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Flynn\_Scenario\_Supplementary data

Table 1 Definition of key terms

| <b>Search term</b>   | <b>Definition</b>  |
|----------------------|--|
| <b>Research</b>      | Gathering of data, information and facts in a systematic manner for the advancement of knowledge, and including activities which attempt to discover new knowledge, information, or new applications of existing knowledge (1).  |
| <b>Arctic</b>        | According to the Arctic Human Development Report boundary (2) this definition includes Alaska, Canada North of 60°N with the addition of northern Quebec and Labrador, all of Greenland, the Faroe Islands, Iceland, the northernmost counties of Norway, Sweden and Finland, and in Russia the Murmansk Oblast, the Nenets, Yamalo- Nenets, Taimyr, and Chukotka autonomous Okrugs, Vorkuta City in the Komi Republic, Norilsk and Igsrka in Krasnoyarsky Kray, and parts of the Sakha Republic closest to the Arctic Circle. |
| <b>Community</b>     | Community in this sense referred to a collection of interrelated stakeholders which had an intimate link to the research study site (3). E.g. Reindeer herders which utilized part of the study space in migration routes.   |
| <b>Adaptation</b>    | The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects (4)   |
| <b>Impacts</b>       | Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system (4)   |
| <b>Vulnerability</b> | The propensity or predisposition to be adversely affected (4)  |

Table 2 Search string terms used during systematic review

| <b>Concept</b>               | <b>Search string</b>   |
|------------------------------|--|
| <b>Participatory methods</b> | stakeholder* OR communit* OR "community-based" OR participat* OR "community-institution* relation*"  |
| <b>Scenario approaches</b>   | multidisciplinary* OR "focus group*" OR "knowledge co-production" OR "indigenous knowledge" OR "traditional knowledge" OR "multiple knowledge*" OR "future studies" OR "decision making" OR storytelling OR scenario* OR decision* OR "action learning" OR workshop* [added in January 2016 visuali* OR vision*] |
| <b>Climate change</b>        | "climat* change*" OR "global warming" OR "sea-level rise" OR "sea-level change" OR "sea ice" OR "permafrost degradation" OR "greenhouse gas*" OR "global emissions" OR "extreme weather" OR "temperature rise"   |
| <b>Arctic</b>                | 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*   |
| <b>Note that for Google search shortened string was needed due to limited search function</b> |  |
| <b>Google scholar search string</b>   | (participation OR community) (“focus group” OR “future studies" OR storytelling OR scenario OR decision OR "action learning" OR workshop OR vision) ("climate change" OR “global warming”) (circumpolar OR polar OR arctic OR Inuit) |

Table 3 Inclusion and Exclusion Criteria

| <b>Inclusion</b>  | <b>Exclusion</b>  |
|---|---|
| English language  | Non-English language  |
| Available online between January 2000-April 1 <sup>st</sup> 2016  | Pre-2000  |
| Must be linked to an Arctic community, Arctic boundary was defined according to the Arctic Human Development Report (2004)            | Only non-Arctic regions or communities discussed  |
| Empirical research from peer reviewed and grey literature: Government documents, NGO and independent research, Conference proceedings | Book reviews, systematic reviews, meeting minutes, legal declarations, funding applications |
| Focus on climate change impacts, adaptation or vulnerability (IAV)  | Non-climate change IAV focus, e.g. national security focus                                  |
| Use of scenarios, visioning, or projections, in order to discuss future vulnerability, impacts or adaptation strategies               | Not forward looking, for example, a collection of historical data and observations          |
| Includes community participation  | No participation of community members   |
| Consideration of the human dimensions of climate change   | Solely biophysical focus, no consideration of socio-economic impacts                        |

Table 4 Data extraction questionnaire used in review process

| <b>Theme</b>                    | <b>Questions</b>                 | <b>Potential answers</b> |
|---------------------------------|----------------------------------|--------------------------|
| <b>Key document information</b> | Title<br>Authors<br>Document URL | Open ended               |

|                                    |   |   |
|------------------------------------|---|---|
| <b>Basic trends</b>                | Date<br>Where does the study take place?<br><br>Origin of first author<br><br>Type of document  | Year<br>List of countries<br><br>University, Government, Not-for-profit organization<br><br>Journal article, Report, Website, Book, Conference proceeding Thesis  |
| <b>Methodology</b>                 | Were scenarios forecasting or backcasting?<br><br>Were climate projections utilized in scenario creation?<br><br>Which stages of the PSP process were completed? Was community participation evident?<br><br>What is the participation rating?  | Forecasting or backcasting<br><br>Yes or no<br><br>Stage 1: Context, Stage 2: Identification of key trends, Stage 3: Scenario creation, Stage 4: Scenario review/feedback, Stage 5: Option identification, Stage 6: Option rating<br><br>High (completion of 5 or more steps in a participatory way), Medium (completion of 3-4 steps in a participatory way), Low (completion of 2 or less steps in a participatory way)                     |
| <b>Utilization of PSP approach</b> | Which environmental drivers were used to create the scenarios?<br><br>Which socio-economic drivers were used to create the scenarios?<br><br>Which sectors were explored during the scenario process?<br><br>Is there clear evidence of traditional knowledge (TK) being used in the case | Changes in: Weather patterns, Temperature or precipitation, Generic climate, Wildlife and vegetation, Oceans and coasts, Freshwater availability, Permafrost<br><br>Changes in: Economy, Traditional activities, Health and Wellbeing, Transport and infrastructure, Government policy, Other<br><br>Traditional livelihoods, Resource management or extraction, Health, Community planning, Shipping routes, Tourism, Other<br><br>Yes or no |

Table 5 Overview of how GCM and climate projections were utilized in reviewed studies (n=25)

| Authors   | How was climate change incorporated?   |
|---|--|
| ACIA  | Used SRES scenario B2 for most of the discussed impacts (this projection falls slightly below the middle range of future emissions. B2 is the basis for all climate maps in the report. Occasionally A2 (which falls slightly above middle of SRES range) was used but it is outlined when this is done. Five climate models were used CGCM2, CSM_1.4, ECHAM4/OPYC3, GFDL-R30_c & HadCM3.  |
| Bergström, I., Mattsson, T., Niemelä, E., & Vuorenmaa, J.             | Climatic models from the Finnish Meteorological Institute. Included mapped data using SRES > projected annual mean temperature change (8C) in northern Europe from 1971–2000 to 2020–2049, computed as the 19-model mean response to the A1B emission scenario   |
| Berman, M., & Kofinas, G.   | Global Circulation models were used but the specific scenarios weren't discussed in the paper. These projections were then fed into the overall model which was used to create a baseline. Climate projections influenced caribou herd population and vegetation patterns. Additionally, local knowledge (through interviews and mapping) was also used as a baseline to consider herd behaviour in past warm winters. Climate change was expected to impact herd migration and decrease heard size.   |
| Bringham, L.  | Used projections from the (ACIA, 2004; IPCC; AMSA 2009; and ACCESS projections for European Arctic, 2014)  |
| Carlsen, H., Dreborg, K. H., & Wikman-Svahn, P.                       | The climate scenario was based on the climate modelling of the Swedish Meteorological and Hydrological Institute (SMHI, 2011). Starting with a global climate model (ECHAM4/OPYC3), SMHI performs calculations with finer resolution over Europe using the regional climate model RCA3. The heat wave scenario was constructed as follows. If for example the minimum temperature in Paris on a particular date during the heat wave of 2003 was 3 standard deviations above the average in Paris, then we assumed a corresponding temperature anomaly over Umeå with a minimum temperature that was 3 standard deviations above the projected climate in Umeå in the year 2030. |
| Ernst, K. M., & van Riemsdijk, M.                                     | Used SNAP data. SNAP uses Global Climate Models to create regional-scale projections for Alaska and the Arctic. SNAP then creates three temperature and precipitation projections for every month of every year until 2100.  |
| Hennessey, R. Käyhkö, J., Horstkotte, T., Kivinen, S., & Johansen, B. | Climate projections were based on the B1 and A1B emission scenarios prepared by the Intergovernmental Panel on Climate Change (IPCC) in their Special Report on Emissions Scenarios (SRES).  |
| Keskitalo, E. C. H.   | Projected temperatures for 2070 are determined through use of 17 GCMs (CMIP5)<br>The statements regarding climate change were derived from a literature survey including international (IPCC), regional (IASC), national (SWECLIM for Sweden, RegClim for Norway and SILMU for Finland) projections as well as the projections found in international and national research programmes, and impacts and scenario   |

| Authors  | How was climate change incorporated?  |
|--|---|
| Keskitalo, E. C. H., & Kulyasova, A. A.  | literature in general. For the purpose of stakeholder interaction, the focus within projections was placed on broad trends such as a more temperate climate with delayed autumn and milder, shorter winters with increased precipitation and a warmer, possibly drier summer.   |
| Kvalvik, I., Dalmannsdottir, S., Dannevig, H., Hovelsrud, G., Ronning, L., & Uleberg, E. | The “if-then” statements regarding climate change were derived from a literature survey including international (IPCC), regional (IASC), national (SWECLIM for Sweden, RegClim for Norway and SILMU for Finland) projections as well as the projections found in international and national research programmes, and impacts and scenario literature in general. For the purpose of stakeholder interaction, the focus within projections was placed on broad trends such as a more temperate climate with delayed autumn and milder, shorter winters with increased precipitation and a warmer, possibly drier summer. |
| Lovecraft, A. L., & Eicken, H. (Eds.).   | At the end of the meetings the participants were presented with downscaled projections for future climatic variables, developed for each municipality by the Norwegian Meteorological Institute. These showed historical and projected changes in temperature, growing seasons, precipitation and snow conditions. The projections are based on emission scenario: IS92a; AOCM: ECHAM3/OPYC3 GSDIO; RCM: HIRHAM4  |
| Merten, A. A., Winters-Staszak, Z., & Kinner, N. E.                                      | Uses the ACIA work, these expected projections of warming feed into the scenarios created through the reduction in sea ice which is expressed in the scenarios as increased shipping access   |
| Mettiäinen, I.   | The reasoning behind the creation of emergency response scenarios for oil spills is linked to the projected impacts on shipping of climate change as reported in Arctic Shipping scenarios.   |
| The Municipal Corporation of the City of Iqaluit   | Used projections provided by the Finnish Meteorological Institute   |
| Ogden, A. E., & Innes, J. L.   | The main focus of the study was to collect information and input from community members. However, the document also summarised the current literature available for Iqaluit and that information included a number of downscaled scenarios created from GCMs developed for the city.  |
| Pearce, T., Ford, J. D., Caron, A., & Kudlak, B. P.                                      | Participants were provided with climate normals and scenarios of climate change for the region obtained from Environment Canada’s Weather Office and Climate Change Scenarios Network. There are 32 climate scenarios available for the southern Yukon. To represent the range of possible future conditions, the 32 scenarios were ranked from lowest to highest according to the change in annual temperature and precipitation. The lower and upper estimates of future change that were used were the 4th and 29th ranking respectively.  |
| Pogodaev, M., & Oskal, A.  | CCCSN (2009) Ensemble scenarios for Canada, 2009. Produced by Mean change in air temperature (degrees C) in Paulatuk region from (1961–1990) to (2041–2070) from the Canadian Climate Change Scenarios Network. Low, medium, and high emissions scenarios are presented for annual, fall, winter, spring and summer time.   |
| Scenarios Network for Alaska + Arctic Planning   | Unclear how well the projections were integrated into the actual scenario creation, but there was clear discussion of the IPCC scenario projections during the discussion and presentation workshop sessions. SNAP uses: CMIP3 model outputs from the IPCC’s (AR4) - Scenarios: 20c3m, B1, A1B, A2 & CMIP5 model outputs from (AR5) - Scenarios: Historical and RCPs 4.5, 6.0, 8.5 These are downscaled to between 2kms or 771m. GCM output variables of surface temperature and precipitation were downscaled via the delta method   |

| Authors  | How was climate change incorporated?  |
|--|---|
|  | using PRISM 1961–1990 2 km resolution or 1971–2000 771 m resolution climate normals as baseline climate across three future climate scenarios (B1, A1B, A2).  |
| Scenarios Network for Alaska + Arctic Planning   | As above  |
| Scenarios Network for Alaska + Arctic Planning   | As above  |
| The University of Alaska Fairbanks   | Downscaling and hindcasting of climate data for Alaska. Unable to find specific models used.  |
| Turunen, M. T., Rasmus, S., Bavay, M., Ruosteenoja, K., & Heiskanen, J.                                | Based on GCM CMIP3 with A1B greenhouse scenarios from IPCC.   |
| Tyler, N. J. C., Turi, J. M., Sundset, M. A., Bull, K. S., Sara, M. N., Reinert, E., ... Corell, R. W. | The projected temperature and precipitation is downscaled from the ECHAM4/OPYC3 global climate model, run with the IS92a emission scenario. To 2050.  |
| Wesche, S. D., & Armitage, D. R.   | Synthesis of existing research on climate change impacts, trends and projections in the North. A summary of past (1950-present) and anticipated future (2050 and 2100) climate change-related trends was collated from studies focused on Arctic and/or sub-Arctic regions and more specifically on the Mackenzie Basin and/or SRD. Projections came from ACIA (see ACIA section for further details) |

Table 6 Overview of how climate change was incorporated by those studies which did not use GCMs or climate projections (n=18)

| Authors   | What did they do instead to incorporate climate change?  |
|---|--|
| Altaweel, M. R., Alessa, L. N., & Kliskey, A. D.          | Forecasting Environmental Resilience in Arctic Landscapes (FERAL) is a modeling and simulation tool that aims to capture social–ecological dynamics at multiple spatiotemporal scales. The model was run for scenarios of 10, 30 and 100 years. For current hydrological processes, they applied a Metropolis-Hastings Markov algorithm that estimates water volume and/or discharge for each day using past data from water bodies, they also spoke to people in the community to collect baseline data on who used certain water sources and their perceptions of water availability. An agent-based model was used to simulate local behaviour. |
| Beach, D. M., & Clark, D. A.                              | Participants created scenarios based on an axis with opposite sentiments at each end. E.g. High cumulative impacts to low cumulative impacts   |
| Chapin, F. S., Knapp, C. N., Brinkman, T. J., Bronen, R., | Climate or environmental impacts were focused on future adaption to current experienced impacts E.g. Flooding and coastal erosion.   |

| Authors   | What did they do instead to incorporate climate change?  |
|---|--|
| Collaborative for Advanced Landscape Planning   | Used previous hazard map for the area based on current landscape hazards. Used these to propose scenarios where current hazard areas would be avoided in future community development projects.  |
| Douglas, V., Chan, H. M., Wesche, S., Dickson, C., Kassi, N., Netro, L., & Williams, M. | Scenarios and adaptation options were created through focus groups and were based on local observations of recent changes in traditional food sources and availability. Adaptation and coping strategies were already being utilized in the community.   |
| Forbes, B. C.   | Current in-situ and historical climate data was used as model input.   |
| Furgal, C., & Seguin, J.  | Observed environmental changes and their impacts were used to determine current and future adaptation. Focus groups and PRA approaches were used. This data was compared to scientific sources but future climate projections weren't considered.  |
| Government of Manitoba, & University of Winnipeg.                                       | Climate change specifics were not given, nor were any scientific or observed impacts referred to. However, climate change was discussed in the vision as providing opportunities for longer shipping seasons and as providing challenges in terms of sea level rise and permafrost impacting roads, and increasing weather unpredictability. Not sure where the data came from though for those impacts to be determined.  |
| Hanssen-Bauer, I.   | Long term historical data on local weather conditions, (temperature, precipitation, snow precipitation/cover/depth) at selected sites at reindeer pastures. Herders' description of regional variation in the types of weather that influence snow conditions in ways important for reindeer herding. Long series of meteorological data from Finnmark and Salekhard Yamal Nenets AO. Using this data, a GIS can be used to develop advanced interpolation techniques that greatly improve the spatial description relative to the original data or standard interpolation techniques. |
| Harper, S. L., Edge, V. L., & Willox, A. C.   | Observed environmental changes and their impacts were used to determine current and future adaptation.   |
| Hawley, M., Booth, P. I., Foster, D., Foster, D., Norton, R., Sage, R., ... others.     | Community members provided data through storytelling, photo-voice and through questionnaires, in-depth interviews and focus groups.  |
| Hovelsrud, G. K., Dannevig, H., West, J., & Amundsen, H.                                | Visioning exercise is based on some hazard assessments for current erosion and flooding risks and community observations.  |
| Johnson, K., Solomon, S., Berry, D., & Graham, P.                                       | Observed environmental changes and their impacts were used to determine current exposure-sensitivity and future adaptation. Local experts from the community discussed observed climate trends and discussed coping strategies.  |
|   | Climate change impacts were recognized by the authors to be likely to cause changes in sea level rise, extent of sea ice and duration and changes in storm severity and frequency. But these were not explicitly included in the projected erosion.  |

| Authors  | What did they do instead to incorporate climate change?  |
|--|--|
| Jones, C. E. ., Kielland, K. ., Hinzman, L. D. ., & Schneider, W. S. | The model created uses a baseline of observed variability and then increases this variability by a factor of 1, 2, and 3 times to consider different scenarios of increased variability.                   |
| Muir, D., Cooper, J. a. G., & Petursdottir, G.                       | This study used local climate observations of changes and impacts to discuss coastal issues  |
| NorthPortal  | This study uses observed environmental impacts as reported by locals across the forestry, tourism and herding sectors. It details impacts and adaptation strategies being employed there.                  |
| Stewart, E., Dawson, J., & Johnston, M.                              | Climate change projections aren't explicitly used but the assumption that climate change in the Arctic may increase cruise tourism is the basis of the research.   |
| van Oort, B.   | GCMs were not used however, presentations were given regarding expected climate change impacts in the area. SSP global scenarios were used to define the key drivers used in creating the local scenarios. |



Figure 1 Location of PSP studies identified in this review

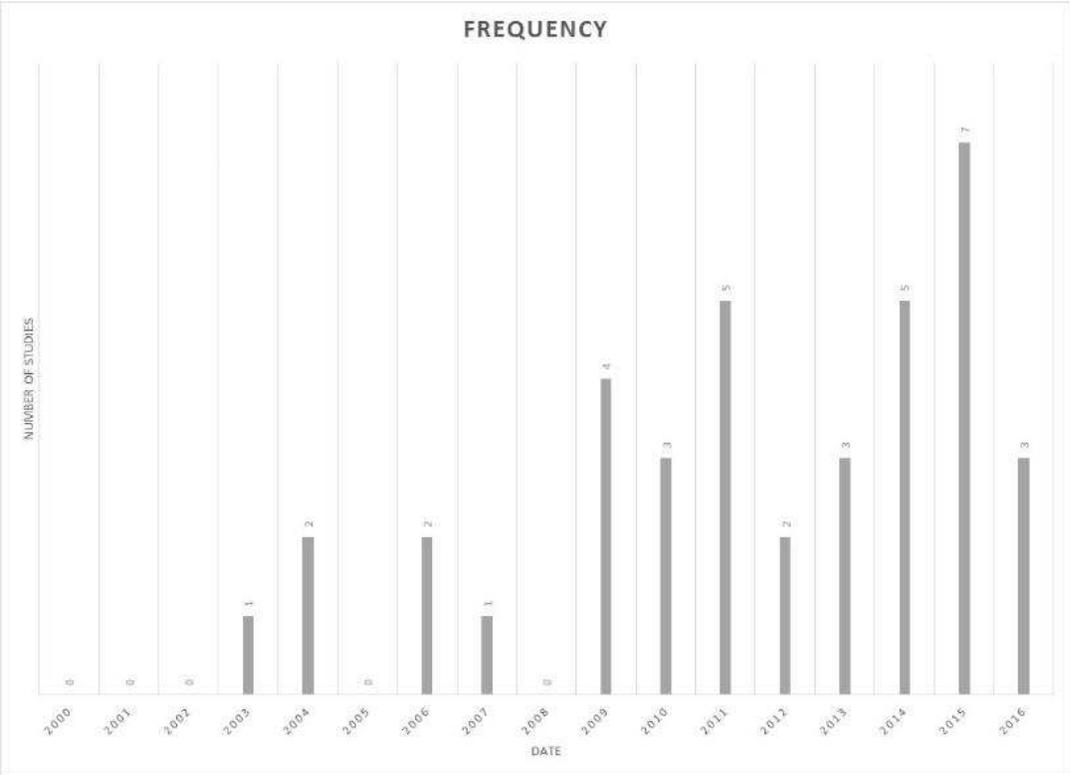


Figure 2 Frequency of studies over time. Note: Sources which had 'no date' (n=5) are not shown in this figure

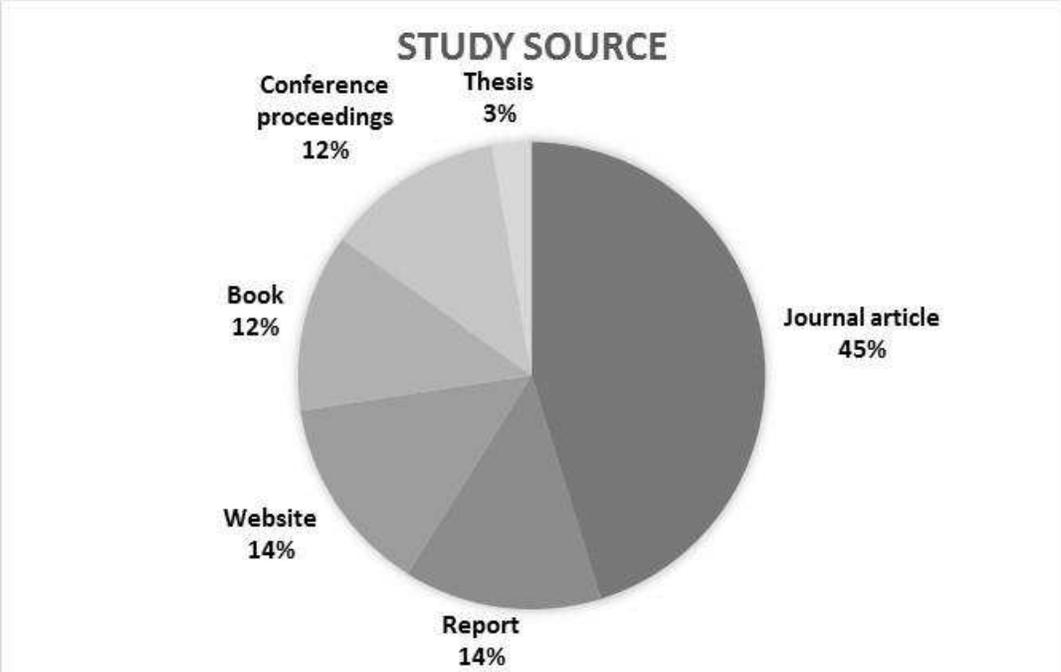


Figure 3 Literature sources for reviewed studies

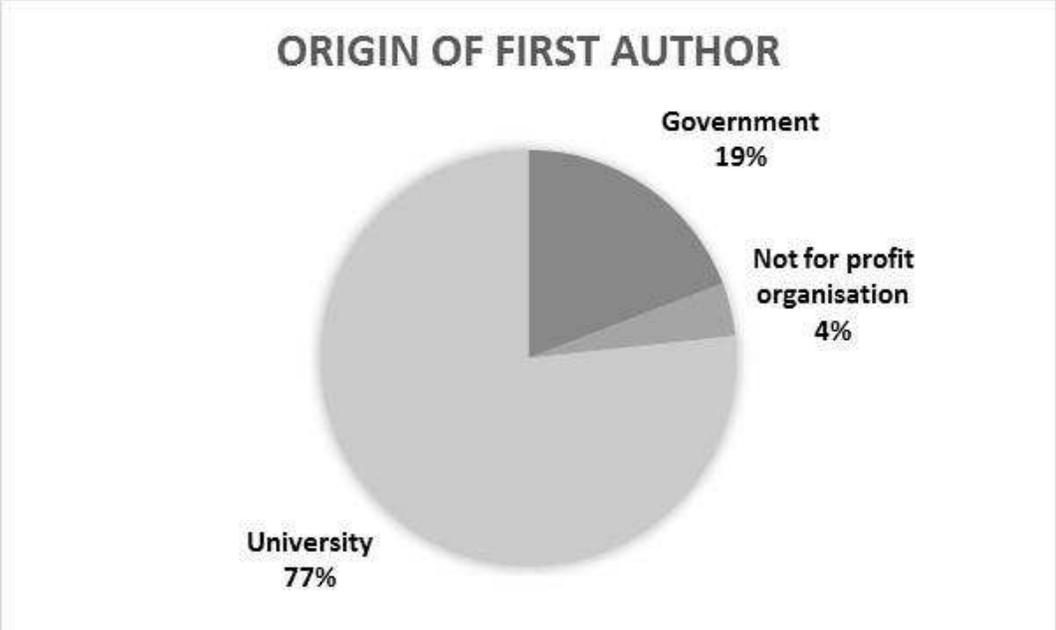


Figure 4 Origin of first author of study

Text box 1: Creating scenarios using the axis approach

**Text box 1: Creating scenarios using the axis approach**

In Beach and Clark (2015), we see the use of a scenario axis to help create future scenarios. The scenario axis was used as a way to group the key drivers of change identified during the participatory workshops. Eight potential scenarios were identified using these axis, however a number of them were deemed to be implausible by participants, in the end four scenarios were chosen. These four scenarios were given titles, visually illustrated and accompanied by a mock local newspaper article written as if taking place in October 2032.

**Table #:** Example of the use of the scenario axis in scenario creation. Based on work by Beach and Clark (2015). Each scenario created reflected one end of the three key axis, Land use, Changing Ecological-Social Interactions, and The Human Factor.

| <b>Scenario 1:<br/>Doom and<br/>Gloom</b>              | <b>Scenario 2:<br/>Slow boil</b> | <b>Scenario 3:<br/>A confused<br/>state</b> | <b>Scenario 4:<br/>Win-Win</b> |
|--|----------------------------------|---|--------------------------------|
| <b>Axis 1: Land use</b>                                |                                  |   |                                |
| High<br>cumulative<br>impact                           | High<br>cumulative<br>impact     | Low<br>Cumulative<br>impacts                | Low<br>Cumulative<br>impacts   |
| <b>Axis 2: Changing Ecological-Social Interactions</b> |                                  |   |                                |
| Unpredictable<br>change                                | Gradual<br>change                | Unpredictable<br>change                     | Gradual<br>change              |
| <b>Axis 3: The Human Factor</b>                        |                                  |   |                                |

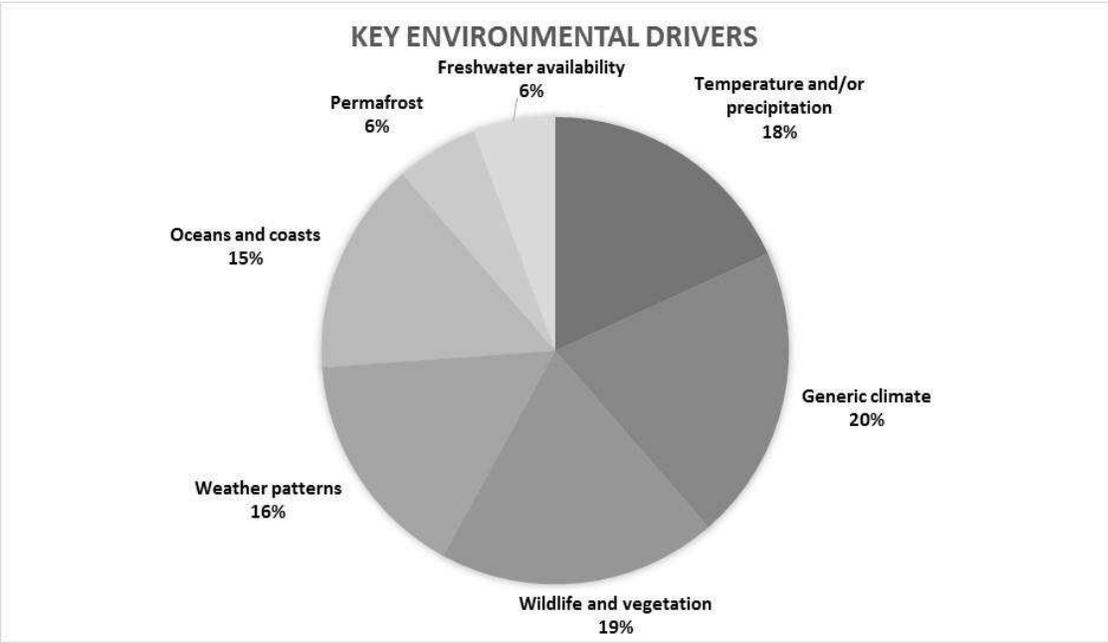


Figure 5 Key environmental drivers used to create Arctic scenarios

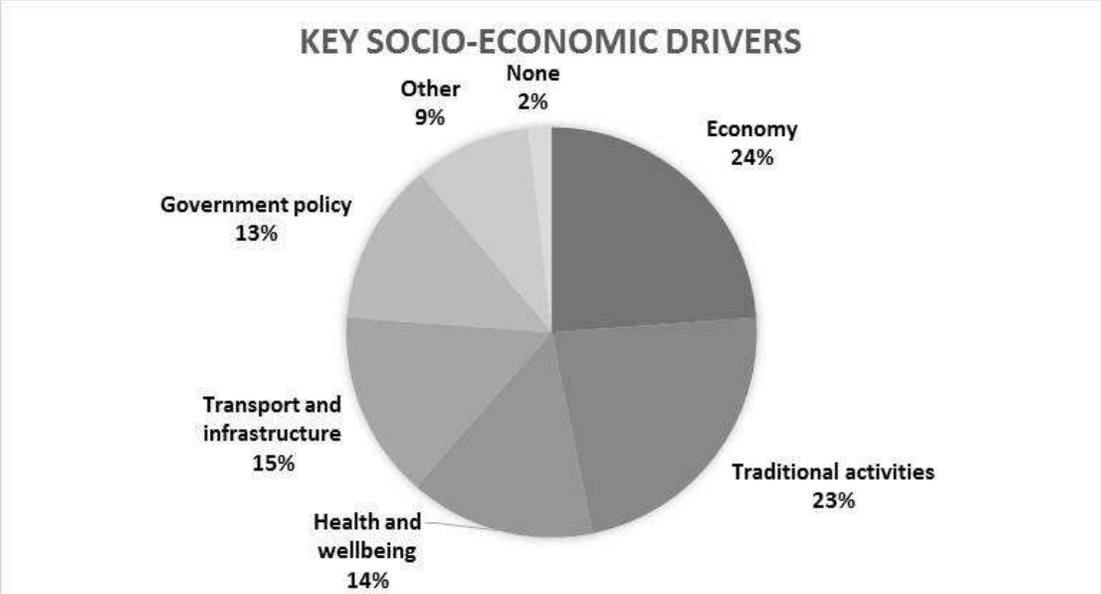


Figure 6 Key socioeconomic drivers used to create Arctic scenarios

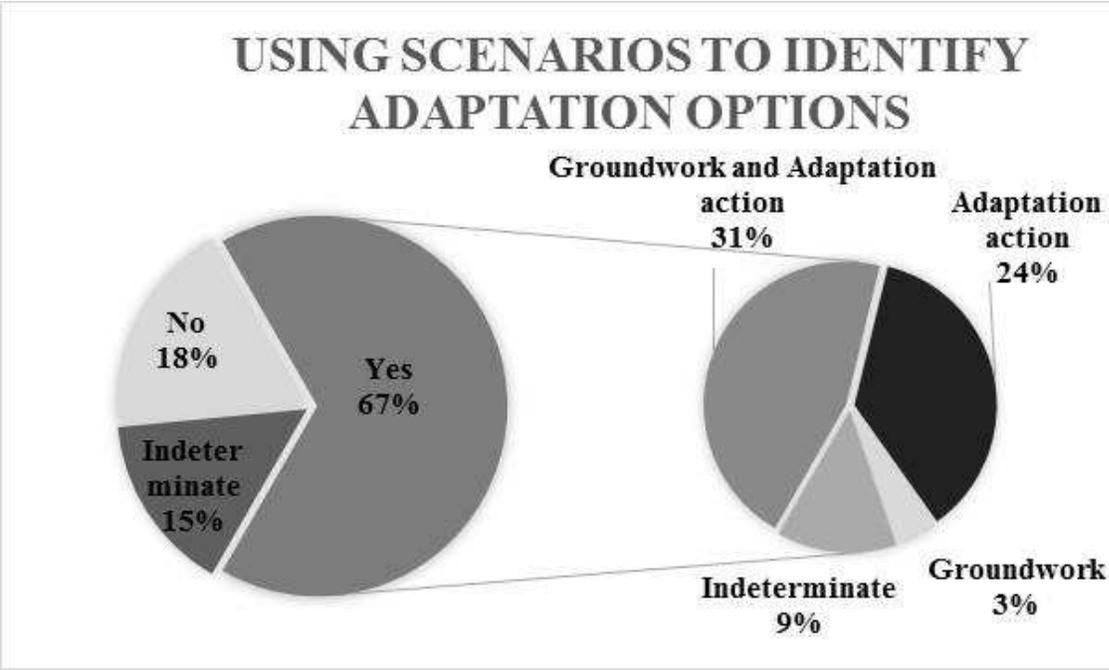


Figure 7 A breakdown of the percentage of studies reviewed which utilized scenarios to identify adaptation options. Followed by the breakdown of adaptation option stages suggested based on Lesnikowski et al. (2011) definitions.

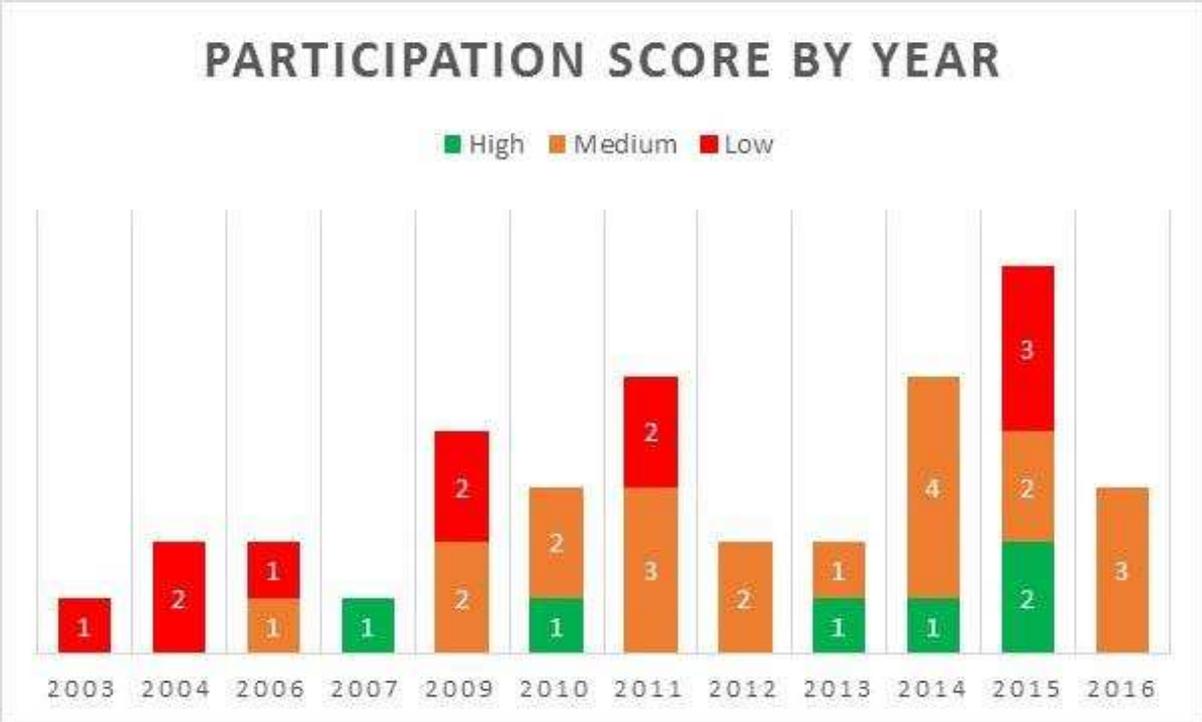


Figure 8 Participation score by year. High: participation in 5/6 stages, Medium: participation in 3/4 stages, Low: participation in 1/2 stages. Studies with no date were excluded from this graph (n=5). An additional 3 studies were excluded from this graph as it.

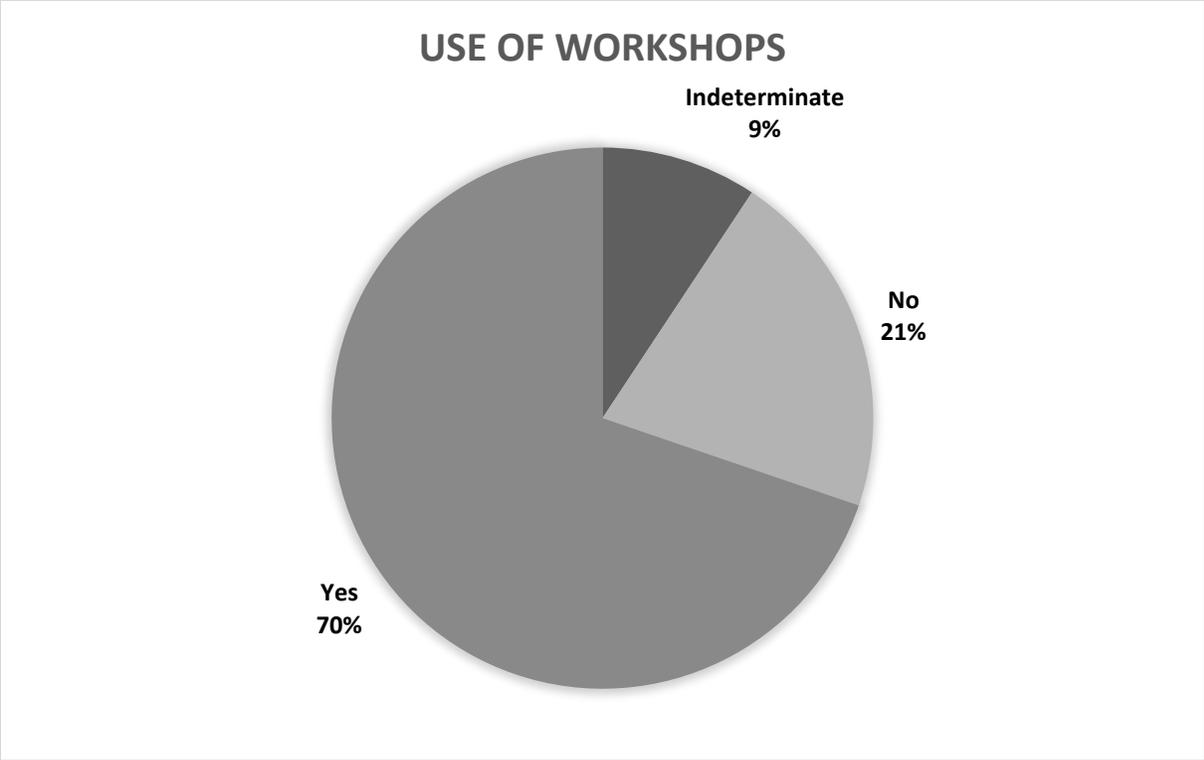


Figure 9 Utilization of workshops in reviewed Arctic studies

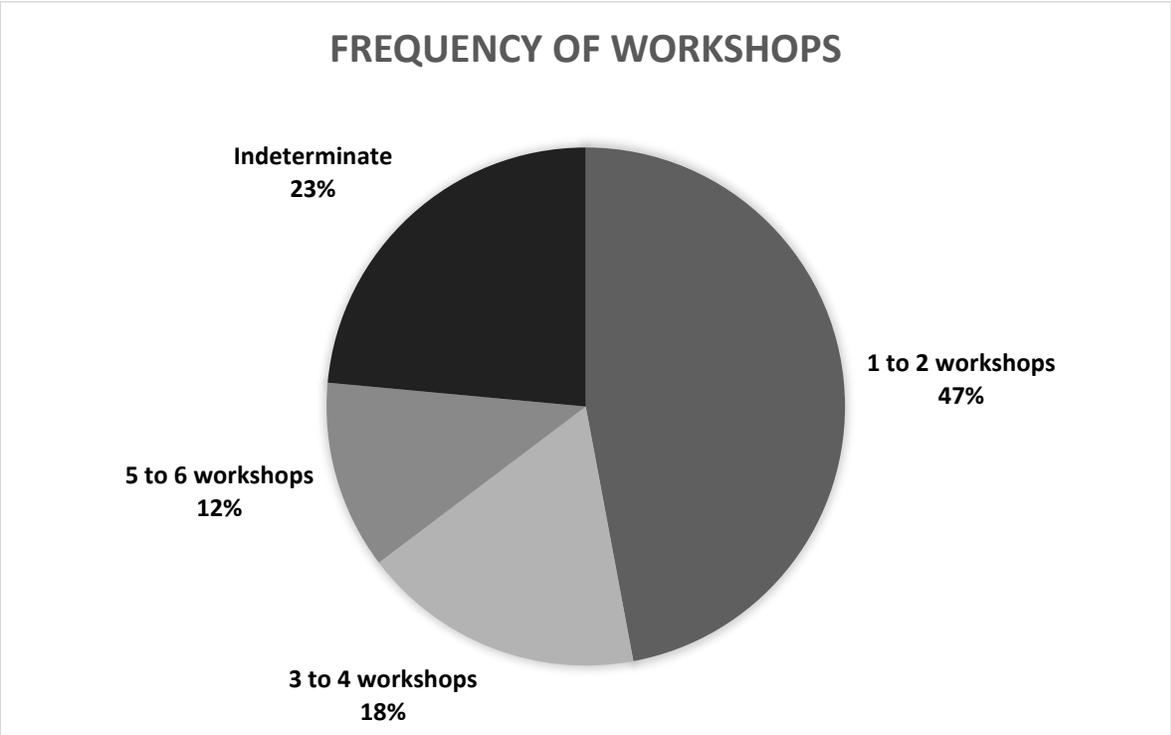


Figure 10 Number of workshops held in reviewed Arctic studies reporting the use of workshops

## BARRIERS TO EFFECTIVE PARTICIPATORY SCENARIO PLANNING

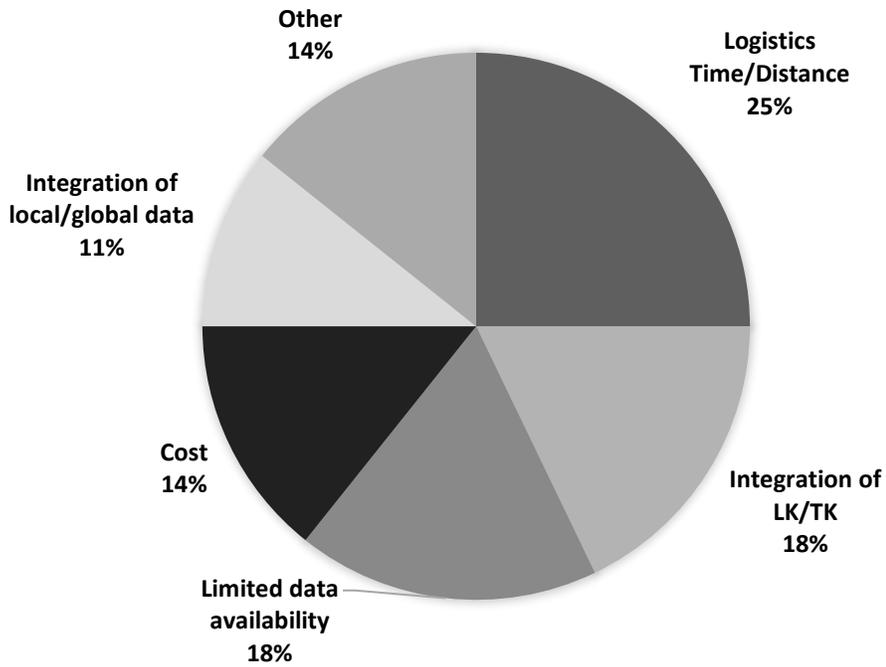


Figure 11 Identified barriers to effective participatory scenario planning in the reviewed Arctic studies