1. **Monitoring Harmful Algal Blooms in Singapore: Developing a HABs Observing System**

Abstract

There is enhanced interest in monitoring and detecting of HABs. An attack leads to massive fish kills and great economic losses. Interdisciplinary approach involving:

* Robotic network adaptation,
* Multi-scale-sensing using autonomous vehicles
* in-situ and
* Real time multidisciplinary data acquisition using unmanned and wireless network

Can be utilized to study and monitor HABs in waters. The study managed to collect high spatial resolution data using.

*Low salinity* was observed near the mouth of the reservoir, and the salinity increased with increasing distance from the reservoir mouth. In contrast, *high phytoplankton biomass* was observed near the reservoir mouth, while lower concentration was found further away from the mouth. This information could assist in *defining bloom parameters* and enhance our ability in determining and detecting pre-bloom condition. In addition, the ASV platform used in this study could assist in collecting high spatial resolution data set, which was not possible with point sampling. The information provided by the present study can assist in refining of bio-optical models for detecting and monitoring of HABs.

Introduction

The magnitude and the duration of a bloom may also determine the degree of impact on an ecosystem. Detecting and monitoring of algal blooms in selected waters are essential to describe the trends of blooms, and thus providing a means for protecting the aquatic ecosystem and public health. The specific causes of HABs are complex, and they vary between species and locations, and are not all well understood.

The detection and monitoring of HABs in a given ecosystem might be challenging due to *regular eutrophication events and high levels of sediments in the water column*. These characteristics make traditional optical and satellite detection methods somewhat unreliable.

Multidisciplinary data and high spatial resolution data sets are essential to observe the oceanographic processes and dynamics of algal blooms in this area. The focus of the present study was to develop mobile sensor networks for monitoring HAB events, formation and the biology of bloom-forming species in Singapore waters.

II. Materials & Methods

Interdisciplinary Approach

The study used a tiered adaptive network for multi-scale sensing, which involved a robotic network adaptation, multi-scale-sensing using autonomous vehicles and in-situ and real time multidisciplinary data acquisition using unmanned and wireless network.

The network consists of ships, fixed instruments, and autonomous vehicles (unmanned aerial vehicle (UAV), autonomous surface vehicle (ASV), autonomous underwater vehicle (AUV).]

Conditions include areas with:

* Possible nutrient input from terrestrial sources,
* Freshwater input and
* Areas with minimum water movement.

III Data Collection and Measurements

*Tiered adaptive network for multi-scale sensing* was used to measure environmental parameters. Areas around a targeted station or area was monitored using UAV. Then the ASVs and AUVs mounted with multiples sensors were deployed accordingly for data collections. Experimental trials were conducted every six months from Dec 2010 to Jan 2012.

The following parameters;

* Temperature,
* Salinity,
* Chlorophyll (chl)-a and
* Dissolved oxygen was measured.

Time series measurements were conducted from Sept 2010 to Jan 2012 at stations. Physical parameters were measure at site.

Sea water samples for:

* Nutrients,
* pigments (chl-a) and
* colored dissolved organic matter (CDOM), were collected from the surface water a clean bucket.

IV. Data Preparation and Analysis

Contour maps are created using ocean data view. *The salinity was lower at the outlet of the Reservoir as compared to salinity measured further away from the reservoir outlet*. (Show maps) On the contrary, *biomass as indicated by chl-a concentration showed a decreased in concentration with increasing distance from the reservoir’s outlet* (Show maps) A significant relationship between salinity and chl-a was found. Similar trend between *salinity and chl-a* was also observed from phytoplankton assemblage from other study areas. This observation suggests that salinity might be an important factor regulating the phytoplankton biomass. *The salinity level might also affect the phytoplankton communities, and thus, it should be considered when monitoring and detecting HABs.*

Data measurements were also conducted at different tide i.e., *ebb tide vs. flood tide.* During ebb tide, narrower range of variability in both environmental parameters and biological measurement were observed (Map). On the other hand, during flood tide, larger range of fluctuation in parameters was observed*. For example, the chl-a concentration was found to differ around two times between ebb and flood tide*.

*As for the time series experiments*, during the sampling period, it was noted that the concentration of colored dissolved organic matter (CDOM) was very high in the East as shown by *the indicative index CDOM (250)*. *CDOM is known as the main absorber of sunlight and a major factor determining the optical properties of coastal waters.* CDOM can also serve as a source of nitrogen in marine waters. There as well exist significant *relationships of between CDOM and chl-a and salinity*.

It has been consistently observed that the quantity of CDOM shows a negative relationship with salinity (i.e., high concentrations were observed at low salinity). This is because high CDOM is usually associated with low salinity and CDOM is normally originated from freshwater sources.

Low salinity and high CDOM might be some of the conditions necessary for high phytoplankton biomass development as pre-conditions of algal bloom especially toxic HAB.

V. CONCLUSION

Circulation patterns driven by tides play an important role in determining the distribution of phytoplankton biomass and other environmental parameters.

Variability in the biomass could be determined by environmental parameters such as salinity and CDOM. The observed variability of environmental parameters in the present study suggested that the condition of this coastal system is subjected to multiple influences such as the input of terrestrial sources, atmospheric conditions, and tidal currents. Characterization of these parameters could assist in the identification of trends, and the estimation of short and long-term implications of such changes for the environment and society. Moreover, such information could assist in detecting and mitigating HABs. *With more data, algorithm could be fine-tuned to provide a means to interpret field populations and enhance the capability for detecting harmful species*.

1. **The Monitoring of Harmful Algal Blooms through Ocean Observing: The Development of the California Harmful Algal Bloom Monitoring and Alert Program**
2. **A Comprehensive Review on Water Quality Parameters Estimation Using Remote Sensing Techniques \_ Enhanced Reader**
3. **Harmful Algal Blooms Threaten the Health of Communities A Case Study in Kisumu Bay, Lake Victoria, Kenya**
4. **EO Lake Watch; delivering a comprehensive suite of remote sensing algal bloom indices for enhanced monitoring of Canadian eutrophic lakes.**

Abstract

To address the constantly deteriorating water quality, EOLakeWatch was developed to deliver a suite of useful, easily interpretable, and accessible EO-derived products to support algal bloom monitoring on these three lakes.

Algal bloom indices, *describing bloom spatial extent, intensity, duration, and severity* were derived using the *European Space Agency’s OLCI (Ocean and Land Colour Instrument) sensor for observations from 2016 to present and its predecessor MERIS (Medium Resolution Imaging Spectrometer) for 2002 to 2011*