Microplastics in the Canadian Arctic

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Environment and Climate Change Canada

and ArcticNet

Goal Statement

To investigate how anthropogenic particles including microplastics are transported to, within and out of the Canadian Arctic, their sinks and how they are introduced into and move up the the food chain.

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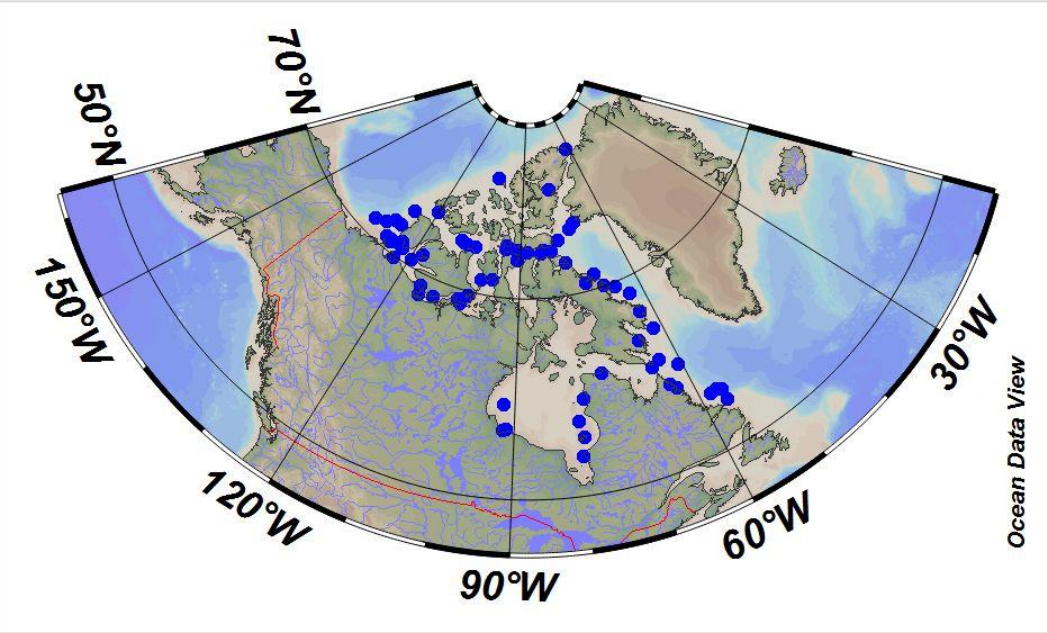
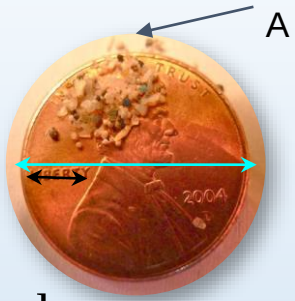
Introduction

- In the Canadian Arctic we collect samples for persistent organic pollutants (**POP**s) and microplastics (**MP**s).
- We do this with funding from ECCC, Northern Contaminants Program and ArcticNet.
- Samples for **POPs** have been collected annually in the Canadian Arctic since 1993 and **MP** sampling started in 2014.
- Samples are collected from **Canadian Coast Guard ships**, this includes the Amundsen, Louis St Laurent, and the Wilfrid Laurier.
- Recently we have been doing more community based sampling.
- **Evaluate sources, transport pathways, and fate**



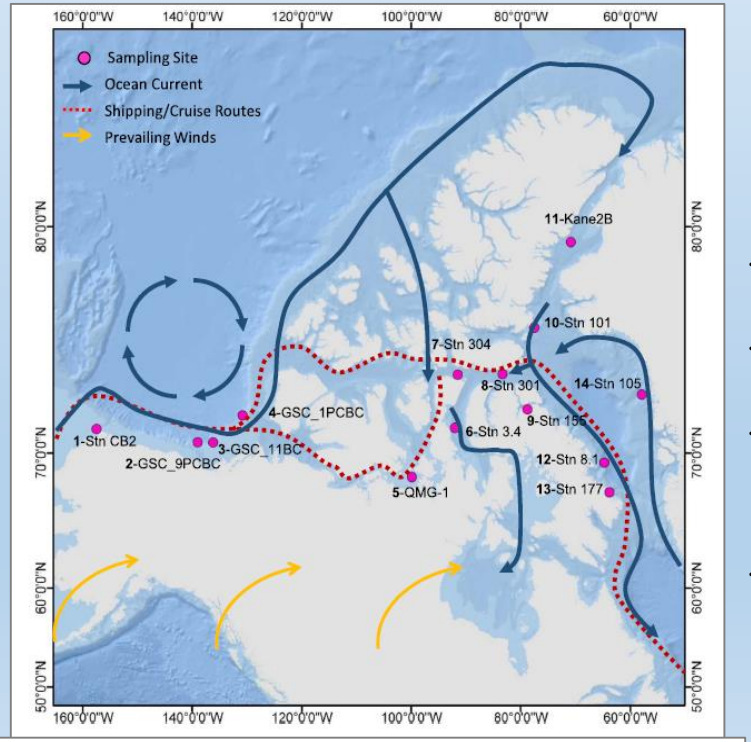
Why do we care about MPs in the Arctic?



Microplastics are fibers, fragments, or beads of plastic <5mm long.

Primary Sources → Manufacturing of MPs.

Secondary Sources → Breakdown of larger plastic debris, fibers released from textiles during manufacturing and laundering, etc…



Source: Adams, Dean, Athey, et al., (2021). Anthropogenic particles (including microfibers and microplastics) in marine sediments of the Canadian Arctic. Figure 1

- **Contaminate oceans and the atmosphere**; from the poles to the equator.
- Contaminate the **entire water column**; the surface to the depths.
- **>1000's of studies** document the MPs across the globe, however have mostly focused on marine systems.
- MPs are like other contaminants; undergo **long-range transport** via air and ocean currents.

5 Primary Threats to Aquatic and Terrestrial Life

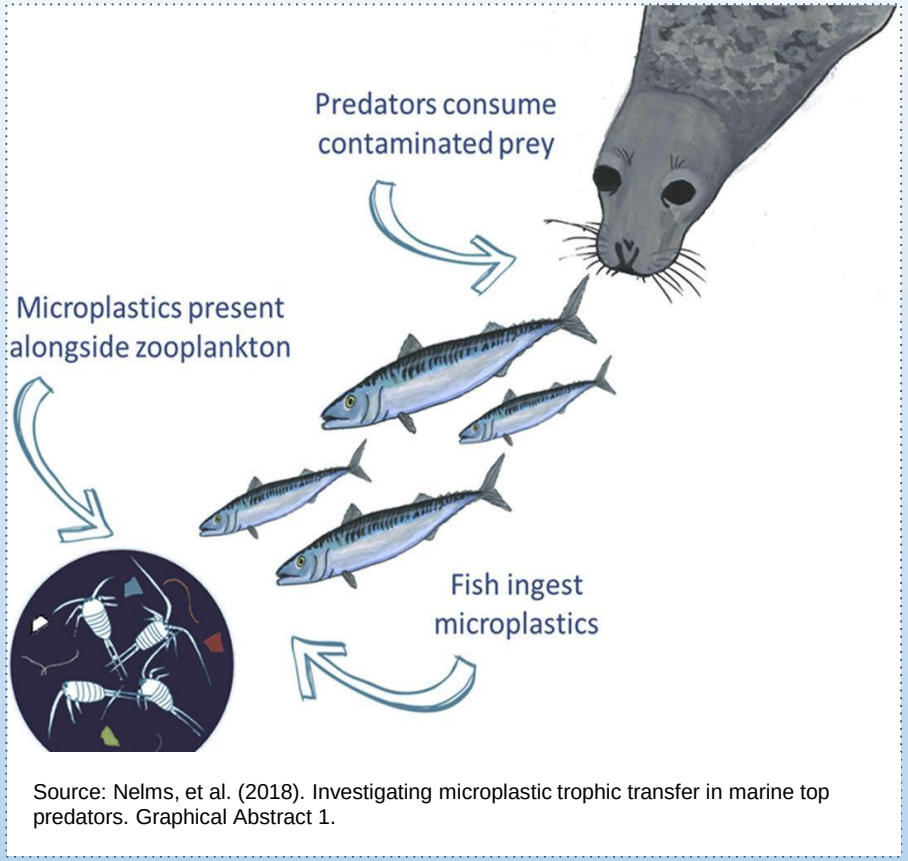
1) Ingestion:

Physical Effects

- Impedes growth due to nutrient dilution,
- Trophic transfer of microplastics

Chemical Exposure

- Plastics contain plastic additives & monomers,
- They adsorb POPs from the environment onto their surfaces.



Source: Nelms, et al. (2018). Investigating microplastic trophic transfer in marine top predators. Graphical Abstract 1.

2) Entanglement

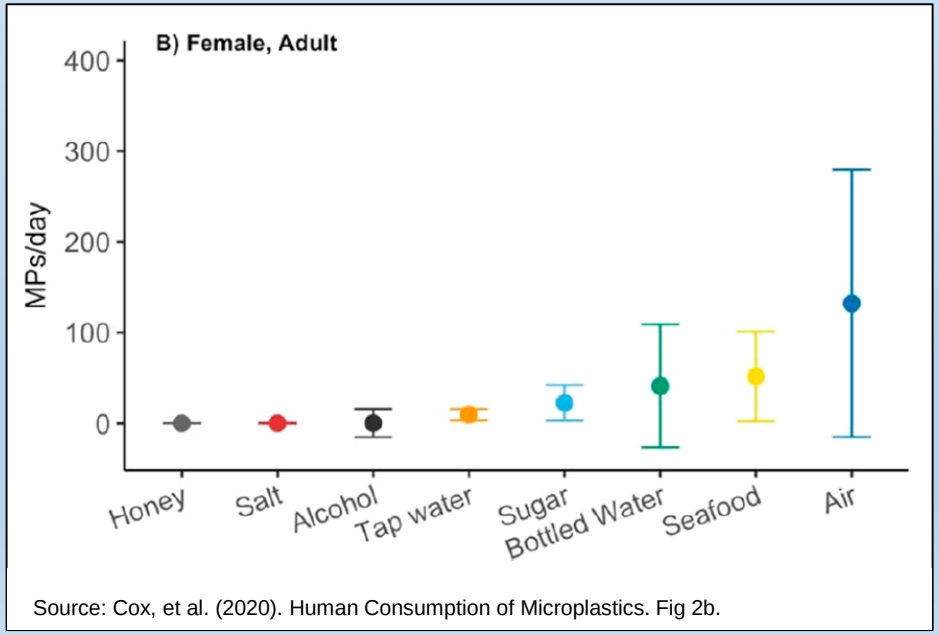
3) Suffocation

4) **Habitat Destruction**

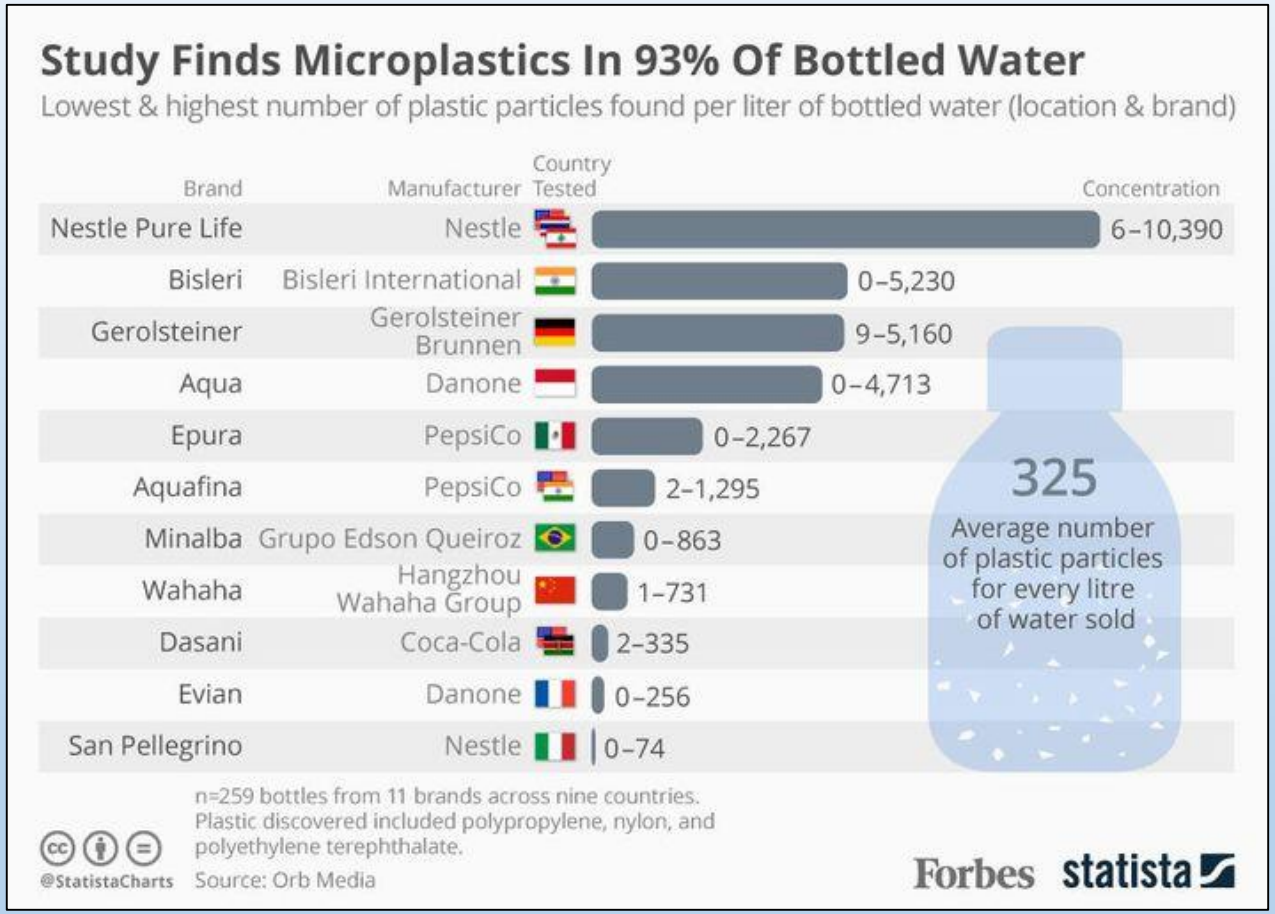
5) Transport of Non-Native Species - 'hitch-hikers'
Migrate along with the transport of microplastics

Potential Threat to Human Health

- MPs have been reported in products sold for **human consumption**
- Exposure to airborne microplastics through **inhalation**
- Human health effects and exposure pathways are currently **under investigation**

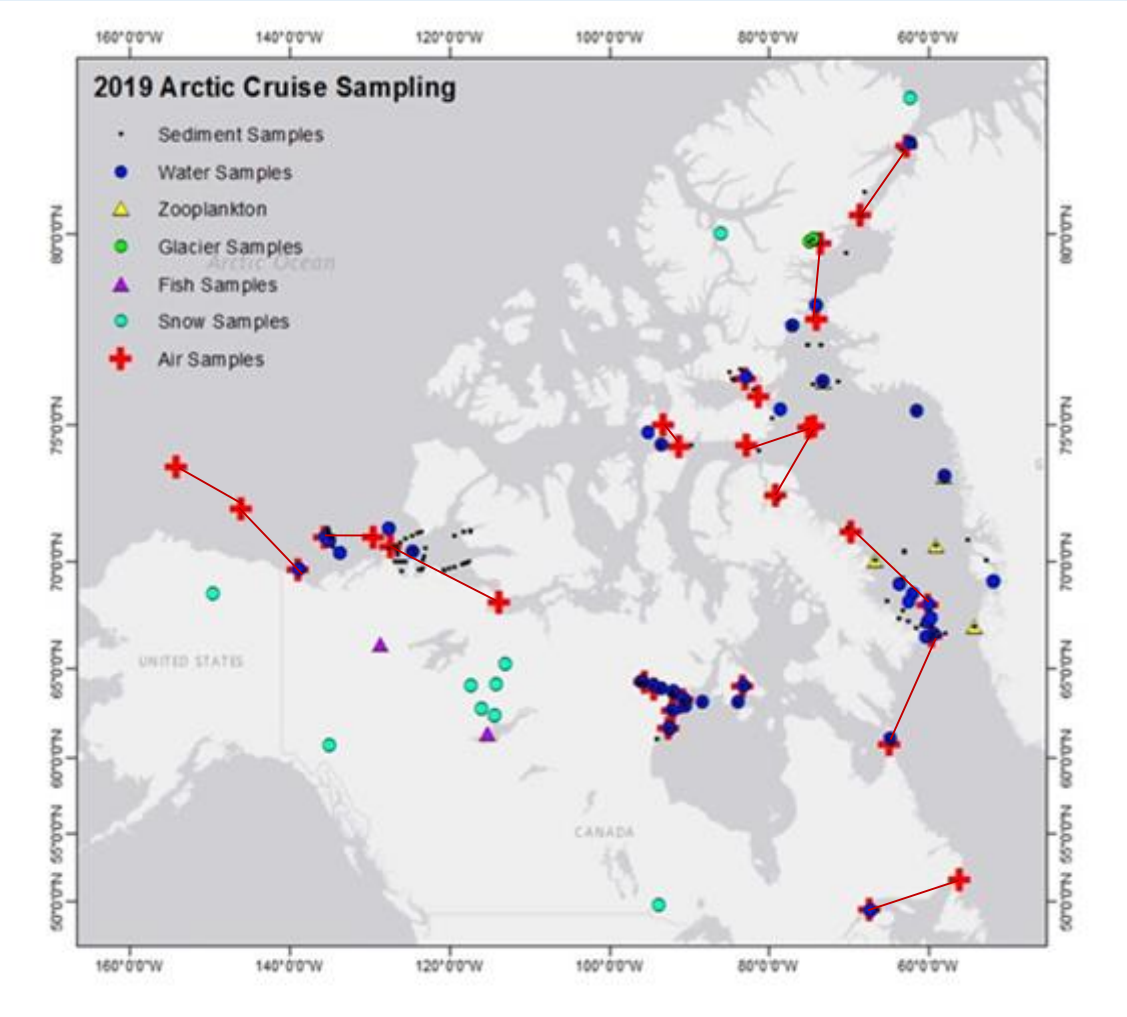


Source: Cox, et al. (2020). Human Consumption of Microplastics. Fig 2b.



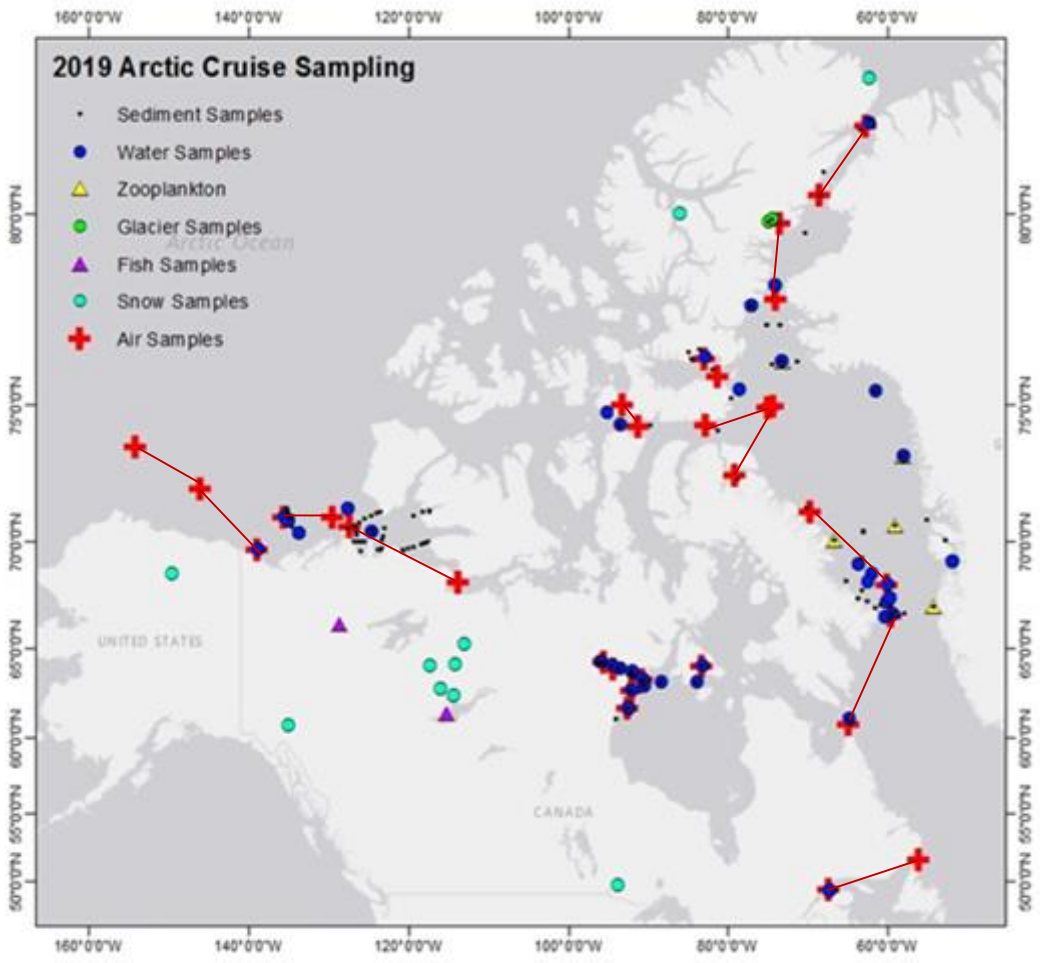
A study came out recently, suggesting plastic pollution is causing low sperm counts.

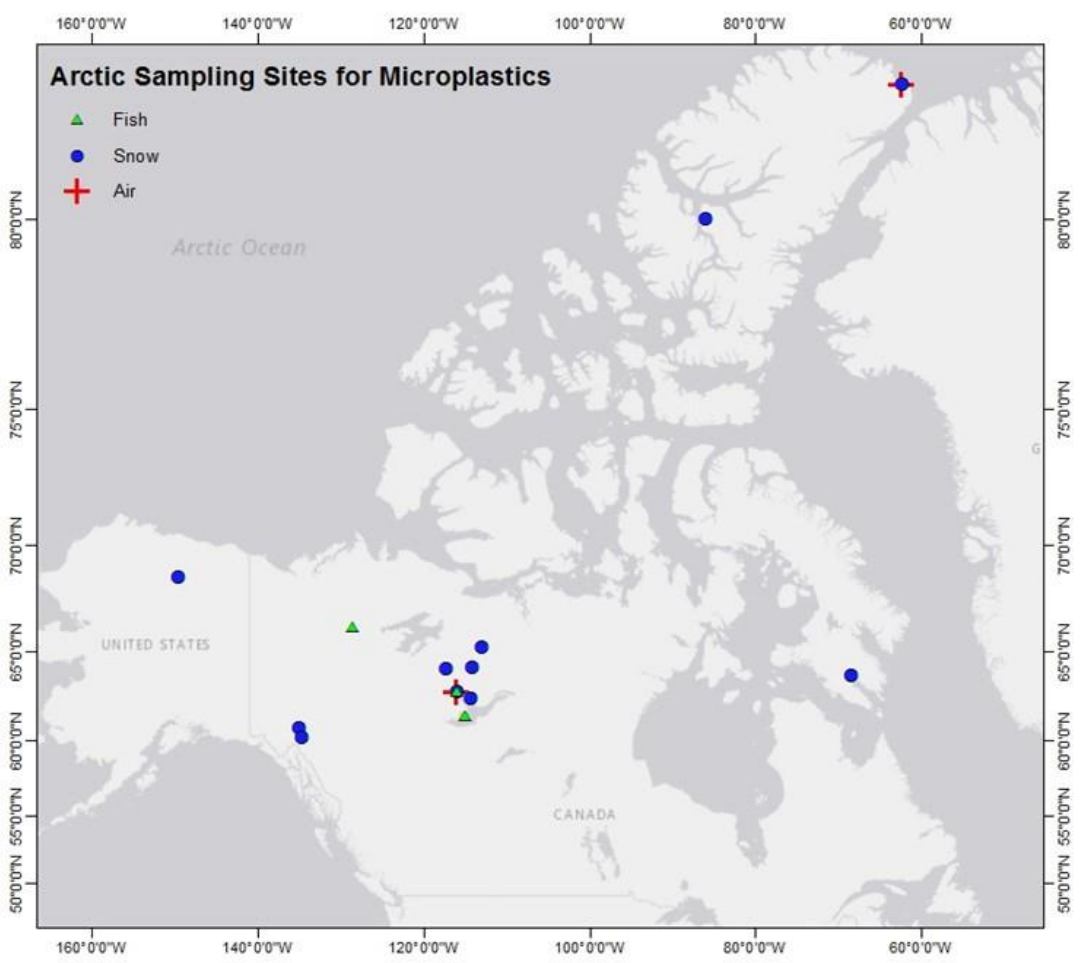
What gets sampled?
How is sampling done?



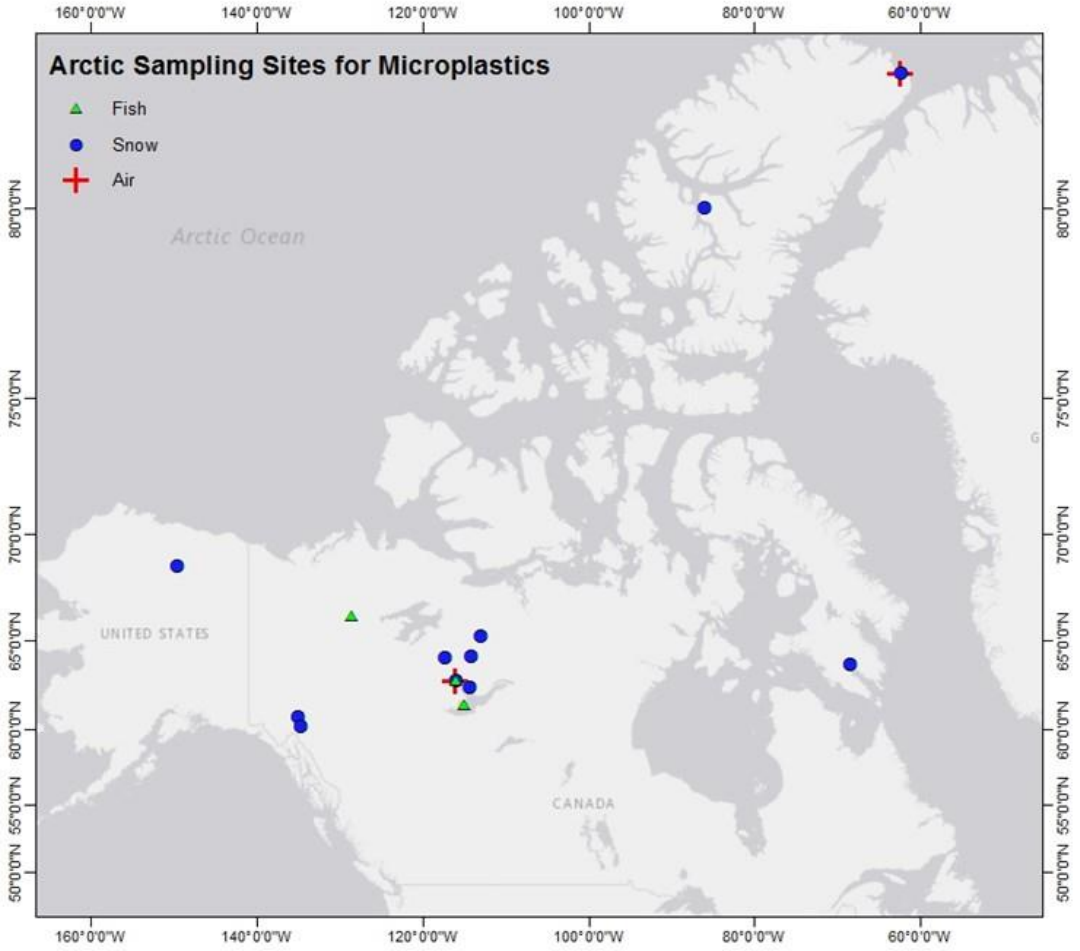
Source: Université Laval CCGS Amundsen | Institut nordique du Québec (ulaval.ca)

Sampling for MPs in 2019 versus 2020 Sampling





Community Based Sampling Site in 2020

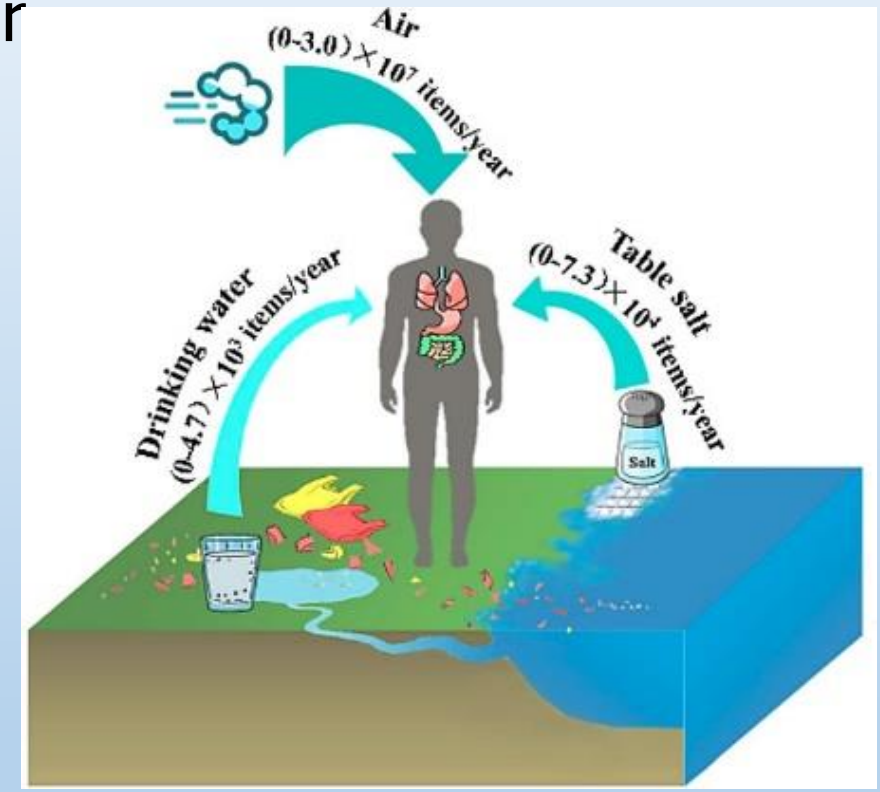


Cruise Based Sampling Sites in 2021

Atmospheric Related Samples: Air and Snow

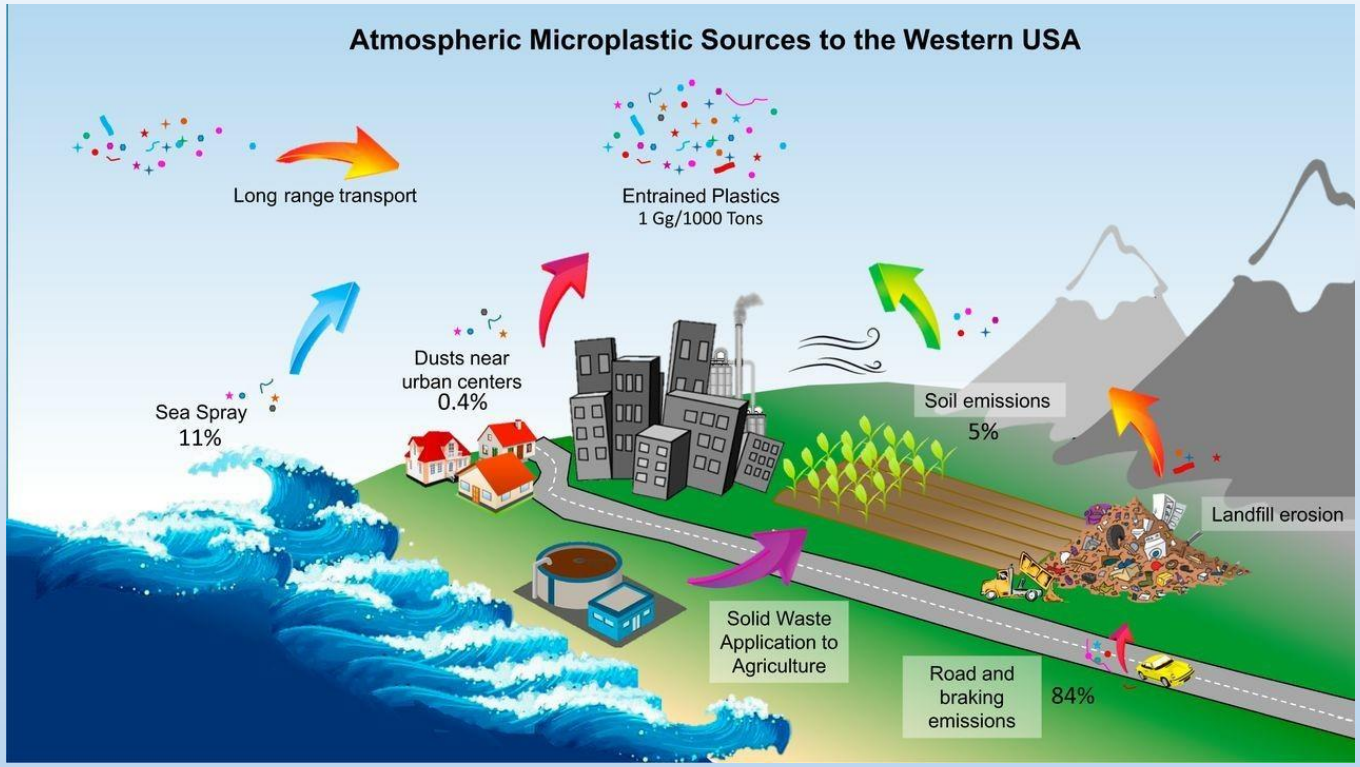
Why care about air pollution?

- We breathe in an average of 10 632 litres air per day
- Winds can take pollution all around the world
- Pollutants go from air into ecosystem, animals and humans
- Estimates indication that we ingest more microplastics through air than through drinking water and table salt



Sources to the Air

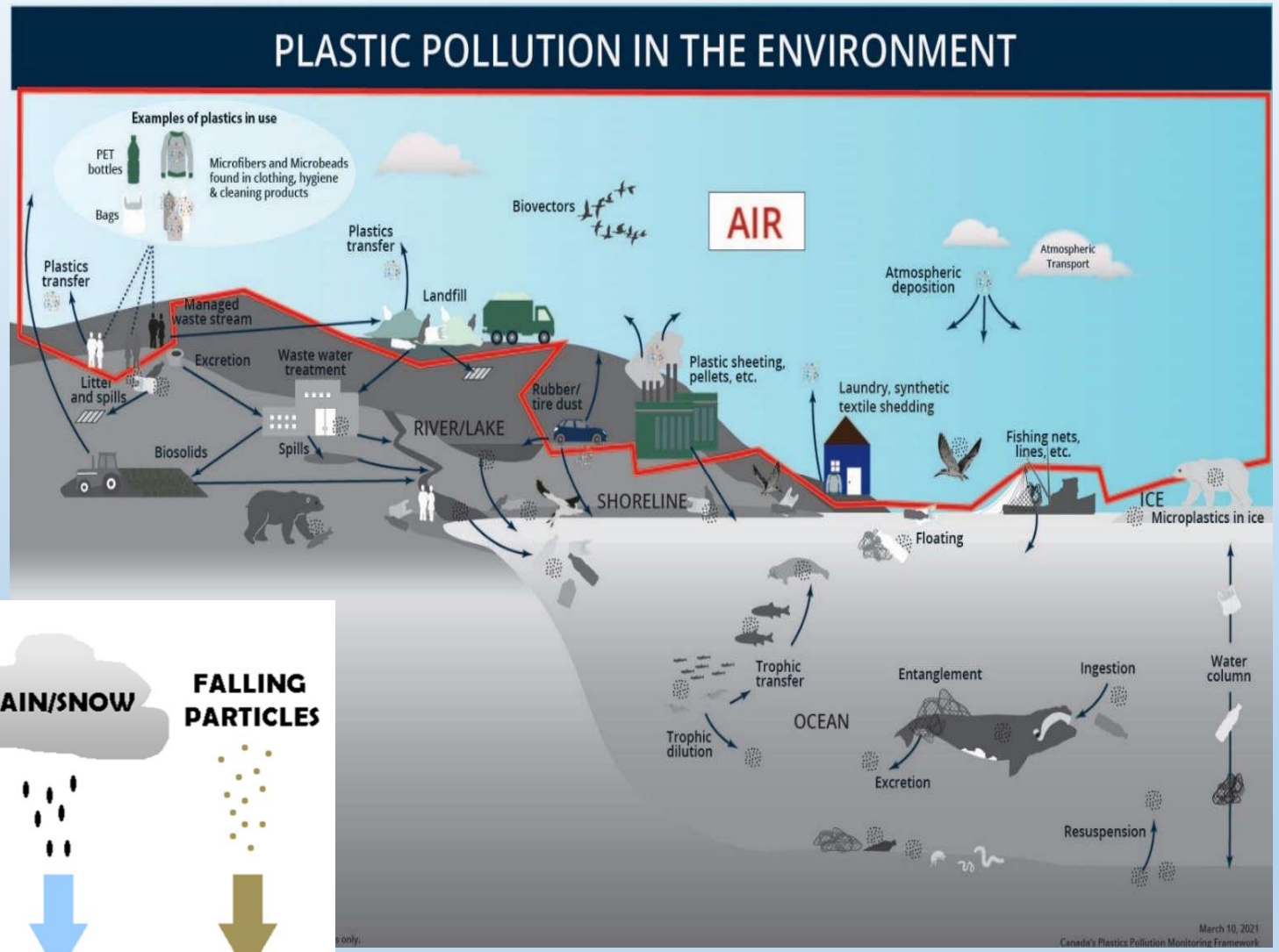
- Industry
  - Manufacturing of
    - Microplastics (nurdles)
    - Microfibers
- Cities:
  - Laundering
  - Tire wear
  - Municipal waste



- Biosolids spreading on agricultural field
- Seaspray
  - Breaking waves release microplastics back into the air.

Atmospheric Microplastics

- Like other particles, microplastics can be atmospherically transported from source regions to remote locations, including the Arctic, where they undergo deposition onto land and water
- Air transport can be very quick
- Evidence of atmospheric transportation and deposition of microplastics has been observed across the globe and in remote areas.



Atmospheric Microplastics continued…

- Methods for microplastic sampling from atmospheric related matrices is still under development.

- QA/QC methods especially for air are still evolving
  - Blanks: contamination is a real issue for smaller size particles
    - Working in a clean room
  - Spikes: what are appropriate material to assess the method efficiency.
  - Standard Reference Materials: under development NIST
  - Intercalibration studies: limited

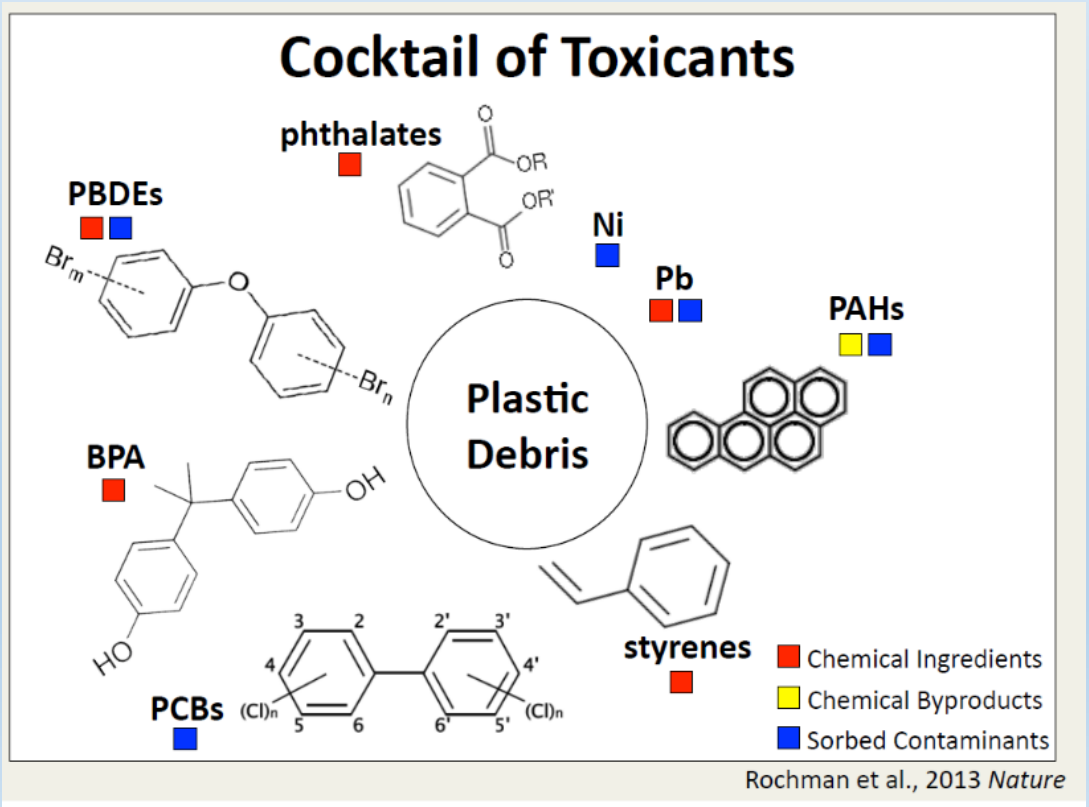
Atmospheric Microplastics continued…

- Microplastics in air are small, we look for all sizes 10um-5mm but most are in the <250um, nano-plastics are also very important
  - Sample contamination is a real concern
- Like other particles, microplastics can undergo changes in the air
  - UV or OH radicals can break them down in to smaller particles that would enhance their air transport
  - Development of organic films that may cause particle aggregation and enhanced deposition
  - Sorption of airborne contaminants

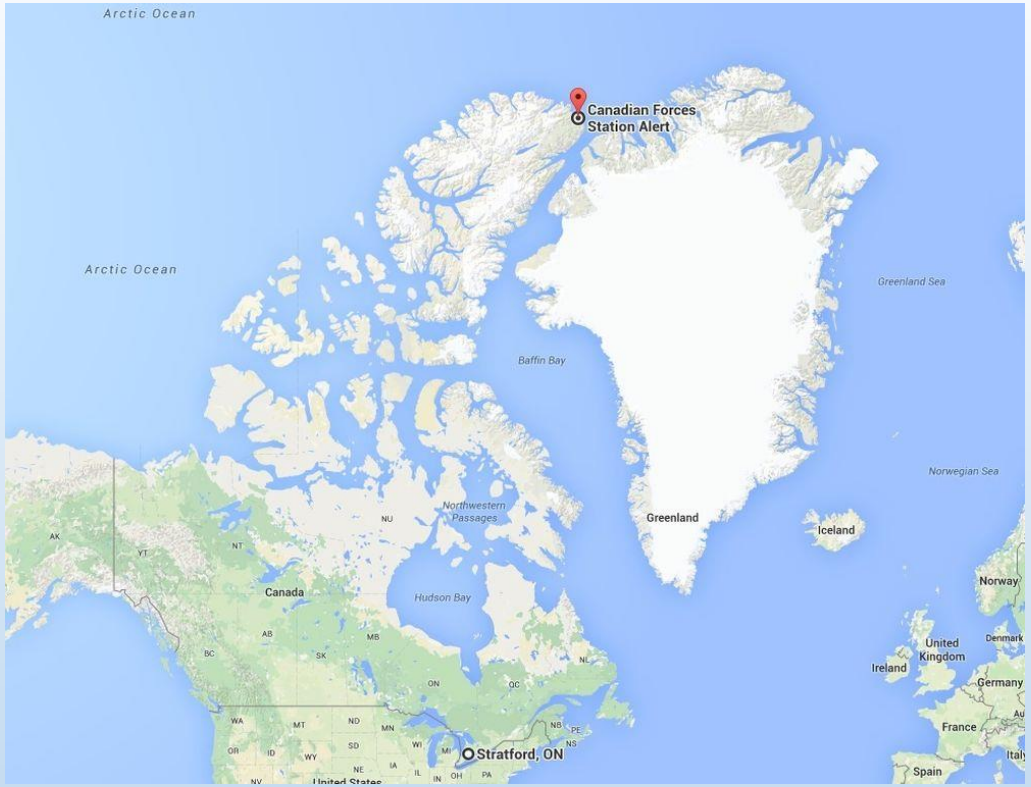
Atmospheric Microplastics continued…

- Atmospheric microplastics may also be a vector for less volatile chemicals that are added to the plastics during manufacturing ie
  - dyes
  - UV filters: UV-328
  - flame retardants
  - tire wear chemicals, etc…
- And can sorb other chemicals

from the air



Alert, NT



- Worlds most northern place where people live
- Canadian Forces Station (spying ….shhhhh)
- Sailboat/ship HMS Alert, 1875
- About 50-60 people stay there
- No one lives there permanently
- Weather station, air laboratory
- 845 km from north pole

Why Alert

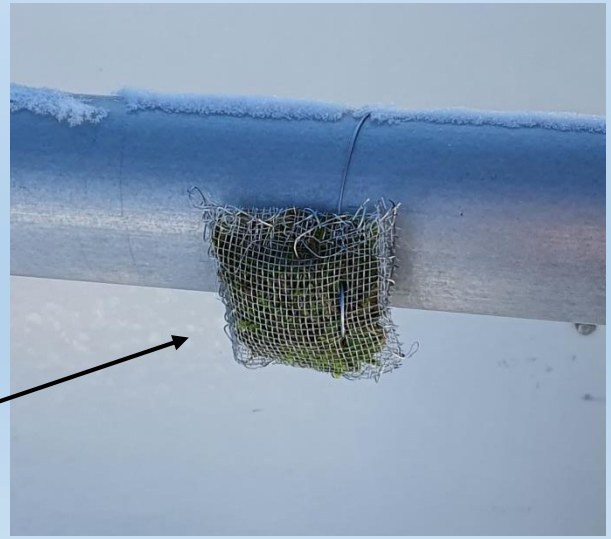
- Air quality monitoring station
- Ancillary data
- Highly trained personnel

- Studying and comparing different ways to collect atmospheric related samples.

  - Active air sampling
  - Passive sampling
    - Moss bags
    - Petri dish

  - Bulk deposition
    - Nipher Gauge
    - Bucket

Passive Petri Dish



Active air Sampler

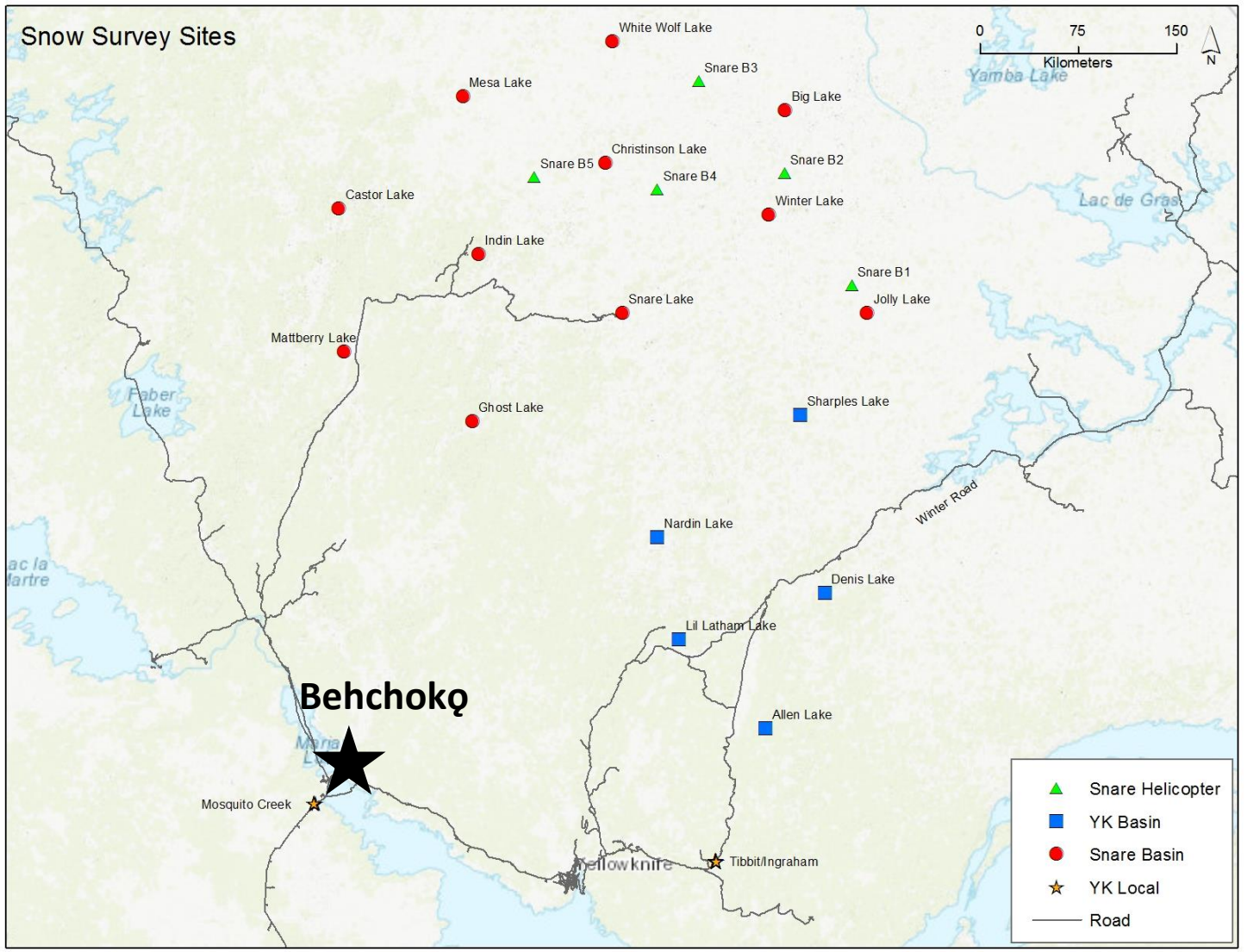
Why is it Important to Sample in the Yukon and NWT

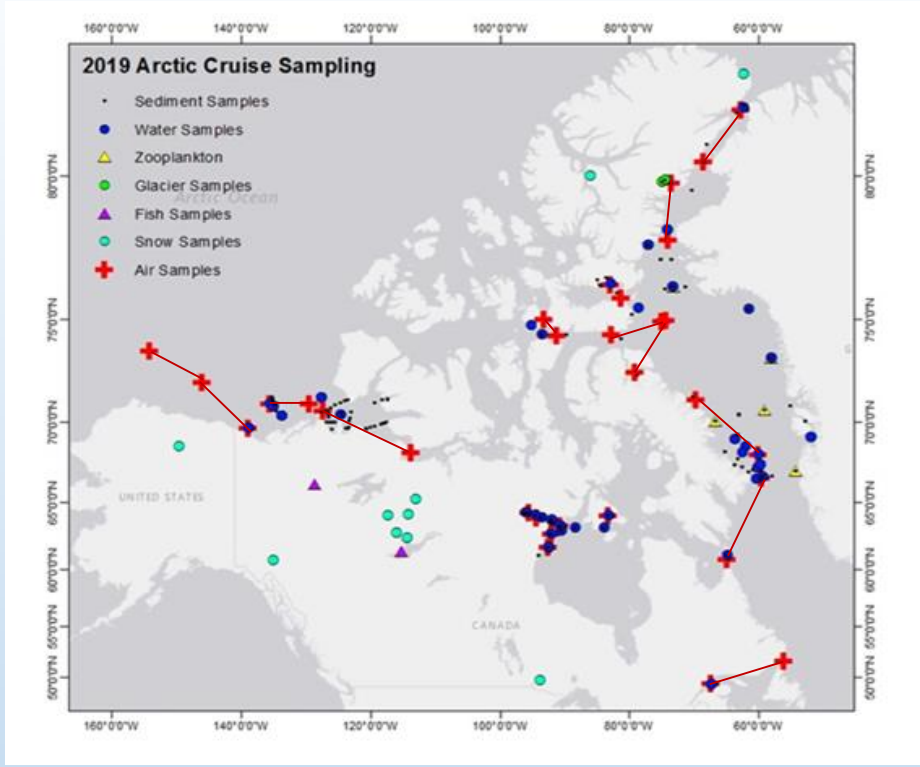
- Impact by transpacific transport
  - This has been seen for contaminants ie Hg and pesticides
- Samples taken at Alert, NT are not representative of the entire Arctic
- Seasonal differences

Sampling in the Yukon

Little Fox Lake: air sampling for contaminants, mercury and snow sampling for microplastics

Snow Sampling Sites in NWT





Samples collected in 2020-2022 by
1) Michael Palmer at the Environment and Natural Resources Department Government of the Northwest Territories
2) Samples at Behchokǫ were collected by Tyanna Steinwand

Additional Sampling in NWT

At Behchokǫ̀, NWT

- Bulk Deposition

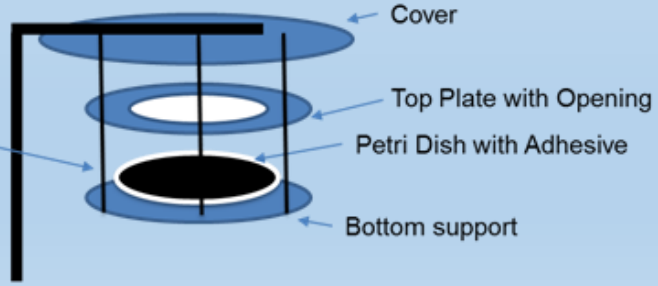
- Passive air

Passive MP Sampler (PAS-MP)

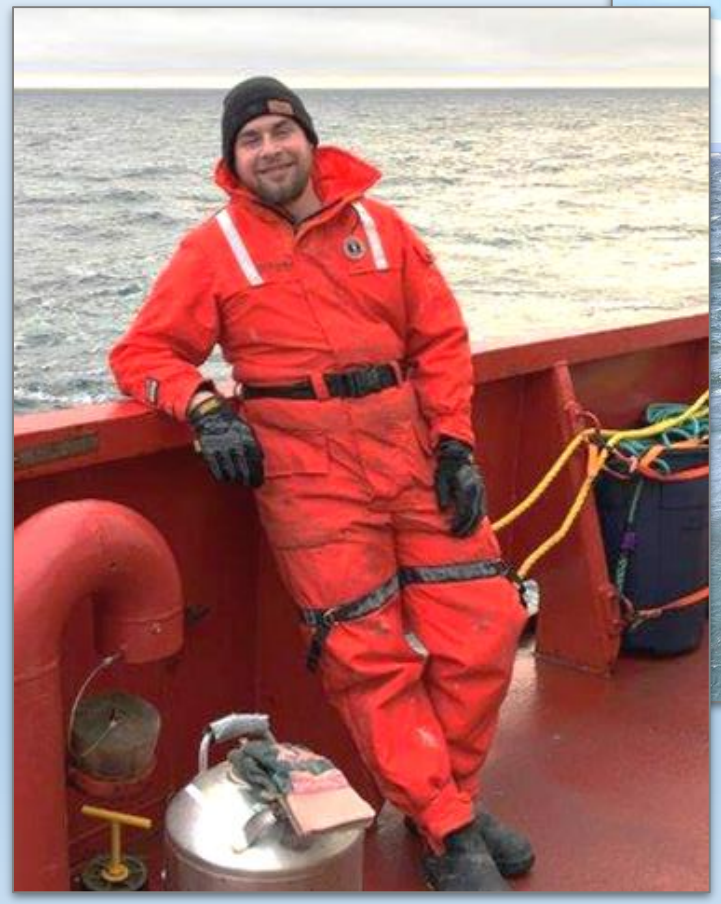
Passive Indoor Sampler

Petri Dish lined with double sided adhesive

Passive Outdoor Sampler



Some Results!

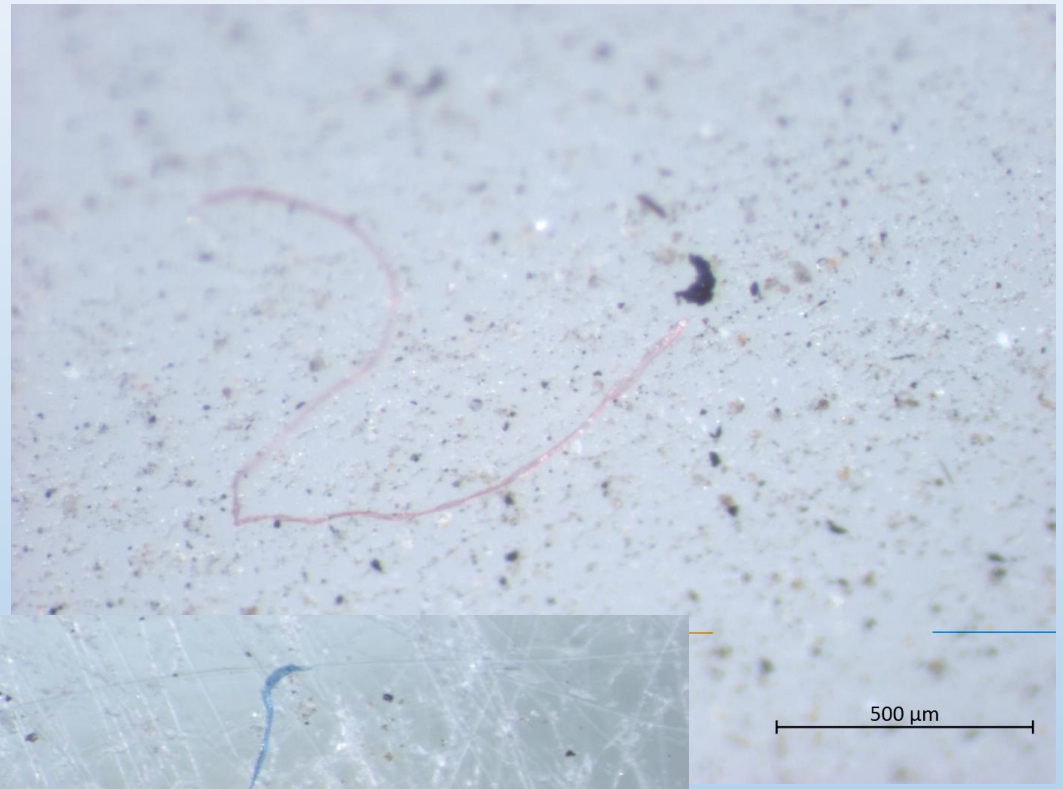


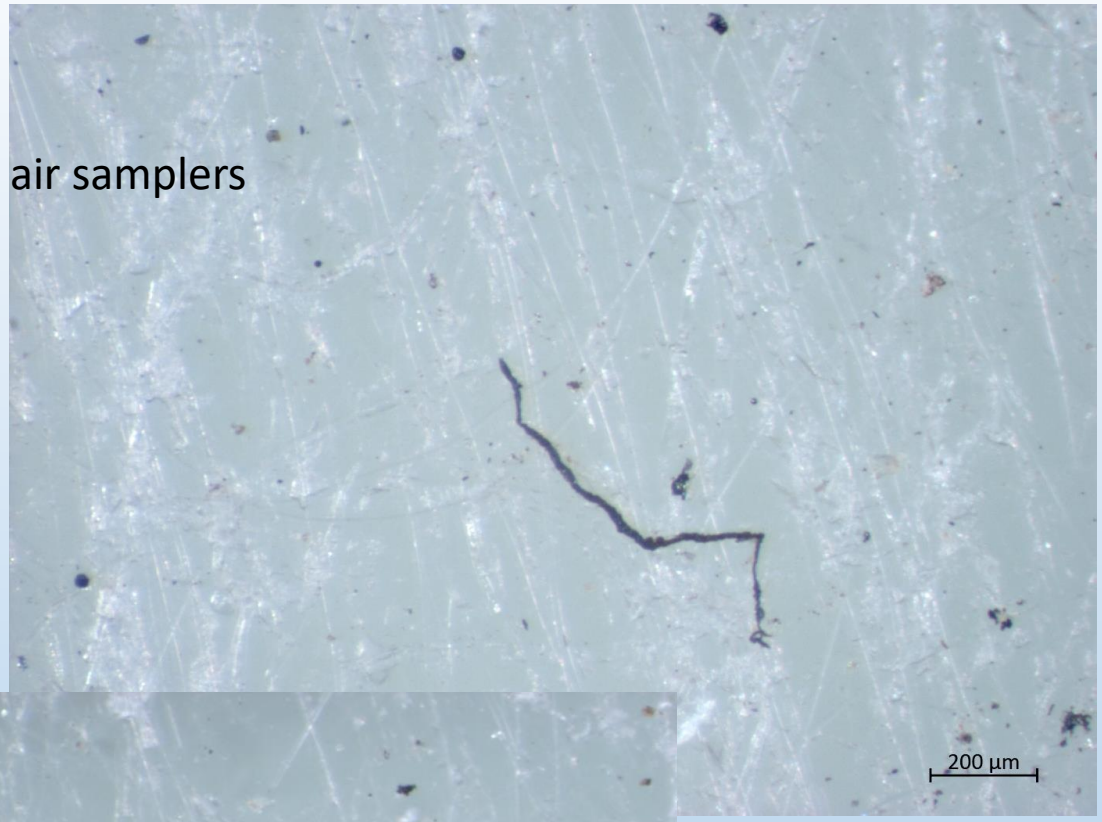
Maxime from Iqaluit

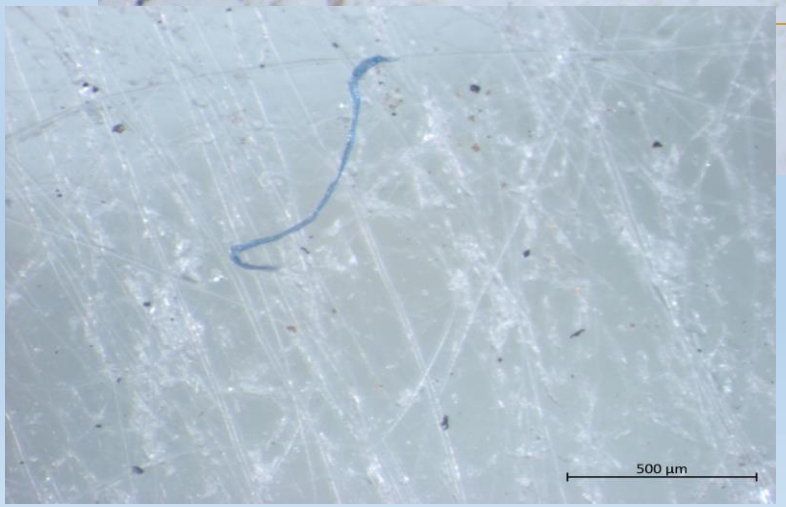
Nicole from Rankin Inlet

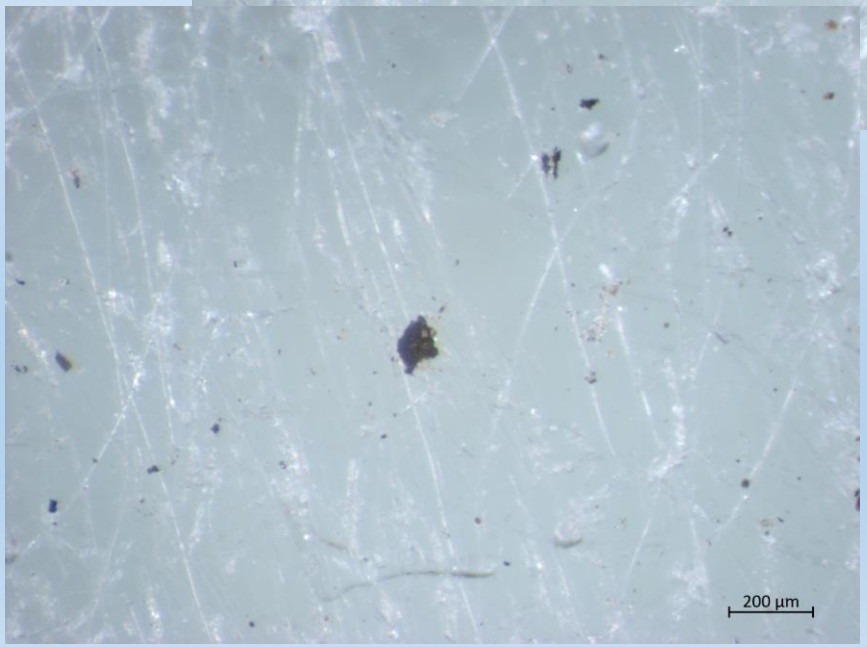
Passive Air Sample

Similar fibers were found on the active air sampler filter and passive air samplers



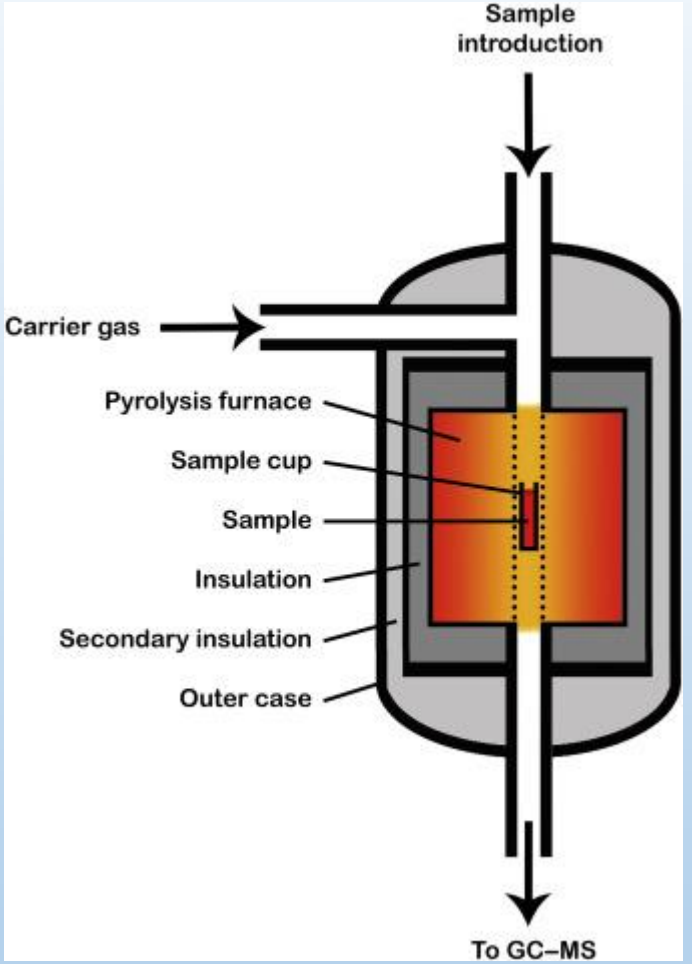




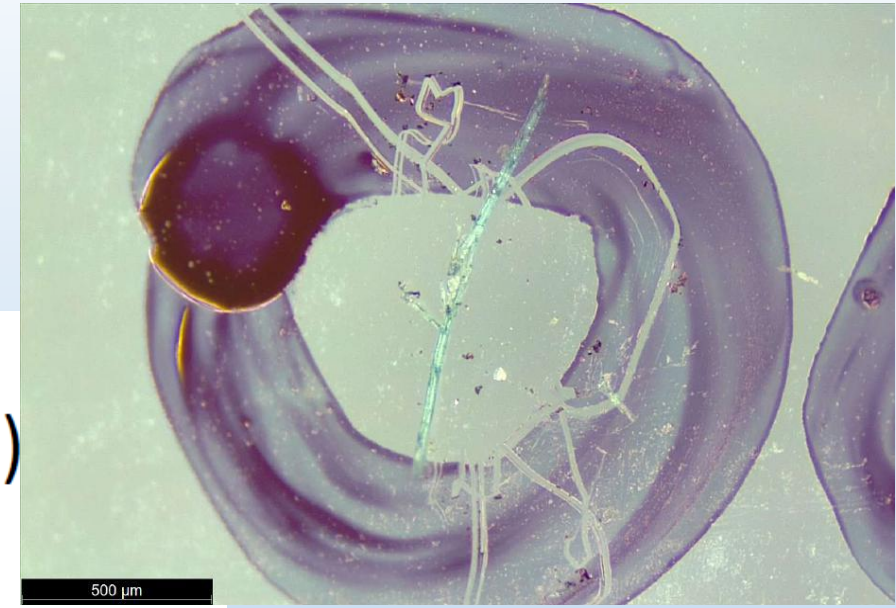


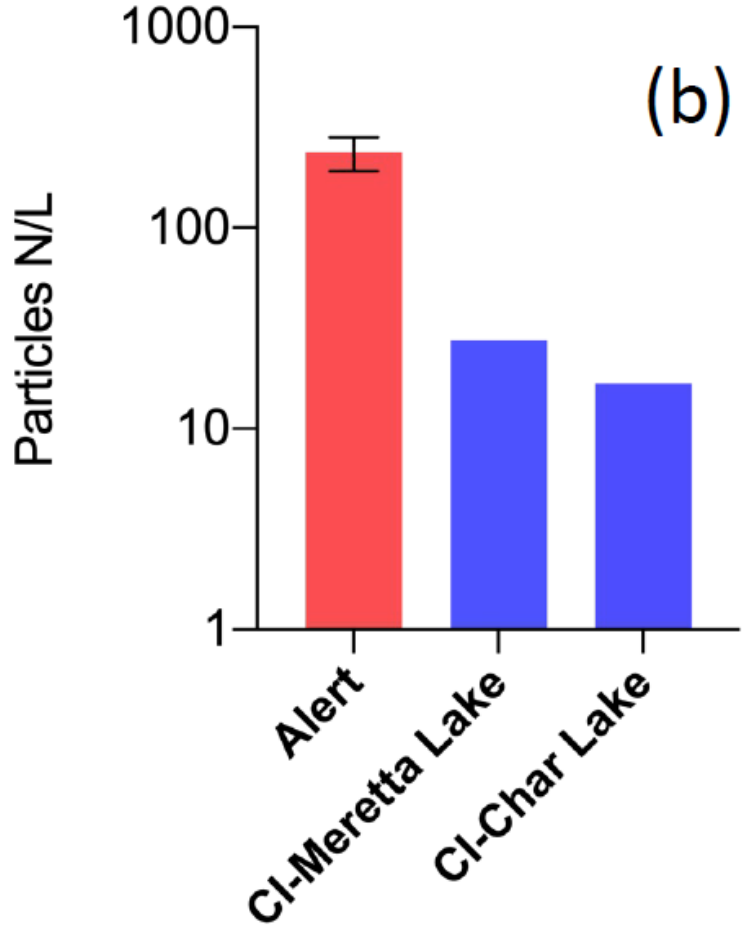
Alert, NT

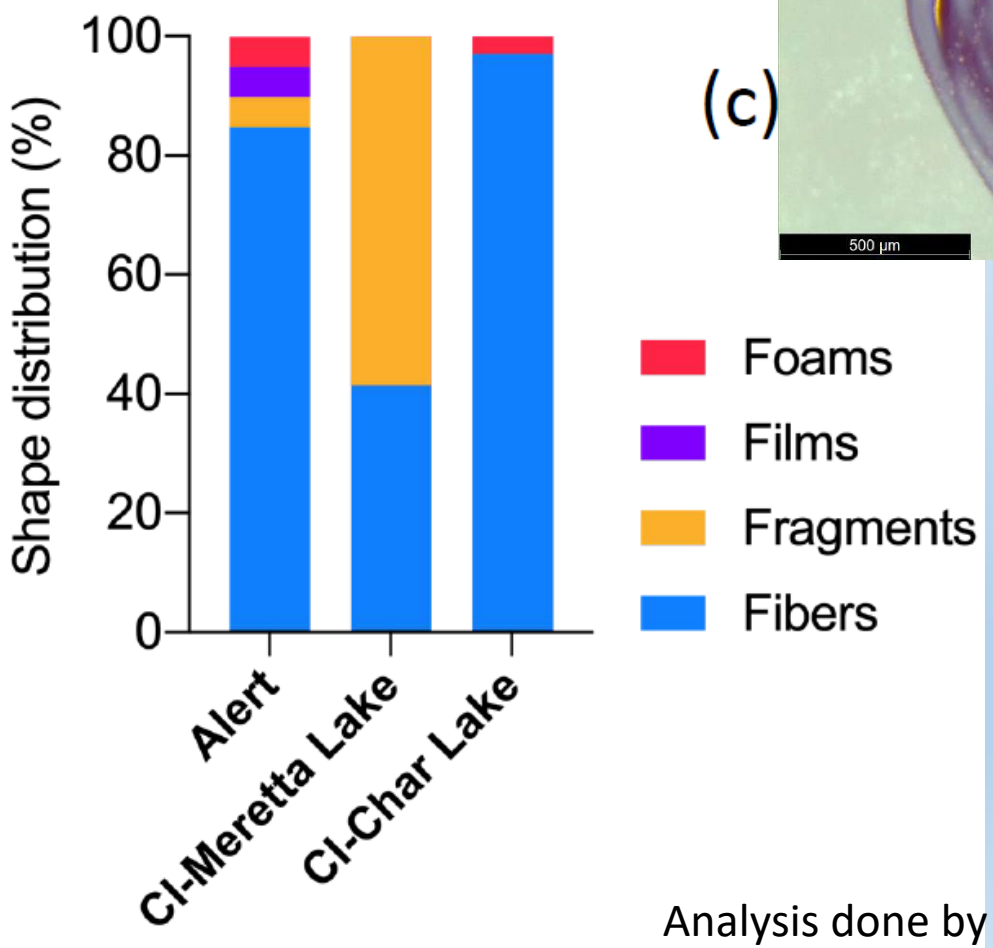
- Sampling since 2019
- Bonnie Hamilton (U of Toronto) analyzed the Alert snow samples by pyrolysis-gas chromatography mass spectrometer and found:
  - Polyvinyl chloride (PVC)
  - Polypropylene (PP)
  - Polyethylene (PE)
    - But did not detect polystyrene, poly(methyl-methacrylate), polyethylene terephthalate or polycarbonate.
- Concentrations ranged from 3-62ug/L of total polymers



Nipher Gauge: bulk deposition

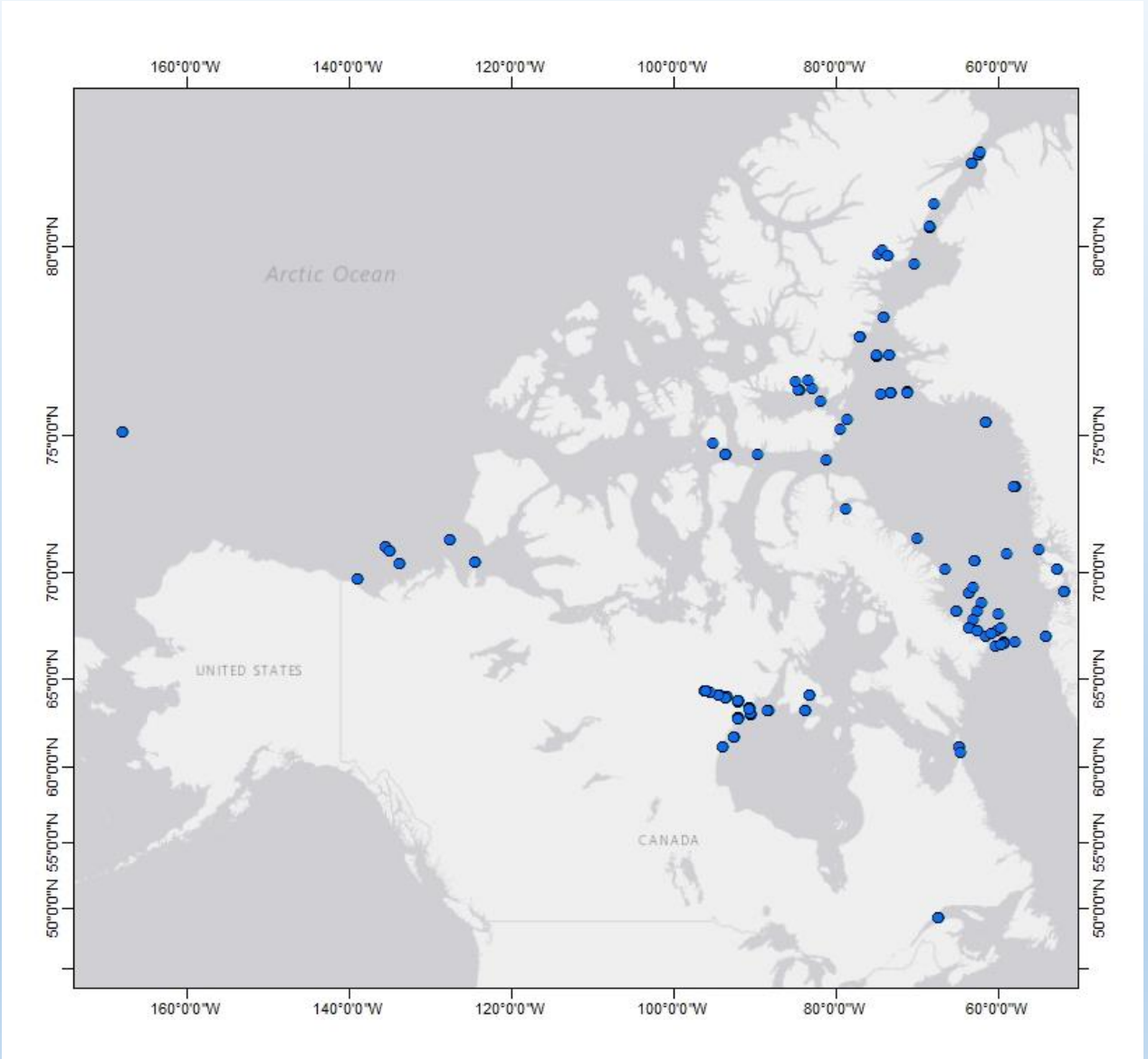






Analysis done by Zhe Lu's group at U Rimouski

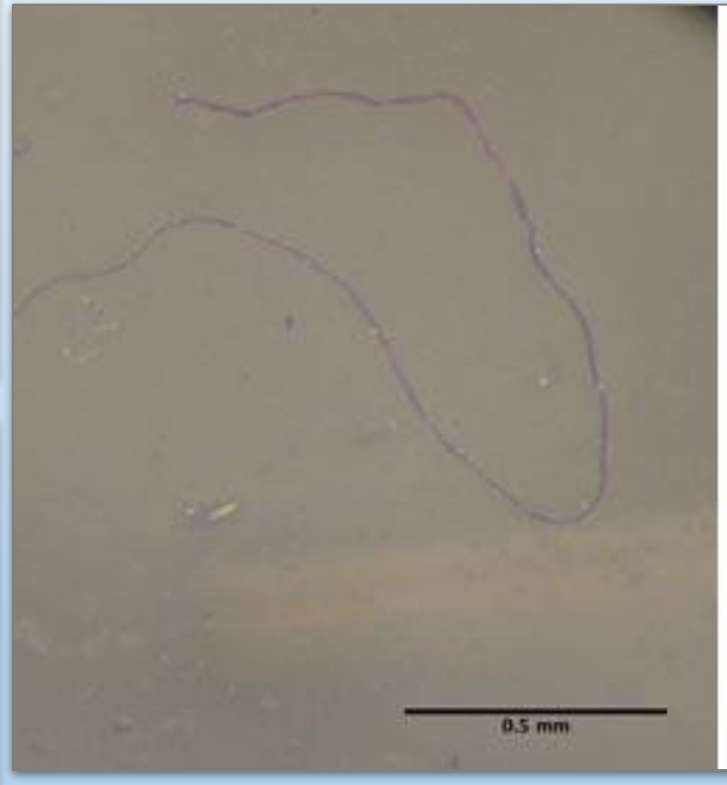
Water Sampling 2019



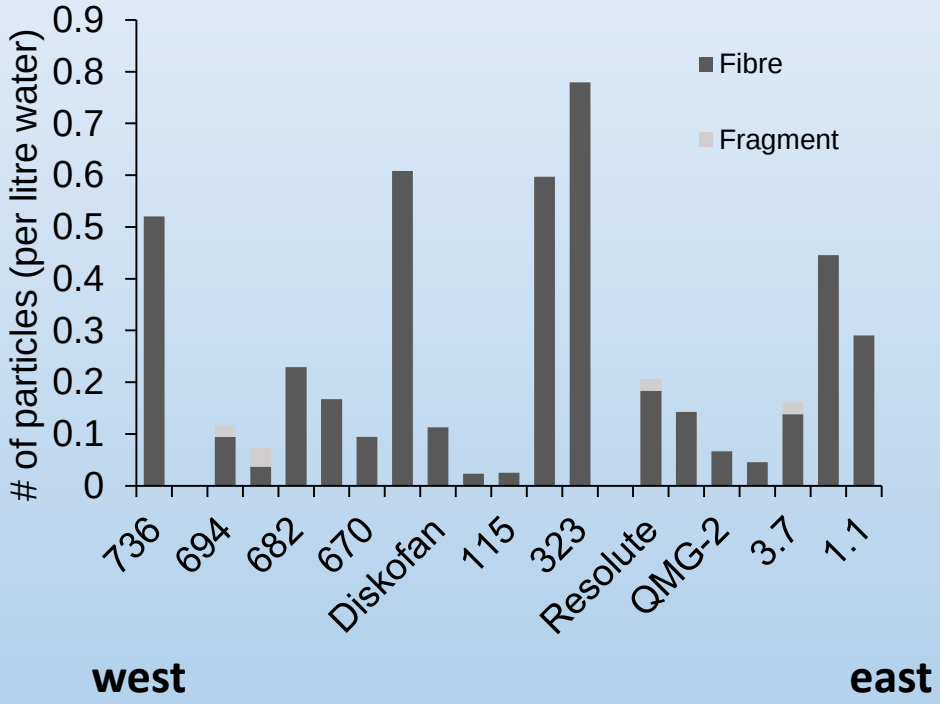
Water Sampling (Grab Samples)

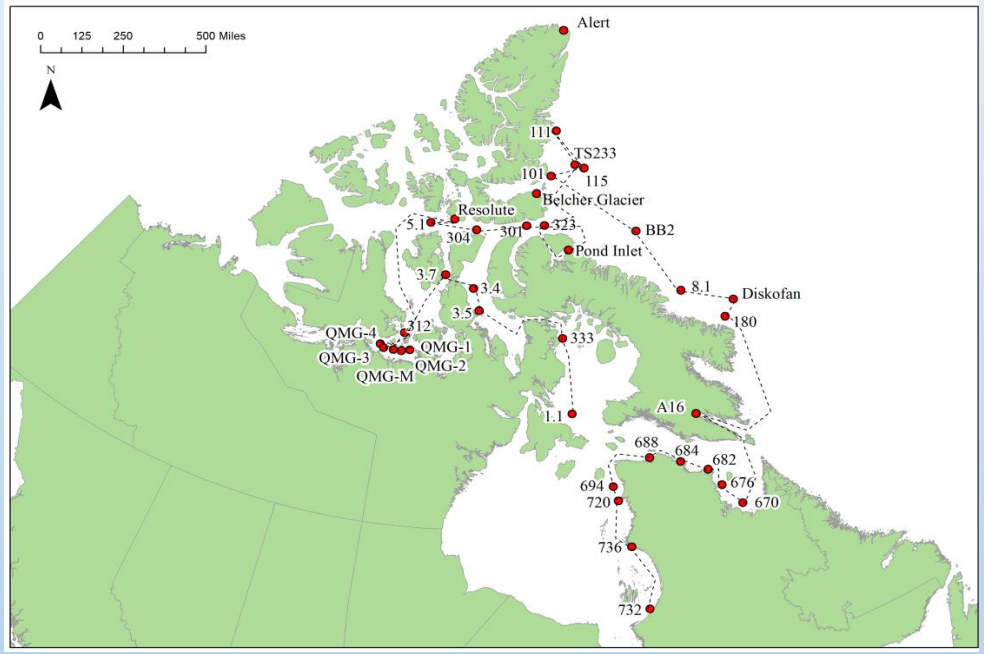
- **Water is sampled at several depths (surface, thermocline, and bottom) and at various volumes for POPs and MPs. These are called *grab samples* - screenshot in time.**
- **There are different types of grab samples: Rosette and Bucketing.**
- **Large quantities of water is collected for different types of filtering.**

Microfibers and Microfragments from Arctic Surface Waters



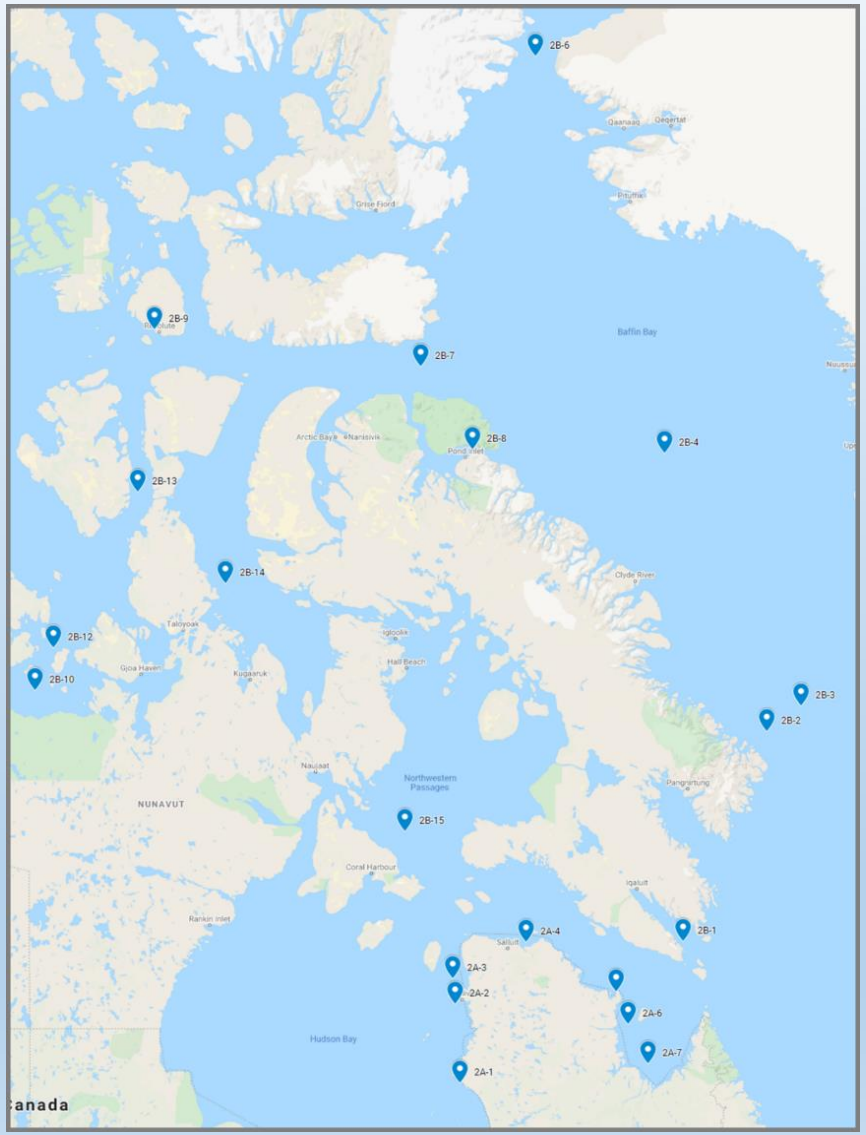
The Microplastics in Surface Water are Dominated by Fibers





Huntington et al., FACET 2020.

Water Samples: Microplastics (filtered with size range of 1.5-106 microns)

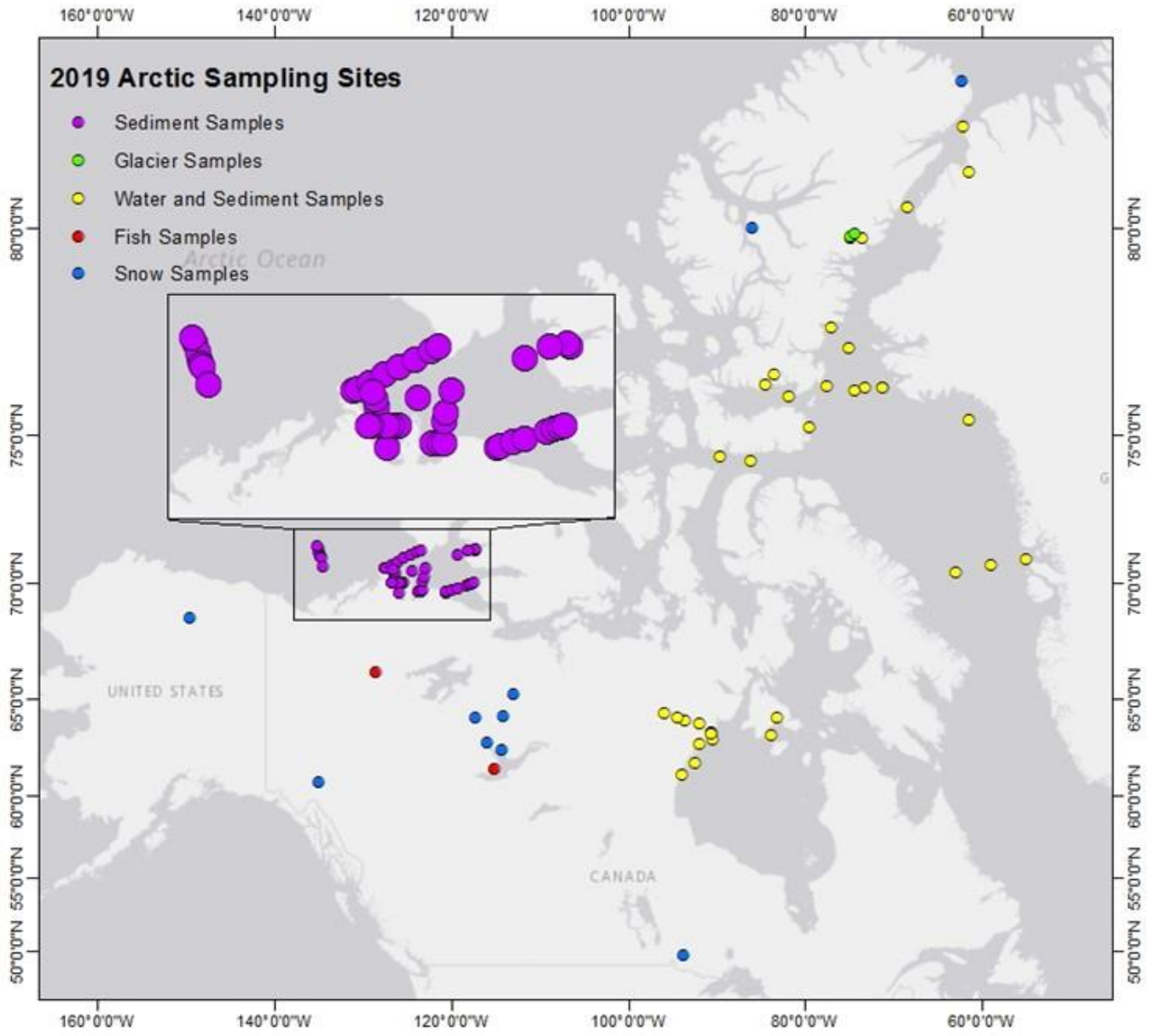


Plastics found in most samples include:

- **Polystyrene (PS),**
- **High density polyethylene (HDPE),**
- **Low density polyethylene (LDPE),**
- **Polyvinyl chloride (PVC),**
- **Polycarbonate (PC),**
- **Polyethylene terephthalate (PET),**
- **Polypropylene (PP) and**
- **Polymethyl methacrylate (PMMA).**

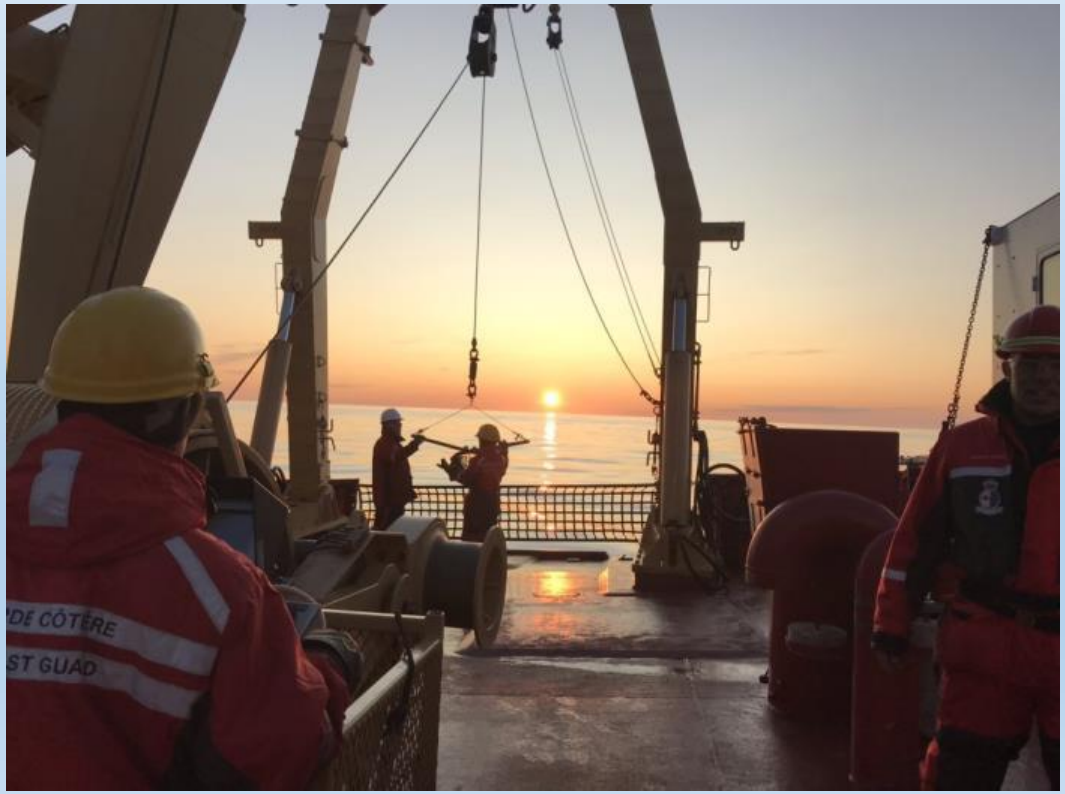
Analysis done by pyrolysis gas chromatography (Nathalie Tufenkji and Laura Hernandez)

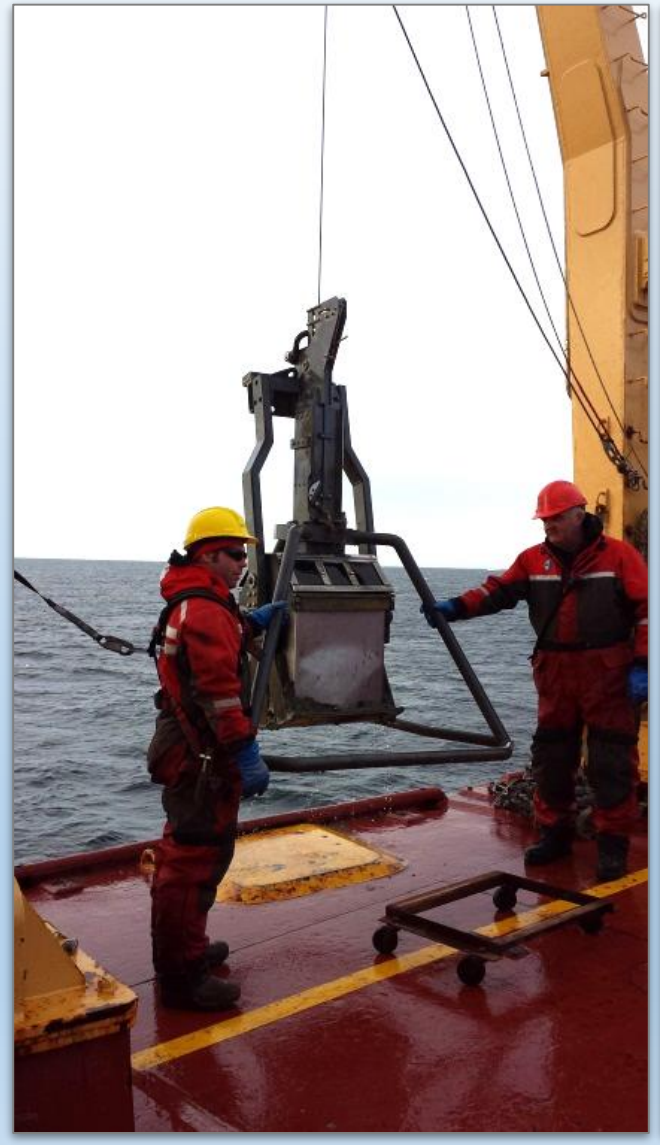
Sediment


2019 Arctic Sampling Sites
Sediment Samples
Glacier Samples
Water and Sediment Samples
Fish Samples
Snow Samples
Arctic Ocean
UNITED STATES
CANADA
160°0'0"W
140°0'0"W
120°0'0"W
100°0'0"W
80°0'0"W
60°0'0"W
80°0'0"N
75°0'0"N
70°0'0"N
65°0'0"N
60°0'0"N
55°0'0"N
50°0'0"N

Sediment Sampling

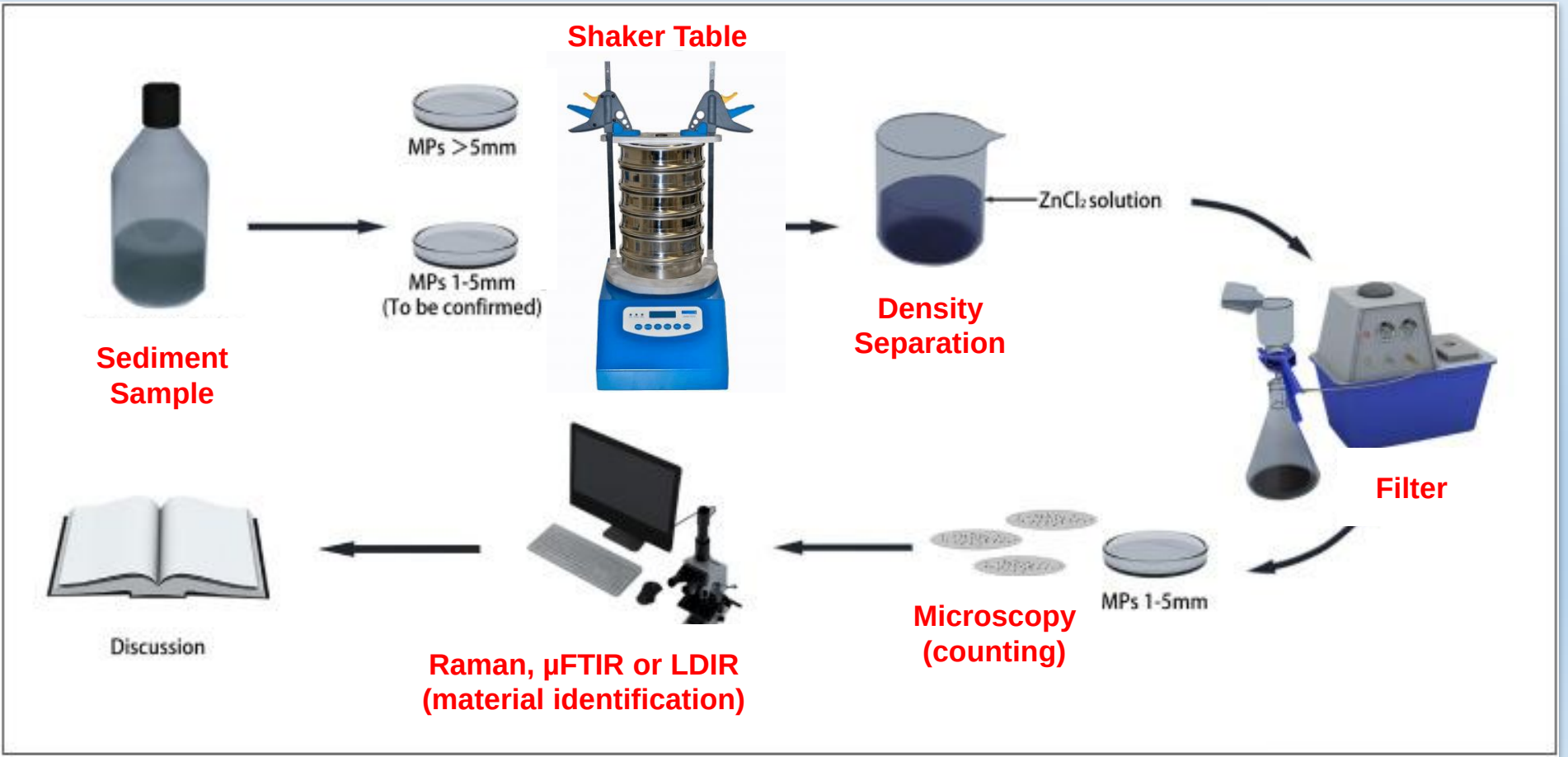
- **Grab sampling since 2014**
- **Surface sediment samples are collected using a box corer**





Sediment Analysis

- **MPs** extracted from sediments via ***density separation*** using polytungstate or $CaCl_2$
- MPs >125 µm are then **identified, counted,** and/or **removed**



MP Sample Analysis - Counting and Identification

Microscopy

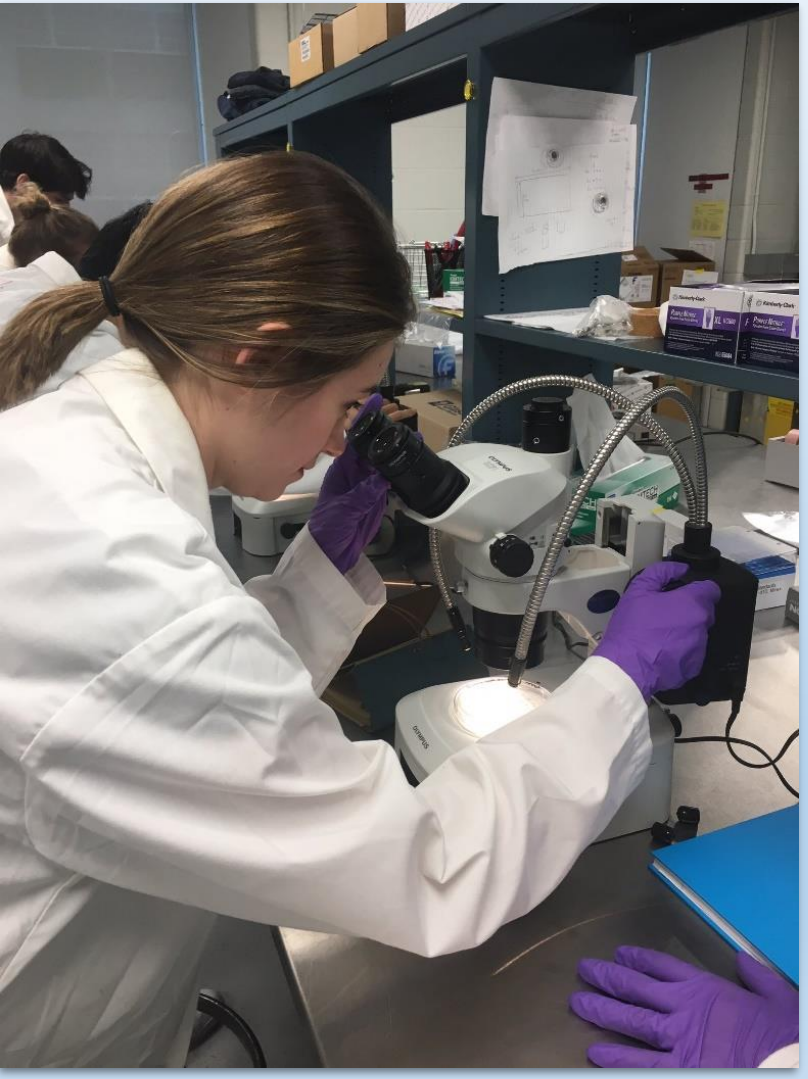


Photo courtesy of Sam Athey

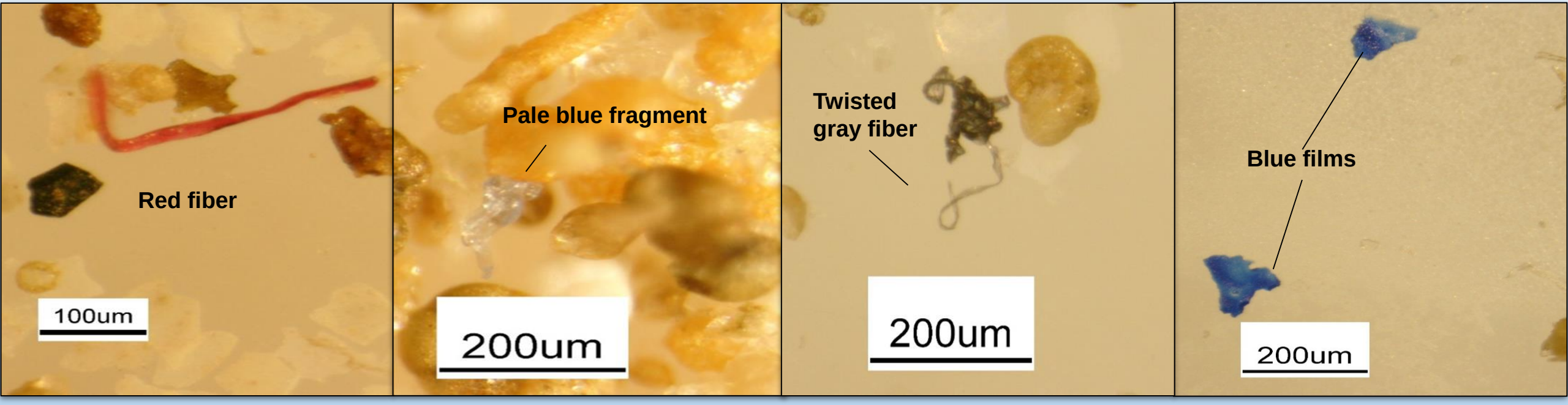
Picking

Photo courtesy of Dr. Chelsea Rochman

Raman

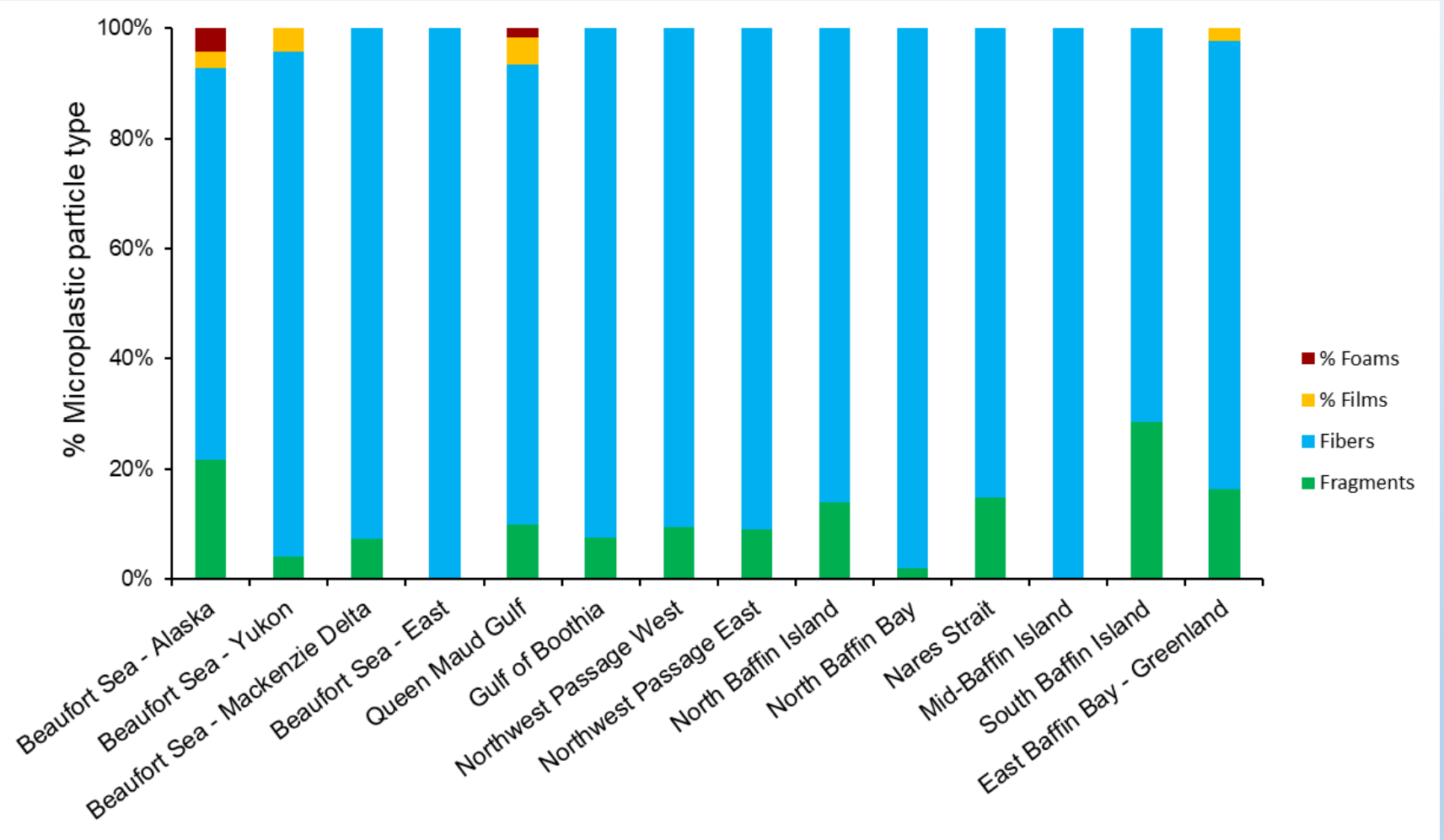
FTIR

Anthropogenic Particles in Sediments



Pictures courtesy of Dr. Patricia Corcoran

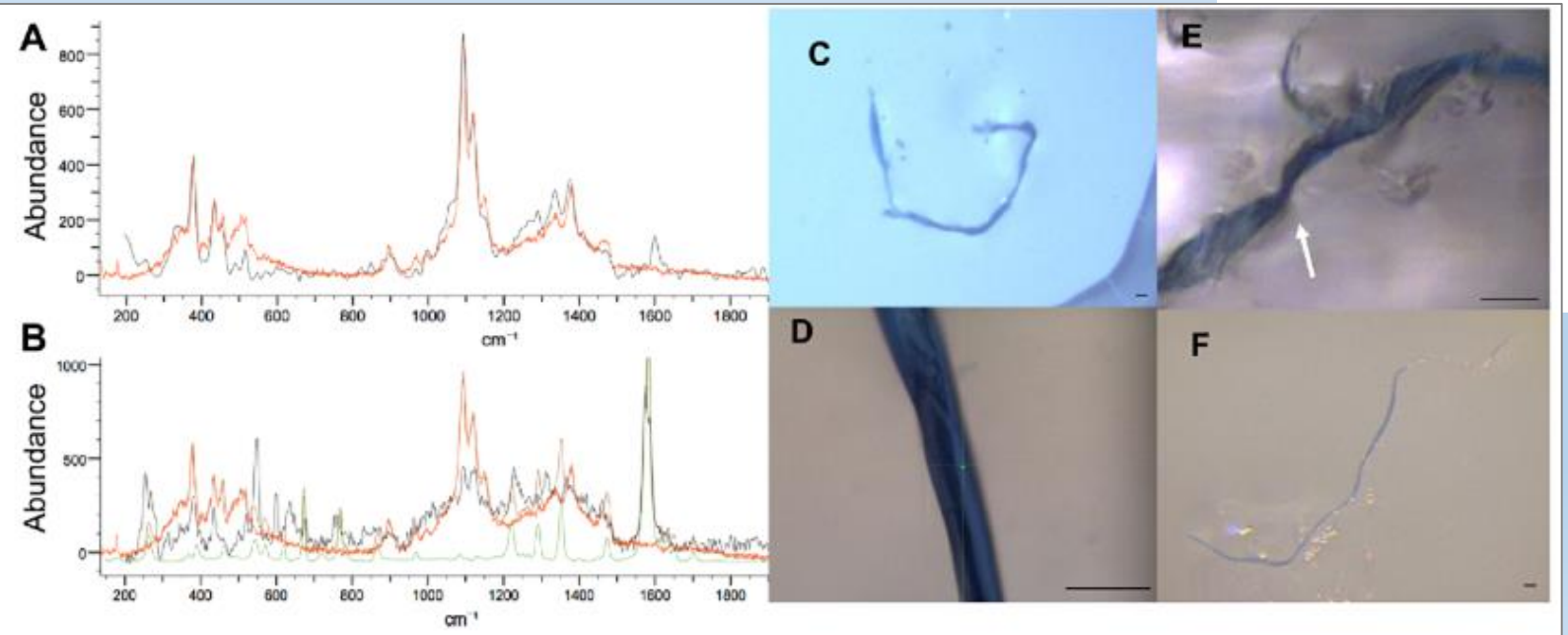
MPs in Sediments are Dominated by Fibers

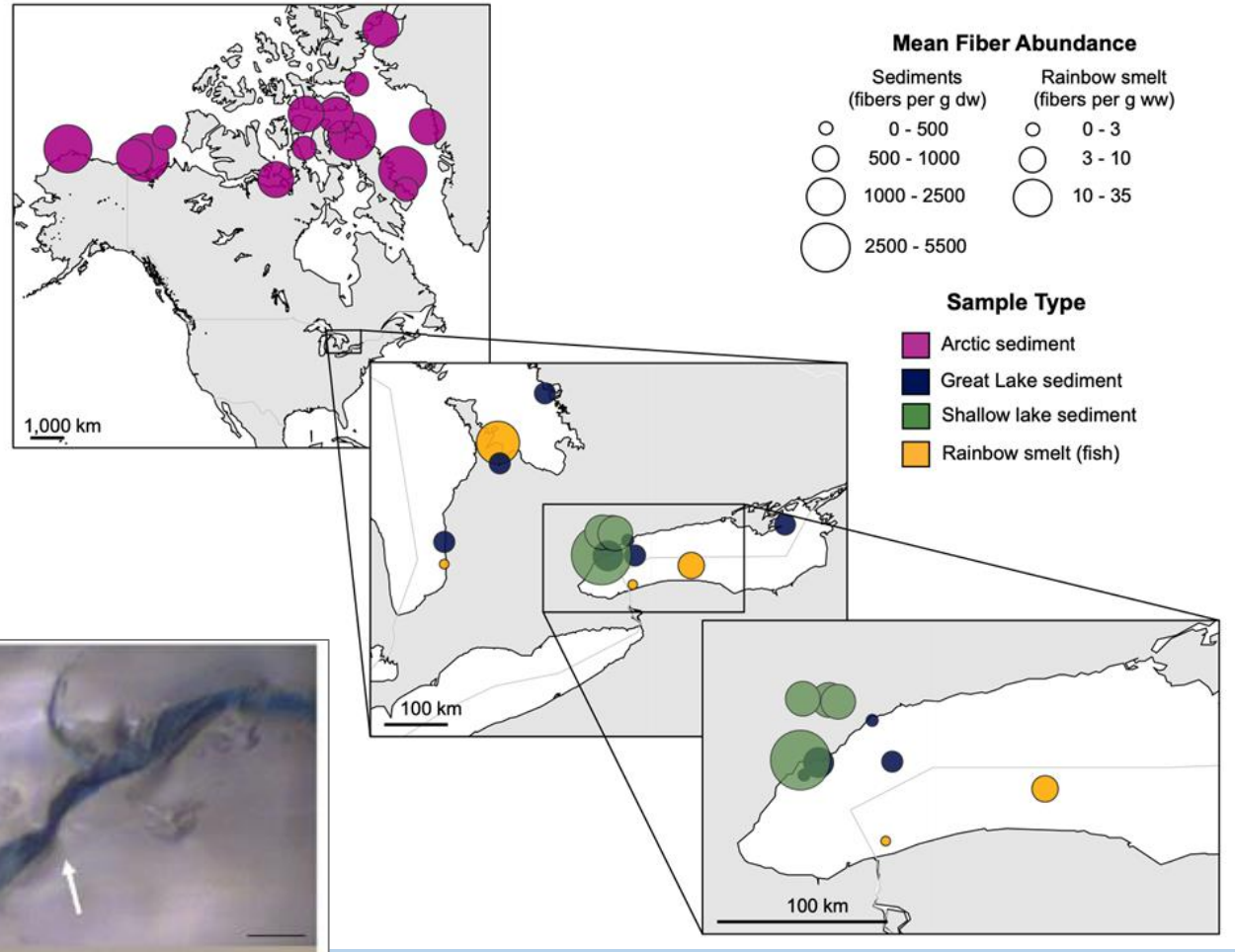


Adams et al., 2021

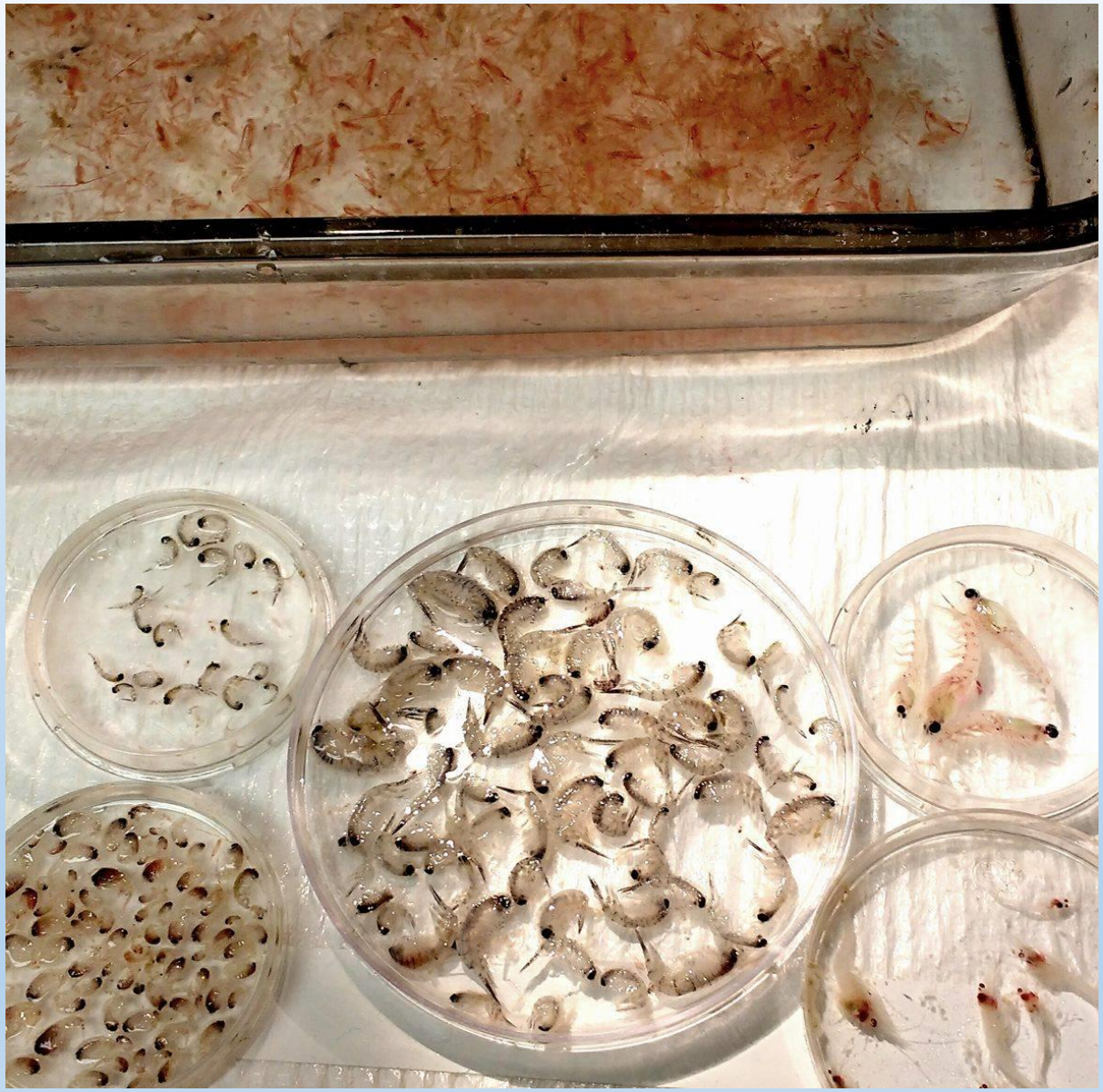
Denim in Arctic Sediment

- Denim is found everywhere and is one of the most versatile garment in the world
- **46–56%** of Canadians wear jeans almost every day
- On average, Canadians wash their jeans after wearing a pair twice instead of monthly
- Washing denim **releases microfibers** to wastewater and dryer vents





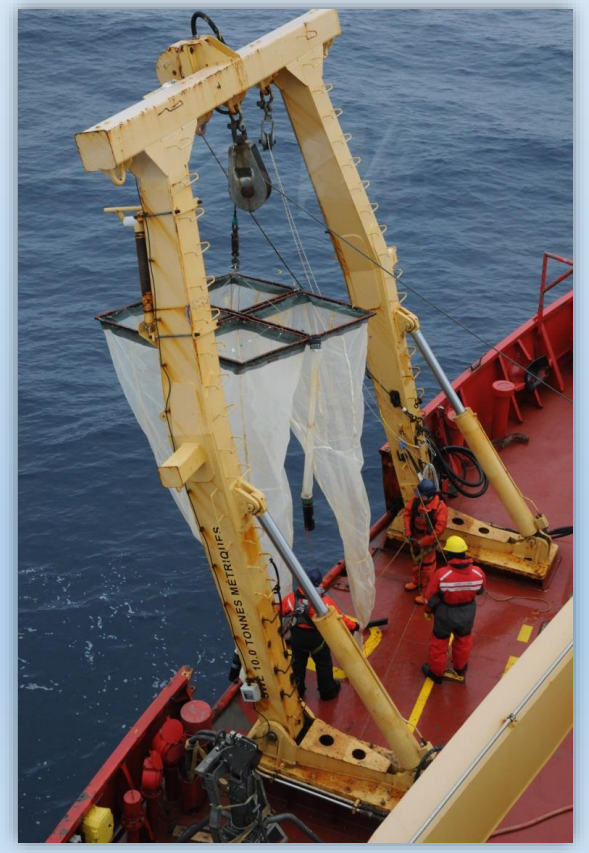
Source: Athey, et al. (2020). The Widespread Environmental Footprint of Indigo Denim Microfibers from Blue Jeans.

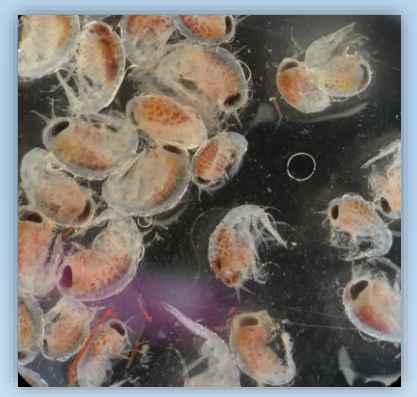


Zooplankton: Samples Taken from the CCGS Amundsen

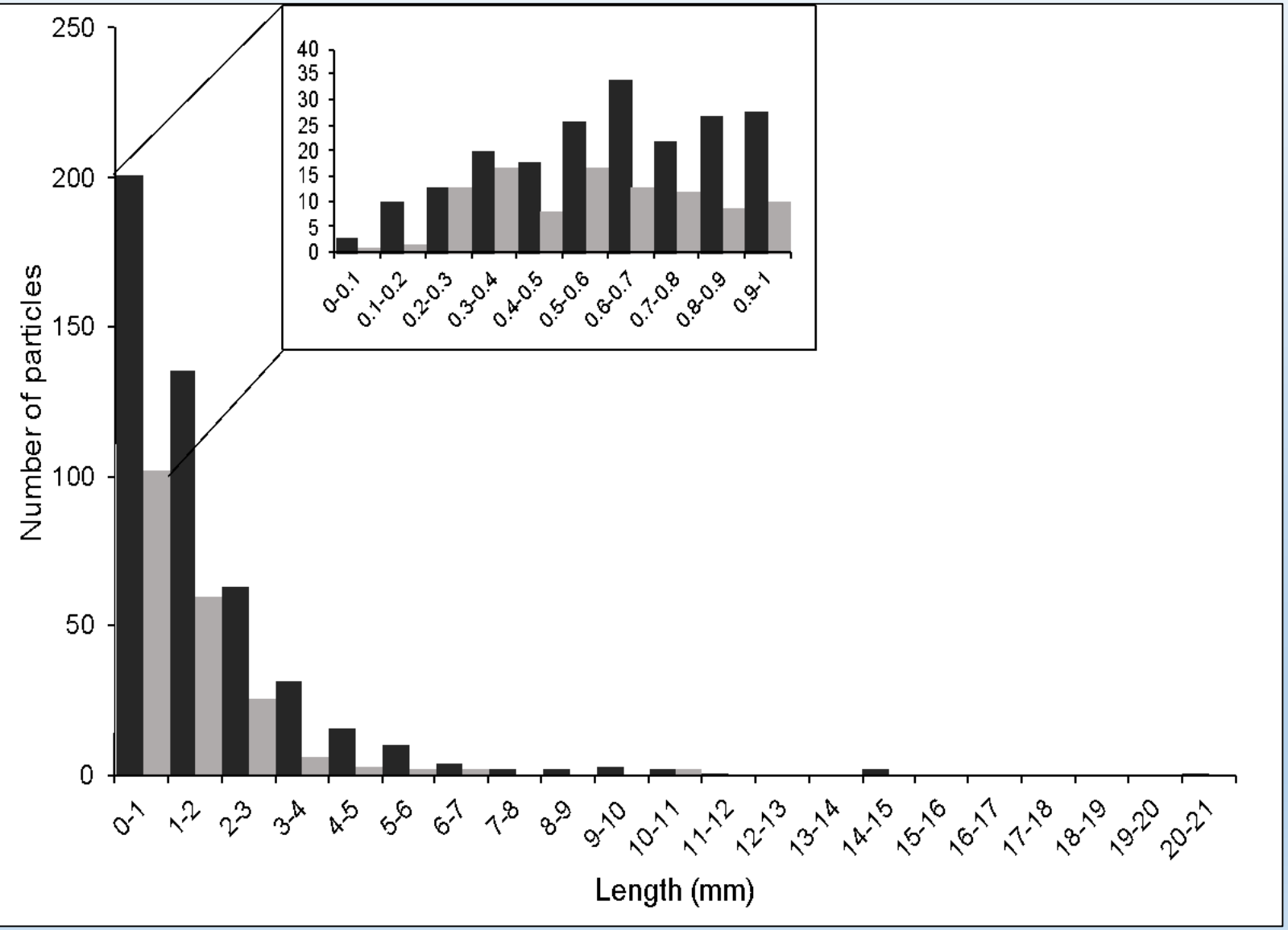
Zooplankton Sampling

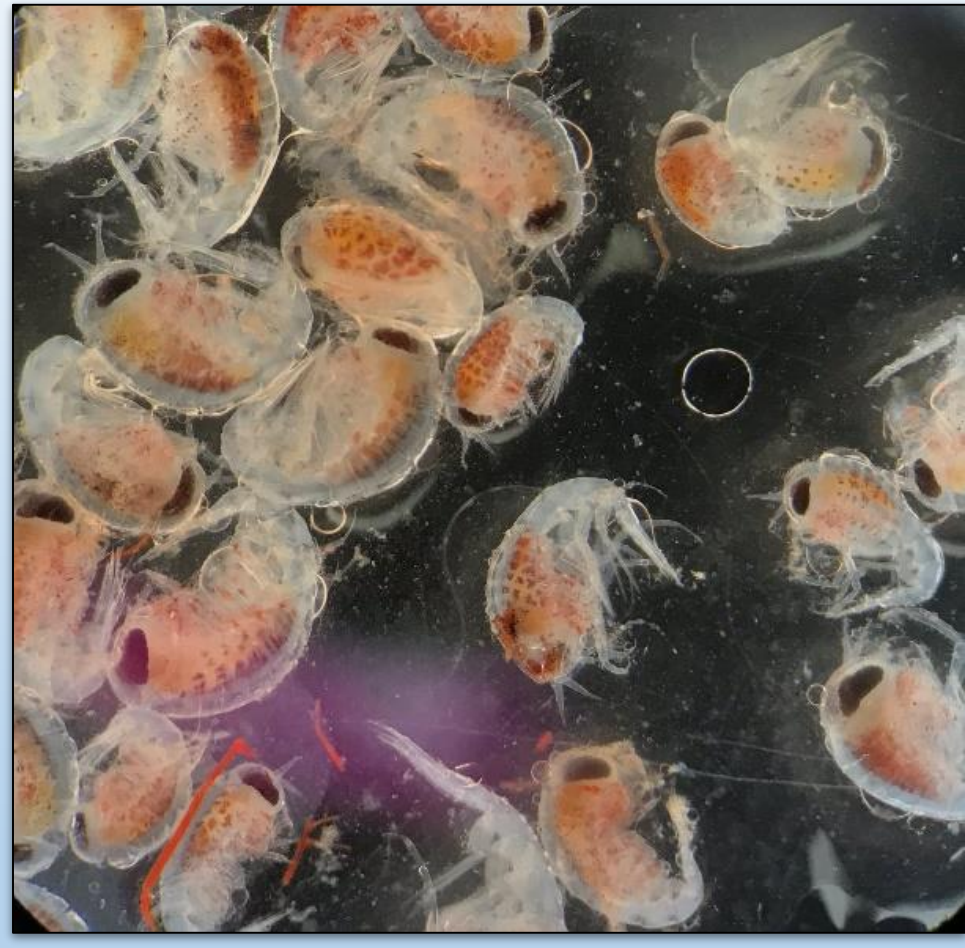
- Oblique and vertical tows to collect for plankton
- Once they are collected, we take the time to carefully **speciate** them





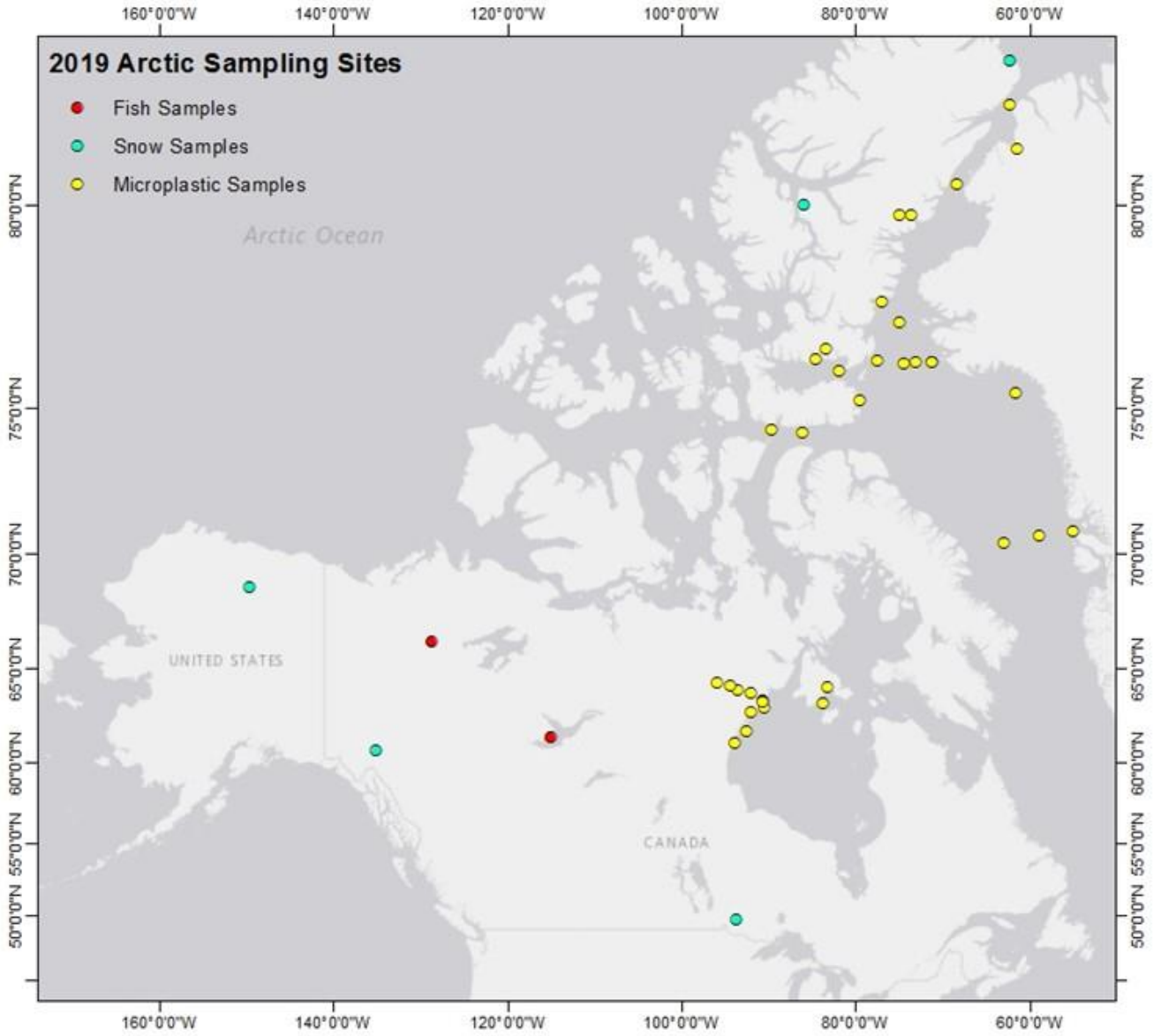
Number of Particles in Water and Zooplankton



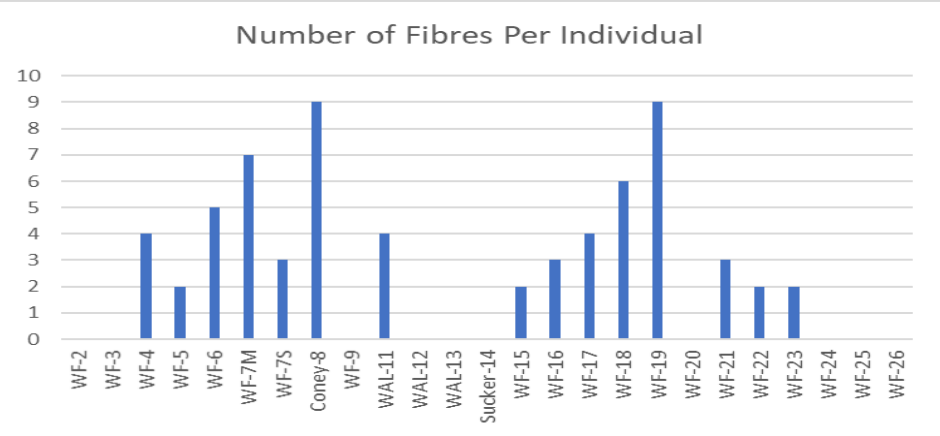


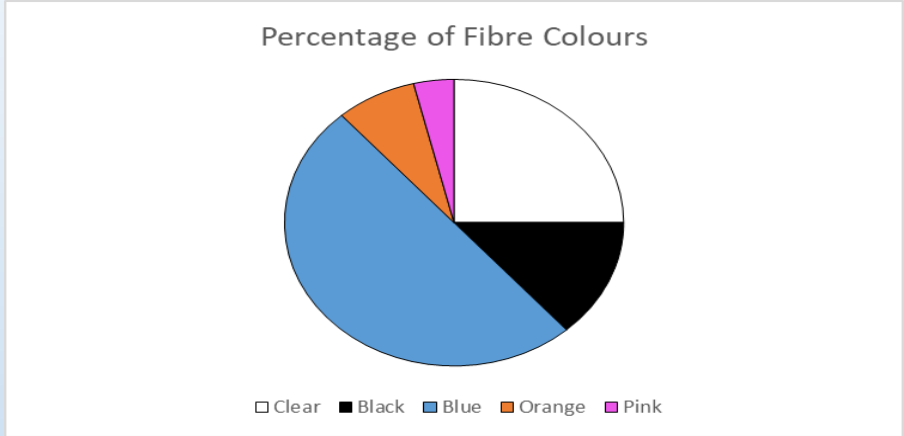
(Huntington *et al., 2021*)

Fish: Sampled at Fort Good Hope, Great Slave Lake and Behchokǫ



Anthropogenic Particles in Fish Stomachs: Behchokǫ

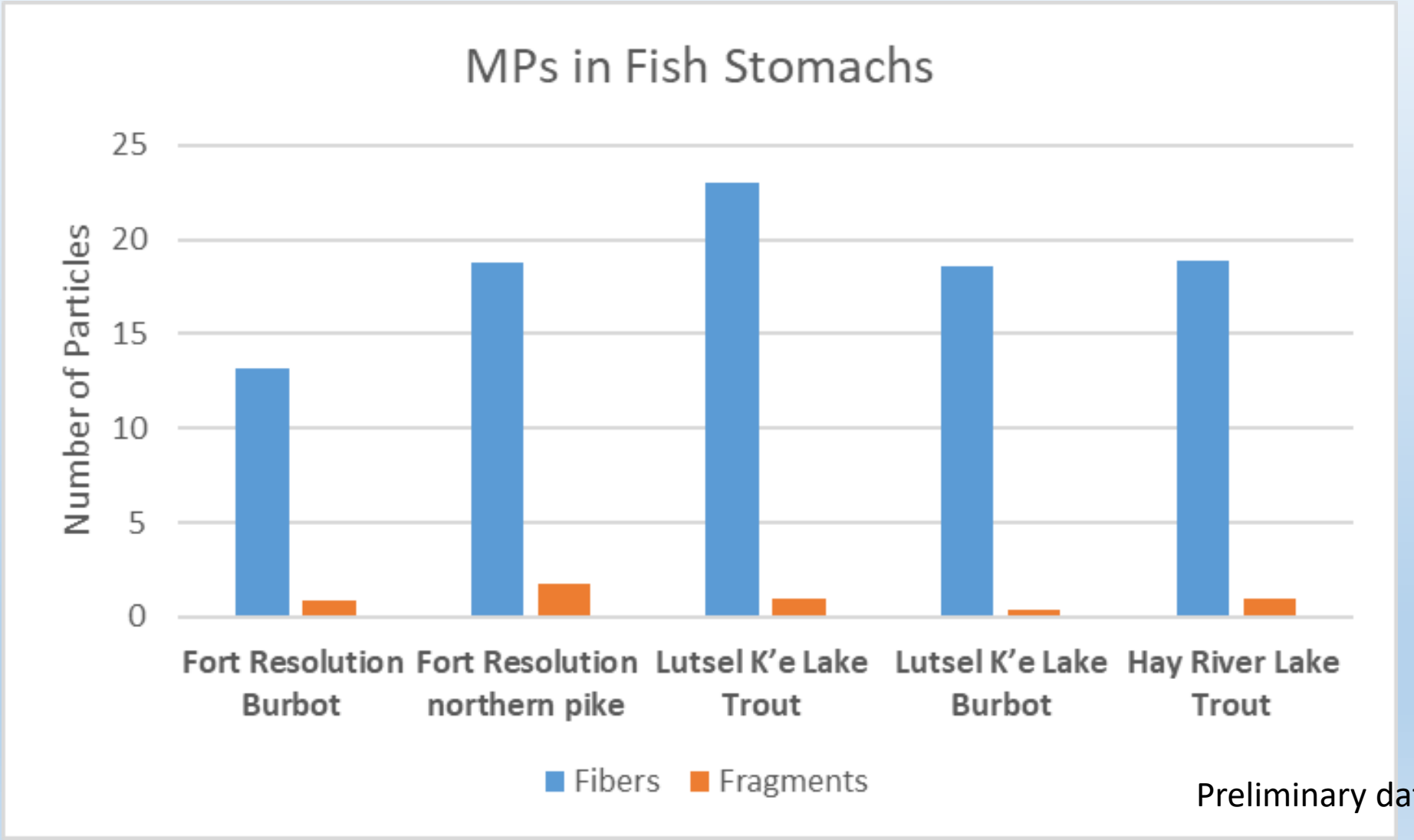




- All particles found are fibres, there are no beads, fragments or films.
- The plastic particles in the fish stomachs are very low and small (<0.3mm)
- Average 2.6 fibres per fish, ranging from 0-9 fibres (10/25 had no particles)
- Blue fibers are probably from denim jeans.
- Pink maybe plastic (PET).

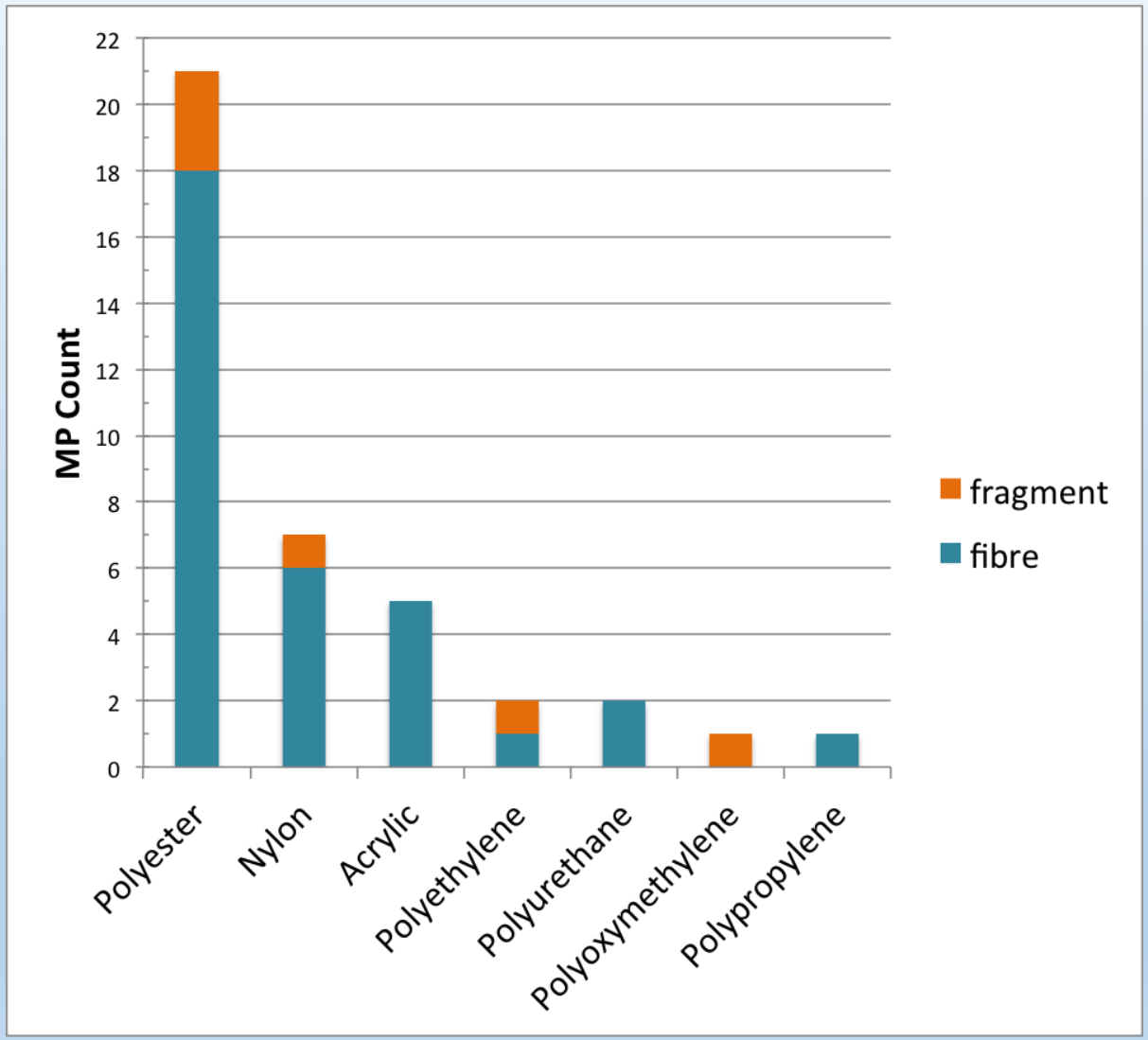
Preliminary data: Corcoran

More Fish Stomachs: dominated by fibers



Preliminary data: Corcoran

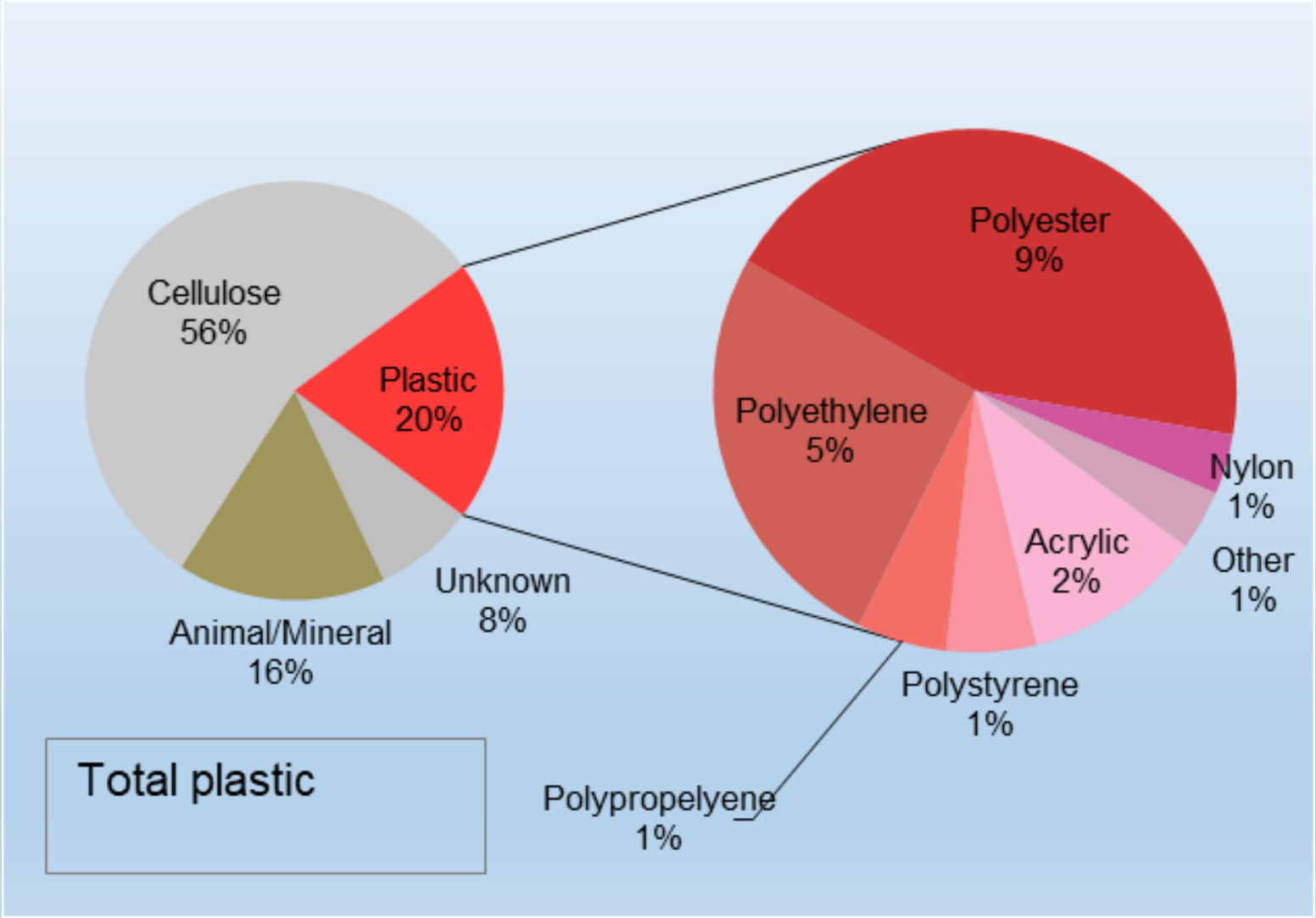
Microplastic ingestion by arctic fish (n=116)



- 21 % of fish contained microplastic
- Average 1.4 ± 0.44 particles per individual
- 80% were fibres

slide and data from Moore, Posacka and Ross @ the Plastics Lab, Ocean Wise

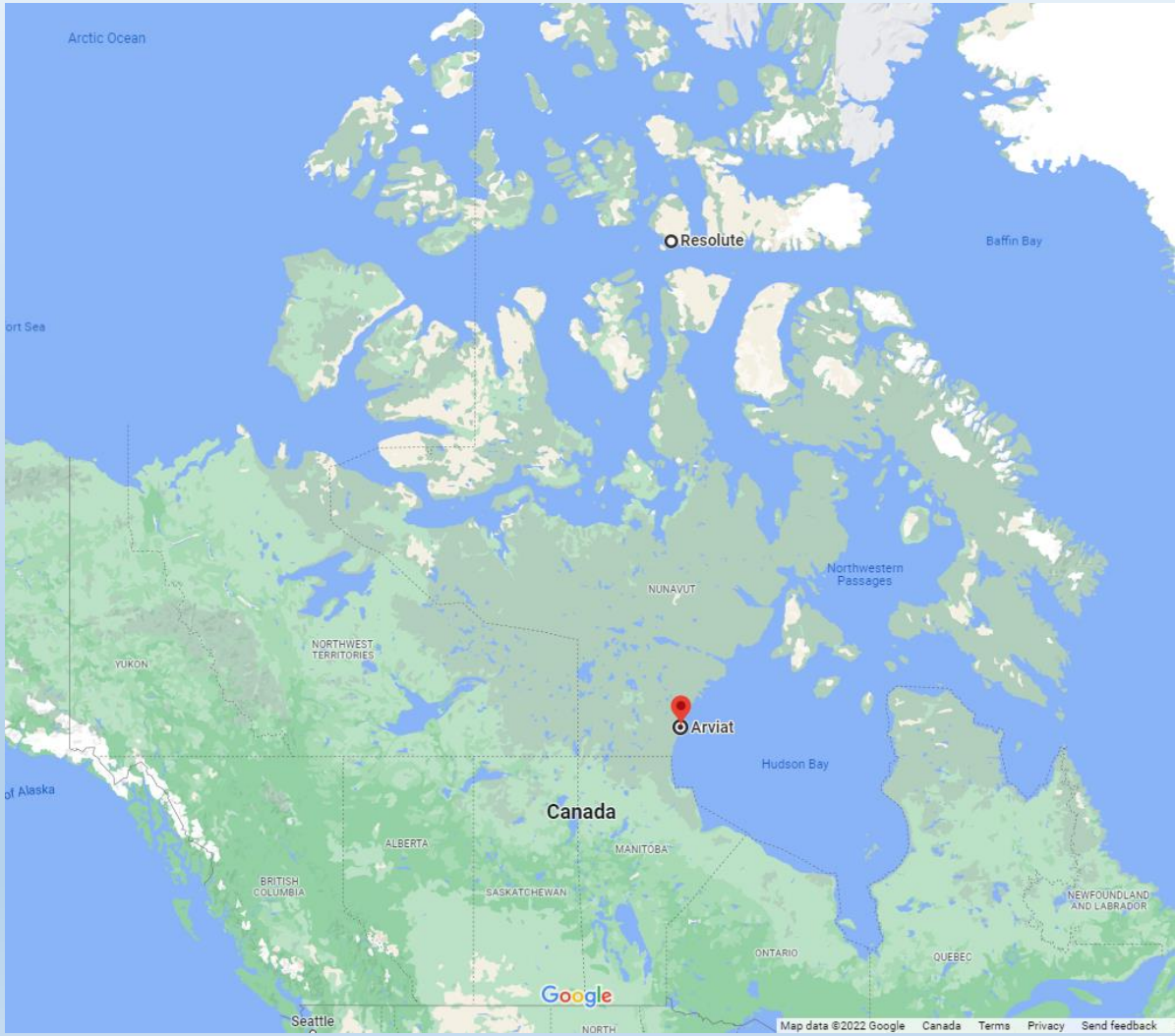
Anthropogenic Particles in Fish



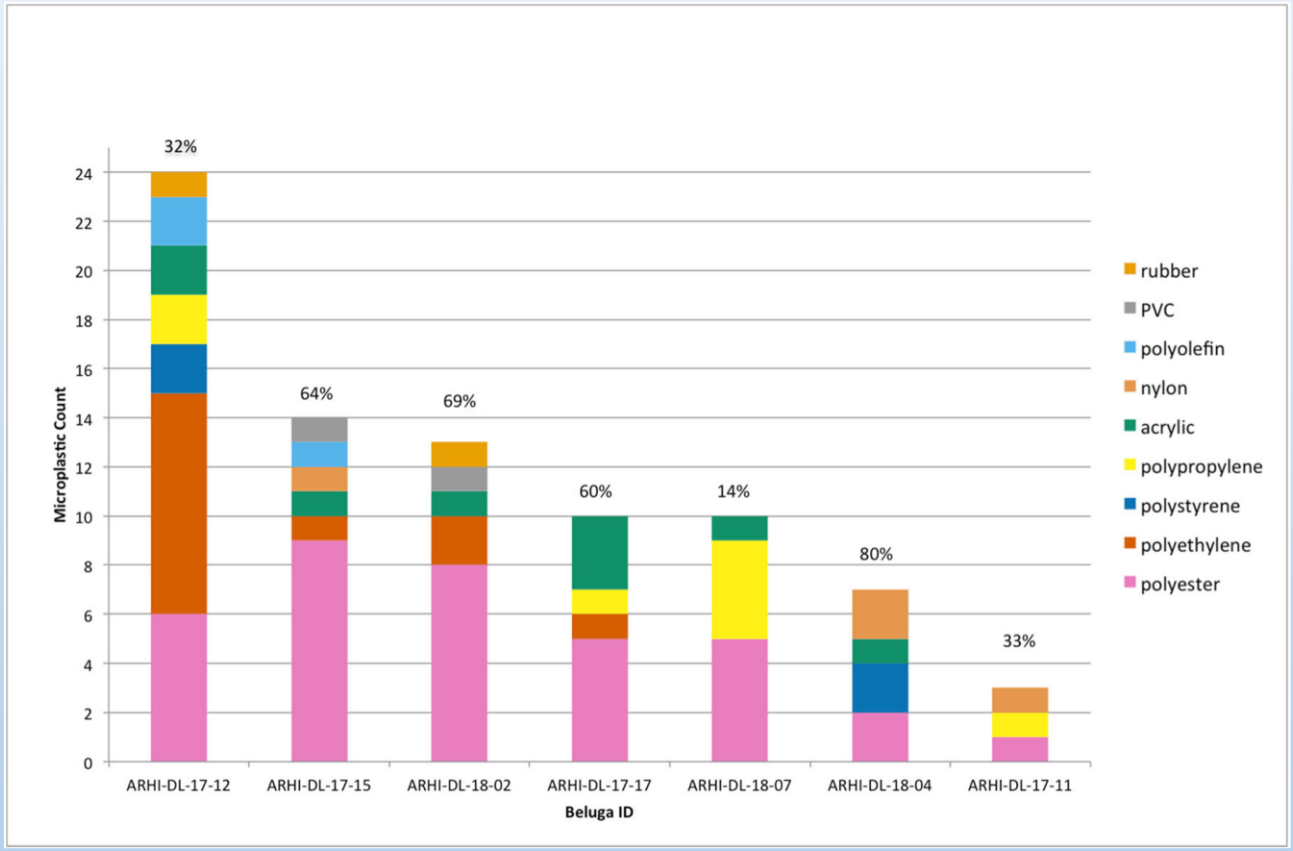
slide and data from Moore, Posacka and Ross @ the Plastics Lab, Ocean Wise

Seal Stomachs

- Working with northern communities in Resolute Bay and Arviat to samples seal stomachs and look for plastics.
- This work is on-going.
- The goal is to investigate how microplastics and other anthropogenic particles are introduced into and how they move up the Arctic food chain.



Microplastics found in beluga whales in the western Arctic



(Moore et al., 2020. Marine Pollution Bulletin)

slide and data from Moore, Posacka and Ross @ the Plastics Lab, Ocean Wise

Assessing the Atmospheric Long Range Transport Potential of MPs

- **We have been working with York University to develop a model to better understand the atmospheric transport of fibers**
  - to determine the aerodynamic characteristics of MPs and how this affects the long range atmospheric transport potential of the plastic particles focusing on microfibers.
- MPs and MFs have a range of densities, lengths and widths which will effect the extent of transport

Modelling the Air Transport of MPs

- **Typical atmospheric models assume particles are spherical**
- **We know most microplastics found in the Arctic are fibers with very different properties**

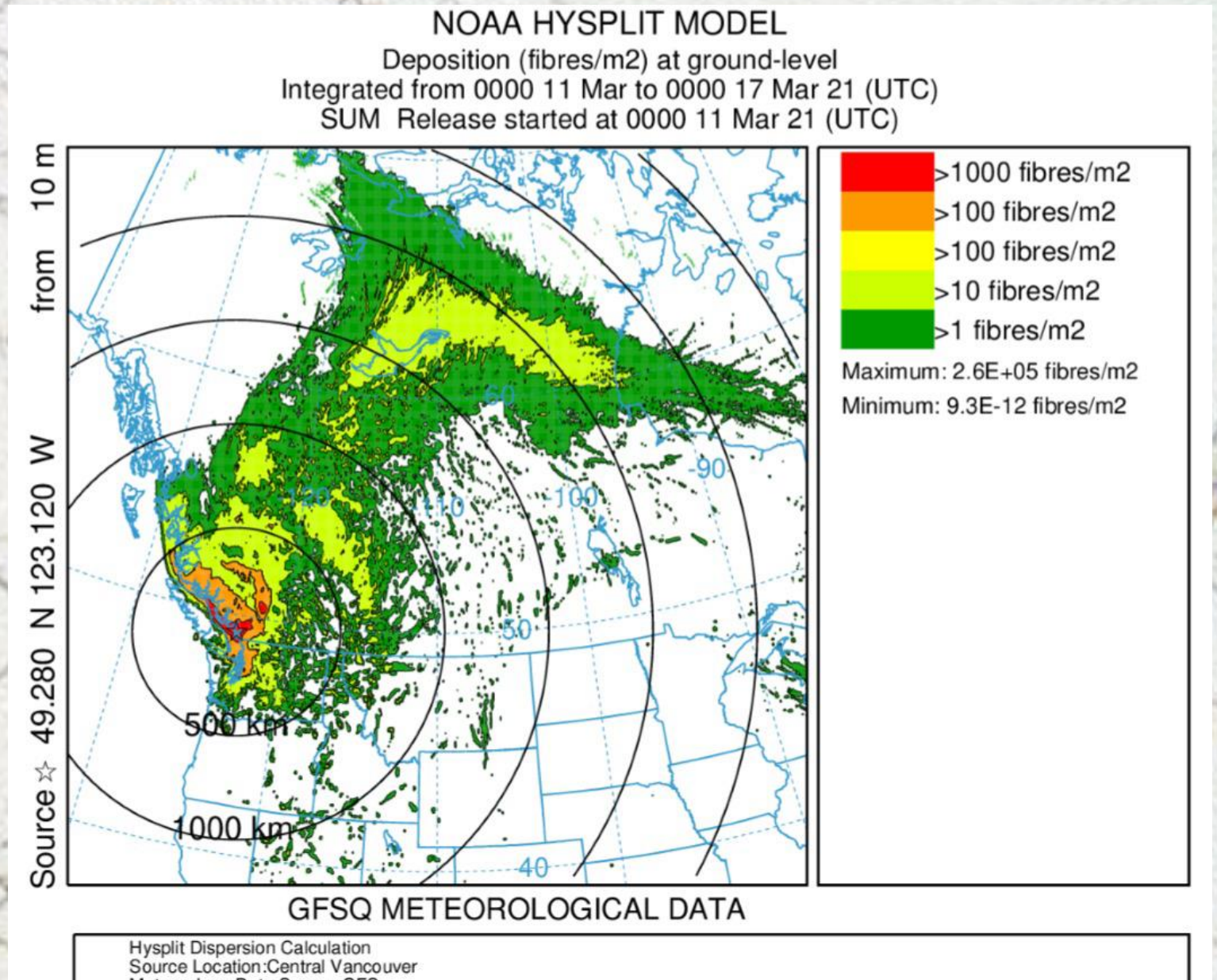


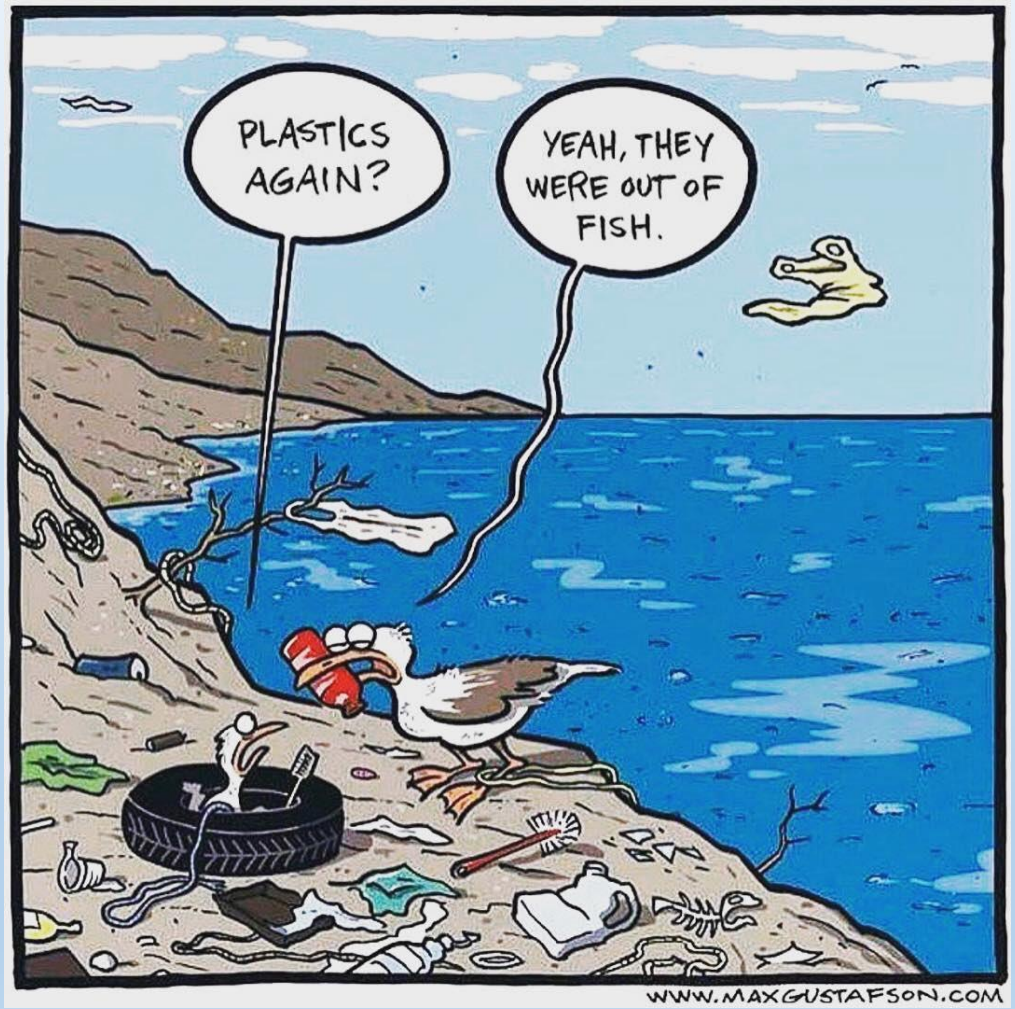
Figure from R. Hanson

Concern about plastics

- They do not fulfill the Stockholm Convention on Persistent Organic Pollutants and are not sufficiently addressed by the current legislation

- Current efforts underway to start negotiations of a global treaty on plastics

- UN Environmental Assembly (UNEA 5.2) February 2022:
  - Basel Convention: Control of Transboundary Movements of Hazardous Wastes and Their Disposal



What is Canada Doing to Address the Plastic Pollution?

Source: IUCN (2019) Ocean Plastics Charter

G7 Plastics Charter

In 2018, Canada, France, Germany, Italy, UK and the EU came together to devise a sustainable approach to plastic management.

- Circular economy,
- Lifecycle approach,
- Research, innovations and new technologies,
- Coastal and shoreline action.

G7 2018 CHARLEVOIX

Canada-Wide Strategy on Zero Plastics Waste (CCME, 2018)

- this strategy takes a circular economy approach to plastics and provides a framework for action in Canada.

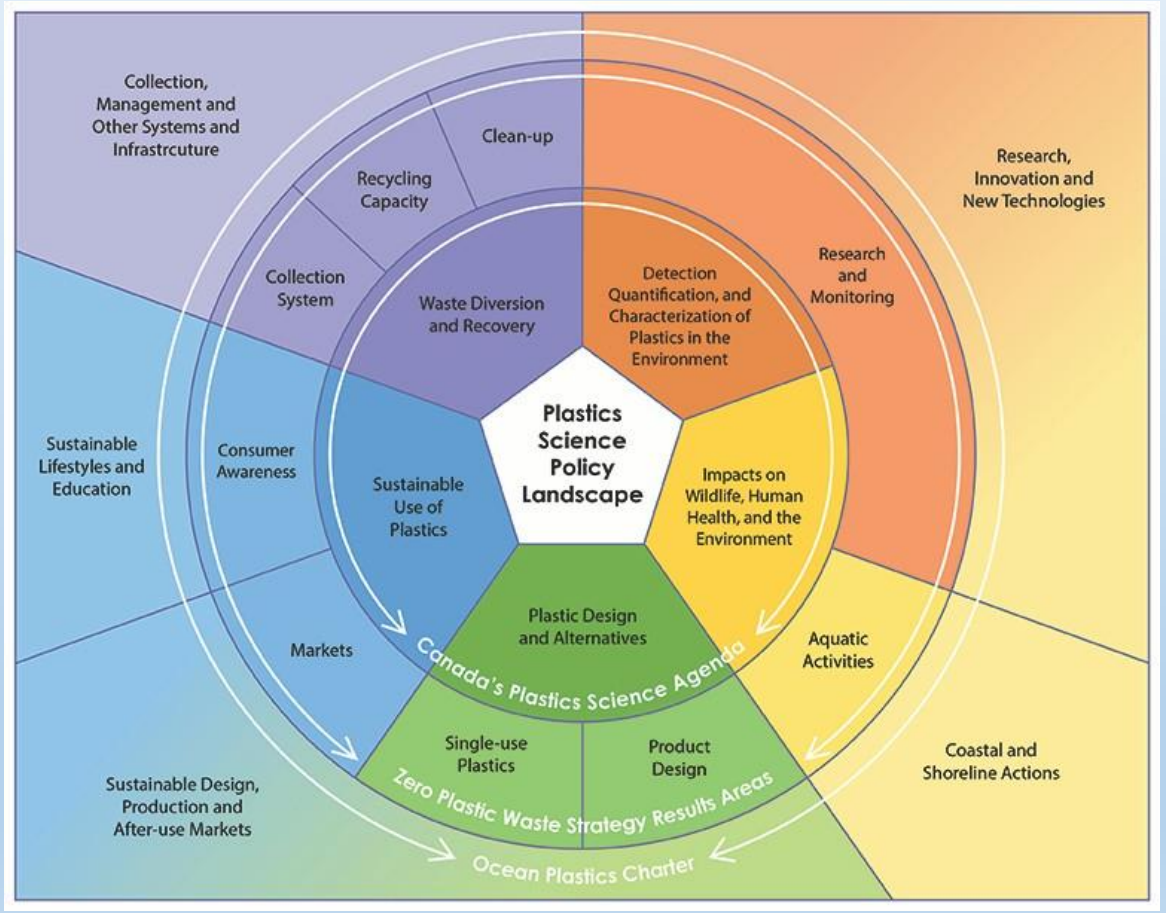
What is Canada Doing to Address the Plastic Pollution?

Canadian Plastic Science Agenda (CaPSA) July 2018:

Funded plastics and microplastics in the North through the Northern Contaminants Program

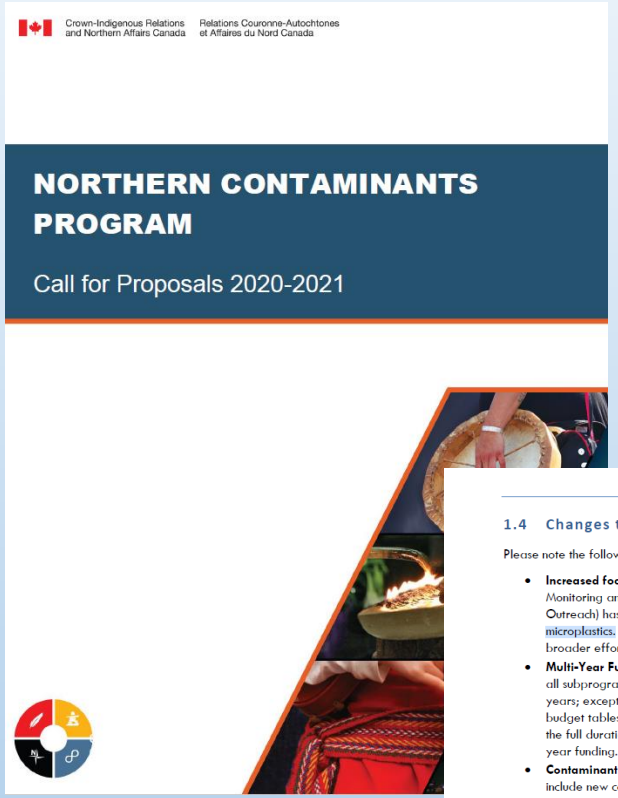
Five themes:

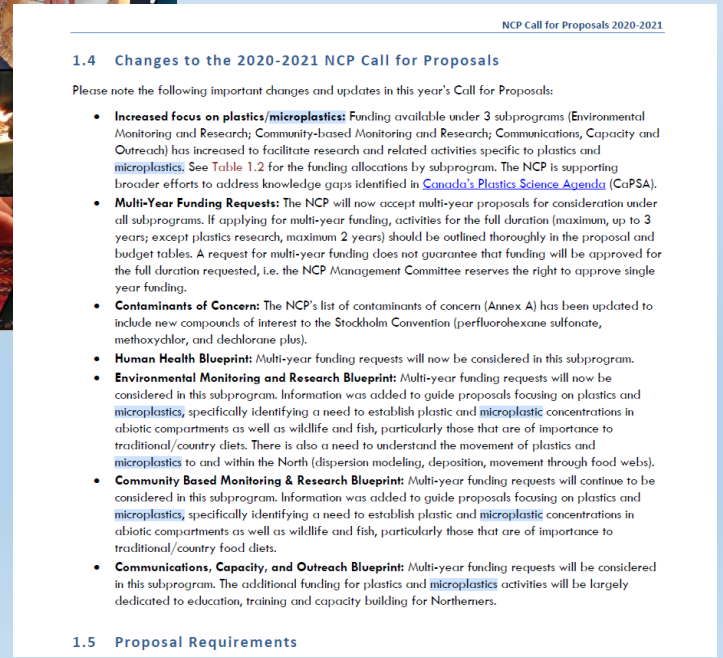
- Quantify and characterize sources, pathways and fate of plastics in the environment
- Understand the impacts of plastics on wildlife and human health
- Increase the safety, recyclability and/or compostability of plastics
- Support informed usage and sustainable management of plastics
- Enhance capture and value recovery of existing and future plastics



Northern Contaminants Program and MPs in Air

- Microplastics declared an issue of Emerging Arctic Concern
- NCP identified atmospheric microplastics as a research priority
- We are currently developing baseline levels in the Arctic
  - Future trends can be developed
  - Assess the effectiveness of national and international regulations





NCP Call for Proposals 2020-2021

1.4 Changes to the 2020-2021 NCP Call for Proposals

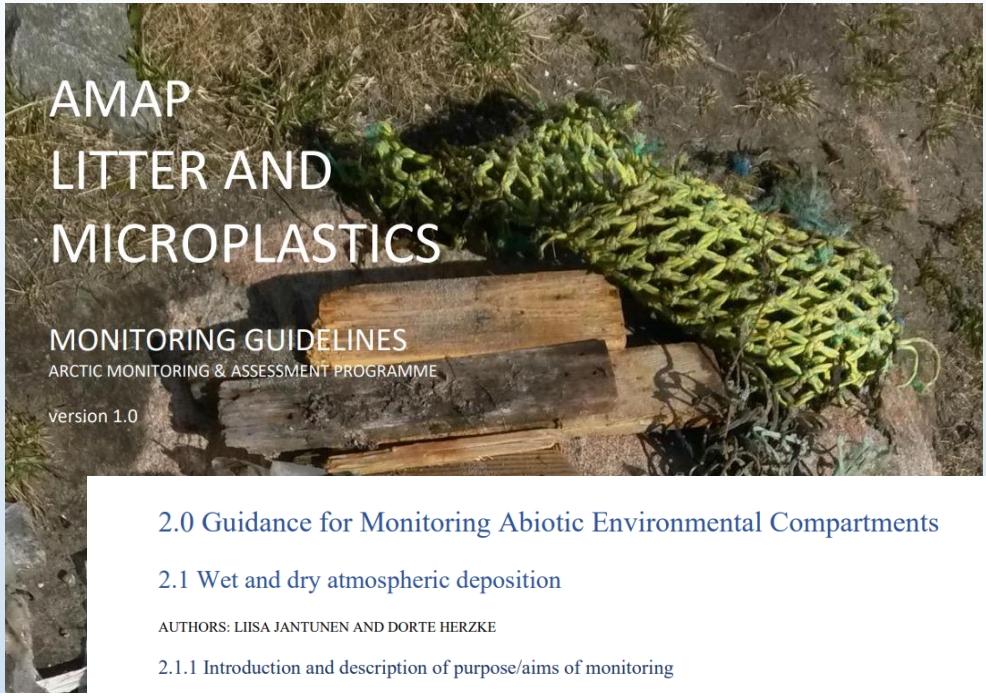
Please note the following important changes and updates in this year's Call for Proposals:

- **Increased focus on plastics/microplastics:** Funding available under 3 subprograms (Environmental Monitoring and Research; Community-based Monitoring and Research; Communications, Capacity and Outreach) has increased to facilitate research and related activities specific to plastics and microplastics. See Table 1.2 for the funding allocations by subprogram. The NCP is supporting broader efforts to address knowledge gaps identified in Canada's Plastics Science Agenda (CaPSA).
- **Multi-Year Funding Requests:** The NCP will now accept multi-year proposals for consideration under all subprograms. If applying for multi-year funding, activities for the full duration (maximum, up to 3 years; except plastics research, maximum 2 years) should be outlined thoroughly in the proposal and budget tables. A request for multi-year funding does not guarantee that funding will be approved for the full duration requested, i.e. the NCP Management Committee reserves the right to approve single year funding.
- **Contaminants of Concern:** The NCP's list of contaminants of concern (Annex A) has been updated to include new compounds of interest to the Stockholm Convention (perfluorohexane sulfonate, methoxychlor, and dechlorane plus).
- **Human Health Blueprint:** Multi-year funding requests will now be considered in this subprogram.
- **Environmental Monitoring and Research Blueprint:** Multi-year funding requests will now be considered in this subprogram. Information was added to guide proposals focusing on plastics and microplastics, specifically identifying a need to establish plastic and microplastic concentrations in abiotic compartments as well as wildlife and fish, particularly those that are of importance to traditional/country diets. There is also a need to understand the movement of plastics and microplastics to and within the North (dispersion modeling, deposition, movement through food webs).
- **Community Based Monitoring & Research Blueprint:** Multi-year funding requests will continue to be considered in this subprogram. Information was added to guide proposals focusing on plastics and microplastics, specifically identifying a need to establish plastic and microplastic concentrations in abiotic compartments as well as wildlife and fish, particularly those that are of importance to traditional/country food diets.
- **Communications, Capacity, and Outreach Blueprint:** Multi-year funding requests will be considered in this subprogram. The additional funding for plastics and microplastics activities will be largely dedicated to education, training and capacity building for Northerners.

1.5 Proposal Requirements

Arctic Council's Arctic Monitoring and Assessment Program (AMAP)

- Recently published a guidance document on monitoring microplastics in the Arctic environment.
- Including a chapter on atmospheric deposition and the cryosphere.
- Paper was just accepted for publication in Arctic Science that combines these two chapters



2.0 Guidance for Monitoring Abiotic Environmental Compartments

2.1 Wet and dry atmospheric deposition

AUTHORS: LIISA JANTUNEN AND DORTE HERZKE

2.1.1 Introduction and description of purpose/aims of monitoring

2.5 Ice and snow (from lakes and rivers, glacier cores, sea ice)

AUTHORS: ILKA PEEKEN, MARIA E. GRANBERG, ALESSIO GOMIERO, INGEBORG HALLANGER, AND KERSTIN MAGNUSSON

2.5.1 Introduction

Both sea ice and snow in the Arctic are highly polluted with microplastics (MP; Obbard et al., 2014; Peeken et al., 2018a; Bergmann et al., 2019; Kanhai et al., 2020; von Friesen et al., 2020). Sea ice sequesters MP from the atmosphere (Bergmann et al., 2019; Allen et al., 2020) and from the underlying seawater and acts as a temporary sink and transport vehicle of MP pollution (Peeken et al., 2018a, Kanhai et al., 2020). Given the marked reduction in age, thickness, and extent of the Arctic sea-ice cover in recent decades (Polyakov et al., 2012; Stroeve et al., 2012), it is likely that this sequestered MP will be increasingly released into the pelagic Arctic and sub-Arctic systems.

2.5.2 Status of global science

Although MP have reached both polar regions (Isobe et al., 2017; Waller et al., 2017; Peeken et al., 2018b; PAME, 2019), so far, detailed studies of MP have mainly been reported for Arctic sea ice and snow (Obbard et al., 2014; Peeken et al., 2018a; Bergmann et al., 2019; Kanhai et al., 2020; von Friesen et al., 2020). Currently nothing is known about the plastic pollution of other components of the cryosphere, for example, Arctic lakes or glaciers (PAME, 2019). However, it is known that MP deposited in alpine glaciers have concentrations comparable to those found in European marine and coastal sediments (Ambrosini et al., 2019) and thus it can be anticipated they might also be found in Arctic glaciers. A high atmospheric input for Arctic sea ice was also claimed by Geilfus et al. (2019),

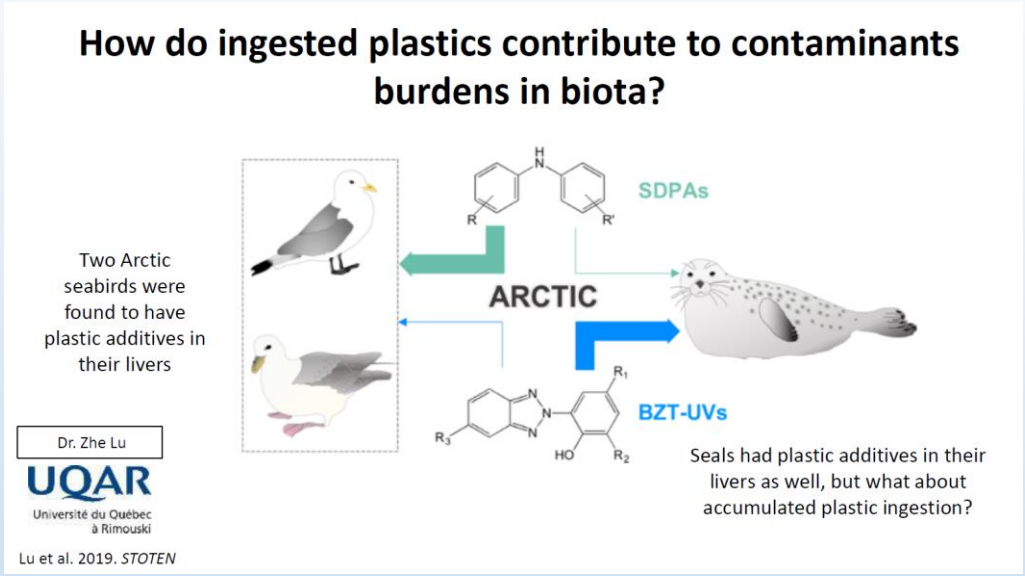
…arine plastic pollution, the PAME report identified
…ollution still lacking in empirical data (PAME,
…able at this point and no harmonized methodology,
…ric transport of microplastics (MP) to the Arctic is
…re. Additionally, local sources have not yet been
…stic waste from landfills and urban settlements during
…rt distances (PAME, 2019).

…ic sampling and the small number of peer-reviewed
…al recommendations on robust procedures are
…lated methods are available, we are reporting on
…mending best practices.

…consist of a variety of polymer types (Enyoh et al.,
…/ of forms such as fragments, foams, films, granules,
…fragments and fibers being the dominant MP (Dris et
…7; Catarino et al., 2018; Allen et al., 2019; Ambrosini
…20) found that seaward winds had higher levels of MP
…, suggesting that sea spray contributes to the

Future Work

- **Plastic associated chemicals in the Arctic**
  - We have published work on
    - flame retardants and plasticizers



- **UV-328 plus other UV-filters**
  - Nominated to the Stockholm Convention
  - Absorbs full spectrum of UV light, used in plastics, paints, construction materials, packaging (including food contact materials)
  - Major use as a plastic additive – plastics litter may be the main source to marine environmental and biota ingesting plastics
  - Little data from the Arctic
  - Controversial discussions around long-range transport of plastics as a valid pathway
  - Adverse health effects include organ toxicity (liver, kidneys, reproductive organs) in animals

Thank you!

Questions?

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