EXPEDITION **GLACIALIS 2021**

> www.glacialis.ch
> www.atlasexpeditions.org


Humpback whale in the province of Kujalleq - Photo : Arnaud Conne - Expedition Glacialis 2021

> Cover image : Humpback whales - **Megaptera novaeangliae** - Photo : Richard Mardens - Expedition Glacialis 2021

Expedition Glacialis

Documentation of marine mammals and their habitat, from the Azores archipelago to Disko Bay - Greenland

Mission report 2021

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The Atlas sailboat in the Kujalleq fjords - Photo : Richard Mardens - Expedition Glacialis 2021

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Thanks

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Thank you to the Atlas Expeditions association for its support throughout the development of the project and for the provision of the Atlas sailboat.

Thank you to the sponsors who helped us gather safety equipment for the mission, kept us warm and helped publicize the project.

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A big thank you to the citizens of Greenland who warmly welcomed us during our stops and took the time to share with us their stories, their concerns, their projects, and their culture!

We thank all the research professionals for their involvement and contribution to this project. Thank you to all the collaborators, friends, families and volunteers for their support in terms of logistics, preparation of the vessel and review of documents.

> Arctic Tern - **Sterna paradisaea** - Photo : Arnaud Conne - Expedition Glacialis 2021

Contexte

The climate is changing faster in the Arctic than in any other region of the planet, air temperatures there are increasing at a rate 2 to 3 times higher than the global average and the extent of sea ice is decreasing at an alarming rate (IPPC 2018, Meredith et al. 2019).

Arctic marine mammals are all strongly linked to ice and are therefore seriously threatened by these changes (Laidre et al. 2008, Kovacs et al. 2011, Meredith et al. 2019).

Ice decline and the associated environmental changes are linked to changes in species distribution (Higdon et Ferguson 2009, Hamilton et al. 2015, 2019a, Rode et al. 2015, Lone et al. 2018), **changes in trophic relationships** (Watt et al. 2016, Hamilton et al. 2017, Yurkowski et al. 2018) **and increased disease risks** (par exemple, Van Wormer et al. 2019).

At the same time, levels of human activity including shipping, tourism, commercial fishing, oil and gas exploration and production have increased. These trends are likely to continue in Arctic regions because declining ice reduces logistical challenges for these industries (Reeves et al. 2019).

There is therefore an urgent need to identify important areas for marine mammals to enable appropriate management and conservation of these species in the context of these multiple stressors (Kovacs et al. 2011, Reeves et al. 2014, Yurkowski et al. 2019, Hamilton et al, 2021).

> **Humpback whale feeding near an iceberg in Disko Bay** - Photo : Arnaud Conne - Expedition Glacialis 2021


Humpback whales at the mouth of the Ilulissat Icefjord - Photo : Arnaud Conne - Expedition Glacialis 2021

Partners

Greenland Institute of Natural Resources
Arctic fish & fisheries.
www.natur.gl

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Oceaneye, *Switzerland*
Microplastic data analysis.
www.oceaneye.ch

Federal Polytechnic School of Lausanne (EPFL), *Switzerland*
Environmental Chemistry Laboratory.
www.epfl.ch

Marine Freshwater Research Institute, *Island*
Identification data analysis.
www.hafogvatn.is

Nature Metrics, *Great Britain*
Biodiversity monitoring - eDNA analysis.
www.naturemetrics.co.uk

Mysticetus, *United States*
Data collection software support.
www.mysticetus.com

The Swiss Cetacean Society - SCS, *Switzerland*
Marine mammal conservation advisor.
www.swisscetaceansociety.org

Humpback whale - **Megaptera novaeangliae** - Photo : Arnaud Conne - Expedition Glacialis 2021

RESUME

Glacialis is an independent scientific expedition working jointly with a variety of academic and industrial actors with the aim of collecting data on marine mammals and their environment in remote areas, particularly in the Arctic.

Glacialis aims to boost data collection by adapting the tools needed for scientific research to small platforms and encouraging citizen science efforts.

From the Atlas sailboat, an excellent micro-platform for research, Glacialis collected data for 5 months in 2021, on a 6,700 NM (11,400 km) route from the Azores archipelago to Ata Sund, in the northern Disko Bay, Greenland.

The team carefully documented over 850 sightings of sea mammals and birds, collected microplastic samples, macro litter information, environmental DNA samples, plankton samples, fish larvae samples, meteorological observations, readings of water parameters, as well as water samples for research on cyanobacteria.

Professional quality photographs and video were captured alongside scientific species identification protocols. In order to generate and maintain the link with its community, the team produced a variety of publications in the media and on social networks throughout the project.

Several classes of primary school students have regularly followed the route of the expedition. Their teachers were able to take advantage of the thematic richness of the project and the strong interest aroused among young people to stimulate their educational program.

The following sections of this report describe the accomplishments and challenges faced by the team as well as the objectives identified for subsequent assignments.

EXPEDITION GLACIALIS

MISSION OBJECTIVES

> Document marine wildlife and its habitat.

> Test, adapt and document data collection protocols from the Atlas sailboat.

> Identify replicable protocols for citizen science at sea.

> Publish the data collected in order to promote the advancement of research and international collaboration.

> Raise public awareness of changing environmental conditions related to the oceans.

> Awaken the interest and environmental awareness of all generations.

> Involve the young by integrating schools into the project's approaches.

TEAMWORK

The project was initiated in 2019 by Virginie Wyss and made possible thanks to the commitment of citizens aged 23 to 69.

The meeting, in May 2020, between skipper and photographer Arnaud Conne (CH), biologists and marine mammal specialists Laurence Tremblay (CA), Mathieu Marzelière (FR), Virginie Wyss (CH), director and biologist Richard Mardens (BE) and the biochemist Matthew Ryle (USA) was decisive for the realization of the project.

The biologist Alexandre Bernier-Graveline and the ornithologist Jessé Roy-Drainville also contributed to the scientific development of the project, as well as Marion Le Bouard, scientific promotion assistant at the CNRS, who supported the team in its communication efforts and in the literature search.

With the support of the Swiss Cetacean Society and the Atlas Expeditions association, several requests for funding were submitted to calls for projects from the public and private sectors in Switzerland and Europe. It was finally thanks to crowdfunding, proposed within the project community, that the minimum budget required was obtained in March 2021.

Humpback whale - Drawing by a student from Switzerland, July 2021

At the end of March, Arnaud Conne and two volunteers from the Atlas Expeditions association, Albert Maillefer and Bernard Capt, started the technical preparation of the Atlas sailboat, then stationed on the island of Santa Maria in the Azores.

Laurence Tremblay and Mathieu Marzelière joined the skipper in April to finalize the preparation of the boat for the mission, deepen the definition of data collection protocols, and work on the integration of research tools on board the sailboat.

After 2 months of intensive preparation, the Atlas platform weighed anchor towards the islands of Pico and Faial with the aim of implementing and testing the multiple data collection protocols. Many

significant sightings were documented during this time (e.g. sperm whales, Risso's dolphins, Cuvier's beaked whale).

The field team for the Greenland mission consisted of Virginie Wyss, Richard Mardens, Matthew Ryle and Arnaud Conne. The president of the Atlas Expeditions association, Roman Hapka, joined the Atlas to support the crew on the great return trip from southern Greenland.

From dry land, navigator and computer engineer Angie Gartz and navigator and radio host Marie-Amélie Lenaerts followed the course of the expedition and supported the skipper with their precious weather routing analyses.

Data collection

All observations and sampling were carried out with respect to animal welfare and the environment (see Repcet approach sheet - Pelagos Sanctuary code of conduct).

During encounters with marine mammals, the approach speed was adapted to the slowest individuals. Animals were approached from the side, without ever cutting them off or splitting the group.

A distance of at least 100 to 300 meters was systematically maintained, letting the animals come to the boat at their own discretion.

The time allowed for each observation was limited to the strict minimum necessary to obtain the essential identification parameters of the species.

> **Microplastic sampling in the icy waters of Groenland** - Photo : Richard Mardens - Expedition Glacialis 2021

A sperm whale in sight from the data entry station - Photo : Arnaud Conne - Expedition Glacialis 2021

1. Visual monitoring

CONTEXT

Conservation efforts are closely linked to the census of species. Quality data are useful for determining trends in distribution, migrations and the quality of the ecosystems that host them (CAFF, 2017). Visual observation data therefore represent the first pillar of the Glacialis project approach.

GOALS

> Develop structured, professional and documented monitoring protocols using the Atlas platform.

> Document each significant observation of marine animals, as well as macro-waste (plastics, fishing equipment, etc.) in a geolocated database.

> When possible, capture identification quality photographs, acoustic recordings, and the science samples for our collaborators described throughout this document.

TOOLS

Binoculars - GPS positioning system - SLR camera - Long focal (zoom) lenses - Laptop - Identification guides for species of birds (S. Howell et K. Zufelt, 2019) and marine mammals (H. Shirai. et B. Jarrett, 2006).

METHODOLOGY

The recording of environmental parameters (Fig.1, p.18) constitutes the basis of the observation methodology, regularly qualifying the meteorological context as well as the observation effort.

In favorable conditions, two observers are posted on deck and equipped with binoculars. Each observer scans the horizon covering an angle of 180°. If two observers can be active, the observation effort is qualified by the ON status. In unfavorable conditions (fog, sea or strong wind) or when only one person is available for observation, the effort is considered COMPROMISED.

Sometimes sightings occur when they are not expected and no observer is on duty. The latter are qualified by the effort status OFF and the end of an observation period is marked by the status END.

For each sighting, the team records the exact time and place, the species, the estimated minimum and maximum number of individuals observed, and the behavioral characteristics of the animals (e.g. foraging, movement, feeding, socialization, indeterminate, etc.) and references to samples, environmental parameters and associated media.

All sighting data is recorded using Mysticetus software.

Exports and daily backups were carried out on external media to prevent possible loss of data in the event of material damage or improper handling.

Scientific partners : Greenland Institute of Natural Resources - Nova Atlantis Foundation - Mingan Island Cetacean Study - Megaptera - Moniceph - Monicet - ROMM - Sea Color Expeditions - Flukebook - Happy whale - Marie la Rivière - Marine and Freshwater Research Institute - North Atlantic Humpback Whale Catalog NAHWC - Ocean Alliance - Allied Whale - R&E Ocean Community Conservation.

Blue whale - **Balaenoptera musculus** - Photo : Arnaud Conne - Expedition Glacialis 2021

I. ENVIRONMENTAL PARAMETERS *(EXCERPT)*

ID	EFFORT	LEG TYPE	CONDITIONS	SHIP SPEED (KTS)	WIND (BFT)	WIND DIRECTION	SWELL (M)	CLOUD COVER	AIR TEMP (C)
E003	COMPROMISED	Transit	Medium	*6.23*	*4*	*N*	*1*	*10*	*20*
E014	ON	Transit	Good	*5.93*	*1*	*S*	*0*	*0*	*21*
E106	OFF	Transit	Medium	*3.03*	*2*	*W*	*2*	*100*	*12*
E118	ON	Transit	Good	*3.65*	*3*	*W*	*1*	*100*	*12*
E290	ON	Transit	Good	*6.55*	*1*	*S*	*0*	*70*	*17*
E328	END	Transit	Good	*5.80*	*0*	*-*	*0*	*20*	*13*
E362	END	Transit	Bad	*0.00*	*1*	*N*	*2*	*100*	*12*

Environmental parameters collected: *Unique ID - Date and Time (UTC) - GPS Position - Observer reference - Effort - Effort type - Leg Type - Conditions - Engine - Ship speed (kts) - Wind (Bft) - Wind direction - Swell (m) - Swell direction - Glare - Glare orientation - Cloud Cover - Air Temp (C) - Comments*

Saisie des données - Photo : Virginie Wyss - Expedition Glacialis 2021

II. OBSERVATION CATALOG *(EXCERPT)*

SGT ID	LOCATION	SIGHTING TYPE	GROUP SIGHTING	SIGHTING	MIN	MAX
V058	AZO	Visual PAM	Odontocète	*Physeter macrocephalus*	8	12
V096	AZO	Visual	Odontocète	*Ziphius cavirostris*	5	10
V098	AZO	Visual	Mysticète	*Balaenoptera borealis*	1	1
V170	ATL	Visual PAM	Odontocète	*Globicephala melas*	50	75
V200	GL	Visual	Mysticète	*Balaenoptera physalus*	4	5
V285	GL	Visual PAM	Odontocète	*Phocoena phocoena*	3	4
V522	GL	Visual	Mysticète	*Baleanoptera musculus*	1	1
V768	GL	Visual	Mysticète	*Megaptera novaeangliae*	6	6
V808	GL	Visual	Odontocète	*Physeter macrocephalus*	1	1
V818	GL	Visual	Mysticète	*Balaenoptera acutorostrata*	1	1
V874	GL	Visual	Odontocète	*Pseudorca crassidens*	2	2

Observation parameters collected : *Sgt Id - Date - Time (UTC) - Ship - Observer - Sighting type - GPS Position - Group sighting - Sighting - Min - Max - Average - Adult - Juvenile - Calves - Certainty - Dist. (m) - Bearing - Min Disp. - Max Disp. - Behaviour - Relation to ship - Active state - Association - Photos - Video - Drone - Footage reference - Acoustic - CTD - Water sample - Sample reference - Notes.*

III. MARINE MAMMAL SIGHTINGS *(SUMMARY)*

SPECIES	MAY	JUN	JUL	AUG	SEP	TOTAL
Common dolphin (Dauphin commun - *Delphinus delphis*)	329	465			91	885
Harp seal (Phoque du Groenland - *Phoca groenlandica*)			112	157		269
Dolphin sp. (Dauphin sp.)	102	143			22	267
Stripped dolphin (Dauphin bleu et blanc - *Stenella coeruleoalba*)	55	150			19	224
Long-finned pilot whale (Globicéphale noir - *Globicephala melas*)		157			22	179
Bottlenose dolphin (Grand dauphin - *Tursiops truncatus*)	27	15			40	82
Humpback whale (Rorqual à bosse - *Megaptera novaeangliae*)			32	41	1	74
Atlantic spotted dolphin (Dauphin tacheté de l'Atlantique - *Stenella frontalis*)					65	65
Sperm whale (Grand cachalot - *Physeter macrocephalus*)	37			1	5	43
Toothed whale sp. (Odontocète sp.)	7		25			32
Rissos dolphin (Dauphin de Risso - *Grampus griseus*)	18					18
Fin whale (Rorqual commun - *Balaenoptera physalus*)		4	2	7	3	16
Seal sp. (Phoque sp.)				12		12
Rorqual sp. (Rorqual sp.)	7	1	1			9
White-beaked dolphin (Dauphin à nez blanc - *Lagenorhynchus albirostris*)		7				7
Cuvier's beaked whale (Baleine à bec de Cuvier - *Ziphius cavirostris*)	7					7
Habor porpoise (Marsouin commun - *Phocoena phocoena*)			6			6
Bearded seal (Phoque barbu - *Erignathus barbatus*)					4	4
Minke whale (Petit rorqual - *Balaenoptera acutorostrata*)				2	2	4
Beaked whale sp. (Baleine à bec sp.)		4				4
False killer whale (Fausse orque - *Pseudorca crassidens*)					2	2
Blue whale (Rorqual bleu - *Baleanoptera musculus*)			2			2
Sei whale (Rorqual boréal - *Balaenoptera borealis*)	1					1

III. Observations of marine mammals: Average number of individuals observed monthly, by species.

Humpback Whales - **Megaptera novaeangliae** - Photo : Arnaud Conne - Expedition Glacialis 2021

RESULTS

More than 850 sightings of marine mammals and birds including no less than 19 species of marine mammals (2,200 individuals) and 28 species of birds (more than 10,000 individuals) have been documented in our database. **The complete observation catalog is made available to researchers, on request at info@glacialis.ch.**

It should be emphasized here that the role of the Glacialis project was not to draw conclusions on the data obtained. This report is intended to be descriptive and presents these data without issuing conclusions.

Data was collected and forwarded to the project partners mentioned in this report, as well as to multiple marine mammal identification catalogs.

DISCUSSION

The visual documentation was one of the great successes of the mission, but also one of the greatest challenges. This approach would not have been crowned a success without passionate naturalists and experts in the identification of marine mammals onboard the vessel.

Having access to good reference books is essential for validating sightings and useful for the on-going training of observers.

Keeping two observers on deck, especially during long crossings, was not always possible due to weather conditions or the commitment of the crew to other tasks.

Entering numerous parameters into the database can be a perilous task at sea, due to boat movements, fatigue or seasickness!

A variety of technical issues were encountered with the computer hardware and Mysticetus data collection software, which presented the team with additional challenges. The recognition of the GPS positioning device by the software at times caused delays in our daily operations.

Our objective for the next missions is to identify or develop data collection software better integrated into navigation devices and automation of the collection of certain environmental parameters via the boat's sensors.


V698 - Canada Geese - **Branta canadensis** - Photo : Arnaud Conne - Expedition Glacialis 2021

BIRD SIGHTINGS *(SUMMARY)*

SPECIES	MAY	JUN	JUL	AUG	SEP	TOTAL
Cory's Shearwater (Puffin cendré - *Calonectris diomedea*)	*3497*	*431*			*40*	*3968*
Black-legged Kittiwake (Mouette tridactyle - *Rissa tridactyla*)			*191*	*450*		*641*
Northern Fulmar (Fulmar boréal - *Fulmarus glacialis*)		*21*	*303*	*140*	*3*	*467*
Common eider (Eider à duvet - *Somateria mollissima*)			*401*	*5*	*11*	*417*
Black Guillemot (Guillemot à miroir - *Cepphus grylle*)			*276*	*136*		*412*
Great Black-Backed Gull (Goéland marin - *Larus marinus*)	*9*		*148*			*157*
Arctic Tern (Sterne arctique - *Sterna paradisaea*)		*3*	*32*	*68*		*103*
Canada Goose (Bernache du Canada - *Branta canadensis*)				*92*		*92*
Razorbill (Petit Pingouin - *Alca torda*)			*51*			*51*
Pomarine Jaeger (Labbe pomarin - *Stercorarius pomarinus*)			*2*	*1*	*44*	*47*
Common Murre (Guillemot marmette - *Uria aalge*)			*42*			*42*
Common Raven (Grand Corbeau - *Corvus corax*)			*32*	*2*		*34*
Harlequin Duck (Canard arlequin - *Histrionicus histrionicus*)			*23*			*23*
Storm petrel (Océanite tempête - *Hydrobates pelagicus*)	*2*	*6*			*13*	*21*
Great Cormorant (Grand Cormoran - *Phalacrocorax carbo*)			*3*	*15*		*18*
Pectoral Sandpiper (Bécasseau à poitrine cendrée - *Calidris melanotos*)			*9*			*9*
Dovekie (Mergule nain - *Alle alle*)		*2*	*7*			*9*
Bald eagle (Pygargue à tête blanche - *Haliaeetus leucocephalus*)			*4*	*1*		*5*
Parasitic Jaeger (Labbe parasite - *Stercorarius parasiticus*)			*2*		*1*	*3*
White-rumped Sandpipier (Bécasseau à croupion blanc - *Calidris fuscicollis*)				*2*		*2*
Thick-billed Murra (Guillemot de Brünnich - *Uria lomvia*)			*2*			*2*
Northern Gannet (Fou de Bassan - *Morus bassanus*)		*1*		*1*		*2*
Sabine's Gull (Mouette de Sabine - *Xema sabini*)				*1*		*1*
Red-necked Phalarope (Phalarope à bec étroit - *Phalaropus lobatus*)				*1*	*1*	*2*
Great Skua (Grand Labbe - *Stercorarius skua*)		*1*				*1*

Bird sightings: Average number of individuals observed monthly by species.

Photographic documentation of sightings - Photo : Arnaud Conne - Expedition Glacialis 2021

2. Photo identification

CONTEXT

Identification photography is a non-invasive process that allows the recognition of individuals within a species. This approach uses particular physical characteristics of an animal (shape of the dorsal fin, coloring pattern of the caudal fin, scars, etc.) to enable identification.

Cross-referencing this information with existing databases allows researchers to better understand patterns of migration, abundance, social structure, and species distribution (Jaquet and Gendron, 2002 ; Matthews et al, 2001).

GOALS

> For each observation, collect images allowing the identification of the individual.

> Share identification elements with marine mammal specialists and databases worldwide.

> Promote collaboration between marine mammal specialists.

> Support the effort of scientists to understand the migration patterns of cetaceans and their evolution in relation to climate change.

TOOLS

Reflex cameras: Canon EOS 7DMII, 5DSR, 5DMIII, 5DMIV. Lenses: Sigma 150-600mm and Canon EF-L 100-400mm, EF-L 70-200mm, EF-L 100mm. Drones: Phantom Pro IV and Mavic Pro II.

METHODOLOGY

If the conditions allow a safe and respectful approach to the animals, the vessel positions itself so that the observers can take images that meet the identification criteria of the target species.

The photographs are referenced in connection with the corresponding visual and environmental observations.

The photographs are then uploaded and checked daily by the team. Elements of sufficient quality for identification are selected and sent to our various partners.

Scientific partners: Greenland Institute of Natural Resources - Nova Atlantis Foundation - Mingan Island Cetacean Study - Megaptera - Moniceph - Monicet - ROMM - Sea Color Expeditions - Flukebook - Happy whale - Marie la Rivière - Marine and Freshwater Research Institute - North Atlantic Humpback Whale Catalog NAHWC - Ocean Alliance - Allied Whale - R&E Ocean Community Conservation.

I . V198 - **Humpback Whale** (Megaptera novaeangliae) - Photo : Arnaud Conne - Expedition Glacialis 2021

II . V769 - **Humpback Whale** (Megaptera novaeangliae) - Photo : Arnaud Conne - Expedition Glacialis 2021

RESULTS

During the expedition, 152 sightings of cetaceans were documented and identification photos of sufficient quality were obtained for 52 individuals.

The results have been shared with researchers in the Azores, Madeira, Canada, Greenland, Iceland, the West Indies, Saint-Pierre and Miquelon and the United States. The photographs were also submitted to the Flukebook online catalog, which uses automatic image correlation algorithms.

At present, three matches have already been established:

- > A humpback whale observed for the first time in the Caribbean in 2014 by the association OMMAG[1], was documented in 2021 by the Glacialis team in southern Greenland (ref. V198).
- > A humpback whale observed in 2017 by the Greenlandic Institute of Natural Resources was paired by the Marine Fresh Water Institute (Iceland) with a whale photographed in Greenland by our team in 2021 (ref. V729).
- > The first match between an individual from threatened populations in the Cape Verde Islands and a feeding area in the western North Atlantic has been established. Photographed by our team in 2021 in the Cape Farewell region of southern Greenland (ref. V211), this humpback whale is catalogued in NAHWC[2] (ref. NA4936), with only one year of previous sightings, in 1999.

We have documented this last individual at an interval of 22 years, which highlights the relevance of the photo-identification process and the importance of sharing data between researchers and institutions.

DISCUSSION

The team was able to capture photographs allowing individual identification for approximately 35% of the large cetaceans encountered on the expedition. Given the exceptional nature of each encounter and the difficulties of the terrain, the teams believes this is a high rate of success. Indeed, cetaceans are generally observed at great distances, and/or do not appear from the right angle, which makes it more difficult to obtain images useful for identification.

The presence of marine mammal specialists and professional photographers on board, as well as the responsiveness and flexibility of the Atlas platform in maneuvers in relation to the animals are elements that have largely contributed to this success!

To date, no pairings were established using Flukebook automated matching algorithm. It is possible that the individuals submitted to the automatic recognition system were new occurrences, which do not appear in the catalogs. Alternatively, the current automated photo matching algorithms may have limited functionality. This is evidenced by the three matches established with correspondences with our partners. This reinforces the utility of the collaborative project approach employed by Expedition Glacialis.

The current low match rate underscores the potential for discoveries about these populations and the importance of expanding the data collection and repeating surveys in these remote areas.

A more concerted effort between institutions as well as the provision of greater resources in the important work of documentation and information sharing would contribute to a better understanding and protection of these magnificent creatures.

[1]Guadeloupe Marine Mammal Observatory, [2]North Atlantic Humpback Whale Catalog

Matthew Ryle deploying the hydrophone - Photo : Arnaud Conne - Expedition Glacialis 2021

3. Acoustic recordings

CONTEXT

As the ice melts, the arctic regions become more accessible. There is an increase in marine traffic, oil or gas exploration and mining. These human activities are in addition to ongoing commercial fishing and generate a modification of the underwater soundscapes. Cetaceans are particularly vocal animals that use sound to communicate, feed, and orient themselves.

The impact of noise pollution on the ecology of these animals is not yet well understood. It is thought to increase stress levels by and their ability to communicate, navigate and reproduce (Ghulam et al, 2018). Underwater acoustic monitoring allows researchers to understand the impact of noise pollution on cetaceans.

GOALS

> Test the citizen science tools offered by the Ear to the Wild project.

> Link recordings of animal vocalizations to visual documentation of species.

> Record underwater ambient sound and document the level of noise pollution.

> Document the soundscapes of the places visited.

TOOLS

E2TW device: Android tablet, iRIG, Aquarian H2A hydrophone.

PAM device: RS Aqua PORPOISE wide frequency range programmable recorder.

AAM device: Zoom H5 recorder, Aquarian H2A hydrophone.

METHODOLOGY

The hydrophone was deployed during visual observations in generally calm weather when the ship was stationary and the engine off.

The recordings were made using the Ear to the Wild device or a Zoom H5 professional portable recorder equipped with a hydrophone..

Scientific partners: Prof. Michel André and Florence Erbs, Ear to the Wild, Laboratory of Applied Bioacoustics (LAB) in Barcelone, www.lab.upc.edu

Shrimp vessel in Disko Bay - Photo : Arnaud Conne - Expedition Glacialis 2021

RESULTS

In total, more than 70 recordings were made and high quality vocalizations were obtained for several species of marine mammals (common dolphins, Risso's dolphins, sperm whales, pilot whales, humpback whales).

All the recordings were shared with our LAB collaborators, for the optimization of the Ear to the Wild device.

When recordings of sounds directly emitted by the animal observed could not be captured, the sound environment in which the wildlife encounter occurred was still of interest and was documented.

Thus characteristic underwater sound environments, natural or anthropogenic, have been captured. The cracking or fizzing of icebergs, the machines of the industrial port of Nuuk, the metallic noises of the nets towed by the shrimp boats in Disko Bay have been the subject of careful recordings.

Also on the surface, a variety of sound atmospheres were recorded: fishing villages, scenes of local life, animal cries and bird songs. This material will be promoted through the production of immersive presentations and used in the soundtrack of the documentary film being produced by Richard Mardens and Arnaud Conne.

DISCUSSION

Rough seas and windy days caused high background noise. Deploying and retrieving the hydrophone cable from the boat was also a challenge. A furling device was developed during the mission and made it possible to simplify these tasks.

Connectors quickly suffer from corrosion due to sea air and mechanical stress. Various problems were encountered in connection with these factors.

One third of the way into the mission, the iRig converter required to connect the hydrophone with the Ear to the Wild tablet stopped working.

Overall, the E2TW app has proven to be an exciting and easy-to-use concept for citizen scientists. Suggestions for improving the system have been forwarded to our collaborators at the University of Barcelona.

Developing a recording device that is both robust and easy to implement is a goal for future expeditions.

Following the advice of the Eco Voyage team from Arvik, a "homemade" device allowing the hydrophone to be dragged at the back of the boat and recordings to be made in motion while minimizing parasitic noise has been designed. This method has proven effective.

The "Porpoise" recorder supplied by RS Aqua, which requires significant training to use, is a suitable tool when it can be deployed remotely over long periods. This was not fully feasible given the time and itinerary requirements imposed by the mission.

This dedicated passive acoustic monitoring recorder has a hydrophone with an extended spectrum, which makes it possible to determine if a species is present in an area, in what season and at what frequency (Frouin-Mouy et al, 2016). These types of tools allow access to impassable areas such as frozen waters in the Arctic winter (DeVresse et al, 2018).

In the future, it would be relevant to focus these passive recording efforts in a dedicated mission, and/or to have autonomous deployment equipment allowing longer recording periods.


Footprint left on the surface by a whale - Photo : Arnaud Conne - Expedition Glacialis 2021

4. Environmental DNA

CONTEXT

Environmentally persistent DNA (eDNA) can be collected, sequenced and analyzed to determine the species present in an ecosystem (Deiner et al, 2017). **This non-invasive technique allows a better understanding of the species richness in the ecosystems visited since not only the whales observed can be detected, but also the food they seek.**

GOALS

> Assess the biodiversity of the environment using environmental DNA.
> Take seawater samples following visual sightings of cetaceans.
> Assess the utility of this innovative technique for citizen scientists to use in species detection.
> Provide information on other vertebrate species present during an observation.

TOOLS

DNA kit: sterile gloves, 3L plastic bag, syringe, filter, preservation solution and packaging pouch.

METHODOLOGY

The defined framework of the field of study of the expedition was to collect DNA samples in the presence of large cetaceans identified visually. The samples were collected as close as possible to the cetacean's Footprint, the oily trace remaining on the surface after a whale had dives (see illustration p.32). A control sample was taken in the absence of visual observation.

The collection sequence is as follows:

> The operator wears sterile gloves so as not to contaminate the samples.
> A quantity of approximately 3 liters of seawater is brought on board using a sterile container.
> The DNA is concentrated by filtration of 2000 ml of sea water through a syringe filter.
> A preservative solution is then introduced into the filter using the syringe.
> The filter is removed from the syringe and stored in an airtight pouch, cool and protected from light.

Scientific partners: Nature Metrics, Dr. Natalie Swan, www.naturemetrics.co.uk

I. Richness in taxa of the samples.

	V601	V697	V718	V727	V736	V744	V808
[7]Humpback whale *(Megaptera novaeangliae)*	●		●	●	●		
[5] Sperm whale *(Physeter macrocephalus)*							●
[4]Reindeer *(Rangifer tarandus)*		●	●	●			
Ringed seal *(Pusa hispida)*					●		
[6]Polar cod *(Boreogadus saida)*			●	●	●	●	
[3] Atlantic cod *(Gadus morhua)*							●
[6]Capelin *(Mallotus villosus)*		●	●	●	●	●	
[1]Greenland halibut *(Reinhardtius hippoglossoides)*			●				●
[2]Lumpfish *(Cyclopterus lumpus)*							●
Rockfish species *(Sepastes sp.)*							●
Northen fulmar *(Fulmarus glacialis)*							●

II. Frequency of occurrence of all detected families.

	Order	Family	V601	V697	V718	V727	V736	V744	V808
Mammalia	Cetacea	Physeteridae	0	0	0	0	0	0	1
Mammalia	Cetacea	Balaenopteridae	1	0	1	1	1	0	0
Mammalia	Carnivora	Phocidae	0	0	0	0	1	0	0
Mammalia	Artiodactyla	Cervidae	0	1	1	1	0	0	0
Actinopterygii	Gadiformes	Gadidae	0	0	1	1	1	1	1
Actinopterygii	Osmeriformes	Osmeridae	0	1	1	1	1	1	0
Actinopterygii	Pleuronectiformes	Pleuronectidae	0	0	1	0	0	0	1
Actinopterygii	Scorpaeniformes	Cyclopteridae	0	0	0	0	0	0	1
Actinopterygii	Scorpaeniformes	Sebastidae	0	0	0	0	0	0	1
Aves	Procellariiformes	Procellariidae	0	0	0	0	0	0	1

RESULTS

Ten DNA samples were collected. Nine samples were taken from whale footprints, the oily spot that can be seen on the surface immediately after a whale has dived, and 1 control sample was taken when marine mammals had not been observed. Samples were submitted blindly to the Nature Metrics laboratory for analysis.

A total of 11 taxa were detected of which 90.9% (10 taxa) were at least 99% similar to species in global reference databases. The remaining taxon has been identified to the genus. A total of 6 fish, 1 bird and 4 mammals were detected. The taxa are divided into 8 orders, 10 families and 11 genera.

Species of note include Greenland halibut[1] (Reinhardtius hippoglossoides - Near Threatened), Lumpfish[2] (Cyclopterus lumpus - Near Threatened), Atlantic cod[3] (Gadus morhua - Vulnerable), reindeer[4] (Rangifer tarandus - Vulnerable) and the Sperm whale[5] (Physeter macrocephalus - Vulnerable).

The relative proportion of sequences found in each of the samples is presented in Table 1 and the diversity is summarized in Table 2.

Capelin (Mallotus villosus), accounting for 33.9% of total sequence reads, is among the most abundant in terms of sequences.

Among the most frequently detected species are Capelin6 (Mallotus villosus, Humpback whale[7] (Megaptera novaeangliae) and Arctic cod[8] (Boreogadus saida).

High quality marine vertebrate sequence data was obtained for 7 of the 10 DNA samples. Samples V478, V522, as well as V621 (control) were amplified, but did not return DNA sequences from marine vertebrates.

Of note, the total number of target sequences for samples V697 and V744 was below the usual quality control threshold. These detections are therefore to be considered as probable.

DISCUSSION

The results confirm the utility of this technique for species identification. Of nine samples taken in the presence of visually identified large cetaceans, the species was confirmed by DNA analysis in 70% of cases. In addition, it was possible to detect in parallel the presence of constituent species of the food chain of the animals in question.

Collecting environmental DNA is one of the most innovative approaches used by the team. This process was facilitated by the presence on board of people trained in the collection and handling of DNA samples.

This is a minimally invasive method that can bring excellent results. It would be interesting to expand the scope of this type of sampling for future missions.

Filtering more water could help mitigate the low DNA recovery observed in 3 out of 10 samples. Fitting, for example, a 12V peristaltic pump to help filter larger volumes of seawater is a developing goal for future voyages.

This type of collection may be very suitable for the diligent citizen-scientist. However, the significant cost of DNA extraction, sequencing and analysis can be prohibitive. The team was fortunate to benefit from the financial support of the Nature Metrics laboratory for the 10 samples taken.

Deployment of the Bongo net - Photo : Arnaud Conne - Expedition Glacialis 2021

Ichtyoplancton - Photo : Arnaud Conne - Expedition Glacialis 2021

Diversity of plankton samples - Photo : Richard Mardens - Expedition Glacialis 2021

5. Ichtyoplancton

CONTEXT

Zooplankton and fish larvae are the main food sources for a variety of fish and cetacean species.

As ocean waters warm, the distribution of these food sources changes. **This can have an impact on the migration patterns of cetaceans and the entire trophic chain that follows** (Laurel et al, 2018).

Content analysis of zooplankton and fish larvae samples allows researchers to identify and quantify a variety of organisms in Arctic waters (Bouchard et al, 2022).

GOALS

> Complement the research efforts of Dr. Caroline Bouchard, researcher at the Greenland Institute of Natural Resources. The goal of her work is to determine the health and abundance of fish populations (Arctic cod, for example).

> Determine the feasibility of such towings from the sailboat Atlas, document the difficulties encountered and the solutions envisaged.

SAMPLING

Ichthyoplankton samples were collected between July 20 and August 12, 2021.

At 11 sites located in Disko Bay and on the continental shelf north of Nuuk where the team observed whales (Figure 1, p.40), a bongo sampler consisting of two 0.6 m diameter frames equipped with a 335 µm mesh net, a 500 µm mesh net and two flow meters, was deployed obliquely at depths of 41-54 m and at a vessel speed of 1-2 knots. After recovery, the nets were rinsed with sea water on board the boat. Whole samples containing zooplankton and ichthyoplankton were preserved in 96% ethanol. Back at the Greenland Institute of Natural Resources laboratory, all fish larvae and juveniles (age 0 fish) were isolated from the samples, counted, identified to the lowest possible taxonomic level, and measured for preserved standard length (SL) and body depth at anus (BD).

A CTD (conductivity, temperature, depth) measuring device was deployed at each station at depths of 36-53 m, except at station 11.

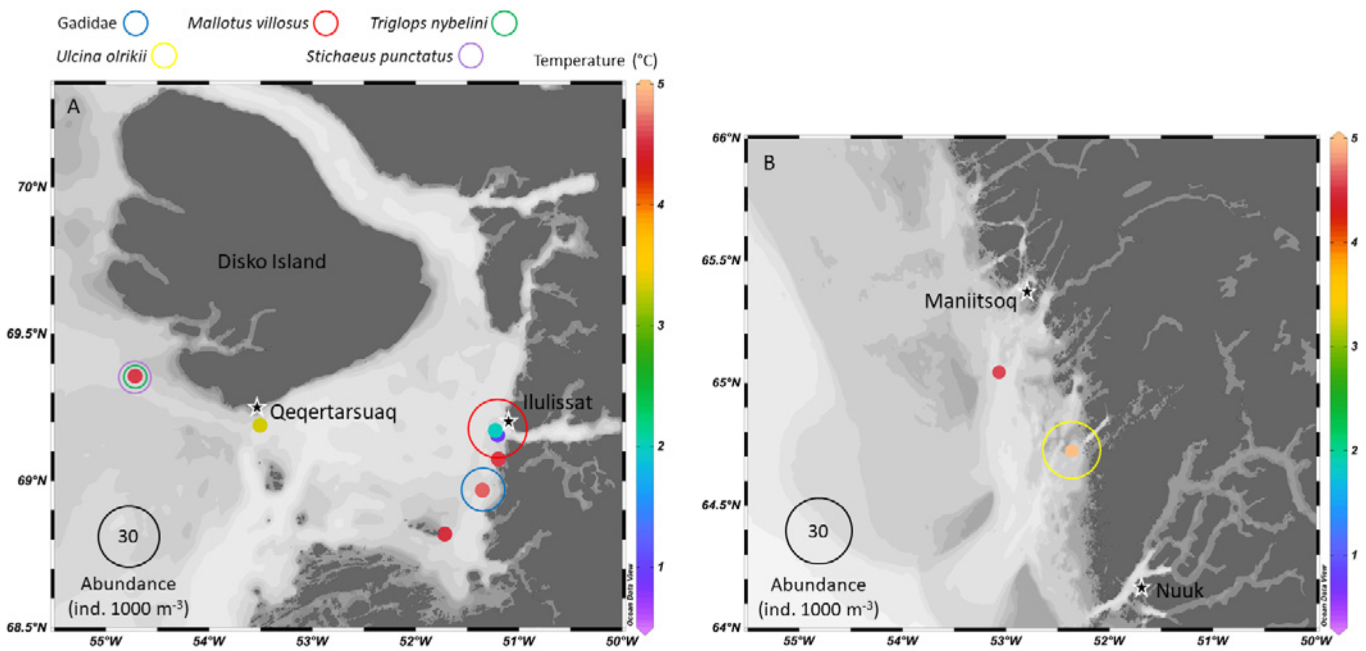
DATA ANALYSIS

The samples were analyzed in Nuuk by Caroline Bouchard.

Age-0 fish abundances were calculated for each taxon by dividing the number of individuals collected in one net by the volume of water filtered during deployment, and the mean was calculated between the two nets for each station. The temperatures of each CTD jet were averaged over the entire profile.

Partenaire scientifique : Dr Caroline Bouchard, Greenland Institute of Natural Resources, www.natur.gl

I. Maps of the study area in A) Disko Bay and B) northwest Nuuk.



II. List of ichthyoplankton caught west of Greenland in July-August 2021.

Station	Mesh size (µm)	ID nr	Scientific name	Family	Common name	SL (mm)	BD (mm)
1-V478	335	1	Ulcina olrikii	Agonidae	Arctic alligatorfish	35	3
1-V478	500	2	Ulcina olrikii	Agonidae	Arctic alligatorfish	30	2
1-V478	500	3	Ulcina olrikii	Agonidae	Arctic alligatorfish	28	2
3-V621	500	4	Triglops nybelini	Cottidae	bigeye sculpin	32	4
3-V621	500	5	Stichaeus punctatus	Stichaeidae	Arctic shanny	17	1.5
3-V621	500	6	Stichaeus punctatus	Stichaeidae	Arctic shanny	12	1
6-V709	335	7	Gadidae	Gadidae	-	19	3
11-V789	335	8	Mallotus villosus	Osmeridae	capelin	13	0.3
11-V789	335	9	Mallotus villosus	Osmeridae	capelin	19	1

> I. Maps of the study area in A) Disko Bay and B) northwest Nuuk showing station locations, mean temperature and age-0 fish abundance by taxon. Star: town or village.

> II. List of ichthyoplankton caught in West Greenland in July-August 2021. SL: standard length. BD: depth from body to anus.

RESULTS

The temperature recorded at the bongo stations (average over 0 and 36-53 m) varied between 1.0°C in front of Ilulissat and 5.6°C at the southernmost station near Nuuk (Fig. 1, p.40) . Nine age-0 fish of five species were collected during the expedition (Fig. 2, p.40).

In Disko Bay, arctic woodcock (Stichaeus punctatus) and bigeye sculpin (Triglops nybelini) were collected near Disko Island, while capelin (Mallotus villosus) and a gadidae that did not could be identified to species level were collected near Ilulissat (Fig. 1A, p.40). Northwest of Nuuk, only arctic alligator fish (Ulcina olrikii) were collected (Fig 1B, p.40).

The average densities recorded varied between 4.5 and 35 individuals per 1000 m3 (Fig. 1, p.40) and the standard length of the individuals collected varied between 12 and 35 mm (Fig.2, p40).

DISCUSSION

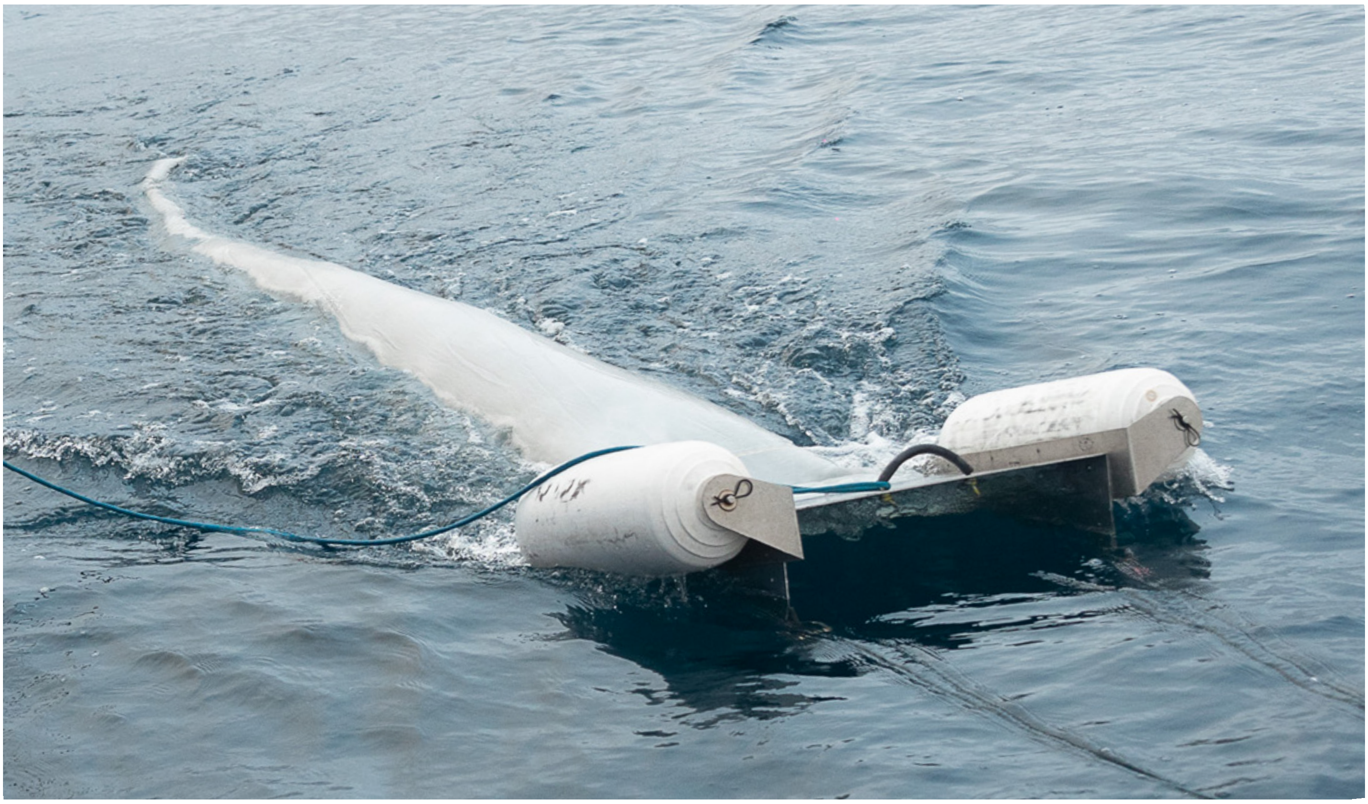
The abundances (or densities, number of individuals per volume of filtered water) of age-0 fish estimated in this study are comparable to values from other studies of age-0 fish conducted in Disko Bay and the surrounding areas of West Greenland in summer in recent years (Bouchard 2021, Bouchard et al. 2021, Bouchard et al. 2022, Munk et al. 2015). However, the low amount of water filtered by the bongo in the present study resulted in a low number of larval and juvenile fish collected. In comparison, the volume filtered by the bongo in the present study was between 15 and 112 m3 (mean ± standard deviation: 42 ± 25 m3), while the volume filtered by the same bongo was between 58 and 705 m3 (mean ± standard deviation: 295 ± 148 m3) during a survey on board the sailboat ATKA (Bouchard et al. 2021) and between 111 and 650 m3 (mean ± standard deviation: 380 ± 152 m3) during a investigation aboard the RV Sanna (Bouchard 2021).

As the duration of the bongo deployments varied between 6 and 17 minutes at a vessel speed of 1 to 2 knots, we recommend that future sailboat ichthyoplankton surveys increase the vessel duration and/or speed (to 20-30 minutes and 2 to 3 knots) to achieve larger filtered volumes and numbers of age-0 fish, sufficient for assemblage and population studies.

Collecting zooplankton samples was one of the most technically demanding activities. The volume of the bongo and the weight of the anchor impose a significant force on the entire device. This work would not have been possible without the motorized (hydraulic) winches available on board the vessel, which greatly facilitated the recovery of the net. A deployment sequence lasted between 1h and 1h30. The Atlas sailboat also has a seawater pump device, which made it possible to carry out the step of rinsing the nets when they came out of the water.

Despite the technical difficulties of throwing and retrieving the net, this sample collection was one of the most rewarding activities. The technical challenges the team faced were amply rewarded with the opportunity to observe the diversity of creatures recovered from the samples. In addition, the sharing of knowledge and the direct collaboration with a researcher engaged in a local government institute gave full meaning to the efforts made.

Considering the amount of experience acquired in this approach, it seems valid for the team to repeat this approach during future expeditions to Greenland.



Manta Trawl - Photo : Richard Mardens - Expedition Glacialis 2021

6. Microplastics

CONTEXT

Microplastics are small plastic particles that result from the physical breakdown of plastics. Although the potential harmful effects are not yet fully understood, microplastics are found on a large scale in ocean waters and seem to be integrated into the food chain (Coffin et al, 2020).

There are relatively few data on the distribution of microplastics in Arctic regions and in the middle of the oceans (Erikssen et al, 2014).

The NGO Oceaneye's surface microplastics sampling device is an example of a well-documented and widely used citizen-science protocol from sailboats.

PURPOSE

- Contribute to Oceaneye's global documentation process.
- Provide data for understudied regions of the northwest Atlantic, between the Azores and Greenland and in arctic environments.

SAMPLING

The Manta Trawl is a conical net placed on an aluminum frame equipped with floats.

A 200 µm mesh nylon thread sock is attached to the end of the net using a stainless steel flange.

The net is deployed laterally using a spinnaker pole. Towed for 30 minutes, at a speed of 3 to 5 knots, it filters a quantity of surface water which is evaluated using a flow meter.

The device is then brought back on board. The sock is removed and filled for conservation with a quantity of sea salt proportional to its organic matter content, then vacuumed and carefully labelled.

Floating debris and other surface pollution observed during the voyage were also documented in the database and characterized according to their type, appearance and dimensions.

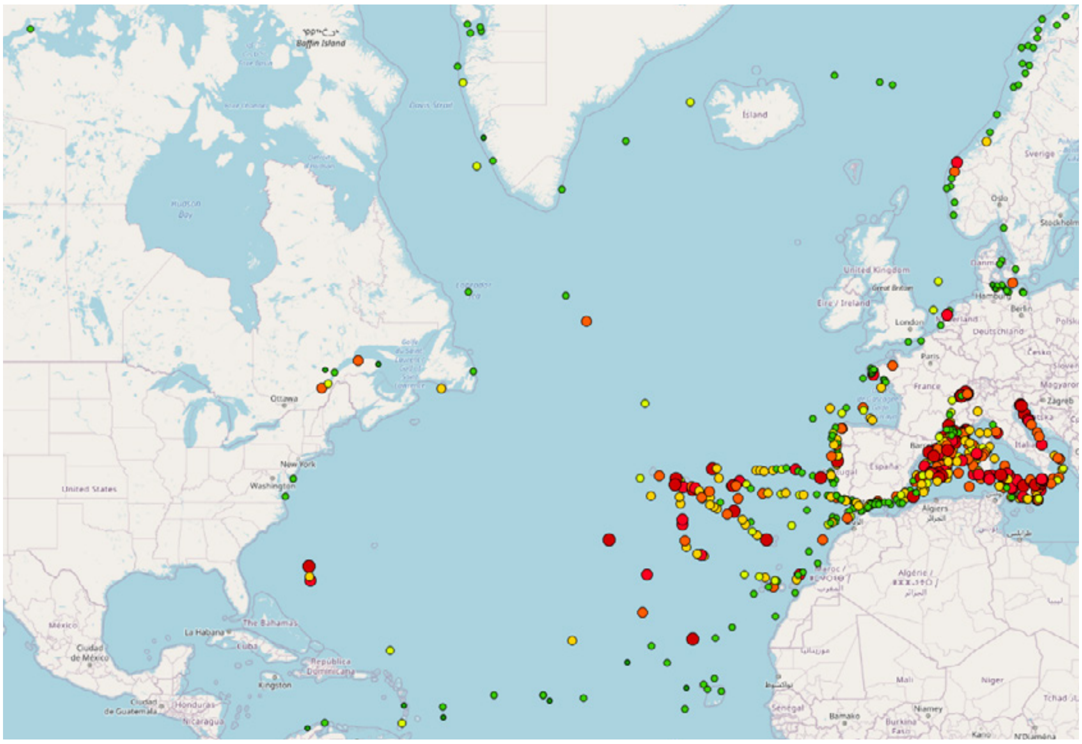
DATA ANALYSIS

The samples are processed in the laboratory by Oceaneye. Rinsed of their salt and dissociated from organic matter by sieving, the plastics are then sorted according to their size: microplastics between 0.1 and 0.5 mm, mesoplastics between 0.5 and 2.5 mm. Plastics (micro and meso) are classified by categories: fragments, thin films, lines/fibers, pellets, foams, others. The particles are counted and weighed.

Scientific partners: Pascal Hagmann and Laurent Cecere, OCEANEYE, www.oceaneye.ch

I. Analysis of a sample in the laboratory - Photo : Oceaneye - Arnaud Conne

II. Extract from the global cartography established by Oceaneye



6. Microplastics

RESULTS

The 10 samples collected were analyzed by Oceaneye in Geneva and sent to the GRID department of the United Nations Environment Program, which makes them available to everyone via its Geodata geographic information system. This guarantees the sustainability of the data generated as well as their free access to all.

A cartography of Oceaneye data is also available at www.oceaneye.ch/cartographie.

In general, microplastics were more abundant in samples from tows in the Gulf Stream, a major ocean current that moves from the Gulf of Mexico towards Europe, as well as in the Azores area.

Samples taken in Greenland showed relatively low levels of microplastics, although pollution was found there in 100% of cases.

Along with the sampling of microplastics, a significant amount of macro litter has been observed along the coasts of Greenland, which appears to be associated with commercial fishing. Broken plastic bins used to store fish, ropes, synthetic lines and buoys were frequently observed.

DISCUSSION

The protocol for collecting microplastics using the Manta Trawl is well documented by Oceaneye. It has been proven by many teams over the past 10 years.

The diversity of data collection objectives carried by the expedition, as well as the issues related to navigation, did not allow more than 10 samples to be taken.

The deployment and recovery of the Manta trawl was facilitated by the hydraulic winches available on board the Atlas sailboat.

There is still little data on microplastics in these remote areas and it will be interesting to follow the evolution of this pollution in the years to come.

Culture of bacteria - Photo : Anna Carratalà - EPFL

7. Micro-organismes

CONTEXT

Alpine and polar lakes are considered sentinels of climate change because they respond quickly to environmental forcing. **Climate change leads to increased surface water temperatures, evaporation rates and a shorter period of ice cover.**

Microorganisms are both key primary producers and degraders of organic matter in lakes and are important drivers of many element cycles, including carbon and nitrogen. They can have very short generation times and large population sizes compared to multicellular organisms, and thus undergo rapid population changes.

Studying genetic responses to environmental changes at the microbial level is therefore ideal because evolution can be observed at small temporal and spatial scales, unlike the larger macrobiota that are typically studied by conservation initiatives.

Furthermore, specific genes responsible for increased resistance to environmental stressors, such as UV radiation or temperature, may be of interest for the development of biotechnological applications.

PURPOSE

> To deepen current knowledge on the ecological roles and metabolic potential of bacteria in cold environments, especially in polar lakes, and contribute to the microbial conservation of the Arctic.

> The aim of the work developed at EPFL is to study the diversity of bacterial communities in Arctic freshwaters with a particular interest in Cyanobacteria.

RESULTS

A total of 25 samples of approximately 50 ml were received from the shipment. The samples were filtered using Millipore filters with a pore size of 0.22 µm and the biomass retained in the filters was used to obtain bacterial isolates in pure cultures for further studies. Aliquots of 1 ml of water were inoculated into BG-11 medium but no freshwater cyanobacteria could be isolated from the samples, most likely due to insufficient concentrations in the volumes of water tested.

In contrast, we managed to obtain 75 bacterial isolates from the samples and grow them in pure culture using the conventional LB medium. These isolates are now being used to study the genetic diversity and activity levels of genes involved in the resistance of arctic bacteria to oxidative stress.

Scientific partner: Dr Anna Carratalà, EPFL, www.epfl.ch

Epilogue

The actors of the Glacialis Expedition project are enthusiasts, but also professionals who have devoted their time, their know-how and their energy on an entirely voluntary basis to make this pilot expedition exist.

When the team comes together to take stock of its achievements, all members agree on the success of the mission.

The 2021 season has provided valuable experience of the Greenlandic territory and its geography, from Cape Farewell to Ataa Sund, north of Disko Bay.

One of the keys to the mission's success was having a crew that was both skilled and deeply motivated. The demands of navigation, coupled with data collection efforts, left the crew little time to rest during the 128-day expedition. We are often asked if it was worth it. The answer is a resounding yes!

It is not for the Glacialis project to draw conclusions about population abundance, climate change or pollution. Our approach, aware of these major issues, aims to facilitate the collection of data for researchers from different backgrounds.

These data may prove valuable in the future, help support new hypotheses, and support new conservation efforts. The team strongly encourages citizens and scientists to collaborate, and grants them free access to the observational data collected during the expedition.

The main postulate of the project is that useful data for scientists can be collected from small private vessels and by properly trained citizens has been largely verified. We are optimistic that this report will serve as a benchmark to facilitate similar efforts.

The preparation, integration and training work that has been carried out on the Atlas sailboat will continue to bear fruit for the future projects of the Atlas Expeditions association. The team is also convinced that the sum of experience acquired on the methods, as well as the data collected will be a valuable resource for scientists and citizens of the future.

We encourage those hoping to conduct similar surveys to establish collaborations with local scientists, organizations and communities. Our objectives and methods clearly improved when we were able to submit them to specialists and discuss the field realities.

Drawing on its experience of working with primary school students, the team sees the importance of sharing with young people. Their energy is contagious, their questions are incredibly relevant and their awareness of the fragility of natural environments is a fundamental for the future!

Aware of these precious achievements, the team is mobilizing to repeat the adventure in the same field, in order to carry out its collection protocols even more effectively, always with the central objective of listing species.

The everyday world in which humans are often consumed seems dominated by rapid changes. Today we are witnesses to war, failure of our economic policies, viral outbreaks and hypocrisy which seems intent on destroying our hopes for a better world. At the same time remote landscapes like the glacially rounded mountains of Greenland seem remarkably static and calm. It is a place where the harmony of nature still dominates.

We maintain great faith in the natural world, of which we consider ourselves an integral part. We have observed how resilient nature can be and marvel at its ability to find its way to develop harmoniously. We hope that reading this report encourages people to find a way to release the pressure we are applying to these fragile ecosystems just a little to help nature find its way!

> Expedition itinerary : 6'600 nautical miles - 12'000 kilometers.

Baffin Bay
Greenland
Davis Strait
Iceland
Labrador Sea
North Atlantic Ocean
Canada
Newfoundland
Azores
500 km

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