AdvanCing knowledge on the present Arctic Ocean by chemical-phySical, biogeochemical and biological obServAtioNs to preDict the futuRe chAnges (**CASSANDRA**)

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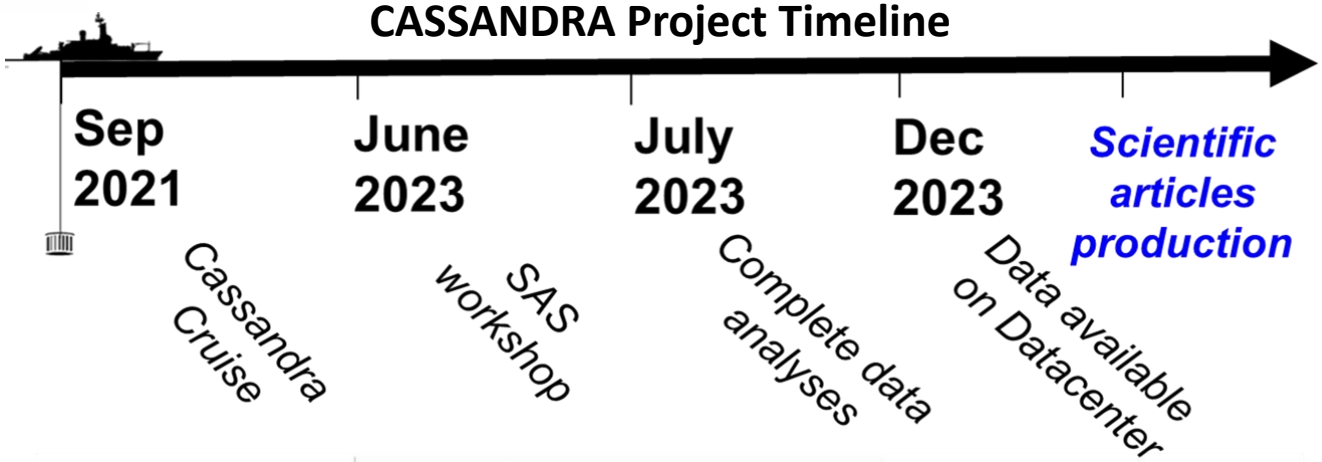
**Physically present at the SAS workshop, 7-9 June 2023, Woods Hole, MA, USA (maurizio.azzaro@cnr.it; mbensi@ogs.it)*

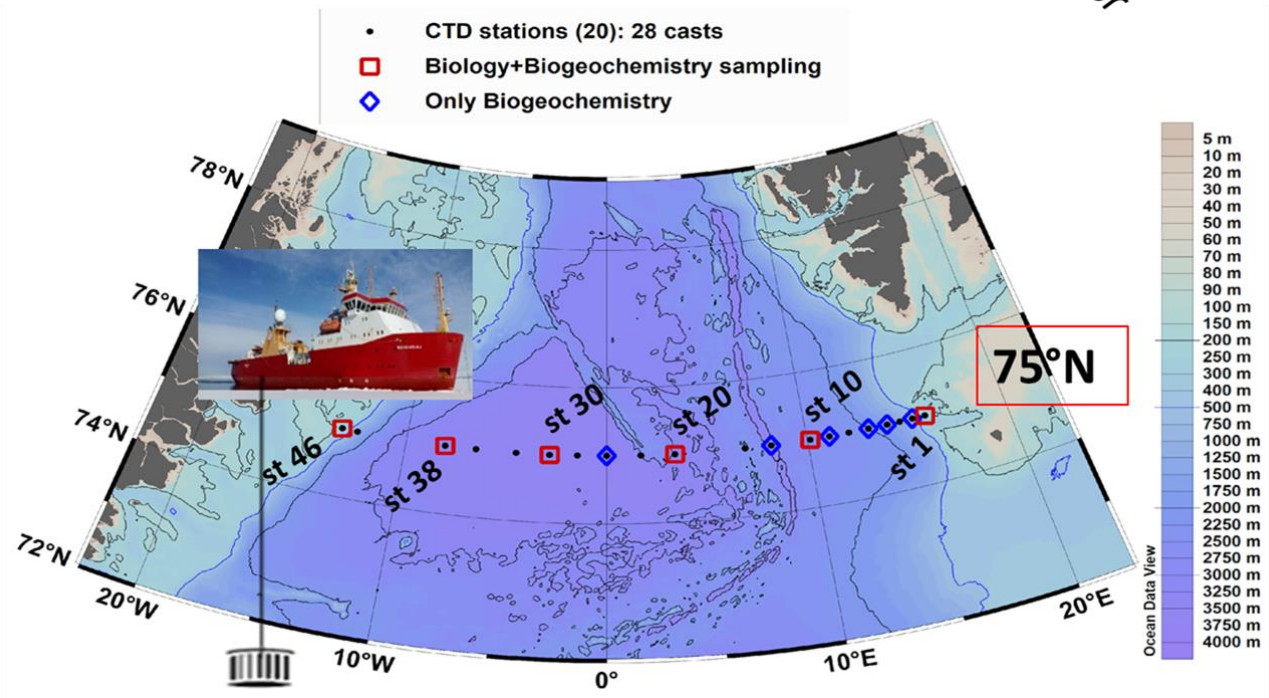
*" We chose the name **CASSANDRA** for this cruise because today the environmental message is able to permeate and penetrate more and more, both in the social strata of the population and at the political level, and we would like to dispel Her legend of an **Unheard Prophetess**! "*

PRA PROGRAMMA DI RICERCHE IN ARTICO

Synoptic Arctic Survey

CASSANDRA Project Timeline





The Italian contribution to the Synoptic Arctic Survey program: the CASSANDRA cruise along the 75°N transect (Greenland Sea)

Azzaro M.[1*], **Bensi M.**[2*], Civitarese G.[2], Giani M.[2], Lo Giudice A.[1], Bechemin F.[1], Borme D.[2], Cairns W.R.L[1], Cappelletti D.M.[1], Caroppo C.[1], Caruso G.[1], Cerino F.[2], Cosenza A.[1], de Olazabal A.[2], Decembrini F.[1], Dentico C.[2], Diociaiuti T.[2], Federici E.[1], Feltracco M.[1], Gandolfi I.[1], Goruppi A.[2], Kovacevic V.[2], Kralj M.[2], La Ferla R.[1], Lupi A.[1], Maimone G.[1], Mazzola M.[1], Miserocchi S.[1], Monti M.[2], Papale M.[2], Patrolecco L.[1], Peloso G.[2], Putelli E.[2], Rappazzo A.C.[1], Relitti F.[2], Rizzo C.[1], Spataro F.[1], Tirelli V.[2], Turetta C.[1], Urbini L.[2], Ursella L.[2], and Vitale V.[1]

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INTRODUCTION

Arctic and subarctic regions are warming and changing faster than other regions of the world. The **Italian project CASSANDRA** aims to contribute to the ambitious **Synoptic Arctic Survey** program and to the understanding of complex Arctic processes by quantifying the state of physical, chemical, biological and biogeochemical systems along the subarctic historical transect at 75°N crossing the **Greenland Sea Gyre (GSG)**. The cruise was carried out in September 2021. Here we summarize the main activities and data collected.

Keywords: Greenland Sea Gyre; Arctic and sub-Arctic circulation; Arctic Atlantification; Airborne Bacteria; Biogeochemistry; Microbial diversity, Biomass and activities; Phyto-Microzoo-Mesozoo Plankton;

Physics: distribution of water masses according to their thermohaline properties

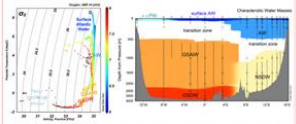

Fig. 2. T-S diagram showing data collected in June 2021 along the transect 75°N (left panel) and "indicative" distribution of principal water masses according to their core values (right panel);
***AW** - Atlantic Water; **GSAW** - Greenland Sea Arctic Intermediate water; **NSDW** - Norwegian Sea Deep Water; **GSDW** - Greenland Sea Deep Water; **PW** - Polar Water or Melting Water.*

Biogeochemistry

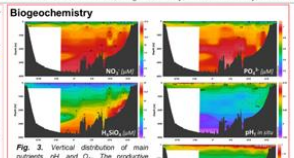

Fig. 3. Vertical distribution of main nutrients, pH, and O_{sat}. The productive surface layer is nutrients depleted and has maximum values of pH. A maximum concentration of silicates was observed in the NSDW. Lowest pH values were detected in Greenland Sea Deep Water (GSDW), where maximum undersaturation of aragonite also occurs (Ω_{ar}<1).

Bioaerosol

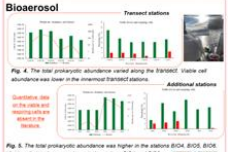

Fig. 4. The total prokaryotic abundance varied along the transect. Viable cell abundance was lower in the innermost transect stations.

Fig. 5. The total prokaryotic abundance was higher in the stations BIO4, BIO5, BIO6. Viable cell abundance was lower in the stations BIO1 and BIO3.

Table 1. Taxonomic identification of bacterial isolates

Microbiology

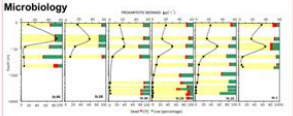

Fig. 14. Vertical profiles of prokaryotic biomass, viable and dead cells (Live/Dead) and respiring cells (CTC)

These are the first results achieved in this area. Prokaryotic biomass patterns (obtained by biovolume cells and prokaryotic abundance) depicted a trend decreasing from the photic towards the aphotic layer. Peaks were found at St 46 and 1. The highest percentage of live cells (about 33%) was observed at St 46 in the photic layer. However, peaks were found in the deeper layers also. The highest percentage of respiring cells was detected below 100 m depth.

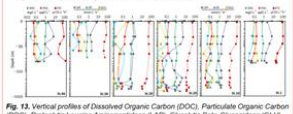

Fig. 13. Vertical profiles of Dissolved Organic Carbon (DOC), Particulate Organic Carbon (POC), Proteolytic Leucine Aminopeptidase (LAP), Glycolytic Beta-Glucosidase (GLU), Alkaline Phosphatase (AP) enzymes and Electron Transport System (ETS) respiratory activity.

Total enzymatic patterns depicted a vertical trend generally decreasing from surface towards deep layers, with some hot-spots of metabolic activity at 20-40 m and in the aphotic layer. LAP activity peaked at the lateral ends of the transect as well as at St 20. AP and GLU decreased from the Western side to St 20, and further increased moving towards the Eastern side (St 10). A high variability was recorded at surface depth for the respiratory activity rates and the organic matter pool (POC and DOC); a decreasing trend up to 1000 m and an interesting increase towards greater depths characterised the vertical profiles of both respiratory activity and DOC.

Project Timeline

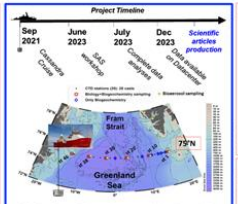

Fig. 1. Map of the study area and location of the sampling stations (Date of cruise: 29 Aug -14 Sep. 2021).

Expected OUTPUT from the cruise

- Publication of data and main results from the cruise on ESSD journal;
- Publication of Metadata and Data on Italian Arctic Data Center (IADC, http://iadc.cnr.it/cnr/) and National Oceanographic Data Centre (NODC, https://nodc.ogs.it/).

Phytoplankton

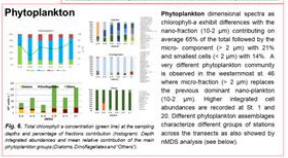

Fig. 6. Total chlorophyll a concentration (green line) at the sampling depths and percentage of fractions contribution (histogram). Depth integrated abundances and mean relative contribution of the main phytoplankton groups (Diatoms,Dinoflagellates and 'Others').

Phytoplankton dimensional spectra as chlorophyll-a exhibit differences with the nano-fraction (10-2 µm) contributing on average 65% of the total followed by the micro- component (> 2 µm) with 21% and smallest cells (< 2 µm) with 14%. A very different phytoplankton community is observed in the westernmost st. 46 where micro-fraction (> 2 µm) replaces the previous dominant nano-plankton (10-2 µm). Higher integrated cell abundances are recorded at St. 1 and 20. Different phytoplankton assemblages characterize different groups of stations across the transects as also showed by nMDS analysis (see below).

Microzooplankton

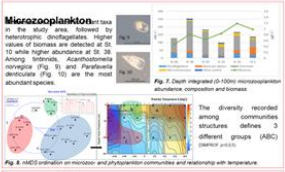

Fig. 7. Depth integrated (0-100m) microzooplankton abundance, composition and biomass

Fig. 8. nMDS ordination on microzoo- and phytoplankton communities and relationship with temperature.

The diversity recorded among communities defines 3 different groups (ABC)

Mesozooplankton

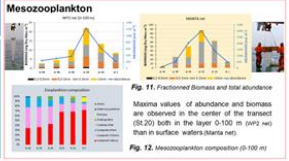

Fig. 11. Fractionned Biomass and total abundance

Maxima values of abundance and biomass are observed in the center of the transect (St.20) both in the layer 0-100 m (WP2 net) than in surface waters (Manta net).

Fig. 12. Mesozooplankton composition (0-100 m)

Biodiversity

The **eDNA** has been extracted from a total of **31 collected samples**, and prepared for sequencing. **The sequencing**, currently underway, was designed for the **whole genome** technique and **target sequencing (barcoding)**. Metabarcoding analysis will be performed to identify *Calanus* species.

CONCLUSIONS in brief

- **August/Sept 2021** represents a **record-low value for the Greenland Sea ice extent**, caused also by sustained southerly winds during July-Aug (https://climate.copernicus.eu/esotc/2021);
- Greenland Sea **Dense and Intermediate Waters** are getting warmer and saltier (comparing our data with those published by Brakstad et al. 2019);
- **Mesoscale and larger scale variability** trigger the biological and biogeochemical data spatial distribution along the transect;
- Airborne isolates are affiliated to **Proteobacteria** and **Actinomycetes**, including spore-forming members and genera able to cope with harsh conditions;
- The percentage of **respiring cells** throughout the water column was minimal compared to **living cells** and to **total prokaryotic cell abundance**;
- Enzyme and respiratory activity profiles confirm that the **microbial community** played an active role in the decomposition and mineralization of organic polymers;
- **Phytoplankton** communities show low abundances and dominance of nano-sized organisms with different assemblages across the transects;
- **Microzooplankton** represent an important fraction of the planktonic community in the area, with tintinnids as major groups. The biomass shows low values related to the small size of tintinnids species.
- **Copepods** (mainly juveniles stages) represent >90% of **mesozooplankton** across the transect: the genera *Calanus* and *Oithona* were the dominant taxa with opposite W-E gradient of contribution (%) to zooplankton communities.

Bibliography

Brakstad et al. 2019, Water Mass Transformation in the Greenland Sea during the Period 1986–2016, JPO, 49,1;
Santi-Temkiv et al., 2018. Aeolian dispersal of bacteria in southwest Greenland: their sources, abundance, diversity and physiological states;
Wang, X., et al. 2021. Transports and accumulations of Greenland Sea intermediate waters in the Norwegian Sea. JGR Oceans, 126;

The project CASSANDRA is funded by the Italian Ministry of University and Research in the framework of the National Arctic Research Programme (PRA). https://www.programmaricercaartico.it/

SAS Workshop, Woods Hole, USA, 7-9 June, 2023

What papers do your cruise participants envision?
What synthesis papers do you see coming out of your cruise?
CASSANDRA Team (2023-24) Chemical-physical, biogeochemical and biological observations along the 75° N transect (Greenland Sea). Earth System Science Data.

What parameters outside of the core parameters were measured on your cruise?

Surface seawater Pollution: Currently Use Pesticides (chlorpyrifos, Endosulfan, Dacthal); 36 PolyClorinated Biphenyls (PCBs); DDT, DDE, alfa-beta-gamma-delta hexachlorocyclohexane; 16 Polycyclic Aromatic hydrocarbons (PAHs); Nonylphenols; Bisphenol A (BPA) (analyzes will be completed in October-November 2023).

Bioaerosol: DNA, prokaryotic abundance and biomass, cell volumes, Biolog, respiring cells (CTC), Live/dead, Isolation of bacterial strains and taxonomic Identification (DNA analyzes will be completed in July-August 2023)

Atmospheric measurements: wind speed and direction; air temperature, pressure and relative humidity; sun infrared radiation and total radiation.

Bioaerosol papers expected!

Azzaro et al. (2023) Concentration, size distribution and physiological profiles of Prokaryotic Community in the air over sub-Arctic region along a cruise path during the CASSANDRA oceanographic expedition. Polar Science, Part A.

Azzaro et al. (2023) Characterization of Arctic Bacterial Communities in the Air over sub-Arctic region along a cruise path during the CASSANDRA oceanographic expedition. Polar Science, Part B.

All Metadata and Data will be stored by December 2023 on the CNR (http://iadc.cnr.it/cnr/) and OGS (https://nodc.inogs.it/) data centers that are first level nodes of the Italian Arctic Data Center (IADC) funded by Arctic Research Programme (PRA)

PRA
PROGRAMMA DI RICERCHE IN ARTICO

IADC ITALIAN ARCTIC DATA CENTER
INAF OGS CNR ENEA INGV

NODC OGS Istituto Nazionale di Oceanografia e di Geofisica Sperimentale

Young Researchers in the CASSANDRA cruise (< 40 years)

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Maria Papale
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Microbial ecology

Matteo Feltracco
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Analytical chemistry

Lidia Urbini
OGS
Biogeochemistry

Tommaso Diociaiuti
OGS
Micro-zooplankton

Federica Relitti
OGS
Biogeochemistry

Thanks for your attention
The CASSANDRA TEAM

Multicorer sampling

CTD water sampling

Zooplankton sampling

I/B L. Bassi in Bergen, at the end of the cruise

Drylab on L. Bassi

Synoptic Arctic Survey