

Spatial patterns of nitrogen-transforming processes in the Southern Ocean: Potential role of Dissimilatory Nitrate Reduction (DNR)

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$\text{NO}_3 \xrightarrow{\text{---}nap,nar\text{---}} \text{NO}_2 \xrightarrow{\text{---}nirS,nirK\text{---}} \text{NO} \xrightarrow{\text{---}nor\text{---}} \text{N}_2\text{O} \xrightarrow{\text{---}nosZ\text{---}} \text{N}_2$
 (Fe, Mo) (Fe, Cu) (Fe, Cu) (Cu)

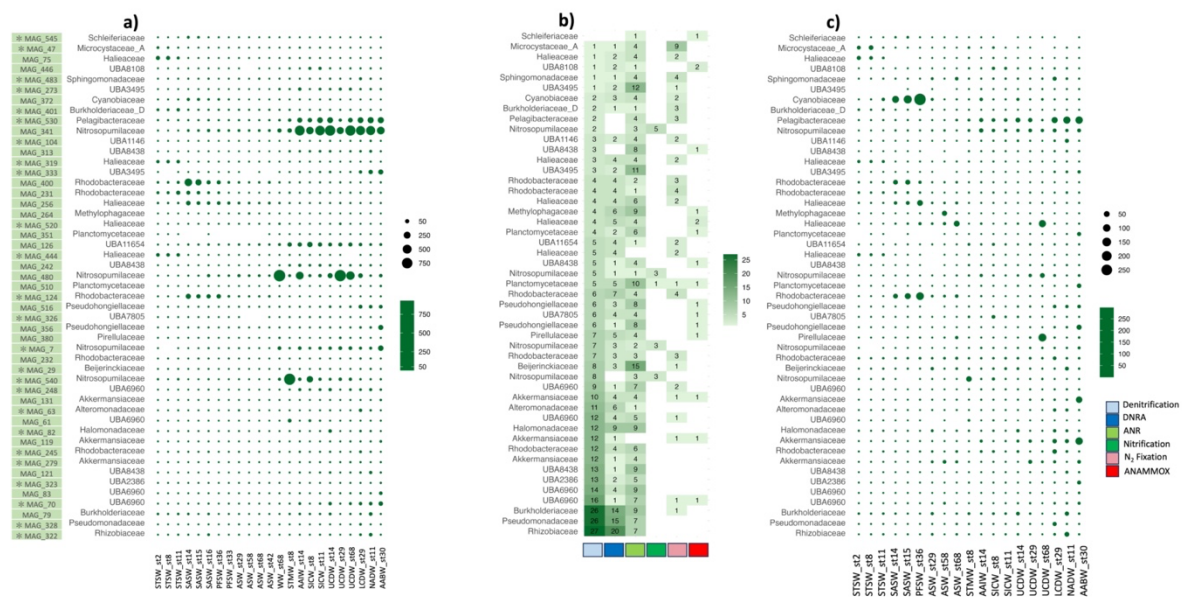
$$\text{NO}_3 \xrightarrow[\text{(Fe, Mo)}]{\text{---} \textit{nap, nar} \text{---}} \text{NO}_2 \xrightarrow[\text{(Fe)}]{\text{---} \textit{nirB-nirD, nrf} \text{---}} \text{NH}_4$$
$$\text{NO}_3 \xrightarrow[\text{(Fe, Mo)}]{\text{---nas,nar---}} \text{NO}_2 \xrightarrow[\text{(Fe)}]{\text{---nirA,NR---}} \text{NH}_4$$
$$\text{NH}_3 \xrightarrow[\text{(Cu)}]{\text{---amo---}} \text{NH}_2\text{OH} \xrightarrow[\text{(Fe)}]{\text{---hao---}} \text{NO}_2 \xrightarrow[\text{(Fe, Mo)}]{\text{---nxr---}} \text{NO}_3$$
$$\text{N}_2 \xrightarrow{\text{---nif---}} \text{NH}_3$$

(MoFe, VFe, FeFe)

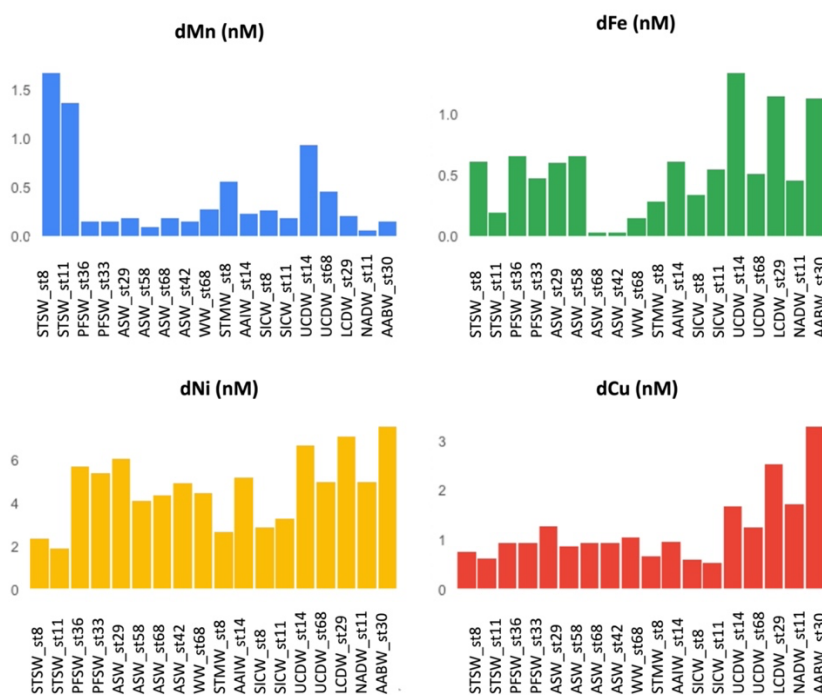
$$\text{NO}_2 + \text{NH}_4 \xrightarrow{\text{hzs, hdh}} \text{N}_2$$

(Mn, Fe)

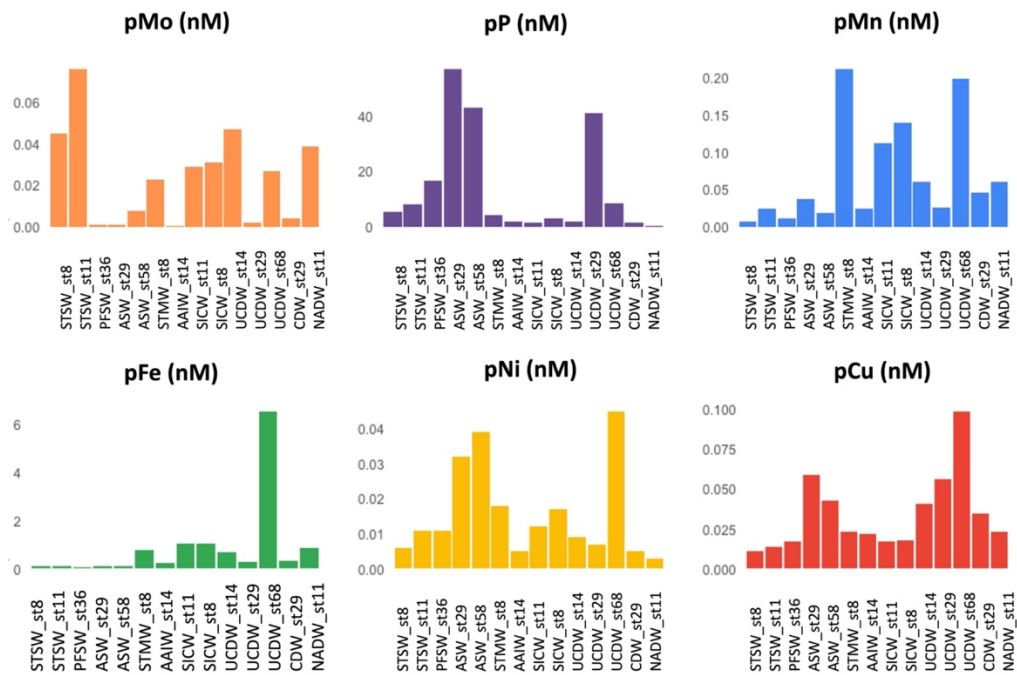
Supplementary Figure. 1 Reactions of N-transforming processes and the corresponding trace metals employed by the metalloenzymes.



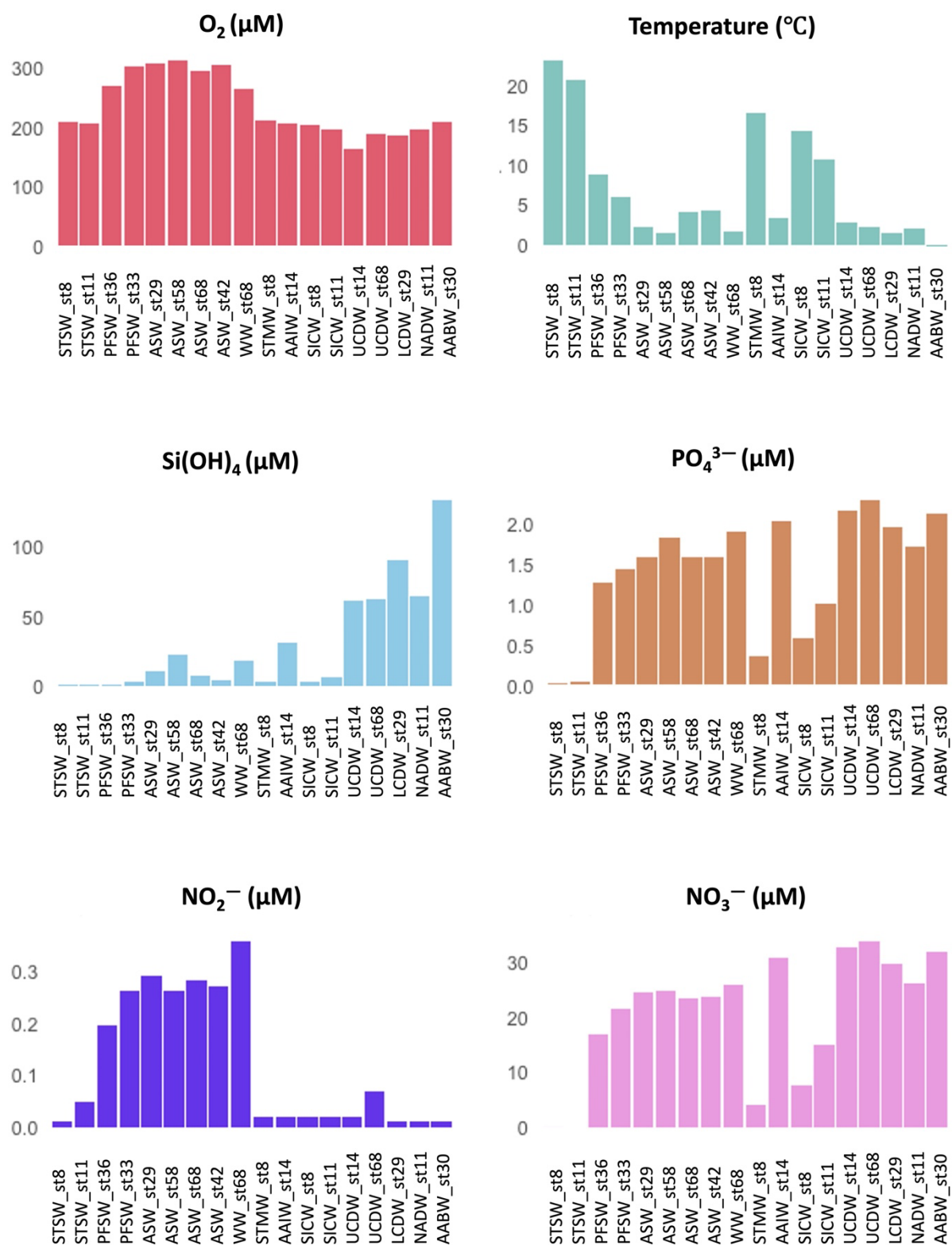
Supplementary Figure. 4 a) Coverage of representative MAGs in FL communities b) Copy numbers of representative N-transforming genes encoded by the MAGs. c) Coverage of representative MAGs in PA communities. Stars represent the MAGs with species affiliation.



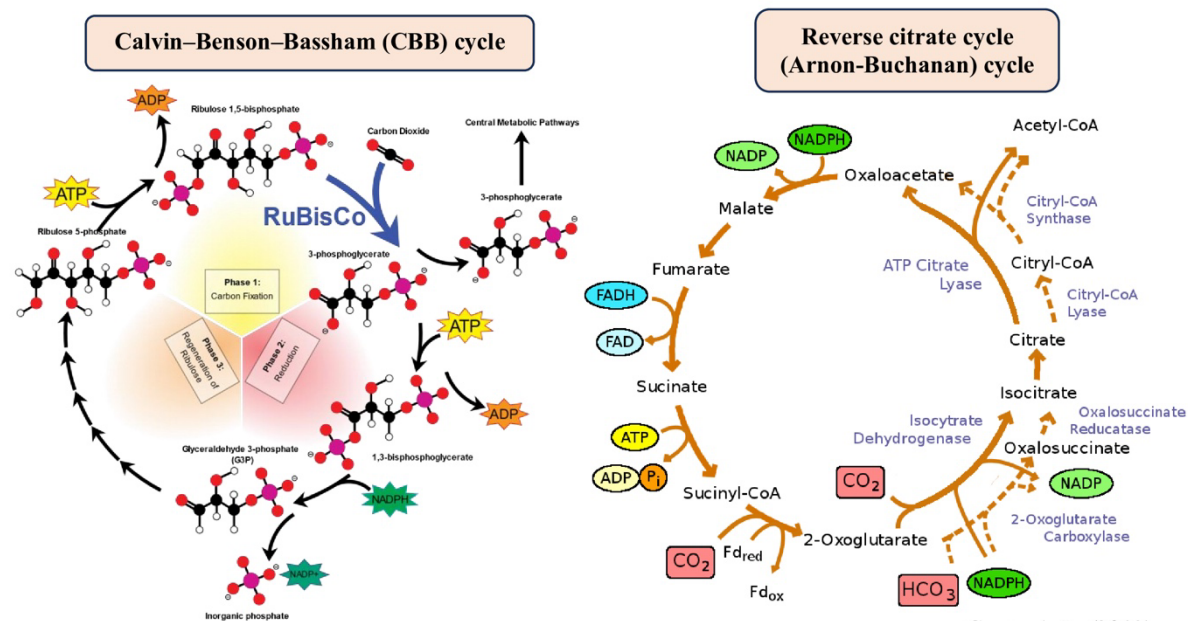
Supplementary Figure. 5 Dissolved TM concentrations at the depth of sample collection for metagenomic analyses.



Supplementary Figure. 6 Particulate TM concentrations at the depth of sample collection for metagenomic analyses.



Supplementary Figure. 7 Physiochemical parameters concentrations, of the samples collected for metagenomic analyses.

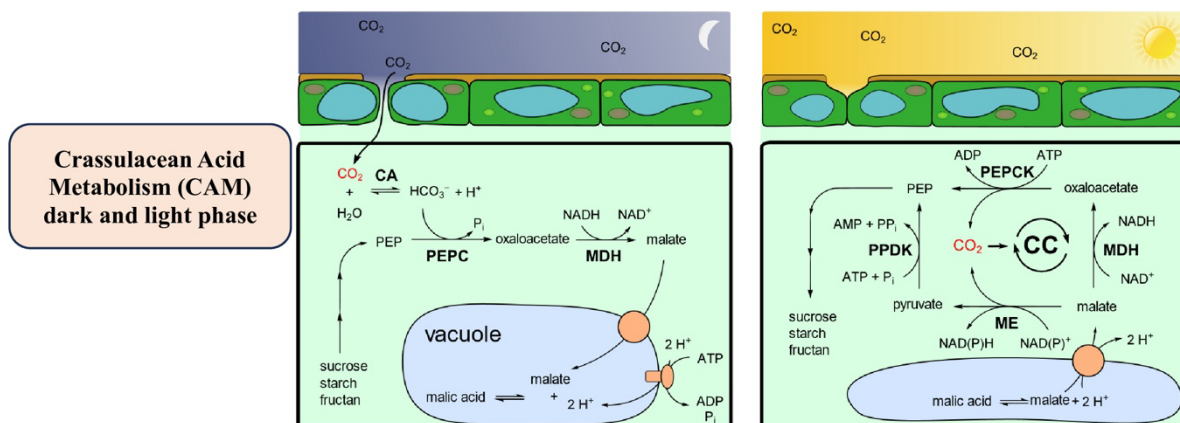


Mike Jones et al., 2010.

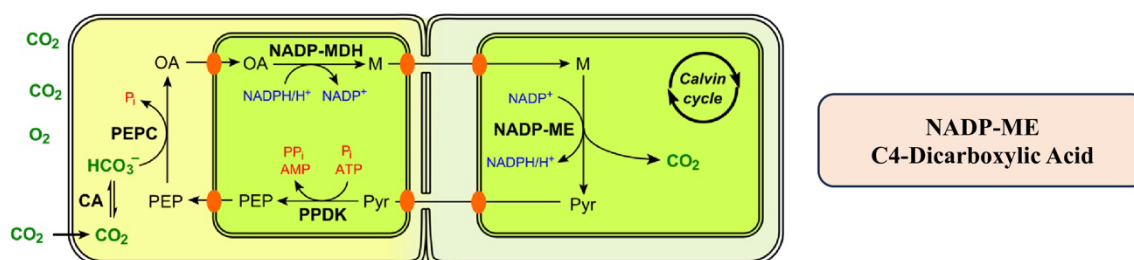
Overview of the Calvin cycle and carbon fixation. CC BY-SA 3.0.

A pathway diagram of the reductive TCA cycle. CC BY-SA 3.0.

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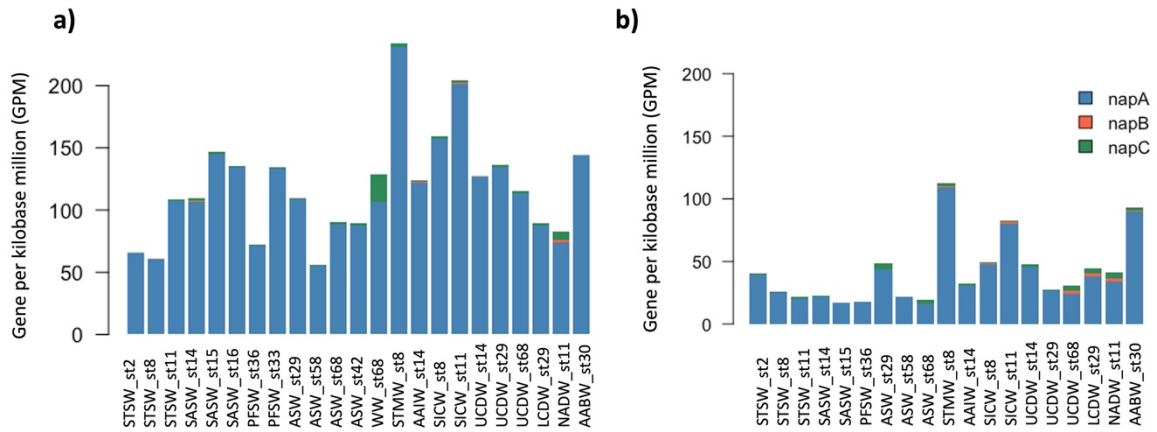
Ed (Edgar181 et al., 2016), based on Yikrazuul. Overview of CAM cycle. Public Domain.



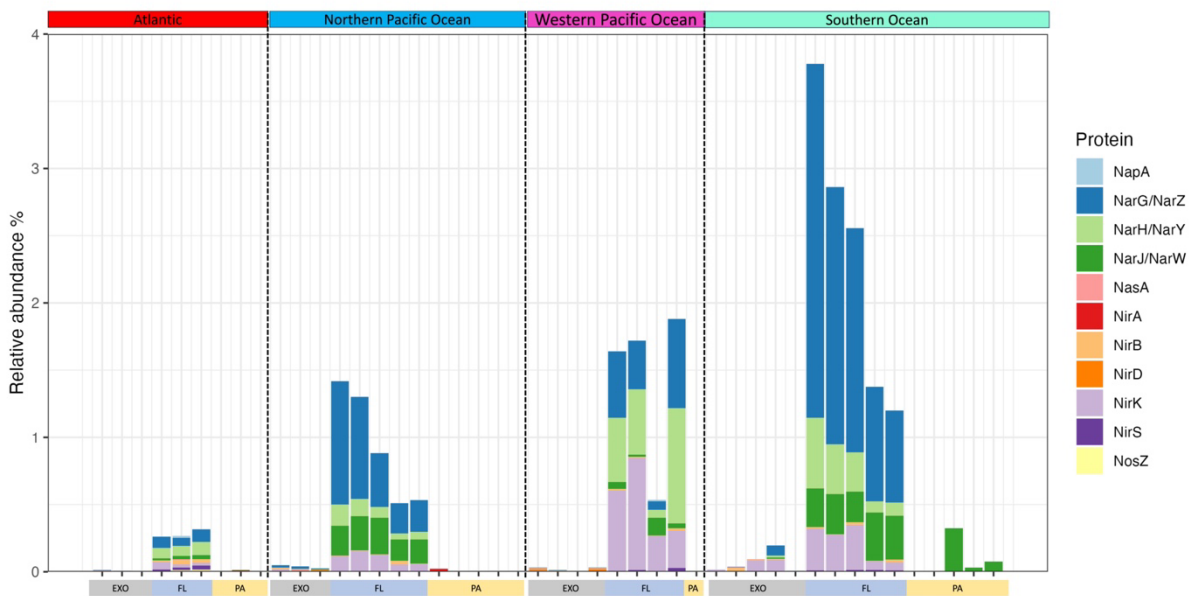
Yikrazuul et al., 2011. Overview of C4 photosynthesis NADP-ME type. CC BY-SA 3.0.

NADP-ME - Nicotinamide adenine dinucleotide phosphate- Malic enzyme, **CA** - Carbonic anhydrase, **HCO_3^-** - Bicarbonate, **PEP** - phosphoenolpyruvate, **Pi** - phosphate, **PEPC** - PEP carboxylase, **OA** - oxaloacetate, **M** - malate, **Pyr** - pyruvate, **PPDK** - Pyruvate phosphate dikinase, **PPI** - pyrophosphate, **PGA** - phosphoglycerate, **FAD** - Flavin adenine dinucleotide, **CC** - Calvin Cycle

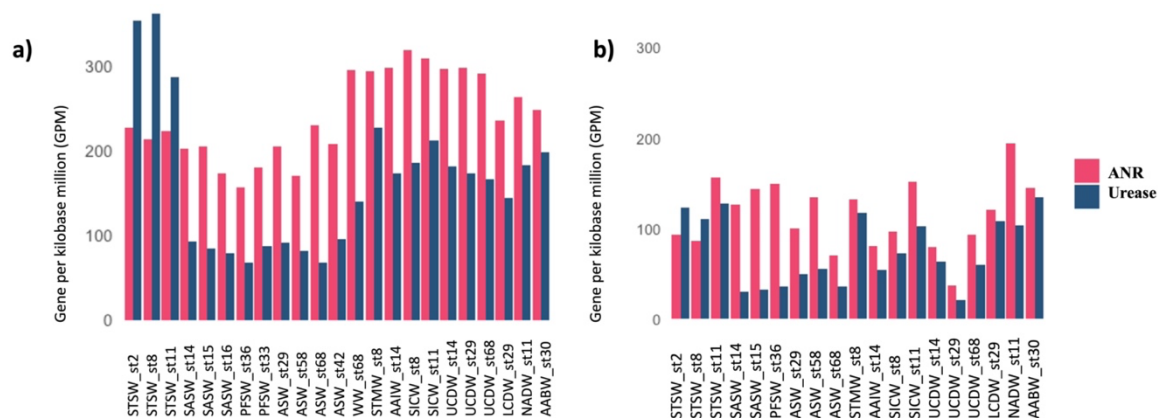
Supplementary Figure. 8 Inorganic carbon fixing pathways observed/detected in MAGs associated with N-transformations.



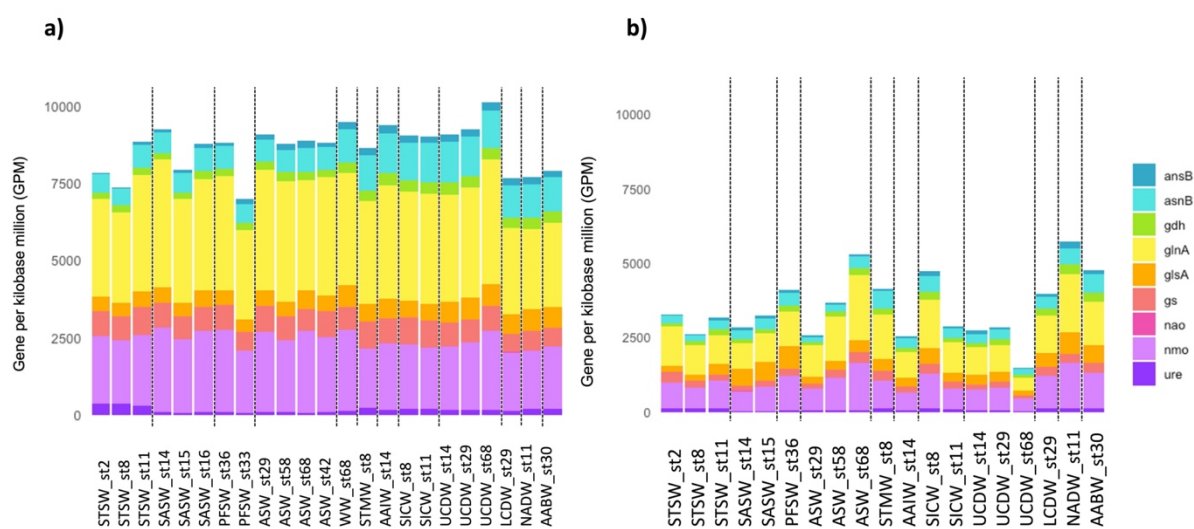
Supplementary Figure. 9 *nap* gene abundances in the a) free-living and b) particle-attached fractions.



Supplementary Figure. 10 Metaproteome representing DNR proteins expressed in free-living, particle-attached and exoproteomes of varying oceans. Data from Zhao et al. 2024.



Supplementary Figure. 11 Urease VS ANR gene abundances **a)** free-living and **b)** particle-attached fractions.



Supplementary Figure. 12 Organic N compounds synthesis and degradation gene abundances **a)** free-living and **b)** particle-attached fractions.