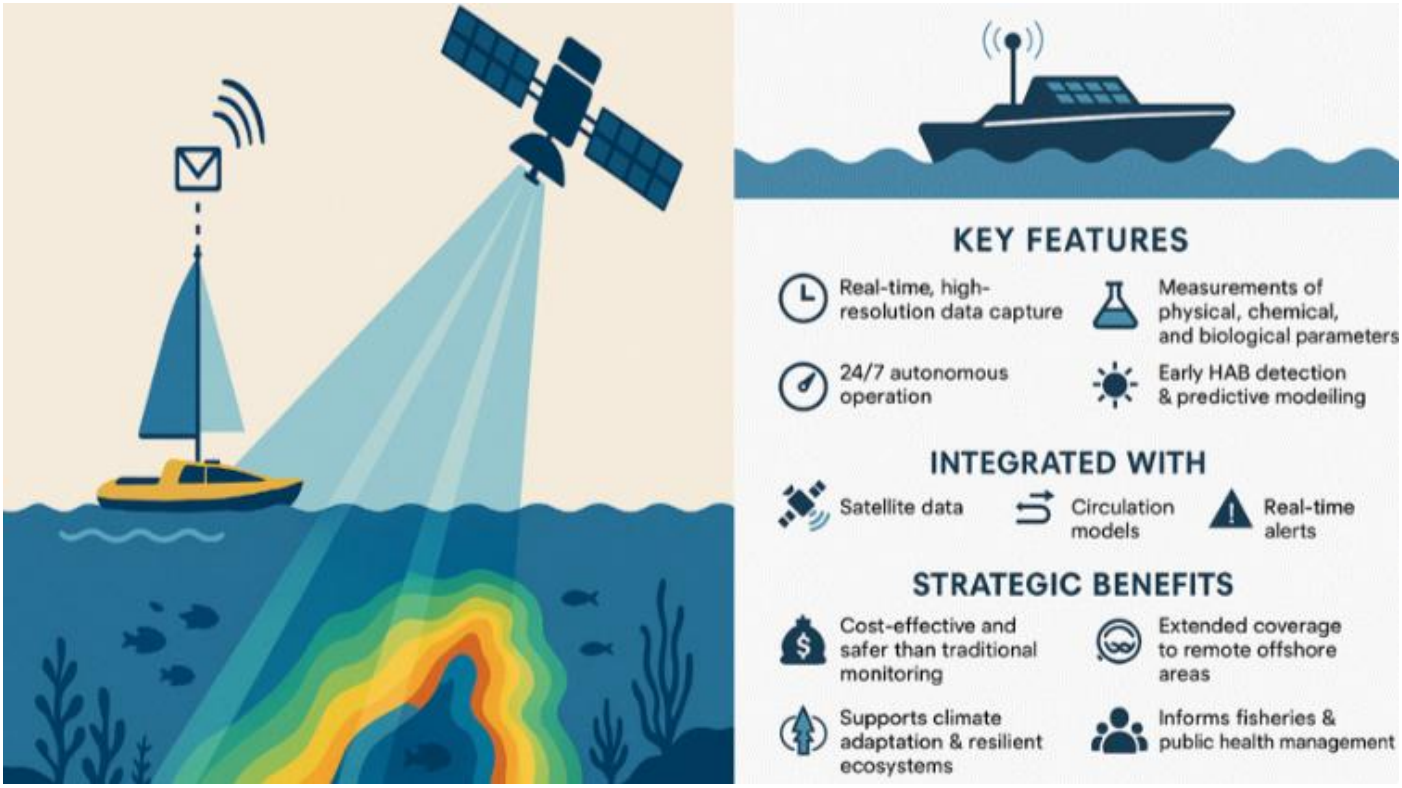

Abstract

South Australia's ongoing HAB reflects the growing convergence of climate-related and local environmental pressures, including marine heatwaves, nutrient-rich flood discharge, stormwater runoff, and seasonal upwelling. With marine ecosystems increasingly vulnerable to rising sea temperatures, sea level rise, and pollution, future scenarios point to more frequent events impacting on water quality and our lives. In response, a scalable, uncrewed, and renewably powered marine monitoring platform has been developed to provide continuous, high-resolution data across coastal and offshore waters. By integrating real-time environmental sensing with satellite data and predictive modelling, this system would enable early detection of harmful algal blooms, monitor restoration efforts, and inform proactive, evidence-based management. This technologically advanced system offers a critical foundation for climate resilience, sustainable fisheries, and long-term protection of South Australia's marine environment.

In my previous two articles, I summarised the state of knowledge on the current HAB (Article 1), as well as the possible future scenarios (Article 2). In this article I briefly summarise the previous articles and extend the critical thinking to propose a monitoring system that meets the present and future needs.

The present article poses the question: Does SA deserve a dedicated, adaptable and persistent monitoring solution? A monitoring system that aligns with SA's capabilities of Robotics, the Internet of Things, Advanced Information and Communication Technologies to truly demonstrate the state's commitment to Science and Research Excellence? If so, please read on and repost this article.

Brief Review of the Current Causes and Compounding Pressures on SA's Marine Estate

The *Karenia mikimotoi* HAB currently affecting South Australia's marine waters is the latest and most severe in a growing series of ecological disturbances. While natural algal blooms have occurred for centuries, the duration, intensity, and spatial extent of this bloom point to the compounding influence of both global climate change and localised environmental degradation.

Key drivers include marine heatwaves, with sea surface temperatures off South Australia recently recorded at 2–2.5°C above average. These elevated temperatures provide optimal conditions for HAB-forming species such as *Karenia*, and are a direct symptom of global climate trends.

Oceanographic phenomena such as seasonal upwelling have further contributed by bringing deep, nutrient-laden water to the surface. When combined with increased surface temperatures and excess nutrients from catchment runoff and urban stormwater, these processes create ideal conditions for blooms to persist. The situation is worsened by the loss of natural buffers such as seagrass meadows. Along Adelaide's metropolitan coast alone, over 5,000 hectares of seagrass have been lost, weakening the ecosystem's capacity to cycle nutrients, stabilise sediments, and sequester carbon.

Local stressors, including sediment disturbance from dredging and sand movement, chemical runoff from agriculture and industry, and degraded stormwater systems, are interacting with these broader climate pressures. The result is a marine environment increasingly vulnerable to systemic collapse.

Emerging Threats and Future Risk Factors

Looking ahead, several factors are likely to continue driving harmful algal bloom events in South Australian waters. Marine heatwaves are predicted to become more frequent and severe, driven by a combination of climate change driven Marine Heatwaves (MHW) and shifts in ocean circulation patterns. These events do not occur in isolation — they often coincide with stormwater runoff from extreme rainfall events that deliver contaminants and nutrients from urban and agricultural areas directly to coastal waters. In South Australia, poor water quality events at beaches driven by stormwater runoff is frequent and severe enough to require Beach Alert and Beach Safe websites to provide information for the community on health advice and pollution.

Further industrial and coastal development, combined with limited vegetation buffers and outdated stormwater infrastructure, is also expected to increase the volume of pollutants entering the marine environment in the future. Emerging biosecurity risks associated with global shipping, aquaculture expansion, and ballast water discharge may also introduce or amplify HAB species in South Australian waters.

In this increasingly complex landscape, single-issue responses will not be sufficient. Effective management must address the compound nature of these threats, from warming seas and nutrient loading to habitat degradation and biosecurity challenges.

Towards a Smarter Marine Monitoring Approach

To manage and adapt to evolving threats, South Australia requires a new model of marine environmental surveillance. Traditional monitoring approaches — reliant on crewed vessels, infrequent sampling, and reactive reporting — are not adequate to detect early signals or track fast-changing marine events. The world is increasingly applying advanced technologies like automated

sampling and satellite remote sensing to provide real-time information and inform modelling of the environment.

A scalable solution is the use of dedicated, renewably-powered, uncrewed marine monitoring platforms, affectionately termed, Robo Boats. Operating autonomously and equipped with real-time environmental sensors, this system can deliver high-frequency, high-resolution data across both coastal and offshore regions. Unlike conventional monitoring, it would continuously collect physical, chemical, and biological data — including temperature, turbidity, chlorophyll-a, nutrient levels, HAB toxins, and oxygen dynamics — without the need for large crews or significant operational downtime. Experienced and qualified crew may account for more than half of the cost of collecting samples. This approach limits the amount of funding that can be used for sample analysis.

By integrating Robo Boats with satellite data and oceanographic models such as PIRSA's eSA-Marine, this system could offer predictive forecasts of bloom development and trajectory, delivering early warnings to aquaculture operators, fisheries managers, public health agencies, and the wider community. Importantly, the system could also support ecosystem recovery by monitoring dissolved oxygen levels, biodiversity indicators, and habitat conditions after bloom events.

Beyond responding to HABs, this technology would also serve broader marine management goals, including habitat mapping, compliance support for marine parks, beach replenishment monitoring, and data collection for coastal resilience and restoration efforts.

Strategic Value and Policy Alignment

This approach directly aligns with South Australia's commitments to climate adaptation, sustainable fisheries, marine park management, water quality improvement, and the Biodiversity Act. It also reflects national and international best practices in ecosystem-based marine governance, supporting the nation's commitment to the blue economy.

As pressure mounts from rising temperatures, more frequent extreme events, and growing coastal development, the case for investment in a forward-looking monitoring infrastructure becomes clear. A system of this kind offers more than improved environmental intelligence — it underpins the ability to make informed, adaptive decisions in the face of uncertainty, safeguarding marine biodiversity and the economic and social benefits it provides.

Conclusion

The current harmful algal bloom is not an isolated incident—it is a symptom of broader ecological strain. Addressing it requires more than temporary responses; it demands an integrated, resilient, and technology-enabled monitoring system that positions South Australia at the forefront of marine environmental management.

By investing now in scalable, renewably-powered, uncrewed monitoring solutions, the state can not only better prepare for the next crisis, but actively build a marine environment that is more robust, informed, and responsive to the realities of a changing climate.