Remote Sensing Strategy for the Study of Algal Monitoring

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Abbreviations

ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ALI	Advanced Land Imager
AVHRR	Advanced Very High Resolution Radiometer
Hyperion	First spaceborne hyperspectral sensor onboard Earth Observing-1(EO-1)
IKONOS	High-resolution satellite operated by GeoEye
IRS-1C/D-	LISS Indian Remote Sensing Satellite/ Linear Imaging Self Scanner
IRS-P6-	AWiFS Indian Remote Sensing Satellite/Advanced Wide Field Sensor
Landsat-4 5 TM	Thematic Mapper
Landsat-7 ETM+	Enhanced Thematic Mapper Plus
MODIS	Moderate Resolution Imaging Spectroradiometer
HABs	Harmful algal blooms
MERIS	Medium Resolution Imaging Spectrometer
AVIRIS	Airborne Visible/Infrared Imaging Spectrometer
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
NOAA	National Oceanic and Atmospheric Administration
Chl a	Chlorophyll a

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1 Introduction

Applications of satellite remote sensing have given very powerful insight to the study of aquatic and freshwater ecosystems because it provides sophisticated information for the management of water conditions and resources. The concept of harmful algal blooms (HABs) expansion in inland water bodies has been increasing worldwide; therefore, algal monitoring and study have their importance and challenge today. Lots of efforts and steps are taken for proper monitoring and management of algal blooms and reducing their expansion; it's a global concern. The impact of the blooms has an effect on human health, ecosystems, and marine mammals, with evidence of economic losses in the fishing, aquaculture, and recreation industries (Camen et al. 2001). In August 2000, nine people in Washington State became ill from PSP (paralytic shellfish poisoning) after consuming recreationally harvested shellfish from closed waters of Carr Inlet in South Puget Sound.

In India evidence of occurrence of algal communities that have 101 cases has been identified; therefore, for the purpose of monitoring, a lot of programs are organized with the participation of many institutions and government agencies like the Bathythermograph (XBT) program; Ballast Water Management Program, India (BAMPI); Ministry of Earth Sciences (MOES); and CSIR–National Institute of Oceanography (NIO) (D'Silva et al. 2012). Under this program, Port Baseline Biological Surveys (PBBS)-like programs are trendy in the port region of some parts of India. It is found that flourishing growth of numerous species of green, red, and brown algae occurs along the southeast coast of Tamil Nadu from Rameswaram to Kanyakumari; also, algal community expansion has been a concern in the Cheriyapaniyam and Kiltan in Lakshadweep. The mission adopted the technique which is commonly used for identification of the Eutrophication Status of the Maritime Area. The NOAA (National Oceanic and Atmospheric Administration) testified the first valua-

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tion on the load and effect of nutrient concentration in US estuaries – National Estuarine Eutrophication Assessment (NEEA). The Helsinki Commission that is also called HELCOM developed many tools and methods for calculation of eutrophication in the Baltic Sea. From the marine study, the red tide phenomena and HABs of the middle Gulf of Oman and outer Arabian Sea have been recorded since 1987 (Thangaraja et al. 2007); there is the detection of the blue-green algae, *Trichodesmium* spp., in coastal Arabian Sea water using Landsat satellite data (Chaturvedi et al. 1986).

1.1 Algal Blooms in Water Bodies

An observable and sticky symptom of eutrophication within water bodies is speedy expansion and growth of phytoplankton leading to fading and pollution of contaminated water. These events are referred as bloom. For estimation of productivity of algal community, we have to combine ancillary data taken from temperature, salinity, and tissue nutrients and get biomass from it. The main impact of eutrophication is the rapid expansion in the amount of algae community in water bodies and wetlands, and a coastal marine ecosystem leads to increase in biomass accumulation. The incident shows highly in cyanobacterial population which have been testified as toxic and harmful worldwide for natural water bodies, and similar trends are reported here both for phytoplankton for causing turbidity in reservoirs and for top algae community in water bodies and rivers. These blooms are responsible for water quality contamination and harm aquatic life, which can lead to bad taste, discoloration, bad odor, decreased amount of oxygen, toxicity, fish kills, and food web alterations (Paerl et al. 2001). The anthropogenic sources like increase in urbanization, agricultural activities, and industrialization cause increment in discharge of phosphorus (P) and nitrogen (N) which are the main nutrient loads in waters, and the increase amounts, proportions, and chemical composition of these nutrients lead to algal bloom (Pearl 2008). The blooms that are not removed from the food web and by other natural means increase sediment load at the bottom of water bodies and are responsible for biological oxygen demand (BOD). Therefore, N and P load of water must be removed by two methods: single nutrient removal like nitrogen and both N and P removal. There are also other removal techniques to overcome these nutrient loads; these are hydrologic manipulations, reducing the water dwelling time via flushing and artificial mixing (Pearl 2008).

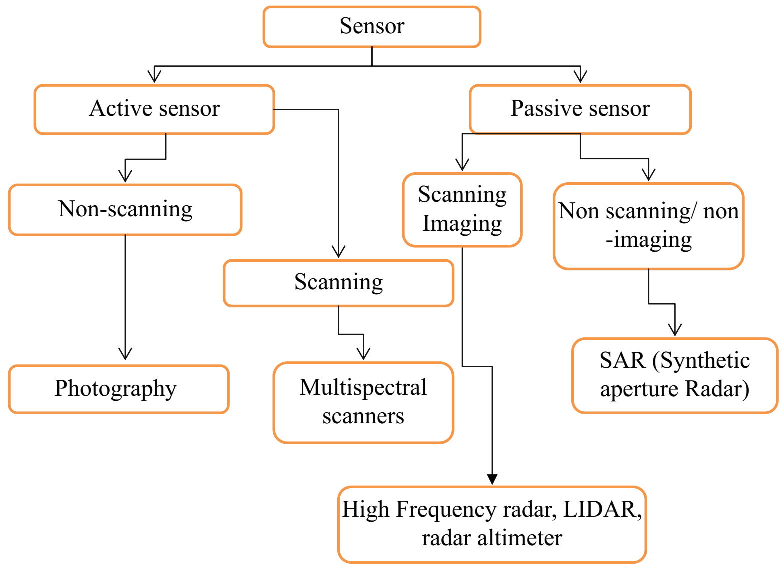
1.2 Harmful Freshwater Algal Blooms (HABs)

There are many harmful phytoplanktons present in water and are capable of forming blooms, an example of which is blue-green algae (or cyanobacteria) which are the most notorious bloom formers. Other examples are scum-forming genera like *Anabaena*, *Nodularia*, *Microcystis*, and *Aphanizomenon*, as well as *Oscillatoria* and *Cylindrospermopsis*. They are subsurface bloom formers and have ability to tolerate nutrient-enriched conditions. These Blooms flourish in extremely productive waters by being able in the direction of speed travels, between top bright surface waters and nutrient-rich area at benthic region. In addition, a lot of detrimental species are tolerant of extremist environmental situation, including incredibly periodic nutrient deprivation, high temperatures, and waterlessness. A lot of the most harmful cyanobacterial bloom genera (e.g., *Nodularia*, *Anabaena*, *Aphanizomenon*, *Cylindrospermopsis*) are capable of setting up atmospheric nitrogen, enabling them to periodically dominate under nitrogen-limited environment. The significance of cyanobacteria is that they produce organic compounds, including those that are poisonous from top trophic-level consumers, like zooplanktons, to uppermost consumer in the food web. The adjustments in the abundances of other organisms are also related to variations in this phytoplankton in the water bodies.

1.3 Overview of Remote Sensing

Remote sensing tool has many attributes for exploring, mapping, and monitoring the environment. Spatial variations complicate the study of recurring and long-term trends of biological conquest. Remote sensing, however, by way of its broad view has the potential on the way to bring the relevant information. Satellite imagery is availably designed for nearly every one of the humankind. The scenery of satellite imagery permits keeping track of dynamic features of landscaping and consequently can provide a means to detect key land cover alterations and measure the rates of change. Remote sensing tool is applied in a variety of fields of science and technical investigations as well as used for monitoring purposes. It covers the area of meteorological studies to measure atmospheric pressure, water vapor, and wind velocity. In oceanographic studies, its utility is toward measuring sea surface temperature, wave energy, mapping ocean currents, and its spectra. It is also applied in the fields of glaciology, disaster management, geodesy, geology, cartography, landscape, planning activities, oil and mineral studies, environmental monitoring and exploring, hydrology, and forestry and in defense. There

Fig. 13.1 Types of sensors (Source: Adapted from Harvey 2008)



are many sensors available in satellites and airborne instruments which are capable of getting information from a targeted area. There are two types of sensors (Fig. 13.1: Types of sensors): active and passive. Active sensors have their own source of light for illumination like radar and passive sensors do not have their own source of light; they detect energy from naturally occurring energy, i.e., sun, like Landsat sensors. All satellite and airborne sensors utilize both active and passive methods of sensing, for example, camera. Another example of active remote sensing is radar instrument to monitor speed of vehicles which is mainly used by police.

2 Remote Sensing in Algal Monitoring and Detection

Satellite remote sensing has a benefit over traditional monitoring strategies for monitoring algal blooms because it offers synoptic coverage and real-time consistency of the data captured plus help when there is unavailability of field data. The reflectance properties of various algal types and estimation of chlorophyll present in the each type of algal bloom can predict the algal bloom characteristics from absorbance spectra (400–600 nm) of each pigment and help in monitoring purposes and identification; remote sensor used for it are TM imagery, AVIRIS, and hyperspectral remote sensing (Richardson 1996). The algal community blooms increased in the eastern boundary along the coasts of Washington-Oregon in California, Northern Peru, Namibia, and south-western part of India; the research demarcated the expansion of harmful algal blooms (HABs) from different satellite sensors and its utility in applying the identification of chlorophyll concentration and reflectance properties for the algal bloom expansion locally and globally (Klemas 2012).

Satellite and aboveground measurements of spectral reflectance (ocean color) assists in monitoring chlorophyll concentration and absorption of phytoplankton; the surface radiances refer to the changes into reflectance, calculated from reflectance values from the remote sensing sensors for classifying chlorophyll and other properties of water. There are many sources of ocean color data from where information can be collected (Table 13.1). For remote sensing of single species of algae (e.g., *Oedogonium*), a study that was conducted on color infrared film observed from aerial photography helped in detecting regions of *Oedogonium* progression which are clearly segregated as a light orange color within the red-colored *Myriophyllum* beds (Michael et al. 1974). To minimize errors in interpretation, atmospheric correction must be accomplished for detection of algal communities from any sensors. The remote sensing survey was conducted to establish visual interpretation of the lake and to calculate the execution of observational and semi-expository calculations in hypertrophic water. For incessant change detection applications in inland waters, MERIS is the ideal sensor. Procedures for estimating chlorophyll a, total suspended solids (TSS), Secchi disc depth (zSD), and other measurements are derived simultaneously which are collected from in situ measurements from MERIS. The review illustrated the current remote sensing techniques, diverse algorithms for detecting HABs, and its spatial scale. With the use of visual interpretation, parameter retrieval, and spectra investigation along with spatial-temporal pattern analysis, the detection of HABs can be frameworked. The research describes the improved way of cyanobacterial sprout transport applying preoperational hydrodynamic model and high temporal resolution satellite imagery. The experiment defines the bloom position and extent of the region; for this purpose a geographic center was calculated and assigned to the bloom

Table 13.1 Details of sources of ocean color* data, information, and products

Satellite	Details	Web source
NASA OceanColor Web	Daily, weekly, monthly, and seasonal climatology	www.oceancolor.gsfc.nasa.gov
	Gathering, processing, calibration, validation, archive, and distribution of ocean-related products from a huge number of operational, satellite-based remote sensing missions providing ocean color, sea surface temperature, and sea surface salinity data	
GlobColour/ HERMES	Merging of MERIS, SeaWiFS, and MODIS	www.hermes.acri.fr
	Daily, weekly, and monthly	
	Extraction of ocean color data for user-defined areas is possible and a free GlobColour subscription service allows users to systematically obtain near real-time products at 1 km spatial resolution for a specific area	
NOAA	Provides access to multiple satellite ocean remote sensing data and products	www.coastwatch.noaa.gov
CoastWatch		
ESA	It is mainly designed to discover out more about the globe, its instantaneous space environment, solar system, and the cosmos and in addition to develop satellite-based technologies and services	www.envisat.esa.int
MyOcean	Provides access to a range of regional and global ocean color data, including GlobColour	www.myocean.eu.org or
		www.hermes.acri.fr

*Ocean color refers to information in relation to the optical properties of the ocean; it includes parameters like concentration of chlorophyll *a* and suspended sediments
Source: Dean (2007)

from satellite data. The position of cyanobacteria is determined by the image pixel which contains the species information and may link between different images for its better interpretation.

3 Sensors and the Modeling Techniques Used for Algal Remote Sensing

For monitoring purposes along with the study of algal population and their growth, remote sensing sensors are available and used as source of gathering information regarding modeling such that all ease the task. A number of modeling techniques demonstrate that multispectral sensors such as Landsat or MODIS, AVHRR, AVIRIS, and SeaWiFS are ineffectual in differentiating waters subjugated as a result of cyanobacteria within water bodies (details of sensors given in Table 13.3). The sensors meant for the study of algal communities have their own characteristics along with some limitations and advancements. MERIS satellite sensors permit the detection of phycocyanin absorption close to 630 nm, along with a little rise in reflectance spectra that settles to 650 nm which is characteristic of waters dominated by cyanobacteria. Consequently, MERIS can be used in identifying cyanobacteria and other species of algae in the event that they are available in moderately substantial amounts (Table 13.2). This is due to the fact that their spectral band pattern will not allow the identification of absorption features produced via phycocyanin pigment (present within cyanobacteria), other than several additional spectral features that are characteristic of cyanobacterial population. Recently, scientific studies show that monitoring of surface water is capable of taking advantage of remote sensing practice which provides a synoptic view over big areas and repeated acquisitions. For this, in situ data are needed for the calibration and justification of satellite-based products. Both MODIS and MERIS imageries are well suited on behalf of regional assessments of chlorophyll and other optically associated water quality features of large inland lakes, other than their coarse spatial resolution which to a great extent possesses restriction for lakes that can be considered. The spatial resolution derived from Landsat satellites facilitates lakes <4 ha appearing in area to be assessed; however, its low spectral resolution confines it toward assessments of water transparency (Olmanson et al. 2011). Yet, there is proof that remote sensing imagery and analysis possibly will be exploited and meant for the implementation of the EU-WFD (Bresciani et al. 2011). On the other hand, the detection of emerging blooms may perhaps not be possible because the phycocyanin absorption feature merely results in being detectable via MERIS as soon as chlorophyll a concentrations access certain standards of approximation (depending on species). MODIS and MERIS imageries have been used regularly and are meant for global-scale assessments of oceanic and sea chlorophyll (Reinart and Kutser 2006; Kutser et al. 2006; Hansson and Hakansson 2007; Kratzer et al. 2008; Park et al. 2010) other than barely a few fields of study that have examined their use in support of studies of coastal waters and lakes (Alikas and Reinart 2008; Tarrant et al. 2010; Guanter et al. 2010; Matthews et al. 2010; Binding et al. 2011; Olmanson et al. 2011) (Table 13.3).

Results from these concluding studies indicate that MODIS along with MERIS compromises good potential for monitoring colored dissolved organic material (CDOM) and

Table 13.2 Sensor used for the species identification

Sensor used	Worked on
TM, AOCI, SeaWiFS, AVIRIS	Chlorophytes (green algae)
	Ankistrodesmus falcatus, Schroederia setigera, Staurastrum natatura
	Chrysophytes (diatom sp.)
	Melosira granulata
	Cryptophytes
	Cryptomonas pusilla, Cryptomonas ovata
	Cyanophytes (blue-green algae)
	Anabaena flos-aquae, Aphanizomenon flos-aquae
	Chlorophytes (green algae)
	Schroederia setigera
	Chrysophytes (diatoms)
	Fragilaria brevistriata, Fragilaria crotonensis
	Cryptophytes
	Cryptomonas pusilla
	Cyanophytes (blue-green algae)
	Anabaena flos-aquae, Aphanizomenon flos-aquae, Microcystis aeruginosa
Landsat series satellite, ALI, IKONOS, MODIS, MERIS, AVHRR, CZCS, SeaWiFS	*Cyclotella cryptica, Aphanizomenon flos-aquae, Aphanizomenon flos-aquae, Anabaena circinalis, Nodularia spumigena, Scenedesmus obliquus*
AAHIS, AVIRIS, Proto, CRESPO, IKONOS, Landsat-ETM+, SPOT-HRV	Mapping the algae, sand, and coral extent
MODIS, AVHRR, SeaWiFS, MERIS	*Microcystis*, *M. aeruginosa*

Table 13.3 Characteristics of sensors used in algal remote sensing

Satellite sensor	Bands	Resolution		
Landsat		Spatial	Temporal	Radiometric
Thematic Mapper (TM)	Six multispectral bands:	30 m for multispectral 120 m for thermal	16 days	8-bit
	(1) 450–520 nm (2) 520–600 nm			
	(3) 630–690 nm (4) 760–900 nm			
	(5) 1550–1750 nm (6) 2082–350 nm			
	One thermal band: 10,400–12,500 nm			
Enhanced Thematic	Six multispectral bands:	30 m and 15 m for panchromatic	16 days	8-bit
Mapper Plus (ETM+)	(1) 450–515 nm (2) 525–605 nm			
	(3) 630–690 nm (4) 750–900 nm			
	(5) 1550–1750 nm (6) 2090–2350 nm			
	One thermal band: 10,400–12,500 nm			
	One panchromatic band: 520–900 nm			
Coastal Zone Color Scanner (CZCS)				
	Five multispectral bands:	825 m for all bands	26 days	8-bit
	(1) 433–453 nm (2) 510–530 nm			
	(3) 540–560 nm (4) 660–680 nm			
	(5) 700–800 nm			
	One thermal band: 10,500–12,500 nm			
SeaWiFS				
	Eight multispectral bands:	1.1 km for all bands	1–2 days	10-bit
	(1) 402–422 nm (2) 433–453 nm			
	(3) 480–500 nm (4) 500–520 nm			
	(5) 545–565 nm (6) 660–680 nm			
	(7) 745–785 nm (8) 845–885 nm			

(continued)

Table 13.3 (continued)

Satellite sensor	Bands	Resolution		
Landsat		Spatial	Temporal	Radiometric
IKONOS				
	Four multispectral bands:	4 m for multispectral	<3 days	11-bit
	(1) 445–516 nm (2) 506–595 nm	1 m for panchromatic		
	(3) 632–698 nm (4) 757–853 nm			
	One panchromatic band: 450–900 nm			
QuickBird				
	Four multispectral bands:	2.44 m for multispectral	1–5 days	11-bit
	(1) 450–900 nm (2) 520–595 nm	0.61 m for PAN		
	(3) 630–690 nm (4) 760–900 nm			
MERIS				
	15 Multispectral bands:	From 300 to 1200 m	3 days	12-bit
	(1) 407.5–4175 nm (2) 437.5–447.5 nm			
	(3) 485–495 nm (4) 505–515 nm			
	(5) 555–565 nm (6) 615–625 nm			
	(7) 660–670 nm (8) 677.5–685 nm			
	(9–15) 700–905			
MODIS				
	36 Multispectral bands:	250 m for bands 1 and 2	1–2 days	12-bit
	(1) 620–670 nm (2) 841–876 nm	500 m for bands 3–7		
	(3) 459–479 nm (4) 545–565 nm			
	(5) 1230–1250 nm (6) 1628–1652 nm			
	(7) 2105–2155 nm (8) 405–420 nm			
	(9) 438–448 nm (10)483 493 nm			
	(11) 526–536 nm (12) 546–556 nm			
	(13) 662–672 nm (14) 673–683 nm			
	(15) 743–753 nm (16) 862–877 nm			
	(17–36) 890–14,385 nm			

Sources: Jensen (2007), McClain et al. (1992, 1998), Hooker et al. (1992), and Rocchio (2010)

chlorophyll. MERIS is maybe best suitable among these sensors used for keeping track of coastal inland water quality, through a full resolution of approximately 260 × 300 m by the side of nadir and 15 spectral bands invisible and NIR wavelengths. MERIS and MODIS satellite imageries help further research to determine their functionality for addressing issues for keeping track of cyanobacteria blooms. This kind of research would include the diligence of algorithms developed and validated in concerned lake from airborne imagery and in situ data.

4 Remote Sensing Approaches Adopted Worldwide

It is very important to know and get all the information about the previous and ongoing research worldwide for monitoring of algal bloom with the help of remote sensing. It is also valuable to consider methodology adopted, type of sensor needed, study outcomes, study area, and contributions of the many scientists in the field of remote sensing for the study of algal blooms (Table 13.4). Many studies and researches have already been done and many approaches are still in a way to come with great advancements and upgrades.

The improved quality of the data products of MERIS is relevant for the algal bloom detection and monitoring system (Folkestad 2005). By the help of optical methods like aerial photography or satellite imagery in Indian River Lagoon (Florida, USA) (Riegl et al. 2005). Spectral reflectance data are useful for remote sensing of shallow habitats and used to monitor their health in Western Atlantic subtropical/tropical region (Thorhaug et al. 2007).

Table 13.4 Methodologies adopted for monitoring algal community

Author	Methodology	Study	Sensor/data	Study area
Dustan et al. (2001)	Change detection analysis	The spatial variations of the reef community decreased in the early 1980s at consistent scales with well-known ecological changes to the coral community	Landsat TM	Largo, Florida
Nayak and Bahuguna (2001)	Spatial analysis	Mapping and extent of stressed area	Indian Remote Sensing Satellite (IRS)	Many coastal regions of India
Kutser et al. (2003)	Reflectance analysis	It provides the ability of optical remote sensing to distinguish between the various building blocks of a coral reef ecosystem	Hyperion HyMap ALI	Great Barrier Reef (GBR), near Townsville
Hochberg and Atkinson (2003)	Reflectance, discrimination, spectral mixture analysis	Available satellite sensor that is insufficient for assessment of global coral reef condition but that it is both essential and possible to design a sensor system suited for various works	AAHIS AVIRIS Proto CRESPO IKONOS Landsat-ETM+ SPOT-HRV	Reefs around the world
Tang et al. (2004)	Oceanographic studies, chlorophyll analysis, and wind detection	Better understanding of the biological oceanography of HABs	SST imagery QuikSCAT data and satellite data of chl a	Southeastern Vietnam
Folkestad (2005)	Specific inherent optical properties (SIOP)	MERIS improved quality of the data products relevant for the algal bloom detection and monitoring system	SeaWiFS MODIS and MERIS	Norwegian Coastal
Riegl et al. (2005)	Optical methods like aerial photography or satellite imagery	A high level of settlement (60 %) with the actual distribution of algae. The study conducted including the actual distribution of algal blooms	QTC survey that acquires acoustic data and AUW-5600 video imagery	Indian River Lagoon (Florida, USA)
Li et al. (2006)	Band ratio detection, chlorophyll analysis	A method for real-time mapping of algal blooms in turbid beachfront waters utilizing the remote detecting reflectance of red band and near-infrared band	AVHRR sensor on the NOAA series satellite	China
Reinart and Kutser (2006)	Chlorophyll concentration analysis, bio-optical modeling, and comparative analysis of different species and the site	The great ability of the MERIS and MODIS fine determination groups to identify cyanobacterial blossom quantitatively is shown	Hyperspectral sensor SeaWiFS, MODIS/Aqua and MERIS	Western part of the Gulf of Finland
Thorhaug et al. (2007)	Spectral reflectance analysis	Spectral reflectance data useful for remote sensing of shallow habitats and used to monitor their health.	UniSpec and spectral reflectance data	Western Atlantic subtropical/tropical
Lekki et al. (2009)	Reflectance analysis	The largest area of variance is in the HSI showing a higher reflectance of blue light than the in situ measurement	Hyperspectral imager (HSI)	Great Lakes
Tyler et al. (2010)	Spectral data and using lookup table approaches. Acoustic	This is an advanced objective for remote sensing and will usually be constrained to the shallowest 10–15 m of the reef and used for habitat mapping and for predicting bloom types	High-resolution satellite (e.g., QuickBird), Airborne, Acoustic, CASI, or HyMap	Reef
Ontract (2011)	Acoustic survey, data processing, interpreting the classification of the training dataset recall, SAV coverage maps, classifying hydroacoustic records discriminant	Understood the goal of founding an accurate, well-organized, and temporally reliable manner for acoustically mapping drift macroalgae biomass	Sonar equipment	Indian River Lagoon

(continued)

Table 13.4 (continued)

Author	Methodology	Study	Sensor/data	Study area
Shanmugam (2011)	Advancement of new algorithms for reflectance analysis and chlorophyll concentration	To be talked in order for the major monitoring sequencers to help safeguard marine ecosystems and to safeguard and preserve sustainable development, the economy of the country, and the environment of the region	High-resolution MODIS/Aqua level 1A	Oceans worldwide
Hamylton et al. (2012)	Classic ordinary least squares and spatial autoregression techniques	Spatially lagged model, assume a vital part in deciding benthic front of the Aldabra tidal pond	Using GIS techniques (water level variation) and satellite remote sensing data (water depth)	Aldabra lagoon
Simon (2012)	Algorithm used to make the use of reflectance properties of algal community, spectral analysis	The new algorithm has the promise to classify and monitor the examined algal blooms	MODIS-Aqua ocean color data	Coastal waters around India
Riha (2013)	A novel model-based inversion algorithm using neural network technique	Algae expansion having chlorophyll fluorescence detected by the sensors of satellite help in measuring chlorophyll concentration	MERIS	Baltic Sea

5 Challenges and Limitations of Remote Sensing for Algal Monitoring

5.1 Challenges

- Identification and acquirement of satellite imagery for specific HABs
- Extracting of thresholds and expressive terms for the study of blooms
- Extraction of cyanobacteria and chlorophyll indices for cell counts
- The HAB models accounting for variation in chlorophyll abundance within a species
- Information gathering for tributary-specific and regional-specific HAB
- Forecasting models for the bays and tributaries for the study

5.2 Limitations

- Data acquisition is inadequate to specific missions to survey specific sites.
- Moving algal communities in water bodies sometimes do not coincide to the data acquisition process, creating difficulties in monitoring and proper observations.
- Sometimes, remote sensing approach is unable to correlate with in situ measurement due to disappointment in environmental adjustment; this failure is due to divergence between the optical properties.
- More advancement may be needed for all prospective and skills also compensate errors.
- The major concern is the data consistency in data acquisition.
- It is difficult to identify a cause of the variation at the largest spatial scale (we had only three replicate sites) and to correlate the sensitivity of a site with environmental variables like coastal, geomorphology, height, and orientation.
- The biomass and productivity data does not resolve the influence of water movement on productivity.
- Available satellite sensor is insufficient for appraisal of worldwide coral reef status, yet it is both essential and possible to design a sensor system suited to the task.
- Other major difficulties lie in the assortment of remote sensing imagery of suitable spectral, spatial, and temporal resolution for HAB study. Spectral resolution is an additional main worry for remote sensing of algal community.

6 Conclusion

The applicability of many remote sensing sensors in the field of monitoring algal communities is discussed in the articles, and it also comprises previous literature about remote sensing study for algal bloom. Although the use of remote sensing techniques for the study related to algal species is increasing rapidly, some techniques fail in accurate monitoring issues and are difficult and costly. Remote sensing plays vital role in detection and monitoring of algal community, which seems to be very harmful and expanding rapidly in water bodies. Since algal bloom causes much harm like eutrophication of lakes, it leads to bad quality of water and also harms aquatic organism associated with it. Therefore, its monitoring and detection is very important. Harmful algal bloom is one of the global concerns, and a lot of efforts are taken to minimize the load of nutrients and reduce the expansion of algal blooms in water bodies. For this purpose, the monitoring programs and researches are carried out for detecting and mapping the extension of algal blooms. Some satellite sensor and data are easily available for the study of algal blooms, but with the advancement in remote sensing, a lot of powerful sensors and technologies are developed but extra charge is required for investigating the algal communities. The chlorophyll present in the algal cell pigments, the color, and the reflectance and absorption properties of algae are the principle source of information required for algal community explorations. The sensor of MERIS is considered useful as its chlorophyll observation bands are very accurate to keep track of chlorophyll concentration found in algae.

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