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Cross-scale Adaptation Challenges in the Coastal Fisheries: Findings from Lebesby, Northern Norway

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ABSTRACT. Cross-scale adaptation challenges in the coastal fisheries in Lebesby municipality, Finnmark County, northern Norway are examined on the basis of fieldwork conducted there. Although fishery actors in Lebesby are aware of, experience, and describe a number of connections between climate variability and coastal fishing activities, they do not characterize their livelihoods as being particularly vulnerable to climate change. Nevertheless, they identify a range of social factors that shape the flexibility of coastal fishing activities and livelihoods to deal with changing environmental conditions. We argue that these factors, and actors' perceptions of their own resilience, constitute important aspects of adaptive capacity and may challenge local responses to climate variability and change. We identified four adaptation arenas: local perceptions of vulnerability and resilience to climate change, Lebesby's social and economic viability, national fishery management and regulations, and the markets and economy of coastal fishing. The adaptation arenas arise and interact across geographic and temporal scales, creating specific barriers and opportunities for local adaptation. Our findings suggest the need to pay close attention to the cross-scale adaptation challenges facing Arctic communities that depend on natural resources. The concept of adaptation arenas helps to illustrate these challenges and should be applied more widely.

Key words: coastal fisheries, northern Norway, Barents Sea, vulnerability, adaptive capacity, climate change, local perceptions, coastal communities, adaptation arenas, scale

RÉSUMÉ. Les défis d'adaptation à plusieurs échelles dans le secteur des pêches côtières de la municipalité de Lebesby dans le comté de Finnmark, nord de la Norvège, sont examinés en fonction des études sur le terrain qui y ont été réalisées. Bien que les parties prenantes du secteur des pêches de Lebesby soient conscientes de l'existence d'un certain nombre de liens entre la variabilité du climat et les activités de pêche côtière, elles n'affirment pas que leur gagne-pain est particulièrement vulnérable au changement climatique. Elles dénotent néanmoins une série de facteurs sociaux qui exercent une influence sur la flexibilité des activités de pêche côtière et le gagne-pain afin de faire face aux conditions environnementales en pleine évolution. Nous soutenons que ces facteurs, de même que les perceptions des parties prenantes quant à leur propre résilience, constituent des aspects importants de la capacité d'adaptation et qu'ils peuvent mettre au défi les réactions locales en matière de variabilité et de changement climatique. Nous avons repéré quatre sphères d'adaptation, soit les perceptions locales de la vulnérabilité et de la résilience au changement climatique, la viabilité économique et sociale de Lebesby, l'administration et la réglementation nationales concernant les pêches de même que les marchés et l'économie de la pêche côtière. Les sphères d'adaptation se manifestent et interagissent à la grandeur des échelles géographiques et temporelles, ce qui crée des obstacles et des occasions d'adaptation locale spécifiques. Nos constatations laissent entendre qu'il faut porter une attention particulière aux défis d'adaptation à plusieurs échelles auxquelles font face les collectivités de l'Arctique qui dépendent des ressources naturelles. Le concept des sphères d'adaptation aide à illustrer ces défis et devrait être appliqué à plus grande échelle.

Mots clés : pêches côtières, nord de la Norvège, mer de Barents, vulnérabilité, capacité d'adaptation, changement climatique, perceptions locales, collectivités côtières, sphères d'adaptation, échelle

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INTRODUCTION

Climate change poses a range of challenges for northern fishing activities and the social, economic, institutional, and legal structures governing them (e.g., ACIA, 2005; Vilhjálmsson et al., 2005). While the current crisis in global fisheries is driven by a range of factors, including overfishing and its effects (Pauly et al., 1998; Allison, 2001; Worm et al., 2006), climate change will increase the need for sustainable management of fish stocks (Brander, 2010). The projected impacts of climate change in the Barents Sea region include an anticipated increase of 1–2˚C in ocean temperature by 2100 (Loeng, 2008; Førland et al., 2009) that is expected to lead to larger areas and improved growth

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conditions for many fish stocks, including Northeast Arctic cod (*Gadus morhua*), northern Norway's main commercial fishery (Loeng et al., 2005; Drinkwater, 2006). Climate change may also lead to northward shifts in cod spawning and feeding locations (Sundby and Nakken, 2008) and to an influx of southerly fish species (ACIA, 2005). These changes may create new economic and societal opportunities, as well as challenges, for fishermen (Vilhjálmsson et al., 2005). However, the potential economic and societal gains will depend on the species of fish, their seasonal distribution, and whether fishermen can both recognize and exploit new fishing opportunities and manage the new risks associated with more extreme and variable weather or the need to travel farther out to sea or to different locations to fish (Hovelsrud and West, 2008).

This paper examines local perceptions of the cross-scale adaptation challenges facing coastal fisheries in Lebesby municipality, Finnmark County, northern Norway. Other studies (e.g., Wilbanks and Kates, 1999; West and Hovelsrud, 2008) have shown that scale is an important element of vulnerability and adaptation assessment and that social processes and institutions at multiple scales govern local responses to environmental change. We use the term "cross-scale adaptation challenges" to describe our finding that adaptation to climate change, though it takes place locally, involves more than discrete actions by individuals. Changes in fish stocks and altered weather patterns under climate change may require adjustments at a range of temporal, geographic, behavioral, institutional, and decision-making scales, with consequences for individual fishermen, municipal and regional labour markets, and the national and international management frameworks within which fishing activities are embedded (West and Hovelsrud, 2008). Although many adaptation measures are connected to political decisions and institutions that lie beyond the influence and control of local fisheries and actors, local perceptions of vulnerability or resilience to change will determine what actions are taken to limit climate risks or make use of new opportunities arising from climate change in particular regions.

Flexibility (fishing farther out at sea, on different stocks, or with different gear) and livelihood diversity are important hallmarks of past adaptation strategies in Norwegian fisheries (e.g., Jentoft, 1998). However, our research shows that fishery actors perceive such flexibility to be constrained by fishing regulations, ongoing market integration and exposure to global market mechanisms, and legal factors affecting the fisheries, such as the national tax systems and insurance requirements for fishing boats. Our findings suggest four adaptation arenas within which barriers and opportunities for adapting to climate change may arise. Using examples from the fieldwork and relevant literature, we illustrate how actions, changes, processes, and trends that occur within each of these arenas affect local adaptation. The findings suggest that adaptation by Lebesby's coastal fisheries to climate change requires coordinated measures across regions, sectors, and institutions.

BACKGROUND AND STUDY REGION

Coastal fisheries have a long history in northern Norway as a basis for settlement, subsistence, and trade (Nilsson and Rydningen, 2004; Vea, 2007). The most important species fished by the coastal fleet is the Northeast Arctic (NA) cod. This demersal, northern-boreal population of Atlantic cod, which traditionally spawns in the Lofoten area close to the Norwegian coastline in the springtime, has been harvested from historical times up to the present (Vea, 2007; Sundby and Nakken, 2008). NA cod feeds primarily on capelin (*Mallotus villosus*) as it migrates to the coastline in the springtime. Coastal fisheries, defined as fishing activities occurring within 12 nautical miles of the outer coastline (Norwegian *grunnlinjen*), account for about 30% of the total quantity of fish landed in Norway today (Statistics Norway, 2004).

Employment in the fishery sector in Norway is less than 2% at the national level, but the figures vary widely at the municipal level (West and Hovelsrud, 2008), indicating a range from fishery-dependent to fishery-independent regions and communities (Lindkvist, 2000). The total number of fishermen in Norway has been in decline since World War II because of technological, structural, and regulatory changes in the fisheries, as well as wider societal trends towards higher education and a service-oriented economy. This trend is also evident in Lebesby. A major restructuring of the Norwegian coastal fishing fleet has taken place since the early 1990s to make it more economically rational and ecologically sustainable (Fiskerirådgivning AS, 2006). This restructuring has been achieved primarily by introducing a quota system that restricts entry to the fishing trade and access to fishing rights (Jentoft and Mikalsen, 2004). Despite this trend, coastal fishing and land-based processing activities remain important to many coastal municipalities in Norway, including Lebesby (Lebesby Kommune, 2008; West and Hovelsrud, 2008).

Lebesby municipality (Fig. 1) is located at 71˚ N, in Finnmark, the northernmost county in Norway, and borders the Barents Sea. The municipality is home to 1357 people, and with a total area of 3458 square km, it has one of the lowest population densities in Norway (Statistics Norway, 2007). Three-quarters of the residents live in the main town and administrative centre Kjøllefjord, and the rest live in or near four smaller settlements along the inner Laksefjord coast. Coastal fishing and fish processing activities account for about 30% of employment in the municipality (Lebesby Kommune, 2008).

Kjøllefjord has a history as a fishing village (*fiskevær*) and fish-trading centre that spans four centuries. Municipal demographic data and prognoses indicate that the population has declined and will continue to decline over the next decades (Statistics Norway, 2007; Lebesby Kommune, 2008). Despite this trend, the local reduction in fishing boats and fishermen, and other challenges associated with its peripheral, northern location, Kjøllefjord remains

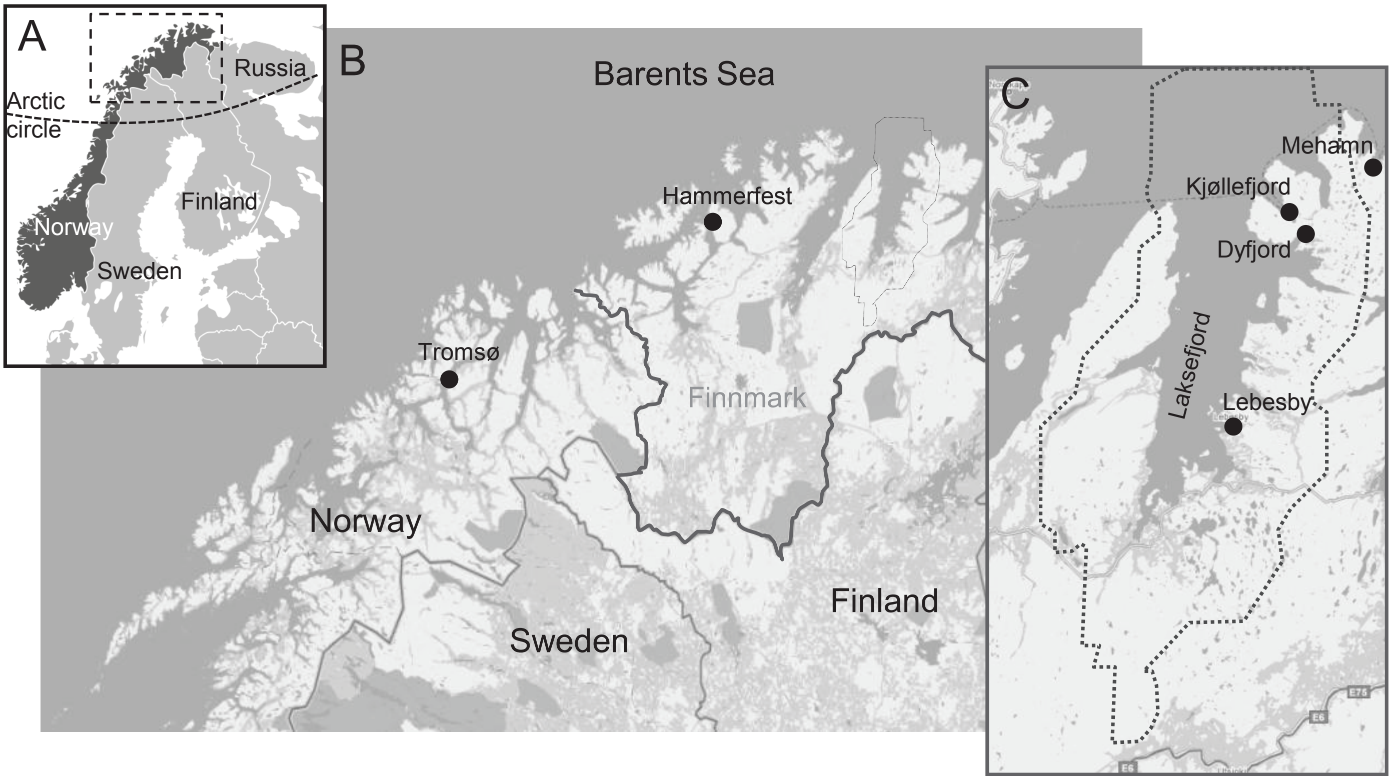

FIG. 1. Lebesby municipality, Finnmark County, northern Norway. The figure shows Lebesby's geographic location in A) Fennoscandia, B) northern Norway, and C) Finnmark County.

a viable fishing port because it is close to important fishing grounds and possesses a deep, protected harbor.

An overview of trends in registration of fishing vessels and fishermen in Lebesby over time is provided in Tables 1 and 2. According to Directorate of Fisheries statistics, 21 (36%) of the 58 fishing vessels registered in Lebesby in 2008 were assigned quotas that permitted them to fish for cod, saithe (*Pollachius virens*), and haddock (*Melanogrammus aeglefinus*), the principal species fished. Many registered fishermen also participated in the open fishery for red king crab (*Paralithodes camtschaticus*), an invasive species introduced to Russian waters in the 1960s (Sundet, 2008), or had been allotted quotas for that species starting in 2007. The 21 vessels having quotas were in turn registered to 18 different owners (Directorate of Fisheries, 2008). Only one of the 58 vessels registered in 2008 is longer than 28 m, the length above which vessels in Norway are designated as ocean fishing vessels. The remaining 57 are classified as coastal fishing vessels.

This local coastal fleet is the primary source of fish landed and processed in Lebesby. The dominant forms of fish processing are now salting and freezing, as opposed to filleting, which was once a strong industry (Fiskerirådgivning AS, 2006). Fresh fish and crab are processed locally and sold for sale both nationally and internationally. There is currently one main landing facility operating in Lebesby municipality, located at Kjøllefjord. It is owned by Aker ASA, a Norwegian holding company involved in offshore fishing, construction, and engineering, which owns and operates the bulk of landing facilities along the Norwegian coast. A local competitor established a small landing facility in Kjøllefjord in 2005 but was forced to close down for economic reasons in 2008. In addition to the Aker facility, a small landing and processing facility operates seasonally in adjacent Dyfjord (Fig. 1C).

Aside from fisheries, Lebesby boasts a small, but modern and competitive, agricultural sector, a newly constructed windmill park, salmon and cod smolt production facilities, aquaculture concessions for cod and salmon, a hydroelectric

TABLE 1. Number of fishing vessels registered in Lebesby, by vessel length, in the period 1988–2008.

Vessel length (m)	1988	1998	2008	Change 1988–2008
0–4.9	27	14	2	- 25
5–9.9	102	61	34	- 68
10–14.9	19	11	20	+ 1
15–20.9	4	2	0	- 2
21 +	2	2	2	0
Total	154	90	58	- 96

TABLE 2. Number of fishermen registered in Lebesby from 1990 to 2008.

	1990	1995	2000	2005	2008	Percent change (1990–2008)
Full-time fishermen	118	95	67	50	48	- 59
Part-time fishermen	33	46	40	37	20	- 39
Total fishermen	151	141	107	87	68	- 55

facility, important summer pastures for reindeer, and a budding tourism sector that draws on the region's rich coastal culture and history and unique ecology. The municipality also supports a viable public sector, and it is serviced by a newly constructed, all-season, high-mountain road. Kjøllefjord is serviced twice daily by the Norwegian coastal liner *Hurtigruten*, and there is a small airport at Mehamn, in the adjacent municipality of Gamvik, with daily domestic flight connections.

METHODS AND DATA

The Arctic Climate Impact Assessment (ACIA) concludes that further research is needed to address the human challenges of rapid climate change in the Arctic at regional and local, including community, levels (ACIA, 2005). Our research aims to meet the need articulated in both research and policy circles (e.g., AHDR, 2004; ICSU, 2004; ACIA, 2005; ICARP II, 2005; Kofinas, 2005; Smit et al., 2008) for better and integrated knowledge of the social, economic, and environmental conditions that underpin community vulnerability to climate change in the Arctic.

Local knowledge and perspectives are increasingly considered to be essential inputs to studies of human-environment interactions in the Arctic (e.g., Gearheard, 2006; Hovelsrud and Winsnes, 2006), and the complexity and uncertainty characterizing coupled social and ecological change is one argument for pursuing interdisciplinary research that incorporates both scientific and lay expertise (Berkes, 2007; Tyler et al., 2007; Smit et al., 2008). The argument that integration of scientific and local knowledge is necessary to understand the societal implications of climate variability and change (e.g., Berkes et al., 2002; ICARP II, 2005; Tyler et al., 2007; Crate, 2008) supports the methods employed in our study. While a growing body of research and literature documents and assesses local observations and perceptions of climate and environmental change (Strauss and Orlove, 2003; Ford and Smit, 2004; Gearheard et al., 2006; Crate, 2008), comparatively little research has been conducted with communities and resource users in the Scandinavian North. Our research aims to address this gap.

The research can be described as an iterative process involving researchers and community members in exchanges of scientific and local expertise. Local feedback and input have been central for shaping the research questions and findings and the direction of the research as it unfolded. Representatives of Lebesby municipality, local fishermen and fishery experts, and residents of Lebesby were consulted throughout the research to ensure that the results would be useful locally (e.g., Berkes and Jolly, 2001; Turner et al., 2003a, b; Ford and Smit, 2004; Keskitalo, 2004; Lim et al., 2004; Tyler et al., 2007; Smit et al., 2008). The main sources of information about local knowledge and perspectives in this study are transcriptions of interviews, discussions with key informants, town meetings, participant observation, and informal discussions with respondents at community meetings and social and cultural gatherings.

Five visits to Lebesby were undertaken during an 18-month period. An overview of fieldwork activities and respondents is provided in Table 3. An initial visit to the community by both authors served to establish contact, present the project, establish legitimacy, secure agreement to collaborate, and determine the research focus (see also Keskitalo, 2004). Twenty-five qualitative, semi-structured interviews were conducted with 29 local fishery stakeholders, several of whom were interviewed more than once. Interviews, key-informant discussions, group discussions, and participant observation were undertaken by West during the second and fourth visits. During the third and fifth visits, both researchers presented their results to the community for discussion and feedback. The fieldwork was carried out in Norwegian, and data were transcribed in Norwegian and English. Relevant scientific and grey literature, including municipal social and economic data and reports, local news publications, and historical documents, were also collected and reviewed to gain additional information about past and current social, economic, institutional, and management aspects of local fisheries.

The fieldwork aimed to document the environmental and societal factors relevant to understanding historical and current coastal fishery adaptations in Lebesby. Respondents were asked to describe their experiences and perceptions of past and current climatic and social change, the impacts of changes on local fisheries, the strategies employed to deal with these changes, and barriers against and opportunities for adapting. In order to ensure a holistic understanding of the challenges and opportunities that coastal fishery actors face, climate change was not the focal theme of interviews and discussions with fishermen, fish buyers, and local fishery experts. Climate variability and topics about the weather that were raised by local participants in connection with livelihoods and logistical activities initially served as an entry point for discussing historical and current climate variability and change, as well as actors' views about them. In other cases, notably in interviews with municipal representatives and at town meetings, we asked deliberate questions about climate change and weather-related topics relevant to local planning. The Norwegian Meteorological Institute later developed downscaled scenarios of these climate elements. We do not discuss these results in this paper. However, the preliminary scenarios were presented and discussed at a town and a municipal meeting during our third visit. These presentations served as background for discussing present and future climate change challenges and opportunities and are therefore included in the description of the fieldwork.

The results from the fieldwork were analyzed in conjunction with a literature review of projected regional climate-change impacts on key fish stocks; social, institutional, and management aspects of local fisheries; and scientific literature on community vulnerability and adaptation to climate change.

TABLE 3. Overview of field visits and activities.

Field Visit 1 (5 days in 2007) – Scoping Visit:

Participants:
- Mayor of Lebesby.
- Municipal harbour coordinator.
- Municipal planning and technical department (2 employees).
- Municipal business and industry department (2 employees).

Field Visit 2 (2 weeks in 2007) – Fieldwork:

Qualitative semi-structured interviews (12)
- Three interviews with 5 fishermen (2 retired, 3 active).
- Two main fish landing/processing facilities.
- Directorate of Fisheries representative.
- Local fishermen's association leader and representative to the county level fishermen's organization (*Finnmark fiskarlag*).
- Salmon smolt producer in inner Laksefjord.
- Local energy provider.
- Mayor of Lebesby.
- Coastal cultural association member and author of a book on the history of Lebesby's coastal fishing fleet.
- Local fisheries expert and former fisherman.

Key informant discussions (10)
- Former fisherman (2 discussions).
- Former employee of the main fish landing facility (2 discussions).
- Three municipal employees and residents of Kjøllefjord.
- Two local tourism operators.
- Fisherman working on an offshore fishing vessel.

Other
- Group discussions with local elderly at their weekly social meetings (2).
- Group discussion with workers at the small landing facility at Dyfjord.
- Informal discussions with town residents and fishermen at social or cultural events and meetings, at the grocery store, at the local diner, while out hiking, at their homes.
- Participant observation of resident interactions at social meetings and events, king crab fishing activities, fishermen at the docks, construction of crab traps, and reindeer gathering.
- Collection and summary of current and historical documents and news publications.

Field Visit 3 (2 days in 2008) – Meetings and Presentation:

- Town meetings with 50 town residents.
- Presentation of preliminary results to five municipal employees.

Field Visit 4 (2 weeks in 2009) – Fieldwork:

Qualitative semi-structured interviews (13)
- Seven coastal fishermen (five interviews) and one young fisherman (employed part-time).
- Three "entrepreneurial" fishermen who cooperate to combine fishing and tourism (group interview).
- Three experienced fishermen, one interviewed during visit 2. One owns a *juksa* vessel (under 10 m) and fishes alone. Two own one or more vessels 15 m or more and hire other men to fish with them.
- Municipal agricultural consultant, on the history of agriculture and fisheries in the inner parts of the municipality.
- Head of the municipal planning and technical department.
- Main landing/processing facility in the municipality (since visit 2, the locally owned and operated competitor closed down).
- Coordinator of a new municipal development and employment program (former head of the municipal business and industry department).
- Coordinator of a new municipal youth development program (former employee within the business and industry department).
- Local representative of the Directorate of Fisheries (interviewed during visit 2).
- Two interviews with three farming families and one retired farmer in Lebesby.

Key informant discussions (7)
- Fisherman employed on an off-shore fishing vessel.
- Two municipal representatives (informants 2 and 3 from field visit 2)
- Long-time resident of Lebesby (town) and caretaker of local museum.
- Two local cultural tourism entrepreneurs.
- Employee of the municipal planning and technical department.

Other
- Attended a local meeting in Lebesby town and observed meeting dynamics.
- Collected and summarised municipal reports and publications.

Field Visit 5 (4 days in 2009) – Fieldwork and Town Meeting:

- Discussed issues previously raised by key informants and respondents with residents on the streets, at the local pub, and at the fishing docks.
- Met with municipal representatives and local tourism operators and fisheries experts to discuss local adaptation challenges.
- Presented research findings to 30 town residents, including fishermen, and municipal representatives.

Analytical Concepts

We employ the analytical concepts of vulnerability, adaptation, and adaptive capacity to discuss and problematize the research findings. Vulnerability is here considered to be a function of peoples' exposure and sensitivity to the direct and indirect impacts of changing climatic and societal conditions, as well as their capacity to respond or adapt to changes (IPCC, 2001; McCarthy et al., 2001; Smit and Wandel, 2006). The adaptive capacity of a local community, municipality, or economic activity is reflected in its ability to manage current and past stresses, anticipate and plan for future changes, and be resilient to shocks and perturbations (Smit and Wandel, 2006; Smit et al., 2008). Adaptation is described by Smit et al. (1999, 2000) and Smit and Pilifosova (2001:881) as "adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts," where adaptation refers to changes in "processes, practices, or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate." In line with other authors (Adger, 2001; IPCC, 2001), we consider adaptation to be a dynamic social process involving adjustments that reduce communities' and regions' vulnerability to climate variability and change.

Vulnerability to climate change varies by region, sector, and social group, and adaptive capacity is unevenly distributed across space and time (McCarthy et al., 2001). Communities or sectors that possess the necessary financial, technological, educational, institutional, environmental, and societal resources to respond to the impacts of climate change are likely to be less vulnerable than those that lack access to these resources and capacities (McCarthy et al., 2001; Smit and Pilifosova, 2001).

It is increasingly recognized that climate change is but one global driver of the changes to which communities across the Arctic are responding (e.g., Ford and Smit, 2004; McCarthy and Martello, 2005) and that people do not respond to the impacts of climate in isolation from other changes (e.g., O'Brien and Leichenko, 2000; Tyler et al., 2007). Research suggests that the Arctic region is experiencing rapid changes in societal, cultural, economic, and political conditions, in addition to climate change (e.g., Fenge, 2001; Nuttall, 2001, 2005; AHDR, 2004; Ford and Smit, 2004; ACIA, 2005; McCarthy and Martello, 2005). At the community level, adaptation to climate change may also take place in the context of multiple factors that are not necessarily related to climate change. This fact suggests that a starting point for determining how science can contribute to decision-making under uncertainty is a solid understanding of the coupled human-environment system within which communities are embedded, including the institutional contexts and social realities that mediate adaptation (Adger, 2003; Keskitalo, 2004; Adger et al., 2009).

A number of studies conducted elsewhere in the Arctic show that dynamic legal, political, institutional, social, and economic environments frame local vulnerability and adaptation responses and that local decision-making processes will need to interact with higher-level governing structures that support local climate adaptation (e.g., Wilbanks and Kates, 1999; Corell, 2003; Keskitalo, 2004, 2008). These studies emphasize the importance of considering scale in vulnerability and adaptation assessments. Thus a fruitful entry point for studying the societal impacts of climate change on fisheries is to consider how vulnerability and adaptive capacity to climate change arise and are shaped and embedded in the context of cross-scale factors and changes to which local fishing activities and actors are exposed.

Climate–Fish Interactions in the Study Region

The Barents Sea marine ecosystem comprises relatively few fish species, but these are highly productive. In particular, the region supports some of the world's largest stocks of NA cod, as well as Norwegian spring-spawning herring (*Clupea harengus* L.) and capelin (Loeng and Drinkwater, 2007). The eggs and larvae of all three species are spawned close to the Norwegian coastline and transported northwards via the Norwegian Coastal Current to the nursery grounds in the Barents Sea and near Svalbard. These fish stocks display strong interactions and dependencies among themselves, as well as with other species and biotic and abiotic components (Sætre, 2007). NA cod, herring, and capelin stocks in the Barents Sea have fluctuated considerably over the past 35 years as a result of fishing pressure and climatic and oceanographic variability (Loeng and Drinkwater, 2007), and future distribution of cod stocks is expected to expand northwards as mean ocean temperatures continue to increase (Loeng et al., 2005; Long and Drinkwater, 2007).

The biophysical conditions in the case study region are to a large extent influenced by Atlantic Water entering the Barents Sea. This inflow varies in volume, temperature, and salinity. The water temperature of the Barents Sea is also determined by the advection and current characteristics of the Nordic Sea (Orvik and Skagseth, 2003; Karcher et al., 2008), and it correlates with the North Atlantic Oscillation (NAO) (Loeng et al., 2005). In addition to advection, strong variability in the local surface heat fluxes in the Nordic and Barents seas contributes to ocean temperature variations. It is well established that ocean temperature variability affects the growth, reproduction, and spawning and feeding migrations of commercial fish species, including NA cod, (Drinkwater, 2005; Loeng and Drinkwater, 2007; Loeng, 2008; Sundby and Nakken, 2008).

Ocean temperature variability in the Barents Sea region during the last century has led to changes in the spatial distribution, abundance, growth rates, and spawning locations and migrations of NA cod, as well as herring and capelin (Ottersen and Loeng, 2000; Drinkwater, 2006; Sundby and Nakken, 2008). Warming of the northern North Atlantic at different times over the past century also led to ecosystem "regime shifts" whereby important commercial species such as NA cod and herring expanded farther north and increased in biomass (Drinkwater, 2006). In addition, it has been shown that the main spawning locations and migrations of NA cod correlate strongly with ocean temperatures (Sundby and Nakken, 2008).

An increase of approximately 1˚C in ocean temperature is anticipated for the western Barents Sea over the next 50 years (Ellingsen et al., 2008; Førland et al., 2009), while a warming range of 1 to 2˚C is projected for the entire Barents Sea by 2070 under a doubling of atmospheric $C0_2$ levels (Loeng et al., 2005). This increase correlates with the average decadal variation (Sundby and Nakken, 2008), illustrating the high natural ocean temperature variability in the region (e.g., Loeng et al., 2005; Førland et al., 2009). A sustained increase in average ocean temperatures in the Barents Sea region as a whole will likely lead to major reductions in the already limited 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., 2008). Potential changes in ocean circulation and a decrease in inflow of warmer, saltier Atlantic Water (see Koenig et al., 2007 and Wu et al., 2008) may also occur. These changes would together have consequences for the marine ecosystems, including cod, herring, and capelin, whose seasonal migrations coincide with the formation and melting of sea ice (Vilhjálmsson et al., 2005).

While the potential impacts of climate change on fish stocks of importance to coastal communities may present both opportunities and challenges, the precise societal outcomes of any such changes are difficult to determine because the dynamics of complex systems over time and in space are inherently uncertain and difficult to predict (Berkes, 2007). Despite uncertainties on many levels, including in the climate modeling and in the precise consequences of climate change on human societies, people are responding and will increasingly be challenged to adapt (see for example Dessai et al., 2009; Pielke et al., 2009).

RESULTS AND DISCUSSION

Observations of Environmental Change

Coastal fishery actors in Lebesby describe a number of connections between climate variability and coastal fishing activities, which are summarized in Table 4. According to fishermen's observations, ocean temperature affects the distribution, behaviour, and types of fish caught, as well as the spawning locations and the ecological (e.g., feeding) interactions between species that are fished. Fishermen observe that fish, including saithe and cod, go deeper in the water column when ocean temperatures are warmer than normal, and note that NA cod spawns farther north along the Finnmark coast in years with warm ocean temperatures. Fishermen and fish buyers have observed warmer-than-average ocean temperatures in the Lebesby region since the year 2000, and fishermen report that greater quantities of southerly fish species, such as blue whiting (*Micromesistius poutassou*), monkfish (*Lophius piscatorius*) and mackerel (*Scomber scombrus*) have been caught in the coastal waters since that time. Species not seen before by fishermen, such as Alaskan snow crab (*Chionoecetes opilio*) and pipefish (*Syngnathus acus*), have also been observed. Many of these observations of environmental change are consistent with the scientific projections of how climate change will affect northern marine ecosystems, including those of the Norwegian and Barents seas.

Fishermen pay close attention to local wind conditions and their variability in combination with other meteorological variables such as temperature and precipitation. These combined weather parameters and local currents regulate when, how often, and at what risk fishermen may go out to catch fish at sea. Local weather patterns, including prevailing wind directions and velocity, affect both the distribution of fish in time and space and safety conditions for navigation. During winter, the main cod fishing season in Lebesby, winds blowing from the south and originating inland are comparatively cold, while winds originating from the east are warmer. Strong, cold winds blowing from inland can lead to ice accumulation on vessels and equipment, and in rare cases, the weight of the ice may cause a vessel to capsize. Polar lows—highly localized storms, often accompanied by hurricane-force winds, that develop quickly and are difficult to predict—are a significant meteorological hazard faced by coastal fishermen in Lebesby during the winter (Hovelsrud and West, 2008). According to fishermen, local fishery experts, and the local Fisheries Directorate representative, the *juksa* vessels (the smallest in the coastal fleet, less than 10 m in length) are particularly vulnerable to gale force winds and bad weather, both because they are smaller and because today, as a result of restructuring and the economics of coastal fisheries, they typically carry a one-man crew.

If storm conditions prevent fishermen from hauling in catch from traps or nets left out overnight, their gear may become tangled and fish quality may suffer, costing fishermen both time and money. According to fish buyers, bad weather also interrupts the supply of raw fish to local fish-processing facilities, which depend on a continuous supply of fish to keep their operations running and profitable. According to municipal planners, such weather may also lead to road, port, and airport closures that, according to fish buyers, affect the transportation of processed fish to larger markets, reducing product quality and price. The projected impacts of climate change on prevailing weather patterns in the study region are not easily discernable, being highly localized, but an increase in the occurrence of maximum wind speeds is expected for northern Norway over the next century (Førland et al., 2009). Modeling of future Polar Low activity suggests that it will decrease along the coast of Norway as sea ice coverage decreases (Førland et al., 2009). Given that fish stocks are also expected to extend their ranges northwards, the risks of Polar Low activity for

TABLE 4. Fishermen's knowledge and perceptions of environmental change, showing importance and observations or implications related to four climate elements.

Climate Element	Importance	Changes Observed and Implications
Ocean Temperature	Affects distribution, behaviour and types of fish caught, spawning locations, role in interaction between species (predator-prey)	Fish go deeper in the water column when ocean temperatures are warmer. "Skrei" cod are spawning farther north. New fish species and greater quantities of southerly species are being observed. These include blue whiting, mackerel, pipefish, monkfish, and Alaskan snow crab.
Wind Direction and Strength[1]	The number of days with westerly winds is important, as these winds influence local sea currents. During winter, winds from the south (originating inland) are cold, while winds from the east are warmer. Periods of gale and bad weather (often a combination of physical and climatological variables) negatively affect coastal fisheries as fishermen are prevented from going out to sea.	Winds are less predictable. The *juksa* vessels (smallest vessel in the coastal fleet) are particularly vulnerable to gale force winds and bad weather. For a vessel of 15 m long, sea conditions with waves over 4 m high are considered too dangerous for fishing.
Polar Lows	Highly localised, difficult to predict, develop quickly, and are often accompanied by hurricane-force winds.	Remain unpredictable; no changes in frequency or intensity noted. Affect the number of days that coastal fishermen can be at sea, also tangle nets; difficulty in accessing fish caught in nets and traps during a storm may reduce quality of fish if they are left too long, affecting price.
Air Temperature	Temperatures below 0˚C in combination with strong winds blowing from inland in the winter may lead to icing and freezing of ship decks and equipment, creating dangerous conditions for navigating at sea.	Air temperatures between 2000 and 2007 were generally warmer but large fluctuations still occur. 2008 was an anomalous cold year. Icing conditions can be highly dangerous for small fishing vessels. In extreme cases vessels may flip over due to the weight of the ice.

[1] Wind is also considered in combination with tides and local currents.

coastal fishers needs to be evaluated in connection with the future mobility of the fleet, which in turn will be shaped by regulatory, economic, and social factors.

In terms of wider ecosystem changes, fishermen in Lebesby raised questions about the impacts of the red king crab on local fish stocks. Their concern is fueled by observations from areas to the east of Lebesby where these crabs have taken over entire ecosystems. King crabs are known to get stuck inside cod fishing nets and destroy them, disturb seafloor fauna, and prey heavily on fish stocks, with perceived repercussions for recruitment, fishing success, and nearshore spawning environments. On the other hand, the crabs provide a financial opportunity for fishermen, as the market price for red king crab is higher than those for other species. While red king crab presents a new economic opportunity for coastal fishermen in Finnmark, the wider problems of marine ecosystem destruction associated with its introduction have yet to be comprehensively addressed (Sundet, 2008). According to several local fishery experts, an explosion of the sea urchin population, a trend that fishermen and ordinary residents alike perceive to have worsened over the past several decades in northern Norway, has led to a lack of seaweed and kelp in the nearshore environments, which in turn has led to a loss of habitat for juvenile and spawning fish. When asked whether climate change might play a role in the population dynamics of these species, actors often expressed doubt that this might be the case, indicating that other factors such as increased pollution from run-off, species interactions, and overfishing, as well as the high natural variability of ecosystems, were more likely the causes. Respondents' observations and perceptions of wider marine ecosystem changes in Lebesby and their potential causes illustrate the difficulty of identifying a climate change signal, distinct from other natural and human-induced signals, when it comes to understanding drivers of change in local fisheries.

Cross-scale Barriers and Opportunities for Adaptation

In addition to marine ecosystem and meteorological observations, actors identify a range of social, cultural, institutional, and economic factors that shape coastal fishing activities, and which they perceive to be of more immediate and fundamental concern for their livelihoods than climate change (Table 5). We argue that these non-climatic factors are pivotal elements of local adaptive capacity that produce barriers to or facilitate opportunities for adaptation of Lebesby's coastal fisheries in four arenas: (1) local perceptions of resilience to environmental variability and change, (2) Lebesby's social and economic viability, (3) national fishery management and regulations, and (4) markets and the economy of coastal fishing. These arenas arise at a range of geographic scales, but with cross-scale interactions, feedbacks, and implications for local adaptation.

TABLE 5. Salient social factors that affect coastal fishing livelihoods, as identified by local stakeholders.

Social Factors Affecting Coastal Fisheries	Identified By	Why Important
Outmigration	• Municipal representatives • Fishermen (active and retired) • Farmers • Lebesby residents (including elderly) • Key informants (tourism, fisheries, municipal services) • Local reports and media	• 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, both in the fisheries, and in the municipality more widely, enabling people to deal with change.
Aging fisherman population	• Fishermen (active and retired) • Local Fisheries Directorate • Key informants	• 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	• Fishermen • Local fisheries experts • Fish buyers/processors	• Affect fishermen's ability to respond to changing fish stocks. • Affect the cost of entering the fishing trade and the profitability of fishing activities. • Affect the stability of supply of raw fish supplied to landing facilities throughout the year. • In combination with local weather conditions, may expose operators of small vessels to higher risks. • Affect spatial and temporal distribution and availability of fish through regulation of fishing pressure in different seasons and regions. • Have led to concentration of fishing rights and increased profitability for some fishermen.
Market factors: *Fish prices (demand/supply)* *Fuel costs* *NOx tax*	• Fishermen • Fish buyers and processors	• Together these factors determine the profitability of fishing for both fishermen and fish landing and processing facilities, with implications for local income and employment in the fisheries.
Legal factors: *Income tax regulations* *Insurance requirements for fishing vessels*	• Fishermen • Fish buyers/processors • Local fisheries experts	• These factors may limit fishermen's flexibility to deal with variable and changing climatic, biological, and societal conditions.

Adaptation Arena 1: Local Perceptions of Resilience to Environmental Variability and Change

While a number of substantial impacts due to climate change are projected for northern fisheries, and the urgent need to adapt is clearly expressed in scientific assessments such as the Arctic Climate Impact Assessment (ACIA, 2005) and Intergovernmental Panel on Climate Change (IPCC, 2001, 2007) assessment reports, our results show that fishery actors in Lebesby do not consider themselves to be particularly vulnerable to climate change. Coastal fishing activities take place amidst high natural climatic and environmental variability, and the actors are accustomed to coping with large interannual and seasonal changes. This long-term history and extensive local experience seem to underpin local discourses of resilience to environmental change. For example, when describing changes in ocean temperatures and the resulting impacts on local fish stocks that they had observed in recent years, experienced and retired fishermen frequently referred to past events and noted that they had seen such changes before. They attributed the causes of past and current fluctuations in fish stocks to a wide range of factors, including natural variation, overfishing, historic mismatches between fishing technology and local fish stocks, invasions of seals due to wider ecosystem imbalance, the introduction of red king crabs, the expanding sea urchin population, decline in near-shore seaweed and kelp, pollution of harbours and fjords from runoff, and illegal fishing. Likewise, the operator of the local landing facility expressed skepticism that variations in fish stocks—which he noted were the norm for the region—were a result of climate change. He emphasized instead that such variation resulted from changes in national fishery politics, regulations, and management.

It is well known that scientific and lay perceptions of climate risk often vary with differences in knowledge and information, priorities, experiences, and planning horizons (e.g., Dessai et al., 2004; Lorenzoni et al., 2005). This is clearly the case in Lebesby, where coastal fishing activities have a long tradition, and where dealing with highly variable weather and fish stocks is a way of life. This history of living with environmental variability was repeated by many fishermen and fishery experts with whom we spoke, and clearly informs the local discourse of resilience to climate variability and change. But the examples provided also underscore the fact that local perceptions and experiences of the causal link between climate variability and change and changing fisheries are mediated by local knowledge and experiences of the wider social, economic, and environmental realities that frame fishing activities.

While coastal fishery actors do not see themselves as being particularly vulnerable to climate change, they are well aware of the interactions between climate variability and fish stocks, and they observe a number of ecosystem changes in connection with warming ocean temperatures, a trend that is projected to continue well into the future, but which fishing actors generally ascribe to the natural variability with which they are already familiar. Notwithstanding these perceptions, the projected continuing impacts of climate changes on fish stocks and weather patterns, discussed in previous sections, raise the question of how well prepared local coastal fishery actors and activities are to respond to the potential need to travel farther out to sea to fish and to potential ecosystem shifts and fishing opportunities as the ocean continues to warm. Local perceptions of high resilience to past and current changes may pose a barrier to adaptation if climate change results in situations or events that challenge the limits of fishermen and communities' collective knowledge, experience, and adaptive capacity, factors which the research shows are closely connected to developments in adaptation arenas 2, 3, and 4, which we discuss below.

Adaptation Arena 2: Lebesby's Social and Economic Viability

As in many small fishing settlements along the Norwegian coast, coastal fishery activities in Lebesby provide a large share of local jobs and income and contribute to local identity (e.g., Lindkvist, 2000). The viability of Lebesby as a coastal fishery settlement is therefore clearly connected to local and regional developments within the fisheries. But according to respondents, the municipality's viability is also shaped by broader demographic, geographic, and societal trends that may strain the capacity of the fisheries to deal with current changes and to develop and innovate over time to adapt to future environmental and social changes.

Outmigration to larger centres and an aging fisherman population are two ongoing trends of central concern in Lebesby. Despite Norway's official national policy of maintaining a dispersed settlement pattern, outmigration from small, rural settlements to larger urban centres continues in Norway. The population of Lebesby has been in decline for several decades—for example, the municipality lost 15% of its population between 1997 and 2008 (Lebesby Kommune, 2008)—and outmigration is projected to continue over the next decades. According to fishery actors, residents of Lebesby, and numerous local reports and publications, outmigration is connected to the municipality's peripheral location and its dependence on a narrow range of economic and income opportunities, as well as to the lack of skilled young men and women who are interested in fishing and in making Lebesby their home. Younger as well as experienced fishermen explained that many young people move away from Lebesby for education and do not want to pursue fishing, with its irregular hours and variable pay, as a full-time career. Fishermen and fishery experts also explained that lifestyle choices, family dynamics, and individual needs have changed over the years. Fishermen with young families (and their partners) are simply not willing to put up with the traditional discomforts that once characterized coastal fishing, such as being out at sea in rough conditions for days at a time, nor are they willing to spend several years training and working for others before they can afford to invest in their own vessels. Many prefer to combine daily fishing with raising a family together with their spouses.

According to municipal representatives, a declining population in turn reduces the municipality's tax base and thus Lebesby's ability to provide infrastructural support (such as landing facilities) and services needed to support fishing activities, as well as social and economic opportunities and support for fishermen's families. In Lebesby, where fish landing and processing employ a relatively large share of the population, local respondents and news publications expressed wide concern that the main landing facility had recently reduced its full-time staff as part of restructuring of its operations, and they questioned the facility's future viability as a local employer. According to one respondent, the fact that this facility is the only one currently operating in Kjøllefjord makes it difficult for the municipality to bargain over plant closures or staff reductions, even though such events have major consequences for local income and employment.

The number of landing and processing facilities in northern Norway has been steadily decreasing over the past several decades (Fiskerirådgivning AS, 2006), and both historical and archive material and interviews with elderly fishermen in Lebesby indicate that this has also been the case in Lebesby, with a reduction in landing and processing facilities in Kjøllefjord from more than 10 after World War II to just one in 2009. This trend, which has also led to the closure of landing facilities in inner Laksefjord, has further concentrated fishing activities in Kjøllefjord, and according to key informants and a municipal consultant, has increased the distance to markets and services for the few part-time fjord fishermen who remain in Laksefjord. Today, agriculture, aquaculture, smolt production, and the public sector are the main employers in these regions and have replaced the traditional livelihood of combined fishing and farming (Lebesby Kommune, 2008). However, national investments in improved road, port, and air infrastructure implemented in order to encourage dispersed settlement patterns have improved connections between Kjøllefjord and smaller municipal settlements, as well as larger centres.

An aging fisherman population further threatens the traditional basis for income and employment in the municipality, and fishermen say it is interrupting the transfer of fishing knowledge and skills from experienced to younger fishermen. The average age of all fishermen residing in Lebesby in 2007 was 49 (Directorate of Fisheries, 2007), and respondents said few youth are being recruited to the trade. Fishermen explained that coastal fishing is a much more profitable livelihood for today's fishermen than in the past. However, they cite the high costs of gaining access to and participating in the current limited-entry, quota-based, management regime as the main reason why few youth choose to become fishermen (see below for a discussion of fishery management). Societal and cultural changes, such as the alienation of youth from fishing, were also cited as factors. Both outmigration and an aging population of fishermen challenge Lebesby's viability as a coastal fishing community, and may also strain its capacity to deal with the impacts of climate change on coastal fisheries. Without landing facilities, fishermen, and active fisheries, the municipality's strong coastal fishery identity and culture may decline, reducing its ability to attract investment. Thus funding may not be available to adjust and innovate current fishery practices as will be necessary if major shifts in fish stocks or fishery management occur because of climate change.

Lebesby's peripheral location, narrow, natural resource–based economy, high dependence on fisheries, and small and declining population all suggest that it may have a relatively limited ability to cope with climate change, and therefore a higher vulnerability, compared with other parts of Norway (e.g., West and Hovelsrud, 2008). Economic activities in Lebesby are closely connected to the marine environment, and employment and incomes are therefore particularly sensitive to changes that affect these resources. However, the municipality has a number of resources to draw upon, including creative local innovators and entrepreneurs who are marketing the municipality through nature-based tourism, alternative clean energy investments, and coastal culture and identity. A central value expressed by nearly all of our respondents is the desire for a sustainable and vibrant community. In the eyes of both residents and decision makers, sustainability is represented primarily by a stable population base that includes young people who are willing to settle in, invest, or return to their community. This requires jobs that attract and retain skilled residents, as well as investments to secure the social, economic, and cultural attractiveness of the community to residents and outsiders (West et al., 2007). The municipality's efforts in this respect include attracting a newly constructed windmill park, trying to secure additional income and employment from the offshore oil and gas development in the region, promoting the municipality at regional fora as an ideal place to live and work, and channeling limited investment funds toward renewal and innovation in traditional fisheries and agricultural sectors.

Fishermen stressed the importance of creating and maintaining local jobs through innovations in the coastal fisheries (such as combining fishing with tourism and investing in gear for labour-intensive fisheries such as line fishing, in which a single fishing vessel can employ up to 20 people on land during busy periods) as a positive force for local investment and employment.

Adaptation Arena 3: National Fishery Management and Regulations

Several authors note that future fishery management and access regulations may play a more important role than climate change in determining the fate of northern fish stocks (Vilhjálmsson et al., 2005; Browman, 2008; Eide, 2008). Actors in our case study consider fishery regulations and management to be major determinants of changes both in fish stocks and in fishermen's potential responses to these changes. As an occupation tied to a naturally varying resource, fishing is by necessity flexible and adaptive (Jentoft, 1998). Flexibility (fishing farther out at sea, for different species, or with different gear) has long been an important component of adaptation strategies to deal with environmental uncertainty and change, and the ability to respond to a changing resource base and to make decisions under environmental uncertainty is perceived to be a hallmark of successful coastal fishing activities past, present, and future (e.g., Jentoft, 1998; Vea, 2007; Eide, 2008; Coulthard, 2009). Diversified livelihoods, once much more prominent among fishermen in Lebesby, but still practiced to an extent, whether formally or informally, are an adaptation to the great environmental variability that characterizes fisheries, and to living in a sparsely populated region with few alternative economic opportunities and service providers (Vea, 2007). Climate change may increase the need for adaptation and flexibility in the fisheries because of a shift in fish species, species interactions, and changing conditions at sea. The adaptations needed to deal with such changes may include different fishing technology and gear, different kinds of knowledge, alternative sources of livelihood and income, and new or altered fishing regulations (Hovelsrud and West, 2008).

Norwegian fisheries are highly politicized and institutionalized (Jentoft, 2004; Keskitalo, 2008). Fishing is regulated for individual fish species, in time and space, and according to vessel length and place of registration, and fishing zones are regulated by both national and international laws (Jentoft and Mikalsen, 2004). The dominant trend in Norwegian fishing regulations over the past four decades has been a transition from an open fishery to a limited entry, quota-based fishery based on the precautionary principle and total allowable catch (TAC). The Barents Sea NA cod stock is managed jointly by Norway and Russia, and Norway has the right to about 45% of the annually agreed quota for this stock (Fiskerirådgivning AS, 2006). The Norwegian NA cod quota is distributed among trawlers and coastal vessels of four different length classes, according to the so-called "Finnmark model" (Fiskerirådgivning AS, 2006). The annual cod quota is determined on the basis of scientific information about the health and size of the fish stocks. These data are collected by fish trawl surveys and biological observations and further elaborated under stock development and exploitation models.

A key effect of the new system has been an increase in the value of delimited fishing rights (quotas) as fish stocks went from being an open, common property resource to being subject to limited entry and strict regulation (Jentoft, 1998). This shift has led to widespread structural changes in the Norwegian fishing fleet, which have reduced total fishermen and fishing vessels and concentrated fishing activities in larger centres (Lindkvist, 2000; Nilsson and Rydningen, 2004). Despite declining employment at the national level, the productivity and income of individual vessels have increased as a result of these changes (Fiskerirådgivning AS, 2006). In general, the changes that have characterized Norwegian fisheries over the past decade reflect both the changing cost structure of participating in limited-access fisheries and national and regional values, priorities, and goals vis-à-vis the fisheries. Such goals are essentially in accord with Norwegian district policy to ensure an equitable balance of fisheries' participation and rights in different regions and to maintain a dispersed coastal settlement pattern, as well as with principles of economic efficiency and ecological sustainability (Jensen, 2008; Keskitalo, 2008).

Because it is designed to limit access to fish stocks and respond to changing environmental conditions and species interactions, Norwegian fishery management can be considered adaptive from the point of view of the marine ecosystems it is designed to manage. However, while adaptive from the point of view of protecting and sustainably managing fish stocks, according to fishermen and fish buyers, it does not necessarily respond to the long-term planning horizons or social needs of fishermen and coastal fisheries (e.g., Coulthard, 2009). Increasing regulation has also considerably limited the flexibility of fishermen to respond to variations in the fish stocks (Jentoft, 1998). Fishing seasons, quotas, and management of individual fish stocks do not take into account the variable weather patterns and longer-term climate trends that often control when, where, and under what conditions coastal fishing activities can take place—conditions that fishermen, scientists, and fishery managers say are already being affected by climate change (e.g., Browman, 2008).

Flexibility in fishermen's mobility, investments, and livelihoods are already circumscribed by existing Norwegian fishery management and fishing regulations. For example, retired fishermen in Kjøllefjord explained that in the "old days," prior to the introduction of the quota system, local fisheries were far more diverse in terms of species fished, and coastal fishermen often travelled far out to distant fishing grounds to fish, staying out at sea for several days or more. If a fishery in a given year failed or was not lucrative in terms of return to efforts, fishermen could switch to fishing other species or travel farther afield to locate the fish. This flexibility was facilitated by a larger crew, which made fishing safer. Nowadays, fishermen are allotted quotas for particular seasons, during which they are required to fish with particular gear in particular regions. They cannot simply switch to fishing a different species if the stock for which they have a quota fails. Although fishermen say that technological innovations, regulatory changes that concentrated fishing rights, and higher (on average) global fish prices have increased the profitability of fishing, at the same time the effects of reduced quotas, higher costs of fishing gear, technology, fuel and vessels, and higher standards of living and material needs in society mean that fishermen typically employ fewer people on board their vessels and invest larger sums in gear and vessels that are aimed at a particular fishery.

Flexibility in the fisheries may be further constrained in the future if management and regulations do not consider climate change impacts on key fish stocks and weather and sea conditions. Fishermen's mobility, or ability to pursue changing fish stocks, may be limited either by the lack of appropriate quotas for new species, or by restrictions on gear types or fishing regions. Lack of incentives to invest in new gear and safer vessels, for example strengthened hulls to respond to an increase in storm activity or to offset the hazards of fishing farther out at sea, may also limit mobility. In comparison to ocean fisheries and fishermen, coastal fishermen currently lack the capacity in terms of vessel size and safety equipment to fish farther out to sea.

The growing number and evolving complexity of fishing regulations also create added paperwork for individual fishermen in our study, limiting the time they have to participate in other economic activities and leading to frustration for those with limited computer skills. As reported elsewhere (e.g., Jentoft and Mikalsen, 2004), the perceived unpredictability and volatility of management decisions based on scientific stock assessments, which do not take into account fishermen's own experiences at sea, have eroded their confidence and trust in fishery science and policy making.

Adaptation Arena 4: Markets and the Economy of Coastal Fishing

According to fishermen and fishery experts in Lebesby, the overall profitability of coastal fishing and ability to make a living as a fisher depend inter alia on the size of quotas for different species, the price of fish and cost of fuel, the location of landing facilities and the relative cost of fishing technology and gear, and national taxes and subsidies. Fishermen identified high fuel costs, the nationally imposed NOx emission taxes (a climate change mitigation measure), and legal barriers, including the current Norwegian income tax system and insurance requirements for fishing vessels, as economic limitations to expanding fishing activities in pursuit of shifting fish stocks. Currently, insurance certificates for fishing vessels require investments in safety equipment and standards correlated to the distance from shore and perceived hazard risks connected with fishing activities. Climate change, if it has consequences for the frequency and intensity of storm activity, will also affect these risks. According to respondents, the current national income tax system and quota maintenance requirements for fishermen restrict multiple incomes. They create a barrier for fishermen who would like to diversify their livelihoods outside of the main fishing seasons to increase income and reduce their dependence on fish landings, while maintaining the flexibility to be full-time fishermen in good seasons and years.

Coastal fisheries in Lebesby, as in the rest of Norway, are increasingly integrated and exposed to global market mechanisms (e.g., Keskitalo, 2008; Keskitalo and Kuyasova, 2009).

For example, the current global financial crisis has reduced international demand for expensive Norwegian (NA) cod, affecting the entire cod marketing chain and causing considerable concern among fishery actors in Lebesby. In recent cases, fishermen have been unable to land their cod locally because of the reduced economy and inadequate storage capacity of the local landing facility. At the same time when international markets were slumping, fishermen reported excellent cod fishing conditions. This example illustrates the cross-scale environmental, institutional, and market linkages, as well as the cross-scale adaptation challenges that characterize coastal fisheries. In order for fishermen and fish buyers and processors to make a sustainable living and continue to employ local people, the supply of, access to, and demand for fish must be synchronized. According to respondents, the supply of fish depends on environmental conditions, while access to fish depends on fishing regulations, technology choice, weather conditions, and price and cost factors. Demand for fish internationally in turn affects whether and at what price the local landing facility will buy fish from fishermen, in turn shaping incentives for fishermen to fish. These factors rarely line up in the real world, creating situations where tradeoffs must be made.

Notwithstanding the current crisis in the international cod market, new market opportunities for coastal fishermen and fish processors in Lebesby are emerging. These include the development and successful international marketing of niche products based on high-quality, locally fished cod and red king crab, for which fishermen are paid a higher price, and the development of combined tourism-fishing operations by small groups of coastal fishermen and residents who have secured national innovation grants, or loan financing, or both, from the local landing and processing facility and the municipality. These innovations may provide additional sources of income, employment, and innovation for coastal fishing actors to deal more effectively with current and future environmental and social challenges and opportunities.

Summing Up: Cross-scale Adaptation Challenges

We have applied the concept of "adaptation arenas" to show how barriers and opportunities for adaptation to climate change in Lebesby's coastal fisheries arise and interact across societal scales. Fishermen and fishery actors in Lebesby are responding to a range of factors, including changing regulatory frameworks, an aging fisherman population, outmigration, market integration, environmental variability, and the ongoing opportunities and challenges of living and fishing in a small, geographically peripheral community. While some of these factors are particular to Lebesby, others are a part of wider regional and national trends, illustrating the important role of scale in analysis and understandings of local adaptation.

The four arenas of adaptation for Lebesby's coastal fisheries arise at different geographic scales, but exhibit cross-scale interactions and feedbacks, creating both barriers and opportunities for local adaptation. At the individual and community level, fishing actors possess specific knowledge and localized experiences of environmental change, and they describe a number of connections between climate variability and seasonal and interannual variability in the fisheries, yet they do not perceive themselves to be particularly vulnerable. The apparent disconnect between local discourses of resilience and academic understanding and communication of the urgent need to address climate change at all levels of society indicates that better understanding of local perceptions of climate change is needed.

Although fishing actors do not consider climate change to be a major threat to their livelihoods, they identify a range of social factors that have relevance for their livelihoods and that we have shown also have relevance for adaptation to climate change. These interpretations challenge the notion that Lebesby's coastal fisheries are resilient to climate change. Lebesby's social and economic viability is one important determinant of continuity and a locus of adaptive capacity for innovation and change in the fisheries. It is in turn shaped by geographic characteristics (its peripheral location) and broader demographic and societal trends (outmigration and the aging fisherman population), as well as by the changing attitudes, priorities, and lifestyle choices of its residents. The third adaptation arena, that of fishery regulation and management, creates the "rules of the game" (Ostrom, 1990) for coastal fishermen, determining when, where, what, and how they may fish, and, together with market factors (the fourth arena), establishes incentives or barriers for innovation and investments to secure fishing livelihoods and respond flexibly to environmental, climatic, and societal changes. Together, these factors shape whether and to what extent actors respond economically, safely, and sustainably to the impacts of climate change on their livelihoods.

Fishermen are members of wider communities and societies, and their activities and adaptation options are circumscribed by wider forces of social, economic, and environmental change. The fact that many adaptation measures that might help fishermen deal more effectively with long-term environmental change are connected to political decisions and institutions that lie beyond actors' immediate influence and control may lead to a sense of complacency about both the need to adapt and the role of local actors in adaptation. Moreover, adaptation measures implemented at one scale—such as within national fishing regulations—for a particular purpose (sustainably managing fish stocks), may create unintended barriers for adaptation among fishermen who are trying to sustain their livelihoods while dealing with a range of social realities and changes. Given the cross-scale nature of adaptation challenges and opportunities for Lebesby's coastal fisheries, it is important to question and problematize the degree to which adaptation can take place locally and to identify the conditions under which initiatives at other scales may be more appropriate.

Local knowledge, held by individual fishermen and residents and collectively by the municipality, will be needed to develop locally appropriate strategies to deal with the impacts of climate change on coastal fisheries in Lebesby. Opportunities in this arena should focus on connecting local actors' own information and experiences of climate variability and change with scientific understanding and identifying relevant adaptation strategies that empower people to take advantage of new opportunities while preparing for or avoiding damages. Partnering with community stakeholders and decision makers has ensured the inclusion of local perceptions and understandings in the formulation of the research discussed here and encouraged local discussion, learning, and debate about climate vulnerability, adaptation, and wider fishery sustainability issues in Lebesby.

From an academic perspective, our investigation into the connections between climate variability, fish stocks, and coastal fishing activities in Lebesby has increased our understanding of how and why its coastal fisheries may be vulnerable to climate change, underscoring the important role of social factors and scale in framing adaptive responses. Cross-scale analyses show that effective local adaptation requires coordinated measures across regions, sectors, and institutions. Such understanding is crucial for meeting the adaptation needs of Lebesby's coastal fisheries, and it should inform future studies of climate change adaptation in other natural resource-dependent communities in the Arctic.

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