Modeling Regulation Mechanisms of N_2 Fixation in *Trichodesmium*: From PhD Research to Future Perspectives

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N_2 fixation is a key process in the marine nitrogen cycle, contributing to primary productivity and carbon sequestration. *Trichodesmium*, a dominant diazotrophic cyanobacterium, performs both N_2 fixation and photosynthesis concurrently during the daytime. This study investigates its regulatory mechanisms using physiological modeling, focusing on intracellular O_2 management, dynamic membrane O_2 permeability, dynamic Fe allocation, and responses to ocean acidification.

(1) **Intracellular O_2 Management**: Our model suggests that temporal segregation of photosynthesis and N_2 fixation can establish the low-O_2 window required for N_2 fixation without spatial segregation. Respiratory protection and alternative electron transfer further facilitate O_2 management.

(2) **Dynamic Membrane O_2 Permeability**: *Trichodesmium* modulates O_2 permeability via hopanoids. High permeability during photosynthesis accelerates O_2 diffusion, reducing photorespiration, while low permeability during N_2 fixation minimizes O_2 stress on nitrogenase, improving carbon and Fe use efficiency.

(3) **Dynamic Fe Allocation**: Diurnal Fe reallocation enhances N_2 fixation by optimizing Fe and carbon use. Fe between photosynthesis and nitrogenase reduces nitrogenase inactivation and lowers respiratory protection requirement, improving carbon and Fe use efficiency.

(4) **Response to Ocean Acidification**: Acidification impairs trichome N_2 fixation due to nitrogenase inefficiency and reduced energy production. However, colonies remain resilient, likely due to enhanced Fe acquisition and reduced NH_3/Cu toxicity.

These findings elucidate *Trichodesmium*'s physiological adaptations and contribute to improving global biogeochemical models with N_2 fixation.

Keywords: *Trichodesmium*; N_2 fixation; O_2; Fe; Ocean acidification.