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Co-producing maps as boundary objects: Bridging Labrador Inuit knowledge and oceanographic research

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ABSTRACT
Climate change is affecting the marine environment in Nunatsiavut, leading to changing sea ice thickness and seasonal timing, and increasing water temperatures. This impacts the lives of Labrador Inuit, whose culture, economy, and history are deeply tied to marine spaces. Recently, research partnerships involving Inuit communities in Nunatsiavut have increased, creating space for Labrador Inuit in large scale marine research agendas. While including Labrador Inuit knowledge is critical for making research relevant to communities, there are challenges to engaging it alongside oceanographic scientific knowledge, as both stem from unique ontologies, at times having different values, scales, and languages of understanding. Boundary work offers a lens to analyze how boundary objects can foster connections between Labrador Inuit knowledge and oceanographic research. This research offers a conceptual exploration of this subject through analysing the co-production of maps representing Labrador Inuit knowledge of ocean features which, as data, were then applied in oceanographic research problems. Framing these maps as boundary objects demonstrates their utility in mobilizing Inuit knowledge into scientific approaches, acknowledging limitations with respect to knowledge that cannot be spatially rendered.

KEYWORDS Boundary work; oceanography; Inuit knowledge; Nunatsiavut; research methods; knowledge mobilization

Introduction

Arctic and sub-Arctic regions are experiencing warming at rates two times faster than the rest of the world (Bush and Lemmen 2019), and communities throughout Inuit Nunangat[1] are experiencing the effects of this warming, manifested through shifting weather patterns, changing sea ice thickness and seasonality, increasing water temperatures, and changing species distributions. These changes can significantly impact Inuit, whose livelihoods and

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culture remain strongly tied to the marine environment. For example, localized weather, ocean, and sea ice conditions can determine travel safety and harvesting success. Changing oceanographic conditions also provoke numerous research inquiries within the field of oceanography, which aims to understand past and present conditions and potential drivers such as seasonal or climatic conditions/trends to help predict future scenarios. Information on oceanographic conditions and possible future trends or changes can be critical for developing appropriate policies and planning for future change throughout Inuit Nunangat. In the Northwest Atlantic (NWA), oceanographic data and direct observations are often compiled at regional scales defined by hydro-morphological characteristics, or scales that coincide with certain marine activities, such as shipping. An example of this is regional sea ice trends, which are well documented at a scale covering the Labrador shelf and offshore waters of the NWA (Government of Canada 2019; Statistics Canada 2011). Observations at this scale (e.g. 100s of metres – 500 kilometres) are important for understanding regional environmental processes, are critical to support safe shipping, and are important for climate change research and decision-making. However, this scale of observation often misses smaller-scale changes occurring in coastal regions (e.g. less than tens of metres), which while less likely to impact shipping safety, can significantly impact the lives of Labrador Inuit living and travelling in coastal Nunatsiavut. Not only do the effects of climate change involve changes to environmental cycles, but they also impact the social, cultural, and physiological well-being of Labrador Inuit, whose history and daily lives are intricately linked to marine spaces, and for whom climate change influences subsistence activities, food security, and physical and mental health (Cunsolo Willox et al. 2012; Ford et al. 2012).

The social, cultural, and environmental ties that Labrador Inuit have to marine spaces are expressed through their knowledge, which has been developed over millennia and passed down through generations, and offers a window to understand oceanographic processes and changes occurring in coastal regions. The term Labrador Inuit knowledge is used here to express this collective cultural knowledge, reflective of social, cultural, and environmental contexts that are tied to geographic scales of environmental use and occupancy. Including Labrador Inuit knowledge in marine research has the potential to broaden the scope of marine observations, while re-focusing research agendas to regions and scales of relevance to Nunatsiavut communities (as opposed to those defined by western intuitions and values). Including such knowledge in oceanographic research has become essential, as Indigenous organizations and scholars have called for the development of better and equal relationships between researchers and Indigenous communities (ITK 2018). Partnerships between researchers/research institutions and Inuit are emerging in support of Inuit-driven research, in support of

Inuit rights and interests, and to broaden available knowledge for decision-making. Yet, currently, there is limited recorded oceanographic data derived from Labrador Inuit knowledge. Partnerships between Labrador Inuit and oceanographic researchers would allow Labrador Inuit values to influence oceanographic research, helping identify research questions and practices that better support community needs and interests. Additionally, this represents an opportunity for oceanographic research to incorporate Labrador Inuit knowledge, which can strengthen research practices and broaden available information for climate change planning at scales more relevant to communities.

Challenges emerge when seeking to engage multiple knowledge systems, particularly since oceanographic scientific knowledge and Labrador Inuit knowledge stem from distinct ontological contexts, leading to potential tensions. While not always explicit, these ontological tensions can manifest in different approaches to communicating and sharing knowledge (e.g. oral vs. written; highly contextualized narratives vs. decontextualized data), or through different conceptualizations of the environment (Aporta et al. 2020). For example, western ontological approaches may frame the marine environment as a provider of services or as a space of transit for humans, while Inuit approaches can involve conceptualizing the marine environment as a social space and even a homeland (Aporta 2009). Further, oceanographic scientific knowledge and Labrador Inuit knowledge may also reflect different values, temporal and spatial scales, seasonal variations, and languages of understanding, which can complicate matters when combining them in the development of research or policy agendas. It is important to note that Inuit and western scientific knowledge are not incompatible, and that there are efforts to consider them as parallel or complementary in a non-hierarchical sense (Davis 2006; Nader 1996). Thus, while ontological differences present challenges, engaging multiple knowledge systems in marine research can strengthen research agendas through meaningful community partnerships and participation.

Boundary work offers a potential path towards resolving some of the ontological tensions that arise in cross-cultural settings because it aims to preserve the integrity of distinct knowledge systems while at the same time allowing them to work together (Nel et al. 2016; Clark et al. 2016). The concept has sociological origins and has been used to express the demarcation of western science from other forms of knowledge and activities. Boundary work has been used as a lens to explore and articulate the ways that actions and structures create, maintain, and break down boundaries within and between knowledge systems (Gieryn 1983; Jasanoff 1990; MacMynowski 2007). Exploring ways to work across disciplinary, social, or cultural boundaries is often a critical component of boundary work. For example, the notion of boundary work has been applied as a lens to understand the relationship between western science and Indigenous knowledge and it has been the foundation for successful participatory research in cross-cultural settings (Robinson and Wallington 2012; Zurba and Berkes 2014; Zurba et al. 2019). A key component of boundary work is the creation of *boundary objects*, which are tangible or intangible objects that can be adaptable to interpretations by different social and/or cultural groups, while remaining robust enough to maintain their identity across them (Star and Griesemer 1989; Star 2010). The effectiveness of boundary objects is in their capacity to create shared dialogical spaces, where communication across disciplinary or cross-cultural boundaries is enabled (Star 2010).

This research uses the lens of boundary work and applies the concept of boundary objects to analyze how co-producing maps can foster communication and translation between Labrador Inuit knowledge and oceanographic research. These concepts will be applied to participatory mapping research that took place in Rigolet and Hopedale, Nunatsiavut, Canada, in 2019 in support of a larger oceanographic research project called Community-based Observing of Nunatsiavut coastal Ocean Circulation (CONOC). The project is focused on developing a community-based ocean observing system for coastal Labrador and is exploring ways that Labrador Inuit knowledge can inform and contribute to oceanographic research. The CONOC project was designed without applying the lens of boundary work. However, it makes use of participatory mapping to document Labrador Inuit knowledge of coastal oceanographic features, which were translated into oceanographic scientific frameworks. Thus, the project provides an interesting case study to retrospectively frame in the context of boundary work, exploring the role of maps produced through participatory mapping as boundary objects.

This paper will look at the representation of Labrador Inuit knowledge within oceanographic scientific frameworks, addressing the role of data as a critical parameter used to represent complex environmental variables in oceanographic science and what it means to translate Labrador Inuit knowledge into data through mapping. It will address how the integrity of Inuit knowledge can be respected when knowledge is translated into data and applied outside of the context of participatory mapping (i.e. in an oceanographic scientific model). Through analyzing participatory mapping research that took place for the CONOC project, the role of a map as a boundary object will be explored. This case study offers an opportunity to investigate and explore the tensions and complementarities that arise when bridging Labrador Inuit knowledge and oceanographic scientific knowledge. Specifically, we are addressing the capacity of maps to "translate" Inuit knowledge for use in oceanographic scientific applications. While the other side of this relationship (namely, how scientific data and knowledge can be translated into Inuit experience and knowledge) is equally important, it is beyond the scope of this present study. As the CONOC project progresses, we hope to further explore the experience from the Inuit perspective.

Researcher positionality

I (Breanna Bishop) am of settler descent, and I am currently a doctoral student at Dalhousie University. I was first introduced to Nunatsiavut in 2018 during my master's research when I joined the CONOC project. Prior to this, my previous academic experiences were grounded in perspectives from human and environmental geography, where I was increasingly drawn to both climate change research and decolonizing methodologies for research with Indigenous peoples. I was keenly interested in "wicked problems" that encompassed climate change and Indigenous rights, and became motivated to explore how I, as a non-Indigenous researcher, could contribute to this field. When my graduate supervisors and co-authors of this paper approached me with the CONOC project, I was excited to join, since it offered a space where I could connect with and learn from Inuit in Nunatsiavut about how they are experiencing environmental change.

As an educated white settler, I hold a position of privilege, particularly in my ability to explore these issues while not being directly impacted by them in any significant way (especially in comparison to the impacts felt by Inuit). Through my work, I aim to utilize my position of privilege to act as an ally and resource to those who are interested in working with me. I hope to shape my role as a knowledge broker as I seek to find ways to communicate across diverse ways of knowing to better address the problems faced as a result of climate change. I recognize that as a settler, my approach to research is inherently structured by a Eurocentric worldview, derived from my western upbringing. This limits my ability to fully comprehend Inuit ways of knowing, and thus my approach requires sustained reflexivity, awareness, and relies on developing meaningful relationships in order to try to understand and learn from Inuit worldviews.

Project background

The CONOC project was initiated by the second author in 2018 with the goal to increase observations of ocean circulation in coastal Nunatsiavut as well as to record Inuit knowledge of the ocean and sea ice so that this knowledge could be seen and valued meaningfully by science. Presently, existing observations are sparse in space and time, making estimates of coastal ocean circulation, let alone climate change, challenging (Colbourne et al. 2015). Ocean circulation is critical to the climate system and influences environmental variables including temperature, salinity, sea ice, and biological productivity.

In Nunatsiavut, Inuit communities depend on predictable sea ice conditions for winter travel, enabling access to fishing and harvesting areas for sustenance and livelihood. As such, the CONOC project is designed to understand ocean circulation in coastal Nunatsiavut and how it may be changing, in order to predict how Inuit winter travel routes and harvesting may be impacted in the future. To establish baseline observations, the project is collecting in-situ observations through a community-based monitoring program where community members assist with identifying areas to collect observations from, and the data collection itself. Additionally, related research will estimate coastal circulation and its change over time through the development of ocean models, which require observations to validate and constrain their estimates of circulation in order to increase the accuracy of model simulations and predictions. These models could then be applied to estimate the effects of climate change on ocean circulation, temperature, sea ice, and biological productivity in coastal Nunatsiavut.

Parallel to this approach, the project also uses participatory mapping methods and interviews to document Labrador Inuit knowledge of coastal oceanographic features (sea ice, ocean currents), including seasonal cycles and changes over time. Thus far, mapping work has taken place in the communities of Rigolet and Hopedale (June 2019), and plans are underway to visit additional communities in 2021. The first stage of data collection informed a graduate research project (Bishop 2020), the results of which have been incorporated into this analysis. Through a staged approach to data collection, there are opportunities to revise methodology based on community input and critical reflexivity. In including Labrador Inuit knowledge throughout the project, the intention is to generate research that is relevant to communities in Nunatsiavut.

Maps as boundary objects

Western cartography had an important role in colonization, and it has been defined and positioned as a tool of state power, due to its role in mapping what was wrongly defined as *terra incognita*. The development of western cartography aligned with the importance that western society placed on *objective* representation of land and resources, which resulted in assertions of ownership over Indigenous lands, and erasure of Indigenous occupation (Offen and Rundstrom 2015). During colonial and postcolonial periods, the production of maps has been a reflection of state control and western scientific authority and expertise (Mason-Deese 2020). The idea of western scientific objectivity positioned maps as incontestable objects of authority, thus creating a division between western cartographic approaches and other ways of understanding the world. The result of this distinction was to assert the authority of western scientific accounts (Bocking 2011).

Counter-mapping emerged as a form of resistance to these efforts, where groups and organizations that were not in a position of power utilized maps to make claims for resources and land, asserting new spatialities counter to those of the state (Mason-Deese 2020). In Canada, Indigenous land use and occupancy mapping became a powerful tool to support legal claims to territories and resources (e.g. Freeman 1976). This, and other counter-mapping efforts challenged the idea that maps/western cartography were solely instruments of the state. The success of these efforts demonstrated that maps, including their claim of objectivity, could be employed by non-dominant groups to assert their rights. Through counter-mapping, these groups are challenging official representations of spatiality (Wood, Fels, and Krygier 2010).

Despite the successful appropriation of maps by Indigenous groups, it should be noted that western cartographic conventions such as linear boundaries do not necessarily accurately reflect Indigenous ontologies, including conceptualizations of the interconnectivity of environmental features and human uses (CSAS 2021). As a result, tensions are inherent in cartographic representations of Indigenous knowledge and practices. The intent of this paper is not to position our work as a process of counter-mapping, nor to explore the power relations embedded in cartographic processes. Instead, this work attempts to show how maps, as boundary objects, can be spaces of knowledge sharing in cross-cultural settings.

In communicating knowledge applicable to different temporal and spatial scales across different social groups, maps have proven to be powerful boundary objects, leading to tangible outcomes such as environmental co-management arrangements or legislated land claims agreements (Nel et al. 2016; Freeman 1976; Brice-Bennet and LIA 1976). A successful boundary object is grounded in action (iteratively produced) and subject to reflection and local tailoring (to meet the needs of each contributing group), while also effectively enabling functionality across and within knowledge holding groups (Star 2010). Maps have been established as boundary objects for a variety of applications, as they can be very effective at communicating and integrating distinct interests and knowledge from multiple stakeholders and rights holders, making them important tools for decision-making in marine or environmental planning (e.g. Noble et al. 2020). While existing research explores the ability of boundary objects to mobilize Indigenous knowledge into decision-making processes (Robinson and Wallington 2012; Robinson et al. 2016), there has been little research on how Inuit knowledge can be mobilized into oceanographic research frameworks through the application of maps as boundary objects. This process involves transformations of Inuit knowledge into information and data that are crucial in the construction of the boundary object (the map) and that sometimes are taken for granted when using maps to document Inuit knowledge.

To address these transformations, we will briefly discuss some ideas regarding existing conceptualizations of the data-information-knowledge process.

The data-information-knowledge-wisdom model emerged as a way to describe the different ways in which the real world is observed and processed through scientific inquiry and human cognition. While often applied within the realms of western science (Rowley 2007; Ackoff 1989), the model has also found use in Indigenous research (e.g. Mercier, Stevens, and Toia 2012) and is appealing because it offers a simple approach to understand knowledge production processes. Each term is associated with varying degrees of ascribed meaning and abstraction, with *data* having the least meaning and highest degree of independence from context, and wisdom at the other side of the spectrum (Figure 1; Hewitt 2019). While wisdom is an important category of the model, this discussion focuses on data, information, and knowledge as they relate to research. The terms are not mutually exclusive, but rather have indistinct boundaries, represented by overlapping interdependencies subject to processes of ascribing different levels of meaning and abstraction. As transitions between categories occur, a degree of filtration and subjective interpretation is also applied. Additionally, not all data can be translated into information and knowledge, and likewise not all knowledge and information can be translated into data. According to

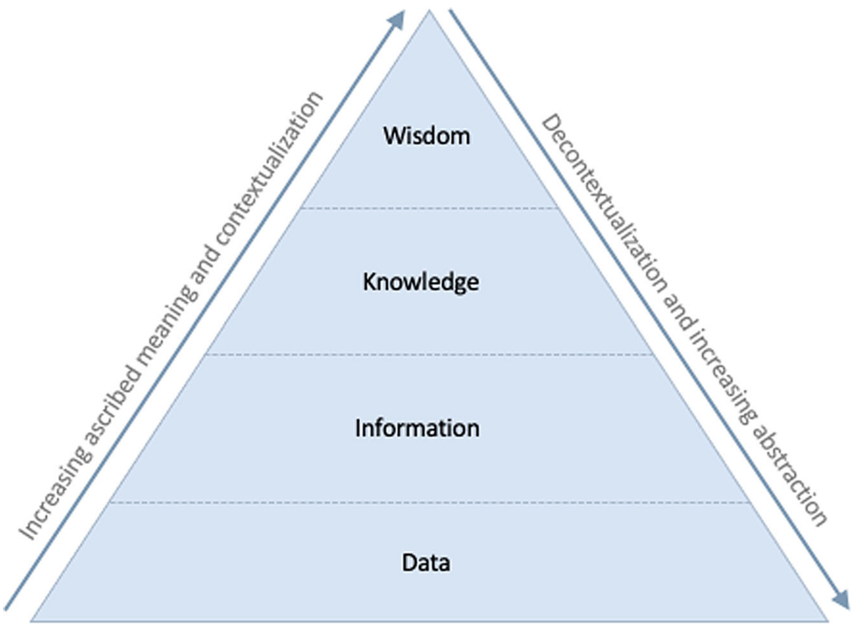

Figure 1. The conventional data-information-knowledge-wisdom pyramid, where each form of representation is associated with varying degrees of ascribed meaning and levels of abstraction (adapted from Aporta et al. 2020; Ackoff 1989).

this conceptualization, consider a physical oceanographer seeking to understand sea surface temperatures (SST). *Data* would consist of specific numerical measurements devoid of context and meaning; *information* would be generated through establishing a pattern of organization (e.g. winter SSTs in coastal Labrador – organized by SST season and location), which requires researcher interpretation to find patterns in the data (Bates 2005). *Knowledge* then would be generated through organizing information and integrating it with other sources of information (Bates 2005). In this example, knowledge would be derived from contextualizing the SST information with other information such as sea ice or weather conditions (e.g. winter SSTs in coastal Labrador are very cold in association with sea ice formation and vary in association with storm systems). At each stage of "transformation", there are subjective and reflexive interpretations being made, thus enabling patterns to be discerned and conclusions to be drawn when generating knowledge from data. Similarly, as knowledge is rendered into data, constraints are added in the form of representation parameters, acting as a means of filtering out contextual meaning. Specific cultural contexts likely contribute to how data and information are perceived, interpreted, and communicated, thus phenomenological explanations (knowledge) can vary substantially across disciplines and cultures (Mercier, Stevens, and Toia 2012).

We will now re-frame the data-information-knowledge model to address mapping Labrador Inuit ocean knowledge in the context of co-producing a boundary object (map). Translating knowledge into mapped spatial data (which is then applied in oceanographic frameworks) involves a decontextualization process by removing relationships and context so that it can fit into frameworks of western scientific inquiry. Because Inuit knowledge is highly contextualized, translating it into data could strip associated values and ontological characteristics, removing the functional integrity of one knowledge system in order to communicate it to another. Figure 2 offers a modification of the conventional data-information-knowledge model, representing the process of using maps as boundary objects to help communicate Labrador Inuit knowledge to oceanographic scientific knowledge. As Labrador Inuit knowledge is mapped and applied in oceanographic scientific frameworks, it is subject to transformations in terms of how it becomes represented as data, and how that data is then reinterpreted through a different lens. The mapped data, stripped from context, can reduce or even remove the ontological characteristics of Labrador Inuit knowledge as it is translated into an oceanographic scientific application. Context, however, can be recreated (Aporta et al. 2020), and hence mapping is not just a process of translation or reduction, but also of potential new knowledge production (similarly to counter-mapping). The following analysis will be developed around the structure of this model, framing maps as boundary objects and exploring the knowledge translations and

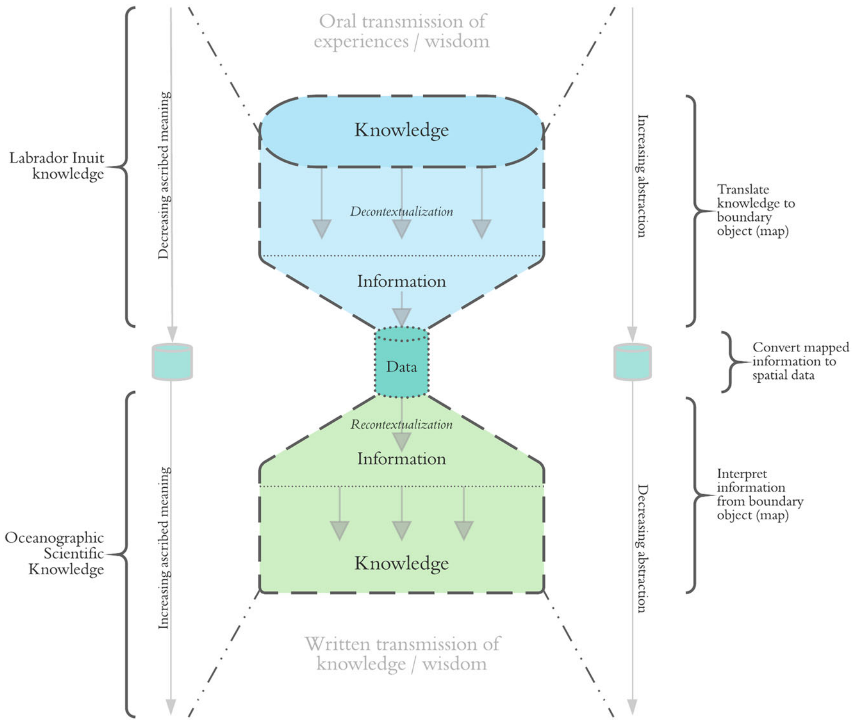

Figure 2. Transformations occurring to Labrador Inuit knowledge as it is decontextualized (translated onto a map), recontextualized (digitized, and interpreted from a map) and applied in oceanographic scientific frameworks (adapted from Aporta et al. 2020).

transformations that took place during participatory mapping workshops that documented Labrador Inuit ocean knowledge for the CONOC project.

Materials and methods

The CONOC project hosted participatory mapping workshops in two Nunatsiavut communities, Rigolet and Hopedale. These communities were chosen in part because of known oceanographic features (e.g. strong tides, year-round open water in Rigolet), and in part through expressions of interest from community members in Hopedale, who wanted to document ice features in the region. Rigolet has a population of just over 300 people and lies relatively isolated from the open Labrador Sea adjacent to a tidal strait, known as the Narrows, that links Lake Melville to Groswater Bay. The Narrows allows for very strong tidal currents and year-round open water conditions. Hopedale has a population of just under 600 people and is located in a more exposed area, characterized by coastal barrens and several elongated bays extending up to 40 km inland. Many small islands near the mouths of the bays provide some shelter from the open ocean while providing Hopedale residents with direct access to and experience of the coastal Labrador Sea, including the Labrador Current and offshore pack ice. In both communities, over 90% of residents identify as Inuk (Inuit) (Statistics Canada 2017a, 2017b).

Participants were recruited with the help of local contacts, who suggested the names of elders and other knowledgeable individuals who might be interested in sharing their knowledge of ocean features. The researchers and local contacts followed-up with these individuals, providing them with more information and inviting them to join the mapping sessions. While Inuttitut (the Labrador dialect of Inuktitut) is spoken in Rigolet and Hopedale, English is the predominant spoken language in both communities. All of the research participants spoke English as their primary language and did not require a translator. In Hopedale, one participant spoke Inuttitut fluently, although they were also comfortable speaking English and primarily mapped with other English-speaking participants. While in many cross-cultural research settings, a language barrier between the researchers and research participants can lead to challenges of translation and conveying specific culturally derived meanings, being able to communicate in the same language allowed any uncertainties to be addressed when they came up during the mapping and interviews. This allowed for clarification of any connotations that Inuit or western scientists might attach to specific ocean features or processes that were being discussed.

Participatory mapping and interviews

The participatory mapping methodology used for the CONOC project was developed in part based on other participatory mapping work conducted with Inuit communities across the circumpolar Arctic (Aporta 2011; Tobias 2009). Two sets of large maps were brought to each community (Rigolet – 9 × 21 ft; Hopedale – 15 × 18 ft; domains indicated in Figure 3), with one map designated to document oceanographic features in the open water season (approximately summer and fall), and the other one to document oceanographic features for the sea ice season (approximately winter and spring). The seasons were chosen by the researchers to broadly encompass the differences in how Labrador Inuit would access marine and coastal areas (e.g. boat vs. sled travel), and the different features and species that would be present. The spatial scale and extent of the maps were determined based on existing studies by the Nunatsiavut Government that focus on community use of marine and coastal areas (Figure 3). The resulting maps were produced by the Dalhousie MAP VisLab in collaboration with the first author, at a scale of 1:39,000 (Rigolet) and 1:47,000 (Hopedale). Hill shading was used to denote local topography, and colour differentiations

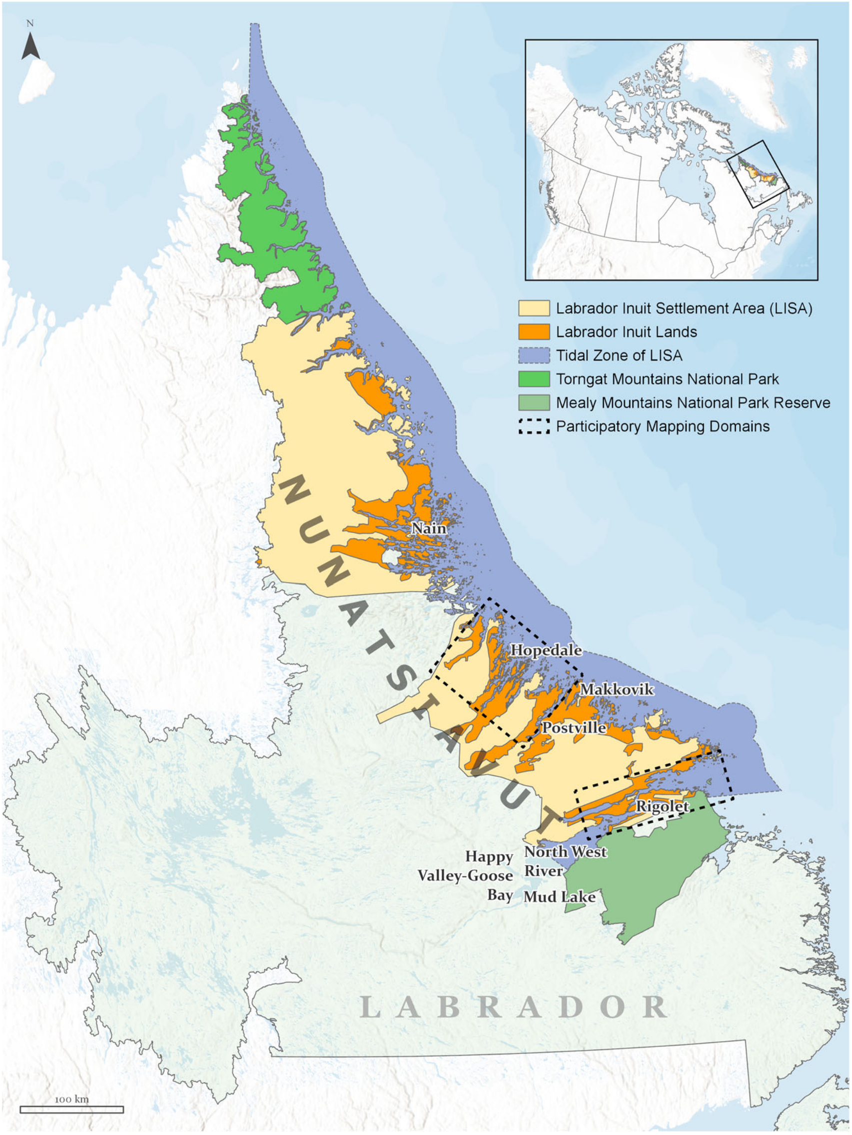

Figure 3. Labrador Inuit Settlement Area, including Labrador Inuit Lands, and the tidal waters (the Zone). The map also includes the CONOC project domains used for participatory mapping in Rigolet and Hopedale.

were used to contrast the ocean from the intertidal zone. Previously documented place names made available through the federal open data portal were included on the maps, which included place names (in English and Inuttitut) from previous research in the region. All of these features were intended to create a more immersive visual experience as participating community members thought about travelling through coastal spaces while they engaged with the maps. Participants continually referenced the place names, intertidal zone, and hill shading as they drew various features.

While the structure of the mapping sessions was designed to engage with knowledge around ocean currents and sea ice at spatial and temporal scales of interest for oceanographic analyses, flexibility was essential to account for participant interests and experiences. The sessions were open to the public to encourage other community members to attend and to foster knowledge transfer, particularly inter-generationally. Rigolet (n = 5) and Hopedale (n = 6) participants arrived over three days, depending on their availability. Because of this, group and individual mapping took place, with the group sessions identifying features through consensus, and individual mapping enabling people to focus on areas specific to their knowledge accumulated through longstanding use and occupation of an area (multi-generational knowledge). In Rigolet and Hopedale, groups of up to 3 people mapped together at one time, without overlap between groups. Participants often revisited the maps after others had been mapping and were able to view others' contributions.

Participants were provided coloured markers to draw on the maps themselves, and they were prompted by questions that aimed to provoke memories of travelling over the land, water, and ice, to uncover what it was they would encounter along the way. Participants were asked to first think about how and why they accessed marine spaces, and they were prompted to draw any travel routes (sled or boat) they used to access marine and coastal areas. They were also asked to think about and draw the features they would encounter when travelling by sled or boat during ice and open water seasons. Features that were mapped include the typical ice edge (*sinâ*; delineating the boundary between the land-fast ice[2] and the open water or pack ice), along with areas of open water and areas of ice unsafe to travel over. Ocean currents were mapped, with strength, direction, and seasonal changes over time also being recorded onto the map. Participants were given the option to add anything else they thought would be important to include, resulting in the addition of cabin locations, and some contextual details on area/feature use (e.g. open water hunting areas) and specific seasons related to features (e.g. late to freeze in fall, first to thaw in spring). Notes were taken to capture any details that could not be drawn on the maps. The completed maps were scanned, georeferenced, and digitized by the first author, checking features against the scanned originals for accuracy.

Interviews held after the mapping sessions aimed to elicit more detailed descriptions of the mapped oceanographic features (Puniwai et al. 2016) and to contextualize peoples' connection to marine and coastal areas. Participants were provided the option of having their names included in any research outputs or to have their identities remain confidential. Most individuals chose to have their names included. Those who wished to have their identities remain confidential were assigned a code and have been referenced in text in association with their community. Individuals have been formally referenced in the text wherever their knowledge is represented (Laidler and Elee 2008).

Interviews were transcribed, and in combination with notes taken during the mapping sessions, details were added to the feature attributes (in the form of metadata) as the maps were digitized. The spatial data resulting from this process was classified by location (Rigolet, Hopedale) season [winter (sea ice), summer (open water)] and theme (travel routes, ice features, current strength), and then organized by category (boat, sled; open water, historic open water, unsafe ice, historic unsafe ice, typical ice edge, direction of ice drift; current). If applicable, current strength and time period were indicated [weak, medium, medium historic, strong, very strong, very strong historic (and if indicated, dominant flow direction)], with other details such as descriptions, processes, and narratives attached to specific features, as indicated by participants. In a digital form, when a specific feature is being viewed, the metadata can be accessed by selecting the feature, displaying these qualitative details. Metadata in this sense provides further context that is not immediately apparent in the spatial data, and it can thus fill in some gaps resulting from the mapping of experiential oral knowledge. The categories of classification were partially pre-determined to include broad categories of oceanographic scientific interest – current location/strength/seasonality and sea ice edge location/drift direction, while flexibility in classification allowed for the expansion and/or redefinition of categories as identified by participants and researchers during the mapping process. Referencing Figure 2, the mapped oceanographic features would classify as spatial data, while the feature attributes described above (metadata) would provide organization and context to that data, providing enough detail for it to be recontextualized as it was applied in an ocean-sea ice model.

Computational ocean-sea ice model

A computational ocean-ice model for Lake Melville and Groswater Bay (together known as Hamilton Inlet, or historically as Aiviktuk) was developed to simulate the state of the ocean and sea ice for the region around the Rigolet Narrows. We used the ROMS ocean model (Shchepetkin and McWilliams 2005) coupled to the CICE sea-ice model (Hunke et al. 2008), with a ca. 500 m horizontal resolution, 40 sigma-levels in the vertical, and ocean bathymetry derived from a blend of General Bathymetric Chart of the Oceans and Canadian Hydrographic Service Non-Navigational data.

The model was initialized with zero current and ice speeds and with a temperature and salinity field derived from historical temperature and salinity profiles (Lu, De Young, and Banton 2014). We simulated the time period from June 2000 to August 2001 using atmospheric forcing (at the surface) from the ERA5 reanalysis and ocean forcing (at the open boundary to the east) from the GLORYS12V1 reanalysis.[3] Riverine freshwater inputs were specified for the Churchill River, Northwest River, Goose River, Kenamu River, Sebaskachu River, Mulligan River and English River which flow into Lake Melville as well as Double Mer Brook and Tom Luscombe Brook which flow into Groswater Bay (Anderson 1985). These rivers currently have a combined freshwater discharge into Hamilton Inlet of ca. 2200 m^3/s in winter and ca. 3800 m^3/s in spring (Demirov and deYoung 2016). Historically, prior to the hydroelectric development of the Upper Churchill River (1971–1974), the seasonal discharge range was much greater dropping as low as ca. 1200 m^3/s in winter and as high as ca. 5500 m^3/s in spring (Bobbitt and Akenhead 1982). We performed two model simulations: one using present-day seasonal river discharge and one using historical, pre-hydroelectric development, seasonal river discharge. The computational model provides daily estimates of ocean current speed and direction, temperature, and salinity as well as sea ice thickness, concentration, and drift. We look at averages of these properties for the months of February and July from both simulations.

Results

The results included here focus broadly on the features/variables that were mapped and associated descriptions/definitions provided by participants in Rigolet and Hopedale. Additionally, we provide an overview of participants' connections to the marine environment (as expressed during interviews), offering a window into the ontological grounding and values that underpin the knowledge that was shared. Spatially, we focus on the region around Rigolet, since that was chosen as the focus for developing and testing the ocean-sea ice model, predictions from which are also included in the results. Overall, the results are presented to describe the process of creating maps derived from Labrador Inuit knowledge and how they were applied in an oceanographic model of the region around Rigolet.

Labrador Inuit connection to the marine environment

During interviews, we asked participants to describe what being out on the land (including water and ice) meant to them, in order to capture a more detailed description of their connections to the places and features being mapped, and how that knowledge has been developed. In addition to supporting subsistence and livelihood activities, being out on the land is highly valued and was described as a way of life, a part of Labrador Inuit social identity and cultural heritage, giving people a sense of pride and belonging. Travelling, fishing, harvesting, and hunting in coastal areas are grounded in generations of family and community tradition, but there is an emotional connection as well, with one participant stating:

> [It's] just part of us, it's part of our heritage and it just becomes almost like part of you, and there's something happens when you go out on the land. It's … I can't explain it … it's … it definitely affects you physically and mentally, emotionally … every how [*sic*] I think. Spiritually too I suppose. Yeah. There's definitely something about being out on the land it does for you. (Baikie 2019)

While Labrador Inuit experience the marine environment in a variety of ways, most of these are facilitated through travel – by sled during the sea ice season, and by boat during the open water season. How, why, and when Labrador Inuit travel are grounded in the seasons (and associated weather and species available for harvesting), which influences where they travel to, and what precautions they must take to safely navigate in the marine environment (see also Aporta 2016). Equally important is the social dimension through which Labrador Inuit engage with coastal Nunatsiavut. Knowledge is cultivated and shared amongst family members and community members while travelling and hunting/harvesting out on the land and water. First-hand experience and learning from others (often grandparents, parents, or extended family) ground different aspects of Labrador Inuit knowledge in both social and environmental relations. For example, when describing a strong current in the Rigolet Narrows, one participant would reference his own experiences of travelling around the current to reach a family cabin, while recounting what he had learned from his father about the current to express how it had changed over time.

Ice features

When participants mapped ice features, they would often describe the features, associated processes, and personal narratives connected to those features. Participants emphasized that the location of the ice edge changes from year to year, and throughout the course of the ice season, due to weather events such as storms and due to seasonally driven fluctuations, so drawing a line on the map that was indicative of one location was challenging. Through conversations amongst researchers and participants, the term "typical ice edge" was agreed upon, with the line on the map representing what would be an average location in recent years, similar to how the ice edge was documented by Brice-Bennet and LIA in the same communities (1976). Locating the ice edge was described by one participant as follows:

> [… If] you're traveling somewhere you always look for the ice edge. You probably go up on a nob or a hill what we call it and you look out over the water and then you could see the ice edge. And usually, you could see if there was new ice formed along the edge. (H. Shiwak 2019)

The ice near the ice edge was also described as changing:

> I know saltwater ice is a lot softer than freshwater ice. We used to go to the edge out there sometimes and it would froze [*sic*] that long and you could walk around and see the ice bending under you so it's a lot of … its really soft ice. (Rigolet participant 2019)

Participants described unsafe ice as areas within the land-fast ice that are not suitable to travel over. In Hopedale, participants defined this as ice that is able to withstand "two chops with the axe", indicative of it being at least 5–6 in. thick, although ideally at least 12 in. in the winter. Areas of unsafe ice change depending on seasons, with some mapped areas of unsafe ice only being considered unsafe in the early fall and late spring, whereas during winter, such areas can freeze solid enough for travel (A. Vincent 2019). This description led to a new category of ice feature being established on the resulting map for Hopedale – late freeze/early thaw – so that anyone from the community using the map could still be aware of the potential risks travelling in the areas, and so that researchers using the maps can be aware of slight differences in the conditions that may be present there, depending on the time of year. In contrast, areas of open water (termed "rattles" in Hopedale, simply "open water" in Rigolet) remain open water year-round usually as a result of strong currents. Participants noted that even during summer months, the tidal currents could be so strong around areas of open water that people need to be careful when travelling by boat. While some areas of open water/rattles may experience a minor amount of ice in the winter, the majority of the year they remain open water and can be important locations for hunting during the sea ice season. In Rigolet, open water areas covered a much larger spatial extent than the rattles mapped in Hopedale, due to the geographic differences and the strong tidal currents present in the Rigolet region.

Currents

Areas with notable ocean currents and tidal flows were documented in both Rigolet and Hopedale. While ocean and tidal currents were documented on both the sea ice and open water season maps, participants in both communities expressed that the location and strength of currents were applicable for both seasons, and what was drawn on one map would be the same on the other. Particularly with respect to currents, participants often related descriptions to other features (both mapped and un-mapped), such as travel routes following the direction of the tidal currents, or ocean currents that influence hunting or fishing. Participants indicated current strength as they drew each current (choosing between weak, medium, strong, and very strong), with the majority of mapped currents falling into medium-strong categories. Although interpretation of the current strength categories remained subjective and may have been influenced by the fact that the participants either had travelled together or would exchange stories of travelling, it is worth noticing that no participant expressed disagreement with how the currents had been collectively mapped and categorized. The majority of the region around Rigolet experiences strong tidal currents, and very few of the mapped currents were categorized as “weak”. People instead emphasized the weakening of current strength over time as a result of a hydroelectric dam developed at Churchill Falls (1971–1974), which reduced freshwater discharge of the Churchill River into upper Lake Melville and thus also reducing the flow through the Narrows into Groswater Bay.

Rigolet oceanographic changes over time

Notable characteristics that were identified for the Rigolet region (Figure 4) include significant changes to sea ice, tidal currents, and ocean currents resulting from the development of the Churchill Falls hydroelectric dam. For example, an area of converging tides in the Narrows that used to be

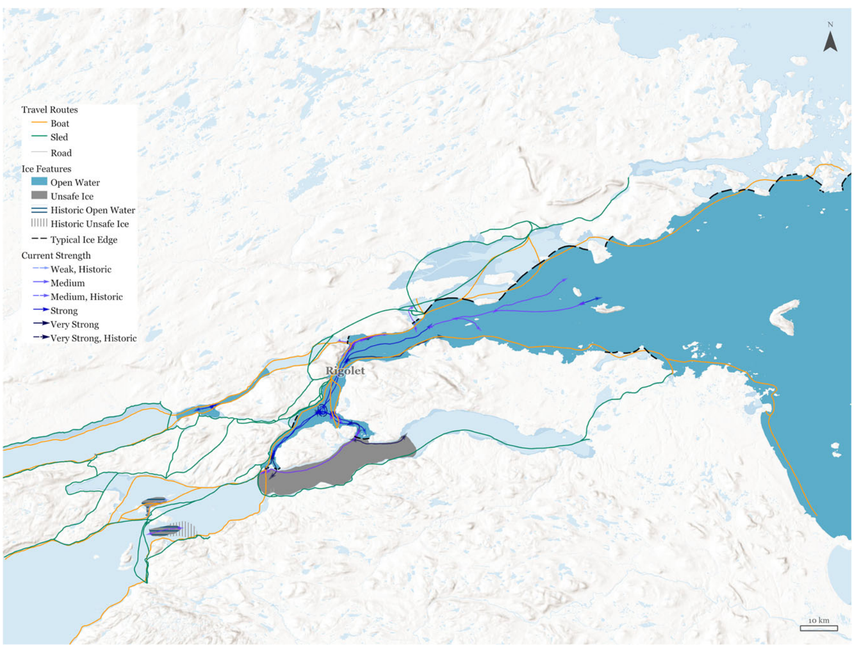

Figure 4. Rigolet community mapped trails and oceanographic features.

considered "very strong" is now considered "strong", with older participants indicating similar observations of reduced strength for most tidal currents in the region. Such changes also corresponded with changes to ice conditions. Especially notable were changes to an area locally referred to as Pelters Island. As two Rigolet participants explained:

> Since Churchill Falls was harnessed right. There's a lot of change in the water, like up there where Pelters Island is […] it was all open water up inside of Pelters Island and Trout Cove way. Now you don't see that anymore […] because people travel all over that ice now all winter long, don't have to worry. (H. Shiwak 2019)

> Some people still won't go onto [the ice] though because they still don't trust it right? […] They say it still make bad there but you know it could … you never know eh, from one year to the next what the change is going to be. (B. Shiwak 2019)

In addition to describing these changes, participants expressed concerns over where other areas of unsafe ice may have formed, and what future changes to the region may look like with the ongoing development of the lower Churchill River (Muskrat Falls). Changes to ice quality were also explained, with participants agreeing that the ice around Rigolet was much softer than it used to be. One participant attributed this to an increased amount of salt water in Lake Melville since the Churchill River was dammed (outflow from the Churchill was responsible for a significant amount of freshwater influx into Lake Melville).

Translating Labrador Inuit knowledge into spatial data

The previous paragraphs describe the features that were mapped by participants, and some key contexts and variables that may be translated into oceanographic research frameworks. To summarize, Labrador Inuit participants shared their knowledge orally during the mapping session and follow-up interviews, often before or while they marked specific routes or oceanographic features on the maps. We took notes and digitized them along with the resulting maps (creating spatial data and metadata which includes qualitative feature categorizations and feature descriptions provided by participants). The resulting digitized maps and interviews were then shared with participants for validation and subsequent use. For the purpose of this analysis, we will focus on the resulting map for Rigolet (Figure 4), since that data was applied when developing and testing the oceanographic model (whose predictions are shown in Figures 5 and 6). The maps were created collaboratively with input from oceanographic scientific interests (in understanding currents and sea ice in the area and how conditions have changed over time) and Labrador Inuit interests (in documenting currents and sea ice conditions that are

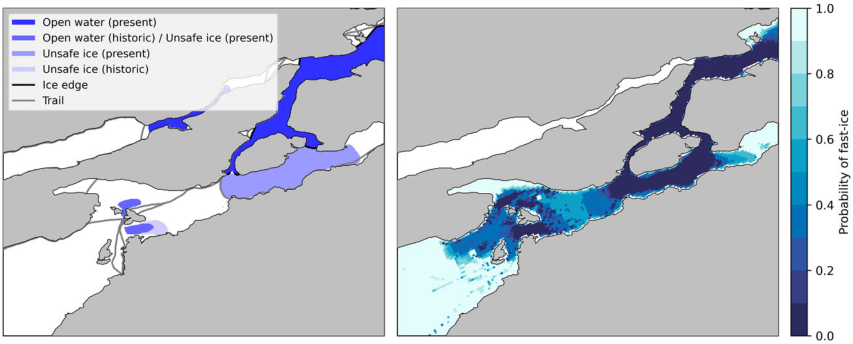

Figure 5. (a) Sea ice features mapped by Rigolet residents including the ice edge and present day and historic areas of open water and unsafe ice. (b) Predictions from the computational ocean-ice model of the probability of land-fast ice. Land-fast ice was defined as a high concentration of ice (>90% area cover) that is moving extremely slowly (<0.00001 m/s). Double Mer, the white area to the north and west of the Narrows, was not part of the model and so predictions are absent there.

important for community members and visitors to be aware of when travelling in the area). Discussions of these respective interests and potential uses for the maps allowed us to collectively develop new categories and definitions to describe specific features that emerged while mapping, for example, the late freeze/early thaw category for sea ice, or the transition of historic open water areas to areas of unsafe ice. The mapping process helped communicate knowledge across those distinct knowledge systems.

Translating data derived from Inuit knowledge into oceanographic frameworks

An ocean-ice model was developed after the mapping workshops took place in Nunatsiavut. The hypothesis of the model was set based on knowledge that was shared by participants in Rigolet: that the changes in river discharge

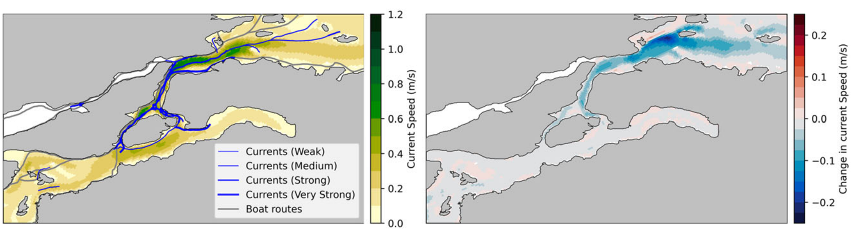

Figure 6. (a) Ocean current features mapped by Rigolet residents (blue lines) and predictions of current speeds from the computational model (yellow-green shading). (b) Model predictions of change in current speeds between after the hydroelectric development of the Upper Churchill River. Blue shading indicates a reduction in current speed.

due to the Churchill Falls hydroelectric development modified sea ice conditions (and reduced current strength) in the Rigolet Narrows area. Knowledge shared during the mapping workshops also directed how the model results were analysed and interpreted, which for a computational model can be done in countless ways and along any possible line of inquiry. While the model configuration was not directly modified based on Labrador Inuit knowledge, the spatial scale and area of focus (Rigolet Narrows) were selected to reflect oceanographic changes that were described by participants. In addition to this, setting the model hypothesis and the approach for analysis and interpretation based on Labrador Inuit knowledge offers a novel approach to bringing qualitative data/information into an oceanographic scientific framework.

Ocean models typically undergo a process of validation whereby direct observations of the ocean state are compared to model predictions and in doing so one can understand the degree to which the model accurately estimates the ocean system as it is reflected through direct observations. The observations are most often taken from in situ measurements (from instruments placed in the water to measure temperature, salinity, and other variables) or from remote sensing data. Here we also used a different type of data source, consisting of the data and information that were obtained through the spatial rendering of Labrador Inuit knowledge. Some of the knowledge shared was easier to render onto maps as spatial data, allowing for comparison with model predictions. These included open water (absence of ice), unsafe ice (described quantitatively in terms of minimum thickness) and areas that were assumed or portrayed to be safe ice (described quantitatively as being a minimum of 5–6 in. thick and ideally at least 12 in. in winter) (Figure 5(a)). Features associated with ocean currents, including their direction and a qualitative measure of their speed (Weak, Medium, Strong, Very Strong) are also readily translated (Figure 6(a)). To help maintain the original context of the mapped features, travel routes were also included when comparing and validating model predictions. Additional features represented spatially and further contextualized by qualitative descriptions can be effective at both constraining and validating the model output. For example, areas that experienced a change in ice conditions from open water to unsafe ice around Pelters Island mapped by participants in Rigolet were described further by participants, including H. Shiwak (2019) and B. Shiwak (2019) whose quotes were included in the previous section. These descriptions contextualized when the changes occurred, and how they influenced travel choices and peoples' confidence in the ice conditions. Similarly, other participants noted reduced current speeds that occurred after the Churchill Falls hydroelectric development. While these reductions were not consistently rendered spatially, the qualitative descriptions allowed us to place our model results in context.

In this case, a model validation can be done visually through representing the model predictions spatially (also as maps). Areas of land-fast ice cover as predicted by the model can be interpreted as safe ice, with less land-fast ice thus corresponding to unsafe ice and ultimately to open water. The probability of land-fast ice as simulated by the model (Figure 5(b)) shows a large contiguous area of very low probability through the Rigolet Narrows and this corresponds well with the area of open water and unsafe ice mapped by Rigolet participants in the same area region (Figure 5(a)). The model also simulates a complex network of low probability of land-fast ice in the vicinity of Pelters Island where areas of open water (historically) and unsafe ice were mapped by Rigolet participants. The ocean model also simulates that ocean currents tend to be stronger in narrow straits such as between the islands or in the Rigolet Narrows itself (Figure 6(a)). This corresponds well with areas Rigolet participants mapped as having notable currents.

Of note here is that the model makes predictions everywhere in the assigned domain while Rigolet residents only mapped in certain areas within that domain (along common travel routes or near important locations). Therefore, we are unable to validate the ocean model in areas beyond that which was mapped by Rigolet participants. One limitation of the use of a map as a boundary object applied for model validation is the use of un-mappable or un-mapped knowledge recorded via interview. For example, multiple residents described how the currents in the Rigolet Narrows area decreased in speed after the hydroelectric development of the Upper Churchill River, but these descriptions were not consistently rendered spatially at the time of research. The model simulates a current speed reduction after the hydroelectric development of the Upper Churchill River (Figure 6(b)) but we have limited spatial representation of Inuit knowledge of this change to effectively compare with the model output. This presents a challenge and demonstrates a limitation of maps as boundary objects, specifically when the maps are brought into new contexts beyond the collaborative context in which they were created. However, while we cannot visually compare mapped knowledge of reduced current speed with model predictions, we can qualitatively compare model predictions with the qualitative descriptions of reduced current speed provided by participants. Interpreting model predictions in the context of such knowledge allows us to both situate model predictions in the context of Labrador Inuit knowledge, and to assess if/how the model could be strengthened or changed to better account for un-mappable/un-mapped knowledge.

Discussion

Boundary work and creating boundary objects can emerge from cooperation without requiring consensus (Star 2010), meaning that while different knowledge systems/social and cultural groups may cooperate and work towards a shared goal, the goal, the interpretation and the application of the boundary object itself may be done according to the needs and interests of contributing groups and respective knowledge systems. In the case described in this study, the physical maps produced from the first stage of participatory research for the CONOC project (and their potential role to support planning for future change in coastal Nunatsiavut) were a shared goal, acting as a place of cross-cultural encounter between Labrador Inuit knowledge and oceanographic scientific knowledge. Participants shared knowledge and contributed to the maps with the hope that they would be of use for safe travel in the area and a helpful way of sharing knowledge with the younger generation, while also supporting the researchers interests in understanding coastal oceanic conditions to help predict future scenarios. The resulting maps emerged as a hybridization of these values and interests – demonstrating a more fluid relationship of knowledge across cultural boundaries (García Canclini 1995) – representing coastal oceanic features that have utility for oceanographic science while reflecting features participants valued and deemed important to know about when travelling over the ice and ocean.

While the application and utility of the maps differed for each contributing group, collaborating on their creation allowed for identification of places and features that were important, valuable, and meaningful. This collaborative process enabled a convergence of understandings through the act of mapping. As such, the "boundary object" is not just the maps, but is encapsulated in the process of their creation and respective interpretation. Discussions during the mapping sessions helped to refine what features were mapped and the non-spatial details that were crucial to contextualizing the maps, allowing the boundary object to be reinterpreted by each contributing group (Figure 7). For example, participants expressed that the maps would be useful for people travelling in the region who were less familiar with the ice/ocean features/conditions – allowing the maps to be reinterpreted by individuals using them in the context of personal safety during travel. This would involve individuals reinterpreting the spatial features in the context of their own knowledge and experiences. Those same features/conditions were reinterpreted in the western scientific framework described previously to support developing and testing the computational ocean-sea ice model. At this stage, we cannot speak to how oceanographic scientific knowledge is interpreted and applied by participating Labrador Inuit (beyond statements that were made during the mapping process, which expressed interest in knowing scientific perspectives on oceanic conditions and ongoing and anticipated change). While participants experience of the boundary object will be critical to explore in future stages of this work, the discussion here focuses on the process of creating the maps and interpreting and applying of them in oceanographic scientific frameworks during the development and testing of the ocean-sea ice model.

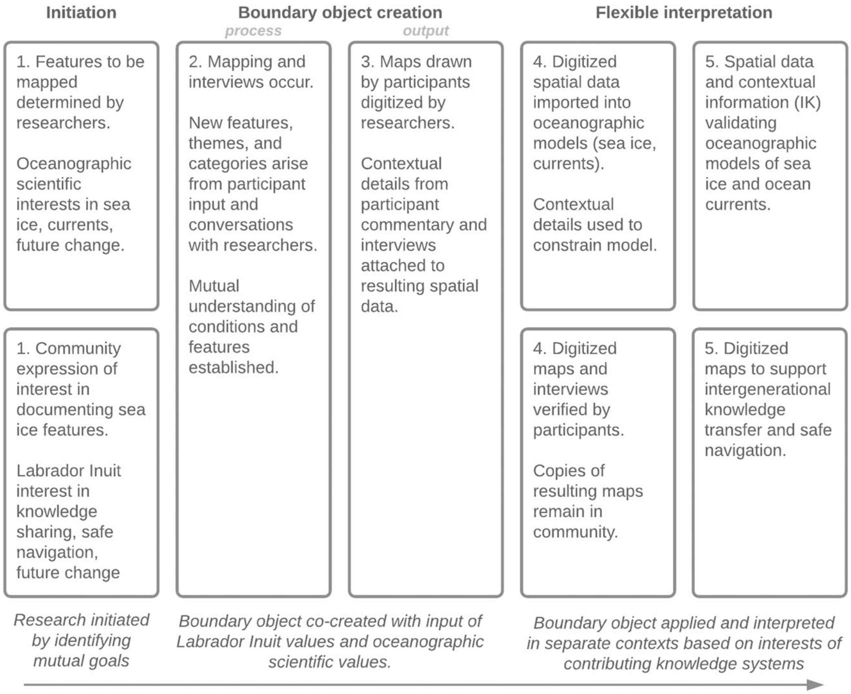

Figure 7. Situating maps as boundary objects within the CONOC project participatory research process. The intent of a boundary object is to facilitate communication and translation in cross-cultural contexts, allowing for cooperation but not requiring complete consensus. The maps in this case represented a mutual goal and a space of co-production, which upon completion can be utilized differently by each contributing group.

To be flexible and provide space for interpretation, boundary objects must be simultaneously concrete and abstract, conventional and customizable (Star and Griesemer 1989), emerging in this case as both a tangible object, and the less tangible process of creation (Cutts, White, and Kinzig 2011). The qualities commonly attributed to "data" are that it has little ascribed meaning and is separated from context (Bates 2005). Framing the CONOC maps in relation to the boundary object concept, spatial data on the maps can be concrete and conventional, represented in a format that can translate across a variety of applications, allowing their mobilization into the ocean-ice model for visual comparison. At the same time, embedding spatial data with context through including qualitative descriptions as metadata and ensuring that the different categories of spatial data remain represented together (e.g. including the travel routes along with the sea ice features when validating the ocean-sea ice model) allows it to retain some of the more abstract and relational characteristics of the original knowledge, which can guide in the representation and subsequent applications of the spatial data.

In the case of mapping Labrador Inuit knowledge, rendering it as spatial data requires preserving aspects of the ontological context of that knowledge. Doing so allows the map to be reinterpreted and applied elsewhere without risking decontextualization/recontextualization processes that would strip associated meaning and values. Conversations and discussions amongst participants and researchers brought to light which contextual aspects were more important to preserve. For example, during the participatory mapping process for the CONOC project, collaboratively determining categories and category definitions allowed for a space of mutual understanding to be established. This also helped identify certain characteristics required to maintain the integrity of Labrador Inuit knowledge when it is reinterpreted and applied outside of the context of the original boundary object (e.g. in the ocean-sea ice model). Such characteristics were reflected in participants expression of their connections to the marine environment, situating how marine spaces are valued and how those values are contained within the knowledge that participants chose to share and map. These include through individual and collective mobilities (expressed as travel routes), seasonality (determining when/where/why participants would be travelling and how travel safety must be considered), and relationality (the interconnectivity/relationships between features/uses). Ensuring the mapped spatial data (and/or metadata) is represented and expressed in formats that allow these characteristics to be conveyed can help provide adequate context to make the boundary object useful for all contributing groups (Lee 2007; Zurba et al. 2019).

These characteristics can also inform how the map would be applied and interpreted by Labrador Inuit, who, while co-producing the maps, framed them as tools to aid safe navigation and share knowledge within their communities, supplementing other modes of knowledge transfer (i.e. oral teachings and experiential learning). Oral methods offer precise geographic descriptions of how horizons are viewed as they are recalled from journeys, referencing named places and features as they would be encountered from particular standpoints while travelling (Aporta 2005). While maps cannot depict experiential interactions with the landscape, they offer a way to spatially represent the trails and features (and seasonal characteristics) that can supplement experiences and oral teachings. These characteristics can also directly inform the ocean-sea ice model, providing context for the model predictions in relation to Labrador Inuit knowledge and use of the region (Figure 7). The ability to represent the computational ocean-sea ice model predictions alongside the Labrador Inuit knowledge facilitated a novel approach for model validation, whereby the knowledge was taken as a new form of "observation" to ground-truth the model. This process is not without challenges. For example, certain knowledge that either was not mapped or cannot be mapped for not being conventionally *spatial* may be helpful to strengthen what the model is able to predict. However, its non-spatiality makes it more challenging to mobilise into the ocean-sea ice model. For example, Labrador Inuit knowledge of changes over time was described, but not spatially rendered by participants in all the areas that were mapped. Incorporating these observations that were shared (but not mapped) could still help qualitatively validate and constrain the model predictions. Similarly, as was expressed before, Inuit-environment interconnections are not readily expressed by linear approximations favoured by cartographic approaches (CSAS 2021), and the challenge of representing the ice edge exposed this tension in our own work. Dynamic oceanic processes such as sea ice changes in time and space do not necessarily align with the static representations of spatial data requested in the CONOC project mapping exercise. Dynamic oceanic processes are addressed in oceanographic research through collecting expansive data on an ongoing basis, which requires computational processing to translate that data into meaningful information about sea ice dynamics. However, spatial data (and qualitative metadata) on a single static map representing coastal ocean and sea ice conditions may fully represent neither the richness of these dynamic oceanographic processes nor the complex Labrador Inuit knowledge of the coastal ocean.

As we continue with work on the CONOC project, and in other cross-cultural participatory mapping contexts, it will be important to maintain reflective dialogue as mapping takes place to ensure that these tensions are acknowledged and discussed, and the co-production of maps as boundary objects creates a space where meaningful dialogue can be facilitated. Tensions such as those encountered through static representations of dynamic knowledge, and knowledge and information that do not fit into the existing and agreed-upon representation parameters for the map (boundary object) can be situated as the basis of *new* boundary objects that could be co-developed in the future (Star 2010). In this sense, it might be more helpful to think of this exercise as a boundary process, moving beyond the limitations that the concept of "objects" may represent. This demonstrates the dynamic processes of boundary work, and how boundary objects can be applied, interpreted, and re-developed when bridging Labrador Inuit knowledge with oceanographic scientific knowledge. While beyond the scope of this study, new mapping technologies such as cybercartographic atlases have also shown potential to play a role in boundary work through offering space-based and multimedia venues to share data and information (in different formats) derived from diverse sources. Importantly, in offering multisensory representations (visual and auditory) and dynamic and interactive formats, some of the linguistic and cultural dimensions of Inuit knowledge can be addressed (Engler, Scassa, and Taylor 2013). However, the success of this technology is contingent on careful curation and representation of data and information derived from Inuit knowledge to ensure that contextual elements are retained and represented properly, and that Inuit will benefit from how their data are presented alongside other data sources if the need arises (Tesar, Dahl, and Aporta 2019).

A re-framing of the processes of decontextualization/recontextualization when co-producing and interpreting maps as boundary objects to communicate across Labrador Inuit and oceanographic scientific approaches to marine processes can be seen in Figure 8, being a modification of Figure 2. Each knowledge system is contributing to the creation of the boundary object, collaboratively determining the scope and categories of spatial knowledge being represented. Equally important, each contributing group is then able to interpret and apply the boundary object based on subjective interests and needs. In this case, mapped spatial data generated through a cross-cultural encounter was concrete enough to facilitate mutual understanding, while also allowing flexible interpretation by each contributing group (Figure 8). Contextual details ensured that the map

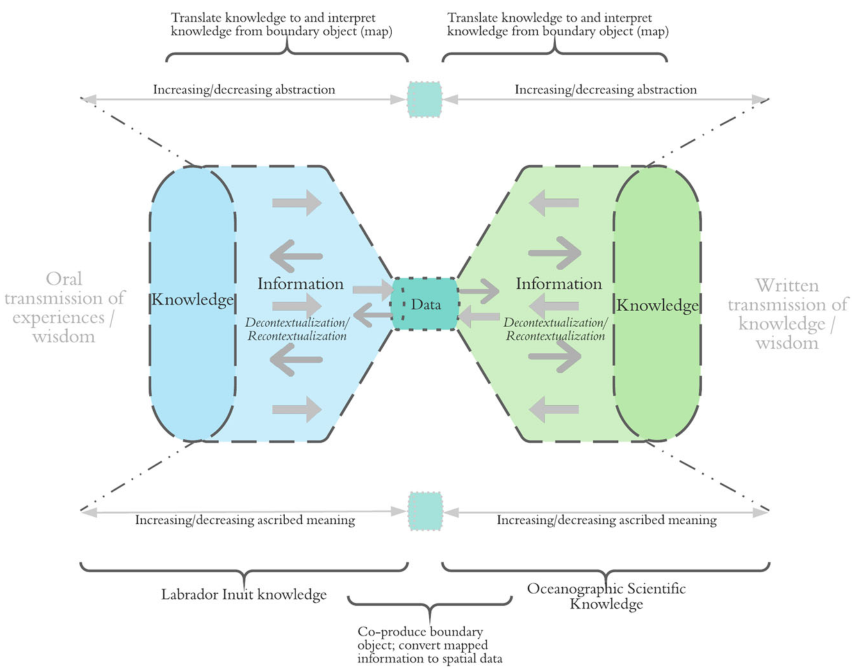

Figure 8. Decontextualization and recontextualization processes that occur when co-producing maps as boundary objects. The square arrows represent contributions to the creation of the boundary object, and the rounded arrows represent interpretations of the boundary object. All "boundaries" are represented as permeable, indicating the non-discrete divide between data, information, and knowledge in the context of boundary object creation and interpretation.

could remain robust enough to have meaning as it was applied in the ocean-sea ice model, while still reflecting certain aspects of the ontological context of Labrador Inuit knowledge. Figure 8 has been flipped (compared to Figure 2) to represent a more evident two-way iterative process, and the "boundaries" between data-information-knowledge-wisdom categories have been expressed with dashed lines to represent permeability that can arise through collaborative cross-cultural exchanges. Collaboratively producing maps as boundary objects can help generate permeable knowledge boundaries, which allow contributing groups to interpret the boundary object fluidly, generating new narratives through different applications, while preserving the values expressed when co-producing the original boundary object.

Conclusion

Framing maps of coastal travel routes, ocean circulation and sea ice features as boundary objects in the research process reveals them as spaces of cross-cultural collaboration, created through contributions from Labrador Inuit knowledge and oceanographic scientific knowledge. This is evident despite the lens of boundary work not having been applied when developing the participatory mapping methodology and the ocean-sea ice model. The output of this collaboration (digitized maps of Labrador Inuit knowledge) provides a space for flexible interpretation and application, as exemplified by applying the spatial sea ice, currents, and travel route data to validate predictions from the ocean-ice model. As researchers engage with Labrador Inuit knowledge, "translations" must occur in order to mobilize that knowledge into specific western scientific frameworks, requiring complex and multifaceted knowledge shared by participants to be filtered down into spatial data and qualitative metadata. By maintaining seasonal categorizations, feature definitions and categories, and how those features relate mobility networks (travel routes) and other ice/ocean features, the original (as well as new) meanings and context of the maps can be recreated in the context of use and interpretation. While we did not speak to use and interpretation of the maps by Labrador Inuit, we demonstrated how meaning was recreated using the maps to interpret and validate predictions of the ocean-sea ice model. Preserving the contextual details described above allowed that meaning to be recreated while still maintaining the integrity of Labrador Inuit knowledge. Challenges emerged with regards to knowledge that was not spatially rendered during the mapping process, making evident the limitations when it comes to maps as boundary objects in this context. However, in the case of mobilizing Labrador Inuit knowledge into oceanographic science, co-producing maps offer an opportunity to manage knowledge transformations that occur and to account for ontological approaches.

The resulting maps (boundary objects) become hybridizations of values and interests that emerge from the conversations and decisions made during their creation. In this case, Labrador Inuit participants expressed the value of sharing knowledge inter-generationally, and how the maps could support that. While we were interested in mapping certain oceanographic features that could lend to scientific applications, values such as intergenerational knowledge transfer determined what participants chose to map and what knowledge they shared during the mapping process. In the case of the maps co-produced for the CONOC project, this hybridization allows the maps to have utility for contributing participants to assist with travel safety and sharing knowledge within the community, while also allowing for their translation into oceanographic scientific frameworks. Contributing knowledge holders can then interpret and apply the boundary object fluidly in different contexts, as related to their subjective goals for the mapping process (Figure 7). For example, participants may use the maps to teach someone about how to reach a specific hunting or fishing location during a certain time of year, the potential sea ice conditions or ocean currents that will impact that travel, and what precautions must be taken (e.g. using a different travel route when certain ice conditions are present). While the map can provide a visual to aid this explanation, the map itself is recontextualized by the participant explaining it with the addition of further details, while the person being taught is also recontextualizing the map by situating the map and explanation in the context of their own experiences and understanding. This recontextualization also happens as the map is translated into the ocean-sea ice model, whereby the spatial data and qualitative descriptions become reference points to interpret and contextualize the model simulation.

This paper has shown that identifying maps as boundary objects is helpful for several reasons: (1) it shows the cross-cultural dynamic of such objects in the context of the documentation and rendering of Inuit knowledge; (2) it shows that maps can be interpreted as fluid objects, allowing for the flux, interpretation and recontextualization of knowledge and data; (3) it presents practical ways to deal with the tensions between qualitative and quantitative data; and (4) it allows for fruitful *conversations* across ontological boundaries. In the case of the CONOC mapping work in Rigolet, these conversations were encapsulated in the process of collaboratively creating the maps, and they led to the hypothesis for an oceanographic scientific model to be set by Labrador Inuit knowledge, and for the model simulations to be analyzed and interpreted based on that knowledge. As cartographic representations, oceanographic modeling and Inuit narratives interact in a dynamic process which has no static end product, co-produced maps as boundary objects remain interactive as they are effectively re-contextualized and re-interpreted into narratives. A critical aspect of this process that we hope to address in future stages of this work, is a consideration of how information from oceanographic scientific research is translated to Labrador Inuit through boundary work and boundary objects. This side of the relationship is equally important, as Inuit self-determination in decision-making relies not only on making this information available but also on producing it in a way that is culturally meaningful.

Notes

1. The four Inuit regions in Canada (Inuvialuit Settlement Region, Nunavut, Nunavik, and Nunatsiavut) are collectively known as Inuit Nunangat, a term that encompasses the land, water, and ice that represent the Inuit homeland and which are integral to Inuit culture and way of life.
2. The land-fast ice consists of sea ice that is anchored or "fastened" to the coastline or sea floor. Unlike pack ice, it is does not move with currents and winds, although both impact how and when land-fast ice forms and breaks up. Currents, tides, and winds also influence the formation of recurrent features within the land-fast ice such as polynyas or tidal cracks.
3. Reanalysis models produce comprehensive records of how oceanic and atmospheric properties are changing over time. The ERA5 reanalysis provides estimates of atmospheric, land, and oceanic climate variables, and the GLORYS12V1 reanalysis provides estimates of physical ocean variables.

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Notes on contributors

Breanna Bishop is an interdisciplinary PhD student at Dalhousie University. She is interested in how Indigenous and western knowledge systems can contribute to understanding complex problems at the intersection of climate change and Indigenous rights. Her current research explores how Inuit describe indicators of oceanographic and climatological variables, including seasonality and change, and the underlying ontological approach to the generation and application of such knowledge. She is interested in understanding where western scientific approaches to oceanographic and climatological phenomena can align with Inuit knowledge to generate locally relevant information for climate change planning and decision-making.

Eric C. J. Oliver is an Assistant Professor of Physical Oceanography in the Department of Oceanography, Dalhousie University. His research interests involve ocean and climate variability across a range of time and space scales including extreme events (marine heatwaves, storms), the predictability of climate variations, and the role of climate change on the mean state, variability and extremes of the climate system. He is an Inuk with roots in Nunatsiavut (northern Labrador). He is interested in Indigenous perspectives on climate, weather and oceans and in working with both Indigenous and scientific knowledge of these systems.

Claudio Aporta is an Associate Professor at the Marine Affairs Program, Dalhousie University. He is a cultural anthropologist who has studied and documented Inuit-environmental and geographic knowledge for over 20 years, across the totality of the Canadian Arctic. His current interests are connected to co-management, sustainable communities, Marine Spatial Planning, Indigenous and local coastal knowledge, and knowledge mobilization.

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