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Coastal communities in the Circumpolar North and the need for sustainable climate adaptation approaches

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Climate change is one of society's greatest contemporary challenges. Increasing global temperatures leave coastal locations in particular, vulnerable to impacts that include rising sea levels and more extreme and variable weather events. Stress can be acute for small coastal communities located in the Circumpolar North, where a lack of capacity and awareness along with institutional constraints, can exacerbate vulnerability. Given that continued climate change is inevitable regardless of the extent of mitigative action, adaptation is a necessity. In northern regions, there is evidence that adaptation planning is occurring in response to observed climate stressors, with structural (or hard) adaptation approaches prevalent across the sensitive coastline. However, structural adaptations are often associated with several drawbacks and may not be suitable, particularly in a region that is facing rapid rates of warming, enhanced exposures, and significant environmental and socio-economic constraints. To enhance resilience, small northern coastal communities should adopt a diversified portfolio of adaptations that incorporate more sustainable non-structural and ecosystem-based (or soft) adaptation approaches.

Keywords: climate impacts; community planning; climate resilience; climate policy, northern communities

Introduction

Climate change is a pressing problem and presents unique challenges for societies across the globe. Coastal communities located in the Circumpolar North, in particular, exhibit a heightened vulnerability to climate impacts given their geographic location, population density, dependence on marine resources, and exposure to a range of climate stressors (Ford, Bell, & Clark, 2018). The Circumpolar North, also referred to as the Arctic Circle, is widely defined as the polar region located approximately 66.5 degrees North of the equator. While definitions of the North can vary substantially, and include delineations based on temperatures, the Arctic tree line, permafrost zones, and political and cultural surroundings, the most reliable definitions are based on constant attributes such as latitude. Located in the northernmost part of the globe, this region is experiencing significant and unprecedented change with rates of climate change more rapid than anywhere else on earth (Emmerson & Lahn, 2012). Further, coastal vulnerability in the North will likely increase as some degree of further climate change is inevitable, even with ambitious mitigation efforts (IPCC, 2018). Indeed, climate scholars have suggested that because of lags in the system, communities are likely to see significant unavoidable changes that will

persist through to the middle of the century (e.g. Wilson, 2006). With this in mind, adaptation comes into play.

Adaptation strategies are intended to moderate or avoid harm associated with climate impacts (IPCC, 2018). The urgency of adaptation is gaining salience among scholars and government decision-makers (e.g. elected officials, senior administration) who stress that a robust response to climate change must integrate aspects of both mitigation and adaptation (e.g. IPCC, 2018; Bulkeley & Tuts, 2013). Yet, at the local government scale adaptation planning is still in its infancy, with approaches often reactionary and fragmented in practice (Wise et al., 2014; Reiblich et al., 2019). Moreover, in northern coastal communities preferred adaptation approaches often lack diversity (Sydneysmitch et al., 2010), with a prevalent reliance on hard structures such sea walls, armoring, and rip rap. Structural (or hard) adaptation approaches hinge on providing visible security through use of engineered structures. However, these approaches are associated with significant drawbacks and lack the flexibility, long term sustainability, and cost efficiency that non-structural and ecosystem-based (or soft) adaptations can offer. Indeed, hard structures may be insufficient in a climate that is becoming increasingly extreme and variable (Rulleau & Rey-Valette, 2017), highlighting the necessity of integrating more sustainable and soft adaptation approaches.

This emerging studies article first, explores climate change vulnerabilities and challenges in the Circumpolar North. Then, provides a description of potential adaptation approaches, including their benefits and drawbacks. Lastly, opportunities for intervention and critical insights are provided.

Communities in the Circumpolar North in a changing climate

Climate change impacts influence communities in a variety of ways, according to differences in exposures, vulnerabilities, and adaptive capacities (Dolan & Walker, 2003). In the Circumpolar North, communities are experiencing unprecedented increases in temperature, with climate impacts becoming more frequent and severe (Emmerson & Lahn, 2012; IPCC, 2018). For coastal communities in the north, sensitivity to environmental change is acute and climate stressors pose a significant threat to assets, infrastructure, and human health and safety.

For example, in small Alaskan communities like Shishmaref, increases in coastal erosion and flooding events have been observed as a result of the cumulative effects of sea level rise, sea ice loss, and storm surge. Ten flooding and 11 intense coastal erosion events were recorded in Shishmaref between 1973 and 2015, with several declared state and federal emergencies (Hamilton et al., 2016). These climate stressors have had a devastating effect on the village. Erosion has undermined buildings, causing several structures to collapse into the sea and flooding events pose a serious threat to infrastructure and resident safety (Hamilton et al., 2016). Further, as permafrost degrades and melts, ground stability becomes inherently unpredictable, resulting in sinking homes, cracking roads, and damaged utilities.

Efforts to reduce vulnerability vary substantially between communities, according to differences in strategic priorities, adaptive capacities, and the nature of the climate stressors. In small northern coastal communities, the ability to respond to climate change through adaptation planning is highly complex. Indeed, scholars emphasize that small communities experience climate threats differently than larger cities (e.g. Hamin et al., 2014). These communities are frequently challenged by a lack of capacity, conflicting perceptions and awareness, and

institutional factors (Birchall, 2019; Betzold, 2015). Further, with a limited tax base, small towns can be challenged by a lack of financial resources, shortages in qualified personnel, and appropriate climate data (Major & Juhola, 2016). Adding further stress, many small coastal communities are heavily dependent on marine resources, which may lead to greater financial stress as climate change impacts threaten the health and functioning of marine ecosystems (Fischer, 2018). Indeed, given the lower levels of biodiversity, for example, marine environments in the Circumpolar North, and Arctic ecosystems in general, can be highly sensitive to changes in climate (Boelter & Mueller, 2016).

Alongside their limited capacity, small communities in the Circumpolar North tend to be remotely located and subject to significant social and political challenges (Betzold, 2015). In this vein, scholarship suggests that the maintenance of livelihoods can overshadow climate stressors in the minds of community members, which can significantly influence momentum for adaptation planning (Fischer, 2018; Nunn et al. 2014). The development of a climate adaptation agenda is further constrained if local decision-makers view climate change as a distant threat, not requiring immediate attention, and/ or if adaptation initiatives are in conflict with goals associated with economic growth (Betzold, 2015; Hamin et al., 2014; Birchall & Bonnett, 2019).

Taking action: Adaptation approaches

The path a community takes to improve its resilience to climate change is often a function of vulnerability, capacity to act, strategic priorities, and relationship with the surrounding built and natural environment. In general, coastal adaptations can be broken down into three approaches: 1) structural adaptations; 2) non-structural adaptations; and, 3) ecosystem-based adaptations (Table 1).

Definition and classification	Examples to reduce vulnerability in practice	Benefits	Drawbacks
Structural (hard adaptations)			
An infrastructural change or improvement that is intended to increase a community's resilience to climate impacts (Wenger, 2015)	To physically protect against storm surge, coastal erosion, sea level rise, permafrost thaw and flood • shoreline armoring • levees • sea walls • drainage channels • dams • dykes • elevated infrastructure (stilts) • heat insulators	• Commonly used and well understood • Quick to install • Associated with a visible sense of security	• Associated with rigidity • Capital intensive • Costly to maintain • Contribute to environmental degradation
Non-Structural (soft adaptations)			
Measures that focus on human behavior and aim to permit the continued use of vulnerable areas by managing climate risks primarily through planning, including the regulation of land use and development (Harman et al., 2015)	To reduce exposure to storm surge, coastal erosion, permafrost thaw, sea level rise and flood • planned relocation or retreat • altered land use and building controls • elevated floor requirements • increased setbacks • emergency management • insurance	• Greater flexibility in responding to climate threats • More cost effective than structural adaptations	• Social barriers challenge implementation • Subject to institutional and political constraints
Ecosystem-Based (soft adaptations)			
Protective strategies that leverage the adaptive opportunities associated with ecosystem services (Wilson & Forsyth, 2018; Jones et al., 2012)	To reduce the impacts of storm surge, coastal erosion, sea level rise, and flood • beach nourishment • sand dune restoration • wetland preservation • rain gardens	• Unobtrusive in nature • Potential to enhance ecosystem health • Additional recreation and aesthetic opportunities	• Limited understanding of how to value ecosystem services in monetary metrics

Table 1. Adaptation approaches.
Structural, non-structural, and ecosystem-based approaches are defined and classified with examples provided according to climate vulnerabilities. Benefits and drawbacks are presented for each approach.

Adaptation approaches in the Circumpolar North

Coastal communities tend to rely on hard-armouring protection measures, including seawalls, rip rap, and dykes to respond to a range of climate stressors (e.g. Harman et al., 2013; Lemmens et al., 2016). This is particularly evident in northern coastal communities that depend on shoreline protection to reduce vulnerabilities to increasing rates of storm surge, coastal erosion, and flooding (Sydneysmith et al., 2010).

Structural and engineered adaptations are more likely to be favored by local decision-makers because of the perceived security that comes with this form of adaptation (Harman et al., 2013; Betzold & Mohamed, 2017). While structural approaches are widespread across coastlines in the Arctic, many of these adaptations are deteriorating. The village of Shishmaref, for instance, has implemented protection measures that include shoreline armouring and other ad hoc structural actions in response to worsening flooding and erosion. However, these structural efforts have largely been ineffective against on-going intense wave action, leaving infrastructure and parts of the village exposed (Hamilton et al., 2016). The effectiveness of structural approaches has been heavily debated in the literature; scholars warn structural adaptations may be inappropriate for long-term development given the financial burden associated with maintenance and knowledge that degradation will continue as climate impacts continute to worsen (Kundzewicz, 2002).

With the weaknesses of structural adaptations becoming increasingly apparent, the use of non-structural accommodation approaches has gained interest (Harman et al., 2013). Coastal communities in North America, for example, frequently develop strategic planning documents that address climate stressors, such as sea-level rise and increased flooding, by prohibiting new development in low-lying areas (Lemmens et al., 2016). Other non-structural efforts include use of exaggerated setbacks, stringent development regulations, and updated building codes (Harman et al., 2013). However, given institutional, political, and capacity constraints, the conception and use of such adaptations, is lagging in small northern communities (Sydneysmith et al., 2010; Hino, Field, & Mach, 2017).

Managed retreat is another form of non-structural adaptation (Alexander et al., 2012). Alongside the hardening of coastlines, many small northern communities have relocated buildings and infrastructure highly susceptible to storm surge, erosion, and permafrost thaw (Sydneysmith et al., 2010). Government decision-makers in Shishmaref have been planning to relocate the entire community, in recognition of intensifying coastal flood and erosion events (Bronen & Chapin, 2013). The village's leadership have been considering relocation since 1976, however, the process of retreat has been significantly delayed by several barriers (Hamilton et al., 2016). The cost of relocating key services and infrastructure, challenges associated with the suitability of the relocation site, lack of a political/institutional framework, and feelings of social disruption have acted to impede the efficiency of inland migration (Hamilton et al., 2016; Bronen & Chapin, 2013).

Ecosystem-based approaches to adaptation are gaining significant traction as a sustainable option for addressing climate impacts. These approaches tend to be complementary strategies to structural adaptations and implementation varies substantially across coastal locations. Beach nourishment has a long history of application in many developed countries, such as Germany, however, ecosystem-based adaptations are not a common approach to

addressing vulnerability in northern communities (Harman et al., 2013). Given the unforgiving climate and sensitivity of ecosystems in the Arctic, the ability to utilize a range of ecosystem services to reduce vulnerabilities is significantly challenged. Though Arctic coastal regions lack diversity in wetlands and ecosystem engineering species (e.g. mussels), ecosystem-approaches are nevertheless possible, e.g. allowing the coast to re-naturalize to undisturbed beach lagoons, estuaries, and tundra.

Opportunities for intervention

Adaptations observed in practice in northern coastal communities largely involve structural approaches, with non-structural and ecosystem-based actions far fewer in application. With vulnerability very likely to increase as climate change continues, it is critical that local decision-makers have a deep understanding of the practicality, sustainability, benefits and drawbacks of various adaptation approaches. The following section outlines several recommendations that coastal communities in the Circumpolar North can pursue to enhance the effectiveness of their climate adaptation efforts.

Recommendations relate to adaptation approaches in practice and interventions that aim to facilitate the implementation of an adaptation agenda.

Recommendations for Coastal Adaptation Approaches

Small northern coastal communities are particularly vulnerable to climate stressors and are subject to unique adaptation barriers. It is therefore critical the cost and feasibility of a variety of adaptation types is considered in planning processes.

Although structural protection measures alone are not a sustainable approach, it is recommended that if local decision-makers prioritize the upgrading of existing hard adaptations, the cost of installment and maintenance be considered. For example, costs should be integrated into community budgets and baseline funding to ensure that structural measures remain operational over time. Further, it is recommended that the upgrading of hard adaptations and implementation of new structural approaches be informed by scaled and reliable climate data to ensure functionality against a range of climate scenarios (Ford & King, 2015; Duvat, 2013).

Moreover, it is recommended that existing structures be used in combination with soft adaptations to reduce costs and create a more robust response to climate stressors. To illustrate, coastal communities can enhance their resilience by making use of existing hard adaptations such as sea walls, while integrating more stringent development and building regulations and ecosystem-based approaches. By preventing further development in hazardous lands and facilitating the preservation of natural systems in proximity to structural adaptations, the cumulative protection of assets and residents is significantly increased (Borsje et al., 2011; Cheong et al., 2013). Combining adaptation approaches also presents a range of co-benefits that may include enhanced recreational opportunities, increased aesthetic appeal, and decreased cost of infrastructure maintenance (Bonnett & Birchall, 2019).

It is recommended that managed retreat not be overlooked. While considered to be a more extreme approach to adaptation, the relocation of residents and assets out of hazard-prone areas presents significant opportunities for risk reduction while offering a long-term response that is financially viable and sustainable (Bronen & Chapin, 2013). Small northern communities can boost the efficiency of managed retreat by looking to cases where this option has already

been successfully employed, for instance, in Australia in order to respond to overwhelming flooding (Sipe & Vella, 2014). Critical to the success of community relocation is support from senior levels of government, cooperation among government decision-makers, high levels of transparency and community participation, similar housing and community design in the resettled area, and a robust planning framework that facilitates the timely and efficient implementation of relocation (Sipe & Vella, 2014).

Recommendations to Facilitate Adaptation Implementation

To increase the efficiency of adaptation implementation, there are several interventions that can be pursued. First, it is critical that climate change adaptation is prioritized by local government to ensure resources are dedicated to adaptation policy conception and implementation. Scholars suggest that the process of local adaptation planning is most effective when adaptation is a strategic priority, political will and championing is evident, capacity to act is sufficient, and cooperation at all levels of government is prominent (e.g. Ford & King, 2015; Pasquini et al., 2015). Further, it is recommended that various forms of education programing be utilized to foster awareness and facilitate buy-in for adaptation. This may involve local decision-makers attending workshops/conferences on climate vulnerabilities and adaptation, collaborating with climate experts, or participating in research networks such as those organized through UArctic. Along this line, is it also important to base planning decisions on current climate data and local risk assessment. While local modeling is often limited in remote communities, regional data can be accessed through higher level government agencies. Ultimately, as climate adaptation gains priority, resources can be dedicated to further develop local data.

Lastly, it is recommended that northern coastal communities develop a strategic planning and policy framework that incorporates adaptation goals into granular plans and regulations. The development of high-level planning and policy frameworks can often involve multiple levels of government, and do not guarantee reductions in vulnerability on the ground. However, translation of broad adaptation goals into more specific regulations and bylaws can improve the likelihood of implementation in practice (XXX, 2019). Development regulations and land use bylaws, for instance, offer greater legislative teeth than do high level strategic plans. Implementation is further enhanced with inter-departmental collaboration with a range of actors to ensure that climate adaptation aligns with other long-term priorities such as growth and development (Measham et al., 2011).

Conclusion

Climate impacts in the Circumpolar North are unprecedented. The need to reduce vulnerabilities is urgent, however, adaptation planning is highly complex and subject to several distinct barriers in small northern communities. While structural approaches such as sea walls and shoreline armoring dominate the landscape, they lack flexibility, are costly to maintain, and are insufficient to protect against a range of climate impacts (and projected scenarios). To address the shortcomings of structural or hard adaptations, communities would strongly benefit from a diversified adaptation approach, including non-structural options. A combination of adaptation efforts can generate synergistic effects and reduce costs, and ultimately enhance coastal community preparedness in a sustainable way. Further, education programming, leadership championing, and support from other levels of government are critical to ensure

adaptation is prioritized, and sufficient resources are dedicated to the implementation of a long-term adaptation agenda.

The need to adapt to climate stressors is not unique to coastal communities in the Circumpolar North. Recommendations presented here may therefore provide insight to local government decision-makers elsewhere who are looking to build resilience to climate change.

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