Out of thin air – how marine bacteria beat nitrogen limitation

Nitrogen (N), one of life's most important building blocks, is often in short supply; both on land and in the ocean (Fig. 1). This shortage means that N is often the factor limiting the growth and abundance of living organisms. Some microbes, the diazotrophs, are capable of circumventing this shortage by using the vast pool of inert N that makes op the majority of Earth's atmosphere, N_2 gas, as a source of N. The process they carry out is known as N_2 fixation. It is a very energy demanding process and the enzymes involved are susceptible to inhibition by oxygen (O_2).

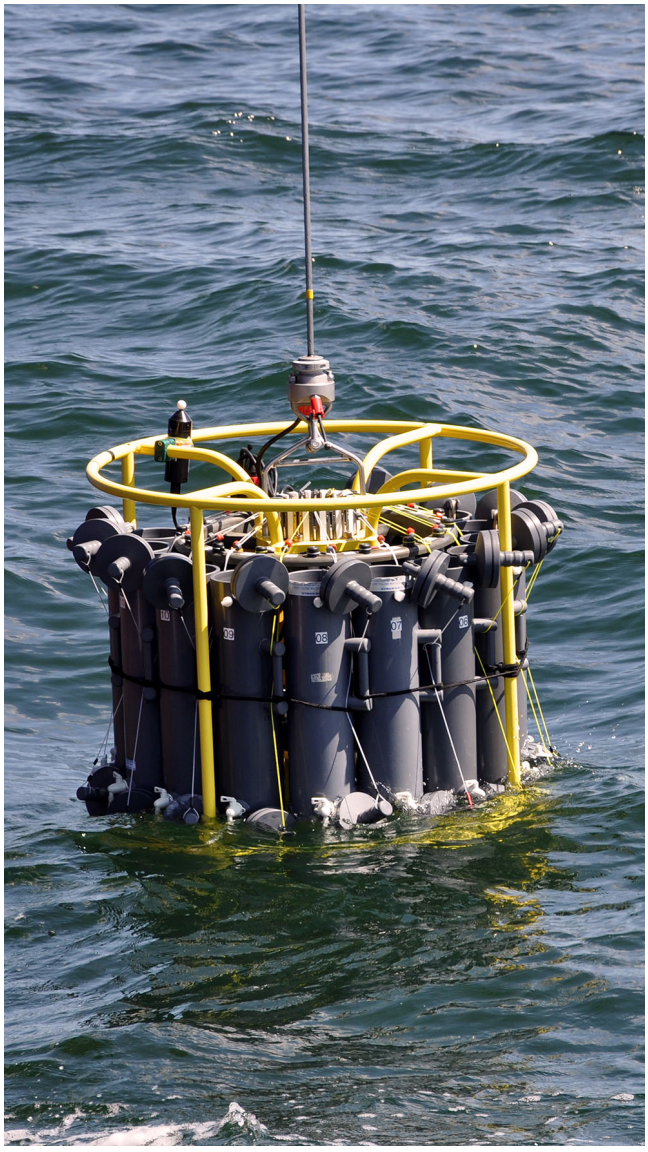

Fig. 1. CTD rosette for sampling seawater on board a research vessel

This imposes significant restrictions on where and how diazotrophs can fix N_2. In the oceans, the best known diazotrophs, the cyanobacteria, fix N_2 using sunlight as a source of energy, and they often have specialized O_2-free compartments where N_2 fixation takes place. In addition to cyanobacteria, however, a broad range of other microbes carry the genetic capacity to fix N_2, and they appear to be widespread throughout the world's oceans. Hence, they could play an important role in the import of biological available N in different N-limited marine environments. Where, when, and how they circumvent the limitations imposed on the N_2 fixation process is, however, currently unknown.

The study describes how bacteria isolated from the Baltic Sea are capable of fixing N_2 at different O_2 concentrations, and in the presence of N sources other than N_2 gas. It seems that small amounts of O_2 may in fact stimulate the fixation of N_2 in these bacteria and some bacteria may sustain N_2 fixation even in the presence of considerable amounts of O_2 by clumping together into gelatinous aggregates or by colonizing particulate material. The study also suggests that some marine N_2-fixing bacteria may actually use N_2 fixation as a means to remove electrons from important cellular electron carriers and these bacteria may use considerable amounts of energy on N_2 fixation, even in the presence of a readily available N source such as ammonium (NH_4^+). Hence, these bacteria seem to be able to fix N_2 at significant rates even under conditions that should not facilitate N_2 fixation. Making predictions about how much these microorganisms contribute to the import of N in marine systems, based on such environmental parameters, is therefore problematic.

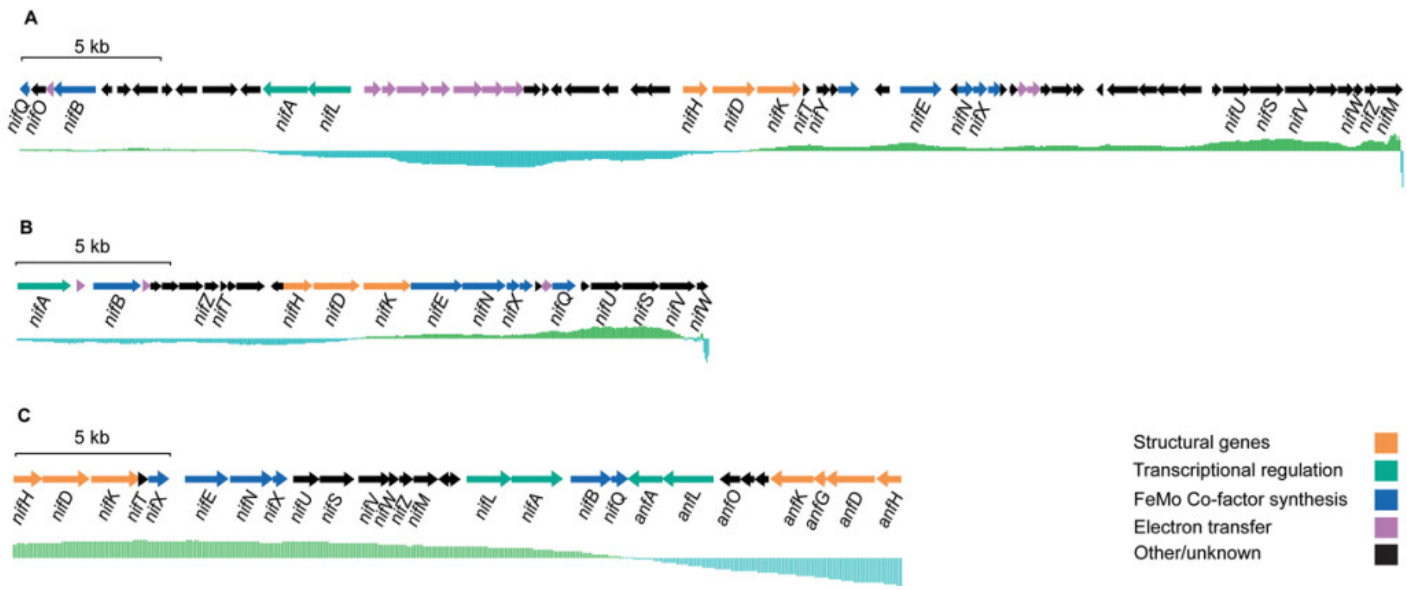

Fig. 2. N2 fixation gene clusters of three bacteria isolated from the Baltic Sea. Pseudomonas stutzeri BAL361 (A), Rhodopseudomonas palustris BAL398 (B), and Raoultella ornithinolytica BAL286 (C).

Analyses of the genomes of the isolated bacteria also supported that they have different strategies to accommodate the environmental restrictions imposed on the N_2 fixation reaction. A bacterium that was found to be able to fix N_2 under relatively high O_2 concentrations was also found to have a large N_2 fixation region in the genome (Fig. 2A). The large size of the region was due to the inclusion of an array of small genes that are known to be expressed during N_2 fixation under high O_2 concentrations in N_2-fixing bacteria from soil.

Thus, both genomic and physiological data suggested that these bacteria, given the right conditions, could import significant amounts of N into certain marine environments. The circumstances under which they do it seem to be hard to predict, however.

Publication

Genomics and Ecophysiology of Heterotrophic Nitrogen-Fixing Bacteria Isolated from Estuarine Surface Water.
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