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ACCESS

Arctic Climate Change, Economy and Society

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D5.91 - Report on cross-sectoral synthesis of economic, policy and governance options for sustainable development

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1. Introduction

During the 20th century, human activities have expanded into a globalized society, enhancing the material standard of living for most people on Earth. To achieve this, humans have fundamentally transformed the planet even in terms of a geological timescale into a new era, the Anthropocene. This process has generated global environmental changes like global climate change and massive biodiversity loss that could potentially reach planetary thresholds and tipping points. Hence, while these developments have led to amazing improvements in human well being in the past, they now challenge the future well-being of the human population on Earth (Lenton 2007, Steffen et al. 2007; Rockström et al. 2009, Steffen et al, 2015).

The impacts are substantial on all parts of the planet, but specific impacts of climate change are exceptionally dramatic in the Arctic. In particular, it faces greater temperature increases compared to the Earth as a whole, as the results of the effects of feedbacks and other processes, also referred to as the polar or Arctic amplification (International Arctic Science Committee, IASC, Kattsov et al. 2004). Climate change is expected to transform the Arctic Ocean from a year round frozen sea of multiple year ice to a sea with open waters in the summer and a layer of annual ice in the winter. Such dramatic change will likely have sizeable impacts on marine ecosystems, economic activities, governance, and indigenous and local peoples in the Arctic. The Arctic Ocean is essential for global climate regulation and provides substantial ecosystem services and benefits to humanity also outside of the region - all of these parameters may be affected.

The European Union (EU) project Arctic Climate Change Economy and Society (ACCESS, 7th framework programme within the call Ocean of Tomorrow, 2011-2015) has studied climatic impacts in the Arctic on marine transportation (including tourism), seafood production (fisheries and aquaculture), marine mammals and the extraction of hydrocarbons up to 2040; with particular attention to environmental sensitivities and sustainability. ACCESS has also focused on Arctic governance issues, including the framework UNCLOS (United Nations Convention for the Law of the Sea) and strategic policy options. The following sections provide an overview of the emerging governance landscape in the Arctic Ocean in the light of climate change within the sectors studied by the ACCESS project.

2. Shipping and Tourism

An objective of ACCESS was to simulate the impacts of Arctic climate change on shipping. Since shipping is a derived demand arising from trade in merchandise and raw materials, the project focused essentially on trade. A meta-analysis of the relevant economics literature on trade flows was carried out in order to extract parameters for the development of a simple simulation model. The focus was on the most popular empirical trade model in applied economics literature: the gravity model. Over 100 papers were reviewed (over 700 estimated parameters) and an initial analysis was carried out. A more thorough meta-analysis was carried out for 244 estimates from papers in high ranking journals. This revealed an average income elasticity of 0.84 suggesting that a one percent increase in the combined GDP of two countries would result in a 0.84% increase in trade and a distance elasticity of -0.81, suggesting that a one percent reduction of distance between two trading partners would increase trade by 0.81%. When these estimates would be used in a simulation, where the reduced travel distance, implied by the utilisation of the Northern Sea Route, would result in a substantial increase in trade. However, the estimates published in the literature were found to be systematically biased. Thus a new set of estimates had to be produced, which was not envisaged in the Description of Work of ACCESS. Apart from the bias in the published result another shortcoming in the literature is the almost exclusive focus on the value of trade rather than the tonnage shipped. The new estimates were constructed for both, value and tonnage, given data availability. Using the estimates it is straightforward to carry out a simulation to estimate the potential effect of the ‘opening’ of the Northern Sea Route. The conclusion is that, in general, there is a substantial potential trade effect through the reduction in distance, which would result in significant additional shipping. The shorter sea routes would be expected to increase trade volumes and therefore shipping significantly. However, when comparing the Suez-Route with the 40% shorter Northern Sea Route between Europe and East Asia an increase in shipping will depend on the winter ice conditions in the Arctic, icebreaker assistance and infrastructure along the Northern Sea Route and also on the speed of building required icebreaking ships. Thus, in practice the potential volumes are unlikely to be reached even in the medium term. In the long term, if largely ice free and with the required infrastructure, the route could carry significant traffic.

3. Arctic Seafood Production

Fisheries and aquaculture is one of the most important industries in the Arctic constituting relatively large shares of GDP in some countries (Greenland 15 %, Iceland 10 %). For local communities, fishing, fish processing and/or fish farming can be even more important, and historically, fisheries have often been the main reason for settlement in rural areas in the Arctic

The main objective regarding fisheries and aquaculture activities was to estimate and quantify how climate change impacts Arctic fisheries and aquaculture, and also the livelihood of communities and economic actors depending on these industries.

3.1 Capture fisheries

Research predictions building on the SINMOD[1] model and the IPCC A1B scenario of possible future climate development, show that primary and secondary production can be expected to decrease on an overall basis in the Arctic waters the next 40-100 years. Coupling these results with catch and survey data for Northeast Arctic cod - the most important Arctic fish stock - shows a somewhat changed distribution of the biomass and a probable 10 per cent increase for the coming 45 years. Ocean temperature development can also impact in which waters the aquaculture productivity will be the best, with possible movements northbound. However, uncertainty in many parameters makes it difficult to conclude. For instance, ocean acidification can play a large role for fisheries and aquaculture in the future but its effects over time are difficult to estimate.

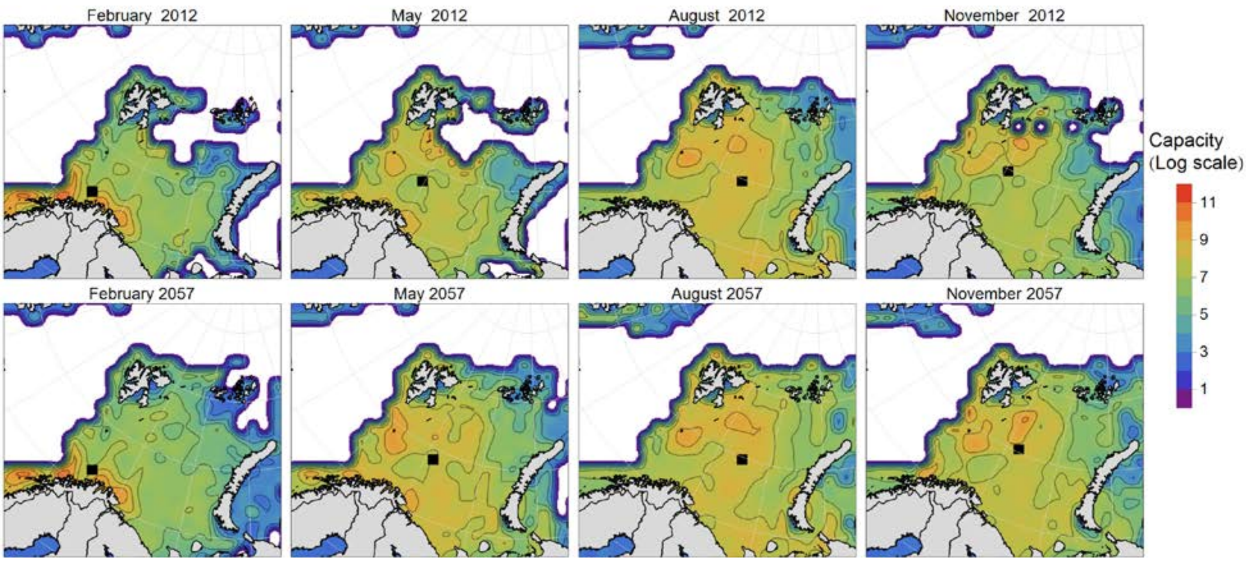

Fig. 1 Geographic representation of potential distribution of North East Atlantic cod in 2012 (upper row) and 2057 (lower row) according to physical and biological environmental constraints. The black square in each panel indicates the centre of gravity of the environmental carrying capacity distribution.

[1] SINMOD is a nested 3D model system that couples physical and biological processes in the ocean. (www.sinmod.no)

Climate change may increase the environmental capacity of holding a cod stock with 10% in biomass terms over a period of 45 years based on SINMOD A1B simulations and initial distribution data from the FishExChange project (2004-2010; Figure 1). Compared with potential impact from other important factors (e.g. management, fleet dynamics and markets, see Eide, 2007 and 2014) the climate change impact turns out to be rather modest. However climate change may also influence other impacting factors, first of all markets, which potentially could have a greater impact on the fisheries than the direct physical changes will have on the stocks and ecosystems.

The distribution area for the cod stock does not seem to change significantly while a slight increase of about 10% in the growth potential is likely to develop over the next 45-year period. Probably this will also be the case for other benthic species in the same area, while the pelagic species vary more in distribution areas also in their normal states. Access to suitable food and physical environment (including spawning grounds) constitute the constraints of spatial distribution of fish stocks. Seafloor bathymetry is a constraining factor not changed by climate, hence benthic species are in general less likely to experience major changes in spatial distribution than pelagic species may be at least as long as climate change does not impact too much on their food.

3.2 Aquaculture

Ice melting will enable farmers to move into new areas but the impact of ice on access to sites is, and will also be in the future, of subordinate importance compared to other factors. Instead future expansion and performance of aquaculture in the Arctic will depend on other regional effects of climate change, i.e. direct and indirect consequences from increased water temperature. Models specifically targeting Norwegian Arctic coasts predict increase in water temperature within the range of 0.5 to 2.5 degrees and, even if detailed impact studies for aquaculture are scarce, the direct effects from such temperature change can to some extent be modelled with fairly good accuracy. This includes the effects on fish growth as well as the economic impacts on the whole industry. The models predict overall positive effects on salmon growth from warming but also negative growth in areas where water temperature becomes suboptimal for salmon. Indirect effects from warming involves changes in storm frequencies and intensities and also changes in occurrence and outbreak of pest species and diseases, which entail large uncertainties.

However environmental conditions will change for sure and that the industry will need to adapt. For enabling the industry to do so there is a need to look over existing regulatory frameworks to find out where and how aquaculture operations can move or how they can change their operations. At present, regulations limit the options Norwegian farmers have to move farms to more favourable conditions. The aquaculture industry's possibility to grow also depends on how other activities like oil extraction, tourism, shipping etc. expand in the Arctic. Especially the oil and gas development have been identified as a potential threat to aquaculture operations. There is a crucial need for regional planning including a multi-stakeholder dialogue (i.e. ecosystem approach).

The aquaculture industry can provide important employment opportunities, especially in remote coastal areas with few alternative livelihoods. However, to understand how this plays out there is a need to identify to what extent labour forces are recruited locally or migrating from outside the region. In addition Arctic aquaculture is connected to international global market systems and through input resources linked to distant ecosystems. This implies that the performance of the aquaculture industry in the Arctic also depends on global market dynamics related to both seafood products and production inputs like aquafeeds. Thus, any effect from climate change on fisheries systems as well as agriculture systems providing raw material for aquafeeds will impact on production costs.

The Arctic Region is currently undergoing multiple changes that will impact differently on different sectors and stakeholders. The role aquaculture will play for economic growth, improved human well-being and sustainable development depends on how it can adapt to new conditions and also if and how it will be included in the broader integrative approach that is needed for successful governance of the Arctic. It is therefore important to examine the role and potential of benefit sharing mechanisms in the contribution of aquaculture development to economic growth, human wellbeing and environmental sustainability.

3.3 Climate change effects on product markets for capture fisheries

ACCESS studied two potential ways by which climate change can impact Arctic fisheries through changed economic conditions: increased fuel taxes and changes in demand. First, authorities might levy or increase taxes on fossil fuel consumption to reduce greenhouse gas emissions. The resulting increase in costs for fishermen would vary for different fleet segments, since different fishing technologies vary with respect to fuel consumption.

Second, changes in demand may influence ex-vessel/first hand prices for fish and, hence, fishing behaviour and operations, if major consumer preferences shift towards species and technologies that are caught in an environmental friendly manner. If a price premium (or antithetical; a price penalty) a can be obtained on seafood that in a credible and transparent way can be shown to come from sustainable managed species (no overfishing) and are caught with the least impact on climate (carbon footprint) and the ecosystem.

The aggregate effects from such cost or income induced changes on the fishing fleet's behaviour are hard to predict. Vessel profit's sensitivity to cost increases will strongly affect the fishing behaviour, and those closest to "break even" will be the first to alter fishing patterns (to reduce costs or increase income). In well managed fisheries, where fishing capacity/effort is aligned with the size of the biomass, a considerable resource rent should be acquired, buffering against the need for immediate change in action. In the long term however, industry actors will adjust their actions (and inputs) to maximise profit, hence, cost saving and income increasing technologies and practices will be implemented.

3.4 Social concerns related to climate change impacts on fisheries[2]

Fisheries provide livelihood and income for many people in Finnmark county (Norway) and Murmansk region (Russia) engaged in the primary production sector, aquaculture, in processing, packaging, marketing and distribution, ship maintenance and recreational fishing. In addition a service sector provides supply, tourism, retail, transport, and administration. Although the fishery sector and fishing efforts in Northeast Norway and Northwest Russia has very distinct characteristics, in which these neighbouring regions depend on each other economically. They cooperate on different sector activities, sharing coastal activities like fish landing, trade and labour flows around common resources like King Crab and salmon.

Fish catch size, and landing location have a most significant impact on the economy of the two advanced fishing nations – Russia and Norway – and neighbouring countries. Finnmark fishermen use their competitive advantage of having coastal vessels close to fishing grounds. Norwegian longliners compensate their limited mobility with higher efficiency in harvesting scattered fish population. Murmansk fleet traditionally uses high mobility of trawlers and targets mainly distant water. They

[2] Further details are available in deliverables D3.41 and D3.42 of ACCESS, which used anthropological methods including substantial fieldwork in Northern Norway and Northern Russia, consisting of first hand participatory observation, semi-structured interviews with several types of actors and analysis of secondary sources like academic literature, media, etc. as well as two stakeholders workshops organized by Arctic Centre (UoL, A.Stammler-Gossmann) in 2014 (*'Arctic Ocean and coastal communities: Changes, challenges and livelihoods'; 'Puzzling about sustainability')*.

compensate longer distances to the fishing grounds and higher fuel costs for the large scale fleet with larger volume and higher catch value.

For Norway, the second biggest seafood exporter in the world, it is essential to also land fish in domestic harbours to contribute to the national industry. However lack of workers in the processing industry is one of the biggest challenges in Northern Norway where strong dependence on foreign employees brings further changes in the traditional processing activities and communities.

In Russia good harvesting performances of the Murmansk fleet do not necessarily contribute to better regional landing statistics because many Russian vessels choose to land fish in foreign ports and fish landed in Murmansk is not necessarily processed in the region. Processing plants in other Russian regions can attract fishermen with more lucrative prices because they have lower costs for operating processing facilities and labour force, making Murmansk less competitive. Hence Murmansk can suffer from fish shortage, which generates internal conflicts within the processing sector. While regional workers in the processing industry require guaranteed catch quota for the sector, occupational organizations of fishers have no incentives to sell fish under the market prices.

Every important fisheries decision is embedded in the societal context and has social outcomes, being part of everyday practices or a field of political struggle. Resource users may react differently from what resource managers intended. For example salmon farming on the Norwegian coast started as a government-supported activity to save wild salmon and create jobs. However it is unclear for today's local fishermen whether aquaculture still supports maintenance of biodiversity or threatens the viability of wild species.

Distant water fishing was once an attractive and lucrative job in the Soviet planned economy but sharp decline of the sector beginning of the century has considerably decreased that prestige. Currently increasing cod quotas are shifting that image upward again though. The delay in developing the Stockman gas field may also contribute to this recent change. Similarly Norwegian fishermen now experience more prestige probably due to higher incomes and living standards.

International activities and transboundary cooperation contribute to the growing indigenous awareness that fishing is a fundamental right of Coastal Sami in Norway and an integral aspect of Sami culture, despite today's marginal economic contribution of sea salmon fishing (Lam and Borch 2011).

The Arctic society developed around fishing activities is extremely resilient to the change resulting from the large natural variations in the environment that usually pertain in these regions regardless of climate change. (Acheson 1981). The fishing societies can handle 'good' or 'bad' fishing periods due to natural variation. A common strategy to adapt to uncertainty is economic diversification such as switching or combining several occupations. Availability of alternative activities in other economic sectors like transportation is particularly important for the distant water fishing community in the Murmansk region. A large city also offers more alternatives for work than tiny Norwegian communities.

However, current change is different and includes ongoing and projected biophysical changes due to climate change, new emerging fields of maritime activity, the prospects of more intensive uses of the sea water, and the increased presence of new non-Arctic actors in the Arctic affairs – altogether, bringing growing concerns about the impact of these developments for local fishery and fishers alternative livelihoods. Social consequences of climate change may materialize locally as unemployment, occupational change, migration or reconsidering the boundaries between different economic sectors and between groups.

3.5 User groups' and stakeholders' behavioural responses to ecosystem changes

There are large uncertainties surrounding direct impacts of climate change on fish stocks (See D3.11) and indirect impacts going through market changes (See D3.31). The way this uncertainty plays out is likely to also influence the way in which fishing activities and consequently fish stocks respond to changes in geophysical conditions, policies or economic factors. Fish stocks may change incrementally or they may respond in a non-linear/abrupt and substantial way. In general management can more easily deal with linear changes than with non linear and abrupt responses (Crépin et al 2011). A growing literature on the economic implications of abrupt environmental change reveals that the outcome to some extent depends on how resource users like fishermen respond to changes in the stock and perhaps most importantly how they deal with the rivalry among resource users (Mäler et al 2003; Crépin and Lindahl 2009).

3.6 Concluding remarks

Most research concerning the effects of climate change on Arctic sea food production and Arctic stakeholders assumes that the rest of the world is not changing, which is particularly unlikely when it comes to climate change. ACCESS results indicate that we should expect some change in plankton biomasses and distribution but these changes do not seem very dramatic although large uncertainties surround them. Climate change is likely to have a larger impact on fisheries through its impacts on global markets. Other elements likely to impact seafood production include changes in: market demand (global change in tastes, awareness); market supply (technological development); policy and conflicts; natural variability in ecosystem dynamics; development of other sectors of activity in the Arctic; behaviour of coastal communities.

The substantial uncertainties surrounding the effect of climate change on ocean production and the complex interactions influencing outcomes in Arctic fisheries makes it difficult to guess whether Arctic fisheries will be able to take an increasing share of world sea food production or not. However unlike many other places in the world Arctic fisheries are relatively well kept today. This gives some hope that if climate change impact turns out to have positive impact on biomass production, the industry may be able to profit from that without undermining the sustainability of that production, provided the market structure doesn't change too much.

4. Resource Extraction

4.1 Natural gas

The production of natural gas in the Arctic, while having some modest regional effects, is certainly not a game changer for Europe. The effects on import diversification are miniscule as economic possibilities on competing markets, especially Asia, are more tempting for natural gas producers. Also the impulses for economic development remain small and confined to the producing countries or selected energy intensive sectors.

4.2 Crude Oil

The conclusion we drew regarding the production of natural gas in the Arctic is also true as a general conclusion for European Arctic offshore oil: while having some modest regional effects, is certainly not a game changer for Europe. Even though oil production and the accompanying price decrease acts as a small stimulus program for European economies, this effect is not confined to Arctic oil, where it is nevertheless connected with especially detrimental environmental risks.

4.3 General observations

Both oil and gas production from the Arctic Ocean are being discussed currently as a solution to diminishing fossil fuel supply and energy security worries in Europe. We conclude that neither European Arctic offshore natural gas, nor European Arctic offshore oil are a game changer for Europe. While production in the European Arctic might in the long term alleviate some effects of severe supply disruptions, attractive markets especially in Asia attract what small realistic production we might witness in Greenland, the Norwegian Barents Sea, or even the Russian Arctic.

Nevertheless, we do project some effects of increased offshore production of hydrocarbons in the European Arctic. We project that under certain conditions, oil and gas projects are viable in existing natural gas locations in Norway and Russia, in Greenland, and in the case of oil production, should the necessary discoveries be made. Nevertheless, most natural gas would be shipped to Asian markets. The economic unviability of new production sites with large step-out distances in Norway and Russia highlights the importance of existing infrastructure for economic development in the High North, which serves as a catalyst for future development.

Given additional Arctic gas or oil production, we project a positive effect on GDP in the producing countries, even larger in the case of oil compared to gas in Norway and about the same for Greenland/Denmark and Russia, with some modest second-round effects for downstream sectors. Regarding countries outside the Arctic, we find by comparing regions that are active on both the gas and the oil market, such as the Middle East (ME) or North Africa (NAF), and comparable oil and gas scenarios, that the effects of oil production in the Arctic are considerably larger than those of natural gas production. This reflects the higher integration of the corresponding global or, respectively, regional markets. The same integration also leads to smaller price decreases in Russia and Denmark/Greenland for oil compared to natural gas. Any hopes that additional natural gas production might lead to reductions in CO_2

emissions do not realize. We find an increase in emissions for both fuels and all scenarios.

4.4 Pollution in the Arctic

Implementation of future International Maritime Organisation (IMO) regulations reducing fuel sulphur content leads to reductions in SO_2 emissions and therefore less production of sulphate aerosols. For the period 2004–2030 this results in a net positive RF in contrast to cooling from present-day and historical ship emissions. This is mainly due to lower predicted sulphate in the future inducing less cooling. Warming from tropospheric ozone produced from NO_x emissions as well as direct and indirect (deposition on snow) warming from BC are also important. Significant RF is found during the melting season in the Arctic in spring and also in the late summer when transit traffic occurs.

In the future shipping may also shift from southerly routes to the Arctic. Fuglestvedt *et al.* (2014) examined impacts of a shift from the Suez route to a new Arctic transit route. This leads to higher emissions in the Arctic, and reduced emissions along the Suez route. With future decline of ice coverage, Arctic transit times become shorter and there is a net fuel saving leading to a net reduction of global shipping emissions Different atmospheric conditions and sensitivity to emissions at high and low latitude determines the resulting climate impacts of short lived air pollutants. In contrast, the impacts of CO_2 and other long-lived greenhouse gases do not depend on emission location. Overall, the shift in traffic leads to an initial global warming due to short-lived pollutants (mainly due to warming from reduced sulphate, indirect aerosol-cloud effects and deposition of BC on snow) followed by cooling on longer timescale (> 150yrs) due to CO_2 emission reductions.

These local emissions are already having significant impacts on local and regional levels of air pollutants, either in the vicinity of the platforms or in coastal regions. Current and potential future impacts on climate have also been assessed. Present-day shipping and petroleum extraction lead to cooling and warming, respectively whereas increases in Arctic shipping as well as shifts from southerly routes lead to warming in the future, at least in the short-term. These results pose a challenge to policy makers. Reducing CO_2 emissions is the key to an effective climate policy whereas reductions in air pollutants may either lead to climate warming or cooling. With the predicted growth in local sources of air pollution in the Arctic impacts on health may increase and require new assessments about which sources to mitigate.

4.5 Oil spills in ice

Oil development in the Arctic is an international news issue from environmental concerns to economic indicators. When oil prices are high, there is increased interest in Arctic oil development, and when oil prices drop, development resources are redistributed based on economics. Over the period of the ACCESS project, the price of Brent Crude, one of the benchmarks of crude oil pricing, has gone from fairly high levels to comparatively low levels, as shown in Figure 2.

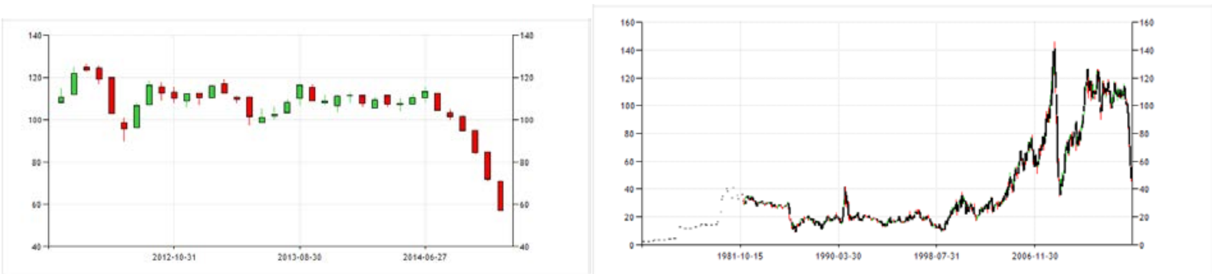

Figure 2 Evolution of the price of Brent Crude oil between 1981 and today. Source: http://www.tradingeconomics.com/commodity/brent-crude-oil accessed 17 Jan 2015.

So what can we do? - Preparation and planning. We prepare for potential oil spills in a variety of ways. Spill statistics, drills and monitoring indicators are first steps. In the ACCESS project, indicators are discussed in D2.91, 3.71 and 4.71. Spill statistics from other areas of development and shipping give us a scale of spills and their likelihood in order to estimate equipment needs, response requirements and logistics. Drill scenarios and response plans are developed for areas of development, coastal areas, ports and harbours. Drills range from small activities where participants in a room work through issues to multiple commands with equipment being brought on-scene and simulating use. Tracking spill statistics over long periods allow us to estimate the statistical likelihood of a spill and track if these spill statistics are changing up or down. Tracking oil spill related indicators provides critical baseline documentation of pristine conditions or background levels of contamination. This information is critical during spill clean-up to set appropriate end points in the clean-up process. Port of Refuge is legally defined for safety of human life, but since we know that offshore spills, such as the Deepwater Horizon and *T/V Prestige*, oil much more shoreline that spills closer to shore, we should consider how important port of refuge will be for sensitive Arctic species and Highly Migratory Species.

Among a range of solid assessments and consolidation of state of the art knowledge of infrastructure and environmental contexts for resource extraction in the Arctic, it was concluded that whilst much work has been performed, knowledge gaps still exist in a number of key areas. These include modeling, detection, and the recovery of oil spills in ice-covered waters, the provision of recommendations for the design of an environmental observing system, tailored to improving our monitoring of the Arctic marine environment. Furthermore, the identification of ecologically vulnerable areas and existing conservation plans for the most rare species in the areas of possible oil & gas development is required, and questions of sound pollution and the endangerment of marine mammals need to be further addressed.

4.6 Noise and marine mammals in the Arctic Ocean

Different economic activities in the Arctic Ocean have through the last 100 years propagated ever more noise, which might impact the marine ecosystem and especially the marine mammals. This noises' effect on marine mammals are under scrutiny in many WPs. In WP 3, however, efforts are undertaken to map the distribution of Arctic marine mammals, and the impact on it from climate change. In that respect, the threats on traditional whaling (i.e. indigenous whaling) from climate change is examined.

The sea environment has always been filled with noise (from animals and physical processes), although the last hundred years have seen the introduction of many anthropogenic sources that are currently contributing to the general noise budget of the oceans. The extent to which noise in the sea impacts and affects marine ecosystems has become a topic of considerable concern to the scientific community. Anthropogenic noise, including acoustic signals necessary to study the marine environment, can interfere with the natural use of sound by sea organisms. For geophysicists, seismologists and oceanographers, sound is the most powerful tool available to determine the geological structure of the seabed and to look for oil and gas reserves deep below the seafloor. As far as defence is concerned, sound is also used to detect long-range targets. On the other hand, unnecessary or unintentional noise sources, i.e. sources that are associated to specific activities but contain no information (shipping for instance) are constantly introduced in the marine environment.

The question is whether human-generated noise may interfere with the normal use of sound by the marine animals (i.e. chronic effects that may affect the long-term ability of marine animals to develop their normal activities, reproduce, and maintain sustainable populations) or cause physical harm to them (i.e. acute effects that may compromise the short-term ability of these animals to survive).

ACCESS has addressed the Arctic Ocean noise issue in different work packages (WP2, WP3 and WP4) understanding that this is a transversal problem that concerns shipping, fisheries and Oil & Gas operations.

Across the different work packages, the presence of marine mammals in the Arctic region was compared with anthropogenic activities. The environmental impact of interest here was either an increased acoustic contribution, reducing the communication or sonar range of many cetaceans (as detailed in deliverable 4.52), and increased human presence in areas that used to be relatively calm, possibly causing displacement. Three types of information were collected for the area under study: 1) Presence of marine mammals; 2) Presence of exploitation platforms; 3) Shipping traffic. This information was then combined with sound exposure modelling, as performed under deliverable 2.4.3, to estimate the acoustic impact on the environment. It also helped identifying zones that are important to the animals and affected by human activities; these zones could be designated as Marine Protected Areas in the future.

5. Cross sectoral interactions and impacts of climate change

5.1 Climate change, ecosystem impacts and the need for marine protected areas

5.1.1 Impact of climate change on ecosystem services generated within the Arctic Ocean

ACCESS analysed the effects of climate change on marine species and the resulting potential change in ecosystem services relevant to ACCESS economic sectors. The focus of this section is on economically important fish species: Atlantic cod, Arctic Char, Herring and Capelin; as well as others species on which they depend in the food chain, for example Calanus spp., (Wassman et al. 2006). The species contributing to the generation of different types of ecosystem services in the Arctic, in the context of fish production, are presented in D3.11 and D 5.71.

Species	**Ecosystem services (Provisioning, supporting, regulating, and cultural)**

Calanus glacialis	Major food source in the Arctic food chain (Supporting)
Calanus finmarchicus	Important food source in the Barents Sea (Supporting)
Polar bear (*Ursus maritimus*)	Top predator (Regulating), Tourism, Education and science, scenic (Cultural)
Capelin (*Mallotus villosus*)	Economically important species (Provisioning). Important food source (Supporting). Fishing culture (Cultural)
Atlantic cod (*Gadus morhua*)	Economically important species (Provisioning)
Herring (*Clupea harengus*)	Economic species (Provisioning). Food source for other fish species (Supporting). Fishing culture (Cultural)
Arctic Char (*Salvelinus alpinus*)	Economically important species (Provisioning). Fishing culture (Cultural)
Red king crab *(Paralithodes camtschaticus*)	Economically important species (Provisioning).
Snow crab (*Chionoecetes opilio*)	Potentially economically important species (Provisioning).

Table 1 Ecosystem services, relevant for the ACCESS economic sectors, generated via specific species. The table is uses the classification of ecosystem services made by the Millennium Ecosystem Assessment (MA 2005).

Figure 3 illustrates the relationships between some of the most important species in the system and the impact of climate change and economic activities on them as well as their role as providers of ecosystem services. A more detailed account of the relationship between the ecosystem services associated to these species, and the possible consequences of climate change, can be found in D5.71.

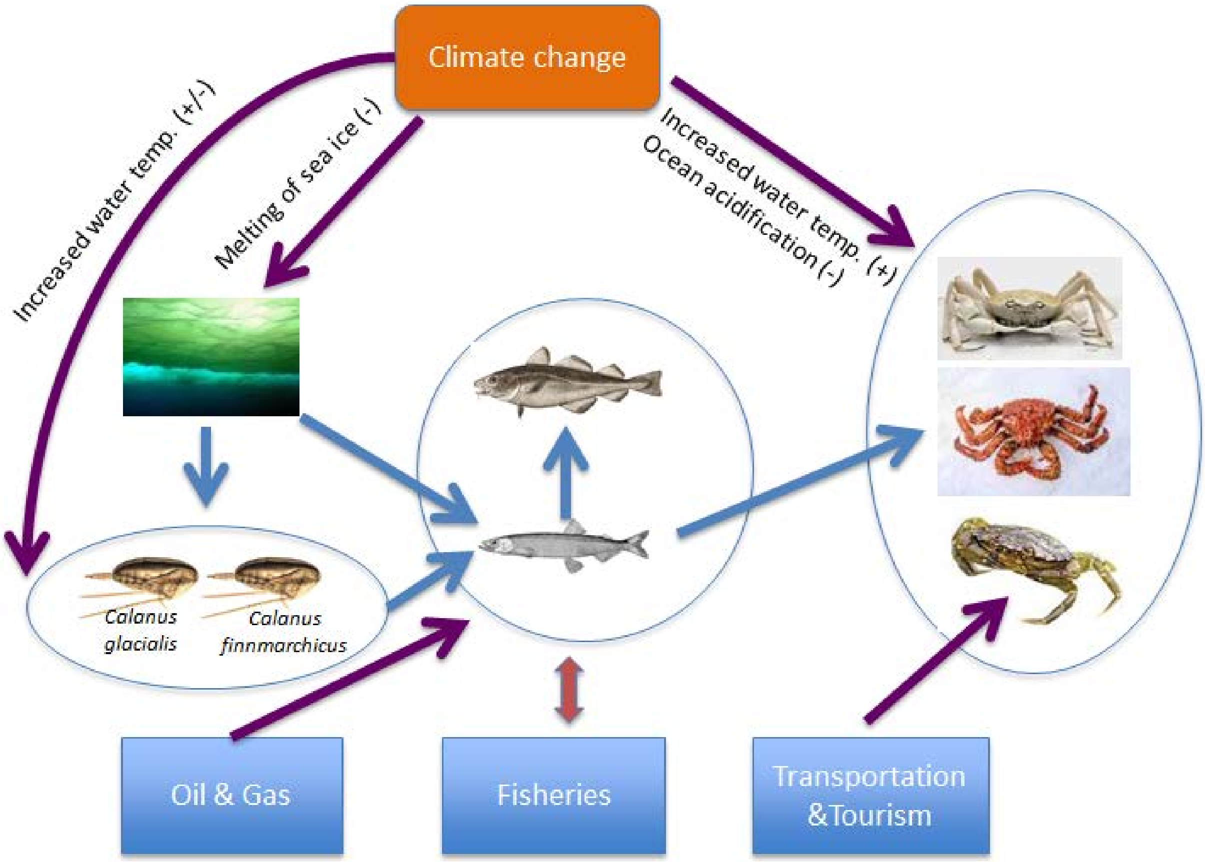

Figure 3 Interaction between different species of the Arctic marine ecosystem, and links to climate change and economic activities.

ACCESS compared the LMEs of the Barents Sea with the presence of marine mammals and anthropogenic activities through several maps (D4.54, "Identification of ecologically vulnerable areas"). The environmental impact of interest here was either an increased acoustic contribution, reducing the communication or sonar range of many cetaceans (as detailed in deliverables D4.51 and D4.52), and increased human presence in areas that used to be relatively calm, possibly causing displacement. Three types of information were collected for the area under study: 1) Presence of marine mammals; 2) Presence of exploitation platforms; 3) Shipping traffic. This information can be combined with sound exposure modelling, as performed under deliverable D2.43, to estimate the acoustic impact on the environment.

The Marine Spatial Planning tool (Deliverable D5.82) can be used to help identify ecologically sensitive zones that are important to animals and may be increasingly affected by human activities. Figure 4 shows an example from the Barents Sea, an area of rich living natural resources, while also experiencing growing exploitation of hydrocarbon resources, and an increase in maritime transport. The need for spatial planning for sustainable development in this region is clear, and as well as possible user-user conflicts; user-environment conflicts are highly probable too. Figure 4 shows one of several areas of heightened ecological significance in the Barents Sea, as well as the distribution of Minke Whales, just one of many cetacean species found in the region. As well as increased acoustic disturbance, pollution is a significant threat to marine wildlife and habitats too. This example illustrates the need for integrated spatial planning across all sectors. The marine spatial planning tool can be used to help identify zones which could be designated as Marine Protected Areas in the future.

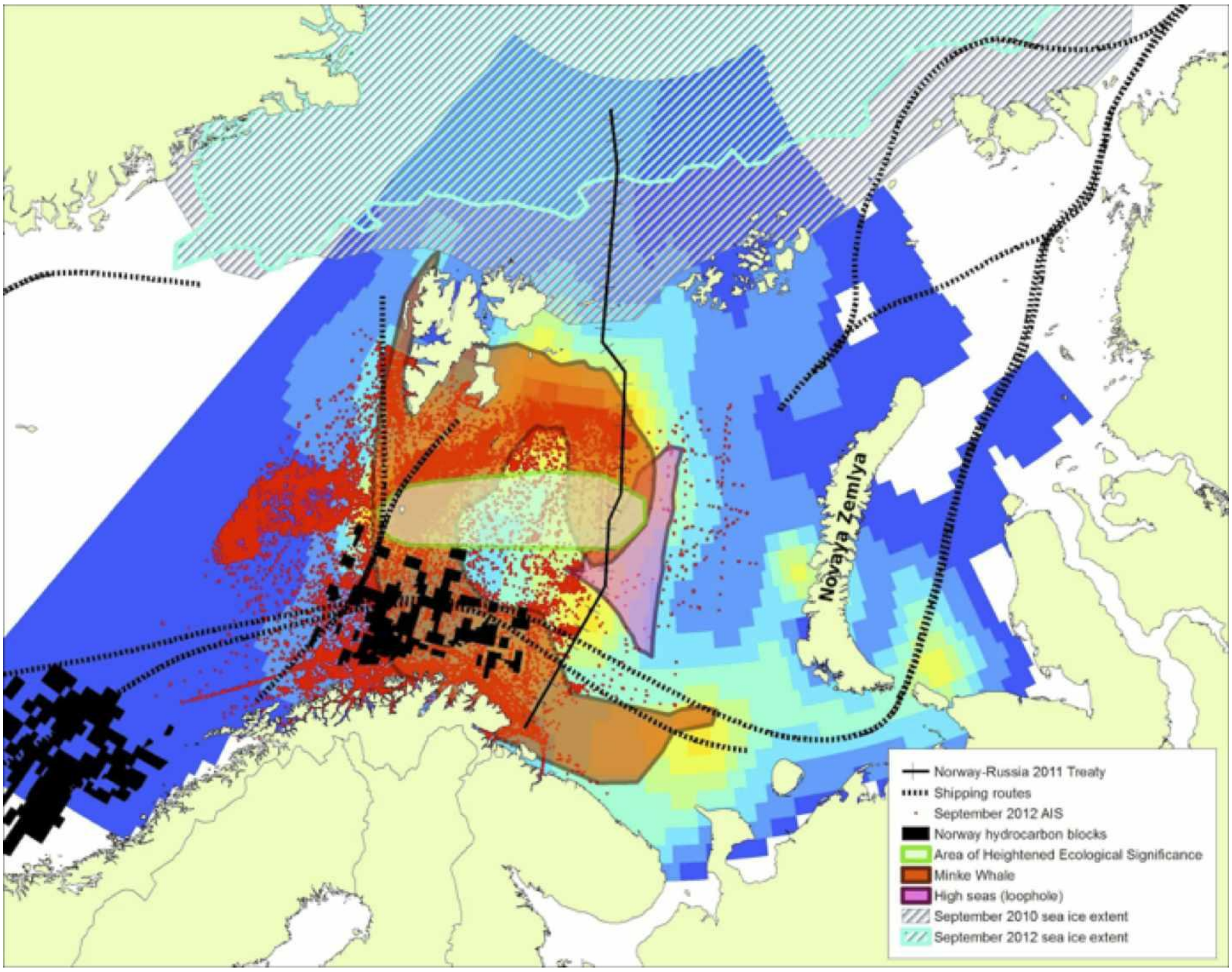

Figure 4 ArcGIS map from the MSP tool showing different economic sectors in the Barents Sea in relation to an identified ecologically significant area. Coloured background grid shows predicted cod stocks for August 2057 (from D3.11) – cold colours show low density, while warm colours show higher density. Red dots show vessel AIS data from September 2012 (from D4.54), while dashed black lines show principal shipping routes. Maritime boundary between Norway and Russia is shown by the black ticked line, while the pink polygon shows an area of High Seas. Norwegian hydrocarbon exploration blocks are shown by black rectangles. Also shown are Minke Whale distribution, and 2010 and 2012 summer sea-ice extents. (Figure source: D5.82)

5.2 Impact of climate change on local and indigenous peoples[3]

5.2.1 Introduction

Indigenous peoples in the Arctic have a long history of dealing with harsh conditions and environmental changes. Traditional knowledge and profound connexion with nature have fostered adaptation strategies. Today, however, the rapid pace of climate change, its impacts and the potential for significant shifts in the economic and cultural landscape raise concerns about adaptive capacity and how to ensure sustainability in the fragile Arctic. The perceptions of indigenous peoples provide a valuable human perspective essential to comprehend the implications of the evolving environmental conditions in the Arctic. These changes are significant for the native peoples, regions neighbouring the Arctic and global citizens.

Arctic indigenous peoples represent about 400 000 individuals, spread around the Arctic and mostly living close to the Arctic Ocean. The human dimension in the Arctic is diverse in terms of culture, governance, demography and economy. Settlements range from modern cities to small villages with indigenous peoples forming part of the communities (Figure 5, Indigenous population in the Arctic regions). Regions have combinations of contemporary formal economies such as services and resource extraction as well as traditional economies based on fishing, hunting and herding. Indigenous peoples hold vast knowledge and experience that are an essential contribution to sustainable development in the Arctic.

[3] The content of this section arise from the summary of observations arising from the ACCESS Indigenous Peoples workshop - Paris, July 2014.

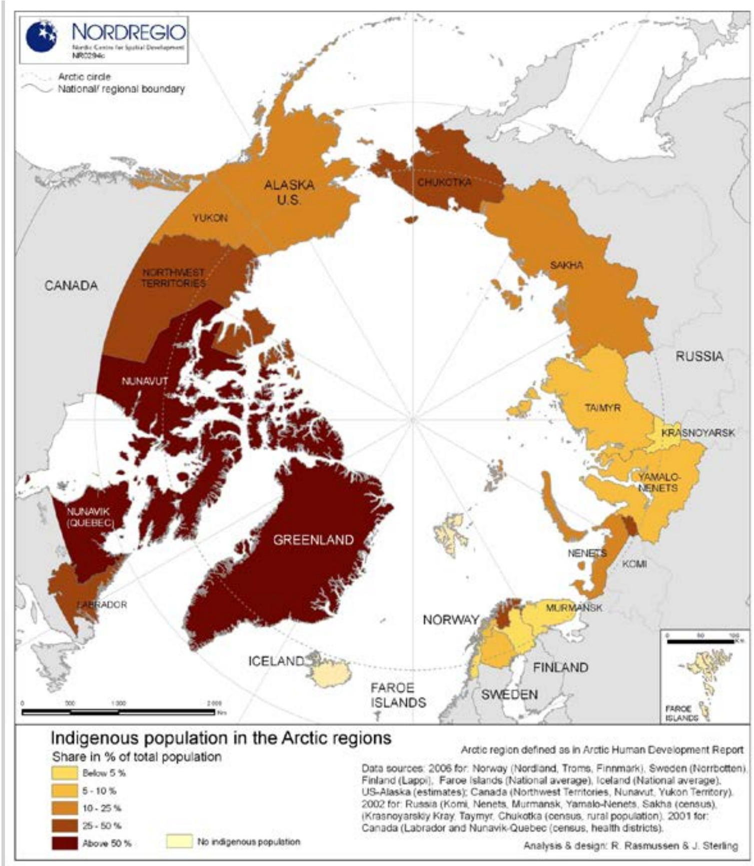

Figure 5 Distribution of indigenous population in the Arctic regions (Nordic Centre for Spatial Development; http://www.nordregio.se/en/Maps--Graphs/01-Population-and-demography/Indigenous-population-in-the-Arctic-regions/)

5.2.2 The human context of Arctic climate change: resilience and adaptation to climate change in the face of existing challenges

Climate change is accelerating the rate and dimensions of changes threatening traditional ways of life but also has the potential of offer economic benefits.

Through millennia of observation and experience, the indigenous peoples of the Arctic have developed extensive knowledge systems about the environment under changing climatic conditions as well as ways to adapt. Today, however, the rapid pace of climate change, its impacts and the potential for significant shifts in the economic and cultural landscape raise concerns about adaptive capacity and how to ensure sustainability in the fragile Arctic. It is reported that "*in many cases, climate change magnifies existing societal, political, economic, legal, institutional and environmental challenges that northern peoples living in resource dependent communities experience and negotiate in their everyday lives*"[4].

5.2.3 Indigenous peoples' environmental knowledge

Knowledge is an important aspect of self-determination. As expert observers of environmental conditions, Arctic indigenous peoples have numerous indicators embedded in traditional knowledge to measure changes in the environment. Enhanced communication and exchange between indigenous peoples' and the science community can benefit both parties. Traditional practices and knowledge are invaluable for adaptation approaches and the development of strategic choices on Arctic issues. This is further evidenced by the wide interest knowledge co-production is attracting in international discussions[5]. Such knowledge sharing may however call for "cultural translation", employing a combined approach of social and natural sciences.

5.2.4 Food security and health

Several representatives of Arctic indigenous peoples' group attending an ACCESS workshop in July 2014 highlighted the link between climate change impacts and the health and availability of both aquatic and terrestrial harvested food resources. More extreme weather conditions impinge upon Indigenous Peoples' food production: stronger wind can keep

[4] Lene Kielsen Holm, presentation of the « Inuit Pinngortitarlu – The People and the Environment » project.

[5] UNESCO, Chantier Arctique Français, IPCC.

fishermen longer onshore, with direct impacts on the economy. Ecosystem changes resulting from ocean acidification may also affect harvest and cultural practices. These impacts pose challenges for Arctic Indigenous people's food security and increase the risks of chronic diseases.

Studies[6], including ACCESS research[7], have shown that atmospheric pollution in the Arctic from short lived climate forcers (SLCFs) such as black carbon represent an important threat for Arctic Indigenous Peoples health.

5.2.5 Communication and dissemination

There are varying degrees of difficulty in communication throughout the Arctic. Transport is expensive and constrained. While new Information and Communication Technologies (ICTs) and connectivity offers some Arctic communities solutions for enhanced self-determination through learning and training[8], in other areas there is no or limited broadband internet access and connections are slow. Also, older people may not possess the skills required to take advantage of the empowering tools of the internet. Communication in all its forms can be further inhibited by multiple languages and insufficient translation options.[9]

[6] For example : Arctic Council (2013) *Recommendations to Reduce Black Carbon and Methane Emissions to Slow Arctic Climate Change*. Arctic Council Task Forces on Short-Lived Climate Forcers. David Leonard Downie, Terry Fenge (2003) *Northern Lights against POPs: Combatting Toxic Threats in the Arctic.* McGill-Queen's Press – MQUP or Thompson , S. (2005). *Sustainability and vulnerability: Aboriginal Arctic food security in a toxic world*. In: Breaking Ice: Renewable Resource and Ocean Management in the Canadian North (F. Berkes, R. Huebert, H. Fast, M. Manseau and A. Diduck, eds.) University of Calgary Press, Calgary, pp. 47-69.

[7] See ACCESS policy brief n°2 Shipping in the Arctic, links to air pollution and climate change (2014).

[8] Notably by bridging communication gaps between remote communities and information from the rest of the world

[9] Hence the importance of suporting such initiatives as the Arctic Council's Arctic Languages Vitality Project or the Saami language retention initiative based at Tromso University (http://giellatekno.uit.no/index.eng.html).

Dissemination through a variety of mediums and in lay language is the ideal and radio is considered a good way to reach communities and has been successful in disseminating information in a trusted manner in many communities.

5.2.6 Effective participation of Arctic indigenous peoples in governance

The dichotomy between traditional management practices of natural resources and national or international regulations was raised by several representatives of indigenous groups participating in the ACCESS workshop. It was felt that some regulations impact negatively livelihoods or the ability to adapt. ACCESS research (D5.51) indicates that the decision-making processes surrounding seal population management as well as the sustainability of Inuit traditional economy calls for the joint involvement of Arctic indigenous representatives, seal product manufacturers and scientific advisors.

Communication and capacity building have been identified by ACCESS as fundamental to the participation of indigenous peoples as stakeholders in the Arctic. In March 2014 this view was echoed by the European Parliament[10] and later by the European Commission, Gap Analysis Report[11].

ACCESS found that Arctic indigenous peoples' participation in governance is highly diverse. Although there is no global system of governance for these populations, indigenous communities in the Arctic are among the most active in the world in defence of their rights. Nevertheless, while aboriginal populations are increasingly aware of and encouraged by international recommendations for their inclusion in

[10] European Parliament, Joint motion for a Resolution on the EU Strategy for the Arctic (2013/2595(RSP)), Articles 41, 42 and 44 :

www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//NONSGML+MOTION+P7-RC-2014-0229+0+DOC+PDF+V0//EN.

[11] www.arcticinfo.eu/en/gap-analysis

decision-making processes, their representation in traditional national institutions is still considered by them as insufficient.

While indicating recognition of indigenous peoples' political rights on the international stage implementation of guidelines derived from international instruments relating to participation of indigenous populations in decision-making, rights and means of political influence in the Arctic are dependent on the decisions of national governments. Such guidelines are likely to encourage national indigenous organizations to pursue their demands for increased participation in decisions affecting them. The Arctic Council is seen as an encouraging supranational instrument but it should be remembered that, as Permanent Participants, indigenous peoples do not have a vote and lack "*full participation in the organization's working groups and activities*", notably because "*they are required to raise the funds domestically*"(Baldesarra 2014).

Within Arctic states disparities exist for the participation of indigenous peoples in decisions affecting them. It is difficult to distinguish a global « pan-Arctic » trend in the evolution of indigenous political participation. The Self-Government Act, places Greenland as the Arctic country where indigenous peoples have the highest means of participation in governance decisions. However indigenous groups of the Russian Federation (besides regional disparities) seem to enjoy a less developed means of political influence.

Five out of seven Arctic states have not ratified ILO Conventions 169, and it is likely that the issue of land rights stands as a major obstacle. Apart from Greenland, whose government is responsible for the inshore and offshore mineral resource area (including oil and gas resources), when land and resource management is concerned, most indigenous peoples have no or only limited decision making power. Indeed, while the cultural aspects of the indigenous demands are usually more easily taken into account by the states in which indigenous peoples live, the "hard" part of their demands deals with land ownership, resource management on their territories and self-governance.

Progress in participation in decision-making, political representation and development, does not mean that the concrete situation for individuals and their individual well-being actually progresses. An important element also revealed for this assessment was the potential gap existing between indigenous leaders' claims and local communities' needs.

5.3 Arctic infrastructures[12]

Changes in the physical environment combined with a great abundance of natural resources in the Arctic Ocean, are likely to provide policy planners and political decision-makers with a wide array of challenges that will require extraordinary measures at the national as well as at the regional and international levels. Among the challenges is planning integrated pan-Arctic infrastructures to accommodate global activities in the Arctic Ocean in a sustainable way to preserve its pristine and sensitive ecosystems.

The Arctic Ocean already has already flipped from a persistent system with multi-year sea-ice throughout the year to a variable system covered mostly by first-year ice during the winter and open water during the summer. For the Arctic Ocean system, the global question is how to respond to its transformation during the 21st century?

The answer relies, in part, on an integrated strategy to assess the risks as well as the opportunities that are emerging from the environmental state-change in the Arctic Ocean and its potentially exploitable resources. Impact responses further require prioritization in terms of their urgency and feasibility so they can be implemented across the Arctic Ocean in a timely fashion. To be sustainable, such an integrated infrastructure system for the new Arctic Ocean will involve the combination of fixed,

[12] This text is based on Paul Berkman and Alexander Vylegzhanin (Environmental security in the Arctic Ocean, Springer) and adapted to ACCESS.

mobile and other built assets (including observing, communications, research and information systems) as well as regulatory, policy and other governance mechanisms (including insurance).

In the context of ACCESS, integrative perspectives are stimulated by systems analyses. Ecosystem based management strategies are being applied to evaluate interactions among dependent and associated species (including invasive species) and habitats in the Arctic Ocean. Additionally there are integrative tools such as Geographic Information Systems (GIS) that are being applied for Marine Spatial Planning (MSP). Risk analyses and impact assessments further elucidate known or anticipated consequences of system changes. Common understanding of the risks and common acceptance of the mitigation and adaptation strategies ultimately facilitate common agreement about policy pathways for sustainable infrastructures. In this integrative process, gaps analyses are being applied to reveal strengths, deficiencies and overlaps among legal solutions. ACCESS recognized gaps in environmental governance, indigenous peoples representation, fisheries management, offshore hydrocarbon activities and shipping.

The Polar Code recently released by IMO is a good example of such a challenge. Taking into account the specific environmental conditions proper to the Arctic Ocean and in order to meet appropriate standards of maritime safety and pollution prevention, in November 2014 the IMO adopted a binding Polar Code covering the full range of design, construction, equipment, operational, training, search and rescue and environmental protection issues relevant to ships operating in Polar Waters.

6. Existing regulations and governance options as a response to climate change

The rates of climate change in the Arctic are uncertain and the responses in natural systems as well as economic, political and social are hard to predict. The Arctic governance system will have to deal with such pervading uncertainty. The Arctic Ocean coastal states and the wider international community face the enormous challenge to develop and maintain governance systems able to respond effectively to change and meet the needs of stakeholders.

The effects of change in the Arctic Ocean with potentially the largest relevance in the context of governance are a reduction in sea ice, reduced sea ice thickness, increased sea ice mobility, sea-water temperature rise and extreme weather focusing. Possibly the most significant of these in terms of governance is the retreat of sea ice. Receding sea ice offers increasing opportunities for human activities in the Arctic Ocean, which also increase threats to the fragile ecosystems and to the way of life of the local populations.

Here we identify the gaps in the existing governance regimes, discuss pan-Arctic governance and present our observations on governance options for Arctic marine shipping, tourism, resource extraction, fishing and aquaculture in the light of climate change over a 30 year period.

6.1 Fisheries

6.1.1 Capture fisheries

The main gaps and limitations in the existing policy and regulatory framework include:

1. High seas RFMO coverage;
2. The limited application of the UNFSA to only straddling and highly migratory fish stocks, hence lack of regulation around shared and anadromous fish stocks;
3. Lack of data to inform governance;
4. Large variations and sometimes insufficiencies in coastal state regulations.

Within the foreseeable future, any changes in fisheries regulation are likely to fall within EEZs - and thus be subject to national rather than international regulation. Arctic coastal states will have to develop national regulation to deal with vessels seeking new fishing opportunities and enforce, and if necessary amend, existing regulations dealing with port state controls and Illegal, Unreported and Unregulated (IUU) fishing.

6.1.2 Seafood Production – Aquaculture

Aquaculture activities fall entirely within coastal waters and hence the implementation of governance regimes for aquaculture falls to individual states. Aquaculture in the Arctic is currently taking place mainly in Norway (predominantly salmon production) with some activity in Iceland, Russia, Canada (Quebec and Newfoundland), US (Alaska), Sweden and Finland although the latter two comprise mainly small volumes of freshwater species.

Even with improved governance, global capture fisheries have only a limited capacity for increased expansion. Consequently, aquaculture is the only option for obtaining more food from aquatic environments. High uncertainty surrounds changes in direct effects such as from storm frequencies and intensities and indirect effects such as diseases and pest species, and freshwater runoff (D3.21). The complex array of environmental and socio-economic changes facing northern communities requires an inclusive and integrated multi-stakeholder approach to aquaculture governance. Reviews of, for example, existing licensing, animal health, and construction of facilities regulations will be necessary in the light of climate change effects.

There is potential for transboundary governance problems as aquaculture is taking place in both Norway and Russia. Legislation, operating standards and practices, particularly on hygiene and pathogen transfer, should be coordinated to limit the risk of disease transfer and development. This is an issue of high importance due to the current and predicted rapid growth in Russian aquaculture[13].

Ultimately, the management of aquaculture will be more important than temperature. In Norway municipal authorities decide where aquaculture is permitted so growth and adaptation will be largely dependent on these decisions. The temperature range across which aquaculture is taking place is relatively wide. The economic sustainability of the activity will depend on the management from both the industry and authorities, particularly of pathogen risks. Important areas of governance include technical standards, monitoring and compliance, sound farm location principles to limit risk of disease transfer between farms and adequate allocation of resources for vaccine and treatment research and development. These areas are also linked to potential climate change effects via, for example, storm strength and frequency and pathogen habitats. How the negative impacts of aquaculture on other sectors are balanced against industry growth is a further illustration of the importance of management within this sector.

6.2 Marine transportation

Decreasing sea ice is the most significant aspect of climate change in relation to shipping in the Arctic Ocean. Both intra and trans-Arctic Ocean routes, at least in theory, offer possible future seasonal alternatives to existing shipping routes. A further driving force for Arctic shipping, in addition to sea ice retreat, is development of natural resource development in the Arctic. The continuing development of natural resources requires Arctic marine transport systems to move cargoes out of the Arctic to global markets. A good indication of this driver is that nearly all the commercial carriers along the NSR today are bulk carriers, tankers and liquefied natural gas (LNG) carriers.

[13] There is likely to be a rapid development of aquaculture as Russia pushes towards self-sufficiency in food. The goal of the Russian Food Security Doctrine, to achieve self-sufficiency in various food products, includes fish products (82%).

The main governance challenges, identified by ACCESS, facing marine transport in the Arctic, now and over the next three decades are:

- The unification of the application and enforcement of ship rules. (IMO mandatory rules and standards for ships operating in polar waters, and coastal state rules such as Russia's NSR rules and Canada's Canadian Arctic Pollution Prevention Regulations.)
- Prediction of transport scenarios and understanding of the lengths of the navigation seasons for the NSR and NWP.
- Inclusion of international economic interests (Arctic natural resource developments) as well as regional / local administration governance and coastal communities (for example local economic and fishery interests); environmental protection and pollution prevention; spatial planning.
- Insurance, liability and compensation arrangements for all Arctic Ocean shipping and marine operations

Predictions that polar shipping will grow in volume and diversify in nature over the coming years (see, for example PAME, 2009; International Chamber of Shipping, 2014; Keil, 2013) have prompted the development, by the International Maritime Organisation (IMO), of a mandatory Polar Code which, after lengthy negotiations, will be fully adopted (SOLAS, MARPOL and STCW amendments) by April 2015. The IMO Polar Code is to be implemented by 1 January 2017.

The development of a mandatory International Code of safety for ships operating in polar waters will fill some of the gaps in existing international shipping rules and standards. The development of the Code has been via amendments and additions to the existing SOLAS[14] and MARPOL[15] instruments. Previously, the only mandatory

[14] SOLAS: IMO International Convention for the Safety of Life at Sea 1974
https://treaties.un.org/doc/Publication/UNTS/Volume%201184/volume-1184-I-18961-English.pdf

regulations covering shipping were global in nature and took no account of the uniquely harsh conditions encountered in polar waters. The new Code will cover design, construction, marine safety equipment, operational, training and environmental protection issues. When in force the Code will ensure that ships transiting or operating in the Polar Regions must meet prescribed standards of construction and materials and crews must have the stipulated level of training. The new Code includes mandatory measures covering safety part (part I-A) and pollution prevention (part II-A) and recommendatory provisions for both (parts I-B and II-B).

As the Code is formulated as a goal-based standard, the details have to be interpreted by individual states. As a consequence it is likely that national and local governance will exert a strong influence. Similarly, enforcement will be by individual states. The insurance industry may gain some reassurance from the requirement for an ice regime methodology to be included on Polar Shipping Certificates. The mandatory Code will require evaluation of risks based on a risk index according to the ice conditions likely to be encountered in the geographical areas through which the ship is intending to travel. The Polar Code is a seminal advance for the marine insurance industry, the ship classification societies, shipbuilders, ship owners and investors.

While filling many of the earlier gaps in shipping legislation in the polar environment the new Polar Code does not cover all polar marine safety and environmental protection issues.

Some issues remain be addressed. There is little if any discussion within the new Code of the impacts of climate change. There is currently no Arctic-specific ballast water convention; however, a global oceans ballast convention is near ratification**.**

[15] MARPOL: IMO International Convention for the Prevention of Pollution from Ships
http://www.imo.org/KnowledgeCentre/ReferencesAndArchives/HistoryofMARPOL/Documents/MARPOL%201973%20-%20Final%20Act%20and%20Convention.pdf

Further significant gaps in regulation of Arctic shipping relate to insurance, liability and compensation in the event of accidents. The current international system for compensation for pollution damage caused by ship-source pollution is fragmented and limited. The geography of the Arctic Ocean as a closed sea makes trans-boundary pollution impacts one of the most difficult issues facing the legal and policy community (Rosen and Asfura-Heim, 2013). Separate conventions address oil pollution liability and compensation from tankers (CLC)[16]; damages from the spill of bunker fuel carried in ships other than tankers, such as cargo ships; and hazardous and noxious substance spills from ships[17]. The 1992 Fund Convention, which is supplementary to the 1992 CLC, establishes a regime for compensating victims when compensation under the 1992 CLC is not available or is inadequate. None of the conventions address damage to the high seas beyond national jurisdiction.

6.2.1 Arctic tourism

The number of tourists visiting the Arctic is predicted to rise in the future. This is due to a range of factors including increasing accessibility due to sea ice retreat and the desire to visit pristine landscapes as well as the desire to visit before they disappear ("doom" tourism). A future driver may also be the redistribution of tourists to higher latitudes and altitudes as temperatures in traditional tourist destinations come be increasingly high (Hamilton et al., 2005).

While the IMO provides generic guidance for vessel security in ice areas there is no specific legislation relating to tourism in the Arctic Ocean. The World Wide Fund for

[16] **International Convention on Civil Liability for Oil Pollution Damage (CLC). Adopted 29 November 1969; Entry into force: 19 June 1975; Replaced by 1992 Protocol: Adopted 27 November 1992; Entry into force: 30 May 1996. http://www.iopcfunds.org/fileadmin/IOPC_Upload/Downloads/English/Text_of_Conventions_e.pdf**

Nature (WWF)[18] and the Association of Arctic Expedition Cruise Operators (AECO)[19] provide voluntary guidelines for tour operators and tourists visiting the Arctic but these need to be carefully integrated with the Polar Code and other developments in order to maintain an appropriate regulatory framework. The Arctic Council has renewed its efforts to analyse and promote sustainable tourism in the Arctic by establishing its Arctic Marine Tourism Project (AMTP). The result of the project will be a best practices document to be put before the Arctic Council Ministers for consideration in spring 2015.

6.3 Oil and Gas

ACCESS Report D4.61 found that state regulatory authority may be invested in a single government body or, more commonly, divided between multiple ministries and departments - making deciphering the regulations a complex task. Hence to be effective the regulatory regime must be coordinated between the different authorities, particularly in areas such as oil spill and emergency response. A spectrum of state regulation exists in Arctic coastal states ranging from prescriptive requirements to performance-based regulation with most regimes containing a combination of both. Performance-based regulation has advantages in promoting innovation and positive development, while a more prescriptive approach provides greater certainty regarding requirements and facilitates easier monitoring and enforcement. In view of the newly emerging nature of oil and gas activities in the Arctic it seems that the application of a performance based regulatory system would be preferable to a prescriptive one designed originally to be applied under different operating conditions. In addition, prescriptive or very detailed regulations may lead to operators meeting only the minimum requirements and no more. This may have the undesired

[17] International Convention on Civil Liability for Bunker Oil Pollution Damage (BUNKER). Adopted 23 March 2001; Entry into force: 21 November 2008
[18] http://wwf.panda.org/what_we_do/where_we_work/arctic/what_we_do/tourism/
[19] http://www.aeco.no/

effect of limiting efforts toward continuous improvement. More details on these issues are available in D4.61.

6.4 Governance summary

While gaps were identified for some activities (for example pan-Arctic shipping, Table 2) and in some geographical areas, for other activities and in other geographical areas the regulatory systems were well developed, as for example the Norwegian hydrocarbon industry.

SECTOR	**MAIN GAPS AND LIMITATIONS**
Marine transport	No binding IMO standards relating, for example, to ballast water exchange, antifouling or emissions in the Arctic Ocean
	No ships' routing system
	No legally binding Arctic Construction, Design, Equipment and Manning (CDEM) standards including any covering fuel content, anti-fouling and ballast water treatment standards
	No mandatory insurance requirements for Arctic shipping
	International liability and compensation regime is fragmented and limited. Separate conventions address pollution from tankers, bunker fuel from non-tankers, and hazardous and noxious substances from all ships
	No convention or protocol addresses damage to the high seas beyond national jurisdiction
	Difficult for coastal states to enforce stringent safety standards against vessels not flying their flag
	IMO guidelines for ships operating in Arctic ice-covered waters do not apply to fishing vessels, military vessels, pleasure yachts or smaller cargo ships
	No mechanism for monitoring, inspection, enforcement of regulations across the Arctic Ocean
Arctic Marine Tourism	No binding regulations relating to tourism in the marine Arctic
Fishing	Other than NEAFC there are no RFMOs covering the high seas in the Arctic Ocean

SECTOR	**MAIN GAPS AND LIMITATIONS**
	UNFSA only applies to straddling and highly migratory fish stocks
	Coastal state regulations are not harmonized and may be inadequate
	Translation of international law into national legislation by Arctic Ocean coastal states and other states with regard to their roles as flag states, port states, market states, natural or juridical persons[2] may not be adequate
	Insufficient knowledge of Arctic Ocean ecosystems and the impacts of climate change to ensure application ecosystem-based management approach
Aquaculture	Limited understanding of impacts of climate change on aquaculture make it difficult to develop ecosystem-based legislation
	Differing and non-harmonized regulatory regimes
Oil and gas	Current regulatory regime varies between states and is fragmented
	Regulation relies on coastal states to implement, monitor and enforce
	No convention addresses liability and compensation arising from offshore oil rigs, pipelines and production systems
General	Gaps in navigational aids, charts, infrastructure, as well as search and rescue and clean-up capacity
	National standards for holding individuals financially accountable for pollution incidents vary widely between states. The possibility to legally limit liability by carrying only enough insurance to meet minimum statutory liability limits – which may be inadequate
	Liability difficult to establish in incidents with trans-boundary impacts

Table 2 The main gaps and limitations in the existing Arctic Ocean regulatory system

6.5 Existing pan Arctic governance

Changes to the historical governance framework in the Arctic Ocean are emerging with an Arctic or at least a polar focus. An example of the latter is the development by the IMO of a mandatory International code of safety for ships operating in polar waters – the Polar Code. Examples of Arctic-specific agreements include those negotiated under the auspices of the Arctic Council, the 2011 Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic (Arctic SAR)[20] and the 2013 Agreement on Cooperation on Marine Oil Pollution Preparedness and Response (Arctic EPPR)[21]. While not a treaty-based organization, the signing of these two agreements, negotiated under the auspices of the Council, may indicate a strengthening of its capacity to respond effectively to the challenges of climate change and a move from a policy *shaping* body to a policy *making* one (Molenaar *et al*., 2014).

Further gaps in the existing regulatory regime are two-fold, one is lacunae in the law and the other is ineffective implementation of existing regulations. In addition, the non-ratification of various important international treaties by some Arctic Ocean coastal states is also an issue. For example, the US have not yet ratified the UNCLOS nor the CBD - although the US considers that it acknowledges its responsibilities and enjoys its rights in the Arctic marine environment as part of its adherence to customary law. Many of the international agreements relevant to the marine Arctic are framework instruments rather than regulatory conventions and, as such, lack details on implementation. It is the implementation by individual states that gives weight to these agreements. However, their effectiveness can be undermined by poor implementation.

Some issues, such as pollution and shipping, are inter-related and some resources are shared across national borders, for example hydrocarbon resources and fisheries, so discreet national or sectoral approaches to governance may not be appropriate. This challenge to effective governance is compounded by lack of harmonization of regulations between Arctic Ocean states. Oil and gas governance

[20]http://www.arctic-council.org/index.php/en/document-archive/category/20-main-documents-from-nuuk.
[21]http://www.arctic-council.org/index.php/en/document-archive/category/425-main-documents-from-kiruna-ministerial-meeting.

options (D 4.61) and climate change effects on aquaculture (D3.21) highlight two sectors where such limitations are apparent.

An ACCESS report (D5.21) reviewed five potential ways forward for future Arctic Ocean governance. These comprised: (A) the establishment of a single over-arching instrument, an Arctic Treaty, similar to the Antarctic Treaty; (B) the strengthening and augmenting of the powers of the Arctic Council to encourage this regional body to establish binding legislation over the Arctic Ocean; (C) the modification, enhancement and amendment of existing regulations and instruments to create a range of standardised regulations; (D) the specific targeting of areas of existing regulations where chronic failure is predicted due to the effects of climate change; (E) retain the *status quo* and maintain without revision the existing complex and diverse panoply of regulatory systems.

These options fitted within a spectrum of governance (Figure 6) extending between the extremes of "fully integrated" and "fully fragmented", corresponding to a level of intervention from option (A) to option (E), above, respectively.

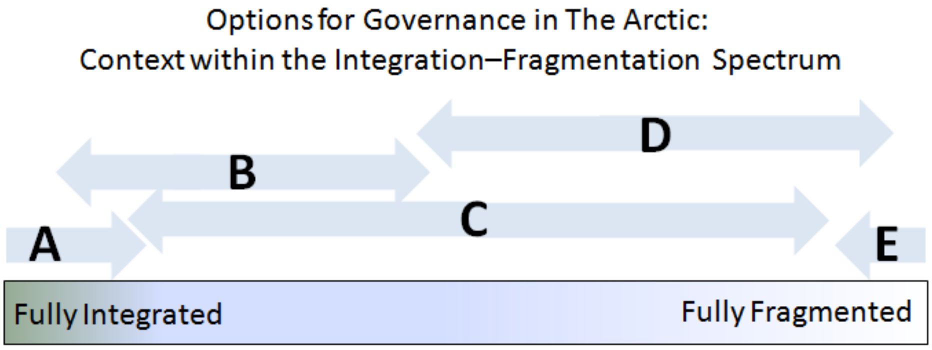

Figure 6 Integration-Fragmentation Spectrum[22] indicating the position of governance options (A) Arctic Treaty; (B) strengthening the Arctic Council; (C) standardisation of existing regulations and instruments; (D) amendment of regulations particularly vulnerable to climate change; (E) *status quo*.

[22] The integration-fragmentation spectrum is a concept developed by Keohane and Victor (2011) in relation to the climate change. The spectrum comprises a continuum of international regulatory

Following the report's review of current thinking and commentary, the authors of D5.21 deduced that a most pragmatic and actionable scenario would be the pursuit of a 'middle ground' of prescription and guidance to expand and strengthen existing instruments and agreements. In effect, this is what is occurring, almost by default. Such a hybrid system would be positioned somewhere in the middle of an 'integration-fragmentation spectrum' (Figure 7). Expanding and strengthening existing instruments and agreements avoids the need to develop entirely new arrangements, which would potentially involve lengthy negotiations, by building on the existing governance frameworks. Protracted policy making risks being out-of-date before it is implemented.

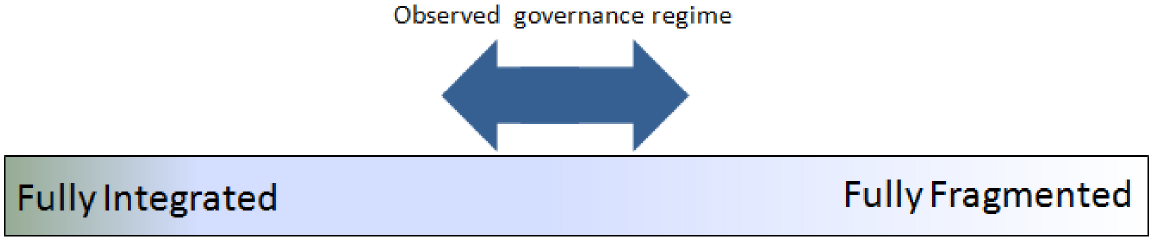

Figure 7 Integration-fragmentation spectrum showing position of observed (current) hybrid governance regime

instruments, at one end a single integrated legal instrument, at the other, highly fragmented arrangements and in between these extremes lies a range of regimes and regime complexes.

The conclusion that expanding and strengthening existing instruments and agreements is the best approach to governance in the Arctic raises clear questions as to how this might best be achieved:

i) How can better coordination amongst the current sectoral and regional approaches be achieved to address future governance needs?

ii) Will better coordination among these approaches will be adequate to meet these needs?

iii) Is a more comprehensive, top down approach required?

The latter question has already been answered - at least from the perspective of the five Arctic coastal states[23].

Identification and analysis of the existing and emerging governance landscape for the Arctic Ocean has allowed ACCESS to consider the implications for governance of changing environmental, social and economic conditions and high uncertainty in this region. These are summarised in Table 3 below. This work can provide a foundation for the ongoing analysis of Arctic Ocean governance and, in addition, provide a potential template for such work in regions of similar of high uncertainty and rapid change.

General observations:	High levels of uncertainty are associated with the environmental and social changes underway in the Arctic. To be able to respond within

[23] The Illulissat Declaration, Arctic Ocean Conference, 28th May 2008. The Declaration, issued by the five Arctic Ocean coastal States, asserts that *"(B)y virtue of their sovereignty, sovereign rights and jurisdiction in large areas of the Arctic Ocean the five coastal states are in a unique position to address*" the emerging "*possibilities and challenges*" in the Arctic Ocean. Furthermore, the signatories consider that the Law of the Sea "*framework provides a solid foundation for responsible management by the five coastal states and other users of the Ocean* ..."and "*see no need to develop a new comprehensive international legal regime to govern the Arctic Ocean*".

	appropriate time scales governance mechanisms must be adaptive and any new instruments or amendments to existing instruments need to be relatively quick to put in place as ponderous and protracted policy making risks being out-of-date before it is implemented. The existing range of approaches to environmental governance from formal to informal ad hoc cooperation offer possible responses to rapid changes. A single pan-Arctic Treaty, similar to the Antarctic Treaty, now seems unlikely. Our observations suggest that no single approach is emerging but rather a range of approaches from formal, legally binding (e.g. the new Polar Code) to ad hoc, local, non-standardised arrangements. While policy / governance decisions need to be agreed on by most (if not all) parties to ensure compliance this should not result in acceptance of the lowest standards. Ad hoc regional or bilateral agreements may offer a more efficient path to solutions than legislatively cumbersome treaties. Treaties may produce weaker commitments than a soft law regime. As soft law agreements are not legally binding, states may be more willing to include substantive commitments and governments may also be more willing to take innovative approaches. A 'soft law' approach, which potentially take less time to develop and are more likely to be adhered to, may be better suited to rapidly changing environment. Increasing interest and activity in the Arctic from non-Arctic States makes a broader dialogue essential. Arctic Council needs to retain dialogue with non-Arctic States since in particular international law requires this for High Seas fisheries and Seabed ABNJ. Transboundary, ecosystem-based approaches to governance are essential. Standardisation / harmonisation of regulations is an ideal – in particular for transboundary resources, living and non-living, as well as other activities. For this to succeed there needs to be a commitment at a national level. Marine spatial planning offers one method through which this can be approached. The changing environmental, economic, social and policy landscapes in the Arctic make it essential that governance arrangements are regularly monitored to gauge how changes in governance may affect / are affecting Arctic users / stakeholders /regional bodies / indigenous peoples.
Indigenous peoples	Processes need to be established or strengthened to ensure meaningful consultation with stakeholders, including indigenous peoples and user groups during development or revision of policy instruments. Participation of indigenous peoples in knowledge sharing and decision

	making processes should in particular be ensured by adequate access to means of communication. National and industry interests should not be given precedence over those of the environment and indigenous and local populations and the policy-making process in the Arctic should incorporate traditional knowledge.
Cross-sectoral	Need development/strengthening of legislation relating to underwater noise in the Arctic
Shipping	Gaps in the mandatory Polar Code need to be addressed: invasive species (ballast water/hull-fouling), noise and air pollution – including black carbon. There is a need for a mandatory regime to be developed for insurance to cover vessels operating in the Arctic Ocean. Such a regime should ensure that all ships carry adequate levels of insurance which take account of the difficult operating and recovery conditions in the arctic. Such a regime also should ensure that ship owners are not able to evade responsibility. Regulation of tourist activities in the Arctic, and associated infrastructure, requires urgent action. The existing voluntary guidelines will need to be carefully integrated with the Polar Code and other regulatory developments to maintain a coherent regulatory framework.
Fisheries and aquaculture	Limited understanding of impacts of climate change on aquaculture makes it difficult to develop ecosystem-based legislation. Aquaculture legislation, operating standards and practices, particularly on hygiene and pathogen transfer, should be coordinated across borders to limit the risk of disease transfer and development.
Oil and gas	There is a need to develop of a fund for compensation in the event of pollution from hydrocarbon activities. There is a need to develop legislation relating to damage from oil pollution in the high seas. Regulations relating to Arctic offshore oil and gas activities need to be strengthened and harmonized while taking into account differences in local conditions in terms of type of resource, infrastructure in place, local and indigenous communities.

Table 3 Key findings and observations (ACCESS D5.41)

7. Management tools

As sea-ice coverage in the Arctic diminishes, the potential for future economic exploitation increases. Failure to plan for cross-sectoral management could potentially lead to negative environmental impacts and user-user or user-environment disputes or conflicts. The Arctic Ocean is surrounded by five coastal states and contains a large area of high seas. Resources and ecosystems extend across political boundaries, while the effects of climate change will be seen on a regional scale. Truly effective governance needs to be considered at a multi-national, Pan-Arctic scale.

ACCESS delivers three management tools aimed to ease integrated approaches to management: a Marine Spatial Planning Tool covering the whole Arctic (6.1), a framework for integrated ecosystem based management (6.2) and a set of indicators of sustainable development (6.3). These tools were designed to offer a non-political, pan-national data integration system for the purposes of planning proposed or unforeseen events or activities. This allows the development of informed planning strategies, and provides a comprehensive framework within which scenarios of governance (as well as events/activities) can be analysed and tested.

7.1 Marine spatial planning tool

Marine Spatial Planning (MSP) provides a practical way to organise the use of marine space and the interactions of its users, both spatially and temporally. MSP aims to balance the demands for development with the need to preserve ecosystems, while also achieving social and economic objectives. An effective Marine Spatial Plan should apply Ecosystem Based Management, balancing ecological, economic and social goals and objectives towards sustainable development. The plan should be integrated across all relevant sectors and agencies, both nationally and regionally, and should be adaptive and anticipatory. MSP needs to be an iterative process that learns and adapts over time.

The Intergovernmental Oceanographic Commission of UNESCO (IOC) has produced a 10-step approach to Marine Spatial Planning (Ehler & Douvere, 2009), while the EU funded Monitoring and Evaluation of Spatially Managed Areas (MESMA 2009-2013) Programme has produced a generic framework (Fig. 8) to monitor and evaluate spatially managed areas (Stelzenmüller *et al.*, 2013).

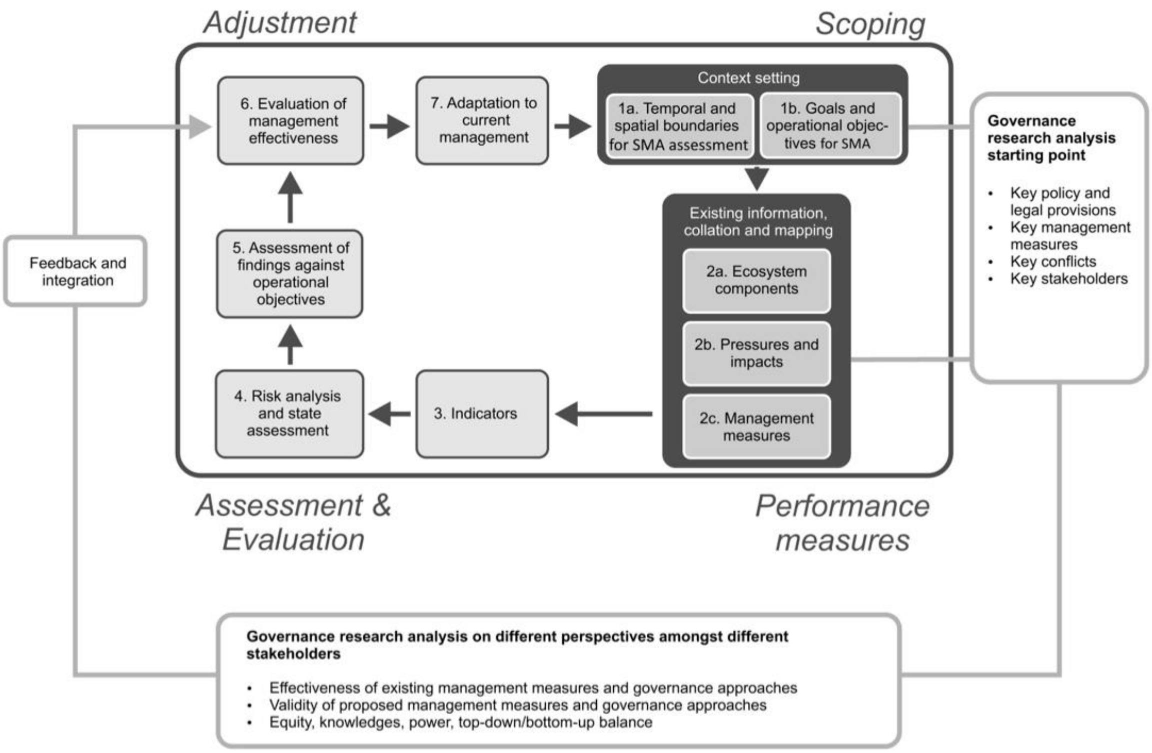

Figure 8 Flowchart showing the proposed MESMA framework with seven key steps to monitor and evaluate spatially managed areas (from Stelzenmüller *et al.*, 2013). The engagement of stakeholders is important at all levels.

ACCESS has developed a MSP tool, enabling the integrated study of information from all sectors under review in ACCESS, and the associated human activities related to and within these sectors. It is beyond the scope of the ACCESS project to produce a marine spatial plan, but instead we establish a framework with which interdisciplinary planning could be affected.

We can describe the ACCESS MSP tool in terms of the 7-step framework provided by the MESMA project. Step 1, the context of the MSP tool, is defined by the project, within the spatial boundary of the Arctic and the temporal scale of 30 years. Step 2 forms the main focus of the MSP tool developed; including collation and mapping of existing and new data, and results from ACCESS deliverables. Data are visualised and accessed using a Geographic Information System (GIS). Indicators developed under ACCESS will be included in the MSP tool where possible (Step 3), equally data from the MSP tool can feed into indicators. Steps 4-6 are addressed by D.5.11, 5.21, D5.31 and D5.41, and demonstrated using the scenario examples given in Section 5.3.

The GIS acts as a coordination tool, receiving inputs from ACCESS research, and allows us to visualise, store, manage, integrate and interrogate data from all sectors. The MSP tool contains a combination of both relevant publicly available data, and data and results generated by ACCESS partners. Users can visualise the various uses of marine space and easily identify overlapping activities. Supporting data, e.g. regulatory, temporal and spatial information, is accessed by hyperlinked documents.

ACCESS used the MSP tool in several specific planning scenarios identified during the project. Scenarios focused on one of each of the ACCESS interest sectors, and each requires the consideration of multiple factors, both anthropogenic and natural, in reaching an understanding of how complex interactions can be visualised, evaluated and managed. The first of these analyses concerned the occurrence of a major oil-spill in an offshore area which not only was the location of a highly developed and sensitive ecosystem, but was also proximal to major shipping routes and tourist interest. The aim was to ascertain how to contain, mitigate and adapt governance and management strategies for the situation on a temporal and spatial basis. Using the principles of MSP and populating the GIS with relevant data, we were able to develop practical options for the scenario

The ACCESS MSP has provided us with an innovative and practical method of to visualise and assess in a qualitative way the factors relevant to sustainable development in the Arctic region, as they are affected by long term climate change, providing key input to scenario planning and cross-sectoral analysis.

7.2 Framework for integrated ecosystem based management

Planning and sustainably managing Arctic activities requires to encompass both direct and indirect effects of climate change on the production of natural resources and services from marine ecosystems of the Arctic and study the implications of these for management. ACCESS D5.71 report presents a framework for Integrated Ecosystem Based Management (IEBM) of the Arctic Ocean that builds on a social-ecological system perspective viewing the Arctic Ocean as one complex system where natural and socioeconomic variables interact in an intricate way. This framework's essential role is to help managers deal with change aiming toward improved and sustained human well-being. It provides general guidelines to support managers in building their own solutions adapted to their particular problem.

The framework contains three elements: 1) An evaluation of how to represent the Arctic social-ecological system that opts for a nested approach with a coarse representation of the whole Arctic complemented with more detailed partial models; 2) An assessment of objectives and general principles for management, which addresses uncertainties, and builds on existing literature related to market failures, problematic dynamics, and how to address them; 3) an overview of tools and methods that could serve an IEBM, where several existing methods are acknowledged and combined and five main steps are suggested to perform an IEBM.

These steps are: understand the system, represent/model the system, test model validity, identify potential change and their impacts and implement results in management. Each of these steps is specified further see Table 4.

Understand the system	1. Assess the most essential elements/nodes/variables of the Arctic system. 2. Gain conceptual understanding and map how these elements interact with each other.
Represent/model the system	3. Build and evaluate conceptual models of partial interactions. 4. Calibrate and validate those models using available empirical data 5. Simulate the models
Test validity of results	6. Perform sensitivity analysis and model perturbations, test model's explanatory power against reality. 7. Analyse results and identify need for further research and data gathering.
Identify potential change and their impacts	8. Identify essential assumptions for scenarios of change, i.e. drivers of change (e.g. climate change, management intervention, catastrophe, new policy instrument, etc). 9. Run the models using scenarios assumptions.
Implement and test results in management	10. Identify management goals. 11. Test and evaluate possible management interventions using simulated models. 12. Compare different management interventions with regard to goal fulfilment and other impacts. 13. Test and evaluate possible management interventions on small scale. 14. Implement management intervention on larger scale and evaluate it.

Table 4 Essential elements of an Integrated Ecosystem Based Management

We use the better understanding gained from the ACCESS project to discuss alternative ways to represent the Arctic system. Figure 9 illustrates potential interactions between essential variables in a model with large degree of abstraction. This would be the kind of answer provided in steps 1-2 of the IEBM process.

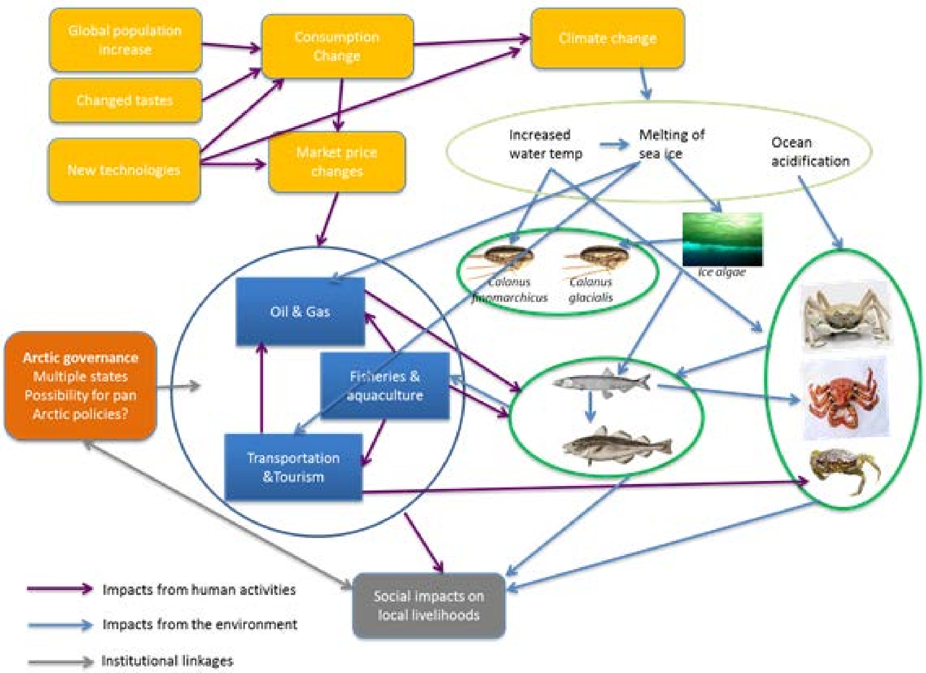

Figure 9 Interlinkages between different parts of the Arctic SES.

We also illustrate how more detailed connections studied under ACCESS could be incorporated in such framework. A further development of this particular work should include an assessment of the compatibility of the different models with each other and the development of a computational framework that allows to 'turn on and off' different parts of the models depending on the needs.

Finally, we use our system representation to discuss six scenarios of ecosystem changes. These scenarios cover changes in zooplankton (*Calanus* species) distribution and abundance, in abundance of different crab species, and in ocean acidification. The scenarios present stories of possible future outcome and questions that become relevant under those particular outcomes. A further development of this work would include a more systematic assessment of the consequences of each scenario for each particular economic sector, and an attempt to rank these scenarios according to their likelihood.

While existing literature provides substantial knowledge for how to move forward with different policy responses, society is better prepared to deal with slow marginal change compared to abrupt and substantial change (Crépin et al, 2012). Hence the ACCESS framework for IEBM focused particularly on how to handle abrupt and substantial change (e.g. Wassman and Lenton, eds 2012, Crépin et al 2012; Levin et al 2013). In particular, abrupt system changes could trigger shifts in production costs, which has repercussions on the choice of policy instruments (taxes or quotas) that would be best to regulate market goods. It turns out that this choice depends, among other things, on how fast the market can adapt compared to the physical changes in the system (Crépin 2015). This kind of insight is a direct result of using an IEBM approach.

An IEBM of the whole Arctic should also identify how the Arctic interacts with the rest of the world. It is important to note that the particular representation we choose is likely to be biased toward the topics that the ACCESS consortium prioritized at the stage of the proposal. A fruitful avenue for further development of an IEBM would be to combine the top-down perspective taken by ACCESS with a more bottom-up approach like the one adopted by the Arctic Council for the forthcoming Arctic Resilience Report.

7.3 Indicators

Indicators perform many functions. Their use can result in better decisions and more effective actions by simplifying, clarifying and making aggregated information available to policy makers. They can help incorporate physical and social science knowledge into decision-making, and they can help measure and calibrate progress toward sustainable development goals. They can also provide an early warning to prevent economic, social and environmental setbacks. They can also be useful tools for communicating ideas, thoughts and values (United Nations, 2007).

ACCESS has developed a set of indicators which aim to highlight the most relevant aspects of change and provide a measure of the direction and sustainability of those changes in the Arctic Ocean. Environmental indicators, such as those included in the European Environment Agency Indicator sets[24] are well established whereas indicators of governance are less well developed. The indicators proposed comprise sub-sets for each of the three economic sectors within the ACCESS project as well as a set of governance indicators. Each sectoral sub-set can be used as a stand-alone product or in combination with the other indicator sets for a more comprehensive picture. The possibility to concentrate on individual sectors allows for a relatively specialized and confined scope, compared to studies and existing indicator sets on sustainable development. Typically, existing indicator sets take a global point of view, e.g. in terms of geographical scope, variety of economic sectors involved, variety of societal groups, variety of threats, or number of directly affected people.[25] However, we apply a more restricted but more clearly defined approach corresponding to the scope and focus of ACCESS and favouring a more in-depth consideration of Arctic peculiarities.

For each of the three sectors, we describe three dimensions of sustainable development, which are laid out in the EU's Sustainable Development Strategy:

- Environmental Protection,
- Social Equity and Cohesion, and
- Economic Prosperity.

Any set of indicators cannot stand alone and for decision support. In particular it should be complemented with other methods that help assess whether current development is sustainable, identifying underlying causes of changes, whether such changes are cause for alarm and if so how can they best be remedied.

[24] EEA Indicators: http://www.eea.europa.eu/data-and-maps/indicators/#c5=&c7=all&c0=10&b_start=0

To allow for different desired levels of depth and width of information, we present the indicators in a pyramid structure (Figure 10), comprising three dimensions for sustainable development, subdivided into policy categories, each described by one or few indicator target areas.

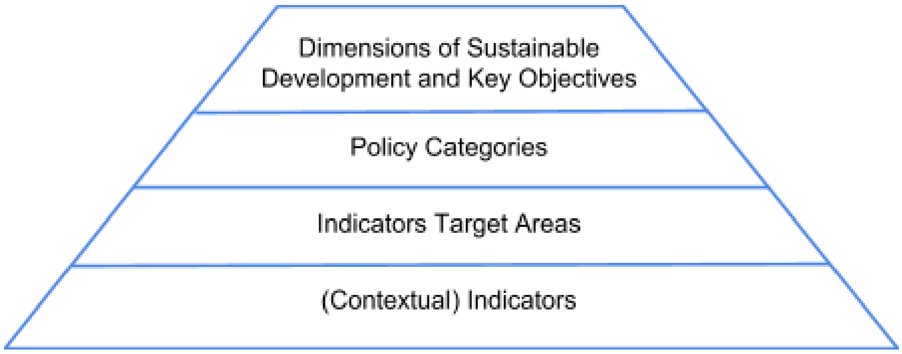

Figure 10 Pyramid structure of indicator system. Source: D3.71.

By choosing this pyramid form, we adopt a top-down approach that avoids defining sustainable development through available data and overlooking areas where data is lacking. We complemented this top-down approach with a bottom-up approach that assessed data availability. Following a consultation process, three indicator subsets for the three ACCESS sectors were proposed (Tables 5, 6 and 7).

[25] Examples are the United Nations Commission on Sustainable Development's (CSD) indicators or the Environmental Performance Index (EPI).

Dimension	Key objective	Policy category	Indicator target area	Variable/ Indicator
Environmental dimension	Ecosystem viability	Pollution	Air pollution	Air pollution from ship engines and other poison inputs
			Noise pollution	Noise in the context of shipping
		Habitat	Marine Protection	Ice information
		Oil spill monitoring	Oil spill prevention and response	Oil spill protection
Social dimension	Social cohesion	Social Inclusion		Indigenous People in Arctic activities
Economic dimension	Sustainable economic development	Regional economic and infrastructure development	Economic development	Mode of operations
			Infrastructure development	Number of ships using the Northern Sea Route
				Infrastructure
		Improvements		Recommendations for improving the NSR shipping

Table 5 Indicators for sustainable development in the sectors of tourism and marine transportation. Source: D2.91.

Dimensions	Policy category	Indicator target area	Variable/ Indicator
Environmental dimension (Ecosystem viability)	Marine resources	Stocks properties	**Stock estimates**
			Age composition
		Species health	Length and weight relationship
	Aquaculture	Fish health	Mortality
		Ecosystem health around the farm	Benthic conditions
	State of the ecosystem or resource base	Alien species	Invasive species
		Marine protection	MPAs
		Pollution	Pollutants in fish
		Habitat	Possible living areas
Social dimension (Social cohesion)	Well being	Human health	Crime rate
		Population characteristics	Population change
			Migration
	Social inclusion	Labour market access	Educational attainment
			Unemployment rate
		Income inequality	Poverty
Economic dimension (Sust. econ. development)	Sustainable seafood industry	Fleet capacity	Fleet capacity indicator
			Fleet utilisation indicator
		Profitability	Return on capital
			Catch (volume/value)
			Aquaculture production
			Resource rent
		Infrastructure investments	Infrastructure availability

Table 6 Indicators for sustainable development in the fisheries and aquaculture sector. Source: D3.71.

Dimension	Key objective	Policy category	Indicator target area	Variable/ Indicator
Environmental dimension	Ecosystem viability	Pollution	Water pollution	Mussel contaminants
			Air pollution	Aerosol and ozone concentration
			Noise pollution	Continuous sound measurements
				Impulsive sound measurements
		Habitat	Marine Protection	MPAs
		Oil spill monitoring	Oil spill prevention and response	Number of oil spills and near misses
Social dimension	Social cohesion	Human Health	Life expectancy	Life expectancy at birth
			Suicides	Deaths from suicide per 100000
		Social Inclusion	Access to labor market	Labor force
				Unemployment
Economic dimension	Sustainable economic development	Affluent and cheap energy supply	Energy production	Oil and gas produced and exported
			Energy price	Oil and gas price
			Exploration	Number of exploration drills
		Regional economic and infrastructure development	Economic development	Regional GDP p.c.
			Infrastructure development	Number of ice-free ports with air field
		Sufficient SAR infrastructure	SAR infrastructure	Human fatalities after accidents

Table 7 : Indicators for sustainable development in the hydrocarbons sector. Source: D4.71.

Whilst the use of indicators such as employment, infrastructure, human development, profit/loss, conflicts and people satisfaction were available for socio-economic indicators; similar 'ready-made' governance indicators are not available. Indicators of governance are largely undeveloped and significant methodological work is needed to produce good, measurable, internationally accepted indicators in this area.

Work within ACCESS (D5.41) to develop a suite of indicators for effective Arctic governance identified eleven potential core indicators, variables and indices based on six goals and targets (Table 8). The goals, targets and indicators are based on concepts identified within the literature (see for example, Ehler, 2003; Breitmeier *et al*. 2006; 2011; Mahon *et al*., 2011; Young, 2011). The importance of concepts such as 'knowledge', 'effectiveness', 'transparency', 'enforcement' and 'compliance' emerged.

Further development of the indicators focussed on finding sources of suitable data and information. These had to be readily available, comparable across the Arctic, regularly updated and quantifiable. Table 8 describes a set of potential governance indicators that might be used for the Arctic Ocean and it also illustrates the limitations associated with each indicator. It should be noted that in addition to difficulty of identifying metrics that represent the criterion in question such as effectiveness, cohesion, inclusion or adaptation, a further problem associated with indicators of governance is causality. Is it possible to attribute any changes in these criteria solely to a governance system?

The work by ACCESS on governance indicators can provide a foundation for further studies on the identification and development of metrics for use in the marine Arctic.

DIMENSION	GOALS / TARGETS	HEADLINE INDICATOR	INDICATOR	Summary of Limitations
Governance	Effective development of governance regime	Development and implementation of policy	Rate of development of policy	Able to summarise development in a timeline; issue with verification of policy stages must be considered.
			Implementation of policy – rate of transposition by national authorities (whether international commitments have been translated into domestic obligations)	Unable to identify forum through which progress in 'domestic obligations' is documented
	Inclusive policy making	Engagement / participation in policy making	Degree of engagement / participation (which coastal states, other states, institutions, NGOs, observers, industry, indigenous / local communities, working groups) are involved in policy /agreement formulation	Similar to 'Inclusion and Representation' headline indicator; difficult to assess participation of different stakeholders (particularly the local population and indigenous people) across different scales
	Informed governance	Scientific knowledge	Trends in dissemination of knowledge: No. of policy briefs, peer reviewed publications, publically available reports, media coverage, public meetings	May be possible to assess the use of scientific knowledge in developing a new form of governance, but assessing its use in previous policies s is difficult
		Traditional knowledge	Degree of acknowledgement and inclusion of cultural values / traditional knowledge into decision making processes	Similar to 'Inclusion and Representation' as well as 'Engagement/Participation in Policy Making' headline indicators.

DIMENSION	GOALS / TARGETS	HEADLINE INDICATOR	INDICATOR	Summary of Limitations
	Cohesive governance	Cohesiveness	Degree to which policy is cohesive between / within sectors / States	Subjective and limited to isolated examples
	Effective governance	Goals and targets	Clearly defined goals / targets towards which progress is measureable	Unable to identify a forum through which progress towards goals is documented
		Transparency	Degree of transparency - of decision making process and procedures	Degree of transparency is subjective
		Compliance	Degree of compliance: number of transgressions / infringements recorded	Possible for high-profile companies; issue with verification of company transgressions must be considered
		Enforcement / sanctions	Number of times sanctions /other enforcement measures are imposed	Unable to indentify standard forum in which sanctions are documented
	Adaptive governance	Continuity and feedback	Institutional capacity and mechanisms to review, assess progress and adapt policy towards sustainable development.	Can be done on a case by case basis. Difficult to identify sources of data and those which are related to climate change

Table 8 Final set of potential Arctic governance indicators and the associated limitations

(Highlighting legend - Green: Potential indicators with good data sources and available data. Light orange: Potential indicators with identified data sources, but limited by data availability/coverage of data. Dark orange: Potential indicators but limited by their subjectivity or difficulty in the identification of a potential data source).

7.4 Integration of tools and use post ACCESS

Post-ACCESS, these tools could and should be further developed and improved. In particular the engagement of the principal stakeholders and users of the region, including all pan-national governance elements (such as the Arctic Council) is needed to take forward the pilot MSP tool in a concerted manner to ensure its structured development into a practical and standardised resource within and across national borders (D5.81; D5.82)

The tools could be used individually but the most of their potential can be released if they are used and further developed in an interactive way. Anybody could use them in the way that fits their own needs. For example they can help local users become more aware of the side effects that their activities have in other places.

These tools can be used to help identify variables in the system that are of particular relevance for the Arctic system's evolution, they could also give some indications of how these variables interact with other essential variables and help quantify these interactions. For example the indicator system proposed can be set up and developed to follow how essential variables of the Arctic social ecological system perform toward particular targets.

8. Closing observations on sustainable development in the Arctic

- The Arctic Ocean is a complex adaptive system in which different parts interact in an intricate and often unexpected way. Geophysical dynamics, ecosystem dynamics at sea but also on land and in the atmosphere, economic and social dynamics in and outside the Arctic are tightly interlinked in ways that are often not obvious. These interactions occur across spatial and temporal scales where global phenomena like climate change fundamentally alter living conditions for local people today and in the future. Also Arctic resources are becoming a global concern as stocks of marine seafood, oil, gas, and minerals deteriorate in the rest of the world.

- Inherently high levels of uncertainty are associated with the environmental and social changes underway in the Arctic. The complex adaptive system nature of the Arctic implies that science will never be able to resolve all the uncertainties involved. What science should provide as a basis for decision making, however, is to attempt determining the uncertainties where possible, to define the range in which society can act or for which it needs to be preparedHence appropriate governance must be able to face those uncertainties and act upon available scientific information. Postponing decisions to learn more can only be motivated when more knowledge can substantially improve management and waiting is not associated with big risks. Governance must find ways to grasp the most important impacts of a particular change no matter whether those impacts are smooth and obvious, or fast, dramatic, indirect, and hit people far away in space or time. Governance mechanisms and policy instruments must be adaptive to respond in a proper way and within appropriate timescales. In addition, the large uncertainties associated with the non-negligible risks of abrupt change motivate precautionary approaches including sometimes even safe standards (See Crépin and Folke, forthcoming 2015 for an overview). Here a good case could be made for the management tools developed on ACCESS to better deal with the changes, as well as necessity for policy making to understand principle characteristics of the system. The latter implies a tight link between science and policy, much tighter than existent today. The more change is expected the more important it is that decision makers need to understand the basic features of the most relevant processes in the system.

- Under such rapidly changing conditions, ponderous and protracted policy making risks to be out-of-date before it is implemented. In response to rapid climate change, new instruments or amendments to existing instruments must be relatively quick to put in place. For example the implementation of the new Polar Code for shipping is overdue and is urgently needed. Similarly regulation of Arctic tourist activities, and associated infrastructure, requires prompt action. The Arctic Council's working group results could benefit from a model for converting into regulations.

- Meanwhile current public management and governance capacity in the Arctic is scattered across national and international authorities as well as global and local stakeholders. Historical legacy can result in particular problem being currently dealt with at an inadequate level of public management (e.g. National authorities dealing with problems of local nature or regional authorities dealing with international problems). For example regulations relating to Arctic offshore oil and gas activities need to be strengthened and harmonized while taking into account differences in local conditions in terms of type of resource, infrastructure in place, local and indigenous communities.

- It is particularly challenging to take a prompt, adequate and integrative approach to public management and governance. There is a substantial trade-off in the sense that, in order to reach agreement quickly, regulatory regimes risk to be set at the lowest common denominator, while the highest standards may have been needed. This trade-off must be urgently resolved.

- Multiple conflicting goals could be another source of conflicts and misunderstanding that lead to poor and slow governance and public management: aiming for sustainable development requires putting in place different and sometimes conflicting policy and governance tools than aiming for current system resilience or short term welfare improvements or support of a particular industry. Governance tools better adapted to fulfil multiple goals need to be developed. National and industry interests should not be allowed to override those of the environment or indigenous and local populations.

- Decision making should be based on best available scientific advice and use more quantified and specific approaches to assess impacts. Such decisions should build on state of the art scientific knowledge and tools like integrated ecosystem based management, marine spatial planning, constructive and carefully chosen indicators, and resilience assessment. The policy-making process in the Arctic should also actively incorporate traditional knowledge. National and industry interests should not be allowed to take precedence over those of the environment or indigenous and local populations.

- Adaptive capacity in policy making needs to be developed and nurtured. Ways to do so include identifying and gathering examples of ‘best practice’ to learn lessons from them and studying and testing more flexible instruments. In particular regulatory instrument at the pan Arctic scale should be developed so that every new updates do not necessarily require new agreement negotiations. In that perspective, instruments conditional on the state of the system may be an interesting avenue to study. Such instruments could also be interesting at lower lever of governance (national and local).

- Regular monitoring of the success or failure of governance arrangements is essential in development and revision of regulations and policy tools. Indicators for governance effectiveness in the Arctic need to be developed. In addition processes must be established or strengthened to ensure meaningful dialogue with stakeholders, including indigenous and local peoples, the research community and other user groups during development or revision of policy instruments. Regular assessments are necessary to gauge how changes in governance requirements may affect / are affecting Arctic users / stakeholders /regional bodies / indigenous peoples.

- Transboundary, ecosystem-based approaches to governance are essential. Standardisation / harmonisation of regulations would be ideal for all activities and in particular for trans-boundary resources, living and non-living. For this to succeed there needs to be a commitment at a national level. Marine spatial planning offers one method through which this can be approached.

- A single pan-Arctic Treaty, similar to the Antarctic Treaty[26], seems now extremely unlikely. Observations suggest that no single approach is emerging but rather a range of approaches from formal, legally binding (e.g. the new Polar Code) to ad hoc, local, non-standardised arrangements. Ad hoc regional or bilateral agreements may offer a more efficient path to solutions than legislatively cumbersome treaties. Binding agreements are not necessarily preferable to

[26] The Antarctic Treaty, in force 1961. http://www.ats.aq/e/ats.htm

voluntary ones, which potentially take less time to develop and are more likely to be adhered to.

- An active dialogue between all international governance stakeholders in the Arctic is essential for successful governance and policy. In particular, the Arctic Council needs to retain dialogue also with non-Arctic States since international law requires this for High Seas fisheries and Seabed areas beyond national jurisdiction, even in waters the Arctic Council considers theirs to manage (UNCLOS Art. 123[27]).

[27] UNCLOS 123 states "*States bordering an enclosed or semi-enclosed sea should cooperate with each other in the exercise of their rights and in the performance of their duties under this Convention. To this end they shall endeavour, directly or through an appropriate regional organisation:*

- *to coordinate the management, conservation, exploration and exploitation of the living resources of the sea;*
- *to coordinate the implementation of their rights and duties with respect to the protection and preservation of the marine environment;*
- *to coordinate their scientific research policies and undertake where appropriate joint programmes of scientific research in the area;*
- *to invite, as appropriate, other interested States or international organisations to cooperate with them in furtherance of the provisions of this article".*

References:

Acheson, J.M. 1981. Anthropology of Fishing. Ann. Rev. Anthropol. 10: 275-316

Baldesarra 2014. Having a say in the North: Indigenous Cooperation and the Arctic Council. Accessed at http://natocouncil.ca/having-a-say-in-the-north-indigenous-cooperation-and-the-arctic-council/

Berkman, P and Vylegzhanin, A. (Eds) 2013. Environmental security in the Arctic Ocean, Springer (Series Title: NATO Science for Peace and Security Series C: Environmental Security)

Breitmeier, H, Young O., and Zurn, M. 2006; Analysing international environmental regimes - from case study to database. The MIT Press, Cambridge, Massachsetts, USA.

Breitmeier, H, Underdal, A. and Yound , O. 2011; The effectiveness of International Environmental regimes: Comparing and Contrasting Findings from Quantitative Research. International STudies Reviews Vol 13, issue 4, pp579-605.

Crépin, A.-S., Biggs, R., Polasky, S., Troell, M and de Zeeuw, A., (2012) Regime shifts and management, *Ecological Economics* 84:15-22.

Crépin, Anne-Sophie and Carl Folke (2015), "The Economy, The Biosphere and Planetary Boundaries: Towards Biosphere Economics", International Review of Environmental and Resource Economics: Vol. 8: No. 1, pp 57-100. http://dx.doi.org/10.1561/101.00000066

Crépin, A.-S. and Lindahl, T. 2009, Grazing Games *Environmental and Resource Economics,* 44:29-46.

Crépin, A-S, J. Norberg and K-G. Mäler, 2011, Coupled economic-ecological systems with slow and fast dynamics — Modelling and analysis method, *Ecological economics* 70(8):*1448-1458*

Ehler, C. N. 2003. indicators to measure governance performance in integrated coastal management/ Ocrean and Coastla Managemebnt 46 335-345

Ehler & Douvere, 2009 Marine Spatial planning - A steP-by-step approach towards Ecosystem-Based Management.
http://unesdoc.unesco.org/images/0018/001865/186559e.pdf

Eide, A. (2007). Economic impacts of global warming: The case of the Barents Sea fisheries. Natural Resource Modeling, 20(2): 199-221.

Eide, A. (2014). Modelling Spatial Distribution of the Barents Sea Cod Fishery. In J. Was, G.C. Sirakoulis, and S. Bandini (Eds.): ACRI 2014, Lecture Notes in Computer Science (LNCS) 8751, pp. 288–299.

Fuglestvedt *et al.* (2014) Fuglestvedt, Jan S.; Samset, Bjørn H.; Shine, Keith P. (2014): Counteracting the climate effects of volcanic eruptions using short-lived greenhouse gases. In Geophys. Res. Lett., pp. n/a. DOI 10.1002/2014GL061886.

Fuglestvedt, Jan S.; et al. (2014): Counteracting the climate effects of volcanic eruptions using short-lived greenhouse gases

Hamilton, J. Maddison, D.J. and Tol, R.S.J. 2005. Effects of climate change in international tourism. Climate Research. Vol 29: 245-254.

Kattsov, V. M., E. Källén, H. Cattle, J. Christensen, H. Drange, I. Hanssen-Bauer, T. Jóhannesen, I. Karol, J. Räisänen, G. Svensson, S. Vavulin, D. Chen, I. Polyakov, and A. Rinke. 2004. Future Climate Change: Modeling and Scenarios for the Arctic. Arctic Climate Impact Assessment – Synthesis report. Impacts of a Warming Arctic. Cambridge University Press.

Lam, M.E and Borch, T. 2011. Cultural valuinmg of fishery resources by the Norwegian Saami. IN Westra, L, Bosselmann, K and Soskolne, C. (Eds) Gobalisation ans Ecological Integrity in Science and INternational Law. Cambridge, UK. Cambridge Scholars Publishing. pp361-376.

Lenton, T. 2007. Tipping the scales. Nature Reports Climate Change. Published online 22 November 2007. doi:10.1038/climate.2007.65

Levin, S. , Xepapadeas, A. , Crépin, A.-S., Norberg, J, de Zeeuw, A., Folke, C., Hughes, T. , Arrow, K. , Barrett, S., Daily, G. , Ehrlich, P., Kautsky, N. , Mäler, K.-G-, Polasky, S, Troell, M., Vincent, J.R. and B. Walker. Social-ecological systems as complex adaptive systems: modeling and policy implications, Environment and Development Economics,18(2):111-132 (April 2013)

Mahon, R., Fanning, L. and McConney, P. 2011. Governance assessment methodology for CLME piot projects and case studies. Centre for Resource Management and Environmental Studies (CERMES), University of the West Indies, Cave Hill Campus, Barbados, Technical Report No 53: 19p.

Johan Rockström, Will Steffen, Kevin Noone, Åsa Persson, F. Stuart Chapin, III, Eric F. Lambin, Timothy M. Lenton, Marten Scheffer, Carl Folke, Hans Joachim Schellnhuber, Björn Nykvist, Cynthia A. de Wit, Terry Hughes, Sander van der Leeuw, Henning Rodhe, Sverker Sörlin, Peter K. Snyder, Robert Costanza, Uno Svedin, Malin Falkenmark, Louise Karlberg, Robert W. Corell, Victoria J. Fabry, James Hansen, Brian Walker, Diana Liverman, Katherine Richardson, Paul Crutzen

& Jonathan A. Foley. 2009 A safe operating space for humanity. Nature 461, 472-475. doi:10.1038/461472a; Published online 23 September 2009

Rosen, M E. and Asfura-Heim, P. 2013. Addressing the Gaps in Arctic Governance. Arctic Security initiative - Hoover Institution . http://www.hoover.org/research/addressing-gaps-arctic-governance

Stelzenmüller *et al.*, 2013 - Monitoring and evaluation of spatially managed marine areas (TBC)

Steffen, W., Crutzen, P.J & McNeill, J.R 2007. The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature? Ambio Vol 36, No 8.

Will Steffen, Katherine Richardson, Johan Rockström, Sarah E. Cornell, Ingo Fetzer, Elena M. Bennett, Reinette Biggs, Stephen R. Carpenter, Wim de Vries, Cynthia A. de Wit, Carl Folke, Dieter Gerten, Jens Heinke, Georgina M. Mace, Linn M. Persson, Veerabhadran Ramanathan, Belinda Reyers, Sverker Sörlin. 2015. Planetary boundaries: Guiding human development on a changing planet . Published Online January 15 2015. Science 13 February 2015: Vol. 347 no. 6223 DOI: 10.1126/science.1259855

United Nations, 2007. Indicators (http://mdgs.un.org/unsd/mdg/Default.aspx)

Wassmann, P. 2006. Structure and function of contemporary Arctic shelves: a pan-Arctic comparison. Progress in Oceanography71:123–477.

Wassmann, Paul, and Timothy M. Lenton. "Arctic tipping points in an earth system perspective." *Ambio* 41.1 (2012): 1-9.