Nitrogen and Carbon Cycling in Marguerite Bay, Antarctica: A One-Dimensional Model

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1. Introduction

Marguerite Bay (Fig. 1) on the West Antarctic Peninsula (WAP) is a highly productive coastal system. High values of Net Community Production (NCP), calculated from nutrient depletion in the upper water column, and high ammonium standing stocks were observed in Marguerite Bay during the US SO GLOBEC surveys in the autumns of 2001 and 2002 (Serebrennikova and Fanning, 2004). There were significant differences in the magnitudes of the nutrient depletions and ammonium stocks between the two years (Table 1).

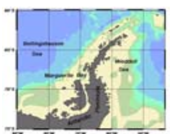

Fig. 1. Map of study area showing the location of Marguerite Bay.

Table 1. Averages (±1S.D.) of Net Community Production (NCP) estimated from deficits of total inorganic nitrogen ($NO_3^- + NO_2^- + NH_4^+$) and integrated standing ammonium stocks (NH_{4ST}) observed in Marguerite Bay in the autumns of 2001 and 2002.

	NCP (mol N m^{-2})	NH_{4ST} (mol NH_4 m^{-2})
Autumn 2001	0.90±0.30	0.40±0.08
Autumn 2002	0.53±0.21	0.21±0.07

Increased sea ice cover (Fig. 2) likely caused the decrease of NCP in Marguerite Bay between the two years. A shorter period of the ice free conditions likely led to lesser nutrient uptake by phytoplankton during the growing season and therefore smaller nutrient deficits in autumn 2002 th

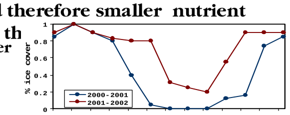

Fig. 2. Average sea ice cover (%) in Marguerite Bay in 2000-2001 and 2001-2002.

The decrease in ammonium stocks between the two autumns might be explained by:
a) The greater abundance of zooplankton in the fall of 2001 compared to the fall of 2002 (Ashjian etal., 2004; Ashjian, per.com.)
b) A lower bacterial ammonification as a result of the decline in accumulation of phytoplankton biomass in 2001-2002 compared to 2000-2001.

The objectives of this study were:
- ❖ To examine the effect of sea ice dynamics on nutrient uptake in Marguerite Bay
- ❖ Determine the major sources of ammonium in Marguerite Bay
- ❖ Determine which processes led to the decrease in ammonium stocks from autumn of 2001 to autumn of 2002.

Acknowledgements: We would like to thank John Walsh (USF) and Dwight Dieterle (USF) for help with the model, Carin Ashjian (WHOI) for providing zooplankton abundance data collected during the SO GLOBEC surveys, and Jason Hyatt (WHOI) for help with sea ice data.

2. Model structure

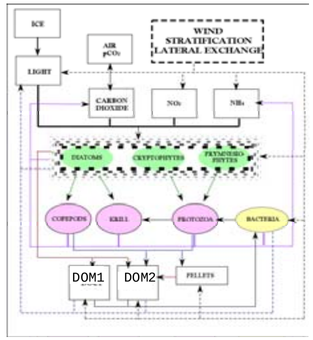

Fig. 3. A structure (adopted from Walsh et al., 2001) of a one-dimensional numerical model of the cycles of carbon and nitrogen between pools of atmospheric and marine carbon dioxide, nitrate, ammonium, three competing groups of phytoplankton (diatoms, cryptophytes, and prymnesiophytes), major zooplankton (krill, copepods, and protozoa), bacteria, zooplankton fecal pellets, monomeric (DOM 1) and macromolecular (DOM 2) dissolved organic matter regulated by the availability of light and the mixing regime of Marguerite Bay.

3. Model Results

Modeled chlorophyll concentrations (Fig. 4) were typical for Marguerite Bay according to the previous observations (Garibotti et al., 2005). The difference in the timing of the bloom between the two modeled years was consistent with the timing of sea ice retreat from Marguerite Bay (Fig. 2). The development of the model's summertime phytoplankton bloom resulted in significant depletion of nitrate in the surface waters (Fig. 5). A greater bloom development led to the greater nitrate depletion in 2000-2001 than in 2001-2002. Modeled production of ammonium during the growing seasons of each modeled year showed a formation of a greater April-May ammonium seasonal maximum in 2000-2001 than in 2001-2002 (Fig. 6). Modeled NCP values and a... t... ...le 2) compared well

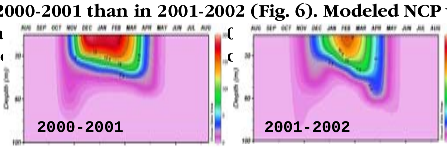

Fig. 4. The modeled cycles of total chlorophyll biomass (mg chl *a* m^{-3}).

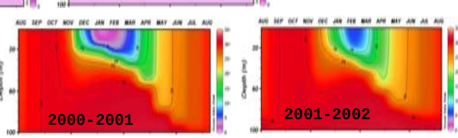

Fig. 5. The modeled cycles of nitrate (µM)
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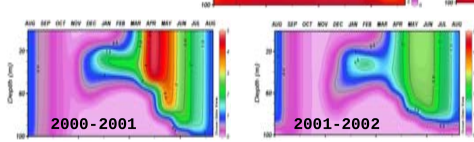

Fig. 6. The modeled cycles of ammonium (µM).

Table 2. Modeled Net Community Production (NCP) and integrated standing ammonium stocks (NH_{4ST}) for Marguerite Bay in 2000-2001 and 2001-2002.

	NCP (mol N m^{-2})	NH_{4ST} (mol NH_4 m^{-2})
2000-2001	0.92	0.39
2001-2002	0.64	0.21

4. Ammonium production

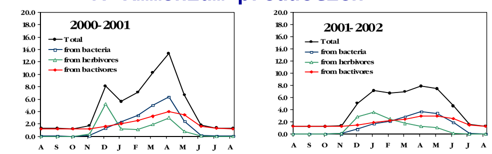

Fig. 7. Modeled ammonium production (mmol NH_4 m^{-2} d^{-1}) by zooplankton, bacteria, and microzooplankton in 2000-2001 and 2001-2002.

- ❖ Greater ammonium production in 2000-2001 compared to 2001-2002
- ❖ Zooplankton – primary source of ammonium in the summer
- ❖ Bacterial ammonification – the largest source of ammonium in the fall

In order to evaluate the major sources of ammonium in Marguerite Bay, model responses to varying zooplankton abundance (Table 3) and bacterial biomass (Table 4) were investigated. Variability in bacterial biomass had the greatest effect on the magnitude of ammonium stocks accumulated during the autumns of both modeled years.

Table 3. Modeled ammonium stocks (mol NH_4 m^{-2}) in response to changes of zooplankton abundance

	2000-2001	2001-2002
high zooplankton abundance	0.39	0.24
low zooplankton abundance	0.30	0.21

Table 4. Modeled ammonium stocks (mol NH_4 m^{-2}) in response to changes of bacterial biomass

	2000-2001	2001-2002
Original model scenario	0.39	0.21
Low bacteria scenario	<0.05	< 0.03

5. Summary

- ❖ The model nutrient fields compared favorably to the observations made during the field surveys in 2001-2002. The seasonal cycles of chlorophyll, bacteria, and dissolved organic matter captured by the model were in agreement with previous observations in Marguerite Bay and/or other similar Antarctic coastal areas.
- ❖ Sea ice cover was shown to be a factor determining the magnitude of phytoplankton production and nutrient drawdown in Marguerite Bay. Bacterial ammonification was found to be the primary source of autumnal accumulation of ammonium in the Marguerite Bay model. Reduced bacterial ammonification led to lower production of ammonium in 2001-2002 compared to that in 2000-2001.
- ❖ Decrease in zooplankton stocks contributed to the decline in

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