Towards Innovation (Eco)Systems: Enhancing the Public Value of Scientific Research in the Canadian Arctic

Ashlee-Ann Pigford, Gordon M. Hickey and Laurens Klerkx

Over the past decade, the Canadian Arctic has seen an intensification of scientific research designed to foster innovation (i.e., the process of transforming ideas into new products, services, practices or policies). However, innovation remains generally low. This paper argues that before we can meaningfully promote innovation in the Arctic, there is a need to first identify the complex systems that support or inhibit innovation. Few, if any studies have taken a systems approach to enrich our understanding of how existing networks may or may not support innovation in the Canadian Arctic. A promising, but under-explored approach is to consider innovation ecosystems, defined as the multi-level, multi-modal, multi-nodal and multi-agent system of systems that shape the way that societies generate, exchange, and use knowledge. This paper presents innovation (eco)systems as a potentially valuable systems-based approach for policy actors to enhance innovation linkages in the Arctic. From a policy perspective, there is a need to embrace and promote more networked approaches to co-create public value and to consider the lifespan of any innovation. Potential directions for future research include: mapping the actors involved in Arctic innovation ecosystems (including intermediaries and bridging agents) at multiple scales; the role that formal and informal institutions play in shaping co-innovation; case studies to evaluate innovation processes; and an assessment of the coupled functional-structural aspects that influence innovation outcomes in the Canadian Arctic.

Introduction: Innovation in the Canadian Arctic

The Canadian Arctic has been identified as an 'up-and-coming' region and has attracted increasing national and international policy interest (Steinberg & Tasch, 2015). It has also been characterized as a region undergoing a series of unprecedented parallel social, political, and environmental transitions (Pauktuutit Inuit Women of Canada, 2006; Wehrmann, 2016). Much attention has been paid to understanding the impacts of climate change, as well as the vulnerability and resilience of Arctic residents who are faced with increasing pressures to adapt to the changing environment (Chapin III et al., 2004; Overpeck et al., 1997; Pelaudeix, 2012; Prowse et al., 2009). Concentrated attempts to

Ashlee-Ann Pigford and Gordon M. Hickey are with the Department of Natural Resource Sciences, Faculty of Agricultural and Environmental Sciences, McGill University. Laurens Klerkx is with the Knowledge, Technology and Innovation Group, Wageningen University.

better link contributions from scientific research and other public interventions to innovation are key to meeting the complex multi-level challenges (e.g., marginalization, poverty, limited infrastructure, poor housing conditions, food insecurity, and limited access to health and education services) associated with concurrent transitions in the Canadian Arctic (Coates & Poelzer, 2014; Exner-Pirot, 2015).

Innovation can be conceptualized as a "new or better way of doing valued things" (The Expert Panel on Business Innovation, 2009) or "as a response to, and as a means for change" (UArctic, 2017). More specifically, innovation is both (1) the process whereby ideas are transformed into something new and (2) the novel outcomes of such processes, such as a product, service, policy or practice (Baregheh, Rowley & Sambrook, 2009; Borrás & Edquist, 2013). Innovations are the result of (co-)learning, collaboration and interactions between multiple actors (e.g., firms, universities, research and public organizations, knowledge infrastructures, end-users and local knowledge holders) (Doloreux, 2004; Klerkx, Seuneke, de Wolf & Rossing, 2017), and are often a co-evolutionary process in which technological change is accompanied by social and institutional changes (Geels, 2004; Kilelu, Klerkx & Leeuwis, 2013). Therefore, coordinated approaches that link interested actors can help to support innovation (Lundvall, 2010).

There is a general expectation that governments and other public organizations make use of policy instruments to formally oversee the processes of defining and implementing innovation agendas to guide innovation efforts (Borrás & Edquist, 2013; Braun, 2008; Martin, 2016). Governments are usually tasked with the coordination of resources from various sources (e.g., private sector, the civil society sector, and the state) to find and support common priorities with a view to creating public value (Benington & Moore, 2011; Moore, 1995). The concept of public value simultaneously reflects what the public values and what strengthens (i.e., adds value to) the public sphere (Benington & Moore, 2011; Moore, 1995), extending the conversation of value beyond purely economic considerations (e.g., returns on research investment) to also consider social, political, cultural and environmental aspects of value (Joly et al., 2015). Public value can be enhanced through the development of innovations (Hartley, 2015).

One way that governments seek to foster innovation (and promote public value) is through policies that stimulate the production and diffusion of 'useful' scientific knowledge, which has the potential to expand policy alternatives, clarify policy choices, and form the basis of new technologies, services, practices and processes (Martin, 2016; McNie, 2007; Schut, van Paassen, Leeuwis & Klerkx, 2013). Over the past decade, the Canadian government has committed substantial financial resources to Arctic research (Nicol, 2016; Ogden, Schmidt, Van Dijken & Kinnear, 2016). National Arctic research funding has supported programs such as: the International Polar Year, the High Arctic Research Station, the NSERC Northern Chairs program, the Northern Scientific Training Program, ArcticNet, Arctic Research Infrastructure Fund, Churchill Marine Observatory, National Research Council Arctic Program, Sentinel North, the Canadian Polar Commission and Polar Knowledge Canada among other initiatives (Government of Canada, 2016, 2017a; Ogden et al., 2016). In 2017, Canada, along with other member states of the Arctic Council, signed the Fairbanks Declaration,

> "…announc[ing] the Agreement on Enhancing International Arctic Scientific Cooperation, the third legally binding agreement negotiated under the auspices of the Arctic Council, which will help increase effectiveness and efficiency in the development of scientific knowledge about the region as well as strengthen scientific cooperation in the Arctic region" (Arctic Council, 2017).

Continued and increasing public investments in the production of Arctic-related scientific knowledge implies that Arctic research has public value (McNie, Parris & Sarewitz, 2016), which may also translate into private value that furthers the public interest (Mazzucato, 2011). However, Arctic residents have repeatedly questioned the public value of Arctic research, arguing that outcomes do not often well-reflect the values, interests and needs of Arctic communities (Brunet, Hickey & Humphries, 2016; Coates et al., 2014; Ibarguchi, Murray, Rajdev & ISAC, 2015; ITK, 2016; Ogden et al., 2016; Tesar, Dubois & Shestakov, 2016). Despite investments in northern research there has been a relative dearth of research directed towards informing the development of northern-specific innovations, resulting in Arctic communities adopting innovations that were designed for southern communities with mixed success (Coates & Poelzer, 2014). Consequently, there have been calls to strengthen science-policy and science-practice interfaces in the region (Tesar et al., 2016), including a recommendation by the Arctic Science Planning Committee to develop improved methods to align research and policy agendas (Kofinas et al., 2005).

The process of transforming scientific knowledge into innovation is complex and requires diverse actors (e.g., from government, university, private sector, civil society and northern citizenry) to navigate large and rapidly growing amounts of information embedded within complex ecological, social, economic, cultural, organizational and political landscapes (Hammond, Mumpower, Dennis, Fitch & Crumpacker, 1983; Joly et al., 2015). A key question that emerges for decision makers is: how to better understand and intervene in the complex systems that support or inhibit innovation at different scales in the Canadian Arctic to enhance the public value of scientific research? This paper seeks to explore this question. In what follows, we present a brief background on the current state of governance and innovation in the Canadian Arctic. This is followed by a review of Canada's efforts to promote scientific research in support of Arctic innovation to identify some of the opportunities for, and challenges to, delivering public value. We then draw on the concept of innovation ecosystems to discuss the potential for an expanded and systems-based model to enhance the public value of northern scientific research investments.

Governance: Policy Coordination Issues Influence Innovation in the Canadian Arctic

Like many countries, Canada has placed increasing policy emphasis on the need to promote innovation to be competitive in a rapidly globalizing world. This is evidenced by the 2017 Federal Budget that focused efforts and resources on promoting innovation, emphasizing that Canada has "an opportunity to be one of the most innovative and competitive countries in the world" (Government of Canada, 2017b). However, to date, evaluations suggest that Canada's innovation performance has been poor (Creutzberg, 2011; Jenkins, 2017; Mitacs, 2016; The Expert Panel on Business Innovation, 2009). Canada has been criticized as having limited innovation from the private sector (Innovation Canada,

2011), poor linkages between high quality university academic research and commercialization (Conference Board of Canada, 2015) and overall poor research and development indicators compared to other countries in the Organisation for Economic Development and Cooperation (OECD) (Science Technology and Innovation Council, 2014).

The most common explanation for Canada's comparatively low innovation performance is that it lacks coordination and policy alignment across and between multiple levels of government (Hawkins, 2009; Mitacs, 2016; Tamtik, 2016). This is likely due to jurisdictional challenges embedded in Canadian constitutional governance structures[1] that divide power between the federal government (power over macro-economic policy, foreign policy, banking, defense) and provincial governments (power over natural resources, property laws, and education) (Halliwell & Smith, 2011). These also include the co-management of shared jurisdictions between provinces and the federal government (social welfare, health care, agriculture and immigration) (Halliwell & Smith, 2011). To varying degrees, local governments also retain community-specific responsibilities which overlap with federal and provincial jurisdictions (power over local security, transportation, infrastructure, planning, services and recreation). Such jurisdictional overlap can create barriers to coordination, communication and collective action with implications for innovation (Creutzberg, 2011; Hawkins, 2009; Mitacs, 2016; Tamtik, 2016).

Focusing on the Arctic region of Canada, it becomes clear that jurisdictional complications are amplified. Nationally, Canada represents both federal and unitary theories of constitutional design, where the federal government manages both constitutionally recognized provinces and federal protectorates, also referred to as territories.[2] In this system, provincial and federal governments cannot unilaterally alter the powers of the others (Hueglin & Fenna, 2015). However, unlike provinces, Canadian territories do not exercise their own constitutional powers; rather they exercise delegated powers under the legislative authority of the federal parliament, which holds supreme legislative power to delegate administrative and regulatory responsibilities and can withdraw these powers from the territories at any time (Government of Canada, 2010; Hueglin & Fenna, 2015). Therefore, although the political, logistical, cultural, environmental and organizational challenges that the territories face can be quite similar to the northern regions of most provinces (Coates et al., 2014), they are nested within very different governance structures. In practice, this has important implications for policy outcomes and support for research and/or innovation initiatives. For example:

> "The Arctic was better studied than the provincial northern hinterlands for two major reasons. The first was the continuing lure of the Arctic, as revealed in its climate, remote grandeur, very special biological productivity, and culture. The second was an administrative consideration. The federal government could direct and mobilize scientific activities more easily within its jurisdiction (Yukon and NWT) than in areas where provincial agreement was needed. In general, provinces had fewer scientific resources than the federal government" (Science Council of Canada, 1977).

The federal government has devolved a range of powers to the three territories, which each have their own legislative assemblies and executive councils (Government of Canada, 2010). This partial decentralization has resulted in the transformation of territories into 'quasi-provinces' with increasing powers and resources (Alcantara, Cameron & Kennedy, 2012; Cameron & Simeon, 2002). However,

the extent of devolution differs depending on the territory (Alcantara et al., 2012). All three Canadian territories are dependent on financial transfers for the majority of their budgets (Rocher & Smith, 2003), such that in 2015-2016 transfers (including grants) from the Canadian government reflected 74% of the Yukon's budget (Government of Yukon, 2017), 78% of NWT's budget (Government of Northwest Territories, 2017) and 89% of Nunavut's budget (Government of Nunavut, 2017). The public sector is the largest employer in the territories, which have become "home to the richest and most entrenched government-centric political environment in the country" (Coates et al., 2014; Government of Canada, 2010). Distinct knowledge economies have also emerged in the three territories, with concentrations of highly qualified personnel in Whitehorse, Yukon and Yellowknife, Northwest Territories (Petrov, 2008, 2016). Historically, regional collaboration between the three territories has been high, but collaboration has slowed and territories have become more competitive, instead focusing on their differences and the unique challenges facing each jurisdiction (Coates et al., 2014).

Indigenous rights movements have also resulted in substantial changes to the governance of the Canadian Arctic, leading to increasing regional capacity and reduced federal administrative presence. Indigenous peoples in the Canadian Arctic include Inuit, First Nations and Métis, most of whom reside in isolated rural and remote settlements. Comprehensive land claims were first recognized by Canada's federal government in 1973 and are "based on the assessment that there may be continuing Aboriginal rights to lands and natural resources. These kinds of claims come up in those parts of Canada where Aboriginal title has not previously been dealt with by treaty and other legal means" (INAC, 2012). Land claims often involve parallel discussion about self-governance agreements, which includes arrangements for Indigenous groups to assume responsibility and govern their own affairs including social and economic well-being (e.g., education, healthcare, social services, housing, property and land rights, economic development) (INAC, 2015). As a result, the Canadian Arctic has regions of Indigenous self-government as well as regions with public government arrangements, whereby Aboriginal self-government arrangements are negotiated within broader public governments (INAC, 2016; Rodon, 2014). There are also a range of co-management systems in place where authority is shared and integrated across multiple levels of decision-making in the Canadian Arctic (e.g., local, territorial/provincial, federal) (Rusnak, 1997). Additionally, Indigenous groups have established bi-lateral agreements with the federal government, most recently the *Inuit Nunangat Declaration on Inuit-Crown Partnership*, which applies to the Inuit homeland, spanning areas in the three territories and the northern regions of two provinces (Québec and Labrador) (Government of Canada, 2017c).

At the international level, Canada participates in several circumpolar transboundary governing bodies, including the Arctic Council, an intergovernmental forum that promotes cooperation and interaction between Arctic states, Indigenous peoples and other Arctic inhabitants (Heininen, Exner-Pirot & Plouffe, 2016). Canada is a signatory to the Arctic Council's Agreement on Enhancing International Arctic Scientific Cooperation, which will shape future regional research and innovation systems. Canada also participates in the Northern Forum and other international civil society organizations/councils that represent the interests of Indigenous people living in Canada, including the Inuit Circumpolar Council, Gwich'in Council International, and the Arctic Athabaskan Council (Dubreuil, 2011). In 2016, Canada announced its full support for the United Nations Declaration on

the Rights of Indigenous People (UNDRIP), which states that "Indigenous peoples have the right to self-determination…[to] freely determine their political status and freely pursue their economic, social and cultural development" (United Nations, 2008). Here, self-determination signifies the right and ability of a defined group to have control over their future beyond the influence of other entities (Christie, 2007). The implications of this declaration for Indigenous peoples living in the Canadian Arctic are in the process of being discussed (ITK, 2017; Mitchell & Enns, 2014).

Clearly, the Canadian Arctic is governed by a diversity of structures, stakeholders and rights- holders that come together to access information and make decisions on issues that span jurisdictional boundaries and are embedded within existing national, territorial, indigenous and international frameworks. Decisions are therefore made in the context of multi-stakeholder frameworks (Binder & Hanbidge, 1993; Rusnak, 1997), ongoing land claims agreements (INAC, 2016), calls to respect traditional Indigenous knowledge (ITK, 2007; Tagalik, 2010), evolving jurisdictional and regulatory requirements (ACUNS, 2003; ITK, 2007) and geo-political considerations (Steinberg & Tasch, 2015). Furthermore, past policy and strategic directions have used inconsistent and at times conflicting boundaries (e.g., geo-political boundaries, climate boundaries, bio-physical and geographic considerations, and Indigenous homelands) to capture 'the Northern regions', 'Northern Canada', 'the North', and 'the Arctic' (Callaghan, Matveyeva, Chernov & Brooker, 2001; Dubreuil, 2011; Steinberg & Tasch, 2015). The fragmented, evolving, nested and transboundary nature of Arctic governance means that the coordination challenges characterizing Canada more broadly (Hawkins, 2009) are likely amplified in the Arctic research and innovation contexts with significant implications for policy design and effectiveness.

Developments in Innovation Policy in the Canadian Arctic: A Focus on the Contribution of Research

Approaches to innovation have evolved from more 'linear' views that assume that scientific knowledge, once generated, will passively diffuse and produce public value (Braun, 2008). Models of complex systems thinking conceptualize innovation as a self-organizing process, bringing together market and non-market resources at various scales to support innovation beyond the production of scientific knowledge and the co-evolution of the technological and socio-institutional products (Braun, 2008; Jucevičius & Grumadaitė, 2014; Klerkx, Van Mierlo & Leeuwis, 2012). Innovation systems are the dynamic and interactive networks that shape the way that societies generate, exchange, and use knowledge (Hall & Clark, 2010; Lundvall, 2010). However, despite this more integrative understanding of innovation, Canadian research policy has yet to embrace complex innovation systems thinking in the Arctic, instead tending towards more linear and sectoral views of what innovation is and how scientific research might best support innovation outcomes.

National Canadian innovation policy generally aims to support technological innovation carried out by universities and the private sector to facilitate job creation (Government of Canada, 2017b; Hawkins, 2009). There is, however, a recognized need to reconsider the scope of the innovation concept itself, to more explicitly include cultural and institutional change (Strand, Saltelli, Giampietro, Rommetveit & Funtowicz, 2016; Wallner & Menrad, 2011). For example, recommendations for a new National Advisory Council on Research and Innovation (NACRI) include moving away from the

current focus on 'science and technology' to be more inclusive of all research disciplines, including the social sciences and humanities (Naylor et al., 2017). There have also been calls to better align innovation incentives with efficacy goals and empower end-users to play a role in stimulating innovative activity (Blomqvist & Busby, 2017). Further, national innovation polices tend to focus on urban areas and it is unclear if innovation patterns are replicated in more sparsely populated rural and remote areas (Kelemen & Teo, 2014). The divergent nature of Canada's national technology-focused innovation policy and the diverse realities of local Arctic communities suggests the need for a more systematic and integrative examination of the dynamic properties that contribute to systems of innovation in the Arctic.

Regional approaches to innovation in other circumpolar nations have also promoted business-centered socio-technological approaches to innovation (Andersen et al., 2007; Hintsala, Niemelä & Tervonen, 2015). Researchers in Finland have examined the existence of an "Arctic business ecosystem" assessing organizations based on their economic value (Hintsala et al., 2015; Hintsala, Niemelä & Tervonen, 2016). Another report reflects on Nordic innovation systems as a way to increase national economic competitiveness (Andersen et al., 2007). These approaches tend not to be reflective of the Canadian Arctic context where a social economy dominates[3] and the universities and businesses that might participate in Arctic-focused product innovation are located in southern Canada (Abele, 2009, 2016; Natcher, 2009; Simon, 2017; Southcott & Walker, 2015). Canada is also the only Arctic nation that does not have an Arctic university. While each territory has a college (Nunavut Arctic College, Aurora College and Yukon College), existing funding structures and eligibility requirements often direct investment for training, research and innovation towards universities in the south, raising important questions for local capacity development and the treatment of northern interests (Carr, Natcher & Olfert, 2013; ITK, 2016; Simon, 2017).

The Canadian Arctic does not have a regional innovation policy; however, several overlapping research-focused strategies have been employed to promote the production and use of scientific research in support of innovation in the Canadian Arctic (Table 1). Although discussion about developing federal guidelines for Arctic research emerged in the early 1970's, in 1977 the Science Council of Canada released the first report on Arctic science policy entitled: *Northward looking: a strategy and science policy for northern development* (Science Council of Canada, 1977). While the report established the foundation for future research policy, it was criticized for failing to recognize the role that political, social and economic factors play in scientific activities (de la Barre, 1979). Subsequent strategies have yet to fully address these issues (Simon, 2017) and recent national policies continue to echo the directions detailed in the 1977 report. In 2016, the three territories launched a "pan-northern" approach to science policy (Government of Yukon, Government Northwest Territories, & Government of Nunavut, 2016), framing northern research as something that needs to be determined by northerners, with a solution-driven, needs-oriented and partnership-based focus. More specifically, they have identified six roles for themselves in the science system: practitioners, consumers of science information, educators, facilitators of research within their own jurisdictions, regulators of research, and partners in regional, national, and international science initiatives (Government of Yukon et al., 2016).

These roles reflect the increasing importance of collaborative research networks and knowledge exchanges across diverse institutions, sectors and countries (Martin, 2016). They also reflect the emergence of multi-stakeholder frameworks to engage in participatory and community-based, co-production research models in the Canadian Arctic (Brunet, Hickey & Humphries, 2014; Brunet et al., 2016; Fletcher, 2003; ITK, 2007), with explicit guidelines and requirements for Indigenous engagement and local capacity building in place (see, for example: ACUNS, 2003; Arctic Council, 2013; Government of Canada, 2014; ITK, 2007; Schnarch, 2004; Simon, 2017; Yukon Indian People, 1973).

Importantly, innovation has been, and continues to be, central to life and livelihoods in the Canadian Arctic. Local knowledge systems, "consist of the knowledge, beliefs, traditions, practices, institutions, and worldviews developed and sustained by [I]ndigenous and local communities, and are believed to represent an adaptive strategy to the environment in which these communities live" (Vandebroek, Reyes-García, de Albuquerque, Bussmann & Pieroni, 2011). According to Wallner and Menrad (2011), innovativeness is a characteristic of culture, making culture a critical component to consider when examining innovation. In the Arctic, institutions that support cultural, social and ecological diversity are recognized as important supports to foster innovation (Chapin III et al., 2004). Recognizing that the production (and use) of scientific research is only one of many enabling factors embedded within an innovation system (Wieczorek & Hekkert, 2012), it is important that we adopt a systems approach to garner a complete understanding of the dynamic relationships that promote innovation processes.

Why an Innovation Ecosystem Approach for the Canadian Arctic?

An innovation ecosystem is defined as "a multi-level, multi-modal, multi-nodal and multi-agent system of systems" (Carayannis & Campbell, 2009) and may offer more nuanced insights for policy actors seeking to design innovation policy for the Canadian Arctic. Innovation ecosystems are generally not considered distinct in many aspects from innovation systems, rather they build on national innovation systems thinking (Lundvall, 2010), placing emphasis on the importance of pluralism with respect to actors, institutions, types of knowledge and paradigms (Adner, 2006; Carayannis & Campbell, 2009). Conceptually, innovation ecosystems seek to explicitly consider the interdependent, nested, transitional and interconnected networks of actors involved in innovation processes, their actions and interactions, and the socio-cultural institutions (e.g., laws, rules, norms) that influence their practices and behaviours (de Vasconcelos Gomes, Facin, Salerno & Ikenami, 2016; Jackson, 2011; Oksanen & Hautamäki, 2015). Differing from business ecosystems, which focus primarily on value capture, innovation ecosystems focus on value creation (de Vasconcelos Gomes et al., 2016).

Table 1. National Research Policy Directions: Strategies and Reports for the Canadian Arctic

Year	Name	Author	Document Purpose	Innovation Considerations
1972	Science and the North: A Seminar on Guidelines for Scientific Activities in Northern Canada	Sub-Committee on Science and Technology of the Advisory Committee on Northern Development (Federal level)	This report presents background material, statements and other information from a seminar held to assist the Government of Canada in developing guidelines and priorities for scientific activities in northern Canada.	- Various factors shape the adoption of southern innovations in the North. - Innovation needs to reflect and adapt to concurrent environmental and technological changes. - Northern development is a dynamic process involving people, resources, the environment and new technological innovations. - To support innovation, one must support northern Indigenous people.
1977	Northward Looking: A Strategy and Science Policy for Northern Development	Science Council of Canada (Federal level)	This is a report on the 3.5 year 'Study of Northern Development' and a proposed strategy based on findings.	- Focus on promoting innovation by implementing science policies for northern development. - Promote technological sovereignty through innovations. - Industrial innovation can be stimulated by research and development programs. - A theoretical Arctic university would promote innovation of northern technologies - Administrative and legislative innovation should aim to provide research support to committees and bolster provincial resources to be equivalent to those offered by the Library of Parliament.

Year	Name	Author	Document Purpose	Innovation Considerations
1987	Canada and Polar Science	Indian Affairs and Northern Development (Federal level)	This report advises on the feasibility of establishing a national polar institute in Canada.	- Innovation is not explicitly identified. - The document calls for science to be more quantitative, technology-oriented, better integrated and more directly involved with or responsive to local concerns.
1991	Northern Science for Northern Society – Building Economic Self-Reliance	Science Council of Canada (Federal level)	This is a report on a study from 1988-1990 on the institutional changes needed to help northerners apply science and technology to support economic development.	- Northern communities partially reject innovation because the conventional structures and methods of science and technology are not evidently useful. - To build northern capacity leaders must foster innovative approaches to technology.
1997	Chapter 8 – Supporting Scientific, Educational and Cultural Cooperation in the Arctic In: Building the Circumpolar Framework- Exercising Canadian Leadership	Library of Parliament Research Branch; House of Commons Standing Committee on Foreign Affairs and International Trade (Federal & International levels)	This extensive review discusses the domestic and international concerns in the circumpolar region in the context of recent changes in technology, communications and geopolitical factors.	- There is a need to balance national interest and science promotion in innovative national, regional and global frameworks. - Recent technological innovations open new opportunities for North-South partnerships.

Year	Name	Author	Document Purpose	Innovation Considerations
2000	Northern Science and Technology in Canada – Federal Framework & Research Plan	Indigenous and Northern Affairs Canada (Federal level)	The Federal Framework and Research Plan presents directions for partnerships with governments, universities and northern peoples to improve the return on federal investment in science and technology.	- Encourage the development of innovative partnerships and links to other programs. - Support for the transfer of scientific knowledge and technology innovation to the private sector to promote economic growth. - Government departments, agencies, and branches are responsible for innovation through science and technology development, trade and market expansion, tourism and youth entrepreneurship, and research and development.
2000	From Crisis to Opportunity: Rebuilding Canada's Role in Northern Research	Natural Sciences and Engineering Research Council of Canada and the Social Sciences and Humanities Research Council of Canada (Federal level)	This report summarizes the findings from consultations by a multidisciplinary Taskforce (established 1998) that investigated concerns about the decline of research in the North.	- The North is identified as a leader in satellite-based innovation. - Northern research institutes are seeking innovative ways of involving local people in the research. - Recommendation to support multidisciplinary northern research projects.
2005	From Opportunity to Action: A Progress Report on Canada's Renewal of Northern Research	Institute on Governance (Federal level)	This report summarizes the results from the Working Group on Northern Research's (established 2003) 'Dialogue on Northern Research Workshop'.	- The North is identified as a welcoming environment for innovation. - Participants identified technological innovation in research and training as an area to build on. - Efforts should be made to modify education in innovative ways (e.g., traditional knowledge). - Action had not occurred with respect to the placement of 'innovators' with field expertise in local schools.

Year	Name	Author	Document Purpose	Innovation Considerations
2008	Vision for the Canadian Arctic Research Initiative: Assessing the Opportunities	Canadian Council of Academies upon request of Indian and Northern Affairs Canada (INAC) (Federal level)	This commissioned report is an independent external perspective on findings from the Visioning Workshop on a new research station.	- Northern citizens have a key role in innovative partnerships to develop community-based environmental monitoring. - Biomimicry may be a key source of innovation in the North. - Technology will play an important role through innovation and commercialization. - Key factors such as the caliber of scientists and infrastructure will likely play a role in the innovation (or lack of innovation) of new technologies. - A call for innovation to be leveraged in the approach to science and technology as identified in the priorities defined for the station.
2009	Canada's Northern Strategy: Our North, Our Heritage, Our Future	Government of Canada; Minister of INAC (Federal level)	This document provides an overview of the federal government's Northern Strategy (vision, four pillars, and activities to date).	- Support for industrial innovation through support to university granting councils. - Highlight existing innovative consultative process.
2014	The State of Northern Knowledge in Canada	Canadian Polar Commission (Federal level)	This report summarizes a study that examined knowledge gains during the seven-year period commencing with International Polar Year in 2007.	- A call for research on governance innovation. - Encourage future collaborative work to identify innovative ways to address socio-economic challenges.

Year	Name	Author	Document Purpose	Innovation Considerations
2017	A New Shared Arctic Leadership Model	INAC Minister's Special Representative on Arctic Leadership (Federal level)	This independent report outlines advice toward the development of a new Shared Arctic Leadership Model.	- Arctic policy should be based in reciprocal relationships built in trust, inclusiveness and transparency to inform innovative policy. - Current innovative thinking supports the creation of an Arctic university. - Innovation and transition will require major investments from public and private sectors. - Clean and renewable energy innovation will require collaboration with key partners. - Structural changes to funding and transfer payments are necessary to ensure that resources are optimized.

Therefore, innovation ecosystems emphasize the multiple positions and roles of local or regional actors in innovation processes that focus on value creation (Oksanen & Hautamäki, 2015). In the context of the Canadian Arctic, innovation ecosystem perspectives have the potential to provide additional scope to reveal opportunities to better manage the formal and informal institutional and relational contexts that govern innovation (de Vasconcelos Gomes et al., 2016; Rabelo, Bernus & Romero, 2015).

The 'Eco' Analogy & Innovation Ecosystems in the Canadian Arctic

Much of the literature on innovation ecosystems takes a somewhat limited view of the relationships between innovation and public value, instead placing emphasis on economic outcomes (similar to innovation systems literature). The conceptualization of innovation ecosystems has been subject to considerable debate (Oh, Phillips, Park & Lee, 2016; Ritala & Almpanopoulou, 2017; Suominen, Seppänen & Dedehayir, 2016) and a range of definitions have subsequently emerged (de Vasconcelos Gomes et al., 2016; Durst & Poutanen, 2013). Nevertheless, "[t]he prefix eco in innovation ecosystems implies a specifically ecological aspect" (Ritala & Almpanopoulou, 2017), with a biological ecosystem defined as "a system that includes all living organisms (biotic factors) in an area as well as its physical environments (abiotic factors) functioning together as a unit" (Jackson, 2011). Building on this thinking, an innovation ecosystem similarly includes all of the elements that come together, to influence innovation dynamics and potential (Jackson, 2011). Shifting emphasis to the ecosystem analogy may also help policy actors at different levels of already established decision-making hierarchies to better consider their roles and responsibilities as well as the agency of natural ecosystems in innovation processes and outcomes (Pilinkienė & Mačiulis, 2014; Vermunt, Negro, Verweij & Hekkert, 2017).

In the Canadian Arctic, the analogy to a natural ecosystem has the potential to enable diverse actors to better comprehend the complex systems underlying the creation of public value through innovation, and improve understanding of the roles of different actors in this process. Ecological analogies have already been used by Arctic residents to describe the research system, with analogies being drawn between researchers and snow geese, both of which arrive in the summer, make a lot of noise, leave at the end of the summer and return the following year to repeat the process (Lemelin, Wiersma & Stewart, 2010). Similar analogies have been made between researchers and ground squirrels, known as 'siksiks' in Inuktitut (Gearhead & Shirley, 2007). Borrowing from ecology, an innovation ecosystem implies a system of systems supporting a range of specialized actors that cooperate, feed-off, adapt to, support, compete and interact with each other (de Vasconcelos Gomes et al., 2016; Shaw & Allen, 2016). Additionally, innovation ecosystems can also be characterized as systems in flux that are emergent, with lifecycles driven by co-evolution processes (de Vasconcelos Gomes et al., 2016). Every part of an ecosystem must be considered in order to comprehend the complex functioning of the whole system (Jackson, 2011).

Arctic Innovation Communities

An innovation community is a collection of actors that dynamically evolve as people and organizations come together to produce and/or use a specific innovation (Wang, 2009). They have also been

conceptualized as innovation platforms, hubs, clusters, learning alliances, etc. (Kilelu et al., 2013; Schut et al., 2016). Innovation communities also reflect the "protected spaces that allow experimentation with the co-evolution of technology, user practices, and regulatory structures" that might promote sustainable development through transitions, as characterized in strategic niche management[4] (Schot & Geels, 2008).

The complex governance issues of the Canadian Arctic speak to the diverse actors that come together to cultivate a multi-innovation, multi-community Arctic innovation ecosystem. Figure 1 presents a re-interpretation of Wang's (2009) theoretical model for innovation ecosystems. As infinite, related innovations co-evolve in the ecosystem, it is important to recognize their relationships to the innovation community. Figure 1 conveys a network of three different innovations, selected to reflect the common Arctic innovations that are briefly discussed later in this paper (technological innovation, administrative innovation and social innovation). The three larger boxes contain an innovation community comprised of diverse actors engaging in the production and use of an innovation, governed by the supply and demand of the innovation. Community members can engage in both the production and use of the innovation and can also participate in multiple innovation communities. Actors may include organizations and individuals (e.g., governments, universities, industry, supporting institutions, specialised people, entrepreneurs, the financial system, consumers, civil society, cultural groups), as well as the emergent relationships, which play various roles throughout the life of an innovation ecosystem (Rabelo & Bernus, 2015). Arctic innovation communities are reflective of the features unique to the complex, hybrid institutions and societies that govern the Canadian Arctic (Abele, 2015). In the Canadian Arctic where the traditional actors in an innovation ecosystem (e.g., universities and a large private sector) are underrepresented, many actors likely reorganize to form different innovation communities. The figure shows the interactive nature of the three innovations, illustrating that as resources move to support one innovation, they "consume attention" requiring additional resources (i.e., time and money), thus influencing the available resources for related innovations. Members of the innovation community can also migrate within and between innovation communities, participating in multiple activities (Wang, 2009). For example, a community member may sit on multiple committees and be both a producer and a user of all three innovations.

To date, innovation communities have not been identified in the literature on the Canadian Arctic. At first glance, it may appear that the innovation ecosystem is like a barren land in which only a few pioneer species are present. However, it can be argued that diversity characterizes the Canadian Arctic innovation ecosystem, much like that of the physical ecosystem:

> "[a]lthough species diversity is generally lower [in the Arctic] than at more southerly latitudes, the diversity of animals and plants, communities, and landforms are surprisingly rich. Patterns of biodiversity are strongly coupled with the wide variety of Arctic environments…[t]he Arctic is therefore far from uniform" (Callaghan et al., 2001).

Diversity of the Arctic innovation ecosystem is reflected by co-occurring knowledge systems, whereby Indigenous local knowledge systems co-exist and interact with formal research and innovation systems in diverse ways (Pierotti, 2010; Scott & Humphries, In Press), as well as the alternative economies that can and do co-exist with larger northern market economies (Abele, 2009; Southcott & Walker, 2015).

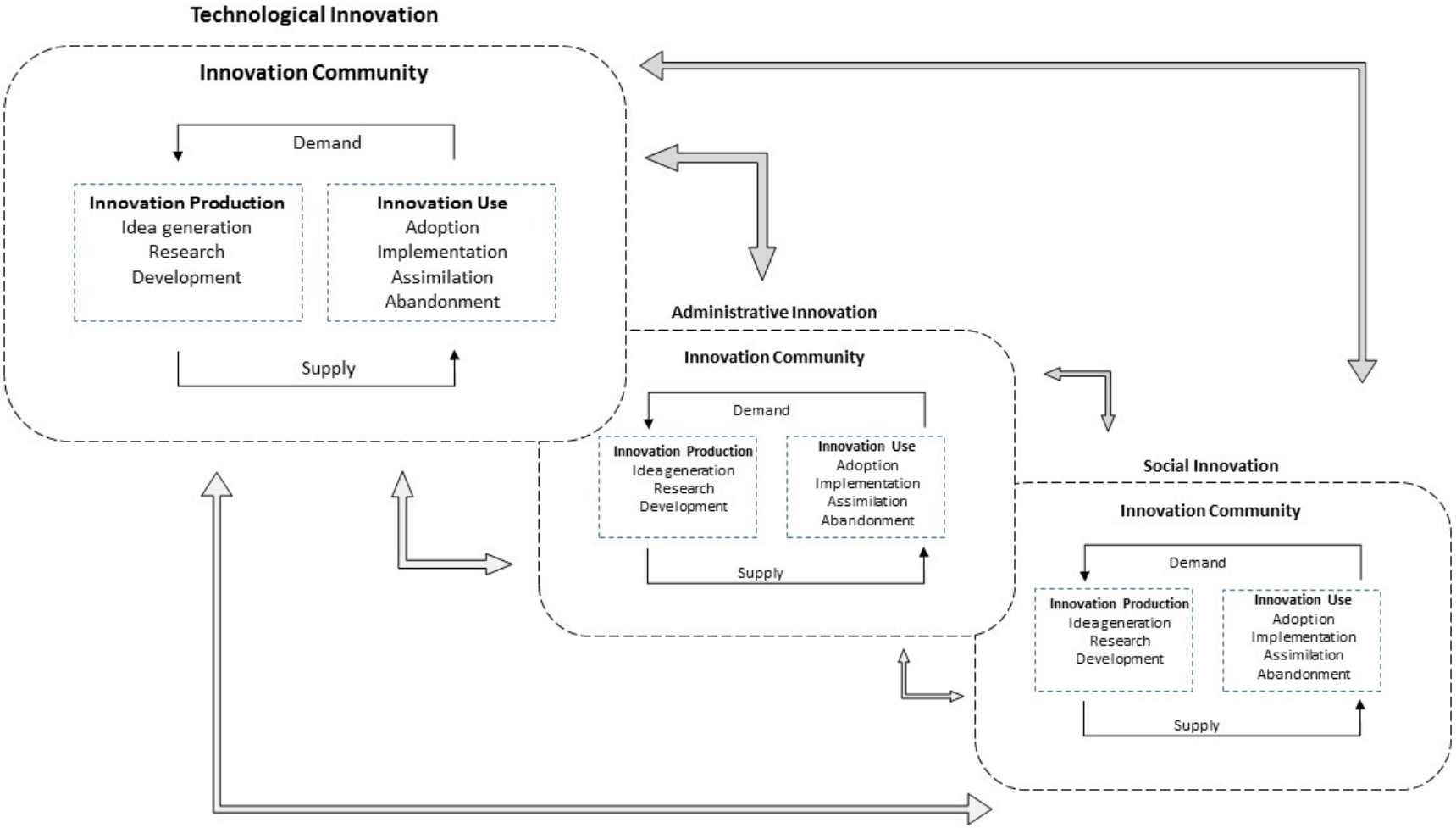
Since biotic and abiotic actors come together to form innovation communities within the innovation ecosystem, an examination of community dynamics can help to provide insight into interdependencies between people and nature. It has been argued that the Canadian Arctic has the potential for an 'innovation environment' with the capacity to support and inspire future innovation based on the ingenuity of Arctic residents, who have persisted in extreme environments for centuries (Coates et al., 2014). Support for an 'innovation environment' is also coupled with the rapid pace and variety of successful administrative innovations (e.g., self-government, co-management, economic development, modern treaty negotiations) (Coates et al., 2014), as well as social innovations that merge southern-based administration and northern cultural values in response to opportunities and pressures from new technologies (Abele, 2015, 2016; Natcher, 2009).

Implications & Future Directions

This review suggests that if governments aim to support the formation of innovation ecosystems in the Canadian Arctic, they likely need to focus their efforts on engaging dynamic innovation communities nested within complex overlaying governance structures and to expand their definition of innovation to better reflect the multiple economies present in the Canadian Arctic.

From a policy perspective, there is a need to embrace and promote more networked approaches to value co-creation, requiring decision-makers to negotiate various boundaries between multiple actors representing diverse interests (i.e., the interests of the state, the private market, civil society and informal community organizations) to co-create public value (Benington & Moore, 2011; Braun, 2008). Aspects such as science-policy linkages, relationships, group dynamics, trust and social capital need to be more carefully considered as they can influence the way that relationships are navigated (McNie, 2007; McNie et al., 2016; Schut et al., 2016). Further research into the actors involved in Arctic innovation ecosystems (Brunet et al., 2016) and the nature and impacts of the knowledge flows between these actors would be helpful. This should include assessment of actors that span boundaries (i.e., intermediaries and bridging agents) and coordinate efforts to support innovation (Howells, 2006). Here, it also becomes important to consider the different institutional dimensions affecting research and innovation organization (Klerkx et al., 2012; Schut et al., 2016), as well as to consider patterns of power relations and knowledge utilization (Steinberg & Tasch, 2015). The mobility of innovation communities is also integral to understanding innovation ecosystems in the Canadian Arctic. For example, people, knowledge and physical supplies are constantly moving between northern and southern Canada for Arctic scientific research and the Arctic Council's *Agreement on Enhancing International Arctic Scientific Cooperation* aims to further promote international mobility among the scientific community (Arctic Council, 2017). Relatively little is known about how mobility influences knowledge flows between members of the Arctic innovation ecosystem and this is an area that requires further research and policy attention

Figure 1: Innovation Communities within Innovation Ecosystems (Based on Wang 2009)



A key challenge for research and innovation policy is to more meaningfully consider the lifespan of any innovation, including the various co-occurring processes of creation and destruction, something that innovation ecosystems thinking may assist with. For example, the boundary between collaborative research–stakeholder relationships is path-dependent, meaning that their feasibility or credibility is influenced by earlier arrangements (Schut et al., 2013). Here, careful efforts to promote path-breaking by challenging the rules, artifacts and habits of the underlying societal system may be warranted to avoid 'groupthink' and path-dependency scenarios (Ölander & Thøgersen, 2014; Walrave, Talmar, Podoynitsyna, Romme & Verbong, 2017). In search of sustainable development, diverse actors will need to develop new modes of production and new institutional arrangements to support these production models (Bouma, van Altvorst, Eweg, Smeets & Latesteijn, 2011). Future research could consider how open innovation systems (Chesbrough, 2006), can be designed to encourage path-breaking. Innovation actors (and communities) that take opportunities to innovate during times of change can also play a unique role in providing bridges to help solve issues and may inadvertently change the system itself (Hartley, 2015).

Future research to better understand the complex dynamics of innovation communities and processes in Canadian Arctic innovation ecosystems is needed. More specifically, there is a need for innovation policy frameworks at different levels to better recognize the coupled functional-structural aspects that influence innovation outcomes in the Canadian Arctic. This will help to identify key leverage points and 'bottlenecks' requiring attention (Meadows, 2008). Here, mapping the various elements of an innovation ecosystem (e.g., actors, capital, infrastructure, regulations, knowledge, ideas, culture, architectural principles, and interface) (Rabelo & Bernus, 2015) would be a useful first step (Wieczorek & Hekkert, 2012). Such an exercise might lead to improved understandings of how institutional dimensions (Schut et al., 2013) and multi-dimensional linkages (i.e., relationships, connections, interactions) (Poteete, 2012) shape innovation outcomes in different Arctic contexts. Further, comprehensive case studies that evaluate innovation successes and failures are needed to examine innovation processes in different contexts. Future research into the current models of co-innovation (Botha, Turner, Fielke & Klerkx, 2017; Klerkx et al., 2017) that exist in the Arctic and the potential for 'grassroots innovation' (Hermans, Roep & Klerkx, 2016) and 'inclusive innovation' approaches to better engage marginalized groups within the innovation ecosystem (Foster & Heeks, 2013) are also warranted.

Acknowledgments

The authors would like to acknowledge funding support from: *Natural Science and Engineering Research Council of* Canada (NSERC) CREATE-Environmental Innovations, *Social Sciences and Humanities Research Council (SSHRC)* Canadian Graduate Scholarships Doctoral Scholarship, a McGill University Graduate Mobility Award and the McGill University William Dawson Scholar Award.

Notes

1. Much of the literature on innovation in Canada highlights the federal nature of the country and the division of powers between the federal and provincial governments. There has been limited evaluation of innovation in the territories, which are constitutionally distinct from the provinces.

2. The three Canadian territories (Yukon, Northwest Territories, and Nunavut) account for approximately three percent of the Canadian population and are located primarily north of 60º latitude, spanning northern Canada and covering 40% of Canada's land mass (Government of Canada, 2010).

3. The extensive northern 'social economy' is "the part of the social productive system that lies outside the direct ambit of government programs and large business. It includes small business, not-for-profits, co-operatives, family-based production, traditional or non-commodified production, and volunteer support to others" (Abele, 2009).

4. Similar to ecological niches, which reflect an animal's place in the biotic environment and its relationship to food sources and other animals, innovation community niches have a finite amount of resources, leading to competition (Wang 2009). According to Wang (2009) "[j]ust like an arctic fox subsisting upon guillemot eggs and the remains of seals killed by polar bears, an innovation concept consumes attention from the member organizations and their people in the community." Conceptualizing innovation as part of an ecosystem means that different innovations "consume attention" and resources from the same community, thus there can be 'innovations' competing for the available resources.

References

Abele, F. (2009). The state and the northern social economy: Research prospects. *Northern Review,* (30), 37-56.

Abele, F. (2015). Chapter 4 State Institutions and the Social Economy in Northern Canada. In C. Southcott (Ed.), *Northern Communities Working Together: The Social Economy of Canada's North*: University of Toronto Press.

Abele, F. (2016). The North in New Times: Revising Federal Priorities. In J. Higginbotham & J. Spence (Eds.), *North of 60: Toward a Renewed Canadian Arctic Agenda*: Centre for International Governance Innovation

ACUNS. (2003). *Ethical Principles for the Conduct of Research in the North*. Ottawa.

Adner, R. (2006). Match your innovation strategy to your innovation ecosystem. *Harvard Business Review, 84*(4), 98.

Alcantara, C., Cameron, K., & Kennedy, S. (2012). Assessing Devolution in the Canadian North: A Case Study of the Yukon Territory. *Arctic, 65*(3), 328-338.

Andersen, P. D., Borup, M., Borch, K., Kaivo-oja, J., Eerola, A., Finnbjörnsson, T., . . . Mölleryd, B. A. (2007). *Foresight in Nordic Innovation Systems*. Oslo: Nordic Innovation Centre. p. 58.

Arctic Council. (2013). Summary for policy-makers. Arctic Resilience Interim Report 2013.

Arctic Council. (2017). Fairbanks Declaration 2017. *On the Occasion of the Tenth Ministerial Meeting of the Arctic Council*.

Baregheh, A., Rowley, J., & Sambrook, S. (2009). Towards a multidisciplinary definition of innovation. *Management Decision, 47*(8), 1323-1339.

Benington, J., & Moore, M. H. (2011). *Public value: Theory and practice*. New York: Palgrave Macmillan.

Binder, L. N., & Hanbidge, B. (1993). Aboriginal people and resource co-management. The Inuvialuit of the western Arctic and resource co-management under a land claims settlement. *Traditional Ecological Knowledge. Concepts and Cases. Canadian Museum of Nature, Ottawa*.

Blomqvist, A., & Busby, C. (2017). The Paradox of Productivity, Technology, and Innovation in Canadian Healthcare. *C.D. Howe Institute Commentary, 480*.

Borrás, S., & Edquist, C. (2013). The choice of innovation policy instruments. *Technological Forecasting and Social Change, 80*(8), 1513-1522.

Botha, N., Turner, J. A., Fielke, S., & Klerkx, L. (2017). Using a co-innovation approach to support innovation and learning: Cross-cutting observations from different settings and emergent issues. *Outlook on Agriculture, 46*(2), 87-91.

Bouma, J., van Altvorst, A., Eweg, R., Smeets, P., & Latesteijn, v. (2011). The role of knowledge when studying innovation and the associated wicked sustainability problems in agriculture. In D. L. Sparks (Ed.), *Advances in Agronomy* (Vol. 113). San Diego, CA: Elsevier.

Braun, D. (2008). Organising the political coordination of knowledge and innovation policies. *Science and Public Policy, 35*(4), 227.

Brunet, N. D., Hickey, G. M., & Humphries, M. M. (2014). Understanding community-researcher partnerships in the natural sciences: A case study from the Arctic. *Journal of Rural Studies, 36*, 247-261.

Brunet, N. D., Hickey, G. M., & Humphries, M. M. (2016). Local participation and partnership development in Canada's Arctic research: challenges and opportunities in an age of empowerment and self-determination. *Polar Record, 52*(03), 345-359.

Callaghan, T. V., Matveyeva, N., Chernov, Y., & Brooker, R. (2001). Arctic ecosystems. *Encyclopedia of Biodiversity, 1*.

Cameron, D., & Simeon, R. (2002). Intergovernmental relations in Canada: The emergence of collaborative federalism. *Publius*, 49-71.

Carayannis, E. G., & Campbell, D. F. (2009). 'Mode 3'and'Quadruple Helix': toward a 21st century fractal innovation ecosystem. *International Journal of Technology Management, 46*(3-4), 201-234.

Carr, K., Natcher, D. C., & Olfert, R. (2013). Measuring the economic impact of publicly funded research in Northern Canada. *Polar Geography, 36*(4), 291-304.

Chapin III, F. S., Peterson, G., Berkes, F., Callaghan, T., Angelstam, P., Apps, M., . . . Danell, K. (2004). Resilience and vulnerability of northern regions to social and environmental change. *AMBIO: A Journal of the Human Environment, 33*(6), 344-349.

Chesbrough, H. W. (2006). *Open innovation: The new imperative for creating and profiting from technology*: Harvard Business Press.

Christie, G. (2007). *Aboriginal Nationhood and the Inherent Right to Self-Government*: National Centre for First Nations Governance.

Coates, K., & Poelzer, G. (2014). Arctic Innovation. *UArctic Shared Voices Magazine* (May).

Coates, K., Poelzer, G., Exner-Pirot, H., Garcea, J., Rodon, T., Schiff, R., . . . Wilson, G. (2014). The Role of the Public Sector in Northern Governance. Ottawa: The Conference Board of Canada.

Conference Board of Canada. (2015). How Canada Performs, Innovation. Retrieved June 9, 2017, from http://www.conferenceboard.ca/hcp/details/innovation.aspx

Creutzberg, T. (2011). *Canada's Innovation Underperformance: Whose Policy Problem Is It?* Mowat Centre for Policy Innovation.

de la Barre, K. (1979). Northward Looking—A Strategy and a Science Policy for Northern Development Science Council of Canada Report No. 26. *Arctic, 32*(2), 170-175.

de Vasconcelos Gomes, L. A., Facin, A. L. F., Salerno, M. S., & Ikenami, R. K. (2016). Unpacking the innovation ecosystem construct: Evolution, gaps and trends. *Technological Forecasting and Social Change,* Available online 24 November 2016.

Doloreux, D. (2004). Regional innovation systems in Canada: a comparative study. *Regional studies, 38*(5), 479-492.

Dubreuil, A. (2011). The Arctic of the regions - Between indigenous people and subnational entities - Which perspectives? *International Journal, 66*(4), 923-938.

Durst, S., & Poutanen, P. (2013). Success factors of innovation ecosystems-initial insights from a literature review. *CO-CREATE 2013 The Boundary-Crossing Conference on Co-Design in Innovation* Aalto University Publication series Science + Technology, 27-38.

Exner-Pirot, H. (2015). Innovation in the Arctic: Squaring the Circle. (Paper presented at the Arctic Summer College.) Retrieved June 9, 2017, from www.arcticsummercollege.org/sites/default/files/ASC%20Paper_Exner-Pirot_Heather_0.pdf

Fletcher, C. (2003). Community-based participatory research relationships with Aboriginal communities in Canada: An overview of context and process. *Pimatisiwin: A Journal of Aboriginal & Indigenous Community Health, 1*(1).

Foster, C., & Heeks, R. (2013). Conceptualising inclusive innovation: Modifying systems of innovation frameworks to understand diffusion of new technology to low-income consumers. *The European Journal of Development Research, 25*(3), 333-355.

Gearhead, S., & Shirley, J. (2007). Challenges in Community-Research Relationships: Learning from Natural Science in Nunavut. *Arctic, 60*(1), 62-74.

Geels, F. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy, 33*(6-7), 897-920.

Government of Canada. (2010). Difference between Canadian Provinces and Territories. *The Federation at a Glance*, Retrieved June 9, 2017, from http://www.pco-bcp.gc.ca/aia/index.asp?lang=eng&page=provterr&doc=difference-eng.htm#1

Government of Canada. (2014). Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans. Secretariat on Responsible Conduct of Research.

Government of Canada. (2016). Northern Scientific Training Program Retrieved April 24, 2017, from http://www.polarcom.gc.ca/eng/content/northern-scientific-training-program

Government of Canada. (2017a). The Canadian High Arctic Research Station. Retrieved June 9, 2017, from https://www.canada.ca/en/polar-knowledge/constructingstation.html

Government of Canada. (2017b). Budget 2017: Building a strong middle class. Retrieved June 9, 2017, from http://www.fin.gc.ca/n17/17-017-eng.asp

Government of Canada. (2017c). Inuit Nunangat Declaration on Inuit-Crown Partnership. Iqaluit. Retrieved June 9, 2017, from http://pm.gc.ca/eng/news/2017/02/09/inuit-nunangat-declaration-inuit-crown-partnership

Government of Northwest Territories. Main Estimates 2017-2018. Retrieved September 26, 2017, from http://www.fin.gov.nt.ca/sites/default/files/documents/2017-2018_main_estimates.pdf

Government of Nunavut. (2017). Budget 2017-2018 Fiscal and Economic Indicators. Retrieved September 26, 2017, from http://www.gov.nu.ca/finance/documents/2017-18-fiscal-and-economic-indicators.

Government of Yukon. (2017). Financial Information 2016-17. Retrieved September 26, 2017, from http://www.finance.gov.yk.ca/pdf/budget/Financial_Info.pdf.

Government of Yukon, Government Northwest Territories, & Government of Nunavut. (2016). A pan-northern approach to science. Retrieved June 9, 2017, from http://www.anorthernvision.ca/documents/A16_Brochure_PanNorthernApproachtoScience_71402_English_WEB-Final.pdf

Hall, A., & Clark, N. (2010). What do complex adaptive systems look like and what are the implications for innovation policy? *Journal of international development, 22*(3), 308-324.

Halliwell, J., & Smith, W. (2011). Paradox and potential: trends in science policy and practice in Canada and New Zealand. *Prometheus, 29*(4), 373-391.

Hammond, K. R., Mumpower, J., Dennis, R. L., Fitch, S., & Crumpacker, W. (1983). Fundamental obstacles to the use of scientific information in public policy making. *Technological Forecasting and Social Change, 24*(4), 287-297.

Hartley, J. (2015). The Creation of Public Value through step-change innovation in public organizations. *Public Value and Public Administration, 82*.

Hawkins, R. (2009). Is Canada Really All That Bad At Innovation?: A Tale of Two Industries. *International Productivity Monitor, 18*, 2009.

Heininen, L., Exner-Pirot, H., & Plouffe, J. (Eds.) (2016). *Arctic Yearbook 2016: The Arctic Council: 20 Years of Regional Cooperation and Policy-Shaping*. Akureyri, Iceland: Nothern Research Forum. Retrieved from, https://arcticyearbook.com/.

Hermans, F., Roep, D., & Klerkx, L. (2016). Scale dynamics of grassroots innovations through parallel pathways of transformative change. *Ecological Economics, 130*, 285-295.

Hintsala, H., Niemelä, S., & Tervonen, P. (2015). Is there an Arctic ecosystem emerging? Oulu region's perspective. *International Journal of Information Technology and Business Management* , *15*(1), 21-27.

Hintsala, H., Niemelä, S., & Tervonen, P. (2016). Arctic potential–Could more structured view improve the understanding of Arctic business opportunities? *Polar Science, 10*(3), 450-457.

Howells, J. (2006). Intermediation and the role of intermediaries in innovation. *Research policy, 35*(5), 715-728.

Hueglin, T. O., & Fenna, A. (2015). *Comparative federalism: A systematic inquiry*: University of Toronto Press.

Ibarguchi, G., Murray, M. S., Rajdev, V., & ISAC, I. P. O. (2015). *Does Funding for Arctic Research Align with Research Priorities and Policy Needs? Trends in the USA, Canada and Europe*. Paper presented at the 2015 AGU Fall Meeting, San Francisco, California.

INAC (Indigenous and Northern Affairs Canada). (2012). Terminology 2017, Retrieved May 8, 2017, from http://www.aadnc-aandc.gc.ca/eng/1100100014642/1100100014643

INAC (Indigenous and Northern Affairs Canada). (2015). Fact Sheet: Aboriginal Self-Government *Comprehensive Claims* 2017, from https://www.aadnc-aandc.gc.ca/eng/1100100016293/1100100016294

INAC (Indigenous and Northern Affairs Canada). (2016). General Briefing Note on Canada's Self-government and Comprehensive Land Claims Policies and the Status of Negotiations

Innovation Canada. (2011). A Call for Action - Review of Federal Support to Research and Development– Expert Panel Report. Government of Canada (Ed.). Ottawa.

ITK (Inuit Tapiriit Kanatami). (2007). Negotiating research relationships with Inuit communities. Retrieved from, http://www.itk.ca/publications/environment-pub/20070305-ITK_Research Relationships.pdf.

ITK (Inuit Tapiriit Kanatami). (2016). Inuit Tapiriit Kanatami Submission To The Naylor Panel For Canada's Fundamental Science Review. Ottawa.

ITK (Inuit Tapiriit Kanatami). (2017). Position Paper: Implementing the UN Declaration on the Rights of Indigenous Peoples in Canada.

Jackson, D. J. (2011). What is an innovation ecosystem. *Arlington, VA: National Science Foundation*, 1-11.

Jenkins, A. (2017). Canada's Innovation Agenda: The same old story? Or a new way forward? : Wilson Center.

Joly, P.-B., Gaunand, A., Colinet, L., Larédo, P., Lemarié, S., & Matt, M. (2015). ASIRPA: A comprehensive theory-based approach to assessing the societal impacts of a research organization. *Research Evaluation, 24*(4), 440-453.

Jucevičius, G., & Grumadaitė, K. (2014). Smart Development of Innovation Ecosystem. *Procedia - Social and Behavioral Sciences, 156*, 125-129.

Kelemen, R. D., & Teo, T. (2014). Law, focal points and fiscal discipline in the United States and the European Union. *American Political Science Review 108*(2), 355-370.

Kilelu, C. W., Klerkx, L., & Leeuwis, C. (2013). Unravelling the role of innovation platforms in supporting co-evolution of innovation: Contributions and tensions in a smallholder dairy development programme. *Agricultural systems, 118*, 65-77.

Klerkx, L., Seuneke, P., de Wolf, P., & Rossing, W. A. (2017). Replication and translation of co-innovation: The influence of institutional context in large international participatory research projects. *Land Use Policy, 61*, 276-292.

Klerkx, L., Van Mierlo, B., & Leeuwis, C. (2012). Evolution of systems approaches to agricultural innovation: concepts, analysis and interventions *Farming Systems Research into the 21st century: The new dynamic* (pp. 457-483): Springer.

Kofinas, G., Forbes, B., Beach, H., Berkes, F., Berman, M., Chapin, T., . . . Semenova, T. (2005). A research plan for the study of rapid change, resilience, and vulnerability in social-ecological systems of the Arctic. *The Common Property Resource Digest, 73*, 1-10.

Lemelin, R., Wiersma, E., & Stewart, E. (2010). Integrating researchers and indigenous communities. In C. Micheal Hall (Ed), *Fieldwork in tourism: Methods, issues and reflections:* Taylor & Francis Group.

Lundvall, B.-Å. (2010). *National systems of innovation: Toward a theory of innovation and interactive learning* (Vol. 2): Anthem Press.

Martin, B. R. (2016). R&D policy instruments – a critical review of what we do and don't know. *Industry and Innovation, 23*(2), 157-176.

Mazzucato, M. (2011). The entrepreneurial state. *Soundings, 49*(49), 131-142.

McNie, E. C. (2007). Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature. *Environmental Science & Policy, 10*(1), 17-38.

McNie, E. C., Parris, A., & Sarewitz, D. (2016). Improving the public value of science: A typology to inform discussion, design and implementation of research. *Research Policy, 45*(4), 884-895.

Meadows, D. H. (2008). *Thinking in systems: A primer*: Chelsea Green Publishing.

Mitacs Policy Team. (2016). Leveraging Canada's Innovation Ecosystem: Opportunities to Increase R&D Investment in Canada.

Mitchell, T., & Enns, C. (2014). The UN Declaration on the Rights of Indigenous Peoples: Monitoring and Realizing Indigenous Rights in Canada. *Policy Brief, 39*.

Moore, M. H. (1995). *Creating public value: Strategic management in government*: Harvard University Press.

Natcher, D. C. (2009). Subsistence and the social economy of Canada's Aboriginal North. *Northern Review,* (30), 83-98.

Naylor, D., Birgeneau, R., Crago, M., Lazaridis, M., Malacrida, C., McDonald, A., . . . Wilson, A. (2017). Investing in Canada's Future: Strengthening the Foundations of Canadian Research *Canada's Fundamental Science Review*: Advisory Panel for the Review of Federal Support for Fundamental Science.

Nicol, H. N. (2016). Ripple Effects: Devolution, Development and State Sovereignty in the Canadian North In L. Heininen (Ed.). *Future Security of the Global Arctic: State Policy, Economic Security and Climate* (pp. 99-120): Palgrave MacMillan.

Ogden, A. E., Schmidt, M., Van Dijken, B., & Kinnear, L. (2016). Science in the Yukon: Advancing a Vision for Evidence-based Decision Making. *Arctic, 69*(2), 210-221.

Oh, D.-S., Phillips, F., Park, S., & Lee, E. (2016). Innovation ecosystems: A critical examination. *Technovation, 54*, 1-6.

Oksanen, K., & Hautamäki, A. (2015). Sustainable Innovation: A Competitive Advantage for Innovation Ecosystems. *Technology Innovation Management Review, 5*(10), 19-25.

Ölander, F., & Thøgersen, J. (2014). Informing versus nudging in environmental policy. *Journal of Consumer Policy, 37*(3), 341-356.

Overpeck, J., Hughen, K., Hardy, D., Bradley, R., Case, R., Douglas, M., . . . Jennings, A. (1997). Arctic environmental change of the last four centuries. *science, 278*(5341), 1251-1256.

Pauktuutit Inuit Women of Canada. (2006). *The Inuit way: a guide to Inuit culture*: Pauktuutit Inuit Women of Canada.

Pelaudeix, C. (2012). Inuit governance in a changing environment: a scientific or a political project? *What Holds The Arctic Together?*, 67-83.

Petrov, A. N. (2008). Talent in the Cold? Creative Capital and the Economic Future of the Canadian North. *Arctic, 61*(2), 162-176.

Petrov, A. N. (2016). Exploring the Arctic's "other economies": knowledge, creativity and the new frontier. *The Polar Journal*, 1-18.

Pierotti, R. (2010). *Indigenous knowledge, ecology, and evolutionary biology*: Routledge.

Pilinkienė, V., & Mačiulis, P. (2014). Comparison of different ecosystem analogies: The main economic determinants and levels of impact. *Procedia-Social and Behavioral Sciences, 156*, 365-370.

Poteete, A. (2012). Levels, scales, linkages, and other'multiples' affecting natural resources. *International Journal of the Commons, 6*(2).

Prowse, T. D., Furgal, C., Chouinard, R., Melling, H., Milburn, D., & Smith, S. L. (2009). Implications of climate change for economic development in northern Canada: Energy, resource, and transportation sectors. *AMBIO: A Journal of the Human Environment, 38*(5), 272-281.

Rabelo, R. J., & Bernus, P. (2015). A holistic model of building innovation ecosystems. *IFAC-PapersOnLine, 48*(3), 2250-2257.

Rabelo, R. J., Bernus, P., & Romero, D. (2015). *Innovation ecosystems: a collaborative networks perspective.* Paper presented at the Working Conference on Virtual Enterprises.

Ritala, P., & Almpanopoulou, A. (2017). In defense of 'eco'in innovation ecosystem. *Technovation,* 60-61(Februrary), 39-42.

Rocher, F., & Smith, M. (2003). *New Trends in Canadian Federalism*. Peterborough, Ontario: Broadview Press.

Rodon, T. (2014). "Working Together": The Dynamics of Multilevel Governance in Nunavut. *Arctic Review on Law and Politics, 5*(2), 250-270.

Rusnak, G. (1997). Co-management of natural resources in Canada: A review of concepts and case studies. *Ottawa, Canada: International Development Research Centre.*

Schnarch, B. (2004). Ownership, control, access, and possession (OCAP) or self-determination applied to research: A critical analysis of contemporary First Nations research and some options for First Nations communities. *International Journal of Indigenous Health, 1*(1), 80.

Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technology Analysis & Strategic Management, 20*(5), 537-554.

Schut, M., Klerkx, L., Sartas, M., Lamers, D., Mc Campbell, M., Ogbonna, I., . . . Leeuwis, C. (2016). Innovation platforms: experiences with their institutional embedding in agricultural research for development. *Experimental Agriculture, 52*(4), 537-561.

Schut, M., van Paassen, A., Leeuwis, C., & Klerkx, L. (2013). Towards dynamic research configurations: A framework for reflection on the contribution of research to policy and innovation processes. *Science and public policy*, *41*(2), 207-218.

Science Council of Canada. (1977). Northward looking: a strategy and science policy for northern development. Minister of Supply and Services Canada: Ottawa, ON.

Science Technology and Innovation Council. (2014). State of the Nation 2014: Canada's Innovation Challenges and Opportunities. Ottawa.

Scott, C., & Humphries, M. M. (In Press). Chapter 5: Metaphors, Models, and Ecological Relations: Intersections of Cree Knowledge and Scientific Ecology. In C.H. Scott, P.G. Brown & J. Labrecque (Eds.), *Dialoguing Knowledges: Finding our Way to Respect and Relationship.* UBC Press.

Shaw, D. R., & Allen, T. (2016). Studying innovation ecosystems using ecology theory. *Technological Forecasting and Social Change,* in press.

Simon, M. (2017). Report: A new Shared Arctic Leadership Model. Retrieved June 18, 2017, from https://www.aadnc-aandc.gc.ca/eng/1492708558500/1492709024236

Southcott, C., & Walker, V. (2015). A portrait of the social economy in northern Canada. In C. Southcott (Ed.), *Northern Communities Working Together: The Social Economy of Canada's North*: University of Toronto Press.

Steinberg, P. E., & Tasch, J. (2015). *Contesting the Arctic: politics and imaginaries in the circumpolar North*: IB Tauris.

Strand, R., Saltelli, A., Giampietro, M., Rommetveit, K., & Funtowicz, S. (2016). New narratives for innovation. *Journal of Cleaner Production*. Available from, http://www.sciencedirect.com/science/article/pii/S095965261631825X.

Suominen, A., Seppänen, M., & Dedehayir, O. (2016). *Innovation Systems and Ecosystems: a Review and Synthesis*. Paper presented at the ISPIM Innovation Symposium.

Tagalik, S. (2010). *Inuit Qaujimajatuqangit: The role of Indigenous knowledge in supporting wellness in Inuit communities in Nunavut*. Child and Youth Health: National Collaborating Centre for Aboriginal Health.

Tamtik, M. (2016). Policy coordination challenges in governments' innovation policy—The case of Ontario, Canada. *Science and public policy, 44*(3), 417-427.

Tesar, C., Dubois, M.-A., & Shestakov, A. (2016). Toward strategic, coherent, policy-relevant Arctic science. *Science, 353*(6306), 1368-1370.

The Expert Panel on Business Innovation. (2009). Innovation and Business Strategy: Why Canada Falls Short. Ottawa. Retrieved June 18, 2017, from http://www.scienceadvice.ca/uploads/eng/assessments%20and%20publications%20and%20news%20releases/inno/(2009-06-11)%20innovation%20report.pdf

UArctic. (2017). Arctic Yearbook 2017 - Change and Innovation in the Arctic: Policy, Society and Environment- Call for Abstracts. Retreived from, https://arcticyearbook.com/images/Pdf/AY2017-Call-for-Abstracts.pdf.

United Nations. (2008). *United Nations Declaration on the Rights of Indigenous Peoples*.

Vandebroek, I., Reyes-García, V., de Albuquerque, U. P., Bussmann, R., & Pieroni, A. (2011). Local knowledge: Who cares? *Journal of Ethnobiology and Ethnomedicine, 7*(1), 35.

Vermunt, D., Negro, S., Verweij, P., & Hekkert, M. (2017). *Bringing ecology and ecosystems in transition research*. Paper presented at the The 8th International Sustainability Transitions Conference, Gothenburg, Sweden.

Wallner, T., & Menrad, M. (2011). *Extending the innovation ecosystem framework*. Paper presented at the XXII ISPIM Conference.

Walrave, B., Talmar, M., Podoynitsyna, K. S., Romme, A. G. L., & Verbong, G. P. (2017). A multi-level perspective on innovation ecosystems for path-breaking innovation. *Technological Forecasting and Social Change,* in press.

Wang, P. (2009, May 28-30, 2009). *An integrative framework for understanding the innovation ecosystem.* Paper presented at the Conference on Advancing the Study of Innovation and Globalization in Organizations Nuremberg, Germany

Wehrmann, D. (2016). The Polar Regions as "barometers" in the Anthropocene: towards a new significance of non-state actors in international cooperation? *The Polar Journal*, 1-19.

Wieczorek, A. J., & Hekkert, M. P. (2012). Systemic instruments for systemic innovation problems: A framework for policy makers and innovation scholars. *Science and public policy, 39*(1), 74-87.

Yukon Indian People. (1973). *Together Today for Our Children Tomorrow. A statement of grievances and an approach to settlement*. Brampton, ON: Charterns Publishing Company Ltd.