Karenia mikimotoi: Key Lessons on the Toxic Algae Bloom in South Australian Waters

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Disclaimer: This work has been prepared for a future toxic algae bloom taskforce, whoever this may be, and anyone who is interested to learn about this environmental disaster. The author does not warrant that the information in this report is free from errors or omissions. The use of data and information contained in this report is at the user's sole risk. This report exclusively expresses the author's view and not that of Flinders University. This technical note may be cited as:

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Background

An unprecedented bloom of toxic algae of the species *Karenia mikimotoi* has infested the waters of South Australian gulfs since mid-March 2025. More details of the bloom spreading can be found in reference [1]. While the alga is harmless to humans, it can cause severe kills of a wide range of marine organisms, from worms, crustaceans to fish. Reference [2] presents an excellent comprehensive review of previous *K. mikimotoi* algae blooms spanning almost 100 years of studies

My motivation to write up this report came from widespread speculations about the causes of the toxic algae bloom, ranging from the Murray River flooding in 2023, a strong coastal upwelling event on the adjacent continental shelf in 2024, and/or a pronounced marine heatwave that occurred in 2025.

It is understandable that lay persons may make such claims, that may be based on hearing reports on other algae blooms from around the world, or coincidences of events that may not be related by cause and effects.

Expert scientists should base their statements on the best available scientific knowledge, and a key in the understanding of *K. mikimotoi* algae blooms is the growth rate of this species. So how do ambient conditions influence algae growth?

Lesson 1: Algae growth under saturated light and nutrient conditions

If the ambient conditions are suitable, the algae concentration increases over time due to the continuous division and growth of individual cells. The growth rate is a measure of the *speed* at which this cell division occurs. For instance, algal cells remain dormant if this growth rate is zero. The growth rate depends on both the existence of sufficient levels of light and dissolved nutrients in the water column, as well as the temperature and salinity (salt concentration) of the surrounding seawater.

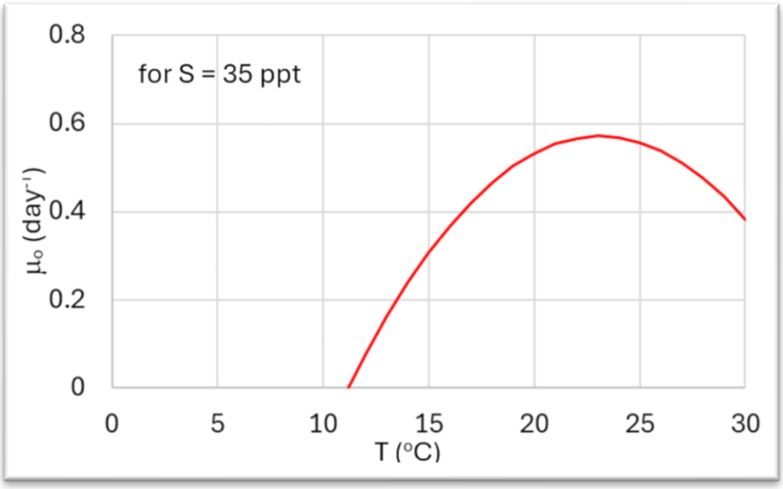
If we ignore specific light and nutrient requirements for a moment, the growth rate of *K. mikimotoi* can be expressed by a polynomial as a function of both temperature (T) and salinity (S). This formula is given by (reference [3]):

$$\mu_o(T,S) = 0.15T + 0.15S - 0.004T^2 - 0.003S^2 + 0.001S \times T - 3.142 \quad (1)$$

Equation (1) has been successfully used in previous and current theoretical studies that replicated the algae bloom development in different regions (see Reference [1] for other examples).

Lesson 1a: How Temperature Affects the Growth Rate

Graph 1 shows the form of this growth rate μ_o as a function of T for a constant typical seawater salinity of $S = 35$ g/l (ppt).



Graph 1: Maximum growth rate μ_o of of *K. mikimotoi* under saturated light and nutrient conditions for a constant salinity of $S = 35$ ppt using equation (1).

The following key features of algae growth can be learned from **Graph 1**:

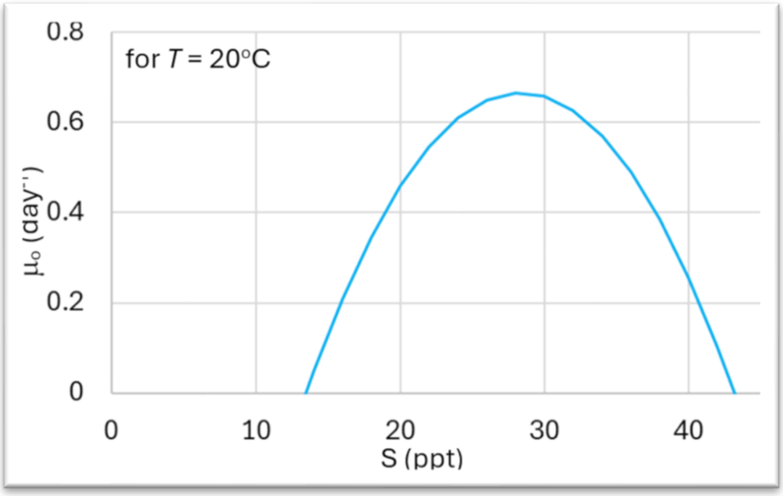
1. Algal growth does not occur in cold water $T < 12$°C.
2. The growth is the fastest in a temperature range from 20°C to 26°C.
3. The growth rate decreases in very warm waters >28°C.

The temperature of gulf waters and the region (outside Backstairs Passage) where the algae bloom was first detected on average exceeds 20°C in late summer (see reference [1]). Lifting this temperature by another 2-3°C has very little effect on the growth rate of *K. mikimotoi*.

Hence, it is likely that the 2025 marine heatwave had only little influence on the growth of the toxic algae bloom.

Lesson 1b: How Salinity Affects the Growth Rate

Graph 2 shows the form of the growth rate μ_o from equation (1) as a function of S for a constant water temperature of 20°C.



Graph 2: Maximum growth rate μ_o of of *K. mikimotoi* under saturated light and nutrient conditions as a function of salinity S (ppt) for a constant temperature of $T = 20$°C, derived from equation (1).

The salinity between 36 ppt and 39 ppt in large portions of South Australian gulfs ranges but reaches > 40 ppt in the upper reaches. Hence, the salinity effect on the growth rate of *K. mikimotoi* is highly relevant for the hypersaline environment of South Australian gulfs.

The key features that we learn from **Graph 2** are:

1. Algal growth cannot occur in low-salinity riverine environments with $S < 14$ ppt.
2. The growth is the fasted in a salinity range from 20 ppt to 35 ppt, that is, in both brackish water and common seawater environments.
3. The algae growth rate decreases under hypersaline conditions with S > 40 ppt.

The harmful alga cannot multiply in freshwater systems of rivers and lakes, which implies that rivers are not transport routes for this alga. Moreover, the growth rate decreases under hypersaline conditions, which gives hope that it the algae will have a lesser impact on the upper reaches of South Australian gulfs.

Lesson 2: The Timescale of Algal Bloom Development

Over time, the growth of *K. mikimotoi* becomes balanced by the mortality of algal cells and the loss in algae due to zooplankton grazing (see reference [1]). The characteristic timescale of algal bloom development is the timespan from the initial seed to the full bloom. This can be derived from mathematical considerations, presented in reference [1].

It turns out that this characteristic timescale is of the order of 1-2 months. Hence, the ultimate seed causing the toxic algae outbreak in South Australian waters happened 1-2 months before the first detection of the toxic bloom. This strongly suggests that the *K. mikimotoi* bloom was initiated in January-February 2025, and not 1-2 years earlier as speculated unfoundedly by some scientists.

Lesson 3: How Light Affects the Growth Rate

K. mikimotoi can grow under relatively low-energy light conditions. A low irradiance of ~1 W/m^2 still supports half the saturated growth rate. Even in winter, such light conditions correspond to 40-m water depth in clear water. Turbid conditions reduce the growth rate. Except close to coasts, light does not limit the growth rate of *K. mikimotoi* in South Australian waters.

Lesson 4: How Excess Nutrients Affect the Growth Rate

It is scientifically well established that an excess of nutrients in our waterways is a principal cause of harmful algae blooms in rivers that are going to worsen under the effect of global warming. This common knowledge relies on the growth of common harmful algae, such as blue-green algae, that thrive in waters with high levels of phosphorus and nitrogen and particular in warm water temperatures >25°C. But does this common knowledge also apply to the harmful algae *K. mikimotoi*?

No, unlike many other algae, *K. mimimotoi* can grow under very low nitrogen and phosphorus conditions and thrives mainly on ammonia (Reference [4]). Low ammonia levels of only 0.01 µmol per L still support half the saturated growth rate. Ammonia levels in South Australian waters tend exceed this value (see reference [1]).

Toxic algae blooms of *K. mimimotoi* do neither rely on nitrate-rich waters from coastal upwelling, nor on phosphorus-rich discharges from rivers. Hence, it is unlikely that river discharges or upwelling events caused this toxic algae bloom.

Summary

This scientific report contains four lessons that are key in the understanding of *K. mimimotoi* blooms. This report should be the "bible" for any natural scientist including plankton biologists in discussions around the development of *K. mimimotoi* blooms that occur worldwide, not only in South Australian waters.

The growth rate of *K. mimimotoi* described by equation (1) is key for these discussions, and any scientist making claims about the toxic algae bloom should be familiar with this growth rate. Statements issued by scientists must always be based on the best available scientific evidence and facts rather than unfounded speculations, rumours, and myths.

The report discussed several myths surrounding the cause of the toxic algae blooms including the Murray River flood in 2023, enhanced coastal upwelling in 2024, and/or the marine heatwave of 2025. Based on the scientific arguments provided, all these events can be ruled out as contributing factor for the outbreak of the toxic algae bloom in South Australian waters. So, what has caused it? Could the "conventional" discharge of ballast water be the major vector of this bio-invasion?

References

[1] Kämpf, J. (2025) Prediction of the spreading of an unprecedented Karenia mikimotoi bloom in South Australian gulfs. Preprint of a manuscript submitted to Continental Shelf Research in July 2025. https://doi.org/10.13140/RG.2.2.28102.59207

[2] Li, X., Yan, T., Yu, R., Zhou, M. (2019) A review of karenia mikimotoi: Bloom events, physiology, toxicity and toxic mechanism. *Harmful Algae* 90, 101702, https://doi.org/10.1016/j.hal.2019.101702

[3] Nielsen, M.V., Tonseth, C.P., 1991. Temperature and salinity effect on growth and chemical composition of Gyrodinium aureolum Hulburt in culture. *J. Plankton Res.* 13 (2), 389–398. https://doi.org/10.1093/plankt/13.2.389

[4] Vanhoutte-Brunier, A., Fernand, L., Ménesguen, A. Lyons, S., Gohin, F., Cugier, F., 2008. Modelling the Karenia mikimotoi bloom that occurred in the western English Channel during summer 2003. *Ecol. Modell.* 210(4), 351–376, https://doi.org/10.1016/j.ecolmodel.2007.08.025