Institution: University of Sheffield

Unit of Assessment: 7 – Earth Systems and Environmental Sciences

Title of case study: Arctic ecosystems and climate change: informing ministers, policy, indigenous societies and education

1. Summary of the impact

The Arctic is undergoing faster rates of climate change than most other regions of the world, with major global consequences. Since the 1990s, Professor Callaghan and co-workers at Sheffield have been at the forefront of determining climate change impacts on Arctic ecosystems. This research has directly led to, and fed into, invited authorship and major co-ordination roles in the authoritative international synthesis reports on climate change impacts commissioned by the *Arctic Council* and the *Intergovernmental Panel on Climate Change* (IPCC). Through these reports our findings have been widely communicated to international policymakers, the media and society. Callaghan and colleagues have provided policy advice directly to ministers, ambassadors, climate negotiators, and other leaders through face-to-face meetings and presentations, and influenced policy debates at regional to international levels. They have actively engaged in knowledge-exchange activities with Arctic indigenous societies, which are improving those societies' strategies for adaptation to climate change. Through public lectures, the media and authorship of a commissioned textbook, the Sheffield research findings have increased public understanding and influenced the A-level Geography curriculum.

2. Underpinning research

The University of Sheffield became a leading contributor to Arctic research with the founding of the *Sheffield Centre for Arctic Ecology* by Callaghan in 1995. His group has provided vital early evidence of global change impacts in the Arctic by establishing, in the 1990s, the first field studies to simulate increased atmospheric CO_2 concentrations and increased UV-B irradiance (due to stratospheric ozone depletion) [**R1**]. These studies were accompanied by among the first field manipulations of warming, nutrient enrichment, and increased precipitation on Arctic ecosystems [**R1**, **R2**]. From 2006, Phoenix and Callaghan have conducted further pioneering experimental studies that have been paradigm-shifting in revealing the severity of impacts of extreme winter warming events on Arctic vegetation caused by the loss of insulating snow cover [**R3**].

These world-leading long-term studies (all of which are ongoing) have advanced understanding of Arctic ecosystem responses to global change [**R4**] and have changed scientific opinion of perceived global change threats, helping to define the key research priorities for policymakers and international funding agencies. The summer warming simulation studies [**R2**] provided early predictions of the increase in plant biomass production and shrub expansion now occurring in the Arctic – which has important implications for ecosystem greenhouse gas fluxes and grazing management by indigenous societies. Against these trends, however, Callaghan and Phoenix have proven that episodic extreme winter warming events are particularly damaging to vegetation [**R3**], so changes in snow and ice cover are now of major concern for the future functioning of Arctic ecosystems. Callaghan's recent work, leading a large international team of experts, predicts that snow cover duration will decrease by about 10–20% over much of the Arctic by 2050, with the largest decreases expected to take place over Alaska and northern Scandinavia (30–40%) [**R5**].

Such changes will have far-reaching consequences for the climate system, hydrology, ecology and human activities. In contrast, the group's studies of UV-B radiation, increased CO_2 and precipitation, which were of major concern in the 1990s, proved these variables to be much less serious threats [**R1, R2**]. Sheffield research has therefore helped determine the most important global change threats, and influenced international research priorities for scientists, policy makers and funding agencies, e.g. Norwegian large initiatives (2012: EWWA (Extreme Winter Warming in the Arctic and its biological effects) and WINNIT (extreme weather and pollution effects on plants).

Callaghan was one of the first scientific leaders to include indigenous peoples' concerns in Arctic climate change research, and engage them directly in knowledge exchange. He collaborated with members of the Sami Parliament and Sami Language & Culture Centre in Norway to benefit from the traditional ecological knowledge of reindeer herders in relation to the shifting timing and patterns of snow and ice cover [**R6**].

This work has attracted much media, public, political and indigenous peoples' attention, and established Callaghan and Phoenix as leading experts in the field of Arctic ecology and climate change. They have played major roles in communicating their research findings to international policymakers, the media, indigenous groups, and wider society, influencing global awareness of the particular threats posed by Arctic climate change, and adaptations of indigenous populations to these threats. For his outstanding contributions to Arctic Science and society, Callaghan was awarded the Swedish Society for Anthropology and Geography's *Vega Gold Medal* in 2011, and *The Polar Medal* for services to the Arctic by H.M. Queen Elizabeth in 2013. Callaghan and Phoenix have published more than 230 peer reviewed journal articles and book chapters on their Arctic research and these publications have received over 8,000 Web of Knowledge citations.

3. References to the research [* = References that best indicate the quality of the research]

R1* Phoenix, G.K., Gwynn-Jones, D., Callaghan, T.V., Sleep, D., Lee, J.A. (2001). Effects of global change on a sub-Arctic heath: effects of enhanced UV-B radiation and increased summer precipitation. *Journal of Ecology,* 89:256-267. doi: 10.1046/j.1365-2745.2001.00531.x . **69 citations** (Scopus)

R2* Press, M.C., Potter, J.A., Burke, M.J.W., Callaghan, T.V., Lee, J.A. (1998). Responses of a subarctic dwarf shrub heath community to simulated environmental change. *Journal of Ecology,* 86: 315-327. doi: 10.1046/j.1365-2745.1998.00261.x **169 citations** (Scopus)

R3* Bokhorst, S.F., Bjerke, J.W., Tommervik, H., Callaghan, T.V., Phoenix, G.K. (2009). Winter warming events damage sub-Arctic vegetation: consistent evidence from an experimental manipulation and a natural event. *Journal of Ecology,* 97:1408-1415. doi: 10.1111/j.1365-2745.2009.01554.x **55 citations** (Scopus)

R4 Callaghan, T.V., *et al*. (2010). A new climate era in the sub-Arctic: Accelerating climate changes and multiple impacts. *Geophysical Research Letters,* 37: L14705. doi: 10.1029/2009GL042064 **55 citations** (Scopus)

R5 Callaghan, T.V., *et al*. (2011). The changing face of Arctic snow cover: a synthesis of observed and projected changes. *Ambio,* 40 (Supplement 1): 17-31 doi: 10.1007/s13280-011-0212-y **13 citations** (Scopus)

R6 Riseth, J.A., Tommervik, H., Helander-Renvall, E., Labba, N., Johansson, C., Malnes, E., Bjerke, J.W., Jonsson, C., Pohjola, V., Sarri, L.E., Schanche, A., Callaghan, T.V. (2011). Sami traditional ecological knowledge as a guide to science: snow, ice and reindeer pasture facing climate change. *Polar Record,* 47:202-217 doi: 10.1017/S0032247410000434 . **12 citations** (Scopus)

4. Details of the impact

Provision of authoritative guidance to international policymakers

Our world-leading research into the impacts of climate change and stratospheric ozone depletion on Arctic ecosystems has fed directly into the authoritative international assessment reports commissioned for policymakers and scientists. Callaghan made major contributions to the *Arctic Climate Impact Assessment* (ACIA 2005) [**S1**] commissioned by the Arctic Council (ministers of the eight Arctic nations). He was a member of the Assessment Integration Team, the liaison for the *Decision Makers' Summary*, a contributing author to three chapters, and lead author of the *Terrestrial Ecosystems* chapter which highlighted the important findings of our long-term field experiments [**R1, R2**]. This led to Callaghan being a lead author for the *Polar Regions* chapter [**S2**] (which built on ACIA 2005) in the *Intergovernmental Panel on Climate Change* 4th Assessment Report (IPCC 2007). This won the Nobel Peace Prize with the authors honoured "*for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change*" (NobelPrize.org). ACIA 2005 and IPCC 2007 have been the main internationally agreed policy-focussed documents on Arctic and Global climate change until 2011 and 2013, respectively.

Recent work on impacts of extreme winter warming on vegetation, and pan-Arctic changes in snow cover [**R3, R4, R6**] has fed directly into the group's major contributions to *Snow, Water, Ice and Permafrost in the Arctic* (SWIPA 2011) [**S3**]. This is the Arctic Council's follow-up to ACIA and contributed to the 5th IPCC report released in Sept. 2013. The commissioning of SWIPA reflects the increasingly serious concerns about climate change impacts on the Arctic cryosphere, and Sheffield research has played a leading role in understanding some of these threats. Callaghan

was a core member of the SWIPA Integration Team, a co-ordinating lead author on part of the *Cross-Cutting Scientific Issues*, and scientific liaison for the *Decision Makers' Summary.* He was co-ordinating lead author on the chapters *Changing Permafrost and its Impacts* and *Changing Snow Cover and its Impacts*, to which Phoenix contributed as an author – as a result of the crucial new insights provided by their research [**R3,R4]** and its implications for indigenous societies **[R6]**.

Stimulating and influencing policy debate

The ACIA [**S1**], IPCC [**S2**], and SWIPA [**S3**] reports have transformed political and public awareness of climate change and its impacts in the Arctic. ACIA and SWIPA are the standard references for policy makers needing to understand global change and its impacts in the Arctic region. The Arctic Council noted *"with concern the impacts documented by the ACIA"* and *"acknowledge that such findings ... will help inform governments as they implement and consider future policies on global climate change"* (Arctic Council's policy document accompanying the ACIA, 2005). US Secretary of State Hillary Clinton joined her counterparts at the 2011 Arctic Council Ministerial Meeting, in welcoming the release of SWIPA: "*a major climate science report on the state of the frozen Arctic*" assessing *"how changes to human activities and ecosystem services within the cryosphere...will impact the Arctic ecosystem as well as people living within the Arctic and elsewhere in the world*" [**S10**].

Callaghan and colleagues have also directly informed and stimulated policy debate from their research findings through face-to-face meetings and platform presentations to ministers, ambassadors, climate negotiators, religious leaders and royalty, including showing visitors to the Abisko Research Station their long-term field experiments and their effects. For example, Callaghan hosted (July 2009), at the Abisko Research Station where he was Director, a meeting of twenty-seven Ministers of the Environment (including David Miliband) that was also attended by fifty ambassadors and climate negotiators [**S4**]. At this meeting Callaghan provided policy guidance on climate change impacts, including effects of loss of snow cover based on his research [**R1-R3**] in preparation for their negotiations at the United Nations Framework Convention on Climate Change (UNFCCC) conference (Copenhagen, December 2009). On a separate occasion, the EU climate negotiating committee (Coreper) was hosted, briefed and shown the Sheffield-led experiments by Callaghan (again at Abisko) prior to their negotiations in Copenhagen. Findings from SWIPA were presented to international ministers and climate negotiators at the UNFCCC Copenhagen conference (2009), and by Callaghan at the UNFCCC Durban conference (2011), including important new evidence of the increasing loss of winter snow cover [**R5**] and its impact on vegetation [**R3**]. Callaghan has also advised on Arctic and climate change policy by invitation to round-table discussions at four Royal Colloquia (2003, 2005, 2011 and 2012, organised by the King of Sweden). Most recently (Oct 2013), Callaghan, in his capacity as lead author of the *Polar Regions* chapter in IPCC 2007, advised on sustainable use of natural resources in polar regions at a strategic level conference organised by MP James Gray [**S5**].

Knowledge-exchange for adaptation to climate change by indigenous peoples

Dissemination of research, contributions to the major international synthesis reports and knowledge exchange with Arctic indigenous communities has allowed Sheffield scientists to improve the way indigenous Arctic societies adapt to climate change. This is exemplified by the impact on changing practices of reindeer herding societies:

> "*the ACIA, the polar chapter of IPCC, and SWIPA have advised the international reindeer herders of ongoing and future Arctic changes*"; "*these publications have been instrumental in preparing a knowledge foundation for circumpolar reindeer herding societies for understanding and adapting to climate change and globalization, and has been instrumental in reindeer herders planning for future sustainable communities*" [**S6**].

Callaghan played a leading role in this engagement with indigenous people, including his invitation of a Sami social anthropologist to be a lead author on the *Terrestrial Ecosystems* chapter of ACIA, and a Sami reindeer herder and economist to be a lead author on the *Changing Snow Cover and its Impacts* chapter of SWIPA. "*Prof. Terry Callaghan was among the first scientific lead authors to include indigenous peoples' concerns and even indigenous co-authors*"; "*Callaghan has been instrumental to bridge the gap between natural science ... concerns of indigenous peoples and their ... traditional knowledge*" [**S7**]. Advice to the herders has been wide ranging, and includes the

direction not to burn forest killed by autumnal moth outbreaks because of the resulting loss of nitrogen. Callaghan's activities to draw on indigenous peoples' traditional knowledge to enhance scientific understanding [**R6**] have been widely recognized. His work has made "*significant contributions to the future sustainability of Arctic reindeer herding communities and thereby reindeer herding cultures*" [**S6**].

> "*For a long time, Professor Terry Callaghan ... has had a close cooperation with the County Administrative Board* [Norrbotten, Sweden] *... as well as the Sämi. This has had great impact on decisions regarding reindeer herding and nature conservation. Many decisions on local, regional and national level have been based on Prof. Callaghan's experiences and suggestions."* [**S8**]

Increasing public awareness and influencing education.

Callaghan's Arctic research has enhanced public understanding of Arctic climate change as evidenced by considerable international media attention. This includes a front-page summary and near full-page main report in Norway's leading daily, *Aftenposten* (19 October 2009) [**S9**], a full-page article in one of Sweden's top newspapers *Nyheter* (15 July 2009) and TV coverage in Sweden, Russia and Greenland. The research has featured in ACIA and SWIPA outreach films. The work has also significantly influenced secondary school education. At the request of the A-level Chief Examiner, Callaghan addressed teachers' conferences, leading to a focus on climate change impacts in the Arctic regions and its global consequences being placed on the Geography A-level syllabus. He was subsequently asked to be lead author on an A-level textbook, *Top Spec Geography: The Rapidly Changing Arctic* (published 2011) and has been asked to simplify this for primary schools.

In summary, the paradigm-shifting research led by Callaghan and Phoenix on climate change impacts on Arctic ecosystem functioning, and their engagement in knowledge-exchange for adaptation to climate change by indigenous peoples, has had major impacts on policymakers and the public in the UK and internationally. The research, and engagement in impact activities, has led directly to provision of authoritative guidance to UK and international policymakers both in formal reports and face-to-face briefings, increased public awareness of the issues through media coverage, outreach films and influencing the A-Level Geography curriculum and education through a school textbook.

5. Sources to corroborate the impact

S1 *Arctic Climate Impact Assessment ACIA* (2005), page ii, iv. http://www.acia.uaf.edu/PDFs/ACIA_Science_Chapters_Final/ACIA_Preface_Final.pdf

S2 IPCC (2007) Anisimov, O.A., Vaughan, D.G., Callaghan, T.V., *et al.* (2007) *Polar regions (Arctic and Antarctic).* In Parry, M.L., *et al.* (eds), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, pp 653-85.

S3 *Snow, Water, Ice and Permafrost in the Arctic (SWIPA): Climate Change and the Cryosphere* (2011). Arctic Monitoring and Assessment Programme (AMAP), Oslo. xii + 538 pp.

S4 Ulrika Barklund Larsson (2009), Swedish Ambassador, Chair of *Coreper I* (EU Permanent Representatives Committee). Letter of thanks to Callaghan. [Letter on file].

S5 James Gray MP (2013). Letter of invitation to Callaghan to participate in strategic level conference [letter on file].

S6 Johan Mathis Turio and Anders Oskal (2013). Joint Statement from The Secretary General, Association of World Reindeer Herders (the international NGO for twenty-four indigenous peoples of the Arctic that live by herding domesticated reindeer), and Executive Director, International Centre for Reindeer Husbandry [letter on file].

S7 Lars-Anders Baer (2013), Chair of the Working Group of Indigenous Peoples in the Barents Euro-Arctic Region. [letter on file].

S8 Per-Ola Eriksson (2013). County Governor, Norrbotten, Sweden (2003–12). [letter on file].

S9 *Aftenposten* – Norwegian newspaper (19 October 2009) Baer blir frostkadet av global appvarming, pp.1, 4.

S10 US State Department: Arctic Council Completes Major Science Report on the State of the Arctic Cryosphere: http://www.state.gov/r/pa/prs/ps/2011/05/163288.htm