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The perception of permafrost thaw in the Sakha Republic (Russia): Narratives, culture and risk in the face of climate change

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ABSTRACT

This article focuses on the social representations of permafrost thaw among people who were born in different regions of the Sakha Republic (Russia) and live in the regional capital city of Yakutsk. Our research aims to obtain a better understanding of the new risk patterns associated to permafrost thaw through the collection and subsequent analysis of narratives of personal experiences in order to identify the main concerns, how these are defined and which coping strategies are considered by local inhabitants. Our respondents insightfully characterized the nature of the multiple interrelated processes and associations that they identified. According to locals' grasp, climate change and permafrost thaw's impacts exceed the merely physical and material dimensions, unchaining simultaneous and deep transformations in their culture. More specifically, physical degradation threatens their symbolic representations, the material practices and the emotional ties that they have developed in that specific land. They also expressed the need for potential mitigation strategies at both a regional and local scale.

1. Introduction

Arctic regions are currently undergoing unprecedented climatic and socio-environmental changes. Both scientific research and the observations and knowledge of Arctic residents provide detailed information about the multiplicity of transformations (Nuttall, 2018).

In this paper we use a risk perception centered analysis of permafrost thaw in order to analyze the situation in the Sakha Republic. We use the following definition of risk: "Risk equals the two-dimensional combination of events/consequences and associated uncertainties (will the events occur, what will be the consequences)." (Aven and Renn, 2009) When considering permafrost thaw and climate change the risk "event" under scrutiny is the increased thawing of the permafrost, and/or, the reduction of the area of permafrost (discontinuous and continuous), and the associated causes (climate change) consequences. The purpose of this paper is to focus on the perceptions, by the local population, of such an event, its causes and its consequences. By focusing on perception we aim at capturing how locally permafrost thaw is associated to causal statements, statements of salience and their justifications (Vanderlinden et al., 2017). Such "risk issues" (see Renn, 2008, pp. 133 and 134) may take material forms, day to day living conditions may be threatened, and non-material forms, well-being, culture, values, for instance, may be

threatened. While the material consequences of permafrost thaw are well documented (see following paragraphs) this is not sufficient to appraise a risk situation: concerns, in all their dimensions, need to be appraised (Renn, 2008, p. 74). Assessing the perceptions of a specific risk contributes to such a concern assessment. Furthermore, including the cultural dimension of climate change while promoting research aimed at understanding communities' perceptions of how these processes threaten their lives and livelihoods is essential. The non-material processes and resources enabling people to lead meaningful and dignified lives, but which are nevertheless at risk, require special attention (Adger et al., 2013).

As a response to a warmer climate in the Arctic, two main phenomena have already been observed: permafrost temperature increases of between 0.5 °C and 2 °C at the depth of zero annual amplitude (Romanovsky et al., 2010; Kholodov et al., 2012) and an increase in the active layer thickness (ALT) in the majority of the regions, especially in the Russian European North (Shiklomanov et al., 2012; Romanovsky et al., 2016). The most visible impacts of these phenomena have been observed in infrastructure, more specifically, the detrimental of gas and oil pipelines, the associated infrastructures and roads (Hjort et al., 2018; Shiklomanov et al., 2017; Streletskiy et al., 2019). Estimations of the potential costs of adapting or maintaining infrastructures have also been

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calculated (Larsen et al., 2008; Melvin et al., 2016; Hjort et al., 2018). Scientific research conducted in Yakutia revealed the ecological effects of climate change on mammals: the northern pika has expanded its geographical distribution; the mortality rate of small rodents has decreased; the abundance of meadow voles has increased; the mean age of sables has increased and important migratory changes have been observed in the Siberian roe deer - which was usually known as a sedentary species- (Argunov and Safronov, 2013; Safronov, 2016). Climate change also accentuates changes in Siberian vegetation, its composition, structure and productivity (Tchebakova et al., 2016). Takakura (2016) also demonstrated that climate change currently represents a limitation for pastoral adaptation of Sakha People depending from grassland resources in river terraces and the alaa thermokarst landscape for cattle-horse husbandry.

Climate change exerts further pressure on cultural dimensions such as beliefs, ritual practices, art forms, identity, community cohesion and the sense of place (Adger et al., 2013; Quinn et al., 2015; Crate et al., 2017). Simultaneously, culture shapes the way societies perceive and respond to new risk patterns associated to climate change and permafrost thaw. By assuming that risk perception is a cultural construct (García Acosta, 2005; Vanderlinden et al., 2017), we recognize that the notion of risk is not pre-determined, but is instead an intellectual construct between the members of a society (Douglas and Wildavsky, 1982). Culture thus needs to be at the core of research aimed at understanding the social impacts of climate change. This is particularly relevant in the Russian Arctic, as communities have developed a particular understanding and sense of place which is closely related to living in the presence of permafrost and extreme climatic conditions. Furthermore, people's perceptions, definitions and assessment of risks will determine whether or not they consider adaptive measures necessary. Finally, taking cultural dimensions into consideration will contribute to understanding the diverse range of possible responses to similar environmental changes.

With this in mind, the purpose of this paper is to explore the perceptions of climate change and permafrost thaw within the inhabitants from Yakutia by collecting and analyzing narratives. As illustrated by McComas and Shanahan (1999), it is only through narratives that humans succeed in weaving together fragmented observations in order to construct meanings and realities. Through narratives, people assign specific meaning and valuation to social and environmental issues. A detailed analysis of their answers will provide us with useful information in terms of how communities perceive changes, while also enabling us to identify the possible differences existing between norms, definitions and expectations among the scientific community and local stakeholders regarding permafrost thaw and climate change. Assessing these differences at an early stage of permafrost thaw science will avoid the difficulties linked to miscommunication between those impacted and the research community, leading to a more fluent conversation (Kane et al., 2014).

2. Methods and data

Sakha Republic (Yakutia) covers an area of over 3,000,000 km² and the Arctic zone represents about 52% of the territory of the republic. Different indigenous groups – mainly of Turkic origin – have traditionally occupied the Russian Arctic territory (Reisser, 2016). Several waves of settlement have also taken place in this area, involving the spatial allocation of new populations (Heleniak et al., 2013). After the collapse of the Soviet Union, this region underwent deep economic restructuring. The current regional demographic composition is nowadays characterized by multi-ethnicity. Such characteristics can certainly influence the way Yakutian population constructs the notion of agency and copes with undesired effects of the changes they are currently facing. And therefore, should also be taken into consideration when addressing mitigation policies to tackle permafrost thaw and climate change impacts in the region.

Furthermore, climate and permafrost shape every aspect of life in the Russian Arctic, and trying to understand their particularities involves exploring numerous complex systems simultaneously. The effects of these factors across several spheres make this socio-environmental system difficult to understand, maintain and predict (Graybill, 2016). Locals' responses to change will be highly conditioned by the interrelationships between them and the different spheres of the system they live in.

In the context of the European Nunataryuk Project, we conducted the fieldwork in Yakutsk (the capital city of the Sakha republic) between June and July 2018. The goal of this scoping was to meet regional authorities and research institutes that were identified as having activities, or a mandate, potentially affected by permafrost thaw and climate change. We met these in order to access a more precise understanding of how permafrost thaw risk issues related to their mandates and concerns. In addition to this more institutional scoping, we also conducted face-to-face semi-direct interviews with 24 individuals directly or indirectly concerned by permafrost thaw in Sakha Republic. Interviews were conducted in English and translated to Russian by a local interpreter.

Three interview frameworks were created in order to address different local stakes (see appended Table A1), these interviews framework were targeted at the individuals belonging to the following groups, identified according to occupational criteria first, and to geographical criteria afterward: governmental authorities or people working in/representing research institutions; inhabitants from non-coastal areas of Sakha Republic (including Yakutsk); people living in Tiksi.

Interviewing the first category of stakeholders aimed at increasing our understanding of how the regional governmental and research structures interpret and address issues related to permafrost thaw. We also aimed at accessing institutional synergies for coordinated action. The purpose of meeting the individuals included in last two categories was to access locals' perception concerning climate change and permafrost thaw within different geographical contexts (inland vs coastal respectively).

Each framework consisted of questions accompanied by complementary prompts.

Semi-direct interviews were designed to ensure a better understanding of the interviewees' experiences, concerns, values, knowledge and ways of thinking, seeing and acting (Schostak, 2006) while giving them the sufficient scope to tell us about anything they considered relevant or important. The challenges associated with this methodology are the difficulty in expressing the results quantitatively and the need for a detailed and repeated interpretation of them. Linguistic limitations due to live translations could also lead to a loss of terminological precision.

An initial sample of key respondents, mainly from institutions and governmental authorities (See appended Table A1), was contacted as advised by our local informants. We subsequently relied on the suggestions of the interviewees to contact new potential respondents. This snowball sampling procedure does not represent the population in statistical terms, but this was not the intended aim. Instead, we wanted to capture the diversity of experiences related to permafrost thawing in the Sakha Republic - as seen from its capital city.

On average, the interviews lasted 50 min with a minimum of 18 min and a maximum of 70 min. In order to facilitate the interviewing process, interviews were conducted by the authors accompanied by an interpreter. All interviews were recorded. A minority of interviewees expressed their willingness to answer in English. Four participants who were not in Yakutsk at that time agreed to answer the questions in Russian by email. These were translated to English.

The whole body of translated interviews was transcribed to English and subjected to qualitative analysis using Atlas.ti 8 (Friese, 2019). This software contributes to elicit meaning from the narratives in a more organized and systemic way. In a first stage, we organized information contained in locals' narratives under the form of thematic codes or categories - a purpose for which atlas.ti has been designed. This forced

us to refine concepts and allowed us to visualize similarities and patterns among respondents (Smit, 2002). During this process, it is also possible to identify contradictions and/or different points of view among locals. Secondly, we used the network-building feature which facilitated visually revealing the existing relationships and connections between the elements that locals mentioned - this is one of the major strength of Atlas.ti (Friese, 2019) and is fundamental in risk perception analysis as causal linkages are central. As an outcome of the analysis of the interviews and trying to respect the order and words used by the interviewees, we created a mental map. It functions as a picture of the data but also contributes to better understand the context, and associated causal understanding, in which actors define, value and respond to risk situations.

For the final stage, we created broader categories to pool the aforementioned codes according to 6 different levels of action or concerns that we identified: Impacts on natural resources (section 3.1.a, for relationship with Table A2, see text in section 3.1); Impacts on infrastructure (3.1.b); Impacts on health and mental well-being (3.1.c); Governance needed (3.1.d); Knowledge related issues (3.1.e) and Opportunities (3.1.f)

3. Results and discussions

3.1. Initial thematic coding results

Throughout the fieldwork, it was noticeable that all the respondents were keen to tell us about their life experiences related to permafrost and their environment. All the interviewees were familiar with the terms “permafrost”, “permafrost thaw” and “climate change”, which were mentioned in our questions and prompts. Some differences were observed in terms of the type and levels of concerns manifested by locals according to their places of origin (big cities, villages or small settlements, coastal or non-coastal areas, urban or rural areas, etc.). However, this does not represent a contradiction. In fact, these concerns

complement each other, demonstrating the wide diversity of dimensions that are currently being affected by climate change and permafrost thaw. It also increases the scientific understanding of local stakeholders’ perceptions regarding the complex network of non-linear and rapid changes in their environment, lives and livelihoods. All the interviewees seem to be aware of the complex chain of modifications and new risk patterns created by changes to permafrost and the climate in Sakha Republic (see appended Table A2 which presents representative quotes while organizing them thematically into 5 categories).

An in-depth, cross-cutting analysis of the narratives demonstrates that interviewees not only have a similar understanding of the multi-dimensional changes their environment and societies are currently experiencing, but also that they are able to link these changes with two main elements: permafrost and climate. Interviewees claim to observe modifications which take a number of different forms, for example, an increase in the number of mammoth remains found, an increase in the number and intensity of floods, the detrimental damage to and collapse of infrastructure (buildings, routes, pipelines), landscape modifications as well as changes in the composition and distribution of flora and fauna in the region. All these modifications represent different facets of the same unpredictable and changing reality they are living in.

Through this further cross cutting analysis, we identified six overarching (“a” to “f” below), integrative categories (plus an extra one) bringing together the different concerns expressed during the interviews (see codes of the mental map in Fig. 1). These were organized into thematic groups. A first general theme refers to “impacts” (“a” to “c” below). The stakeholders interviewed clearly identified several negative impacts of permafrost thaw on the physical elements of their environment, including:

- a) **Impacts on natural resources:** rivers, soils, mammoth tusks, flora, fauna, etc. They consider these to be closely related to the maintenance of their traditional occupations such as herding, fishing and hunting.

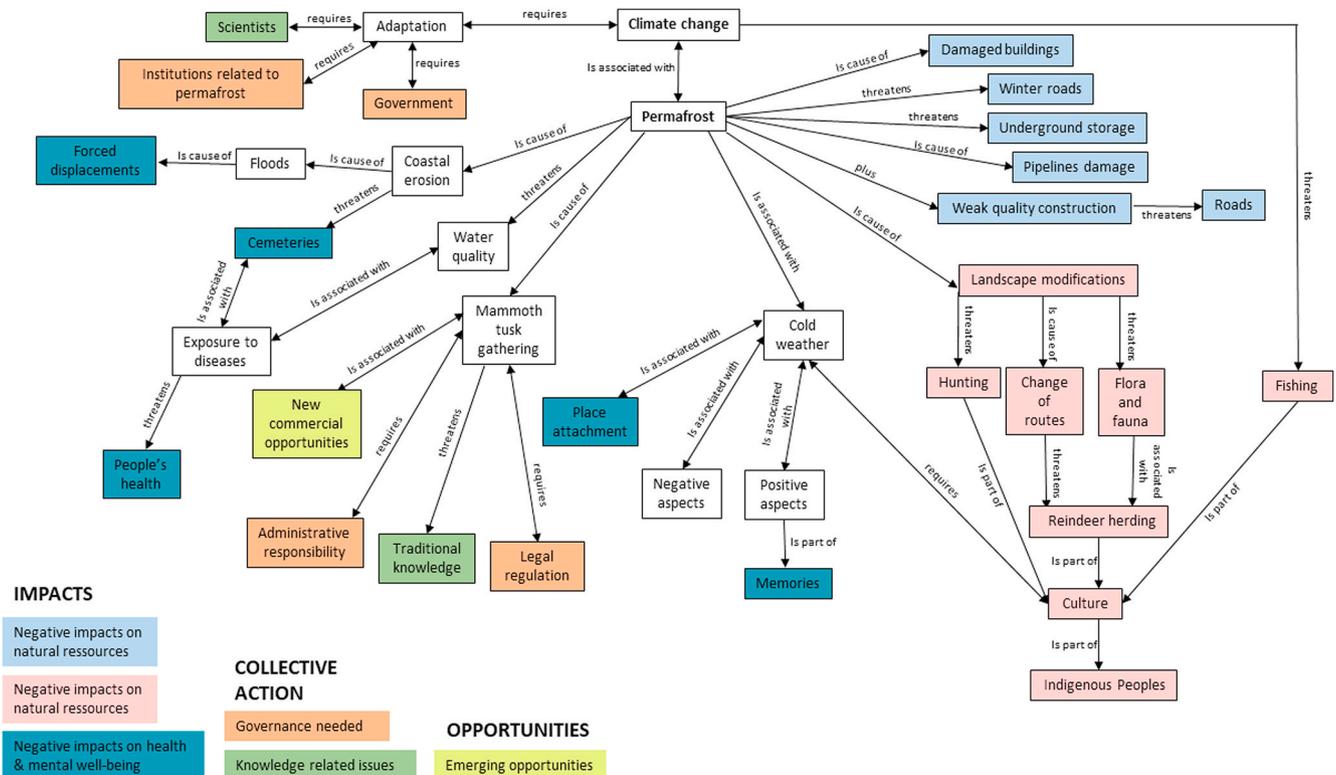


Fig. 1. Mental map created with Atlas.ti 8. It shows the relationship between the issues associated to climate change and permafrost thaw, organized in 6 broad categories according to the operators that are described in the text.

“It [permafrost] affects reindeer herders because before we were moving along the coastline. Now the climate has changed, big bushes have appeared and it has become really hard to herd the deer. (...) Because the soil has changed, the lakes are disappearing, there are landslides, insects have appeared, polar bears have started to move around, everything has changed. The birds, the water, the nature, the soil and the weather of course. It appears that the weather affects many things, the routes taken by birds and animals have changed and there are also migrations, animal diseases.” (quote #1, for more examples see sample quotes #3, 4, 7, 12, 13 in [Table A2](#))

- b) **Impacts on infrastructure** (roads, buildings and pipelines) which reduce the possibility for different settlements/villages/towns in Sakha Republic to transport people, goods and supplies between them.

“Another challenge for our people is the catastrophic flooding observed in recent years. Why does this happen? Many reasons. More meltwater. More rain. Another reason: maybe because the deltas of these rivers now are not dug and that’s why water can’t flow. But hydrologists say that one of the main reasons for the new floods in the northern rivers is the amount of water which gets accumulated in the surface (more than 30%) due to melting permafrost. Then, it comes to the rivers and this is another challenge of permafrost melt.” (quote #2, for more examples see sample quotes #5, 7 in [Table A2](#))

“Permafrost affects badly our buildings and on summer buildings that were built on permafrost, when it melts, they are just going down and the walls are being destroyed because of the movement. In Yakutia, the technology should be special for building houses on permafrost and the materials must be of high quality. I would like to say for roads as well.” (quote #8, for more examples see sample quotes #5, 7 in [Table A2](#))

Interviewees also identified other impacts linked to non-material dimensions that dignify their lives and livelihoods in the region including health, mental well-being, identity and a sense of belonging:

- c) **Impacts on health and mental well-being** which conveys an holistic understanding of health and its relationship to ecosystem integrity under climate change. It also conveys that permafrost thaw has the double impact of reducing one’s ability to act (a) because of potential health related physical weaknesses and (b) because of stress.

“...earlier, 2 or maybe 3 centuries ago, we had epidemics such as the black death. The people and the cattle were buried in some places but we don’t know exactly where. Now the permafrost is melting and they (dead bodies) are appearing during the autumn or they come to the water, rivers, lakes. However, we don’t have any diseases or epidemics in Yakutia yet, but the example of Yamal shows us that this is one of the big problems for us and the future.” (quote #6, for more examples see sample quotes #2, 5, 11, 12, 13, 14, 15 in [Table A2](#))

A second theme concerns issues relating to collective action and refers to:

- d) **Knowledge-related issues:** these refer, on the one hand, to how the new risk patterns affect their traditional knowledge systems and on the other hand to the need for scientific participation and research in terms of permafrost thaw and climate change processes.

“...because the ground is moving, changing, that’s why we have to change our migration routes. Sometimes we don’t know what the best route is because everything has become unpredictable. Normally we could predict the weather for one month, for seasons,

years! Using these predictions, we could choose routes for more comfort. Now we can’t do it because we don’t know what is happening. All of our traditional knowledge about the weather is being destroyed.” (quote #16)

“Most people don’t want to know about the conditions of permafrost. This is a topic for scientists.” (quote #26; for more examples see sample quotes 1, 4, 8, 12, 13, 15, 16 in [Table A2](#))

- e) **Governance needed:** multidimensional and multi-scale changes to the environment have created governance gaps that interviewees deemed necessary to be identified, treated and filled by authorities. More specifically, they emphasized the need for new, better adapted norms/regulations.

“...all our life is regulated by the official laws, orders and others decrees, for example, period of the year when we can catch fish. But these laws were for the past, now everything has changed and people are losing their harvest (...) And the procedure for changing this regulation is very hard, very bureaucratic. The fish spawning time has changed and all the laws and directives regulated this but now everything has changed and people can’t do anything. And if they go to fish during the real spawning time, this might be considered illegal (...) Three years ago, people raised the question of traps for wolves because wolf traps are banned, but now wolves are becoming an epidemic for us. This is a big challenge because every year they take 5–10 thousand reindeer from us” (quote #18 in [Table A2](#))

- f) An additional category, entitled “**Opportunity**”, was included. Throughout the interviews, people expressed concern about the negative character of perceived changes while only one opportunity was identified, referring to the commercial opportunities that an increase in the number of mammoth tusk finds – sold at impressively high prices in the Asian markets – represent for local inhabitants. However, this is not entirely positive, as it was identified to be an activity that goes against the traditional beliefs of indigenous peoples. With this in mind, one representative of the people of the North said:

“In the minds of traditional Northern Peoples, the mammoth is the God of the underworld. And it was a taboo to pick and collect bones. We believe that if, for example, we take this bone or tusk, it opens the door to the underworld. And it will bring us many troubles. It is one of the strongest taboos in our culture. Sometimes, however, some people try to sell them (...) and now we see that collecting mammoth bones is one of the biggest businesses in the North and many people get involved in this business. I see big changes in our traditional life or traditional worldview, because it destroys our traditional beliefs and the connections between older and younger generations. I can say that we are losing our traditional ecological worldview because if you can pick the land ground, you collect these bones, it means that you have stopped believing in our traditions. “

3.2. On causality, values at risk and uncertainty

We further analyzed the causal statements that were associated with these multidimensional impacts, sticking closely to the respondents’ stories of permafrost thaw. In doing so, we identified five categories of operators linking permafrost thaw to its perceived origin and impacts: “threatens,” “is the cause of,” “is associated with,” “requires,” and “is part of.” “Threatens,” “is part of” and “is the cause of” are unidirectional operators. “Associated with” and “requires” are bidirectional - which is quite unusual for the latter. These relationships, as observed in our

interviews, are mapped in Fig. 1.

Impacts are identified along causal chains which jointly find their origin in permafrost thaw. A fine distinction is made in our corpus: the “is the cause of” and “threaten” distinction. Actual observations are required for the respondent’s explicit causal statements (that we associate with the “is the cause of” operator) to be expressed - these observations are expressed as verbs describing (unwanted) impacts. A series of permafrost thaw risks have already been identified and their causal origin is, in the respondents’ eyes, quite clear. These impacts and associated causal statements are erosion, floods and forced displacement; mammoth tusk poaching, cultural erosion; damage to pipelines and buildings; and changes in the migration routes of wild and domestic animals.

The “threaten” operator refers to causal statement loaded with uncertainty that are associated with objects/values at risk, either directly or indirectly, including cemeteries, health, water quality, underground storage, infrastructures, hunting, reindeer herding, fishing, flora and fauna, roads (see Fig. 1).

The “associated with,” and “requires” bidirectional operators show that the respondents believe that the impacts of permafrost thaw are part of complex interrelated phenomena. Some of these could be expected, such as associating a threat to flora and fauna with a threat to reindeer herding. Some indicate a grasp of climate change and its specific place in the changes observed. For instance, climate change is jointly associated with permafrost thaw and the future. It also allows a threat to be linked to cultural heritage (cemeteries) and health through potential diseases. The “requires” operator reflects the identification of a call to action within the respondents’ narratives. Most of these solutions refer to some sort of collective action be it through state institutions, science, regulation or administrative responsibility.

Finally, the “is part of” operator captures causal statements where an initial impact on part of a greater ensemble has an impact on this greater ensemble. This operator is particularly important here as it captures multiple impacts, in the form of threats to hunting, fishing and migratory routes that lead to a general threat to the greater ensemble of local culture.

3.3. Furthering the analysis of the “requires” operator - looking for risk-mitigation options through collective action

In order to cope with the new non-linear changes and impacts, respondents explicitly mentioned the need for further action and identified the government and the scientific community as being responsible for developing adaptive measures related to permafrost and climate change

“[...] we can say that the permafrost is really melting and this can only worry the inhabitants of Tiksi. Something has to be done.” (quote #20, for more examples see sample quotes #19, and 21 in Table A2)

“Roads cannot be of very good quality because in spring or summer you can take very good roads but then, in winter they can be broken because winters are too cold. We need new methods but it is very expensive. And for me, honestly, the government doesn’t pay attention to roads in Yakutia. As you know, our city is very small so I think that the government can try to create some new methods in our city” (quote #24 for more examples see sample quotes #23, 25, 26 and 27 in Table A2)

They also mentioned the need to update the norms and laws, as in some cases they are no longer adapted to the current changing environment people are living in (see sample quote #17 above). Finally, they also highlighted the importance of defining the administrative responsibility for some new resources resulting from changes to permafrost such as mammoth tusks, as they are being found more frequently. In this respect, a representative of the Melnikov Permafrost Institute

said:

“In Yakutia now, there have been long discussions with Moscow and the central part of Russia concerning the status of the mammoth tusks. Is it a national resource or not? The issued is raised because all national resources are subject to a special law. They all belong to the central federation, not to the local governments. The Yakutsk Academy for Sciences has a Department of mammoth fauna that is partly working on these issues (...) It is very chaotic and unknown, but very important for making a point on the permafrost economy in coastal areas and climate impacts.”

From the analysis of this operator, we can infer that collective action is essentially conceived as something that can only be achieved through the intervention of “upper external” actors. In this respect, the notion of agency could – a priori – be related to a vertical and hierarchical relationships. This confirms some of the findings in Kennedy et al. (2018), including a case study from Sakha Republic. In that case study, agency, or the lack thereof, is identified as limiting local adaptation to climate change.

3.4. Furthering the analysis of the “is part of” operator: when material impacts threaten culture

The unidirectional “is part of” operator reflects how changes might lead to physical and material impacts but also represent a threat to cultural dimensions, including the three main traditional activities practiced in Sakha Republic: hunting, fishing and reindeer herding. These are not only economic activities but are also strongly linked to the identity and the worldviews of indigenous people.

“...because the ground is moving, changing, that’s why we have to change our migration routes. Sometimes we don’t know what the best route is because everything has become unpredictable. Normally we could predict the weather for one month, for seasons, years! Using these predictions, we could choose routes for more comfort. Now we can’t do it because we don’t know what is happening. All of our traditional knowledge about the weather is being destroyed. You can say the same about each of our traditional occupations, fishing, hunting too. Not only infrastructure.” (excerpt of quote 16 in Table A2)

The increasingly unpredictable environmental and climatic conditions put these traditional occupations at risk of disappearance, and with it, the potential loss or degradation of their traditional knowledge and culture.

A deeper analysis of the elements mentioned by respondents appearing in the mental map also reveals an interconnection between the physical and the cultural dimensions

“We started to feel these (climatic) changes a very long time ago. In 1995, at the meeting of reindeer herders in the Itum Kalinsky region, we spoke about it. And we spoke about the need to change the migration routes of the reindeer herders because some changes have been observed. This is why the melting of permafrost has a major impact on our traditional lifestyle.” (excerpt of quote #19, see sample quotes #16 and 19 in Table A2)

More specifically, physical changes represent a threat to their culture. This is the case of forced displacements, the destruction of underground caves traditionally used by reindeer herders and hunters during migrations, the erosion of places of cultural value such as cemeteries, and the shorter periods of winter roads on which several communities depend to obtain goods and supplies.

3.5. What did we learn in terms of permafrost thaw risk perception

As stated in the introduction and method sections, we accessed

perceptions through the narratives told by our respondents. As has been explored in other settings, we did this through the identification of different categories of claims: evidence claims, causal statements; salience claims, statements pointing toward what matters to the respondent; and normative claims, in the form of statements judging the moral dimensions associated to a risk issue (Touili et al., 2014; Vanderlinden et al., 2017).

Our results indicate that the causalities associated with permafrost thaw in the interviewees' narratives are quite aligned with current scientific knowledge: climate change is causing annual and seasonal average temperatures changes, which affects permafrost, which in turn affects things that are of interest to humans. This seems to be a relevant result. When envisioning permafrost thaw risk mitigation, there might not be a need for knowledge-centered interventions as our respondents do know what is going on.

Furthermore, our results point to the fact that their knowledge and associated causal statements go beyond simple linear causal relationships. Our respondent qualify quite finely the nature of the associations at hand - this was unexpected to us. The various operators that we identified indicate/reveal intervention points. For instance, the "threaten" or "requires" operators point to a quite precise intervention uphill in the causal chain. Alternatively, the "is part of" operator points to larger scale, multiple benefits interventions. These results indicate the complementary nature of scientific knowledge (elucidating the nature of causalities) and layperson narratives (embedding these causalities in everyday observations). The complex fabric of life in a changing environment is better ascertained through local narration and may allow for a better identification of salient issues. Individuals in the Sakha republic perceive permafrost thaw regularly, in context. They understand what is involved, in many dimensions. Their perceptions may inform scientists and policymakers alike.

The salience claims that we observed are also informing us on the specifics of permafrost thaw and associated knowledge systems. Our respondents shared the interest that scientists have for infrastructure, biological and non-biological resources and associated economic dimensions (see introduction). Yet they also expressed interest in their culture, their minority status, their cultural reliance on a quite unique environment. When considering the current scientific interest into permafrost thaw (see introduction) there seems to be a discrepancy between what scientists find salient (material dimensions) and what our respondents find salient (a mix of material and non-material concerns). Again, this illustrates the importance of accessing locals' perceptions when envisioning permafrost thaw risk issues. The complementarity of scientific knowledge and locals' perception includes bettering the identification of what matters, to who, and why.

Finally, our respondents' narratives include risk mitigation. This stresses the fact that when laypersons perceive permafrost thaw risks, they connect it to its mitigation options. As our respondents appraised the risk situation, they simultaneously imagined potential permafrost thaw risk mitigation avenues. On this dimension, our respondents seem to hold quite a monolithic view: intervention should originate and be conducted from the outside world. This results allows us to ascertain a supplementary dimension of permafrost thaw risk perception analysis. The narratives of the respondents do not only talk about permafrost thaw, but also talk about who they are, in the face of permafrost thaw, and how they construe their ability to face the associated risks. This final result is of critical importance, as action will be needed, and these actions will call for local agency. Our results point to a genuine need for further research into the determinants of local agency in Yakutia.

4. Conclusion

Using a series of interviews and coding them thematically, we explored how, when relating their experiences, the inhabitants of Sakha

Republic express their understanding of permafrost thaw. During this process, we uncovered key elements such as a high level of awareness regarding permafrost thaw and its impacts - permafrost thaw is a salient issue in Yakutia; an explicit understanding of the complex causal webs that permafrost thaw entails; and the expressed need for potential mitigation strategies that seems to reflect an agency deficit and an associated reliance on external authorities.

In this paper, we also clarify how, through the intermeshing of ordinary life experiences, material and cultural impacts are connected and need to be taken into account simultaneously in order to understand precisely how permafrost thaw is taking shape within Sakha Republic. Ordinary life and everyday concerns, both practical and symbolic, ranging from personal to local, regional and national levels, are interconnected and, according to our respondents, should remain so. The material and cultural dimensions of permafrost thaw are two sides of a single coin and are strongly interrelated. The analysis of narratives demonstrated that for locals, geo-physical processes unchained by changes in climate and permafrost undoubtedly transform landscape and alter ecological patterns. But these transformations exceed the physical and material dimensions, and also exert supplementary pressure on the northern culture. Physical degradation (manifested under different forms: as thawing cemeteries, increasing mammoth tusks appearing on permafrost or forced displacements, among others) threatens their symbolic representations, the material practices and the emotional ties that they have developed in that specific land. For locals living in the North, their land is filled with memories, life experiences, and contributed to develop a site-specific way of interpreting and valuating events. Forced restructuring of their cultural features caused by climate change and permafrost thaw might lead to an occasional or irreversible inner fragmentation and socio-cultural rupture.

This is why, maintaining a focus on both material and cultural dimensions while conducting research in Siberia may be quite a formidable challenge. This is even more important as our results show that science is understood, by our interviewees, to be one of the central sources of solutions with regard to permafrost thaw. Science-based solutions seem legitimate to our respondents. In this conclusion, we argue that maintaining this close association of material and cultural dimensions while conducting research may help to support this legitimacy.

Our results successfully map out permafrost thaw and its impacts, using local interests as an entry point. Furthering this analysis, outside of the capital city, would facilitate a much-needed finer analysis that goes beyond the scope of this paper. Finally, the translation of these results in terms public policies in the face of climate change would appear to us, and we hope to our readership, to be something of a necessity.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendices.

Table A.1 List of interviewees from the scoping fieldwork in Yakutsk

Category	Interviewee
Representative of ethnic minorities	Office of the Northern Arctic People's Culture Institute for Humanitarian Research and Indigenous Issues Ex-representative of the Indigenous People in Parliament
Educational authorities	Upper Authorities from the North Eastern Federal University of Yakutsk
Governmental authorities	Minister of Nature Protection
Cultural institutions	Mammoth Museum
Research institutions	The Melnikov Permafrost Institute Office of the Arctic
Students	4 researchers in the medical field Journalism student from Tomponsky District Law student from Yakutsk History student from Tiksi Financial economics student from Anabarsky District 2 students from Tiksi Financial economics student from Vilyuysky District
Traditional occupations	Reindeer herder Seamstress
Other occupations	Entrepreneur from Momsky District Biologist from Kazachie (Ustiansky District) Power supply worker from Siktyakh (Bulunsky District)
TOTAL INTERVIEWEES	24

Table A.2

Sample quotes representative of the 7 central initial results that were identified: awareness of permafrost thaw (1) linking it to climate change and (2) not linking it to climate change; judgment on the (3) weak and (4) strong relevance of permafrost thaw; (5) expression of the threat to traditional activities represented by permafrost thaw; (6) need for further action; and (7) key stakeholders for implementing adaptive measures related to climate and permafrost

(1) Samples associating changes with both permafrost thaw and climate change	Interviewee	Quote #
"It (permafrost) affects reindeer herders because before we were moving along the coastline. Now the climate has changed, big bushes have appeared and it has become really hard to herd the deer. (...) Because the soil has changed, the lakes are disappearing, there are landslides, insects have appeared, polar bears have started to move around, everything has changed. The birds, the water, the nature, the soil and the weather of course. It appears that the weather affects many things, the routes taken by of birds and animals have changed and there are also migrations, animal diseases."	Reindeer herder from Kolimskoie	1
"Another challenge for our people is the catastrophic flooding observed in recent years. Why does this happen? Many reasons. More meltwater. More rain. Another reason: maybe because the deltas of these rivers now are not dug and that's why water can't flow. But hydrologists say that one of the main reasons for the new floods in the northern rivers is the amount of water which gets accumulated in the surface (more than 30%) due to melting permafrost. Then, it comes to the rivers and this is another challenge of permafrost melt."	Representative of the Institute for Humanitarian Research and Indigenous Issues	2
"Actually, there was an article maybe a month ago. They found a huge glacier that broke away from the shore and the main reason I read in the article was because of permafrost, the weather is getting hotter and today is close to 19 °C – a week ago it was –2 °C. When I was studying there (Tiksi), the weather was not like that. Maybe we got a few days which were very hot in the middle of July and afterward it was always very foggy and under 2°. I was really surprised by the news."	Student #2 from Tiksi	3
"People living in Tiksi are concerned about climate change and permafrost thaw. (...) For example, I know that students of the Arctic Gymnasium (High School) conduct their own research to identify changes in climatic conditions. (...) Changes in permafrost affected the flora and fauna most severely. New plants are appearing in the tundra, which are more common in the western and southern regions of Yakutia. The animal world has changed habitat. (...) Local hunters also agree with the fishermen and believe that animals traditionally being hunted (deer, arctic foxes) have changed their habitat and moved further away from old places."	Student #3 from Tiksi	4
(2) Samples associating changes solely with permafrost thaw	Interviewee	Quote #
"...in the houses built on permafrost, the permafrost will soon melt and the building will be destroyed so we need another place to build the houses. Such cases are in villages (...) The special areas for fishermen are being eroded and they need to move their houses in order to survive. And even technology cannot move that."	Seamstress from Saskylakh	5
"...earlier, 2 or maybe 3 centuries ago, we had epidemics such as the black death. The people and the cattle were buried in some places but we don't know exactly where. Now the permafrost is melting and they (dead bodies) are appearing during the autumn or they come to the water, rivers, lakes. However, we don't have any diseases or epidemics in Yakutia yet, but the example of Yamal shows us that this is one of the big problems for us and the future."	Representative of the Institute for Humanitarian Research and Indigenous Issues	6
"I think yes (people are concerned about permafrost) because permafrost thaw begins the erosion process. People start losing their houses which are destroyed. And in the tundra, it creates holes."	Biologist from Kazachie	7
"Permafrost affects badly our buildings and on summer buildings that were built on permafrost, when it melts, they are just going down and the walls are being destroyed because of the movement. In Yakutia, the technology should be special for building houses on permafrost and the materials must be of high quality. I would like to say for roads as well."	Student from Yakutsk	8
(3) Samples identifying a weak relevance of permafrost	Interviewee	Quote #
"...people in our city and in our Republic don't usually think about permafrost. We don't care. We only care about winter and I guess people from villages must care about the weather in winter because sometimes they get food	Law student from Yakutsk	9

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Table A.2 (continued)

(1) Samples associating changes with both permafrost thaw and climate change	Interviewee	Quote #
for themselves by fishing or hunting and they need to understand when they can go outside and how to get dressed. So, nobody cares about permafrost, we don't think about this."	Student #1 from Tiksi	10
"...most people don't want to know about the conditions of permafrost (...) People are interested in knowing about the conditions of the land under Tiksi because there are seismic movements."	Representative of the Institute for Humanitarian Research and Indigenous Issues	11
"I can't say whether it (permafrost) is important or not, because permafrost is part of our lives. The entire territory of Yakutia is covered by permafrost and our traditional lifestyle is connected with this, it depends on it."	Interviewee	Quote #
"Our culture, or circumpolar civilizations, is based on these territories where there is permafrost or a cold climate. And that is why each change to permafrost or our climate has an impact on our culture. We started to feel these changes a very long time ago (...) when reindeer herders or fishermen come to a place, they have like a storage place. They put their meat and fish one or 2 m deep, but now this is disappearing because the permafrost is melting. All these places are destroyed. However, we still try to make them, but they will be destroyed every time."	Former representative of the Indigenous People in the Parliament	12
"I cannot speak on behalf of the whole population of Sakha Republic, but for our district it is definitely very important because our entire life is related to it (...) I think that all our life depends on the permafrost so we wouldn't exist without it. We get food from the reindeer, so if there are no reindeer we cannot survive, and we also obtain fish."	Seamstress from Saskylakh	13
"First of all, it (permafrost) is a visiting card, an image of Yakutia. Secondly, permafrost is really cold and people who live in the cold have a long life expectancy. And thirdly, it's our culture."	Young entrepreneur from Momsky District	14
"That (permafrost) is our outstanding special point and that is why we are in a unique place in the world. In earlier times, people just got used to living in such conditions and dislike the heat."	Financial Economics student from Anabarsky District	15
(5) Samples asserting that traditional knowledge and occupations are being threatened by changes in their environment	Interviewee	Quote #
"...because the ground is moving, changing, that's why we have to change our migration routes. Sometimes we don't know what the best route is because everything has become unpredictable. Normally we could predict the weather for one month, for seasons, years! Using these predictions, we could choose routes for more comfort. Now we can't do it because we don't know what is happening. All of our traditional knowledge about the weather is being destroyed. You can say the same about each of our traditional occupations, fishing, hunting too. Not only infrastructure."	Representative of the Institute for Humanitarian Research and Indigenous Issues	16
"...the young generation is not interested in our traditional occupations like reindeer herding, hunting, fishing, because they understand that they are not comfortable: "they don't give us enough profit for our life", but this is the base of our traditional lifestyle and knowledge! If these young people find one tusk, the price of this tusk is more than the money from one-year's work as a reindeer herder or hunter. This is why we can now say that our traditional occupations – reindeer herding, fishing and hunting – are in crisis because people involved in these are very old. They are over 50. If we sustain this situation for a long time, it means we might lose these traditions."	Former representative of the Indigenous People in the Parliament	18
"...all our life is regulated by the official laws, orders and others decrees, for example, period of the year when we can catch fish. But these laws were for the past, now everything has changed and people are losing their harvest (...) And the procedure for changing this regulation is very hard, very bureaucratic. The fish spawning time has changed and all the laws and directives regulated this but now everything has changed and people can't do anything. And if they go to fish during the real spawning time, this might be considered illegal (...) Three years ago, people raised the question of traps for wolves because wolf traps are banned, but now wolves are becoming an epidemic for us. This is a big challenge because every year they take 5–10 thousand reindeer from us"	Interviewee	Quote #
(6) Samples identifying a need for further action "We started to feel these (climatic) changes a very long time ago. In 1995, at the meeting of reindeer herders in the Itum Kalinsky region, we spoke about it. And we spoke about the need to change the migration routes of the reindeer herders because some changes have been observed. This is why the melting of permafrost has a major impact on our traditional lifestyle. Today it is a reality and every year, on the northern river, Alezeya, there are floods. This is the result of changing permafrost. Not long ago, the members of the local parliament were interested in this question, and at the beginning of June they organized parliamentary discussions about the impact of climate change on the traditional lifestyles and traditional occupations of indigenous peoples in the North. Now, scientific expert groups and authorities examine the system to make research on this process in order to face this challenge and think about the changes we need. (...) Many changes ... We have never paid too much attention to this but now it is urgent. (...) (People) always try to adapt to these changes just as they happen. And they try to raise these questions with their officials to fight against wolves and bears, to help them in flood situations, etc. When we speak about this during parliamentary discussions, I say we don't have a normal program or plan on how to mitigate this, we only act with the results, not to mitigate or to prevent, only after something happens (...) We must do something to prevent it. We must adapt. We must understand where we are going. All these global questions are for all mankind, we must all work on them."	Former representative of the Indigenous People in the Parliament	19
"People living on the coast feel climate change. For example, the winters are very short and almost windless. Strong winds no longer reach the maximum level, as they did 10 years ago. The summers have become mild, the temperature has increased. The reservoirs of ice have changed in the autumn. (...) we can say that the permafrost is really melting and this can only worry the inhabitants of Tiksi. Something has to be done."	Student from Tiksi #3	20
"Yes, there are several conflicts. It is commonly known that where there it is legal to obtain (mammoth tusks) there is also illegal trade. And the point is that the tusks are going to China. It is the imperfection of the laws that regulate how to obtain these tusks. I hope for your next visit, everything will be clearer."	Guide from the Mammoth Museum	21
(7) Samples identifying key potential stakeholders associated with the implementation of responses related to permafrost thaw and climate change impacts	Interviewee	Quote #
"The influence of climate on the population is not an issue for the Ministry for Nature Protection. It thinks you should look at the research done by the Institute of Health. You should get in contact with the Ministry of International Relations of our region because it is in charge of the research related to health, ecology, life etc."	Minister of Nature Protection	22
		23

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Table A.2 (continued)

(1) Samples associating changes with both permafrost thaw and climate change	Interviewee	Quote #
Now it is the Federal Authorities (responsible for fixing quotas and dates). It's very hard to change because they are for the whole Russian territory. They don't think that maybe each territory is different. And the procedure for changing this regulation is very hard, very bureaucratic. The spawning time for fish has changed and all the laws and directives regulated this, but now everything has changed and people can't do anything. And if they go to fish during the real spawning time, they might be considered illegal. We need to think about regional conditions. For example, three years ago, people raised the question of traps for wolves because you know wolf traps are banned, but now wolves have started to become an epidemic for us. This is a big challenge because every year they take 5 or 10 thousand reindeer from us. This question was only raised when we brought experts from the European Union to this Arctic area four years ago, and they prepared a special document to start treating this problem. However, you see that it is not only a federal responsibility but also an international responsibility!"	Former representative of the Indigenous People in the Parliament	
"Roads cannot be of very good quality because in spring or summer you can take very good roads but then, in winter they can be broken because winters are too cold. We need new methods but it is very expensive. And for me, honestly, the government doesn't pay attention to roads in Yakutia. As you know, our city is very small so I think that the government can try to create some new methods in our city"	Law student from Yakutsk	24
"I think the main actor must be the government: federal, local, regional government. They must implement special programs on how to mitigate the effects of this climate change or melting permafrost. But we must understand that all that I say is measured by the results. We must think how to prevent and how to support (people from Yakutia)."	Representative of the Institute for Humanitarian Research and Indigenous Issues	25
"I think that the industrialists will cope with the problems (of permafrost thaw) because they do all their business on the permafrost. In permafrost there is oil, natural resources, precious resources, the entire periodic table is there, and of course there are so many people interested in the Arctic in terms of business."	Seamstress	26
"Most people don't want to know about the conditions of permafrost. This is a topic for scientists."	Student from Tiksi #1	27

References

- Adger, W.N., Barnett, J., Brown, K., Marshall, N., O'Brien, K., 2013. Cultural dimensions of climate change impacts and adaptation. *Nat. Clim. Change* 3, 112–117. <https://doi.org/10.1038/nclimate1666>.
- Argunov, A.V., Safronov, V.M., 2013. Demographic structure of Siberian roe deer (*Capreolus pygargus* Pall.) population in central Yakutia. *Russ. J. Ecol.* 44 (5), 402–407. <https://doi.org/10.1134/S1067413613050032>.
- Aven, T., Renn, O., 2009. On risk defined as an event where the outcome is uncertain. *J. Risk Res.* 12 (1), 1–11. <https://doi.org/10.1080/13669870802488883>.
- Crate, S., Ulrich, M., Habeck, J.O., Desyatkin, A.R., Desyatkin, R.V., Fedorov, A.N., Hiyama, T., Iijima, Y., Ksenofontov, S., Mészáros, C., Takakura, H., 2017. Permafrost livelihoods: a transdisciplinary review and analysis of thermokarst-based systems of indigenous land use. *Anthropocene* 18. <https://doi.org/10.1016/j.ancene.2017.06.001>.
- Douglas, M., Wildavsky, A., 1982. How can we know the risks we face? Why risk selection is a social process. *Risk Anal.* 2 (2), 49–58. <https://doi.org/10.1111/j.1539-6924.1982.tb01365.x>.
- Friese, S., 2019. *Qualitative Data Analysis with Atlas.Ti*, third ed. SAGE, Thousand Oaks.
- García Acosta, V., 2005. El riesgo como construcción social y la construcción social de riesgos. *Desacatos* 19, 11–24. <https://doi.org/10.29340/19.1042>.
- Graybill, J.K., 2016. Urban vulnerability to climate change in the Russian Arctic. In: Orttung, R. (Ed.), *Sustaining Russia's Arctic Cities: Resource Politics, Migration, and Climate Change*, vol. 2. Berghahn Books, New York-Oxford, p. 221.
- Heleniak, T., 2013. Boom and bust: population change in Russia's Arctic cities. In: Laruelle, M., Orttung, R. (Eds.), *Urban Sustainability in the Arctic: Visions, Contexts, and Challenges*, pp. 429–435.
- Hjort, J., Karjalainen, O., Aalto, J., Westermann, S., Romanovsky, V.E., Nelson, F.E., Eitzelmüller, B., Luoto, M., 2018. Degrading permafrost puts Arctic infrastructure at risk by mid-century. *Nat. Commun.* 9, 5147. <https://doi.org/10.1038/s41467-018-07557-4>, 2018.
- Kane, I.O., Vanderlinden, J.-P., Baztan, J., Touili, N., Claus, S., 2014. Communicating risk through a DSS: a coastal risk centred empirical analysis. *Coast Eng.* 87, 240–248. <https://doi.org/10.1016/j.coastaleng.2014.01.007>.
- Kennedy, G., Raimonet, M., Berman, M., Gaye, N., Huctin, J.-M., Kaleekal, T., Vanderlinden, J.-P., 2018. Environmental history and the concept of agency: improving understanding of local conditions and adaptations to climate change in seven coastal communities. *Global Environment* 11 (2), 405–433. <https://doi.org/10.13197/ge.2018.110209>.
- Kholodov, A., Gilichinsky, D., Ostroumov, V., Sorokovikov, V., Abramov, A., Davydov, S., Romanovsky, V., 2012. Regional and local variability of modern natural changes in permafrost temperature in the Yakutian coastal lowlands, Northeastern Siberia. In: *Proceedings of the Tenth International Conference on Permafrost*, Salekhard, Yamal-Nenets Autonomous District, Russia, pp. 25–29.
- Larsen, P., Goldsmith, S., Smith, O., Wilson, M., Strezepek, K., Chinowsky, P., Saylor, B., 2008. Estimating future costs for Alaska public infrastructure at risk from climate change. *Global Environ. Change* 18 (3), 442–457. <https://doi.org/10.1016/j.gloenvcha.2008.03.005>.
- McComas, K., Shanahan, J., 1999. Telling stories about global climate change: measuring the impact of narratives on issue cycles. *Commun. Res.* 26 (1), 30–57. <https://doi.org/10.1177/009365099026001003>.
- Melvin, A.M., Larsen, P., Boehlert, B., Neumann, J.E., Chinowsky, P., Espinet, X., Martinich, J., Baumann, M.S., Rennels, L., Bothner, A., Nicolosky, D.J., Marchenko, S., 2016. Climate change damages to Alaska public infrastructure and the economics of proactive adaptation. *Proc. Natl. Acad. Sci. Unit. States Am.* 114 (2), E122–E131. <https://doi.org/10.1073/pnas.1611056113>.
- Nuttall, M., 2018. Arctic environments and peoples. *Int. Encycl. Anthropology* 1–7. <https://doi.org/10.1002/9781118924396.wbiea1480>.
- Quinn, T., Lorenzoni, I., Adger, W.N., 2015. Place attachment, identity and adaptation. In: O'Brien, K., Selboe, E. (Eds.), *The Adaptive Challenge of Climate Change*. Cambridge University Press, New-York, pp. 160–170.
- Reisser, C., 2016. Russia's Arctic cities: recent evolution and drivers of change. In: Orttung, R.W. (Ed.), *Sustaining Russia's Arctic Cities: Resource Politics, Migration and Climate Change*. Berghahn, New-York, pp. 1–22.
- Renn, O., 2008. *Risk Governance: Coping with Uncertainty in a Complex World*. Earthscan, London.
- Romanovsky, V.E., Smith, S.L., Christiansen, H.H., 2010. Permafrost thermal state in the polar Northern Hemisphere during the international polar year 2007-2009: a synthesis. *Permafrost. Periglac. Process.* 21 (2), 106–116. <https://doi.org/10.1002/ppp.689>.
- Romanovsky, V.E., Smith, S.L., Christiansen, H.H., Shiklomanov, N.I., Streletskiy, D.A., Drozdov, D.S., Malkova, G.V., Kholodov, A., Isaksen, K., Marchenko, S.S., 2016. Terrestrial permafrost [in "state of the climate in 2015"]. *Bull. Am. Meteorol. Soc.* S148–S152.
- Safronov, V.M., 2016. Climate change and mammals of Yakutia. *Biol. Bull.* 43, 1256–1270. <https://doi.org/10.1134/S1062359016110121>, 2016.
- Schostak, J., 2006. *Interviewing and Representation in Qualitative Research*. Open University Press, New York.
- Shiklomanov, N.I., Streletskiy, D.A., Nelson, F.E., 2012. Northern hemisphere component of the global circumpolar active layer monitoring (CALM) program. *Proc. 10th Int. Conf. on Permafrost*, 1, 377–382.
- Shiklomanov, N.I., Streletskiy, D.A., Swales, T.B., Kokorev, V.A., 2017. Climate change and stability of urban infrastructure in Russian permafrost regions: prognostic assessment based on GCM climate projections. *Geogr. Rev.* 107, 125–142. <https://doi.org/10.1111/gere.12214>.
- Smit, B., 2002. *Atlas. ti for qualitative data analysis*. *Perspect. Educ.* 20 (3), 65–75.
- Streletskiy, D.A., Suter, L.J., Shiklomanov, N.I., Porfiriev, B.N., Eliseev, D.O., 2019. Assessment of climate change impacts on buildings, structures and infrastructure in the Russian regions on permafrost. *Environ. Res. Lett.* 14 (2), 025003 <https://doi.org/10.1088/1748-9326/aa5e6>.
- Takakura, H., 2016. Limits of pastoral adaptation to permafrost regions caused by climate change among the Sakha people in the middle basin of Lena River. *Polar Science* 10 (3), 395–403. <https://doi.org/10.1016/j.polar.2016.04.003>.
- Tchebakova, N.M., Parfenova, E.I., Soja, A.J., 2016. Significant Siberian vegetation change is inevitably brought on by the changing climate. In: Mueller, L., Sheudshen, A., Eulenstein, F. (Eds.), *Novel Methods for Monitoring and Managing Land and Water Resources in Siberia*. Springer Water. Springer, Cham, pp. 269–285.
- Touili, N., Baztan, J., Vanderlinden, J.-P., Kane, I.O., Diaz-Simal, P., Pietrantoni, L., 2014. Public perception of engineering-based coastal flooding and erosion risk mitigation options: lessons from three European coastal settings. *Coast Eng.* 87, 205–209. <https://doi.org/10.1016/j.coastaleng.2014.01.004>.
- Vanderlinden, J.-P., Baztan, J., Touili, N., Kane, I.O., Rulleau, B., Diaz Simal, P., Pietrantoni, L., Prati, G., Zagonari, F., 2017. Coastal flooding, uncertainty and climate change: science as a solution to (mis) perceptions? A qualitative enquiry in three coastal European settings. *Journal of Coastal Research*. SI 77, 127–133. <https://doi.org/10.2112/SI77-013.1>.