The value of ecosystem services at risk from oil spills in the Barents Sea

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Foreword

This paper was prepared for the ISEE conference in Rio de Janeiro 16-19 June 2012 and describes work completed in the *Arctic Games* research project, funded by Swedish research program *MISTRA Arctic Futures in a Global Context* (2011-2013).

An increasing global scarcity of vital natural resources, advances in extraction and communication technology, and global warming, will change the stakes of nations and other actors in the Arctic. Tradeoffs between different financial, social and ecological interests are unavoidable, and the crucial challenge is to find tradeoffs that are consistent with sustainable development and are implemented by efficient and accepted governance structures. In *Arctic Games* these tradeoffs are explored by developing an analytical framework for analyzing and assessing strategic behavior of various stakeholders; economic values of ecosystem services and the role of appropriate governance structures.

One specific task of *Arctic Games* is to carry out an ex ante economic valuation study focusing on the willingness to pay of Norwegian residents to avoid a future oil spill in the Lofoten area of northern Norway. Key economic drivers in Lofoten include oil and gas, fisheries, and tourism. These sectors affect and depend on ecosystem services such as biodiversity, recreation and scenery. The purpose of this study is to analyze the impact on ecosystem services resulting from a future oil spill, as well as already existing policy measures. A monetary value of avoiding a decreased provision of ecosystem services will be estimated using the contingent valuation method. The results of the study are of interest since non-use values can be expected to make up for a large share of the total economic value of ecosystem services in Lofoten and the Arctic area in general.

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1. Introduction

The future development of the Arctic region is of global interest. The area is biologically connected to the rest of the world by, for example, migrating fishes and mammals. In the Arctic region there is also a multitude of unique non-migrating life forms, highly adapted in their life history, ecology and physiology to the extreme and seasonal conditions of their environment (Gradinger et al. 2004). The area provides several important ecosystem services: supporting services such as maintenance of habitats; regulating services such as climate regulation; provisioning services such as food for consumption; and cultural services, such as recreation and cultural heritage (Magnussen et al. 2010). Several of the habitats and plant and animal species in the area are threatened (CAFF 2010), and the preservation of well-functioning ecological systems in the area is an important policy task. Further, the Arctic is the region where the environmental impacts of climate change are most strongly expressed (Gradinger et al. 2004).

The Arctic is also an area of strategic interest given the extraction of natural gas and oil, fisheries, tourism, shipping, etc. (AGP 2010). An increasing global scarcity of vital natural resources, advances in extraction and transportation technology, and global warming will change the stakes of nations and other actors in the area. Trade-offs between different financial, social and ecological interests are unavoidable, and the crucial challenge is to find trade-offs that are consistent with sustainable development. To better assess these trade-offs, policy makers require, among other things, better information associated with the social costs of environmental degradation.

The Arctic is one of the most important oil-producing regions in the world (OECD/IEA 2008), yet it is particularly vulnerable to oil spill damages due to sensitive ecosystems, increasing human pressure, and natural circumstances such as cold water and harsh weather. These circumstances suggest a difficult clean-up process and a slower recovery from oil damages. Further, oil spill response and preparedness in the region is expensive relative to more populated regions. Gautier et al. (2009) show that 13 percent of the world's undiscovered oil may be found in the Arctic and new extraction opportunities are increasing due to rapidly melting Arctic ice. Increased drilling activity implies an increased spill risk at the point of extraction and from increased oil tanker traffic. Further, the forecasted increase in overall economic activity in the region leads to increased non-tanker shipping, which also poses an increased spill risk.

Our study identifies the types of social costs that may arise from a future oil spill in the Lofoten - Barents Sea region. The study area is part of the Arctic Ocean, extending from the area of Lofoten in the north of the Norwegian Sea to the Russian coastline. The objective of our study is to describe oil spill threats in the region and identify the ecosystem services that are most likely to be affected by a future oil spill. Further, we aim to shed light on the possible economic values at stake.

The results from this paper are useful for policy decisions on several levels. A first question is: is it economically sound to allow extraction? Second, what regulations should be applied to meet the risk from sea based transports? The transports are expected to increase in the region, not only due to oil and gas extraction, but also due to increased commerce (Starberg et al. 2004). Policy makers will have to take a stance regarding these issues and decide what level and type of precautionary measures should be taken, and what level and type of oil spill response capacity should prevail in the region. Measures are costly, but so is also inaction. Information on the potential costs of an oil spill is crucial in this sense, in order to be able to make sound socio-economic trade-offs possible. Finally, to the extent that future international agreements (or national legislation) require compensatory restoration following a spill, this paper will help identify the types of values affected and thus may help inform the type and scale of compensatory measures.[1]

1.1. Previous literature

A number of studies have attempted to estimate the cost of a large scale oil spill accident, either *ex ante* or *ex post* (the former asks respondents about their willingness to pay (WTP) to prevent a spill before it happens, while the latter estimates the actual damage after an oil spill has occurred). For example, Ahtiainen (2007) uses contingent valuation (CV) to estimate the WTP for improving the oil spill response capacity in the Gulf of Finland. The estimated WTP amounted to 112 million EUR in total. Liu et al. (2009) used a choice experiment (CE) to estimate the WTP for improving oil spill preparedness in the Wadden Sea (along the German, Dutch and Danish coasts). The survey estimated WTP for several attributes that may be affected by a future spill including coastal waters, beaches, Eider ducks, and the oil collection ratio (collected/spilled). The study estimated a mean WTP of 29 EUR per household. Given 39 million households in Germany, the study estimated a total WTP of 1.1 billion EUR for a number of improvements in oil spill response capacity. Carson et al. (2003) reports on a CV study performed after the Exxon Valdez oil spill (Alaska 1989) which aimed to estimate non-use values lost from a typical oil spill. The study found a total lost value of 2.8 billion USD based on multiplying the median household WTP (48 USD; ibid, p. 277) by the number of English-speaking households in the US. Loureiro et al. (2006) estimated the cost from the Prestige oil spill along the Spanish coast in 2002. As a basis for valuation, they used market prices of lost catches in commercial fisheries and other seafood industries such as fish farming and the fish processing sector. Further, they estimated the cost of environmental losses by using reposition costs of birds and mammals. They also include clean-up costs in their estimations. The total cost of the accident was estimated at 770 million EUR, as a lower bound. Van Biervliet et al. (2006) used CV to estimate the WTP for preventing hypothetical oil spill scenarios along the Belgian Coast. The total WTP is estimated to 120 to 606 million EUR, depending on the size and the frequency of the oil spill scenario.

[1] For example, compensatory requirements under US law require polluters to pay to repair environmental damage even after clean up activities are completed (see Natural Resource Damage Assessment regulations as described in Carson et al. 2003).

In addition to these studies found in the academic literature, there are a vast number of estimates available in the grey literature covering e.g. loss of revenue in tourism and fisheries and loss of welfare in recreational activities. SwAM (forthcoming) present an overview. A conclusion from this report is that *"While there are several credible and existing valuation methodologies available, very few of them have been applied to the case of oil spills and ecosystem services."* (p.66).

A review of these studies suggests a number of preliminary conclusions. First, estimates are highly dependent on contextual factors such as the type and amount of recreational usage in the area or the extent of commercial fishing activity. Direct point estimates are thus not easily transferred across areas. In order to draw policy-making conclusions on the level of preventive measures and preparedness, a more focused approach is required. Second, the Arctic is not a well-studied area in the context of oil spills. This might become problematic, given the importance of the region for future development. Third, the existing literature does not take an ecosystem services approach, which makes it more difficult to assess the effects of oil spills on human well-being.

1.2 Study framework

The costs from an oil spill could be divided into three categories (Fejes et al. 2011): *Direct costs,* which include e.g. financial damage and clean-up expenditures; *Market costs* which include losses of profits and welfare imposed on producers and consumers in markets dependent on natural resources affected by the oil spill, such as tourism; and *Non-market costs,* which could be defined as social welfare losses that are not priced in a market. This categorization of costs provides a framework for valuation. In general, studying one category of costs (e.g., clean-up) implies only a partial valuation. Results from e.g. Carson et al. (2003) suggest that non-market costs may be substantial. We argue that an ecosystem services approach to valuation is preferable for future policy decisions regarding oil spill prevention and preparedness in the Arctic. This is also the kind of approach that is now formally recommended by the EU to assess the cost of environmental degradation in relation to the Marine Strategy Framework Directive (MSFD; Directive 2008/56/EC). Further, two recent studies have recommended an ecosystem services approach when assessing the environmental impacts of oil spills particularly (Boyd 2010; NRC 2011).

The paper is organized as follows: In Section 2, we provide a background on the study area. In section 3, we describe the main sources of threats in the region. In Section 4, we provide an overview of ecosystem services likely to be affected from an oil spill in the region. Finally, in Section 5, we discuss our findings.

2. The Lofoten- Barents Sea region

The Barents Sea is a part of the Arctic Ocean to the north of Norway and Russia (see Figure 1). It covers an area of about 1.4 million km^2 and has an average water depth of 200 m (aari.nw.ru). There is significant variation of climate conditions in the Barents Sea due to the influence of the cold Arctic Ocean and the warm Norwegian Sea. The severity of climate in the Barents Sea increases when moving from south to north and from west to east (Ibid.). The warm North Atlantic Current allows one quarter of the Barents Sea to remain ice-free even in winter, unlike most other Arctic seas.

The Barents Sea area has a crucial position in the High Arctic ecosystem as it provides key habitat for a number of migratory birds, mammals and fish. The Lofoten area is an important spawning ground for the northeast Atlantic cod, one of the world's largest healthy fish stocks (Durant et al. 2008).

The Barents Sea area is also a rich source of oil and gas exploration. While many fields have already been utilized, the majority of the resources remain undiscovered (barentssea.no).

Figure 1. The Arctic Ocean and the Barents Sea.[2]

For the purposes of international cooperation on issues concerning the Barents Sea the Barents Region was formally established in 1993. The Barents Region includes the northern

[2] Source: Wikimedia commons. http://upload.wikimedia.org/wikipedia/commons/e/ea/Barents_Sea_map.png (accessed 2012-04-26)

territories close to the Barents Sea coastline in four countries: Nordland, Troms, and Finnmark in Norway; Västerbotten and Norrbotten in Sweden; Lapland Province, Northern Ostrobothnia, and Kainuu in Finland, and Murmansk Oblast, Arkhangelsk Oblast, Komi Republic, Republic of Karelia and Nenets Autonomous Okrug in Russia (see Figure 2). The area covers 1.75 million km² and includes approximately 5.5 million inhabitants. 75% of the territory and population is Russian. The cooperation is organized on both local and national government level (barentsinfo.org).

The study area includes the Lofoten islands in the northern Norwegian Sea and north along the Russian coastline to Novaya Zemlya.

Figure 2.The Barents Region.[3]

[3] Source: www.barents.no (accessed 2012-04-26)

3. Threats

Oil exports from Russia have increased by ~10 % during the last 10 years (Bambulyak & Frantzen, 2009), and one third of future Russian oil production is planned to be exported via the Barents Sea (future exports are expected to be 80-150 million tons of oil in 2015). This may lead to 1,150-1,500 tanker trips every year and a similar number of ballast voyages (Dalsøren et al. 2007). Further, the Barents Sea, together with deep waters in the Norwegian Sea and areas outside Lofoten and Vesterålen in the northern Norwegian Sea, contains the largest petroleum resource base in Norway. It is estimated to constitute up to 37 percent of the as-yet undiscovered petroleum resources on the Norwegian continental shelf (Meld.St. 10 2010-2011). The expected increase in the export of oil and gas from the Norwegian production is expected to lead to 400 tanker trips per year[4] (Dalsøren et al. 2007). Vestfjorden in northern Norway is an open and exposed seabight between the Lofoten archipelago and mainland Norway that currently supports passenger transport, cargo vessels and large fishing vessels. The most active shipping in the area is ore transport from Narvik, a major port in northern Norway. Starberg et al. (2004) suggest that in addition to increased transport of oil and gas, other types of transports are also expected to increase in the Barents Sea through 2020.

Transports by ships as well as activities linked to oil extraction can cause oil spills. The oil spills from ships could be due to either accidents or operational discharges. The spills from drilling, exploration or production could either be pipeline ruptures and leakages, or marine blowouts. While oil tanker accidents were more frequent in past decades, the number of accidents has decreased in recent years (IMO 2008) due in part to improvements in tanker design and new policy measures (Jernelöv 2010). Globally, the total volume of oil spilled from operational discharges has exceeded the volume from tanker spills. Operational spills occur when ships wash out their tanks, empty ballast tanks, or spill fuel-oil sludge.

Spills from drilling or pipeline ruptures and leakages are increasing (GESAMP 2007) because the number and length of the pipelines are increasing and existing pipeline infrastructure is aging. Obvious trends are lacking for oil spills due to blowouts, however given improved drilling technology; activity is being performed in deeper and more complicated situations, thus increasing risks (Jernelöv 2010). A general trend of increasing oil spill threat from transport (rather than extraction) also holds for Arctic waters. The main source of risk for oil spills in the Lofoten- Barents Sea area is collisions between ships. (Meld.St. 37, 2008-2009)

[4] Only one active petroleum field is located in the Barents Sea today and one is under development. Snöhvit is a field in Hammerfest basin outside Finnmark, Norway, which started in 2007. It is expected to produce gas for the next 30 years. (Meld.St. 10 2010-2011 p63). The Goliat field, located 85 km northwest from Hammerfest, Norway, is the first oil field to be developed in the Barents Sea.

In the Lofoten- Vesterålen area the forecasted probability of an oil spill is once every 50-100 years, while it is once every 100 years or more seldom in the Barents Sea area (Brude et al. 2011). To limit the probability of major oil spills from ships in the Barents Sea region, minimum sailing distance from the coast and traffic separation schemes and other measures have been introduced. Other measures that have been introduced are requirements regarding the construction of ships, crews and ship owners (Meld.St. 37, 2008-2009). Due to these measures, the expected probability (until 2025) for an accident in the Barents Sea and the Lofoten-Västerålen area is more or less unchanged despite a projected increase in traffic (Brude et al. 2011).

In order to assess the potential damage from an oil spill, it is important to distinguish between damages caused by light and heavy oil products, as well as to consider the location of the spill. On the sea surface and beaches (where birds and mammals live) the damage potential[5] for heavy products is higher than for lighter products due to the stickiness of heavy products. In the water column the impacts are reversed, i.e. heavy products lead to a damage potential that is lower than for lighter products because lighter products mix into the water column leading to harmful effects for fish and other species (Brude et al. 2011).

4. Affected ecosystem services and their economic value

Ecosystem services is a term that helps to explain the ways in which ecosystems are useful to humans. The concept was defined by Daily (1997, p. 3) as *"The conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life"*. Other definitions are for example *"The benefits human populations derive directly or indirectly from ecosystem functions"* (Costanza et al. 1997, p. 253) and "*The benefits people obtain from ecosystems"* (MA 2005, p. 30 in executive summary).

Ecosystems contribute to human well-being in many different ways. The Millennium Ecosystem Assessment (MA 2005) provides a commonly-used categorization (see Figure 3), which led to the 2010 TEEB report (The Economics of Ecosystems and Biodiversity). The purpose of TEEB is to, "*promote a better understanding of the true economic value of ecosystem services and to offer economic tools that take proper account of this value"* (TEEB 2010).

The definitions and categorization of MA (2005) have been applied for example by the Swedish Environmental Protection Agency (Garpe 2008 and SEPA 2009) for the case of marine ecosystems in the Baltic Sea and Skagerrak, and by Magnussen et al. (2009) for the case of marine ecosystem services in the Barents Sea - Lofoten. The four categories of ecosystem services suggested by MA (2005) were provisioning, supporting, regulating and cultural ecosystem services (see Figure 3). Furthermore, they are often divided into

[5] Damage potential is based on the type and amount of oil and the probability for an oil spill. The damage potential is divided into classes (SP1-SP6) where increased class means higher damage potential for environments. See Brude et al. (2011) for a more detailed description of the damage potential levels.

intermediate and final services in order to avoid double-counting when attributing economic values to these services, see for example Fisher et al. (2009) and Boyd (2010).

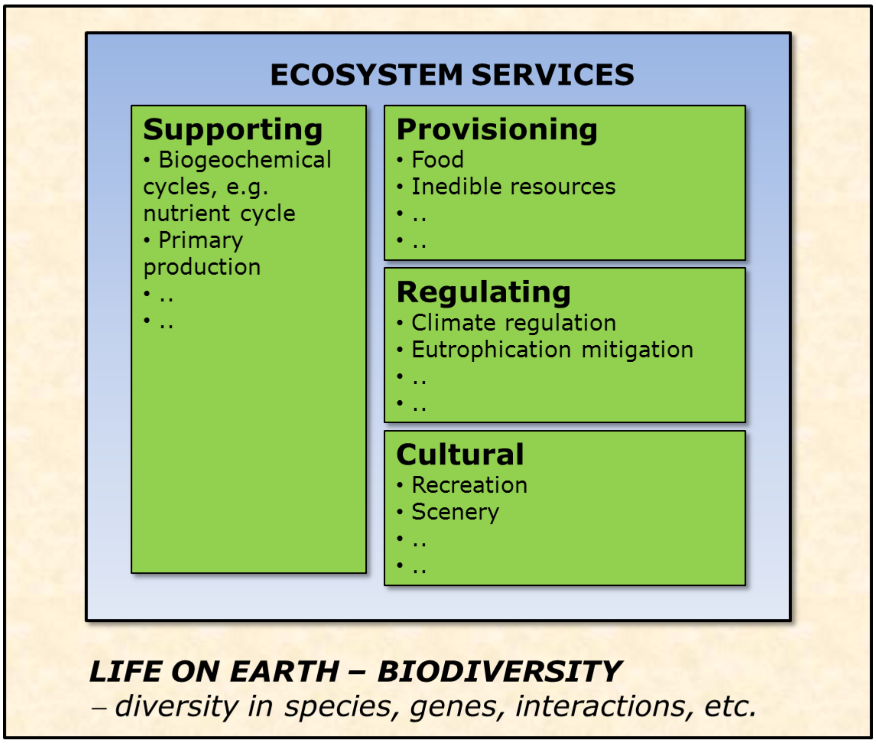

Figure 3. Four categories of ecosystem services.[6]

Of interest for this paper is the effects on ecosystem services in the Lofoten- Barents Sea area from a possible future oil spill, which in turn requires local knowledge. Magnussen et al. (2010) provide a first attempt to map the ecosystem services of the Lofoten- Barents Sea area, and also discuss how these have been, or may be, economically valued. Some of the most important supporting, regulating, provisioning and cultural ecosystem services identified by Magnussen et al. (2009) include:

i) The biogeochemical cycles laying the foundation for primary production, habitats and nutrient dynamics (*supporting* ecosystem services).

ii) The sea's capacity to slow down the accumulation of atmospheric CO_2, i.e. climate regulation (*regulating* ecosystem service).

iii) Provision of food through commercial fishing of species such as cod, Atlantic halibut, Greenland halibut, capelin, coalfish, haddock and shrimp (*provisioning* ecosystem service).

iv) Recreational opportunities such as fishing, sea safari, boating, bird watching and being at the beach. The sea also provides opportunities to enjoy scenic amenities (*cultural* ecosystem services).

[6] Source: Adapted from MA (2005).

A key information need for policy makers is which ecosystem services are most vulnerable -- or at the greatest risk -- in the event of a future oil spill. To our knowledge this specific linkage between oil spill and ecosystem services has not been assessed for the Lofoten-Barents Sea area. However, a similar effort was conducted in 2011-2012 by the Swedish Agency for Marine and Water Management (SwAM, forthcoming) for the Baltic Sea and the Skagerrak under the initial assessment of the EU Marine Strategy Framework Directive (MSFD). The Arctic Games project is focusing on how to value ecosystem services potentially affected by oil spills. Work by ecologists are on-going in order to identify specific services in the study area that may be affected by oil spills, but this paper assumes that the same types of services identified in the Swedish Analysis are likely to be affected by oil spills in the Barents sea.

In SwAM (forthcoming) the effects on ecosystem services due to oil spill are listed for the Baltic Sea and Skagerrak based on work carried out by Garpe (2008) in the project Economic Marine Information by the Swedish Environmental Protection Agency. The ecosystem services for which a documented decrease have been observed are: i) biogeochemical cycling, ii) habitat, iii) food, iv) recreation and v) scenery, i.e. ecosystem services that have been identified as important in the Lofoten- Barents Sea area as well.

Furthermore, in SwAM (forthcoming) are also listed major factors which will determine the *extent* to which various ecosystem services are affected if an oil spill happens. These are: 1) the *size* of the spill, 2) the *environment* in which the spill occurs (different areas are more or less sensitive), 3) the *type of human use* of the area (some areas are more important to human activities than others), 4) the *season* in which the spill occurs and 5) the *type of oil* product spilled. Based on expert judgement, conclusions are made regarding the impact on ecosystem services. It can for example be mentioned that any spill in recreational areas was found to have high impact on recreation in any type of shoreline, and any spill in fisheries areas would have a high impact on food in any type of shoreline. Another conclusion is that a spill from a tanker in the most sensitive shorelines has a high impact on almost all ecosystem services.

Many of the shorelines of the Barents Sea (not the least in the Lofoten area of Norway) constitute sensitive environments with many vulnerable species (e.g. birds, mammals, fish) and the area is also important for human activities such as fisheries and tourism/recreation. Together, this makes the area vulnerable to oil spills. Adding to the risk are the increasing numbers of maritime transports in the Barents Sea (see section 3 on threats).

The human activities of fisheries and tourism/recreation in the Barents Sea are now used to illustrate what some of the potential economic and social impacts of degraded ecosystem services may be. The exemplified ecosystem service related to fisheries is “food” (a provisioning ecosystem service). The exemplified ecosystem services related to tourism and recreation are “recreation” and “scenery” (cultural ecosystem services). See Figure 3 for an overview of the categories of ecosystem services.

4.1 Fisheries

For the Lofoten area of Norway it has been concluded that the main impact of an oil spill would be on fish eggs and larvae (Meld.St.37, 2008-2009). The level of harm would depend upon the factors listed in SwAM (forthcoming), e.g. when and where the spill occurs, fluctuations in fish stock, as well as the properties of the oil. Consequently, the most serious effects on the provisioning ecosystem service “food” can be expected during periods when concentrations of eggs and larvae are high.

As for the economic impacts of degraded fish populations due to oil spill, it can be noted that the fisheries sector in the three northernmost counties of Norway is of high importance. The fisheries-related sectors’ contribution to the GDP of Norway was NOK 15.7 billion (around 2 billion EUR) in 2004 (and nearly the double if spin-off effects are included). The social importance of the fisheries sector can be viewed in terms of employment. In 2004 there were around 15 600 registered fishermen in Norway, of which 7650 lived in the northernmost counties (Meld.St., 2005 and Statistics Norway, 2012).

In the Russian regions around the Barents Sea, the importance of the fisheries sector is reflected by the sector’s share of total regional GDP. In 2009, this share was 8.2 % in the Murmansk region. In the other Russian regions (Karelia Republic, Komi Republic and the Nenets part of the Arkhangel region), the fisheries sector’s share of regional GDP did not exceeded 1 %.

Losses of revenues and employment in the commercial fisheries sectors of the Norwegian and Russian parts of the Barents Sea are examples of the economic and social values which are at risk if an oil spill takes place which would harm ecosystem services, especially if the spill happens during a sensitive time period and in a vulnerable place.

4.2 Tourism and recreation

Serious impacts on tourism and recreation can also be expected in the event of an oil spill. Hotels, restaurants, museums and many more tourism related commercial activities as well as activities such as swimming, angling, bird watching and hiking are all threatened. What is also of importance to many people, and at risk, is the opportunity to enjoy beautiful scenery (cultural ecosystem service) at and around the sea.

The importance of the tourism sector in the three northernmost counties of Norway has increased over the years and is expected to continue doing so. The market value of tourism is considerable. The total tourism related turnover in these counties amounted to NOK 11.8 billion (around 1.5 billion EUR) in 2004 (Meld, St., 2005). Moreover, non-market values linked to tourism and recreation are probably also considerable in Lofoten. The area is perceived as a national treasure for many Norwegians and it is likely that also people living very far away from Lofoten are willing to pay for measures to avoid damages caused by oil spills. These existence values should be taken into account and added to the market value generated by the tourism sector in order to achieve a more complete picture of the total economic value of cultural ecosystem services that risk being lost in the event of an oil spill.

The Russian Arctic area is rather extended and includes regions with different geographical, climatic, cultural and infrastructure characteristics, thus the opportunities for tourism differ between regions. The Murmansk region, mainly located on the Kola Peninsula in the Barents Sea, is the Russian Arctic region which resembles Lofoten the most. The climate is rather mild compared to other Russian Arctic regions due to the warm North Atlantic Current, the northeast continuation of the Gulf Stream. Water resorts and the Khibiny Mountains allow for various recreation opportunities such as fishing, hunting, mountain skiing, mountain climbing, hiking, biking, kiting, whitewater sports, wild berries and mushroom gathering etc. The experience tourism is evidently important in the region. However, culture related tourism is also taking place and ecotourism is becoming more common.

The Khibiny Mountains located on the Kola Peninsula are known for their special flora, many species of which are included in the IUNC Red List of Threatened Species. The Karelia Republic also attracts many tourists by its water resorts and forests. In 2010 it was visited by 480 000 tourists, while the total number of inhabitants is 684 000 (Gov.karelia.ru.). More eastern Arctic regions such as the Chukotsky Autonomous Region and the Sakha (Yakutiya) Republic have less friendly climate and less developed infrastructure and tourism in these areas is not very developed. One illustrative example of this is that the Chukotksky Autonomous Region was visited by only 800 tourists in 2010 (Wek.ru 2011). However, as a whole, the tourism sector in the Russian Arctic region currently tends to develop. Apart from the natural resources and cultural heritage some northern areas have additional value in terms of cultural tourism, being the places of pilgrimage for the Christians. These are for example Solovetsky monastery, Valaam monastery, and Kizhi.

Losses of revenues and employment in the tourism and recreation sectors of the Norwegian and Russian parts of the Barents Sea are examples of the economic and social values which are at risk in the event of an oil spill, especially if the spill occurs in an important area for coastal tourism and during tourism high season.

5. Conclusions and discussion

Several ecosystem services are at risk from oil spills in the Barents Sea, with the largest impact likely to be on biogeochemical cycling, habitat, food, recreation and scenery. However, the impact is highly dependent on contextual factors such as type of oil, location, and season. This paper suggests that based on the economic activities in the area the effect of an oil spill on ecosystem services may be significant. To our knowledge this is the first assessment of potential costs from the oil spill threat in the Arctic based on an ecosystem services approach. Future research should build on these findings. Our analysis suggests that *market* and *non-market* costs might be substantial and that estimating total welfare impacts from oil spills based exclusively on clean-up costs would surely understate the total costs to society from future oil spills in the Barents Sea.

The uniqueness of the Barents Sea -- in particular the warm North Atlantic Current and ice-free winters -- affects the way oil is distributed and degraded in the event of an oil spill. However, the same type of effects on ecosystem services can be expected for oil spills in other parts of the Arctic, although local effects are likely to vary somewhat.

The threat of oil spills in the Arctic is expected to increase due to increased extraction and shipping activities. Shipping is the most prominent threat in the Barents Sea due to expected increases in both tanker and other vessel traffic. Measures to reduce the risk of oil spill damages should target risky activities by reducing the probability of spills occurring, but measures should also target improved response and preparedness. We argue that policy makers should select among alternative measures by weighing the measure's costs and benefits against a no action alternative. The results of this paper, which focuses on affected ecosystem services, provides a key piece of the puzzle: information on the potential benefits from avoiding an oil spill or reducing the impact from spills that occur. The amount and type of human activities in an affected area may affect the total costs of an oil spill. For example, a spill in an important fishery or tourism area will lead to high social costs. The ecosystem services approach to decision making in this article helps to highlight this type of valuable information for designing policy.

Further, drawing on Fejes et al. (2011), it is clear that an ecosystem approach to valuing the damage of an oil spill in the Arctic illuminates the fact that the existing oil spill compensation regime might imply that not all damages are compensated. Fejes et al. argue that this is a problem since efficient policy should make the polluter responsible for damages, in order to stimulate an ‘optimal’ level of prevention. It is generally hard to claim compensation for damages to ecosystem services from an oil spill, and the effect to ecosystem services in the Arctic from an oil spill is potentially large. As a potential policy tool in the area, we suggest that the possibilities to include ecosystem services into the compensation requirements be evaluated.

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