction factor
- Species vulnerability index = (Exposure factor + Sensitivity factor + Recovery factor +Red List factor)/4

Exposure classification by habitat & behaviour (slightly modified from Offringa & Lahr, 2007)

Class of habitat/behaviour	Code	Behaviour factor (heavy crude oil)
Mobile pelagic species. Any free-swimming organism. Examples are dolphins, whales and round fish	MP	0.1
Mobile shore species that occur on the beach such as wading birds	MS	0.5
Marine mammals swimming at or near the surface such as seals, otters and polar bears	MM	0.6
Birds, flying. Seabirds that spend a relatively long time on the wing (fulmar)	BF	0.6
Birds, swimming. Seabirds that swim most of the time (sea ducks, divers, grebes, auks)	BS	0.9
Birds near the shore. Seabirds that stay relatively close to the coast (terns, gulls)	BN	0.7
Courser birds (waders)	BC	0.2

Time spent in/on the sea (seasonal)		Time Spent
24/7 on land	None	0.00
Occasionally at sea, better part of the day on land/ice	Little	0.25
Part of the day at sea, part of the day on land/ice	Medium	0.50
Better part of the day at sea, occasionally on land/ice	Most	0.75
24/7 at sea	Constant	1.00

Sensitivity to stress (very loosely based on Offringa & Lahr, 2007)

Smothering	Sensitivity factor
Swimming mammals with fur that keeps them warm (polar bear, sea otter)	0.8
Swimming mammals with little fur that keep themselves warm with a layer of blubber (seals, etc.)	0.3
Swimming mammals without fur with baleens (whales)	0.3
Swimming mammals without fur and with teeth (dolphins, toothed whales)	0.1
Birds that swim most of the time and dive under water (ducks, grebes)	1.0
Birds that fly, (plunge) dive and swim (auks, gannets)	1.0
Birds that fly a lot but that eat floating food items and do not dive deeply (fulmar, kittiwake)	0.8
Birds that fly a lot but also land on water (most gulls, terns)	0.5
Birds that walk/run most of the time on land or on the shore but also swim (phalarope)	0.4
Birds that walk/run most of the time on land or on the shore (waders, coarser birds)	0.2

Recovery potential

Mobility (according to de Lange et al., 2006)	Class	Mobility factor
	High	0.00
	Moderately high	0.25
	Medium	0.50
	Low	0.75
	Very low	1.00

Reproduction (similar classes, but method not by de Lange et al., 2006)	Class	Reproduction factor
	High	0.00
	Moderately high	0.25
	Medium	0.50
	Low	0.75
	Very low	1.00

Red List of Norway (of Svalbard when provided separately for a species)	Code	Red List factor
Data deficient	DD	0.5
Least critical	LC	0.0
Near threatened	NT	0.2
Vulnerable	VU	0.4
Endangered	EN	0.6
Critical	CR	0.8
Regionally extinct	RE	1.0

Annex 4 Vulnerability of Svalbard species to oil

Species	Polar bear	Walrus	Ringed seal	Blue whale	Minke whale	Humpback whale	Beluga	White-beaked dolphin	Glaucous gull	Kittiwake	Ivory gull
Parameter	*Ursus maritimus*	*Odobenus rosmarus*	*Phoca hispida*	*Balaenoptera musculus*	*Balaenoptera acutorostrata*	*Megaptera novaeangliae*	*Delphinapterus leucas*	*Lagenorhynchus albirostris*	*Larus hyperboreus*	*Rissa tridactyla*	*Pagophila eburnea*
Behaviour	0.6	0.6	0.6	0.1	0.1	0.1	0.1	0.1	0.7	0.7	0.7
Time spent in/on the sea	0.25	0.75	0.75	1	1	1	1	1	0.75	1	0.75
Exposure factor	0.43	0.68	0.68	0.55	0.55	0.55	0.55	0.55	0.73	0.85	0.73
Sensitivity factor	0.8	0.3	0.3	0.3	0.3	0.3	0.1	0.1	0.5	0.8	0.5
Mobility	0.75	0.75	0.75	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Reproduction	0.75	0.75	0.75	1.00	1.00	1.00	0.75	0.75	0.50	0.50	0.50
Recovery factor	0.75	0.75	0.75	0.50	0.50	0.50	0.42	0.42	0.33	0.33	0.33
Red list status Svalbard	VU	VU	VU	VU	LC	LC	DD	LC	NT	NT	VU
Red List factor	0.4	0.4	0.4	0.4	0.0	0.0	0.5	0.0	0.2	0.2	0.4
Species Vulnerability Index	0.59	0.53	0.53	0.44	0.34	0.34	0.39	0.27	0.44	0.55	0.49

Species	Arctic tern	Puffin	Brünnich's guillemot	Black guillemot	Little auk	Fulmar	King eider	Eider	Red-throated diver	Grey phalarope	Purple Sandpiper
Parameter	*Sterna paradisaea*	*Fratercula arctica*	*Uria lomvia*	*Cepphus grylle*	*Alle alle*	*Fulmarus glacialis*	*Somateria spectabilis*	*Somateria mollissima*	*Gavia stellata*	*Phalaropus fulicarius*	*Calidris maritima*
Behaviour	0.7	0.9	0.9	0.9	0.9	0.6	0.9	0.9	0.9	0.5	0.2
Time spent in/on the sea	0.75	1	1	1	1	1	0.75	0.75	0.75	0.75	0
Exposure factor	0.73	0.95	0.95	0.95	0.95	0.80	0.83	0.83	0.83	0.63	0.10
Sensitivity factor	0.5	1	1	1	1	0.8	1	1	1	0.4	0.2
Mobility	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Reproduction	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Recovery factor	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Red list status Svalbard	LC	LC	NT	LC	LC	LC	NT	LC	LC	LC	LC
Red List factor	0.0	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Species Vulnerability Index	0.39	0.57	0.62	0.57	0.57	0.48	0.59	0.54	0.54	0.34	0.16

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