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Indicators for sustainable seafood production

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Abstract

This report aims to develop a set of indicators that measure sustainable development of Arctic seafood production. It builds on an environmental, a social, and an economic dimension, three dimensions of sustainable development. Our indicator system provides decision support information and monitoring tool for relevant decision makers. It aims to facilitate orientation in a complex multitude of social and ecological systems as well as their intersection. The indicator set is structured as a pyramid made up of the three dimensions of sustainable development, subdivided into policy categories, each described by one or few indicator target areas, supplemented by a number of more contextual indicators. We give a short presentation of each indicator and assess data availability. While this report provides decision support it cannot stand alone and is part of the synthesis of the European Union project Arctic Climate Change Economy and Society.

[1] The authors are all researchers involved within the European Union Seventh framework program ACCESS. All authors except for Petrick and Morgenroth are active within the work package 3 on fisheries. In addition, Morgenroth and André also work in work package 2 on marine transportation and tourism, Petrick and André in work package 4 on resource extraction and Crépin, Petrick, André, Eide and Isaksen in work package 5 on governance, sustainable development and synthesis.

[2] Assistance from Daniel Ospina (Stockholm Resilience Centre) is gratefully acknowledged.

Contents

Executive summary

The aim of this report is the development of a set of indicators that measure sustainable development in the Arctic seafood production sector. The indicator set aims to inform about the sustainability of the state and direction of development in the Arctic Ocean. This report focuses on the impact of and on seafood production, but it is embedded in a series of reports on sustainable development indicators in the Arctic Ocean that cover shipping and tourism activities, energy production, and a synthesis addressing cross-sector and governance aspects. This series of reports form part of the synthesis of the European Union Seventh Framework project Arctic Climate Change Economy and Society (ACCESS). The information provided by this report is meant to support decision makers concerned with the Arctic as well as to aid researchers with the development of scenarios on future developments.

"Sustainable development means that the needs of the present generation should be met without compromising the ability of future generations to meet their own needs" according to the European Council. The European Union's sustainable development strategy breaks down the overall goal of sustainable development into key objectives:

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

These objectives correspond with the three dimensions prevalent in the existing discourse on sustainable development, the environmental dimension, the social dimension, and the economic dimension. The indicator set laid out in this report is structured along these dimensions of sustainable development, breaking down the dimensions into policy categories, indicator target areas, and finally, indicators. The role of indicators is to condense, estimate, or proxy information on a potentially abstract, not directly measurable

entity in a single variable, which can inform about changes and direction of development. Details on the design of the indicator set can be found in Section 1.4 of the report.

Accordingly, the aim of our indicator systems is to provide coherent information as decision support and monitoring tool for relevant decision makers. The indicator system aims to facilitate orientation in a complex multitude of social and ecological systems as well as their intersection. These systems may interact in various ways; they may be sensitive to exogenous determinants as well as random shocks. Their reaction to shocks, both from neighbouring systems as well as from the outside, may be non-linear. Their development may be self-enforcing or self-regulating. The indicator set may ideally also provide an early warning of drastic changes that allows for prompt control or counteraction. The role of the indicator system is to simplify substantial complexity to a manageable amount. Apart from dynamics and nonlinearities, uncertainty is a major challenge for indicator systems.

We structure our indicator set as a pyramid of indicators. The pyramid is made up of the three dimensions of sustainable development, subdivided into policy categories, each described by one or few indicator target areas, supplemented by a number of more contextual indicators (cf. Table 1). This top-down approach avoids overlooking areas where data is lacking. We complemented the top-down approach by a bottom-up approach that assessed data availability. The difference between the two reveals areas for future research.

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 1: Proposed indicators related to fisheries within different policy areas, headline indicators in bold

Finding a large number of different indicators is easy, but most users ask for a concise and limited concentration on the essential. We based our selection of indicators broadly on how well they perform with regard to policy relevance, efficient communication, and statistical quality. Usually, however, we had to compromise between these three classes of criteria, since no indicator could meet all of them. Some of the indicators we propose have been monitored for a long time and large time series are available allowing for all kinds of analyses, like catch and unemployment rates. These two could well serve as headline indicators in the social and economic dimensions. However current knowledge of the state of the marine ecosystem does not allow us to summarize in a satisfying way the environmental dimension into a handful of time series. For most of the social indicators and indicators of the state of the ecosystem the amount of data available is limited, and the necessary information has often not been collected in the same way in the different Arctic countries or regions.

The indicators were provided through expert solicitation from the heterogeneous experts assembled by the ACCESS project, covering a multitude of disciplines, nationalities and subjects of study. The result of this build-up process is a compendium of indicators, organized along the environmental, social, and economic dimension (cf. Table 1) and presented in Section 3-5 of this report.

Several relevant indicators are not represented in this report, since they are exogenous and crucial to any sustainable development in the Arctic, beyond sea food production. Such external indicators may be temperature, ice conditions and other environmental factors, but also indicators within other dimensions like governance. These indicators will be covered in the cross-sectoral synthesis of all sectoral indicator sets.

The indicator system proposed cannot either be used solely to guide policy. It must be complemented with other management tools like a marine spatial planning tool (ACCESS D5.82, forthcoming) and an integrated model of the social ecological interactions in the Arctic Ocean (ACCESS D5.71, forthcoming). These tools produced within the ACCESS project should be used to assess and identify variables in the system that are of particular relevance for the Arctic system’s evolution toward sustainable development. If they are complemented with proper models of interactions between the most important variables or indicators it would also be possible to simulate different policy responses and compare them to each other with regard to how they perform in the different dimensions of sustainability.

1. Introduction

The aim of this report is the development of a set of indicators that measure sustainable development in the Arctic sea food production sector[3]. The indicator set aims to inform about the sustainability of the state and direction of development in the Arctic Ocean. While this report focuses on the impact of and on sea food production, it is embedded in a series of reports on sustainable development indicators in the Arctic Ocean that cover shipping and tourism activities, energy production, and a synthesis addressing cross-sector and governance aspects.[4] This series of reports form part of the synthesis of the European Union Seventh Framework project Arctic Climate Change Economy and Society (ACCESS) together with a marine spatial planning tool, a framework for integrated ecosystem based management and a synthesis report. The information provided by this report is meant to support decision makers concerned with the Arctic as well as to aid researchers with the development of scenarios on future developments. The set of indicators proposed is a working document that could be continuously refined after the ACCESS project, based on improved knowledge of the Arctic social-ecological system. A set of indicators can typically not stand alone, and for decision support in particular it should be complemented with other methods that would help assess whether current development is sustainable, what are the underlying causes of particular changes, whether such changes are reasons for alarm and if so how can they best be remedied.

1.1 Sustainable development in the Arctic Ocean – definition and relevance

The concept of "Sustainable Development" was coined by the World Commission on Environment and Development (WCED) in its final report "Our Common Future", or "Brundtland Report" after the name of the commission's chairwoman, Gro Harlem Brundtland. The report defines Sustainable Development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987). This definition has since become the seminal definition of Sustainable Development and is also taken up by the Council of the European Union's Sustainable Development Strategy (EU SDS): "Sustainable development means that the needs of the present generation should be met without compromising the ability of future generations to meet their own needs" (European Council 2006). This notion emphasizes an inter-generational or inter-temporal view of Sustainable Development. Practical implementation can only partly incorporate that component, since inter-temporally

[3] The sea food production sector is defined as including both capture fisheries and aquaculture

[4] The report at hand is the first to be written in the series.

comparable data with sufficient disaggregation and frequency is scarce. Complementing the inter-temporal perspective, the European Union's sustainable development strategy (EU SDS) breaks down the overall goal of sustainable development into key objectives:

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

The three key objectives correspond with the three dimensions, or themes, prevalent in the existing discourse on sustainable development, the environmental dimension, the social dimension, and the economic dimension. The indicator set laid out in this report is structured along these dimensions of sustainable development, breaking down the dimensions into policy categories, indicator target areas, and finally, indicators. Details on the design of the indicator set can be found in Section 1.4.

Focusing on the Arctic sea food production sector, this report is restricted to a relatively specialized and confined scope, compared to other 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.[5] Indeed, a global perspective gives appropriate justice to the multiple regional, sectoral, or societal interactions that might easily be neglected by a more confined view on sustainable development. However, we apply a more confined and yet more clearly defined approach that corresponds with the scope and focus of the ACCESS project and that favours a more in-depth consideration of Arctic peculiarities.

1.2 The use of indicator systems for measuring the immeasurable

The role of indicators is to condense, estimate, or proxy information on a potentially abstract, not directly measurable entity in one variable, and that this variable will generate understanding about changes and direction of development. In our case, we attempt to measure sustainable development, as defined in Section 1.1. In order to compromise between conciseness and accurate coverage of the different dimensions of sustainable development, we introduce a set of indicators. Details on how we compose this set can be found in Section 1.4.

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

The need to measure sustainable development in the form of indicators was already identified in the early days of the modern sustainability debate, the Agenda 21, the seminal action plan adopted by the Rio Conference in 1992 states:

> *"Indicators of sustainable development need to be developed to provide solid bases for decision-making at all levels and to contribute to a self-regulating sustainability of integrated environment and development systems."* (United Nations 1992, § 40.4)

Accordingly, the aim of our indicator systems is to provide coherent information as decision support and monitoring tool for relevant decision makers (see e.g. Meadows 1998 or Bossel 1999 for an overview on aims of indicators on sustainable development). While diagnosis of the success or failure of decisions is a central role of the indicator system, we also regard diagnosis of the developments in the Arctic as a relevant aim per se. For example, researchers may want to use the indicator system defined in this report for the definition and development of model scenarios.

The indicator system aims to facilitate orientation in a complex multitude of social and ecological systems as well as their intersection. These systems may interact in various ways; they may be sensitive to exogenous determinants as well as random shocks. Their reaction to shocks, both from neighbouring systems as well as from the outside may be non-linear. Their development may be self-enforcing or self-regulating. The indicator set may ideally also provide an early warning of drastic changes that allows for prompt control or counteraction. The role of the indicator system is to simplify substantial complexity to a manageable amount. Hence, indicators should preferably be selected at a level where they perform overarching functions. For example if some variable is maintained within some predefined levels, this should be a good indication that several functions of the system also remain within some acceptable predefined range. This is the case for umbrella species for which preservation goals are defined. To achieve such goals one needs to protect the species habitat and thus many other species and ecosystem functions. However the price of such simplification is that some information is lost during the simplification process. In that sense, the indicator system is by construction an imperfect proxy for reality.

Apart from complex dynamics including nonlinearities, uncertainty is a major challenge for indicator systems. Given the vast changes the Arctic Ocean and the sea food production industry in general are facing, it is impossible to cover changes in sustainable development in a comprehensive way. Uncertainty comes in various forms. To begin with, we simply do not know about all indications of changes in sustainable development, no matter how important some of them might be. In some cases, we might miss a whole dimension of sustainable development or its indication. In other cases, we might know about some cause-and-effect chains that affect sustainable development in the Arctic Ocean, but we may not know how, or in which direction, sustainable development is affected. In these cases, we do capture the relevant dimension of sustainable development, but we may fail in correctly interpreting changes in the indicators. These various types of uncertainty will affect the explanatory power of any indicator system. Furthermore, unexpected exogenous events, such as natural disasters, world market movements, or global economic crises will, although influencing sustainable development, impede the ability of the indicator set to reflect the success or failure of policy measures. For that reason, indicators will usually be merely descriptive of potential outcomes of decisions, without necessarily implying an underlying causality. Assessing causality between changes in different indicators will then require the use of additional explanatory tools like models. In spite of this, the choice of a relevant set of indicators should still be driven by an underlying understanding of dimensions that would potentially affect the direction of sustainable development.

Even though there are some exceptions, many dimensions of sustainable development are meaningful only in a relative sense, also because there is rarely any general consensus about the optimal, sustainable state of the World and, in this specific case, about sustainable development in the Arctic Ocean. This means that we can only make statements that one observed state (e.g. in a specific region or point in time) is more or less sustainable than another state, provided that we have information on both states, and this statement may even vary for different stakeholders' points of view or even when we look at different dimensions of sustainable development. Thus many indicators are meaningful only in comparison and not in absolute values, even though decision makers may want to define their own normative target corridors. For some indicators we will be able to provide some guidance on what a sensible target or threshold value might be based on research or experts' heuristics.

Indicators describing sustainable development, on one hand, and sustainable development and decisions impacting development on the other hand may refer to different stages of an underlying impact process. These different stages can be used to develop taxonomy of indicators such as the pressure-state-response taxonomy (cf. McCool and Stankey 2004 or United Nations 2007) and its various extensions. Pressure indicators reflect some kind of (positive or negative) pressure that human activity poses on ecosystems, social cohesion, or economic prosperity. State indicators describe the state of ecosystems, social groups, or the economy. Response indicators reflect how decision makers, economic agents, etc. respond to changes in ecosystems, social cohesion, or economic prosperity. While the pressure-state-response taxonomy has been extended to incorporate more dimensions of the underlying impact path, we feel that it covers our indicator system sufficiently well.

1.3 Criteria for good indicators

Restriction is a key problem in assembling an indicator set. Finding a large number of different indicators is usually easy, but most users of the indicator system ask for a concise and limited concentration on the essential. A concise set of indicators has the advantage that one can focus limited resources on gathering good quality information for this particular set of indicators. This selection process must be based on quality criteria or requirements that define what makes an indicator better or worse than its counterparts.

Eurostat, in its report on the European Union sustainable development strategy, distinguishes three quality criteria for indicators: policy relevance, efficient communication, and statistical quality (Eurostat 2011, p. 37). This general criteria catalogue is a common basis to many indicator systems, which is in line with an extensive discussion on quality criteria of sustainability indicators summarized by the "Bellagio Principles" (Hardi and Zdan 1997). Hass et al. (2002) summarize the quality criteria derived from the Bellagio Principles as policy relevance, simplicity, validity, availability of time-series data, good quality and affordable data, ability to aggregate information, sensitivity to small changes, and reliability. Further compilations of similar-in-spirit quality criteria catalogues include Coenen (2000) or work from the Organisation for Economic Co-operation and development (e.g. OECD, 2013; see Hass et al. 2002 for details).

We based our selection of indicators broadly on how well they perform with regard to policy relevance, efficient communication, and statistical quality. Usually, however, we had to compromise between these three classes of criteria, since no indicator could meet all of them.

1.4 Build up strategy for the indicator system

Any indicator system must accommodate the conflicting interests of accessibility versus scope and detail. Some users would rather have in a quick glance, requesting only very condensed and yet interpretable information. Other users, more deeply interested in specific dimensions of sustainable development, require multidimensional information reported by a multitude of variables. To accommodate these two needs, and following the European Union sustainable development strategy, we structure our indicator set as a pyramid of indicators. The pyramid is made up of the three dimensions of sustainable development, derived from the dimensions' three key objectives, subdivided into policy categories, each described by one or few indicator target areas, supplemented by a number of more contextual indicators (cf. Figure 1).

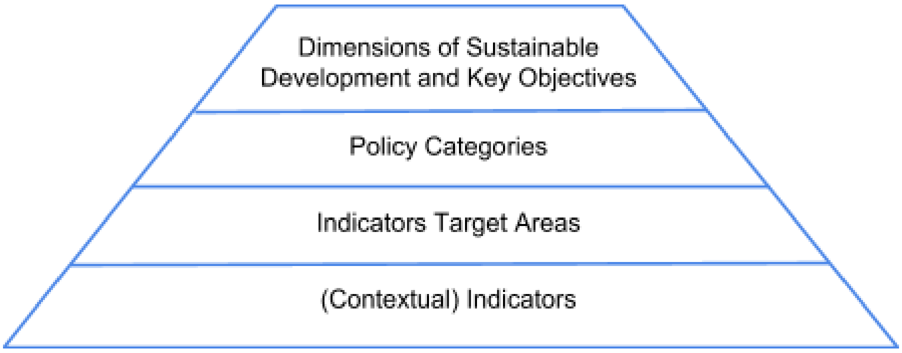

Figure 1: Indicator Pyramid, illustration by Sebastian Petrick

By choosing this pyramid form, with the three dimensions of sustainable development as the starting point, and deducing actual indicators from there, we adopt a top-down approach that avoids defining sustainable development through the power of facts (i.e. available data) and overlooking areas where data is lacking. We complemented this top-down approach by a bottom-up approach that assessed data availability. The difference between these two reveals areas for future research.

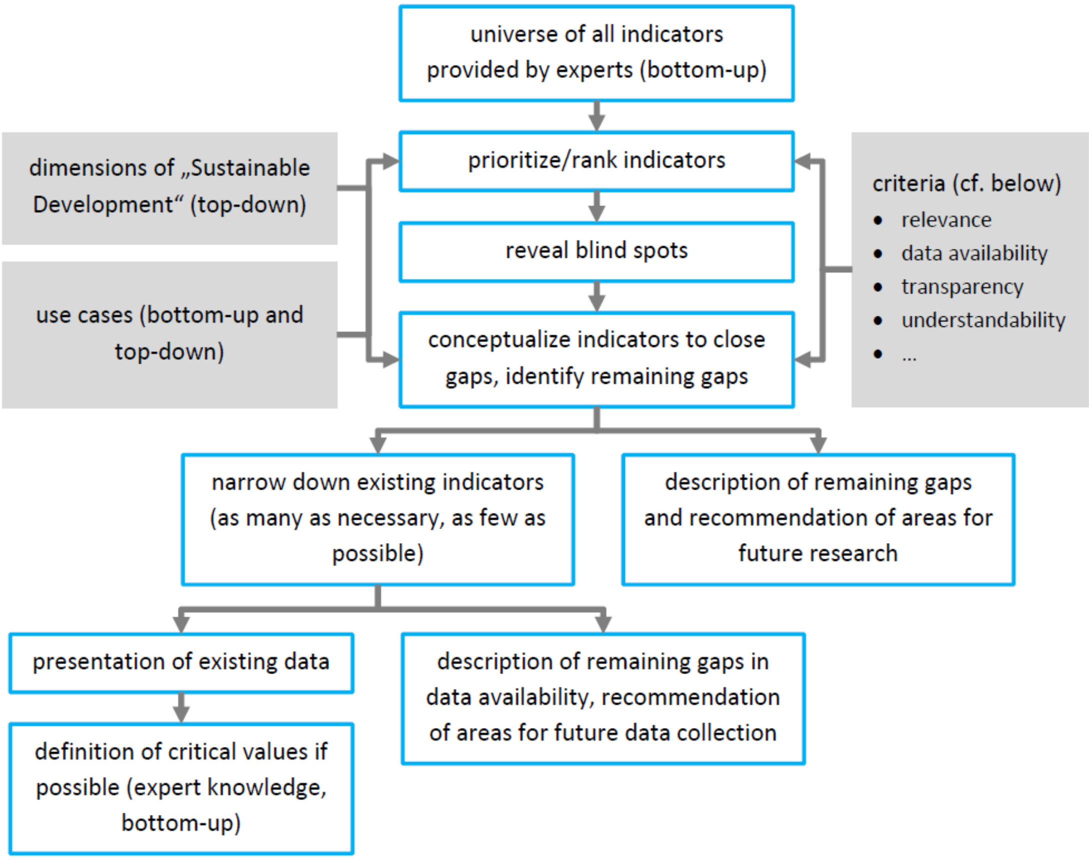

Figure 2: Build up strategy for the indicator system, illustration by Sebastian Petrick

The indicators themselves were provided by the heterogeneous experts assembled by the ACCESS project, covering a multitude of disciplines, nationalities and subjects of study. This ensured a high diversity of potential indicators and avoided narrowness. In a first step we held a breakout group session at the third ACCESS general assembly meeting in Villanova, where different strategies for selecting indicators were discussed and an attempt was made to identify relevant indicators for sea food production. In a second step we built a questionnaire that task leaders of ACCESS had to fill in ahead of a work package meeting dedicated to selecting relevant indicators. During this meeting the pyramid concept in Figure 1 was introduced, each participant presented their responses to the questionnaire and raised issues related to the particular indicators proposed. During the second meeting day, the universe of indicators provided by the experts were narrowed down and ranked within each dimension.

We used a canon of classical quality criteria for indicator systems that are described in Section 1.3. For an overview on the build-up strategy, see Figure 2. The result of this build-up process is a compendium of indicators, organized along the environmental, social, and economic dimension (cf. Table 1) and presented in Sections 3-5. It should however be noted that the borders between the different dimensions in terms of concrete indicators are not equally obvious in all cases. Where possible, this is reflected in Table 1, where for example the target area on income inequality is placed within the social dimensions next to the economic. In each of these sections we introduce the particular indicator target area and identify and describe indicators.

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 1: Proposed indicators related to fisheries within different policy areas, headline indicators in bold

We choose to focus almost exclusively on few indicators rather than a multitude of indicators because of the lack of information in the region, which does not allow collecting time series data with appropriate geographical precision for a wide range of variables. We tried to identify some headline indicators, i.e. less than a handful of indicators that one could look at to get a quick glance on the state of the whole system. These are highlighted in bold in table 1. The indicators presented here can also serve as a first target for improved data collection. When presenting each particular indicator we aim to motivate our choice, describe how to calculate it, discuss available data, strength and weaknesses of that particular indicator and finally discuss possible threshold value of relevance. Then in Section 6, we identify remaining gaps and give recommendations for future research and data collection.

In addition several relevant indicators are not represented in this report because they are exogenous and crucial to any sustainable development in the Arctic, beyond sea food production. Such external indicators may be temperature, ice conditions and other environmental factors in particular, but also indicators within other dimensions like governance. These indicators will be covered in the cross-sectoral synthesis of all sectoral indicator sets. It should be noted that these indicators could be identified as “drivers” instead of indicators and that the multiple effects that these give rise to will in many ways be captured by the indicators listed in Table 1 (e.g. increased temperature causing changes in stocks, mortality, new invasive species, etc.)

2. The sub-Arctic seafood industry

The seafood industry consists of the primary producers (capture fishery and aquaculture), the seafood processors and the marketing/exporters (the service industry). The final downstream link - the seafood consumers - is decisive for upstream activity, since products with no demand will not be put through the value chain. The selection of suitable indicators should focus on indicators that are over-arching to such degree that they include most of these links in the seafood value chain.

The geographical definition of a sub-Arctic seafood industry is challenging and requires an assessment of the regional dimensions that should be included. Also, the border of the Arctic may exclude parts of nations, as is the case for Scandinavian countries, Russia, and Canada. This impacts on data availability because data collection and granularity are in most cases nationwide. Here we follow the definition of the Arctic given in the ACCESS -Aquaculture report (Hermansen and Troell 2012), that includes Iceland and Greenland. The main nations involved in Arctic fisheries are Norway, Russia, Iceland and Greenland. The Pacific, American and Siberian parts of the Arctic (the Bering Sea, Alaska, Canada and Eastern Russia) are not included, since we narrow the analysis to the European areas. However for some indicators for example the social indicators we also consider these regions.

2.1 Status of Arctic capture fisheries

FAO's fish statistics - covering the whole Northeast Atlantic Sea[6] - indicates that these four countries' uptake of seafood constitute more than 55 percent of the total uptake of fish and crustaceans in 2011[7]. If Faroese Islands were included the share would be 60 per cent. The other large fishing nations in these waters are Denmark (9%), UK (6%), France and the Netherlands (3 % each). If we narrow the fish capture area to only cover the Barents Sea, Norwegian Sea, Spitsbergen and Bear Island, Icelandic and Faroese Grounds, and East Greenland[8], we find that in 2011, of a total catch of 4.256 thousand tonnes live weight, Norway's share is 40 per cent, Iceland 27 per cent, Russia 20 per cent, Faroe Islands 8 per cent and Greenland 1 per cent (altogether 96 per cent). The remaining is caught mainly by vessels from Denmark, Germany, UK, Spain and 10 other European countries.

The main species caught in these waters were herring (25 %), cod (21 %), capelin (19 %), haddock (9 %) and saithe (pollock) (6%) according to ICES catch statistics[9]. For the time being (2013/2014), the fish stocks mentioned in the North East Atlantic (NEA) are generally in good condition. The NEA cod spawning stock biomass is the largest observed and quotas are record high. The Icelandic cod stock shows an increasing trend. NEA haddock biomass is considered in good condition, but catches and agreed quotas (between Norway and Russia) have decreased; Icelandic haddock catches and TAC recommendation were reduced considerably from 2007-2010. For NEA saithe there is a risk that the stock is not harvested sustainably and quotas have decreased recently, from 220,000 tonnes in 2009 to 120,000 tonnes in 2014. Icelandic saithe catches have been above ICES recommendations in later years, nevertheless, the stock shows a slightly increasing trend.

The Barents capelin stock, shared between Norway and Russia and known for its size variability, has been harvested since 2009 but in 2014 in small quantities, since quota is set

[6] FAO Area 27: from the Gibraltar Strait in the south to the North pole, from Cape Farewell in the West (42° W) to the north eastern corner of Novaja Semlja (68° 30' E).

[7] FAO Fisheries and aquaculture statistics available online (http://www.fao.org/fishery/statistics/en)

[8] ICES Fishing Sub Areas I, II, V and XIV (see http://www.fao.org/fishery/area/Area27/en#str).

[9] ICES catch statistics available online http://www.ices.dk/marine-data/dataset-collections/Pages/Fish-catch-and-stock-assessment.aspx

to only 65,000 tonnes. For capelin in the Iceland-East Greenland -Jan Mayen area, stock and catches have increased since 2009 when there was almost no catch. After a catch in 2012/2013 of 551,000 tonnes the TAC of 2013/2014 is 160 000 tonnes. Catches of Norwegian Spring Spawning herring have been reduced since its peak in 2009, when TAC among coastal states (Norway, EU, Russia, Iceland and Faroe Islands) was set to 1,600,000 tonnes. In 2013 no agreement was reached between the coastal states, and ICES argues that fishing does not follow the management plan. Expected landings in 2013, according to the sum of coastal states' national quotas, is anticipated to exceed the recommended 2013-TAC of 619,000 tonnes with 12 per cent. For 2014, ICES recommended a quota of 418,500 tonnes.

The geographic distribution of mackerel in later years has shifted North-East, making the species available in richer quantities in Faroese and Icelandic waters. Also for mackerel finding an agreement between coastal states on a quota distribution has been challenging. In Arctic shrimp fisheries, a moratorium is in effect for Flemish Cap, after steady reductions following a catch peak in 2003 (60,000 tonnes). Also for the Newfoundland/Labrador Grand Banks shrimp TAC-recommendations have fallen after a 30,000 tonnes level in 2009 to merely 8,600 tonnes in 2013. Shrimp fisheries off West Greenland (also in Canadian EEZ) produced relatively stable catches in the period 2004-2012 (115-160,000 tonnes), but advised TACs have been reduced later years (80,000 tonnes for 2013). Off the East coast of Greenland, only 10-40 per cent of 12,400 tonnes TACs after 2005 have been caught, while in Barents/Svalbard area, up to 40 to 75 per cent of TACs in the range of 40-60,000 tonnes were caught from 2006-2012.

2.2 Status of Arctic aquaculture

Turning to aquaculture, Norwegian enterprises produce the vast majority of farmed fish in the Arctic with 98 per cent of total Arctic production. However Arctic aquaculture also takes place in Iceland, Northwest Russia and in the inlands of Sweden and Finland (Hermansen and Troell, 2013). The dominant species is salmon, but also small volumes of Arctic char, trout and cod are farmed. In total, Arctic aquaculture constitutes only 2 per cent of global production, but has the same size as the total EU aquaculture production.

For some species and countries, information about production and geographical distribution are not readily available. The salmon industry is relatively young but has been growing fast since its emergence in the late 1960's. Salmonid aquaculture also occurs in North and South America and in Australia. Farming in Arctic waters only takes place in Northern Europe thanks to the Atlantic current providing higher sea temperatures than in other places at comparable latitudes.

Culture is predominantly based in net pens in the sea for grow-out stages. Production is limited by the authorities through licensing and biomass limits in Norway. Lately, the industry has seen some problems particularly with a parasitic crustacean (sea lice) that has prompted the authorities to restrict further growth.

The industry seems well adapted to coping with issues stemming from climate change. Farming is already taking place in areas that experience a considerable range of climatic variability - from the relatively warm waters in Scotland and Ireland to the colder waters in the Kola Peninsula. It has also developed strategies enabling to cope with severe weather and wave heights. This development is ongoing. However, climatic changes will likely affect aquaculture productivity in different areas thereby changing areas' comparative advantages. In particular, increased sea temperatures will improve competitiveness for farming further into Arctic areas.

2.3 Seafood trade and employment

Fish and seafood are important global trade items, most captured fish is landed in ports belonging to the flag state, for processing - either domestically or abroad. For Norway and Iceland the share of total landings conducted in foreign ports in 2011 were only 11 and 6 per cent respectively. Substantial shares of Russian catches were earlier landed abroad. In 2010 a law amendment abolished the high taxes or tariffs that Russian vessels landing in home ports used to meet. After that, Russian domestic landings increased dramatically with more than 1 million tonnes since 2004 (FAO 2012). Also, the problem with illegal, unreported and unregulated (IUU) fishing seems to have declined in the North-East Atlantic (FAO 2007) after a binding port state control agreement within the NEAFC, contributing also to increased domestic landings in Russia according to the Ministry of Fisheries and Costal Affairs of Norway (2010).

The seafood processing industry in these high latitudes is to some degree species dependent. Establishments are reserved for demersal, pelagic and farmed fish. Processing infrastructure for demersal and pelagic fish is often temporally and spatially confined, whenever fish is not supplied by larger offshore vessels (mainly trawlers and, to some degree, long liners), which to a greater extent is the case for Iceland and Russia. For pelagic species, processing is often narrowed to limited time windows when the catch takes place. However, a fleet of large vessels is able to reach landing sites far away. For demersal catches, at least for Norway, distinct fishing seasons - often in relation to feeding and spawning migration – limit the time window for processing catch that is not supplied from offshore vessels.

The activity and employment generated on land, based on farmed or wild fish, depends not only on which species are landed and how they are used, but also on whether the fish is landed frozen or fresh. However, the major trend is toward reduced land operations (as well as at sea) in the wake of technological development and increased global division of labour.

In Norway, employment in salmonid aquaculture has remained stable (3,500 persons) between 1994 and 2011 while production increased from 220 to 1,120 thousand tonnes. In the fishing industry, restructuring and consolidation led to a substantial drop in employment and number of vessels. In 1994 roughly 3,000 (whole year operated) vessels caught 2,140,000 tonnes, while in 2011, 1,525 vessels landed only 120,000 tonnes less. In 1994, fishing was the main occupation for 16,000 persons. This figure dropped to 10,000 in 2011. The Norwegian seafood processing industry has undergone similar changes, and even though volumes of caught wild fish have remained stable, in the period 2000-2011, the number of employees in the wild-fish processing industry has dropped by 35 per cent (from 13,000 to 8,000) in the period 2000 to 2011 (Bendiksen, 2013). In the same period, aquaculture production more than doubled, without seeing the same effect in the processing sector employment, since most fish is sold fresh, gutted with head (80 %). Statistics Iceland's labour market statistics[10] reveals the same tendencies. In the period 2000-2008, employment in fishing fell from 6,100 to 4,200 (-31 %) while in the fish processing industry, employment was reduced from 6,700 to 3,100 (-54 %). During this period the number of foreign employees increased, now constituting up to 10 per cent of the total workforce of the processing industry in both nations.

In addition to the FAO principles, the main existing sustainability's frameworks for fisheries are: the FAO Code of Conduct for Responsible Fisheries, the Canadian Code of Conduct for Responsible Fishing Operations, the Consensus Code, and the Marine Stewardship Council Principles and Criteria for Sustainable Fishing. The FAO code also contains specific text related to responsible aquaculture, and Aquaculture Stewardship Council (ASC) has recently been developed and implemented.

3. Environmental dimension

The environmental dimension in this report focuses mainly on ecosystem viability and its capacity to produce ecosystem goods and services related to fisheries and aquaculture. We identified three relevant policy categories. For the first one, related to marine resources being directly harvested, we identified two sets of indicators of relevance to assess sustainable development. Indicators of fish stock properties like stock estimates (3.1) and their age composition (3.2) are essential to assess the abundance of fish and the potential

[10] Statistics Iceland, available online: http://www.statice.is/Statistics/Wages,-income-and-labour-market/Labour-market

for future growth. Another essential aspect is species and fish health, which ultimately indicates long term viability of e.g. a fish population. Indicators of length and weight relationship (3.3) can help measure such aspect for fish.

Fish health is also highly relevant for the policy category related to aquaculture and is measured by mortality (3.4) in captivity. Aquaculture operations release nutrients (dissolved and particulate) to surrounding environment, resulting in negative local to regional impacts. Local impact includes changed benthic conditions in the vicinity of farms (3.5).

The state of the ecosystem or resource base has a general relevance for the continued provision of ecosystems services in the sense that it constitutes the production base for all fish populations in the sea, something that indirectly affect aquaculture through its dependence on fish resources in feed and suitable farming areas with good water quality. Four dimensions of a sustainable state of the ecosystem were identified. Introduction and spread of alien species indicate possible risks for transformation of ecosystem structure and functions, which may impact negatively on the potential for provision of ecosystem goods and services. In particular invasive species able to compete effectively with existing species or occupying empty niches may result in significant changes (3.6). The extent of marine protected areas indicate acceptance of a specific management measure but it does not say anything about how effective these are (3.7). Environmental quality can be measured in many ways and can partially be captured by different pollution parameters. With respect to fish the concentration of pollutants in the fish themselves (3.8) could serve as an indicator, but one needs to consider that the accumulation is a result from the whole life cycle of the fish. This means that any changes in pollution can in most situations not be linked to any specific ecosystem. To achieve this, one needs to identify specific areas/habitats that the fish is connected to and measure how the qualities of these are changing (3.9). If not measuring changes in concentration of pollutants in e.g. sediments or species, one can look at ecosystem structure and use species biodiversity as a proxy of ecosystem health. Important here is to not only consider general diversity but also look at changes in functional diversity.

3.1 Stock estimates

Although the stock size of individual fish species can vary substantially due e.g. to migration or predator prey interactions, it gives nonetheless an essential indication of the potential of a particular species to sustain a viable stock in the long run. Low stock sizes for a species works as a warning indicator that sea food production based on that particular species may not be sustainable. Hence while large variation may be acceptable, it is likely that each particular species has a minimum threshold under which it may become threatened, which motivates stock estimate as a relevant indicator.

Stock sizes of wild fish cannot be directly measured and are instead estimated using different methods. Historical catches form the most important source of information for the estimation of the size of a fish stock biomass in nature. Over the last fifty years Gulland's method, Virtual Population Analysis (VPA) has been the dominant technique to perform such estimations. The method works like an accounting system, back-calculating previous age composition and year class strengths consistent with assumed biological properties (growth and mortality) and historical catches. The VPA can be tuned using additional available information from research cruises, recruitment success rate, catch efficiency by different gears, in different areas, etc. The Extended Survivors Analysis (XSA) methodology is a common tuned VPA method.

The VPA method is most accurate when fishing mortality constitutes a large fraction of the total mortality of the fish stock and gives a more robust estimate some years back in time. The tuned XSA improves current stock estimates.

Stock estimates are carried out by working groups of The International Council for the Exploration of the Sea (ICES) for all the economically most important fish species in the area covered by this report. Threshold values may be available that would indicate for example the minimal viable stock for successful reproduction. Data is available online through ICES[11].

3.2 Age composition

Age composition of a species stock can convey substantial information about potential for future growth of a stock. Substantial unbalance toward younger individuals would indicate that mature fish is intensively harvested thereby influencing the current quality of the catch and also long run potential for stock growth. Substantial unbalance toward mature individuals would instead indicate that breeding grounds may be threatened thereby affecting the fish's reproduction capacity.

The single measure which presumably reflects the most essential information found in the age composition of a stock is ratio between the immature and the mature fractions of stock in terms of biomass:

$$\text{Mature biomass fraction (MBF)} = \frac{\mathrm{B_M}}{\mathrm{B}},$$

Where B is the total biomass of a fish population and B_M is the mature fraction of this biomass.

This estimate is also available from the ICES working group.

[11] http://www.ices.dk/marine-data/Pages/default.aspx

3.3 Length and weight relationship

Although species health would convey substantial information about the potential for sustainable fish stock development, it is practically difficult to measure directly on a large scale and would require substantial monitoring programs, as well as an indicator system with many dimensions. The relationship between length and weight is a proxy for fish health that can more easily be measured. Fulton's condition factor uses such relationship and aims to reflect how much food is available to the particular stock. It could be compared to a body mass index (BMI) for humans. Fulton (1902) introduced this indicator, aiming to quantify the physical condition of a single fish:

$$\text{Fulton's condition factor (FCF)} = \frac{\mathrm{W}}{\mathrm{L}^3}$$

Where *W* is the weight and *L* the length of the fish or the corresponding average values for each year class of the entire fish population. Length and weight data is obtained from catch samples or tuned estimates from these samples since weight and length distributions in the catches may differ from the distributions in the standing stock.

3.4 Aquaculture mortality

Fish health is an important aspect of sustainability in aquaculture. Diseases and fish death before harvest are unwanted but unavoidable features of all biological production processes, including aquaculture. While fish health could be tricky and costly to measure, fish mortality in captivity is a measure that is relatively easy to monitor and that is linked to fish health. Hence we suggest using mortality as a proxy. Mortality rate measures the number of death in a population, scaled to the size of the population and per time unit. It can be calculated for example as number of death per 1000 individuals per year. The levels vary with several parameters, particularly between species (i.e. how sensitive they are to diseases, stress, etc.), but also as a result of operational and strategic practices. Defining mortality or disease thresholds for sustainable practice is difficult, but comparing the current level against the industry's own historic figures within the region and in other similar countries may serve as a good indicator of viability and trajectory.

The most readily available aquaculture data is for Norwegian salmon culture. The data is reported from individual farmers to the Directorate of Fisheries and published on-line at their web-pages[12]. Losses are measured in number of individuals lost among juveniles and presented by county and on an annual basis, thus allowing defining an Arctic-specific

[12] http://www.fiskeridir.no/english/statistics

indicator. The reason for losses is, however, not specified so the losses cannot be correlated to any specific factors.

Losses in terms of absolute numbers of fish in aquaculture are closely linked to the stocked number of fish; hence the indicator should be relative losses - per cent of losses. For comparability and due to seasonal variations (slaughter etc.) we used the stock at the beginning of the year and related the annual losses to this figure. Figure 3.1 illustrates relative mortality in salmon culture in the Norwegian Arctic between 2002 and 2012. Relative mortality is shown for each of the three counties within the Arctic along with the weighted average for the rest of Norway.

There are relatively large annual variations in mortality in salmon culture, particularly for the Arctic Norwegian counties. For non-Arctic Norway, mortality is generally between 15 and 17%, with a considerable reduction in 2012. Early in the period, the Arctic countries generally experienced less mortality, but have in the latter half been at similar levels except for the northernmost county of Finnmark, where mortality has been considerably higher than the others. Further studies would be needed to explain the reasons for these changes.

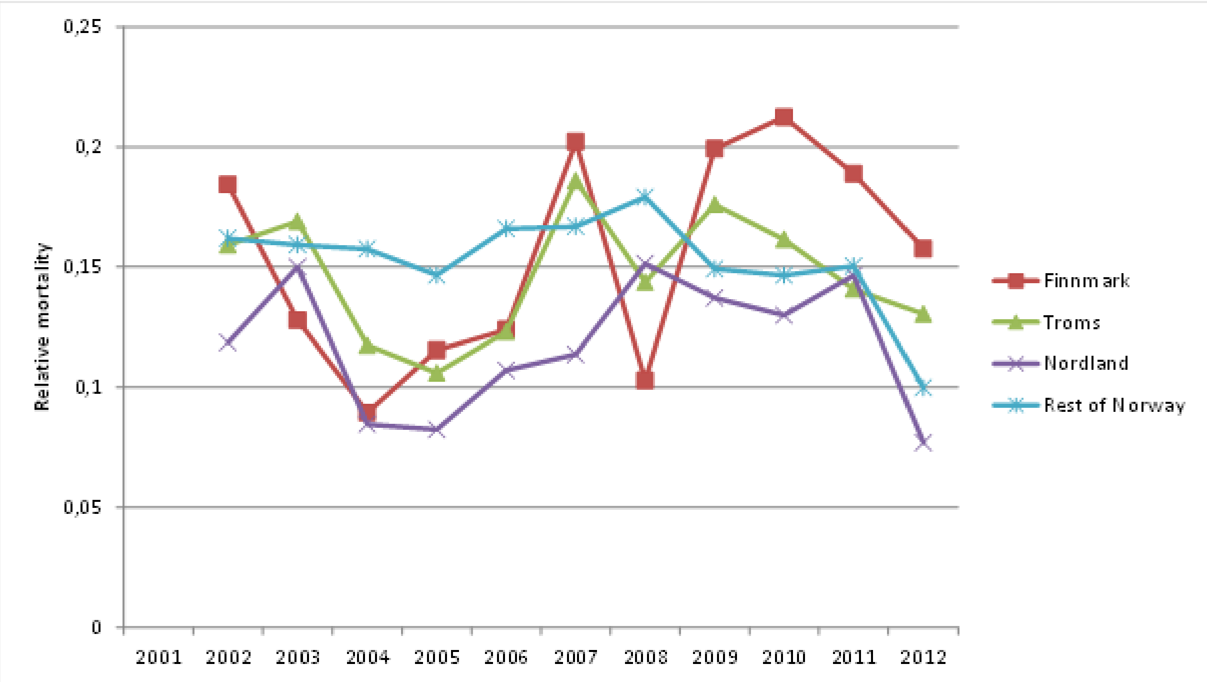

Figure 3: Relative mortality in Salmon aquaculture in Norway between 2002 and 2012

3.5 Benthic conditions

Benthic condition is a commonly used set of indicator for status of near-shore coastal areas. Although there is not a single indicator that can capture all the dimensions of benthic conditions it is possible to identify a limited set of indicators that can cover these dimensions. It is a relatively broad concept that can include different aspects of physicochemical water quality characteristics that may affect the ability of species to remain in a particular habitat. It could also include indicators for habitat (like vegetation cover) and sediment composition (toxicity, chemistry, etc.) Especially response to eutrophication is monitored through changes in sediment chemical properties or benthic organism community composition. In this report this indicator is only related to impacts on surrounding ecosystem under and near cage aquaculture operations - i.e. specifically conditions of bottom sediments (but this could also be expanded to the adjacent "phytal zone" - i.e. including both soft sediment vegetation and rocky shore vegetation). Benthic conditions could also be related to effects on bottom systems from bottom trawling or from oil extraction - both having an impact on biodiversity and also on the fishery itself.

Like other countries with coastal aquaculture, Norway has regulations in place regarding to how much dissolved nutrients and particulate matter is allowed to be released from a farm (based on production, or recipient sensitivity). Generally the farmers are responsible for performing regular monitoring. They can monitor water themselves but usually need to engage specialised consults to monitor sediment impact. They monitor organic accumulation (% organic matter) in the sediment but also species diversity (e.g. Shannon-weaver or Simpson index) and occurrence of sulphide bacteria. Organic accumulation is allowed near the farm and rotation schemes are often in place to let the local environment (and sediment) recover from continuous exposure to high nutrient concentrations and organic accumulation. Normally the sediment ecosystem recovers within a few years depending on hydrology but some of the larger animal species may not return.

3.6 Invasive species

Invasive species are new species establishing themselves successfully in a system through rapid growth or efficient occupation of an empty ecological niche. Rapid growth or spread can together with efficient competition for resources (food, nutrients, space, light, etc.) result in structural ecosystem changes (biodiversity loss/or enhancement), or have consequences for functional properties (i.e. changing production of desired species) or some regulating/supporting function (i.e. nutrient transfer or decomposition, etc.). In addition, new species can also function as vectors for diseases or pest species.

The warming of the Arctic sea increases the potential for new species being introduced. New species to a marine environment can enter a system through e.g. ship's ballast water, escapes from cultivation and rapid migration from distant ecosystems due to changes in climatic factors. Increase in ship traffic through the Northeast and Northwest Passages may increase ballast water exchange. However, it is not at all certain that new species will thrive, or even survive. Even if new species establish themselves in the system they may not alter the system in any significant way. Again, the invasiveness of new species needs to be monitored. Based on previous knowledge about how these species behave it will be possible to make a risk analysis about the kind of impacts that can be expected. Resulting impacts will however not be possible to fully anticipate but understanding the behaviour of the new species will help. There is currently not much data available as time series to monitor the occurrence of invasive species. A rather straight forward way to proceed in order to remedy this lack of data would be to establish a database on species with invasive behaviour. This could be done using existing literature on invasive species in cold sea waters. It would then be useful to monitor their appearance and distribution in the Arctic to help predict their future impacts.

However it is unclear where such monitoring data could come from and information could be learned from results from task 1.1 in the ACCESS project for how this could best be performed.

3.7 Marine Protected Areas

Authorities' willingness to protect areas of particular importance for sustainable development also indicate to what extent the state of the ecosystem or resource base can be sustained in the long term. Marine protected areas could be a proxy for such a measure. Marine protected areas are regions where human activity is restricted to help protect the natural environment, surrounding waters and ecosystems, or cultural or historical resources that may require preservation or management.

Marine resources are protected by local, state, territorial, native, regional, or national authorities and may differ substantially from nation to nation. This variation includes different limitations on development, fishing practices, fishing seasons and catch limits.

Marine protected areas are included on the World Database on Protected Areas (WDPA)[13], which, since 2010 is viewable via Protected Planet[14], an online interactive search engine hosted by the United Nations Environment Programme's World Conservation Monitoring Center (UNEP-WCMC).

While the total area of marine protected areas being established in a particular region gives some indication that this region is protected, another possible indicator could be the percentage of protected area in a particular region, which also conveys information about the size of the protected area in relation to the area that is not protected. This indicator is

[13] Available online: http://www.wdpa.org/

[14] http://www.protectedplanet.net/

rather coarse however and should be complemented with information about the kind of area that is protected (breeding or feeding grounds, etc.) and what activities are allowed within the protected area. Given the slow changes in the areas protected, time series data may not convey very much information.

3.8 Pollution

The "Group of Experts on the Scientific Aspects of Marine Pollution" (GESAMP) defined already in 1969 marine pollution in the following way: "*the introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of sea water, and reduction of amenities*."(GESAMEP, 1983). With specific focus on the increasing oil and gas exploration, as well as increased shipping, monitoring of polluting substances from these activities seems appropriate. Accidental pollution and operational pollution can be identified in offshore oil and gas installations. The former involves blow-outs, pipeline ruptures, tankers spillages etc. and the latter involve discharges of drilling fluids and cuttings, both usually containing hydrocarbons and surface active materials. Disposal of atmospheric emissions, oil effluents, chemicals and other harmful substances as well as discharges of drilling muds results from operational operation.

Pollution is typically measured as the concentration of a particular pollutant in the environment (typically air or water) where it is found. However it is difficult to define what kind of pollution is the most interesting to measure from an indicator point of view. Ideally one would be able to identify the pollution that is expected to become an increasing problem but it is a challenging exercise given the amount of innovation occurring among the processes leading to pollution and the often unknown routes that pollutants take in nature from their source to the place where they cause damage. Pollutants that may impact on future sea food production and should thus probably be monitored include hazardous air pollutants (HAP), volatile organic compounds (VOC), bioaccumulation of polycyclic aromatic hydrocarbons (PAH). However these pollutants impact on different marine species in a complex way and different species have also different capacity to get rid of these after uptake. More research is needed in this area to better understand what needs to be monitored.

3.9 Living area

An important element for sustained healthy stocks of all kinds of Arctic species is the availability of habitat or living area where they can strive. Habitat loss is generally viewed as the largest single cause of biodiversity loss worldwide. The development of economic activities in the Arctic is likely to lead to some radical changes in habitat at least in particular locations due for example to trawling (fisheries), increased deposition of pollutants (transportation), and building of infrastructure (resource mining). The AMSA report identified oil spills as the most significant threat associated with Arctic marine shipping. Oil spills impacts on adult fish are likely to be restricted to fish stock relocation as the fish will try to avoid the oil. Large spills on breeding grounds may knock out a year class of fish. Similarly such spill may impact negatively on aquaculture however in such protected areas, skimming is likely to be effective. Other potential impacts of economic activities on particular living areas include ship strikes on marine mammals, disruption of migratory patterns, noise disturbance, and introduction of alien species. Fish, birds and mammals that gather in large number for purposes such as migration, staging, breeding, feeding, and resting, are to varying degrees sensitive and potentially vulnerable to oil spills and disturbances. Areas where such aggregations occur would also generally be considered ecologically important and thus of heightened ecological significance. While an area can be ecologically important without necessarily being particularly sensitive or vulnerable, there is a broad correspondence between ecological importance and sensitivity (and potential vulnerability) for areas used by aggregations of animals.

Areas of heightened ecological significance have been identified for each of the 16 Large Marine Ecosystems (LMEs) within the Arctic area. A total of about 97 areas of heightened ecological significance have been identified within the Arctic Large Marine Ecosystems. The areas were identified primarily on the basis of their ecological importance to fish, birds and/or mammals, as these species are the most widely studied Arctic groups. The majority of areas identified are used by birds (85) and marine mammals (81), with a lower number used by fish (40, most of them spawning areas). About 70 areas are used both by birds and mammals, and only two of the areas identified are used only by fish.

Three different approaches were used to identify these areas. (1) Areas identified as vulnerable areas in the AMAP Assessment of Oil and Gas Activities in the Arctic[15] were used as the basis for 'AMSA IIC' areas in 11 LMEs (located in the Northeast Atlantic sector, in the Russian Arctic, Bering and Chukchi Seas, and the Central Arctic Ocean). (2 and 3) Canada and Denmark/Greenland had separate national processes to identify areas of heightened ecological significance for their waters (five LMEs, from the Beaufort Sea to the Greenland Sea).

[15] Available online: www.amap.no/oil-and-gas-assessment-oga

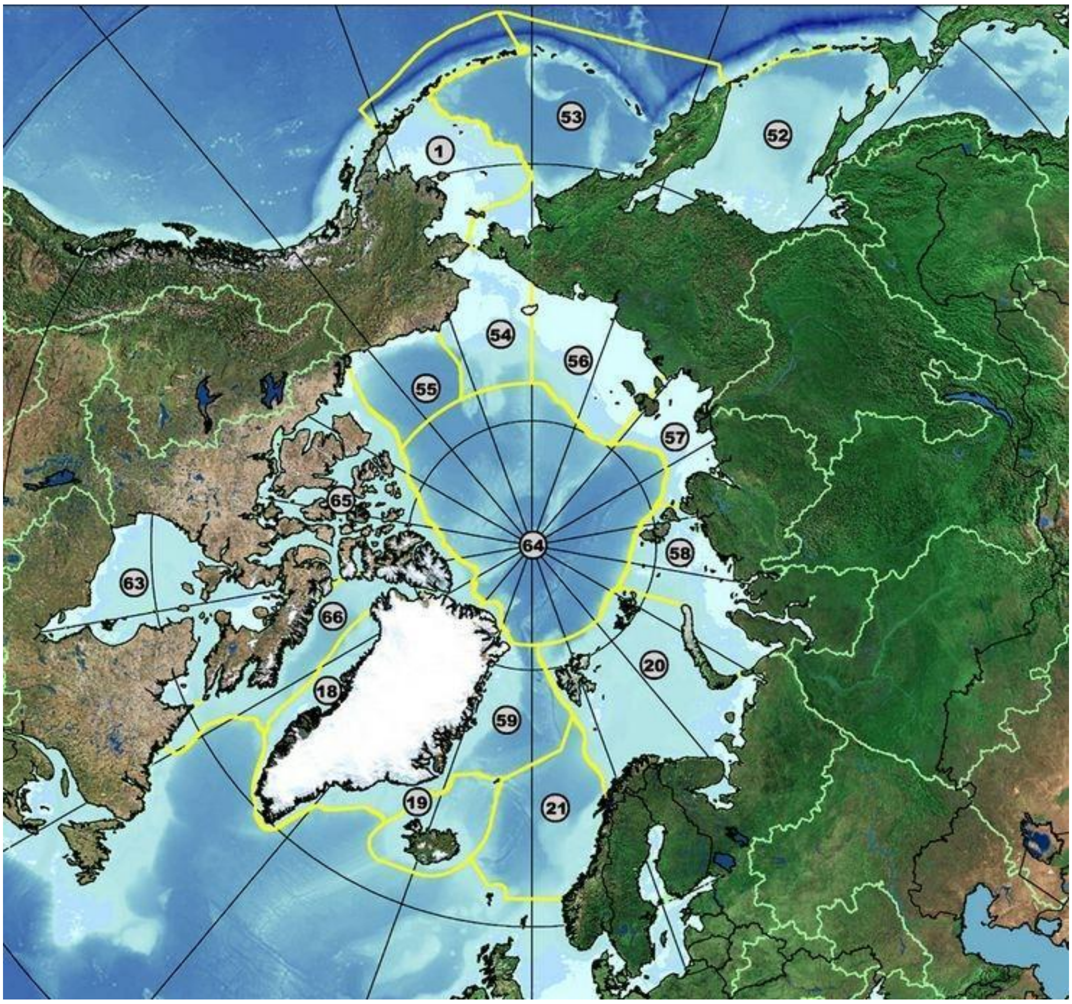

Figure 4: The 16 Arctic Large Marine Ecosystems. Source: Protection of the Marine Environment (PAME)

The areas are essentially stationary habitats (even if they feature a current flowing through them) and the uses of the areas by aggregations of animals provide close links between species and habitats in a functional ecological sense. This is important in relation to use of the information in the context of the ecosystem approach to management.

Areas of heightened ecological significance are defined as areas that are ecologically important. All areas of nature have some ecological function for the animals, plants and microbes that occupy or use the areas, either permanently or seasonally. 'Heightened ecological significance' and 'ecologically important' are understood in a relative sense, as areas that are more important than other areas. This does not mean that those other areas are not ecologically significant or ecologically unimportant, only that they are less significant and less important than the identified 'important' areas.

Ecological sensitivity of an area is not strictly the same as ecological importance. An area may be ecologically important without necessarily being ecologically sensitive. However, the two aspects of sensitivity and ecological importance are often related in reality. This is particularly the case where the ecological sensitivity is reflected in the use of areas by animals for biological or ecological purposes such as breeding, feeding, migration, wintering, etc. Aggregations of fish, birds or mammals at particular geographical locations will often convey an ecological significance to those locations in that they may serve as important or critical habitats during the annual or life cycles of the animals.

Vulnerability is related to sensitivity but the two are not the same. Vulnerability relates to specific pressures or threats. If there are no activities or threats, an area may be considered sensitive but not vulnerable. The properties of sensitivity and vulnerability of areas may be seen as comprising three levels. The first level relates to the intrinsic properties of organisms or habitat features that reflect whether they are sensitive or fragile to external disturbances. Animal species may be sensitive to disturbances through changes in behaviour or other biological effects, and may be slow to recover should they be impacted due to low rates of reproduction. Habitat features may be physically fragile and easily impacted by physical stress, for example, cold-water corals being impacted by bottom trawling. The second level relates to the ecological setting. An area where many sensitive organisms or habitat features are concentrated is more sensitive or fragile than a comparable area where they are more scarce and dispersed. The third level relates to the presence of pressures and impacts from human activities. Whether an area identified as sensitive should also be considered vulnerable depends on whether there are direct or potential threats.

There are several sets of criteria for identifying sensitive and ecologically important areas. Of particular relevance in the present case are the IMO criteria for Particularly Sensitive Sea Areas (PSSA)[16], which are mentioned as an appropriate tool in AMSA Recommendation IID (Arctic Council, 2009). The UN Convention on Biological Diversity has adopted another set of criteria for identifying Ecologically and Biologically Significant Areas (EBSAs). The International Union for the Conservation of Nature (IUCN) has also proposed criteria for selecting Marine Protected Areas (MPAs).

While it is clear that living areas play an important role for maintaining species and biodiversity, it is much less clear how a proper indicator should look like. Living areas range from the whole pelagic system to all coastal habitats and it is impossible to build an indicator capturing the health status of all these different kinds of systems. A possible very rough proxy that we propose using is the share of areas of heightened ecological significance that are relatively unaffected by economic activities over the total area in the region. This indicator is very coarse but has the advantage that data may be relatively easy and cheap to collect from observation during other monitoring activities that are already taking place.

[16] IMO 2006, revised guidelines for PSSA, available online: http://www.imo.org/blast/blastDataHelper.asp?data_id=14373&filename=982.pdf retrieved March 28, 2014.

More research is needed though to assess how such observation could be made in a systematic way.

4. Social dimension

While environmental and economic sustainability have been extensively researched and debated, social sustainability is less well understood. Varying definitions of social sustainability can encompass social equity, liveability, health equity, community development, social capital, social support, human rights, democracy, labour rights, place-making, social responsibility, social justice, cultural competence, community resilience, and human adaptation. Thus it is a very wide concept and given different values placed on some aspects of this broad concept of social sustainability, measures can be interpreted very differently. For example democracy or certain human rights are not valued highly in some countries. Furthermore, many of the concepts are difficult to measure. For example people may have very different views on the 'liveability' of an area depending on personal preferences. As such it is difficult to put forward a definitive set of general social sustainability indicators. However, a range of indicators that are less subjective and cover key aspects of social sustainability have been put forward in the academic literature. Our suggestions build very much on such previous approaches.

Unfortunately data availability for social dimensions indicators is a serious problem particularly if the focus is on regions rather than countries, which typically is the case. Thus, some indicators are not available for all regions. This is a substantial issue for the Russian Federation for which very little data was found and available data may not be broadly accessible due to language barriers. The data presented in Figures 5-8 shows national figures and represent a placeholder rather than an accurate indicator. There are also differences in the size of region for which data is available. For example for Alaska the data is at county level while for Canada only province and territory level was found. Such data is likely to exist but again language barriers make access difficult.

In addition, there are some differences in definitions, particularly with respect to the definition of poverty. Finally, except for population change most data on social indicators is static i.e. refers to a point in time. Hence it would be useful to also monitor changes in the indicators.

For the social dimension of sustainable development we focus on the two policy categories of well-being and social inclusion. We follow a pragmatic approach, which considers data for key indicators related to the indicator target areas of population characteristics, human health, and labour market access and income inequality.

4.1 Population change and migration

Population change is important because social sustainability is irrelevant without people. Population demography is an important domain on the list of statistical monitoring of broad areas of social concern (United Nations 1975, 1989, 1996). In the sparsely populated Arctic areas and especially in the rural communities even relatively small changes in population dynamics can drive many challenges for sustainable development. Areas that experience population decline may become socially unsustainable as the population shrinks below a minimum size to maintain services. In contrast, areas with particularly strong population growth may experience significant social pressures, perhaps due to change in the way of life, increased ethnic heterogeneity or competition for resources and services. Figure 5 illustrates population change for the most recent two years for which data is available. This change is measured as a percentage of increase in the population due to migration and natural reproduction between two years. Parts of Alaska (North Slope Borough, Denali Borough, South Fairbanks, Lake and Peninsula Borough, Matanuska-Susitna) experienced significant population growth. Likewise in Canada, Alberta and Seskatchewan grew significantly. However some parts of Alaska (Yukon-Koyukuk and Nome) and Canada (Northwestern Territories) also recorded a population decline. Greenland, Iceland and parts of Northern Sweden and Northern Finland also declined.

While basic population statistics are among the most important indicators and are routinely collected by governmental agencies, migration could be considered as relevant sustainability indicator of the fishery sector. Migration in general is one of the significant demographic forces in the North. In Northern Norwegian communities there is a mismatch between employment opportunities and the labour forces primarily in the fish processing sector, which triggers changes in population structure. While employers do not find adequate labour force, there is still a large rate of unemployment and sickness in the region (Anna Stammler-Gossmann, ACCESS report D3.41, forthcoming). This problem is often solved by attracting foreign labour force. Net migration has particular importance for Arctic places, where the arrival of newcomers or departures of local young adults can quickly reshape community life (ASI 2010: 41).

Out-migration by young people and aging population in small settlements can bring following economic and infrastructural decline, interruption in fishermen's knowledge transmission as experienced by some communities in Finnmark /Northern Norway (Anna Stammler-Gossmann, ACCESS report D3.41, forthcoming).

The in-migration may indicate an economic revival or growth, but may also be perceived at the local level as certain disturbance on the community's way of life. At the same time the newcomers may experience some stress because of the lack of language skills, different cultural background, and lower wages. In the Arctic to a greater degree than elsewhere, net migration often dominates population structure and change. Population and migration growth may also indicate an increased pressure on resources.

Although demography/migration is an appropriated indicator related to sustainability, its application is no straightforward task. Not all statistics in Norway and Russia, for example, are sensitive to the ethnic components of migration and substantial interpretational effort may be required. However, progress in this issue is essential to understand how to keep Arctic communities and specifically fishery sector viable.

Study in the borderland between Norway and Russia (Finnmark/Northern Norway and Murmansk region/North West Russia) shows that presence of the Russian fishermen in the Norwegian harbours can significantly influence Norwegian landing statistics as well as supportive service infrastructure in the community (landing services, ship repair, food and fuel delivery, fish storing terminals). Russian workers have also become important component of the labour force in the aquaculture sector. (Anna Stammler-Gossmann, ACCESS report D3.41, forthcoming)

National census data, in-between census estimates of population, register statistics on different scales provide time series of total population down to the community or enterprise level. Socio-economic circumpolar database ArcticStat provides data on the movements of the population according to variables Internal Movements, Immigration/ Emigration, Residents One Year Ago, Moved, Entered, Year of Entry etc. This web portal provides access to web pages with links to data produced by the national statistical agencies of Arctic countries.

The long-term SLiCA (The Survey of Living Conditions in the Arctic[17]) survey may provide a supportive part in understanding the role of demography/migration for the present living conditions relevant to Arctic communities. Data is available from Eurostat New Cronos database, Statistics Canada, Statistics Norway and data for Russia can be found through the World Bank World Development Indicators.

[17] Available online: http://www.arcticlivingconditions.org/ Retrieved March 28, 2014

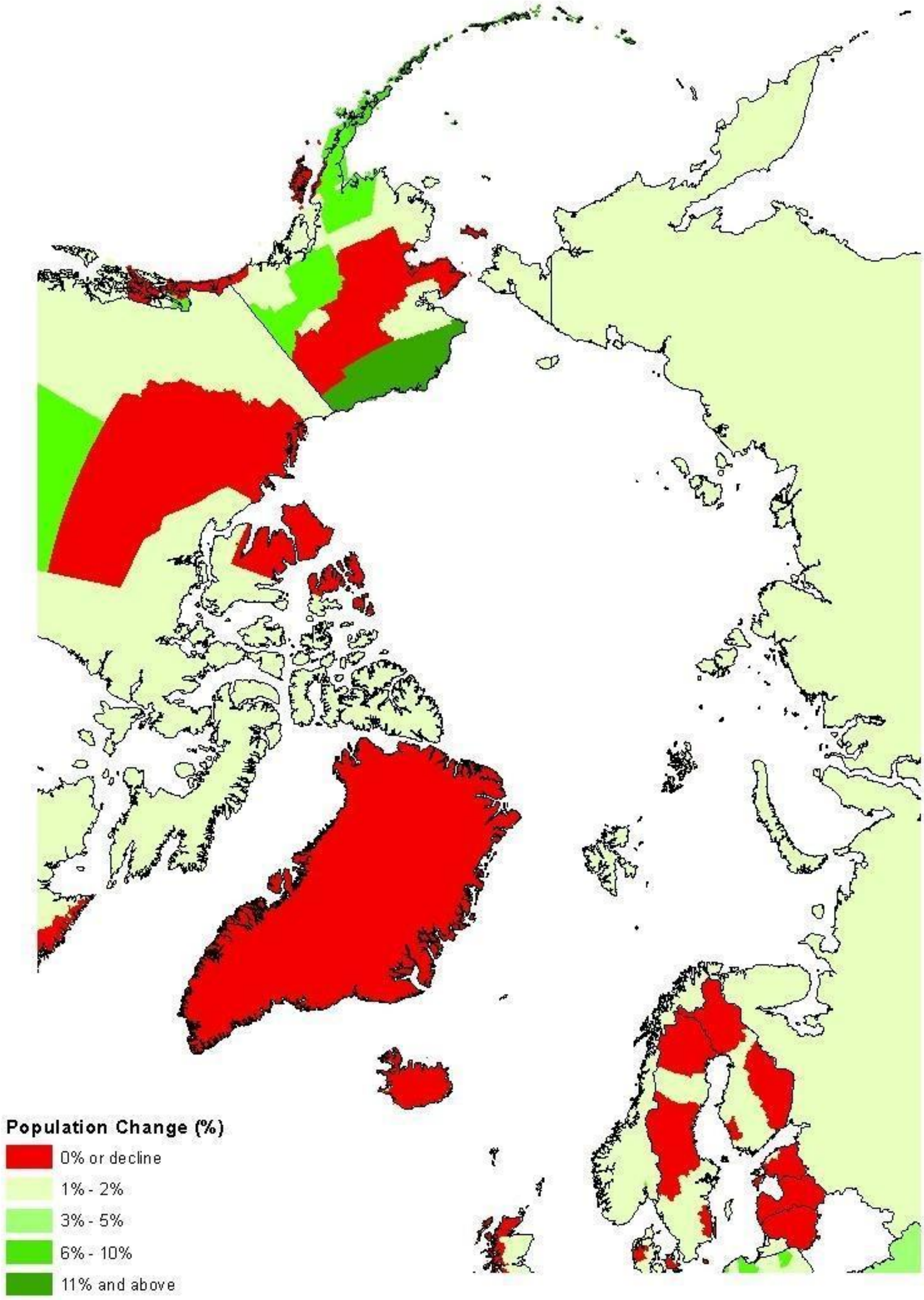

Figure 5: Population Change (%), between two most recent years. Sources: For EU countries, Iceland and Norway the data is from EUROSTAT New Cronos database, Data for Canada is from Statistics Canada, data for the USA is from the US Census Bureau, data for Greenland is from Statistics Greenland, data for Svalbard is from Statistics Norway and data for Russia is from the World Bank World Development Indicators. For Canada, EU and Norway the data are for 2010/11, for Alaska 2009/10, Russia for 2011/12 and for Iceland 2012/13.

4.2 Crime rates and other indicators of human health

Human health is a tricky target area to monitor. We suggest focusing on crime rates as a relevant indicator. High crime rates lead to a lower sense of security among residents and visitors and they are also an indicator of the effectiveness of the rule of law. High crime rates against property tend to be associated with a lack of economic opportunities while crimes against persons (assault, rape, murder) tend to have socio-demographic drives. Given the focus on social sustainability, crime is measured as the homicide rate. This indicator has the advantage of being similarly defined across jurisdictions, and unlike crime against property is typically well reported.

Figure 6 shows homicides rates across Arctic regions. These appear to be higher in Nunavut, Greenland and most of Alaska. In Europe, Northern Finland was found to have higher rates.

Other health indicators are related to population characteristics discussed in Section 4.1. For example, the numbers of births and deaths are essential health indicators. Population characteristics such as size, sex ratios, age structure, in- or out-migration, and rates of growth or decline are widely recognized as a reflection of the health of a community. Population growth, presence of young people, return or circular migration in the small coastal communities of the Barents region is considered by the local residents as powerful factor for the community viability. (Anna Stammler-Gossmann, ACCESS report D3.41, forthcoming)

Data is available from EUROSTAT, New Cronos database, from Alaska County Health Rankings, Statistics Greenland, and Canadian Centre for Justice Statistics. For the Russian Federation no regional data was found but national homicide rate can be obtained from the UNODC Global Study on Homicide.

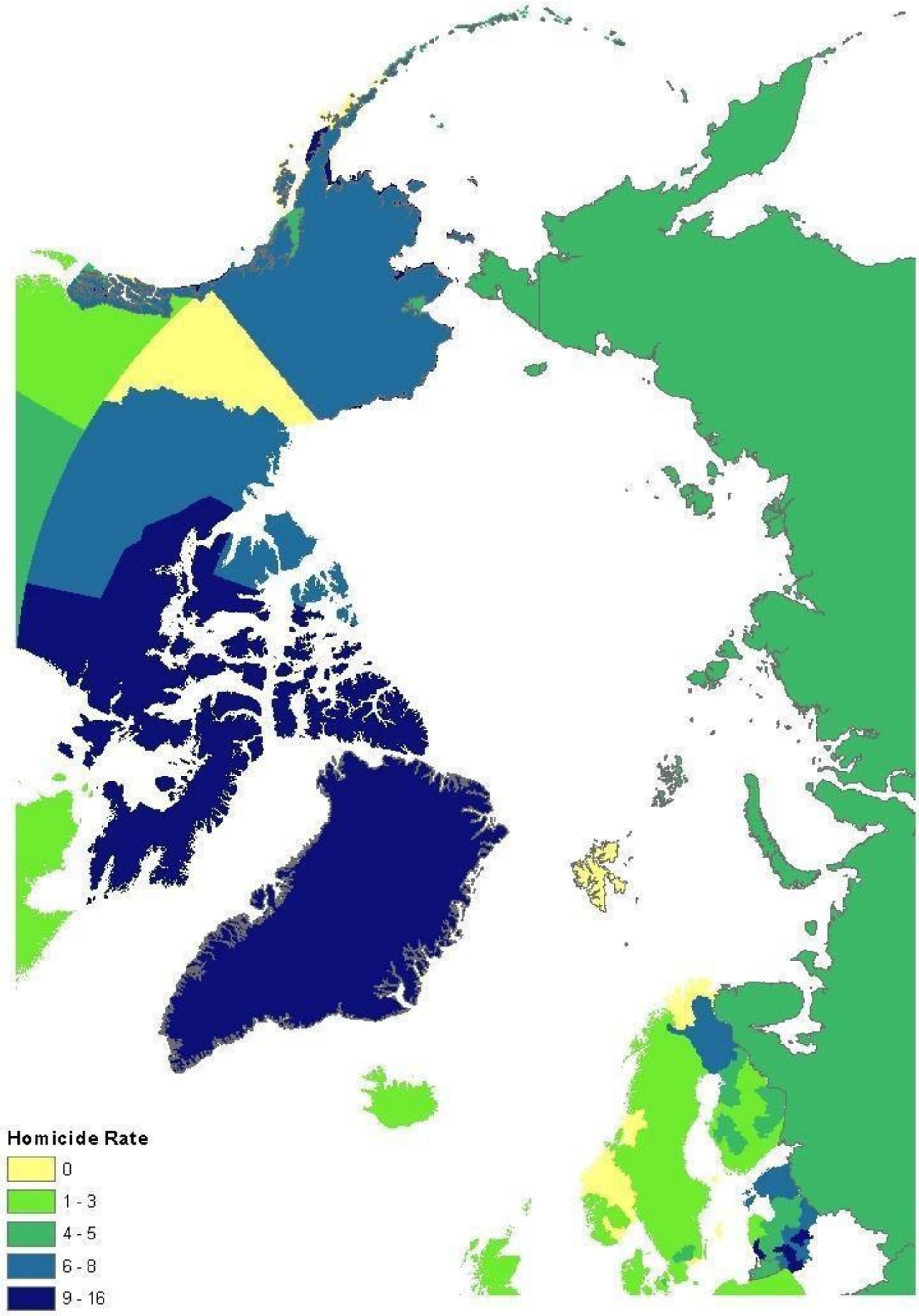

Figure 6: Homicide Rate (Homicides per 100,000 persons), for the most recent years Sources: For EU countries, Iceland and Norway the data is from EUROSTAT, New Cronos database, for Alaska the data was obtained from County Health Rankings 2011, for Greenland the data is sourced from Statistics Greenland, for Canada the data was taken from the Canadian Centre for Justice Statistics. For the Russian Federation only the national homicide rate is available from the UNODC Global Study on Homicide. All data are for 2009, 2010 or 2011.

4.3 Unemployment rate

The unemployment rate is a useful indicator of labour market access, i.e. the degree to which individual can partake in paid economic activity, which impacts on their living standards, the status that people have within society and the degree to which they can participate in wider social activities. This is an indicator related to the policy category of social inclusion, which focuses particularly on access to labour market.

It is measured by relating the number of unemployed people to the total size of the labour force. This is unfortunately measured differently in different countries official statistics making straightforward comparisons between countries challenging.

Figure 7 suggest like for population changes that there are large variations between the different Arctic regions. The unemployment rate is low in all of Norway, Iceland, Greenland and North Slope Borough in Alaska, while particularly high levels of unemployment were recorded in Wade Hampton, Denali Aleutian-East and Skagway boroughs of Alaska. Unemployment is also relatively high in most other parts of Alaska and Nunavut and Newfoundland and Labrador.

Data is available from EUROSTAT New Cronos database, Statistics Canada, US Census Bureau, and Statistics Greenland.

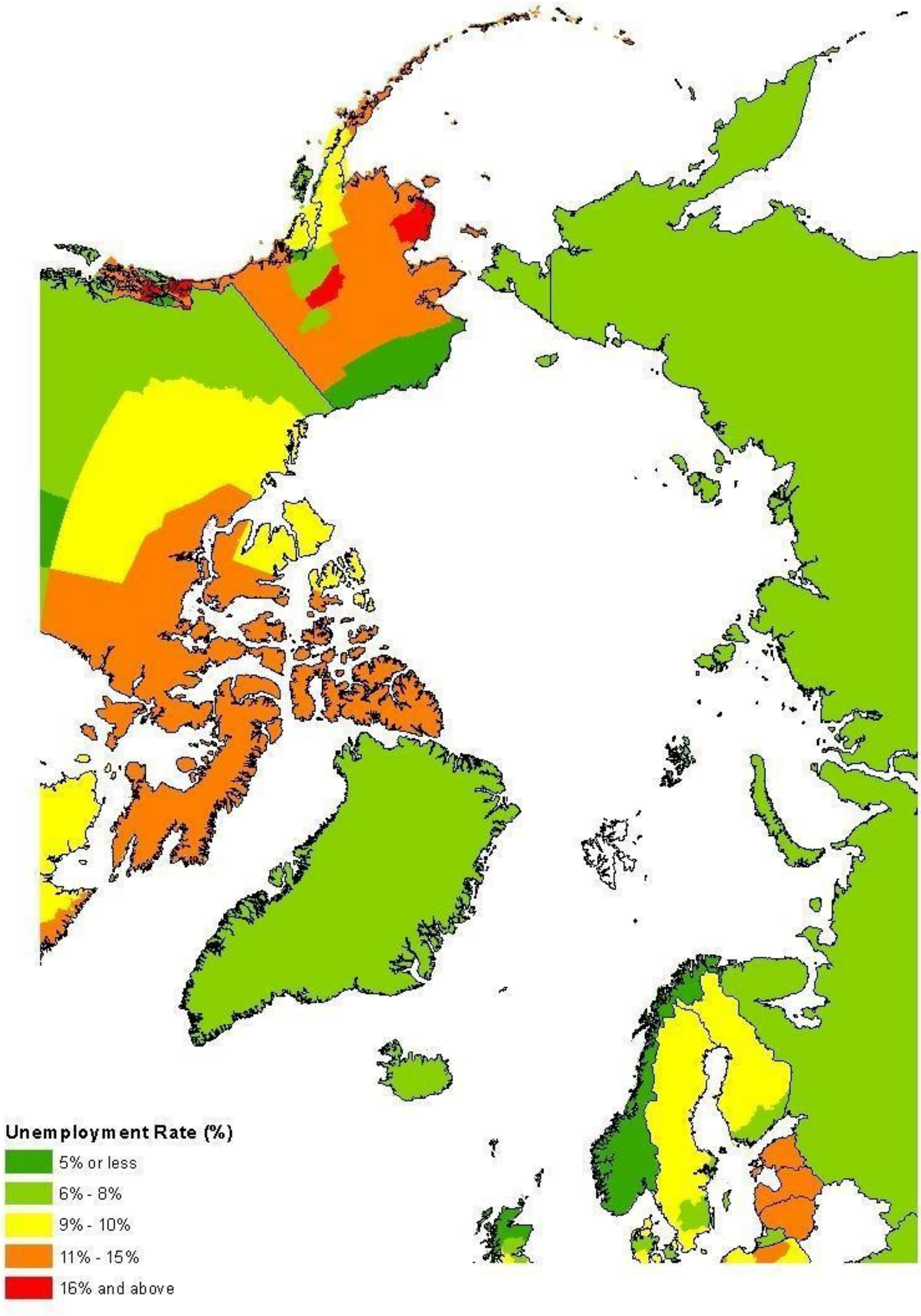

Figure 7: Unemployment Rate (%) 2013. Sources: For EU countries, Iceland and Norway the data is from EUROSTAT New Cronos database, Data for Canada is from Statistics Canada, data for the USA is from the US Census Bureau, data for Greenland is from Statistics Greenland

4.3 Educational attainment

Educational attainment is a useful indicator both of the educational opportunities an area provides as well as the economic return on educational qualifications. Areas that offer few employment opportunities tend to have a lower average educational attainment rate, which in turn limits the type of economic activities that can be carried out in these areas. This in turn tends to result in out-migration of better educated individuals to areas with better job opportunities and thus further reduces the average educational attainment rate. Such, areas, unless they are rich in natural resources, tend to be economically underdeveloped.

Here we suggest using a measure of educational attainment as the percentage of the population without a High School Certificate. With respect to educational attainment (Figure 8) there is a relationship between the latitude and the percentage of the population that does not hold at least a high school diploma, with the highest rates recorded in Greenland and NunavutMap. With the exception of North Slope, the northern parts of Alaska also have a lower educational attainment rate. For Europe, Iceland and Northern Parts of Norway also have lower attainment rates.

Data is available from EUROSTAT New Cronos database, Statistics Canada and US Census Bureau.

4.4 Poverty

Poverty is a function of earned and unearned income and the distribution of income across the population. High levels of poverty in particular areas tend to reduce social cohesion within countries, but also within affected areas. Poverty is measured as the percentage of poor people in the population. Data with a common definition across all countries is not available. For Alaska the poverty rate is measured relative to an income cut-off defined by the US Census Bureau, whereas for the EU, Norway and Iceland, the indicator is the percentage of the population living in severe material deprivation, which is a wider concept.

Only limited consistent data is available across Arctic regions. However, Figure 9 shows the poverty indicators for Alaska and Europe calculated as the percentage of poor persons in the total population. In Alaska Northern and Western parts tend to have a higher level of poverty than Southern parts. In Europe only the Baltic countries have high levels of poverty, but this is related to the differing levels of wealth across the countries shown in the map, primarily Norway, Sweden, Finland and Iceland and differing social welfare systems.

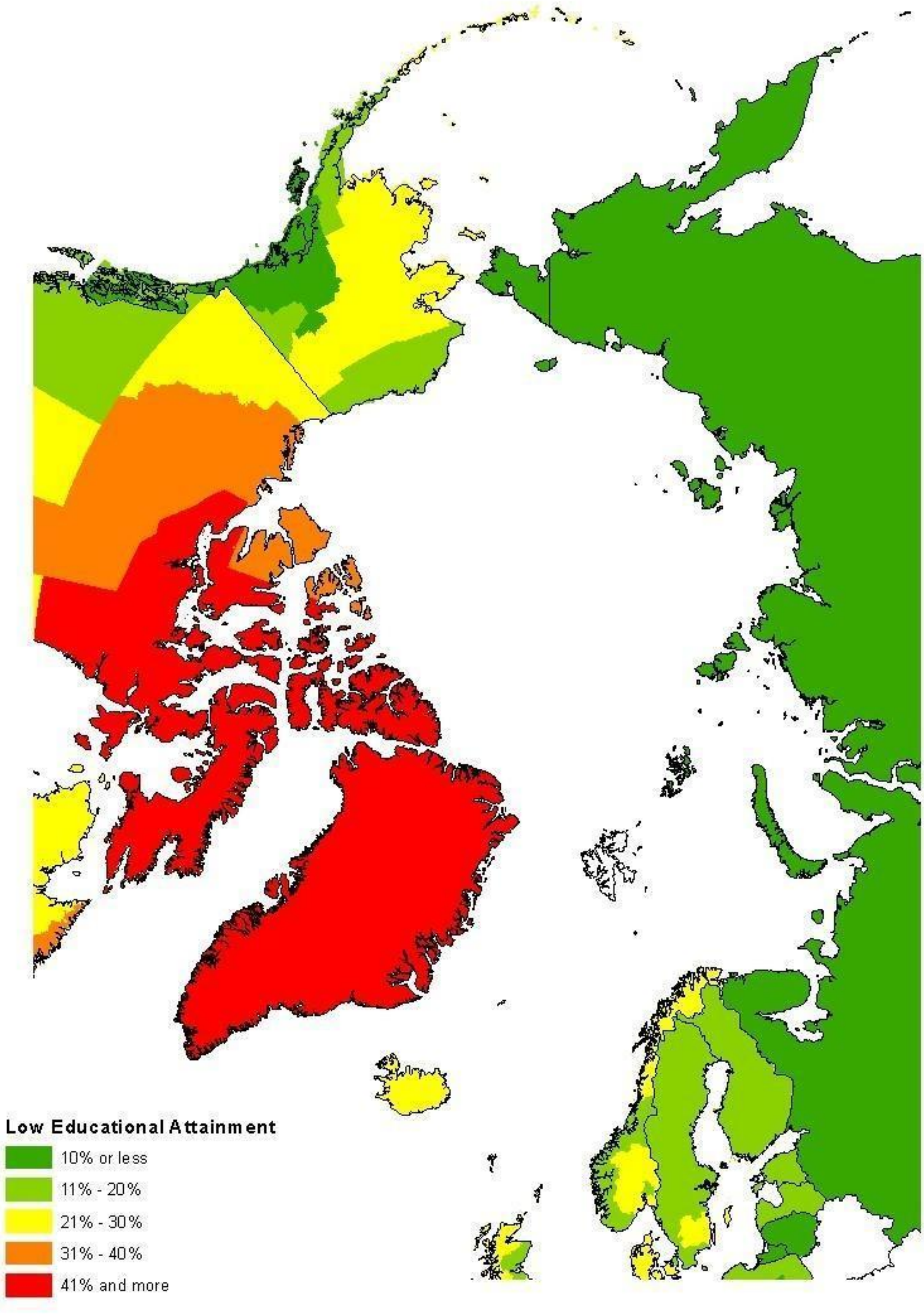

Figure 8: Percentage of the Population without a High School Certificate. Sources: For EU countries, Iceland and Norway the data is from EUROSTAT New Cronos database, Data for Canada is from Statistics Canada, data for the USA is from the US Census Bureau. Data for the EU, Norway, Iceland and Greenland is for 2012, data for Alaska is for 2011, for Canada 2006 and Russia for 2011.

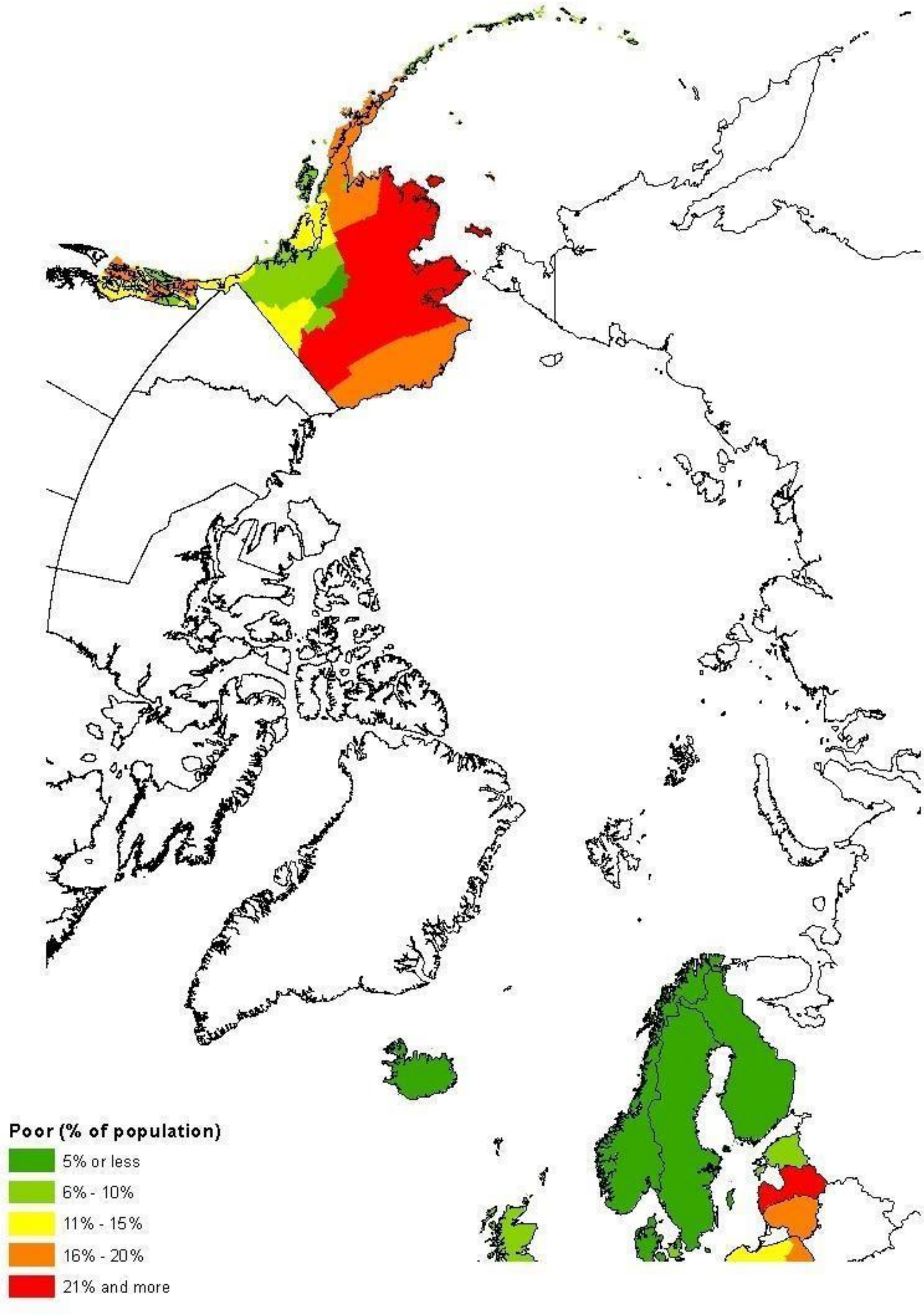

Figure 9: Poverty Rate (poor persons as % of total population, 2012) Sources: For EU countries, Iceland and Norway the data is from EUROSTAT New Cronos database and data for the USA is from the US Census Bureau.

5. Economic dimension

In the economic dimension we focused on a unique policy goal of having an economically sustainable seafood industry. We identified three essential target areas of a sustainable seafood industry: fleet capacity, profitability and investments in infrastructure. Fleet capacity is an essential element of a sustainable seafood industry pertaining to the fisheries sector. A too large fleet capacity could result in lower flexibility or trigger overfishing behaviour thereby eroding the natural resource base of the fisheries. We propose a fleet capacity indicator (5.1) and a fleet utilisation indicator (5.2) to measure that dimension. The reason for these two indicators is that they give different dimensions of fleet capacity. A high fleet capacity indicator combined with a low utilisation indicator would indicate overcapitalisation.

Profitability is another key element of sustainable seafood industry as activities with negative profits cannot be maintained in the long run. This is an issue in many regions where the fisheries sector is maintain through substantial subsidy system (EU fisheries subsidies[18]). We propose several indicators of profitability in the seafood industry: resource rent (5.3), catch (5.4), aquaculture production (5.5) and return on capital (5.6). Finally investments in infrastructure are essential to provide a capacity to process, transport and distribute seafood products to the market. We propose distance to agglomeration as a proxy to measure this dimension (5.7).

5.1 Fleet capacity indicator

The proposed indicator should provide a fleet capacity measure independent of capitalisation level, differences in vessel length, age, etc. and types of fisheries. Three specific measures are selected: Horsepower, number of vessels and number of fishermen. The proposed indicator is:

$$\text{fleet capacity indicator (FCI)} \ = \frac{1}{3}\left(\frac{\text{hp(t)}}{\text{hp(t}-1)}+\frac{\text{nf(t)}}{\text{nf(t}-1)}+\frac{\text{nv(t)}}{\text{nv(t}-1)}\right)-1$$

hp(*t*): Horsepower (total) in year *t*

nf(*t*): Number of fishermen in year *t*

nv(*t*): Number of fishing vessels in year *t*

This index gives a proxy for the percentage annual change in fishing capacity from year t to year t+1, giving equal weight to three capacity measures: horsepower, fishers and vessels.

[18] Available online: http://ec.europa.eu/fisheries/state_aid/index_en.htm Retrieved March, 19, 2014

Combining horsepower and vessels adjust capacity changes by vessel age and vessel size, while horsepower in combination with number of fishers may adjust capacity changes due to more or less capitalisation in the fisheries.

Data to calculate this indicator is available from The Norwegian Fisheries Directorate's web site for Norwegian data.[19]

5.2 Fleet utilisation indicator

A measure for fleet utilisation is obtained by combining actual catch and the fleet capacity indicator (*FCI*)

$$\text{catch per unit of effort measure (CPUEM)} = \frac{\text{catch(t)}}{\prod_{i=1}^{t} (1 - \text{FCI(i)})}$$

$$\text{fleet utilisation indicator (FUI)} = \frac{\text{CPUEM(t)}}{\text{CPUEM(t} - 1)}$$

An example from Norwegian fisheries based on data obtained at The Norwegian Fisheries Directorate's web site serves as an illustration.[20] Applying the proposed *FCI* on Norwegian fisheries indicates a decline in fishing capacity of about 28% over the period from 1996 to 2005. Left panel of Figure 10 shows how this decline is distributed on the different years during the period.

The fleet utilisation indicator (*FUI*) (right panel in Figure 10) suggests however that the decline in fleet capacity coincides with a higher degree of utilisation of the remaining fleet capacity. The difference between the two indicators also gives some ideas of the magnitude of technological changes.

[19] Available online http://www.fiskeridir.no/statistikk/fiskeri/fiskere-fartoey-og-tillatelser/fiskefartoey-og-fiskere-konsesjoner-og-aarlige-deltakeradganger retrieved March 31, 2014.

[20] Available online see footnote 19.

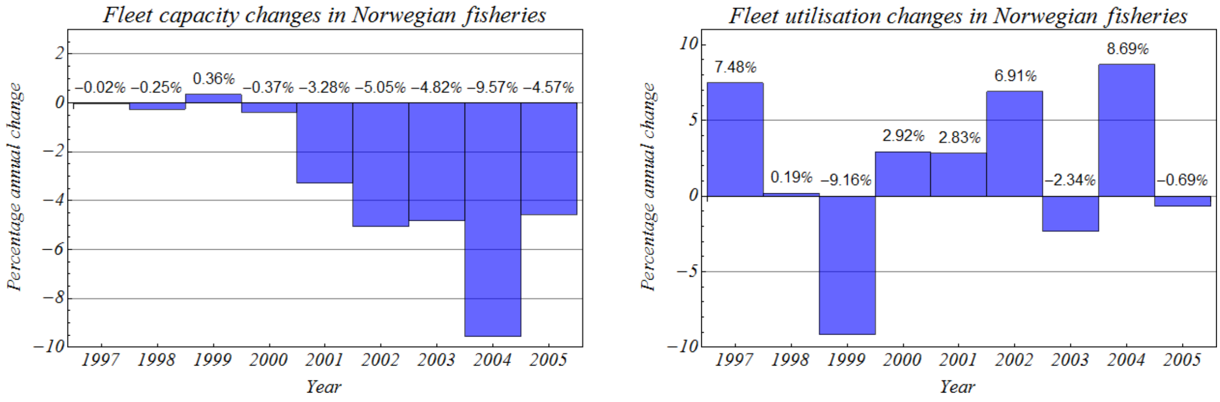

Figure 10: Estimated percentage annual changes in total fleet capacity (left) and utilisation (right) in the Norwegian fisheries between 1997 and 2005.

5.3 Resource rent

The resource rent can be seen as a measure of economic efficiency when harvesting natural resources, like fisheries. The level of the measure represents both the state of the resource management and the use of input in the activity.

> *The extraction or harvesting of natural resources can produce substantial rents - revenues above the cost of extracting them - which are calculated as the difference between the price of a commodity and the average cost of producing it* (World Bank, 2011, p. 151).

More specifically, the resource rent is the net surplus from a given activity, to remunerate capital and labour, above the rate that is achieved in other business sectors. Hence, it deviates from ordinary return measures by including so-called *normal returns*, achieved in ordinary business sectors - typically in the range of 5-10 per cent. When calculating profits, ordinary business costs are included, but when rents are assessed, inputs should be valued at costs similar to what would be the normal remuneration in alternative uses. For example the remuneration of labour (wage) should be similar to that in alternative, comparable employment. For a fisherman, an alternative job might be within the processing industry.

In their resource rent indicators, the World Bank utilises the rents from oil, gas, coal and other mineral production, as share of the Gross National Income to measure to what degree a nation's non-renewable resources (in addition to over-harvesting of forests) liquidate their capital stock - and borrow against future consumption. The challenge is to transform non-renewable natural resources into other forms of wealth, for instance by increasing national savings or investing in education (human wealth).

For renewable resources, sustainable management together with cost-efficient harvesting should ensure the highest potential rent generation. Sustainable management would ideally strive for ecosystem based management. However when ecosystem knowledge is not available, a single stock approach to management combined with a precautionary approach is a possible target while gathering more information to aim toward ecosystem based management.

In fisheries, the level of resource rent generation can reveal the degree to which managers and industry actors are able to produce the potential of the resource. Similarly, within aquaculture, rent generation could occur when free or limited access to productive sea and fjord environments enter as one of the main inputs, and optimal harvesting is carried out under a regime with minimised influence on the environment. Economic rent generation could also stem from the limited access to the resource within both fisheries and aquaculture (*monopoly rent*) or from *intra-marginal rent,* which occur when production factors are productive to a different degree (smart workers, better water through-flow, etc.).

In any case, calculating rents is not a straightforward exercise, among other things since alternative costs and normal returns are not easily accessible or possible to calculate. In addition, data availability issues are pertinent. If resources (i.e. fish stocks) are not managed properly, and no entry barriers to the fishing industry exist, (i.e. an open access fishery) then rents will be foregone and dissipated, since equilibrium will be found where marginal revenue equals average costs. In a closed fishery with access control, the potential resource rent in the fishery can be revealed by the auction of fishing rights (if information is perfect), since the maximum willingness to pay for the right will be equal to the rent generated from fishing.

In the seafood industries resource/economic rent generation usually takes place in proximity to the resource and is connected to its extraction/production. Hence, vertical integration - where adjacent stages in the value chain are under the same company/ownership - can complicate economic rent calculations even further. As a proxy indicator to the resource/economic rent, profits in the primary seafood industries (fisheries and aquaculture) could be compared to the profit obtained elsewhere in society, for instance against the average normal rate of return in the national industrial sectors over time (usually a return on total capital in the range of 5-10 per cent annually). The labour input should first be valued at what it could have obtained in its best alternative utilisation, since rent generation normally also give higher remuneration of the labour. In some nations (i.e. Norway and Iceland), the fishing industry practices *share cropping*, where the remuneration of fishermen is a fixed share of the value of the catch - implying that market price variations have great implications on the remuneration ability of the fleet.

Data for evaluating and calculating the resource rent are available in national profitability studies for the fishing fleet. The Norwegian Directorate of Fisheries (NDoF) annually publishes a profitability study for the fleet[21] (NDoF, 2013). For Iceland a similar, but not so detailed, published survey can be found at Statistics Iceland[22]. For the national fishing fleets of the EU, data about fleet profitability is collected by member states authorities under the Data Collection Framework (DCF) and grouped and compared in the "Annual Economic Report on the European Fishing Fleet" for the Scientific, Technical and Economic Committee for Fisheries (STECF)[23]. We have no knowledge of similar profitability studies for the Russian and Greenlandic fleets operating in these waters. Adaptations based on other nation's cost and earnings figures are also problematic.

By utilising the imputed values over labour costs and man-years (full time equivalents-FTE's) from the profitability studies, the opportunity cost of labour can be calculated (at, say, average industrial worker salaries). Also, capital costs should be evaluated at an alternative capital remuneration rate (say, the interest rate of government bonds). However, no uniform common method exists on the issue on how to evaluate the vessel capital assets (quota/permission assets, hull, engine, replacement or insurable value, etc.). By comparing the resource rent (i.e. fleet profits when labour and capital are evaluated by to their costs in alternative usage) in national fisheries as share of total capital employed, with the return on total capital in other the national industries as a whole, comparisons both between nations and industries can be made. Also, comparisons between current and maximum resource rent - as a result of long run bio-economic models - can reveal how much more fisheries can contribute to society.

5.4 Catch

Catch indicators help provide a direct measure of production in the fisheries sector. In addition catch changes may help monitor fish stocks. Although catch does not reflect the state of a stock (a fishery can overexploit a stock for a long time before it may impact on the catch), a decline in catch when a catch quota defined by some authority is constant may indicate a stock decline. Information about catch is used to calculate the state of the stock (See section 3.1) as well as the intensity of exploitation.

High resolution catch statistics are available in most fishing nations. The challenge is how to select the most useful indicators from what often appears as an overwhelming amount of information. Figure 11 gives an impression of the magnitude of the problem based on Norwegian catch statistics over the period 2009-2012.

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[21] http://www.fiskeridir.no/statistikk/fiskeri/loennsomhetsundersoekelse-for- fiskefartoey-publikasjoner

[22] http://www.statice.is/Pages/452?itemid=8e72229c-4757-4c25-9e1d-b77b0aee1b4e

[23] See Anderson & Carvalho (2013)

Figure 12 shows two simple bar charts embedding much of the information included in Figure 11, splitting the species into two groups: demersal and pelagic species. The four indicators shown in Figure 12 are

$$\text{catch volume indicator (CQI)} = \frac{\text{total catch(t)} - \text{total catch(t}-1)}{\text{total catch(t}-1)}$$

$$\text{catch value indicator (CVI)} = \frac{\text{catch value(t)} - \text{catch value(t}-1)}{\text{catch value(t}-1)}$$

$$\text{catch volume ratio indicator (CQR)} = \frac{\text{demersal catch(t)}}{\text{pelagic catch(t)}}$$

$$\text{catch value ratio indicator(CVR)} = \frac{\text{demersal catch value(t)}}{\text{pelagic catch value(t)}}$$

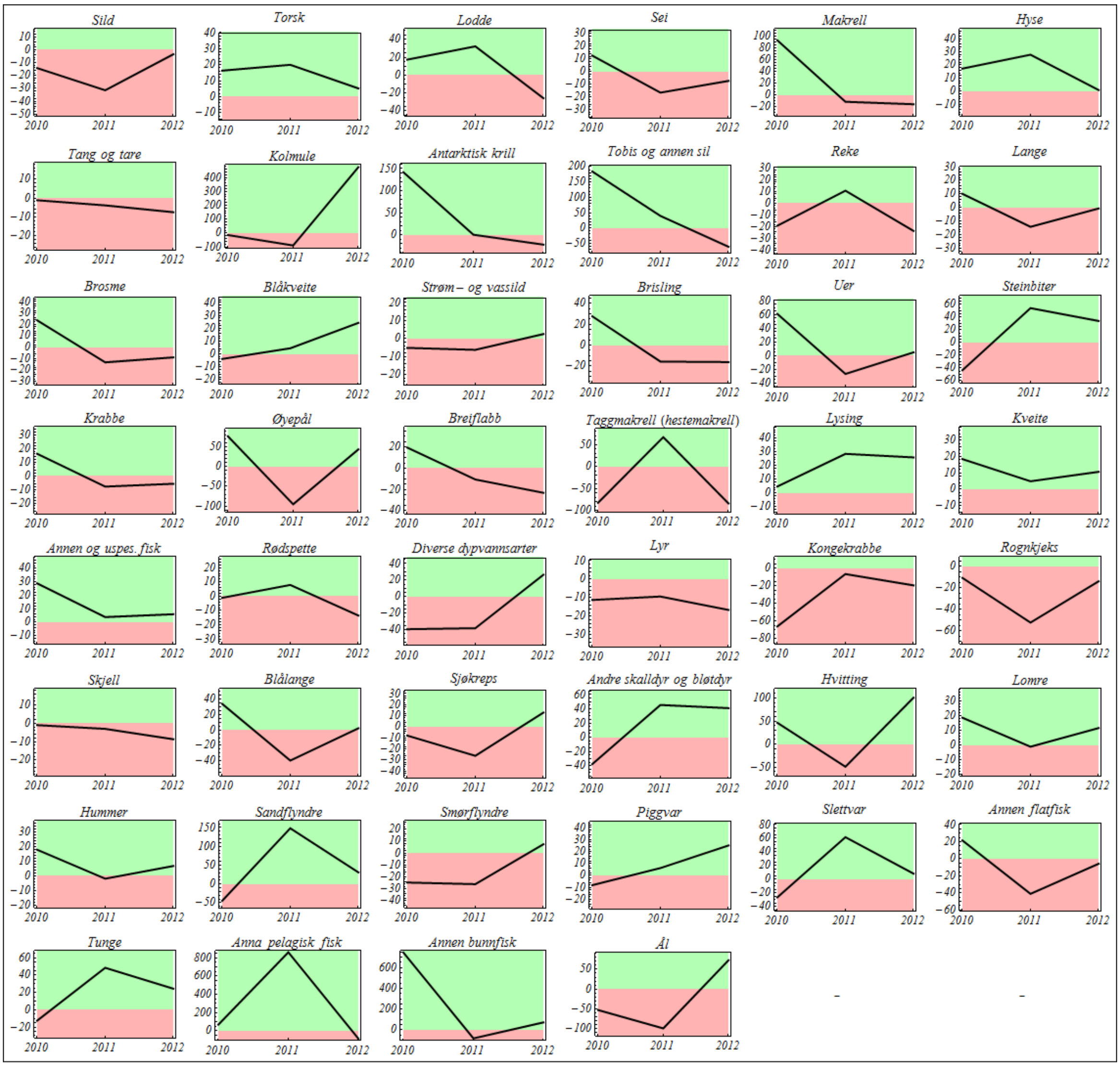

Figure 11: Percentage annual changes in catch quantities of different species in the Norwegian fisheries. The green areas indicate positive changes while red areas indicates decline in catches.

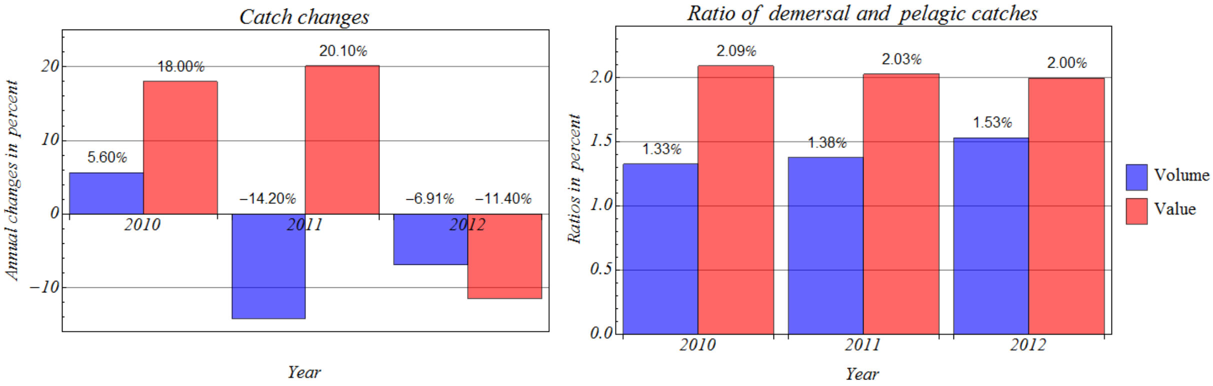

Figure 12: Annual changes in total catch volumes and values in the Norwegian fisheries (left) and annual ratios of demersal and pelagic volumes and values in the same fisheries (right panel).

5.5 Aquaculture production

An economic indicator corresponding to catch for aquaculture would be the size of production. This gives an indication of the output produced from aquaculture. It is useful to measure this output in units comparable to other outputs, for example output from fisheries.

For example one could measure farm gate value instead of volumes, as different species generates different values, and value and surpluses are really at stake when economic sustainability is under scrutiny. An even more valid, but more difficult to obtain, measure would be to include the overall value generated throughout the value chain. As for catches in capture fisheries, production from aquaculture does not in itself say anything about sustainability either from a strict economic perspective or from a social or environmental perspective. Other complementing indicators from other dimensions need to be included in any analysis. Capture fisheries is depending on the management of a natural living dynamic resource, i.e. the fish populations, and this is indirectly also true for aquaculture as e.g. salmon farming still depends on forage fish in feeds. This dependence or its vulnerability is not captured in any of the listed indicators. In the case of Norway - the largest Arctic aquaculture nation - data is available from The Norwegian Directorate of Fisheries (NDoF), which collects data about aquaculture biomass, sales, costs and earnings, and other aquaculture statistics[24].

5.6 Return on capital

An industry's economic sustainability depends on its ability to renew or buy the required operating assets. In fisheries the primary assets are vessels, fishing gear and processing

[24] Available online: http://www.fiskeridir.no/statistikk/akvakultur Retrieved March 28, 2014

equipment. Acquiring these requires capital and usually this capital comes from people or organisations that demand some form of return on the capital they provide. The largest sources of funds are typically loans from banks that require interest. Other investors obtain compensation of various kinds: higher valuation of the asset, dividend, and repurchase of stock, to name a few. To attract this capital the industry must be able to provide a return to capital providers that matches the risk they perceive to be associated with the industry. Some industries are subsidized by authorities through different arrangements, and this can imply that lower returns are sufficient.

Many models can be used to measure the return on capital. Often, data availability limits the choice substantially. The Return on Invested Capital (ROI) model performs in a satisfying way and requires data that is usually available. It calculates the ratio between operating profit and invested capital. One would rather not include capital that does not require returns, like debt to providers, but data to identify this is not always available.

5.7 Infrastructure availability

The seafood value chain, and especially its upstream links, is usually located in the coastal areas often far from the main markets and demographic centres of gravity. Technological innovations within seafood handling, processing, logistics and transport have to some degree loosened this tie, making it possible to freeze fish on board, transport it to China and other low-cost nations, to take advantage of labour intensive processing at favourable salaries, before re-exporting it to European consumers. But still the vast majority of seafood industry activity occurs in rural areas, often characterised by demographic challenges connected to centralisation, increase in the share of elderly, challenge with communications and other periphery challenges.

In a society with increased globalisation where communication technologies contribute to shorten transport and travelling times, the disadvantages from being located far from markets become increasingly more visible. Rural communities' lack of good communication infrastructure can easily contribute to an increased disadvantage. Therefore, a sound seafood industry development in the Arctic are in many cases dependent on good infrastructure for sea transport (port facilities, fairways, vessel traffic services, fishing harbours, etc.), and other general transport services like telecommunications, air traffic, roads, railroads and other. As an example, in 2010, Russian landings of Barents Sea capelin were only 77,000 tonnes of the 115,000 tonnes quota. One explanation is that the Russian quota is taken by trawl rather than purse seiner, as in the case with Norway, where the latter gear (and following on board technology) is a better caretaker of raw material quality. Another is that the capelin processors in North-West Russia struggled with bad logistics and low demand, which led to full storehouses, which with lacking distribution made it impossible to uphold a continuing fishery within the limited time-frame for capelin (end of

January - mid March). At the same time Russia was the second largest importer of frozen capelin from Norway (Isaksen et al., 2011). Hence, infrastructure challenges can constitute barriers for carrying out an effective and profitable fishery, which bear implication for the following links in the value chain and can impact the socio-economic potential and sustainability.

One way to address the infrastructure issue, from an indicator point of view, would be to examine the level of governmental and private investments in infrastructure supporting the industry. However we would meet the same obstacles mentioned before regarding data availability and geographical limits, but also would need to choose which investments should be included in the indicator - and which should not. What counts as investments and what are operational or maintenance expenditures? Since these investments in many cases bear the nature of public goods (i.e. one person's consumption do not reduce the availability of the good for another person and it is difficult to exclude some from taking advantage of the good once it is produced) the seafood industry is not the only industry to reap the fruits from these. In addition, different topographic conditions, or other geographical peculiarities, variations in initial infrastructure level, or natural disasters (like for instance the effects from climate change) can be the cause for variations between nations or regions, or from one year to another.

Obviously more research is needed to assess a satisfying indicator for infrastructure investment. In the absence of such, rough proxies must be used. A proxy based on some measurement combining distance to some agglomeration and size of that agglomeration could be a possibility to study further as such data is available and a larger agglomeration would indicate that some level of infrastructure should be present.

6. Discussion

This report is an attempt to provide advice for selecting a relevant set of indicators of sustainable seafood production that may be used for monitoring purposes. A proper set of indicators has the potential of being a powerful monitoring device that conveys useful diagnosis of the system based on relatively limited available information. Sets of indicators have shown to be efficient inputs in a number of different control systems. Fuzzy logic control represents a formalised theoretical framework for such systems, also taking into consideration the vagueness associated with the measured indicators and the aim of controlling the system.

Formalised Harvest Control Rules (HCR) have been in place in the management of many important European fisheries over the last decade. A HCR system makes use of sets of indicators (often only two indicators: A measure of fishing mortality rate in the fishery together with an estimated spawning stock biomass) as input in predefined quota setting rules. The rules links the measured indicators to predefined targets and/or limits, forming if-then relations (*if* the indicator 1 is between A and B and indicator 2 is between C and D, *then* …). Efficiency and reliability of fuzzy logic control depends on the identification of relevant indicators, but also of critical target and limit values of each identified indicator. Both the identification of relevant indicators and useful targets/limits, depend of course of the objectives of the control. This is however first of all a political issue, even though it needs to be funded on reliable scientific inputs on consequences and possibilities.

There are substantial limitations associated with both the identification and the measurement of useful indicators and sets of indicators. Some of these limitations appear obvious in the descriptions parts of each indicator. For example the amount of data available is often limited and there are usually only few and limited time series for some of these indicators. In addition, the necessary information has generally not been collected in the same way in the different Arctic countries or is not collected at regional level making data for Alaska or Russia for example quite irrelevant as most of the data applies to regions in these countries that are outside of the Arctic.

Even if data is limited, there is a plethora of possible indicators of dimensions of sustainable development and monitoring all of them is costly and not very informative, as one cannot see the forest for all the trees. Ideally, one would like to have a very limited set of so called headline indicators that would really be able to represent the main trends for the whole system. Some of the indicators suggested in this report have the potential to serve as such headline indicators. For example, fish catch is a good candidate as it can be used to retrieve stock estimates as well as profitability in the industry. Unemployment rate is another candidate to monitor the social dimension of sustainable development as it is often somehow correlated to several of the other social indicators presented here.

However some dimensions are particularly challenging to represent with a small set of indicators. In particular the state of the marine ecosystem that is the base for the whole seafood industry is difficult to summarize into a handful of time series given the current knowledge about the system. The interactions between species, their habitat, the geophysical environment and the economic activities taking place in the seascape form a complex adaptive system. Our lack of data and monitoring information about the Arctic implies that we probably only have information about the variables that have been changing relatively quickly with observable impacts. However coming changes may be triggered by accumulating stocks that are unnoticed at the moment but can cause substantial system transformation when released, so called regime shifts. (Crépin et al, 2012 and Regime Shifts Database: www.regimeshifts.org)

The indicator system proposed cannot either be used solely to guide policy. While an indicator system may help identify unsustainable trajectories, it is unlikely that the best response to change this trajectory can be identified by just looking at the indicators. More information is available about how different variables impact and feedback on each other. The interactions between different variables in a complex adaptive system are by definition complex and can take unexpected routes before some “final” impact occurs. For example, current climate change will have direct impact on fisheries activities that may influence their sustainability, but it may also have indirect impacts via market changes initiated in other parts of the world sometimes very far away. (ACCESS D5.71, forthcoming)

Hence this indicator system must be complemented with other management tools like a marine spatial planning tool (ACCESS D5.82, forthcoming) and an integrated modelling framework of the social ecological interactions in the Arctic Ocean (ACCESS D 5.71, forthcoming). These tools produced within the ACCESS project should be used to assess and identify variables in the system that are of particular relevance for the Arctic system’s evolution toward sustainable development. Such information would help further refine the set of indicators proposed here and also help identify the headline indicators, i.e. the key variables in the Arctic social-ecological system related to sea food production. Such set of indicators would provide a system for early warnings to help identify unsustainable trajectories early on so that a proper set of policy tools can be put in place.

If these tools are complemented with proper models of interactions between the most important variables or indicators it would also be possible to simulate different policy responses and compare them to each other with regard to how they perform in the different dimensions of sustainability.

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