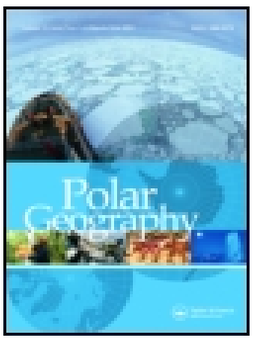

Polar Geography

ISSN: 1088-937X (Print) 1939-0513 (Online) Journal homepage: https://www.tandfonline.com/loi/tpog20

Matching societal knowledge demand, research funding and scientific knowledge supply: trends and co-creation dynamics around reindeer management in Finland

Simo Sarkki, Sirpa Rasmus, Mia Landauer, Élise Lépy & Hannu I. Heikkinen

To cite this article: Simo Sarkki, Sirpa Rasmus, Mia Landauer, Élise Lépy & Hannu I. Heikkinen (2020): Matching societal knowledge demand, research funding and scientific knowledge supply: trends and co-creation dynamics around reindeer management in Finland, Polar Geography, DOI: 10.1080/1088937X.2020.1755905

To link to this article: https://doi.org/10.1080/1088937X.2020.1755905

Published online: 23 Apr 2020.

POLAR GEOGRAPHY
https://doi.org/10.1080/1088937X.2020.1755905

Taylor & Francis
Taylor & Francis Group

Matching societal knowledge demand, research funding and scientific knowledge supply: trends and co-creation dynamics around reindeer management in Finland

Simo Sarkki [a,b], Sirpa Rasmus [c], Mia Landauer [c,d], Élise Lépy [a] and Hannu I. Heikkinen [a]

[a]Cultural Anthropology, University of Oulu, Oulu, Finland; [b]Vaartoe – Centre for Sami Research, Umeå University, Umeå, Sweden; [c]Arctic Centre, University of Lapland, Rovaniemi, Finland; [d]International Institute for Applied Systems Analysis, Laxenburg, Austria

ABSTRACT

Matching knowledge Demand, research Funding and knowledge Supply (DFS) is important in order to enhance societally and policy relevant research, target funding appropriately and enhance the connectivity between science, policy and society. The DFS field around reindeer management in Finland offers a fertile case study to examine interconnected and complex trends as well as the relations between herders' and policymakers' knowledge demand, ministerial funding and independent supply of knowledge by science. We identify matches and mismatches between the DFS in a case study of reindeer management in Finland across ten inductively identified themes and in time scales of 2000–2009 and 2010–2018. The main finding was that, during the latter period, the DFS matched significantly better than in the earlier period. In order to explain this, we identify and discuss five alternative and legitimate co-creation dynamics that explain how the DFS is organizing around the reindeer management in Finland. The five dynamics represent variations in the co-creation approach, fit to varying situations, which can inform of alternative ways to better match the DFS around reindeer management, and they are also applicable in other contexts.

ARTICLE HISTORY
Received 1 February 2019
Accepted 14 February 2020

KEYWORDS
Arctic; reindeer herding; science-policy-practice interfaces; co-creation; environmental governance

Introduction

Matching knowledge **D**emand, research **F**unding and knowledge **S**upply (DFS) is important in order to promote societally and policy relevant research as well as to enhance the connectivity between science, policy and society (Sarewitz & Pielke, 2007; van den Hove, 2007). Current calls for societally relevant research have become pervasive across disciplines and can be considered as among the most important drivers influencing current research policy and science-policy-society relationships (Editorial, Nature, 2018). The common idea to ensure societally relevant research is simply 'to ask from the people' (Richardson & Perry, 2018) what researchers should study. This implies that policymakers and stakeholders should co-define the research priorities, which determine the scope of funding

CONTACT Simo Sarkki simo.sarkki@oulu.fi Cultural Anthropology, University of Oulu, PO Box 1000, 90014 Oulu, Finland; Vaartoe – Center for Sami Research, Umeå University, SE-901 87 Umeå, Sweden

programs, and then funded research would supply knowledge on these societally important questions.

Co-creation approaches to connect science, policy and society have boomed recently and applied also to Arctic areas (Armitage et al., 2011; Nilsson et al., 2019). The science-policy-society literature often focuses on criticizing the linear model where scientists should speak truth to power (Hoppe, 1999; Young et al., 2014), but rarely addresses variations by which co-creation can take place. In order to go beyond simplistic views that co-creation is just about asking from the people (Richardson & Perry, 2018) or promoting iterative interactions with stakeholders (e.g. Mauser et al., 2013), we employ a retrospective policy evaluation (IPBES, 2016) as our methodological tool to create basic qualitative storylines on the dynamics between DFS.

In the present paper, we examine the interrelations between the demand, funding and supply of scientific knowledge in a case study of reindeer management in Finland for the periods 2000–2009 and 2010–2018. Reindeer management in Finland is a traditional livelihood practised by indigenous Saami and Finn herders. It is practised in a large geographical area (36% of Finland) and, therefore, it links to many questions and developments in Northern Finland. Practices, policies and science are interlinked around reindeer management in Finland. Therefore, a case study offers a constructive avenue to examine the matches and mismatches between the demand, funding and supply. The selection of these time periods is justified because, around the turn of the millennium, research on reindeer pastures started to diversify by considering that other land uses (e.g. forestry) also impact the state of reindeer pastures (Kumpula, 2003). On the other hand, participatory approaches in research, also engaging herders in knowledge production, started to emerge (e.g. Hukkinen et al., 2006). The year 2009 was chosen as another time interval due to the rise of many relevant themes around reindeer management, like increased attention paid to climate change, mining developments, increasing challenges caused by predators and attention to cumulative pressures. In addition, by 2009, the emphasis on participation and co-creation approaches between stakeholders, researchers, policymakers and research funders has been established as a general framework in the efforts to enhance the connectivity between science, policy and society (see Armitage et al., 2011). The research questions examined in the present paper are: (1) What were the trends and themes in knowledge demand by herders and policymakers, research and development funding by Ministry of Agriculture and Forestry (MAF) and Reindeer Herders' Association (RHA), and knowledge supply by scientists in international peer-reviewed publications in periods 2000–2009 and 2010–2018? (2) Do the addressed themes match across demand, funding and supply and, if so, how? (3) What kind of varying co-creation dynamics can be derived from the identified trends and themes to match societal knowledge demand, research funding and knowledge supply?

The significance of this paper relates to an empirical assessment of the trends in DFS around the reindeer management in Finland. While reindeer management is highly researched in general, the approaches explicitly tackling the complex dynamics between DFS are lacking. In terms of the theory on science-policy-society interactions, we emphasize the plausible variations in co-creation approaches that fit different situations and explain the matches and mismatches between DFS. We assess the connectivity between DFS via themes occurring as important in relation to knowledge demand, research funding and knowledge supply. Therefore, we contend that there is a match when DFS cover the same themes, and a mismatch where the addressed themes are different.

Methodology

Case study: understanding the interconnected demand-funding-supply landscape in the context of reindeer management in Finland

Finland includes 54 Reindeer herding cooperatives (RHC) which are part of the Reindeer Herders' Association (RHA). The reindeer management area in Finland comprises two main geographical areas: the North (area specifically intended for reindeer husbandry, including Saami homeland) and the South (the remaining reindeer management area). Reindeer management belongs under the jurisdiction of the Ministry of Agriculture and Forestry (MAF). Some sectoral research institutes (Since 2015 LUKE merging the previous RKTL; METLA; MTT) are relevant for reindeer management and work under MAF, which is responsible for rural livelihoods and needs related knowledge for policymaking. In the late 1980s, updating the Reindeer Husbandry Act was in progress, and the maximum number of breeder reindeer for each RHC from the beginning of the 1990s were set. Reindeer numbers had grown significantly during 1980s, new herding practices had been adopted and new research methods provided new data about the ecological state of pastures, which is oftentimes referred to the 'ecological carrying capacity' of pastures (see Forbes et al., 2006). Legislation functionality was monitored during the 1990s, and the reindeer numbers were again set in the late 1990s. Therefore, knowledge demand by the policymakers was most strongly linked to knowledge of pasture quality and quantity. The same trend continued until the end of the 1990s.

Some funding for reindeer related research in Finland is based on academic funders, such as Academy of Finland, Nordic funding instruments and EU funding, but in terms of reindeer herding this funding is relatively small, competed and sporadic. Therefore, we concentrate on two instruments, MAKERA and RHA funding, which focus on practical reindeer management with results often published as gray literature, yet also supporting academic peer-reviewed publishing and vice versa. In 1986–2016, the MAF has had a specific funding instrument, MAKERA, to finance research and development projects on rural livelihoods. Within this instrument, a certain portion of funding was targeted towards projects on reindeer management. After 2016, reindeer management-related funding has been governed by the Centre for Economic Development, Transport and the Environment of Lapland (Lapin ELY-keskus). Projects funded by MAF had to have practical objectives. Therefore, MAKERA funding also had a clear connection to policy, and it was also a way to meet the knowledge demand by MAF. MAKERA is funding that supports research that is not directly covered by sectoral research institutions working under MAF. Henceforth, part of the reindeer management relevant funding is not 'visible' for our analysis here but supported by researchers with varying and shifting backgrounds and affiliations to academic and applied research institutions. However, MAKERA funding gives indicative information on the DFS dynamics.

The Reindeer Herders' Association (RHA) represents, on the one hand, the interest of herders and herding cooperatives in its communication towards MAF. It is also responsible for the PR-work towards society and promoting reindeer management and the research conducted on it. RHA gets its own funding from MAF and can, on the other hand, be understood as a regional administrative body of central government (practical administration and regulation of reindeer management and guidance for herders being among its key operations). Therefore, RHA is at times criticized for its dualistic role and biased interest commitment (Hukkinen et al., 2003a, pp. 26–27). Furthermore,

Saami reindeer herders' have expressed their will to have an organization of their own to defend their interests. RHA distributes some funding on research and development projects and has been responsible for initiating, applying and managing funding for these projects. These projects have aimed to respond to the needs of herding cooperatives and, sometimes, proactive investigation or development has been carried out (personal communication, Matti Särkelä, Office and quality manager of RHA Finland, 29 January 2019). In conclusion, RHA and MAKERA funding have interdependencies and are often targeted at advancing practical reindeer management, publishing in gray literature, and conducted by people outside of academia.

Reindeer management related knowledge supply as examined in the present paper has been published in international peer-reviewed publications within research projects funded by the Academy of Finland, Finnish private foundations, Nordic funding instruments and the EU. Even though academic funding for the reindeer related research is limited, this funding is important because it gives more freedom for topics and approaches taken in research than, for example, practical research and development funding of the MAF. For keeping our focus on peer-reviewed international publications as knowledge supply, we excluded gray literature and research in Finnish language from our analysis because the former often report outputs from MAKERA and RHA funded and MAF guided or commissioned projects. Figure 1 outlines the interconnected field of knowledge demand, research funding and knowledge supply around reindeer management in Finland.

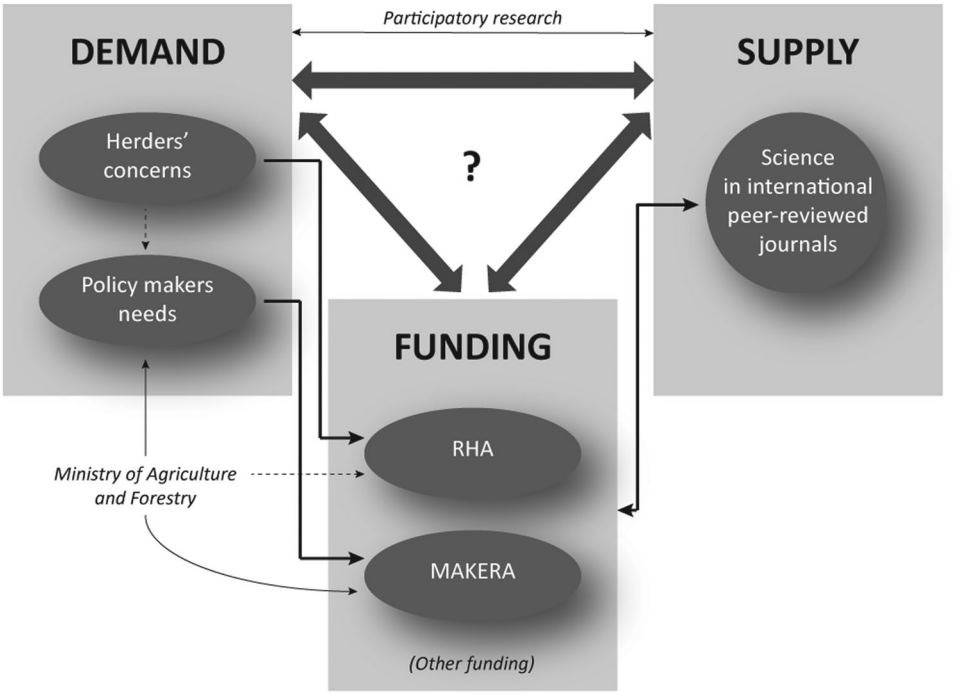

Figure 1. Field of demand, funding and supply around reindeer management in Finland. The question mark in the middle stresses whether and how the demand, funding and supply can be matched.

Research materials

Knowledge demand by policymakers

Legislation is under continuous development, and the targets of laws also reflect policymakers' knowledge demand, as policymakers need knowledge to develop laws on specific themes. Here, we scanned policymakers' views via screening of laws relevant for reindeer management that started to evolve faster since the Reindeer Husbandry Act (848/1990) was under reformulation. Furthermore, the current views especially of MAF policymakers were found in administrative reports: Ruuhela et al. (2011); MAF (2014); Peltonen-Sainio et al., (2017) and Tennberg et al. (2017) commissioned by MAF.

Knowledge demand by herders

Reindeer herders' knowledge demand is addressed via a participatory research approach. Participatory research with reindeer herders has also been conducted elsewhere, but here our material comprises the knowledge needs of reindeer herders collected through the following major research efforts that fit our time span of the analysis. First, the national report of Kemppainen et al. (2003) is a comprehensive work explicitly targeted to formulate the future research needs. According to the report, herders' knowledge needs and concerns were identified based on two workshops in 2002 and 2003 in Inari and Salla. Sixty 60 participants in these workshops consisting of herders and other stakeholders, such as scientists, dealing with reindeer management were aimed at 'developing reindeer husbandry and facilitating policymaking' by identifying knowledge needs based on herders' views. Second, the research reports of large international consortiums that have conducted transdisciplinary and participatory research in the 1990s and early 2000s: the pioneer EU FP5 project 'The Challenges of Modernity for Reindeer Management' RENMAN (2001–2004) (Forbes et al., 2006) is a good example. Finally, the recent research of the large international research consortium ReiGN (Nordforsk Nordic Centre of Excellence 'Reindeer husbandry in a Globalising North – resilience, adaptations and pathways for action') that organised a workshop for herders in February 2018. This 'dinner workshop' included 12 herders from eight RHCs in Finland, consisting of eight RHC leaders and indigenous Saami herders. These participants represented the two main geographical areas of reindeer management in Finland. The purpose of the workshop was to allow open discussions on relevant topics, such as predator damage, land use change and governance of reindeer management in Finland in general. Emerging issues and research needs were explicitly asked. We aimed at opening discussions on topics chosen by herders. The aim was for the discussions to reflect herders' concerns of today.

Ministerial research and development funding

We examined projects funded by the MAKERA and RHA funding instruments. Altogether, 144 projects received MAKERA-funding during the years 1986–2016 (including 58 projects in 2000–2009 and 25 projects in 2010–2016). RHA has been conducting its own research and development activities since 2000 and managed 88 projects until 2016. Lists of the projects have been requested and were received from the persons responsible for funding administration.

Knowledge supply by peer-reviewed publication

We analyze scientists' knowledge supply via international peer-reviewed publications between 2000 and 2018. In order to map what kind of scientific knowledge on reindeer

management in Finland has been published, we used the comprehensive scientific literature review first presented by Landauer et al. (2018): the literature searches were conducted in Google Scholar, Scopus and Web of Science databases with a combined use of the search words 'Finland' and 'Reindeer herding'. Additional manual searches were done by screening the reference lists of the publications found during the main search (i.e. snowball sampling). The literature search was limited to peer-reviewed international publications, and book chapters published between the years 2000 and 2018 in the English language. The selected peer-reviewed publications ($N = 85$) focus on reindeer management in Finland. According to the Acknowledgements statements of these publications, only five out of the 85 scientific publications were funded by MAKERA.

Analysis methods

The first task of the analysis was to identify themes that allow comparisons between the five DFS aspects (Figure 1). This was done by starting the analysis from the available databases: the lists of MAKERA and RHA funded projects, and peer-reviewed scientific publications. The scientific literature review revealed eight themes that have been studied (Landauer et al., 2018). The MAKERA projects were clustered into nine themes. The RHA funding was clustered into five themes. These categories were further clustered into ten overall themes, and the subcategories were identified under each theme (Table 1). We used these ten themes to categorize reindeer herders' and policymakers' knowledge demands.

In order to examine the evolving matches and mismatches between demand, funding and supply (DFS), we look backwards to analyze matches and mismatches between the DFS. We identify (1) the most relevant actors (Figure 1), and (2) themes by which the matches and

Table 1. Themes, abbreviations and short explanations on the classification of the material.

Theme	Abbreviation	Explanation
Climate and climate change	Climate	Climate change, impacts of climate change on pastures and reindeer management, herders' adaptation to climate change
Economy and profitability	Economy	Productivity and profitability of reindeer management, employment and part-time complementing employment (e.g. tourism), entrepreneurship related to reindeer management and tourism, handicrafts, marketing, reindeer meat and products
Governance and legislation	Governance	Governance of reindeer management and its working environment, legislation, rights and responsibilities in reindeer management
Reindeer physiology and health	ReinHealth	Reindeer health and healthcare, diseases, parasites and insects, reindeer physiology
Multiple land uses and implications on reindeer management	Land use	Land use in reindeer management area, multiple pressures by other land users (e.g. protected areas, mining, wind parks, forestry, tourism, traffic losses)
Pasture quality and quantity	Pastures	Pasture quality and quantity, impacts of reindeer management on pastures, pasture conditions and carrying capacity estimation methods
Reindeer management practices	Practices	Supplementary feeding and fodder, slaughtering and slaughtering houses, breeding and development of reindeer stock, practical herding methods, technology and information technology and management, working skills, educational material
Predators and their implications on reindeer management	Predation	Predators, losses of reindeer on predation, predator watching tourism
Sociocultural aspects	Socio-culture	Herding culture and traditional knowledge, traditions, Sámi culture and herding, social changes and crises, image of reindeer management
Herders' well-being	HerdersWell	Well-being of herders at work, occupational health

mismatches between the DFS can be assessed (Table 1). Thereafter, we can (3) assess the trends in recognition of the ten overall themes by the actors (Figure 3). After (semi-)quantified results, we discuss five types of the dynamics of co-creation addressing past dynamics between the DFS (Figure 4; Section 4). These co-creation dynamics provide qualitative explanations for some of the results rising from Section 3.

Results: trends and themes in demand, funding and supply around reindeer management

Knowledge demand: policymakers' knowledge needs

Present day knowledge needs can be found in the policy documents: Ruuhela et al. (2011) mention only general 'research on the use of environment and natural resources' and MAF (2014) 'research on climate change impacts and climate risks'. Two recent reports (Peltonen-Sainio et al., 2017; Tennberg et al., 2017) emphasize the need for the multidisciplinary research, in which herders and other stakeholders genuinely participate. They include a comprehensive list on knowledge needs complemented by the screening of laws related to reindeer management (Table 2). The land use regulation in Finland is still developing, including changes in the National Land Use Guidelines in 2018 (*Valtakunnalliset alueidenkäyttötavoitteet, VAT*), which has also affected reindeer management.

Knowledge demand: Herder's concerns and knowledge needs

Herder's concerns and knowledge needs are shown in Tables 3 and 4. Table 3 lists the identified knowledge needs in the early 2000s based on the national report of Kemppainen et al. (2003) and on RENMAN publications which list several policy recommendations, concerns and needs of herders and herding communities. RENMAN applied transdisciplinary, co-design and co-production approaches (Hukkinen et al., 2003a; 2003b; 2006). Table 4 identifies herders current knowledge needs based on the ReiGN participatory workshop with herders organized in 2018.

Funding managed by the Ministry of Agriculture and Forestry: MAKERA and RHA

The overall MAKERA focus targeted herding practices and economic studies, together with socio-cultural and historical aspects. When looking at the period 2000–2016 (altogether 83 projects), studies on economy, herding practices, socio-cultural aspects and reindeer physiology and health have been most often funded by the MAKERA instrument (Figure 2). In the 2000s (58 projects in 2000–2009), the economy, reindeer physiology and health and development of herding practices were funded; in the 2010s (25 projects in 2010–2016), the socio-cultural aspects were also addressed. Furthermore, governance related projects were more common. Predation related studies emerged from 2002 onwards in the MAKERA projects. RHA managed funding has been an instrument that allows for the consideration of issues which are perhaps considered as minor by other funders, but which are important to herders (e.g. well-being of herders, certain land-use and predation related issues). However, a large share of the projects have concentrated on the economic aspects and herding practices (Figure 2).

Table 2. Policymakers' knowledge needs.

Policy makers' knowledge needs 2000–2009 (Screening of laws related to reindeer herding)	
Pastures & Governance	• Reindeer Husbandry Act (848/1990; e.g. rights and responsibilities of herding cooperatives)
Socio-culture	• Act on Saami Parliament (974/1995; prerequisites of herding in the Saami area)
Predation	• Compensations for predator-caused reindeer damages (Game Animal Damages Act, Riistavahinkolaki 105/2009 and 309/2013),
Policymakers' knowledge needs 2010–2018 (Screening of laws related to reindeer herding; MAF 2014; Peltonen-Sainio et al., 2017; Ruuhela et al., 2011; Tennberg et al., 2017).	
Climate	Climate change impacts and risks; Research improving the adaptation of herding to climate change: more detailed climate co-creation dynamics, impact studies with regional or local scale. • Compensations for weather-related damages (Act about compensating the damages caused to reindeer herding, Laki porotaloutta kohdanneiden vahinkojen korvaamisesta 987/2011 and 655/2016).
Economy	Profitability and sustainability of reindeer husbandry, economic and employment effects of herding, reindeer entrepreneurship. • Subsidies for reindeer herding and natural economy (986/2011 and 418/2018; Laki porotalouden ja luontaiselinkeinojen rakennetuista)
ReinHealth	Reindeer condition and health (including parasites)
Land use	Drivers of change, cumulative impacts of land-use. • Act on Metsähallitus (234/2016, obligations of the state-owned enterprise Metsähallitus to consult and consolidate with herding)
	• Mining Act (621/2011, obligations to consult and consolidate with herding)
	• Water Act (587/2011, obligations to consult and consolidate with herding)
	• Compensations for traffic-caused reindeer damages (Act on traffic insurances, Liikennevakuutuslaki 460/2016),
Pastures	Reindeer forage plants and pastures
	• Act about the largest allowed reindeer numbers per RHC and per reindeer owner (857/2014)
Practices	Herding practices in relation to drivers of change, e.g. technical aids and digitalization
Predation	Predation and compensations related to predator-caused losses
Socio-culture	Sociocultural impacts of changing operational environment of herding
HerdersWell	Work safety, health and well-being of herders, ageing of herders

Overview of knowledge supply based on peer-reviewed publications on reindeer management in Finland

The percentage of publications regarding the ten themes is shown in Figure 2. In 2000–2009, 'pastures' and 'climate' were the themes the most studied (7 publications each one). While the number of publications concerning 'pastures' and 'climate' slightly increased (respectively 10 and 9) in 2010–2018, "governance' and land use' are the themes which have got the highest increases in their representation of the total amount of publications between

Table 3. Herders' knowledge needs in the early 2000s (Kemppainen et al., 2003; Hukkinen et al. 2003a, 2003b).

Herder's knowledge needs in the early 2000s	Category
Kemppainen et al., (2003)	
Information management	Practices
The future of reindeer husbandry	Socio-culture
Cash and material flow in reindeer husbandry	Economy
The reindeer and tourism	Economy
Reindeer products and markets for them	Economy
The status and significance of reindeer husbandry	Socio-culture
Reindeer management and meat processing	Economy
Reindeer management and other land use	Land use
The operating environment for reindeer husbandry (society, other businesses, the European Union, free trade and changes in consumer habits and values)	Economy
Other research subjects (animal diseases, developing the administration)	ReinHealth; Governance
Hukkinen et al. (2003a, 2003b)	
Land use	Land use
Legal framework	Governance
Social legitimacy of herding	Socio-culture

Table 4. Herders' recent concerns and knowledge and research needs as heard at a dinner workshop organized by ReiGN in 2018.

Knowledge needs expressed in the ReiGN workshop 2018	Themes
Risk for chronic wasting disease (CWD) spreading to reindeer	ReinHealth
Risk for additional loggings due to fungi and diseases (e.g. Cronartium flaccidum and Peridermium pini) which spread particularly in monoculture forests	Land use
Mines: direct pollution risk of waters, and increasing risk of meat quality change, and/or image damage of reindeer meat	Land use
Mines: mineral exploration is increasing, new companies appear, extensions of currently existing sites, large-scale pasture losses due to mining.	Land use
Image of herding and reindeer meat	Socio-culture
Railroad to the Arctic Ocean that would lead to increase in traffic accidents and to pasture fragmentation	Land use
Tourism/outdoor recreation related photographing: use of carcasses are used to attract predators to be photographed but it increases the risk of reindeer losses due to predators.	Predation
Technological innovations have potential to change herding practices further, and very quickly, and unexpectedly (as evidenced by the introduction of snowmobiles and mobile communications). These can have unexpected consequences, both positive and negative.	Practices
Governance issues such as setting largest allowed reindeer numbers (mainly based on the estimated pasture carrying capacity)	Governance; Pastures
EU subsidies	Economy; Governance

2000–2009 and 2010–2018 (+12.1% and + 10%, respectively). On the other hand, 'economy', 'predation' and 'reindeer health' are the themes which have been published less in 2010–2018 (with a decrease in the representation of the total amount of publications of −7.8%, −5.5% and −5%, respectively). The sociocultural topic was addressed by some publications only as a minor issue, not as the main theme and, therefore, the classification Sociocultural is missing from Figure 2. Sociocultural topics were discussed in the papers in the Practices and Economy categories and appeared mainly in the publications from 2010 onwards.

Do the demand, funding and supply match?

The matches and mismatches between knowledge demand, funding and supply for the periods 2000–2009 and 2010–2018 are indicated in Figure 3. It is noteworthy that the

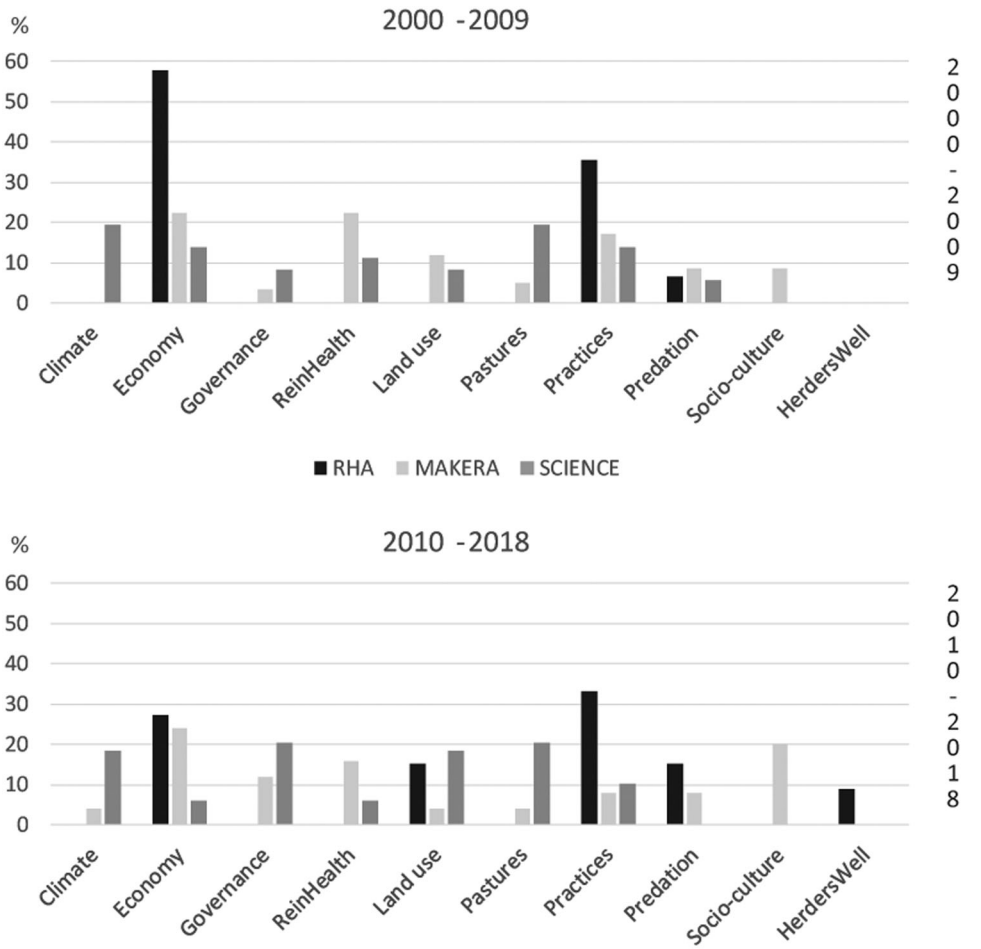

Figure 2. Percentage of projects funded by RHA and MAKERA in the periods 2000–2009 and 2010–2016, and the percentage of scientific publications regarding the ten themes for the periods 2000–2009 and 2010–2018.

mismatches between all of the actors are quite common even though these decades have shown a large variety of themes. The latter examination period illustrates significantly more matches than the earlier period. Below, we pick up some interesting observations from Figure 3 and discuss plausible explaining dynamics for the (semi-)quantitative examinations above.

There are five key findings from this analysis. First, predation is a theme missing from the list of reindeer herders' concerns in 2000–2009, and from the peer-reviewed publications in 2010–2018 (Figure 3). Second, pastures occur as an addressed theme for many actors in both periods, but why is there not a full match despite the pastures being the basis for free grazing reindeer herding? And what explains the steady interest of peer-reviewed publications on pastures, while MAKERA and RHA funding for pastures is almost non-existent in both examined periods (See Figure 2). Third, climate change has been targeted by peer-reviewed publications from early on, and in 2010–2018, it was a target of peer-reviewed publications and policymakers' knowledge needs. Fourth, land-use issues are addressed by all the actors in 2010–2018, but according to our material, the theme is missing from the policymakers'

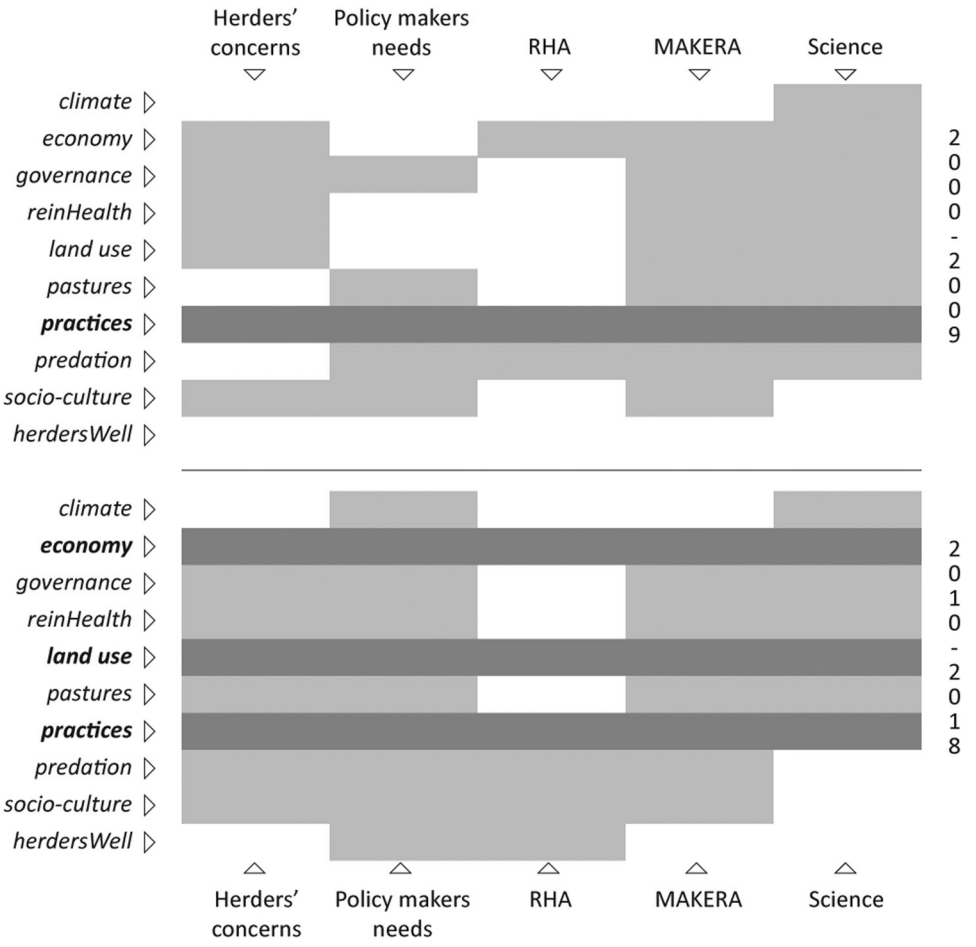

Figure 3. Matches (in bold and dark) and mismatches between policymakers' and reindeer herders' knowledge demand, Ministerial research and development funding and peer-reviewed publications for the periods 2000–2009 and 2010–2018.

knowledge needs and RHA research themes in 2000–2009. We take highly topical mining as an example for a more in-depth discussion. Fifth, herders' well-being is shown only as a theme for Policymakers' knowledge needs and RHA funding in 2010–2018, and not at all in the period 2000–2009 (Figure 3).

Discussion

Co-creation dynamics to match demand, funding and supply

Based on the results, the themes addressed by policymakers' and herders' knowledge demands, supply of science and available funding match significantly more between the time period 2009–2018 than 2000–2009 (Figure 3). The change seems to be in line with general tendencies in environmental policy and governance to change from hierarchical top-down approaches towards participatory governance (Challies et al., 2017). In research, the movement towards the co-creation of knowledge approaches with an emphasis on

societally relevant research, are bridging the gap (Nilsson et al., 2017). The idea that science, policy and society need to be better connected in knowledge production and policy design (Armitage et al., 2011) are probable reasons as to why the gap between demand, supply and funding is narrowing. On the other hand, some previously budget-funded sectoral research institutes currently face pressures to find more and more of their own funding, meaning that they compete for research funding. This has narrowed the gap between research under Ministerial funding and independent research under external competed academic funding. Next, we discuss five specific co-creation dynamics, explaining how the gap has been narrowed around the reindeer management in Finland (Figure 4). None of the co-creation dynamics is better than another, but they rather fit into different situations and purposes. The numbering of co-creation dynamics corresponds with those of the key findings hereinabove. Thus, the discussion on the five co-creation dynamics is explaining and providing more details on our five key findings.

Co-creation dynamics 1: meeting societal knowledge demand

Co-creation dynamics 1 depicts a situation where knowledge demand by policy and society comes first and it is then taken up by researchers and funders. This is a common view in the current discussions emphasizing that research must be societally relevant, and thereby research and its funding need to follow concrete societal or policy needs and concerns for knowledge (McNie, 2007; Sarewitz & Pielke, 2007).

Predator discussions provide an example of the logics following the co-creation dynamics 1. Predator problems have been increasing since Finland joined the EU in 1995 and predator damages increased due to regulatory changes (e.g. nature conservation and species protection

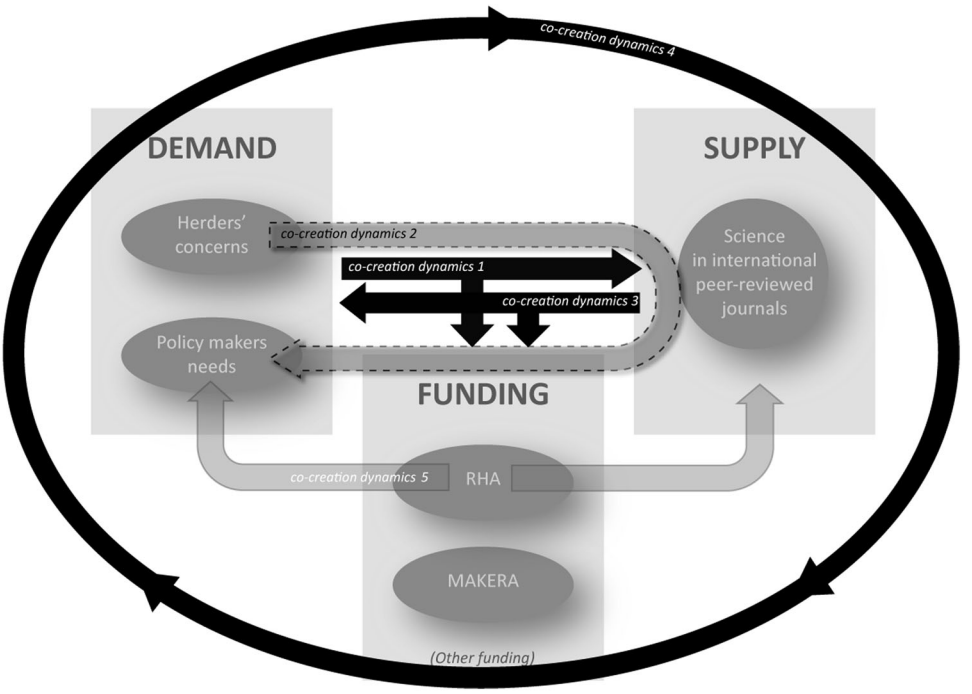

Figure 4. Five co-creation dynamics to match knowledge demand, research funding and knowledge supply derived from the trends around reindeer management in Finland.

regulations) (Turunen et al., 2017). The absence of the predator theme from herders' knowledge needs in our material is probably explained by the fact that our materials are from the year 2003, when the steadily growing predator damages were at their lowest point (Paliskuntain yhdistys: https://paliskunnat.fi/py/porovahingot/petoelainvahingot/). Herders' concerns regarding predators have especially increased in the southern and eastern cooperatives of the Finnish reindeer management area during the last decade. The predator issue has also been visible in recent news reports related to reindeer management (e.g. Koillismaan Uutiset 11 May 2018). In addition, the RHA funding for predator related projects has increased when comparing the 2010–2018 period to the 2000–2009 period (Figure 2). This highlights that policy changes have created a new problem, which is first recognized by herders', and then policymakers who need to deal with the new problem (see The Game Animal Damages Acts 2009 and 2013). The lack of a predator theme in peer-reviewed publications in 2010–2018 is probably due to many of the publications focusing on predator governance and being classified as a governance theme instead of predators (Heikkinen et al. 2011). That the MAKERA funding on predators has slightly decreased is explained by sectoral research institutes having a rather strong research focus on predators as part of their job. Administration produces predator-related gray reports as part of the everyday work of sectoral research institutes in relation to their legal tasks in game management. Therefore, the complex role of sectoral research institutes in being guided by MAF and carrying out science complicates the picture.

Ongoing discussions on the predators' link to the practice of supplementary feeding of reindeer in corrals to, in addition to other reasons to feed, mitigate predator damages. This, however, changes the reindeer management from free-grazing to reindeer farming (see Heikkinen et al., 2012; Lépy et al., 2018). On the other hand, recent developments in predator photographing tourism have been found to be contested especially in the east (e.g. Kuusamo region), where carcasses are used to lure predators, and which takes place in the same areas where reindeer graze (Iivari, 2017). In conclusion, herders are among the first to acknowledge the implications of increasing predators and related tourism activities on herding. The administration is then burdened by a flow of applications for compensations due to lost reindeer for predators. The co-creation dynamics 1, therefore, highlights that researchers and funders should be alerted to the changes that are observed on the ground and by the administrators to keep up to date on the topical issues.

This co-creation dynamics can be applied elsewhere by starting from societal knowledge demand to identify priorities for research. Here, it is essential to note that knowledge demand consists of policymakers and reindeer herders' knowledge demand. Policymakers' demand as a starting point for the co-creation of the knowledge approach has been taken as a starting point by the recent EU Polar Net white paper methodology to connect science and policy (https://www.eu-polarnet.eu/news-and-events/conferences-and-workshops/white-paper-workshop/). The co-creation dynamics 1 would look quite different if starting from indigenous and local peoples' concerns. For example, in connection to Arctic Council proposals for the 'meaningful engagement' of indigenous and local people to inform policymakers have been developed (PAME, 2019). Furthermore, community based adaptation research has addressed local concerns and conditions for adapting to climate change in order to make adaptation research more democratic and responsive to local needs (Ford et al., 2016). Therefore, the co-creation dynamics 1 is relevant when aiming to match better research and funding to societal concerns, and yet varying significantly whether focusing on demand by policymakers or local communities.

Co-creation dynamics 2: researchers as issue advocates of societal concerns

Co-creation dynamics 2 illustrates a situation where societal actors first notice a knowledge need or a governance failure. However, the resulting criticism may not be able to change the situation alone. Hence, researchers and participatory approaches are needed to work as issue advocates towards policymakers, other researchers and funders to facilitate learning and governance changes for sustainability (Ballard & Belsky, 2010; Marshall et al., 2018).

Pasture research and setting the maximum allowed number of reindeer for each RHC have been connected for the three last decades and they, together with presented criticism, provide an illustration of the dynamics portrayed by the co-creation dynamics 2. Policymakers' knowledge needs have centered continuously on pasture research and the carrying capacity of the pastures since the end of the 1980s when the act on reindeer management was under reformulation. MAKERA funding for pasture research has, however, decreased steadily since the 1990s, probably because the former Finnish Game and Fisheries Research institute (RKTL) focused on that with permanent personnel and 'reindeer research station' profiled to ecological research.

The importance of pasture research for administration, especially for MAF, has been manifested by the provisioning of direct funding from MAF to pasture research and inventories. This has happened via other channels than MAKERA and RHA, which show low interest in pasture research in Figure 2. Currently, the new largest allowed reindeer numbers for RHCs are being set by the MAF. This process highlights the persisting knowledge need by policymakers on pastures. In peer-reviewed research, the interest in pasture research has also remained high. Here, the research under sectoral research institutes has also produced peer-reviewed publications (e.g. Akujärvi et al., 2014). The recent focus has been on the cumulative impacts of various land uses on reindeer management as a whole (Sarkki et al., 2016). It seems that, for a long time, there was a self-reinforcing feedback loop between the governance of reindeer numbers and bioeconomic pasture research. This pattern has been gradually eased by some critique from herders and researchers. Herders have clearly demanded the emphasis of issues other than the ecological carrying capacity of especially winter pastures for a long time.

Thus, herders' views supported by research have somewhat altered the perceived knowledge needs by policymakers (e.g. recognition of the importance of cumulative impacts) (e.g. Peltonen-Sainio et al., 2017). Nevertheless, it seems that researchers were needed because herders' critiques have often been labeled as biased and driven by their own interests. In terms of research programs, the EU FP RENMAN (2001–2004) project was revolutionary in communicating the holistic view deriving from herders to policymakers (Hukkinen et al., 2006). The RENMAN results emerged at the same time when the Saami parliament pointed out the need to examine competing land uses at the end of 1990s, and to use herders' knowledge (Ministry of Agriculture and Forestry, 1999). The participatory research has continued, for example, in recent Nordforsk funded consortiums ReiGN and TUNDRA.

The co-creation dynamics 2 depicts a typical situation for participatory action research, where researchers consider themselves as guests hosted by local communities and indigenous peoples, from whom the researchers can learn, and whose interests the researchers can promote (e.g. Openjuru et al., 2015). Social equity and the 'no one should be left behind' logic by UN Sustainable Development Goals are key policy justifications for this co-creation dynamics. In addition, recent developments in research ethics drive research practices in this co-creation dynamics (e.g. Fitzpatrick et al., 2016). In this co-creation dynamics, researchers do not have favorite or pre-determined research topics, but instead they rely on local

problem definitions and aim to co-produce knowledge that is useful and beneficial for local communities.

Co-creation dynamics 3: science-driven research enriched by societal views

Co-creation dynamics 3 pictures a situation when the supply of knowledge by science is a starting point for identifying priorities for policymakers, funding and even society. Climate change is a phenomenon that takes place in long temporal horizons and, therefore, it is difficult to realize in day-to-day activities. Therefore, the supply of knowledge by science, which can examine long-term trends and make assessments on future dynamics, is crucial. However, climate science can be significantly enriched by societal views on adaptation and mitigation in order to inform the administration and identify the priorities for funding (Alexander et al., 2011; Turunen et al., 2016).

With the case of reindeer management, it seems that policymakers' views, herders' concerns and funding priorities are lagging behind science regarding climate change. Policymakers formally acknowledged the climate change issues by Act about compensating the damages caused to reindeer herding (Laki porotaloutta kohdanneiden vahinkojen korvaamisesta 987/2011 and 655/2016) introducing compensations also for weather-related damages. Published research on climate change was relatively extensive in the 2000s but slightly increased towards the 2010s. However, MAKERA funding on climate change-related issues started only after 2010. Policymakers have also recognized the importance of climate change adaptation related to reindeer management in recent years. Herders themselves did not directly state the importance of climate change according to the 2003 policy reports, nor at the ReiGN workshop held in 2018. However, at the ReiGN workshop, they brought up some interesting issues indirectly linked to climate change. Reindeer health and pasture condition related issues, as well as increasing land-use pressures, are partly connected to changing climate and, therefore, can be considered as partly driven by climate change-related knowledge needs. Furthermore, the Arctic Corridor (https://arcticcorridor.fi/) and plans to build a railroad through northern Finland were also raising concerns at the ReiGN workshop. The Arctic Corridor links to climate change impacts: melting sea ice and the indirect impact of it, opening of new sea routes. Therefore, it seems that climate change is an issue first recognized by researchers and then by the administration. For herders, there are often more acute issues and pressures than climate change, but the concrete implications of climate change evoke concerns. Herders are more interested in changing weather conditions and concrete implications of changes in temperatures, precipitation and snow cover on grazing conditions instead of climate change in general. Herders, however, are the experts in observing environmental changes as they operate in nature on a daily basis. Therefore, after science has established climate change on the administrators and herders' mindset, herders can have an important role in monitoring the environmental changes brought by climate change (Riseth et al., 2010), and in identifying and implementing adaptation actions themselves (Lépy et al., 2018; Vuojala-Magga et al., 2011).

This co-creation dynamics could also be called an 'enriched linear model'. Basically, the idea is that the danger of the 'scientification' of politics can be avoided by negotiating the evidence with societal actors before it is used in decision making. In addition, Head (2019) notes that practice-based perspective and political judgement also need to be incorporated into evidence-based decision making. This co-creation dynamics posits that science can identify important emerging issues, which are then brought on the table to be enriched by societal views and political debates. In addition to climate change, ecological

knowledge on biodiversity and its links to ecosystem services can be addressed by the co-creation dynamics 3 (e.g. CAFF, 2015). The perspective of biodiversity can be incorporated into indigenous and local communities by using the concept of biocultural diversity (Kassam, 2009), and by focusing on values and trade-offs associated with ecosystem services (Malinauskaite et al., 2019).

Co-creation dynamics 4: co-identification of relevant themes

Co-creation dynamics 4 illustrates a case when the match between science, society and policy is found by collaborating from early on to co-identify relevant themes as well as co-define the problems to be addressed by research, policymakers, funders and herders. It is recognized here that some themes and problems cannot even be properly identified without equal participation from all these domains. This has been emphasized, for example, in the literature on deliberative democracy and environment (Berg & Lidskog, 2018).

Regarding land use issues, mining and its relationships to reindeer management are illustrative for the co-creation dynamics 4. Herders are increasingly noticing the environmental risks of mining. Before the 2000s, mining was not an issue in the reindeer management area, but the mining boom in Finland in the new millennium brought mining as an acute issue in herders' agenda. Surprisingly, recent reports to the administration do not explicitly mention mining, just cumulative pressures (Peltonen-Sainio et al., 2017; Tennberg et al., 2017). We assume that the reason for it is that the pressures that mining is posing for reindeer management are more relevant near the mining sites, which are not evenly distributed across the reindeer management area in Finland. Therefore, on the one hand, the conflict potential between mining and herding varies according to the specific localities (Brown et al., 2017). On the other hand, a lack of mentions of mining in the administration's recent reports (Peltonen-Sainio et al., 2017; Tennberg et al., 2017) on herders' knowledge needs may be explained by the fact that Finland has been identified as the most attractive political and operational context for the mining industry due to loose regulation for exploration and exploitation for multinational mining companies (Stedman & Green, 2018). It is also difficult to follow the mineral exploration and mining development because the economy of this industry is based on global markets which highly fluctuate. Due to heterogeneous site-specific relationships between mining and herding, and due to the potential interests at play, it seems that matching supply, demand of knowledge and research funding would require collaborative and site-specific problem identifications. This could happen in multi-actor participatory workshops and (public) meetings aiming at identifying the key knowledge needs, e.g. by utilizing maps as boundary objects, similarly to the Environmental Impact Assessment (EIA) procedures which could serve as entry points for discussions and show where the potential conflict areas are, and to visualize cumulative land use pressures on reindeer pastures (cf. Brown et al., 2017; Landauer & Komendantova, 2018).

Co-creation dynamics 4 represents a view on science-policy-society relationships that is based on the co-production of knowledge. Here, scientists, societal actors and policymakers interact in processes 'bringing a plurality of knowledge sources and types together to address a defined problem and build an integrated or systems-oriented understanding of that problem' (Dale & Armitage, 2011, p. 440). Unlike in other co-creation dynamics, here, the process is not started by a specific actor, but it is rather continuous and the iterative interactions between science, policy and society are taking place. However, due to the above-mentioned power imbalances, the equal participation in the knowledge co-production processes can be compromised by economically or otherwise more powerful actors. Therefore, Diver

(2017, p. 1) has proposed a framework of indigenous articulations, 'where indigenous peoples self-determine representations of their identities and interests in a contemporary socio-political context'.

Co-creation dynamics 5: funding to identify emerging issues

Co-creation dynamics 5 pictures a situation where funders first recognize an emerging issue leading to policy interest also towards that issue. In general, this co-creation dynamics highlights the power of funders to identify emerging or urgent issues, which then become policy priorities.

Reindeer herders' well-being represents an issue taken up by RHA research funding and starting to be addressed by policymakers. It may be that herders are proud practitioners of their livelihood, and do not prefer to talk about the challenges for their well-being connected to the livelihood. There may be a so-called 'happiness wall' meaning that internal problems are not discussed with outsiders. On the other hand, herders may 'refuse to resist' mining projects because they want to maintain social capital at the local level (see Komu, 2019). Therefore, herders may not want to raise issues at the table that may lead to negative views on reindeer management. It may be perceived that negative issues expose herders to additional criticism, which may be used to legitimate actions and decisions that compromise herders' interests and values. Against this backdrop, it seems logical that the herders' interest organization, RHA, first identified the issue of herders' well-being, and this was also then acknowledged to some extent by policymakers' knowledge demand. On the other hand, this may relate to the trend of being more sensitive towards occupational health issues in recent years compared to the past.

Co-creation dynamics 5 may be rarer than the other four co-creation dynamics to match DFS requiring that indigenous or livelihood-based organizations can fund research, or act as gatekeepers for the research. Such organizations can also identify sensitive topics to be more easily researched than livelihood practitioners who may want to avoid conflicts or negative views on the livelihood. Even if the indigenous or local organizations are not funders, they are gatekeepers of what can be researched, and thereby their approval for the research plans is crucial and gives them the possibility to define what kind of research will take place. The initiative for addressing certain research topics thereby comes in co-creation dynamics 5 from funders or gatekeepers for research.

Assessing the co-creation dynamics

We can note that none of the co-creation dynamics is the best to match the DFS, but all five dynamics have strengths and weaknesses, and they seem to be applicable to different contexts of which we have provided examples in this paper. Table 5 proposes strengths, weaknesses and application contexts for the five co-creation dynamics. It is important to understand the application context while aiming at matching DFS as there are no 'magic bullets' that can solve all the problems. Instead, different solutions work in different contexts. The application context here links to the extent of problem structuration (Hisschemöller et al., 2001), wickedness of the issue (e.g. divergent values, complex solutions; uncertainties) (e.g. Funtowicz & Ravetz, 1993; Head, 2019), and the position of the addressed community (like reindeer herders) in policy and governance discussions and platforms (e.g. Stringer et al., 2006).

Table 5. The strengths, weaknesses and potential application contexts for the five co-creation dynamics.

Co-creation dynamics	Strengths	Weaknesses	Application context
Co-creation dynamics 1	Ensures societally and policy relevant research and funding	Discoveries by science may be buried under policy and societal needs	When the problem is well researched, and the uncertainties are low and associated interests known
Co-creation dynamics 2	Takes concerns of local communities as a starting point to be supported by scientists	May neglect policy needs, and researchers may be labeled as issue advocates undermining their 'objectivity'	When the local communities are in a marginal position and there is need to bring in subaltern voices into the policy discussions
Co-creation dynamics 3	Allows scientific discoveries to guide policy and research funding	May lead to overtly optimistic reliance on science, and lead to technocratic policymaking	When there are a lot of uncertainties even in understanding what the problem and its implications are
Co-creation dynamics 4	Integrates societal groups, policymakers, funders and scientists from the beginning to define the needs to be addressed	It is often difficult to get everybody around the same table, and if consensus is needed it may stall the process	Contested situation with many contradictory interests and values.
Co-creation dynamics 5	Allows funders close to communities to identify concerns based on inside experiences, but still 'from the outside'	May reveal insights from local communities that are negative	When the addressed community has sensitive issues, which they are reluctant to communicate

Conclusion

In the present paper, we have examined the trends and relations between demand, funding and supply (DFS) around reindeer management in Finland. We identified five co-creation dynamics on divergent, but equally legitimate ways to connect the DFS. Therefore, these co-creation dynamics can inform future efforts to enhance the connectivity between the DFS in relation to reindeer management, but also beyond. The added value of these co-creation dynamics is to show that the co-creation of knowledge to match the DFS may be done in diverse ways that fit the different types of objectives and situations. The complexity of research funding, knowledge supply and societal demand even around a single livelihood necessitates diverse strategies to match the DFS in varying situations. The present paper offers new insights to meet this challenge.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This paper was supported by Nordforsk under two of its Nordic Centres of Excellence: Resource Extraction and Sustainable Arctic Communities (REXSAC: project number 76938) and Reindeer husbandry in Globalizing North – resilience adaptations and pathways for actions (ReiGN: project number 76915) as well as by the University of Oulu under the Transformation and Social Innovation for Sustainable Arctic Communities (TransArct) project.

ORCID

Simo Sarkki http://orcid.org/0000-0002-7790-0600
Sirpa Rasmus http://orcid.org/000-0001-8106-0299

Mia Landauer http://orcid.org/0000-0002-7153-8495
Élise Lépy http://orcid.org/0000-0001-9985-5049
Hannu I. Heikkinen http://orcid.org/0000-0001-7765-3825

References

Akujärvi, A., Hallikainen, V., Hyppönen, M., Mattila, E., Mikkola, K., & Rautio, P. (2014). Effects of reindeer grazing and forestry on ground lichens in Finnish Lapland. *Silva Fennica*, *48*(3), 1153. https://doi.org/10.14214/sf.1153

Alexander, C., Bynum, N., Johnson, E., King, U., Mustonen, T., Neofotis, P., Oettlé, N., Rosenzweig, C., Sakakibara, C., Shadrin, V., Vicarelli, M., Waterhouse, J., & Weeks, B. (2011). Linking indigenous and scientific knowledge of climate change. *BioScience*, *61*(6), 477–484. https://doi.org/10.1525/bio.2011.61.6.10

Armitage, D., Berkes, F., Dale, A., Kocho-Schellenberg, E., & Patton, E. (2011). Co-management and the co-production of knowledge: Learning to adapt in Canada's Arctic. *Global Environmental Change*, *21*(3), 995–1004. https://doi.org/10.1016/j.gloenvcha.2011.04.006

Ballard, H. L., & Belsky, J. M. (2010). Participatory action research and environmental learning: Implications for resilient forests and communities. *Environmental Education Research*, *16*(5–6), 611–627. https://doi.org/10.1080/13504622.2010.505440

Berg, M., & Lidskog, R. (2018). Deliberative democracy meets democratised science: A deliberative systems approach to global environmental governance. *Environmental Politics*, *27*(1), 1–20. https://doi.org/10.1080/09644016.2017.1371919

Brown, G., Kangas, K., Juutinen, A., & Tolvanen, A. (2017). Identifying environmental and natural resource management conflict potential using participatory mapping. *Society & Natural Resources*, *30*(12), 1458–1475. https://doi.org/10.1080/08941920.2017.1347977

CAFF. (2015). *Actions for Arctic Biodiversity, 2013-2021: Implementing the recommendations of the Arctic Biodiversity Assessment*. Conservation of Arctic Flora and Fauna, Akureyri, Iceland. ISBN: 978-9935-431-41-7.

Challies, E., Newig, J., Kochskämper, E., & Jager, N. W. (2017). Governance change and governance learning in Europe: Stakeholder participation in environmental policy implementation. *Policy and Society*, *36*(2), 288–303. https://doi.org/10.1080/14494035.2017.1320854

Dale, A., & Armitage, D. (2011). Marine mammal co-management in Canada's Arctic: Knowledge co-production for learning and adaptive capacity. *Marine Policy*, *35*(4), 440–449. https://doi.org/10.1016/j.marpol.2010.10.019

Diver, S. (2017). Negotiating indigenous knowledge at the science-policy interface: Insights from the xáxli'p community Forest. *Environmental Science & Policy*, *73*, 1–11. https://doi.org/10.1016/j.envsci.2017.03.001

Editorial Nature. (2018). The best research is produced when researchers and communities work together. *Nature*, *562*(2018), 7. https://doi.org/10.1038/d41586-018-06855-7

Fitzpatrick, E. F., Martiniuk, A. L., D'Antoine, H., Oscar, J., Carter, M., & Elliott, E. J. (2016). Seeking consent for research with indigenous communities: A systematic review. *BMC Medical Ethics*, *17*(1), 65. https://doi.org/10.1186/s12910-016-0139-8

Forbes, B. C., Bölter, M., Müller-Wille, L., Hukkinen, J., Müller, F., Gunslay, N., & Konstantinov, Y. (Eds.). (2006). Reindeer management in Northernmost Europe. In *Ecological studies* (Vol. 184). Springer-Verlag.

Ford, J. D., Stephenson, E., Cunsolo Willox, A., Edge, V., Farahbakhsh, K., Furgal, C., Harper S., Chatwood S., Mauro I., Pearce T., Austin S., Bunce A., Bussalleu A., Diaz J., Finner K., Gordon A., Huet C., Kitching K., Lardeau M. P., McDowell G., McDonald E., Nakoneczny L., & Sherman, M. (2016). Community-based adaptation research in the Canadian Arctic. *Wiley Interdisciplinary Reviews. Climate Change*, *7*(2), 175–191. https://doi.org/10.1002/wcc.376

Funtowicz, S. O., & Ravetz, J. (1993). Science for the postnormal age. *Futures*, *25*(7), 739–755. https://doi.org/10.1016/0016-3287(93)90022-L

Head, B. W. (2019). Forty years of wicked problems literature: Forging closer links to policy studies. *Policy and Society*, *38*, 180–197. https://doi.org/10.1080/14494035.2018.1488797.

Heikkinen, H. I., Sarkki, S., & Nuttall, M. (2012). Users or producers of ecosystem services? A co-creation dynamics exercise for integrating conservation and reindeer management in northeast Finland. *Pastoralism: Research, Policy and Practice*, *2*(1), 11. https://doi.org/10.1186/2041-7136-2-11

Hisschemöller, M., Hoppe, R., Groenewegen, P., & Midden, C. (2001). 'Knowledge use and political choice in Dutch environmental policy: A problem structuring perspective on real life experiments in extended peer review'. In M. Hisschemö ller, W. Dunn, R. Hoppe, & J. Ravetz (Eds.), *Knowledge, power and participation in environmental policy analysis* (pp. 437–470). Transactions Publishers.

Hoppe, R. (1999). Policy analysis, science and politics: From 'speaking truth to power' to 'making sense together'. *Science and Public Policy*, *26*(3), 201–210. https://doi.org/10.3152/147154399781782482

Hukkinen, J., Jääskö, O., Laakso, A., Müller-Wille, L., Nevalainen, S., Raitio, K. 2003a. *Poronhoitokulttuurin arvo Suomessa – Haasteet hallinnolle, ohjaukselle ja valvonnalle*. Teknillisen korkeakoulun ympäristösuojelun laboratorion julkaisu. Technology, society, environment 1/2003. Espoo 2003. Publisher Helsinki University of Technology.

Hukkinen, J., Müller-Wille, L., Aikio, P., Heikkinen, H. I., Jääskö, O., Laakso, A., Magga, H., Nevalainen, S., Pokuri, O., Raitio, K., & West, N. (2006). Development of participatory institutions for reindeer management in Finland: A diagnosis of deliberation, knowledge integration and sustainability. In B. C. Forbes, M. Bölter, L. Müller-Wille, J. Hukkinen, F. Müller, N. Gunslay, & Y. Konstantinov (Eds.), *Reindeer management in Northernmost Europe. Ecological studies* (Vol. 184, pp. 47–71). Springer-Verlag.

Hukkinen, J., Müller-Wille, L., & Heikkinen, H. 2003b. *Development of participatory institutions for reindeer management in northern Finland: preliminary synthesis and report*. Teknillisen korkeakoulun ympäristösuojelun laboratorion julkaisu. Technology, society, environment 6/2003. Espoo 2003. Publisher Helsinki University of Technology.

Iivari, P. (2017). Land-use conflict and perspectives for its Resolution – wildlife watching meets reindeer management in the European North. In I. B. de Lime & R. J. Green (Eds.), *Wildlife tourism, environmental learning and Ethical Encounters. Ecological and conservation aspects* (pp. 235–246). Springer, International Publishing AG.

IPBES. (2016). The methodological assessment report on co-creation dynamicss and models of biodiversity and ecosystem services. In S. Ferrier, K. N. Ninan, P. Leadley, R. Alkemade, L. A. Acosta, H. R. Akçakaya, L. Brotons, W. W. L. Cheung, V. Christensen, K. A. Harhash, J. Kabubo-Mariara, C. Lundquist, M. Obersteiner, H. M. Pereira, G. Peterson, R. Pichs-Madruga, N. Ravindranath, C. Rondinini, & B. A. Wintle (Eds.), *Secretariat of the Intergovernmental science-policy Platform on biodiversity and ecosystem services* (p. 348).

Kassam, K.-A. (2009). *Biocultural diversity and indigenous ways of knowing: Human ecology in the Arctic*. University of Calgary Press.

Kemppainen, J., Kettunen, J., & Ja Nieminen, M. (2003). Porotalouden taloustutkimusohjelma 2003–2007. *Kala- ja Riistaraportteja*, *281*.

Koillismaan Uutiset. (2018). *Karhuvahinkoja eniten Oivangissa*. http://www.koillismaanuutiset.fi/karhuvahinkoja-eniten-oivangissa/.

Komu, T. (2019). Manoeuvring conflict: Industrial land use projects and 'refusal to resist' among reindeer herding communities in northern Fennoscandia. *Ethnos*. https://doi.org/10.1080/00141844.2019.1580304

Kumpula, J. (2003). *Metsänkäsittelyn vaikutukset porolaitumiin. Riista-ja kalat- alouden tutkimuslaitos*, Kala-ja riistaraportteja no. 286.

Landauer, M., & Komendantova, N. (2018). Participatory environmental governance of infrastructure projects affecting reindeer husbandry in the Arctic. *Journal of Environmental Management*, *223*, 385–395. https://doi.org/10.1016/j.jenvman.2018.06.049

Landauer, M., Rasmus, S., & Forbes, B. (2018, September 17–20). *Critical tipping points of reindeer management in Finland*. In Cool forests at risk. The critical role of boreal and mountain ecosystems for people, bioeconomy, and climate, IBFRA Proceedings, IIASA, Laxenburg, Austria. https://ibfra18.org/wp-content/uploads/sites/2/2018/10/IBFRA18-Book-of-abstracts.pdf.

Lépy, É, Heikkinen, H. I., Komu, T., & Sarkki, S. (2018). Participatory meaning-making of environmental and cultural changes in reindeer management in the northernmost border area of

Sweden and Finland. *International Journal of Business and Globalisation*, *20*(2), 203–221. https://doi.org/10.1504/IJBG.2018.089868

Malinauskaite, L., Cook, D., Davíðsdóttir, B., Ögmundardóttir, H., & Roman, J. (2019). Ecosystem services in the Arctic: A thematic review. *Ecosystem Services*, *36*, 100898. https://doi.org/10.1016/j.ecoser.2019.100898

Marshall, F., Dolley, J., & Priya, R. (2018). Transdisciplinary research as transformative space making for sustainability: Enhancing propoor transformative agency in periurban contexts. *Ecology and Society*, *23*(3), 8. https://doi.org/10.5751/ES-10249-230308

Mauser, W., Klepper, G., Rice, M., Schmalzbauer, B. S., Hackmann, H., Leemans, R., & Moore, H. (2013). Transdisciplinary global change research: The co-creation of knowledge for sustainability. *Current Opinion in Environmental Sustainability*, *5*(3-4), 420–431. https://doi.org/10.1016/j.cosust.2013.07.001

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. https://doi.org/10.1016/j.envsci.2006.10.004

Ministry of Agriculture and Forestry. (1999). Porolukujen tarkistamistyöryhmän esitys suurimmiksi sallituiksi eloporoluvuiksi. *Työryhmämuistio MMM*, *1999*, 20.

Nilsson, A. E., Bay-Larsen, I., Carlsen, H., van Oort, B., Bjørkan, M., Jylhä, K., Klyuchnikova E., Masloboev V., & van der Watt, L.-M. (2017). Towards extended shared socioeconomic pathways: A combined participatory bottom-up and top-down methodology with results from the Barents region. *Global Environmental Change*, *45*, 124–132. https://doi.org/10.1016/j.gloenvcha.2017.06.001

Nilsson, A. E., Carson, M., Cost, D. S., Forbes, B. C., Haavisto, R., Karlsdottir, A., Nymand Larsen, J., Paasche, Ø, Sarkki, S., Vammen Larsen, S., & Pelyasov, A. (2019). Towards improved participatory scenario methodologies in the Arctic. *Polar Geography*. https://doi.org/10.1080/1088937X.2019.1648583

Openjuru, G. L., Jaitli, N., Tandon, R., & Hall, B. (2015). Despite knowledge democracy and community-based participatory action research: Voices from the global south and excluded north still missing. *Action Research*, *13*(3), 219–229. https://doi.org/10.1177/1476750315583316

PAME. (2019). Meaningful *engagement of indigenous people and local communities in marine activities*. Part II, findings for policy makers. PAME (Protection of Arctic Marine Environment). Arctic Council.

Peltonen-Sainio, P., Sorvali, J., Müller, M., Huitu, O., Neuvonen, S., Nummelin, T., Rummukainen, A., Hynynen, J., Sievänen, R., Helle, P., Rask, M., Vehanen, T., & Kumpula, J. (2017). *Sopeutumisen tila 2017: Ilmastokestävyyden tarkastelut maa- ja metsätalousministeriön hallinnonalalla*. Luonnonvara- ja biotalouden tutkimus 18/2017. 87pp.

Richardson, L., & Perry, B. (2018). Craft metrics to value co-production. *Nature*, *562*(2018), 32–33. https://doi.org/10.1038/d41586-018-06860-w

Riseth, JÅ, Tømmervik, H., Helander-Renvall, E., Labba, N., Johansson, C., Malnes, E., Bjerke, J. W., Jonsson, C., Pohjola, V., Sarri, L.-E., Schanche, A., & Callaghan, T. V. (2010). Sámi traditional ecological knowledge as a guide to science. Snow, Ice and reindeer pasture Facing climate change. *Polar Record*, *47*(3), 202–217. doi:10.1017/S0032247410000434.

Ruuhela, R. (toim.). (2011). *Miten väistämättömään ilmastonmuutokseen voidaan sopeutua? Yhteenveto suomalaisesta sopeutumistutkimuksesta eri toimialoilla*. Maa- ja metsätalousministeriön julkaisuja 6/2011.

Sarewitz, D., & Pielke, R. A. (2007). The neglected heart of science policy: Reconciling supply of and demand for science. *Environmental Science & Policy*, *10*(1), 5–16. https://doi.org/10.1016/j.envsci.2006.10.001

Sarkki, S., Komu, T., Heikkinen, H. I., Acosta García, N., Lépy, É, & Herva, V.-P. (2016). Applying a synthetic approach to the resilience of Finnish reindeer management as a changing livelihood. *Ecology and Sociology*, *21*(4), 14. https://doi.org/10.5751/ES-08819-210414

Stedman, A., & Green, K. P. (2018). *Survey of mining companies 2017*. Fraser Institute Annual.

Stringer, L. C., Dougill, A. J., Fraser, E., Hubacek, K., Prell, C., & Reed, M. S. (2006). Unpacking "participation" in the adaptive management of social–ecological systems: A critical review. *Ecology and Society*, *11*(2), 39. https://doi.org/10.5751/ES-01896-110239

Tennberg, M., Emelyanova, A., Eriksen, H., Haapala, J., Hannukkala, A., Jaakkola, J. J. K., Jouttijärvi, T., Jylhä, K. M., Kauppi, S., Kietäväinen, A. T., Korhonen, H., Korhonen, M., Luomaranta, A., Magga, R., Mettiäinen, I., Näkkäläjärvi, K., Pilli-Sihvola, K., Rautio, A., Rautio, P., … Vihma, T. (Eds.). (2017). *The Barents area changes – How will Finland adapt?* [Barentsin alue muuttuu – miten Suomi sopeutuu?]. Prime minister's office - Adaptation Actions for a Changing Arctic (AACA), Publications of the Govenrment´s analysis, assessment and research activities 31/2017, Helsinki, Finland.

Turunen, M., Rasmus, S., Bavay, M., Ruosteenoja, K., & ja Heiskanen, J. (2016). Coping with increasingly difficult weather and snow conditions: Reindeer herders' views on climate change impacts and coping strategies. *Climate Risk Management*, *11*(2016), 15–36. https://doi.org/10.1016/j.crm.2016.01.002

Turunen, M., Rasmus, S., Norberg, H., Kumpula, J., Kojola, I., & Ja Ollila, T. (2017). Porot ja pedot – kuinka poronhoidon sopeutuminen petoihin on muuttunut 90 vuodessa? *Suomen Riista*, *63*, 19–42.

van den Hove, S. (2007). A rationale for science–policy interfaces. *Futures*, *39*(7), 807–826. https://doi.org/10.1016/j.futures.2006.12.004

Vuojala-Magga, T., Turunen, M., Ryyppö, T., & Tennberg, M. (2011). Resonance strategies of Sami reindeer management during climatically extreme years in northernmost Finland in 1970-2007. *Arctic*, *64*(2), 227–241. https://doi.org/10.14430/arctic4102

Young, J., Waylen, K., Sarkki, S., Albon, S., Bainbridge, I., Balian, E., Davidson, J., Edwards, D., Fairley, R., Margerison, G., McCracken, D., Owen, R., Quine, C. P., Stewart-Roper, C., Thompson, D., Tinch, R., van den Hove, S., & Watt, A. (2014). Improving the science-policy dialogue to meet the challenges of biodiversity conservation: Having a conversation rather than talking at one-another. *Biodiversity & Conservation*, *23*(2), 387–404. doi:10.1007/s10531-013-0607-0