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Thinning Sea Ice and Thawing Permafrost: Climate Change Adaptation Planning in Nome, Alaska

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Climate change is among the most critical challenges facing local government decision-makers in the north. Yet while risk is clear, with climate impacts occurring there more rapidly than many regions on Earth, integrated policy and planning for climate adaptation often remains a low priority for decision-makers. In an effort to extend the discussion and contribute to scholarship in this area, this paper explores climate change stressors and policy response in the coastal town Nome, Alaska. Through narratives of local government key actors and informed by strategic planning documents, this study sheds light on the decision dynamics around local climate change actions as well as preparedness for climate variability in general. In particular, this work highlights that thinning sea ice and thawing permafrost are both having an influence on life in Nome. Yet climate change adaptation remains a low priority for decision-makers, with the link to strategic policy often peripheral and not solutions orientated. As Nome is not unique in its need to adapt to climate change, findings from this work may provide communities experiencing similar climate stressors with awareness for the importance of incorporating adaptation thinking with long-term strategic policy and planning.

Keywords: coastal towns; climate change resilience; community planning; climate adaptation; local government decision-makers

1. Introduction

Climate change is among the most critical and complex challenges facing local government decision-makers today. Policy approaches to facilitate a low-carbon economy, and therefore avoid dangerous climate change, have featured in international policy discussions, with governments exploring long-term solutions such as greenhouse gas (GHG) emissions trading schemes and carbon taxes (e.g. Birchall 2014, 2017). Yet global concentration of atmospheric GHG emissions continue to increase unchecked (e.g. Hansen, Sato, & Ruedy, 2012).

With climate models projecting additional increases in global temperature (IPCC, 2013), the value of adaptation to minimize risk of dangerous climate change is becoming apparent. Adaptation is particularly important at the local scale (e.g. towns, cities), where decision-makers represent both the level of government nearest to the impacts, and the communities directly affected by the changing climate (e.g. Forino, von Meding, Brewer, & van Niekerk, 2017). Indeed, forward thinking leaders have an opportunity to improve their community's resilience through incorporation of adaptation thinking with policy tools such as strategic plans, zoning and regulations (e.g. Stults and Woodruff, 2017).

Yet, as climate change garners the attention of local government decision-makers (Bulkeley and Betsill, 2013), the literature suggests that efforts are fragmented, with a tendency to present as a peripheral mandate (e.g. Carter, Cavan, Connelly, Guy, Handley, & Kazmierczak, 2015; Kithiia and Dowling, 2010). What's more, local actions are often characterized as reactionary, instead of anticipatory or forward thinking in nature (e.g. Pearce, Ford, Duerden, Smit, Andrackuk, Berrang-Ford, & Smith, 2011; Preston, Westaway, & Yue, 2011).

In coastal communities, where a flexible and integrated policy approach would be well suited to the challenge of climate extremes (e.g. Labbe, Ford, Araos, & Flynn, 2017; Manning, Lawrence, King, & Chapman, 2015; Hino, Field, & March, 2017), decision-makers instead demonstrate a propensity for rudimentary hard structures such as seawalls (e.g. Geisler and Currens, 2017; Betzold and Mohamed, 2017). To be sure, this approach is visible and thus can assuage tax-payer support. However, hard structures may also result in a false sense of security, and further increase the risk of those that rely on them for safety (e.g. Cooper and Pile, 2014; Rulleau and Rey-Valette, 2017).

Integrated and proactive adaptation solutions can also be hindered by decision-makers that characterize climate change impacts as insignificant, or only relevant in the future (Moench, 2014; Birchall, 2019). Similarly, adaptation planning can be displaced by other priorities (e.g. Berrang-Ford et al., 2011), including new economic opportunities stemming from the warming climate.

Small coastal towns in particular can be susceptible to such challenges, given their need to supplement often limited resources with new sources of revenues (e.g. Major and Juhola, 2016). Indeed, this can make it difficult to build the necessary internal capacity to effectively move forward on a climate adaptation agenda (e.g. Nalau et al., 2015),especially when combined with a lack of support from upper levels of government (e.g. Juhola et al., 2012; Kettle and Dow, 2014).

While discourse into climate change adaptation is mounting, key stressors (specific climate impacts) and resultant decision-dynamics around local action draws less attention (Labbe et al., 2017; Bradley, van Putten, & Sheaves, 2014). Towns in the far north, in particular, lack in-depth investigation in this area, despite experiencing the impacts of climate change more dramatically than other regions of the globe (e.g. Birchall and MacDonald, 2019; Pearce et al., 2011).

In an effort to extend the discussion and contribute to scholarship, this study considers the experience of Nome, Alaska. Specifically, this work explores how the town is influenced by thawing permafrost (building subsidence, utility failure, road undulation) and thinning sea ice (longer ice free season, weaker sea ice), and discusses the subsequent policy response.

Through narratives of key actors and investigation of Nome's strategic planning documents, this paper sheds light on the decision dynamics around local government climate change actions as well as the town's preparedness for climate variability in general. As Nome is not unique in its need to adapt to climate change, findings from this work may provide communities experiencing similar climate stressors with insight into the nuanced challenges and value of integrating adaptation thinking with long-term strategic community planning.

2. Nome, Alaska

The town of Nome, Alaska, was chosen for this research because it provides an opportunity to investigate climate change impacts and planning response from the viewpoint of a smaller community. With a population of 3500,[1] the case of Nome will contribute to a scholarship dominated by studies on larger cities (Hamin, Gurran, & Mesquita, 2014).

Located in Northwest Alaska, Nome is a coastal town situated on the southern edge of the Seward Peninsula, in the Bering Sea (Figure 1). Like many Alaskan communities, Nome is highly remote from urban centres such as Anchorage (870km by air) and Fairbanks (840km by air) (City of Nome, 2010). Isolated from the interior, Nome is considered a regional hub for public services such as health and education, as well as commercial and industrial needs; Nome is supported by the region's only port capable of accommodating bulk cargo and fuel (City of Nome, 2012).

The climate in Nome is characterized as subarctic, with short, cool summers, and long, cold winters (City of Nome, 2010). Because of the community's coastal nature, however, seasonal weather is moderated by the Bering Sea. February is the coolest month, with an average temperature of -14C, July the warmest month with an average temperature of 11C; average annual temperature is -2.8C (City of Nome, 2010). As climate continues to shift, the area has experienced a mean seasonal temperature increase of approximately 2C (1949-2016) (converted from ACRC, 2017).

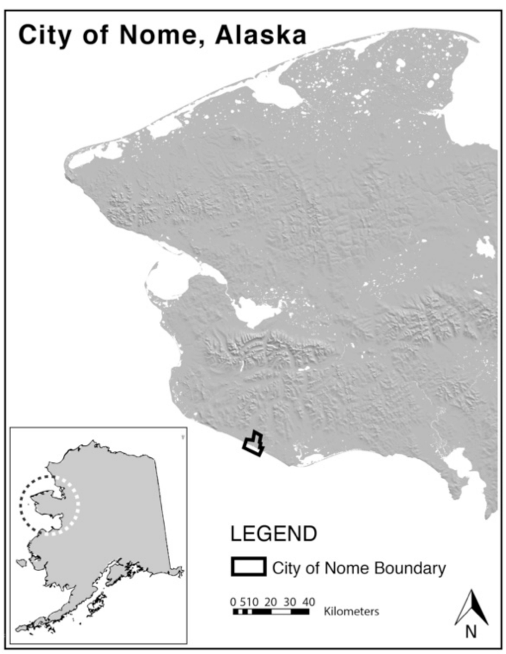

Figure 1. The City of Nome, Alaska

The following is the source information used by the authors to create the map: Coordinate System: NAD 1983 Alaska Albers; Projection: Albers; Datum: North American 1983; Data Source: Alaska Department of Natural Resources State Geo-Spatial Data Clearinghouse; Date Created: June 25, 2018.

[1] http://www.visitnomealaska.com/history-culture/

3. Approach

From an approach perspective, the goal of this inductive study was to elicit rich context-orientated discussion around climate change stressors (climate impacts) and local government response. Qualitative inquiry is quite well suited to this approach, as it provides the researcher the opportunity to explore meaning, interpretations and individual experiences (Birchall, Murphy, & Milne, 2016). With this in mind, the research involved semi-structured interviews with purposively selected key actors associated with Nome's climate change agenda.

Climate change and resilience thinking benefits from consideration of a variety of viewpoints (e.g. Horney, Nguyen, Salvensen, Dwyer, Cooper, & Berke, 2017; Masson et al., 2014). As a result, and to increase the rigour of the study in general, a range of local government decision-makers and relevant stakeholders were included in the study (n=9). For example, senior local government managers (n=6) that could speak to governance around adaptation plan conception and development, as well as how implementation is incorporated into land use planning, transportation planning, infrastructure and utilities in Nome (e.g. city manager, port authority director, planners, engineer); an elected official (the Mayor of Nome) who could shed light on the community's long-term vision and general support for climate change actions; as well as relevant environmental professionals (n=2) from the University of Alaska, who could more generally address climate change trends and projections moving forward.

Recruitment began with an introductory email which detailed the research objectives and approach, as well as general information concerning security and confidentiality. Those that agreed to participate in the research were also provided an opportunity to view the general interview protocol in advance of the interview.

The underlying tone of the interview protocol was conversational, with an aim to encourage dialogue and free flow discussion around local climate change stressors and challenges, as well as the extent and nature of the community's climate change agenda. The semi-structured interview design allowed for high-level exploratory questions, which were followed with more targeted probs as necessary. For instance:

- *In your view, how do the physical impacts of climate change influence your community?*
  - *What are the main physical climate change impacts affecting your community?*
  - *How are these physical impacts affecting your community?*
  - *Have these impacts been increasing in severity? If so, how would you describe the increase in severity?*

- *How would you describe your community's climate change adaptation agenda?*
  - *How is adaptation thinking incorporated into policy and planning?*
  - *What adaptive actions are being implemented in practice?*
  - *With respect to climate change adaptation, how would you describe decision-maker buy-in/ support?*

Interviews and follow-up occurred between August and December 2016; six interviews took place on site in Nome, two in Anchorage and one in Fairbanks. The interviews were executed in a setting that was comfortable and non-threatening to both the interviewee and the researcher (e.g. interviewee's office or boardroom), and ranged in duration from 70 minutes to 90 minutes.

The audio from each the interview was digitally recorded, then transcribed verbatim by a professional service. In advance of data analysis, interviewees were provided the opportunity to review their respective transcript for accuracy and context.

Following interviewee approval of the transcripts, the authors manually coded the data (organizing the data from across the transcripts into salient topics, key ideas, or quotes), then compared the emerging themes. In an effort to maintain transparency and improve validity, the theme development process was thoroughly documented (Polkinghorne, 2007).

While narrative analysis was the principal analytical approach, the study also involved the general review of strategic planning documents (e.g. comprehensive plans, zoning codes, Hazard Mitigation Plan). Engward and Davis, (2015) suggest that this extra layer of evidence helps triangulate the findings and improve reliability.

4. Key Stressors

Arctic temperatures are rising faster than global mean (IPCC, 2014), and over the previous 60 years, warming in Alaska has been occurring at a rate twice as quick as the rest of the United States (e.g. Stewart et al., 2013). Although climate change impacts are not new to Alaska, many have begun to increase in occurrence and magnitude (e.g. ADEC, 2010; Melvin et al., 2016). For the decision-makers in Nome, rising temperatures present two key stressors: thawing permafrost and thinning sea ice. The following section highlights how these climate change impacts manifest in Nome.

4.1. Thawing Permafrost

Permafrost is a specific form of ground (composed of soil, rock, organic matter) that is at or below 0C for a minimum of 2 consecutive years; over 80% of Alaska's land surface includes permafrost (Hong et al., 2014; Alaska Sea Grant, 2018a). Though the permafrost layer beneath Nome is defined as continuous (perennially frozen) (City of Nome, 2017), it is becoming increasingly thaw unstable as the active layer, or the component of permafrost that thaws during summer months, penetrates deeper into the perennially frozen ground. Additionally, evidence suggests that permafrost temperatures in Alaska have risen by 2C in the last 30 years (Alaska Sea Grant, 2018a).

Owing to Nome's coastal location and subarctic climate, the permafrost layer beneath the community is relatively thin, at approximately 15-50 meters (Hinzman et al., 2005), and is thus increasingly susceptible to warming temperatures. Indeed, with mean seasonal temperatures having risen approximately 2C (1949-2016) (converted from ACRC, 2017), permafrost degradation is becoming an on-going challenge for local government decision-makers in Nome, particularly with respect to the integrity of infrastructure.

According to the interviewees, thawing permafrost influences infrastructure in three critical ways: building subsidence, utilities failure and road undulation. Buildings erected on permafrost require construction in a manner that shields cold permafrost from the building's radiant heat. Otherwise, the permafrost layer will thaw and undermine the building above (ADEC, 2010). As a result, many buildings in Nome rest on meter-high stilts or stacks of blocks, elevating the structure above the ground's surface and consequently allowing the building's heat to dissipate. Though innovative, historically these buildings would nevertheless require consistent attention:

> Y*ou have to keep it off the permafrost, if you don't, you sink. In Nome, people have [had] to have their houses levelled every several years…*
>
> *But now, it's almost yearly.*

Yet, while increased levelling may be considered an inconvenience, perhaps the more worrying threat is linked to the rising occurrence of sinkholes beneath buildings:

> *This year particularly, there was about five or six [sinkholes]; kind of shocked me. So permafrost is feeling it… could put a lot of our homes at risk in the next five or ten years.*

For major edifices such as the Norton Sound Regional Hospital, this has necessitated additional mitigative engineering, including the incorporation of freon in the building's pilings to help keep the permafrost frozen (Figure 2).

Figure 2. The Norton Sound Regional Hospital
View of piles used to mitigate permafrost degradation beneath the structure. Photo was taken by author during the summer.

Similar challenges exist with the community's industrial fuel tank farms. An isolated location, Nome relies on large fuel tanks to store fuel shipped in for heating, power and transportation. As the permafrost thaws, the concrete foundations upon which the tanks sit become destabilized. As an interviewee explained:

> *It used to be that it was every five or six years we had to get in there and shove dirt underneath and straighten the walls. Now we're pretty much doing it annually.*

To be sure, a damaged tank can influence fuel availability, but a fuel leak will have devastating impacts on the surrounding environment.

Environmental risk in Nome is further exacerbated by water and waste water pipe breaks. In order to maintain circulation in winter months, to ensure that contents remain liquid, the pipe system in Nome is in a loop. As one of the interviewees noted, however, during the warmer months, melting permafrost has lead to mainlines heaving, dropping and separating in multiple locations throughout the loop. In addition to service disruption, the escape of water and waste water causes erosion, and waste water in particular can have environmental and health implications.

In an effort to remedy the situation, utility crews excavate deeper to reach thaw stable ground, with every year the depth continuing to increase. This ultimately makes infrastructure costly and difficult to maintain:

> *We're having to remove more and more materials to actually get to that layer… the utility infrastructure we need to maintain is problematic, it doesn't last as long.*

Thawing permafrost also influences the roads in Nome. Roads in high northern latitudes are exposed to prolonged sunlight during summer months. Because dark surfaces such as pavement have a low albedo (minimal reflectivity), a great deal of heat is absorbed at the surface, where it is transferred to the permafrost below. This causes the permafrost to thaw, and the road above to undulate, as described by an interviewee:

> *It's very difficult in an area like this to have pavement because of the underlying permafrost… you have a rollercoaster a year after you build [the road].*

Indeed, one interviewee conceded that the roads in Nome are in 'horrible condition', and that the lifespan of the infrastructure is typically a year, rather than three or four years. This challenge is echoed at the State level, where the Department of Transportation and Public Facilities Northern Region has allocated approximately $10 million to cope with the impacts of thawing permafrost on the State's highway network (ADEC, 2010). In Nome, this impact has resulted in a road system dominated by gravel or dirt surfaces.

Generally, the interviewees suggested that challenges associated with infrastructure are ongoing, and difficult to prevent:

> *I mean, if we had a year or two to work on something, we could design and address it, but basically we run around and put out fires, fill holes, and as soon as we fill one, we're moving onto the next. We see this happening constantly.*

4.2. Thinning Sea Ice

While thawing permafrost presents decision-makers in Nome with troubles in warmer months, thinning sea ice leaves the community vulnerable during the cooler months. Warmer temperatures result in sea ice (frozen sea water) that is weaker and more variable in extent. An important factor in Arctic sea ice decline is the reduction in thicker, more solid multi-year ice. With winter ice cover now dominated by weaker and thinner first year ice, summer ice is more susceptible to warming and thus lower extents (e.g. Perovich, et al., 2017).

In general, the Arctic Ocean's sea ice extent has been rapidly declining since a baseline year of 1970 (IPCC, 2014). The lowest ten summer ice extents have all occurred within the last decade (e.g. Stroeve, Serrexe, Ornaheim, Holland, Vavrus, Meier, & Fetterer, 2017; Parkinson and DiGirolamo, 2016). Further, as Rolph, Mahoney, Walsh, & Loring (2018) describe, it is taking longer for sea ice to freeze-up, and less time to break-up; and, projections suggest that by 2050, south of the Bering Strait, winter sea ice cover could be fifty per cent the average of recent years (e.g. Overland and Wang, 2007).

According to the interviewees, thinning sea ice influences the community in two related ways: a longer ice-free season and weaker sea ice, both resulting in increased exposure to storms and flooding. With sea ice developing later in the winter season and thawing earlier in spring, open water days are increasing (e.g. Stroeve et al., 2012). In particular, with sea ice forming later, the coastline is becoming increasingly vulnerable to storms:

> *So out there in December, there was open water… basically there's two months less in the year where the ice is protecting the coast.*

Exacerbating the risk, storms are becoming progressively unpredictable in occurrence, with the season beginning earlier:

> *Typically, our storms would be in October; we're seeing pretty good consistent storms in August, July where we can see consistent afternoon build up.*

Weaker sea ice in general has dramatic implications for communities like Nome, as sea ice can serve to buffer the force of winter storms. Specifically, thinner ice that is reduced in extent will facilitate a larger ocean fetch (e.g. Wadhams, 2012), which will allow a larger surge (larger waves):

> *If you have a nice quarter mile stretch of ice and you have a storm surge, the ice is going to kind of help protect the community.*

Compounding vulnerability further, diminished shore-fast ice permits greater direct wave contact with the coastline (Overeem et al., 2011; Alaska Sea Grant, 2018b). The combination of stronger surge and a reduced sea-ice wall can result in increased flooding and coastal erosion (City of Nome, 2017). With respect to the former, one of the interviewee's explained the new trend:

> *Typical events, the average storm would be a two to five foot surge. Whereas now, the average storm brings six to eight foot waves.*

Indeed, as highlighted in Nome's Flood Insurance Study (FEMA, 2010), stretches of the community near the coastline are susceptible to flooding associated with storm surge, regardless of the presence of the armour-stone sea wall. This was reiterated by an interviewee:

> *With a 10-foot swell, we do see flooding occurring in some of the lower lying areas; [and]…*
>
> *There can be material loss.*

Moreover, because shore-fast ice that develops is now characteristically thin and light, it becomes a hazard, as described by an interviewee:

> *It gets lifted with the surge, and becomes projectiles; that's been a problem.*

Coastal erosion is also an issue, though not as immediately pressing in Nome as in other areas of northwest Alaska (e.g. Shishmaref). Erosion remains nevertheless an on-going challenge to coastal landscapes (FEMA, 2010) and infrastructure (e.g. Gorokhovich and Leiserowitz, 2012; Kettle, Martin, & Sloan, 2017). For instance, according to the interviewees, strong wave action is persistently undermining the sea wall that protects downtown Nome, which has lead to slumping of the armour stone. Similarly, sections of Nome-Council Highway have become prone to erosion, which has resulted in collapse and road closure (Figure 3). This risk was made particularly poignant during the 2011 Bering Sea storm which resulted in an estimated at $24 million worth of damage to the Nome-Council Highway, primarily from erosion and debris (Alaska Public Media, 2011).

Figure 3. The Nome-Council Highway
View of erosion and road collapse. Photo was taken by author during the summer.

5. Policy Response to Climate Change

The following section discusses Nome's policy response to climate change, and situates the discussion in the relevant scholarship.

5.1. Policy Approach

In Nome, decision-makers understand that climate change impacts are indeed influencing the community, and accept that future change will be increasingly unpredictable (City of Nome, 2011). However, the interviewees suggested that at present, the community is not overwhelmed by the changing climate, adding…:

> *We see it coming, our heads are not in the sand, but we're not saying the sky is falling.*

Instead, the interviewees emphasized the need for education, sharing experiences with other communities and monitoring the changes, so as to avoid an emergency in the future. A lack of urgency is evident in the literature as well, where studies demonstrate that without a (recent) major precipitating event, decision-makers often lack the initiative to mobilize adaptation actions (e.g. Birchall and Bonnett, 2019; Staupe-Delgado, Kruke, Ross,& Glantz, 2017; Moench, 2014; Rulleau and Rey-Valette, 2017).

Nevertheless, there is an understanding amongst the interviewees that persistent stressors, such as thawing permafrost and thinning sea ice, require on-going attention, in particular in terms of the influence on infrastructure. In this respect, an interviewee conceded that '[the town is] not necessarily on top of it'. Moreover, when it comes to climate change impacts on infrastructure, the town's approach is largely reactionary out of necessity: 'We don't have the luxury of an ounce of prevention'.

5.2. Policy Tools: Strategic Plans

This inability to get in front of the challenge may be linked to its lack of attention in strategic policy. For instance, the Nome Comprehensive Plan 2020 prioritizes policy actions into one of three categories: *High-priority* (highest priority); *secondary strategies* (initiation expect within next 5 years); and, *long-term strategies* (initiation not expect within next 5 years) (City of Nome, 2012). Climate change adaptation only peripherally features on the list of actions, as a *long-term strategy.* Even then, action is principally related to developing infrastructure that can accommodate greater marine traffic, rather than bolstering infrastructure to support increased climate variability and extreme weather.

Indeed, the longer ice-free period has facilitated a rise in marine traffic through the Bering Strait (e.g. ICCT, 2015; Huntington et al., 2015), as reiterated by an interviewee:

> *I noticed that we do have increased traffic because of the reduction in ice… small sailboat traffic has increased significantly. And we're seeing increased larger [vessels] sitting off shore. Ten years ago you might have seen two vessels off shore, this year we have a consistent pattern of anywhere from eight to 12 vessels sitting off shore.*

However, the benefits (e.g. more tourism, more shipments, cheaper goods, lower cost of living in Nome and surrounding communities) can be quickly offset by potential vessel exposure to the increasingly volatile fall/winter storm season (e.g. Kettle et al., 2017). Similarly, failure to consider and build climate change adaptation into long range planning can allow poor land-use decisions and ultimately expensive maladaptations (e.g. Baynham and Stevens, 2014; Jones, Champalle, Chesterman, Cramer, & Crane, 2016; Melvin et al., 2016).

While challenges remain, decision-makers are working to create policy solutions that facilitate greater forward thinking. For instance, the Hazard Mitigation Plan acknowledges that as the climate continues to change, Arctic weather will become more difficult to predict, and highlights the importance of preparing for increasingly severe conditions (City of Nome, 2017). In particular, the Hazard Mitigation Plan identifies key risks, such as flooding and erosion, and prioritizes actions moving forward through a mitigation strategy. However, while the strategy ultimately aims to reduce vulnerability and damage, main actions to achieve these aims lack the necessary resolve. For example, a number of legacy actions from the previous plan, released in the 2008, were not carried forward into the 2017 plan (City of Nome, 2017):

- establish zoning code and subdivision regulations that are specific to development within the flood prone areas
- research advanced risk analysis projects, which include GIS and other methodology
- limit building city owned buildings in the 100 and 500-year flood zone
- improve areas subject to chronic erosion
- obtain funding to increase the height and impermeability of the Nome seawall

With that said, the new plan does carry forward actions to assess the vulnerability of flood prone buildings, improve access to flood insurance, and improve community awareness about flood risk in general (City of Nome, 2017). Additionally, the new plan sets an action to better understand how to reduce structural damage from thawing permafrost (City of Nome, 2017).

The Hazard Mitigation Plan is an ideal tool for decision-makers to explore, organize and address climate change risks. With vulnerability likely to increase as temperatures continue to rise, the value the plan brings to decision-makers could be augmented through a more direct incorporation of climate change language throughout the plan, including greater attention to what projections of extreme weather could mean for Nome. Likewise, a more thorough description of how actions will be implemented and evaluated could increase the likelihood of their long-term success (e.g. Stults and Woodruff, 2017).

5.3.Policy Tools: Zoning and Regulations

Zoning is a relatively new policy tool in Nome, and like the Hazard Mitigation Plan, demonstrates that decision-makers are beginning to consider environmental risk in the town's strategic planning. Among the seven districts identified in the Nome Zoning Code is the Open Space/ Recreation district (City of Nome, 2008). As one of the interviewees explained, while not directly motivated by climate change, the intent of the district is to limit development in areas that are prone to storm damage.

Likewise, the Flood Hazard Overlay district avoids language related to climate change, but nonetheless serves to improve community resilience to impacts of climate change. While this district does not limit permitted use, nor establish a higher threshold for setbacks, it does require that flood risk is minimized through measures including obtaining an Elevation Certificate and a Flood Plain Permit (City of Nome, 2008). In order to gain the latter, applicants must comply with the City of Nome Code of Ordinances (11.50, Protection Against Flood Damage), including providing details about the site and evidence of flood proofing (City of Nome, 2008). As an interviewee indicated, if you build in the floodplain, you have to mitigate risk:

> *They got to build so that they don't wash away. They got to have flood vents so that the waves can wash through… they're supposed to come in compliance with that on their foundation.*

The Elevation Certificate is administered through the National Flood Insurance Program. As a planning tool, the certificate documents and assists with compliance around floodplain management and the provision of flood insurance. This is particularly important in Nome as approximately fifty percent of the population and geographic area of the community is vulnerable to flood (City of Nome, 2017).

Storm surge is responsible for the greatest property damage across Alaska, and is considered Nome's largest risk (City of Nome, 2017). Nome has a long history of dangerous storm surge, from 1900 through modern times, and through it's Hazard Mitigation Plan, identifies flood hazard as 'critical' and 'likely' to occur in the future (City of Nome, 2017).[2] To this point, it is conceivable that the town could benefit from greater restrictions on development within the Flood Hazard Overlay district, including more appropriate setbacks to lower flood damage (Figure 4).

Figure 4. The Nome seawall
View of proximity of buildings/ infrastructure to seawall. Photo was taken by author during the summer, at low tide.

[2] Interestingly, there are no wave observation data or tidal records for Nome, despite a history of coastal flooding (FEMA, 2010). Another interesting note, because the tidal fluctuation at Nome is relatively small at 0.3 meters, it's potential to have an exacerbating effect on the severity of coastal flooding is minimal (City of Nome, 2017).

Presently, the community relies on a seawall to guard against storm surge. While hard structures like seawalls can elicit a sense of security, they often carry large maintenance costs, and can lead to complacency (e.g. Cooper and Pile, 2014; Betzold and Mohamed, 2017). This is an important consideration for decision-makers in Nome as the seawall is aging, and in need of repair and expansion (City of Nome, 2017). As an interviewee explained:

> *I consider myself spoiled; we have a nice seawall that protects our community, so we're good for now. But… that thing is not going to be there forever.*

In addition, the sea wall has minimal to zero effect against 100 and 500 year floods (FEMA 2010; City of Nome, 2017).

Moreover, with shore-fast ice becoming less effective at neutralizing waves associated with fall/winter storms, the burden on the town's seawall is increasing, correspondingly so to is the risk to those that rely on it for safety. Indeed, given the concentration of infrastructure and property currently exposed to flooding in Nome, perhaps the seawall should be considered an interim solution (e.g. Geisler and Currens, 2017), with some degree of organized retreat from the coast line a prudent goal. While dramatic and certainly controversial (e.g. Rulleau and Rey-Valette, 2017; King et al., 2014), in addition to reducing risk, the benefits of managed retreat can include significant long-term cost savings (e.g. Hino et al., 2017). However, in the case of Nome, inland retreat may be complicated by thawing permafrost and the associated impacts on utilities and infrastructure.

5.4.Lack of Resources

While decision-makers in Nome work towards becoming more resilient to climate variability and stressors such as thawing permafrost and thinning sea-ice, proactivity is made difficult by a pronounced lack of resources. Both the Nome Comprehensive Plan 2020 and the Emergency Operations Plan, for instance, note a lack of financial support, primarily due to a small tax base in Nome, but also as a result of the State's fiscal situation (City of Nome, 2012; City of Nome, 2011). To be sure, the State has little resources for climate change. In 2011, for example, Governor Parnell cut the sub cabinet tasked with assessing climate change impacts and developing strategies around adaptation; between 2014 and 2017, the Alaska Department of Environmental Conservation had its budget cut by 1/3 between (Flavelle, 2017).

Indeed, without adequate support, it is difficult for decision-makers to secure appropriate personnel (e.g. Thorne et al., 2017). As an interview explained:

> *Our city planner, I don't think is as well versed in [climate change resilience]. So as far as personnel go, we just don't have the money for it.*

Without the personnel necessary to navigate and champion this kind of thinking (e.g. Payne and Shepardon, 2015), climate change in general and adaptation in particular, remain perisperhal as an agenda, instead of integrated with strategic policy.

6. Small towns in a changing climate

Small towns experience pressures differently compared to larger cities, and in some ways are at a disadvantage when it comes to climate change (e.g. Hamin et al., 2014; Paterson et al., 2017). For example, owing to a limited tax base and often lack of economic diversity, small towns can be acutely sensitive to local environmental change, which can influence economic drivers such as tourism or agriculture, and increase costs associated with municipal operations.

When it comes to developing and implementing a climate adaptation agenda, small towns can also be handicapped by limited internal capacity, both in terms of personnel in general and expertise around climate change and resilience planning in particular (Birchall, 2019). A further challenge includes access to appropriately scaled climate data, since such data is typically regional or global in scale and therefore not sufficiently granular to serve the needs of local decision-makers (Major and Juhola, 2016).

Nevertheless, decision-makers in small towns tend to have greater access to the community at large, which can facilitate engagement with stakeholders on critical issues such as climate change. Further, achieving consensus on a plan forward may be easier in a small town, given the potential for fewer conflicting points of view (often a barrier for climate action in larger cities). Moreover, small towns are often characterized as low density, which can allow greater flexibility when it comes to implementation of climate adaptation actions, especially ecosystem-based approaches that require more space (Heang & Birchall, 2019; Birchall & Bonnett, 2019).

The town of Nome demonstrates some of the challenges of small size, but also highlights opportunities. For instance, thinning sea ice and thawing permafrost have resulted in on-going operational challenges that are difficult to resolve given the town's limited budget. Yet the warming climate has also created new opportunities around marine traffic, which could facilitate tourism and lower the cost of living.

However, the planning foundation necessary for the town to thrive in a changing climate is weakened by the low priority given to actions around climate adaptation.

As with other small towns, it is difficult to build momentum for climate adaptation in Nome when internal capacity (expertise) is low and local data on environmental impacts is limited (e.g. wave observation data) (e.g. FEMA, 2010). Decision makers in Nome recognize these limitation however, and emphasize the value of education and networking in order to learn from the experience of other communities.

Further, given the town's small size and low built density along the shoreline, decision-makers in Nome also have the opportunity to explore the appropriateness of coastal naturalization (Birchall & Bonnett, 2019). Coupled with more restrictive zoning, an ecosystem-based approach to storm surge/ flood management could alleviate strain and serve as an alternative to expanding the seawall that shelters the downtown core. This option may become increasingly appealing given the infrastructure/ utilities challenges the town would encounter with inland retreat from the coast.

7. Conclusions

With atmospheric GHG emissions continuing to increase unchecked, climate variability is fast becoming a reality for local government decision-makers around the world. Vulnerability is particularly pressing in the north, where communities are experiencing impacts faster than anywhere else on Earth. The case of Nome, Alaska offers the opportunity to investigate climate stressors and adaptation policy response from the vantage of a small town, a scale underrepresented in the scholarship. For decision-makers in Nome, thawing permafrost and thinning sea ice represent two key climate change stressors facing the community today. While decision-makers in Nome suggested that they are not overwhelmed by climate change, the impacts associated with these stressors do necessitate on-going attention, and are proving difficult to proactively resolve.

Indeed, impacts such as building subsidence, utilities failure, road undulation, and flooding do present in strategic policy, however attention is often peripheral and not solutions orientated. For instance, the Nome Comprehensive Plan 2020 notes climate change adaptation, but in the context of economic opportunities; the newly released Hazard Mitigation Plan, while demonstrating forward thinking through attention to thawing permafrost, fails to carry-forward (from the previous plan) key actions intended to bolster the town's resilience to storm surge and flooding. In a similar vein, zoning restrictions within the floodplain district demonstrate a reliance on the seawall to shield the community from harm. Yet the seawall is in need of repair and expansion, a pressure that will increase with storm exposure.

Through this research, a number of important areas for further investigation have been identified, including the following:

- The Alaska Native population represents a majority in Nome (City of Nome, 2012), and their cultural traditions (e.g. subsistence lifestyles) are influenced by the changing environment. A better understanding of their experience, and how tribal communities are engaging in discourse around next steps, could provide valuable insights for the co-development of strategies to improve overall community resilience.
- The Hazard Mitigation Plan was released a year after key actor interviews for this study occurred (in 2017). It would be interesting to further investigate why decision-makers elected to not carry forward certain legacy actions from the 2008 plan, such as establishing zoning codes and subdivision regulations specific to development in flood prone areas. This could be particularly interesting given that the Flood Hazard Overlay district does not limit permitted use.
- Further research into how Nome will be influenced by thawing permafrost, and the resultant policy response, is also critical. This could be particularly interesting as the community seeks to expand the port (e.g. Grueskin, 2018) and promote tourism. The importance of this consideration is also echoed in the recent Hazard Mitigation Plan (City of Nome, 2017).

While this research is limited to a small town in Alaska, implications of the findings may apply to other locations with similar climate stressors and policy related challenges. Indeed, the case of Nome demonstrates the need to incorporate climate change thinking with long-term strategic planning policy, and emphasizes how inadequate personnel can hinder such planning. Further, this study underscores the need to balance new economic opportunities resulting from climate change with the stresses extreme weather will place on existing infrastructure, in order to avoid maladaptations and potentially expensive land use decisions.

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