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Identification of oceanic hotspots for production of the neurotoxin β-N-methylamino-L-alanine: a multidisciplinary ocean-prospecting study

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Abstract

Background β-N-Methylamino-L-alanine (BMAA) is an inducer of neurodegenerative disorders. Chronic ingestion of BMAA through the food chain has been suggested to cause amyotrophic lateral sclerosis and other related pathologies, including Parkinson’s. BMAA is produced by cyanobacteria in various environments, including the ocean, and BMAA production increases under nitrogen-depleted conditions in pure cultures of non-nitrogen-fixing cyanobacteria. In the ocean, a large proportion of primary production of biomass is done by cyanobacteria, mostly in regions connected to highly productive eastern boundary upwelling systems. Those regions are often characterised by strong oxygen depletion, and enhanced nitrogen loss, but provide an essential fraction of fish production for local and global nutritional needs. Thus, these upwelling areas connected to oxygen-depleted intermediate waters are of great interest in terms of BMAA transfer to humans through the food chain. The predicted expansion of those oxygen-depleted and nitrogen-depleted waters might thus have a severe effect on BMAA production and consequently on human health.

Methods In this multidisciplinary ocean-prospecting study, we used a coupled approach of satellite monitoring, chlorophyll, nitrogen, and oxygen sensing via autonomous ocean profilers (gliders) and ship-board measurements, and metagenomics mining to identify possible hotspots of BMAA production in two upwelling systems near Mauritania and Peru. The obtained environmental datasets were complemented with studies of cyanobacterial pure cultures and enrichments to quantify potential rates of BMAA production. From this, we could identify the amount of BMAA produced under different levels of oxygen and nitrogen depletion. We used a multivariate statistical model to estimate the BMAA production in the two upwelling systems under different nitrogen availabilities, and the amount of BMAA found in anchovies, which form a major part of the fish catch in those areas.

Findings Since December, 2009, we have repeatedly (at least twice per year) identified blooms of Prochlorococcus species capable of BMAA production along several hundred kilometres of the coasts of Peru and Mauritania by satellite analysis and direct pigment measurements. We measured high abundances of cyanobacteria in the range of 10⁸ cells per mL seawater, accounting for up to 80% of picoplankton in the photic zone with the genetic capability for BMAA production. Our culture experiments with Prochlorococcus species present in both investigated regions showed a BMAA production of around 30 µg BMAA per g cells. BMAA production doubled under nitrogen-depleted conditions, with nitrogen concentrations of 3 µM as present in the oxygen-depleted waters near Peru leading to production of up to 70 µg BMAA per g cell. Considering the cell abundance of Prochlorococcus in those nitrogen depleted waters, our multivariate model predicts an accumulation of BMAA in anchovies of 3–27 µg BMAA per g, which might, depending on diet, accumulate to up to 1320 µg BMAA per g in human beings living at the coast.

Interpretation Follow-up analysis will target a potential increase in BMAA production and its transport through the food chains in both upwelling systems in the context of climate change and expansion of nitrogen depleted waters along productive upwelling regions.

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Declaration of interests I declare no competing interests.