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# Harmful Algal Blooms: An Increasing Problem and Potential Solutions

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## ABSTRACT

The expanding problem of harmful algal bloom outbreaks has caused the need for new research and advancements in predicting and controlling outbreaks. Studies show that harmful algal blooms have been increasing in frequency of outbreaks worldwide over the last few decades, as well as in spatial distribution of individual outbreaks. As a result, the effects that harmful algal blooms create have become more problematic. These problems include human illness resulting from ingesting contaminated seafood, as well as an offset of the aquatic ecosystem, which can result in mass fatalities of fish and other products of the aquacultural industry. Recent studies provide a sense of what can trigger algal bloom outbreaks to create prediction methods, and potential models of control to limit the growing problem. Further research is necessary to assure the effectiveness of these methods and models.

**KEY WORDS:** harmful algal blooms, contaminated seafood-related illness, fish kill, prediction methods, control models

## INTRODUCTION

There has been an increasing vigilance from the expanding problem of harmful algal bloom outbreaks worldwide. Although algal blooms are a natural phenomenon, the increase in frequency of outbreaks, spatial distribution of outbreaks, and occurrence of harmful species rather than benign species reveals an arising problem. Commonly referred to as "red tide," "green tide," "brown tide," etc., these blooms result from an overgrowth and buildup of algae. Depending on how severe the buildup is, the algae often produce a film on the surface of the water, commonly referred to as "scum." The causative species are types of single-celled algae including dinoflagellates and phytoplanktonic diatoms.(1) Despite the terminology, some harmful algal blooms are cyanobacterial rather than algal.

The increase in number and severity of outbreaks are becoming a danger to public health due to the various illnesses that result.(2) (ADD GRATTAN CITATION) In addition to public health, harmful algal blooms are also becoming a danger to coastal ecosystems

and the aquaculture industry.(2) However, there have been numerous studies that investigate ways to ameliorate the problem. As a result, there have been various methods and models proposed that could aid in predicting and identifying outbreaks and determining severity. In turn, these methods and models would help in keeping this danger to a minimum.

## **FREQUENCY OF OUTBREAKS AND DETECTION METHODS**

The frequency of harmful algal bloom outbreaks has increased over the years. One study focused specifically on outbreaks in the Bohai Sea near China between 1952 and 2014.(3) The data were gathered from different records throughout the years from state and city reports, and then compiled into charts and figures. The figures were maps of the sea with a dot on the area where an outbreak was reported to show spatial distribution of outbreaks. These maps were made using geographic information systems (GIS).(3) The data in the tables showed a variable, but drastic increase since the early 2000's.(3) Only two outbreaks existed in the earliest reports, but that could be a result of the lack of technology and methods for detecting algal bloom outbreaks.

New advancements have been made in detecting outbreaks. One recent study introduced the benefits of using MODIS (MODerate Resolution Imaging Spectroradiometer) measurements when determining the spatial characteristics and severity of harmful algal bloom outbreaks.(4) This method, used in case studies during a Red Tide outbreak in the Persian Gulf in October of 2008, obtained measurements from satellite images.(4) This method is much more efficient than earlier methods since it utilizes satellite images. Blooms are identified by spectral changes in the water of areas under surveillance on the Terra and Aqua satellites. MODis sensors have been on Terra since 1999, and on Aqua since 2002.(4) This method could explain the reason the outbreaks in the Bohai Sea study drastically increased after 2000, but it is not stated which detection methods were used in the original reports.

## **EFFECTS AND RESULTS OF HARMFUL SPECIES**

Algal blooms are deemed to be harmful when they produce either of these two results: contamination of seafood, or an offsetting effect to the marine ecosystem.(5) Seafood contamination results from toxin-producing algae, and offset ecosystems result from high-biomass-producing algae.(5) Both harmful and benign algal species were identified in the outbreaks in the Bohai sea study.(3) The second most recorded species was *Prorocentrum Dentatum*, which is the cause of one of the five most common algal bloom-related illnesses.(1, 3) This species belongs to a family of dinoflagellates that produces the okadaic acid toxin that contaminates the surrounding shellfish and, when ingested through consumption of contaminated shellfish, *diarrhetic shellfish*

*poisoning* can occur.(1) The other most common algal bloom-related illnesses are *amnesic shellfish poisoning*, *ciguatera fish poisoning*, *neurotoxic shellfish poisoning*, and *paralytic shellfish poisoning*.(1, 5) Table 1 describes the most common species responsible for harmful algal blooms, the dangers they cause, and where they have been found.

The most common species recorded in the Bohai Sea study was *Noctiluca Scintillans*, a non-parasitic, non-toxic species of dinoflagellates.(2) This species is under the aforementioned high-biomass-producing algae category. High spatial and dense levels of these blooms can accumulate high levels of ammonia in the water, killing the surrounding fish.(2) The 2008 Red Tide outbreak in the Persian Gulf was caused by *Cochlodinium polykrikoids*, a species of dinoflagellates, and caused a huge loss of large fish and other marine animals, and had a detrimental affect on coral reefs and different marine filtration plants.(4) In Alfacs Bay in the Mediterranean Sea, a major area for harvesting shellfish, the conditions for algae growth (specifically the *Karlodinium* and *Pseudo-nitzschia* species) were important to shellfish production. However, high levels of such algae became harmful to those who consumed the shellfish that were harvested in that area.(6) The Wuxi Water Crisis of 2007 was caused by the cyanobacterial species *Microcystis aeruginosa*.(7) A toxic black bloom occurred in the fresh water areas in Wuxi City, China and cut off drinking water supplies to the city's entire population.(7) The cyanobacteria that caused the black bloom in Wuxi City also caused a bloom in Lake Tiahu in 2010 that offset the ecosystem and caused a massive fish kill.(7)

## **FACTORS THAT INCREASE OUTBREAKS**

Different weather and meteorological factors have recently been found to affect algal bloom outbreaks significantly. Due to the undoubted presence of global warming, certain climate factors have deviated from the historical norm, such as temperature, precipitation, and wind.(8) Meanwhile, the algal species that have been present in Earth's waters for millions of years have been emitting higher levels of carbon dioxide, resulting in higher acid levels.(8) These two recent changes in global weather and aquatic conditions have reacted with one another and increased algae growth in waters throughout the planet.(8) Specifically in lake settings, certain meteorological properties and deviations in those properties affected the outbreaks of algal blooms. One study conducted in Lake Tiahu (in China) investigated the effects of meteorological factors that appeared to increase the probability of harmful outbreaks.(7) These factors that increased the probability of outbreaks included increasing climate temperatures, decreasing wind speeds, and decreasing air pressures.(7) Another factor that is likely to increase algae growth is excessive nutrient loading.(9) In this case, excessive nutrient loading is the result of excessive of sunlight, carbon dioxide, and other photosynthetic

reactants. However, one study contemplated whether that is the true cause of the outbreaks of the phytoplankton *Aureoanra lagunensis*, which is the causative species of brown tide in the Gulf of Mexico, or whether they are caused by a decrease or absence of the zooplankton species that consume the phytoplankton.(9, 10)

## **POTENTIAL PREDICTION/CONTROL METHODS**

There are a number of advancements in research on harmful algal blooms that offer potential control and prediction methods. The Lake Taihu study determined thresholds for deciding whether or not certain conditions are harmful to water filtration plants or not, and therefore to know whether or not to temporarily shut down plants to avoid disasters such as that of the Wuxi Water Crisis.(7) Another study proved the use of the fungi *Phanerochaete chrysosporium* as a successful inhibitor of harmful algal blooms.(11) The fungi caused cell death of the algal cells through destruction of the cell membrane and nucleic acids.(11) Due to the fickle conditions of the area in the Alfac Bay study, legislation was passed in 1987 that requires weekly sampling of algae levels to ensure safety for food production.(6) Such testing should be done in other areas prone to harmful outbreaks.

More than 20 years worth of data from the Alfac Bay study allowed scientists to develop forecast models to predict when harmful blooms will occur. One of these models included an Artificial Neural Network (ANN).(6) An ANN is a figure/table that shows the relationship between one subject (harmful algae) and multiple factors (temperature, salinity, oxygen levels, etc.). The key to developing ANNs is large data samples.(6) Complex time series and large data sets allow for an algorithm to be developed that can reliably predict outbreaks from certain input factors (temperature, salinity, oxygen levels, etc.).(6) Other studies provided helpful research on certain weather conditions that could predict harmful algal bloom outbreaks. Although it would be difficult to execute, if a downscaled global climate prediction model was developed, a valuable prediction model for harmful algal blooms could also be developed.(8) By being able to predict the rate of temperature changes, prediction of bloom outbreaks would be feasible.

## **CONCLUSION**

The arising problem of harmful algal bloom outbreaks is apparent through the increase of frequency of outbreaks, the increase in spatial distribution of outbreaks, and the occurrence of harmful species rather than benign species of algae. Due to the recently acquired knowledge of factors that increase the occurrence of outbreaks, potential methods of prediction and control have been proposed. The fungi-control method has been proven to have potential, as well as the prediction model that utilizes weather

forecast, given that a downscaled model of global climate forecast is feasible. Further studies and presumed advancements on these potential methods will assure the effectiveness of such methods.

**Table 1. Common Species found in Harmful Algal Blooms**

<b>SPECIES</b>	<b>HARMFUL EFFECTS</b>	<b>RESULTS</b>	<b>AREAS WHERE SPECIES HAVE BEEN FOUND</b>	<b>CITATION</b>
Gamberidius toxicus	Contamination of seafood	Ciguatera fish poisoning	French Polynesia	(2, 5)
Pyrodinium Bahamense	Contamination of seafood	Paralytic shellfish poisoning	Atlantic Ocean	(5, 12){, 2010 #23}
Species of Alexandrium genus	Contamination of seafood	Paralytic shellfish poisoning	Australia, American West Coast, Ireland	(5, 13)
Species of Dinophysis genus	Contamination of seafood	Diarrhetic shellfish poisoning	Worldwide oceans	(5, 14) (1)
Prorocentrum Dentatum	Contamination of seafood	Diarrhetic shellfish poisoning	China	(5) (1) (3)
Gymnodinium breve	Contamination of seafood	Neurotoxic shellfish poisoning	Gulf of Mexico, Florida, New Zealand	(5) (2)
Species of Amphidinium genus	High biomass production	Fish kills	Northern Atlantic, Gulf of Mexico, Baltic Sea, Mediterranean sea, Brazil, New Zealand	(5) (15) (16)
Cochlodinium polykrikoides	High biomass production	Fish kills, offset of ecosystem	Caribbean Sea, Northern Atlantic coast, North-Western Pacific coast, Persian Gulf	(5) (2) (4)
Species of Chrysochromulina genus	High biomass production	Fish kills	Baltic Sea, Brazilian coastline	(5) (15) (17)

Species in Raphidophyceae class	High biomass production	Fish Kills, Allergic skin reactions in swimmer	Fresh waters in Southeastern Brazil	(5) (18)
Pseudo-nitzschia australis	Contamination of seafood	Amnesic shellfish poisoning	Worldwide coastal waters	(1, 5, 6) (13)
Noctiluca Scintillans	High biomass production	Fish kill	Worldwide warm coastal waters	(3) (2)
Species in Karlodinium genus	High biomass production	Fish kill	Worldwide coastal waters	(6) (19)
Microcystis aeruginosa	High biomass, Neurotoxin production	Fish kill, Drinking water toxicity,	Fresh waters	(7)
Aureoumbra lagunensis	High biomass production	Shellfish and fish kills	Gulf of Mexico	(9) (10) (20)

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