Marine carbon is fixed into biomass at a rate equivalent to ten fully loaded Boeing 747 airplanes crashing into the ocean every second of every day [ref 50Pg IPCC(?), ref Boeing weights]. In most of the surface ocean this flux is controlled by the availability of nitrogen, an element with a complex and incompletely characterized biogeochemical cycle [@Capone2008; @Moore2013; @Hutchins2022]. Organic nitrogen in particular is often treated as a black box despite substantial variability in its bioavailability and chemical nature. While extensive work has been done to characterize the forms and fluxes of nitrogen within the inorganic pool, the equivalent for the organic pool is woefully underdeveloped [@ref, prob NME2008 or Hansell2024, maybe @Hutchins2022 for visual?]. This is largely due to the difficulty of comprehensively measuring the many organic molecules that contain nitrogen in the marine environment [@Boysen2018; @Moran2022]. The bioavailability of the nitrogen atom is in the environment is largely determined by the form of the organic material it composes.

The mechanisms by which dissolved nitrogen becomes biomass and vice versa are major factors in our ability to predict ecosystem productivity and therefore carbon fixation and export. Traditionally, the conversion of inorganic material into organic substrate was thought to be limited to autotrophs while remineralization was performed by the heterotrophic community. Today, it’s known that many photosynthetic organisms are able to take up and use organic nitrogen [@Anita1991; @Morando2018; @Hugo2021] and that only a select subset of phototrophs are capable of nitrate reduction or nitrogen fixation [@ref], while inorganic nitrogen is directly accessible to heterotrophs as well. This means that the transformations possible for a given N-containing compound are a function of the microbial community and its environment while the microbial community is in turn also expected to be a function of the N-containing molecules available. This creates a recursive network that’s difficult to untangle and cannot necessarily be extrapolated from axenic culture studies.

One way to reveal the pathways and transformations that marine N undergoes in a natural community is via 15N labeling paired with metabolomics. Metabolites that incorporate the labeled nitrogen can then be separated on the mass spectrometer and quantified separately from the unlabeled pool. Here, we trace the uptake and use of labeled ammonia, nitrate, arginine, and guanosine monophosphate in a natural community from the NPSG at multiple depths and diel conditions. Our application of metabolomics to these samples allows us to map out the pathways and restructuring that organic nitrogen experiences in the largest biomes on the planet, quantifying the pool sizes and turnover rates for various low molecular weight compounds that serve as building blocks and intermediates of cell biology.

* mention the expected differences with depth and diel effects
* detail which compounds we chose and why?
* expand on DON-PON interactions and importance?

-Extracellular enzymes, organic use as ammonia vs as-is?

* expand on the importance of biogeochemical models and why we need pathways mapped out?
* mention basic biosynthetic pathways (maybe better suited to discussion?)
* new (nitrate) vs regenerated (ammonia and DON) production (maybe also discussion?)

It is assumed that most fixed nitrogen becomes protein, presumably based on the large fraction of cell nitrogen in protein and previous research showing how quickly it enters the (free?) amino acid pool. However, 1) important intermediates molecules 2) doesn’t explain where biounavailable N comes from 3) makes gene-based molecular modeling really difficult.

In each case, assimilation into organic matter is typically done via the glutamine synthetase (GS)/glutamate synthase (GOGAT) or glutamate dehydrogenase (GDH) pathways to produce glutamate from α-ketoglutarate [@ref, see bronk chapter]. Glutamate then serves as a nitrogen supply in an enormous number of biochemical pathways in both primary and secondary metabolism [@Walker2016].

nitrate amendments typically resulting in diatom blooms while ammonia incubations favor cyanobacteria [@Glibert2016].

Communities to distinguish are 1) surface (largely regenerated production) and 2) 175m (largely new production(??))

use of organics vs synthesis of organics

Compounds such as non-proteinogenic amino acids (e.g., ornithine, citrulline, creatine, MAAs), osmolytes like betaines, nucleobases, and sulfur-containing molecules like taurine represent significant but poorly quantified pools. Understanding the rates and pathways by which these compounds are utilized is crucial, as they form the fundamental unit linking genetic potential to elemental cycling in biogeochemical models.

Nitrogen use varies significantly between the sunlit surface where productivity is largely regenerated through recycling of ammonia and organic nitrogen, and deeper waters near the base of the euphotic zone, where nitrate supports “new” production. Quantifying rates of nitrogen assimilation into ammonia and downstream products across these gradients is therefore essential for predicting marine productivity and nutrient cycling.

Nonetheless, *how* the community uses a substrate is arguably more important than whether it can.