Name of the case study	Paamiut – Cod to shrimp fishery transition – 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?	As in other Atlantic fisheries, Greenland experienced a cod-to-shrimp transition in the 20th century mediated by climatic changes and overfishing which followed an initial seal-to-cod transition (1,2). This case presents the transition from cod-to-shrimp fishing in the west Greenland community of Paamiut. The approach of this case in terms of its natural and social capital and how these factors influenced the different outcomes. (Note: the main references compared this to the unsuccessful transition in the community Sisimiut, for the sake of the ARR we have separated these two cases) Paamiut's cod fishery developed slowly until it was built up as a specialised cod-centre by the Danish government. By the time the processing plant was built the cod catches started to become already unpredictable and the expected in-migration did not materialise. The focus on cod led to a lack of diversity in skills and initiatives in Paamiut when the cod disappeared. Although shrimp started to appear around Paamiut the initial small quantities did not make up for the loss in catches of cod. By the time shrimp also started to become more common off the shore of Paamiut, other centres further north on the west coast had already built all necessary processing plants. Finally, snow crab populations started to appear, which became a centre for the new fishery along the coast but in Paamiut processing lagged until the government transferred a processing vessel to Paamiut, as yet another external intervention. Top down development and lack of local initiatives left Paamiut in a less adaptive state. Today, snow crabs comprise only a small part of landing values in Greenland whereas shrimp and Greenland halibut are the two main species (4).					
Template completed by:	Cornelia Ludwig, Stockholm Resilience Centre		**Key references: Cite in the text using (1), (2), (3) etc. and provide a reference list at the bottom of the template.** (7) Hamilton, L. C. 2007. Climate, fishery and society interactions: Observations from the North Atlantic. *Deep-Sea Research Part II: Topical Studies in Oceanography* 54(23): 2958-2969.			
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	Paamiut	200 nautical miles around community		Fishing	Cod collapse	

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)				? snow crab		Cod collapse, increase in shrimp, snow crab arrival

	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? - Marine system off the coast of west Greenland with previously predator-dominated regimes (cod and other ground fish), now with a crustacean-dominated regime - Greenland ice sheet Key components include the commercially interesting species: - Cod (*Gadus Morhua*): top predator and thus dominated the ecosystem - Atlantic halibut (*Hippoglossus, hippoglossus*) and Greenland halibut (*Reinhardtius hippoglossoides*) - Shrimp (*Pandalus borealis*) - Snow crab b) How are the case boundaries defined in terms of ecosystems or biophysical characteristics? The waters off the coast of West Greenland within 200 nautical miles as well as the coastal areas that harbour the fishing community of Paamiut.	c) Who are the key groups of people in this case? - Fishermen, local actors and residents of Paamiut - Local and Home Rule politicians d) What kinds of livelihoods are important in the system? - different fisheries and hunting were important over time: first came Atlantic halibut and seal hunting, then Greenland halibut, cod, shrimp and finally snow crab - Hunting and fishing is still important for food supply (2) e) What institutions are key to this case? If possible, define what scale it addresses. - Danish government - Home Rule government - local actors - subsidies for hunting from the state (2) - Not key, but present: Home Rule regulation that requires 25% shrimp to be landed and processed on shore. All inshore fished shrimp MUST be landed and processed onshore in Greenland (4) f) How are the case's boundaries socially defined, and how do these social boundaries relate to biophysical boundaries? - fishing community of Paamiut located on the west coast of Greenland. - Today Paamiut has about 1500 inhabitants (3) - Denmark (government)

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?	(All from (1), unless stated otherwise) Around 1910: commercial fishing started in Sisimiut (a community 500 kilometres away). Initiatives came first from outsiders, but Greenlanders did inshore catching and processing work, often with own equipment. Danes fished for Atlantic halibut and taught Greenlanders how to fish. Before 1920: seal hunting as traditional livelihood. Around 1920: Irminger current carried cod to southwest Greenland from spawning grounds in western Iceland. Cod fishery grew as warmer water brought in cod (*Gadus morhua*) to spawn in southwest Greenland. Warmer water and overhunting also led to decline in seal hunting, the traditional livelihood. Seal-to-cod transition - Focus for economy and infrastructure on this new industry. In Paamiut: trading with first wave of cod started. Building for salting was erected. Mid-1930s: Atlantic halibut had disappeared, aided by overfishing of European longliners. Canning factory owner decided to shift to shrimp. 1935: shrimp fishery started slowly in other communities. In 1950 Disko Bay was most important for the inshore shrimp fishery 1930s and 1940s: Cod becomes more important as everyone with a boat could fish for this species. Shrimp needed larger vessels. Post-WW2: Heavy fishing pressure of cod from international fleet. 1953: Greenland status changes form Danish colony to Danish county Late 1950s: after slow development of cod industry in Paamiut, government identified the location as ideal for industrial development due to location in open-water district and access to cod. 1950s and 1960s: cod landing comparable in Sisimiut (community 500 kilometres along the coast) and Paamiut Late 1960's: decline of cod due to overfishing and arrival of cold waters. 1967 until early 1970s: Investments in new fish processing plant and processing in Paamiut. Expectation was for population growth due to in-migration but this did not materialise due to unpredictable cod catches.

Identify disturbances or events that challenged, built, or reduced resilience or adaptive capacity in the system.	1960s-1990s: various Great Salinity Anomalies (GSA) due to North Atlantic Oscillation (NAO) changes and discharge from the Greenland Ice Sheet led to unfavourable conditions for cod, but peaks with higher cod catches did occur during that period. Water became too cold for spawning and lack of recruitment when Irminger current stopped flowing northwards.* 1979: Greenland is granted limited sovereignty of Home Rule government* 1980s: Paamiut was developed as a specialised cod centre. Population declines due to outmigration. Early 1990s: cod was essentially gone. Increasing offshore shrimp concentrations discovered south of Nuuk and towards Paamiut but the shrimp did not make up for loss of cod, nor were there large enough processing facilities available in the area. Population declines in Paamiut. 2000: Snow crab production lagged behind in Paamiut until government transferred a processing vessel to the port. Another example of top down management. Population: steady decline for Paamiut (3) Today: most shrimp is frozen at sea and packaged whole. This creates higher prices, but fewer jobs. In order to maintain employment, Home Rule government requires that 25% of the shrimp catch must be landed and processed onshore. However, shrimp catches gave limited benefits to Paamiut as processing capacity was built up in other communities and there is no room for new local investments.	
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? - Depletion first of Atlantic halibut, then of cod stocks, first by international fleets and later by Greenland fishermen. Heavy fishing pressure from international fleet after WW2 on cod. Trawlers rapidly removed larger and mature specimens. Increased stock's vulnerability to climatic changes - Adverse climate: unusually cold waters reflected NAO north Atlantic circulation/circulation abnormalities and	b) Have there been major social disturbances that are relevant for the case? - Decline in seals and changes in traditional livelihood - Investment and development to cod-centre in Paamiut by government - Collapse of the cod fishery, felt acutely in Paamiut - Sudden increase of unemployment (Paamiut) - Increased outmigration (Paamiut) (1, 2, 3)

	discharge from the Greenland Ice Sheet leading to Great Salinity Anomalies (GSA) during 1960s to 1990s. This led to unfavourable conditions for cod to grow. The recruitment from Iceland through the Irminger current ceased when it stopped flowing northwards (1)	
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? Lack of predatory pressure due to cod and other fish stocks depletion played some role in the increase of crustaceans on Greenland's shores Climate change is linked to variability in NAO leading to changes of water temperature (5) and changing therefore breeding and growing conditions for cod and crustaceans. Colder waters are advantageous for crustaceans and disadvantageous for cod (6, 7)	b) What are the key social drivers of change? - Shift from labour to capital intensive fisheries and jobs in general - Market value and demand for crustacean products (Japan is a strong force on the market). Higher prices for frozen whole shrimp instead of peeled and processed lead to fewer jobs on shore. - Location of natural resources: Paamiut did not have access to shrimp resources as early as Sisimiut. - Small boat owners disadvantaged for shrimp fishing. Cod could be fished by anyone with a small boat
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? - Biodiversity and healthy populations would provide resilience to the marine environment, but the fishing pressure led to the collapse of the former regime (-)	b) Within society (e.g. people, social capital, management, institutions, infrastructure): - "Paamiut: limited social contact between local community and institutional framework behind decision processes" (-) (1) - Decrease of human capital in Paamiut due to increased outmigration (-) and increased average age (-) - Paamiut's ideal location for cod fishing led to created focused governmental investment and specialisation, which reduced overall adaptive capacity (-) - Generally: hunting contributes to food supplies for subsistence and commercial uses (+) (2)

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	b) Within society Hunting and fishing by private people for subsidence
II.2. What are the system's key components?	Key Ecological components (e.g. lakes, coastal zones, caribou) - Cod (*Gadus Morhua*) - Atlantic halibut (*Hippoglossus, hippoglossus*) and Greenland halibut (*Reinhardtius hippoglossoides*) - Shrimp (*Pandalus borealis*) - Snow crab - Coastal and off-shore waters of west Greenland - Greenland Ice Sheet - Atlantic Ocean currents	a) Actors in society (e.g. individuals, groups, public or private organizations)? How are people organised – by geography, livelihood, family, etc.? Residents in the coastal communities are organised in: • Families • Individuals and private companies • Local government and community representatives therein • Greenland Technical Organization in Copenhagen that drove development of Paamiut as a cod centre
II.3. What are the key linkages? E.g. ecosystem services, resource extraction.	a) From nature to society (e.g. ecosystem services) - Resource extraction: fish, crustaceans, - Hunting and fishing for subsistence and for cultural identity of Greenland-born (2) - Mining, hydroelectric and aluminium are being explored (2)	b) From society to nature – modifying nature, extracting resources (e.g. hunting, mining, water pollution) - Fishing and sometimes stock-depletion of: halibut, cod, other fish species, crustaceans, seals - Resource development for mining, hydroelectric and aluminium is being explored (2)

These linkages should exist. If there are not mutual links between social and ecological components the case is not a social-ecological system.		
II.4. What are key interactions?	a) What are the key ecological interactions within the case? - Climate i.e. north Atlantic circulation/circulation abnormalities that leads to GSA and reduces cod recruitment from Iceland, and also growth of cod in cold waters - Predator/prey relationships between cod and shrimp, possibly also the snow crab b) What are the most important biophysical tele-connections to distant systems? - Like above, climate i.e. north Atlantic circulation/circulation abnormalities, Irminger current from Iceland - Greenhouse gases released into the atmosphere to contribute to climate change (there is even speculation that climate change could help reverse the regime shift from cod to crustacean, (8))	c) What collaborations, conflicts, or other key linkages exist between actors? - Greenland self-government and communities - Greenland self-government and fisheries (e.g. transferal of fishing vessel for crab) d) Between local actors and distant actors? - Danish government and fisheries rulings - Danish Government and Greenland/Paamiut cod-centre development - Market demand influences the viability of the fishery and related industries
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?	c) What are key cultural features of relevance for the case? Natural resource extraction (hunting and fishing) has always been the major livelihoods here. Natural resources are traditionally core to community livelihood.

		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). - Overfishing of cod and Atlantic halibut - Taking older specimens, which undermined the resilience of the fish stocks - Changes in water circulations bringing colder waters and fewer cod for recruitment	b) Describe important social shock and stresses (e.g. austerity policies, changes in government policy, introduction of new technologies, etc.) - Danish Government investing in Paamiut cod-centre development. Top-down management - Change from labour to capital intensive fisheries - Technical advancement of fishing equipment, bigger boats - Introduction of destructive fishing practices, like trawling - Increased unemployment - Outmigration - Reduced human capital - Generally: Greenland underwent a transformation from traditional life style to industrial/post-industrial in a very short time period (2)
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? - Warming oceans: good for cod recruitment, bad for cold-water shrimps - Climate change leads to increased variability of NAO and hence water temperatures (5)	b) What types of slow social processes (e.g. aging, population growth, loss of language) are driving important changes in social institutions and behaviours? - Reduced human capital due to outmigration - Population decline Greenland generally: - Transformation to automatic fish processing reduced jobs for female workers -> outmigration - Few jobs for women with high qualification, especially in small settlements with more traditional life styles -> outmigration (2)

II.8. Relationships with ecological regime shifts	a) Are ecological regime shifts driving further ecological change or pressure? b) Are external or internal ecological dynamics potentially or actually producing ecological regime shift(s)? - Climate change can influence dynamics of growth and recruitment or fish and crustaceans as well as zooplankton affecting other trophic levels (5)	c) Can social stresses or major changes be attributed to ecological regime shifts? - A change in human demand for fish/eating behaviour/increased wealth created demand for more cod and therefore intensification of fishing efforts which led to overexploitation - Technological changes to larger boats with bigger nets and more destructive fishing methods contributed to the depletion of cod stocks and possibly influenced the shift towards a crustacean-dominated regime - Allocations of shrimp fishing quotas by the government - Danish government-led development of and focus on a narrow cod fishing based economy in Greenland d) Are there specific social practices that might be contributing to ecological regime shifts - Fishing and hunting

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)? The regime in the waters along the west coast of Greenland used to be ground fish-dominated; first by Atlantic halibut, and later with cod and Greenland halibut. However, changes in water temperature, due to changes in NAO/climate change and to a degree the removal of predator species, allowed for a steep increase in crustaceans such as shrimps and snow crab, which led to this new crustacean-dominated regime. 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) If cod and Atlantic halibut-fisheries were part of a regime on land, then there was a regime shift towards crustacean-fisheries, but requirements for gear and boat size, as well as new licenses, meant that crustacean could not be fished by the same people who fished cod. While cod was accessible to many, even those with small boats, shrimp fishing could only be carried out by those who had already access to bigger boats or funds to buy appropriate gear and licenses. On land there were different winners and losers based on the regime-shift in the water. Capital was concentrated and more unevenly distributed. There were new geographical advantages for some areas due to access to rich invertebrate resources. Paamiut's development has been managed top down with investments by the government and has lacked local initiatives. After peaking in 1985, population in Paamiut has declined by about 40%.	
II.8.b. Feedback mechanisms within the system that maintain each regime	Ecological feedback mechanisms - Change in water temperature creates more or less favourable conditions. Cold waters are favoured by shrimp and snow crab, while warmer waters are better for cod recruitment and growth. Recruitment of cod is, however, quite dependent on currents from Iceland - In part, lack of predatory pressure due to the disappearance of cod stocks and other ground fish allows	Social feedback mechanisms - Market demands for crustaceans and fish keep the fisheries going - Quotas and policies that favour certain groups and people

	for an increase in crustacean populations	
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). - Market demands for cod and Greenland halibut, as well as crustaceans - Policies and quotas for fishing cod and crustaceans - New fishing techniques and intensification - Climate change due to increased greenhouse gases lead to a change of ocean temperatures and circulation patterns - All influence the biomass of species, and influence the balance between regimes and dominating species b) How do these changes alter biophysical feedback processes? - climate change has been linked to a change in variability for the NAO and other circulation patterns that bring warmer and cod or colder water, which has direct effects on biomass of cod and crustaceans - all of the above named influence the biomass of species and influence the balance between regimes and dominating species	c) Drivers of social regime shifts (either social or ecological). - Cod and Atlantic halibut-stock depletion d) How do these changes alter the social feedback processes? - Depletion of cod stocks and halibut led to a shift towards crustacean fisheries which were favourable for owners of larger ships and those who had funds to invest in appropriate gear - Loss of cod fisheries were economically disastrous for Paamiut, where the economy was wholly centred around the cod fishery - Outmigration due to unemployment lead to loss in human capital, which affects the adaptability of the area (Paamiut)
II.8.d. Ecosystem services substantially impacted by regime shift	a) Changes in ecological processes that produce ecosystem services The marine system is still providing biomass for harvest, but the majority in landing value comes from shrimp and Greenland halibut (4).	b) Changes in demand for ecosystem services (market and non-market) There is a high demand for crustaceans from Japan, but worldwide shrimps have gained popularity (4, 7). 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.
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 - Loss of employment (Paamiut) (-) - Need to form new policies and distributions of quotas by the government (potential for + and -) - Demographic changes: outmigration (-)
II.8.f. Potential cascading effects	Describe, if any, the likelihood of potential ecological cascading effects to other SES	Describe, if any, the likelihood of potential social cascading effects to other SES
II.8.g. Where do actors intervene to alter regime shift dynamics and who can do the intervening?	Ecological oriented interventions The government has stepped in to manage fish stocks and allow recovery where necessary. Quotas and management by the self-government, based on accurate scientific knowledge, can influence the dynamics with the marine ecosystem. Fishermen can continue to use/develop fishing gear with less detrimental effect on non-targeted populations.	Socially oriented interventions Government transferred a vessel to Paamiut to be able to use for fish for snow crabs that have appeared in the vicinity.

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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.