Global Biogeochemical Cycles

RESEARCH ARTICLE
10.1029/2019GB006452

Physical Forcing Controls the Basin-Scale Occurrence of Nitrogen-Fixing Organisms in the North Pacific Ocean

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Key Points:
- Diazotrophs showed seasonal succession and different longitudinal patterns, which were explained with their different temperature preference
- Abundant diazotrophs were detected in the North Pacific transition zone in both western and eastern North Pacific
- Diazotrophs in western and eastern North Pacific were correlated with proxies of mesoscale eddies and coastal upwelling, respectively

Supporting Information:
- Supporting Information Data S1

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Citation:
Cheung, S., Nitanai, R., Tsurumoto, C., Endo, H., Nakaoka, S., Cheah, W., et al. (2020). Physical forcing controls the basin-scale occurrence of nitrogen-fixing organisms in the North Pacific Ocean. *Global Biogeochemical Cycles*, *34*, e2019GB006452. https://doi.org/10.1029/2019GB006452

Received 12 OCT 2019
Accepted 30 AUG 2020
Accepted article online 2 SEP 2020

Abstract Biological nitrogen fixation is increasingly recognized as an important source of new nitrogen in a warming ocean. However, the basin-scale spatiotemporal distribution of nitrogen-fixing organisms (diazotrophs) in the ocean and its controlling environmental factors remain unclear. Here we examined the basin-scale seasonal distribution patterns of major diazotrophs (filamentous cyanobacterial *Trichodesmium*, unicellular cyanobacterial UCYN-A1, and proteobacterial Gamma-A) in surface waters of the North Pacific from 2014 to 2016 with unprecedented coverage and resolution. In general, UCYN-A1, *Trichodesmium*, and Gamma-A were abundant during spring-autumn, summer-autumn, and spring respectively. Regarding latitudinal patterns of abundance, UCYN-A1 showed dome shape; *Trichodesmium* was gradually decreasing from low- to high-latitude regions; and Gamma-A did not show a clear pattern, which were coincident with the distinct correlations between the diazotrophs and temperature. All three diazotrophs were abundant (reached 10^6–10^7 *nifH* gene copy number L^{-1}) in the North Pacific transition zone and subtropical gyre, where the cyanobacterial diazotrophs were more abundant in both the western and eastern North Pacific than in the central North Pacific. The diazotroph abundance in the western North Pacific was positively correlated with eddy kinetic energy and sea surface height anomaly, which implies an enhancement of diazotrophs in mesoscale eddies associated with the western boundary current Kuroshio and its extension. The cyanobacterial diazotrophs were positively correlated with wind stress curl, a measurable parameter of wind-driven upwelling, in the eastern North Pacific. Our study refines the biogeography of three major diazotrophs and highlights the importance of physical forcing in mediating their dynamics.

1. Introduction

Biological nitrogen fixation (BNF) reduces dinitrogen to bioavailable nitrogen, which fuels primary production and biological pump in the ocean (Capone et al., 2005; Capone & Carpenter, 1982; Karl et al., 1997) and also plays a major role in the global oceanic nitrogen budget (Galloway et al., 2004). A large portion of marine BNF occurs in the Pacific Ocean. A recent model-based study estimated that the Pacific Ocean contributed to more than half of biologically fixed nitrogen input in the global ocean (Wang et al., 2019), which is in agreement with the estimation that based on data synthesis of actual BNF rates (Luo et al., 2012). In the North Pacific subtropical gyre (NPSG), it has been suggested that the supply of bioavailable nitrogen from subsurface waters to the euphotic zone has been decreasing in recent decades, which could enhance BNF activities (Corno et al., 2007; Karl et al., 1997, 2001). Furthermore, nitrogen isotopic records in coral skeletons collected from Hawaiian archipelago indicated that BNF has increased in the NPSG since the end of Little Ice Age (Sherwood et al., 2014).