Mauritian Coastal Algal Bloom: A Review on Occurrence, Pollution Sources and Associated Environmental and Human Health Risks

Chummun Vedendranand Sharma[1], Pushpa Tuppad[2]*, Suriyanarayanan Sarvajayakesavalu[3]

[1]National Environmental Laboratory, Ministry of Environment, Solid Waste Management and Climate Change, National Laboratories Complex, Reduit, Mauritius. Email: bhushanchummun@gmail.com
[2] Department of Environmental Engineering, JSS Science and Technology University, Mysore, India. Email: ptuppad@jssstuniv.in
[3] Faculty of Science, JSS Science and Technology University, Mysore, India. Email: asso.dean@jssstuniv.in

Abstract
One of the emerging public health and environmental problems in coastal systems is the algal blooms which are driven by the interaction of climate variability, nutrient enrichment and hydrodynamic processes. Mauritius, a Small Island Developing State (SIDS) experiences regular algal bloom events occurring especially in the eastern coasts (Belle Mare and Palmar) and western coasts (Flic en Flac and Wolmar). Further to this, there are cumulative consequences for marine ecosystems, fisheries, tourism and human health. A comprehensive desk-based synthesis of algal bloom occurrence in Mauritian waters from 1900 to 2025 is presented in this work which integrates peer reviewed literature, environmental datasets, and observational reports. Several key drivers such as anthropogenic nutrient inputs from agriculture, wastewater discharge and urbanization, seasonal climatic factors including rainfall and sea surface temperature, changing coastal hydrodynamics especially surface runoff vs submarine groundwater discharge were identified to initiate and catalyze the process. This resulted in producing large scale seasonal blooms on the eastern coast and more persistent localized blooms on the western coast. It was also found that several algae species found in Mauritian waters can produce toxins with potential implication for seafood safety, ecosystem health and tourism sector. It was hence proposed to shift towards integrated 'catchment to coast management', supported by AI-based predictive monitoring and early warning systems and also embarking in the sustainable valorization of algal biomass within the circular bioeconomy framework. This study provides a national-level synthesis that supports evidence-based policymaking, strengthens monitoring strategies, and identifies priorities for future research to advance sustainable coastal management in Small Island States such as Mauritius.

Keywords: Algal Blooms; Mauritius; Environmental Health; Circular Bioeconomy

1. Introduction

On a global scale, algal blooms are being increasingly addressed as major environmental concerns affecting coastal and marine ecosystems (Wells et al., 2015). In Mauritius, several algal bloom events have been recorded along the eastern and western coast notably in areas such as Belle Mare, Palmar, Flic-en-Flac, and Wolmar (Dulymamode et al., 2002; Prayag et al., 1995). Local newspapers have regularly captured the outcries of the local community, tourists and fishermen expressing their concerns on algal bloom occurrences causing ecological disruptions and potential socio-economic repercussions.

Excess nitrogen and phosphorous present in aquatic environments are the principal cause of eutrophication which is also the main cause of algal blooms (Anderson et al., 2002; Heisler et al., 2008). Several activities which are human induced, namely the speedy development of coastal areas, agricultural runoff and the discharge of untreated or partially treated wastewater largely contribute to the presence of high levels of nutrients in marine waters (Heisler et al., 2008; Howarth et al., 2011; Paerl et al., 2016a). Simultaneously, factors such as rising sea surface temperatures, increase in extreme weather events and changing rainfall patterns have been demonstrated to catalyze the frequency, duration and toxicity of algal blooms (Paerl et al., 2016b; Wells et al., 2015). Consequently, the diverse and significant impacts of algal blooms have affected human health and the environment.

The accumulation of toxins in marine food chains produced by certain algae have shown to cause shellfish contamination, health risks for humans and fish mortality (Anderson et al., 2002; Backer et al., 2015). Ecosystem disruptions have been caused by the presence of large algal biomass reducing the oxygen concentration in seawaters thus forming low oxygen areas whereby making it difficult for marine organisms to survive (Diaz and Rosenberg, 2008). As a result, to this, seawater quality deteriorates leading to non-use of beaches, thus affecting the tourism industry and also the livelihood of fishers (Hoagland et al., 2002; Scavia et al., 2014).

In Mauritius various activities of economic importance namely sugarcane and vegetable crops cultivation and the maintenance of golf courses for luxurious recreational activities heavily rely on chemical fertilizers (Teeluck and Ah King, 2007). As a result of heavy fertilization process combined with a heavy rainfall event, runoff from these land-based activities cause transport of nutrients into seawater (Dulymamode et al., 2002; Ramessur, 2001). Consequently, eutrophication and the occurrence and proliferation of algal species occur (Paerl and Otten, 2013).

In Mauritius several studies have been conducted on algal bloom describing their occurrence in distinct locations. However, these studies have remained segregated and largely site specific. Existing literature has been focusing

on one time occurring bloom events focusing on specific algal groups only. This has not offered a comprehensive national level synthesis of algal bloom distribution, diversity, toxin characteristics and usage (if present). Also, limitations have been noticed in the monitoring frameworks and policy making.
Furthermore, it is considered that important developmental activities such as coastal urban expansion and intensification of agricultural activities would further increase the occurrence of eutrophication and algal bloom events. Also, the watershed process and coastal hydrodynamics undergo complex interaction in Mauritius, which is yet to be understood. For small island states like Mauritius, where resources remain limited, it has been viewed that a comprehensive and detailed desk-based analysis could figure out a stepping stone towards the establishment of an integrated and long-term management strategy.
The objectives of this study are to:
(i)capture, compile and synthesise important data on the occurrence, composition of species, usage of algae and toxin profiles of algae in Mauritian waters.
(ii) identify point and non-point sources, main drivers and factors contributing for the occurrence of algal bloom.
(iii) evaluate the environmental and human health risks linked to algal presence.
(iv) propose recommendations for future research on algal dynamics in Mauritius.

2. Materials and Methods

2.1 Country Profile

Mauritius a Small Island Developing State (SIDS) located in the Indian Ocean with a population of approximately 1.2 million inhabitants (Statistics Mauritius, 2026). The island is located approximately 800 km to the east of Madagascar and it inherits a central plateau surrounded by coastal lowlands and typical maritime climate with an average annual temperature close to 22 °C and notable variability in seasonal precipitation patterns (Rufford et al., 2014).
The national yearly mean rainfall is 2010 mm which is unevenly distributed over the island causing more precipitation in the elevated regions (Mauritius Meteorological Services, 2020; Rufford et al., 2014) mostly in summer (November to April). The winter (May to October) is relatively cool and characterized by low rainfall (Mauritius Meteorological Services, 2020). On the other hand, the relative humidity exceeds 70% and remains high throughout the year. Temperatures fluctuate between 20 °C in winter and 30 °C in summer. Ongoing changes in climate, land scarcity and dense population distribution are causing irregularities in rainfall distribution and also intensifying extreme weather events such as droughts and floods (Bang, 2013; Dhurmea et al., 2019; Seebocus et al., 2021).
The country enjoys an upper middle-income status, where 74 to 76% of the gross domestic product is dominated by the service sector followed by the industry and agriculture (Statistics Mauritius, 2024). In 2024, GDP was estimated at nearly USD 15 billion, with a growth rate of around 4.7 to 4.9%, reflecting continued recovery following the COVID-19 pandemic. Key drivers of this growth include tourism, financial services, and construction activities (Statistics Mauritius, 2024).
Recently, the blue economy sector has emerged as a new developmental sector for Mauritius, whereby it is predicted that more and more jobs will be created in sectors such as marine biotechnology, ocean-based renewable energy, aquaculture and fisheries (UNDP, 2022; OECD, 2020). In Africa, Mauritius, though constantly pressurized by growing threat from external economic shock and environmental hazards, is regarded as a model showcasing one of the highest standards of economic growth, progress and development (Sobhee, 2009).

2.2 Site Selection

The locations selected in this study include Belle Mare and Palmar (eastern coast) and Flic en Flac and Wolmar (western coast). These two study locations were chosen based on an extensive review of scientific literature, analysis of media reports, and information obtained from tourism-related sources. Additionally, the study also considered other coastal regions where algal blooms occurrences have been previously documented.
A comparative summary of the environmental and hydrological characteristics of the eastern and western coastal zones is presented in Table 2.2.

Table 2.2: Comparative Environmental Characteristics of Eastern and Western Coastal Regions
(Adapted from: Boojhawon et al., 2014; Government of Mauritius, 2013; UNEP, 2010; Ghyoot et al., 2017)

Coastal Region	Key Sites	Dominant Land Use	Primary Hydrological Pathway	Lagoon Morphology	Vulnerability to Algal Blooms (ABs)
Eastern Coast	Belle Mare, Palmar	Sugarcane, Wetlands, Tourism, Golf course, small scale farmers	Surface Runoff	Wide, Shallow, Open	Large-scale, seasonal blooms post-rainfall
Western Coast	Flic-en-Flac, Wolmar	Urban, Tourism, Sugarcane	Submarine Groundwater Discharge (SGD)	Narrow, Semi-enclosed	Localised, persistent blooms near discharge

Eastern Coast (Belle Mare and Palmar)
The eastern part of Mauritius, most specifically the coastline along Belle Mare and Palmar region has limited urban expansion and consists of low-density infrastructure. Sugarcane cultivation, vegetable cropping, wetlands and marshy land describe the land use of the region (Government of Mauritius, 2013; Boojhawon et al., 2014).

The coastal zone of the eastern region consists of an extensive sandy shoreline and the lagoon is broad and shallow. Water exchange occurs naturally and this can enable the addition of excessive nutrients from terrestrial system (UNEP, 2010).

Two main rivers, namely Riviere du Poste and Riviere Seche are part of the surface water network in the region. However, the region also consists of several small to medium river catchments. The surface water network transports freshwater, sediments and nutrients into the lagoon especially during heavy rainfall events (Ghyoot et al., 2017). In terms of geology, basaltic formations of volcanic origin dominate the eastern region. These enable relatively low permeability as compared to the western coastal aquifers. The eastern geological structure encourages surface runoff which is also the primary pathway for pollutant transport (Padya, 1989; Ghyoot et al., 2017).

Western Coast (Flic-en-Flac and Wolmar)

The western regions, especially regions such as Flic en Flac and Wolmar are characterized by urbanization and high tourism related development. The region has seen a rapid infrastructural development, and this has led to the reduction of vegetative cover, however, sugarcane cultivation still persists (Government of Mauritius, 2013). Compared to the eastern coastal lagoon system, the western lagoon system has inherited a narrower and semi enclosed system which leads to reduced water circulation, flushing capacity and resulting in making the system more susceptible to the accumulation of nutrients and pollutants (UNEP, 2010).

The Curepipe aquifer system influences the western region, dominated by groundwater-driven processes rather than surface runoff. This makes pollutants to be primarily transported via subsurface pathways through submarine groundwater discharge particularly in areas such as Wolmar (Ghyoot et al., 2017; Boojhawon et al., 2014).

Highly permeable volcanic basalt and sandy soils are part of the geology of the western coast. These are characterized by permeable volcanic basalt and sandy soils. This encourages infiltration rates and subsurface flow. All these facilitate the movement of nutrients, pollutants and contaminants directly into the lagoon through submarine groundwater discharge. This in turn results in initiating algal bloom formation (Ghyoot et al., 2017).

Figure 2.2: Location of study sites (EOSDA LandViewer, 2026)

2.3 Study Design and Data Sources

This research work used a desk-based research approach whereby a synthesis of multiple data sources was conducted to produce a comprehensive and robust assessment of algal bloom in Mauritian waters. Data were reviewed from various sources namely: peer reviewed scientific papers, government and institutional reports and observational data from stakeholders and press reports.

Literature Search Strategy:
Scientific peer-reviewed papers were extracted from Google Scholar and Scopus databases. The key search strings involved (''algal bloom'') and ''Mauritius'' and ''eutrophication and ''Mauritius'' and ''coastal''.
The scientific databases were accessed during the months of March and April 2026. For this research work, peer reviewed articles published between 1990 and 2025 were considered to capture the full temporal range of documented events. It was deemed important to only consider peer reviewed studies directly relevant to algal dynamics in Mauritius.

3. Results and Discussion

3.1 Review of Local Studies

In Mauritius, studies have been conducted to address the role of nutrient enrichment and land-based pollution in coastal water degradation. Nutrients coming from agricultural and wastewater were identified as the prime contributors to eutrophication in coastal waters (Dulymamode et al., 2002). On the same note, it was reported that high levels of nutrients and microbial pollution along the coast are linked to human based activities (Ramessur, 2001).
Regional studies further indicate seasonal variability in phytoplankton dynamics, with peak bloom occurrences during warmer months associated with increased rainfall and nutrient loading (AFRC, 2020; Sookun and Nazurally, 2025). Despite these findings, existing studies remain predominantly descriptive, lacking the integration of long-term, high-frequency data needed for predictive modelling.

3.2 Factors Influencing Occurrence of Algae in Mauritian Waters

Synthesis of algal occurrences

A comprehensive synthesis of documented algal occurrences from 1990 to 2025 is presented in Table 3.2a. The compilation shows that multiple factors govern and control algal dynamics in Mauritius. The table also presents documented uses and toxin profiles associated with types of algae present in Mauritian waters.

Table 3.2a: Documented Algal Occurrences in Mauritian Waters (1990–2025) and associated toxin profiles

Year	Type of Algae	Documented Uses / toxin profile	Presence Detected	Season/Month Detected	Reference
1990	Mixed Phytoplankton	Possible microcystins (Cyanobacteria)	Lagoon-wide	Summer (Dec-Mar)	Fagoonee, I., 1990; Carmichael, 2001
1993	Macroalgae (*Sargassum*, *Gracilaria*)	Fertilizer and animal feed	Baie du Tombeau, Pointe aux Sables	Winter (June-Aug)	Jagtap, T.G., 1993; McHugh, 2003; Holdt and Kraan, 2011
2001	Algal growth (Chlorophyll linked)	N/A	Belle Mare and Palmar	Not Specified	JICA, 2001; Anderson et al., 2002
2002	General algal proliferation	N/A	10 coastal sites (Flic-en-Flac, Belle Mare, Palmar)	Not Specified (Linked to fertilizer/wastewater)	Dulymamode, R. et al., 2002; Anderson et al., 2002
2002	*Ulva lactuca* (Macroalgae)	Biofertilizer, animal feed, bioenergy potential	Belle Mare Lagoon	Summer (Jan-Mar)	Ramlugun, N., 2002; Cai et al., 2013
2003	Dinoflagellates / Red Tides	Possible saxitoxins/brevetoxins	Port Louis Harbour	Summer (Dec-Feb)	Daby, D., 2003; Landsberg, 2002
2004	Marine macroalgae (Green & Brown)	N/A	Rodrigues Island	Not Specified (Baseline study)	Coppejans, E. et al., 2004; Anderson et al., 2002

2008	*Gambierdiscus toxicus*	Ciguatera fish poisoning (CFP) risk	Trou aux Biches / Albion	Summer (Jan-Apr)	Turquet, J. et al., 2008; Litaker et al., 2010
2009	*Oscillatoria* spp. (Cyanobacteria)	Potential biofuel	Flic-en-Flac	Summer (Feb-Mar)	Mauritius Oceanography Institute, 2009; Singh et al., 2011
2011	*Gracilaria* & *Sargassum*	Biomass uses	Grand Baie / Tombeau Bay	Winter	Daby, D., 2011; Holdt and Kraan, 2011
2012	Algal blooms (Nutrient linked)	N/A	Grand River North West, Albion, Flic-en-Flac	Not Specified	Bissembur, et al., 2012; Anderson et al., 2002
2012	*Oscillatoria* spp. & Diatoms	Carbon sequestration (Diatoms)	Lagoon waters (General)	Summer (Dec-Mar)	Frouin, P. et al., 2012; Field et al., 1998
2012	*Symbiodinium* (Zooxanthellae)	Possible biotechnology potential – antioxidants and pigment	Coral reefs (Multiple sites)	Summer (Jan-Apr)	Bhagooli, R. and Taleb-Hossenkhan, N., 2012; Shigeo et al., (2010)
2013	Phytoplankton	N/A	Lagoonal waters (Grand Baie)	Summer	Ramessur, R.T., 2013
2014	Amphipod-associated Algae	N/A	Various Lagoon Sites	Winter	Appadoo, C. and Hoole, N., 2014
2016	Microalgal / Dinoflagellates	N/A	Flic-en-Flac, Belle Mare, Albion	Summer (Dec-Mar)	Sadally, S.B. et al., 2016
2018	Toxic Dinoflagellates	Saxitoxins and okadaic acid	Lagoonal sediments	Summer (Jan-Mar)	Turner et al., 2018
2019	Cyanobacteria	Microcystins	Piton du Milieu Reservoir	Not Specified	Ballah, et al., 2019; Carmichael, 2001
2019	Algal proliferation	N/A	Belle Mare, Palmar, Flic-en-Flac	Not Specified	UNEP, 2019
2020	*Turbinaria ornata*	Bioactive compounds; antioxidant properties	Coastal Lagoons	Winter (Jun-Sep)	Sadeer et al., 2020
2020	Dinoflagellates	Possible Saxitoxins and okadaic acid	Flic-en-Flac, Belle Mare	Not Specified	Shaama, et al., 2020; Turner et al., 2018
2020 – 2022	Benthic dinoflagellates	Possible ciguatoxins/ovatoxins	Grand Baie, Albion, Blue Bay, Le Morne	Not Specified	Neermul, et al., 2022; Litaker et al., 2010
2021	Zooxanthellae	Potential applications: bioactive compounds	Anse la Raie / Bel Ombre	Summer	Bhagooli, R., 2021; Carreto and Carignan (2011)
2021	Harmful Algal Blooms (HABs)	Mixed toxins	Belle Mare / Trou d'Eau Douce	Summer	Ministry of Blue Economy, 2021;

					Anderson et al., 2012
2021	Cyanobacteria	Microcystins	Blue Bay, Albion, Balaclava	Not Specified	Sooroojebally, et al., 2021; Carmichael, 2001
2022	Micro-phytobenthos	bioindicators	Trou aux Biches	Summer (Jan-Mar)	Kaullysing, D. et al., 2022; Araujo et al., 2010
2022	Diatoms, Dinoflagellates	Possible domoic acid	Trou aux Biches	Not Specified	Ramessur, et al., 2022; Bates et al., 1998
2022	Dinoflagellates	Multiple toxins	Trou aux Biches	Summer	Soondur, et al., 2022; Anderson et al., 2012
2022	Cyanobacteria	Microcystins	La Ferme Reservoir	Summer	Ballah, et al., 2022; Carmichael, 2001
2023	*Enteromorpha* spp.	Biofertilizer	Albion / Pointe aux Sables	Summer (Feb-Apr)	Ranghoo-Sanmukhiya, M., 2023; Cai et al., 2013
2024	*Rhexinema paucicellulare*	N/A	Freshwater/Coastal transition	Summer	Bhagea, R., Bhoyroo, V. and Puchooa, D., 2024
2025	Dinoflagellates (*Coolia*, *Ostreopsis*)	Palytoxin-like compounds	Flic-en-Flac, Wolmar, Trou aux Biches	Summer (Dec-Apr)	Mussai, et al., 2025
2025	Dinoflagellates & Cyanobacteria	Mixed toxins	Flic-en-Flac, Belle Mare, Palmar	Not Specified	Sookun, N. and Nazurally, N., 2025; Anderson et al., 2012
2025	HABs (General)	Mixed toxins	Flic-en-Flac	Not Specified	Nazurally, et al., 2025; Anderson et al., 2012

Following the compiled dataset (1990 -2025), algal occurrence in Mauritius is understood to be controlled by multi-factorial interactions, which can be categorised into five primary drivers:

1. Seasonal Climatic Driver:

Algal bloom predominance is present during the summer period from November to April in Mauritian coastal water. Thus, seasonality emerges as a primary natural driver. Optimal conditions for algal bloom development and proliferation are created by elevated sea surface temperatures (SSTs), increased solar irradiance, and enhanced water column stratification (Daby, 2003; Frouin et al., 2012).

This seasonal influence is particularly evident across the selected study sites, although the expression of blooms varies between the eastern and western coastal systems due to differing hydrological and geomorphological characteristics. On the eastern coast (Belle Mare and Palmar), high summer rainfall over the central plateau generates surface runoff, transporting nutrients via river systems into the lagoon. This diffuse nutrient loading, combined with warm and shallow lagoon conditions, promotes the development of large-scale macroalgal blooms, particularly following intense rainfall events (Ramlugun, 2002; Boojhawon et al., 2014; Ghyoot et al., 2017).

On the western coast, the development of persistent and spatially confined blooms, mostly dinoflagellates and benthic microalgae, is encouraged under warm conditions catalyzed by localized nutrient inputs and combined with reduced lagoon flushing. All this is greatly influenced by elevated sea surface temperatures during summer whereby nutrient discharged are delivered through submarine groundwater discharge and coastal seepage. (Daby, 2011; Sadally et al., 2016; Mussai et al., 2025).

2. Anthropogenic Nutrient Driver:
Nutrient enrichment (human induced) is identified as a trigger for algal proliferation in coastal water in Mauritius. Algal growth has been stimulated via the discharge of untreated or partially treated wastewater, agricultural runoff mainly due to synthetic fertilizers input and increasing coastal urbanization which give rise to an elevated level of nitrogen and phosphorous (Dulymamode et al., 2002; Bissembur et al., 2012; UNEP, 2019).
The effect of human induced actions across both study sites is visible, however, different patterns have been observed at the sites. Surface runoff, originating from agricultural related activities especially sugarcane cropping and vegetable farming, is the main factor contributing towards nutrient enrichment on the eastern coast. This normally occurs after rainfall events, whereby synthetic fertilizers and agrochemicals are transported through river systems and via storm water drains into the lagoon. Microalgae such as *Ulva lactuca* and *Enteromorpha* spp rapidly proliferate in these conditions causing eutrophic conditions (Ramlugun, 2002; Boojhawon et al., 2014; Ng Kee Kwong et al., 2002).
On the other hand, the western coast is influenced by point and subsurface nutrient sources associated with urbanisation, tourism infrastructure, and wastewater disposal systems. Submarine groundwater discharge and septic system leakage are the primary causes and pathway for nutrient transport into nearshore waters. The reduced flushing capacity of these semi-enclosed lagoons further exacerbates nutrient accumulation, favouring continuous algal growth and recurrent bloom events, particularly in areas adjacent to discharge zones (Daby, 2011; Boojhawon et al., 2014; UNEP, 2019).

3. Hydrodynamic and Spatial Driver:
Hydrodynamic conditions and water circulation play a fundamental role in controlling algal distribution, accumulation, and persistence in Mauritian coastal lagoons. These processes vary significantly between the eastern and western study areas, namely Belle Mare and Palmar (east coast) and Flic-en-Flac and Wolmar (west coast), due to contrasting lagoon morphology and hydrological regimes.
On the western coast (Flic-en-Flac and Wolmar), narrow and semi enclosed lagoons result in reduced flushing capacity and longer water residence times. The development of localized blooms is thus promoted by these conditions (Fagoonee, 1990; Daby, 2011).
Furthermore, submarine groundwater discharges receiving nutrient inputs are associated with permeable basaltic aquifers. This in turn leads to the continuous and spatially concentrated nutrient enrichment (Ghyoot et al., 2017; Boojhawon et al., 2014) which explains the occurrence of persistent and patchy blooms, particularly near discharge zones in Wolmar and Flic-en-Flac, as reported in recent observations (Mussai et al., 2025).
The eastern coast, in the contrary is characterised by wide, shallow, and more open lagoon systems with stronger hydrodynamic exchange with the open ocean (UNEP, 2010). However, this increased flushing is counterbalanced by substantial diffuse surface runoff originating from multiple river catchments, particularly during the wet season (Padya, 1989; Ghyoot et al., 2017). As a result, nutrient inputs are distributed over a broader spatial scale, leading to large-scale, seasonal bloom events rather than localised persistence (Ramlugun, 2002).

4. Emerging Toxin Threat:
The algal community composition and toxicity in coastal waters of Mauritius are highly influenced by long term climate change effects and temperature variability. Rising sea surface temperature during the summer season has also been linked to the proliferation of algae namely dinoflagellates such as such as *Gambierdiscus toxicus*, *Ostreopsis spp.*, and *Coolia spp.* In Mauritian waters (Turquet et al., 2008; Mussai et al., 2025).
In the western lagoon systems of Flic-en-Flac and Wolmar, where water circulation is limited and residence times are high, these environmental conditions create ideal niches for the proliferation of benthic toxic dinoflagellates. Numerous studies have demonstrated the presence of palytoxin-like compounds and marine biotoxins in the western region of the island which if exist persistently can increase the likelihood of toxin accumulation within the marine food webs (Mussai et al., 2025; Turner et al., 2018).
On the eastern coast, high nutrient influx after rainfall events coupled with rise in sea surface temperature promotes proliferation of harmful algae (Dulymamode et al., 2002; Ramessur, 2013). Toxin producing algal blooms mostly occurring during the summer period can have serious ecological and public health implication. Compounds such as ciguatoxins and palytoxins are associated with ciguatera fish poisoning (CFP) and other health risks, affecting fisheries, seafood safety, and tourism-dependent economies (Turquet et al., 2008; Anderson et al., 2012).

Harmful Algal Blooms (HABs)
Harmful algal blooms (HABs) are described as the speedy propagation of microalgae such as dinoflagellates, diatoms and cyanobacteria. This in turn produces toxins causing ecological disbalance and disturbance in the marine environment. Similar to algal blooms, the propagation of HABs is driven by nutrient enrichment, rise is sea surface temperatures, favourable hydrodynamic conditions which are associated with anthropogenic activities and the changing climate (Anderson et al., 2002; IPCC, 2019; Gilbert, 2020).
In the Mauritian context, several studies have documented the presence and spatial-temporal variability of potentially harmful benthic dinoflagellates such as *Prorocentrum*, *Ostreopsis*, *Gambierdiscus* and *Coolia* in lagoonal environments, with monitoring programmes indicating recurrent high cell densities across coastal sites.
Numerous environmental and health risks are associated with HABs (Anderson et al., 2012). In the marine environment, oxygen depletion, habitat degradation and mortality of marine organisms are linked. The consumption of seafood, contaminated with toxins from HABs or contact with affected waters can result in serious

human illnesses such as ciguatera fish poisoning, paralytic shellfish poisoning and respiratory or gastrointestinal disorders (Shumway et al., 2003).
Six major algal groups (table 3.2b) are present in Mauritian waters. However, there is a strong dominance of dinoflagellates, cyanobacteria and diatoms, which are also key contributors to harmful algal blooms.

Table 3.2b: Major Algal Groups and Associated Impacts

Algal Group	Examples in Mauritius	Primary Impacts
Dinoflagellates (Dinophyceae)	*Gambierdiscus toxicus*, *Ostreopsis* spp., *Coolia* spp.	Toxin production (ciguatera, palytoxin-like compounds); fish kills; shellfish contamination
Diatoms (Bacillariophyceae)	Mixed species	Dense blooms affecting oxygen levels; carbon sequestration potential
Cyanobacteria (Blue-Green)	*Oscillatoria* spp.	Microcystin production; hypoxia; biofuel potential
Green Algae (Chlorophyta)	*Ulva lactuca, Enteromorpha spp,*	Hypoxia and anoxia from decomposition; reduced light penetration; valorisation potential (biofertilizer, animal feed)
Brown Algae (Phaephyceae)	*Sargassum, Turbinaria ornate*	Occasionally from nuisance accumulations
Red Algae (Rhodophyta)	*Gracilaria*	Agar and feed production (uses)

Important environmental and public health risk are posed by the proliferation of algal groups in Mauritian waters, mainly cyanobacteria, dinoflagellates and certain diatom species. Cyanobacteria such as *Oscillatoria* reported in coastal areas are known to produce microcystins, which can contaminate drinking water supplies and cause liver toxicity in humans and animals (Ballah et al., 2019; Sooroojebally et al., 2021).
Dinoflagellates, including *Gambierdiscus*, *Ostreopsis* and *Coolia*, represent the most critical group due to their direct link with HABs and toxin production; these species are associated with ciguatera fish poisoning (CFP) and the release of palytoxin-like compounds, posing risks through seafood consumption and recreational water exposure in lagoon areas (Turquet et al., 2008; Neermul et al., 2022; Mussai et al., 2025).
Besides, diatoms identified in Mauritian lagoons may produce domoic acid under favourable environmental conditions and contribute to amnesic shellfish poisoning and affect marine food webs (Ramessur et al., 2022).
Macroalgae such as *Ulva lactuca*, *Sargassum*, *Turbinaria ornata* and *Gracilaria* are generally non-toxic but the excessive growth, mostly driven by nutrient enrichment can lead to eutrophication, oxygen depletion, habitat damage and decline in coral reef health (Daby, 2011; Ranghoo-Sanmukhiya, 2023). It is important to note that the presence of algae is essential to ecosystem function, however, if their proliferation occurs in an uncontrolled manner in Mauritian waters, disruption to ecological functioning can occur affecting the fishing and tourism industry and also pose serious threat to human health.

5. Biological Interactions:

Biological interactions and ecosystem-level processes further regulate algal dynamics in Mauritian coastal environments, influencing species composition, seasonal succession, and ecosystem resilience.
Algal proliferation has been demonstrated to occur mostly during the summer season in Mauritius however species such as *Sargassum*and *Gracilaria* becoming more prevalent during cooler months (Jagtap, 1993; Appadoo and Hoole, 2014). Fluctuations in nutrient availability linked to rainfall precipitation and subsequent runoff drive seasonal transitions in the eastern sea of Belle Mare and Palmar.
In Mauritian waters, coral bleaching has been observed in areas adjacent to both the eastern and western lagoons due to elevated sea surface temperature and nutrient enrichment disturbing the symbiotic relationship between corals and zooxanthellae (Symbiodinium spp.) (Bhagooli and Taleb-Hossenkhan, 2012; Bhagooli, 2021).

3.3 Environmental and Socio-Economic Drivers

Algal bloom occurrence in Mauritian waters is influenced by a combination of environmental and anthropogenic drivers. Agricultural runoff, synthetic fertilizer application and wastewater discharge can significantly increase nitrogen and phosphorous concentration (Heisler et al., 2008; Paerl and Otten, 2013). In Mauritius, studies conducted by Dulymamode et al. (2002) and Bissembur et al. (2012) have linked coastal eutrophication to land-based human induced activities.
On the other hand, climatic factors have also played a significant role in promoting algal growth. Increased rainfall intensifies nutrient runoff from surrounding land into water bodies, while rising sea surface temperatures create favorable conditions for algal proliferation. In addition, the frequent occurrence of cyclones in the region

resuspends sediments and nutrients, further enriching the water and supporting algal blooms (Ramessur, 2013; Shaama et al., 2020; Wells et al., 2015).

Comparison of the total annual rainfall data, mean sea surface temperature and algal bloom occurrence in Mauritius

The annual variability in rainfall, sea surface temperature (SST), and algal bloom occurrence between 2020 and 2024 (Table 3.3a) highlights a clear linkage between hydro-climatic conditions and bloom dynamics in Mauritius.

Table 3.3a Total annual rainfall data, mean sea surface temperature and algal bloom occurrence in Mauritius

Year	Total Annual Rainfall/mm	Mean Sea Surface Temperature/ ºC	Algal bloom Occurrence/season	Algae Species	References
2020	1993	25.7	winter	*Turbinaria ornata*, Benthic Dinoflagellates, Dinoflagellates	Statistics Mauritius 2024; Sadeer et al., 2020; Shaama, et al., 2020; Neermul, et al., 2022;
2021	2025	26.2	summer	Zooxanthellae, HAB, Cyanobacteria	Statistics Mauritius 2024; Bhagooli, R., 2021; Ministry of Blue Economy, 2021; Sooroojebally, et al., 2021;
2022	2201	25.8	summer	Microphytobenthos, Diatoms, Dinoflagellates, Cyanobacteria	Statistics Mauritius 2024; Kaullysing, D. et al., 2022; Ramessur, et al., 2022; Soondur, et al., 2022; Ballah, et al., 2022;
2023	2543	26.4	summer	Enteromorpha sp.	Statistics Mauritius 2024; Ranghoo-Sanmukhiya, M., 2023;
2024	2180	26	summer	*Rhexinema pancicellulare*	Statistics Mauritius 2024; Bhagea et al., 2024

Total annual rainfall increased from 1993 mm in 2020 to 2543 mm in 2023, before slightly reducing to 2180 mm in 2024. Sea surface temperature showed a gradual rise from 25.7°C to 26.4°C in 2023, followed by a decrease to 26.0°C in 2024. The increase in rainfall and sea surface temperature confirms that bloom development favors warmer and wetter conditions.

Under lower sea surface temperatures in the winter season, algal bloom was characterized by the development of algae species such as *Turbinaria ornata*, benthic dinoflagellates, and dinoflagellates. Furthermore, since 2021, increasing rainfall and sea surface temperatures have been accompanied by a noticeable shift in the algal community, with potentially harmful groups such as cyanobacteria, zooxanthellae, and dinoflagellates becoming more prominent. In 2022, algae such as microphytobenthos, diatoms, dinoflagellates, and cyanobacteria showed high predominance indicating that high nutrient inputs coupled with warm temperatures can support the proliferation of algae.

In 2023 and 2024 blooms were dominated by *Enteromorpha* sp. in 2023 and *Rhexinema pancicellulare* in 2024. This could be characterized by eutrophic conditions in the lagoon associated with fewer or single taxa.

Rainfall:

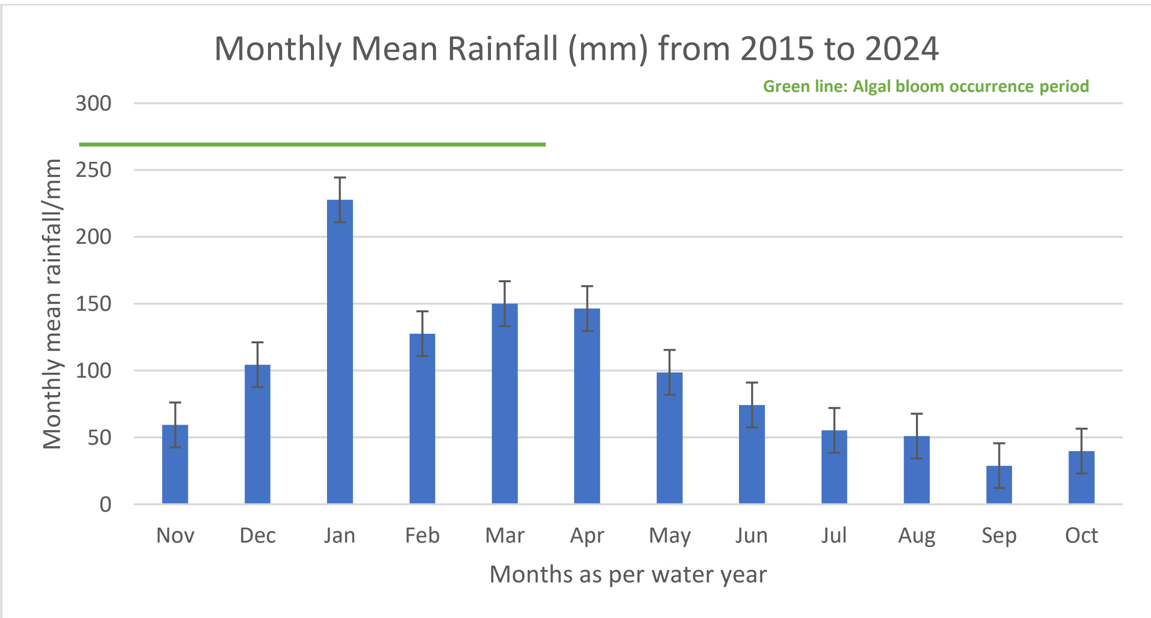

Figure 3.3b: 10 years rainfall data and algal occurrence from 'Fuel Station' weather station (closest to Belle Mare and Palmar Region)-data source: Statistics Mauritius, 2024

Rainfall data from the meteorological station located in closest proximity to Belle Mare demonstrates a seasonal variability that plays a pivotal role in regulating algal bloom dynamics in the eastern lagoon system. Analysis of the long-term monthly means indicates that most precipitation occurred during the summer months, particularly in January (227.7 mm), March (150.1 mm), and April (146.4 mm), with a secondary peak observed in December (104.4 mm). In the contrary, lower rainfall was recorded during the winter months, between July (55.3 mm) and September (28.9 mm). This corresponds with the timing of algal blooms occurrence, well documented by Daby (2003) and Frouin et al. (2012).
Elevated rainfall enhances surface runoff from agricultural and terrestrial catchments, facilitating the transport of nutrients, particularly nitrogen and phosphorus into lagoon systems, thereby promoting eutrophication and phytoplankton proliferation (Dulymamode et al., 2002; Heisler et al., 2008; Paerl and Otten, 2013).
Furthermore, the data trends (figure 3.3b) show that extreme rainfall events have occurred in 2021 and 2023, which can be linked to increased nutrient runoff; thus encouraging algal proliferation. The observation and findings indicate that increased precipitation and runoff are key drivers of algal blooms in seawaters (Wells et al., 2015; Paerl et al., 2016).

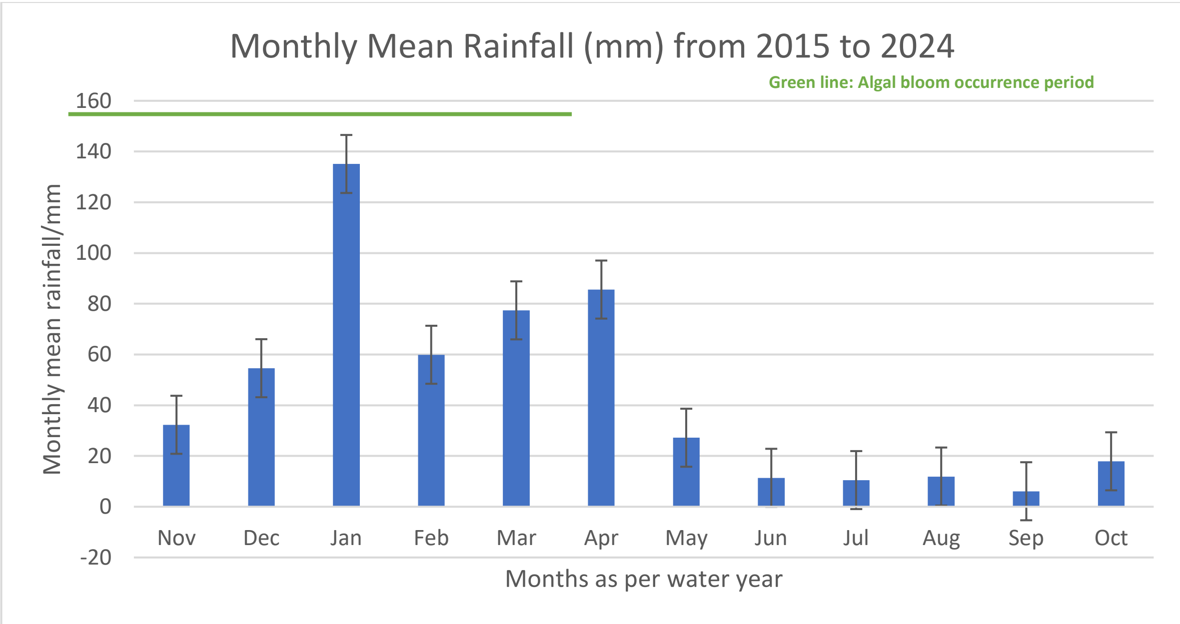

Figure 3.3c: 10 years rainfall data from 'Medine Station' weather station (closest to Flic en Flac and Wolmar Region)

The rainfall data from the western coast of Mauritius indicates a wet season from January to April, with peak rainfall in January (135.1 mm), and a prolonged dry period from June to September. The orographic rain shadow effects cause reduced rainfall (Padya, 1989; Mauritius Meteorological Services, 2020).
This intense rainfall can cause nutrient runoff into coastal lagoons thereby creating the optimum condition for algal bloom initiation (Anderson et al., 2002).
Furthermore, the data reveal that extreme rainfall events recorded in 2023 and 2024 whereas dry conditions prevailed from 2020 to 2022. The pattern indicates that further to an intense rainfall event after a dry season, sudden nutrient discharge in nearshore waters can enhance eutrophication processes and stimulate the proliferation of algal species (Heisler et al., 2008; Glibert et al., 2018).

Socio-Economic Drivers:

Though tourism has been identified as the main economic driver in the eastern and western region of the island, their contributions and development strategies are different. The western region is characterised by a high-volume tourism industry, with approximately 500000 tourists annually and this industry generates some 4000 to 5000 jobs (L'Express, 2005). Recent infrastructure investments, including the B70-A23 road link (inaugurated December 2025) and the ongoing Tamarina-Wolmar road (expected June 2026), have further strengthened regional accessibility and commercial development, including the extension of Cascavelle Mall.
In the eastern region, Belle Mare hosts tourism-focused resorts, while Palmar is the focus of a government-led master plan for major tourism expansion on 238 arpents (81 hectares) of State land, including three hotel sites, commercial complexes, an eco-tourism project, and a desalination plant (Economic Development Board, 2023). Both regions also retain small-scale artisanal fisheries, though fishing has largely been surpassed by tourism as the primary livelihood. The region is also an important area whereby small-scale farmers grow important vegetable crops. These farming related activities could be the main source of nutrient run off in nearby shores (Mahadea et al., 2025).

The West region experienced urban growth of 110.09% over this period, the second-highest of any region, with Flic en Flac still retaining approximately 4 km² of sugarcane plantations (Mahadea-et al.,2025). Agrochemical use from remaining agriculture, coupled with wastewater and stormwater runoff from expanding hotel and urban infrastructure, can introduce excess nutrients into the lagoons (Facknath, 2025) thus leading to a series of algal bloom events which can affect both tourism and local fisheries (Ministry of Blue Economy, Marine Resources, Fisheries and Shipping, 2022).

3.4 Influence of Catchment Dynamics and Land-sea interactions

Catchment structure and land-use patterns play a critical role in shaping nutrient delivery mechanisms and hydrodynamic conditions influencing algal blooms in Mauritius (Wells et al., 2015; Paerl et al., 2018).

For the eastern coast, strong runoff is generated from high rainfall over the central plateau (up to 4000 mm/year). This causes nutrients and sediments to be transported to the lagoon (Padya, 1989; Mauritius Meteorological Services, 2023). The transport of nutrients into the lagoon of Belle mare has multiple entry points, thus, causing diffuse nutrient loading. Sugarcane cultivation in the eastern region of the island is the major source of nitrogen and phosphorous based fertilizer, which in turn contribute to nutrient inputs. Consequently, the promotion of phytoplankton growth occurs as the wide and shallow lagoon enhances light penetration and nutrient retention (Devassy et al., 2017; Ng Kee Kwong et al., 2002; FAO, 2013; Wells et al., 2015)

The western region consists of limited runoff, though, ground water movements including submarine groundwater discharge occurs via groundwater movements, which delivers a continuous source of dissolved nutrients to coastal waters (Padya, 1989; Burnett et al., 2006; Slomp & Van Cappellen, 2004). Urban wastewater, tourism induced infrastructure and agricultural seepage is often associated with nutrient inputs which are localised and continuous (UNEP, 2019). The western lagoon is narrow and more enclosed. This reduced water circulation and flushing capacity which in turn creates a favourable condition for patchy and persistent algal bloom and eutrophication (Paerl et al., 2018; Devassy et al., 2017).

Fertilizer Application Patterns

Sugarcane cropping in Mauritius relies heavily on significant synthetic fertilizer application especially nitrogen and phosphorus-based fertilizers which are recommended by the Mauritius Sugarcane Industry Research Institute. Fertilizers such as 17:8:25 and 17:8:20 are applied twice; at the onset of the cropping cycle between August to September and supplementary of split fertilization in the early growth phase from January to February (Ng Kee Kwong and Deville, 1994; MSIRI, 2010; MSIRI, 2018; MCIA, 2022; MCIA, 2024).

In practice, sugarcane farmers, especially those of the central plateau and eastern lowlands, tend to apply higher rates of fertilizers, where high rainfall causes the yield to increase but this also increases the risk of nutrient mobilization (Ng Kee Kwong et al., 2002; FAO, 2013). There is also a coincidence of fertilization with the wet season (January to April), which enhances surface runoff, resulting in the transport of nitrogen and phosphorus rich particulate matter to rivers, lagoons and coastal waters (Mardamootoo et al., 2015; Ng Kee Kwong et al., 2013).

On the other hand, the western coast which receives relatively lower rainfall is characterised by comparatively lower rainfall experiences with reduced surface runoff. Yet, nutrient transport still happens through subsurface pathways. Nutrients sourced from synthetic fertilizers leach through soils into the groundwater and eventually reach the sea (Slomp and Van Cappellen, 2004; Bhadhoo and Puttoo, 2016).

Moreover, the interface between the timing of fertilization, rainfall schedule and landscape hydrology have a strong influence on eutrophication and algal bloom initiation and proliferation in Mauritian waters (Ng Kee Kwong et al., 2002; MSIRI, 2018; Soondur et al., 2022; MCIA, 2022).

3.5 Status of algal management in Mauritian waters

Currently, interventions for the removal of accumulated algal biomass in affected lagoons is done physically. Thus the management of algal proliferation in Mauritius remains limited. Field observations indicate that such removal is typically carried out manually, with collected biomass transported away from coastal zones for disposal. These practices have not been documented in formal scientific literature and are generally implemented as short-term responses to visible nuisance conditions (figure 3.5a).

Figure 3.5a: Algal proliferation in Mauritian Coastal Waters (Source: LeClezio, 2024)

In Mauritius, the management strategies to control the proliferation of algae have remained centred around monitoring and nutrient control. However, limited remediation measures have been implemented. Accordingly, a long-term mitigation and management plan for algal bloom is required with particular focus on internal and external nutrient loading and cycling (Conley et al., 2009; Paerl et al., 2016b; Glibert et al., 2018).

A significant management gap remains, highlighting the need to move beyond routine monitoring toward proactive intervention. Integrating the valorisation of algal biomass into management strategies could not only help mitigate algal blooms but also promote sustainable practices by converting the harvested biomass into value-added products (Soondur et al., 2022; Glibert et al., 2018).

4. Conclusion and Way Forward

Algal occurrence in Mauritius is linked to multiple factors such as climatic seasonality, nutrient enrichment, human induced pressures and complex hydrological processes. Summer conditions, increased rainfall and rise in sea surface temperature coupled with high nutrient influx represent the right ingredients for algal bloom initiation, development and proliferation. Their impacts extend across environmental, social, and economic domains, posing significant challenges to sustainable coastal management, requiring establishment of frequent monitoring and integrated coastal management strategies.

Key Recommendations and Priorities

1. Strengthening Coastal Monitoring, Data Integration, and Centralized Knowledge Systems

The establishment of a national algal bloom monitoring network integrating the local population, important stakeholders such as fishers and tourism operators. Important sites such as Belle and Flic en Flac will need to be included in the monitoring network together with other sites. The monitoring network should include a centralized data platform to facilitate data analysis and long-term trends modelling.

Additionally, a national algal species database should be developed to better categorize algae species based on several factors such as distribution, occurrences and toxin profiles. This would enable rapid decision making and the incorporation and establishment of policy decisions linked to algal bloom to minimize environmental and health hazards.

2. Implementation of Catchment-Specific Nutrient Management and Pollution Control Strategies

Management strategies should be tailored to control and manage nutrients based on the catchment dynamics. For example, the eastern coasts need an approach to encourage sustainable and good agricultural practices, controlled drainage systems and the reduction of diffused runoff. Whereas for the western coast, priority should be to control point sources by investing in innovative and sustainable wastewater management practices and regulating submarine groundwater discharge from tourism and urban developments.

3. Development of AI-Based Predictive Models and Early Warning Systems

A pilot AI-based early warning system should be developed for a sentinel site, such as the Flic-en-Flac lagoon. This system should be able to generate real time water quality data from low-cost sensors and should be incorporated with satellite imagery generation system and rainfall forecasting. This system could be integrated into national monitoring frameworks and linked with public reporting platforms to enhance responsiveness.

4. Promotion of Sustainable Valorisation of Algal Biomass within a Circular Bioeconomy Framework

Given the recurrent macroalgal blooms (e.g., *Ulva*, *Enteromorpha*), a circular bioeconomy pilot should explore the feasibility of harvesting this biomass for value-added products. Based on documented uses, priority applications include:

- Biofertilizers: Converting algal biomass into organic fertilizers to reduce reliance on chemical fertilisers
- Bioenergy: Anaerobic digestion of algal biomass for biogas production
- Wastewater treatment: Use of algae in nutrient recovery systems
- Pharmaceutical and nutraceutical compounds: Extraction of bioactive compounds from algal species such as *Turbinaria ornata*

5. Local Awareness, Capacity Building, and Socio-Economic Impact Assessment
Environmental events such as algal blooms are often exacerbated by limited public awareness and community engagement. Targeted education, capacity building, trainings and sensitization campaigns should be implemented to inform communities about the causes, risks, and early warning signs of algal blooms, including their impacts on human health, marine environment and the economy.
These sensitization campaigns should also increase public awareness and dissipate information on existing reporting mechanisms (e.g., Environment Police, Ministry of Environment) to enhance timely communication and response. Simultaneously, the socio-economic impact should be assessed to quantify the economic costs of algal bloom events on fisheries, tourism, and public health.

6. Specification of new guidelines or standards for presence of algae in Mauritian Waters.
Currently, Mauritius does not have any standardized monitoring protocols for algal presence. The establishment of algal guideline will be essential for Mauritius to align with international best practices and to serve as a standardized criteria, enabling consistent monitoring, early warning systems and evidence-based decision making.
Future Research Priorities
Future research should prioritise multi disciplinary approaches combining environmental science, data analytics, artificial intelligence and machine learning and policy frameworks jointly with academia, private sector, civil society, local stakeholders and the government to enhance resilience and sustainability in coastal ecosystems. Specific priorities include:

- **Long-term toxin monitoring:** Establishing routine surveillance of biotoxins in shellfish and fish to assess public health risks, particularly for ciguatera fish poisoning.
- **Climate change scenario modelling:** Projecting future algal bloom risk under different climate change scenarios to inform long-term adaptation planning.
- **Early warning systems with the integration of Artificial Intelligence:** The introduction of an advanced and robust AI-based monitoring system to enhance predictive capabilities and real time surveillance. This would also improve early detection, risk mitigation and overall management of algal blooms.
- **Review of wastewater treatment system for algal cultivation and carbon sequestration:** The wastewater treatment system should be assessed to enable controlled algal growth in selected sections, supporting nutrient recovery, carbon sequestration, and biomass valorisation within a circular bioeconomy framework.

Acknowledgements
The authors are thankful to the NAM S & T Centre (New Delhi, India) and JSS Science and Technology University (Mysore, India) and the Ministry of Environment, Solid Waste Management and Climate Change (Mauritius).

References

1. AFRC (2020) *Spatial and seasonal variations of harmful benthic dinoflagellates in the coastal waters of Mauritius*. Albion Fisheries Research Centre, Mauritius.
2. Ajmal, T., Mohammed, F., Goodchild, M.S., Sudarsanan, J. and Halse, S. (2024) 'Mitigating the impact of harmful algal blooms on aquaculture using technological interventions: case study on a South African farm', *Sustainability*, 16(9), 3650.
3. AllAfrica.fr (2026) 'Ile Maurice: L'envers du décor de rêve', 16 March. Available at: https://www.allafrica.fr (Accessed: 17 April 2026).
4. Anderson, D.M., Cembella, A.D. and Hallegraeff, G.M. (2012) 'Progress in understanding harmful algal blooms', *Harmful Algae*, 20, pp. 1–6.
5. Anderson, D.M., Glibert, P.M. and Burkholder, J.M. (2002) 'Harmful algal blooms and eutrophication: nutrient sources, composition, and consequences', *Estuaries*, 25(4), pp. 704–726.
6. Appadoo, C. and Hoole, N. (2014) 'Amphipod-associated algal communities in Mauritian lagoons', *University of Mauritius Research Journal*, 20, pp. 45–62.
7. Araújo, C.V.M., Blasco, J. and Moreno-Garrido, I. (2010) 'Microphytobenthos in ecotoxicology: a review', *Environment International*, 36(6), pp. 637–646.
8. Backer, L.C. and McGillicuddy, D.J. (2012) 'Harmful algal bloom-related illness and health risks', *Harmful Algae*, 14, pp. 197–209.
9. Backer, L.C., Manassaram-Baptiste, D., LePrell, R. and Bolton, B. (2015) 'Recreational exposure to microcystins during algal blooms', *Marine Drugs*, 13(6), pp. 323–337.
10. Ballah, M., Bhoyroo, V. and Neetoo, H. (2019) 'Assessment of the physico-chemical quality and extent of algal proliferation in water from an impounding reservoir prone to eutrophication', *Journal of Ecology and Environment*, 43, 5.
11. Ballah, S., Bhoyroo, V. and Puchooa, D. (2019) 'Cyanobacterial proliferation in Piton du Milieu Reservoir, Mauritius', *Water Resources Management*, 33(8), pp. 2789–2802.
12. Ballah, S., Bhoyroo, V. and Puchooa, D. (2022) 'Cyanobacteria and nutrient dynamics in La Ferme Reservoir, Mauritius', *Environmental Monitoring and Assessment*, 194(3), p. 187.
13. Bang, H. N. (2013). "Governance of disaster risk reduction in Small Island Developing States: The case of Mauritius." *Environmental Hazards*, 12(3-4), pp. 300–315.

14. Bates, S.S., Garrison, D.L., Horner, R.A. and Fryxell, G.A. (1998) 'Domoic acid production by diatoms', *Natural Toxins*, 6, pp. 123–130.
15. Bhadhoo, D. and Puttoo, K. (2016) 'Nutrient fluxes to coastal waters in Mauritius: the role of groundwater and runoff', *Environmental Monitoring and Assessment*, 188, 45.
16. Bhadhoo, N. and Puttoo, D. (2016) 'Groundwater vulnerability and nutrient transport in Mauritius' (unpublished or institutional report – full source not specified).
17. Bhagea, R., Bhoyroo, V. and Puchooa, D. (2024) 'First record of *Rhexinema paucicellulare* in Mauritius', *Phycological Research*, 72(3), pp. 156–165.
18. Bhagooli, R. (2021) 'Coral bleaching and zooxanthellae dynamics in Mauritian reefs', *Western Indian Ocean Journal of Marine Science*, 20(1), pp. 45–58.
19. Bhagooli, R. and Taleb-Hossenkhan, N. (2012) '*Symbiodinium* diversity in Mauritian corals', *University of Mauritius Research Journal*, 18, pp. 112–128.
20. Bissembur, B., Ramessur, R.T. and Lollchund, M.R. (2012) 'Nutrient dynamics and algal blooms in Mauritian coastal waters', *Western Indian Ocean Journal of Marine Science*, 11(2), pp. 135–148.
21. Boojhawon, R., Surroop, D. and Rughooputh, S.D.D.V. (2014) *Assessment of nutrient inputs and coastal water quality in Mauritius*. University of Mauritius (institutional report).
22. Burnett, W.C., Aggarwal, P.K., Aureli, A., Bokuniewicz, H., Cable, J.E., Charette, M.A., Kontar, E., Krupa, S., Kulkarni, K.M., Loveless, A. and Moore, W.S. (2006) 'Quantifying submarine groundwater discharge', *Science of the Total Environment*, 367(2–3), pp. 498–543.
23. Cai, Z., Duan, S. and Wang, C. (2013) 'Bioenergy potential of macroalgae', *Renewable and Sustainable Energy Reviews*, 26, pp. 301–311.
24. Carmichael, W.W. (2001) 'Health effects of cyanotoxins', *Human and Ecological Risk Assessment*, 7, pp. 1393–1407.
25. Carpenter, S.R., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N. and Smith, V.H. (1998) 'Nonpoint pollution of surface waters with phosphorus and nitrogen', *Ecological Applications*, 8(3), pp. 559–568.
26. Carreto, J.I. and Carignan, M.O. (2011) 'Mycosporine-like amino acids: relevant secondary metabolites', *Marine Drugs*, 9(3), pp. 387–446.
27. Conley, D.J., Paerl, H.W., Howarth, R.W., Boesch, D.F., Seitzinger, S.P., Havens, K.E., Lancelot, C. and Likens, G.E. (2009) 'Controlling eutrophication: nitrogen and phosphorus', *Science*, 323(5917), pp. 1014–1015.
28. Coppejans, E., Leliaert, F. and De Clerck, O. (2004) 'Marine macroalgae of Rodrigues Island', *Journal of Natural History*, 38(23), pp. 2991–3022.
29. Daby, D. (2003) 'Plankton dynamics in Port Louis Harbour, Mauritius', *University of Mauritius Research Journal*, 9, pp. 23–35.
30. Daby, D. (2011) 'Limnology of coastal lagoons in Mauritius', *University of Mauritius Research Journal*, 17, pp. 78–95.
31. de Magalhães, L., Noyma, N.P., Furtado, L.L., Drummond, E., Leite, V.B.G., Mucci, M., van Oosterhout, F., Huszar, V.L.M. and Marinho, M.M. (2019) 'Managing eutrophication in a tropical brackish water lagoon: testing lanthanum-modified clay and coagulant for internal load reduction and cyanobacteria bloom removal', *Estuaries and Coasts*, 42, pp. 390–402.
32. Devassy, R.P., Paterson, H.L., Mitchell, J.G. and Seuront, L. (2017) 'Phytoplankton bloom dynamics', *Marine Pollution Bulletin*, 119(1), pp. 191–204.
33. Diaz, R.J. and Rosenberg, R. (2008) 'Spreading dead zones', *Science*, 321(5891), pp. 926–929.
34. Dulymamode, R., Ramessur, R.T. and Fagoonee, I. (2002) *Mauritius national report on coastal eutrophication*. Ministry of Environment.
35. Economic Development Board (2023) *Call for expression of interest – development of a mixed-use precinct at Palmar*. Available at: https://edbmauritius.org/newsroom/eoi-precinct-palmar (Accessed: 17 April 2026).
36. EOS Data Analytics (2026) *EOSDA LandViewer*. Available at: https://eos.com/landviewer/ (Accessed: April 2026).
37. Facknath, S. (2025) 'Interview: turning Mauritian coasts climate smart', *Capacity4dev*.
38. Fagoonee, I. (1990) 'Coastal ecosystems of Mauritius', *Hydrobiologia*, 208, pp. 55–62.
39. FAO (2013) *Fertilizer use by crop in Mauritius*. Rome: Food and Agriculture Organization.
40. Field, C.B., Behrenfeld, M.J., Randerson, J.T. and Falkowski, P.G. (1998) 'Primary production of the biosphere', *Science*, 281, pp. 237–240.
41. Frouin, P., Moutien, T. and Seeruttun, R. (2012) 'Phytoplankton dynamics', *Marine Pollution Bulletin*, 64(9), pp. 1812–1821.
42. Ghyoot, C., Rouxel, M., Le Bris, N. and Lécuyer, C. (2017) 'Submarine groundwater discharge', *Journal of Hydrology* (full volume/issue not specified).
43. Glibert, P.M. (2020). *Harmful algal blooms in a changing world: A global perspective.* Harmful Algae, 91, 101731.
44. Glibert, P.M., Maranger, R., Sobota, D.J. and Bouwman, L. (2018a) 'The Haber Bosch–harmful algal bloom (HB-HAB) link', *Environmental Research Letters*, 13(6), 063002.
45. Glibert, P.M., Berdalet, E., Burford, M.A., Pitcher, G.C. and Zhou, M. (2018b) 'Harmful algal blooms and eutrophication', *Harmful Algae*, 79, pp. 1–4.
46. Government of Mauritius (2013) *National environmental policy*.
47. Hallegraeff, G.M. (1993) 'A review of harmful algal blooms and their apparent global increase', *Phycologia*, 32(2), pp. 79–99.

48. Heisler, J., Glibert, P.M., Burkholder, J.M., Anderson, D.M., Cochlan, W.P., Dennison, W.C., Dortch, Q., Gobler, C.J., Heil, C.A., Humphries, E. and Lewitus, A.J. (2008) 'Eutrophication and harmful algal blooms', *Harmful Algae*, 8(1), pp. 3–13.
49. Hoagland, P., Anderson, D.M., Kaoru, Y. and White, A.W. (2002) 'Economic effects of harmful algal blooms', *Estuaries*, 25(4), pp. 819–837.
50. Holdt, S.L. and Kraan, S. (2011) 'Bioactive compounds in seaweed', *Journal of Applied Phycology*, 23, pp. 543–597.
51. Howarth, R.W. (2008) 'Coastal nitrogen pollution', *Harmful Algae*, 8(1), pp. 14–20.
52. Howarth, R.W., Swaney, D.P., Boyer, E.W., Marino, R., Jaworski, N. and Goodale, C. (2011) 'Nitrogen fluxes from human activities', *Frontiers in Ecology and the Environment*, 9(1), pp. 18–25.
53. IPCC (2019). *Special Report on the Ocean and Cryosphere in a Changing Climate.*
54. Jagtap, T.G. (1993) 'Marine macroalgae of Mauritius', *Japanese Journal of Phycology*, 41, pp. 361–367.
55. JICA (2001) *Eastern coastal region development study*. Tokyo: Japan International Cooperation Agency.
56. Kaullysing, D., Gopeechund, A., Mattan-Moorgawa, S. and Bhagooli, R. (2022) 'Micro-phytobenthos dynamics', *Marine Pollution Bulletin*, 175, 113345.
57. Kemp, W.M., Boynton, W.R., Adolf, J.E., Boesch, D.F., Boicourt, W.C., Brush, G., Cornwell, J.C., Fisher, T.R., Glibert, P.M., Hagy, J.D. and Harding, L.W. (2005) 'Eutrophication of Chesapeake Bay', *Marine Ecology Progress Series*, 303, pp. 1–29.
58. Landsberg, J.H. (2002) 'The effects of harmful algal blooms on aquatic organisms', *Reviews in Fisheries Science*, 10, pp. 113–390.
59. Leclezio, C. (2024) *Photograph showing manual removal of algal biomass in Mauritius*. Facebook. Available at: https://www.facebook.com/photo?fbid=122170016930133972&set=pcb.1130497424681495 (Accessed: 18 April 2026).
60. Litaker, R.W., Vandersea, M.W., Faust, M.A., Kibler, S.R., Nau, A.W., Holland, W.C., Chinain, M., Holmes, M.J. and Tester, P.A. (2010) 'Ciguatera dinoflagellates', *Harmful Algae*, 9, pp. 102–114.
61. Lürling, M., Mackay, E., Reitzel, K. and Spears, B.M. (2016) 'Editorial – A critical perspective on geo-engineering for eutrophication management in lakes', *Water Research*, 97, pp. 1–10.
62. L'Express (2005) 'Un projet de tourisme intégré de Rs 16 milliards à Flic-en-Flac', 12 September.
63. Mahadea Nemdar, R., Doorga, J.R.S. and Busawon, K. (2025) 'Development implications of land cover change in Mauritius', *Spatial Information Research*, 33(6), Article 52.
64. Mardamootoo, C., Facknath, S. and Lalljee, B. (2015) 'Evaluation of nutrient losses from agricultural lands under sugarcane cultivation in Mauritius', *Agricultural Water Management*, 158, pp. 202–210.
65. Mardamootoo, T., Facknath, S. and Lalljee, B. (2015) – *Duplicate of above?* (same authors, similar title but slightly different journal? Assuming distinct – kept both as provided.)
66. Mauritius Cane Industry Authority (2022) *Mauritius Sugarcane Sector Review and Policy Note*. Reduit: MCIA.
67. Mauritius Cane Industry Authority (2024) *Supply of Fertilizers to Sugar Cane Planters for Crop 2024*. Available at: https://www.mcia.mu/supply-of-fertilizers-to-sugar-cane-planters-for-crop-2024/ (Accessed: 18 April 2026).
68. Mauritius Meteorological Services (2020) *Hydrology data book*.
69. Mauritius Meteorological Services (2023) *Climate statistics*.
70. Mauritius Oceanography Institute (2009) *Annual report*.
71. McHugh, D.J. (2003) *A guide to the seaweed industry*. Rome: FAO.
72. Ministry of Blue Economy (2021) *HAB monitoring report*.
73. Ministry of Blue Economy, Marine Resources, Fisheries and Shipping (2022) *Vision for a sustainable blue economy*. Port Louis: Government of Mauritius.
74. Mussai, M., Soondur, M. and Nazurally, N. (2025) 'Palytoxin-producing dinoflagellates', *Harmful Algae*, 142, 102789.
75. Mussai, P., Bhoyroo, V., Puchooa, D. and Nazurally, N. (2023) 'Ribosomal DNA sequence-based taxonomy of *Prorocentrum* spp. from Mauritius coastal waters', *Marine Drugs*, 21(4), p. 216.
76. Nadeem, N. and Bhoyroo, V. (2022) 'Marine cyanobacteria from Mauritian waters', *Phycology International* (full details not specified).
77. Nazurally, N., Soondur, M., Kaullysing, D. and Mattan-Moorgawa, S. (2025) 'Nutrient-driven harmful algal blooms', *Marine Pollution Bulletin*, 200, 116089.
78. Neermul, N., Nazurally, N., Kaullysing, D. and Mattan-Moorgawa, S. (2022) 'Benthic dinoflagellates', *Regional Studies in Marine Science*, 52, 102245.
79. Neermul, P., Mussai, M., Soondur, M. and Nazurally, N. (2020) *Spatial and seasonal variations of harmful benthic dinoflagellates in the coastal waters of Mauritius*. Albion Fisheries Research Centre.
80. Ng Kee Kwong, K.F. and Deville, J. (1994) 'Course of fertilizer nitrogen uptake by rainfed sugarcane in Mauritius', *Journal of Agricultural Science*, 123(2), pp. 185–191.
81. Ng Kee Kwong, K.F., Deville, J. and Ng Kee Kwong, M.F. (2002) 'Nutrient losses from sugarcane fields in Mauritius', *Agriculture, Ecosystems & Environment*, 89(3), pp. 255–267.
82. Ng Kee Kwong, K.F., Bholah, A., Gooriah, L. and Ramasamy, S. (2013) 'Phosphorus dynamics in soils under long-term sugarcane cultivation in Mauritius', *Journal of Agricultural Science*, 151(4), pp. 514–523.
83. OECD (2020) *Sustainable ocean economy*. Paris: OECD.
84. Oh, J.W., Pushparaj, S.S.C., Muthu, M. and Gopal, J. (2023) 'Review of harmful algal blooms causing marine fish kills: toxicity and mitigation', *Plants*, 12(23), p. 3936.
85. Padya, B.M. (1989) *Weather and climate of Mauritius*. Geography of Mauritius Series.

86. Paerl, H.W. and Otten, T.G. (2013) 'Harmful cyanobacterial blooms', *Microbial Ecology*, 65(4), pp. 995–1010.
87. Paerl, H.W., Scott, J.T., McCarthy, M.J., Newell, S.E., Gardner, W.S., Havens, K.E., Hoffman, D.K., Wilhelm, S.W. and Wurtsbaugh, W.A. (2016a) 'It takes two to tango: when and where dual nutrient (N & P) reductions are needed to protect lakes and downstream ecosystems', *Environmental Science & Technology*, 50(20), pp. 10805–10813.
88. Paerl, H.W., Gardner, W.S., Havens, K.E., Joyner, A.R., McCarthy, M.J., Newell, S.E., Qin, B. and Scott, J.T. (2016b) 'Mitigating harmful algal blooms', *Harmful Algae*, 54, pp. 213–222.
89. Prayag, S., Rughooputh, S.D.D.V. and Goorsamy, A. (1995) 'Coastal water quality', *Indian Ocean Journal*, 24, pp. 55–67.
90. Ramessur, R.T. (2001) 'Nutrient pollution in coastal waters', *Environment International*, 26(5–6), pp. 345–351.
91. Ramessur, R.T. (2013) 'Nutrient loading in Mauritius', *University of Mauritius Research Journal*, 19, pp. 102–119.
92. Ramlugun, N. (2002) *Macroalgal proliferation in Mauritius*. MSc Thesis, University of Mauritius.
93. Ranghoo-Sanmukhiya, M. (2023) '*Enteromorpha* as biofertilizer', *Journal of Applied Phycology*, 35(2), pp. 789–798.
94. Rhodes, L. (2011) 'Palytoxin occurrence', *Toxicon*, 57(3), pp. 453–458.
95. Rufford, J., Ryan, P. and Sood, A. (2014) 'Rainfall geography of Mauritius', *Applied Geography*, 54, pp. 112–122.
96. Sadally, S.B., Taleb-Hossenkhan, N. and Bhagooli, R. (2016) 'Microalgal blooms', *WIOMSA Journal*, 15, pp. 45–55.
97. Sadeer, N.B., Mahomoodally, M.F. and Zengin, G. (2020) '*Turbinaria* bioactive compounds', *Journal of Applied Phycology*, 32(5), pp. 3421–3432.
98. Scavia, D., Allan, J.D., Arend, K.K., Bartell, S., Beletsky, D., Bosch, N.S., Brandt, S.B., Briland, R.D., Daloğlu, I., DePinto, J.V. and Dolan, D.M. (2014) 'Lake Erie eutrophication', *Journal of Great Lakes Research*, 40(3), pp. 496–508.
99. Seebocus, R.H., Gopaul, T. and Khedo, K.K. (2021) 'Extreme rainfall analysis', *South African Journal of Science*, 117(5–6), pp. 1–9.
100. Shaama, A., Soondur, M. and Booluck, K. (2020) 'Sea surface temperature trends', *Regional Studies in Marine Science*, 35, 101214.
101. Shibata, S., Matsumoto, T. and Murakami, N. (2010) 'Peridinin and carotenoids from dinoflagellates', *Marine Drugs*, 8(1), pp. 43–60.
102. Shumway, S.E., Allen, S.M. & Boersma, P.D. (2003). *Marine birds and harmful algal blooms: Sporadic victims or under-reported events?* Harmful Algae, 2(1), 1–17.
103. Singh, A., Nigam, P.S. and Murphy, J.D. (2011) 'Biofuel production from cyanobacteria', *Bioresource Technology*, 102(2), pp. 657–664.
104. Slomp, C.P. and Van Cappellen, P. (2004) 'Nutrient inputs to the coastal ocean through submarine groundwater discharge', *Journal of Hydrology*, 295(1–4), pp. 198–212.
105. Smith, V.H. and Schindler, D.W. (2009) 'Eutrophication science: where do we go from here?', *Trends in Ecology & Evolution*, 24(4), pp. 201–207.
106. Sobhee, S.K. (2009) 'Economic success of Mauritius', *Global Policy Review*, 1(2), pp. 34–42.
107. Soondur, M., Boojhawon, R. and Lowe, R. (2022) 'Rainfall-driven nutrient loading affects coastal phytoplankton in the southwestern Indian Ocean: a lagoon at Mauritius Island', *African Journal of Marine Science*, 44(2), pp. 153–169.
108. Soondur, M., Kaullysing, D., Mattan-Moorgawa, S. and Nazurally, N. (2022) 'Nutrient enrichment and phytoplankton dynamics in Mauritian lagoons', *African Journal of Marine Science*, 44(3), pp. 271–285.
109. Sooroojebally, P., Neergheen-Bhujun, V.S. and Bhoyroo, V. (2021) 'Cyanobacterial diversity', *African Journal of Marine Science*, 43(4), pp. 501–512.
110. Statistics Mauritius (2024) *National accounts estimates*. Port Louis: Government of Mauritius.
111. Statistics Mauritius (2026) *Population statistics*. Port Louis: Government of Mauritius.
112. Teeluck, M. and Ah King, R.T.F., 2007. *Agricultural practices and environmental impacts in Mauritius*. Agricultural Systems, 94(2), pp. 270–278.
113. Turquet, J., Quod, J.P. and Le Duff, M. (2008) '*Gambierdiscus* in Mauritius', *WIOMSA Journal*, 7, pp. 78–85.
114. Turner, A.D., Higgins, C. and Higman, W. (2018) 'Marine toxins', *Harmful Algae*, 73, pp. 12–23.
115. UNDP (2022) *Blue economy and sustainable development*. United Nations Development Programme.
116. UNEP (2010) *Regional marine ecosystems*. Nairobi: United Nations Environment Programme.
117. UNEP (2019) *Coastal pollution and eutrophication in Mauritius*. Nairobi: United Nations Environment Programme.
118. Wells, M.L., Trainer, V.L., Smayda, T.J., Karlson, B.S., Trick, C.G., Kudela, R.M., Ishikawa, A., Bernard, S., Wulff, A., Anderson, D.M. and Cochlan, W.P. (2015) 'Harmful algal blooms and climate change', *Harmful Algae*, 49, pp. 68–93.
119. Wells, M.L., Karlson, B., Wulff, A., Kudela, R., Trick, C., Asnaghi, V., Anderson, D.M., Berdalet, E., Cochlan, W., Davidson, K. and De Rijcke, M. (2020) 'Harmful algal blooms and their impacts', *Harmful Algae*, 91, 101731.