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Unpacking plastics in Antarctica: ECR-driven priorities for Antarctic plastics research

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Abstract

Plastic pollution in the Antarctic region presents a significant environmental challenge due to its increasing presence and impacts on the remote and fragile polar ecosystem. The upcoming fifth International Polar Year (IPY-5, 2032–33) presents an opportunity for intergenerational engagement between Early Career Researchers (ECRs) and professionals in polar sciences to develop long-term research goals to address the current issues facing the polar regions. To understand the existing knowledge and views of ECRs, who will be at the forefront of the next IPY, we conducted a workshop at the Polar Early Career World Summit (PECWS, 2025), focused on concerns around plastic pollution in Antarctica. This workshop engaged ECRs from various disciplines within polar sciences to discuss the complexities of plastic pollution in the Antarctic region and to help inform future planning and decision-making in Antarctic environmental research. This essay synthesises the discussions from the workshop and incorporates current understandings from the polar plastic research sphere. The importance of standardised scientific methods, strengthening international collaborations, embedding ethical and diverse considerations into plastics research and improving communication strategies to enhance awareness and engagement is emphasised. This essay also highlights the need for enforceable measures on plastics under the Antarctic Treaty System (ATS) and calls for more equitable representation in Antarctic decision-making processes. The insights from this workshop provide a broad vision for the future of this field, using the upcoming IPY and involving ECRs to shape and undertake future Antarctic environmental research and governance directions.

1. Introduction

Plastic pollution in the Antarctic and the Southern Ocean is of growing environmental concern. The presence of plastics in this region is from a combination of sources,

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including local anthropogenic activities, such as research operations, fishing, tourism, and more distant sources, via long-range oceanic and atmospheric transportation, making it a complex transboundary issue [1–6]. To address this growing issue, multidisciplinary and collaborative approaches that integrate scientific research, policies, regulatory mechanisms, and diverse stakeholder engagement are required. Currently, collaborative institutional responses addressing plastic pollution in the Antarctic region are lacking. However, there is a growing understanding of the presence and impacts of plastics on the Antarctic ecosystem, highlighting the urgent need for coordinated efforts to generate relevant scientific data and inform decision-makers of the measures required to address this issue.

To develop insight into Early Career Researcher (ECRs) perspectives on plastics in Antarctica, three of us, as ECRs working in Antarctic plastics research space, from Australia, Italy and New Zealand, collaborated and convened a workshop at the Polar Early Career World Summit (PECWS, 2025), in Boulder, Colorado, USA. This workshop discussed the various dimensions of plastic pollution in the Antarctic region, including its presence, impacts, and governance. ECRs play a crucial role in advancing discussions on Antarctic science and governance, bringing together new perspectives and emerging knowledge. With the upcoming International Polar Year (IPY) scheduled for 2032–33, current ECRs will be at the forefront, leading crucial research projects. Engaging current ECRs in the initial planning stages for the next IPY will ensure that researchers can contribute to long-term scientific and governance endeavours and guarantee continuity from vision to implementation. Drawing on the insights and outcomes of the workshop discussions, this essay discusses the key priority areas identified by ECRs to inform actionable steps to tackle plastic pollution in Antarctica and the Southern Ocean.

2. Discussion

2.1. Understanding the room: voices behind the Antarctic plastics dialogue

The workshop brought together a diverse group of ECRs who shared a common interest in plastic pollution in Antarctica, or more widely, the polar regions. Workshop attendees were all selected through an application process to be attending the Polar Early Career World Summit (PECWS) which this workshop was a part of. The majority of attendees were based in North America (seven), primarily in the United States (six) and Canada (one). Five participants were located in Europe, split between Norway (two), Portugal (two) and Italy (one). Two participants were based in Oceania, Australia (one) and New Zealand (one). One participant worked in South America (Brazil) and one participant was based in Asia, (South Korea) (Fig 1). Notably, there were no ECRs from the African continent present at this workshop, and representation from South America and Asia was minimal. This highlights potential barriers to participation and underscores the need for greater inclusion of researchers from these regions.

Most workshop participants conducted field-based research in the polar regions, with 43% focusing on Antarctica and 29% on the Arctic. Others worked on remote non-polar environments (21%) or contributed to Antarctic research without

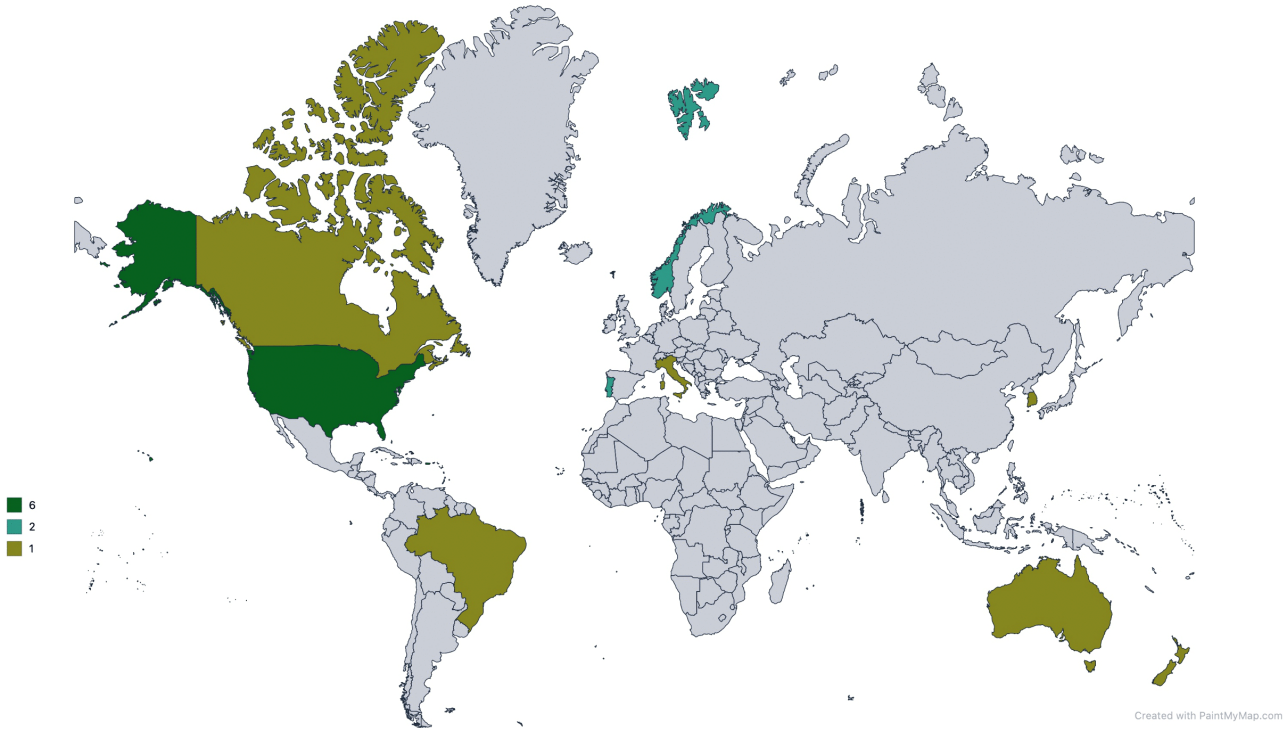

Fig 1. Map of workshop participants' location, colour corresponds to the number of attendees.

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participating in fieldwork (7%), enriching the range of perspectives in the room. When asked about surprising facts regarding plastic pollution in Antarctica, participants overwhelmingly emphasised its pervasive and widespread presence (Fig 2).

Most participants (71%) had no direct experience with plastic pollution research in Antarctica, while a few had hands-on experience (14%), and one person worked on plastics but not in Antarctica (7%). When prompted to write an answer to the question 'W*hat comes to mind when you think about plastics in Antarctica?',* all workshop participants expressed concern about the proliferation of plastic pollution in the Antarctic region (Fig 3). Although not all participants were fully aware of the scale of this issue before the session, everyone showed a willingness to learn more and actively engage in the discussions.

Fig 2. Word cloud showing responses from workshop participants on what fact surprised them the most about plastics in the Antarctic region.

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Fig 3. Word cloud showing responses from workshop participants on their thoughts on plastics in Antarctica.

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2.2. Key knowledge gaps identified in plastic monitoring in Antarctica

This breakout group explored the observational and monitoring aspects of plastic pollution in Antarctica, bringing together five researchers from various disciplinary backgrounds and career stages. The introductory workshop materials and the subsequent discussions highlighted the limited availability of data on plastic pollution in the Antarctic region and the necessity to expand our understanding of the presence, distribution and quantity of macro- (>5 mm), micro- (<5 mm-1 μm), and nanoplastics (<1 μm- 1 nm) in this environment. Although scientific observations are increasing, with plastics now being detected in Antarctic seawater, sea ice, snow, air, freshwater lakes, sediments, and biota [7], data collection is hindered by inconsistent sampling, preparation, and analysis methodologies used across these studies [8]. The lack of standardisation across studies makes comparing datasets difficult. Given that research on Antarctic plastic pollution is already limited compared to our global understanding of this pollutant, a lack of comparability hinders our knowledge of this topic. The need for stronger international collaboration and coordination was called for, noting that the sharing of resources, expertise, and increasing open-access data will be foundational in building a progressive plastic research community.

Most research in Antarctica is focused on marine environments, resulting in a serious lack of data from terrestrial environments, as well as limited data for Antarctica in general compared to other areas of the world [9]. Temporal and spatial data are also lacking, which limits our ability to assess trends or understand the extent of the issue. The group raised Antarctica's unique position as a 'natural laboratory' for studying plastic dispersal, with its limited direct inputs of plastics compared to the rest of the world. Participants highlighted the need to develop our understanding of how plastics behave in polar marine ecosystems, specifically their ecological effects and potential toxicity to organisms and food webs. Changes in Southern Ocean circulation and the Antarctic Circumpolar Current were raised as influences for the movement and accumulation of plastics in the region [10,11]. There was also interest expressed in exploring how plastic buoyancy and vertical transport dynamics affect environmental exposure and biological interactions in the ocean [12].

Effective science communication and engagement were identified as fundamental for raising awareness and building support for action on plastic pollution in polar regions. The power of visual storytelling, including tracing the journey of a single plastic item to the Antarctic, to make complex issues like remote plastics more relatable to the public, was raised. Tools such as 'systems mapping' were also discussed as valuable ways to boost both public engagement and research outputs, using visual maps to make sense of complex, interconnected problems. Tailored messaging for specific audiences would ensure that communication is impactful and appropriately framed.

Three additional themes were also touched upon: the environmental impact of polar research, social and ethical considerations, and partnerships and innovation. Participants recognised that polar research activities contribute to plastic inputs in the region and that wealthier nations, through their National Antarctic Programs (NAPs), bear a particular responsibility

to minimise the environmental footprints of scientific efforts. Social inequities tied to plastic production and disposal are part of the broader ethical context and highlight the need to embed these considerations in Antarctic governance regarding plastic pollution [13]. Participants also saw potential in partnering with industries (e.g., outdoor gear brands or logistics companies) to drive innovation and secure funding for future research. The importance of aligning science practices with sustainability principles to work towards reducing plastic pollution in the Antarctic region was emphasised.

2.3. Key challenges identified in addressing the impacts of plastic pollution in Antarctica

This breakout group explored the topic of the impacts of plastic pollution in Antarctica. None of the four participants engaged in direct research on plastic pollution, which provided valuable interdisciplinary views on the topics being discussed. While the impacts of plastic pollution are well-documented globally, the Antarctic region remains underresearched, particularly when it comes to understanding the biological effects of plastics [11]. Some studies focus on the ingestion of plastics or the entanglement of Antarctic species, but limited attention is given to key areas such as sub-lethal effects, trophic transfer, impacts on microbial and benthic communities, or broader ecosystem consequences [3,14]. This group determined that one of the most significant barriers is the limited availability of scientific data.

The group linked this knowledge gap to the region's remoteness and inaccessibility, which makes sampling logistically and financially challenging. The harsh environmental conditions of the Antarctic limit the frequency and coverage of sampling efforts to short seasonal windows, usually over summer. Consistent monitoring efforts are then limited by access to the region, traditionally provided through NAPs, and equipment constraints. As previously discussed, the detection and quantification of micro- and nanoplastics currently present significant challenges. The difficulty of analysing synthetic particles in samples demands specialised techniques for analysis and field campaigns that ensure high levels of contamination control, which are often impractical in Antarctic field campaigns [15,16].

Environmental extremes in Antarctica present challenges to designing laboratory experiments that can accurately replicate the unique conditions [17]. Many Antarctic species have specific adaptations, are slow-growing, and possess unique life-history traits that are difficult to replicate under controlled laboratory conditions. This makes ecotoxicological testing and long-term impact assessments of plastics challenging, with the lack of baseline data for many Antarctic organisms [18,19]. As warming accelerates from global climate change, glacial melting and sea-ice retreat may release previously trapped plastics into the environment, while shifts in ocean currents and food webs alter exposure pathways for organisms [20,21]. Further research on the broader climate implications of plastic pollution is needed, with initial research highlighting their role in cloud formation processes and effects on radiative forcing [22,23].

A lack of standardisation in scientific methods was also flagged as a significant limitation in the development of our understanding of this issue. Comparing results remains difficult without shared protocols for sample collection, preparation, identification, and quantification. This limits the ability to draw conclusions or advocate for policy change. The discussion emphasised the need for the development of internationally agreed research protocols that would enable more reliable and comparable data collection. The participants stressed that interdisciplinary collaboration across ecotoxicology, oceanography, economics, legal, and social sciences is essential to addressing plastic pollution in Antarctica and the Southern Ocean.

Further discussions touched upon how human presence is a key source of plastic pollution in the region. Despite existing environmental regulations from the Council of Managers of National Antarctic Programs (COMNAP) and various NAPs, reliance on plastics for packaging, working materials, and scientific equipment, including appropriate clothing, remains high. This group emphasised the need for more substantial reduction and disposal guidelines of plastic waste in the Antarctic, noting that minimising plastic inputs is essential to limit further ecological impacts. Finally, the group discussed how low public awareness of plastic pollution in Antarctica is primarily due to its invisibility when compared to the visible severity of plastic pollution seen in other regions of the world. Public engagement, education, and accessible communication will play roles in raising awareness and developing actionable responses to address plastic pollution in the Antarctic.

2.4. Key challenges identified in governance of plastic pollution in the Antarctic region

This breakout group consisted of six participants and discussed key challenges with the governance of plastic pollution in the Antarctic region. Although most participants in this group had no direct experience in the Antarctic plastics research space, their personal experiences of plastic pollution offered valuable contributions to the discussion. One participant had witnessed plastic waste emerge during spring snowmelt in Alaska, and another recalled seeing plastic debris on a remote island in Cape Verde and inside the stomachs of stranded cetaceans. Other participants shared knowledge from colleagues working on plastic pollution in Brazil's rivers and coastal zones. A discussion around the documentary '*Plastic People'* also served as a touchpoint for reflecting on the health implications of microplastics and the global nature of the issue.

This group of participants discussed personal experiences around plastic pollution in the Arctic, highlighting the ubiquitous nature of plastic pollution throughout remote environments [24–26]. In response, they proposed regionally grounded policy solutions, such as changing packaging practices, modifying how hay is wrapped for reindeer in the Arctic, improving community waste management systems, and promoting plastic-free, traditional crafting methods that do not rely on plastics. While these ideas emerged from an Arctic context, participants agreed that the Antarctic will also benefit from similar precautionary approaches, particularly by using Indigenous knowledge and embedding it within the Antarctic Treaty System (ATS) decision-making processes [27–30].

One of the most pressing issues identified in addressing plastic pollution in Antarctica is the absence of enforceable measures specifically targeting plastic pollution [31]. Some examples of possible measures to reduce plastic pollution discussed included implementing strict plastic-free packaging measures on vessels going to the Antarctic region, wearing natural fibres on board all vessels in the region, requiring the use of microplastic filters in all research stations, and improving grey water treatment techniques to capture microplastics. Participants in this group emphasised that as human activities in the Antarctic region increase, primarily through science programs, tourism and fishing activities, so will plastic pollution. This highlights the urgency of proactive and enforceable measures required to limit the impacts of plastics in the region.

Further interconnected challenges that were identified include the invisibility of pollution, especially in Antarctica where there are no permanent populations, which makes it difficult for the public to engage emotionally with the issue and understand the urgency surrounding this. This is compounded by weak governance infrastructure for plastics, especially in Antarctica, where resources and enforcement capacity are limited. A lack of widespread awareness and knowledge around Antarctic plastic pollution, both in scientific and public spheres, is limiting actionable governance measures. The participants recognised the ethical dimensions of plastic production and use, emphasising the need to acknowledge socio-economic structures that influence the impacts and responses to the issue. Lastly, there was consensus on the need for increasing diverse perspectives and ECRs in the policy and research processes that are currently in place, without which there is a lack of inclusive and innovative governance.

2.5. Key priorities identified by ECRs on plastic pollution in the Antarctic

Following the in-depth discussions held in the breakout groups, we synthesised a set of key priorities aimed at strengthening efforts to address plastic pollution in the Antarctic region. The discussion outcomes were synthesised into three key priority areas formed from the interrelated findings across all groups (Table 1). These are expanded on in the points below the key themes.

1. Methodological standardisation and the collection of robust data for informed action
    - Urgent need to standardise sampling, preparation, and analysis methods.
    - Expand spatial and temporal data collection by increasing the number of study areas across the continent and establishing long-term monitoring programmes to generate multi-year datasets.

Table 1. Key themes, suggested actions, and the links to broader challenges in relation to addressing plastic pollution in Antarctica.

Key Themes	Linkages to Broader Challenges	Suggested Actions
1. Methodological standardisation and collection of robust data for informed action	• Lack of comparability across datasets • Fragmented data limits policy relevance and long-term trend analysis • Marine environments dominate research focus • Poor understanding of ecosystem-level or sub-lethal impacts	• Develop and implement standardised sampling and analysis protocols • Launch coordinated efforts (e.g., IPY-wide intercalibration projects) • Increase studies on terrestrial plastics and under-researched taxa • Improve spatial and temporal coverage
2. Collaboration and interdisciplinary research	• Global funding gaps for Antarctic research • Systemic inefficiencies and wasted resources • Need for inclusivity of Indigenous voices • Lack of representation limits creativity and accountability • Missed opportunity for long-term investment in future leaders	• Increase collaborative research and mentorship with the SCAR Expert Group on Plastic Pollution (SPEG) • Build lasting partnerships through IPY-5 • Work with and incorporate traditional knowledge systems from Southern Hemisphere Indigenous communities • Create formal roles for ECRs in governance dialogues
3. Prevention, policy and public engagement	• Low public visibility of Antarctic plastic pollution • Difficult to mobilise support without public resonance • No binding obligations under the ATS regarding plastics • Voices from developing states remain unheard in Antarctic discourse	• Use visual storytelling and relatable narratives • Introduce enforceable plastic-free protocols for all Antarctic activities • Regulate greywater discharge and microfiber release • Diversify participation in polar research and policy

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- Ensure methodological consistency to improve data comparability.
- Strengthen laboratory approaches to reflect Antarctic conditions, gain ecotoxicological data and produce reliable impact assessments aimed at protecting local biota.

2. Collaboration and interdisciplinary research

- Promote global coordination, with a focus on initiatives like the Fifth IPY, which will also encourage pooling of funding and resources.
- Develop standardised protocols and share resources across institutions and nations.
- Engage diverse teams to progress current research and our understanding of the issue and increase interdisciplinary solutions.
- Build inclusive platforms for collaboration, with early-career researchers and voices from underrepresented regions at the forefront.
- Increase mentorship programs that help ECRs gain knowledge and expertise from professionals in the field.

3. Prevention, policy and public engagement

- Reduce plastic use at the source, with a particular focus on sustainable practices in field operations, including both scientific and tourism activities.
- Create legally enforceable measures to address plastic pollution in the Antarctic and implement existing technologies for waste management.
- Use creative tools to raise awareness, increase both public and political engagement, and make Antarctic plastic pollution more visible.
- Ensure adherence to ethical research practices and promote social equity in decision-making.

3. Directions for addressing plastic pollution in the Antarctic

As a result of this workshop, we have combined the knowledge gained with our own expertise on the key themes relating to plastic observations and monitoring, plastic impacts, and plastic governance in the Antarctic to provide direct and actionable recommendations to the Antarctic plastic community. Moving forward, we envision a research and governance landscape for addressing plastic pollution in Antarctica that prioritises coordinated science efforts, promotes inclusivity, and allows for responsive governance actions. At the heart of this vision is a recognition that Antarctica, as a dedicated place of peace and science [32], offers a unique opportunity to lead globally relevant conversations on internationally coordinated research efforts to address plastic pollution, strive towards environmental justice, and promote sustainable science practices.

3.1. Working towards an Antarctic-wide plastic research campaign as part of the Fifth IPY

We envision this field moving towards the development of standardised, open-access methodologies for the collection, analysis and monitoring of plastic pollution to further the field and help inform regulatory processes. To do so, developments will require a diverse international research community to come together and develop long-term infrastructure, including shared protocols, collaborative sampling campaigns, and open-access data platforms.

The upcoming IPY-5 can serve as a launchpad for these efforts, fostering a coordinated, international polar plastics research campaign. With strong global and interdisciplinary involvement, there is an opportunity to develop a standardised plastic research campaign using best practices for the collection, preparation, and analysis of samples. The goal will be to collect comparable data with broad spatial and temporal coverage over the IPY to ensure consistency and comparability across all study stages. It will provide an opportunity to develop standard operating procedures, unify methodologies and work together across NAPs and research institutes to collect large-scale datasets. Utilising icebreakers and Antarctic research stations to install equipment and run experiments in parallel would help achieve a thorough spatial dataset. Ultimately, this will enable us to produce robust, globally relevant datasets that are comparable across studies and advance the global understanding of plastic pollution.

As part of an Antarctic-wide plastic research campaign, ecotoxicological studies should also be carried out to evaluate the impacts of plastics, from macro- to nanoplastics, on species and ecosystems across the continent. Laboratory experiments and field assessments will serve to investigate the physiological, behavioural, and reproductive effects of plastic exposure on organisms belonging to different trophic levels and the potential for bioaccumulation and biomagnification through the food web. Combined effects of plastics and associated chemicals, as persistent organic pollutants and heavy metals, should also be explored to understand the potential for synergic interactions. These findings will provide essential data to understand the broader consequences of plastic pollution on Antarctic ecosystem health and resilience and inform mitigation and conservation strategies during the campaign.

This will be an enormous undertaking, not only because of the current limitations and unknowns in this field, but also because of the resources required for such a project's success. With seven years until the IPY, we have an opportunity for international collaboration across NAPs to make this happen. International Polar Years provide an opportunity to pool funding and resources from a collection of countries to address a common goal. Because funding is always a limitation to the success of global initiatives, planning collaborative efforts in which resources can be pooled and shared will help achieve this goal. For the future success of such a project, three essential aspects will be required:

1. Strong international collaboration and cooperation, which will unite NAPs and promote multinational coordinated efforts, working together with the Scientific Committee for Antarctic Research (SCAR) and the International Arctic Science Committee (IASC).
2. An agreement on best practices for sample collection and analysis, and an understanding of the most critical knowledge gaps to address in this space.

3. The establishment of an international working group of experts to develop best practices and a plan over the next five years, and to implement and action this plan from 2030 and undertake the campaign from 2032-33.

In the framework of the upcoming IPY 2032–33, we also advocate for coordinated initiatives in which nations operating in Antarctica collaborate on practical waste reduction actions and clean-up operations to minimise plastic footprints and demonstrate a commitment to environmental protection. Suggested actions include avoiding single-use materials where possible within bases and field camps and standardising waste management and recycling protocols across research stations, which would ultimately limit the direct input of plastics into the Antarctic and therefore the dispersal further afield. Such measures should also be implemented by tour operators, who accompany tourists on cruises around Antarctica and on visits to the continent, and fishing vessels, which operate in the Southern Ocean. Standardised clean-up programs focused on equipment removal and abandoned historic waste sites also need to be undertaken by all NAPs to restore polluted areas and limit further harm.

3.2. Developing governance structures to address plastic pollution in the Antarctic

The institutional structures within the ATS must acknowledge plastic pollution as a threat to the region's unique ecosystem and provide a clear framework to address it. The IPY-5 offers an opportunity to re-examine the policies currently in place and propose specific measures that will help reduce plastics coming into the region and implement technologies to capture the release of microplastics from NAP activities. To work towards this goal, we think that parties within the ATS should:

1. Draft and implement specific, legally binding measures that phase out single-use plastics from all activities taking place in the Antarctic region, including fishing, tourism, and scientific expeditions.
2. Include precautionary and polluter responsibilities across decision-making within the different institutions of the ATS and self-regulatory bodies like the International Association of Antarctic Tour Operators (IAATO).
3. Strengthen coordination across the global environmental governance scale, including greater interaction with the International Maritime Organisation (IMO) and the emerging Global Plastics Treaty.

3.3. Interdisciplinarity, collaboration, inclusivity and equity for a more sustainable world

An inclusive and empowered research community is central to developing this field of research. ECRs must be meaningfully involved in shaping future research and governance strategies, with leadership and decision-making opportunities provided to develop crucial skills and a platform for involvement. For this to be entirely equitable, the structural barriers that prevent full participation from underrepresented groups within Antarctic science and governance processes need to be addressed. A good place to start is by addressing barriers to international events and conferences. These are often held in high-income countries, with visa restrictions and financial costs limiting diverse attendance. However, these events are essential spaces for networking, collaboration and laying the groundwork for the future of research spaces. To address this, the polar research community needs to ensure that conferences and workshops are hosted in geographically and politically accessible locations, with travel support for underrepresented ECR groups provided.

The field of plastics research is focused on a more sustainable world, and this needs to be reflected in every level of operation. NAPs and research institutions must commit to reducing their plastic footprints and pilot low-impact logistics. There are opportunities to develop sustainable alternatives and circular systems for all activities taking place in the Antarctic region. Our discussion in this essay and the proposed priority areas highlight an urgent need to transition from siloed approaches to collaborative governance frameworks. This will provide opportunities to embed ethical and social dimensions of plastic pollution into decision-making. By rethinking our plastic consumption patterns, learning from Indigenous and underrepresented groups, we can move towards making the ATS more inclusive and transparent. We strongly believe

that by centring collaboration and equity, we will be able to safeguard the Antarctic region from increasing plastic pollution while also setting precedent for global environmental stewardship.

4. Conclusions and future directions

The discussions across all three breakout groups highlight the urgent need for continued, interdisciplinary dialogue to advance our understanding of plastic pollution in the Antarctic region and strengthen efforts to address it. Holding a workshop and encouraging discussion with diverse perspectives of participants who could draw upon personal experiences of plastics added depth to the material presented here and provided a strong basis for a collaborative approach to formulating ideas for the future of this research space. Key priorities were established from this workshop, synthesised and elaborated on to ideate potential paths forward for this field. As the region faces mounting pressures from scientific activity, tourism, and global plastic production, it is critical that research and governance efforts remain responsive, collaborative, and forward-looking. ECRs are uniquely positioned to contribute fresh perspectives, drive methodological innovation, and advocate for more inclusive and sustainable approaches to polar science and policy. Ensuring that ECRs are meaningfully engaged in ongoing conversations related to both research and governance, especially in the lead-up to large-scale efforts such as the upcoming IPY, is vital for building a more equitable and practical framework to understand and limit the impacts of plastic pollution in Antarctica and the Southern Ocean.

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