Chapter

Considering Harmful Algal Blooms

Ruby E. Jalgaonwala

Abstract

Problematic harmful algal bloom is wide and tenacious, upsetting estuaries, coasts, and freshwaters system throughout the ecosphere, alongside disturbing human health, social life as well as national economy. Particular environmental factors supports growth of algal blooms, temperature always is significant when speaking about water-ecosystem. Disparity in temperature also found to affect the interaction of physical, chemical and biological parameters so it is equally imperative to consider effects of climate change, as change in climatic conditions supports unwanted growth of algae. Also inconsistency in climate equally contributes to the apparent increases of HAB, therefore effects of climate change needs to be totally comprehended along with development of the risk assessments and effective management of HABs. Increased HAB activities have a direct negative effect on ecosystems and they can frequently have a direct commercial impact on aquaculture, depending on the type of HAB. Causing economic impact also, as there is still insufficient evidence to resolve this problem. Therefore this chapter considers the effects of past, present and future climatic variability on HABs along with impacts of toxins release by them, on marine organism as well as human beings correspondingly, mitigation of HAB with help of suitable biological agents recognized.

Keywords: algal blooms, toxins, mitigate, climate change

1. Introduction

Ecosystems on earth plays an important role in regulating climate and as well as a fundamental life-giving resource for human kind. Aquatic ecosystems are majority supported by photosynthetic organisms that fix carbon and produce oxygen, comprise the base of food web. Though, under sure circumstances, the abundance of various taxa reaches level that cause harm to humans and other organisms. These proliferations habitually are referred to as 'harmful algal blooms' (HABs), that includes a variety of species and consequences that humans perceive as adverse. HABs occur in all aquatic environments such as freshwater, brackish and marine and at all latitudes. We know in the nature algae are a normal part of the aquatic ecosystem, forming the actual base of the aquatic food web as they are large and very diverse group of organisms, the majorities are microscopic in size, except some macroscopic algae. Mainly the microscopic algae are most often as single cells, other than some can form chains and colonies. For the most part micro algae live in the water, whereas others live in or near to the sediment or attached on to some of surfaces for some time also for entire life cycle. Many of macro algae are also known as seaweeds they can be multicellular and complex. Algal blooms also acts as natural important component for many aquatic systems, generally spring blooms are triggered by some seasonal warming, increased availability of light and nutrient and also water column stratification. These blooms are significant part for energy and material transport through the food web, as well plays an important role in the vertical flux of material out of the surface waters therefore these blooms are known to be prominent considering with those acknowledged as "harmful." These algae can form harmful algal blooms, when they assemble and grow in massive amounts damaging the ecosystem, or if the algal community shifts to species that makes some toxin compounds disrupting the normal food web and also harmful to human beings [1]. Problem of harmful algal bloom is wide and persistent, affecting numerous estuaries, coasts, and freshwaters system throughout the world, along with disturbing ecosystems, human health, social life style as well as dilemma for economy systems.

2. Algal blooms

HABs consist of organisms which are able to deplete oxygen levels in water systems; it also kills life in same water system and lasts for several days to months [2]. They are considered harmful as producing massive biomass and toxins. Huge amount of cell biomass produced by them hinders the light penetration resulting into decreased density of submerged aquatic vegetation [3]. Decaying, these algal blooms increases oxygen consumption leading to mortality of aquatic life in that area [4]. The effects of the blooms have been identified in numerous ways, even in the marine ecosystem were aquatic life gets exposed to toxins by ingestion. Therefore biological control of HABs is seen to be an economically and environment-friendly resolution [5]. In addition some biotic organisms were isolated and used to eradicate HABs, for example secretion of *Cyanobacteriolytic* substances by bacteria [6]. Characteristic species-specific interaction by some virus [7], the bursting of host cells, and the virus lytic cycle [8]. Viral degradation has the benefit of the species-specific attack. Golden algae have also been found as a mitigator of microcystis cells as well as toxin degraders. (**Figure 1**) shows spreading of algal blooms in different climatic conditions [9].

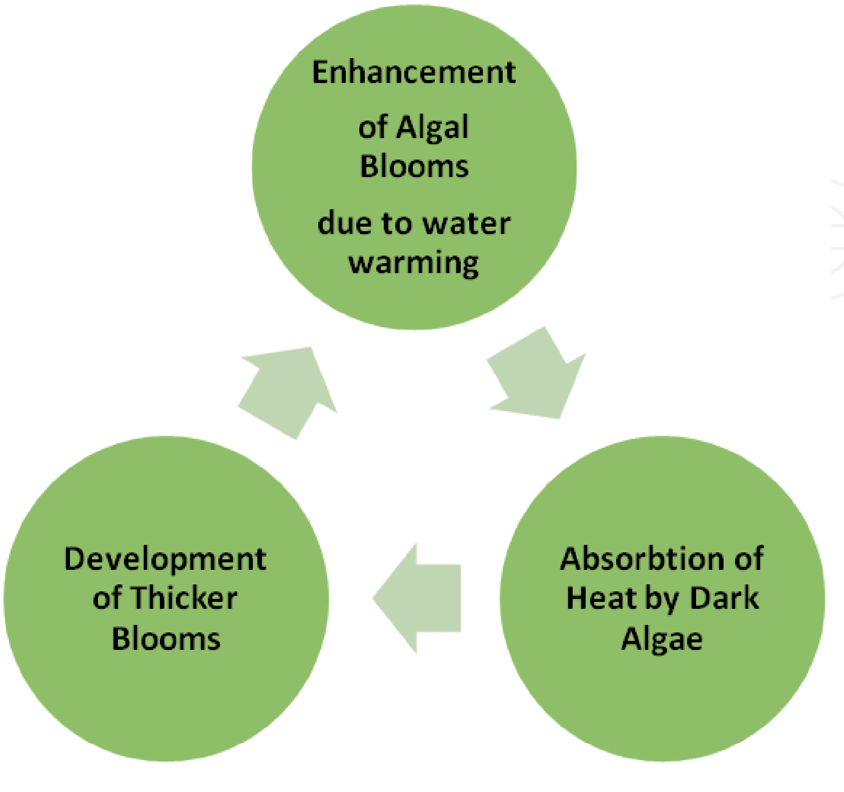

Figure 1.
Pervasiveness of different conditions enhancing HABs.

Some environmental factors found to supports growth of algal blooms. The temperature always is important when bearing in mind about water-ecosystem [10]. Increase in heat could significantly expand Chlorophyll-*a* concentration, signifying that warmer conditions could develop a dominant population of Cyanobacteria [11]. Reports suggest that variation in temperature also affects the interaction of physical, chemical, and biological parameters in shallow lakes. Were for Cyanobacteria, these factors emulate fluctuating physiological changes such as nutrient uptake capacity, N-fixation, as well as optimum temperature. Effect of temperature was also noticed with *Microcystis aeruginosa* biomass production [12]. It is important to note that freshwater HABs caused by Cyanobacterial blooms appear to be the most noticeable examples of warming induced intensification indicating that the temperatures yielding maximal growth rates for many Cyanobacterial HABs [13, 14].

Evident shows that there is an increase and spreading of phytoplankton bloom globally in the sea and also nutrient loading is dependent on biomass composition. As such autotrophic growth can result only from the increased photosynthesis and primary production must be an outcome of improved nutrient levels. All through addition of nutrients, variation in the amount of nutrient be practical, encouraging struggle for resources among various community and species. As near to coast food fortification is caused due to riverine input in connection with dissimilar discharges, resultant of new nutrient input eliciting some new algal blooms. Breathing space and geographical location generally influences nutrient availability, acting as significant aspect in defining their eutrophication values. As known geographical factors including latitude, elevation, and longitude possibly affects the openness of nutrients to algal growth. Were elevation is amazingly associated with strength of light and also human interference. Availability of nutrition also found to be elevated in some of the lakes at high elevation [15]. Accordingly the all-inclusive occurring of marine phytoplankton blooms can be linked to improved primary production rates. It is important to note that global wave of phytoplankton was firstly reported on Dino-flagellate *Gyrodinium aureolum* in some European waters, which was beforehand present in some other north-east coast of the U.S. Similarly, many species spread globally and was responsible for shellfish poisoning global wave of HABs [16]. Lake Taihu was also reported for annual Cyanobacteria occurrence [17]. Considering research from last some decades, capabilities for management of HABs have grown with scientific advances working independently. New technological developments have altered the way to monitored and managed HABs [18–20]. Problems related to HAB are serious and worse in many parts of the world, however thinking, working capabilities and existing knowledge can help to curtail impacts to protect marine resources community health.

3. Control agents related to HABs

Studies have been carried out to find a better way of controlling HABs. Different biotic factors have been identified to mitigate the option of HABs. Where use of different bacteria was done to tone down HABs in coastal and freshwater community [21].

4. Toxins

The most toxic algal strain is *M. aeruginosa,* which constantly produces microcystins, acts harmful to aquatic organisms as well as to humans. Were microcystins have been reported as tumor-promoting [22]. Some bacteria mainly acts antagonistic towards Cyanobacteria and are predatory bacteria, some other acts as toxin-degrading. Were Predatory helps to make an environmentally pleasant solution to available HABs. Also number of prey–predator and the mechanism of Cyanobacterial lysis, were some effectual biological control approach [23]. Few of Cyanobacteria mitigated using the secretion of *Cyanobacteriolytic* substances by some *Bacillus* Sp. typically *Bacillus cereus* and [24], *S. neyagawaensis* [25], *Streptomyces* [26], *Pseudomonas fluorescens* species [27]. *Pedobacter* Sp. secretes some mucus-like secretion as self-defense against *M. aeruginosa*. *Raoultella* Sp. removes *M. aeruginosa* by dissolving microbial metabolites and humic acid [28]. *Agrobacterium vitis* use Quorum sensing to lyse *M. aerugenosa* [29]. *Sandaracinobactor sibiricus, Methylobacterium zatmanii* and *Rhizobium* Sp. use lytic mechanism to remove *M. aeruginosa* [30]. Some *Bacillus* Sp. use cell-to-cell contact mechanism and production of an extracellular product to remove *Aphanizomenon flos-aquae* [31] and *M. aeruginosa* [32, 33]. Several reports suggested that algal viruses often existed at stable numbers, even when their hosts were absent [34]. With claim of that summer and spring season showing the eminent decay of cultivated viruses succeeding to four-seasons of analysis [35]. The regular seasonal study also noticed that the stumpy decay of algal virus during the wintry weather that permitted for the survival of about 126 continues days under the ice-cover in the freezing freshwater pond [36]. These agents show high specificity and high efficiency, but it gain limited attention due to high cost, as also requires upscaled level experiment confirmation [37].

5. Fish species used to mitigate HABs

Fish species for all time used an option for bloom removal as number of fishes can ingest and digest the toxin itself. Therefore Bio-manipulation is a promising tool to control HABs for the lake-ecosystem [38]. High toxin production during bloom conditions [39] the massive fish kill was also reported, as its challenging for fishes to survive in oxygen-poor conditions, which suggest result another option to remove HABs [40].

6. Zooplanktons used to mitigate HABs

Several natural grazing environments are having selective herbivores like *Cyclopoid, Copepods*, and *Calanoid*, affecting Cyanobacterial growth by lowering Cyanobacterial densities [41]. Zooplankton show eco-friendly, contamination-free, and low-cost exclusion, but not beneficial at low oxygen conditions. Furthermore it was found that *Daphnia longispina* can ingest many Cyanobacteria [42]. For example grazing is one of the fore most mitigation options for zooplankton, *Daphnia ambigua, Eudiaptomus gracilis* shows graze on *M. aeruginosa* [41]. Besides *Cyclopoid copepods* graze on *Anabaena, Microcystis,* and *Planktothrix* species [41].

7. Fungi used to mitigate HABs

Studies, show that fungi have algicidal activity, and some findings also showed that fungi could produce antibiotics to lyse HABs [43]. Some fungal species, attack directly for lysis of Cyanobacteria or algal species [43]. *Trichaptum abietinum, Lophariaspadicea, Irpexlacteus, Trametes hirsute, Trametes versicolor* and *Bjerkandera adusta* was used to remove *Microcystis* and *Oocystisborgei* [43]. Uses of bio-flocculation method were algae, itself used as a control agent (**Figure 2**) [44]. Flocculating micro

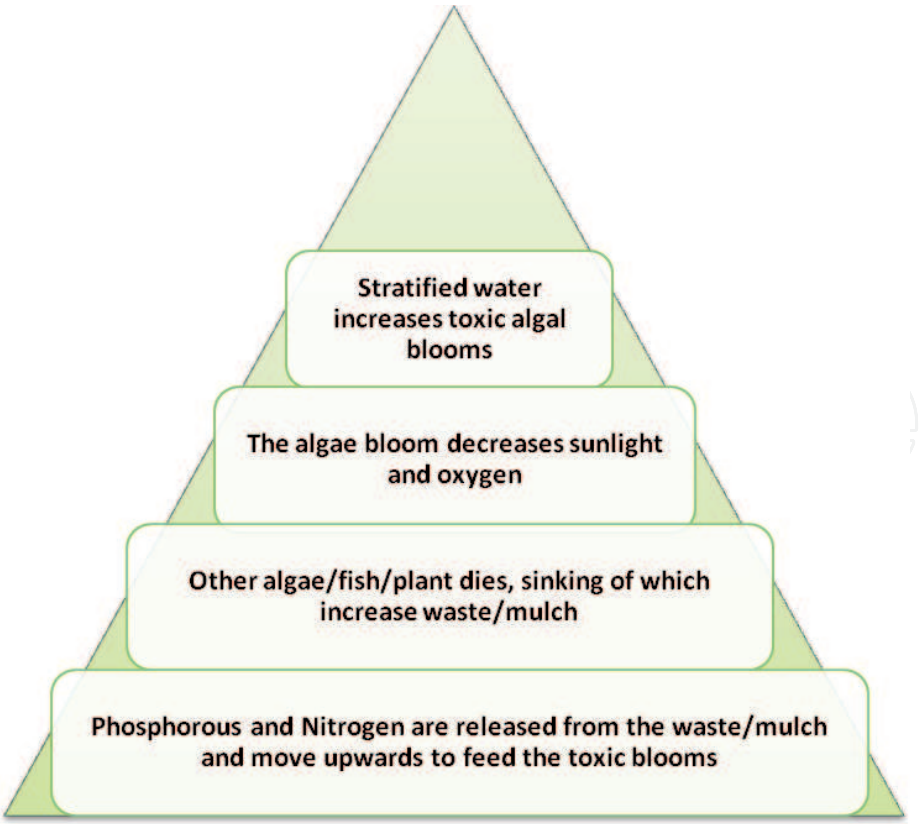

Figure 2.
Interface events of environment and microorganism with HABs.

alga could be used to concentrate non-flocculating alga of attention. The main advantage of this method is that it does not require any flocculating agent [44]. *Ankistrodesmus falcatus, Scenedesmus obliquus* flocculate *Chlorella vulgaris,* and *Tetraselmis suecica* flocculates *Neochloris oleoabundans* [44]. A species of golden alga (*Poterioochromonas* Sp. strain ZX1), is identified as a feeding agent for toxic *M. aeruginosa* and also does not affected by cyanotoxin.

When working with HAB it becomes equally important to consider effects of climate change, as change in climatic conditions supports unwanted growth of algae. At many instance record shows that HABs intensify as water have warmed closer to temperatures that yield maximal growth [18, 45, 46]. It becomes essential to notice that in marine systems, warming has been concerned with intensifying multiple HABs in a number of mid and higher latitude regions [45–47]. On the other hand, these regions with increasing frequencies and intensities of HABs due to progressive warming may be balanced by region that warms beyond of the optimal range for other HABs [47]. Considering together, all such circumstances hypothesis avowed by several case studies explains that HABs may be migrating pole-ward with progressive warming [46–48]. Such migration of HABs to new ecosystems, conversely may create significant risk to aquatic ecosystems, humans and other animals living near them. Because of which indigenous species, experiences selective pressures and thus suffer the most population declines [49, 50].

8. Intention for formation HABs

There is no conclusive report available for the causes of HABs, unfortunately, the causes of HABs are uncertain to date. Though, some of the factor which are thought accountable for causing HABs are briefly described here. An attempt made in **Figure 2** to show interface between some environmental events and microorganism with HABs.

Coastal contamination from a variety of source including household and industrialized effluents is most imperative factors in the growth of HABs. The majority times eutrophication by nutrient enrichment outcomes as blooms of algal growth, from which several are toxic to humans and as well as marine organisms. Contemporary research suggests that eutrophication and climate change are two most important processes that help for proliferation and expansion of Cyanobacterial blooms [51]. It is also important to know that nutrient enrichment can modify the species framework of ecological system [52]. Also inhabitant biota gets displace as the surroundings becomes enriched with nitrates and phosphates [53]. As the coastal eutrophication and improved offshore nutrient concentration taking place offshore due to vertical integration have been linked with the expansion of large biomass, eventually foremost to harmful impacts on ecosystems, human health and fisheries resources. At the same time if eutrophication increases nitrogen and phosphorus inputs, the ratio of these nutrients to silicates becomes very high. This favors non-diatom species including several harmful species. Additionally, it is believed that high concentration of phosphorus, and a low total nitrogen to total phosphorus (TN:TP) TN: TP ratio, are favorable for the production of Cyanobacteria blooms. Recent studies, represents that Cyanobacteria usually dominates in lakes with low TN/TP ratio and are rare in lakes with high TN:TP ratios [54, 55]. Cyanobacteria dominate in lakes where TN:TP mass ratio is below 29:1.

Nutrients consequent from anthropogenic activities have resulted in the increase in HAB account also at some places, unusual heavy rains have resulted in blooms of *L. polyedrum* owing to nutrient rich runoff into the coastal waters. Blooms of Dinoflagellate *Pfiesteria* are found in estuaries of middle and southern Atlantic coasts. The main factors controlling cycles of Dinoflagellates, includes water salinity, pH, nutrients and temperature to one side from these, studies in North California have illustrated that they thrive well near sources of organic phosphates released from sewage treatment plants [56, 57], talk about some Coastal and Continental Shelf Zone (CCSZ) and also Open Oceanic Zone (OOZ) of the Indian segment, were algal blooms can develop only when the calculated rate of biomass increase exceeds the rate of loss generally the grazing and sedimentation rates. As once a bloom develops, it persist for a long epoch under low growth if the rate of loss is small. Still the interactive effects of future eutrophication and changed climate on harmful algal blooms are versatile, and according to current knowledge such processes are likely to enhance the magnitude and frequency of these events. Temperature rise and precipitation associated with climate change falls into broad ranges, also qualms exist in their upshot stratification as North Sea flushing species like *Dinoflagellates* and *Raphidophytes* increase considerably. Some species of *D. acuminata, P. minimum, F. japonica and C. antique* are observed in this region frequently, representing an increase in HAB [58]. Discrepancy in temperature affects circulation patterns, and causes variation in the physical structure of water column that supports occurrence of HABs [59].

9. HAB and impacts

It is very important to consider harmful Cyanobacterial blooms (cHABs) as they are have noteworthy socioeconomic and environmental outlay, by having impact on water quality, drinking water, agriculture, fisheries, tourism, food web pliability, habitats, along with anoxia and fish kills [60]. Also high biomass accumulation and degradation of algal blooms possibly leads to depletion of dissolved oxygen, light attenuation and clogging of fish gills, resulting in fish kills and thousands of other marine life, as direct degradation of the ecosystem [61]. The most critical impacts of algal blooms are on human being health, toxins, produce HABs cause acute and chronic health effects in mammals including humans. For example toxins produced during harmful algal blooms are some of the natural toxic substances directly killing fish/shellfish and other marine life also accumulating in fish and sea food leading to human poisoning after ingestion of contaminated sea food [62]. Sometimes toxins produced during algal blooms may not found toxic to fish and other marine existence. On the other hand, they accumulate in fish and mollusks and move up the food chain and showing shocking impact on humans. Therefore aquatic toxin diseases are categorized into two types as. Shellfish carry toxins that facilitate to paralytic, neurotoxic, diarrheic and amnesic shellfish poisoning. Next type of poisoning is through mollusks tend that occurs during algal blooms. Fish takes toxin that escort to ciguatera and tetrodotoxin poisoning. Poisoning of fish is found more localized and also associated with parts of specific reefs and fishes. Sometimes bloom occurrence of species of Dinoflagellate *Pfiesteria* in estuaries of some middle and Southern Atlantic coast hint that anthropogenic stress on marine environment has caused fish kills and related health hazards in humans also [56]. Species of *Pfiesteria* are also known to cause lesions in fishes. Additionally, we humans can be exposed to toxins that are directly released into water and air. This occur as expected, cell disruption caused through human activities including water treatment. As known such phenomenon frequently occurs in the Gulf of Mexico where residents and beach goers are exposed to toxins through seas spray. Toxins can then be inhaled and lodged in the nose and throat and can down into the lungs. General symptoms associated with this are irritation in respiratory system and frequent coughing.

10. Oceans upwelling

Ascending motions caused due to oceanic circulation is well-known as 'Upwelling', which bring into being some affects to the environmental conditions, beside increases the nutrient content in euphotic zone thus increasing the productivity of the province. Noteworthy findings [63] suggested various factors inducing upwelling off the south west coast of India [64], also have worked to come across the occurrence of the upwelling route along the Dakshina Kannada Coast of India and description shows that upwelling was found to occur from month of March to October along the coast this could be one of the factor for occurrence HABs along the southwest coast of India.

11. Unhealthy coral reefs

Unhealthy coral reefs play a very imperative role in the formation of blooms, as healthy coral reefs are free of external algal growth [65]. Unhealthy conditions/death of corals is generally for the reason that pollution of oil or depositions of sediments leading to encrustations of corals by calcareous materials and algae, plus may in turn lead to the death of zooplanktons and some higher fishes in the food web. Also endolithic algal bloom can cause disease named White Syndrome (WS), entailing of distinct lines between healthy and strong corals and dead ones. Such endolithic algae, including *Ostreobium* Spp. penetrate the coral tissues of tabular *Acropora* Spp., in turn affecting the corals with micro-lessions, which makes them susceptible to infiltration by many pathogens. Some example includes *Gambierdiscus toxicus,* a benthic Dinoflagellate finds way on the dead corals, releasing ciguatoxin which is responsible for causing Ciguatera Fish Poisoning (CFP) [65]. Thus if contaminations affects water quality and coral reefs are affected than *G.toxicus* is likely to bloom, causing widespread release of ciguatoxin. The loads for food, water and fuel continue to increasing to support this ever increase human population. These changes in climate and nutrients are contributing to eutrophication and expanding global footprint of harmful algal blooms (HABs) worldwide. It is now clearly known that the global expansion of HABs is continuing, with increasing abundance, frequency, and geographic extent of HABs, with new species being documented in some new areas [48].

12. Influences of climate change

Inconsistency in climate equally contributes to the apparent increases of HAB, therefore effects of climate change needs to be seriously understood alongside with development of the risk assessments and effective management of HABs. This chapter considers the effects of past, present and future climatic variability on HABs. The one thing we are sure regarding climate is that it is changing and for all time. With complex nature of climate, temperature is only one of many factors to be considered. Each biological life has a temperature window within which it can survive. The direct upshot of global warming with elevated water temperature may affect seasonal composition of the phytoplankton, including changes in seasonal succession, and the position of biogeographic boundaries. There is still insufficient evidence to resolve this problem.

There has been a considerable boost in phytoplankton biomass over the last decades in definite regions of the North-East Atlantic and North Sea, particularly more in the winter months. Also in the North Sea a significant increase in phytoplankton biomass has been found in both intensely anthropogenically-impacted coastal waters and the comparatively less-affected open North Sea. Considerably decreasing trends in nutrient concentrations suggest that these changes are not being driven by nutrient enrichment. The increase in biomass appears to be associated to warmer temperatures and evidence that the waters are also becoming less turbid, thus allowing the normally light-limited coastal phytoplankton to more effectively utilize lower concentrations of nutrients [66]. A study of entity phytoplankton groups has shown increased temperatures were associated with an earlier timing of the highest abundance of some Dinoflagellate species. In disparity, the diatom species examined have not shown such a shift [67]. Coastal time series of HAB phytoplankton are much shorter in extent. Most began in the 1990s various HAB species are flagellates, life forms that are favored by augmented temperatures though direct influences on cellular processes and circuitously through increased stability of the water column. An increase in sea surface temperatures may facilitate the range expansion of HAB species [48].

Eventually elevated and extreme bursts of precipitation be able to increase the amount of runoff from the land and number of floods also. This may enhancing stratification in estuaries and sea lochs favoring the growth of Dinoflagellates. Some humic material during these events may increase the absorption of available nutrients which may promote growth of phytoplankton [48]. It is well-known that changes in temperature, pH, light, nutrient supply and water movement affects algal bloom dynamics as well as their toxicity. Climate change show predictable impact on these variables to differing extents in dissimilar regions [48, 68]. Also a lower pH has the potential to influence the speciation of

Predator/Killer	Habitat	Mode of action	Major host	Reference
Rhizobium sp.	Ambazari Lake, Nagpur India	Lysis	*Microcystis aeruginosa*	[30]
Halobacillus sp.		Bioflocculation	*Microcystis aeruginosa*	[33]
Pedobacter sp. (MaI11–5)	Lake and water treatment plant	Mucous-like secretion from cyanobacteria for self-defense	*Microcystis aeruginosa*	[5]
Myoviridae	Shallow lowland dam reservoir in Central Poland	Species specific interaction	*M. aeruginosa*	[7]
Cyclopoid copepods	Lake Ringsjon southern Sweden	Grazing	*Anabaena, Microcystis*and Planktothrix species	[41]
Trichaptum abietinum	The soil of bamboo forests (Hangzhou, China)	Direct attack	*Microcystis aeruginosa, Microcystis flosaquae Oocystisborgei*	[43]
Lophariaspadicea	The soil of bamboo forests (Hangzhou, China)	Direct attack	*Microcystis aeruginosa*	[43]
Ankistrodesmus falcatus	Freshwater	Bio-flocculation	*Chlorella vulgaris*	[44]
Scenedesmu sobliquus	Freshwater	Bio-flocculation	*Chlorella vulgaris*	[44]

Table 1.
Removal of harmful algal blooms by means of some microorganisms.

nutrients for example nitrogen, phosphate and silica which accounts important for phytoplankton growth [69]. Increased HAB events have a direct detrimental effect on ecosystems and they can often have a direct commercial impact on aquaculture, depending on the type of HAB. Causing economic impact which will be severe as in rural areas impacts to the aquaculture industry will have a disproportionate impact on the economy of the local area. Considering all known aspects about HABs some attempts were made for removal of harmful algal blooms with help of microorganisms as shown briefly in **Table 1**.

13. Manifestation of climate change and HABs

Climate change is negatively impacting health and leading to harmful transformation in aquatic ecosystems [70, 71]. Rising temperatures leading to acidification and oxygenation which alters basal metabolic functioning and species distributions along with the timing of essential biological activities [72, 73]. Due to acidification physiological stress found to increase among sensitive marine species along with growth inhibition of calcifying organisms. As ocean deoxygenation alters the distribution and survival of aquatic organisms [74, 75]. This further alters structure and functioning of marine and freshwater ecosystems. Temperatures rise have predictable impact on the occurrence and concentration of marine diseases, habitat loss, including ocean deoxygenation inviting various environmental contaminants [76, 77]. As increased level of carbon dioxide in atmosphere has generated decreased value of pH in surface waters, offshore, coastal and upwelling marine regions, including freshwater environments [78, 79]. Decreased pH shifts the carbonate system to decrease bicarbonate concentrations and increases dissolved CO_2, thereby increasing carbon availability for photosynthesis [80]. Now such process downgrades the value of metabolically costly carbon-concentrating-mechanisms so that many species of phytoplankton evolved change that may alter the competitive balance among the species [81]. Climate change is now shifting the occurrence and distribution of marine species of various organisms around the world. Therefore frequency and impact of algal blooms have considerably increased around the world in recent decades [82]. Human modifications of the environment such as port construction, release of contaminated water, enriching nutrient by recreation, tourism, fishery, aquaculture, impacts harmful algal contributions [83]. As the reason HABs are now migrating to new ecosystems, therefore considerable risk to aquatic ecosystems and the humans is also found to increase. There is no doubt that oceans are getting warm because of accumulation of CO_2 in the atmosphere through various activities [78]. Elevated CO_2 offers the potential to rebalance the distribution of primary producers that rely upon inorganic carbon for performing photosynthesis [84]. Hence co-occurrence of climate change stressors and their physiological impacts have been in continue study from the past decade, excessive level of biomass generated creates high levels of organic matter which, when respired, promotes hypoxia and acidification [85].

Coastal zones are host to a varied type of aquatic life and are known dynamic ecosystems [86]. Such locations found to be impacted by climate change as several coastal regions are getting warm hastily than the open-ocean [87]. It is also important to note that coastal areas are also prone to eutrophication, acting as stressors, as unnecessary nutrient loading promotes HABs [88]. As result of ecological changes spring diatom blooms within temperate latitudes, surface waters speedily warm and stratify, which isolates bottom waters from surface influxes of dissolved oxygen and lowers CO_2 water, making the condition promoting concurrent hypoxia and acidification [89]. Various HABs flourish in stratified water columns, in late spring and early-summer time's stressor-sensitive, early-life stages of many aquatic genera/species are present in coastal systems [90, 91]. Because of migrating of HABs to new ecosystems native species, experience selective pressures and consequently suffer the greatest population declines [92]. Generally Cyanobacterial HABs are associated with fresh to brackish water, even though blooms of *Trichodesmium* sp. and *Lyngbyaa* sp. in saline tropical and subtropical waters are considered as harmful mainly in Asian and South Pacific nations. Were Cyanobacterial HABs in the marine and freshwater bodies gets worsened due to elevated anthropogenic nutrients that can be the consequences of regional and local population density. Evidence shows that Cyanobacterial HABs are enhanced by elevated temperature [93], Likewise, elevated CO_2 leads to increased growth rates of Cyanobacteria. But surplus inputs of N and P relative to Si shifts the conception from eukaryotic like diatom to Cyanobacteria creation. Noteworthy finding shows that internal loading of phosphorus together with decreasing N:P ratios able to enhance blooms of nitrogen-fixing Cyanobacteria over the other phytoplankton at some area like Baltic Sea.

HABs species too have harmful effects solely on fish other invertebrates. Variety of planktonic algae forms HABs which are associated with killing of fish in nature [94–96]. Example algal blooms of planktonic fish killers haptophyte *Prymnesium parvum,* has caused fish killing blooms worldwide since the first recorded bloom in Danish waters in the 1930s. Some studies show that HABs effects physiology of fish indicating respiratory effect. Evidence shows that on exposure of fish to *P. parvum* reflects toxic effects related to fish gill damage. *P. parvum* exposure may effects fish health as increase in gill permeability found to cause sensitivity to subsequent secondary toxicity, as well as effects of hemolysis and anti-coagulant being noted [97, 98]. Even mammals and birds exposed to Cyanobacterial toxins may become ill or sometimes die. Records show that when other bacteria in the water break-down dead Cyanobacteria, the dissolved oxygen may become depleted, which may responsible to kill fish. Also dense algal blooms in the water column blocks sunlight therefore other organisms cannot survive. Wildlife and pets can become more prone by drinking algal bloom water as very small amount of toxin can also cause illness to some of small animals if ingested. From past few decades, unexpected HAB phenomena have been recognized responsible for eutrophication and ballast water introductions, mean while climate is changing continuously. Changing atmospheric CO_2 concentrations, with rise in global temperatures, melting of glaciers, changing of rainfall and stratification. Seeing that HABs are a global phenomenon requires international understanding, so need has been expressed for generating Global HAB Status.

From last some decade's algal blooms are considered with more importance because of their impact on health and economies around the world [82]. Human modifications of the environmental activities could alter the composition of the phytoplankton community, with varied occurrence and geographic spread of bloom-forming species, also timing of phytoplankton blooms found to changed with increased window each year when blooms can develop [99–102]. Considering example of *Karenia mikimotoi* blooms which are characteristically associated with high rainfall and following low-salinity, high-nutrient run off from land [102]. As temperatures of sea surface in the North Sea have found risen more than the global average over the past 50 years [103]. Practically temperature rise initiates with increase in phytoplankton in the North Sea and North-East Atlantic. Most notably diatoms like *Pseudo-nitzschia* spp. [104, 105]. Increased blooms of *K. mikimotoi* have been seen further in north around the British Isles as compared to past and most potentially linked to changes in duration of stratification [104, 105]. On the other hand, many Dinoflagellates like *Prorocentrum* spp. have decreased in abundance in the North Sea over the last decade, as outcome of increasing temperatures conditions [104–107]. Also shellfish found in Scottish waters have witnessed a decline in the toxins linked with paralytic shellfish poisoning in the last decade [104–107]. These examples show that different species are affected in different ways by changes in environmental conditions. By integrating knowledge of biogeography keen on impact of climate change will be fundamental key for better understanding the effects of change in environment on biodiversity with intention to predict the occurrence and location of an individual bloom event. Now it's time to consider the future directions for HABs and climate change research by bringing together physiologists, ecologists, oceanographers, modelers and climate change specialists to develop consent with priority research for future HABs and climate change effects. In spite how the intensity of HABs changes, the certainty of ecosystems and their toxins creating serious physiological threat to aquatic.

14. Conclusion

The increasing incidences of toxic algal blooms have been reported at international level in the past decades. Which are contributed by various causes including eutrophication, climate changes, upwelling of oceans, including unhealthy coral reefs. All information presented here do recapitulate the current state of knowledge about HABs to better understand how change in climate affecting HABs and also coastal communities worldwide. This chapter highlights environmental factors like temperatures, nutrient and turbulence as scorable aspects for HABs. Also, it is essential to note that these type of change also have the potential ability to decrease magnitude of HABs. Not any of the effects of change in climate discuss at this point are restricted comparatively to few HAB species only. Consequently allowing for the more possibility that in at least some cases several other species could also better exploit to resulting changes in the environmental conditions. Still there is insufficient evidence to resolve this issue. Considering the prediction of outlook HABs, scientists are increasingly being asked to envisage the effects of global change in environments. Now days advances in the understanding and prophecy of HABs is changing worldwide so it's time to formulate international scientific program/committee on harmful algal blooms for providing systematic knowledge to manage and mitigate their impacts.

Author details

Ruby E. Jalgaonwala
Department of Microbiology, Shree Ramkrishna Institute of Computer Education and Applied Sciences, Surat, Gujarat, India

*Address all correspondence to: r_jalgaonwala@yahoo.co.in

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