A Review of Climate Change Adaptation in the Arctic

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Abstract

The Arctic is experiencing rapid climate change impacts necessitating adaptation. This systematic literature review provides an overview of the recent climate change indicators necessitating adaptation and the actions implemented in response. Articles included in the review focused on communities across the Arctic and were published between the years 2000 and 2020. Through qualitative analysis of the literature, four indicators of climate change were presented through a social-ecological lens: (1) the degradation of ice, (2) changes in ecosystems, (3) changes in weather patterns, and (4) changes in hydrogeological risk. Further, three main types of adaptation were presented: (1) behavioral changes, (2) regulatory initiatives, and (3) changes to livelihoods or economics. Critically, most of these adaptation actions were implemented at an individual level.

Keywords

Arctic; climate change; adaptation; systematic review

Introduction

Originating in medicine, a systematic review provides an overview of a body of literature by addressing a specific research question or questions (Gough, Oliver, & Thomas, 2017; Grant & Booth, 2009). A strict set of researcher-defined protocols, such as inclusion and exclusion criteria, must be developed before and followed throughout the review process (Moher et al., 2015). Due to the rigor of the literature screening process and the focused scope of the research question(s), systematic literature reviews typically include fewer studies than other reviews (Fink, 2020; Petticrew & Roberts, 2008).

While systematic reviews are common in the health sciences (Purssell & McCrae, 2020), fewer examples exist in the social and environmental sciences (Landauer, Juhola, & Söderholm, 2015). However, they have been conducted in this literature since at least the 1970s (Hunt, 1997). More reviews are needed that focus explicitly on climate change adaptation in the Arctic (Canosa et al., 2020; Ford, McDowell, & Jones, 2014; Hahn & Nykvist, 2017; Janssen, et al., 2006). Indeed, within the climate change adaptation literature more broadly, many assessments, reports, and studies do not describe their selection criteria when attempting to uncover generalizable trends, which reduces their replicability and usability (Dupuis & Biesbroek, 2013; Eisenack & Stecker, 2012).

A systematic review of climate change adaptation strategies in the Arctic was conducted using peer-reviewed journal articles that included or focused on community-based

perspectives to advance the climate change adaptation literature. This review aimed to understand better the early climate change indicators impacting Arctic people and environments, including how these indicators are being prepared for and responded to, as gleaned from the collective human experience (Pelling, 2011). A systematic literature review of climate change adaptation is presented in what follows, as uncovered through content analysis (Franzosi, 2008). Namely, this review presents a summary of (1) the four indicators of change necessitating adaptation, (2) the types of climate change adaptations being implemented, and (3) the topical areas where more research is needed.

Background

Over the past thirty years, since 1990, the Arctic has warmed by over .05º Celsius per decade (Jeffries, Richter-Menge, & Overland, 2012) with an increasing rate of warming over time when compared to average global rates of warming (IPCC, 2014). This is important because even minor temperature fluctuations can cause significant states of change within the social and environmental systems of the Arctic due to their magnification within narrow or sensitive ecosystems (Duerden, 2004; Stien et al., 2012).

Here, the Arctic is defined as the area of the Earth at or above 60-66º North latitude and areas near this latitude that encompass the regional dynamics of the Arctic (e.g., cultural and political dimensions) (Einarsson et al., 2004). By this definition, the Arctic covers eight territories surrounding the Arctic Ocean: The United States (Alaska), Canada (Yukon, Northwest Territories, Nunavut), Greenland, Iceland, Norway, Sweden, Finland, and Russia. Nearly four million people live throughout these Arctic territories, of which ten percent of the population identifies as Indigenous (Arctic Council, n.d.). This definition is important because culture shapes how risk is understood and acted upon (Adger et al., 2013; Beck, 2009).

Across the Arctic, peoples and environments are on the frontlines of climate change, often necessitating adaptation. Climate change adaptation is a cultural process of adjustment owing to individuals' collective behaviors that seek to reduce adverse effects and find opportunities that arise from change (Adger, Arnell, & Tompkins, 2005; Deneva, 1983; Smit et al., 2000). Adaptation to realized or expected changes can be proactive or reactive, autonomous or planned (IPCC, 1996; IPCC, 2012), and can range from short-term reactive coping mechanisms to long-term planning or transformational changes (Pelling, 2011). Alongside adaptation, mitigation is an important complementary action to prevent additional or worsened impacts of climate change (IPCC, 2014). Thus, there is a longstanding and globally recognized need for mitigation and adaptation efforts to reduce climate change-induced risks through developing and implementing policies and strategies informed by research (Smith & Lenhart, 1996; UNFCCC, 1992).

In reflection of the globally recognized need for climate change mitigation and adaptation in the Arctic, many adaptation strategies were and are implemented under the auspices of "the urgency to do good" (Cameron, 2012). For example, adaptations can leave a legacy of colonialism, marginalization, disempowerment, and questions of sovereignty (Keskitalo & Kuulyasova, 2009). Thus, we must never forget to ask what is being adapted, who is adapting at what scale, and how the adaptation is occurring (Smit et al., 2000). Indeed,

any action to increase the adaptive capacity of certain actors may simultaneously reduce the adaptive capacity of other actors (Moser & Ekstrom, 2010), including the more-than-human.

In recognition of the need for climate change adaptation in the Arctic, this systematic review answers the following research questions:

1. What indicators of climate change necessitated adaptation?
2. What types of climate change adaptation were implemented?

Methods

First, a search string was developed to identify peer-reviewed case studies of climate change adaptation in the Arctic. This search string was then applied to titles and abstracts in Google Scholar and seven databases covering various social and environmental topics (see Appendix). To reflect current adaptations to climate change, and because studies on climate change adaptation have grown tremendously since the 1990s (Carson & Peterson, 2016; Larsen et al., 2014), the search was constrained to articles published over a twenty-year time frame from 2000 through 2020.

The initial search resulted in 375 articles, all of which underwent an inclusion and exclusion process before analysis was conducted. Articles were excluded if they: (A) were published before 2000, (B) were not peer-reviewed journal articles, (C) were not written in or translatable to English, (D) were not in the Arctic or did not define a geography, (E) did not discuss outcomes of relevance to climate change adaptation, (F) did not engage with or focus on a specific community or communities, and (G) were a duplicate of a previously identified article. Ultimately, 49 articles were chosen for inclusion and analysis.

Next, full-text PDF versions of the articles were downloaded. A bibliometric analysis was conducted by recording objective information in a spreadsheet database. Then, a qualitative codebook was created to guide a secondary, more subjective data collection process around specific qualitative themes (Franzosi, 2008) (see Appendix). Articles were reviewed one at a time in alphabetical order by the first author's last name. After an initial assessment was completed, articles underwent a second review for accuracy, and data were updated and iteratively compared across studies for evaluation consistency (Srivastava & Hopwood, 2009). Papers were iteratively reviewed until a saturation point in themes was reached, wherein no new information arose from additional data collection (Baxter & Eyles, 1997; Crabtree & William, 1999). Together, these analyses served to classify information within the articles. The results are presented in what follows.

Results

Indicators of Climate Change Necessitating Adaptation

Research must examine how adaptations are framed within their broader-scale social-ecological processes (McGovern et al., 2007; Wilbanks & Kates, 1999). Few adaptations are understood or enacted in response to climatic drivers alone (Labbé, Ford, Araos, & Flynn, 2017). Thus, indicators of change were identified from a social-ecological systems

perspective (Ostrom, 2009), wherein causal relationships connect a set of elements through the flow of energy, materials, or people (Gallopin, 1991; Hepple, 2009; Herrero-Jauregui et al., 2018). Using this social-ecological systems perspective, a systematic review allowed for the information presented in case-level studies to produce generalizable knowledge claims within a common framework of understanding (Eisenack, Lüdeke, & Kropp, 2006; Ford et al., 2012; Loring, Chapin, & Gerlack, 2008; Keskitalo & Kuulyasova, 2009). Here, four primary indicators of change (Ritchie et al., 2021) necessitated adaptation: (1) the degradation of ice, (2) changes in ecosystems, (3) changes in weather patterns, and (4) changes in hydrogeological risk.

The degradation of Arctic ice was experienced in locations throughout the Arctic and included land and marine environments alike. Case studies presented evidence of degradation to the amount (Ignatowski & Rosales, 2013), extent (Kofinas et al., 2010), depth (Wesche & Chan, 2010), and quality of ice (Fawcett et al., 2017). Case studies also presented evidence for the degradation of the amount of shore-fast and multi-year ice (Brubaker et al., 2011), such as a delay in annual freezes (Ford, Smit, & Wandel, 2006), an earlier annual break-up of ice (Pearce et al., 2012), and more freeze-thaw and snow-on-ice events (Furberg, Evengård, & Nilsson, 2011; Ford, 2009).

Risks posed by the degradation of ice included the loss of natural protection from waves and rough open waters (Fang et al., 2018), more accidental drownings (Giles et al., 2013), and the loss of species requiring ice-dominated habitats, such as caribou, reindeer, and many marine mammals (Burek, Gulland, & O'Hara, 2008; Kovacs et al., 2011; Rattenbury et al., 2009). The degradation of ice also posed barriers to the gathering, preparation, and storage processes that rely on ice-dominated landscapes, such as those needed for ice cellars, sometimes leading to increased instances of food insecurity and food poisoning (Driscoll et al., 2013; Rosol, Powell-Hellyer, & Chan, 2016; Ristroph, 2019), as reflected in the broader literature on climate change and nutrition (Borelli et al. 2020; Brubaker et al. 2011; Powell et al., 2022).

Alongside the degradation of Arctic ice, changes to ecosystems motivated adaptation. Nearly two-thirds of all case studies cited changing ecosystems, including changes in wildlife species composition (Forbes & Stammler, 2009; Kofinas et al., 2010; Prno et al., 2011), declines in native wildlife and landscape health (Fawcett et al., 2017; Furberg, Evengård, & Nilsson, 2011; Ogden & Innes, 2009; Takakura 2016), changes in the timing of species migrations (Keskitalo & Kuulyasova, 2009), and the appearance of new species (Trainor et al., 2007), including invasive and biting species (West & Hovelsrud, 2010). Indeed, since the Industrial Revolution, climate change and land-use practices have resulted in the loss of nearly one-third of Arctic terrestrial species (Larsen et al. 2014). For example, many native Arctic species are disappearing (Ford & Smit, 2004), changing their behaviors (Huntington, Quakenbush, & Nelson, 2017), or exhibiting poor-quality fur and meat due to disease (Wesche & Chan, 2010).

Changes in weather patterns were also occurring, including increases in air and water temperatures (Gosselin et al., 2011; Healey et al., 2011; Manrique, Corral, & Pereira, 2018), less extreme winter low temperatures (Kaján, 2014; Keskitalo & Kuulyasova, 2016), and less predictable weather patterns and environmental cues (Ignatowski & Rosales, 2013; Loring et al., 2011; Ogden & Innes, 2009; Wesche & Chan, 2010;). These weather patterns changes

enabled further social and environmental changes, such as an increased presence of wildfire events (Skrylnikova et al., 2014; Trainor et al., 2009) and atmospheric allergens and particulates (Driscoll et al., 2013). Further, weather pattern changes rendered it difficult to read the land and weather using traditional cues and place-making capacities (Loring et al., 2011; Pearce et al., 2015), which sometimes led to a loss of ecological knowledge and traditional practices (Pearce et al., 2012), thus also eroding an Arctic sense of place that is closely tied to cold environments (Healey et al., 2011; Kofinas et al., 2010).

Finally, evidence of changes in hydrogeological risk were present throughout the literature (Ford et al., 2012), including more thunderstorms and extreme weather events (Kaján, 2014; Pearce et al., 2015), flooding events (Herman-Mercer et al., 2016; Takakura, 2016), landslides (Skrylnikova et al., 2014), and declines in the quality of freshwater (Goldhar, Bell, & Wolf, 2014). Changes in permafrost extent and depth also contributed to or were instigated by these increasing hydrogeological risks (Healey et al., 2011), including the freer transport of materials like harmful pollutants by way of bioaccumulation processes (Alexander, 1999; Larsen et al., 2014). In response to changes in hydrogeological risk, some communities experienced a loss of critical infrastructure, such as communication, energy, transportation, and water systems (Healey et al., 2011; Skrylnikova et al., 2014). Historical and cultural sites were also more frequently prone to the impacts of hydrogeological events (Pearce, 2009), and in some cases, entire communities required relocation (Manrique, Corral, & Pereira 2018).

Over the past 20 years, ice degradation and the changes in ecosystems, weather patterns, and hydrogeological risk necessitated climate change adaptation across the Arctic. In response to these indicators of change, three main types of adaptation strategies have been followed. They are discussed below.

Climate Change Adaptations

Most climate change adaptations implemented were behavioral, meaning they occurred at an individual level. Of these adaptations, most were led or enabled by the collective action of individuals, households, and communities (Ford, McDowell, & Jones, 2014), rather than other actors, such as government officials or non-governmental organizations. However, when national and regional governments or academic organizations or institutions implemented behavioral actions (Labbé, Ford, & Flynn, 2017), these actors were typically working to educate individuals to promote behavioral change. For example, there were calls to raise household awareness about raw water consumption risks amid freshwater availability declines (Martin et al., 2007; Wesche & Chan, 2010). Indeed, there were many sub-types of behavioral adaptations implemented.

A second type of behavioral change was modifying subsistence activity patterns by changing when, where, or how subsistence activities occurred (Berkes & Dyanna, 2002; Huntington, Quakenbush, & Nelsen, 2017; Pearce, 2015). Further, to prepare for and execute subsistence activities amid a changing climate, behavioral changes also included the use of GPS, satellite phones, radios, locator beacons, and the addition of extra supplies like food and gas to maintain safety when out on the land and water (Aporta, 2003; Fawcett et al., 2017; Ford & Smit 2004; Ford, Smit, & Wandell, 2006; Pennesi, 2012; Prno et al., 2011). Safety

amid changing environmental conditions—and often increasingly lengthy and risky travel to subsistence areas (Goldhar, Bell, & Wolf, 2014)—was maintained by improving knowledge of and skills on the land and water through story-sharing and practice (Giles, 2013; Pennesi, 2012). Safety was also maintained by consulting with satellite imagery (Fawcett, 2017) and the incorporating new technologies, such as snowmobiles, to varying degrees of success (Kaján, 2014; Rattenbury et al., 2009).

An additional behavioral change was the increased sharing of information and resources within and between individuals, households, and communities (Ford et al., 2008). For example, exchange through social networks allowed for more intercommunity connections (Baztan et al., 2017; Berkes & Dyanna, 2002; Kofinas et al., 2010), collaborative engagements (Manrique, Corral, & Pereira 2018; Trembley et al., 2008), the development of stronger adaptation options (Flynn et al., 2018; MacDonald et al., 2015; Takakura, 2016), stronger intergenerational connections (Ford et al., 2007; Rosol, Powell-Hellyer, & Chan, 2016), and the promotion of education and outreach (Ford et al., 2017). Underpinning the success of many of these and other behavioral changes was the allowance for change to be enacted within and for existing and traditional cultural frameworks (Einarsson, 2009; Forbes & Stammler, 2009).

Following behavioral changes, regulatory actions were a common type of adaptation implemented, including the development of rules, laws, statutes, and guidelines. Among these regulatory changes, there were calls for institutions to rectify environmental injustices (Cameron, 2012; Trainor, 2007), such as through the development of cross-scalar structures that incorporate local communities in decision-making (Berkes & Dyanna, 2002; Brunner et al., 2004; Ford et al., 2017; Kofinas et al., 2010). For example, there were calls for the co-management of agreements for economic and subsistence wildlife activities (Keskitalo & Kuulyasova, 2016; Ogden & Inne, 2009). This is important because the timing of hunting seasons in policy does not necessarily coincide with when animals are available and appropriate for consumption (Loring et al., 2011). Behavioral and regulatory adaptations occurred in 69% of the studies included in this review.

The third most common type of adaptation focused on maintaining livelihoods and economic activity, occurring in 49% of the studies in this review. Livelihood and economic adaptations included taking on additional jobs (Rattenbury et al., 2009), diversifying jobs (Ford, 2009; Pearce et al., 2012), embracing tourism (Kaján, 2014), and as previously mentioned, changing the timing, method, or location of subsistence activities (MacDonald et al., 2015; Pearce et al., 2015; Ristroph, 2019; Wesche & Chan, 2010).

Additional adaptations included improvements to healthcare systems (Driscoll et al., 2013; Healey et al., 2011) as well as the creation of environmental monitoring systems to support decision-making for environmental health (Brubaker et al., 2011; Ogden & Innes, 2009), collaborative research (Pearce, 2009), and responsible environmental economic accounting (Skrylnikova et al., 2014). A few communities also developed local-scale adaptation plans (Ignatowski & Rosales, 2013) and community wildfire plans (Trainor et al., 2009), in some cases leading to the relocation of critical infrastructure (Gosselin et al., 2011; Prno et al., 2011).

Conclusion

Across the Arctic, peoples and environments are experiencing the impacts of climate change, necessitating adaptation. This systematic literature review provides an overview of the recent climate change indicators necessitating adaptation, as well as the adaptations implemented. The results of this systematic review are based on a qualitative analysis of the peer-reviewed literature published on climate change adaptation in the Arctic over 20 years from 2000 to 2020. Four indicators of climate change and three main types of adaptation were presented, the majority of which were enacted at an individual level. The four indicators of climate change were (1) the degradation of ice, (2) changes in ecosystems, (3) changes in weather patterns, and (4) changes in hydrogeological risk. The three main types of adaptation were (1) behavioral changes, (2) regulatory initiatives, and (3) changes to livelihoods or economics. Additional adaptations included changes or improvements to healthcare systems, emergency planning, and critical infrastructure. Taken together, the evidence indicates that individuals are implementing a variety of climate change adaptations across the Arctic.

References

Adger, W. N., Arnelll, N. W., & Tompkins, E. L. (2005). Successful Adaptation to Climate Change Across Scales. *Global Environmental Change, 2,* 77-86.

Adger, W. N., Barnett, J., Brown, K., Marshall, N., & O'Brien, K. (2013). Cultural Dimensions of Climate Change Impacts and Adaptation. *Nature Climate Change, 3*(2), 112-117.

Alexander, D. E. (1999). Bioaccumulation, Bioconcentration, Biomagnification. In *Environmental Geology: Encyclopedia of Earth Science*, 43-44. Springer.

Anderson, D. G. (2000). *Identity and Ecology in Arctic Siberia: The Number One Reindeer Brigade.* New York: Oxford University Press.

Aporta, C. (2003). New Ways of Mapping: Using GPS Mapping Software to Plot Place Names and Trails in Igloolik (Nunavut). *Arctic, 56*(4), 321-327.

Arctic Council. (n.d.). *Arctic Peoples*. Arctic Council. https://arctic-council.org/explore/topics/arctic-peoples/

Baxter, J., & Eyles, J. (1997). Evaluating Qualitative Research in Social Geography: Establishing 'Rigour' in Interview Analysis. *Transactions of the Institute of British Geographers, 22*(4), 505-525.

Baztan, J., Cordier, M., Huctin, J. M., Zhu, Z., & Vanderlinden, J. P. (2017). Life on Thin Ice: Insights from Uummannaq, Greenland for Connecting Climate Science with Arctic Communities. *Polar Science, 13,* 100-108.

Beck, U. (2009). *World at Risk.* Polity.

Berkes, F., & Dyanna, J. (2002). Adapting to Climate Change: Social-Ecological Resilience in a Canadian Western Arctic Community. *Conservation Ecology, 5*(2).

Berkes, F., & Folke, C. (2000). Linking Social and Ecological Systems for Resilience and Sustainability. In F. Berkes, C. Folke, & J. Colding (Eds.), *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience* (pp. 1-25). Cambridge University Press.

Borelli, T., Hunter, D., Powell, B., Ulian, T., Mattana, E., Termote, C., Pawera, L., Beltrame, D., Penafiel, D., Tan, A., Taylor, M, & Engels, J. (2020). Born to Eat Wild: An Integrated Conservation Approach to Secure Wild Food Plants for Food Security and Nutrition. *Plants, 9*(10), 1299.

Brubaker, M., Berner, J., Chavan, R., & Warren, J. (2011). Climate Change and Health Effects in Northwest Alaska. *Global Health Action, 4*(1), 8445.

Brunner, R. D., Lynch, A. H., Pardikes, J. C., Cassano, E. N., Lestak, L. R., & Vogel, J. M. (2004). An Arctic Disaster and Its Policy Implications. *Arctic*, *57*(4), 336-346.

Brubaker, M., Berner, J., Chavan, R., & Warren, J. (2011). Climate Change and Health Effects in Northwest Alaska. *Global Health Action*, *4*(1), 8445.

Burek, K. A., Gulland, F. M., & O'Hara, T. M. (2008). Effects of Climate Change on Arctic Marine Mammal Health. *Ecological Applications*, *18*, 126-134.

Cameron, E. S. (2012). Securing Indigenous politics: A Critique of the Vulnerability and Adaptation Approach to the Human Dimensions of Climate Change in the Canadian Arctic. *Global Environmental Change*, *22*(1), 103-114.

Canosa, I. V., Ford, J. D., McDowell, G., Jones, J., & Pearce, T. (2020). Progress in Climate Change Adaptation in the Arctic. *Environmental Research Letters*, *15*(9), 1-10.

Carson, M., & Peterson, G. (2016). *Arctic Resilience Report*. Stockholm: Stockholm Environment Institute and Stockholm Resilience Centre.

Crabtree, B. F., & William, W. L. (1999). *Doing Qualitative Research*. Sage.

Deneva, W. M. (1983). Adaptation, Variation, and Cultural Geography. *The Professional Geographer*, *35*(4), 399-407.

Driscoll, D. L., Sunbury, T., Johnston, J., & Renes, S. (2013). Initial Findings from the Implementation of a Community-Based Sentinel Surveillance System to Assess the Health Effects of Climate Change in Alaska. *International Journal of Circumpolar Health*, *1*, 21405.

Duerden, F. (2004). Translating Climate Change Impacts at the Community Level. *Arctic*, *57*(2), 204-212.

Dupuis, J., & Biesbroek, R. (2013). Comparing Apples and Oranges: The Dependent Variable Problem in Comparing and Evaluating Climate Change Adaptation Policies. *Global Environmental Change*, *34*(6), 1476-1487.

Einarsson, N. (2009). From Good to Eat to Good to Watch: Whale Watching, Adaptation and Change in Icelandic Fishing Communities. *Polar Research*, *28*(1), 129-138

Einarsson, N., Nymand Larsen, J., Nilsson, A., & Young, O. R. (2004). *Arctic Human Development Report*. Stefansson Arctic Institute.

Eisenack, K., Lüdeke, M., & Kropp, J. (2006). Construction of Archetypes as a Formal Method to Analyze Social-Ecological Systems. *Proceedings of the Institutional Dimensions of Global Environmental Change Synthesis Conference*, *6*, 1-17.

Eisenack, K., & Stecker, R. (2012). A Framework for Analyzing Climate Change Adaptations as Action. *Mitigation and Adaptation Strategies for Global Change, 17*(3), 243-260.

Fang, Z., Freeman, P. T., Field, C. B., & Mach, K. J. (2018). Reduced Sea Ice Protection Period Increases Storm Exposure in Kivalina, Alaska. *Arctic Science, 4*(4), 525-537.

Fawcett, D., Pearce, T., Ford, J. D., & Archer, L. (2017). Operationalizing longitudinal approaches to climate change vulnerability assessment. *Global Environmental Change, 45*, 79-88.

Fink, A. (2020). *Conducting Research Literature Reviews: From the Internet to Paper* (5 ed.). Sage.

Flynn, M., Ford, J. D., Pearce, T., Harper, S. L., & IHACC Research Team. (2018). Participatory Scenario Planning and Climate Change Impacts, Adaptation and Vulnerability Research in the Arctic. *Environmental Science & Policy, 79,* 45-53.

Forbes, B. C., & Stammler, F. (2009). Arctic climate change discourse: the contrasting politics of research agendas in the West and Russia. *Polar Research, 28*(1), 28-42.

Ford, J. D. (2009). Dangerous Climate Change and the Importance of Adaptation for the Arctic's Inuit Population. *Environmental Research Letters, 4*(2), 1-9.

Ford, J. D., Bolton, K. C., Shirley, J., Pearce, T., Tremblay, M., & Westlake, M. (2012). Research on the Human Dimensions of Climate Change in Nunavut, Nunavik, and Nunatsiavut: A Literature Review and Gap Analysis. *Arctic, 65*(3), 289-304.

Ford, J. D., Labbé, J., Flynn, M., & Araos, M. (2017). Readiness for Climate Change Adaptation in the Arctic: A Case Study from Nunavut, Canada. *Climatic Change, 145*(1), 85-100.

Ford, J. D., McDowell, G., & Pearce, T. (2015). The Adaptation Challenge in the Arctic. *Nature Climate Change, 5*(12), 1046-1053.

Ford, J. D., McDowell, G., & Jones, J. (2014). The State of Climate Change Adaptation in the Arctic. *Environmental Research Letters, 9*(10), 1-9.

Ford, J. D., Pearce, T., Smit, B., Wandel, J., Allurut, M., Shappa, K., Ittysyjurat, H., & Qrunnut, K. (2007). Reducing Vulnerability to Climate Change in the Arctic: The Case of Nunavut, Canada. *Arctic, 60*(2), 150-166.

Ford, J. D., & Smit, B. (2004). A Framework for Assessing the Vulnerability of Communities in the Canadian Arctic to Risks Associated with Climate Change. *Arctic, 57*(4), 389-400.

Ford, J. D., Smit, B., & Wandel, J. (2006). Vulnerability to climate change in the Arctic: A case study from Arctic Bay, Canada. *Global Environmental Change, 16*(2), 145-160.

Ford, J. D., Smit, B., Wandel, J., Allurut, M., Shappa, K., Ittusarjuat, H., & Qrunnut, K. (2008). Climate Change in the Arctic: Current and Future Vulnerability in Two Inuit Communities in Canada. *Geographical Journal*, *174*(1), 45-62.

Franzosi, R. (2008). Content Analysis: Objective, Systematic, and Quantitative Description of Content. In *The Content Analysis Guidebook* (pp. 21-29).

Furberg, M., Evengård, B., & Nilsson, M. (2011). Facing the Limit of Resilience: Perceptions of Climate Change Among Reindeer Herding Sami in Sweden. *Global Health Action, 4*(1), 8417.

Gallopin, G. C. (1991). Human Dimensions of Global Change: Linking the Global and the Local Processes. *International Social Science Journal*, *43*(4), 707-718.

Giles, A. R., & Castleden, H. (2008). Community Co-Authorship in Academic Publishing: A Commentary. *Canadian Journal of Native Education*, *31*(1), 208-213.

Giles, A. R., Strachan, S. M., Doucette, M., Stadig, G. S., & Pangnirtung, M. O. (2013). Adaptation to Aquatic Risks Due to Climate Change in Pangnirtung, Nunavut. *Arctic,* 66(2), 207-217.

Goldhar, C., Bell, T., & Wolf, J. (2014). Vulnerability to Freshwater Changes in the Inuit Settlement Region of Nunatsiavut, Labrador: A Case Study from Rigolet. *Arctic, 67*(1), 71-83.

Gosselin, P., Bélanger, D., Lapaige, V., & Labbé, Y. (2011). The Burgeoning Field of Transdisciplinary Adaptation Research in Quebec (1998–): A Climate Change-Related Public Health Narrative. *Journal of Multidisciplinary Healthcare, 4,* 337-348.

Gough, D., Oliver, S., & Thomas, J. (Eds.). (2017). *An Introduction to Systematic Reviews*. Sage.

Grant, M. J., & Booth, A. (2009). A Typology of Reviews: An Analysis of 14 Review Types and Associated Methodologies. *Health Information & Libraries Journal*, *26*(2), 91-108.

Hahn, T., & Nykvist, B. (2017). Are Adaptations Self-Organized, Autonomous, and Harmonious? Assessing the Social-Ecological Resilience Literature. *Ecology and Society, 22*(1), 12.

Healey, G. K., Magner, K. M., Ritter, R., Kamookak, R., Aningmiuq, A., Issaluk, B., Mackenzie, K., Allardyce, L., & Moffit, P. (2011). Community Perspectives on the Impact of Climate Change on Health in Nunavut, Canada. *Arctic*, *64*(1), 89-97.

Hepple, L. (2009). Complexity Theory. In D. Gregory, R. Johnson, G. Pratt, M. J. Watts, & S. Whatmore (Eds.), *The Dictionary of Human Geography* (5th ed., pp. 105-106). Blackwell Publishing Ltd.

Herman-Mercer, N. M., Matkin, E., Laituri, M. J., Toohey, R. C., Massey, M., Elder, K., Schuster, P. F., & Mutter, E. A. (2016). Changing Times, Changing Stories: Generational Differences in Climate Change Perspectives from Four Remote Indigenous Communities in Subarctic Alaska. *Ecology and Society, 21*(3).

Herrero-Jáuregui, C., Arnaiz-Schmitz, C., Reyes, M. F., Telesnicki, M., Agramonte, I., Easdale, M. H., Schmitz, M. F., Aguiar, M., Gómez-Sal, A., & Montes, C. (2018). What Do We Talk About When We Talk About Social-Ecological Systems? A Literature Review. *Sustainability, 10*(8), 2950. Sustainability, 10(8), 2950.

Hunt, M. (1997). *How Science Takes Stock: The Story of Meta-Analysis*. Russell Sage Foundation.

Huntington, H. P., Quakenbush, L. T., & Nelson, M. (2017). Evaluating the Effects of Climate Change on Indigenous Marine Mammal Hunting in Northern and Western Alaska Using Traditional Knowledge. *Frontiers in Marine Science, 4*, 319.

Ignatowski, J. A., & Rosales, J. (2013). Identifying the Exposure of Two Subsistence Villages in Alaska to Climate Change Using Traditional Ecological Knowledge. *Climatic Change, 121*(2), 285-299.

IPCC. (1996). *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses.* R. T. Watson, M. C. Zinyowera, & R. H. Moss (Eds.) Cambridge University Press.

IPCC. (2012). *Glossary of terms*. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Annex. Cambridge University Press.

IPCC. (2014). *Climate Change 2013: The Physical Science Basis*. New York: Cambridge University Press.

Janssen, M. A., Schoon, M. L., Ke, W., & Börner, K. (2006). Scholarly Networks on Resilience, Vulnerability and Adaptation within the Human Dimensions of Global Environmental Change. *Global Environmental Change, 16*(3), 240-252.

Jeffries, M. O., Richter-Menge, J., & Overland, J. E. (2012). *Arctic Report Card*. National Oceanic and Atmospheric Administration.

Kaján, E. (2014). Arctic Tourism and Sustainable Adaptation: Community Perspectives to Vulnerability and Climate Change. *Scandinavian Journal of Hospitality and Tourism, 14*(1), 60-79.

Keskitalo, E. C., & Kuulyasova, A. A. (2009). The Role of Governance in Community Adaptation to Climate Change. *Polar Research, 28*(1), 60-70.

Kofinas, G. P., Chapin, F. S., BurnSilver, S., Schmidt, J. I., Fresco, N. L., Kielland, K., Martin, S., Springsteen, A., & Rupp, T. S. (2010). Resilience of Athabascan

Subsistence Systems to Interior Alaska's Changing Climate. *Canadian Journal of Forest Research, 40*(7), 1347-1359.

Kovacs, K. M., Lydersen, C., Overland, J. E., & Moore, S. E. (2011). Impacts of Changing Sea-Ice Conditions on Arctic Marine Mammals. *Marine Biodiversity, 41*(1), 181-194.

Labbé, J., Ford, J. D., Araos, M., & Flynn, M. (2017). The Government-Led Climate Change Adaptation Landscape in Nunavut, Canada. *Environmental Reviews, 25*(1), 12-25.

Landauer, M., Juhola, S., & Söderholm, M. (2015). Inter-Relationships Between Adaptation and Mitigation: A Systematic Literature Review. *Climatic Change, 131*(4), 505-517.

Larsen, J. N., Anisimov, O. A., Constable, A., Hollowed, A. B., Maynard, N., Prestrud, P., Prowse, T. D., Stone, J. M. R. (2014). Polar Regions. In *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects, Contributions of Working Group II Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1567-1612). Cambridge University Press.

Loring, P. A., Chapin, F. S., & Gerlach, S. C. (2008). The Services-Oriented Architecture: Ecosystem Services as a Framework for Diagnosing Change in Social Ecological Systems. *Ecosystems, 11*(3), 478-489.

Loring, P. A., Gerlack, C., Atkinson, D. E., & Murray, M. S. (2011). Ways to Help and Ways to Hinder: Governance for Effective Adaptation to an Uncertain Climate. *Arctic, 64*(1), 73-88.

MacDonald, J. P., Willox, A. C., Ford, J. D., Shiwak, I., Wood, M., Government, R. I., & Team, I. (2015). Protective Factors for Mental Health and Well-Being in a Changing Climate: Perspectives from Inuit Youth in Nunatsiavut, Labrador. *Social Science and Medicine, 141*, 133-141.

Manrique, D. R., Corral, S., & Pereira, Â. G. (2018). Climate-Related Displacements of Coastal Communities in the Arctic: Engaging Traditional Knowledge in Adaptation Strategies and Policies. *Environmental Science & Policy, 85*, 90-100.

Martin, D., Bélanger, D., Gosselin, P., Brazeau, J., Furgal, C., & Déry, S. (2007). Drinking Water and Potential Threats to Human Health in Nunavik: Adaptation Strategies under Climate Change Conditions. *Arctic, 60*(2), 195-202.

McGovern, T. H., Vésteinsson, O., Friðriksson, A., Church, M., Lawson, I., Simpson, I. A., Einarsson A., Dugmore, A., Cook, G., Perdikaris, S., Edwards, K., J., Thomson, A. M., Adderley, W. P., Newton, A., Lucas, G., Edvardsson, R., Aldred, O., Dunbar, E. (2007). Landscapes of Settlement in Northern Iceland: Historical Ecology of Human Impact and Climate Fluctuation on the Millennial Scale. American Anthropologist, 109(1), 27-51.

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., Stewart, L. A., & PRISMA-P Group (2015). Preferred reporting items for systematic

review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews, 4*(1), 1-9.

Moser, S. C., & Ekstrom, J. A. (2010). A Framework to Diagnose Barriers to Climate Change Adaptation. *Proceedings of the National Academy of Sciences, 107*(51), 22026-22031.

Natcher, D. C., Huntington, O., Huntington, H., Chapin, F. S., Trainor, S. F., & DeWilde, L. O. (2007). Notions of Time and Sentience: Methodological Considerations for Arctic Climate Change Research. *Arctic Anthropology, 44*(2), 113-126.

Ogden, A. E., & Innes, J. L. (2009). Adapting to Climate Change in the Southwest Yukon: Locally Identified Research and Monitoring Needs to Support Decision Making on Sustainable Forest Management. *Arctic, 62*(2), 159-174.

Ostrom, E. (2009). A General Framework for Analyzing Sustainability of Social-Ecological Systems. *Science, 325*(5939), 419-422.

Pearce, T. D. (2009). Community Collaboration and Climate Change Research in the Canadian Arctic. *Polar Research, 28*(1), 10-27.

Pearce, T., Ford, J. D., Caron, A., & Kudlak, B. P. (2012). Climate Change Adaptation Planning in Remote, Resource-Dependent Communities: An Arctic Example. *Regional Environmental Change, 12*(4), 825-837.

Pearce, T., Ford, J., Willox, A. C., & Smit, B. (2015). Inuit Traditional Ecological Knowledge (TEK), Subsistence Hunting and Adaptation to Climate Change in the Canadian Arctic. *Arctic, 68*(2), 233-245.

Pelling, M. (2011). *Adaptation to Climate Change: From Resilience to Transformation.* Routledge.

Pennesi, K. (2012). Integrating Local and Scientific Weather Knowledge as a Strategy for Adaptation to Climate Change in the Arctic. *Mitigation and Adaptation Strategies for Global Change, 17*(8), 897-922.

Petticrew, M., & Roberts, H. (2008). *Systematic Reviews in the Social Sciences: A Practical Guide.* John Wiley & Sons.

Powell, B., Bhatt, I. D., Mucioki, M., Rana, S., Rawat, S., & Kerr, R. B. (2023). The need to include wild foods in climate change adaptation strategies. *Current Opinion in Environmental Sustainability, 63*, 101302.

Prno, J., Bradshaw, B., Wandel, J., Pearce, T., Smit, B., & Tozer, L. (2011). Community Vulnerability to Climate Change in the Context of Other Exposure-Sensitivities in Kugluktuk, Nunavut. *Polar Research, 30*(1), 1-21.

Purssell, E., & McCrae, N. (2020). A Brief History of the Systematic Review. In E. Purssell, & N. McCrae, *How to Perform a Systematic Literature Review: A Guide for Healthcare Researchers, Practitioners and Students* (pp. 5-17). Springer.

Rattenbury, K., Kielland, K., Finstad, G., & Schneider, W. (2009). A Reindeer Herder's Perspective on Caribou, Weather and Socio-Economic Change on the Seward Peninsula, Alaska. *Polar Research, 28*(1), 71-88.

Ristroph, E. B. (2019). Still Melting: How Climate Change and Subsistence Laws Constrain Alaska Native Village Adaptation. *Colorado Natural Resources, Energy & Environmental Law Review*, *30*, 245.

Ritchie, M., Frazier, T., Johansen, H., & Wood, E. (2021). Early Climate Change Indicators in the Arctic: A Geographical Perspective. *Applied Geography*, *135*, 102562.

Rosol, R., Powell-Hellyer, S., & Chan, H. M. (2016). Impacts of Decline Harvest of Country Food on Nutrient Intake Among Inuit in Arctic Canada: Impact of Climate Change and Possible Adaptation Plan. *International Journal of Circumpolar Health, 75*(1), 31127.

Skrylnikova, N. A., Lozhnikova, A. V., Muravyov, I. V., Kirpotin, S. N., & Ozheredov, Y. I. (2014). Forecasting the Local and Global Socio-Economic Impact of Climate Change in the Boreal and Arctic Regions of Siberia. *International Journal of Environmental Studies, 71*(5), 774-778.

Smit, B., Burton, I., Klein, R. J., & Wandel, J. (2000). An Anatomy of Adaptation to Climate Change and Variability. In S. M. Kane, & G. W. Yohe (Eds.), *Societal Adaptation to Climate Variability and Change* (pp. 223-251). Springer.

Smith, J. B., & Lenhart, S. S. (1996). Climate Change Adaptation Policy Options. *Climate Research, 6*(2), 193-201.

Srivastava, P., & Hopwood, N. (2009). A Practical Iterative Framework for Qualitative Data Analysis. *International Journal of Qualitative Methods, 8*(1), 76-84.

Stien, A., Ims, R. A., Albon, S. A., Fuglei, E., Irvine, J., Ropstad, E., Halvorsen, O., Loe, L. E., & Veiberg, V. (2012). Congruent Responses to Weather Variability in Higher Arctic Herbivores. *Biology Letters, 8*(6), 1002-05.

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.

Trainor, S. F., Calef, M., Natcher, D., F, S. C., McGuire, A. D., Huntington, O., Duffy, P., Rupp, T. S., DeWilde, L., Kwart, M., Fresco, N., & Lovecraft, A. L. (2009). Vulnerability and Adaptation to Climate-Related Fire Impacts in Rural and Urban Interior Alaska. *Polar Research, 28*(1), 100-118.

Trainor, S. F., Stuart Chapin III, F., Huntington, H. P., Natcher, D. C., & Kofinas, G. (2007). Arctic Climate Impacts: Environmental Injustice in Canada and the United States. *Local Environment, 12*(6), 627-643.

Tremblay, M., Furgal, C., Larrivée, C., Annanack, T., Tookalook, P., Qiisik, M., Angiyou, E., Swappie, N., Savard, J.-P., & Barrett, M. (2008). Climate Change in Northern Quebec: Adaptation Strategies from Community-Based Research. *Arctic, 61*(1), 27-34.

Tyler, N. J., Turi, J. M., Sundset, M. A., Bull, K. S., Sara, M. N., Reinert, E., & Corell, R. W. (2007). Saami Reindeer Pastoralism Under Climate Change: Applying a Generalized Framework for Vulnerability Studies to a Sub-Arctic Social–Ecological System. *Global Environmental Change, 17*(2), 191-206.

UNFCCC. (1992). *United Nations Framework Convention on Climate Change*. United Nations.

Wesche, S. D., & Chan, H. M. (2010). Adapting to the Impacts of Climate Change on Food Security among Inuit in the Western Canadian Arctic. *EcoHealth, 7*(3), 361-373.

West, J. J., & Hovelsrud, G. K. (2010). Cross-Scale Adaptation Challenges in the Coastal Fisheries: Findings from Lebesby, Northern Norway. *Arctic, 63*(3), 338-354.

Wilbanks, T. J., & Kates, R. W. (1999). Global Change in Local Places: How Scale Matters. *Climatic Change, 43*(3), 601-628.

Appendix

Search string used:
("adaptation" OR “adapt” AND "climate change" AND ("Arctic" OR "arctic" OR “Alaska” OR “Canada” OR “Finland” OR “Iceland” OR “Norway” OR “Sweden” OR “Russia” OR “Siberia”))

Databases searched:

- Academic Search Complete
- Directory of Open Access Journals
- Google Scholar
- ScienceDirect
- Taylor & Francis Journals
- Wildlife & Ecology Studies Worldwide
- Wiley Online Library
- Web of Science

Information gathered and qualitatively coded from articles:

- Title
- Abstract
- First author name
- First author country of institutional affiliation
- Year of publication
- Journal of publication
- Country of focus
- Adaptation definition
- Climate change indicator
- Actor leading adaptation
- Adaptation type
- Adaptation description