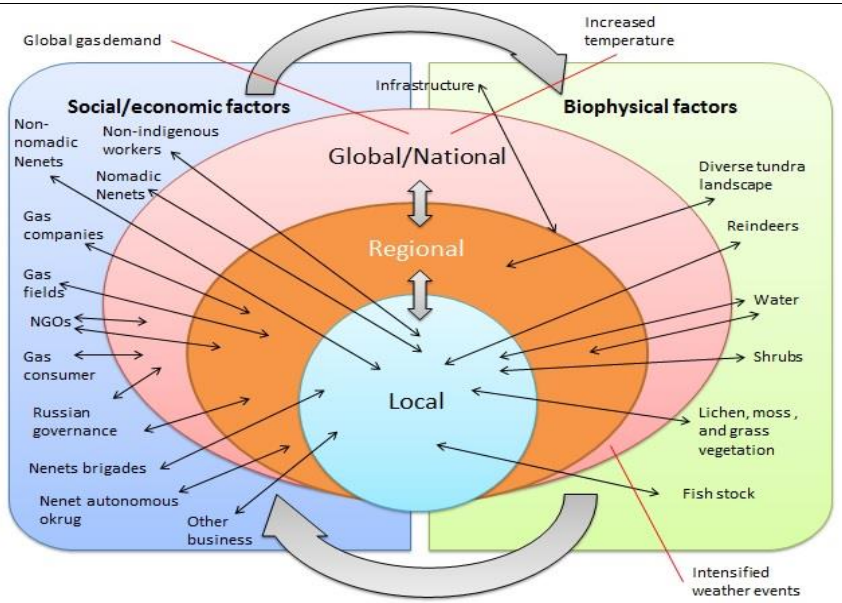
Name of the case study	Yamal Peninsula - Reindeer herding in the Yamal Peninsula in Yamal-Nenets Autonomous Okrug (YNAO) – Russia [Resilience]	
What about this case makes it interesting? How does this case contribute to understanding of resilience and/or regime shifts in the Arctic?	Herding has been a traditional livelihood in different communities across the Arctic. These communities link their cultural practices and well-being to key ecological dynamics. These dynamics are inherently variable, but these are changing in novel ways. The Nenets have been adapting to these changes. Additionally, herding in the Yamal Peninsula fared comparatively well to other herding cases in Siberia in terms of being able to maintain their traditional way of life during the past. Currently, the largest disturbance to herding is the increase in infrastructure related to gas exploration and transportation, to which Nenets herders have adapted.	
Contributors	Students from the 2014 *Systems Theory and Resilience Thinking* course at the Stockholm Resilience Centre (Stockholm University): Svetlana Avelova, University of Russia Anna Degteva, St. Petersburg State University Jonas Gren, Stockholm Resilience Centre Viveca Mellegård, Stockholm Resilience Centre Hanna Ahlström, Stockholm Resilience Centre Linda Lindström, Stockholm Resilience Centre Ashley Perl, Stockholm Resilience Centre Philipp Siegel, Stockholm Resilience Centre Svein Mathiesen*, International Centre for Reindeer Husbandry Miriam Huitric, 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.** (1) Mathiesen, S. 2014. *Yamal reindeer herding practices*. [Skype interview] (Personal communication, 9 January 2014). (2) Degeteva, A. and C. Nellemann. 2013. Nenets migration in the landscape: impacts of industrial development in Yamal peninsula, Russia. *Pasoralism: Research, Policy and Practice*, 3:15. (3) Forbes B.C., F. Stammler, T. Kumpula, N. Meschtyb, A. Pajunen, E. Kaarlejärvi, and B.L. Turner. 2009. High Resilience in the Yamal-Nenets social-ecological system, West Siberian Arctic, Russia.

								Proceedings of the National Academy of Sciences 106:22041-22048.
Reviewed by (Name and affiliation)	*							
Category	**Resilience/ Adaptability**		**Loss of resilience**			**Transformation**		
	X							
Case study details:	**Country**	**Place**	**Scale – space**	**Scale – time**		**Sector(s)**		**Other (e.g. disturbance)**
	Russia	Yamal Peninsula	700 kilometres (north-south)	1930-date (500 AD to date)		Reindeer herding		Increased infrastructure related to gas exploration and transportation
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	X					

	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?** Yamal Peninsula in western Siberia Tundra – pastures, wetlands Taiga – pastures, wetlands Water/ Ice crossings **b) How are the case boundaries defined in terms of ecosystems or biophysical characteristics?** Tundra/ Taiga – climatic zone Movement through the boundaries varies annually and depends on: season, herd's welfare, weather conditions, grazing status, mosquito status, etc. (1) A system map of social and biophysical actors and components including the main global drivers of the YNAO's SES and how they are connected on a global/national, regional, and local scale.	**c) Who are the key groups of people in this case?** Nenets – The indigenous people living in the Yamal region, the Yamal Nenets Autonomous Okrug (YNAO), can be either nomadic herding or non-nomadic. Nenets nomadic herders, around 5000, have been reindeer herding for up to 2000 years in the southern part of the peninsula and at least 700 years in the Bovanenkovo area (2); Reindeer herders and their organizations: The herding activities are structured in different enterprises, composed by several *brigades* which in turn consist of herding families. (2). Local indigenous NGOs: play an important role in promoting their organization's interest, such as Nenets' rights (1). Local and regional governmental agencies Extractive industries Recently immigrated workers – especially late 2000's – development of modern communities along the coastline – for extraction and communities (1, 7). **d) What kinds of livelihoods are important in the system?** Most important ES for herders are provisional services, such as reindeer or fish, during winter and summer migration (5). Cultural services are provided by specific sites that serve rest or spirituality purposes (1). Reindeer herding. Livelihood is connected to traditional ecological knowledge (TEK) and local ecological knowledge



(LEK) of herding practices and land (1).

Gas production/export – largely recent immigrant workers reliant on income for livelihoods. Dependent on land availability and environmental conditions (7).
Gas production – main use of land for access and export of hydrocarbons
Gas transport – pipeline
Gas/other goods transport – train
Gas/other goods transport – ports

e) What institutions are key to this case?

Nenets regulations: culture, language, TEK, and sense of place contribute to institutions around organizing herding; *Brigades* constitute the local level of governance in the Yamal Nenets (1).

National regulations for:
- herder mobility,
- social organization (school),
- veterinary regulations,
- land access and use regulations,
- recognition of Nenets rights (1)

Russian authorities own the land, and along with *regional authorities*, have a strong interest in controlling the hydrocarbon resources as means to improve the national economy. Simultaneously, the government wants to preserve indigenous heritage and therefore subsidizes and treats the herding society as a part of its agricultural sector (1). National authorities provide, for instance, subsidies to herding Nenets for slaughtering reindeer to regulate herd size (8).

		International human rights agreements and indigenous peoples' legislations give the basis for the national legislation (9). **f) How are the case's boundaries socially defined, and how do these social boundaries relate to biophysical boundaries?** The social boundaries are defined through the individual Nenets reindeer herding brigades. The social boundaries also extend to those groups who interact with the reindeer brigades (such as the hydrocarbon workers, government representatives, and NGO representatives). Nenets herder brigades travel from the south end of the peninsula in the winter in the taiga area, to the north end in tundra pastures in the summer months. Moving through grazing grounds and grounds for calving, approximately 1200 kilometres. Notably, hydrocarbon development has impacted the brigade's migration routes.

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

Following 2 diagrams are by template contributors.

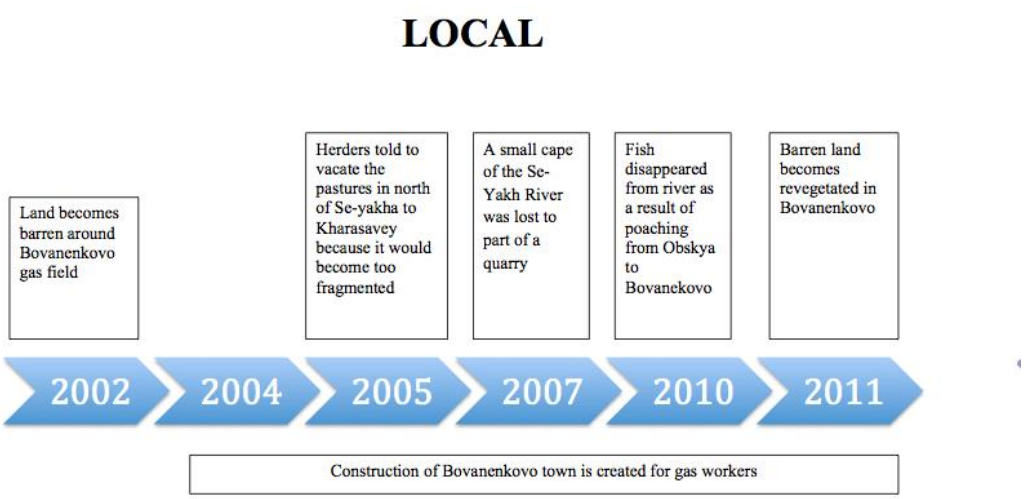
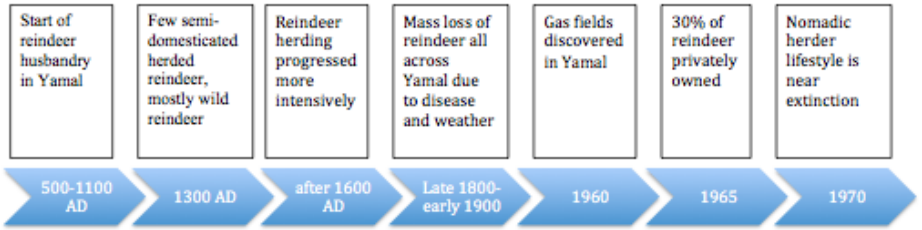
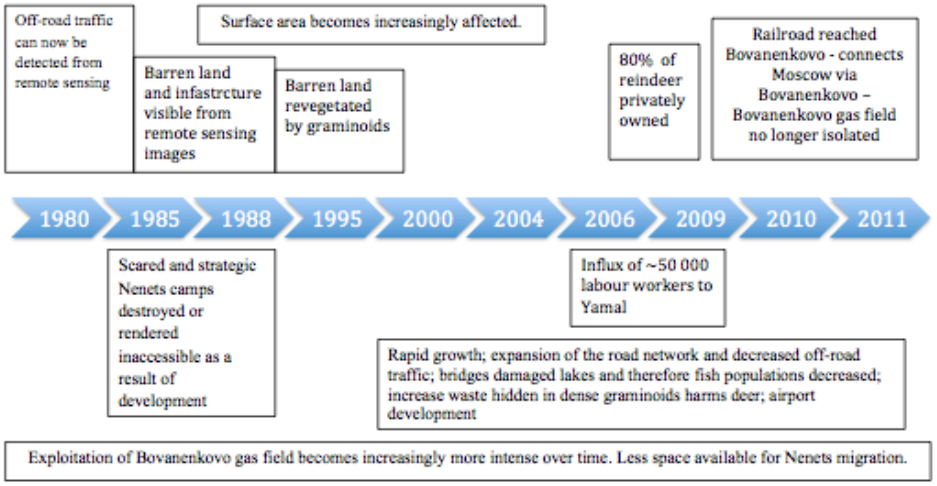


Figure 3a. Key events at a local level of the Yamal Nenets SES

Forbes et al. (2009); Kumpala et al. (2012)

challenged, built, or reduced resilience or adaptive capacity in the system.	**REGIONAL**  **Figure 3b.** Key events of the Nenet SES from 500-2011 AD *Forbes et al. (2009); Forbes (1999); Kumpala (2000); Kumpala et al. (2012)*

REGIONAL



Forbes et al. (2009); Forbes (1999); Kumpala (2000); Kumpala et al. (2012)

NATIONAL/GLOBAL

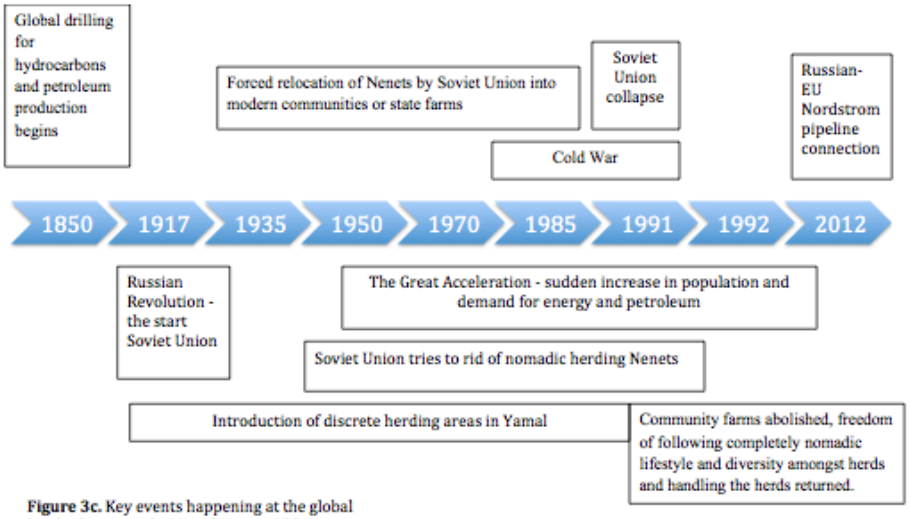


Figure 3c. Key events happening at the global level relevant to the Yamal Nenets SES

Kumpala et al. (2012); Forbes et al. (2009); Forbes (2013); Kumpala (2000)

900 – Reindeer husbandry on the Peninsula
1500 – Road to Ob' River opens

*1922 – Formation of USSR

1930s –
Establishment of school in Yar-Sale
Establishment of Yamal National Okrug
Sedentarization

	1939-45 – WW2 1950 – Ob Bay did not freeze – spent winter on autumn pastures Decree of central committee of farmers' amalgamation 1960s Sovkhozy – strict borders for the brigades From 1960s onwards – increased immigration onto peninsula. Until then mainly inhabited by Nenets 1971 – Bovanenkovo – gas field exploration 1973 – Law on 2dry education 1974 – Port Kharasavey 1980s – Fur trade collapses Kruzenshternskoe gas field exploration. In the 1980s hydrocarbon exploration began in the YNAO, which contains the largest known gas deposits in the world (7). The development of infrastructure and industry has changed the land use and degraded pastures in some parts of the Yamal Peninsula (7). Change of migration routes in northern Yamal Dismiss (?) hunting brigades of Yarsalinsky – increase private herders?? 1985 - Conflict with gas company – brigadier commits suicide 1985 – Start railway by Transstroy 1987 - Perestroika 1987 – reduced control of number of reindeer slaughtered *1989 – Gazprom company started Bovanenkovo gas field active 1989 – NGO Yamal to decedents 1990s *1991 – USSR collapses 1990-98 economic crisis At the same time, climate change – began to be felt in the 1990s, is affecting tundra vegetation and producing unexpected climatic conditions that pose challenges to the Nenets' migrations and a resulting loss of reindeer (7).

	1994 – first private gas company 1998 – regional laws on reindeer husbandry 1999, 2000, 2001 – Laws on indigenous peoples 1999 – ice event kills part of herds 2000 – gas and oil prices increase – increased number of plants built, and railways 2002 – EU slaughter house 2006 – influx of labour begins 2006 – ice cover of pastures which blocks access 2007 – Northern Sea Route opened for first time 2010 – decrease herb size 2011 – early melt of Ob Bay 2013 – suspected Brucellosis cases	
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?** Snow/ice cover events – unexpected and extreme events: permafrost thawing, rain-on-ice events Insect swarms – must find less infested grounds, which reduces survival of young. Infrastructure-related events – loss of grounds/ routes – must change and increase routes to go around infrastructure and plants Reindeer – hoof disease caused by litter and waste hidden in shrubs from hydrocarbon industry. Reindeer step on litter, causing wounds and infections Reindeer – warble fly outbreaks – can be treated Industrial waste – damages reindeer hooves (1, 6, 7, 12, 22, 23)	**b) Have there been major social disturbances that are relevant for the case?** Restrictions to traditional family units – boarding school (1) Loss of TEK – e.g. herd structures, migration patterns. Issues related to globalization and sedentarization of Nenets are seen as the largest threat to the survival of their traditional knowledge and lifestyle due to the foreign influence, increased modernization of the society (1, 6). After 1990s crisis – loss of income due to loss of subsidies; results in subsistence husbandry. Forced relocation of Nenets by Soviet Union from 1935-1985 Development of the hydrocarbon industry starting in the 1980's

		Herders forced to relocate from certain parts of the peninsula due to land fragmentation Russian-EU pipeline built in 2012 (1, 6, 7, 8)
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?** Reindeer herd – maintain the herd through calve production, in turn affected by disease, survival, attacks from worker's dogs (1, 4) Land cover changes: The vegetation available determines the land's carrying capacity for reindeer. Gone from: shrub to grass/ lichen/ moss cover – this is regulated by grazing rates of reindeer and clearing of land for infrastructure by gas companies (10, 5, 7). Shrub encroachment in the north (12). Fragmentation of landscape: Changes in vegetation cover – shrub encroachment, reduces grazing – due to increased temperatures and over grazing. Lichen cover – takes 15-20 yeas to re-establish, long time to recover from shrub cover. Loss of grazing lands – lost to infrastructure and plants for resource extraction. Loss of access to grazing lands – cut off by infrastructure and plants. (17-24) Climate change: Temperature changes: Arctic temperatures have increased an average of 2 °C with forecasts suggesting a 7 °C increase over 30 years.	**b) What are the key social drivers of change?** The main social shock – and subsequent drivers – that the Nenets experienced was the establishment of the USSR (14), which limited freedom or their traditional lifestyle. TEK not valued/ captured by science and non-indigenous managers – loss of activities and knowledge. Loss of TEK – e.g. herd structures, migration patterns. Issues related to globalization and sedentarization of Nenets are seen as the largest threat to the survival of their traditional knowledge and lifestyle due to the foreign influence, increased modernization of the society (1, 6). 1990s – fall of the USSR increased ability to live by traditional lifestyle, while economic crisis meant fewer subsidies (2). Demands on stable production of reindeer: Subsidies were introduced to regulate herd size but appear to cause have the opposite effect because they are an incentive to keep a big herd and sell more reindeer (8). Ended in 1990s. *Developers* to Yamal-Nenets SES influence soil formation, landscape fragmentation, and other environmental factors through creating infrastructure (7). Development contributes to a warming of the permafrost, which again encourages

	This has already resulted in longer growing seasons (12), and would impact the migration route and vegetation available to reindeer (1, 4, 8). Warmer summers – Permafrost thawing; insect harassment of reindeer increases, earlier break-up of ice in spring and later setting of the ice – reducing time to complete migrations. More frequent abrupt weather events; extremely high temperatures, sea level rise, new disease and pests (5, 7). Loss of fish due to poaching from gas workers, which is an important part of Nenets summer diet. Reindeer could be lost due to poaching as well (5, 7).	shrubs to establish (10). Global market for gas (7): The global market price for gas is the main indirect driver to historic and further exploitation on the Yamal peninsula (15). The higher the price gets due to increased consumer demand, the more profitable gas extraction becomes. Russia has a special interest in Yamal's hydrocarbon resources as means to secure energy for the whole nation until 2030 (16). Loss of access to /between grazing grounds: The Nenets are concerned about the progressive loss of pastures, campsites and sacred sites; and gas workers' poaching of reindeer and fish (5, 7). Competition for higher terrain between Nenets and industry. For the former it offers good sites and shelter from heat and mosquitoes that stress their reindeer. For industry high terrain offers better drainage. The outcomes for Nenets of this competition could be: poor grazing and possible herd loss; stressed herds caused by loss of higher ground to escape mosquitoes; and change migration route leads to delay in getting to next grazing area (at higher scale this affects other brigades) (2). Nenets – suffering lung disease New resource exploiters – increased since 1980s and even faster in 2000s. Increased immigrant population, industrial development (1, 6).

		Misunderstandings between local communities of non-indigenous workers and Nenets is an issue in the region as field workers frequently disrespect and/or do not understand Nenet traditions (5, 7).
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?** (+) Nenets know that smaller herds increase overall herd heterogeneity. Reduced herd sizes are more resilient because every herd has specific individual characteristics (6). Phenotypic variance amongst reindeer within herds increases resilience because diverse types of reindeers cope differently with various environmental situations (9). (-) With respect to Nenets usage of YANO, land conversation has degraded the ecosystem that the Nenets rely on (1, 2). (-) Climate change has reduced the ecosystem's adaptive capacity through creating extreme and unexpected weather events, and changing the season length (1, 8, 12).	**b) Within society (e.g. people, social capital, management, institutions, infrastructure):** (+) The Nenets' understanding of natural processes and their environment is that everything underlies constant change. Every year is different and there are weather variations as well as human influence. Their frame of mind is highly resilient through their acceptance of change. The Nenets have established methods to cope with disturbances, which has allowed them to keep their lifestyle in the face of change (8, 6). They are adaptive and flexible when it comes to land changes. (+) At the landscape level, Nenets' knowledge at the micro scale about growth cycles of lichen enable them to travel to the best pastures at the right time of year to ensure the reindeer get the right minerals and nutrients for optimal health (2). This intimate knowledge of the landscape enables them to be flexible when there are obstacles such as physical barriers because of land use change, industrialization and, climate events. In spring 2005, Se-Yakha River thawed two weeks early and the Nenets speeded up the migration to get to cool pastures providing insect relief and nutritious meadows for growth of calves (6). (+) Nenets culture and way of life has survived despite enormous social, political and economic events, including collectivization between 1928-1933, the collapse of the

		USSR and the subsequent economic crisis in the 1990s (2,3). (-) At higher scales the Yamal SES is constrained by governance and legislation about land rights. For example, in 1961 the Sovkhozy was established with defined borders for each brigade's migration. The implications across scales is that external drivers such as land use change and pasture degradation due to industrialization can force Nenets to use migration routes outside their specified territories. This might increase competition between brigades for good pastures. Sudden acceleration and expansion of Bovanenkovo Gas Field (BGF) alongside industrial development at the regional scale would reduce the choices of migration routes available (1, 6, 7). (-) One of the key factors during the Soviet-era administration to remain resilient was that the government did not restrict private ownership of animals. The intrusion of the Soviet system made the other indigenous groups lose their adaptive capacity through confiscation of private property, and forcefully sedentarizing nomads (6). (+/?) The Nenets were the only indigenous group in Siberia that was able to cope with this political change and not lose its autonomy. When the Soviet Union collapsed, Nenets were still self-sufficient because they had maintained private herd ownership (1). Adapting to new development: (+) Nenets have domesticated their reindeer to such an extent that they are able to cross gas installations, which would be considered impossible among the wilder Norwegian reindeer (1).

		(+/0) There is some cooperation between Nenets and hydrocarbon workers. For instance, Nenets accept mobile phone communication to co-ordinate migration through BGF, but refuse car transportation through BGF (2); However, it's hard to say if this is helping to degrading Nenets adaptive capacity with respect to their nomadic way of life. (+/?) National legislation today allows the Nenets to remain resilient.
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 change and resilience in the face of change?	**a) Within nature** Genetic diversity in herds – within and between (9).	**b) Within society** Reindeer herder NGOs (1). Flexibility – open to and understand change (6, 8). Mobility – resilient herders must migrate constantly (6, 8). Independence – rely on herds for sustenance (food and clothes), and also self-autonomous (making decisions at the herd level) (6).

II.2. What are the system's key components?	**a) Key Ecological components (e.g. lakes, coastal zones, caribou)** Grazing lands – taiga tundra Reindeer Waterways	**b) Actors in society (e.g. individuals, groups, public or private organizations)? How are people organized – by geography, livelihood, family, etc.?** Sedentary Nenets Nomadic Nenets reindeer herders – organized in brigades. Groups of families migrating together, and also communicate between brigades for migration. Gas extraction-related communities. Organized in sector: gas production/extraction; transport: rail, pipeline or ship communities: eg. shops, schools (?)…
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)** Dry, high grounds – desired for grazing and animal relief and for infrastructure (2, 3, 7). Grazing grounds for reindeer – move by season and for female and male grounds – need areas for grazing and shrubs for fuel wood (2, 3). Provisioning ES – reindeer, salmon, fuel wood. Cultural ES – spiritual grounds, interaction between nature and society. Nenets culture is deeply rooted in the landscape (cultural ecosystem service) (6, 8). Hydrocarbon extraction from the landscape for societal use in Russia and Europe (2, 7).	**b) From society to nature – modifying nature, extracting resources (e.g. hunting, mining, water pollution)** Overexploitation of fish in waterways – poaching by hydrocarbon workers (3, 11). Pollution from development (1). Landscape fragmentation (2, 3, 6) Overgrazing and shrubification (13, 21).

II.4. What are key interactions?	**a) What are the key ecological interactions within the case?** Grass/shrubland Open/covered water ways **b) What are the most important biophysical tele-connections to distant systems?** Climate change – increased hydrocarbon development will not only indirectly contribute to climate warming, but will also reduce Albedo (removing vegetation for development creates a warming effect on the Yamal peninsula) (23).	**c) What collaborations, conflicts, or other key linkages exist between actors?** Conflict: Lack of feedback to the groups of actors associated with gas mining creates conflict between these and the Nenets (1, 2). Both Nenets and industry want higher terrain because it is beneficial for reindeer or hydrocarbon extraction, respectively (2, 3, 7). Industry and infrastructure is fragmenting the landscape – reducing access to grounds needed and increasing migration routes. Not yet a conflict but could become (7). Immigrants do not understand or respect indigenous way of life (2, 3). Immigrants over-fishing water ways (3, 7). Collaboration: Plants stop transport and activity to allow herders and herds through (2). National government supports indigenous rights and way of life (2). **d) Between local actors and distant actors?** Governance and legislation about land rights (2). Sudden acceleration and expansion of Bovanenkovo Gas field (BGF) alongside industrial development at the regional

		scale would reduce the choices of migration routes available Global gas market influences gas companies on Yamal (2, 6).
II.5. Culture	**a) How is the relationship between society and nature viewed?** Seen as a holistic system (3). **b) What meanings are attributed to nature and to interactions with nature?**	**c) What are key cultural features of relevance for the case?** Nenets livelihood, way of life and cultural identity is inextricably linked to both their reindeer and the land on which they live and depend (3). **d) What are key cultural practices and beliefs related to nature?** Get meat from reindeer, create clothes from hides (3). Nomadic way of life relies on migration between summer and winter pastures (6).
II.6. Disturbance What are important types of stress & shock	**a) Describe important biophysical or ecological shocks and stresses (e.g. floods, storms, etc).** Non-crossable ice Water on ice events Insect infestations	**b) Describe important social shock and stresses (e.g. austerity policies, changes in government policy, introduction of new technologies, etc.)** USSR – limited way of life, size of herds, ownership rights (14). 1990s – subsidies removed 1980s to date – increased competition from extraction and transport of gas. Globalization Development of hydrocarbon industry Potential for governmental changes to influence the Yamal peninsula, and therefore the Nenets population. (1, 2, 8)

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?** Reinforcing feedback – large shrubs cannot be grazed by reindeers → more shrubs → warmer soil ↑ nutrients → plant growth (3, 17). Large numbers of reindeer graze shrubs and grass and trample and add nutrients to the soil, so as to enforce the productive grass-dominated state (3, 18). Fragmentation of the pastures could have nonlinear effects on RH in Yamal. High connectivity between the parts is important for the resilience of RH, since mobility between seasonal pastures underpins the function of the system through provision of grazing land, insect relief areas and resting places (2). Increased temperatures – warmer summers (3). Faster thawing of permafrost and ice cover (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?** There are two stable regimes for the Nenets, one nomadic and one sedentary (3, 7). There is a strong consensus among Nenets, scientists and Russian society that keeping the Nenets' nomadic lifestyle is the desirable state, since it is part of a long Arctic tradition, is an important source of knowledge about tundra life and forms a rich culture (1). It is not clear whether the shrub or the grass state is desirable. Reindeer depend on a diversity of shrubs, moss, lichen, grass pastures (13). In a future case where most of the shrub land turned to grass, or vice versa, the resilience of nomadic herders would likely decrease.
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)?**	**c) Can social stresses or major changes be attributed to ecological regime shifts?** Development is contributing to land and vegetation change (6, 15). Development is also contributing directly to local warming and indirectly to climate change (23).

		d) Are there specific social practices that might be contributing to ecological regime shifts? Development is changing the vegetation – land fragmentation has caused areas to become densely covered in shrubs (6, 15)
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)?** Potential regime shifts are from: steppe to tundra, and tundra to shrub-dominated. Steppes are grass-dominated systems usually in drier environments, which have higher primary production and nutrient cycling. Tundra are dominated by moss and have lower primary production and nutrient cycling (3, 19). **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)** From the ecological perspective, a shift towards bushy vegetation will further reduce the grazing area for reindeers. Warmer climates could also promote permafrost thawing with implication for global carbon storage. From the social perspective that could represent a major impact on traditional livelihoods and therefore their culture (3, 12 19, 20, 21).	
II.8.b. Feedback mechanisms within the system that maintain each regime	**Ecological feedback mechanisms** - Grazing - Nutrient cycling feedback - Competition between vegetation types - Soil moisture	**Social feedback mechanisms** - Castration regulations (national) - Controlled prices (national) - Landscape reading according to current and previous years for pasture condition and accessibility; and

	- Shrub microbial activity - Albedo - Soil drainage - Shrub permafrost mechanism	snow/ ice cover - Migration feedback: determining when to move. - Market feedbacks: demand of meat is unclear - In the past subsidies were offered for production issues
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)**. Warming (slow variable) – affects: freezing and thawing events (fast variables) – changes land cover, access to grounds (12, 20, 21, 22, 23, 24). Herbivory, herding, and grazing intensity; hunting; temperature increase; climate change; greenhouse gas emissions (18, 19). **b) How do these changes alter biophysical feedback processes?** Herbivory mediates competition between grasslands and shrub lands, while climate change increases temperature, extreme events, and precipitation regionally. Warmer temperatures promote shrub encroachment further north (18, 19).	c) **Drivers of social regime shifts (either social or ecological)**. Energy and infrastructure development, competing land uses (6). **d) How do these changes alter the social feedback processes?** The development sectors encroaches the area available for herding (3).
II.8.d. Ecosystem services substantially impacted by regime shift	**a) Changes in ecological processes that produce ecosystem services**	**b) Changes in demand for ecosystem services (market and non-market)** Increasing demand of energy, development of infrastructure (6, 15). **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** (-) Shifts in land cover have potential impacts on the albedo feedback, climate regulation and carbon sequestration which reinforces itself and potentially other regime shifts in the Arctic (22, 23).	**b) Impacts from regime shift on social actors** (-) The shift will decrease the adaptive capacity of herders by further encroachment of their activities threatening their livelihoods (1).
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? This can be listed here or marked with (*) in the table above	**Ecological oriented interventions** At the local to regional scale, actors can intervene by changing grazing pressure and migration patterns (17, 19).	**Socially oriented interventions** Government intervention that historically have affected the system includes the introduction of mandatory schooling. Ensuring that Nenets are able to pass down their TEK to younger generations would be one way to intervene with the social regime shift (1).

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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.