

Microbial Ecology and Biogeography  
OF THE  
Southern Ocean

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# Acronyms

**AZ** Antarctic Zone.

**CEAMARC/CASO** Collaborative East Antarctic Marine Census/Climate of Southern Ocean.

**CTD** Conductivity, Temperature and Depth.

**NZ** North Zone.

**OTU** Operational Taxonomic Unit.

**PF** Polar Front.

**PFZ** Polar Frontal Zone.

**SZ** South Zone.

**UFO** Unidentified Flying Object.





# Acknowledgements



# Abstract

# Introduction

This is a test of the acronyms: I saw a Unidentified Flying Object (UFO). It was not the first UFO I'd ever seen. In fact, I've seen 100 UFOs.

Here is some greek:  $\mu\text{g}$ .

## **Microbial ecology of the Southern Ocean**

## **Oceanography of the Southern Ocean**

**Water masses and fronts**

**Effect of climate change**

**Role of the Polar Front in biogeography**

**Project questions and hypotheses**



# The Polar Front as a major biogeographic boundary in the Southern Ocean

Sections of this chapter have been previously published in Wilkins D., Lauro F. M., Williams T. J., Demaere M. Z., Brown M. V., Hoffman J. M., Andrews-Pfannkoch C., McQuaid J. B., Riddle M. J., Rintoul S. R., and Cavicchioli R. Biogeographic partitioning of Southern Ocean picoplankton revealed by metagenomics. *Molecular Ecology*, 2012.

## Summary

## Introduction

## Methods

### Sampling and metagenomic sequencing

Sampling<sup>1</sup> was conducted on board the RSV *Aurora Australis* during cruise V3 Collaborative East Antarctic Marine Census/Climate of Southern Ocean (CEAMARC/CASO) from 13 December 2007 – 26 January 2008. This cruise occupied the SR3 latitudinal transect from Hobart, Australia (44° S) to the Mertz Glacier, Antarctica (67° S) within a longitudinal range of 140–150° E. Nineteen samples (16 surface, 3 deep) were obtained along almost the entire latitudinal range (Figure 1).

A range of data were recorded by integrated instruments on the RSV *Aurora Australis* including location, water column depth, water temperature, salinity, fluorescence and meteorological data (Table 1). These data were used to locate the Polar Frontal Zone (PFZ) based on a surface temperature gradient of ~ 1.35 °C across a distance of 45–65 km, placing the Polar Front (PF) at approximately –59.70° of latitude, consistent with previous descriptions (Moore *et al.*, 1999; Sokolov and Rintoul, 2002). Samples were accordingly grouped into “North” and “South” zones, while the three deep samples composed a “Deep” zone (Table 1). The North Zone (NZ) represents waters from the Subtropical, Subantarctic and PFZ regions, while the South Zone (SZ) represents the Antarctic Zone (AZ).

At each station, ~ 250–560 L of seawater was pumped from ~ 1.5–2.5 m below the sea surface into drums stored at ambient temperature on deck. In the case of deep samples, ~ 225–230 L of seawater was collected from Niskin bottles attached to a CTD (SeaBird, Bellevue, USA). Seawater samples were

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<sup>1</sup>Sampling was performed by Jeffrey M. Hoffman and Jeffrey B. McQuaid

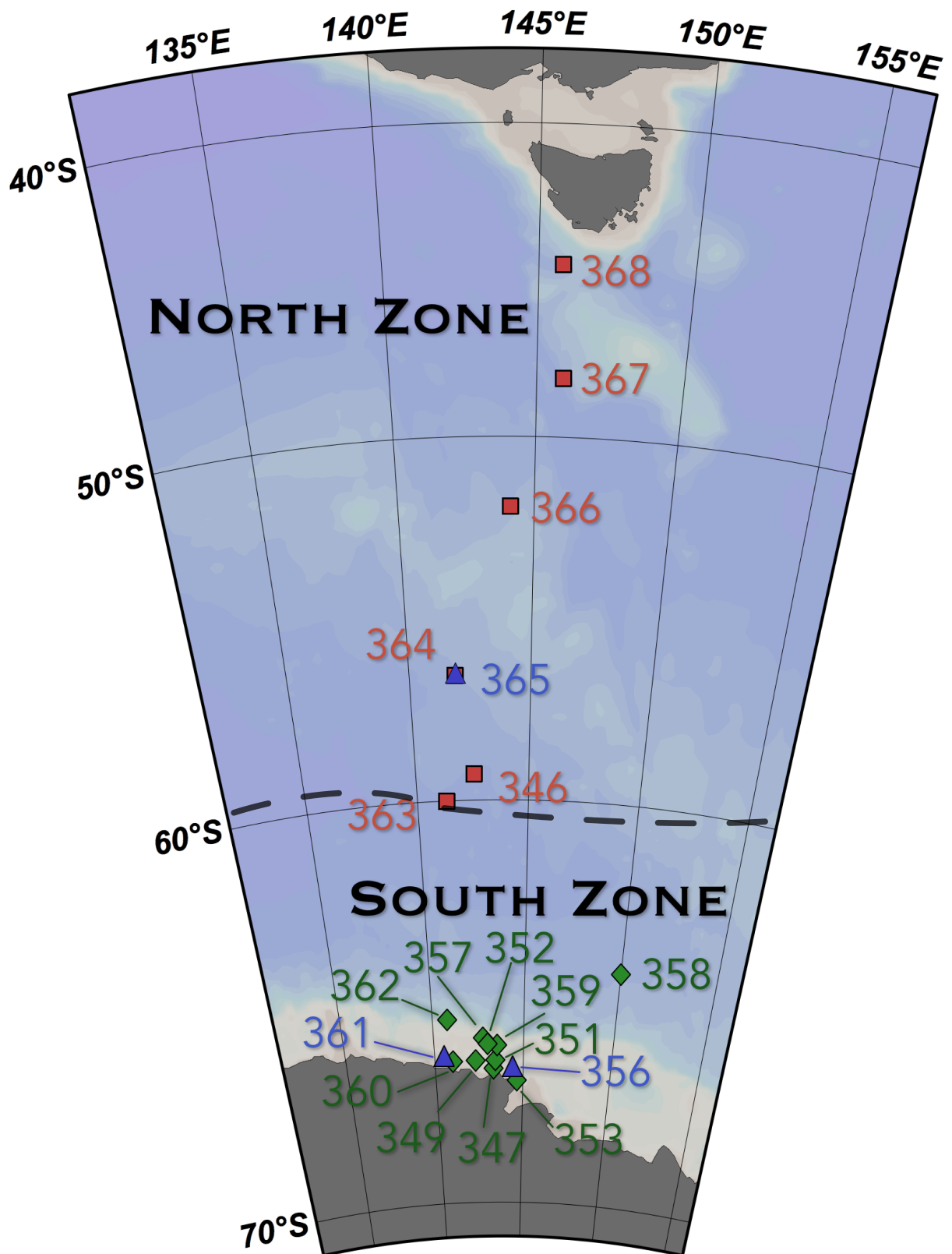


Figure 1: Sites of seawater samples used in this study. Red squares indicate surface samples from the North Zone; green diamonds samples from the South Zone; and blue triangles indicate deep samples. The dashed line gives the approximate location of the Polar Front.



Table 1: Sampling time, location and physiochemical properties of samples used in this study. All data were retrieved from underway instruments aboard the RSV *Aurora Australis*, with the exception of temperature, salinity and fluorescence data for the three deep samples, which was obtained from the CTD TODO CTD manufacturer.

| Sample | Zone  | Local Time | Latitude | Longitude | Water Column Depth (m) | Sample Depth (m) | Water Temperature (°C) | Salinity (PSU) | Fluorescence (µg/l) | Volume seawater filtered (L) |
|--------|-------|------------|----------|-----------|------------------------|------------------|------------------------|----------------|---------------------|------------------------------|
| 346    | North | 20/12/07   | -59.312  | 142.5949  | 4294                   | 2                | 2.9                    | 33.75          | 0.25                | 500                          |
| 347    | South | 23/12/07   | -66.0213 | 142.738   | 450                    | 2                | 0.6                    | 34.2           | 4                   | 250                          |
| 349    | South | 27/12/07   | -66.5662 | 142.3169  | 370                    | 1.5              | -1.3                   | 34.4           | 2.3                 | 250                          |
| 351    | South | 28/12/07   | -66.5587 | 143.4303  | 823                    | 1.5              | -0.55                  | 34.3           | 1.3                 | 500                          |
| 352    | South | 29/12/07   | -66.765  | 143.324   | 164                    | 2.5              | -0.75                  | 34.3           | 3.1                 | 500                          |
| 353    | South | 30/12/07   | -67.0521 | 144.6786  | 180                    | 2                | -1.8                   | 34.4           | 0.3                 | 500                          |
| 356    | Deep  | 03/01/08   | -66.7617 | 144.4138  | 920                    | 920              | -1.89                  | 34.69          | 0.1                 | 230                          |
| 357    | South | 05/01/08   | -66.1719 | 143.0193  | 580                    | 2                | -0.4                   | 34.15          | 2.5                 | 500                          |
| 358    | South | 09/01/08   | -64.3001 | 150.0306  | 3550                   | 2                | 0                      | 33.55          | 0.45                | 500                          |
| 359    | South | 12/01/08   | -66.1903 | 143.5292  | 540                    | 2                | -0.24                  | 34.21          | 2.5                 | 500                          |
| 360    | South | 13/01/08   | -66.5817 | 141.0211  | 316                    | 2                | -0.65                  | 34.04          | 6.19                | 500                          |
| 361    | Deep  | 14/01/08   | -66.4727 | 140.5572  | 1203                   | 1170             | -1.77                  | 34.56          | 0.1                 | 225                          |
| 362    | South | 19/01/08   | -65.5367 | 140.8287  | 1064                   | 2                | 0.7                    | 32.2           | 0.5                 | 500                          |
| 363    | North | 22/01/08   | -60.0001 | 141.3094  | 4473                   | 2                | 3.3                    | 33.77          | 0.1                 | 500                          |
| 364    | North | 23/01/08   | -56.6953 | 141.878   | 3693                   | 2                | 4                      | 33.7           | 0.5                 | 500                          |
| 365    | Deep  | 23/01/08   | -56.6967 | 141.9125  | 3693                   | 3693             | 0.48                   | 34.69          | 0.1                 | 230                          |
| 366    | North | 24/01/08   | -52.0233 | 144.1362  | 3180                   | 2                | 7.6                    | 33.84          | 0.25                | 500                          |
| 367    | North | 25/01/08   | -48.2487 | 145.9025  | 3490                   | 2                | 11                     | 34.43          | 0.2                 | 500                          |
| 368    | North | 26/01/08   | -44.718  | 145.7775  | 3201                   | 2                | 14.75                  | 34.96          | 1.25                | 560                          |

prefiltered through a 20 µm plankton net, then filtrate was captured on sequential 3.0 µm, 0.8 µm and 0.1 µm polyethersulfone membrane filters (Port Washington, USA), and immediately stored at −20 °C (Rusch *et al.*, 2007; Ng *et al.*, 2010).

DNA extraction<sup>2</sup> was performed at the J. Craig Venter Institute (Rockville, USA) as described in Rusch *et al.* (2007). Pyrosequencing was performed on a GS20 FLX Titanium instrument (Roche, Branford, USA) also at the J. Craig Venter Institute as described in Lauro *et al.* (2011). Duplicate reads and reads with many pyrosequencing errors were removed as described in Lauro *et al.* (2011).

## **Phylogenetic analysis of metagenomic data**

A subset of the RefSeq microbial (bacterial and archaeal) genome database (release 41, retrieved May 31 2012 from <ftp://ftp.ncbi.nih.gov/refseq/release/>) was prepared by excluding sequences with the words “shotgun”, “contig”, “partial”, “end” or “part” in their headers (Angly *et al.*, 2009). Because this database was not expected to contain representative genomes for every species present, Operational Taxonomic Units (OTUs) in this study are defined by the best species match to this database, and may for example represent congeners.

The metagenomic reads from each sample were compared against this database using TBLASTX, with default parameters except for: E-value threshold  $1.0 \times 10^{-3}$ , cost to open gap 11, cost to extend gap 1, masking of query sequence by SEG masking with lookup table only.

TODO HERE

## **Functional analysis of metagenomic data**

## **Results**

### **Metagenomic sequencing**

### **Phylogenetic analysis of metagenomic data**

### **Functional analysis of metagenomic data**

## **Discussion**

## **Conclusions**

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<sup>2</sup>DNA extraction was performed by Cynthia Andrews-Pfannkoch and others at the J. Craig Venter Institute

# **Meso-scale biogeographic drivers of planktonic diversity**



# Conclusions



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