Canadian Science Publishing

REVIEW

From participatory engagement to co-production: modelling climate-sensitive processes in the Arctic

Katy Davis, James D. Ford, Claire Quinn, IHACC Research Team, and Sherilee L. Harper

Abstract: Participation is increasingly being used in the modelling of climate-sensitive systems to improve usability. Bottom-up, place-based approaches to modelling can challenge the dominantly positivist approaches used until recently. We examined how participation is reported within modelling research that uses participatory approaches, focusing on the Arctic. Our systematic scoping review identified 26 articles that used participatory approaches in modelling research to explore a climate-sensitive process in an Arctic setting and analysed the degree of participation at each stage of the process for each article. A diversity of topics, modelling approaches, and participant groups were identified. Most studies (71%) occurred in Arctic North America, and all studies engaged with non-Western knowledge types to some degree. Participation was most commonly reported at the model generation and participant identification stages, and least commonly reported in the choice of modelling type. Participatory scores — based on the number and degree of participatory stages of a study — were higher where authors gave instrumental or transformative rationales for the use of participation, and among studies that described prioritising non-Western knowledge types. Detailed reporting of participatory processes was frequently absent, suggesting a need for clearer discussions of these issues in the descriptions of the process.

Key words: Arctic, climate change, participatory modelling, participation, community-based participatory research, non-Western knowledge systems.

Résumé : La participation est de plus en plus utilisée dans la modélisation des systèmes sensibles au climat afin d'en améliorer la convivialité. Les approches de modélisation ascendantes, basées sur le lieu, peuvent remettre en question les approches positivistes dominantes utilisées jusqu'à récemment. Les auteurs ont examiné comment la participation est rapportée dans la recherche en modélisation qui utilise des approches participatives, en se concentrant sur l'Arctique. Leur synthèse systématique a identifié 26 articles qui ont utilisé des approches participatives dans la recherche en modélisation pour explorer un processus sensible au climat dans un cadre arctique et analysé le degré de participation à chaque étape du processus pour chaque article. Une diversité de sujets, d'approches de modélisation et de groupes de participants a été identifiée. La plupart des études (71%) se sont déroulées dans l'Arctique nord-américain, et toutes les études faisaient appel à des

Received 27 August 2020. Accepted 3 March 2021.

K. Davis. Priestley International Centre for Climate, University of Leeds, Leeds LS2 9JT, UK.
J.D. Ford. Priestley International Centre for Climate, University of Leeds, Leeds LS2 9JT, UK; Indigenous Health Adaptation to Climate Change Research Team, University of Alberta, Edmonton, AB T6G 2R3, Canada.
C. Quinn. School of Earth & Environment, University of Leeds, Leeds LS2 9JT, UK.
IHACC Research Team. Indigenous Health Adaptation to Climate Change Research Team, University of Alberta, Edmonton, AB T6G 2R3, Canada.
S.L. Harper. School of Public Health, University of Alberta, Edmonton, AB T6G 2R3, Canada.
Corresponding author: Katy Davis (e-mail: eekda@leeds.ac.uk).

types de connaissances non occidentales dans une certaine mesure. La participation était le plus souvent signalée aux étapes de génération du modèle et d'identification des participants, et le moins souvent au moment du choix du type de modélisation. Les scores de participation — basés sur le nombre et le degré d'étapes participatives d'une étude — étaient plus élevés lorsque les auteurs donnaient des justifications instrumentales ou transformatives à l'utilisation de la participation, et parmi les études qui décrivaient la priorité accordée aux types de connaissances non occidentales. La description détaillée des processus participatifs étaient souvent absente, ce qui suggère un besoin de discussions plus claires sur ces questions dans les descriptions du processus. [Traduit par la Rédaction]

Mots-clés : Arctique, changements climatiques, modélisation participative, participation, recherche participative communautaire, systèmes de connaissances non occidentaux.

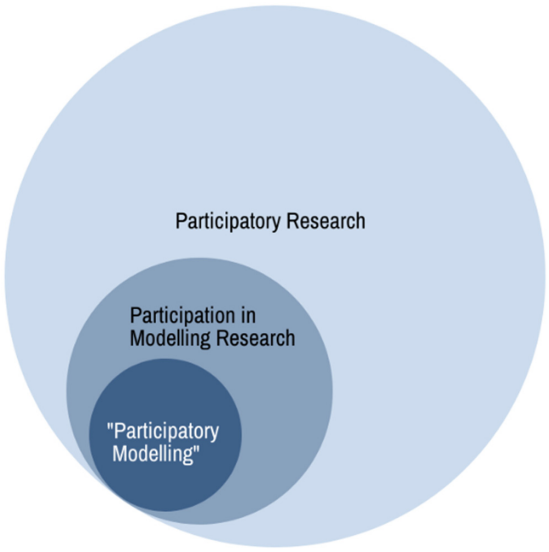
Introduction

The interaction of climate-related hazards with multiple socioeconomic inequities poses a profound challenge to society at multiple scales (Gaillard 2010; Tschakert 2012; Watts et al. 2019). The experience of climate change will differ among groups in diverse and unequal ways, the root causes of which are embedded in development issues (Hewitt 1983; Kelman et al. 2016). Attempts at understanding and adapting to climate change in the context of these multiple hazard drivers will need to be sensitive to complexity and context, integrate diverse local perspectives, and involve deliberate and transformative change to existing power structures underlying these inequities (O'Brien 2012; Tschakert et al. 2013; van Bruggen et al. 2019; Ford et al. 2020).

It is increasingly understood that the knowledge required for this must include diverse perspectives and modes of production (Dilling and Lemos 2011). In climate research, positivist forms of knowledge have previously been prioritised at the expense of experiential knowledge, which can result in the creation of knowledge both detached from its local context and embedded in Western scientific epistemologies that are shaped by histories of colonisation (Conway et al. 2019). Engaging citizens and rightsholders in research and decision-making is one way to challenge these in-grained hierarchies of knowledge and their problematic manifestations in the creation of knowledge relevant to climate change (Sawatzky et al. 2018; Kipp et al. 2019; van Bavel et al. 2020). Participatory processes, including collaborative, co-productive, and cross-cultural methods for knowledge production, can provide more place-based and contextual nuance to previously positivist climate and environmental modelling processes (Lynam et al. 2007; Nakashima et al. 2012; Alshaikh 2013; Crate et al. 2019; Gotts et al. 2019; Mach et al. 2020).

The term "model" refers to any abstract representation of reality (van den Belt 2004). For the purposes of this paper, however, in which we are examining participation in the modelling of climate-sensitive processes, we are focusing on models used or created as part of a participatory research process, including conceptual models, fuzzy cognitive maps, Bayesian belief networks, and statistical modelling (Voinov and Bousquet 2010). Within this field, various structured approaches have evolved to guide those seeking to engage participants in natural resource management, often brought together under the name of "Participatory Modelling" (Voinov et al. 2016). These tend to refer to a number of flexible tools or approaches including Group Model Building and Mediated Modelling (Andersen and Richardson 1997; van den Belt 2004) that involve a number of iterative and adaptive stages including scoping, planning, model choice, model building, simulation, evaluation, and monitoring (Videira et al. 2010; Dreyer and Renn 2011; Duboz et al. 2018). The fundamental goals of these approaches are to foster social learning, shared commitment and buy-in, successful policy implementation, and conflict resolution for decision-making

Fig. 1. Illustration of the scope of this review.



(Voinov and Bousquet 2010), and frameworks have been developed for evaluation of these processes (Jones et al. 2009).

Although we recognise the value of these structured processes, particularly for problems that require collaborative decision-making, we see these "Participatory Modelling" approaches as a subset of a wider body of literature that engages participants and stakeholders in some form of modelling process as part of a participatory analysis. This more diverse body of research has its roots in participatory action research, and although it may not use the specific language of "Participatory Modelling" it encompasses research that uses modelling processes for knowledge co-production more broadly and is not limited to decision-making (Cooke and Kothari 2001; Leal 2007; Cornwall et al. 2011). We refer descriptively to this as "participation in modelling research." An example would be modelling as a research collaboration between academic researchers and an Indigenous organisation, in which the meeting of two knowledge types (scientific and Indigenous) is key to the process (Ford et al. 2019). We therefore distinguish between this broader conceptualisation of "participation in modelling research," and the more formal approaches referred to by some as "Participatory Modelling" (capitalised to demonstrate the difference), which is a sub-group of the former, as illustrated in Fig. 1 (Voinov et al. 2016).

Participation in modelling research in the Arctic

The Arctic is undergoing rapid environmental changes, including significant reductions in sea ice extent and thickness, permafrost thawing, changes to species distributions, and air temperature increases three times the global average over the past 30 years (Nickels et al. 2005; Hoegh-Guldberg et al. 2018; Meredith et al. 2019). This is taking place in the context of ongoing social, economic, and political processes including colonisation, marginalisation, histories of forced relocations, sedentarisation, residential schooling, and cultural assimilation (Furgal and Seguin 2006; AMAP 2017, 2018). The Arctic is, thus, understandably the site of a significant amount of climate modelling research (Hua et al. 2012; Ford et al. 2014).

There is a diversity of Arctic stakeholders, rightsholders, and knowledge types that can and must contribute to the building of knowledge and understanding around climate-sensitive processes (Duyck 2011; Ernst and van Riemsdijk 2013; Flynn et al. 2018). Arctic residents possess a multiplicity of experiential and place-based knowledge types that are not grounded in Western scientific paradigms, including Indigenous Knowledge (IK), locally-held or community-based knowledge (LK), land-based knowledge, and practitioner knowledge (Cunsolo Willox et al. 2012; Tengö et al. 2014; Crate et al. 2019). We refer broadly to these as non-Western knowledge types. IK, for example, is grounded in long histories of a people's interaction with their surroundings, and flexibility to drivers such as climate change is present in relationships with the land (Wenzel 2009; Ford et al. 2015; Abram et al. 2019). Participatory approaches to modelling complex, climate-sensitive processes are, thus, highly applicable to an Arctic context.

Increased calls for engagement of IK and LK in climate research cites both the value of non-Western knowledge types for broadening and enriching perspectives on complex climate-related problems, and the importance of ethically engaging Indigenous Peoples and community groups as rightsholders in decision-making (Nakashima et al. 2012; Maynard 2014; Meredith et al. 2019). This may include research in which only academic researchers and Indigenous communities or researchers are engaged, and although there may not be more than these two stakeholder groups, there are still conflicts of interest in many of these studies, that exist as conflicts of perspectives between scientific/Western knowledge and Indigenous Knowledge, such that the academic researchers are a stakeholder group also participating in the knowledge creation (Barber and Jackson 2015).

However, shifts towards participatory methodologies in the Arctic have been limited, fragmented, and at times tokenistic (Ford et al. 2016; Jones et al. 2018; Carter et al. 2019), and although Indigenous Peoples are increasingly involved in research, the degree to which they are involved varies hugely (Brunet et al. 2014; Flynn and Ford 2020; Mosurska and Ford 2020). There are concerns that "participation" has become a buzzword in research and policy discourse more broadly, that lacks true attempts to engage with transformative processes (Leal 2007; Castleden et al. 2012), and can in fact lead to further marginalisation and reinforcement of existing power relations (Cornwall and Jewkes 1995; Guta et al. 2013; Janes 2016; Berrang-Ford et al. 2018). It is, therefore, essential that attempts at participation do not end up taking a superficial or "extractive" approach to engaging non-Western knowledge types, in which IK is compartmentalised, distorted, and decontextualised (McDowell et al. 2016; David-Chavez and Gavin 2018; Dentzau 2019).

It is important to take a critical approach to any effort at participatory research, to understand the goals and achievements, and this includes participatory research involving modelling processes (Arnstein 1969; Cooke and Kothari 2001; David-Chavez and Gavin 2018). Examining the nature and structure of participation power dynamics can reveal the degree to which participants had autonomy over the process (White 1996) or the "depth" of participation (Király and Miskolczi 2019). What's more, some have argued that we need to move away from taking a "tool-kit" approach, which focuses on appropriate tools for the job, and towards approaches that re-centre the process of participation itself, and the associated empowerment, equity, trust, and learning (Reed 2008; Ford et al. 2016). Attempts to characterise differing degrees of participatory research include Arnstein's (1969) "Ladder of Participation", Pretty's (1995) classification based on the purpose of the process, and Lynam et al.'s (2007) summary of "extractive use, co-learning, and co-management". Some further suggest breaking studies down into stages to look at the role of participation in each (Jonsson et al. 2007; David-Chavez and Gavin 2018).

Objectives

Given the importance of participation in climate change modelling and research for achieving transformative change, we set out to review how it is being implemented in the Arctic. We are not just interested in studies that carry out the idealised, participatory-intensive process encouraged in "Participatory Modelling" studies, but also in the broader body of studies that are seeking to use participation in research, regardless of the extent to which they are achieving the higher degrees of participation or the ideals of a structured "Participatory Modelling" process. In doing so we aim to capture a wider diversity of approaches to participation in modelling research and their lessons for processes of participation in an Arctic context and related to modelling research. We look at the extent to which key elements of participation have been employed and reported within published research applying participation to a modelling process, drawing from existing frameworks for analysing the degree of participation in research. We specifically focus on the Arctic, as a region undergoing significant climatic change (Nickels et al. 2005; Hoegh-Guldberg et al. 2018; Meredith et al. 2019), and due to the current drive among researchers and funding bodies for enhanced participation in Arctic research (Nakashima et al. 2012; Maynard 2014; Meredith et al. 2019).

We set out to (1) to identify and characterise participatory climate modelling processes used in climate and environmental change research in the Arctic, and (2) assess the structure and degree of reported participation in these modelling processes. We do not examine the "success" of the project in terms of the outcome, due to the diversity of contexts and desired outcomes among modelling processes. Rather, we focus on the extent to which the conception, design, management, process, and use of outcomes are participatory in nature, using a set of criteria to assess the degree of participation. These criteria are described in the next section and were compiled through an iterative and emergent process, based on a number of frameworks and theories that identify the key components of effective, ethical, and sustainable participatory engagement.

Methods

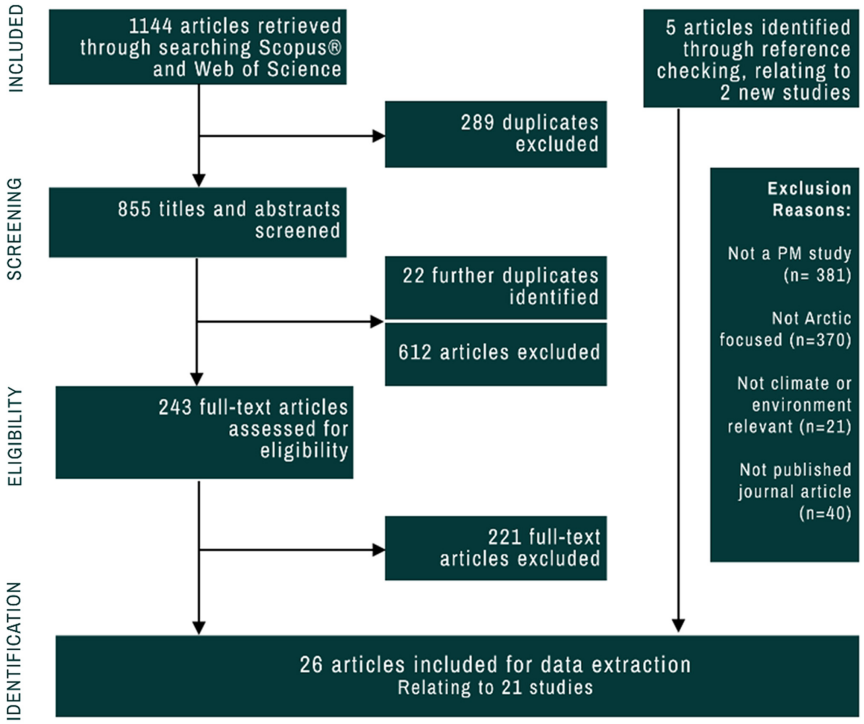
Systematic review methodology

We employed a systematic scoping review of the published literature to identify and evaluate how participation in modelling of climate-sensitive processes is being reported in research in the Arctic, and to what extent these reported processes are participatory. Countries with Arctic boundaries include the United States (Alaska); northern Canada; Greenland; the Faroe Islands; Iceland; and the northern parts of Norway, Sweden, Finland, and Russia (Einarsson et al. 2004). The search is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses' reporting guidelines for scoping reviews (Tricco et al. 2018, Fig. 2).

Identifying modelling studies

We intentionally kept our definition of participation in modelling research broad to include the diversity of modelling approaches that we have described, including qualitative and conceptual models, and enabling us to capture studies that may use participation with a modelling process, but that do not necessarily explicitly refer to it as "Participatory Modelling". We also considered a range of methods and tools being applied to the process; we included studies using participatory mapping, for example, as the use of this tool can enable participants to visualise and model their problems spatially (Voinov et al. 2018). Nuance was, thus, required in identifying studies that met our criteria.

Fig. 2. Flow chart illustrating the number of articles identified through initial searches, then screened for relevance and eligibility. PM, Participatory Modelling.



Search procedures

A search string was developed to locate published articles (Table 1) and was designed to be broad to capture all potentially relevant articles discussing modelling processes engaging with participants, which may or may not have explicitly specified "Participatory Modelling". Search terms consisted of three conceptual parts: the climate or weather concept, the participation in modelling concept, and the Arctic concept, combined with the operator "AND". Regarding climate and weather, terms referred directly to the climate or to climate-sensitive socio-environmental systems. These terms were identified based on the Intergovernmental Panel on Climate Change (Masson-Delmotte et al. 2018) and the 2015 Lancet Commission on Climate Change and Health (Watts et al. 2015). The literature was also searched for common ways the climate or environment was discussed in the context of modelling with stakeholders. Thus, the participation in modelling search terms included commonly used keywords, terms, and phrases that describe participation, involvement, and stakeholder knowledge in modelling processes.

The search string was used to perform a title, key word and abstract search in Scopus and Web of Science CORE Collection, providing a robust search of the literature. The search was limited to academic published literature and we applied no language or date restrictions. The search was conducted in June 2019 and updated in April 2020. Search results were exported to Mendeley reference management software and duplicate articles were eliminated. Citations were then uploaded from Mendeley into Rayyan QCRI (Ouzzani et al. 2016) to facilitate relevance screening.

Table 1. Search strings used in Scopus and Web of Science.

Component	Search terms in Scopus	Search terms in Web of Science
Climate/environment context	**TITLE-ABS-KEY** (climat* OR weather OR "Natural resource" OR "Global warming" OR "Water management" OR "Land management" OR "Land-use" OR "Coastal management" OR "Forest management" OR "Trail use" OR "Sea ice" OR "Sustainability assessment" OR "Rural appraisal" OR watershed OR "Biodiversity management" OR "Ecological planning" OR dryland OR precipitation OR rainfall OR drought OR "temperature" OR flood OR "Sea level rise" OR "Ecological systems" OR "Coastal areas" OR "Delta management" OR "Ice sheet" OR "Saltwater intrusion" OR "Biodiversity loss" OR "species loss" OR extinction OR "Forest fires" OR "Invasive species" OR "ocean acidity" OR "ocean oxygen" OR "Marine Biodiversity" OR fisheries OR ecosystem OR "Coastal resources" OR aquaculture OR heatwave OR "Water resource" OR "water stress" OR "Air pollution" OR agricultur* OR storm* OR hurricane OR cyclone OR blizzard OR disaster OR wildfire OR "environmental model*" OR wetland OR monsoon)	**TS =** (climat* OR weather OR "Natural resource" OR "Global warming" OR "Water management" OR "Land management" OR "Land-use" OR "Coastal management" OR "Forest management" OR "Trail use" OR "Sea ice" OR "Sustainability assessment" OR "Rural appraisal" OR watershed OR "Biodiversity management" OR "Ecological planning" OR dryland OR precipitation OR rainfall OR drought OR "temperature" OR flood OR "Sea level rise" OR "Ecological systems" OR "Coastal areas" OR "Delta management" OR "Ice sheet" OR "Saltwater intrusion" OR "Biodiversity loss" OR "species loss" OR extinction OR "Forest fires" OR "Invasive species" OR "ocean acidity" OR "ocean oxygen" OR "Marine Biodiversity" OR fisheries OR ecosystem OR "Coastal resources" OR aquaculture OR heatwave OR "Water resource" OR "water stress" OR "Air pollution" OR agricultur* OR storm* OR hurricane OR cyclone OR blizzard OR disaster OR wildfire OR "environmental model*" OR wetland OR monsoon)
	AND	**AND**
Participation in modelling research	**TITLE-ABS-KEY** ((participat* PRE/2 model*) OR "group model*" OR (companion PRE/2 model*) OR "participatory system dynamics" OR "community model*" OR (collaborative PRE/2 model*) OR (cooperative PRE/2 model*) OR "mediated model*" OR (model* AND ((indigenous W/1 knowledge) OR (traditional W/1 knowledge) OR (local W/1 knowledge) OR "community knowledge" OR "popular epidemiology" OR "participatory map*" OR "participatory GIS" OR "participatory workshop" OR "community workshop" OR agroecolog* OR ethnobotany OR ethnoecology OR ethnoclimat* OR "citizen science")))	**TS =** ((participat* NEAR/2 model*) OR "group model*" OR (companion NEAR/2 model*) OR "participatory system dynamics" OR "community model*" OR (collaborative NEAR/2 model*) OR (cooperative NEAR/2 model*) OR "mediated model*" OR (model* AND ((indigenous NEAR/1 knowledge) OR (traditional NEAR/1 knowledge) OR (local NEAR/1 knowledge) OR "community knowledge" OR "popular epidemiology" OR "participatory map*" OR "participatory GIS" OR "participatory workshop" OR "community workshop" OR agroecolog* OR ethnobotany OR ethnoecology OR ethnoclimat* OR "citizen science")))
	AND	**AND**
Arctic focus	**TITLE-ABS-KEY** (circumpolar OR polar OR nunavut* OR nunavik* OR nunatsiavut* OR inuvialuit* OR yukon* OR "northwestterritories" OR norw* OR greenland* OR alaska* OR russia* OR swed* OR finland OR iceland* OR arctic OR indigenous* OR "first nation*" OR inuit* OR saami OR nenets OR Khanty OR evenk OR chukchi OR aleut OR yupik OR iñupiat OR kalaallit OR "NorthernCanada" OR alberta OR "Newfoundland and Labrador" OR Ontario OR Quebec OR Svalbard OR "Nordic countr*")	**TS =** (circumpolar OR polar OR nunavut* OR nunavik* OR nunatsiavut* OR inuvialuit* OR yukon* OR "northwest territories" OR norw* OR greenland* OR alaska* OR russia* OR swed* OR finland OR iceland* OR arctic OR indigenous* OR "first nation*" OR inuit* OR saami OR nenets OR khanty OR evenk OR chukchi OR aleut OR yupik OR iñupiat OR kalaallit OR "Northern Canada" OR alberta OR "Newfoundland and Labrador" OR ontario OR quebec OR svalbard OR "Nordic countr*")

Table 2. Inclusion and exclusion criteria for first round of screening.

Inclusion criteria	Exclusion criteria
Studies that have implemented or evaluated modelling research that includes participants or describes a method or framework for doing so	Studies that do not discuss participatory modelling with stakeholders
The modelled process is climate- or weather-sensitive, or is likely to be influenced by climate in the future	The modelled process is not climate-sensitive
Process takes place entirely or partially within the Arctic (as per the definition of the Arctic defined by the Arctic Human Development Report (Arctic Human Development Report: Regional Processes and Global Linkages 2015))	Study takes place in a non-Arctic region
Peer-reviewed journal articles	Literature not subject to peer review

Relevance screening

Relevance screening took place in two stages, in which studies captured by the search terms, but not involving a modelling process, were screened out. All screening was carried out by KD. In stage 1, we screened the title and abstract of each citation using the inclusion and exclusion criteria outlined in Table 2. Potentially relevant articles proceeded to stage 2. In stage 2, we reviewed the full text of each article for relevance using the criteria outlined in Table 2. If an article did not meet all criteria at stage 2, it was excluded. To ensure that relevant articles had been captured, snowball sampling of references and citations of included articles was conducted. Where supplementary materials were available, these were also screened for information.

Data extraction and analysis

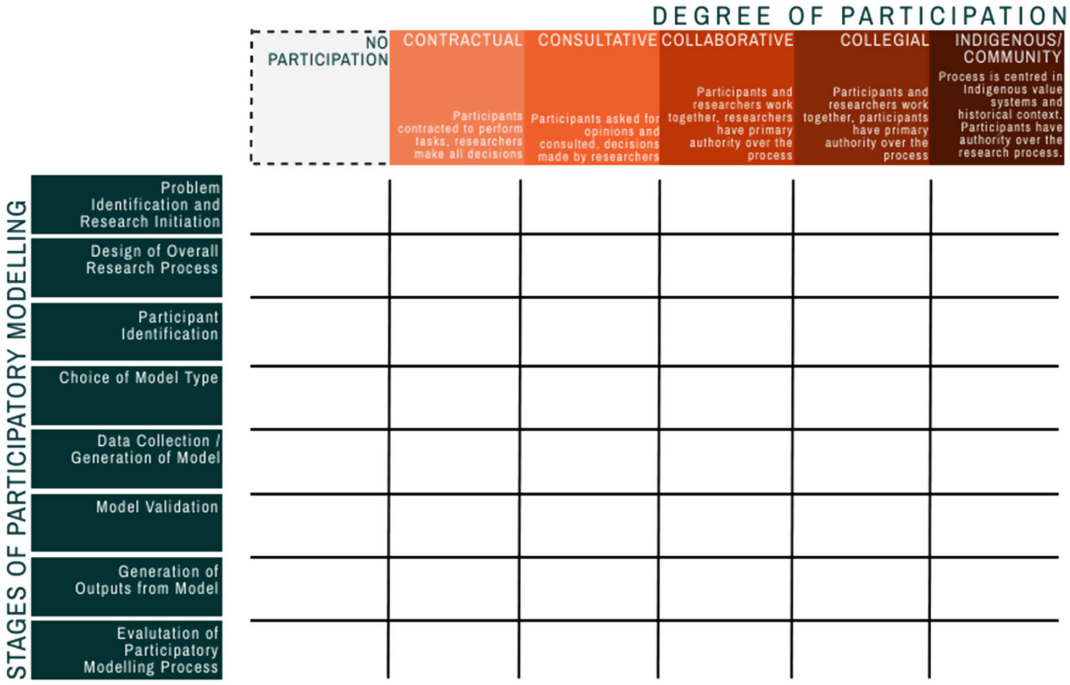
Descriptive analysis

Google Forms was used to create an extraction sheet to facilitate the systematic extraction of qualitative data. Information was extracted for analysis based on four themes: (1) study information including title, authorship, location, and discipline of the lead author; (2) focus of study, including the phenomenon modelled and the scale of the focus; (3) reported participatory structure, including participants, the reported reasons for use of participation and how participation was used in the research process; and (4) descriptive data on nature of engagement with non-Western knowledge types. These data were exported into Microsoft Excel for descriptive analysis.

Evaluation framework

We created an evaluation framework that enabled the analysis of participatory structure by appraising each study for the degree of participation reported at each stage of its modelling process. To do so, we adapted David-Chavez and Gavin's (2018) "Scale for assessing levels of Indigenous community participation based on who has authority over the research process". Their scale was selected due to their inclusion of the "Indigenous" degree of participation, in which community members have full control over the process. Although their review focused specifically on work with Indigenous Peoples, we were interested in research engaging participants who may not identify as Indigenous. Therefore, we added to their "Indigenous" degree of participation a "community" degree of participation, although we recognise that these are distinct categories. To examine participation reported at different study stages, we added to this framework a conceptualisation of the common stages of participation in modelling approaches, drawing in particular from literature on specific "Participatory Modelling" methods, such as Jonsson et al. (2007) and Voinov et al. (2016), as these have formalised some of the ideal structures of participation that can be used in modelling with participants more broadly. These stages are flexible and any one

Fig. 3. Matrix of degree of participation throughout the process of modelling with participants, adapted from David-Chavez and Gavin (2018), Jonsson et al. (2007) and Voinov et al. (2016).



process might use repetitive loops of these stages, or might break one of more of these steps down. Specifically, we adapted Jonsson et al.'s (2007) "six key dimensions of participatory modelling", and added aspects of Voinov et al.'s (2016) "components of the participatory modelling process", including validation and evaluation (Fig. 3) (Jakeman et al. 2006; Refsgaard et al. 2007; Voinov and Bousquet 2010; Voinov et al. 2016).

To quantify the structure and degree of reported participation for analysis, each study was scored based on the number of stages of the process that were participatory and the degree of participation in these stages. For each stage that was consultative, a study was awarded one point, each that was "collaborative" was awarded two points, each that was "collegial" was awarded three points, and each that took an "Indigenous" or "community" approach to participation was awarded four points. As the "contractual" degree does not describe a process where participants had autonomy over the research process, this was awarded 0 points.

It is important when deciding how to employ a participatory process that researchers consider their reasons for and intentions in engaging participants, as these are key to deciding which tools or processes are chosen for use (Voinov et al. 2016, 2018). To understand these objectives, we sought to identify for each study: (1) stated reasons why participation was used as an approach to modelling, and (2) stated reasons for the specific use of participation throughout the study. We further analysed each study's use of participation in terms of whether normative, instrumental, substantive, and (or) transformative functions were stated (see Table 3 for examples). These represent different rationales for the use of participation in deliberative processes based on the value of the process (Fiorino 1990). Normative rationales for participation are based on the concept that inclusion of citizens in decision-making processes is democratic and a successful end in and of itself, i.e., self-evidently positive, and, thus, increases the legitimacy of the process (Fiorino 1990; Cass 2006;

The Nuffield Council on Bioethics 2012; Mere et al. 2019). Substantive rationales are based on the premise that this democratic participation will, through incorporating multiple and diverse perspectives, produce benefits of better quality and more useful policies, management plans or, in this case, models (Fiorino 1990; Cass 2006; Király and Miskolczi 2019). Instrumental rationales prioritise the relationship building between participants that gives the resulting decisions or policy more chance of success, particularly in terms of participant buy-in (Fiorino 1990; Cass 2006; Stave 2010; Mere et al. 2019). Others have proposed a fourth rationale, this being a transformative one, in which the participatory process can be educational and empowering, and, thus, a transformative experience, in terms of power relations, for all participants (Voinov and Bousquet 2010; Voinov et al. 2018; Király and Miskolczi 2019; Mere et al. 2019).

Finally, we aimed to identify the nature of engagement with non-Western knowledge types for each study. We examined if and how the article described the overall process of engaging with non-Western Knowledge. We categorised the approaches as: no engagement with non-Western knowledge types (e.g., where only policy or governmental stakeholders were participating); an "add-on" approach where non-Western knowledge types provide additional information to modelling approaches prioritising Western or scientific knowledge; "bridging" or connecting non-Western knowledge types and science with an even emphasis; and an approach in which non-Western knowledge types are prioritised in the modelling process, that is they are privileged over Western knowledge.

Results

Searches of the two databases identified 833 citations once duplicates had been removed (Fig. 2); we screened articles written in English, Spanish, French, Russian, Italian, Portuguese, Arabic, Chinese, Croatian, Czech, Korean and German. After screening, 21 articles, relating to 19 studies that carried out modelling with participants, met the full inclusion criteria. Five articles were identified through reference checking, which related to two new studies. In total, 26 articles, relating to 21 studies, underwent data extraction and analysis. As some articles referred to the same study, the subject of analysis was individual studies. All included articles were written in English.

Publication trends over time and place

The greatest number of studies were identified in the North American Arctic, with fifteen studies in Arctic Canada and (or) Alaska. The European Arctic was the location of six studies, including three in Norway, one in Finland, one in Sweden, and one in Russia (Fig. 4). Most studies focused on a regional scale ($n = 14$). Of all studies, five were locally focused and two were nationally focused. Only regionally focused studies were carried out in Europe, whereas studies in North America varied from local to regional to national (Fig. 5A).

The number of studies that engage participants in modelling research in the Arctic has increased in the last decade. There was little difference between the number of studies taking an approach in which the phenomenon of interest was modelling a broader socio-environmental system ($n = 11$) and those that focused on a single issue ($n = 10$) (Fig. 5B). Topics modelled included marine and land ecosystems ($n = 10$), environmental and weather conditions ($n = 3$), transport ($n = 3$), natural resource management (including subsistence and land-use, $n = 2$), integrated sustainability assessments ($n = 2$), and health ($n = 1$) (Fig. 5C). There were no clear geographic trends in the modelling topics.

We considered researchers, academics, and scientists to be participants in the research, particularly where the emphasis in a study was on collaboration between researchers and community members. Researchers were, therefore, understandably the most common

Fig. 4. Geographic distribution of the location of identified studies. Map created using QGIS (https://qgis.org/en/site/) software and Natural Earth (https://www.naturalearthdata.com/) boundary basemap.

participant group reported across studies ($n = 21$). This was followed by community members or partners ($n = 17$) and Indigenous Peoples ($n = 14$) (that were not mutually exclusive), community organisations ($n = 11$), and government bodies ($n = 7$). Some studies also engaged with non-governmental organisations ($n = 2$), natural resource managers ($n = 3$), and the private sector and tourism industry ($n = 3$) (Fig. 5D). The number of different participant groups engaged with in each study ranged from 2 to 7, with an average of 4.

Participatory structure

Modelling approaches

The diversity of topics modelled was reflected in the diversity of modelling approaches reported (Table 4). These ranged from conceptual modelling ($n = 6$), modelling based on systems dynamics and fuzzy logic ($n = 4$), and participatory mapping processes ($n = 2$), to increasingly quantitative modelling approaches including species habitat models ($n = 2$), agent-based modelling ($n = 1$), computer-based climate modelling ($n = 4$), and threshold models ($n = 2$). Reported methods most commonly included participatory workshops and (or) interviews, and some studies incorporated one or more of mapping, photovoice, role-play, and local observations (Fig. 5E).

Use of participation

All studies reported engagement with participants in two or more research stages: problem identification; planning and design; participant identification; choice of model; data generation; model validation; model output generation; and (or) evaluation of the process,

Fig. 5. Graphs displaying publication trends over time and place. (A) Geographic scale at which research was conducted for each country of study. (B) Number of participatory modelling (PM) studies by year and scope; *note that 2020 was not a full year as the literature search took place in April 2020. (C) Topics of participatory modelling studies. (D) Number of studies reporting engagement with different participant groups. (E) Number of studies using different methods as part of the participatory process. (F) Number of stages in studies reported to employ participation.

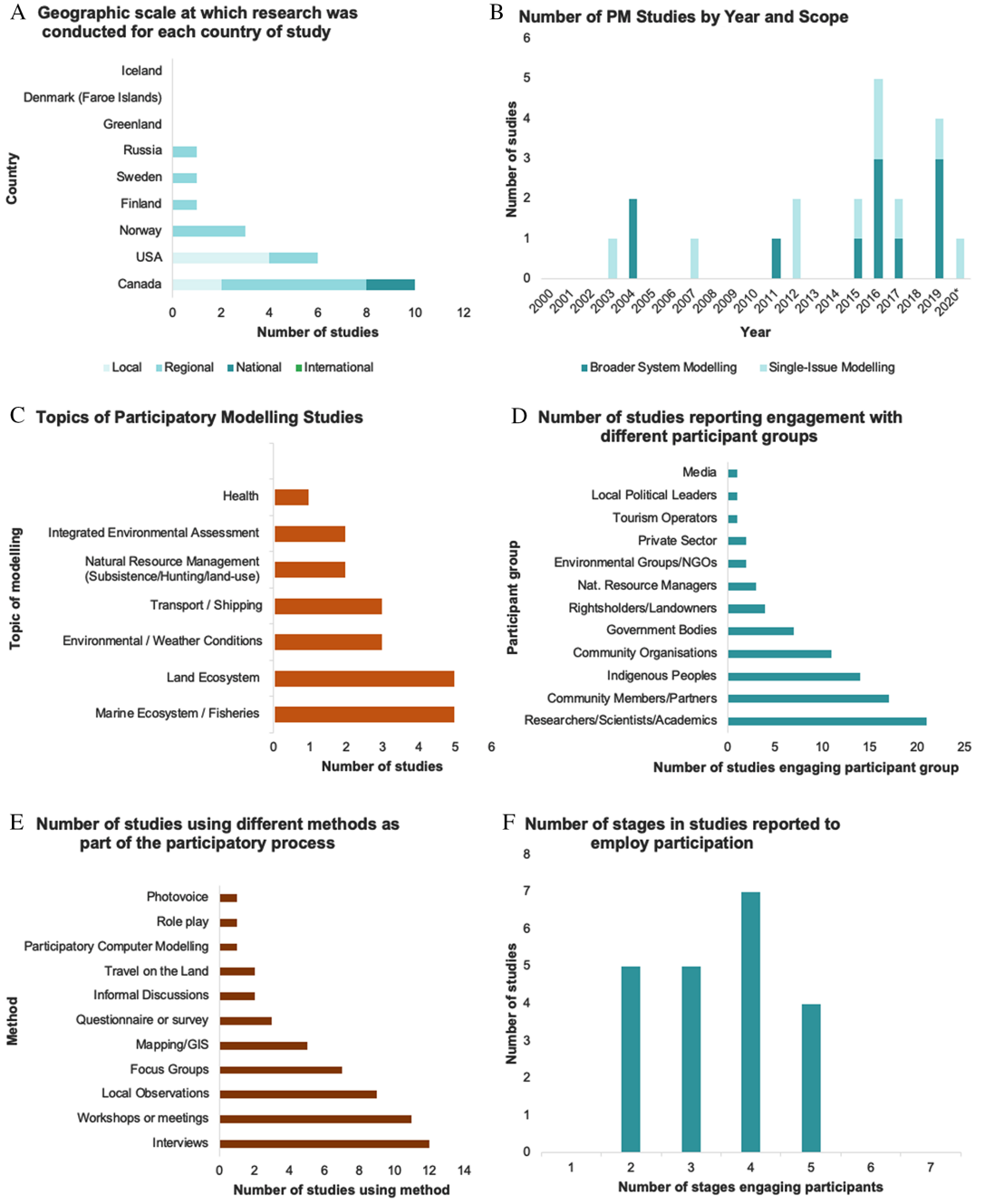


Table 3. Definitions and examples of rationales for participation.

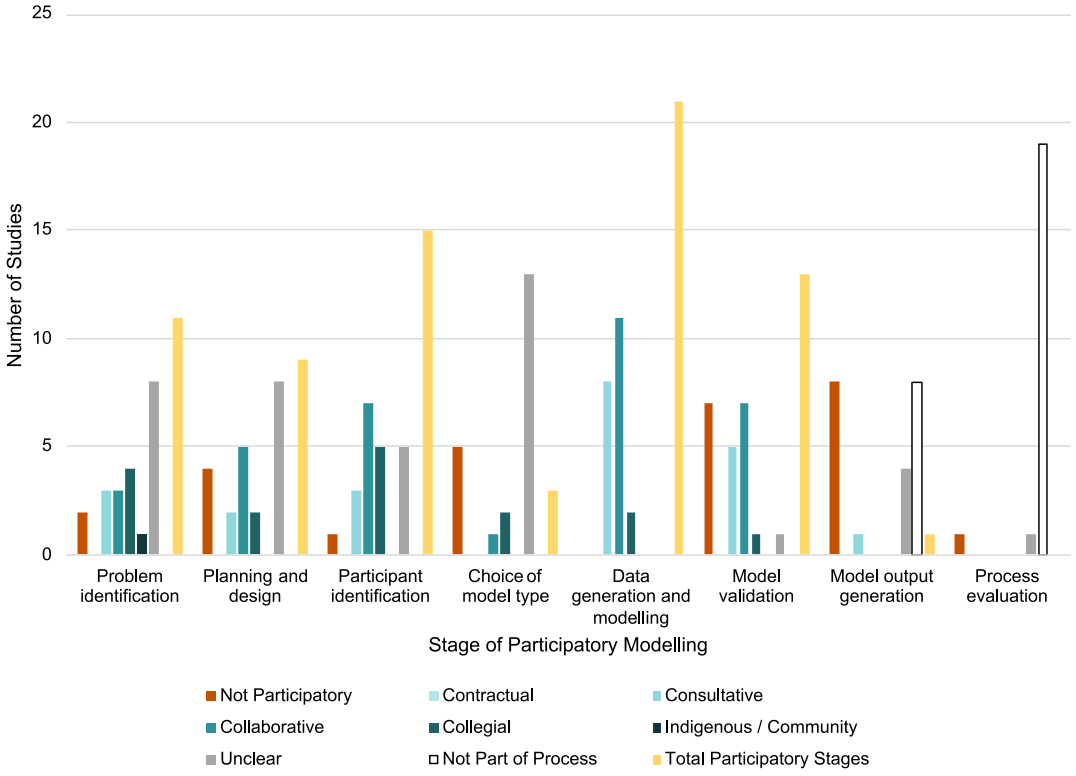
Function	Definition	Examples
Normative	Increases legitimacy through increased democracy	• Consistency with local priorities and norms • Good research practice • Democratically involve rightsholders • Increased transparency of process • Incorporation of non-Western knowledge types (if there is not a further reason for this)
Substantive	Increase value, quality and effectiveness of results and information produced, i.e., better knowledge	• Decision Support • More robust planning • Access knowledge base • More credible research • More sustainable outcomes • More effective outcomes • Add legitimacy to management decisions • Improves accuracy • To be more context-sensitive • More relevant • Better at identifying problems
Instrumental	Increases social learning, relationships and public buy-in and investment, i.e., more chance of success	• Conflict resolution • Overcome cross-cultural misunderstandings • Social/collaborative learning • Fosters trust between participants and researchers • Develop further/promote methodologies of collaboration in field of study
Transformative	Something is tangibly transformed, be it the participants or the power structure	• Capacity building • To address power relations • Better outcomes for the community/ participants • Leads to more equitable management/ control over resources • At request of population or to provide info direct to participants (shift in power in terms of who defines research priorities and what types of knowledge are prioritised)

with an average of three participatory stages reported per study. Four studies reported to be participatory in five of their stages (Fig. 5F). Across studies, the stages that were most frequently reported to be participatory were the data and model generation process and the participant identification process (Fig. 6). Participation was least commonly reported at the research planning stage and in the process of choosing the modelling type. Reported participation was also low in model output generation and evaluation of the process, but a number of studies did not report including these stages as part of their research process. Lack of clarity in reporting across studies and stages meant that the degree of autonomy that participants had over a stage in the process could not always be determined.

Degree of participation

Where participation was reported in the article, it was most frequently collaborative or consultative (Fig. 7). Eight articles described a collegial degree of participation in one or more stages, with one article describing a collegial approach to participation through five of the research stages. Collegial approaches were most commonly described at the problem

Fig. 6. Number of studies reporting each degree of participation by stage.



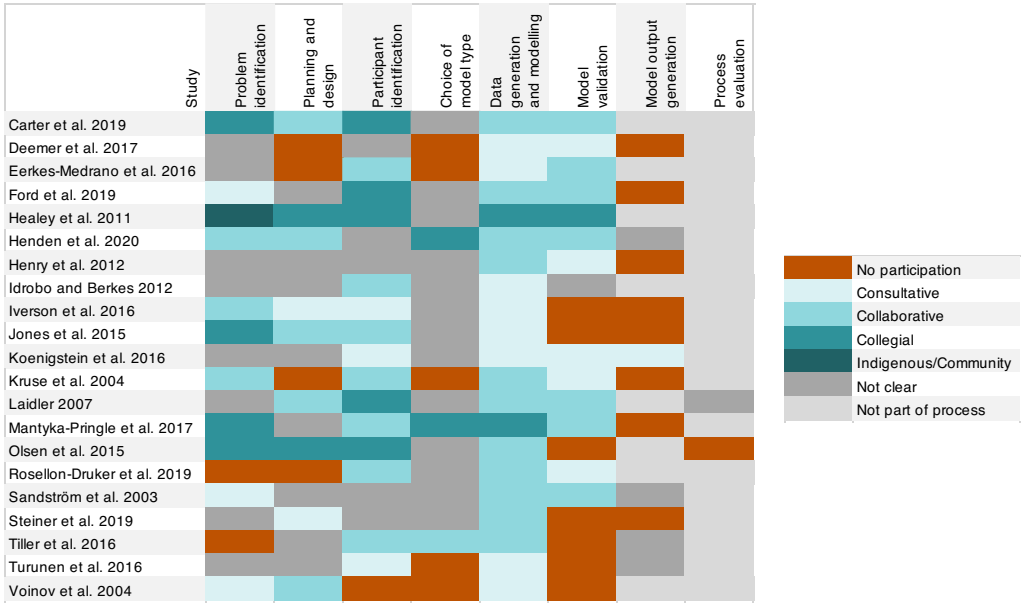
identification and participant identification stages of research. Collaborative approaches were most commonly described for the data or model generation stage, followed by the participant identification stage. Only one study described an Indigenous/Community degree of participation and this was at the problem identification stage. No studies described the use of a contractual approach to participation at any stage, so where participation was reported, it was, at the very least, reported to be consultative. As mentioned, however, in many cases the degree of authority over the process afforded to participants was not clear.

Studies' participatory scores (based on the number of stages of the process that were reported to be participatory and the degree of participation described in these stages) ranged from 2 to 15, with an average score of 6.7. Lower scoring studies tended to describe a "consultative" approach in two or more stages. Higher scoring studies described engaging participants in five or more stages of the process, often with a "collegial" or "collaborative" approach. Most studies described a mix of "degrees" of participation throughout the process (Fig. 7). There was a small difference between the average score for Arctic North America (7.3; $n = 15$) and Arctic Europe (5.3; $n = 6$). There was little association between the affiliation of the authors of a study and its score, except for those that included authors that were community members or were affiliated with a community organisation, which had an average score of 9.4 ($n = 6$). There was no trend in participation score over time.

Reasons for use of participation

The stated reasons for the use of participation were not always explicit, so we included each paper's discussion of why participation in modelling research has value, as well as

Fig. 7. Structure and degree of participation for each study (Sandström et al. 2003; Kruse et al. 2004; Voinov et al. 2004; Laidler 2007; Healey et al. 2011; Henry et al. 2012; Idrobo and Berkes 2012; Jones et al. 2015; Olsen et al. 2015; Eerkes-Medrano et al. 2017; Iverson et al. 2016; Koenigstein et al. 2016; Deemer et al. 2017; Tiller et al. 2016; Turunen et al. 2016; Mantyka-Pringle et al. 2017; Carter et al. 2019; Ford et al. 2019; Rosellon-Druker et al. 2019; Steiner et al. 2019; Henden et al. 2020).



the reasons given that were specific to the research project in question. Substantive rationales for the use of participation were most commonly given (18 studies), such as the pursuit of more credible, sustainable, effective, and legitimate research outcomes. This was followed by instrumental rationales (13 studies), such as conflict resolution, trust-building and social learning, and normative rationales (nine studies) that include the need to adhere to good research practice and local norms. Only two studies gave one or more transformative rationales for participation, which included local capacity-building and power shifting in resource management. Studies giving instrumental and (or) transformative rationales for participation, on average, achieved a higher participatory score (8.2) than those providing normative and (or) substantive rationales alone (4.2). There was little discussion of why participation was being used at certain stages of the research process and not others.

Nature of engagement with non-Western knowledge types

The majority of studies (62%; $n = 13$) described "integrating" or "bridging" knowledge types, placing an even emphasis on Western and non-Western knowledge. Five studies (24%) described a process that prioritised IK or community-based knowledge over Western knowledge, including those studies that were requested by a community or initiated by Indigenous scholars. Three studies (14%) described a superficial form of engagement with non-Western knowledge types. On average, studies that described prioritising non-Western knowledge types had a participation score of 11.2, whereas those that described bridging knowledge types and "adding on" non-Western knowledge types had scores of 5.9 and 2.6, respectively.

Table 4. Examples of modelling approaches used.

Modelling approach	Example	
Conceptual modelling ($n = 6$)	Laidler et al. 2008	Conceptual modelling of Inuit knowledge of sea ice processes, conditions, and features in Pangnirtung, Cape Dorset and Igloolik, Nunavut.
Systems dynamics and fuzzy logic ($n = 4$)	Tiller et al. 2016	Fuzzy cognitive mapping of Norwegian marine food system stakeholders' perspectives of the risk of climate change to marine environments.
Quantitative climate modelling ($n = 4$)	Turunen et al. 2016	Combining Herder knowledge with future snow condition projections to simulate the impacts of changing snow conditions on herders in Finland, and to identify coping strategies.
Participatory Mapping ($n = 2$)	Sandström et al. 2003	The use of participatory geographic information systems, with reindeer herders in northern Sweden, to model land-use activities and patterns among multiple land users.
Agent-based modelling ($n = 2$)	Kruse et al. 2004	Creation of a computational discrete-choice travel-cost model of subsistence hunting in Old Crow, Yukon, Canada, relying on research and Indigenous Knowledge to provide rules and parameters for individual and collective decision making.
Species habitat models ($n = 2$)	Olsen et al. 2015	Indigenous-Knowledge-informed use of remotely sensed environmental data and geospatial training data to create habitat suitability maps for marine mammals in Alaska, USA.
Threshold models ($n = 2$)	Ford et al. 2019	Modelling, with Indigenous Knowledge holders, to create threshold models of access to informal ice, sea and land trails in Inuit Nunangat.

Discussion

This systematic scoping review has identified and characterised published reports of participation in modelling research taking place in the Arctic over the last 20 years. In doing so, it has highlighted and examined the diversity of approaches that can and are taken to engage participants in climate and environmental modelling processes. This scoping review reveals key characteristics of participation in modelling research in the Arctic, and presents an approach to interrogating articles that report the use of participatory methods that is of value outside of the contexts in which it is used here. The approach creates a composite score for studies based on the temporal structure of participation throughout a participatory study and the degree of participation at each stage.

Participants and topics

Most studies reported engaging with Indigenous and non-Indigenous Peoples in their participatory processes, which involves engaging with both Western and non-Western knowledge. This is likely to be due to the presence of multiple autonomous Indigenous Peoples and community groups in the Arctic, who are increasingly carrying out or commissioning their own research and research agendas, alongside expectations of Western researchers to adhere to protocols such as the duty to consult (Haida Nation v. British Columbia (Minister of Forests) 2004), research agendas developed by Indigenous organisations (Inuit Tapiriit Kanatami 2018), and research funding that is specifically allocated to communities (Peace and Myers 2012). This is not an unexpected finding, considering this context. However, this does not necessarily mean that these knowledge holders are being

engaged in processes that are highly participatory, such as those that achieve an "Indigenous" or "Community" degree of engagement, and may be the result of tokenistic solutions to these calls for inclusion. The breadth of topics of study identified in this review represent the diversity of issues that the Arctic is facing in the context of climate change, from impacts on species and habitat health, land use, subsistence, employment, and tourism, to the direct impacts of changing environmental and climatic conditions.

The participant identification stage involves both the process of defining the criteria for participation in the research process, and the process of selecting participants that met these criteria. Studies did not always distinguish between these two steps, but it was often clear that participants had been heavily involved in the selection, but not the definition, of participants. Similarly, there was rarely a discussion on the groups or individuals who may have been excluded from the process due to practicalities such as the time-consuming and intensive nature of a highly participatory modelling process. This is yet another part of the process in which clearer reporting on research design, in general, would be beneficial, as understanding who has defined the criteria for participation, as well as who may be actively or inadvertently excluded from the process, helps to identify the perspectives that are and are not represented in the resulting models (Hitomi and Loring 2018). Others have similarly called for greater clarity in how participatory research more generally is reported (Mosurska and Ford 2020).

Structure of studies

The research stages that were most regularly reported as participatory (regardless of the degree of participation) were the participant identification stage, and data or model generation. It is understandable that participants would be a valuable source of knowledge for identifying the scope of relevant stakeholders for a given issue. Utilising this participant expertise demonstrates a move away from more traditional approaches in which participants or stake/rightsholders are defined and identified by the subjective assessments of researchers, and places value on the social relationships and communication networks that exist among participant groups (Mitchell et al. 1997; Prell et al. 2007). However, it was not always clear whether the researchers had already imposed restrictions or criteria for participants, or whether these criteria were identified collaboratively.

It is also understandable that the data and model generation stage would tend to be reported as participatory, as this is the focal part of the study in which diverse knowledge types can be brought together in the process of collaborative learning. Reviews of participatory monitoring research have similarly observed participation most commonly characterised as data collection (Thompson et al. 2020). However, although some studies reported using participatory workshops to combine data and knowledge generation with model building and synthesis (Healey et al. 2011; Mantyka-Pringle et al. 2017), others reported using two distinct stages of data elicitation, such as a round of interviews or focus groups with participants, followed by a subsequent modelling process in which participants may or may not have been involved (Iverson et al. 2016; Ford et al. 2019). In these cases, it was challenging to summarise the studies into the stages we had initially identified.

Excluding the model output generation and evaluation stages (as many studies did not include these stages as part of their modelling process), participation was least commonly reported at the choice of model stage. We found that unclear reporting was particularly high at this stage, preventing us from determining whether participatory processes were, in fact, used. Participants and communities have pointed to the benefits that early research engagement can bring to the levels of participation and autonomy throughout the rest of the research process, and for enabling their priorities to define this process (Harper et al. 2012; Carter et al. 2019; Flynn and Ford 2020). This highlights that breaking participation

down into stages, although useful to evaluate, is somewhat artificial because it is also important to consider the threads of participation that run throughout the entire process of a study. It is, therefore, important for articles to clearly report participation at these early stages of research, as they can reveal nuances about the degree of participation afforded in subsequent stages, provide accountability to the interests of those involved as participants, and draw links to where participation was used in the study, to what degree, and why.

This review identified great diversity in the methods, tools and types of modelling used. Workshops were frequently used as part of the modelling process, which are known to be effective in bringing diverse knowledge holders together and promoting social learning, participatory analysis, and relationship building (Huntington et al. 2002; Knapp et al. 2011). Other participatory methods, such as photovoice, and traditionally non-participatory methods, such as interviews, were used, sometimes blended or integrated into one research stage. Although the choice of methods is important, as methods can empower some participants over others (Voinov et al. 2018), few studies discussed power dynamics within and between participant groups.

Degree of participation

Only one study reported an "Indigenous" or "community" degree of participation. This was a study where the problem identification and initiation of the research was driven by the community and centred on community priorities (Healey et al. 2011). Nevertheless, most studies reported incorporating one or more stages of collaborative or collegial participation into their process, and this occurred most often at the data and model generation stage, suggesting that these model building stages are regularly being used to create space for social learning, genuine exchange and the meeting of different knowledge types. Again, unclear reporting meant that determining the degree of participation was challenging. As Carter et al. (2019, p. 390) point out, historically "a lack of research reporting has been a key factor in exploitative research relationships and lack of community trust in research" (Inuit Tapiriit Kanatami 2018); thus, reporting is important for accountability.

There is often a trade-off between breadth and depth of participation (McCall et al. 2015; Voinov et al. 2016). The degree of participation afforded to participants as a group, and the degree of participation that any one individual participant has are not necessarily the same, although it was most often the former that was reported in the included papers. The more participants and participant groups that are involved, the less power each individual will have. Here, we have assessed the degree of power that was possessed by the participant group in contrast with the power held by the researchers in any one study, but not enough information was provided to interpret power relations between participants.

Reasons for use of participation

The motivations, from those initiating the research, for using participation in the process are important for understanding specific choices of nature of participation and at what stage in a study. Again, we found lack of clarity in reporting in a number of studies around their specific reasons for using participation, which is consistent with other literature reviewing participation in modelling studies (Voinov et al. 2016). Where reasons were given, they were most frequently substantive ($n = 18$), often referring to the value of engaging non-Western knowledge types for the quality of the research outcomes. Instrumental functions were stated in 13 studies, highlighting the accepted value, and mutual benefit of, the social learning that can take place through the modelling process. Only two studies gave transformative rationales for the use of participation, which prioritises the benefits for the participants in terms of the power shift and tangible change that can come about through the research process itself. This included studies that sought to directly address and change

power relations in research and natural resource management (Rosellon-Druker et al. 2019), and those that incorporated research capacity building into the process as a key objective (Healey et al. 2011). Studies stating instrumental and (or) transformative rationales demonstrate the importance that they are placing on the value of the process itself, particularly for participants. These studies' average participation score was 8.2. Studies giving only normative or substantive rationales for participation demonstrate a greater focus on the value of the outcomes of the process, and their average participation score was 4.3. This suggests that studies are using more frequent and higher degrees of participation to achieve more instrumental objectives such as social learning, and potentially transformative change for participants.

Review limitations

Our approach relies on reporting in the published literature on processes that are often complex and nuanced. Understanding participatory processes involves understanding the social relations between participants, autonomy over decision-making, ability to communicate and exchange knowledge, and their skills, tools, and experience that allow them to do so (Voinov and Bousquet 2010). Although there are examples of how these descriptions of participation, autonomy, and power relations in research can be reported clearly and succinctly (Carter et al. 2019), we understand the constraints placed on authors when publishing with limited word counts. Nevertheless, the growth in the use of supplementary materials reduces such challenges in contemporary scientific publishing. We included supplementary materials in our review, but they were rarely used by their authors to add more detail to the description of the participatory process. As a result, our evaluation has been dependent on often incomplete descriptions of participatory processes, in which researchers and participants may have engaged in higher degrees of participation and collaboration that we were unable to credit. In journal articles these descriptions are usually from the perspective of the researchers and, thus, are sensitive to bias. Furthermore, we were unable to investigate outcomes of these research processes, including short- and long-term outcomes and whether there were direct benefits for the participants. Interviews with both researchers and participants could be one way to address both of these issues.

Jones et al. (2009) have put forward a framework for participatory modellers to self-evaluate their studies in reference to their original goals. Fundamentally, part of this evaluation is carried out by the participants engaged in the process. This provides insights on the value of the process from multiple perspectives and holds the research to account over its goals. Additionally, a further question remains around how this coproduced information is taken up and used in policy, management, and decision-making, particularly that which engages with non-Western knowledge types (Thompson et al. 2020).

Conclusion

This review has identified a diversity of approaches being used in the Arctic to engage participants in modelling climate-sensitive processes. These studies comprise a range of both degree of participation and ways of engaging with non-Western knowledge types. It is noteworthy that more participation is not necessarily better participation, nor necessarily favoured by participants. It is challenging to comment on what is best or most effective in terms of stage and degree of participation, as this depends on the objectives of the process and there will likely be different participants or stakeholders with different ideas of what a successful outcome would be. However, we have identified examples of research in the Arctic that are successfully implementing highly participatory modelling processes, while working with and for non-Western knowledge holders in the region.

Considering how few studies in this review reported engaging participants in an evaluation process, this may be a priority area for improvement, and one that needs to be planned for at the project planning stage to ensure resources and time are allocated to this task. Equally, it is also important that readers are able to critically appraise the participatory processes in a study, and currently we find that the level of detail available is, in general, not enough for this. Reporting criteria may be useful to improve the quality and clarity of the communication of this important information. To move towards research on what types of participation work in what contexts and for whom, we need to understand in greater depth what is happening in these modelling processes in terms of power, participation, and autonomy, particularly in the context of diverse, non-Western knowledge types, and this requires clearer discussions of these issues in the descriptions of the process.

Acknowledgements

This work has been financially supported by the Indigenous Health Adaptation to Climate Change (IHACC) Research Team, University of Alberta, Edmonton, Alberta, Canada. The IHACC team contributed to the conceptualization of the work and to reading and editing of the manuscript. Members of the IHACC team include Shuaib Lwasa, Patricia J. García, Didacus B. Namanya, Lea Berrang-Ford, and Cesar Carcamo. Additional financial support has been provided to KD by the University of Leeds Priestley Scholarship.

References

Abram, N., Gattuso, J.-P., Prakash, A., Cheng, L., Chidichimo, M.P., Crate, S., et al. 2019. Framing and context of the report. *In* IPCC special report on the ocean and cryosphere in a changing climate. *Edited by* H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, et al. IPCC. Available from https://www.ipcc.ch/srocc/.

Alshaikh, M.I. 2013. From fragility to resilience: participatory community mapping, strategic planning, and knowledge management in Sudan. *In* Who counts?: the power of participatory statistics. *Edited by* J. Holland. Practical Action Publishing.

AMAP. 2017. Adaptation actions for a changing Arctic: perspectives from the Bering-Chukchi-Beaufort Region. Arctic Monitoring and Assessment Programme (AMAP).

AMAP. 2018. Adaptation actions for a changing Arctic: perspectives from the Baffin Bay/Davis Strait Region. Arctic Monitoring and Assessment Programme (AMAP).

Andersen, D.F., and Richardson, G.P. 1997. Scripts for group model building. Syst. Dyn. Rev. **13**(2): 107–129. doi: 10.1002/(SICI)1099-1727(199722)13:2<107:AID-SDR120>3.0.CO;2-7.

Arctic Human Development Report: Regional Processes and Global Linkages. 2015. Nordisk Ministerråd. Available from http://urn.kb.se/resolve?urn=urn:nbn:se:norden:org:diva-3809.

Arnstein, S.R. 1969. A ladder of citizen participation. J. Am. Inst. Plann. **35**(4): 216–224. doi: 10.1080/01944366908977225.

Barber, M., and Jackson, S. 2015. 'Knowledge making': issues in modelling local and Indigenous ecological knowledge. Hum. Ecol. **43**(1): 119–130. doi: 10.1007/s10745-015-9726-4.

Berrang-Ford, L., Ford, J.D., Edge, V., Namanya, D., Harper, S., Marcello, T., et al. 2018. Preparing for the health impacts of climate change in Indigenous communities: the role of community-based adaptation. Global Environ. Change, **49**: 129–139. doi: 10.1016/j.gloenvcha.2018.02.006.

Brunet, N., Hickey, G., and Humphries, M. 2014. The evolution of local participation and the mode of knowledge production in Arctic research. Ecol. Soc. **19**(2): 69. doi: 10.5751/ES-06641-190269.

Carter, N.A., Dawson, J., Simonee, N., Tagalik, S., and Ljubicic, G. 2019. Lessons learned through research partnership and capacity enhancement in Inuit Nunangat. Arctic, **72**(4): 381–403. doi: 10.14430/arctic69507.

Cass, N. 2006. Participatory-deliberative engagement: a literature review. Working Paper. Available from https://core.ac.uk/reader/16285075.

Castleden, H., Morgan, V.S., and Lamb, C. 2012. "I spent the first year drinking tea": exploring Canadian university researchers' perspectives on community-based participatory research involving Indigenous peoples. Can. Geogr. **56**(2): 160–179. doi: 10.1111/j.1541-0064.2012.00432.x.

Conway, D., Nicholls, R.J., Brown, S., Tebboth, M.G.L., Adger, W.N., Ahmad, B., et al. 2019. The need for bottom-up assessments of climate risks and adaptation in climate-sensitive regions. Nat. Clim. Change, **9**(7): 503–511. doi: 10.1038/s41558-019-0502-0.

Cooke, B., and Kothari, U. 2001. Participation: the new tyranny? Zed Books Ltd.

Cornwall, A., and Jewkes, R. 1995. What is participatory research? Soc. Sci. Med. **41**(12): 1667–1676. PMID: 8746866.

Cornwall, A., Stiefel, M., and Wolfe, M. (*Editors*). 2011. The many faces of participation. *In* Participation reader. Zed Books Ltd.

Crate, S., Cheung, W., Glavovic, B., Harper, S., Combes, H.J.D., Ell Kanayuk, M., et al. 2019. Indigenous knowledge and local knowledge in ocean and cryosphere change. *In* PCC special report on oceans and cryosphere in a changing climate. Cambridge University Press.

Cunsolo Willox, A., Harper, S.L., Ford, J.D., Landman, K., Houle, K., and Edge, V.L. 2012. "From this place and of this place:" climate change, sense of place, and health in Nunatsiavut, Canada. Soc. Sci. Med. **75**(3): 538–547. doi: 10.1016/j.socscimed.2012.03.043. PMID: 22595069.

David-Chavez, D.M., and Gavin, M.C. 2018. A global assessment of Indigenous community engagement in climate research. Environ. Res. Lett. **13**(12): 123005. doi: 10.1088/1748-9326/aaf300.

Deemer, G.J., Bhatt, U.S., Eicken, H., Posey, P.G., Hutchings, J.K., Nelson, J., et al. 2017. Broadening the sea-ice forecaster toolbox with community observations: a case study from the northern Bering Sea. Arct. Sci. **4**(1): 42–70. doi: 10.1139/as-2016-0054.

Dentzau, M.W. 2019. The tensions between indigenous knowledge and western science. Cult. Stud. Sci. Educ. **14**(4): 1031–1036. doi: 10.1007/s11422-018-9903-z.

Dilling, L., and Lemos, M.C. 2011. Creating usable science: opportunities and constraints for climate knowledge use and their implications for science policy. Global Environ. Change, **21**(2): 680–689. doi: 10.1016/j.gloenvcha.2010.11.006.

Dreyer, M., and Renn, O. 2011. Participatory approaches to modelling for improved learning and decision-making in natural resource governance: an Editorial. Environ. Policy Gov. **21**(6): 379–385. doi: 10.1002/eet.584.

Duboz, R., Echaubard, P., Promburom, P., Kilvington, M., Ross, H., Allen, W., et al. 2018. Systems Thinking in practice: participatory modeling as a foundation for integrated approaches to health. Front. Vet. Sci. **5**. doi: 10.3389/fvets.2018.00303.

Duyck, S. 2011. Participation of non-state actors in arctic environmental governance. SSRN Scholarly Paper ID 2331165. Social Science Research Network, Rochester, NY. Available from https://papers.ssrn.com/abstract=2331165. [Accessed: 15 April 2020]

Eerkes-Medrano, L., Atkinson, D.E., Eicken, H., Nayokpuk, B., Sookiayak, H., Ungott, E., and Weyapuk, W., Jr. 2017. Slush-ice berm formation on the West Coast of Alaska. Arctic, **70**(2): 190–202. doi: 10.14430/arctic4644.

Einarsson, N., Larsen, J.N., Nilsson, A., and Young, O.R. 2004. Arctic human development report. Stefansson Arctic Institute, Akureyri, Iceland.

Ernst, K.M., and van Riemsdijk, M. 2013. Climate change scenario planning in Alaska's National Parks: stakeholder involvement in the decision-making process. Appl. Geog. **45**: 22–28. doi: 10.1016/j.apgeog.2013.08.004.

Fiorino, D.J. 1990. Citizen participation and environmental risk: a survey of institutional mechanisms. Sci., Technol., Hum. Values, **15**(2): 226–243. doi: 10.1177/016224399001500204.

Flynn, M., and Ford, J.D. 2020. Knowledge mobilization in community-based Arctic research + Supplementary Appendix 1 (see article tools). Arctic, **73**(2): 240–260.

Flynn, M., Ford, J.D., Pearce, T., and Harper, S.L. and IHACC Research Team 2018. Participatory scenario planning and climate change impacts, adaptation and vulnerability research in the Arctic. Environ. Sci. Policy, **79**: 5–53. doi: 10.1016/j.envsci.2017.10.012.

Ford, J.D., McDowell, G., and Jones, J. 2014. The state of climate change adaptation in the Arctic. Environ. Res. Lett. **9**(10): 104005. doi: 10.1088/1748-9326/9/10/104005.

Ford, J.D., McDowell, G., and Pearce, T. 2015. The adaptation challenge in the Arctic. Nat. Clim. Change, **5**(12): 1046–1053. doi: 10.1038/nclimate2723.

Ford, J.D., Stephenson, E., Willox, A.C., Edge, V., Farahbakhsh, K., Furgal, C., et al. 2016. Community-based adaptation research in the Canadian Arctic. Wiley Interdiscip. Rev. Clim. Change, **7**(2): 175–191. doi: 10.1002/wcc.376. PMID: 27668014.

Ford, J.D., Clark, D., Pearce, T., Berrang-Ford, L., Copland, L., Dawson, J., et al. 2019. Changing access to ice, land and water in Arctic communities. Nat. Clim. Change, **9**(4): 335–339. doi: 10.1038/s41558-019-0435-7.

Ford, J.D., King, N., Galappaththi, E.K., Pearce, T., McDowell, G., and Harper, S.L. 2020. The resilience of Indigenous peoples to environmental change. One Earth, **2**(6): 532–543. doi: 10.1016/j.oneear.2020.05.014.

Furgal, C., and Seguin, J. 2006. Climate change, health, and vulnerability in Canadian northern Aboriginal communities. Environ. Health Perspect. **114**(12): 1964–1970. doi: 10.1289/ehp.8433. PMID: 17185292.

Gaillard, J.C. 2010. Vulnerability, capacity and resilience: perspectives for climate and development policy. J. Int. Dev. **22**(2): 218–232. doi: 10.1002/jid.1675.

Gotts, N.M., van Voorn, G.A.K., Polhill, J.G., Jong, E.D., Edmonds, B., Hofstede, G.J., and Meyer, R. 2019. Agent-based modelling of socio-ecological systems: models, projects and ontologies. Ecol. Complexity, **40**: 100728. doi: 10.1016/j.ecocom.2018.07.007.

Guta, A., Flicker, S., and Roche, B. 2013. Governing through community allegiance: a qualitative examination of peer research in community-based participatory research. Crit. Public Health, **23**(4): 432–451. doi: 10.1080/09581596.2012.761675. PMID: 24273389.

Haida Nation v. British Columbia (Minister of Forests). 2004. 3 SCR 511 (Supreme Court of Canada). Available from http://canlii.ca/t/1j4tq.

Harper, S.L., Edge, V.L., Cunsolo Willox, A., and Rigolet Inuit Community Government. 2012. 'Changing climate, changing health, changing stories' profile: using an ecohealth approach to explore impacts of climate change on Inuit health. EcoHealth, **9**(1): 89–101. doi: 10.1007/s10393-012-0762-x. PMID: 22526749.

Healey, G.K., Magner, K.M., Ritter, R., Kamookak, R., Aningmiuq, A., Issaluk, B., et al. 2011. Community perspectives on the impact of climate change on health in Nunavut, Canada. Arctic, **64**(1): 89–97. doi: 10.14430/arctic4082.

Henden, J.-A., Ims, R.A., Yoccoz, N.G., Asbjørnsen, E.J., Stien, A., Mellard, J.P., et al. 2020. End-user involvement to improve predictions and management of populations with complex dynamics and multiple drivers. Ecol. Appl. **30**(6): e02120. doi: 10.1002/eap.2120.

Henry, G.H.R., Harper, K.A., Chen, W., Deslippe, J.R., Grant, R.F., Lafleur, P.M., et al. 2012. Effects of observed and experimental climate change on terrestrial ecosystems in northern Canada: results from the Canadian IPY program. Climatic Change, **115**(1): 207–234. doi: 10.1007/s10584-012-0587-1.

Hewitt, K. 1983. Interpretations of calamity. 1st ed. Allen & Unwin.

Hitomi, M.K., and Loring, P.A. 2018. Hidden participants and unheard voices? A systematic review of gender, age, and other influences on local and traditional knowledge research in the North. FACETS, **3**(1): 830–848. doi: 10.1139/facets-2018-0010.

Hoegh-Guldberg, O., Jacob, D., Taylor, M., Bindi, M., Brown, S., Camilloni, I., et al. 2018. Impacts of 1.5°C of global warming on natural and human systems. *In* Global warming of 1.5°C. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. 138 pp.

Hua, W., Yuan, S., Yan, M., and Li, Y. 2012. A quantitative analysis of Arctic related articles in the humanities and social sciences appearing in the world core journals. Scientometrics, **91**(3): 703–718. doi: 10.1007/s11192-012-0690-0.

Huntington, H.P., Brown-Schwalenberg, P.K., Frost, K.J., Fernandez-Gimenez, M.E., Norton, D.W., and Rosenberg, D.H. 2002. Observations on the workshop as a means of improving communication between holders of traditional and scientific knowledge. Environ. Manage. **30**(6): 0778–0792. doi: 10.1007/s00267-002-2749-9.

Idrobo, C.J., and Berkes, F. 2012. Pangnirtung Inuit and the Greenland shark: co-producing knowledge of a little discussed species. Hum. Ecol. **40**(3): 405–414. doi: 10.1007/s10745-012-9490-7.

Inuit Tapiriit Kanatami. 2018. National Inuit Strategy on Research. Available from www.itk.ca.

Iverson, S.A., Forbes, M.R., Simard, M., Soos, C., and Gilchrist, H.G. 2016. Avian Cholera emergence in Arctic-nesting northern Common Eiders: using community-based, participatory surveillance to delineate disease outbreak patterns and predict transmission risk. Ecol. Soc. **21**(4): 12. doi: 10.5751/es-08873-210412.

Jakeman, A.J., Letcher, R.A., and Norton, J.P. 2006. Ten iterative steps in development and evaluation of environmental models. Environ. Model. Softw. **21**(5): 602–614. doi: 10.1016/j.envsoft.2006.01.004.

Janes, J.E. 2016. The "will to participate": governmentality, power, and community-based participatory research. Intersectionalities, **5**(1): 110–125.

Jones, C.E., Kielland, K., Hinzman, L.D., and Schneider, W.S. 2015. Integrating local knowledge and science: economic consequences of driftwood harvest in a changing climate. Ecol. Soc. **20**(1): 25. doi: 10.5751/ES-07235-200125.

Jones, J., Cunsolo, A., and Harper, S.L. 2018. Who is research serving? A systematic realist review of circumpolar environment-related Indigenous health literature. PLoS ONE, **13**(5): e0196090. doi: 10.1371/journal.pone.0196090. PMID: 29795554.

Jones, N., Perez, P., Measham, T.G., Kelly, G.J., d'Aquino, P., Daniell, K.A., et al. 2009. Evaluating participatory modeling: developing a framework for cross-case analysis. Environ. Manage. **44**(6): 1180. doi: 10.1007/s00267-009-9391-8. PMID: 19847478.

Jonsson, A., Andersson, L., Alkan-Olsson, J., and Arheimer, B. 2007. How participatory can participatory modeling be? Degrees of influence of stakeholder and expert perspectives in six dimensions of participatory modeling. Water Sci. Technol. **56**(1): 207–214. doi: 10.2166/wst.2007.453. PMID: 17711017.

Kelman, I., Gaillard, J.C., Lewis, J., and Mercer, J. 2016. Learning from the history of disaster vulnerability and resilience research and practice for climate change. Nat. Hazards, **82**(1): 129–143. doi: 10.1007/s11069-016-2294-0.

Kipp, A., Cunsolo, A., Gillis, D., Sawatzky, A., and Harper, S.L. 2019. The need for community-led, integrated and innovative monitoring programmes when responding to the health impacts of climate change. Int. J. Circumpolar Health, **78**(2): 1517581. doi: 10.1080/22423982.2018.1517581. PMID: 31066653.

Király, G., and Miskolczi, P. 2019. Dynamics of participation: system dynamics and participation — an empirical review. Syst. Res. Behav. Sci. **36**(2): 199–210. doi: 10.1002/sres.2580.

Knapp, C.N., Fernandez-Gimenez, M., Kachergis, E., and Rudeen, A. 2011. Using participatory workshops to integrate state-and-transition models created with local knowledge and ecological data. Rangeland Ecol. Manage. **64**(2): 158–170. doi: 10.2111/REM-D-10-00047.1.

Koenigstein, S., Ruth, M., and Gößling-Reisemann, S. 2016. Stakeholder-informed ecosystem modeling of ocean warming and acidification impacts in the Barents Sea region. Front. Mar. Sci. **3**(Jun): 93. doi: 10.3389/fmars.2016.00093.

Kruse, J.A., White, R.G., Epstein, H.E., Archie, B., Berman, M., Braund, S.R., et al. 2004. Modeling sustainability of arctic communities: an interdisciplinary collaboration of researchers and local knowledge holders. Ecosystems, **7**(8): 815–828. doi: 10.1007/s10021-004-0008-z.

Laidler, G.J. 2007. Ice, through Inuit eyes: characterizing the importance of sea ice processes, use, and change around three Nunavut communities. Ph.D. Dissertation. University of Toronto. 508 p.

Laidler, G.J., Dialla, A., and Joamie, E. 2008. Human geographies of sea ice: freeze/thaw processes around Pangnirtung, Nunavut, Canada. Polar Rec. **44**(4): 335–361. doi: 10.1017/S003224740800750X.

Leal, P.A. 2007. Participation: the ascendancy of a buzzword in the neo-liberal era. Dev. Pract. **17**(4/5): 539–548.

Lynam, T., de Jong, W., Sheil, D., Kusumanto, T., and Evans, K. 2007. A review of tools for incorporating community knowledge, preferences, and values into decision making in natural resources management. Ecol. Soc. **12**(1): 5. doi: 10.5751/ES-01987-120105.

Mach, K.J., Lemos, M.C., Meadow, A.M., Wyborn, C., Klenk, N., Arnott, J.C., et al. 2020. Actionable knowledge and the art of engagement. Curr. Opin. Environ. Sustain. **42**: 30–37. doi: 10.1016/j.cosust.2020.01.002.

Mantyka-Pringle, C.S., Jardine, T.D., Bradford, L., Bharadwaj, L., Kythreotis, A.P., Fresque-Baxter, J., et al. 2017. Bridging science and traditional knowledge to assess cumulative impacts of stressors on ecosystem health. Environ. Int. **102**: 125–137. doi: 10.1016/j.envint.2017.02.008. PMID: 28249740.

Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., et al. (*Editors*). 2018. 2018: summary for policymakers. *In* Global warming of 1.5°C. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. World Meteorological Organization. 32 pp.

Maynard, N.G. 2014. Native peoples-Native homelands climate change workshop II — final report: an Indigenous response to climate change.

McCall, M.K., Martinez, J., and Verplanke, J. 2015. Shifting boundaries of volunteered geographic information systems and modalities: learning from PGIS. ACME, **14**(3): 791–826.

McDowell, G., Ford, J., and Jones, J. 2016. Community-level climate change vulnerability research: trends, progress, and future directions. Environ. Res. Lett. **11**(3): 033001. doi: 10.1088/1748-9326/11/3/033001.

Mere, K.M.L., Mäntyniemi, S.H.P., Vanhatalo, J.P., and Haapasaari, P.E. 2019. Making the most of mental models: advancing the methodology for mental model elicitation and documentation with expert stakeholders. Environ. Model. Softw. **124**: 104589. Available from https://researchportal.helsinki.fi/en/publications/making-the-most-of-mental-models-advancing-the-methodology-for-me. doi: 10.1016/j.envsoft.2019.104589.

Meredith, M., Sommerkorn, M., Cassotta, S., Derksen, C., Ekaykin, A., Hollowed, A., et al. 2019. Polar regions. *In* IPCC special report on the ocean and cryosphere in a changing climate. *Edited by* H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, et al. IPCC. Available from https://www.ipcc.ch/srocc/.

Mitchell, R.K., Agle, B.R., and Wood, D.J. 1997. Toward a theory of stakeholder identification and salience: defining the principle of who and what really counts. Acad. Manage. Rev. **22**(4): 853–886. doi: 10.5465/amr.1997.9711022105.

Mosurska, A., and Ford, J.D. 2020. Unpacking community participation in research: a systematic literature review of community-based and participatory research in Alaska. Arctic, **73**(3): 347–367. doi: 10.14430/arctic71080.

Nakashima, D.J., Galloway McLean, K., Thulstrup, H.D., Ramos Castillo, A., and Rubis, J.T. 2012. Weathering uncertainty: traditional knowledge for climate change assessment and adaptation. *Edited by* D. McDonald. UNESCO. Available from https://unesdoc.unesco.org/ark:/48223/pf0000216613.

Nickels, S., Furgal, C., Buell, M., and Moquin, H. 2005. Unikkaaqatigiit: putting the human face on climate change: perspectives from Inuit in Canada. Joint publication of Inuit Tapiriit Kanatami, Nasivvik Centre for Inuit Health and Changing Environments at Université Laval and the Ajunnginiq Centre at the National Aboriginal Health Organization, Ottawa, Ont., Canada.

O'Brien, K. 2012. Global environmental change II: from adaptation to deliberate transformation. Prog. Hum. Geogr. **36**(5): 667–676. doi: 10.1177/0309132511425767.

Olsen, P.M., Kolden, C.A., and Gadamus, L. 2015. Developing theoretical marine habitat suitability models from remotely-sensed data and traditional ecological knowledge. Remote Sens. **7**(9): 11863–11886. doi: 10.3390/rs70911863.

Ouzzani, M., Hammady, H., Fedorowicz, Z., and Elmagarmid, A. 2016. Rayyan — a web and mobile app for systematic reviews. Syst. Rev. **5**(1): 210. doi: 10.1186/s13643-016-0384-4. PMID: 27919275.

Peace, D.M., and Myers, E. 2012. Community-based participatory process — climate change and health adaptation program for Northern First Nations and Inuit in Canada. Int. J. Circumpolar Health, **71**(1): 18412. doi: 10.3402/ijch.v71i0.18412.

Prell, C., Hubacek, K., Reed, M., Quinn, C., Jin, N., Holden, J., et al. 2007. If you have a hammer everything looks like a nail: traditional versus participatory model building. Interdiscip. Sci. Rev. **32**(3): 263–282. doi: 10.1179/030801807X211720.

Pretty, J.N. 1995. Participatory learning for sustainable agriculture. World Dev. **23**(8): 1247–1263. doi: 10.1016/0305-750X(95)00046-F.

Reed, M.S. 2008. Stakeholder participation for environmental management: a literature review. Biol. Conserv. **141**(10): 2417–2431. doi: 10.1016/j.biocon.2008.07.014.

Refsgaard, J.C., van der Sluijs, J.P., Højberg, A.L., and Vanrolleghem, P.A. 2007. Uncertainty in the environmental modelling process — a framework and guidance. Environ. Model. Softw. **22**(11): 1543–1556. doi: 10.1016/j.envsoft.2007.02.004.

Rosellon-Druker, J., Szymkowiak, M., Cunningham, C.J., Kasperski, S., Kruse, G.H., Moss, J.H., and Yasumiishi, E.M. 2019. Development of social-ecological conceptual models as the basis for an integrated ecosystem assessment framework in Southeast Alaska. Ecol. Soc. **24**(3): 30. doi: 10.5751/ES-11074-240330.

Sandström, P., Pahlen, T.G., Edenius, L., Tommervik, H., Hagner, O., Hemberg, L., et al. 2003. Conflict resolution by participatory management: remote sensing and GIS as tools for communicating land-use needs for reindeer herding in northern Sweden. AMBIO, **32**(8): 557–567. doi: 10.1639/0044-7447(2003)032[0557:Crbpmr]2.0.Co;2. PMID: 15049353.

Sawatzky, A., Cunsolo, A., Jones-Bitton, A., Middleton, J., and Harper, S.L. 2018. Responding to climate and environmental change impacts on human health via integrated surveillance in the circumpolar north: a systematic realist review. Int. J. Environ. Res. Public Health, **15**(12): 2706. doi: 10.3390/ijerph15122706.

Stave, K. 2010. Participatory system dynamics modeling for sustainable environmental management: observations from four cases. Sustainability, **2**(9): 2762–2784. doi: 10.3390/su2092762.

Steiner, N.S., Cheung, W.W.L., Cisneros-Montemayor, A.M., Drost, H., Hayashida, H., Hoover, C., et al. 2019. Impacts of the changing ocean-sea ice system on the key forage fish arctic cod (*Boreogadus saida*) and subsistence fisheries in the western Canadian Arctic—evaluating linked climate, ecosystem and economic (CEE) models. Front. Mar. Sci. **6**(Apr): 179. doi: 10.3389/fmars.2019.00179.

Tengö, M., Brondizio, E.S., Elmqvist, T., Malmer, P., and Spierenburg, M. 2014. Connecting diverse knowledge systems for enhanced ecosystem governance: the multiple evidence base approach. AMBIO, **43**(5): 579–591. doi: 10.1007/s13280-014-0501-3. PMID: 24659474.

The Nuffield Council on Bioethics. 2012. Public perspectives. *In* Emerging biotechnologies: technology, choice and the public good. The Nuffield Council on Bioethics. Available from https://nuffieldbioethics.org/publications/emerging-biotechnologies.

Thompson, K.-L., Lantz, T., and Ban, N. 2020. A review of Indigenous knowledge and participation in environmental monitoring. Ecol. Soc. **25**(2): 10. doi: 10.5751/ES-11503-250210.

Tiller, R., De Kok, J.-L., Vermeiren, K., Richards, R., Van Ardelan, M., and Bailey, J. 2016. Stakeholder perceptions of links between environmental changes to their socio-ecological system and their adaptive capacity in the region of Troms, Norway. Front. Mar. Sci. **3**: 267. doi: 10.3389/fmars.2016.00267.

Tricco, A.C., Lillie, E., Zarin, W., O'Brien, K.K., Colquhoun, H., Levac, D., et al. 2018. PRISMA Extension for Scoping Reviews (PRISMA-ScR): checklist and explanation. Ann. Intern. Med. **169**(7): 467–473. doi: 10.7326/M18-0850. PMID: 30178033.

Tschakert, P. 2012. From impacts to embodied experiences: tracing political ecology in climate change research. Geogr. Tidsskr. **112**(2): 144–158. doi: 10.1080/00167223.2012.741889.

Tschakert, P., van Oort, B., St. Clair, A.L., and LaMadrid, A. 2013. Inequality and transformation analyses: a complementary lens for addressing vulnerability to climate change. Clim. Dev. **5**(4): 340–350. doi: 10.1080/17565529.2013.828583.

Turunen, M.T., Rasmus, S., Bavay, M., Ruosteenoja, K., and Heiskanen, J. 2016. Coping with difficult weather and snow conditions: reindeer herders' views on climate change impacts and coping strategies. Clim. Risk Manage. **11**: 15–36. doi: 10.1016/j.crm.2016.01.002.

van Bavel, B., Ford, L.B., Harper, S.L., Ford, J., Elsey, H., Lwasa, S., and King, R. 2020. Contributions of scale: what we stand to gain from Indigenous and local inclusion in climate and health monitoring and surveillance systems. Environ. Res. Lett. **15**: 083008. doi: 10.1088/1748-9326/ab875e.

van Bruggen, A., Nikolic, I., and Kwakkel, J. 2019. Modeling with stakeholders for transformative change. Sustainability, **11**(3): 825. doi: 10.3390/su11030825.

van den Belt, M. 2004. Mediated modeling: a system dynamics approach to environmental consensus building. Island Press.

Videira, N., Antunes, P., Santos, R., and Lopes, R. 2010. A participatory modelling approach to support integrated sustainability assessment processes. Syst. Res. Behav. Sci. **27**(4): 446–460. doi: 10.1002/sres.1041.

Voinov, A., Bromley, L., Kirk, E., Korchak, A., Farley, J., Moiseenko, T., et al. 2004. Understanding human and ecosystem dynamics in the Kola Arctic: a participatory integrated study. Arctic, **57**(4): 375–388. doi: 10.14430/arctic515.

Voinov, A., and Bousquet, F. 2010. Modelling with stakeholders. Environ. Model. Softw. **25**(11): 1268–1281. doi: 10.1016/j.envsoft.2010.03.007.

Voinov, A., Kolagani, N., McCall, M.K., Glynn, P.D., Kragt, M.E., Ostermann, F.O., et al. 2016. Modelling with stakeholders — next generation. Environ. Model. Softw. **77**: 196–220. doi: 10.1016/j.envsoft.2015.11.016.

Voinov, A., Jenni, K., Gray, S., Kolagani, N., Glynn, P.D., Bommel, P., et al. 2018. Tools and methods in participatory modeling: selecting the right tool for the job. Environ. Model. Softw. **109**: 232–255. doi: 10.1016/j.envsoft.2018.08.028.

Watts, N., Adger, W.N., Agnolucci, P., Blackstock, J., Byass, P., Cai, W., et al. 2015. Health and climate change: policy responses to protect public health. Lancet, **386**(10006): 1861–1914. doi: 10.1016/S0140-6736(15)60854-6. PMID: 26111439.

Watts, N., Amann, M., Arnell, N., Ayeb-Karlsson, S., Belesova, K., Boykoff, M., et al. 2019. The 2019 report of The Lancet Countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate. Lancet, **394**(10211): 1836–1878. doi: 10.1016/S0140-6736(19)32596-6. PMID: 31733928.

Wenzel, G.W. 2009. Canadian Inuit subsistence and ecological instability — if the climate changes, must the Inuit? Polar Res. **28**(1): 89–99. doi: 10.3402/polar.v28i1.6103.

White, S.C. 1996. Depoliticising development: the uses and abuses of participation. Dev. Pract. **6**(1): 6–15. doi: 10.1080/0961452961000157564.