Chapter 2
Adaptation in Fisheries and Municipalities: Three Communities in Northern Norway

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Abstract In this chapter we focus on how changing societal and climatic conditions have consequences for current and future vulnerability and adaptation in three municipalities in Northern Norway: Hammerfest and Lebesby, in Finnmark County, and Vestvågøy in the Lofoten Islands, Nordland County. Through local consultations and discussions, fisheries and municipal planning were identified as having particular relevance in the case communities. Climate change is not perceived to be a major challenge locally, nevertheless, when climate projections are considered alongside locally defined and relevant socio-economic and climatic concerns that are particular to local contexts, multiple and interrelated factors emerge that are likely to shape future vulnerability. Focussing on coastal fisheries and municipal planning as two major arenas for change, we find that adaptation takes place along a number of dimensions and at several societal levels. Adaptive strategies occur in response to changing socio-economic conditions, to variable weather and environmental conditions, or to a combination of both. There are three interlinked factors that our empirical findings show are currently of concern for coastal fisheries: changes in bio-physical conditions (ocean temperature and fish distribution and behaviour); fisheries management and regulations (vessel size, species, quotas) and societal conditions (outmigration, market factors and transfer of knowledge). The interlinkages between these changes, and community responses to them, have first and foremost been captured and understood through local involvement in our research.

Keywords Coastal fisheries · Municipal planning · Northern Norway · Climate scenarios and elements · Local perceptions of change · Coupled systems

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2.1 Introduction

In this chapter we present results from case studies carried out in the municipalities of Vestvågøy, Hammerfest and Lebesby in Northern Norway (see Fig. 2.1). We frame the discussion of locally identified current exposure-sensitivities with respect to climatic, ecological, economic and societal trends in the context of fisheries and municipal planning. The coastal fishing sector was identified locally as being particularly appropriate for this study because the communities identify themselves as fishing communities, both historically and currently, and coastal fishing is one of the main activities in the communities. Municipal planning was also identified locally as an important focus because of the critical responsibility of local government for facilitating local adaptation.

Consistent with the CAVIAR Framework described in Chapter 1, we focus on locally relevant societal and climatic conditions and how these combine to create current exposure-sensitivities. In particular we investigate the relevant dimensions of exposure-sensitivities within the coastal fishing and municipal sectors and current local adaptation strategies. Based on our analysis of the adaptations that are currently being undertaken and an assessment of future exposure-sensitivities, we discuss communities' adaptive capacity to deal with future changes.

The chapter begins with a description of the societal and geographic context and background of the case study areas, and continues in Section 2.3 with a description of the methods we employed. In Section 2.4 we discuss

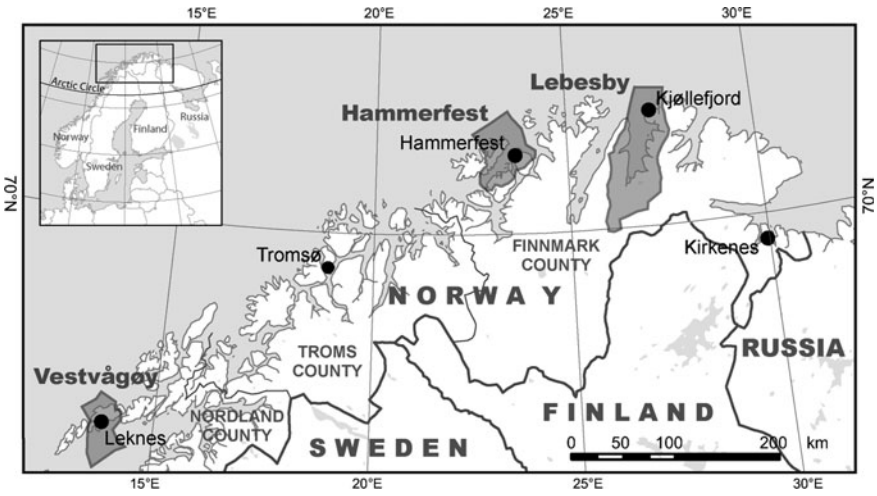

Fig. 2.1 The case study sites in Northern Norway. *Source*: Winfried Dallman

some of the findings relating to current exposure-sensitivities of the coupled climatic, ecological and societal conditions that were identified locally, and how they affect municipalities and their coastal fisheries. In Section 2.5 we discuss current socio-economic exposure-sensitivities with a focus on aspects of fisheries management and municipal planning that may facilitate or constrain adaptation and shape the vulnerability of the case study areas. Section 2.6 outlines some of the downscaled climate projections, which were made specifically for the case study areas, and discusses our local partners' reflections on how these projected changes may impact their livelihood activities, and the overall adaptive capacity of the municipalities. We conclude by reflecting on the importance of focussing on the interlinkages between societal and environmental conditions for understanding adaptation and vulnerability.

2.2 Background and Context

2.2.1 Northern Norway: The Background and Context of the Case Areas

The peripheral positioning of Northern Norway, both in a Norwegian and a European geographical sense, somewhat belies its economic importance. Northern Norway is perhaps one of the richest peripheral regions in the world in terms of the potential contained in its natural resources, such as fisheries and petroleum (e.g. Rydningen 2004). In a Norwegian context, however, it still lags behind other regions on several counts: education levels and numbers employed in the private sector are relatively low in the northern counties compared to the country as a whole, and the population growth is smaller or in decline (Nilsson 2004). The region relies heavily on natural resources for income, employment, culture and lifestyle, and historically technology has been developed with the aim of increasing the efficiency and yield of existing resources, such as stockfish and aquaculture, rather than being directed at innovations (Watten 2004).

The traditional combination of fishing and farming livelihoods (*fiskarbonden*), which was historically significant for culture and livelihoods (Brox 1966), has to some extent been replaced by modern, intensified agriculture, aquaculture, and public sector employment (Holm 1996; Karlsen 2004; Rydningen 2004). Coastal fisheries nonetheless continue to provide a large share of local jobs and income, as well as local identity and culture (e.g. Lindkvist 2000). The viability of coastal fishing communities is nevertheless closely connected to local and regional developments in fisheries policy and legislation.

2.2.1.1 Climate

Northern Norway has a mild climate compared to other regions at the same latitude, due to an influx of mild air and warm ocean masses from the Atlantic Ocean (the Gulf Stream). The annual mean temperature varies from 4°C in the coastal areas in Nordland County to minus 4°C in the interior of Finnmark County. Temperature and precipitation in Northern Norway fluctuate significantly within and across years, decades and centuries. Nevertheless, over the last 100 years an increase in the annual mean air temperature, with a rapid increase since the 1960s, has been observed (see Fig. 2.2) (Førland et al. 2009).

The ocean temperature in the Barents and Norwegian Seas shows major annual and decadal variations, primarily influenced by the fluctuations of the North Atlantic Oscillation (NAO) which determines the influx of warm, Atlantic water in the northern waters. Over the last 15 years the ocean temperatures have increased in both the Barents and Norwegian Seas (see Fig. 2.3).

2.2.1.2 Coastal Fishing Communities

Coastal fisheries, defined as activities that occur within 12 nautical miles of the continental shelf, have provided a foundation since early settlement in Northern Norway until the present, and remain important for employment, income and culture in many small communities in the region (e.g. Karlsen 2004;

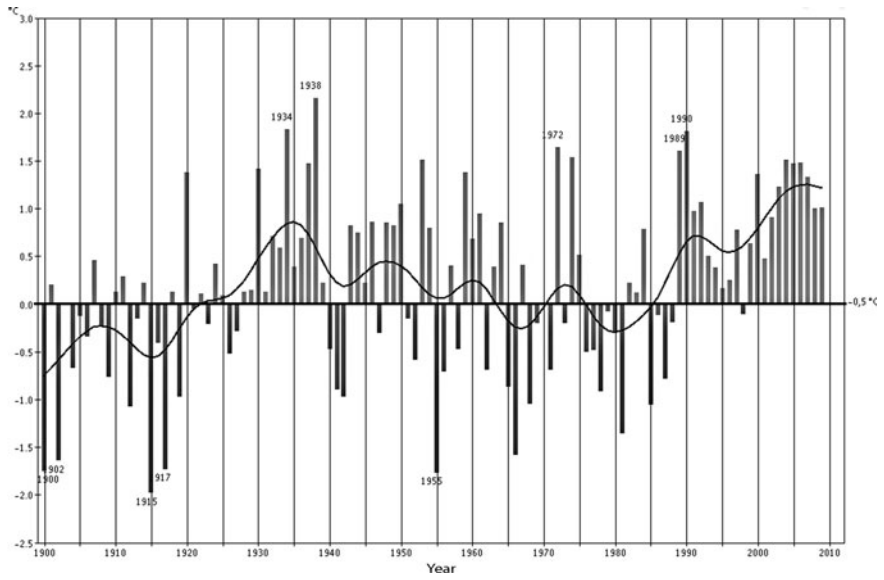

Fig. 2.2 Temperature development (deviation from normal temperature) in Northern Norway from 1900 to 2009. *Source*: Norwegian Meteorological Institute

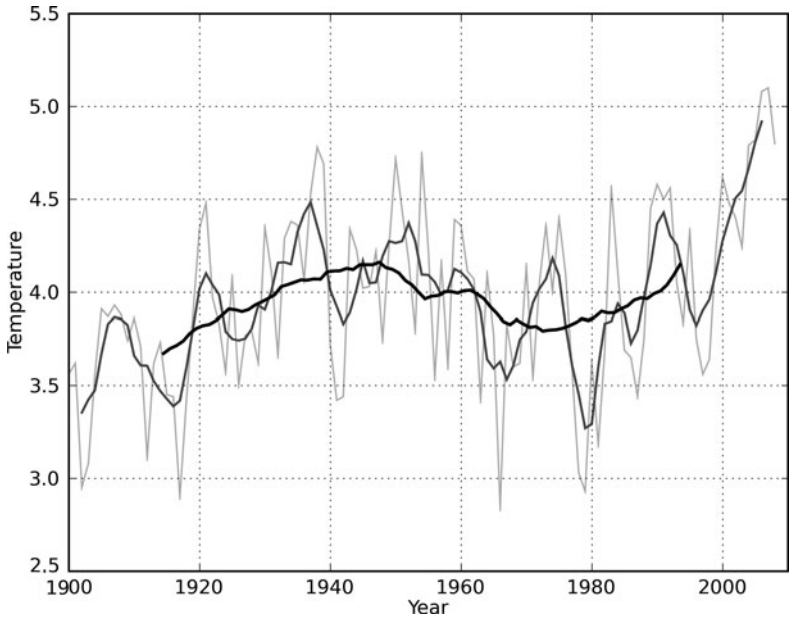

Fig. 2.3 Ocean temperature development in the eastern Barents sea in the 20th century. Light grey, dark grey and black curves display respectively annual, five year and 30 year mean temperatures in degrees celcius. Data from PINRO, Murmansk. *Source*: Bjørn Ådlandsvik, Institute for Marine Research, Norway

Keskitalo 2008; West and Hovelsrud 2010). Northern Norway is located near some of the world's richest cod fisheries and has for more than 1,000 years produced stockfish for national and international markets (Berge 1996). While the importance of fisheries to coastal communities in terms of employment has declined in recent years due to a number of technological, regulatory, economic and wider societal changes, fishing activities still remain a significant feature of the local economy (see Figs. 2.4 and 2.5). In addition to fisheries and related processing activities such as stockfish production, agriculture, aquaculture, small-scale tourism and the service sector provide additional jobs in our case study areas.

Economic, cultural, and recreational activities are closely connected to the natural environment, and communities are therefore particularly exposed to environmental changes, including those that are driven or reinforced by climate change. Generations of fishers have over time developed extensive local environmental knowledge, making them highly adaptable to the natural variability in climate and fish stocks. Today, fisheries in Norway are highly regulated and managed on many levels, differentiated by vessel length, gear type, species quota and fishing ground. Recent and ongoing structural reforms have contributed to a reduction in the number of fishers and fishing vessels, particularly in the coastal fleet (see Fig. 2.4).

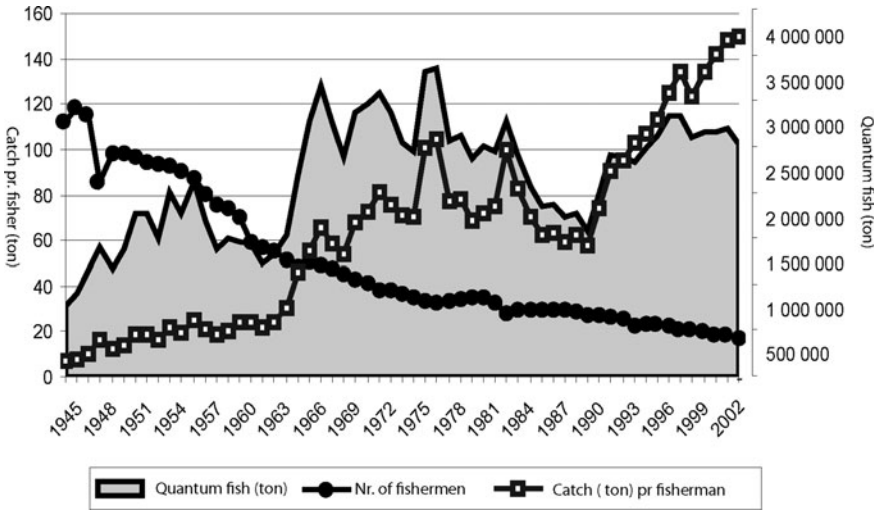

Fig. 2.4 Development in numbers of fishermen, catch, and catch per fisherman in Norway from 1945 to 2002. *Source*: MOFC 2006

2.2.1.3 The Municipal Sector in Norway

Municipalities (430 in total) are the local level of government in Norway and serve as a link to national management bodies and governance institutions. The municipal authority provides a number of important services for its inhabitants. These include elementary schools, local road maintenance, waste collection and management, emergency response, provision of social services, fire protection, water supply and local spatial planning. The services are highly regulated by national laws and regulations, and the majority of the municipal budget is spent on fulfilling mandatory obligations. Norwegian municipalities have the main responsibility for local land use planning, and for preventing damage from extreme weather events, such as floods and avalanches. Municipalities also have an important role in coordinating responses to future extreme events and damage through 'rebuilding' after an event (see Næss et al. 2005 for an overview). The tools available to municipalities include the prohibition of new buildings in areas prone to flooding or slides, and the construction of landslide and avalanche protection for existing infrastructure.

2.2.2 Case Area Descriptions

2.2.2.1 Hammerfest

Hammerfest municipality is located in western Finnmark at 70° N (see Fig. 2.1). Hammerfest is the northernmost city in the world and an important port for

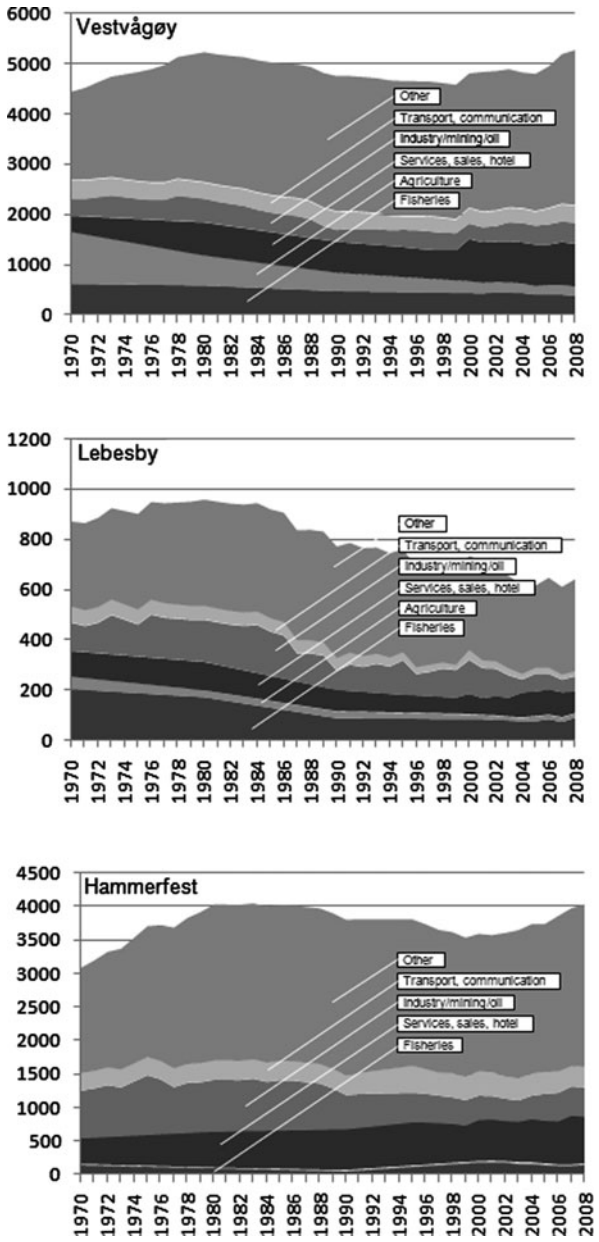

Fig. 2.5 Development in employment composition in number of persons in the case municipalities from 1970 to 2008

trade, shipping and fisheries. The municipality has about 9,500 inhabitants with more than 75% living in the city. The natural resources derived from and beneath the Barents Sea, such as fish, oil and gas, and associated production facilities, provide the economic foundation for Hammerfest. Currently,

fisheries and the liquefied natural gas (LNG) landing and production facility at Melkøya constitute the most important industries. The gas field outside Hammerfest was discovered in 1984, and the production of LNG started in 2007 (Store Norske Leksikon 2009). The development of the LNG plant has had a multiplier effect within Hammerfest, providing impetus for secondary services and provisions such as local tankers for distributing LNG, the development of a local gas-fired power plant, the supply of production inputs, as well as increased demand throughout the service sector. Bucking the demographic trend seen in other municipalities in Finnmark County, the population in Hammerfest has increased over the last few years, highly likely as a consequence of the construction of the LNG plant. Fisheries remain important in Hammerfest in terms of employment and maintaining local identity, culture and knowledge. The average age of the fishers is high, mainly due to young people seeking employment elsewhere, combined with the high initial entry cost associated with high quota prices and costs of purchasing fishing vessels. The discovery of LNG off shore and the development of the Melkøya facility have given Hammerfest an economic boost, both in terms of soaring real estate costs and an optimistic view of the future. Hammerfest is a vibrant municipality that is seeking innovative solutions to range of policy issues such as housing developments, harbour rejuvenation, environmental improvements and population stabilisation (see employment configuration in Fig. 2.5).

2.2.2.2 Lebesby

Lebesby municipality is located at 71°N, in the eastern part of Finnmark County, and is home to 1,350 inhabitants (see Fig. 2.1). From the original settlement until the present day fisheries and land-based fishing activities have provided the cultural and economic foundation for the municipality. While the number of fishers and vessels based in Lebesby have declined over the last decades in line with national trends, coastal fisheries remain important to the local economy and employment. In addition to fisheries and fish processing activities, agriculture, wind and hydropower, aquaculture, smolt production, coastal cultural and nature-based tourism, and the public sector, are important local employers in Lebesby (see also Fig. 2.5). The Nordkyn peninsula is also an important summer pasturing area for reindeer. The municipality has a number of social, economic and cultural resources to draw on, including the presence of creative innovators ('*ildsjeler, idemakere*'), a vibrant coastal cultural society, a small but growing number of nature-based tourism operators and innovators, a new windmill park, and most recently, renewed central government economic support (*omstillingskommune*) aimed at increasing jobs, well-being and migration to the municipality. Nonetheless, the latter is an economic rescue measure that effectively weakens the municipality's control over its budget and financial decisions, placing these in the hands of higher government levels.

2.2.2.3 Vestvågøy

Vestvågøy municipality, in Nordland County, is located at 68°N in the Lofoten Archipelago. It has approximately 11,000 inhabitants in a number of smaller communities, with the majority settled in the small commercial centre of Leknes and the fishing villages of Ballstad and Stamsund. The main employer in the municipality as a whole is the service sector. However, fisheries and associated industries are the cornerstone of several of the smaller communities in the municipality even though the total share of fisheries employment has been decreasing in recent decades. Agriculture is also an important sector, and tourism is growing rapidly, replacing fisheries in some communities as the main source of income (see Fig. 2.5). Vestvågøy is located near some of the world's richest Atlantic cod (*Gadhus morhua*) fisheries. The climatic conditions in the Lofoten islands are known to be highly favourable for stockfish production, and the region boasts a 1,000 year old tradition of exporting stockfish.[1]

As in the other case study communities, the fishery sector in Vestvågøy has been in flux due to changing fisheries management regulations and higher efficiency requirements that have reduced the number of fishers. The stockfish industry is also exposed to major annual fluctuations in prices and demand in international markets.

2.3 Methodology: Local Approach

Consistent with the CAVIAR framework described in Chapter 1 our research is driven by locally relevant questions. Our case specific research questions were initially framed in cooperation between researchers and local stakeholders, and the research was undertaken in collaboration with local partners. Our local partners include officials and elected representatives in the municipalities, fishers, fish buyers, employees in the fish processing industry, and officials at the Fisheries Directorate. Working closely with local partners is an iterative process in which preliminary results are presented to the community for feedback and adjustments. Our research began with an initial visit to the communities where we invited municipal officials and other community members to meet with us to establish legitimacy and face-to face contact (see also Keskitalo 2004). The research focus was determined in consort with the community and fieldwork was undertaken to identify current and future exposure-sensitivities, adaptive

[1] Stockfish is produced by drying the fish on outdoor racks. This conserves the fish. Different fish species may be used, but the most common is North Atlantic cod. Successful drying and preservation of the fish requires sufficient quality of raw material and appropriate drying conditions. The Lofoten-region fulfills both of these requirements and has for a long time been the world's largest exporter of stockfish. It is documented that the Lofoten stockfish trade began in 875 AD and in the medieval age it was the most important trade in Norway. The single most important market for Norwegian stockfish is Italy, which has imported stockfish for a century (Berge 1996).

capacities and strategies, and vulnerabilities to differentiated exposures, including climate change. This means that the particular research focus varied according to the specific concerns identified by each of the three case communities, but our common methodology allows for comparison between sites. A team of researchers has made repeated visits to the case communities (see Fig. 2.1), engaged in participant observation and conducted semi-structured interviews with elected and non-elected municipal representatives, the oil and gas industry, fishers, the fishing industry, farmers, reindeer herders, entrepreneurs, the tourist industry, store owners and 'people at the local pubs', as summarised in Table 2.1. During follow-up visits, the researchers received feedback from the local partners and communities on the preliminary interpretations and understandings of current and future exposures-sensitivities and current and future adaptive strategies and capacity articulated by the researchers.

The climate related observations were quite similar across the cases but were defined as relevant to community livelihoods and activities in myriad ways. Common to local definitions of important climate elements is that they often include more than one variable, such as precipitation *in combination with* certain temperatures. An example of this is freezing rain in winter, which is a shared concern amongst the sites as it creates dangerous conditions for navigation on roads and at sea, and interrupts important services such as electricity supply, and transportation. The Norwegian Meteorological Institute (met.no) has developed scenarios of locally identified climate elements where possible (see Section 2.6 below). The downscaling results were presented to the communities for feedback, and discussed in terms of present and future challenges and opportunities, and the capacity of the community to deal with current and expected changes in climate.

Table 2.1 Summary of research methods and interviews

Methods	Vestvågøy	Hammerfest	Lebesby
Semi-structured interviews	21	20	25
Town meetings	1	1	2
Group discussions	With farmers, fishers, and the municipality	With municipality, fishers, and local inhabitants	With local elderly, fishers, local inhabitants, and municipality
Other	Attended and observed community events and meetings, collected grey literature and documents	Attended and observed community events and meetings, collected grey literature and documents	Key informant discussions, participant observation on board fishing vessels and at community events, collection of grey literature and documents

2.4 Coupled Climatic, Ecological and Societal Components

In this section we describe how current climatic, ecological and societal conditions combine to create a range of exposure-sensitivities and adaptive strategies in the three case communities. We have structured the results according to climate- and social-ecological exposure-sensitivities. See Table 2.2 for a summary of the locally identified climate elements and associated weather conditions, and associated exposure-sensitivities.

2.4.1 Changes in Distribution and Abundance of Commercially Important Fish Stocks

Warming oceans are likely to affect the distribution and abundance of the regions' commercially important fish stocks, including cod, herring, and capelin, and to lead to an increased influx of southern species such as mackerel (*Scomber scombrus*) monk/goose fish (*Lophius piscatorius*) and blue whiting (*Micromesistius poutassou*) to the coastal waters of Finnmark. The three Norwegian case communities have all identified increased ocean temperature and its impact on fisheries as a factor that can be described as a current exposure-sensitivity. Coastal fishers are accustomed to high natural variability

Table 2.2 Current climate exposures as identified in communities

Climate or weather condition	Exposure-sensitivities
Increased ocean temperature (V, L, H)	Changes in fish distribution, abundance and species composition
Storms, extreme weather, and polar lows. (H, L)	Create hazardous conditions at sea, may hamper fishery activities and destroy equipment
Shorter winter season (V, L)	Affects the onset of the stockfish production season. Poorer conditions for snow dependent activities as winter tourism
Higher winter temperatures (V, H, L)	Affect stock fish production
Reduced snow depth and cover (L)	Poorer conditions for snow dependent activities
'0'degree conditions combined with precipitation (H, L)	Dangerous road conditions, higher risk of avalanches
Icing due to certain combinations of wind and temperatures (H, L)	Dangerous icing on fish vessels and oil- and gas installations
Rain in winter (H, L)	Road maintenance challenges, increased avalanche risk, floods
Increased winter precipitation combined with wind and higher temperatures (H, L)	Affects road maintenance and avalanche risk
Sea level rise and storm surge (V, H, L)	May threaten harbours, sea side buildings and roads

H = Hammerfest, *V* = Vestvågøy, *L* = Lebesby

in weather, climate and the resource base. Recent observations by fishers of changes in ocean temperature and in the distribution of fish species are consistent with scientific measurements and results. The scientific results show that the ocean temperature in the Norwegian and Barents Seas fluctuates between cold and warm periods, but that the last 30 years show a rapid increase to levels higher than the long term mean, and in recent years, temperatures are the highest that ever have been recorded (Hanssen-Bauer et al. 2009).

Increased ocean temperature affects the production and distribution of marine biomass (Loeng and Drinkwater 2007), and a linear relationship has been established between ocean temperature and the distribution of spawning cod and herring (Sundby and Nakken 2008). In Lebesby, our local partners have observed a change in the distribution and behaviour of cod (*Gadhus morhua*) and saithe (*Pollachius virens*) since the year 2000, a period of relative ocean warming. They report that these species are currently found farther out to sea, in deeper waters, and correlate this change with fluctuations in ocean temperatures (West and Hovelsrud 2010). Coastal fishers in our case areas are adapted to major inter-annual, decadal, and multi-decadal changes in ocean temperatures and their corresponding effects on fish stocks. For example, the average decadal variation in ocean temperature in the eastern Barents Sea during the 20th century was 1.5°C (Sundby and Nakken 2008), well within the range of the 1–2°C warming that is projected for the entire Barents Sea by 2070 under a doubling of atmospheric CO_2 levels (Loeng et al. 2005). It is perhaps not surprising then that fishers do not consider themselves to be particularly vulnerable to climate change. In many ways they express great pride in being adaptive to constantly changing conditions. Nevertheless, the current distributional shift of stocks has created a number of exposure-sensitivities for the fishers as local knowledge about the location of important species is not as reliable as it once was, and this is viewed by some fishers as a challenge. Reliance on local experience–based knowledge of species interactions and of local ocean currents and weather patterns is fundamental for successful and efficient catches, as well as safety at sea.

In Hammerfest and Lebesby local fishers are concerned that they do not have quotas for species such as mackerel, whose abundance, due to warmer ocean temperatures, is increasing in their fishing areas. Many fishers sold their mackerel quotas to vessels from southern counties long ago. New species such as the Alaskan snow crab (*Chionoecetes opilio*) and pipefish (*Syngnathus acus*), have also been observed, both in Lebesby and Hammerfest (see also Chapter 13, this volume), but according to some fishers, this may be attributed to wider marine ecosystem imbalance, rather than ocean temperature change (West and Hovelsrud 2010). Moreover these species do not currently present a commercial opportunity. Fishers in Lebesby explain that the red king crab, an invasive species that has been fished commercially for the past several years, represents an important source of income, but it is also seen as an indication of a changing ecosystem with unknown consequences for traditional fisheries such as cod. According to current research the invasion of the red king crab does not appear to be related to increasing ocean temperatures (Sundet 2008).

In Vestvågøy, in contrast to the two Finnmark municipalities, the north- and outward shift in the cod fisheries is perceived by fishers, fish buyers and stockfish producers to present the greatest adaptation challenge for the fish buyers. The proximity of the fisheries to the landing facilities is a major determinant for stable landings and a fish buyer's success or failure, and as our local partners explain, landing facilities are closing due to a shift in the distribution of spawning cod. The closures have resulted in many fish buyers moving out of the region, leading to a loss of employment and income. In addition, some fishers point to the use of modern fishing gears, such as the '*snurrevad*' as responsible for the loss of fishing grounds. They also report an increase in herring abundance, which they attribute to the cod migration into eastern Lofoten.

Successful fishers, in general, have historically adapted to changes in distribution and abundance of commercial fish stocks. The fishers who survived the collapse of the cod stock during the 1980s did so by adjusting to fishing different fish species, fishing further out at sea, and working longer days. Currently some fishers combine tourism with fishing to increase and diversify their income. Inevitably there are constraints which limit adaptation possibilities, particularly with regard to changes in fish distribution and species. During the 1960s in Lebesby the traditional saithe (coley) fishery was affected by overfishing of the herring stock, its main food source. As a result the saithe retreated to lower depths. Pursuing the fish required adjustments to the dimensions of the not fishing gear traditionally used to fish for saithe. Not all fishers in Lebesby made the transition, and many sold their boats rather than invest in new technology. This is in stark contrast to the less conservative fishers of Måsøy, a neighbouring municipality, who adopted the new gear and are today recognized as regional leaders in the coastal saithe fishery (Tomas Sagen, pers. comm).

According to the fishers in Vestvågøy, adaptation to the northerly outward shift in the cod fisheries involves following the fish, and with modern equipment this is not perceived to be difficult. Fishing vessel insurance and management regulations however dictate just how far off shore the smaller fleet may fish, which restricts their adaptive strategy. The fishers in general display a high confidence in their ability to adapt to changes in fish stocks and weather conditions, however as the example from the saithe fisheries in Lebesby illustrates, traditions and cultural values may hamper introduction of new and beneficial technologies. Fishers can travel farther to catch the fish, however the same is not true for fish buyers. As one fisherman stated, 'the fisherman can follow the fish, but cannot bring the landing facilities with him'.

Various adaptive strategies have been developed to encourage fishers to land their catch locally, including offering a competitive premium price. The attainable price is not the only determinant of landing site, as trading fish is connected to a number of other long-term relationships. As an adaptive strategy to maintain good relations, some buyers may even buy fish despite a low resale price; others assist fishers in securing additional fish quotas tied to their vessels.

This reinforces the mutual bond between fish buyers and fishers. As one fish buyer and stockfish producer said:

> It is kind of a responsibility to the community, like a duty, to buy fish from the fishers in the community even if the market is poor. But then I also know that they will land their catch at my facility when I need it.

For some fish buyers in Vestvågøy this bond has been instrumental in their successful adaption to the northward shift in the fisheries activities. Recently, land based transportation from landing facilities near the fishing grounds to the fish buyers- and processors in less accessible locations has increased, and the local stockfish producers are increasingly sourcing their fish from other regions. The fishers' sales organization and/or the national government may subsidize the transportation in order to ensure buyers for the catch.

Throughout all our cases, fish buyers, landing facilities and fish processors are, albeit in different ways, all affected by the dynamics of sea temperature and species composition, abundance and distribution.

A number of social factors affect fishers and fish buyers/processors' exposure-sensitivity and adaptive capacity for dealing with climate variability and change. A fishing regulatory framework that is perceived and described by our local partners as being bureaucratic and unpredictable may limit fishers' flexibility and mobility to respond to climate change impacts on fish, while cultural values and individual preferences may affect the choice of fishing technology and species fished, either facilitating or hindering adaptation.

2.4.2 Living with Storms and Extreme Weather

As we have emphasised, people in northern Norway pride themselves on being used to living with storms and extreme weather. '*Vi står han av*' is a common phrase in the region, broadly translated as 'we stand tall in the face of storms'. Nonetheless, storms and extreme weather are discussed locally as affecting the fishing activities, the supply of fish to local fish processors and the subsequent shipment to market. Furthermore storms and extreme weather are a concern to the municipalities because they may threaten electricity supply, close roads and isolate communities. Recent climate modeling results suggest a future increase in strong wind events in the Barents and Norwegian Seas (Barstad et al. 2009).

The smallest vessels in the coastal fleet which typically employ the '*juksa*', type gear (a hand line previously jigged manually, now frequently automated) at less than 10–11 m, and usually consisting of a one man crew, are particularly vulnerable to gale force winds and bad weather. Storm conditions may prevent fishers from leaving harbour to hauling their catch in from traps or from nets left at sea, which may result in gear entanglement. This may have consequences for fish quality, and incur additional costs in returning to the fishing ground both in terms of time and money (West and Hovelsrud 2010). A combination of storm activity such as unpredictable polar lows, and fish

moving farther north or off shore and into deeper waters, as a response to warmer ocean temperatures, can be described as a current exposure-sensitivity for coastal fishers.

Polar lows constitute one example of natural hazard to high-latitude operations such as fishing vessels, shipping, and oil and gas platforms, and are particularly hazardous partly because of the difficultly in detecting and predicting them using conventional weather forecasting tools. A polar low is a small, localized cyclone that forms quickly over open sea during the cold season within polar or arctic air masses (Hamilton 2004).

Polar lows are particularly important in the Hammerfest and Lebesby cases, where they occur more frequently due to the particular atmospheric and ocean interactions in the Barents Sea. In one interview an incident was reported of a rescue vessel leaving the harbour in Hammerfest in brilliant sunshine, and 15 minutes later, and a long distance from shore found itself in the midst of a major storm caused by a polar low. There was no indication or forecast that the storm was on its way, and it created potentially dangerous conditions for all the vessels in the area.

Our local partners in Lebesby and Hammerfest have explained in interviews and discussions that stormy weather often leads to road, port and airport closures, interrupting the transportation of processed fish out of the region. In addition, small fishing vessels engaging in recreational fishing for tourists have expressed concern about the increased storm activities. Storms present major challenges for such boat captains, in terms of safety, comfort, tourists' experience and evaluation, insurance, income and regulations.

In Vestvågøy few fishers were under the impression that the rate of bad weather, locally defined as too harsh to fishing, had increased in their area, although some reported that they 'compete' among themselves about who dare go fishing in the worst weather. According to fishers, polar lows do not generally occur in the Lofoten area and are therefore not a concern among coastal fishers in Vestvågøy. On the other hand there are reports of several accidents associated with bad weather and linked to a new type of fishing vessel, the so-called 'speed *sjark*'.[2] The accidents were caused by a combination of vessel overloading and lack of equipment familiarity, combined with heavy seas and strong winds. The fishers explain that because they have to travel farther out to sea to fish, they are also more exposed to weather. The accidents illustrate an increased exposure-sensitivity for the smaller coastal fishing fleet connected with warmer ocean temperatures, an outward shift of cod, regulations out of step with biophysical changes and new equipment.

There is a difference in the mobility of fishers in Vestvågøy compared to Lebesby, which manifests itself in how they respond or adapt to bad weather. In Vestvågøy and in Lofoten in general, the cod season lasts from January to

[2] The speed 'sjark' is a small vessel typically around 30 feet that is built for higher speed than traditional fishing vessels.

March. In late spring to early autumn many of the fishers from Lofoten go to Finnmark, a distance of nearly 300 nautical miles, taking three days of travel. If bad weather prohibits landing the entire cod quota in Lofoten, they can catch the remainder of their quota when in Finnmark, where the cod fishing is good later in the season. In Lebesby the fishers, typically fish closer to home during the winter cod season due to excellent fishing, harbour and landing conditions, and more variable weather conditions. However, some fishers travel south to fish for blue whiting in the summer months when the weather is better.

Icing conditions are a current exposure-sensitivity noted by many of our local partners across the case areas. Coastal fishers explain that during winter, the main cod fishing season, strong winds from both the south and inland are often cold. When these meet the warmer, moist marine air, ice may develop on fishing vessels and gear. Accumulation of ice on vessels and equipment may in rare cases lead vessels capsizing, and the fishers are acutely aware of the danger. The combination of wind, temperature and moisture represent hazardous conditions which until recently were not commonly forecasted. Instead the fishers rely solely on their own experience and knowledge for assessing the conditions.

Power companies are always on the alert for forecast of icy conditions, which may lead to accumulation of ice on power lines and potential power failure. In 2006, an offshore winter storm ('*Narve*') caused a major power failure in Hammerfest, revealing a high degree of sensitivity to storms of this nature. The energy company, currently in the planning stages of a regional supply line, has sought better projections for future wind and snow load conditions in order to better adapt to extreme events. The adaptive strategies against such storms by companies such as Statoil and Hammerfest Energy include a call for changing the national standards for acceptable weather, and seeking knowledge of future weather and climate projections.

Shifting wind directions and changing snow patterns have been identified by municipalities as a current exposure-sensitivity. Municipal planners and road maintenance crews are continuously monitoring current conditions and seek to improve their knowledge about weather and climate especially with regard to consequences for road access and maintenance, infrastructure and housing.

Both Hammerfest and Lebesby have only one major road serving their municipalities and are therefore highly dependent upon proper road maintenance and open roads for access and supplies. In Finnmark County in particular, many major roads cross mountain passes that are prone to severe snow and wind, and it is quite common for such roads to be closed or passable only with an official escort vehicle. As an adaptive measure in Hammerfest a tunnel, funded by the national government, will be built for the main road into town, to avoid road closure and secure an uninterrupted connection. Lebesby municipality, in partnership with neighbouring Gamvik and with regional and national financing, has built a new all-season road to lessen transport delays and road closures due to bad weather during the long winter.

Municipalities know that major snowstorms and icy conditions require sufficient adaptive strategies to reduce the vulnerability of their communities, some of which are remote and isolated. To meet the challenges, the municipalities are equipped with major snow removing equipment, skilled operators, and an in-depth understanding of the various road conditions and the consequences for motorists, community supplies and safety. Their adaptive strategies also include a careful monitoring of the conditions and weather forecasts, proper maintenance of equipment and a sufficient workforce.

2.4.3 Winters are Not What They Used to Be

Our local partners identified an array of changing winter conditions, which are described below (see Table 2.2 for level of detail).

2.4.3.1 Shorter and Warmer Winters

Local observations from our case areas describe shorter winter seasons with respect to reduced snow depth and cover. In Lebesby, the municipality increasingly supports and promotes winter tourism, in particular snowmobiling, connected to the coastal liner and passenger ship Hurtigruten. The snow is expected to arrive in November-December, and tourist trips are booked in advance for these periods. Since the year 2000, the snow has arrived later than usual on the Nordkyn peninsula. Such conditions have reduced the winter ski and tourist season significantly and the potential for employment and income for small, local tourism outfits. People in both Lebesby and Hammerfest use nature extensively for recreational and food gathering purposes, and a lack of snow, or a delay in its arrival, affects peoples' sense of wellbeing locally.

For the stockfish producers in Vestvågøy, shorter and warmer winters require an earlier start for the stockfish production. Traditionally the production started in mid March, however currently the cod may be hung on the outdoor racks (see Fig. 2.6) as early as the beginning of February. The ideal outdoor temperature for drying cod is around 4°C (Tideman 2008). Significantly lower or higher temperatures will damage the fish. Warmer winter temperatures make regions further north more suitable for stockfish production, which may lead to increased competition for producers in Vestvågøy. Historically more northerly regions have been too cold to yield the same high quality of stockfish as the Lofoten region.

The adaptation strategies to reduce the effect of unfavourable drying conditions include selecting only the highest quality fish for production to ensure the best price, and ensuring that drying conditions are optimal when the fish is initially hung. The producer can choose to divert more or less of the

Fig. 2.6 Stockfish on drying racks at Steine, Vestvågøy. (Photo: Halvor Dannevig)

landed catch to stockfish and use the remainder for more reliable, but also less profitable products, such as salted fish. Nevertheless, all stock fish producers consider stockfish production as a risky business. As one of them described:

> In order to be a stockfish producer, you need to be like an extreme sports athlete. You buy fish worth millions and let it hang out exposed to weather, cross your fingers and hope that it turns out all right.

2.4.3.2 Avalanches

Avalanches are a major concern in both Hammerfest and Lebesby, and can be characterized as a current exposure-sensitivity. In both places the major towns are nestled against steep hills, which are prone to both snow avalanches and rock fall, and an important adaptive strategy for the municipalities is to reduce vulnerability by building and maintaining avalanche protection. The combined effects of increased precipitation, warmer winter temperatures and wind, increases the risk of avalanches in winter (Hanssen-Bauer et al. 2009).

Hammerfest municipality considers itself to be exposed and sensitive to avalanches and has undertaken extensive adaptation measures to reduce its vulnerability. Hammerfest town, being located between a steep hill and the sea, has a limited area for housing development, and the pressure on the municipality is high for approving new buildings. Hammerfest has been quite active in increasing knowledge and expertise about avalanches by developing and updating risk maps (in collaboration with the Norwegian Geotechnical Institute, NGI), prioritising areas to protect, restricting new construction, and securing expert assistance and financial assistance from the Norwegian Water resources and Energy Directorate. With national financial support,

Fig. 2.7 Avalanche protection in Hammerfest. (Photo: Grete K. Hovelsrud)

slide protection has been built to protect more than 530 buildings located in the municipality (see Fig. 2.7), and a priority list for further protection infrastructure has been developed. In addition, the municipality participates in an inter-municipal agreement for avalanche early warning, reducing the costs for such services. Different conditions cause avalanches in different areas, and for Hammerfest wind from the southwest is a determining factor. By being in close contact with the Norwegian Meteorological Institute and avalanche experts the municipality is able to anticipate and prepare for potentially dangerous events.

In Lebesby, much of the town centre is located under a steep mountainside, exposing houses and infrastructure to avalanches and rockslides. A fatal snow avalanche event in the municipality in 1958 led to the first construction of avalanche protection a year later. Since that time avalanche barriers have been upgraded and extended a number of times, and the risk of slide events has been mapped by NGI. However, due to the high costs of constructing protection in all areas, the municipality has had to prioritize coverage in the most exposed and high-risk areas.

Some municipal officials express concern about freeze-thaw cycles that increase risk of rock slides in exposed areas, and those responsible for roads have identified icy conditions caused by freeze-thaw cycles, as particularly perilous, and thus, a current exposure-sensitivity. This is a challenge for municipal maintenance of road safety. Their current adaptive strategies include keeping abreast of forecasts indicating road icing, and attempting to forestall the risks by sanding or salting the roads.

Three municipal departments in Hammerfest, dealing with housing, the airport and harbours respectively, are concerned with how the prevailing wind direction and snow load should determine the orientation of new houses, and the location of the new airport and harbour. Careful consideration of the

siting of these developments constitutes an acknowledgement of the need to adapt planning specifications in the light of new climatic challenges. The municipality has developed wind maps for all potential development areas, and has for some years, required that new housing developments take climate change into consideration both in terms of where and how to build. Through its collaboration with the Norwegian State Housing Bank Hammerfest municipality has developed climate adapted housing.

With the introduction of the new national planning and building legislation, more legislative focus is placed on climate related requirements for new housing construction, although direct reference to climate change adaptation is omitted. As demonstrated above, Hammerfest has previously devised its own adaptation strategies in response to local climatic and weather conditions, independent of legislative requirements, indicating a high degree of adaptive capacity.

Another concern in Hammerfest is rain on frozen ground, leading to river flooding as the ground cannot absorb excess rainwater. Lack of sufficient municipal drainage capacity, due to inadequate pipe dimensions, may lead to flooding within Hammerfest city. Our local municipal partners in Hammerfest also expressed deep concern about extreme precipitation in both winter and summer which increases the run-off into the harbour. This runoff is likely highly contaminated by sediments from closed polluted ship yards and fish processing industrial sites. This can be characterized as a current exposure-sensitivity and the current adaptive strategy involves monitoring the pollutant levels on the harbour sea floor to assess the rate at which pollutants trapped in the sediment seep out into the sound. The municipality is also looking into ways of securing the sediments, by studying how the problem has been dealt with elsewhere.

2.4.4 Are We Building Too Close to the Sea?

First came the harbour and then came the town – the harbour master in Hammerfest.

Our case areas are all located by the sea, and have extensive experience with storm surges, spring tides and waves crashing against docks, installations and ships. Sea level rise in Norway is currently counterbalanced by land rise which will not continue in the future, and long-term future projections indicate significant sea level rise (Hanssen-Bauer et al. 2009). Our local partners noted that storm surges and spring tides present risks to housing, docks, harbours and installations such as the Melkøya LNG plant, thus additional projected sea level increase will inevitably have future consequences for the communities. These structures and facilities have been based on historic sea level and historic storm surge maximums, and have not taken into account current and future increases in storm surges.

This is also true of the docks and harbour currently under construction in Hammerfest. This is in stark contrast to the requirements placed on housing

developments to take into consideration provisions for storm surge water drainage. The new cultural centre in Hammerfest has been built on stilts in the harbour spurring discussions among locals on whether it has been wise to construct housing and other buildings close to or even into the harbour. Arguments in favour note that the options for constructing new buildings are limited because of the physiographic features of Hammerfest. Likewise in Lebesby, the recent construction of a modern dock to service the town and the coastal liner Hurtigruten, did not consider projections of future storm surge and sea level rise.

Traditionally docks and harbours were used for ships and cargo storage, whilst in modern times breakwaters are built along the shore and housing close to the docks. This resembles mal-adaptation, because during heavy storm surges the sea water may overflow the docks and into the houses located behind. Storm surge and spring tides have been identified as current exposures-sensitivities with respect to the harbours, docks and housing. The municipal planners and decision-makers have to balance the need for housing and development with national regulations and safety issues. Their current adaptive strategy is to anticipate projected sea level rise and storm surges in determining the minimum building distance and elevation from the sea. This was done by Vestvågøy municipality when they changed the plans for the new dock and fish processing plant currently under construction by adding 20 cm in height to the original plans. This was a result of the municipal planners of the dock inquired about projected sea level chart adjustments to 2050, and recommendations by the Norwegian Coastal Administration. The municipality combined the sea level projections for 2050 with local experience of salt water drain inundation during spring tide, particularly when in combination with on-shore winds. Following a precautionary principle and showing a willingness to pay the costs the municipality by adjusting the distance from the sea devised an adaptive strategy.

2.5 Socio-Economic Exposure-Sensitivities

Concurrently with discussing locally significant weather and climate elements, the researchers and local partners have identified non-climatic exposure-sensitivities shaping the vulnerability, adaptation and the adaptive capacity of the communities. These include social conditions, economic factors, demography (outmigration and age structure of the labour force), municipal capacity and institutions for natural resource management (e.g. Eakin and Lemos 2006; Smit and Pilifosova 2001; Tol and Yohe 2007). In Table 2.3 we present a summary of the locally identified current socio-economic exposure-sensitivities.

Table 2.3 Socio-economic factors

Socio-economic condition	Exposure-sensitivities
Outmigration (L)	A stable population base is crucial for maintaining viable communities and municipal services for fishermen and their families. Returning, educated youth are seen as a resource and basis for innovations in the fisheries and municipality to deal with change.
Aging fisherman population and recruitment (L,V)	Affects the continuity of coastal fishing activities, the attractiveness of the trade to youth, and the transfer of knowledge from older to younger fishermen
Fishing regulations- and policy (H, L, V)	Affects fishermen's ability to respond to changing fish stocks. Affects the cost of entering the fishing trade and the profitability of fishing activities. Affects the stability of supply of raw fish supplied to landing facilities throughout the year. Affects spatial and temporal distribution and availability of fish through regulation of fishing pressure in different seasons and regions. Has created incentives for possible unsafe vessels in a context of more extreme weather. Has led to concentration of fishing rights and increased profitability for some fishermen.
Legal factors (H, L) -Income tax regulations -Insurance requirements for fishing vessels	These factors may limit fishermen's flexibility to deal with variable and changing climatic, biological and societal conditions
Market factors -Price paid for fish to fishers (H, L, V) -Price paid for fish products - Fuel prices (V)	International market price for fish and fishproduct determines the profitability for fishers, fish buyers- and processers. Fuel prices influence the profitability of fishers.
Food authority regulations (V)	In 2004, new food security regulations were imposed upon fish landing facilities- and processors, which required substantial investment in buildings and equipment and imposed a demanding quality control regime.
Capacity of municipal departments (H, L, V)	Ability to cope with new situations, plan for climate change
Municipal economy (V)	Ability carry out non-mandatory tasks, support industry development

H = Hammerfest, *V* = Vestvågøy, *L* = Lebesby

2.5.1 A Fishery Sector Under Changing Management and Market Conditions

Our local partners involved in fisheries identify a complex set of factors that influence the overall profitability and the ability to make a living of coastal fishing, including the size of quotas for different species, the price of fish, the cost of fuel and fishing gear, the location of landing facilities, and national taxes and subsidies.

Coastal fisheries are increasingly integrated and exposed to global market mechanisms (e.g. Keskitalo 2008, 2009; Keskitalo and Kulyasova 2009). The current global financial crisis has led to a reduced demand for the exclusive Norwegian cod, which unfortunately has coincided with reported excellent fishing conditions. Fewer landing facilities, with weakened economic resources, do not have the storage capacity required to purchase all catches from the coastal fishers not being able to deliver their catch, and the coastal fisheries are suffering as a result. The important interplay between small coastal fishing communities and the broader social and economic contexts in which fishing activities are embedded illustrates the cross-scale challenges for adaptation in coastal fisheries: Supply of fish depends on environmental, including climatic conditions, while access to fish depends on fishing regulations, technology, choice, weather conditions, and price and cost factors (West and Hovelsrud 2010).

In the past coastal fishers were also farmers ('*fiskarbonden*') or held part-time jobs to ensure a stable year-round income. This was a successful adaptation strategy to a seasonal and variable resource-base (e.g. Brox 1966; Vea 2007). However, the current national income tax and quota systems for fishers restrict multiple incomes and encourage specialisation by requiring people to state a primary livelihood, and via financial and tax penalties for income earned in additional activities. This creates barriers for livelihood diversification that might otherwise help to enhance the adaptive capacity of individuals as they face a range of social, environmental and economic realities.

Another factor that contributes to existing exposure-sensitivities identified locally is the increasing debt rate of the coastal fishing fleet caused by the recent quota reforms (MoFC 2006). According to fishers, the increasing debt rate, caused by hedging in future fishing quotas, has altered the seasonality of fishing operations. Previously, the fishers in Vestvågøy were able to wait for the spawning cod to reach Lofoten, which normally occurred in mid-February. Currently, and because of heavy financial obligations, the fishers cannot afford to wait, and they travel north to catch the spawning cod as soon as the fisheries open on 1st January. When the cod finally reaches south to Lofoten, most fishers have already landed their full quota at facilities farther north, resulting in less cod being landed locally.

Stockfish producers and the fish processing industry face a complex set of non-environmental exposure-sensitivities, including food safety requirements as stipulated by the national authorities and the European Union, landed fish price and international fish market conditions. The stockfish industry, for example, is highly dependent on the Italian market, where the large annual fluctuation in price is closely connected to the quantity and quality of stockfish, and a range of factors influencing the demand in the Italian market.

The producers aim to reduce their dependency on the Italian market by developing new stockfish-based products, as well as creating and gaining entry to new markets for traditional stockfish. Furthermore, the stockfish

producers are dependent upon good relationships with banks, to avoid bankruptcy should there be consecutive years with losses. The stockfish producers are at the whim of the Italian market and may end up buying fish at a higher price than it will sell for in a particular year, and resort to storing the fish until the price increases. As one employee in the stockfish industry said:

> Several years ago, a stockfish producer was not able to sell stockfish for three years. The first year passed, the prices were too low, and he did not sell. When next season came, he went to the bank and got a loan to buy fish for making new stockfish. But also this season the prices were too low, so he could not sell. And also this time he got a loan from the bank when the next season started, so he could buy the catch. Then finally he got a good price for his stockfish and could pay his debt to the bank.

Despite the economic challenges that fishers face, new market and innovation opportunities emphasising fish quality, and combined fishing-tourism activities, are some of the adaptive strategies that fishers and fish producers in the fish industry in our case studies are implementing to deal with the economic variability to which fisheries are exposed. In Lebesby the local landing facility is marketing high quality cod and red king crab products for export to Europe, Japan, and North America. Innovation of new products seeks to capitalise on locality, environmental sustainability and quality issues associated with the gear employed to fish and process the product. Several local fishers in Lebesby also combine fishing with tourism, and receive economic support (in the form of low-interest or interest-free loans) from the local landing facility and national innovation funds for entrepreneurs. The local landing facility in Lebesby has plans to open up its processing facilities to tourists to try to diversify its income and capitalise on the inflow of tourists from the coastal liner Hurtigruten.

2.5.2 Outmigration, Recruitment and Aging Fishers

The cultural, social and demographic factors that currently shape coastal fishing activities are perceived by our local municipal and fisheries partners to be of particular concern for their livelihoods. The socioeconomic exposure-sensitivities are further magnified when seen in combination with climate related exposure-sensitivities.

Outmigration to larger centres, an aging fisher population and declining recruitment to fisheries are three ongoing trends of concern in our case communities. Despite Norway's official national policy of maintaining a dispersed settlement pattern, outmigration from small, rural settlements to larger urban centres, continues. The population in Lebesby, for example, has been in decline for several decades, with a reduction of 15% between 1997 and 2008 (Lebesby kommune 2008). While Hammerfest, in the same county, has experienced a stable population, due to oil and gas development and production. Vestvågøy

further south and with a more diversified livelihood base than Lebesby maintains a stable population, with many young people settling in the municipality. The Lofoten region, where Vestvågøy is located, has however experienced a steady decline in its total population. According to municipal representatives in Lebesby, a declining population is a problem on many levels, one important one being that it reduces the municipality's tax base, and in turn its ability to provide infrastructural support such as landing facilities, the docks and storehouses where the fish is delivered to the buyers, and services needed to support fishing activities, as well as social and economic support for fishers' families (West and Hovelsrud 2010).

According to fishers in Lebesby, and supported by municipal reports and discussions, outmigration is connected to the municipality's peripheral location and its dependence on a narrow range of economic and income opportunities, as well as a lack of interest amongst skilled young men and women in entering the fishing industry. Likewise in Hammerfest the local fishers are concerned that young men and women will be absorbed into the petroleum industry, thus reducing recruitment to the coastal fisheries. The young and educated are often not interested in pursuing fishing, with its irregular hours and variable pay, as a full-time career. Fishers also surmise that lifestyle choices and family dynamics have changed over the years, and as a consequence fishers with young families are less willing to accept being at sea, in small vessels, in rough conditions for any length of time. Many prefer instead a fishery where they can come home every day to be with their families, but this seldom gives a satisfying income if not combined with other jobs. Others take jobs aboard supply ships in the offshore oil and gas industry to earn money for purchasing their own fishing vessels, and are therefore not participating in the fisheries as hired hands, but wait until they can captain their own fishing vessels.

An aging fisher population further threatens the traditional basis for income and employment in the case areas. The average age of all fishers residing in Lebesby in 2007 was 49 (DoF 2007), and few youth are being recruited to the trade. The active fishers are concerned that lack of recruitment interrupts the transfer of fishing knowledge and skills between generations. Coastal fishers in Northern Norway rely primarily upon their own experience-based and locally transferred knowledge about weather, ocean and fish interactions, and adjust their activities according to their own observations, discussions with peers and local forecasts. Detailed local knowledge about environmental conditions is imperative for safety at sea and for success in catching fish, and without close contact between the older and the younger fishers this knowledge will not be transferred and over time may be lost. In Lebesby and Vestvågøy, the municipalities have various adaptive strategies to hamper outmigration, including creating jobs for the youth, providing support for entrepreneurs and affordable housing, and creating incentives for expansion in the coastal fishing fleets and relocation to the municipalities.

2.5.3 *Fisheries Management*

> It depends on whether the politicians want lights in all the houses in each cove and on each island, or larger boats which may deliver the fish locally and provide more jobs–*fisher in Hammerfest*.

Our case study partners describe fisheries management as influencing both fish stocks (by controlling fishing pressure on particular species in time and space) and fishers' adaptation to these changes. Fisheries activities are inherently flexible and adaptive in order to deal with a variable and migratory resource (see Coulthard 2009; Jentoft 1998). Norwegian fisheries are shaped by a range of institutions, such as the quota negotiation process and the market for first order sale of fish, and are highly politicized (e.g. Jentoft 1998; Keskitalo 2009; Keskitalo and Kulyasova 2009). Fishing is regulated for individual fish species, in time and space, according to vessel lengths and place of registration, and fishing zones are regulated by both national and international laws (Jentoft and Mikaelsen 2004). Norwegian fishing regulations have transitioned over the past four decades from an open, to a limited entry, quota-based fishery based on the precautionary principle and total allowable catch (TAC) (MoFC 2007). The Barents Sea – North Atlantic (NA) cod stock is managed jointly by Norway and Russia, with Norway having the rights to about 45% of the annually agreed quota for this stock (Fiskerirådgivning AS 2006). The annual cod quota is based on scientific assessments of the size and health of the fish stocks, which can be seen as a national adaptation strategy to ensure a healthy and sufficient stock.

A key effect of the introduction of the quota system has been an increase in the value of delimited fishing rights, strictly regulated and with partly saleable quotas. This has led to widespread structural changes in the Norwegian fishing fleet that have reduced the number of total fishers and fishing vessels, and concentrated fishing activities into larger centres such as Hammerfest (Karlsen 2004; Lindkvist 2000). Because of the declining employment in fisheries (in Hammerfest reduced by 50% and in Vestvågøy by 30% between 1970 and 1990), the productivity and income of the individual vessels have increased as a result of the structural changes (see Fig. 2.4) (Fiskerirådgivning AS 2006). Questions are raised among our local partners about the relationship between the Norwegian regional development policies and fisheries management that seek to ensure an equitable balance of fisheries participation and rights in different regions, economic efficiency and ecological sustainability. Recent changes in fisheries management have reduced the size of the vessels that may participate in certain fisheries such as the red king crab, making it possible for smaller vessels, often with only one fisher, to travel farther out to sea to fish.

The characteristics and features of fisheries management regulations determine the range of adaptive strategies available to fishers for dealing with the various exposure-sensitivities identified in Section 2.5. Adaptive strategies include finding ways to navigate institutional settings in ways that provide profitability and greater income security for individual fishers. Warmer ocean

temperatures and changing fish distribution, abundance and species composition may provide new opportunities for local fishers in all three case communities. However, potential economic gains will depend on the species, its location, its market demand (and price), the availability of processing facilities that can land and process new species, appropriate fishing technology, and appropriate fishing regulations.

2.5.4 Municipal Capacity

All our municipal partners emphasize that they have developed adaptive strategies based on their experience in dealing with weather and climate over the years. We found, not surprisingly, that municipal officials were highly knowledgeable and had much expertise concerning local environmental conditions and how best to deal with them. However, several studies of municipalities and adaptation in Norway have concluded that few municipalities have prioritised a systematic approach for confronting the challenges of climate change (e.g. Amundsen et al. 2010; Næss et al. 2005; Vevatne and Westskog 2007). That Hammerfest and Lebesby have sought external expertise about avalanche conditions, and have invested in avalanche protection is both a reactive adaptation to historic events, and an adaptive strategy for future events. However the exposure is not directly attributed by the municipalities to climate change. Hammerfest has only recently started to include future climate change in its long term planning.

The municipalities are central actors in maintaining sustainable and functioning communities. They provide favourable conditions for local industries through infrastructure provision such as roads and harbours, and entrepreneurial business support, either directly through shared financing schemes or municipal ownership. In addition to dealing with the stresses of occupying a geographically peripheral location, an aging population, and outmigration, our case municipalities face multiple challenges connected with capacity problems and budget constraints.

A major and shared challenge for the three municipalities is a lack of adequate human capacity and finances to plan and prepare for new and different conditions despite their efforts to seek expertise and funding. As stated by one of our partners – 'the officials are so occupied managing their little piece of legislation that no one gets the broader picture'. Such fragmented organization and lack of capacity are identified by one of our partners as a major barrier for planning for adaptation to climate change. Both the large municipalities (Vestvågøy and Hammerfest), and the smaller one (Lebesby) have similar capacity problems. There are simply not enough human or financial resources available to carry out the different tasks required to maintain municipal services and at the same time increase expertise and knowledge in relation to potential climate change risks and opportunities. A common result is that the municipal human resources become exhausted. Across the cases, the impressive

engagement and efforts of individual municipal officials is a major driver behind many of the current projects and increasing local expertise. The limited financial and human resources and burnout among engaged individuals ('*ildsjeler*') have consequences for the adaptive capacity of the municipalities to plan and prepare for current and future climate changes.

Lebesby municipality draws on a number of engaged inhabitants, including local innovators and entrepreneurs who are marketing the municipality through nature-based tourism, alternative clean energy investments and coastal culture and identity. However, our partners note that it is often the same individuals who sit on a range of voluntary committees and occupy leadership positions within the community. Without adequate compensation and support, over time these innovators may become discouraged and lose their motivation. The municipality has made efforts to diversify the local employment profile and create more jobs (e.g. via tourism), and maintain its population (the agricultural generation shift fund is one example) in order to make the community an attractive place to live and work, and to maintain a stable tax base. Here a sustainable and vibrant community is seen as a central social, economic and cultural value. In Hammerfest municipality, individual efforts and interests, in collaboration with external scientists, have led to a remarkable successful recovery operation to restore destroyed sea bed vegetation. The destruction of the coastal fish habitat is a current exposure-sensitivity for the coastal fishermen in Hammerfest, and the restoration effort is an adaptive strategy for the fishers in the municipality. Without the enthusiasm and efforts of individuals such projects would not have occurred. In Vestvågøy individual municipal officials also exhibit enthusiasm and engagement with respect to being involved in research projects such as CAVIAR to increase their knowledge, expertise and adaptive capacity.

Hammerfest municipality has had a substantial increase in revenue in connection with the establishment of the LNG facility at Melkøya, which is increasing the general adaptive capacity of the municipality, but has not yet resulted in expanding the local workforce, beyond the two employees dealing with climatic and environmental topics. Such topics appear not to be high on the political agenda in Hammerfest. Vestvågøy on the other hand struggles with the municipal economy and has been forced to make unpopular spending cuts, such as school closings. Lebesby has status as a 'transformation municipality' entitling it to subsidy from the central government, which is a type of financial assistance to counter declining revenues, high debt and outmigration.

Our municipal partners with extensive knowledge and deep engagement in local issues and conditions, have noted that they simply do not know how and where to find the relevant information about the consequences of climate change, how to develop adaptive strategies and how to inform the public. With a poor information flow from the national to local level, the municipalities are dependent upon individual engagement and ability to seek knowledge. Our findings show that it is not only the institutional factors which determine the adaptive capacity but the efforts of engaged individuals is also a critical factor across the communities.

2.6 Future Conditions

In our case studies we work closely with climatologists in an iterative process to develop the climate elements that are most relevant and feasible for downscaling. This is based on identification of relevant climate elements by the local communities. A main scenario was based upon output from the regional climate model HIRHAM (Haugen and Haakenstad 2006), but adjusted to the local topography by a method developed by Engen-Skaugen et al. (2007). In order to get a measure for uncertainty of the main scenario, the projected local changes in temperature and precipitation were further compared to the results from empirical-statistical downscaling (Benestad et al. 2008) from a large multi-model ensemble.

Table 2.4 lists of some of the relevant future climate elements as identified by the communities. The list reflects the weather conditions that our local partners are currently concerned with and their interest in how these develop in the future. Through discussions with climatologists we have been able to determine which of these elements can be downscaled for future projections, and which ones, such as wind, cannot. The table also shows that many weather related conditions of local concern occur when combining climate elements such as precipitation and temperature, above or below freezing. The process of

Table 2.4 List of climate elements identified in cooperation with local partners for downscaling of climate model projections

Climate element identified for downscaled projection	Result
Extreme weather and storms (V, H, L)	n
Polar lows (H, L)	n
Sea level rise (V, H, L)	y
Storm surges and wave height (V, H, L)	y
Low pressure trajectory (H)	n
Air moisture (V)	n
Precipitation - Extremes (V, H, L)	y
Precipitation- Monthly mean (V, H, L)	y
Precipitation – Rain combined with frozen ground (H, L)	y
Precipitation – Composition- snow, slate, rain (H, L)	y
Precipitation – Snow cover- and amount (H, L)	y
Temperature – Extremes (V, H, L)	y
Temperature – Monthly mean (V, H, L)	y
Temperature - Freeze-thaw and 'zero degree' conditions (H, L)	y
Sea temperature (V, H, L)	y
Wind- Extremes (V, H, L)	n
Wind, wave height and sub zero conditions (H, L)	n
Wind – strength and directions pr. Season (V, H, L)	n

H = Hammerfest, *V* = Vestvågøy, *L* = Lebesby, *N* = not possible to model and project, Y = projections is produced and discussed with local partners. Represented in the forms of maps, column- and line diagrams

identification, which was a highly collaborative effort between scientists and local partners, shows that there are salient interlinkages between future projected climate change and societal conditions. In this section, we present some of the downscaled projections that have been presented to the case study communities for feedback and discussion. Being a work in progress we also present some of the case study communities' responses to the projected changes in climate, in terms of the implications and challenges such changes may signify. The downscaled climate projections are currently being discussed in the case communities and the final results will be presented in forthcoming publications.

2.6.1 Climate Projections and Local Implications for Case Communities

2.6.1.1 Ocean Temperature

An increase of 1–2°C in ocean temperature is projected for the Barents Sea by 2070 under a scenario of doubled atmospheric CO_2 levels (see Fig. 2.8) (Førland et al. 2009; Loeng et al. 2005). A sustained increase in average ocean temperatures in the Barents Sea region will likely lead to major reductions in the already reduced seasonal ice cover (Overland and Wang 2007) and may result in a shift in the location of the Polar Front, where warmer Atlantic and colder Arctic waters meet, to the north and east of its present location (Ellingsen et al. 2009). Potential changes in ocean circulation and a decrease in inflow of warmer, saltier Atlantic Water (see Koenigk et al. 2007; Wu et al. 2008) may also occur.

Future ocean warming is expected to lead to a northward shift in the distribution of cod spawning areas and to changes in the distribution of key commercial species, and a potential influx of southerly species (ACIA 2005; Drinkwater 2005; Loeng and Drinkwater 2007; Sundby and Nakken 2008). These changes may represent new opportunities for the fishers and communities, but may require adjustments in fishing technology, traditional or local knowledge, and in management regulations (West and Hovelsrud 2010). The fishery actors in all the three cases interpret future climate change in the context of continuously changing conditions, which they consider themselves to be highly adaptable to. Hence fishers do not perceive themselves to be negatively affected by climate change. Their future adaptive capacity, however, is not only determined by their current adaptability but by changes in fisheries management and market conditions. Fisheries regulations, while on the one hand potentially enabling greater geographic mobility in the future, may also increase the already hazardous occupation of coastal fishers, and add an unexpected exposure-sensitivity to the fishing activities (MoFC 2006). West and Hovelsrud argue that perceptions of being highly adaptable may be a barrier to adaptation (West and Hovelsrud 2010).

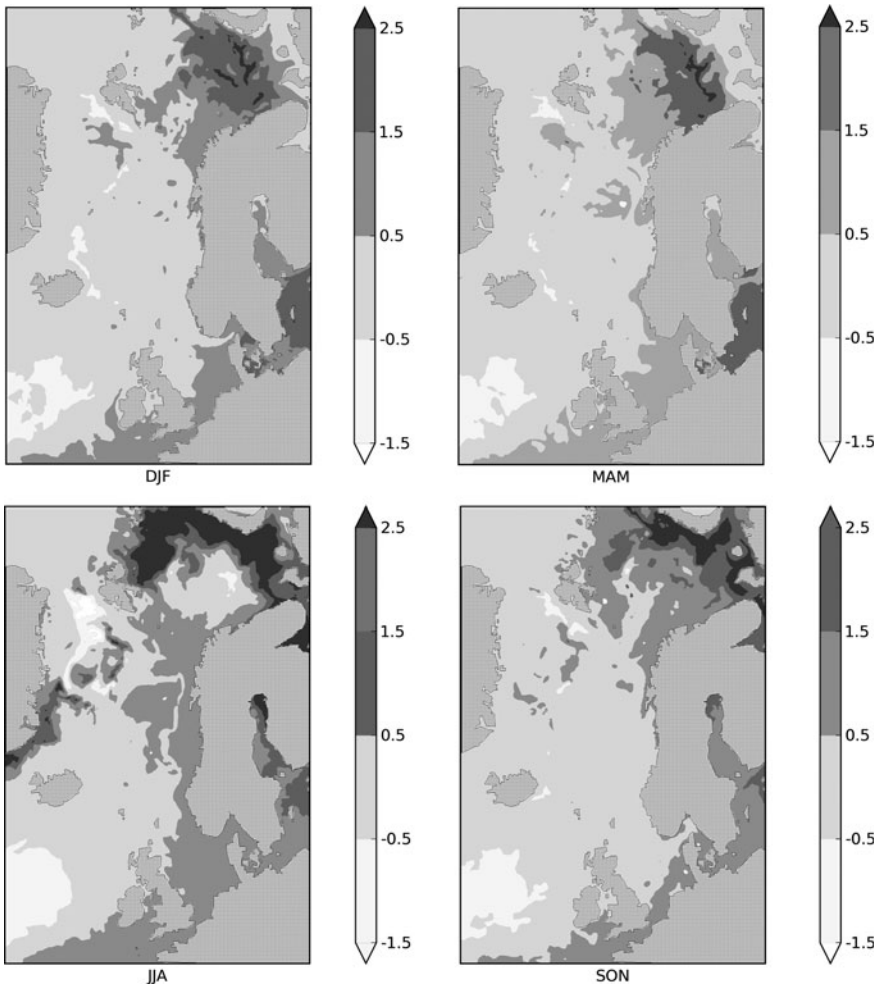

Fig. 2.8 Projected changes by season for sea surface temperature in the Nordic seas from 1986–2000 to 2051–2065. The north-eastern Barents Sea shows the largest increase, and the increase is largest during summer and autumn. The Mid-Atlantic shows a temperature decrease as a response to a projected weakened North Atlantic Oscillation. *Source*: Bjørn Ådlandsvik, Institute for Marine Research, Norway

Fishers in Vestvågøy do not perceive a northward shift of fish species as problematic, while Lebesby fishers view potential fishing further offshore in combination with storm activity as a potential challenge when considered in the context of current fisheries regulations and management. That a continued northward shift of species could eventually lead to less spawning cod near Lofoten and Vestvågøy, has not been identified as a future exposure-sensitivity by our local partners. However, the fishers recognize that new species such as mackerel and crab will be commercially important and may replace spawning cod.

A continued northward shift in the cod fisheries would create increased challenges for landing facilities in Vestvågøy, and is recognized as a contributing future exposure-sensitivity when combined with other non-climatic exposure-sensitivities such as market conditions and framework regulations. Combined, these could increase future vulnerability for the industry.

The municipality, in an effort to meet the future challenges posed by the northward shift in fisheries, has plans for developing and strengthening one harbour on the north side of island, to be closer to the northern fisheries (Vestvågøy municipality 2008). Similarly the municipality has plans to improve road access in two fishery communities, Ballstad and Stamsund, in order to facilitate transportation from landing facilities in the north to the fish buyers in these communities, as well as supporting fish buyers in the municipality to establish landing facilities further north. This kind of infrastructure development is dependent upon financial contributions from the national government.

2.6.1.2 Temperature and Precipitation

Regional climate simulations (HIRHAM 25) project an air temperature increase of 1°C in coastal areas in Northern Norway by 2050 and a 1.5–2°C increase in the eastern part of Finnmark county, with the strongest increase in winter temperature (Førland et al. 2009). Figure 2.9 shows the downscaled temperature projections for Vestvågøy. By the end of the century the temperature is expected to increase by 2.5–3.5°C for Northern Norway (Førland et al. 2009).

The future climate could reach a point where it is too warm and moist for optimal stockfish production in Vestvågøy. This is likely to have graver implications for the producers in Vestvågøy than further west, as the temperature increases more towards the east than the west. Producers point out that there has been stockfish production in the region for more than 1,000 years and therefore they do not perceive the projected climate change as a threat. Furthermore, the risk of a chronological mismatch between availability of cod catch and the drying season (as discussed in Section 2.4) could be ameliorated through existing strategies such as land-based transport. The stockfish producers are not particularly concerned about this potential climate development, indicating a high confidence in financial capacity.

For Northern Norway, the precipitation is expected to increase by 20–30% by 2050, with the largest increase in Winter and Spring (Førland et al. 2009). The combination of increases in both temperature and precipitation will change the composition and timing of snow and rain through out the seasons, as shown in Fig. 2.10.

Hammerfest municipality is concerned that increased precipitation in the future will increase run-off to the harbour, accentuating highly polluted sediments. Such run-off combined with increased wave action raises concern that pollutants trapped in the sea-bed will be released. A future adaptive response being considered is to reduce runoff from land and find ways to secure the

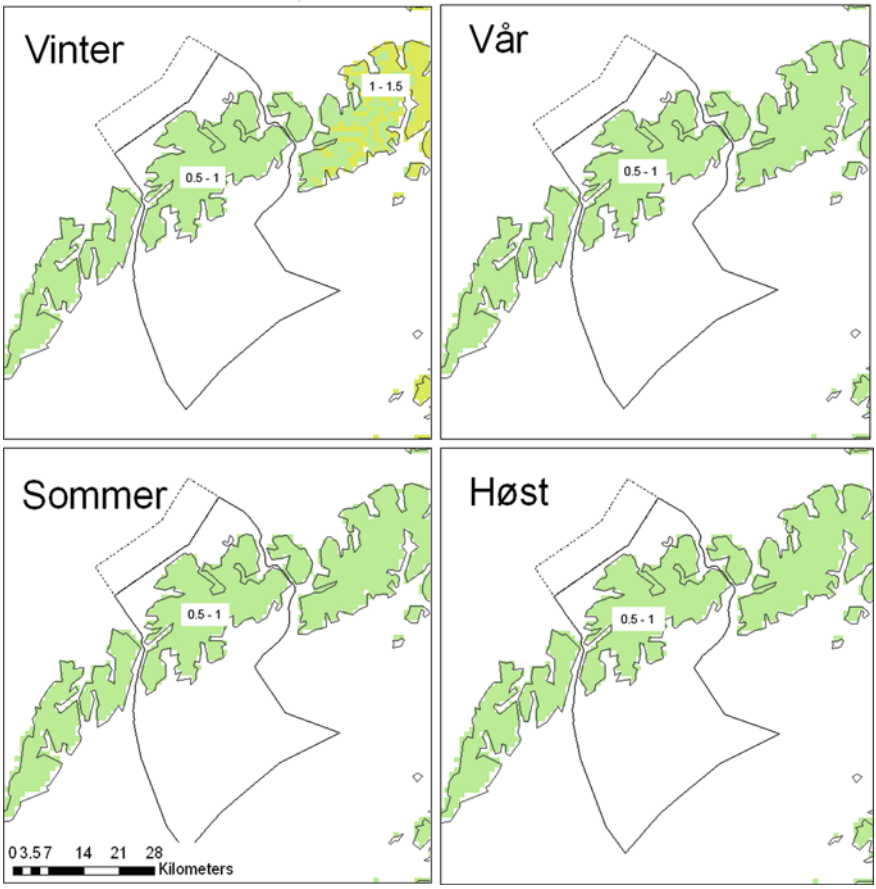

Fig. 2.9 Projected changes in mean temperature pr. season (Vinter - Winter; Vår - Spring; Sommer - Summer; Høst - Autumn) in Vestvågøy municipality from the period 1981–2010 to the period 2021–2050. Projection: ECHAM4/OPYC3 GSDIO. Emission scenario: IS92a. Downscaled to 25 km resolution with regional climate model HIRHAM and adjusted empirically to 1 km resolution. *Source*: Torill Engen Skaugen, Norwegian Meteorological Institute

sediments in the sea-bed. The municipality, inspired by successful measures near Oslo, has discussed the possibility of mixing sediments with concrete and constructing a breakwater in town.

Lebesby and Hammerfest municipalities note that if the future projections indicating less snow are correct (see Fig. 2.10), their snow clearing budget could be reduced, resulting in more money for other tasks. The new national regulations for snow load on housing and buildings have doubled the removing costs for municipalities. The road maintenance workers expressed great interest in how snow conditions may change in the future, and whether new adaptive strategies would be necessary. The projected warmer temperatures in

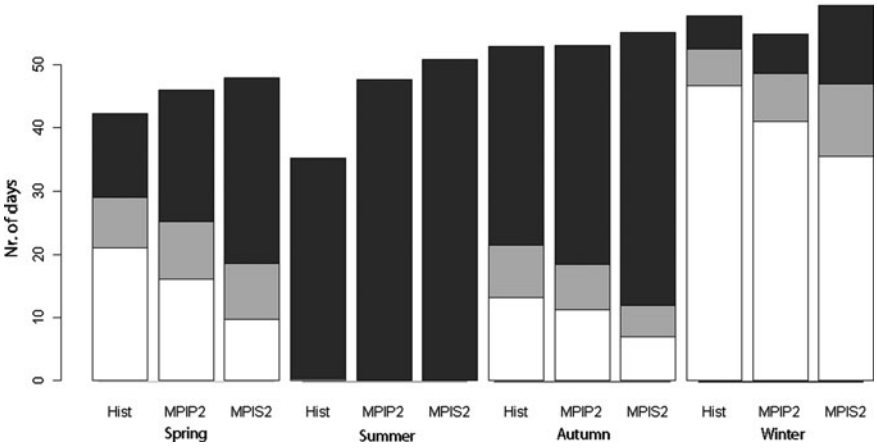

Fig. 2.10 Projected changes in composition of precipitation (snow, slate and rain). Each group of three bars represents a season. For each season, the *left bar* displays the period 1961–1990, the *middle bar* represent the period 1981–2010 and the *right bar* displays the period 2021–2050. *White colour* represents snow, *grey* represent slate and *black* represent rain. *Source*: Hans Olav Hygen, Norwegian Meteorological Institute

winter combined with precipitation will likely create more days with icing and freeze-thaw cycles, and the reduced snow removal budget may be used for sanding and salting the roads instead.

In Lebesby, a number of areas remain at risk of avalanches, including the local cultural tourism facility Foldal, where avalanche fears caused the evacuation of tourists as recently as 2009 (Kjell Wien, pers. comm). A potential increased avalanche risk at Foldal under climate change could pose a problem for museum tours and overnight guests in the municipality.

2.6.1.3 Sea Level Rise and Storm Surges

There are major uncertainties associated with global sea level rise (SLR), and it is widely recognized that models used in IPCC AR 4 underestimates future SRL (Hanssen-Bauer et al. 2009). For Norway it is also necessary to consider the land isostasy (land uplift) that has taken place since the last ice age when the Fennoscandian ice cap disappeared (Hanssen-Bauer et al. 2009). Here we have used estimates by Drange et al. (2007), who have calculated sea level rise and storm surge for 2050 and 2100 for all Norwegian coastal municipalities. These estimates have taken the isostasy into account. For Northern Norway, sea level is projected to increase by up to 35 cm by 2050 and up to 1 m from current maximum level, by the end of the century (Hanssen-Bauer et al. 2009). Storm surges are expected to increase by 2.5–4% by 2050 (ibid).

Discussions in Hammerfest revealed a concern about future increase in ocean swells and fetch as a result of less sea ice further north. The magnitude of fetch and storm surge have consequences for safety and preparedness in shipping and installations at sea, and for exposed harbours. Future changes in such conditions may call for new requirements and a heightened awareness of national government officials and local planners. Municipal planners in Hammerfest and Vestvågøy are increasingly concerned with future SLR and have taken this into account in land use planning. They are also discussing adaptive measures to deal with sea water intrusion into existing buildings. Farmers in the Laksefjord area of Lebesby expressed concern that SLR would cause inundation of salt water and threaten agricultural land that is located adjacent to the fjord.

2.6.2 Discussion of Future Conditions and Adaptive Capacity

When discussing future conditions in Vestvågøy there is one topic that overshadows climate change and most other issues: oil drilling in the Lofoten waters. The fishers are certain that the oil activity will result in a loss of fishing ground access, and that oil drilling possibly could harm the fisheries. Some claim that it will be the end of Lofoten as a major fishing and spawning region. In all case areas, fisheries remain according to our partners, a vital industry, even though the share of employment in fishing continues to decline.

The stockfish industry will likely be reliant upon innovation in order to sustain its current turnover and employment, in face of the other challenges mentioned in Sections 2.4 and 2.5, particularly market challenges. The projected changes in temperature would probably lead to higher frequency of failed drying seasons, and combined with more challenges with securing raw material as a response to the northern shift in cod fisheries, this will be a disadvantage to the Vestvågøy producers in the competition with producers further west and north. Willingness to innovate (e.g. by developing new stockfish products for Norwegian consumers), has been clearly demonstrated by some producers, indicating high adaptive capacity. The question remains whether these developments are sufficient to maintain the importance of the sector within the region.

Several authors note that future fisheries management and governance decisions may play a more important role than climate change in determining the fate of northern fish stocks (Hovelsrud and West 2008; Eide 2008; Vilhjálmsson et al. 2005). In partial support of this position we further argue that climate change represents an additional stress to current resource management regimes, which may increase local vulnerability. Fishing seasons, quotas and management of individual fish stocks do not take into account the variable weather patterns and longer-term climate trends which often determine when, where and under what conditions coastal fishing activities can

take place. These are conditions that, according to fishers, scientists and managers are already being affected by climate change (Browman 2008). If regulations expand the fishing zones farther out to sea, and this coincides with an expected increased frequency in extreme weather conditions, it also increases the hazards for small, single manned fishing vessels, while at the same time giving access to more distant fish stocks. Climate change may therefore increase the need for flexibility in the fisheries because of the combination of a shift in fish species and interactions, and changing conditions at sea (Hovelsrud and West 2008). The fishers that are currently in business have proven to have high adaptive capacity to the changing regulatory frameworks of the past and present. But currently the regulations do not add to the adaptive capacity of fishers to future exposure-sensitivities. The future economic, social and environmental viability and sustainability of the coastal fisheries have consequences for the future viability and sustainability of the municipalities. Information flow and financial security are two major factors enabling municipalities to develop successful adaptation strategies for future exposure-sensitivities, and hence these two factors are crucial determinants of adaptive capacity to future exposure-sensitivities. The municipal budgets, albeit being solvent, are already strained, and preparing for changing climatic conditions that are uncertain is not a priority among politicians. It is, however, not sustainable for municipalities to rely on engaged individuals to reduce future vulnerability. It is also necessary to strengthen the local institutional capacity.

2.7 Conclusions

For the municipalities in our case areas to continue to provide the services and ensure community wellbeing, which they are designed to do, they will need better access to information about how to assess future climatic and societal changes. The case studies presented in this chapter were developed in close cooperation with our local partners in Hammerfest, Lebesby and Vestvågøy municipalities. We have found that local involvement is beneficial along a number of dimensions including to ensure proper focus, to increase local awareness about climate change adaptation, to provide necessary input to climatologists, and to highlight the complex linkages between climatic and socio-economic conditions. By involving local partners we have been able to unpack the high level of detail needed to understand how climate change will impact local communities. Through a description and analysis of the different exposures-sensitivities to change (climatic and non-climatic) we have increased our understanding of how these in combination have consequences for current and future adaptation and vulnerability. We have focussed on coastal fisheries and municipal planning as two major arenas for change, and have shown that

adaptation takes place along a number of dimensions and at several societal levels. Many adaptive strategies occur in response to socio-economic conditions, some are implemented to deal with variable weather or environmental conditions, and others seek to address a combination of both.

Three interlinked factors are according to our empirical findings, currently of concern for coastal fisheries: changes in bio-physical conditions (ocean temperature and fish distribution and behaviour); fisheries management and regulations (vessel size, species, and quotas) and societal conditions (outmigration, market factors, and transfer of knowledge). The interlinkages between these have first and foremost been captured and understood through local involvement in our research. In many ways this is a classic example of that the whole is more than the sum of its parts. Climate change is currently not seen by our partners as the major driver of change locally, and we have found that fishers interpret the current changes in a familiar context of natural variability. Nonetheless, both outmigration and an aging fisher population challenge coastal communities' viability, and will likely strain the capacity to deal with the impacts of climate change on coastal fisheries. Without landing facilities, fishers and active fisheries, the municipalities' strong coastal fisheries identity and culture may decline. This may in turn reduce the attractiveness of fisheries investments necessary to meet future environmental and societal challenges (West and Hovelsrud 2010).

Municipalities operate in a world bound by regional and national rules and regulations and local responsibilities combined with deep knowledge and an affinity to place and people. The institutional role of municipalities vis-a-vis other institutional levels is clear, nevertheless we find that the engagement of individuals (*ildsjeler*), and their understanding of local conditions is invaluable for adapting to changing climatic and societal conditions in all of the case sites. We conclude that current and future exposure-sensitivities must be understood against a backdrop of multiple interlinked factors, across a variety of scales. The communities have, in terms of the topics covered in this chapter, displayed a high general adaptive capacity, but future adaptation will be contingent upon access to relevant information, innovation, finances and individual and institutional engagement.

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