Prof Caitlin Byrt, Australian National University, and Dr Ben Long, University of Newcastle Adapted from our submission to The Global Plant Council, published on the 3rd June 2025, source: https://globalplantcouncil.org/feeding-the-bloom-the-role-of-co%E2%82%82-nutrients-and-heat-in-algal-proliferation/

Harmful Algal Blooms (HABs) are becoming more frequent, their scale is growing and so are their impacts on food, water and ecological security.

HABs are being fed by increases in water temperature, dissolved CO_2 concentration and nutrient availability in our oceans and freshwater bodies. Algal blooms act as a sink for atmospheric CO_2, but blooms of toxin-producing algal species harm biodiversity[1] and disrupt ecosystems and food chains[2].

Rising Frequency and Impact of Harmful Algal Blooms

Over the last half a century changes in Earth's climate and human land use activities have led to conditions of increasingly warmer water with more dissolved carbon and nutrients, and this is likely to have supported the observed increases in algal productivity. The number of news reports[3] and public health advisories related to algal blooms in 2025 is higher than in typical years in the previous five decades, especially compared to the 1980s and 1990s. In the 1980s and 1990s, news reports and official accounts of HABs were relatively rare. For example, in North America, there were only 12 published accounts in the 1980s and 19 in the 1990s[4]. By the mid-2000s, reports began to rise sharply, with nearly 1,700 HAB-related warnings and public health advisories issued in the US alone by 2021. Scientific studies confirm a global increase in algal bloom frequency, especially since the 2010s, with a marked acceleration after 2015[5].

In 2025, there have been multiple news reports and government updates regarding significant algal bloom events, such as the *Karenia mikimotoi bloom*[6] off the South Australian coast, which received extensive media and public health[7] attention. The 2025 South Australian event is described as "significant," with widespread impacts[8] on beaches, fisheries, and public health, prompting frequent updates[9] from government agencies[10] and environmental authorities.

Satellite data from 2003-2022 show a global median annual increase in algal bloom frequency of +1.8% per year[5], with the most pronounced surge after 2015. The proliferation of blooms is attributed to factors including climate warming and nutrient pollution[4], with blooms now occurring annually in many lakes and coastal areas that previously saw only sporadic events. News[11] coverage and public advisories[12] continue as algal bloom ecological and health impacts[6] become more acute and widespread.

In inland freshwater systems such as rivers, lakes and farm dams, blue-green algae (cyanobacteria) are also an ever-growing concern. Blooms can generate deadly toxins and often lead to negative ecological impacts including mass fish kills from oxygen depletion in the water and reduced light penetration that prevents aquatic plants from growing. Recent HABs in Australia's Murray-Darling basin, such as the Menindee Lakes bloom events[13], caused waterways to be unsafe for human use, and ecologically desolate. The toxins[14] produced are of particular concern, since they are harmful to both humans and other animals and take weeks or even months in water systems to degrade to levels safe for human consumption.

Climate Change and Human Activities as Key Drivers

Critical to making headway to curb the impacts of algal blooms is a solid understanding of algal biology and how it is affected by a changing climate and human influence. For instance, as atmospheric CO_2 increases, this inevitably leads to higher dissolved CO_2 concentrations in ocean and fresh water. This in turn changes the water chemistry as it becomes more acidic, while also supplying additional CO_2 that supports algal photosynthesis. In marine systems species like *Heterosigma akashiwo* (a harmful dinoflagellate) show increased growth rates under high levels of CO_2, up to 1,000 ppm, potentially overtaking diatoms like *Skeletonema dohrnii* as dominant bloom-forming species[15]. Even slightly elevated temperatures from global warming[16] give algae a boost in growth, and sea surface temperatures are already more than 1°C above the 1901-2000 average, and warming ever more rapidly, promoting bloom formation and sometimes tipping the balance in favour of one species over another. This can lead to somewhat unpredictable outcomes as complex ecological food webs are disturbed.

Climate change is causing greater variability in weather which complicates analysis of the ocean currents and river flows that impact nutrient availability and feed algal blooms. Changes in currents and flows can boost the ingredients required to supply algae with their building blocks for life. Drought events and intense rainfall are both associated with climate change, and they both exacerbate bloom conditions because intense rainfall is associated with increases in nutrient runoff and drought events can cause concentration of nutrients in waterways.

Monitoring, Prediction, and Technological Responses

As the frequency and severity of algal blooms is likely to increase, the importance of reducing nutrient pollution will grow, as will the need to implement bloom detection and prediction[17] systems. Satellite technology can offer scalable algal bloom monitoring and predictive insights. Changes in water colour, temperature and chlorophyll-a can be detected remotely to identify blooms before they become severe and this information can be used to enable targeted responses, such as closing water intakes or deploying cleanup crews to reduce economic[18] and health impacts[11] in the future.

Understanding and mitigating the drivers[19] of harmful algal blooms is a global challenge. As nutrient pollution and climate change intensify, the need for sustainable agricultural practices becomes more urgent. Improving crop nutrient use efficiency, fostering plant-microbiome interactions, and advancing climate-resilient agriculture directly supports efforts to reduce nutrient runoff—one of the key contributors to algal bloom proliferation. A focus on both understanding and mitigating HABs within the broader scope of plant biology plays a vital role in addressing the interconnected issues of food security, ecosystem health, and climate resilience.

Sustainable Solutions to Mitigate Nutrient Pollution

Reducing nutrient pollution will require actions from many sectors and across agricultural, industrial and urban areas: Actions such as improved organic and nutrient-rich **waste management**[20] and chemical use practices, land use planning changes and community engagement. Towards managing nutrient pollution from agricultural activities it will be important to invest in research translation activities that enable plants to thrive with limited fertiliser inputs, adopt optimised crop rotations to maximise nutrient retention, build synergies between crops and beneficial microbiota, and tailor fertilizer use and recycling systems to crop needs and environmental conditions.

References

1. https://www.bbc.co.uk/news/articles/cqxewn0z2v8o; 2. https://theconversation.com/mystery-solved-our-tests-reveal-the-tiny-algae-killing-fish-and-harming-surfers-on-sa-beaches-252810; 3. https://www.abc.net.au/news/2025-03-18/algae-bloom-likely-cause-fish-deaths-foam/105064874; 4. https://www.bbc.com/future/article/20230110-the-pollution-causing-harmful-algal-blooms; 5. Wang, Y., Zhao, D., Woolway, R.I., Yan, H., Paerl, H.W., Zheng, Y., Zheng, C. and Feng, L., 2025. Global elevation of algal bloom frequency in large lakes over the past two decades. National Science Review, 12(3), p.nwaf011. https://doi.org/10.1093/nsr/nwaf011; 6. https://www.environment.sa.gov.au/news-hub/news/articles/2025/05/investigations-into-fish-deaths-and-sick-kangaroos; 7. https://www.pir.sa.gov.au/research/research_areas/aquatic_sciences/marine_ecosystems/harmful_algal_bloom; 8. https://www.theguardian.com/environment/2025/may/13/a-horror-movie-sharks-and-octopuses-among-200-species-killed-by-toxic-algae-off-south-australia; 9. https://www.sahealth.sa.gov.au/wps/wcm/connect/public+content/sa+health+internet/public+health/water+quality/water+quality+alerts; 10. https://www.environment.sa.gov.au/news-hub/news/articles/2025/05/investigations-into-fish-deaths-and-sick-kangaroos#:~:text=We%20encourage%20anyone%20who%20discovers,Primary%20Industries%20and%20Regions%20website; 11. https://www.sbs.com.au/news/article/why-south-australian-harmful-algae-bloom-is-killing-fish/0lhchg2oh; 12. https://www.environment.sa.gov.au/news-hub/news/articles/2025/05/sa-harmful-algal-bloom-update; 13. https://www.waternsw.com.au/water-services/water-quality/algae-alerts/algae-alerts/2025/blue-green-algae-red-alert-for-lake-menindee2#:~:text=20%20MARCH%202025,alert%20warning%20areas%20is%20advised; 14. Orr, P.T. and Jones, G.J., 1998. Relationship between microcystin production and cell division rates in nitrogen-limited Microcystis aeruginosa cultures. Limnology and oceanography, 43(7), pp.1604-1614. https://doi.org/10.4319/lo.1998.43.7.1604; 15. Qin, J., Jia, M. and Sun, J., 2024. Examining the effects of elevated CO2 on the growth kinetics of two microalgae, Skeletonema dohrnii (Bacillariophyceae) and Heterosigma akashiwo (Raphidophyceae). Frontiers in Marine Science, 11, p.1347029. https://doi.org/10.3389/fmars.2024.1347029; 16. https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature; 17. Kim, D. and Chung, S., 2025. Enhancing harmful algal bloom predictions through integrated modeling of turbidity and nutrient dynamics in monsoon climate reservoirs. Journal of Environmental Management, 381, p.125291. https://doi.org/10.1016/j.jenvman.2025.125291; 18. https://www.abc.net.au/news/2025-05-25/algal-bloom-harming-marine-life-is-now-hitting-livelihoods/105324808; 19. Xiao, X., Agustí, S., Pan, Y., Yu, Y., Li, K., Wu, J. and Duarte, C.M., 2019. Warming amplifies the frequency of harmful algal blooms with eutrophication in Chinese coastal waters. Environmental Science & Technology, 53(22), pp.13031-13041. https://pubs.acs.org/doi/abs/10.1021/acs.est.9b03726; **20. Arsic, M., Byrt, C.S., De Rosa, A., Hilder, P., Iqbal, S., McGaughey, S., Prasad, S., O'Sullivan, C., Wu, X., Xie, Z., 2024. Biomimetic membrane technology developments relevant to sustainable reuse of resources. Australian Water Association Water e-Journal https://info.awa.asn.au/water-e-journal/biomimetic-membrane-technology-developments-relevant-to-sustainable-reuse-of-resources**