Elemental composition of meso-zooplankton around the Crozet Islands (Southern Ocean) and their role in iron biogeochemistry

NATURAL ENVIRONMENT RESEARCH COUNCIL

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INTRODUCTION

Zooplankton take up trace metals either from the surrounding aquatic medium or from their food. Accumulated trace metal concentrations therefore vary with the bio-availability of the metal in seawater and in the diet, and with the physiology of the organisms (Rainbow, 2002).

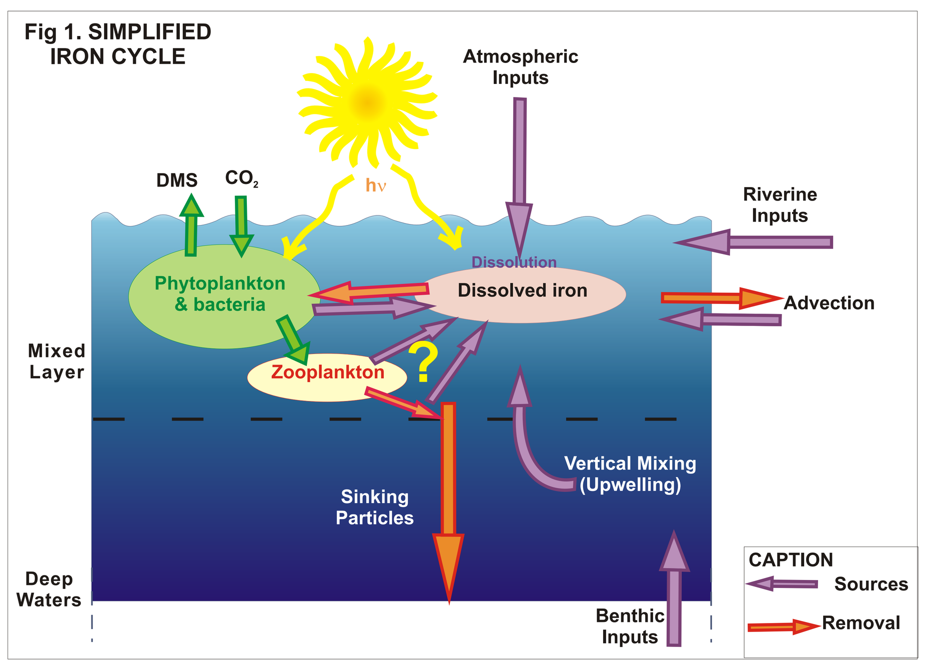
The Antarctic copepods *Rhincalanus gigas*, and *Calanus* sp. are herbivorous, and the amount of Fe assimilated by these grazers is affected by the iron status of their prey. In incubation experiments the Fe:C ratio of copepods was lower than their prey. This may be due to copepods having a lower iron demand than phytoplankton, or to iron not being efficiently assimilated (Schmidt *et al.*, 1999). If iron is not assimilated efficiently and given that respiratory systems may require more iron than photosynthetic systems, copepods may potentially suffer from iron deficiency in iron-poor waters. A threshold Fe:C ratio corresponding to the estimated enzymatic requirement for iron may therefore be used to define the iron status of copepods. If the Fe:C ratio is higher than the threshold value, then copepods may play a significant role in the recycling or export (in faecal pellets) of iron in the upper ocean (Fig 1). This work investigates the role of meso-zooplankton play in the iron biogeochemical cycle within the ocean.

Zooplankton samples were collected during the CROZet EXperiment (CROZEX, 2004-2005) in- and outside the bloom observed around the Crozet archipelago (Southern Ocean), which is thought to be controlled by iron inputs. Iron, copper, and manganese concentrations in copepods and euphausiids were compared to reported values from different oceanic provinces. Values were then compared to the estimated enzymatic requirement of metals by crustaceans to determine their potential iron status, and the copepods body Fe:C ratio was discussed.

The aims of this work are :

1. To determine and compare trace metal content of Antarctic zooplankton

2. To examine the possibility for iron limitation in copepods around the Crozet Islands



MATERIALS and METHODS

Sampling: Copepods were sampled between 0 - 100 m during the CROZEX cruises D285 and D286 in the Southern Ocean between November 2004 and January 2005 (Fig 2).

Analysis: Animals were acid digested in whole after freeze-drying. Samples were analysed for trace metals using a PerkinElmer Aanalyst 800 THGA graphite furnace atomic absorption spectrometer. Data quality was verified following the method of Kahle *et al.* (2001). Carbon and nitrogen were determined by elemental analysis.

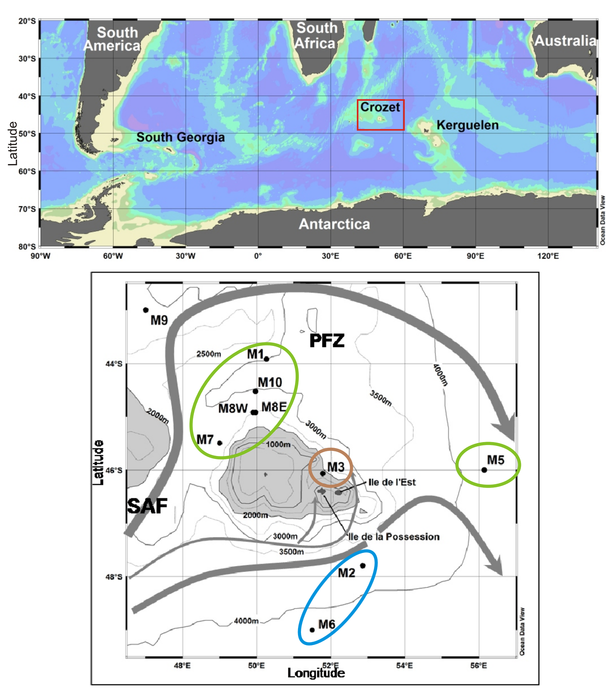


Fig. 2. The sampling region and positions of the major stations of the CROZEX cruise in the Southern Ocean. Main water masses (coloured circles) and circulation pathways (grey arrows) are identified after Pollard *et al.* (in preparation).

CONCLUSIONS

Trace metals (Fe, Cu, Mn) body concentrations were determined in copepods in- and outside the naturally iron-fertilised HNLC waters surrounding the Crozet archipelago (Southern Ocean). The following results were found:

1. Concentrations were mostly lower than previously reported, even in other polar waters.

2. The main source of iron for copepods at Crozet was likely their food.

3. Most of the Fe body concentrations fell below the estimated enzymatic requirement for crustaceans suggesting that copepods may potentially be iron-stressed and may result in lower Fe:C body ratios.

The potential biogeochemical implication of iron-stressed copepods in these waters is that their assimilation efficiency of iron may increase and less iron would be packaged in faecal pellets. This would decrease the export of iron and increase the residence time of iron in surface waters.

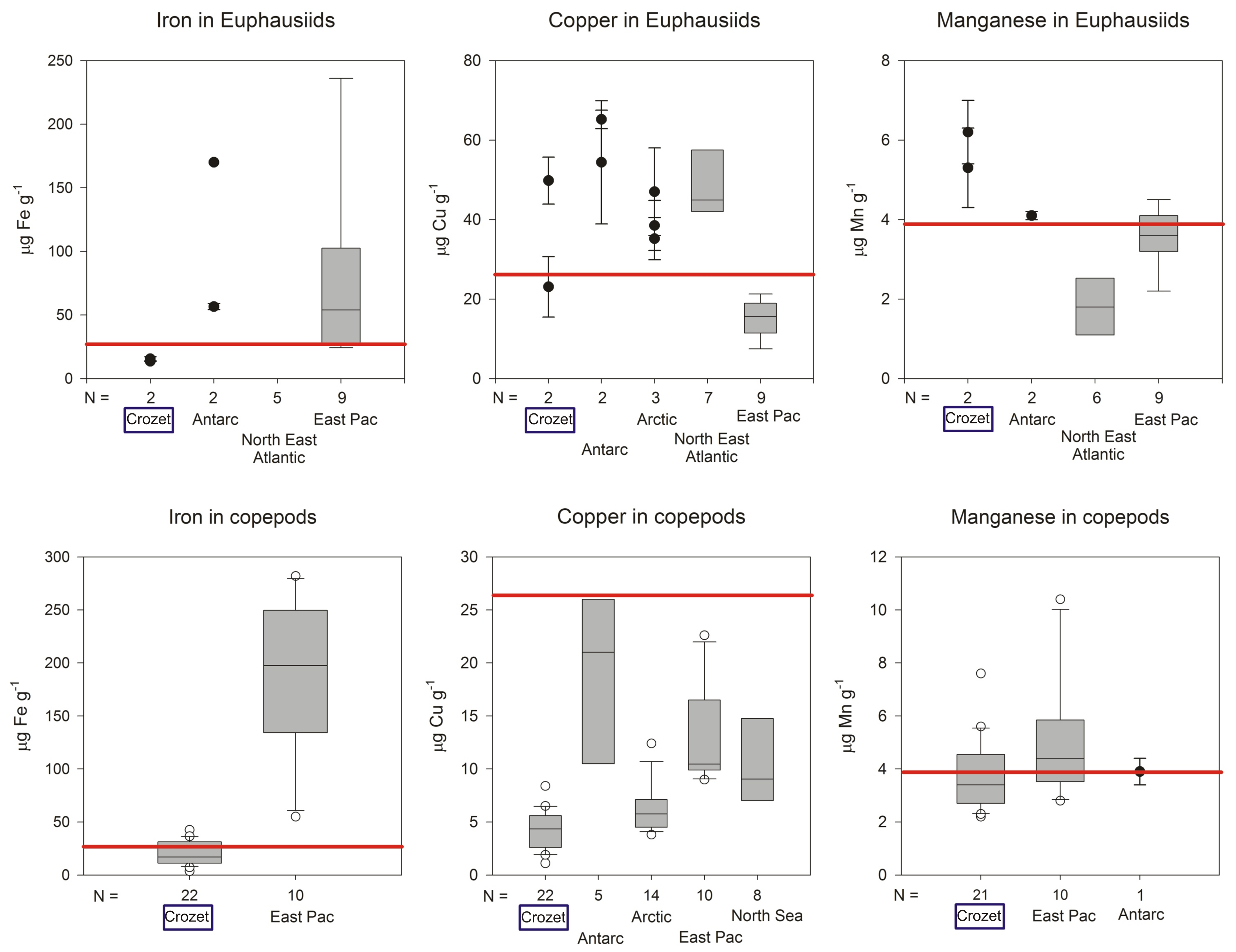


Fig 3. Comparison of iron, copper, and manganese concentrations in copepods (*Rhincalanus gigas* and *Calanus* sp.), and euphausiids from the Crozet archipelago (Southern Ocean) with data reported in the literature from the East Pacific, Antarctic, Atrcic, North Sea, and North East Atlantic. Red lines indicate the estimated enzymatic requirement for crustaceans (White and Rainbow, 1987). Box plots were used when 5 or more data points were available. Bottom boundary of the box: 25th percentile; line within the box: median; upper boundary: 75th percentile; whiskers above and below: 90th and 10th percentiles; open circles: outliers. Filled circles are scatter plots when too few data were available.

RESULTS and DISCUSSION

- Trace metal concentrations (Fe, Cu, Mn) in copepods, and euphausiids were generally lower than or similar to those reported in the literature from other oceanic regions, except for Mn in euphausiids which was higher (Fig 3). These results indicate that trace-metal clean sampling and analysis were successful.

- Iron content in copepods was 20.3 ±11.1 $\mu g.g^{-1}$ (*Rhincalanus gigas* 17.0 ± 11.0 $\mu g.g^{-1}$, *Calanus* sp. 24.4 ± 10.3 $\mu g.g^{-1}$), and in euphausiids 14.6 ± 1.0 $\mu g.g^{-1}$. These values are the lowest iron concentrations in copepods observed in the natural ocean. They can be considered as natural background concentrations of metals in the biota, given that the Crozet archipelago is remote from any major human activities. These data reflect natural bio-accumulation in this region.

- An additional pathway for iron assimilation is by adsorption onto crustaceans exoskeleton. Dissolved iron concentrations measured during the CROZEX cruises were low (< 500 pM) in the upper 100 m (Planquette *et al.*, in preparation), adsorption of trace metals onto the copepods exoskeleton was assumed to be negligible and the main source of iron for copepods to be their food.

- Most of the Fe body concentrations determined in copepods in the vicinity of the Crozet Islands fell below the estimated enzymatic requirement (EER) for iron of crustaceans (Fig. 3 and 4). Iron concentrations reached or exceeded the EER in the heart of the bloom near the main islands, at the northern limit of the studied area, and in the western part of the bloom. These stations were generally productive with high biomass (Seeyave *et al.*, in preparation), these results suggest that copepods could then meet their iron metabolic needs.

- Fe:C ratios in *Rhincalanus gigas* and *Calanus* sp. generally fell within the range of Fe:C assimilation ratios of copepods determined from incubation experiments by Schmidt *et al.* (1999) (Fig 4). The Fe:C ratio was higher than this range at the most productive stations (Fig 4). The Fe:C ratio was found lower than this range for *Rhincalanus gigas* at the end of the bloom, at the least productive stations even though a diatom bloom started. This species was possibly iron-stressed.

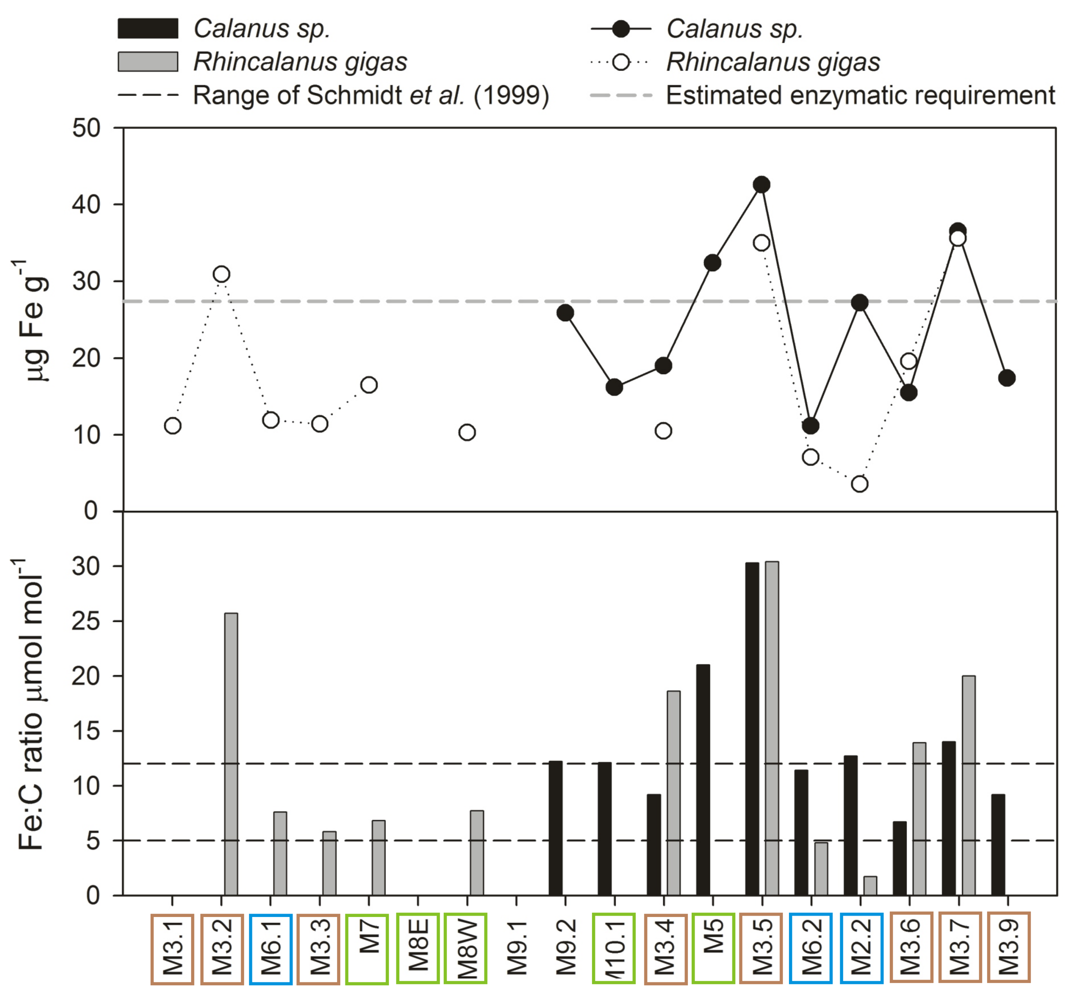


Fig 4. Upper plot: Body iron concentrations (µg Fe g⁻¹) in *Calanus* sp. (●) and *Rhincalanus gigas* (o) at each station sampled during the CROZEX cruises (D285-D286). Grey dashed line marks the estimated enzymatic requirement of crustaceans for iron.
Lower plot: Fe:C ratio (µmol mol⁻¹) in *Calanus* sp. (black) and *Rhincalanus gigas* (grey). Dashed lines mark the lower and upper limit of the range of Fe:C assimilation ratios of copepods in incubation experiments (Schmidt *et al.*, 1999). See map Fig 2 for geographical colour code of the boxes.

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