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Climate Impacts on Migration in the Arctic North America: Existing Evidence and Research Agenda

Abstract: Arctic temperatures are rising four times faster than in lower-latitude regions. Some of the hardest-hit places are rural, coastal, predominantly Indigenous, communities. Many such communities face multiple urgent climate-related challenges, including thawing permafrost, rising sea levels, declining sea ice cover, coastal erosion, and extreme storms. One response is migration to a new community or relocate an entire community. However, research on Arctic out-migration and community relocation is limited, even for the most threatened communities. This paper reviews existing research on the environmental factors affecting migration and community relocation in North America Arctic with the purpose of developing new research directions and identifying drivers of migration and relocation in this region. Research gaps and data limitations are evaluated, resulting in a model to guide future research and policy development. This review provides a foundation for empirical migration and community relocation research to better understand the challenges faced by Arctic communities and the solutions to these challenges.

Keywords: Climate change, environmental stressors, migration, community relocation, Arctic, indigenous peoples

1. INTRODUCTION

Climate changes and variations drive migration worldwide, as evidenced by a large and rapidly growing body of literature investigating the impact of environmental change on migratory processes (IPCC 2021; Warner et al. 2010). Globally, rising temperature, irregular precipitation, and environmental disasters such as wildfires, tsunamis, and hurricanes have triggered large-scale internal and international migration in recent decades. According to the Internal Displacement Monitoring Centre (IDMC), environment-related disasters internally displaced 32.6 million people, accounting for 53% of global internal displacements in 2022 (IDMC 2016). Drought- and desertification-related environmental migration is particularly pervasive in African countries, while floods are the primary environmental trigger for migration in some European countries (Piguet, Kaenzig, and Guélat 2018). In coastal regions and some island countries, environmental migration is more likely to be triggered by disasters, such as hurricanes, tsunamis, and sea-level rises. In South Asia, irregular rainfall and delayed monsoons contribute to out-migration (Thiede and Gray 2016). In tropical regions such as Indonesia and the Philippines, deforestation is an important environmental factor in migration decision-making (Darmawan, Klasen, and Nuryartono 2016). Migration can also exacerbate environmental degradation, for instance when remittances from migrants are channeled into grain and livestock farming, intensifying deforestation (Angelsen et al. 2020).

Arctic regions are largely absent from this literature and global debates on climate and migration. This is an important gap due to the severity of Arctic climate change impacts and the regional predominance of Indigenous communities many of which have already been negatively impacted by centuries of racism, cultural loss, and political disenfranchisement. Arctic temperatures are rising four times faster than in lower-latitudes (Anderson 2009; Rantanen et al. 2022; Wadhams 2017), resulting in permafrost thaw, rising sea levels, declining sea ice cover, and extreme storms, which are threatening community viability, health, and livelihoods. Scientists predict an increase in major Arctic cyclone events, leading to an increase in extreme weather events, like the 2022 Typhoon Merbok, devastating coastal communities and exacerbating coastal erosion and sea ice loss (Parker et al. 2022). These are rapidly eroding Arctic coasts, threatening subsistence food systems and residents' safety, and damaging community infrastructure and cultural heritage (Serreze 2018). These impacts create complex problems, raising critical social, legal, environmental, and engineering science questions.

Some of the hardest-hit areas are rural and coastal, with a predominantly Indigenous population. These areas have strong connections to the local landscape, upon which they depend (Borish et al. 2021; Hamilton et al. 2016; Marino 2015; Serreze 2018). One response to increased environmental variability and associated loss of livelihood security is to migrate to less impacted communities. Another leads to rural to urban migration as residents, especially younger ones, search for jobs and housing (Crate and Nuttall 2016; Hamilton et al. 2016; Marino 2015). Community relocation might protect particularly impacted coastal communities, but is extremely expensive and often impractical (Huntington et al. 2017; Magnan et al. 2022; Marino 2015). To date there is little evidence of large-scale Arctic rural out-migration, even from the most threatened communities, and existing evidence is inconsistent. Thus, it is important to develop better understanding of migration drivers and make policy-relevant recommendations to tackle the challenges faced by Arctic communities.

In our review of the Arctic migration literature, we focus on the potential drivers of environmental migration but also include the intermediate factors that link them. We address major gaps precluding a comprehensive understanding of patterns and processes within the context of rapid climate change and social, ecological, and infrastructure disruptions. We also examine the gaps in migration data at individual, household, and community levels. Ultimately, the goals of this paper are to review the evidence and build a research agenda and conceptual framework for Arctic environmental migration that establishes research needs and directions, evaluates existing and potential data sources, and lays a foundation for informed policy directions. Specifically, the paper will:

(1) Provide a comprehensive review of the roles that environmental stressors along with demographic, socioeconomic, legal, policy, cultural, and infrastructural factors and their interactions play in Arctic migration decision-making;
(2) Identify research gaps, recommend research directions, and propose a convergent approach to Arctic migration research.

This paper is organized into four sections, starting with a background of Arctic environmental change and migration, followed by a comprehensive review of Arctic migration literature and existing data inclusive of gaps and future research recommendations. We then conclude with recommendations for Arctic social science research and a new approach to Arctic environmental migration research. The focus is on the North American Arctic, reserving review of the environmental migration literature for the eight European countries with Arctic territory — Denmark, Finland, Iceland, Norway, Sweden, and Russia — for future work. Given geographic, cultural, and demographic similarities across the Arctic, the approach and recommendations from this paper should be relevant to migration research in all Arctic countries and provide a benchmark for future work.

2. BACKGROUND

2.1. Arctic Environmental Changes and Impacts

Rapidly occurring Arctic environmental changes require accelerated response and adaptation to the magnitude of damages (Ford, McDowell, and Pearce 2015; Rantanen et al. 2022). Permafrost is thawing, snow and ice cover is decreasing, and wildland fires are becoming more frequent (van Luijk et al. 2022; Schaffner 2020; Thoman and Walsh 2019). For example, in northwest Alaska, all permafrost is predicted to thaw by 2150 (Batir, Hornbach, and Blackwell 2017). Rapidly receding summer sea ice is another telling sign of Arctic's rising temperature. Sea ice recession has been observed since satellites first began taking measurements in 1979; recent estimates suggest the Arctic could be free of *all* summer sea ice by as early as 2026 (Guarino et al. 2020) and a 60% overall decrease in sea ice by the end of the 21st century (Parker et al. 2022).

Significant changes in the extent of sea ice have already led to new shipping routes that will have important economic and governance implications for the Arctic (Ford et al. 2021; Mudryk et al. 2021; Smith and Stephenson 2013). New shipping routes provide opportunities for new extractive industries in the Arctic.

These environmental changes will damage some existing infrastructure and can impact human health and quality of life, altering subsistence routines and ways of life (Ford et al. 2021; Harper et al. 2020). For example, increasing rainfall in the summer and fall months challenge fish drying and smoking preservation techniques. In some places, environmental change has resulted in long-term or seasonal loss of important sources of protein and food—for example, subsistence salmon closures on the Yukon River in the last several years or the loss of access to caribou, but an influx of moose, in some Bristol Bay communities in Alaska. Shifting freeze-thaw regimes in rivers and sea ports and increasingly unpredictable weather affect barge shipping of store-bought foods to remote communities, resulting in spoilage of perishable items and longer periods of time with sparsely stocked shelves (Mead-Morse et al. 2010). Dangerous winter travel over unstable and thinning ice and shifting wildlife populations increase risks of hunting excursions (Fleischer et al. 2013). Less sea ice overall may also open up new opportunities for offshore oil extraction and mining.

2.2. Arctic Migration and Demographics

Migration is a complicated and multifaceted decision-problem for individuals, families, and communities. This complexity is illustrated by migration duration (short term vs. long term); destination (domestic vs. international; nearby town, regional center, big city); status (current vs. seasonal vs. return), and population dynamics. The dynamics change over time and across space. During the past 100 years, there have been significant changes in the population of the Arctic, reaching a peak in 1989, and declining after the collapse of the former Soviet Union (Smirnov 2020). Over the last thirty years, in Alaska and Northern Canada, the Arctic population has increased about 25% due to natural increase (Hamilton, Wirsing, and Saito 2018a). Both Canada's Nunavut and northern Alaska had high natural increases over 1990–2017, but the latter's growth was partially offset by large out-migration. Surprisingly, Arctic communities that experienced high rates of coastal erosion (e.g., Kivalina, Shaktoolik, Shishmaref, and Unalakleet in Alaska) are also places with population growth due to high birth rates and relatively low net out-migration (Hamilton et al. 2016). Indigenous people make up most of the North American Arctic population and have deep ties to the land and its resources. Thus, migration determinants for Indigenous households relocating from or to remote rural Arctic communities are fundamentally different than migration considerations for people living in other parts of North America. Historically, Indigenous migration patterns were related to food resources, and Inuit peoples of Alaska and Canada were often nomadic or semi-nomadic (Brown 1969; Damas 2002). Government policies and colonization have been a driver of the sedentarization of Indigenous communities, eliminating traditional seasonal mobility and promoting the establishment of permanent villages (Ferris 2013; Wenzel 2009).

Contemporary migration in the Arctic is intimately connected to livelihoods, sustainability, and economic conditions (Dombrowski et al. 2016; Holen 2014). Individuals may migrate to seek better economic or educational opportunities, leaving other family members behind to continue subsistence livelihoods. Recent migration of non-Indigenous people to the Arctic has been driven largely by natural resources, mainly minerals such as gold, diamonds, oil, and gas (Heleniak 2014). There are also gender differences in migration, with women generally more likely to leave Arctic villages for urban destinations and men more likely to return to villages (Howe, Huskey, and Berman 2014; Martin 2009). Migration may also be a family or community decision through collective decisions to relocate. Infrastructure and general place amenities also play an important part in Arctic migration (Howe and Huskey 2022). For instance, the availability of housing, healthcare, clean water, modern septic or sewer systems, public safety, and educational

opportunities all impact migration decisions. Historically, changes in the environment, built infrastructure, and school relocations have influenced movement from Arctic villages, with especially drastic changes causing abandonment of entire villages (Brown 1969).

3. What We Know: Findings and Gaps from Existing Research

3.1. Theories

Much of the published Arctic migration literature is based on decennial Census data from Alaska or Canada, with additional sources from household surveys and qualitative and observational studies. Most focus on indigenous communities and seek to identify who moves and the push and pull factors that drive migration decisions and behavior. Many of these studies are descriptive, while others test standard and classical migration models explicitly or implicitly. These include formulations based on Ravenstein and colleagues' "laws of migration" (Ravenstein 1889), Todaro and colleagues' individual investment model (Todaro 1969), place amenities (Tiebout 1956), and related economic theories, including household production models and human capital theories. Cultural theories are sometimes invoked, and the role of environmental amenities and subsistence in the migration decision have been hypothesized, tested, and found to play a significant role (Berman 2009).

Hierarchical and stepped migration to increasingly urbanized centers are among Ravenstein's "laws of migration" and have been observed and tested in a few studies using data from northwest Alaska (Howe et al. 2014). Migration patterns, however, vary by population and place. Studies find that women leave small Arctic communities for larger urban centers at greater rates than men, while men are more likely to return to small communities (Hamilton et al. 2011; Hamilton and Seyfrit 1994; Howe et al. 2014; Martin 2009). In the Canadian North, White settler youth are more likely to migrate south than to other indigenous communities primarily for economic reasons and opportunities (Hillier et al. 2020).

Economic reasons for out-migration are central to a number of theories, including Todaro's model of expected wages in rural to urban migration decisions (Berman 2009; Howe et al. 2014) and Tiebout's hypothesis about the importance of place amenities in moving decisions (Howe and Huskey 2022). Other economic theories follow the new economics of labor migration (NELM) (Stark and Bloom 1985) to posit a household production model across origin and destination areas, where choices between formal employment, subsistence work, and leisure are a household-level negotiation (Howe 2009). Human capital theory is frequently cited as a primary driver of migration, with women migrating from rural to urban areas for higher education (Lowe and Sharp 2021). The super-household theory hypothesizes that 30% of households in a given community are extremely important harvesters, food sharers, and keepers of knowledge; if a super-household leaves, community food security and ways of life are gravely impacted. (Lowe 2010; Magdanz et al. 2011).

Theories that focus on the environmental consequences of climate change hypothesize that the impacts of disasters, environmental degradation, and loss of ecosystem services increasingly become major drivers of rural to urban migration. To date, there is little direct evidence to support this theory in the Arctic (Hamilton, Wirsing, and Saito 2018b). As climate related disasters increase, it will be important to further test it, especially since there is evidence that environmental amenities and subsistence opportunities are related to migration decisions, and climate change affects both of these.

Finally, taking the opposite approach, social-ecological resilience theory focuses on "stayers" rather than migrants, identifying mechanisms that keep people in place, including cultural and emotional ties and economic resources (McLeman et al. 2014). These include "attachment" reflecting deep identity and affinity with place; "alternatives" that identify small-scale substitutions to livelihood practices to maintain community life, even if at a lower standard of living; and "buffering," drawing on external resources such as subsidies and transfers (Huntington et al.

2018). Examples of each are found across the Arctic (Cunsolo Willox et al. 2012; Voorhees 2010) and should play a role in theorizing climate related migration.

3.2. Linking Environmental Changes to Arctic Migration

While the general environmental migration literature presents clear evidence that environmental changes have both direct and indirect impacts on migration in lower-latitude regions, the Arctic has mixed findings, differing on the scale of migration—individual, household, and community. Existing Arctic migration literature finds no evidence that environmental changes directly drive migration for individuals and households. For example, a study of 43 Alaska towns and villages, that covered places most threatened by climate-linked erosion and flooding, found no indication of enhanced out-migration between 1990 and 2014 compared with places without risk (Hamilton et al. 2016). The reasons residents decided against out-migration include not wanting to leave ancestral homes and lack of appealing alternatives. The literature suggests that it is other factors—e.g. jobs, education, and healthcare—that matter (Czaika and Reinprecht 2022; Mallick and Hunter 2023; Zickgraf 2021).

Results are different at the community level where community relocation—a planned and voluntary migration process—is widely studied in the Arctic context (Albert et al. 2018). Community relocation is defined as the wholesale relocation of a community's housing and public infrastructure to a safer location when it can no longer be protected in place (Bronen 2015). Arctic communities under environmental threats are forced to relocate because flooding, erosion, and storms are destroying their homes and civic infrastructure. Community relocation from climate-related environmental changes is a widely considered option in Alaska (Bronen and Chapin 2013), but it is an expensive process (Magnan et al. 2022). For example, Newtok village, a Yup'ik community on Alaska's west coast, will have expended more than $200 million to complete its relocation efforts, which has already taken more than 30 years (U.S. Government Accountability Office 2020). Even with financial resources available, some communities in the circumpolar North, especially Indigenous communities, have opposed community relocation because of past experiences with displacement or forced and semi-forced population movements (Ford et al. 2015; Stepien et al. 2014). As of 2022, 144 of the 229 Alaska Native Tribes are under environmental threats (Division of Community and Regional Affairs 2021), 15 are exploring relocation, and only one, Newtok, is about to complete its relocation (U.S. Government Accountability Office 2009). Many communities facing environmental threats cannot meet the overly burdensome requirements of federal disaster mitigation programs and are ineligible for disaster funding (Korkut et al. 2022; Waldholz 2017).

3.3. Other Driving Factors of Arctic Migration

Migration decision making at the individual, household, and community levels could be affected by a wide range of factors including demographic, socioeconomic, legal, policy, cultural, and infrastructural factors. Existing migration literature often found it is these factors, not environmental stressors, that drive migration in the Arctic (Huntington et al. 2018). Table 1 summarizes these factors and their evidence in the North American Arctic, and identifies research gaps to address. A detailed review of these factors is provided in the Supplementary Material. In this article we focus on environmental migration.

3.4. Existing/Traditional Data

Environmental migration studies require data that measure migration as well as environmental factors (see Table 2 for existing environmental migration-related datasets in the Arctic North America). Censuses and surveys are common datasets that enable researchers to construct migration measures. Environmental datasets consist of land-based weather stations, remote-sensing images, and model-based estimates. However, the availability and quality of these sources have been a major issue.

Official, publicly available statistics are the source of most data, including data from the U.S. Census, the American Community Survey (ACS), Alaska vital statistics, and a variety of State of Alaska sources. Although valuable in contributing to demographic understanding, each is limited for social and demographic research purposes. For example, ACS data are unreliable for small rural areas, given increased sampling error, estimated to be on average 75% larger than sampling error in the 2000 decennial census long form data (Spielman, Folch, and Nagle 2014). Alaska official data are primarily conducted for tangential purposes. For example, the Alaska Department of Fish and Game (ADFG) conducts surveys of Alaskan wildlife resources, household subsistence activities, and harvest counts. Some ADFG surveys include migration questions, but they are not the primary focus and vary over time and place, with long lags between collection. Almost all Alaskans apply annually for the Alaska Permanent Fund Dividend (PFD); related data can allow one to identify where individuals live, which allows some migration analysis by age and gender, but analysis using other socioeconomic characteristics is restricted. In the Canadian Arctic, the Canadian Census and the Canadian Community Health Survey are two major sources for constructing migration-related measurement but they have similar problems as the U.S. data such as large sampling errors.

Beyond official sources, numerous surveys and qualitative case studies have been conducted by researchers, but the expense and logistics of conducting research in a territory as large as Alaska or Canada, with very small, scattered communities, means that most studies are very focused and limited in time and place. One comprehensive source of survey data across Arctic comes from the SLiCA survey that was administered to multiple Indigenous populations in the circumpolar North between 2001 and 2006 (Eliassen et al. 2012). However, SliCA data are quite old, as is much of the existing research. Most studies are at least five years old, with many of the most informative quite a bit older.

4. Recommendations for Arctic Social Science Research

4.1. Considering the Complexity and Uniqueness of Environmental Migration in the Arctic Context

In the Arctic, little evidence exists of climate-driven migration at the individual and household levels, but clear evidence is available at the community level. This may reflect that migration is a complex and unique system in the Arctic context. We suggest three directions for future research. First, net migration (in-migration – out-migration) or gross migration (in-migration + out-migration) does not reveal the full picture of migration in the Arctic context. Rather, migration should be measured by its typology—modeling in-migration and out-migration separately; examining stepwise and circular migration; and considering duration (short term, long-term, and seasonal). Partitioning migration into different components is particularly important in the Arctic because its demographic composition, socioeconomic status, and culture vary greatly from one place to another.

Second, environmental stressors in the Arctic differ significantly from those in lower-latitude regions. Permafrost erosion and diminishing sea ice are unique to the Arctic and have significant implications for community well-being, which consequently has implications for migration. Permafrost erosion and diminishing sea ice are predominately chronic or slow onset environmental stressors, with thresholds problematic to human wellbeing only recently approached. Thus, long-term consequences of climate change in the Arctic are yet to be fully realized. Further investigation of how these are evolving and how complex environmental stressors will influence migration decisions over time is necessary.

Third, the drivers of climate and environmental migration need to be disentangled from other factors described in this review. Climate change impacts are tied to tangible and pressing economic and social issues in communities. In response to questions about climate and migration it is possible that respondents are more inclined to see the economic and social factors driving

their actions than the impacts of climate change (Huntington et al. 2018). Climate change may be the exogenous variable that determines economic wellbeing, social status, and health outcomes which motivate migration decisions. Modeling and unraveling relationships among a suite of drivers, including environmental change, is challenging given the complexity, quality, and extent of data, but will greatly increase our understanding of the drivers and their interactions. Models must include scale and time factors and "regional and national socioeconomic and sociopolitical conditions as well as household compositional characteristics" (Hunter, Luna, and Norton 2015: 379).

4.2. Systematic Data Collection and Integration

Data obstacles to acquiring comprehensive understanding of migration behavior and decisions are rooted in inconsistent units of analysis and study areas and lack of comparable data. Studies often are conducted at different levels of analysis, from individuals to families and households, whole communities, and multiple administrative units. Each may be informative, but they lack consistency and comparability. Similarly, the geography often is not comparable, limiting comparisons across places. The small populations in widely scattered rural places mean there are small numbers of cases, even in quantitative studies, which limits multivariate data analysis. The failure to systematically include demographic variables of interest has already been noted. There are difficult data management decisions and tasks if data are collected from different sources, such as matching geophysical data on environment and climate with social and demographic data related to migration.

The urgency of managing, mitigating, and adapting to climate change means that more comprehensive efforts at collecting data across Arctic regions should be a priority. This can be done in three ways. First, existing social data, collected by federal, state, and regional agencies, could be collaboratively integrated into a clean database. Such a database should clearly specify the geography, time, scale, variables, and other information. The Integrated Public Use Microdata Series (IPUMS) data that were assembled and harmonized by the Minnesota Population Center is a good example.

Second, federal, state, and regional agencies that collect social data, as well as public and private funding agencies should collaborate to make data more comparable, available and, less redundant for research and policy purposes. For example, in the North Slope of Alaska, the US Census Bureau has conducted the decennial census and American Community Survey as in other regions; the North Slope Borough has conducted their own census every five years; and the National Science Foundation has funded several projects over the years that collect social data. With planning and integration, duplication and overburdening Arctic communities could be avoided, producing value for Arctic communities and the broader scientific community. However, more often than not, these data are generated and used separately. Federal and State agencies should work together to develop a protocol for future social data collection and integration.

Third, a higher proportion of research funding should be allocated to Arctic social science research to enable primary data collection including geographically referenced longitudinal migration data. Over the past two decades, only 5% of funding globally has been allocated to social science research, and much less is known about Arctic social science than social science in other regions. Given the progression and urgency of climate change, understanding their impacts on human beings from the lens of social science is essential to adaptation, policy, and resilience. Recently, the National Science Foundation has encouraged social science research in the Arctic through convergent research, such as the newly formed Navigating the New Arctic program (National Science Foundation 2022). Yet more is needed from a wider range of sources (Osipov et al. 2016; Overland and Sovacool 2020).

4.3. Utilizing Nontraditional Data

Traditional data collection methods for migration studies are usually done using surveys, interviews and focus groups, which can be expensive and time consuming. The research community has long advocated for alternative data sources to study human migration (Yin and Chi 2021). Nontraditional data sources, such as digital trace data**,** are records of human activities undertaken through online information systems, including social media, search engines, websites, and transaction systems. The whereabouts of individuals can be observed whenever they interact with the information systems, such as making a phone call, posting a social media message, or swiping a credit card. A common use of geo-located digital trace data for migration studies is to track the movements of migrants by generating the location history of individuals over time. Three types of geo-located digital trace data are identified in the literature:

(1) *Mobile device location data:* The geo-locations of mobile devices can be identified by mobile positioning technology through cell towers, GPS, and Wi-Fi. Because of the ubiquitous use of mobile devices, mobile device location data are useful in studying population distribution, short-term urban mobility, and large-scale human migrations (Hankaew et al. 2019).

(2) *Geo-located social media data:* When people interact on social media, the location information of the interactions is collected by social media platforms. Researchers have used Facebook data to study migration patterns (Spyratos et al. 2018) and their ties to specific events, such as the impact of Hurricane Maria on out-migration from Puerto Rico (Alexander, Zagheni, and Polimis 2019).

(3) *Residential history data:* Residential history data, also known as consumer reference data, are collected through activities related to consumer transactions. Compared with the two aforementioned data sources, residential history data can provide a much more accurate estimation of an individual's residence (Stewart 2021). The migration flows generated from these data are used to explore regional factors and neighborhood effects tied to immigration (Amornsiripanitch et al. 2021). The data are particularly useful for examining migration patterns at fine spatial and temporal scales.

While digital trace data show great potential for migration research, there is concern about the digital divide in the Arctic. The availability of digital trace data is dependent on the adoption of digital technologies. However, digital information systems, such as smartphones, high-speed Internet, and digital payment systems, are limited in the Arctic (Abramov, Burlov, and Tatarnikova 2021). Social media use is skewed toward a younger demographic, there is a lack of cell phone use in some populations (particularly low income or homeless), and certain populations have poor access to and use of digital transaction systems. Yet, with fast Internet connections from 5G networks and from potential worldwide satellite broadband, it is expected that more people will adopt digital technologies.

5. Convergent Approach to Arctic Environmental Migration Research

Given its complexity, migration should be studied comprehensively as a consequence of changes in environmental, economic, and sociodemographic components across space and over time. A creative approach is needed that combines existing data with new data collection and innovative sources while engaging meaningfully and equitably with communities to understand what drives migration and at what scales. This approach includes partnership and engagement with local communities to ground the process and outcomes in community needs and challenges. We recommend a complex systems approach in close collaboration with local communities to model the pathways from environmental changes to ecological and infrastructure disruptions that lead to migration. This approach could develop a convergent environmental migration theory and models that predict tipping points to estimate nonlinear relationships between environmental change and Arctic migration.

5.1. Comprehensive Conceptual Framework

Environmentally driven migration is much less understood than migration caused by socioeconomic factors because of fewer environmental migration theories, the unknowns of the pathway mechanisms, the complex dynamics (e.g., tipping points, nonlinearities) of the many factors involved, and the difficulty in integrating social and natural science data and findings. Arctic environmental migration research is even less understood (Marino 2015). We build on existing theoretical perspectives of migration but extend our conceptual framework to include the Arctic's unique characteristics. Our approach considers migration as a consequence of changes along spatial and temporal dimensions of environmental, economic, cultural, and sociodemographic factors. Our conceptual framework (Figure 1) illustrates how environmental stressors disrupt civil infrastructure, and coastline protection facilities, resulting in ecological disruptions, impacting food security and nutrition, and possibly leading to migration or community relocation both directly and indirectly (Penn, Loring, and Schnabel 2017). In building and testing this model, it is important to consider the different levels of migration decisions within and among families and communities closely connected by culture and history. Migration, as a consequence of environmental stressors, should be examined at different levels. Further, the typology of migration—in-migration and out-migration, stepwise and circular migration, and duration (short term, long-term, and seasonal)—should be carefully considered because the migration outcome can differ considerably, depending on which migration variables are measured. The conceptual model will guide hypothesis generation and testing that will build the convergent approach we identify as necessary for Arctic climate and environmental change research.

5.2. Methodological Approach

The complex systems approach we recommend combines spatial analysis, interviews and surveys, multilevel regression models, and agent-based modeling to measure migration and its driving factors and model their relationships. The interactions among the drivers must be included as part of complex environmental migration dynamics. This approach must include local community engagement and community based participatory research methods, including as project co-leaders, sustained collaboration, and integration of local and Indigenous perspectives. Potential quantitative analyses include structural equation models (SEMs) and path analysis to identify latent and salient variables and the strength of interactions among key factors and sensitivity analysis of the SEM to explore potential thresholds of the effects. Community meetings and focus groups can be used to test and validate models to ensure the drivers and processes being examined are grounded in local experiences and decisions. Survey data and multivariate regression analysis can be used to explore the extent that coastal erosion affects a household's decision to stay or move. The analyses and modeling will be both exploratory and hypothesis testing—theory driven where the literature is well-developed, and exploratory for relationships across complex systems such as the pathways from environmental stressors to migration. This is an opportunity to develop system models to mirror the complex relationships that have not been adequately examined in this environment or with these populations, and can then be subject to further empirical tests.

5.3. Engaging Local Communities and Arctic Research Ethics

It is critically important to engage and collaborate with local communities throughout the lifecycle of a research project. It helps ensure the success of a project and will lead to wider community and societal impacts. Participatory and community engaged approaches with Indigenous and other communities, that have experienced trauma from colonization and extractive and problematic research practices, is becoming more widely accepted in many disciplines. Demographers studying migration have the opportunity to adapt this approach for reciprocal benefit. Communities in the Arctic have both local and Indigenous knowledge that can complement and enhance western science knowledge. Particularly for environmental migration,

oral histories of ecosystems and society can inform the condition of landscapes and the movement of people over generations, contributing detailed case studies which can be scaled up (Thornton and Scheer 2012). Communities are also interested in learning more about broad migration trends in and out of their town as it impacts long-term strategic plans of community development and many facets of life (Rosellon-Druker et al. 2021).

In the last several years an apology from the American Anthropological Association (American Anthropoligical Association 2021) and a petition from Tribal governments and Alaska Native organizations to the National Science Foundation have emphasized the crucial importance of community engagement and collaboration and proper community based research ethics across all disciplines and forms of research. Tribal and Alaska Native organizations noted the lack of consultation and inclusion of Tribes in projects taking place in rural communities that are predominately Alaska Native for the NNA Initiative (The National Science Foundation 2021). A good starting point for community engaged and participatory research in the Arctic is the Alaska Federation of Natives Guidelines for Research (Alaska Native Knowledge Network n.d.) and the National Science Foundation's Office of Polar Programs Principles for Conducting Research in the Arctic (U.S. Interagency Arctic Research Policy Committee 2018). Knowledge co-production is an important component of a successful collaborative project with rural communities, with guidelines outlined by the Inuit Circumpolar Council and others (Yua et al. 2022).

Arctic temperatures are rising four times faster than in lower-latitude regions (Anderson 2009; Rantanen et al. 2022; Wadhams 2017). The impacts create complex convergent research problems with important societal implications, raising critical social, legal, natural, and engineering science questions. Some of the hardest-hit places are rural coastal, predominantly Indigenous, communities with vibrant cultures that closely intersect with local land and seascapes. Many face urgent challenges from multiple climate-related changes (Hamilton et al. 2016; Marino 2015; Serreze 2018), that threaten subsistence food systems, residents' safety, and community infrastructure and cultural heritage (Serreze 2018). Even though the total population is small, the rapidity and extremeness of climate changes make the Arctic the proverbial canary in the coal mine. Migration as a possible coping strategy to climate change is important to understand but much less studied in the Arctic. This paper provides an overview of the major findings and gaps in the literature, and recommends strategies and directions to understand the drivers and determinants of migration as part of the efforts to tackle the challenges faced by Arctic communities.

Statements and Declarations

Competing Interests

The authors declare no competing interests.

Data Availability

This review article does not include any empirical data.

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Table 1. Driving Factors of Migration in the Arctic

Components	Key references	Major findings	Research recommendations (based on gaps in the literature)
Environmental stressors: permafrost erosion, flooding, storms	Bronen 2015; Bronen and Chapin 2013; Hamilton et al. 2016	1. No clear evidence of direct effects from environmental stressors to out-migration at the individual/household level. 2. Strong evidence of community relocation related to environmental threats.	1. Collect longitudinal data-tracking migration and its drivers (including direct and indirect effects of environmental stressors). 2. Include causality in analysis, not only association. 3. Consider the typology of migration. 4. Collect more social data and consider the use of nontraditional data sources.
Demographics: age, gender, race/ethnicity, family	Emelyanova and Rautio 2019; Hamilton and Seyfrit 1994; Howe, Huskey, and Berman 2014; Kleinfeld, Kruse, and Travis 1983	1. Youth and women are more likely to leave rural villages for education, jobs, and marriage. 2. Men are more likely to stay or return for subsistence activities. 3. Seniors are more likely to return to home villages on retirement. 4. Family dynamics are especially influential for women's migration.	1. Determine how demographics influence migration decisions and behavior and if climate stressors are implicated. 2. Examine multiple demographic factors and their intersections simultaneously. 3. Disaggregate demographic data, where available, and collect new data where it isn't.
Social capital: social ties, migrant networks	Lowe 2010, 2015; Massey and España 1987; Voorhees 2010	1. Social ties in rural areas are critical resources sustained by relationships of reciprocity. 2. Migrants maintain strong ties to their rural communities through visits, continued engagement in subsistence, and exchanges of traditional foods. 3. Ties to family members in cities facilitate the migration of children and youth for educational purposes.	1. Understand how social capital in both origin and destination areas shapes decisions about whether and where to migrate. 2. Explore how out-migration impacts social cohesion in origin communities. 3. Examine interrelationships among climate change vulnerability, social capital, and migration.
Food security: subsistence, store-bought foods, food sovereignty, super-households	Baggio et al. 2016; Berman 2021; Brown et al. 2008; Cidro et al. 2015; Wolfe 1987	1. Food (in)security is hypothesized to be a cause or impact of migration. 2. Migration to urban places may expedite nutrition transition and deteriorate household food security in Indigenous households. 3. Households with characteristics that explain success in subsistence are less likely to migrate out of rural Alaska and Canada.	1. Demonstrate if and how migration impacts household and community food security (and vice versa) using simultaneous effects. 2. Examine the role and impact of subsistence vs. store bought foods security/sovereignty and environmental change in household migration decisions. 3. Investigate gendered migration and its influence on household and community roles in subsistence harvest and security.

Infrastructure: roads, bridges, airports; electricity, gas, public water, sewage, telecommunication	Hjort et al. 2018, 2022; Howe and Huskey 2022; Lynda and Phyne 2014; Ramage et al. 2021	1. Permafrost degradation, coastal erosion, and flooding impact physical infrastructure and population growth. 2. Infrastructure development drives population displacement and in-migration for economic opportunities. 3. Climate-related infrastructure damage reduces water quality and access, local mobility, and health outcomes. 4. Receding sea ice results in new mineral, oil, and gas extraction and new shipping traffic, leading to new development opportunities, in-migration, and employment. 5. Government spending includes critical infrastructure support and transfer payments.	1. Understand how climate risks deter infrastructure development in rural Alaska, especially in communities that relocate but want to maintain cultural continuity and subsistence activities in place. 2. Identify resilient infrastructure situated within socio-environmental systems. 3. Understand climate impacts on housing quality and residents' wellbeing and sustained residence.
Healthcare and education: quality, affordability, accessibility, disparities	Allen, Levintova, and Mohatt 2011; Christensen et al. 2017; Driscoll et al. 2010; Hotez 2010; Howe et al. 2014	1. Lack of accessible, affordable, and quality health care and education drives rural to urban migration and amplifies chain migration. 2. Temporary migration of teachers into small remote rural communities creates unique opportunities and challenges. 3. Arctic communities face physical and mental health disparities.	1. Understand the impact of climate change on health and education infrastructure and quality and their interactions with migration. 2. Examine the dynamics between school presence and migration behaviors. 3. Explore the variation in health and healthcare-motivated migration across the life course.
Legal and policy: availability of government programs for community relocation	Dundon and Abkowitz 2021; Mach et al. 2019; Saunders-Hastings, Barnard, and Doberstein 2020; Whittaker 2021	1. Community relocation as a proactive adaptation strategy is widely discussed in the United States but underfunded. 2. Less discussion of community relocation in other Arctic countries.	1. Examine the influences or motivations that affect discussions about community relocation across the Arctic. 2. Study the implementation of proactive community relocation programs as an adaptation strategy in Arctic countries.
Staying factors: family, culture, feeling safe, jobs, subsistence lifestyle, sense of community, tranquility, natural environment, living costs	Dombrowski 2007; Holen 2014, 2017; Huntington et al. 2017; Marino and Lazrus 2015	1. Reasons to remain in place are consistent across regions: family, culture, and the subsistence way of life. 2. Subsistence foods and their places and cultural connections are reasons for vulnerable and food-insecure households to remain in place.	1. Generate information on place amenities that allow residents to feel safe and have adequate services, e.g., housing availability, infrastructure maintenance, sanitation, health services, and law enforcement. 2. Understand impacts of lack of basic services, health care, and law enforcement in rural communities.

Table 2. Existing Environmental Migration–Related Datasets for Alaska

Dataset	Time period	Description	Source
Arctic Data Center	Dataset time periods vary across data products	Arctic-related studies including data, software, and documents	https://arcticdata.io
Arctic Biodiversity Data	Dataset time periods vary across data products	Biodiversity data across the Arctic region	https://www.abds.is/
Arctic Demography Index	2011–2019	Data on population change and educational, labor, snowbird, and sunshine migration in the five Arctic Council member-states (Russia, Finland, Norway, Sweden, Canada)	https://www.arctic-council.org/projects/arctic-demography-index
Scenarios Network for Alaska and Arctic Planning (SNAP)	Dataset time periods vary across data products	Historical and projected climatic conditions such as temperature, precipitation, and permafrost thickness	https://uaf-snap.org
U.S. Census	1790–2020	Enumerations and estimates of the U.S. population across time	https://www.census.gov
Canadian Community Health Survey	2001–2021	Health-related data at the community level in Canada including Canadian Arctic	https://www.statcan.gc.ca/en/survey/household/3226
Internal Revenue Service (IRS)	1990–2019	County-to-county migration flows based on address changes reported in tax files	https://www.irs.gov/statistics/soi-tax-stats-migration-data
National Oceanic and Atmospheric Administration	Dataset time periods vary across data products	Data on weather conditions, ecosystems, and natural resources in Alaska	https://www.noaa.gov/
Alaska departmental databases	Dataset time periods vary across data products	Vital statistics and historical and projected population in Alaska; can be used to construct migration measures and contextual socioeconomic and demographic factors	https://dhss.alaska.gov/Pages/default.aspx https://labor.alaska.gov
Alaska Satellite Facility	Dataset time periods vary across data products	Remote-sensing data in Alaska such as land cover and NDVI	https://asf.alaska.edu

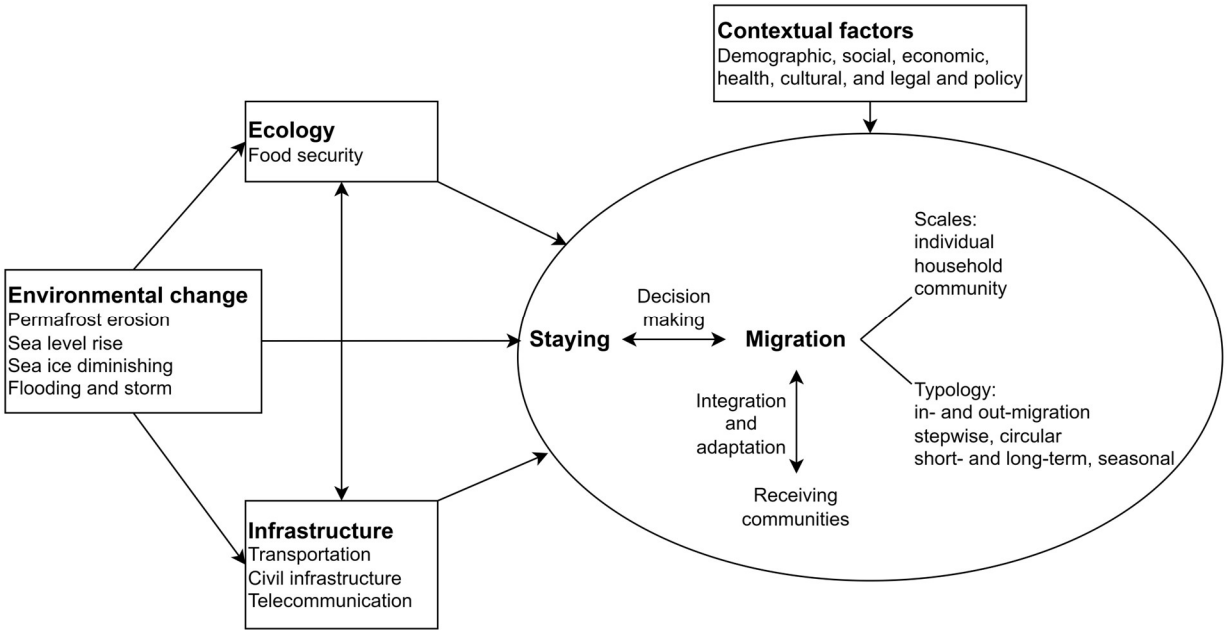

Figure 1. A conceptual framework of environmental migration