Technical Project Description for The B.I.G. Project

Objectives of the Expedition

A 5-woman team will ski from Borden Island to Isachsen on Ellef Rignes Island across the Prince Gustaf Adolf Sea, camping on sea ice and collecting small-volume surface snow, surface ice and water samples, as well as data for two citizen science studies. The expedition route is approximately 150km and is expected to take 10 days of ski travel. While acknowledging the impact our presence will have, the design of the expedition is intended to ensure minimal possible negative impact to environment, wildlife and people.

At five locations along the expedition route across the Prince Gustaf Adolf Sea the expedition will collect surface snow, surface ice and (where possible) water samples in 500ml containers. No motorized or power tools are used to collect the samples – only a scoop, an ice axe and a hand augur. Weather and snow conditions will be recorded at each sample location.

At regular intervals throughout the expedition snow characteristics will be recorded and contributed to the Snow Scope platform to an open access, citizen science database. Data will also be gathered for the citizen science Globe Observer platform, an open access database recording Arctic cloud cover.

The snow, ice and water samples collected by the expedition team will be analysed at the University of Colorado in the US and at the National Oceanography Centre in the UK. The samples will be analysed for black carbon, microplastic and heavy metal content to explore the distribution by the atmosphere across the Arctic region of these materials generated in northern Europe and North America. Similar expedition projects have been completed in Svalbard, Greenland and Iceland.

Detailed scientific rationale

The dramatic growth since the 1950s in the commercial mass production of plastic materials that are very slow to degrade has led to an accumulation of plastic waste. There is now a planetary-wide concern about the negative impact on human and environmental health this pollution could represent. Chemicals known to be detrimental to humans and the living environment are routinely added to plastic materials during their production, thus plastic pollution can serve as a means of transporting toxic chemicals into and throughout the ecosystem. In addition, plastic pollution can absorb chemicals from the surrounding environment becoming enriched with hazardous substances. The potential negative impact of additives and chemicals carried by plastic material is as of much concern as the polymeric raw material, particularly in regard to human exposure.

Plastic pollution can be degraded by the environment, for example by the action of waves, abrasion, UV radiation, or photo-oxidation. In combination with biological processes, this degradation leads to the formation of smaller plastic debris. Such fragments of disintegrated plastic elements along with plastics manufactured in microscopic dimensions, are, due to their size, especially difficult to remove from the environment and are more easily spread throughout the biosphere and food chain. Smaller plastic debris is commonly categorized by size with nanoplastic defined as $< 1\ \mu m$ in diameter, microplastic $1\ \mu m$ to 1 mm, mesoplastic 1 mm to 5 mm and macroplastic > 5 mm.

An abundant and ubiquitous microplastic presence in the environment will inevitably lead to human exposure primarily through ingestion, inhalation, and dermal contact. Given the potential severity of the impact of plastic pollution and the chemicals it may carry, it is imperative that we gain a greater understanding of its sources and the consequences of this pollution. In order to design effective management and mitigation strategies of this pollution in the future, it will be necessary to have clear knowledge of the spatial and temporal distribution, transport mechanisms and cycling processes of microplastic pollution in all environments.

Evidence of plastic pollution in the marine environment and the ecological concern it presents has been increasingly documented since the 1970s. In more recent decades, growing numbers of studies are finding evidence of significant plastic pollution in remote terrestrial areas far from any sources. Microplastic content has been found in fresh snowfall in Antarctica and in snow on the summit of Mount Everest. The discovery of significant microplastic contamination in remote areas has been explained as the result of convective atmospheric transfer of small and light plastic particles. The indication is that, due to their small size and low density, plastic particles can be transported long distances from their original source by wind and atmospheric circulation and may potentially have long atmospheric residence times. Therefore, it is reasonable to consider that atmospheric transport and deposition is potentially a major pathway of microplastic into remote regions, such as the Arctic, Antarctic, Alps, Tibetan Plateau, and Andes. Accordingly, attention has turned to the greater understanding of transport of plastic pollution by the atmosphere.

In order to gain a greater understanding of the threat posed by airborne microplastics it is necessary to explore how plastics are emitted to the atmosphere, where they come from, how long they remain airborne, the spatial and temporal distribution of the deposition of plastic via the atmosphere, how the rate of deposition might alter in the future and any links between the management of plastic waste disposal and transport patterns or deposition rates. The potential detrimental impact of airborne microplastic on human health makes this a particularly urgent area of research.
The Arctic is a region identified as being a particularly sensitive receptor region to deposited light-absorbing material. There is much concern about what possible effects microplastic pollution of Artic sea ice might be having now and in the future, particularly as the Arctic undergoes significant environmental change. The detection of microplastics in snow and ice samples taken from the surface of Arctic Ocean sea ice has demonstrated that as well as marine transport of plastic pollution, the transport of microplastic by the atmosphere extends to the Arctic region and may play a role of previously unacknowledged significance. However, further understanding is hampered by the lack of empirical data across the Arctic region (PAME, 2019), particularly regarding atmospheric deposition on Arctic Ocean sea ice and Arctic glaciers. While a modelling study completed by Evangeliou *et al.* (2020) found high transport efficiencies of microplastic particles produced by road traffic in Europe and North America to remote regions such as the Arctic were likely, no field studies exist to support these findings. To date, only five studies investigating microplastic in Arctic sea ice exist of which only one focuses explicitly on the atmospheric input contribution to ice-trapped plastic particles. However, these limited studies have found concentrations of microplastic in Arctic sea ice to be orders of magnitude higher than in surface seawater indicating that sea ice is potentially capable of trapping a sufficient volume of contaminants for further quantification and characterisation to be important. However, considerable uncertainty in the methods used are noted by the authors of the research as well as significant unexplained discrepancies in comparison with modelled studies.

It has been proposed that the concentration of plastic content in snow samples from Arctic Glaciers might be comparable to that found in Alpine, Andean and Asian glaciers and remote mountain catchments but to date there is almost no published data on the presence of microplastics in Arctic glaciers or the Greenland ice sheet. It is therefore unknown if microplastics possibly deposited via the atmosphere onto the surface of Arctic glaciers accumulate or are discharged with seasonal glacial surface melt. As we continue through a period of glacial recession, such information will become increasingly important in order to understand what happens to any microplastic pollution previously sequestered into Arctic glacier ice.

Black carbon is a form of pollution that results from the incomplete burning of fossil fuels. There are anthropogenic sources such as vehicles, shipping and industry as well as natural sources such as wild fires. The resulting black carbon can be transported around the world by the atmosphere and deposited far from its source.

Black carbon can be carried into the Arctic where it can be deposited on snow and ice. There, it can contribute to increased melting because it is a material that absorbs light to a greater degree than other particles that might be present. It is thought the black carbon on sea ice absorbs light and therefore melts the snow and ice around it.

Little is known about the spatial and temporal distribution of black carbon deposited from the atmosphere across the Arctic region and in particular on high latitude Arctic Ocean sea ice. This information is particularly crucial when it comes to using computer models to accurately recreate conditions in the Arctic and therefore be able to provide greater understanding of the changes taking place in the past and present as well as predicting possible future outcomes.

<u>Research Questions and Method Development</u>

a) **What are the source regions of microplastic and lead contaminants deposited via the atmosphere in the Arctic and what are the possible routes of transport?**

Snow, ice and water samples from high latitude Arctic Ocean pack ice would be collected during a planned ski expedition. The samples will undergo lead isotope analysis to fingerprint the likely sources of both lead and plastic pollution. Hindcast modelling will be employed to backtrack atmospheric transport routes of any detected lead into the Arctic, while Fourier-transform infrared (FTIR) spectroscopy techniques and spectral analysis will enable identification of microplastic constituents in snow and ice samples taken from the same sea ice locations. A comparison of the sources and transport findings will be used to investigate sources and pathways of atmospheric deposition onto high latitude Arctic sea ice. Hindcasting techniques can be used separately on any findings of microplastic contamination as a complementary approach to examining sources and routes of transportation.

b) **What can be discovered about the cycling and incorporation of atmospheric deposition within sea ice?**

A comparison of the concentration of microplastics and other pollutants atmospherically deposited on first-year versus multi-year sea ice will be made in order to investigate the longevity, incorporation and exclusion processes, and seasonal variation of contaminants. The age of sea ice from which snow and ice samples are collected will be assessed using observation of surface roughness, thickness and salinity. Laboratory studies will allow the study of incorporation and exclusion processes involving the Sea Surface Microlayer which can then be calibrated and explored using the field samples.

Methodology Development:
Experiences in the field and the subsequent analysis of the snow, ice and water samples collected, enabled initial protocols to be established which are being continuously refined. As well as creating routines of work for both the laboratory and in the field, there are a number of specific areas in which significant developments have been made:

- Protocols were developed for sample collection and the analysis process that sought to minimise any potential contamination of samples, as well as methodology that takes into account contamination identified in field and process blanks. Reduction of possible contamination from clothing and tools, as well as during the preparation and transportation of sample containers was also considered.

- The location of the sampling sites being remote and subject to extreme environmental conditions, as well as the nature of a ski expedition requiring that all equipment must be carried, meant that there were several factors that had to be considered when sourcing tools for the sampling. These included power source, weight, ease of use and response to freezing. It was also necessary that all parts of the tools be of appropriate material (including any coatings) in order to minimise potential contamination of samples. The food industry was discovered to be the most prolific source of useful tools for sampling with stainless steel flour scoops, fish fryers and cheese corers all proving to be highly successful.

<u>Progress and Fieldwork</u>

A training expedition across Vatnajökull in Iceland in November 2021 was used to test much of the methodology designed for the Arctic Ocean. The samples gathered during this training expedition were processed and analysed following the same protocol prepared for the anticipated samples from the Arctic Ocean. Replicated samples of surface snow were collected for analysis of microplastic content in three different locations on the glacier. Replicated samples of surface snow for analysis of lead content were collected separately in the same locations. Surface snow was then cleared and samples of ice taken from the surface of the glacier. Samples for analysis of microplastic content were collected in 500 ml aluminium containers while samples for analysis of lead content were collected in 500 ml polypropylene containers. In each of the three locations, field blanks were also collected as well as relevant weather, snow characteristic and location information.

- Iceland samples processing

Between December 2021 and March 2022, the samples collected for analysis of microplastic content were filtered in a class 100 lab space specially designed for low concentration level sample preparation in laminar flow hoods to ensure there was minimal risk of environmental contamination. The filters were analysed for deposited microplastic using FTIR imaging spectroscopy and spectral analysis using the Systematic Identification of MicroPLastics in the Environment (siMPle) spectral analysis software developed by Aalborg University, Denmark and Alfred Wegener Institute, Germany. Microplastic content was observed and identified in 7 of the 17 samples that were processed and analysed.

- Svalbard 2022 and 2023

Located at a latitude of approximately 78°N, Svalbard does not present the opportunity to access ocean pack ice but does feature plenty of fjords covered in fast ice. Fast ice does not have the same characteristics as ocean pack ice but fast ice in the fjords of Svalbard are subject to similar circumpolar atmospheric circulation and similar cycling and incorporation processes. Furthermore, it has been suggested that because it has a known history, findings from sampled fast ice might be easier and more reliable to interpret. It was anticipated that sampling snow, ice and water from the fast ice of the fjords in Svalbard could allow for the investigation of some of the same research questions as well as providing an opportunity to develop and test vital sampling routines and methodology in an environment very similar to that expected on the Arctic Ocean.
The first expedition took place between 12th and 19th April 2022 along a route between two fast ice locations where snow, ice and water samples were collected. A hand augur was then used to drill a hole through the sea ice so that bulk water samples could be collected. In both sampling locations, field blanks were collected as well as relevant weather, atmospheric

particulate matter, snow characteristic and location information. In April 2023, there was an opportunity to return to Svalbard and collect snow, ice and water samples from fast ice in the same two fjords sampled in 2022. Unfortunately, on arrival it was discovered that one of the fjords had not frozen that year. The second fjord was frozen and was accessed by snowmobile. The sampling protocol from 2022 was followed.

- Drangajökull 2022 and 2023

A sampling expedition was undertaken on Drangajökull in Iceland in May 2022. Drangajökull is the most northerly glacier in Iceland and is located at 66°N very close to the Arctic Circle and on the periphery of circumpolar atmospheric circulation. Approximately 20km in length, it is also one of the most remote glaciers in the country with no close settlements. Obtaining information about pollution deposited by the atmosphere here, in combination with the information from Svalbard and other Arctic sampling expeditions, could provide valuable comparisons and insight of regional or pan-Arctic trends of deposition. Five replicates of surface snow and ice samples for both microplastic and lead analysis were collected from two locations on the glacier. Surface snow and ice samples were collected in 500 ml glass jars or plastic containers while samples for lead analysis were collected in 500ml HDPE bottles.
In April 2023 a traverse of the glacier from its westernmost periphery to the summit of Jökulbunga and along a central ridgeline to the glacier's easternmost highpoint took place. Surface snow samples were collected at five locations along the traverse as well as weather, snow characteristic and location information.

- Arctic Ocean 2024

The Prince Gustaf Adolf Sea (approximately 78°N 106°W) in the Nunavut region of Canada is one of two areas of the Arctic Ocean in which the oldest and thickest pack ice accumulates each spring. Being able to access both first year and multi-year pack ice in such a part of the Arctic Ocean remote from areas of concentrated urbanisation or industrial activity makes it an appealing sampling destination. Snow, ice and water samples collected during a traverse of the Prince Gustaf Adolf Sea would be valuable on their own as well as in combination with the samples collected on previous expeditions in Iceland and Svalbard.

Research Output

Analysis of samples returned from Iceland, Greenland and Svalbard from 2021 until 2023 – as well as any samples returned from the Prince Gustaf Adolf Sea in 2024 – will be undertaken at the National Oceanography Centre in Southampton UK by Felicity Aston as part of her research as a PhD student with the University of Southampton.

A regularly reviewed data management plan is in place and it is intended that the results of the analysis will be published in a series of papers which will form the basis of Felicity's PhD thesis. The results will also be shared with any and all organisations or individuals that have an interest in the information. Help will be sought from the NRI and other bodies in a position to offer advice on the most effective communication and outreach strategies available to share research outputs.

Dr Ulyana Horodyskyj is a climate communications specialist for the North Central Climate Adaptation Science Center at the University of Colorado Boulder in the USA. She will analyse samples returned by the expedition for levels of black carbon. This information will be used as part of a wider project to gain a greater understanding of the distribution of black carbon across the globe and will be available as an open access dataset along with similar information from remote regions around the world including K2 and Antarctica.