Name of the case study	Disko Bay – Sea ice reduction's impact on resource dependent communities – Greenland [Loss of resilience]					
What about this case makes it interesting? How does this case contribute to understanding of resilience and/or regime shifts in the Arctic?	Since the 1980s, the climate in Disko Bay has warmed substantially (1, 9) with an increase in the average temperature by 3.5ºC. Observations indicate that the sea-ice cover has decreased by 50%. The Bay has started to freeze later and the sea-ice cover, which is used as a platform for harvesting walrus and seal (2), is being formed much later (1). Changes in climate and sea-ice conditions will result in multi-faceted and cascading effects (4). Warmer climate and decreasing sea-ice affect the distribution (4), migration routes and behaviour of the habitat of marine mammals, birds and fish (10), in turn communities' livelihoods and living conditions that are strongly dependent on those species. Changes in living conditions include shift from ice- to open-sea hunting and fishing (10), changes in transport mode, food security, safety, shift in gender roles, etc. (1, 2, 7, 8). Local communities are adapting in numerous ways to the new ice and climate conditions (2). However, many of the challenges require the revision of regulations and resource management. Although local residents have learnt how to cope with changing ice conditions (1), current government regulations (licence distribution, quotas, harvesting regulations) and new living conditions (most of the population lives in towns and settlements and depend on modern conveniences) limit local residents' ability to be as flexible and mobile to manage environmental change as they used to be (2). Regulations should be reviewed in light of climate change perspectives.					
Template completed by: *Main contributor	Grete Hovelsrud,* Nordland Research Institute, University of Nordland Julia Olsen, Nordland Research Institute, University of Nordland	**Key references: Cite in the text using (1), (2), (3) etc. and provide a reference list at the bottom of the template.** (7) Holm, L.K. 2010. Sila-Inuk: Study of the impact of climate change in Greenland. Pages 145-160 *in* I. Krupnik, C. Aporta, S. Gearheard, G. J. Laider, and L. Kielsen Holm, editors. *SIKU: Knowing our ice – Documenting Inuit sea-ice knowledge and use*. Springer Netherlands, Netherlands.				
Reviewed by (name and affiliation)						
Category (mark with X)	**Resilience/ Adaptability**		**Loss of resilience**		**Transformation**	
			X			
Case study details:	**Country**	**Place**	**Scale – space**	**Scale – time**	**Sector(s)**	**Other (e.g. disturbance)**
	Greenland	Disko Bay, 2 communities: Qeqertaq and Qeqertarsuaq	Disko Bay and coastal communities	1980-present	Fishing and hunting	Climate change, institutional barriers

Drivers (mark with X in appropriate boxes)	**Climate**	**Geopolitical**	**Mineral/ oil extraction & infrastructure**	**Tourism**	**Shipping**	**Biological invasion**	**Rapid demographic change**	**Other:** ***state here***
	X	X(national)						

	Biophysical	**Social**
1. Basic description of coupled social-ecological system in focus **(**What are the key components and stake holders) If possible draw a systems diagram or conceptual map of the case – this can be a series of diagrams to capture different periods in the case and the drivers/ actors/ events that characterize the period.	**a) What types of ecosystem(s) and other major biophysical features are present?** Disko Bay is about 800 metres deep Populated by shrimp, fish and whales and seal Sea-ice **b) How are the case boundaries defined in terms of ecosystems or biophysical characteristics?**	**c) Who are the key groups of people in this case?** In this case we describe two communities (urban or rural) that are located in Disko Bay, west coast of Greenland. Qeqertaq – is a rural Greenlandic community that is located on a small island in Disko Bay, Northwest Greenland. Population 147 (1). The town of Qeqertarsuaq, with a population of 907, is located on Disko Island, west coast of Greenland. The town has a mixed subsistence-cash economy and includes wage employment and subsistence hunters and fishers (2). **d) What kinds of livelihoods are important in the system?** Both communities (Qeqertarsuaq and Qeqertaq) have a subsistence economy (hunters and fishers), and wage employment: commercial fishing, public sector and tourism. Communities are closely connected to the local environment and dependent on natural resources. Until recently sea ice was a platform for both harvesting walrus and seal and for social activities in community (1). Hunting and fishing have cultural values in many indigenous communities and are important for health, nutrition, community economies, as well as cultural, spiritual and social well-being (4). **e) What institutions are key to this case? If possible define what scale it addresses.** Both hunting and fishing are tightly regulated in Greenland with two hunting licensing systems (occupational and non-occupational hunters that are restricted from harvesting certain

		species) and three fishing types of licences (temporary licences with an upper limit for allowing catch, temporary licence without an upper limit, and permanent licences with an upper limit) (2). Residents are allowed to fish for personal consumption without selling their catch (2). **f) How are the case's boundaries socially defined, and how do these social boundaries relate to biophysical boundaries?** In this case we describe two communities: urban – the town of Qeqertarsuaq, and rural – Qeqertaq; which are both located in Disko Bay, west coast of Greenland (1, 2).

2. Timeline Draw a timeline of *key* events/ developments to the case. Points to include: Make clear the period of time over which the change is being considered. Provide a brief description of event/ actors, and ecological impacts. Mark particularly significant events with *. Consider both biophysical and social dimensions. Additional points that can be considered: Is it possible to identify periods of change from one type of system to another, transformations? Identify disturbances or events that challenged, built, or reduced resilience or adaptive capacity in the system.	

3. Disturbances What are the key disturbances in the system (present and past)	**a) Have there been major biophysical disturbances that are relevant for the case?** From 1980s the climate in Disko Bay warmed substantially (1, 9) with average temperatures increasing by 3.5ºC. Observations indicate that the sea ice cover has decreased by 50%. The bay starts to freeze later and the sea ice cover, which is used as a platform for harvesting walruses and seals (2), is being formed much later (1). - Melting sea ice - Increased variability in weather patterns - Changed migration routes for sea mammals, birds and fish - Fast algae growth (7)	**b) Have there been major social disturbances that are relevant for the case?** - Decreased availability of and access to marine mammals and birds (2, 7) has impacted local food security and resulted in diet changes. Seal skin clothes are also less used nowadays (1) - Shift from ice- to open-sea hunting and fishing (10) - Shift in women's roles from hunting to wage workers (2) - Changes in the communities' social life (1), which were directly connected to sea ice availability - More accidents have occurred due to reduced ice stability (1, 7) To continue to afford hunting and fishing with high investments in new equipment (1, 2, 3), some of occupational hunters attained non-occupational licences in order to earn income (2). This transition involves additional restrictions through governing the catch or sale. Non-occupational licences do not allow for catching polar bears, walruses and whales, and subsistence fishers cannot sell their catch. Those regulations limit the income possibility and were a source of conflict within communities (2). Full-time hunters and fishers are not satisfied with income restrictions that limit the ability to find a part-time job. In addition, regulations limit the ability to adapt harvesting practices to recent climatic changes (2). Regulations (quotas, season dates and location) do not correspond with environmental changes. Narwhal whale quotas in combination with the cultural value of species have resulted in conflict between occupational and non-occupational hunters and their unions (2).

4. Drivers of change Clarify what impacts these drivers have on the SES and if these are direct or indirect	**a) What are the key biophysical drivers of change?** From 1980 the climate in the Disko Bay has warmed substantially (1) with average temperature increase of 3.5ºC. Observations indicates that the sea ice cover has decreased by 50%.	**b) What are the key social drivers of change?** - Regulations, quotas and licences limit hunters' and fishers' ability to be more flexible and mobile
5. Sources of adaptive capacity: What factors allow(ed) the system to adapt to disturbances in the past and present? Give a brief assessment of recent or on-going changes (+/-/0 = increasing/ reducing/ not affecting adaptive capacity)	**a) Within the ecosystem?** (-/+) Migration patterns are changing: • (+) Increasing availability of cod (2) • (-) Harp seals now stay year-round in the bay and eat the cod stock (7) • (-) Decreasing the availability of and access to marine mammals and birds (1, 2, 7) – hunters catch less migratory birds and seals	**b) Within society (e.g. people, social capital, management, institutions, infrastructure):** Second income in the family. More women seek wage jobs to support their partners in response to recent stressors (2, 3). However, a lack of jobs in Greenland resulted in outmigration of educated women from coastal communities (2). (-) Shift from ice to open-sea hunting and fishing which requires investments in new equipment, such as VHF radio, GPS, cell phones, snowmobiles, larger boats, etc. Investment costs are high (1, 2, 3). (+) Sea ice reduction improves shipping conditions and opens new opportunities for fishing. (+/-) Behaviour modification including changing the location, timing and species harvested (2) (-) To be able to afford to continue hunting and fishing with the high investments in new equipment (1, 2, 3) some of occupational hunters attain non-occupational licences in order to earn income from wage-based jobs (2). This transition involves additional restrictions by governing the catch or sale. Non-occupational licences do not allow catching polar bears, walruses and whales, and subsistence fishers cannot sell their catch. Those regulations limit income possibilities and were source of conflict within communities (2).

		(-) Flexibility and mobility – hunters and fishers adjusting methods and travel strategies. However, government regulations and living in the settlements and towns decreases the ability to be more mobile. Fisheries apply for licences further north or to the south, but many failed to receive them (2). At the same time those who own these licences attempt to receive licences closer to home in order to reduce rising travel and fuel cost. (-) The environmental knowledge and land-skills need to develop (2). (-) Illegal hunting (3).
The next two sections break down the information in Section I. While it is not necessary to fill these sections, if you have additional information pertinent to specific rows below feel free to enter the material.		
II.1-8 SES, resilience and adaptive capacity		
	Biophysical	**Social**
II.1. Where do we find changes and resilience in the face of change?	**a) Within nature** Climate change and sea ice decreasing resulted in changes in wildlife migration routes. Increasing availability of cod (2). Decreasing the availability of and access to marine mammals and birds (1, 2, 7). Hunters catch less migratory birds and seals.	**b) Within society** Changes in ice conditions have impact on livelihoods and living conditions and triggered socio-economic and cultural changes in the communities' lifestyle: - Decreasing the availability of and access to marine mammals and birds (2, 7) has impact on the local food security and has resulted in diet changes. Also, seal skin clothes are less used nowadays (1). Residents buy more imported and expensive food (1). - Shift from ice- to open-sea hunting and fishing (10) and thus more investments in expensive equipment. - Shift of women' roles from hunting women to wage-based workers (2) in order to secure the income in the family - Changes in the communities' social life (1) which was directly connected to sea ice availability - More accidents have occurred due to undermine ice

		stability (1, 7). More residents use snowmobiles instead of dogsleds.
II.2. What are the system's key components?	**a) Key Ecological components (e.g. lakes, coastal zones, caribou)** Coastal zones, marine mammals, fish stock, birds	**b) Actors in society (e.g. individuals, groups, public or private organizations)? How are people organised – by geography, livelihood, family, etc.?** - Fishers and hunters and their wives - Local and national government - Occupational and non-occupational hunters and their representative unions
II.3. What are the key linkages? E.g. ecosystem services, resource extraction. These linkages should exist. If there are not mutual links between social and ecological components the case is not a social-ecological system.	**a) From nature to society (e.g. ecosystem services)** Sea ice decreasing changes sea mammals and fish migration with direct impact on communities' livelihoods.	**b) From society to nature – modifying nature, extracting resources (e.g. hunting, mining, water pollution)** Hunting and fishing
II.4. What are key interactions?	**a) What are the key ecological interactions within the case?** Minke whale and seals are moving to the north (2, 10). The harp seal stays year around due to ice absence and they disturb the fisheries by eating the cod stock (7). **b) What are the most important biophysical tele-connections to distant systems?**	**c) What collaborations, conflicts, or other key linkages exist between actors?** Nutall (2009:307) argues that changes in policies and regulations have a greater impact on local populations compared to climate change: *"Long-term policies of shifting demographics, investment in a few major centers, a reluctance to introduce development policies for small villages and settlements, a redefinition of resources and rights of access to them, and a political desire to*

		encourage the depopulation of some communities all perhaps have greater significance for changing hunting and fishing practices than climate change does," (6). *"In an effort to avoid hazardous weather conditions in Disko Bay, fishers are applying for licences further north in the Upernavik area or to the south near Sisimiut. Current fishing licences and quotas are regionally specific however; the most common licences held in Qeqertarsuaq are limited to Disko Bay. The spatial limitations imposed on licences restrict the mobility of fishers who wish to take advantage of favourable conditions in neighbouring districts. Some respondents described failed attempts to gain licences in northern or southern districts for time periods that coincide with stormy weather in Disko Bay" (2).* **d) Between local actors and distant actors?**
II.5. Culture	**a) How is the relationship between society and nature viewed?** **b) What meanings are attributed to nature and to interactions with nature?** Sea mammals are not only a source of food, but also vital for production and reproduction of Inuit culture and have a powerful ideological and symbolic value (11, p.97).	**c) What are key cultural features of relevance for the case?** Hunting and fishing have cultural values in many indigenous communities and are important to health, nutrition, community economies, as well as cultural, spiritual and social wellbeing (4). The local population relies on the ability to predict weather conditions and wildlife migration. This knowledge is critical for hunting safety and success (3). **d) What are key cultural practices and beliefs related to nature?**
II.6. Disturbance What are important types of stress & shock	**a) Describe important biophysical or ecological shocks and stresses (e.g. floods, storms, etc).**	**b) Describe important social shock and stresses (e.g. austerity policies, changes in government policy, introduction of new technologies, etc.)** Additionally, due to recent climate changes hunters and fishers

		struggle with government regulations, quotas and licenses, which create a stressful context. The number of motorboats has increased (7, 8). The local population has to invest in boats and modern, expensive equipment because of the sudden changes in weather and longer hunting and fishing periods in open-water during the year (1, 3). However, hunters and fishers with small boats are very sensitive to changes in climatic conditions (2). Additionally, small floating pieces of ice and icebergs damage boats and propellers forcing boat owners cope with increasing repair costs (1).
II.7. What are key slow variables Changes that occur over decadal or longer time scales	**a) What types of ecological processes (e.g. loss of permafrost, shifts in species composition) are driving important long-term changes in ecological structures and processes?** Winter weather is more unpredictable. Sudden storms or ice floes, direction of wind is changing (3, 7). Local populations rely on the ability to predict weather conditions and wildlife migration. This knowledge is critical for hunting safety and success (3). Due to recent changes in climate, the local population now lack this ability (2). Unpredictable changes in wind have caused hunters and fishers to return back. (2) Decreasing sea ice. Ice is much thinner and strong winds can easily break it. This increases hazards and safety concerns, and decreases safe harvesting days (2). More accidents have occurred due to ice instability (1, 7). Decreasing availability of and access to marine mammals and birds (2, 7). Their behavior is changing (7). Minke whales and seals are moving further north (2, 10). The harp seal stays year round due to ice absence and they disturb the fisheries by eating the cod stock (7).	**b) What types of slow social processes (e.g. aging, population growth, loss of language) are driving important changes in social institutions and behaviours?** Shift from ice to open-sea hunting and fishing (10). Feeling of isolation increases. The winter sea routes are no longer safe and local populations have to use private boats to visit family and friends, which is possible only during calm weather (2). Decreased seal hunting (1, 7). Less seal meat available, and seal skin clothes are less used nowadays (1). The use of dogsleds decreases (1, 7, 8). In Qeqertaq, the rate of dogs per inhabitant has decreased from 2.0 to 1.6 (1). Changes in the communities' social life: teachers cannot take students on the sea ice to educate them about ice fishing, hunting and traveling (1). There are no more soccer ice tournaments or dogsled races (1). Food security/dietary changes due to diminished access to Greenlandic food (2).

	Increasing availability of cod (2). The Bay started to freeze later and the sea ice cover is being formed much later (1). Sea ice has been decreasing since 1980 (1, 2 ,7, 8). Winters are warmer and springs are colder (7). More rain (7). Fast algae growth (7).	Transitioning role of women from role of a 'hunter wife' to wage-based worker. More women seek wage-based jobs to support their partners in response to recent stressors (2, 3).
II.8. Relationships with ecological regime shifts	**a) Are ecological regime shifts driving further ecological change or pressure?** New climate and ice conditions have different impact on the habitats for marine mammals, fish and birds, including changes in their migration routes. Minke whales and seals are moving further north (2, 10). The harp seal stays year round due to ice absence and they disturb the fisheries by eating the cod stock (7). **b) Are external or internal ecological dynamics potentially or actually producing ecological regime shift(s)?**	**c) Can social stresses or major changes be attributed to ecological regime shifts?** New climate and ice conditions have impacted the habitat of marine mammals (10) and thus have changed the socio-economic situation and have contributed to cultural changes in the communities' livelihoods and living conditions. Changes are associated with fishing and traditional marine harvests including shift from ice to open-sea hunting and fishing (10), changes in transport mode (the number of motorboat and snowmobiles increases (7, 8), while the use of dogsleds decreases (7,8)), food security (less seal meat available), safety (more accidents have occurred due to ice instability), changes in the community social life, shift in gender roles (transitioning role of women from role of a 'hunter wife' to wage-based worker) (1, 2, 7, 8). **d) Are there specific social practices that might be contributing to ecological regime shifts** Shift from ice to open-sea hunting and fishing (10). Hunters and fishers are adjusting to different methods and travel strategies. Behaviour modification includes changing the location, timing and species harvested (2). Occupational hunters attain non-occupational licences in order to

		earn income from wage-based jobs (2).
II.8 Regime shifts	**If a regime shift exists and is important to this case describe it below.** Please indicate whether the regime dynamics are well-established, contested, or speculative.	
II.8.a. Detailed description of alternate regime shifts A case study can contain more than one type of regime shift	**Briefly describe the structure of each regime. What does each regime look like?** **What are differences in ecosystem structure and function? (e.g. permafrost loss, vegetation change)?** Loss of sea ice. Decreasing the availability of and access to marine mammals and birds (2, 7). Fast algae growth (7). Algae seen on the skins of the seals (7). Snow cover is decreasing (7). **How do the properties and behaviours of regimes differ?** **e.g. collapse of subsistence food sources, fundamental change in types of livelihoods, change in governance institutions, new actors with significant political power who transform decision making)** - Collapse of subsistence food sources - Fundamental change in types of livelihoods - Change in governance institutions - Migration routes of mammals, birds and fish are changing	
II.8.b. Feedback mechanisms within the system that maintain each regime	**Ecological feedback mechanisms**	**Social feedback mechanisms**
II.8.c. What key changes drive regime shifts? Describe how these changes alter the state of the system or feedback processes.	**a) Drivers of ecological regime shifts (either social or ecological).** Climate change: warmer temperatures, increasing ocean temperature. **b) How do these changes alter biophysical feedback processes?**	**c) Drivers of social regime shifts (either social or ecological).** Sea ice disappearing. Unpredictable weather and wind patterns. Changes in sea mammals' behaviour. **d) How do these changes alter the social feedback processes?**
II.8.d. Ecosystem services substantially	**a) Changes in ecological processes that produce ecosystem services**	**b) Changes in demand for ecosystem services (market and non-market)**

impacted by regime shift	Shift from ice to open-sea hunting and fishing include investments in expensive equipment and boats.	Less seal meat is available and it has become more expensive. Increasing dependence upon imported and expensive food (1). **c) Changes in the institutional context of ecosystem services e.g. changes in access and changes in how ecosystem services are valued as expressed by rules and regulations.** To afford to continue hunting and fishing with high investments in new equipment, some of occupational hunters attain non-occupational licences in order to earn income from wage-based jobs (2). This transition involves additional restrictions by governing the catch or sale. Non-occupational licences do not allow for catching polar bears, walruses, and whales and subsistence fishers cannot sell their catch. Those regulations limit the income possibility and were source of conflict within communities (2).
II.8.e. What is (+/-) impacted by changes in ecosystem services directly or indirectly	**a) Impacts from regime shift on ecological components**	**b) Impacts from regime shift on social actors** Women (usually wives of fishers and hunters) provide second income in the family. Hunters and fishers have to earn extra income outside of hunting and fishing. Hunters and fishers have to adjust their fishing and hunting techniques due to new conditions. Local communities in general facing limited use of sea ice for travel and social life.
II.8.f. Potential cascading effects	**Describe, if any, the likelihood of potential ecological cascading effects to other SES** Sea ice was used for drinking water (data from 1987, (1)). In	**Describe, if any, the likelihood of potential social cascading effects to other SES** New hunting and fishing conditions force hunters to attain non-

	order to get fresh water during summer small floating icebergs were collected. There is no information on whether local communities will continue with this practice.	occupational licenses that allow them to have a wage-based job. Some have begun working in the tourist sector and/or use the alternative economic opportunities offered by government. Additionally, the role of women shifts from role of a 'hunter wife' to wage-based workers. More women seek wage-based jobs to support their partners in response to recent stressors. This occupational shift is likely has spillover effects on SES.
II.8.g. Where do actors intervene to alter regime shift dynamics and who can do the intervening?	**Ecological oriented interventions**	**Socially oriented interventions**

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GLOSSARY OF TERMS IN THE TEMPLATE

Actor	We use this term generally to look for individuals, groups, organisations, and so on that structure actions and/ or are stakeholders.
Adaptive capacity	Is the capacity of actors in the system to manage resilience in order to stay within a desired state during periods of change. This is related to the diversity in the system behind the provision of a function.
Disturbance	This refers to any disturbance to the system, regardless of scale, duration, intensity and frequency. See shock and stress.
Driver	Actor or process that directly or indirectly affects change in a social-ecological system. External means that the system in question (the scale being looked at) is unable to affect the driver in question – there is no feedback from the system to the driver.
Ecosystem services	The goods and services humans derive from ecosystems. These include: provisioning, regulating, cultural ecosystem services respectively.
Feedbacks	A change within a system that occurs in response to a driver, and that loops back to control the system. A feedback can help to maintain stability in a system (negative or balancing feedback), or it can speed up processes and change within the system (positive or enhancing feedback). Feedback processes play a very important role in determining system thresholds and in maintaining system resilience.
Institution	Here we refer to the humanly devised constraints that shape human interactions, such as rules, norms and laws. These can be formal or informal. Note that we are not referring here to institutions as organisations.
Regime shift	For complex systems, a substantial and enduring reorganization of the system, where the internal dynamics and the extent of feedbacks undergo change.
Resilience	This is a property, in this context of social-ecological systems. It relates to the capacity of a system to cope with disturbances and recover in such a way that they maintain their core function and identity. It also relates to the capacity to learn from and adapt to changing conditions, and when necessary, transform.
Shock	A sudden, unexpected disturbance. This kind of disturbance is often punctual, and has important impacts on large parts of the system.
Slow variable	When analysing complex system is often useful separating “fast” and “slow” variables. Fast variables often represent the primary concern of ecosystem users, for instance game or crop production. Slow variables shape the behaviour of fast ones but change slowly with respect to the overall dynamics of the system. Examples of slow variables might include permafrost thawing for a social-ecological system of Arctic hunters where the fast variable is game, or soil organic matter for an agricultural system where the fast variable is crop production.
Stress	This is a disturbance that has long persistence and often low intensity in impact.
Social-ecological system	This is an interwoven system of human societies and ecosystems. This concept emphasises that humans are part of nature and that these components function in interdependent ways. In the template identifying these interactions between the components aims to identify the processes and actors/ components that interact and particularly the feedbacks between the human-related components and the ecosystems/ biophysical components.
Stakeholder	See “actor”
Systems Diagram	This is using a diagram to illustrate the configuration of a system. This is done by defining its structure, function, and feedbacks. For a case there may be more than one diagram if the system changes in character (actors, processes, drivers, disturbances, feedbacks etc.) over time.
Timeline	The goal with the timeline is to capture important events – both punctual and over longer periods of time, identifying the causes of these events and the actors/ processes involved. This should be done chronologically and distinguishing events.