

ESSAY

From concept to action: Driving impact through responsible research practices in the International Polar Year 2032–2033 *An early career perspective*

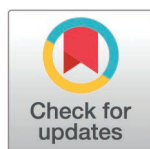
Samuel G. Hartharn-Evans¹*, Chloe Nunn², Amy Macfarlane^{1,3}, Natalia Banega⁴, Anna Belcher⁵‡, Radiance Calmer⁶‡, Svenja Holste⁷‡, Louise Mercer⁸‡, Ningning Sun^{9,10}, M. A. J. van Soest⁵, Zoe Wright^{5,10,11}

1 School of Geography and Natural Science, Northumbria University, Newcastle upon Tyne, United Kingdom, **2** Training, U.K. Polar Network, Cambridge, United Kingdom **3** Earth Observation, UiT The Arctic University of Norway, Tromsø, Troms, Norway, **4** Leadership, APECS Argentina, San Martín de los Andes, Neuquén, Argentina **5** UK Centre for Ecology and Hydrology, Lancaster, United Kingdom, **6** APECS RISE Working Group, APECS International, Tromsø, Troms, Norway **7** Bielefeld University, Bielefeld, Germany **8** Memorial University of Newfoundland and Labrador, St. John's, Canada, **9** Scott Polar Research Institute, Cambridge, United Kingdom **10** Arctic Centre, University of Lapland, Rovaniemi, Finland **11** Lancaster University, Lancaster, United Kingdom

* These authors contributed equally to this work.

‡ These authors also contributed equally to this work.

* sam.hartharn-evans@northumbria.ac.uk



OPEN ACCESS

Citation: Hartharn-Evans SG, Nunn C, Macfarlane A, Banega N, Belcher A, Calmer R, et al. (2026) From concept to action: Driving impact through responsible research practices in the International Polar Year 2032–2033 *An early career perspective*. PLOS Clim 5(10): e0001062. <https://doi.org/10.1371/journal.pclm.0001062>

Editor: Xun Zou, University of California San Diego Scripps Institution of Oceanography, UNITED STATES OF AMERICA

Published: October 8, 2026

Copyright: © 2026 Hartharn-Evans et al. This is an open access article distributed under the terms of the [Creative Commons Attribution License](https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Funding: This work was supported by the Natural Environment Research Council (through a United Kingdom and Japan Arctic Research Bursary to MAJS), which supported the PECR workshop at the Centre of Ecology and Hydrology, Bangor, UK. The funders had no role

Abstract

Regions at the poles are warming at rates two to four times higher than the global average, driving profound environmental, societal, and geopolitical changes. As Polar Early Career Researchers with careers extending into and beyond the 5th International Polar Year in 2032–2033, we have a responsibility to shape research practices that are impactful, ethical, and sustainable. We argue that current definitions of research impact often prioritize narrow, quantifiable metrics, overlooking cultural, environmental, and long-term consequences. Building on interdisciplinary workshops held in 2025 at the Polar Early Career World Summit (USA) and the Centre for Ecology and Hydrology (UK), this paper redefines research impact for polar science and presents tangible action for integrating responsible practices ahead of the next IPY. We outline priorities across three levels: 1) individual researchers, who should practice reflexivity, promote interdisciplinarity, and implement environmentally responsible methods; 2) regional and national institutions, which must provide equitable funding, training, and inclusive protocols; 3) international IPY planning bodies, which should strengthen communication, publish guidelines, and implement regulations to prevent exploitative practices. Our call to action emphasizes collaboration, transparency, and improved impact evaluation frameworks to ensure that polar research delivers

in the decision to publish or preparation of this manuscript. Other authors received no specific funding for this work.

Competing interests: The authors have declared that no competing interests exist.

societal and environmental benefits while minimizing unintended consequences. This vision begins now and extends beyond the IPY, offering a roadmap for responsible polar science.

1. Introduction

As Polar Early Career Researchers (PECRs) whose careers will span up to and beyond the 5th International Polar Year (IPY-5) in 2032–2033, it is vital that we both shape and engage in responsible research practices and steer the direction of polar research for the better. While the work of PECRs contributes to scientific breakthroughs and innovation it is necessary to investigate the extent and nuances of research impact in detail. Assessing the positive and negative impacts of science is typically limited by time, funding, institutional constraints, and know-how. Even with these barriers removed, the question “What is the impact of my research?” prompts many more questions, making it hard to know where to start. While the positive impacts of polar research should not be taken for granted, there is a need to consider how it can be made more widely relevant to society. Our career timelines will place us directly in leadership positions with the potential to decide on funding, priorities and strategies for polar research during the next IPY. Redefining the impact of research now, and creating the framework to incorporate responsible research practices from the outset, is necessary to shape the forthcoming IPY, which aims to “address urgent global challenges by advancing polar research” through coordinated efforts (see info box). By building experience with interdisciplinary teams, we can learn from each other, change perspectives and help reduce misunderstandings or translation problems. Such a vision is already built into the guiding principles of the IPY, which identify the need to foster international collaboration; encourage open data and open science; holistic, systemic approaches to research; produce actionable knowledge with direct societal relevance; commit to inclusive, diverse, and equitable research practices; ensure balanced involvement from both the Arctic and Antarctic; and co-design and co-produce research with multiple knowledge systems [1].

Recent workshops (Polar Early Career World Summit, Boulder, USA and a PECR workshop at the Centre of Ecology and Hydrology, Bangor, UK) have centred on the complex and multifaceted nature of research impact including direct and indirect influences, defining and measuring impact, timelines and communicating impact [2], and this authorship group came together as a result of these meetings. As an interdisciplinary group from within and outside academic institutions, in this document we present a vision of what the impact of polar fieldwork could look like in 2032, learning from wide-ranging interdisciplinary conversations and case studies. Our perspective is as an international group of PECRs in preparation for the IPY, and we present a full positionality statement at the end of this article. We expand on previous work [3,4] by asking how research impacts can be redefined, and eventually evaluated/measured.

The 5th International Polar Year (IPY-5, 2032–33) is a large-scale international programme responding to global challenges of rapidly changing polar regions. It coordinates and fosters collaboration between researchers, rightsholders, knowledge holders, communities, educators, organisations and countries “to produce urgently needed and actionable knowledge to more deeply understand global processes, support informed decisions and offer effective and implementable solutions” [1].

The IPY planning group consists of representatives of international organisations. Among providing over-all direction, it sets up task groups to work on specific issues.

Representatives of the International Arctic Science Committee (IASC), the Scientific Committee on Antarctic Research (SCAR), the World Meteorological Organization (WMO) and the International Science Council (ISC) form the IPY-5 Executive Committee.

The establishment of an IPY-5 International Coordination Office is planned for 2027, replacing the current Interim Secretariat.

National committees link national initiatives to international collaboration.

IPY-5 spans three phases: The planning phase (2021–25), the project phase (2026–33), as well as the legacy phase (2034+).

1.1 Why is research impact an important topic for polar researchers?

Regions of the poles are warming at 2–4 times the rate of other geographies and the resulting changes have global impacts [5,6]. Corresponding with these changes in climate are reductions in sea ice thickness and extent, decreases in permafrost and ice sheet loss, and changing habitats all directly impacting plants, wildlife and people [7,8]. Changes occurring in these regions have global consequences. This makes the Antarctic and Arctic crucial for climate change research, including forecasting and mitigation efforts, across numerous disciplines. Data-driven research, evidence and understanding can inform those in power to make decisions which support environmental and societal benefits across various scales from local and Indigenous Peoples to national governments and international bodies. High quality research in these regions has the potential to bring about important societal and environmental benefits.

However, this growing interest and need for polar research comes during a time when regions are facing heightened geopolitical pressures, access and commercial interests, much of which is driven by climate change [9,10].

Polar research activities are inherently resource intensive. Activities associated include, but are not limited to, field-work, training, attendance at workshops/conferences, use of different types of facilities (such as labs), remote sensing, computer simulations, and community and stakeholder engagement. These activities often require complex and carbon-intensive logistics, potentially producing economic, social, cultural, and environmental impacts. For funders to realise the social and environmental benefits of polar research, there must be evidence that the benefits of the research outweigh the economic costs.

In addition to the societal benefits of research, responsible research practices, such as addressing ethical concerns and assessing environmental impact should be adopted [11–13]. In the polar regions these considerations can be particularly important because polar environments are amongst the most fragile and pristine. In particular, in Antarctica the scientific community is the only permanent presence and operates under more permissive rules and regulations than tourism; the human impact of research on this environment is important to consider. The Arctic has been the home of Indigenous Peoples since time immemorial [14]. Yet, research is often conducted on Indigenous lands and in communities without sufficient engagement or collaboration making considerations of societal impact crucial for research of any discipline. Steps should be taken to increase equitable research processes and self-determination of Indigenous Peoples across the Arctic.

Polar research priorities are frequently driven by funding agencies and policymakers. Within some academic environments, this pursuit of quantifiable, societal benefit of research has led to a restricted definition of “research impact”. For example, the UK Economic and Social Research Council defines impact as “the demonstrable contribution that excellent research makes to society and the economy” [15] and is broadly applied across UK government funding. It neglects other potential forms of impact and potential adverse impacts. This institutional and policy-level movement towards exclusively

quantifiable assessment of societal benefits in a way that can be rewarded [16], drives research towards that which is likely to score highly on that country's metrics, changing the types of projects conducted, in particular marginalising non-mainstream research [17–19]. Acknowledging that biases exist which support research design benefitting funding and policy making agencies helps us recognise strengths and weaknesses of different research impact definitions. Whilst some funding agencies are beginning to align research priorities with guidance protocols (e.g. National Inuit Strategy on Research [20]) and Indigenous evaluation frameworks, it is our responsibility to ensure such research activities are responsible and ethical, understanding, acknowledging and minimising any adverse impacts wherever possible.

2. Research impact

The poles (as with many regions of the planet) are highly interconnected systems that require interdisciplinary research to fully understand them. Therefore, the definition of “research impact” should be understood across disciplines and sectors; we argue for holistic approaches to measure the impact of polar research. We build on the UK's Research Excellence Framework (REF) definition of “research impact” as “an effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia” [21] to consider all effects that research might have. We recognise that the framing of impact as positive and negative is highly subjective, and changes through time and perspectives, so we steer the narrative to focus on where improvements can be made without framing impacts as explicitly positive or negative. In this way, expectations by funders and institutions to present a positive spin on outputs can be navigated, whilst acknowledging and addressing other forms of impact.

In this section, following six headings, we discuss different categories that we find crucial when reflecting about our research impact: 2.1 Scientific output, 2.2 Economic, 2.3 Societal and Cultural, 2.4 Public Policy and Services, 2.5 Environmental, 2.6 Health and Quality of Life.

2.1 Scientific output



How does one research project support knowledge expansion and development of future research? This first impact category considers this question by reflecting on how new knowledge causes us to change our view of how the world functions. We also consider that meaningful scientific impact can be achieved through developing people, capacity, and knowledge. This includes building strong intellectual foundations and a diverse research community, specifically expanding opportunities for PEERs (who in turn should continue building these opportunities once in leadership positions [22]). Working towards IPY-5, high-quality scientific projects should strive for excellence and offer capacity-building opportunities for PEERs to experience and navigate the scientific environment. Scientists designing their research projects have an invested interest to ensure their outputs have high scientific impact for their own academic careers. We highlight that it can also be extended beyond the individual level. In fact, the scientific impact spans across individual, national and international levels.

Scientific impacts of research outputs are often measured through academic metrics, including publications in “high quality” journals (e.g., Journal Impact Factor), citations and H-indices, which can indicate academic validation through their utility and use in other works. However, a growing movement recognises the limitations and dangers of using these metrics as a sole measure of research quality, catalysed by the Declaration on Research Assessment [23,24].

Scientific projects should incorporate legacy into their design for two reasons, 1) supporting the continuation of the investigation long into the future, and 2) sustaining the research's benefits throughout its lifetime. One way to achieve both of these is through establishing long-term observing networks that produce high-resolution environmental baseline datasets. These observing networks support the development of innovative technologies, infrastructure, and capacities to enable monitoring to continue outside traditional fieldwork seasons. Projects should a) publish open-source datasets using the FAIR (Findable, Accessible, Interoperable, and Reusable) framework [25], b) use transparent and accessible methods, c) support sustained access to research infrastructure, d) provide salaried positions in communities (financial, training) to

maintain monitoring and infrastructure, and e) incorporate mixed levels of academic, sectoral, disciplinary, and knowledge systems experience in teams which demonstrate racial, gender, geographic, and generational diversity. In the Arctic, focus should be on supporting Indigenous data governance and sovereignty by adhering to CARE (Collective Benefit, Authority to Control, Responsibility, and Ethics) and OCAP (Ownership, Control, Access, and Possession) principles [26].

2.2 Economic

The economies of the Arctic and Antarctic differ greatly. Approximately 4 million people live across the Arctic region [27]. In contrast, Antarctica lacks permanent residents, and lacks a land connection restricting human travel to ships and flights. Human activity in Antarctica and the Southern Ocean - almost entirely beyond national jurisdiction - is governed by the Antarctic Treaty System [28]. In contrast, the Arctic Ocean is surrounded by multiple states with differing national policies governing terrestrial and marine space [29]. No single agreement covers the management of the Central Arctic Ocean, an area beyond national jurisdiction. Despite the lack of permanent human settlement in the Antarctic, there are highly productive fisheries, a growing tourism industry, and economic impacts related to research [30,31]. Individual researchers, influenced by budget generosity and allowances, typically make economic decisions themselves relating to travel, accommodation, subsistence, food, logistics management, and local guides [32]. Their own motivations shape considerations of ethical, environmental, and social influence on economics [33].

In this section, two case studies will be explored to show how sustainable activities in polar regions are motivated and monitored through economics by differing governing organisations that facilitate activity within polar regions. The observations from these practices will help to highlight the areas for improvement or caution when it comes to building sustainable economies for researchers within polar regions. Improving how researchers interact with polar environments through economic motivators is integral for IPY goals/motivations such as; reducing carbon emissions (such as by understanding impacts of who can access polar regions and how often [34]), improving economic resilience of indigenous communities [35], and promoting ethical research questions and practices [36]. Understanding how economies drive these responses is key for addressing systemic issues inhibiting progress [37].

2.2.1 Case Study 1: International Association of Antarctica Tour Operators (IAATO). Anyone conducting activities which may impact the Antarctic region must respect the Antarctic Treaty. This includes researchers and tourists. The management of the Antarctic Treaty is predominantly governed by research, via the Antarctic Treaty Consultative Meetings where 'Parties' are defined by either being one of 12 original Parties to the Treaty, or by conducting substantial research activity in Antarctica [28]. Best practice for research is considered at an international level via the Council of Managers of National Antarctic Programs (COMNAP).

Regulation on tourism activities conducted in the region is facilitated by the International Association of Antarctica Tour Operators or IAATO which formed in response to the Antarctic Treaty [38]. A membership based organisation bringing together government and non-governmental organisations, its general aim is to facilitate sustainable travel in Antarctica by addressing the impact of human-environment interactions. Common guidelines must be adhered to by anyone facilitating tourism activities within the region.

There are strong efforts to bring science directly into IAATO through schemes such as the IAATO Antarctic Fellowship, citizen science programmes, and research partnerships (e.g., with the Scott Polar Research Institute). IAATO operators contribute to scientific research by transporting researchers (e.g., Oceanites' Antarctic Site Inventory and Mapping Application for Penguin Populations and Projected Dynamics) [39], and by collecting data, for example through IAATO's Voluntary Cetacean and Pinnipeds Sightings program [40]. Outputs of this research inform sustainable tourism practices that enhance tourist experiences and protect the environment.

Antarctic tourism can be exploitative when operators bypass IAATO and forego the resources to support understanding and mitigate impact. Membership is voluntary and operators are driven to join based on business benefits and promoting the intrinsic value of the region, but may still lack financial capacity or interest in integrating research impact management

practices. IAATO is solely-funded by members through a fee model tied to passenger numbers [41]. Operators such as Plantours Kreuzfahrten, whose Antarctic cruises cost guests €7,300 to €18,000 per person [42], pays 65% per passenger to IAATO, contributing a significant sum. In order for IAATO to provide funding to research activities and support ongoing monitoring, its membership model must remain strong. This places economics at the forefront of membership motivation which inherently leaves room for exploitation, exacerbated by the reliance on individual governments for legal repercussions in the event that the Antarctic Treaty is broken.

2.2.2 Case Study 2: Association of Arctic Expedition Cruise Operators (AECO). The Association of Arctic Expedition Cruise Operators (AECO) was established in 2003 by 8 arctic cruise operators inspired by IAATO. Its members pay a fee ranging from 7,000–23,000 Norwegian kroner, with scaled costs based on cruise ship capacity [43]. AECO works with multiple arctic countries and organisations including Svalbard, the Norwegian Polar Institute, WWF's Arctic Program Office, Visit Greenland and Greenland's Ministry of Nature and Environment to develop guidelines. Similarly to IAATO, AECO promotes and creates guidance on sustainable operations in several areas: community and research stations, environment and cultural remains, guest guidance, operational and marketing strategies, and special sites guidance.

With Norwegian origins, AECO has a eurocentric view on activities limiting a cohesive approach to regulating pan-Arctic activities. There are weaker connections with the Canadian and North American Arctic outside of Nunavut, and the Russian Arctic due to geopolitical tensions. Their guidelines do include inland areas people may visit from a ship (e.g., Kangerlussuaq, SW Greenland, an inland area of Greenland accessed via a fjord [44] but these are limited. AECO is well-positioned to translate IAATO's mission into the Arctic as a convener of rightsholders and stakeholders, but would need to adopt a wider focus on land-based activities and increase transparency in its documentation which is currently only accessible to members.

The juxtaposition of AECO compared to IAATO comes from its advocacy for environment- and human-focused transitions (e.g., sustainable fuels, risk assessment infrastructure etc.). This comes alongside supporting an expanding sector relying on its paying guests to accumulate large carbon footprints just to get to their starting destination (e.g., Americans typically have to fly to Denmark or Iceland en route to Greenland). Again, they support Indigenous communities through their guidelines [45], but don't inherently encourage cruise operators to facilitate the transfer of cash into communities as guests' needs are wholly catered to on the ship.

2.2.3 Evaluating impacts. AECO, and IAATO, could support sustainable research by guiding safe, environmentally considerate, and economically viable travel practices in the form of open-access resources and ship travel/time. This would reduce the funding divide in research (from fieldwork costs to publication pay walls) which often disadvantages PEERs, and could better streamline resources and enhance collaboration. PEERs in particular would benefit from the enhanced network access who despite often being loud advocates for championing Indigenous leadership and voices, often don't have connections to Indigenous communities. These are important principles of IPY-5.

Both organisations experience similar vulnerabilities in balancing the commercial interests of their members while guiding ethical and sustainable tourism activities, which in turn can garner environmental support amongst a community of affluent and consequently powerful guests. Expanding their work to better incorporate, support, and exchange knowledge with research communities is an opportunity to strengthen both organisations. Researchers would also gain additional governance around sustainable and economic travel for their work, while implementing citizen science approaches, and building partnerships with tourism operators to continue long-term monitoring and conservation programmes. Co-creating the future of AECO and IAATO requires the inclusion of Indigenous communities in the Arctic and southern hemisphere gateways to Antarctica so that local economies and wellbeing are supported, local knowledge leads science, and the IPY-5 goals can be achieved.

However, it is important to note that economical impacts are not solely driven by these large private organisations that facilitate travel to polar regions, but by grants received from global governments. These grants allow for the engagement

and support of local Indigenous people through spending of research personnel within these communities, or through direct employment of Indigenous people within the project. For example, the marine Environmental Observation, Prediction and Response Network community-led funding and 'Our land for the future' initiative in NWT. \$20 million in initial funding will be provided to 23 Governments in the Northwest Territories to support Indigenous led-conservation, job creation and economic opportunities (seasonal, part time, full time, guardian programs, ecotourism) and sustainable economic development [46]. Other research funders including MEOPAR's Community-Led Research Seed Fund and the Canada-Inuit Nunangat-United Kingdom Research Program (CINUK) were designed to ensure relationship building, research co-design, and capacity development occurs within Arctic funded research.

This form of economical support, helps to facilitate more sustainable research practices through reducing travel to remote polar regions. The reliance therefore on companies which are not indigenous-led such as some cruise operators, can be reduced, as more opportunities open up for local communities [47]. While these funding grants have seen positive impacts to indigenous people [48], the stability of the economical input is unreliable, as geopolitical views or priorities shift over time. For example, the UK no longer funds the CINUK program. This often results in a loss of created practices [49] and can leave communities vulnerable if the majority of their economy is supported by research activities [50]

It is evident therefore, that the economics of research is controlled by large organisations that dictate not only the ability to carry out research in polar regions, but the sustainability of actions taken to conduct that research in an environmentally friendly way. This in turn controls the impacts on the Indigenous communities who are best able to facilitate sustainable practices within research.



2.3 Society and culture

We emphasise that societal and cultural engagement - be it engagement with communities in Arctic or sub-Arctic regions, and/or science communication activities in its various forms - needs to be acknowledged as part of a researcher's impact, here we present three aspects of the impacts of polar research on society and culture locally and globally.

2.3.1 Current Arctic communities. Polar research has perpetuated "parachute science" or "helicopter research" practices. Especially for research in the Arctic region with permanent inhabitants, researchers from high-income nations and institutions have conducted research in historically marginalised communities that are often left out of the research activities [51]. In recent years, recommendations for non-Indigenous researchers looking to conduct research with Indigenous communities have been helpful for guiding research approaches towards supporting reconciliation [14], self-determination [20], and ethical and equitable engagement [52]. The support of Indigenous steering committees such as the International Arctic Science Committee Standing Committee on Indigenous Involvement is working to ensure society and culture is sufficiently acknowledged and addressed when conducting polar research whether that be to engage respectfully or ensure that outcomes benefit society and culture in the region. This can be achieved by aligning research priorities with community priorities, supporting youth engagement, cultivating cross-cultural and broader knowledge exchange, or offering paid positions within research teams, among others.

2.3.2 Education and outreach in global and remote communities. Polar society and culture has influence beyond the geographic regions themselves, however a communication gap exists between scientists and society [53,54]. Policy is not enacted until the topic reaches societal acceptability [55]. This is one of many barriers which limit the flow of science into decision-making. Others include a credibility crisis in scientific publishing and growing misinformation movements [54]. One way to strengthen the science-policy-society interfaces is by supporting organisations working across different sectors, a key outcome from the last IPY in 2007–2008 [56,57]. PECRs are well placed to support these activities [53] through networking organisations such as the UK Polar Network (UKPN) in the UK, and international organisations such as the Association of Polar Early Career Scientists (APECS). The UKPN is a PECR-led organisation promoting and enhancing polar research including through outreach to young people. Notably the Antarctic Flags Programme [58] annually sends over 1000 flags designed by school children from over 300 schools to Antarctica with researchers to build

connections between researchers and society. Other outreach activities include Polar Beers, bringing researchers into conversations with the general public in casual environments. Similarly, Polar Educators International acts as a bridge between educators and polar researchers, with a focus on high quality practice-based engagement [59].

2.3.3 Antarctic heritage. According to Nuviala Antelo and Nuviala Antelo [60], Antarctic heritage is affected by the dismantling and removal of structures that are no longer in use or are considered obsolete. They describe this as a process promoted by the Antarctic Treaty System to reduce anthropogenic impact, through the removal of these structures and their eventual replacement by environmentally sustainable architectures. They state that, as a consequence, this process will lead, in the short and medium term, to the partial disappearance of Antarctic architectural heritage and to the loss of information about earlier ways of inhabiting the continent.

This issue should be considered in IPY-5 planning, especially where Antarctic infrastructure is removed, replaced, or redesigned to reduce environmental impact. In such cases, archival and heritage documentation would help preserve information about Antarctica's human history before material evidence is lost.

This approach is exemplified by the 6044SUR Interdisciplinary Research Team, which developed SUR, the Virtual Archive on Architecture and Dwelling in Antarctica (*Archivo Virtual de Arquitectura y Hábitat en Antártida*). The project website describes SUR as the first virtual archive on architecture and dwelling in Antarctica. It gathers Antarctic architectures designed and built during the twentieth and twenty-first centuries, drawing on institutional documentary collections and personal memories.

2.4 Public policy and services



Polar research has the potential to support the development of better public policy and services for people living in the polar regions. This can occur by strengthening the contributions of research to decision-making, ensuring research addresses scientific and local priorities through equitable research processes; and by supporting Indigenous representation in projects, institutions and international governing bodies [61,62]. Whilst this section predominantly focuses on the research impacts on public policy and services local to the poles, and as such is mostly Arctic focused, it is worth acknowledging that Antarctic research also impacts globally on public policy and services in the form of environmental protections, the Antarctic Treaty System, geopolitics, and sea level projections [63].

One example of this representation at the research programme scale in an Arctic context is the Canada-Inuit Nunangat-United Kingdom (CINUK) Arctic Research Programme (<https://www.cinuk.org/>). The CINUK programme was a collaborative program between the UK and Canadian Governments, and the Inuit Tapiriit Kantami (ITK), built upon an innovative memorandum of understanding ensuring equitable and appropriate outcomes of the funded research [64]. The CINUK program reframed the way in which research projects were designed, implemented and evaluated, with emphasis placed not only on innovative science methodologies but also on Indigenous self-determination in research. The program was designed to support Indigenous engagement and leadership at all stages from funding call development to project implementation and evaluation. This transitions away from engagement with Indigenous and local communities only occurring after project funding is awarded, which has been a common practice [64]. The CINUK program supported over 20 PECRs to build respectful and responsible relationships with communities addressing relevant priorities, through training and financial support. It would be effective to build on this program by including cultural awareness training that would embed reflexive research processes and soft skill development necessary to engage with a wide range of groups outside of academic institutions. This would make space for capacity sharing, and multi-directional knowledge exchange including across diverse knowledge systems. The resulting positive research impact would allow outputs to directly meet community interests. A co-benefit of elevating PECR impact is a strong legacy, going beyond traditional metrics of success like peer-reviewed publications.

The ITK continues to be supportive of public policy and services in Inuit Nunangat through research guidance with the release of the National Inuit Strategy on Research [20]. Knowledge exchange between funding agencies to share best

practice and lessons learnt through collaborative funding calls supports two IPY-5 goals: “Build specifically on the methodological, technological, educational, and epistemological advancements of the 4th IPY, including major shifts toward working across knowledge systems and transdisciplinary research with specific emphasis on equitable and ethical engagement with Indigenous Peoples and their knowledge systems.” & “Support, connect and extend networks of Indigenous Peoples, academics, local leaders, and early career and community researchers to understand the human and environmental links, impacts and feedbacks with the polar regions and beyond.”

2.5 Environmental

The Polar Regions function as critical sensors for global climate change, and research conducted there is intrinsically linked to understanding and safeguarding planetary environmental health. As a result, environmental impact is a primary concern of polar research activities. Polar researchers often have to reconcile two interdependent measures that shape our activities: the research footprint and its handprint.

The environmental footprint, a concept introduced to measure human demand on ecosystems [65], represents the multi-faceted impacts generated *by the process* of research activities. Within the polar regions, this includes a range of impacts documented by the European Polar Board, such as carbon emissions, the introduction of invasive species, wildlife disturbance, pollution from microplastics, noise and light, and challenges with waste management—impacts we have a responsibility to measure and mitigate [11]. Conversely, the environmental handprint is an emerging concept that represents the tangible “effect on, change or benefit to... the environment” generated *by the outcomes* of our research—the very justification for the footprint in the first place [66]. A handprint represents the scientific and societal value of research, including informing climate policy, improving conservation strategies, or contributing to environmental governance. A responsible research framework requires us to be transparent about both, actively minimizing our footprint while intentionally maximizing our handprint. Taking stock of the footprint is not merely an accounting exercise; it is a call to foster a culture of critical reflexivity within the research community, encouraging and equipping us to justify the footprint of our research relative to its handprint [67], and actively work to translate research into relevant outputs for society.

2.5.1 Travel efficiency and reduction. A first step in reducing the environmental footprint of polar research is to ask whether remote fieldwork is necessary to answer the research question. In some cases, high-quality research can be conducted, or field campaigns can be reduced, through existing datasets, modelling, satellite observations, remote sensing, autonomous monitoring systems, or collaboration with established observing networks. Where fieldwork remains necessary, projects should consider whether instruments, methods, and logistics can first be tested in more accessible environments before deployment in remote polar regions. This can reduce avoidable failures, improve training for early career researchers, and help ensure that polar field campaigns are better justified and better prepared. However, it should not be assumed that use of satellites, numerical models or use of AI tools as an alternative to remote fieldwork come without environmental costs, and instead a full complement of approaches may be best [3,68].

As PECRs, we are acutely aware of time and consideration required to measure the footprint of polar science, but that climate change brings an urgency to our work. Polar regions are challenging environments, requiring reliable energy for life support and scientific systems. This, combined with seasonal limitations on solar availability and extreme conditions, has led to a deep-seated reliance on non-renewable fuels and high carbon footprints of conducting research. We are not alone in this; there is a growing concern amongst the scientific community broadly to maintain high-quality research while minimizing its environmental cost. This is driving a continuous process of standard setting already spurring action across multiple levels (Fig 2).

Reaching and operating in these remote regions requires long-distance travel via ships and planes resulting in substantial emissions and forming a significant portion of research footprints. During the 2023/2024 season, the UK’s RRS Sir David Attenborough was responsible for 50.57% of the British Antarctic Survey’s entire emissions (Scopes 1–3), equating to 27,585 tCO₂e—the equivalent of running 9,545 average UK homes for a year [69]. Similarly, the year-long MOSAiC

expedition, where the RV Polarstern drifted with Arctic sea ice, produced 47,864 t of CO₂e, contributed to local air pollution principally because of the ship exhaust, deployed 1500 kg of scientific instrumentation intentionally left behind (buoys, sensors, etc.), generated 750 kg of unintentional scientific waste (materials that were unrecoverable) 20,000 m³ wastewater and an unknown amount of microplastics, noise and light pollution [13].

Despite the high numbers, the RRS Sir David Attenborough's annual emissions are equivalent to only 16 minutes of the entire global shipping industry's 2022 emissions [70]. While the sector's footprint is not a primary driver of global emissions, it represents a significant and manageable component of our research community's direct impact—an issue that, given the fragility of the polar environment, ethically and strategically must be managed. Macfarlane *et al.* [13] created a methodology which included the above impacts and assigned an impact index (i-index) as a comparison tool for future environmental impact assessments.

Environmental responsibility also applies to the way polar researchers meet, collaborate, and disseminate results. Conferences, workshops, and planning meetings can generate substantial travel emissions, particularly when participation requires long-distance international flights. Virtual and hybrid formats should therefore be treated as part of responsible research practice, not only as accessibility measures but also as tools for reducing the environmental footprint of polar science.

2.5.2 Community guidance. Guidelines and protocols are being developed at the global and multi-national scale. Practical operational guides for fieldwork are being developed by regional networks, such as the Arctic-focused INTERACT [71,72]. This operational focus is complemented by the multinational Forum of Arctic Research Operators, which develops best practices for shared logistics and coordination of research activities to reduce the overall environmental footprint in the Arctic. Furthermore, the Council of Managers of National Antarctic Programs (COMNAP) facilitates international environmental practices by creating and sharing practical manuals and protocols for its members, such as the Guidelines for Environmental Impact Assessment in Antarctica [73] and COMNAP/SCAR Inter-continental Checklists for reducing the risk of transfer of non-native species [74]. This body of guidance is further integrated into a circumpolar standard by the Synthesis Report produced by the European Polar Board [11], which combines best practices and scientific data from both the Arctic and Antarctic to inform the setting of environmental norms.

2.5.3 Efficiency of infrastructure and technology. Initiatives like the UK's Future Marine Research Infrastructure program are explicitly designed “to examine how to meet environmental targets whilst maintaining leading marine research.” These represent the larger-scale programmes that will be needed for Antarctic work to become carbon neutral and create “sustainable, future-ready infrastructure.” To reduce shipping emissions, trials using Hydrotreated Vegetable Oil to fuel the RRS Sir David Attenborough show potential to reduce carbon emissions by up to 94% compared to conventional diesel fuel [75].

At smaller scales, the deployment of remote autonomous vehicles and technology (equipment, transport, and data-led route optimization) is being prioritized to reduce footfall and associated carbon footprint in the field [11]. Projects like the Climate Sentinels in Svalbard are testing and demonstrating the measures needed to move toward carbon-neutral Arctic fieldwork [72]. Similarly, community-engaged research (and training for) in the Arctic can reduce environmental impact through community-led practices and transference of the project to the community for long-term operation and autonomy. This takes significant time and resources to build the relationships, support mechanisms, and infrastructure to do this responsibly and equitably [64].

Research infrastructure at the poles must continue to move away from energy-intensive construction and logistics towards lower-impact designs, more efficient energy systems, and support systems that reduce local disturbance. The European Polar Board report identifies large research stations as sources of multiple environmental impacts, including carbon emissions, black carbon, noise and light pollution, wildlife disturbance, waste management challenges, soil degradation, and microplastics [11]. Future infrastructure planning should therefore consider the full lifecycle of buildings,

energy systems, logistics, waste, and water management, rather than treating environmental performance only as an operational issue.

A shift is also needed in how polar infrastructure, solid waste, and wastewater are managed. Waste generated by polar research can be stored and exported to processing facilities outside the polar regions, processed locally where possible, or discarded in the surrounding environment. However, local disposal can have lasting impacts because waste biodegrades extremely slowly in cold polar environments [11]. Wastewater management is also a concern, as many research stations are not connected to sewage infrastructure and practices vary across stations. Research stations can use wastewater treatment systems to avoid polluting the direct environment, and stations not connected to regional sewage systems should install filters [11]. Princess Elisabeth Antarctica provides one example of a lower-impact approach: its water treatment system purifies wastewater and recycles treated water for non-drinking purposes [11].

A central goal for IPY-5 should therefore be to support lower-impact polar research systems that consider the full life-cycle of infrastructure, energy, waste, water, and logistics. To support this transition, environmental impact assessments should be planned from the beginning of research projects, with transparent data collection and knowledge exchange so that future activities and infrastructure can learn from previous lessons.

2.6 Human health and quality of life

Polar research can impact the health and quality of life of three distinct groups in society: Arctic communities, including Indigenous communities; researchers; and the global populace. Research should not come at the expense of health and quality of life across any group, but measuring and concretely demonstrating the impact of non-health sector research on people is not commonplace.

To ensure the health and quality of life of the indigenous communities in the Arctic, research programs increasingly provide guidance and leadership when it comes to ensuring the health and quality of life within their local communities is safeguarded through both holistic research directly addressing the topic, as well as impacts of other research fields. For example, the Ärramät Project supports the strengthening of health and wellbeing through Indigenous-led conservation and sustainable relationships with biodiversity [76].

The way in which research is conducted in the Arctic, irrespective of its focus, influences the health and quality of life of Indigenous communities through the project's engagement approaches. Those with equitable, reciprocal, and respectful collaborations across knowledge systems will have better health and quality of life outcomes for Arctic communities. Additionally, the research will be improved [77]. The Ikaarvik SciQ project is an Inuit youth-led initiative that provides recommendations for meaningful engagement with Indigenous communities in the Arctic, inviting Western researchers to improve their Inuit Qaujimajatuqangit (IQ) attitudes when doing research with Inuit communities. Their recommendations include respecting time and knowledge of collaborators, where research often coincides with important hunting activities. Research can support cultural healing and cross-generational knowledge exchange when done appropriately, this can include embedding on the land learning activities and culture camps into research design [78]. On the land activities are directly related to cultural hunting and subsistence which strongly influence health and quality of life. Aligning research with these activities can support greater engagement and scientific outcomes. This has particularly been seen in community-based wildlife programs, but it requires early and sustained engagement to ensure co-development of appropriate and ethical research methods [79,80]. Accommodating translation to communicate and disseminate research processes and findings in the local language (specific to the region) can work to increase the reach of the research as well as sustaining language, an important contributor to health and wellbeing.

Moving beyond the REF research impact definition of 'health and quality of life' as relevant for human communities only, Indigenous-led guidance and projects such as the One Arctic, One Health III project [81] and the Sámi Arctic Strategy [82] highlight the needs and rights of non-human and more-than-human species and entities.

The One Health project recognises that health is inseparable from the human-animal-ecosystem interface. This supports the same sentiment in the Good Practices for Environmental Impact Assessment and Meaningful Engagement in the Arctic report of 2019 [83] from the Arctic Council which suggests, due to the interdependencies between the environment, culture, and health, a health impact assessment is conducted to understand health and wellbeing impacts of research in the Arctic.

The Study of Environmental Arctic Change co-production teams, including one focused on Human Health and Wellbeing (HWB), are also attempting to shift the needle on research impact in the decision making world. The HWB Team has contributed the most cited chapter of a National Climate Assessment report for the USA [84], developed a one page information document regarding the teaching of cultural practices in Alaskan schools to Alaska Native students, and written a peer-reviewed paper on the co-production method, including its influence on the team members wellbeing [85].

Fieldwork practices of polar research have an impact on the inclusion of marginalised groups in polar science [86] and PECRs are leading advocates on this topic. The UKPN supports safe and inclusive working environments in polar research, where challenges still persist (for example physical and psychological safety, female hygiene), despite recent progress [87,88]. Underrepresented groups in polar science (i.e., women, LGBTQ+, BAME, first generation students) are supported at the local, regional, and national levels through training, education, and creating safe spaces. The UKPN's Dartmoor field skills training course propagated a broader conversation about mechanisms to address these issues [87]. In academia, percentages of women decrease dramatically when progressing to more senior roles [89] and beyond academia where professions are typically focused on trade skills, engineering, or otherwise typically male-dominated fields, even fewer women work in the polar sector. APECS and associated PECS support organisations, which came out of the last IPY, foster greater connections between science and society and health and quality of life in polar field environments [90]. As we move towards the next IPY, more work is required to continue to break down barriers and foster training of the next generations of PECS whether working within research, policy or other polar related careers [91].

3. Successful research impact in the IPY-5

We need to make changes now to see the goals of IPY-5 achieved. The current ECRs will progress into supervisory roles during IPY-5. This is our chance to shape the research impact we want to lead in 2032 and beyond. This will require action from individual to institutional and global scales as we advocate for a deep shift in research values. Interdisciplinary, cross-sectoral, and multi-knowledge system collaboration is vital to ensure that creatives, social acceptability experts, designers, communicators, and technologists are part of the re-imaging of station infrastructure, field science and its logistical footprint, as well as the societal impact of research. Fig 1 summarizes the recommendations we propose to reflect, prepare and implement scientific projects during the IPY-5.

Our ultimate goal is to minimize our research footprint and maximize our research handprint which by default, are treated as equal and integrated components of responsible research. In section 2, we have discussed a variety of interconnected solutions being implemented to improve the impact of our research. Measuring this impact is another area of expertise we did not have scope to include here, but must balance a suite of methods which consider not only our 'footprints', but also our 'handprints' [66,92]. This framing encourages positivity without removing the tradeoffs which are inevitable in research impact [93].

Using the REF impact categories, which are not perfect, but offer a structure to our discussions, we outline examples of successful components of responsible research. There are many overlaps, yet no one example demonstrates consideration of research impact at an entirely holistic level. Working towards this broader approach to research impact we turn to enabling components such as data collection frameworks (FAIR, CARE, OCAP, DORA) and place-based approaches. Evaluation and measurement of research impact demands a multi-faceted approach which moves beyond simple reporting and embraces novel success metrics outside of academic publication. Quantitative and qualitative tools and plans determined at project inception, and iterated upon throughout, which can support accountability and transparency are essential for effective decision-making and dissemination. Values, policy, and funding push and pull one another to shape

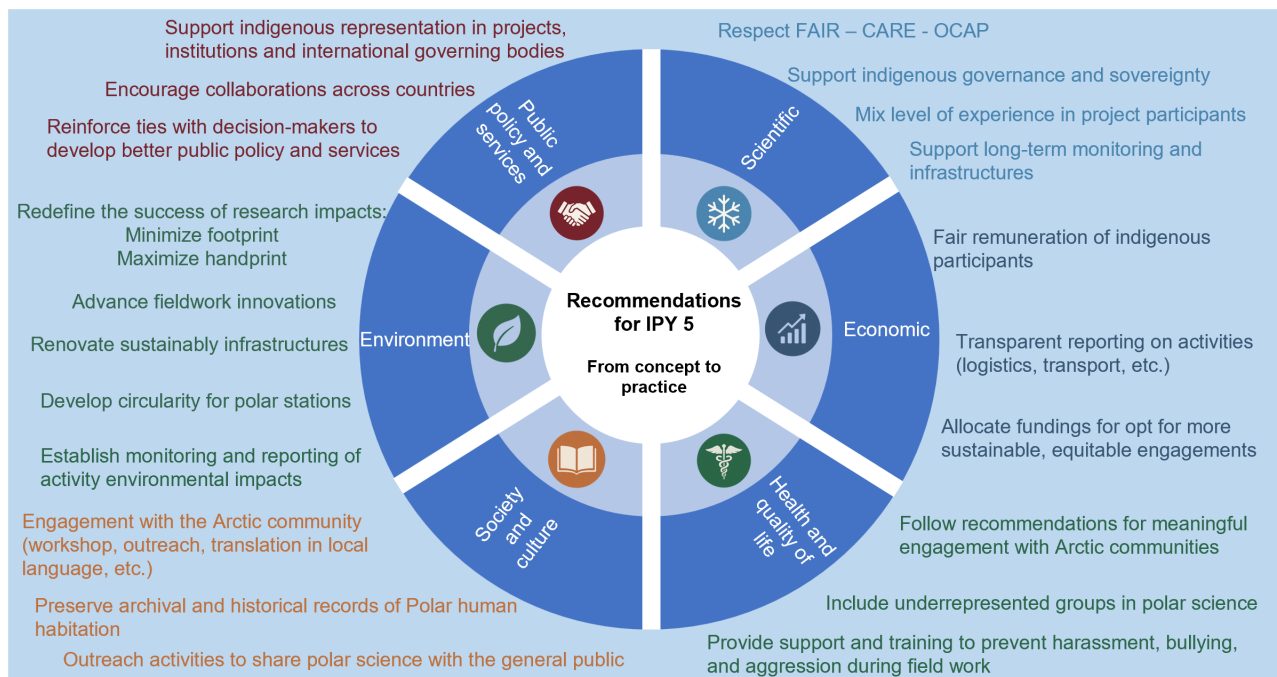


Fig 1. Recommendations for the International Polar Year 2032-33 (IPY-5) to design scientific projects and minimize the research impact on the following categories: Scientific, economic, health and quality of life, society and culture, environment, and public policy and services.

<https://doi.org/10.1371/journal.pclm.0001062.g001>

these monitoring systems, but above all they must recognise that no single metric meets the needs of all projects, nor can any evaluation anticipate all entities impacted by the research or *through doing* the research.

4. Taking action

Moving beyond examples of success and their enabling mechanisms, we suggest tangible actions which can be taken at the individual, institutional, national, and international level to actively embrace respectful research through holistic impact considerations (Fig 2).

As current PECRs, our hope is to welcome IPY-5 as a milestone through implementation of these actions. Importantly, all readers should recognise that in some way you are a decision maker and there is power even in small decisions.

4.1 Individual researchers should

- **Practice Reflexivity:** identify what power you hold, and where your impact may be.
- **Promote interdisciplinarity:** promote and engage in collaboration across interdisciplinary groups, which is critical for delivering research impact as well as for discussing impact.
- **Implement environmental practices:** consider and implement environmentally friendly practices and monitoring in all research projects, based on environmental impact assessments.
- **Incorporate IPY recommendations** into research projects
- **Organise monitoring:** implement and support the effective, appropriate and sustainable monitoring and evaluation plans developed at the regional and national level

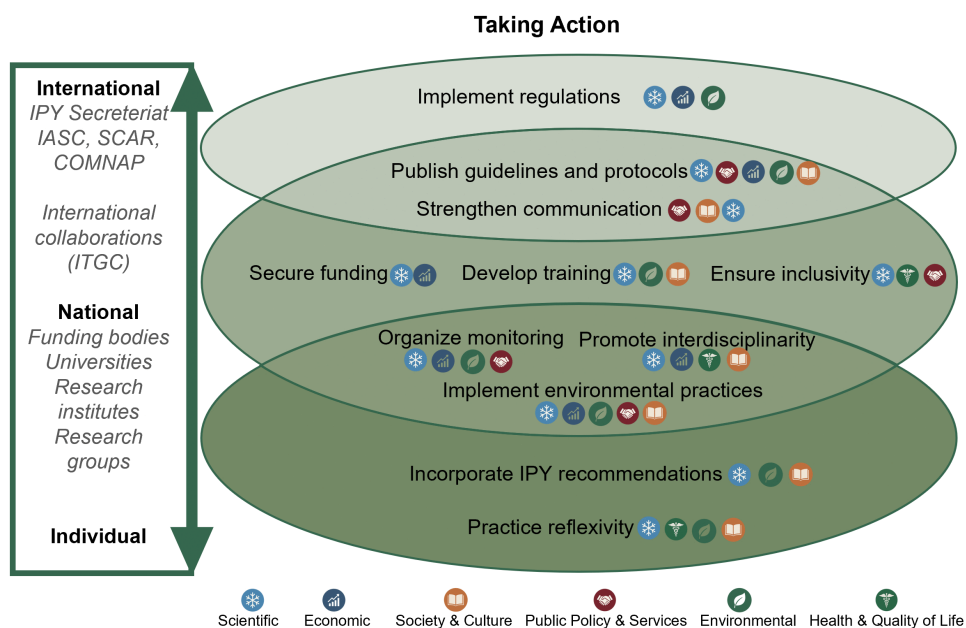


Fig 2. Summary of level of involvement for taking actions and the research impact categories associated with actions, each action is discussed in further detail in section 4.

<https://doi.org/10.1371/journal.pclm.0001062.g002>

4.2 Regional and National Level (Research Institutions, Funders) organisation should support individual action through

- **Organise monitoring:** develop effective, appropriate, and sustainable monitoring and evaluation plans
- **Implement environmental practices:** at the institutional infrastructure level
- **Promote interdisciplinarity:** provide administrative project support that is necessary to support interdisciplinary work across diverse disciplines and knowledge systems
- **Secure funding:** equitable funding models are needed especially those which allow PECRs to build connections and collaborate internationally, allowing diverse project outputs and make time to build trusting relationships with Indigenous communities
- **Develop training:** Provide training for PECRs that builds capacity and resilience to understand and evaluate research impact
- **Ensure inclusivity:** Fund non-research activities to better include marginalised youth, communities, and Indigenous people to participate, co-produce, and lead projects
- **Publish guidelines and protocols:** identify and share ways of implementing best practices in line with national, regional and local settings and differences

4.3 At the international level of planning processes within the IPY, organisations should

- **Strengthen communications:** improve communication within and beyond the research community to increase awareness and participation in research activities

- **Publish guidelines and protocols:** co-produce guidelines and protocols with those impacted by research
- **Implement regulations:** Adhere to international treaties, declarations, and agreements in the environmental, social, and economic sectors (e.g., DRIP, AT, UNCLOS, Paris, Kyoto, Montreal etc.)

As we have shown, many steps can be taken - at individual, project or national level. Improved impact evaluation frameworks which accommodate hidden consequences and co-benefits are inevitable. While these concepts are not unique to polar sciences, we call for collaboration and transparency in this regard. At each level, these actions can only be achieved with the support of organisations at the next level up, in particular, that the abilities of individual researchers to practice reflexivity, and implement various practices is dependent on support in the form of training, monitoring, funding and guidelines from the regional and national levels.

Positionality. The authorship team includes PECRs working across a range of different disciplinary backgrounds, engaged within and outside academic institutions and sectors. Our research spreads across terrestrial, marine, freshwater, social and natural science disciplines, and we work across both poles and diverse knowledge systems. We are also science communicators, storytellers, and leaders of organisations supporting PECR engagement and involved in international processes including the Fourth International Conference on Arctic Research Planning (ICARP IV), the UN Ocean Decade and Antarctica InSync. We recognise our responsibility to shape the new path forward for PECRs in the next IPY by identifying, analysing, documenting, and addressing the impact of our activities on the poles - unique and sensitive environments. When we conduct polar research (including fieldwork, labwork, office work, scientific travel, and engagement with local communities), we face political, environmental and social challenges, and take on responsibilities to ensure there is a culture within the research community that encourages us to critically reflect on our impact and justify the footprint of our research. As polar scientists, we focus primarily on the most unique aspect of polar research, namely polar fieldwork, but touch on other aspects where appropriate.

Declarations. The use of artificial intelligence: Artificial Intelligence (e.g., ChatGPT, Claude) was used through an AI aggregator platform (Mammouth AI), which is based in Europe, following the privacy and security rules of the General Data Protection Regulation (GDPR). AI was used to generate the icons with typing a prompt. The purely AI-generated icons fall under the public domain, and do not require a copyright content permission.

Author contributions

Conceptualization: Samuel Hartharn-Evans, Chloe Nunn, Natalia Banega, Louise Mercer.

Funding acquisition: M. A. J. van Soest.

Investigation: Samuel Hartharn-Evans, Chloe Nunn.

Project administration: Samuel Hartharn-Evans, Chloe Nunn.

Writing – original draft: Samuel Hartharn-Evans, Chloe Nunn, Amy Macfarlane, Natalia Banega, Anna Belcher, Radiance Calmer, Louise Mercer, M. A. J. van Soest, Zoe Wright.

Writing – review & editing: Samuel Hartharn-Evans, Chloe Nunn, Amy Macfarlane, Natalia Banega, Anna Belcher, Radiance Calmer, Svenja Holste, Louise Mercer, Ningning Sun, Zoe Wright.

References

1. IPY Secreteriat. International polar year progress update report. 2025. <https://ipy5.info/media/0fdfsje5/ipy-5-progress-update-report-october-2025.pdf>
2. Dryák-Vallies MC, Strand SM, Payne MR, Schlindwein A. Polar early career world summit synthesis report. Association of Polar Early Career Scientists (APECS) International Directorate and Polar Science Early Career Community Office (PSECCO); 2025. <https://doi.org/10.5281/zenodo.16994869>

3. Moraru A, Rasmussen LH, Cali Quaglia F, Middleton A, Huynh HM, López-Quirós A. Polar fieldwork in the 21st century: Early career researchers considerations regarding safety and sustainability. *PLOS Clim*. 2024;3(7):e0000415. <https://doi.org/10.1371/journal.pclm.0000415>
4. Nicola L, Frøystad R, Juarez-Martinez A, Menthon M, Luzardi ACM, Turner KA. Where do we want the glaciological community to be in 2073? Equality, diversity and inclusion challenges and visions from the 2023 Karthaus Summer School. *J Glaciol*. 2025;71:e68. <https://doi.org/10.1017/jog.2025.18>
5. Rantanen M, Karpechko AY, Lipponen A, Nordling K, Hyvärinen O, Ruosteenoja K, et al. The Arctic has warmed nearly four times faster than the globe since 1979. *Commun Earth Environ*. 2022;3(1). <https://doi.org/10.1038/s43247-022-00498-3>
6. Casado M, Hébert R, Faranda D, Landais A. The quandary of detecting the signature of climate change in Antarctica. *Nat Clim Chang*. 2023;13(10):1082–8. <https://doi.org/10.1038/s41558-023-01791-5>
7. IPCC. The ocean and cryosphere in a changing climate: Special report of the intergovernmental panel on climate change. 1st ed. Cambridge University Press. 2022. <https://doi.org/10.1017/9781009157964>
8. Li X, Guo H, Cheng G, Song X, Ran Y, Feng M, et al. Polar regions are critical in achieving global sustainable development goals. *Nat Commun*. 2025;16(1):3879. <https://doi.org/10.1038/s41467-025-59178-3> PMID: 40274805
9. Gricius G. Conceptualising the Arctic as a zone of conflict. *Cent Eur J Int Secur Stud*. 2021;15:4–30. <https://doi.org/10.51870/CEJISS.A150401>
10. Heininen L. Geopolitical features, common interests and the climate crisis: The case of the Arctic. *Geneva Pap Res Ser*. 2024;35.
11. Elshout P, Chappellaz J, Gibéryen T, Hansen C, Jania J, Jones-Williams K. Synthesis report on the environmental impacts of polar research and logistics in the polar regions. Zenodo; 2023. <https://doi.org/10.5281/zenodo.7907235>
12. van Soest MAJ. An Arctic expedition: a supposedly useful thing I'll never do again. *Polar Research*. 2023;42. <https://doi.org/10.33265/polar.v42.9070>
13. Macfarlane AR, Smith MM, Calmer R, Droste ES, Tippenhauer S, Angot H, et al. Environmental impact assessments of scientific fieldwork as a path to sustainability: A case study from the MOSAiC expedition. *Elem Sci Anth*. 2025;13(1). <https://doi.org/10.1525/elementa.2025.00035>
14. Wong C, Ballegooyen K, Ignace L, Johnson MJ, Swanson H. Towards reconciliation: 10 calls to action to natural scientists working in Canada. *FACETS*. 2020;5(1):769–83. <https://doi.org/10.1139/facets-2020-0005>
15. ESRC. Defining impact. 2025. Accessed 2025 October 16. <https://www.ukri.org/councils/esrc/impact-toolkit-for-economic-and-social-sciences/defining-impact/>
16. Oancea A. Research governance and the future(s) of research assessment. *Palgrave Commun*. 2019;5(1). <https://doi.org/10.1057/s41599-018-0213-6>
17. De Lange P, O'Connell B, Mathews MR, Sangster A. The ERA: A brave new world of accountability for Australian university accounting schools. *Aust Account Rev*. 2010;20:24–37. <https://doi.org/10.1111/j.1835-2561.2010.00078.x>
18. Smith S, Ward V, House A. 'Impact' in the proposals for the UK's Research Excellence Framework: Shifting the boundaries of academic autonomy. *Res Pol*. 2011;40(10):1369–79. <https://doi.org/10.1016/j.respol.2011.05.026>
19. Parker J, van Teijlingen E. The Research Excellence Framework (REF): Assessing the impact of social work research on society. *Practice*. 2012;24(1):41–52. <https://doi.org/10.1080/09503153.2011.647682>
20. ITK IT. National Inuit strategy on research. Ottawa, Ontario, Canada. 2018. <https://www.itk.ca/national-strategy-on-research-launched>
21. Research Excellence Framework: Assessment framework and guidance on submissions. Research Excellence Framework; 2011. <https://2014.ref.ac.uk/pubs/2011-02/index.html>
22. Moreno-Ibáñez M, Casado M, Gremion G, Rabanal V, Adojoh OC, Anoruo CM. Engagement of early career researchers in collaborative assessments of IPCC reports: Achievements and insights. *Front Clim*. 2024;6. <https://doi.org/10.3389/fclim.2024.1395040>
23. DORA. San Francisco declaration on research assessment. 2013. <https://sfdora.org/read/>
24. DORA. Guidance on the responsible use of quantitative indicators in research assessment. 2024. <https://doi.org/10.5281/ZENODO.10979644>
25. Wilkinson MD, Dumontier M, Aalbersberg IJJ, Appleton G, Axton M, Baak A, et al. The FAIR guiding principles for scientific data management and stewardship. *Sci Data*. 2016;3:160018. <https://doi.org/10.1038/sdata.2016.18> PMID: 26978244
26. Jennings L, Anderson T, Martinez A, Sterling R, Chavez DD, Garba I, et al. Applying the "CARE Principles for Indigenous Data Governance" to ecology and biodiversity research. *Nat Ecol Evol*. 2023;7(10):1547–51. <https://doi.org/10.1038/s41559-023-02161-2> PMID: 37558804
27. Nymand LJ, Gail F. Arctic human development report: regional processes and global linkages. Nordisk Ministerråd; 2015.
28. ATS. The Antarctic Treaty. 1959.
29. Stokke OS, Hønneland G. International cooperation and Arctic governance: Regime effectiveness and northern region building. London: Routledge; 2007.
30. White KJ. Tourism and the Antarctic economy. *Annal Tourism Res*. 1994;21:245–68. [https://doi.org/10.1016/0160-7383\(94\)90043-4](https://doi.org/10.1016/0160-7383(94)90043-4)
31. Tin T, Lamers M, Liggett D, Maher PT, Hughes KA. Setting the scene: Human activities, environmental impacts and governance arrangements in Antarctica. In: Tin T, Liggett D, Maher PT, Lamers M, editors. *Antarctic futures: Human engagement with the Antarctic environment*. Dordrecht: Springer Netherlands; 2014. 1–24. https://doi.org/10.1007/978-94-007-6582-5_1

32. Saville SM. Tourists and researcher identities: Critical considerations of collisions, collaborations and confluences in Svalbard. *J Sustain Tour*. 2019;27:573–89. <https://doi.org/10.1080/09669582.2018.1435670>
33. Duveau S. Frozen data? Polar research and fieldwork in a pandemic era. *Polar Record*. 2021;57. <https://doi.org/10.1017/s0032247421000541>
34. Zhao P, Li Y, Zhang C, Kang T, He Z, Huang G, et al. Arctic Sea Route access reshapes global shipping carbon emissions. *Nat Commun*. 2025;16(1):8431. <https://doi.org/10.1038/s41467-025-64437-4> PMID: 41022844
35. Selle P, Wilson GN. Economy, territory, and identity: A Rokkanian analysis of Indigenous self-determination in Canada and Norway. *Polar Record*. 2022;58. <https://doi.org/10.1017/s0032247421000772>
36. Huesemann MH. The inherent biases in environmental research and their effects on public policy. *Futures*. 2002;34(7):621–33. [https://doi.org/10.1016/s0016-3287\(02\)00004-6](https://doi.org/10.1016/s0016-3287(02)00004-6)
37. Park JT. Climate change and capitalism. *Consilience*. 2015;:189–206.
38. IAATO. Antarctic Treaty. Accessed 2025 December 3. <https://iaato.org/antarctic-treaty>
39. Humphries GRW, Naveen R, Schwaller M, Che-Castaldo C, McDowall P, Schrimpf M, et al. Mapping Application for Penguin Populations and Projected Dynamics (MAPPPD): Data and tools for dynamic management and decision support. *Polar Record*. 2017;53(2):160–6. <https://doi.org/10.1017/s0032247417000055>
40. IAATO. IAATO site management methods. 2024. https://iaato.org/system/files?file=2025-01/ATCM46_ip108_e_IAATO-Site-Management-Methods.pdf
41. Lynnes A. The International association of Antarctica tour operators: 28 years and counting. *Antarct Aff*. 2019;6:1–8.
42. PLANTOURS. Cruises with expedition character – PLANTOURS Cruises. 2025. Accessed 2025 December 3. <https://www.plantours-kreuzfahrten.de/kreuzfahrten-mit-expeditionscharakter/>
43. AECO. Apply for membership. 2024. Accessed 2025 November 27. <https://aeco.no/membership/apply-for-membership/>
44. AECO. Kangerlussuaq community specific guidelines. 2025. <https://aeco.no/wp-content/uploads/2024/04/kangerlussuaq-new-profile.pdf>
45. AECO. Community and research station. 2024. Accessed 2025 November 27. <https://aeco.no/guideline/community-and-research-station/>
46. Our land for the future. 2024. Accessed 2026 July 14. <https://nwtourlandforthe future.ca>
47. Beaulieu L, Arreak A, Holwell R, Dicker S, Qamanirq O, Moorman L, et al. Indigenous self-determination in cryospheric science: The Inuit-led Sikumik Qaujimajjuti (“tools to know how the ice is”) program in Inuit Nunangat, Canada. *Front Earth Sci*. 2023;11. <https://doi.org/10.3389/feart.2023.1076774>
48. Sadowsky H, Brunet ND, Anaviapik A, Kublu A, Henri D. Inuit youth-engaged community-based environmental research as supporting local development in Nunavut, Canada. *Polar Geography*. 2022;45(4):275–92. <https://doi.org/10.1080/1088937x.2022.2105972>
49. Vidal F, Saas L. Fragmented Arctic science: Permafrost as a salient feature in the divergence between geopolitical and chronopolitical perspectives. *Polar Science*. 2025;44:101207. <https://doi.org/10.1016/j.polar.2025.101207>
50. Elomina J *, Živojinović I *, Robertsen R, Tuulentie S, Rautio P. Learnings from the changing Arctic: Economy, society, and sustainability. *J Land Use Sci*. 2025;20(1):264–75. <https://doi.org/10.1080/1747423x.2025.2576064>
51. Minasny B, Fiantis D, Mulyanto B, Sulaeman Y, Widyatmanti W. Global soil science research collaboration in the 21st century: Time to end helicopter research. *Geoderma*. 2020;373:114299. <https://doi.org/10.1016/j.geoderma.2020.114299>
52. Inuit Circumpolar Council Canada. Circumpolar inuit protocols for equitable and ethical engagement. 2022. Accessed 2025 November 21. <https://www.inuitcircumpolar.com/project/circumpolar-inuit-protocols-for-equitable-and-ethical-engagement/>
53. Guimarães HR, Fragão J, Abreu J, Rettinger C, Queirós JP. Empowering ECRs: Bridging the educational gap for polar regions. *PLOS Clim*. 2024;3(2):e0000353. <https://doi.org/10.1371/journal.pclm.0000353>
54. Mallett R, Fernández Rivera A, Muhammad S, Born A. Tackling crises in cryospheric research. *PLOS Clim*. 2024;3(7):e0000439. <https://doi.org/10.1371/journal.pclm.0000439>
55. Johnson EA, Hardill I, Johnson MT, Nettle D. Breaking the overton window: On the need for adversarial co-production. *Evid Policy*. 2023;20(3):393–405. <https://doi.org/10.1332/17442648Y2023D000000005> PMID: 40557681
56. Provencher J, Baeseman J, Carlson D, Badhe R, Bellman J, Hik D. Polar research education, outreach and communication during the fourth IPY: How the 2007–2008 International Polar Year has contributed to the future of education, outreach and communication. 2011. <https://doi.org/10.13140/RG.2.1.4451.5369>
57. Salmon RA, Roop HA. Bridging the gap between science communication practice and theory: Reflecting on a decade of practitioner experience using polar outreach case studies to develop a new framework for public engagement design. *Polar Record*. 2019;55(4):297–310. <https://doi.org/10.1017/s0032247418000608>
58. Buzzard SC, Young TJ. The Antarctic Flags project: A flagship outreach campaign for international cooperation. UCL Press; 2022. <https://doi.org/10.14324/111.9781800081444>
59. Roop HA, Wesche G, Azinhaga PF, Trummel B, Xavier JC. Building collaborative networks across disciplines: A review of polar educators international's first five years. *Polar Record*. 2019;55(4):220–6. <https://doi.org/10.1017/s003224741800061x>
60. Antelo DraVN, Antelo MgArqVN. El archivo arde, el archivo hiela. MCV. 2024;54–1. <https://doi.org/10.4000/11r3o>

61. Blaskey D, Mercer L, Crimpen F v a n, Devoie É. Perspectives on funding structures, cross-cultural collaboration and institutional support needed to support the next generation of convergence climate scientists. *PLOS Clim*. 2024;3:e0000330. <https://doi.org/10.1371/journal.pclm.0000330>
62. McAllister TG, Walker LA, Smiles ND, Jennings L, Moggridge B, Naepi S, et al. Decolonize scientific institutions, don't just diversify them. *Nature*. 2025;644(8076):331–4. <https://doi.org/10.1038/d41586-025-02516-8> PMID: 40781554
63. Pertierra LR, Santos-Martin F, Hughes KA, Avila C, Caceres JO, De Filippo D. Ecosystem services in Antarctica: Global assessment of the current state, future challenges and managing opportunities. *Ecosyst Serv*. 2021;49:101299. <https://doi.org/10.1016/j.ecoser.2021.101299>
64. Mercer L, Whalen D, Pokiak DL, Lim M, Mann PJ. Ensuring continuity and impact in Arctic monitoring: A solution-orientated model for community-based environmental research. *Environ Res Ecol*. 2023;2:045001. <https://doi.org/10.1088/2752-664X/ad0241>
65. Wackernagel M, Rees WE. Our ecological footprint: Reducing human impact on the earth. New Society Publishers; 1996.
66. Norris GA, Burek J, Moore EA, Kirchain RE, Gregory J. Sustainability health initiative for NetPositive enterprise handprint methodological framework. *Int J Life Cycle Assess*. 2021;26(3):528–42. <https://doi.org/10.1007/s11367-021-01874-5>
67. Macfarlane AR, Ben-Ari T, Blanc G, Bozzato D, Calmer R, Haslett S. A call for funding bodies to influence the reduction of environmental impacts in remote scientific fieldwork. *Front Sustain*. 2024;5. <https://doi.org/10.3389/frsus.2024.1338660>
68. Knödseder J, Brau-Nogué S, Coriat M, Garnier P, Hughes A, Martin P, et al. Estimate of the carbon footprint of astronomical research infrastructures. *Nat Astron*. 2022;6:503–13. <https://doi.org/10.1038/s41550-022-01612-3>
69. British Antarctic Survey. Carbon footprint reporting 2023–24. 2025. <https://www.bas.ac.uk/science/science-and-innovation/towards-net-zero-fit-for-the-future/bas-carbon-emissions/carbon-footprint-reporting-2023-24/>
70. Clarke D, Chan P, Dequeljoe M, Kim Y, Barahona S. CO2 emissions from global shipping: A new experimental database. OECD Publishing; 2023. <https://doi.org/10.1787/bc2f7599-en>
71. Rasch M, Topp-Jørgensen E, Fugmann G, Hansen FS. Interact fieldwork planning handbook. Rasch M, Topp-Jørgensen E, Fugmann G, Hansen FS, editors. Denmark: DCE – Danish Centre for Environment and Energy, Aarhus University; 2019.
72. Holste S, Rasch M, Topp-Jørgensen E. INTERACT reducing CO2 emissions of arctic science. Zenodo; 2022. <https://doi.org/10.5281/zenodo.6683739>
73. COMNAP. Guidelines for environmental impact assessment in Antarctica. 2016.
74. COMNAP, SCAR. Inter-continental checklists for supply chain managers for the reduction in risk of transfer of non-native species. 2019.
75. British Antarctic Survey. Trial of lower carbon alternative fuel begins on RRS Sir David Attenborough. 2023. Accessed 2025 November 11. <https://www.bas.ac.uk/media-post/trial-of-hvo-fuel-sda/>
76. Lafferty A, Lucason S, Koch C, Mercer L, Young A, Raymond V. ICARP IV Research Priority Team (RPT) 5 final report: Co-production and indigenous-led arctic research. 2026.
77. Pedersen C, Otokiak M, Koonoo I, Milton J, Maktar E, Anaviapik A, et al. SciQ: an invitation and recommendations to combine science and Inuit Qaujimajatuqangit for meaningful engagement of Inuit communities in research. *Arctic Science*. 2020;6:326–39. <https://doi.org/10.1139/as-2020-0015>
78. Ljubicic GJ, Mearns R, Okpakok S, Robertson S. Nunami iliharniq (Learning from the land): Reflecting on relational accountability in land-based learning and cross-cultural research in Uqšuuqtuuq (Gjoa Haven, Nunavut). *Arctic Science*. 2022;8:252–91. <https://doi.org/10.1139/as-2020-0059>
79. Henri DA, Jean-Gagnon F, Gilchrist HG. Using Inuit traditional ecological knowledge for detecting and monitoring avian cholera among Common Eiders in the eastern Canadian Arctic. *Ecol Soc*. 2018;23.
80. Ostertag SK, Loseto LL, Snow K, Lam J, Hynes K, Gillman DV. That's how we know they're healthy: The inclusion of traditional ecological knowledge in beluga health monitoring in the Inuvialuit Settlement Region. *Arctic Science*. 2018;4:292–320. <https://doi.org/10.1139/as-2017-0050>
81. SDWG. One Arctic, One Health 2020 project proposal. 2020. <http://hdl.handle.net/11374/2483>
82. Saami Council. The sami arctic strategy. 2019. <https://icipp.unfccc.int/sites/default/files/2022-06/The%20Sami%20Arctic%20Strategy.pdf>
83. Sustainable Development Working Group (SDWG). Good practices for environmental impact assessment and meaningful engagement in the arctic. 2019. <http://hdl.handle.net/11374/2377>
84. Change S, Ahkinga O, Alexander E, Apassingok MD, Baker B, Baker M, et al. Consequences of rapid environmental arctic change for people. 2022. <https://doi.org/10.25923/kgm2-9k50>
85. Turner DT, Schaeffer JQ, Donatuto J, Landrum L, Nunn C, Lukin MK, et al. Nunakut naguatun atugluu/Co-stewardship: Co-production' through the lens of the study of environmental Arctic change's human wellbeing team. *PLOS Clim*. 2025;4(8):e0000692. <https://doi.org/10.1371/journal.pclm.0000692>
86. Carlin B, Sikka T, Hopkins P, Braunholtz L, Mair L, Pattison Z. Identifying the barriers to inclusion in field-based environmental sciences research. *Stud High Educ*. 2024;49:1652–65. <https://doi.org/10.1080/03075079.2023.2274378>
87. Dance M, Duncan RJ, Gevers M, Honan EM, Runge E, Schalamon FR, et al. Coming in from the cold: Addressing the challenges experienced by women conducting remote polar fieldwork. *PLOS Clim*. 2024;3(6):e0000393. <https://doi.org/10.1371/journal.pclm.0000393>
88. Walker C. It's time to talk about menstruation and fieldwork. *Nature*. 2024;630(8017):777–9. <https://doi.org/10.1038/d41586-024-02021-4> PMID: 38877131

89. Natcher D, Maria Bogdan A, Lieverse A, Spiers K. Gender and Arctic climate change science in Canada. *Palgrave Commun.* 2020;6(1). <https://doi.org/10.1057/s41599-020-0407-6>
90. Hindshaw RS, Mariash H, Vick-Majors TJ, Thornton AE, Pope A, Zaika Y, et al. A decade of shaping the futures of polar early career researchers: A legacy of the International Polar Year. *Polar Record.* 2018;54(5–6):312–23. <https://doi.org/10.1017/s0032247418000591>
91. Figuerola B, Valiente N, Barbosa A, Brasier MJ, Colominas-Ciuró R, Convey P. Shifting perspectives in polar research: Global lessons on the barriers and drivers for securing academic careers in natural sciences. *Front Ecol Evol.* 2021;9. <https://doi.org/10.3389/fevo.2021.777009>
92. Biemer J, Dixon W, Blackburn N. Our environmental handprint: The good we do. In: 2013 1st IEEE Conference on Technologies for Sustainability (SusTech), 2013. 146–53. <https://doi.org/10.1109/sustech.2013.6617312>
93. Guillaume JHA, Sojamo S, Porkka M, Gerten D, Jalava M, Lankoski L. Giving legs to handprint thinking: Foundations for evaluating the good we do. *Earths Future.* 2020;8:e2019EF001422. <https://doi.org/10.1029/2019EF001422>