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MARINE FISHERY RESOURCES
DEVELOPMENT AND MANAGEMENT
DEPARTMENT OF SEAFDEC

KUALA TERENGGANU, MALAYSIA

SEAFDEC MFRDMD RM/5

# REPORT OF THE MFRDMD/SEAFDEC FIRST REGIONAL WORKSHOP

# ON

# REMOTE SENSING OF PHYTOPLANKTON

Organised by:

**MARINE FISHERY RESOURCES DEVELOPMENT
AND MANAGEMENT DEPARTMENT (MFRDMD)
SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER (SEAFDEC)**

**Kuala Terengganu, Malaysia**

**17-18 November 1998**

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# Report of the MFRDMD/SEAFDEC First Regional Workshop on Remote Sensing of Phytoplankton

17 - 18 November 1998
Kuala Terengganu, Malaysia

Edited by:

Ku Kassim bin Ku Yaacob

**Marine Fishery Resources Development and Management Department**
**SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER**
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## FIRST REGIONAL WORKSHOP ON REMOTE SENSING OF PHYTOPLANKTON

*17-18 November 1998*

*Kuala Terengganu, Malaysia*


Sitting From Left : Dr. Gires Usup, Ms. Hajjah Mahyam Mohd. Isa, Prof. Dr. Y.Okada, Mr. Ismail Awang Kecil, Mr.Ismail Taufid Md.Yusoff (Chief MFRDMD), Dato' Mohd. Mazlan Jusoh(D.G of Fisheries & C.D of SEAFDEC, Malaysia), Mr. H. Fujita (Deputy Chief MFRDMD), Mr. Raja Mohammad Noordin Raja Omar, Sri Yono Wirjosuwarno, Ms. Montana Piromnim, Mr. Ku Kassim Ku Yaacob,

Standing From Left : Dr. Lokman Shamsudin, Mr. Jefri Mat Saad, Mr.Sulong Ibrahim, Mr. Soo Soong Kwan, Dr. Mansor Mat Isa, Dr. Mohd Kushairi Mohd Rajuddin, Mr. K. Shiomi, Dr. Koji Takahashi, Mr. Nguyen The Thien, Mr. Richard Rumpet, Dr. Somboon Sirirsksophon, Dr.Kiyoshi Kawasaki, Mr. Shunji Fujiwara, Mr. Adeli Abdullah, Mr. Rupert Elstow, Mr. Ahmad Kamel Abdul Ghani

# CONTENTS

## Report of the MFRDMD/SEAFDEC First Regional Workshop on Remote Sensing of Phytoplankton

## INTRODUCTION

The remote sensing techniques have been widely used especially in the studies of widely spatial phenomena such as the ocean fronts. The algal blooms occurrence could be effectively detected in open waters using remote sensing techniques. Biological information on the algal blooms is readily available in the region but the remote sensing studies on the subject are still lacking. Thus it is befitting to hold a regional workshop to identify gaps in these areas before further research is conducted.

### Objective

To create an awareness of the marine remote sensing applications and to establish regional research priorities in the field.

### Date and venue

Hotel Grand Continental, Kuala Terengganu, Malaysia; 17-18 November 1998.

### Participation

The Workshop was attended by participants from Indonesia (1), Japan (1), Malaysia (3), Thailand (1) and Vietnam (1). A country report from the Philippines is printed in the proceedings. Singapore and Brunei were not represented. There were 6 resource persons comprising of 2 planktonologists, 3 oceanographic remote sensing experts, and one remote sensing expert. The Workshop was also attended by the observers from Malaysia (3), Training Department (SEAFDEC)(2), and MFRDMD (8). The list of participants is shown in Annex 1.

## OPENING CEREMONY

In his Welcome Speech, Mr. Ismail Taufid bin Md Yusoff, the Chief of MFRDMD pointed out that he was very glad to have this Workshop held as planned, although MFRDMD experienced difficulties initially in identifying resource persons and experts. Mr. Ismail expressed his thanks to all the participants, observers and researchers for their valuable support. He hoped that this workshop would provide the opportunity to discuss and obtain a clear information on the status of current research, identify regional research work, establish mechanism for regional collaboration and set up networking among the scientists in this field, in the region. He also thanked Y. Bhg. Dato' Mohd. Mazlan bin Jusoh for his willingness to officiate the Workshop. The text of his speech appears in Annex 2.

The Workshop was officiated by Y. Bhg. Dato' Mohd. Mazlan bin Jusoh, Director General of Fisheries Malaysia and SEAFDEC Council Director for Malaysia. In his Opening Address (see Annex 3 for full text), the DG pointed out that everybody is aware of the capabilities of remote sensing technology, but in the field of fisheries, the potentials have yet to be realised in the Southeast Asian countries. With newer knowledge he hoped researchers and resource managers will be better equipped to manage the resources effectively and in a more sustainable manner. In his speech, the DG also mentioned that SEAFDEC as well as ASEAN member countries had a strong support from the Japanese remote sensing experts for providing advice and guidance, for the benefit of the region. The Workshop was the first step towards probing into the use of higher technologies to exploit fish resources. From such technologies, locating fish schools could be made indirectly and as such, the recent call for countries to adopt the Code of Conduct for Responsible Fisheries can be considered favourably. The DG also mentioned about the upgrading of MFRDMD facilities to also receive SeaWiFS data, which could be used for detecting phytoplankton distribution in the sea. Finally, he congratulated MFRDMD for organising this Workshop. Y. Bhg. Dato' Mohd Mazlan bin Jusoh, then declared the Workshop open by clicking the PC mouse for 5-minute multimedia show.

## GLOBAL STATUS OF REMOTE SENSING OF PHYTOPLANKTON

Session I started just after the multimedia show. This session discussed about 'Global Status of Remote Sensing of Phytoplankton', and the paper was presented by Assoc. Prof. Dr. Yoshihiro Okada. In his lecture, Dr. Okada had elaborated briefly the basic theory of remote sensing for ocean colour. He also mentioned that since remote sensing of phytoplankton pigment (ie., chlorophyll-a) was based on optical properties or colour of the constituents of seawater, it was often referred as ocean colour remote sensing. He had listed down the available sensors for ocean color study with their characteristics. Dr. Okada discussed about the global status of ocean colour remote sensing, which started since the launching of the NASA's space-borne sensor, CZCS in 1978. The CZCS ceased in 1986. The Japanese ADEOS OCTS sensor was launched in 1996. This satellite had gone out of operation in June 1997. The latest ocean colour sensor was SeaWiFS on board SeaStar satellite. This was the only ocean colour sensor of the day. The future satellite, ADEOS-II would be launched in June 2000. More ocean colour satellites would be launched from Taiwan, India and Korea. Dr. Okada also described in detail about the application of remotely sensed phytoplankton pigment concentration. In conclusion, he recommended that; 1) the scientific community in remote sensing of ocean colour, evolves a program for technical collaboration with their counterparts in the countries that have more experiences; 2) a working group should be established in the region; 3) developed nations in Asia should provide and share the data with their counterparts in Southeast Asia; and 4) more trained manpower should be generated. His full paper is in Annex 5.

## ADOPTION OF AGENDA

The Agenda and Timetable (Annex 4) was adopted.

## ELECTION OF CHAIRMEN AND RAPPORTEURS

Since this was the first workshop, the Workshop Committee had decided to nominate the Chairmen and Rapporteurs prior to the Workshop. Mr. Ismail Taufid Md Yusoff, Mr. Hitoshi Fujita, Mr. Ibrahim Saleh, Dr. Yoshihiro Okada and Mr. Raja Mohammad Noordin were nominated to be the Chairmen for the various sessions. Mr. Ku Kassim Ku Yaacob was appointed to be the Rapporteur.

## COUNTRY STATUS REPORT

The Country Status Report was presented by each country. It started with Indonesia and followed by Japan, Malaysia, Thailand and Vietnam. These reports were presented to inform the participants of the status of marine remote sensing applications in each participating country.

Mr. Sri Yono Wirjosuwarno, representing Indonesia pointed out the current status of marine fisheries in Indonesia particularly in the South China Sea, which included the gears used and the resources available (Annex 6). The remote sensing technology has not been used in Indonesian fishery management since there was no 'satellite sea-watch' program in the country to monitor phytoplankton and fish resource. Indonesia needed future development in this aspect.

Dr Kiyoshi Kawasaki, from Japan, highlighted the use of ADEOS OCTS data for mapping ocean color in Japan. There were two main research frameworks in Japan, ie, ocean color analysis and mapping for locating fishing ground (NASDA-JAFIC), and in-water algorithm for determining chlorophyll-a and primary production (NASDA-NRIFS). The red tide occurrence was observed using a plane (airborne remote sensing). He also mentioned about the use of Bands 1, 2 and 3 of LANDSAT data for determining of chlorophyll in the water. (See Annex 7 for details.)

Ms. Hajjah Mahyam Mohd Isa representing Malaysia presented a paper entitled the "Status of Marine Remote Sensing Application in Malaysia" (Annex 8). Ms. Hajjah Mahyam pointed out that in Malaysia, the marine remote sensing study was conducted by local universities as well as the Department of Fisheries. Remote sensing activities were coordinated by the Malaysian Center for Remote Sensing (MACRES). Among the remote sensing data users were Fisheries Research Institute (FRI), MFRDMD, local universities as well as researchers from MACRES itself. Some of the past and on going projects of each agency were also outlined. She also listed down the published research findings on algal blooms in Malaysia. The problems associated in applying the remote sensing technology in marine environment were also mentioned. She noted that it was problematic to apply this technology in Malaysia (especially DOF) due to lack of skilled personnels, high degree of cloud cover over the region, capital for ground / sea truthing was very high, lack of persons with excellent knowledge in marine remote sensing, and atmospheric correction problem.

Ms. Montana Piromnim representing Thailand briefed on the status of marine remote sensing in Thailand. Since the government was aware of the large extent of maritime waters in Thailand, the satellite ground station was set up by the government of Thailand to receive data from NOAA, LANDSAT, SPOT and MOS. Landsat-5 TM data had been used from 1993 to 1994 for studying the chlorophyll distribution in the Gulf of Thailand. A band ratioing technique was used to study seawater substances. Ms. Piromnim mentioned about some problems faced by Thailand in implementing the project, which were as follows: 1) Logistics of the establishment of a seatruth; 2) Cloudy images; 3) Cloud edge diffusion; and 4) The water turbidity hiding of the chlorophyll distribution. As a result, Thailand did not use satellite imagery in its phytoplankton program. Generally, there were three major constraints in using this technology in Thailand, ie, firstly, difficulties in establishing seatruth program; secondly, water turbidity factor; and lastly, the atmosphere was high in the dust concentration, resulting in unreliable satellite data. She mentioned in passing the SEAWATCH program in Thailand that could be used for monitoring phytoplankton, remotely. The details of her paper is as in Annex 9.

The fifth Country Report entitled "Application of remote sensing in fisheries research in Vietnam" (Annex 10) was delivered by Mr. Nguyen The Thien of Vietnam. In his presentation, Mr. Thien mostly highlighted the phytoplankton study using conventional techniques in Vietnam. He explained very briefly the phytoplankton species and their distribution in Vietnamese waters. Vietnam needs satellite data, training in marine remote sensing and more exposure to marine remote sensing. Mr. Thien welcomed any collaboration program with regional or international organisations in the field of marine remote sensing.

## BIOLOGY OF PLANKTON

Dr. Lokman Shamsudin presented the first Technical Paper entitled "Biology of Plankton". According to his presentation, phytoplankton could be classed into blue-green algae, diatoms and dinoflagellates. Phytoplankton also could be classified in terms of their size such as macroplankton, megaplankton, microplankton, nanoplankton and ultrananoplankton. Almost 50% of the phytoplanktons in Malaysian waters were classified in the nanoplankton group. It was noted that maximum photosynthetic activity occurred among the nanoplanktons. He highlighted the phytoplankton distribution study in Sabah-Sarawak, Gulf of Thailand, East Coast of Peninsular Malaysia and Philippine waters. Common statistical analyses in planktonology were also covered. He had pointed out the problems in determining chlorophyll-a for *Trichodesmium*. The accessories pigment might have overlapped the chlorophyll-a light absorption data and the sample should be reanalysed, to get maximum absorption value of chlorophyll. He hoped that remote sensing techniques would be extensively used in the future in phytoplankton and chlorophyll studies. His paper is as in Annex 11.

The second Technical Paper was presented by Dr. Gires Usup from Universiti Kebangsaan Malaysia. His paper entitled "Harmful Algal Blooms – Possible Causes", is in Annex 12,. He had listed down the possible causes of HABs, which were among others, 1) release from nutrient limitations, 2) favorable hydrographic conditions, 3) release from predation and 4) competitive advantage. The occurrence of HABs could be predicted with some certainty in the temperate waters, but in the tropics, it was quite difficult. Dr. Gires had discussed in detail the macronutrients, micronutrients, hydrography, physiology and the predation factors which results in the harmful algae blooms. Some slides of the harmful alga species were shown. He suggested that *in situ* studies should be conducted for better understanding of the events. Dr. Gires further pointed out that some of the dinoflagellate, for example *Alexandrium tamarense* is toxic in certain area (such as in Northern America), but this species is non-toxic in Europe. This depends on geographic as well as genetic factors. Dinoflagellate could grow rapidly from 100 cells/litre to $10^6$ cells/litre within 2 weeks, depending on conducive environment and the absence of other competitors. Dr. Gires commented on harmful algal blooms study using remote sensing. He felt that the remote sensing techniques are difficult to apply in studying HABs, since the HABs' pigment overlapped, and hence could not be detected clearly by the remote sensor. He suggested that a special sensor, which could detect specific HAB pigment, be used in the sea.

## APPLICATION OF REMOTE SENSING IN PHYTOPLANKTON STUDIES

Mr. Adeli Abdullah presented the third Technical Paper, which covers the use of satellite sensors to detect phytoplankton (ocean color). He pointed out the basic principles of electromagnetic radiation (EMR), resulting in phytoplankton detection using remote sensing. The participants were introduced to the types of sensor, which were passive (EMR from sunlight) and active (radar). In ocean color remote sensing, visible band of EMR spectrum was used. Mr. Adeli noted that the blue light (which is also Band 1 of Landsat TM), could penetrate clear water up to 60 meters deep, this was followed by green light (Band 2), 15 meters; and red light (Band 3), up to 5 meters. He listed down the ideal remote sensing system, which should be, 1) real time imagery, 2) high spatial resolution, and 3) high radiometric resolution. The ocean color sensors were also mentioned, which were Nimbus-7 CZCS, SeaStar SeaWiFS, ADEOS OCTS, JERS, NOAA AVHRR, Landsat 4 and 5 TM, Landsat 7 TM and ADEOS II GLI. He highlighted the current research in marine remote sensing undertaken at University of Technology Malaysia. His paper is in Annex 13.

Dr. Koji Takahashi of Japan Fisheries Information Center (JAFIC) presented his paper "Production and distribution of phytoplankton observed by ADEOS: Application of satellite imagery for fisheries" (Annex 14). JAFIC had used ADEOS OCTS images to study ocean color in Japan. Dr. Takahashi mentioned that the major fishing areas in Japan were Hokkaido and Tohoku. The fish forecasting system in Japan comprised of four components, namely, oceanographic data provider (satellites, hydrographic and military vessels, research institutes, etc.), fishing conditions information (from fishermen, research vessels, etc.), JAFIC (coordinating agency) and users. From ADEOS OCTS, it was found that in the waters of Japan there were a lot of fish in the area of water temperature range 17.5 – 19.5 °C, and 0.6 – 1.4 μg/l of chlorophyll-a concentration. Dr. Takahashi described about the migration patterns of phytoplankton blooms which followed the warm waters. The formations of cold and warm core rings were also covered. The phytoplankton density was high in the warm core ring, where the sardine fish were also found to be abundant. He pointed that during winter (February) the water circulation was from East China Sea, moving southwest to Vietnam towards Peninsular Malaysia and Indonesia. In summer (August), the current direction was from Indonesia and Peninsular Malaysia to the northeast of Vietnam and China waters.

The last Technical Paper was presented by Mr. Ku Kassim bin Ku Yaacob of MFRDMD. His paper, jointly authored with counterparts from University of Technology Malaysia, is entitled "Phytoplankton distribution mapping using NOAA AVHRR data". In their study, they used band 1 and band 2 of AVHRR to correlate with phytoplankton density. There were two parts of the study namely, phytoplankton sampling and analyses and NOAA AVHRR data analyses. The details of their works can be referred to Annex 15. Mr. Ku Kassim concluded that the ratio technique of Band 2 over Band 1 was the best combination to extract phytoplankton densities. The phytoplankton distribution map was also shown. He also introduced the participants to the Remote Sensing Unit of MFRDMD, which was equipped with HRPT NOAA AVHRR data receiving system. A plan to upgrade the facilities and receive SeaWiFS data was also highlighted (Annex 16). MFRDMD had purchased the SeaWiFS Profiling Multichannel Radiometer (SPMR) that could be used in seatruthing works. In response to Mr. Ku Kassim's paper, Dr. Lokman Shamsudin suggested that the smaller mesh size of plankton net should be used, since nanoplankton contents in the sea is about 50% of the total phytoplankton. The net used in this study was quite large in mesh size. The other alternative was to use large volume water sampler. The comment was supported by Dr. Gires Usup and Ms. Montana Piromnim. The phytoplankton sampling and analyses should be conducted more carefully, for better results. For fisheries purposes, researchers should correlate between fish distribution and phytoplankton rather than temperature. Water turbidity should also be analysed. For ocean colour study, chlorophyll measurement rather than phytoplankton density analysis was recommended.

The Session Chairman, Mr. Raja Mohammad Noordin, then briefed on the on going remote sensing research projects undertaken by MFRDMD. He showed the photographs of air balloon platform used to carry the digital video camera / sensor in "Airborne Video Remote Sensing" project. The images taken from this platform would be analysed to estimate the suspended sediment concentration in the water, and then the correlation between sediment and phytoplankton / fish larvae would be better understood.

## QUESTIONS AND DISCUSSIONS AFTER PRESENTATION OF PAPER

The comments and suggestions made after the presentation of the various papers are included in the above write-up.

## RECOMMENDATIONS

Recognising the importance of remote sensing of phytoplankton technology leading to fisheries management and the fragmentation of expertise among different disciplines such as fisheries, biological, chemical and physical oceanography and remote sensing, the workshop participants recommended that:

1. As there are two classified areas of interest: - open seas (Case I Waters) and coastal zones (Case II Waters), participants from each country will conduct seatruth experiments of phytoplankton in their coastal areas whilst MFRDMD will work in the open seas.

2. A validation program is required to compare information from satellite data to sea conditions.

3. Participating researchers should adopt standard methodologies in data collection such as those in the UNESCO/IOC manuals.

4. A working group among the participating countries should be established to conduct collaborative programs.

5. A network of participants will be established for frequent interaction and identification of common areas of interest and the dissemination of updated information. Participants should list and submit past and current research projects in their respective fields to MFRDMD who will coordinate them.

6. The skill of participants and MFRDMD researchers should be upgraded in their respective disciplines with assistance from experts experienced in marine remote sensing.

7. If comparative studies show a need for nationally derived algorithms, then the results from these should be reported by each country at the next workshop.

## CLOSING CEREMONY

Mr. Ismail Taufid, the Chief of MFRDMD gave a short speech for the closing session. He thanked all the resource persons, participants and observers for attending this Workshop. The Chief expressed his gratitude to the Organising Committee and everyone for their contribution in making this Workshop a success. He hoped to meet all the participants again in the next Workshop.

# ANNEXES

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# ANNEX 2

## WELCOME ADDRESS BY MR. ISMAIL TAUFID BIN MD. YUSOFF, CHIEF OF MFRDMD, SEAFDEC

Y. Bhg. Dato' Mohd. Mazlan Bin Jusoh Director General of Fisheries Malaysia and SEAFDEC Council Director for Malaysia

Mr. Hitoshi Fujita, Deputy Chief MFRDMD

Honorable Participants

Distinguished Guests, Ladies and Gentlemen

Firstly I would like to say welcome or "Selamat Datang" and a very good morning to everyone present here today. We are pleased that all of you could come to Malaysia, despite the attention and focus on Malaysia in the news media lately. As you can see Malaysia is very safe and we are going about our ways in still the same manner.

We are very fortunate to have with us today Dato' Mohd. Mazlan Bin Jusoh, the Director General of Fisheries Malaysia and also the SEAFDEC Council Director for Malaysia, who has graciously agreed to officiate our function this morning, despite his very busy work schedule.

We do hope that you have rested well and feeling very refreshed to start our two-day session, beginning today and tomorrow.

Incidentally, our workshop coincides with the APEC meeting that is being held in Kuala Lumpur, almost around the same time. However our meeting is more technical and non-political. So please feel free to engage in free discussions and deliberations on the subject matter, without fear or favor.

Although this workshop was planned for this year, the organizing committee was uncertain whether we could proceed as planned. We experienced difficulties in identifying suitable experts and resource persons. Fortunately, we got positive indications and responses to enable us to go ahead. Today we have with us experts and resource persons from Japan, University Putra Malaysia, University Kebangsaan Malaysia, University Teknologi Malaysia and MFRDMD.

The participants for this workshop are from Japan, Malaysia, the Philippines, Thailand, Vietnam and Indonesia. We also received positive response and support from our brother Department TD, who showed a keen interest to participate as observers, together with researchers from other institutions in the host country. Thank you for your valuable support.

The capabilities of remote sensing when successfully harnessed can fulfil the needs of a new technology as envisaged under Articles 7 and 8 of the Code of Conduct for Responsible Fisheries, for Fishing Operation and Management, in providing the best scientific evidence for fisheries management.

Remote sensing needs highly sophisticated scientific equipment, which are rather expensive. With the financial and economic constrains being faced by countries in the region, it is imperative that institutions and researchers, collaborate and optimize the available research funds.

This workshop will provide us the opportunity, to discuss and obtain, a clear information on the status of current research, identify regional research work, establish a mechanism for regional collaboration, and set-up a net-working among researchers in the region for closer communication and interaction.

With that I would like to end my short address, and wish that all of you will have a fruitful meeting. Thank you.

# ANNEX 3

Annex 3

# OPENING ADDRESS BY Y. BHG. DATO' MOHD MAZLAN BIN JUSOH DIRECTOR GENERAL OF FISHERIES MALAYSIA, DEPARTMENT OF FISHERIES MALAYSIA and SEAFDEC COUNCIL DIRECTOR FOR MALAYSIA

Mr. Ismail Taufid bin Md. Yusoff, Chief of MFRDMD, SEAFDEC,

Mr. Hitoshi Fujita, Deputy Chief of MFRDMD,

Workshop Participants, Distinguished Guests, Ladies and Gentlemen.

*Assalamualaikum* and Good Morning.

I am honored to be here with you this morning to welcome you all, on behalf of the Government of Malaysia and the Southeast Asian Fisheries Development Center (SEAFDEC), to the first Regional Workshop on Remote Sensing of Phytoplankton in the South China Sea. I thank MFRDMD for inviting me to say some few words and open the workshop. For those who have been here before, I bid you welcome back and it is nice to see you again. In view of the usual wet season at this time of the year, I hope the organising committee has forewarned you to bring your umbrellas. Nevertheless, we will ensure that you will not get wet.

I understand that for the next two days, you will be listening to talks on the status of remote sensing applications in fisheries in the region. According to the program, you will also dwell on the research priority areas in remote sensing for the region, and I trust that from your discussions, the regional research priorities can be agreed upon, perhaps through the integration of your national priorities. Intergovernmental collaboration has been the focus of a regional body such as the SEAFDEC. Through regional cooperation, the limited funds and time can be optimally utilised. This workshop, I am certain will come up with a regional research program which will benefit the fishermen in the region.

We are all aware of the capabilities of remote sensing technology, but in the field of fisheries, the potentials have yet to be realised in the Southeast Asian countries. With newer knowledge we hope to be better equipped to manage the resources effectively, and coupled with other factors, in a more sustainable manner.

I notice that we also have with us today, experts from Japan. Japan has an excellent fishery forecasting service that now uses satellite technology. We are therefore very fortunate that SEAFDEC has the strong support of expertise in providing advice and guidance to researchers in SEAFDEC and ASEAN member countries. It is unfortunate that the Japanese sensor for ocean colour studies, the OCTS[1] is short-lived and now dysfunctional, for otherwise we can understand by now the oceanic processes occurring in the region. Nevertheless, we look forward to seek the understanding, even when using historical data.

[1] OCTS=Ocean Colour and Temperature Scanner. This is one of the eight sensors on board the ADEOS (Advanced Earth Observing Satellite) launched by Japan on 1 July 1997. A sudden power loss of ADEOS may have been caused by malfunction of the solar paddle. On 30 June 1997, ADEOS ceased to reply to any commands from the ground.

Through this workshop, I believe that we, Southeast Asians have begun our first step towards probing into the use of higher technologies to exploit fish resources. From such technologies, locating fish schools could be made indirectly and as such, the recent call for countries to adopt the Code of Conduct for Responsible Fisheries can be considered favourably. It was only last week that SEAFDEC has organised a consultative meeting on the Code of Conduct for Responsible Fisheries. The main objective of the meeting is to formulate regional guidelines by which SEAFDEC and ASEAN member countries would consider adopting in their national efforts to ensure sustainable development. A fishery forecasting service is very relevant to the Code of Conduct for Responsible Fisheries, as locating fish schools using satellite technology can save operational costs thus energy. Time and money saved can be used in other socio-economic activities.

Another area where remote sensing can be applied, I believe which you all will look into also, is the pattern of phytoplankton or algal bloom occurrences. Prediction of harmful algal bloom phenomena, also known as the red-tide is being looked into by many researchers and last month, the ASEAN-Canada Cooperative Program on Marine Sciences-Phase II has concluded the program with a conference in Pulau Langkawi, and many research findings were made known. As one of the key aspects included in the program is the investigation of red tides, I am certain that through such a workshop as this one, linkages between biology and physics can be bridged. Without the use of remote sensing technology, it will take hundreds of research vessels and longer cruise time to be able to make predictions if one wishes to go into, the studies of red-tide occurrence.

The Chief of MFRDMD informs me that MFRDMD is currently upgrading her facilities in order to receive the SeaWiFS[2] data that is considered THE data of the day in marine environmental applications. Detailed studies can be conducted to understand the influences of the oceanic processes on the movement of fish stocks, especially those that are shared. In the context of the workshop, we hope to see in the future, from the analyses of the oceanic processes and the occurrences of phytoplankton blooms as processed from the SeaWiFS data, possible indications of the routes of fish movement. Once this is established the management of the shared stocks will be more effective and accurate.

May I congratulate the MFRDMD, SEAFDEC and the Organising Committee for promoting new technologies in fisheries and making this workshop a reality. I wish all participants, the best wishes in your deliberations on the future research directions in fisheries remote sensing. I will be keeping a close watch on the outcome of the workshop resolutions. I trust you all will be given time out to see what Kuala Terengganu has in store for you with her beautiful shores and interesting culture. I hope you all will have a nice stay in Kuala Terengganu and with that, in the name of ALLAH, the Beneficent, the Merciful, I declare the workshop open.

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[2] Sea-viewing Wide Field-of-view Sensor. This sensor was launched on the SeaStar satellite on 1 August 1997, after many years of delay. Now SeaWiFS is producing data at rate unprecedented in the history of oceanographic remote sensing. Providing scientists with a nearly comprehensive global view of the oceans every two days. SeaWiFS data can be captured by the HRPT (High Resolution Picture Transmission) system located in MFRDMD and currently receiving NOAA AVHRR data.

# ANNEX 4

Annex 4

# AGENDA AND TIME TABLE

## DAY ONE
## Tuesday, 17 November 1998

| | |
|---|---|
| 0830-0900 | Registration |
| 0900-0910 | Welcome Speech by Mr. Ismail Taufid bin Md. Yusoff<br>*Chief, MFDRMD/SEAFDEC* |
| 0910-0930 | Opening Remark by Y.Bhg. Dato' Mohd. Mazlan bin Jusoh<br>*Director General of Fisheries Malaysia and Council Director of SEAFDEC, Malaysia* |

**SESSION I – Global Status**

| | |
|---|---|
| Chair Person : | *Mr. Ismail Taufid bin Md. Yusoff*<br>*Chief, MFRDMD/SEAFDEC* |
| 0930-1015 | Global Status of Remote Sensing of Phytoplankton<br>*- Assoc.Prof. Dr. Yoshihiro Okada* |
| 1015-1025 | Photo session |
| 1025-1045 | Break |

**SESSION II – Country Report Presentations**

| | | |
|---|---|---|
| Chair Person: | *Mr. Hitoshi Fujita*<br>*Deputy Chief, MFRDMD/SEAFDEC* | |
| 1040-1045 | Adoption of Agenda | |
| 1045-1105 | CR1 | Indonesia<br>Remote Sensing Technology for Utilizing Fishery Resources in Indonesia<br>*- Mr. Sri Yono Wirjosuwarno* |
| 1105-1125 | CR2 | Japan<br>Activity on the Remote Sensing of Phytoplankton in Japan<br>*- Dr. Kiyoshi Kawasaki* |
| 1125-1145 | CR3 | Malaysia<br>Status of Marine Remote Sensing Applications in Malaysia<br>*- Ms. Hajah Mahyam bte Mohd Isa* |

| | | |
|---|---|---|
| 1145-1205 | CR5 | Thailand<br>Status of Remote Sensing of Phytoplankton in Thailand<br>*Ms. Montana Piromnim* |
| 1205-1225 | CR6 | Vietnam<br>Application of Remote Sensing in Fisheries Research in Vietnam<br>*- Mr. Nguyen The Thien* |
| 1230-1400 | Lunch | |

**SESSION III – Phytoplankton and Remote Sensing**

Chair Person : *Mr. Ibrahim bin Saleh*
*Head, Fisheries Biology and Stock Assessment Division, MFRDMD, SEAFDEC.*

| | | |
|---|---|---|
| 1400-1445 | TR I | Background of Plankton I – Biology of Plankton<br>*- Assoc. Prof. Dr. Lokman Shamsudin* |
| 1445-1530 | TR II | Background of Plankton II – Phytoplankton Blooms and Causes<br>*- Assoc.Prof.Dr. Gires Usup* |
| 1530-1545 | Break | |
| 1545-1630 | TR III | Remote Sensing Technology for Phytoplankton<br>*- Mr. Adeli Abdullah* |
| 1630 | Close for Day One | |

## DAY TWO
## Wednesday, 18 November 1998

**SESSION IV – Remote Sensing of Phytoplankton**

| | |
|---|---|
| Chair Person : | *Mr. Raja Mohammad Noordin bin Raja Omar*<br>*Head, Fisheries Oceanographic and Resource Exploration Division, MFRDMD, SEAFDEC.* |
| 0900-0945 | TR IV Production and Distribution of Phytoplankton Observed by ADEOS<br>*- Dr. Koji Takahashi* |
| 0945-1030 | TR V Phytoplankton Distribution Mapping Using NOAA AVHRR Satellite Data<br>*- Mr. Ku Kassim bin Ku Yaacob* |
| 1030-1045 | Break |

**SESSION V – Research Priorities Setting**

| | |
|---|---|
| Chair Person: | *Assoc. Prof. Dr. Yoshihiro Okada*<br>*Tokai University, Japan* |
| 1045-1245 | Discussion on Research Priorities in Remote Sensing of Phytoplankton for the South China Sea Area |
| 1245-1330 | Lunch |
| 1330-1515 | Excursion<br>Visit Handicraft and Batik Factories<br>Visit MFRDMD/SEAFDEC |
| 1515-1545 | Break |

**SESSION VI – Adoption of Report and Closing**

| | |
|---|---|
| Chair Person : | *Mr. Ismail Taufid bin Md. Yusoff*<br>*Chief, MFRDMD, SEAFDEC* |
| 1545-1630 | Adoption of Report |
| 1630-1645 | Closing Ceremony |
| 2000-2200 | Farewell Dinner |

# ANNEX 5

THE MFRDMD/SEAFDEC FIRST REGIONAL WORKSHOP ON
REMOTE SENSING OF PHYTOPLANKTON

Kuala Terengganu, Malaysia, 17-18 November, 1998

SEAFDEC/MFRDMD/WS/98/WP. 1

# GLOBAL STATUS OF REMOTE SENSING OF PHYTOPLANKTON

By:

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**ABSTRACT**

The color of the ocean as measured by the space-borne sensors contains the quantitative information on phytoplankton pigments, especially chlorophyll. In this paper we have reviewed principle of ocean color remote sensing. The concept of spectral, spatial, temporal and radiometric resolutions are first described followed by a discussion on present status of ocean color sensors. A brief account on various applications of remotely sensed ocean color information is presented with the examples from several sensors and region. In the open ocean, the techniques for measuring chlorophyll is almost established, where as in coastal waters the retrieval of ocean color information becomes complicated because of the interference of suspended sediments. Ocean color images are found useful to trace the mesoscale dynamics. Remotely sensed phytoplankton are also found useful to understand Carbon at basin as well as global scale. The paper concludes with comment on future of ocean color remote sensing and recommendations for promotion of ocean color science in Southeast Asia.

## 1.0 Introduction

The phytoplanktons are the floating microscopic plant population found in the ocean. They contribute over 25% of the total vegetation of the planet. They are often referred as primary producers as they produce organic substances from carbon dioxide and water within the cell, utilizing the sun light by photosynthesis, and make the base of food chain which support either directly or indirectly, the entire animal population of the ocean. Chlorophyll is the principal plant pigment of phytoplankton, acts as an agent in the photosynthetic process. Phytoplankton also plays an important role in maintaining balance of atmospheric carbon dioxide. Phytoplankton distribution depends on certain physical oceanographic set-up; thus they manifest dynamic oceanographic phenomena of the ocean through their distribution. Hence they are often considered as the tracers for upper ocean dynamics. Realizing their importance in ocean ecosystem, measurement of phytoplankton biomass has drawn considerable attention of oceanographers during last half of the present century. Because of its photosynthetic function, chlorophyll is considered, as an indicator of oceanic plant biomass and productivity and it is one of the most frequently measured biochemical parameters in oceanographic investigations. Although conventional ship measurements provide accurate estimates of chlorophyll pigment, vastness of the oceans does not allow us to get the information about its spatial and temporal variability ,in the oceans. Hence during the 1970s remote Sensing had evolved as the preferred technology for phytoplankton study that can provide the synoptic information from the upper ocean. Since remote sensing of phytoplankton pigments is based on the optical properties or color of the constituents of seawater, it is often referred as ocean color remote sensing. Satellite remote sensing of ocean color is already established as a dependable tool to provide estimates of phytoplankton stock both on global and regional scale. With recent launching of new ocean color sensors remote sensing of phytoplankton has got increased attention of oceanographers round the World.

In this paper, first the principle of ocean color remote sensing is reviewed providing different correction techniques involved with remotely sensed ocean color data processing and interpretation. We then discuss characteristics of ocean color sensors, which include spectral, spatial, temporal and radiometric sampling aspects. This is followed by a brief account on present status of ocean color sensors. In the following section various applications of remotely sensed phytoplankton pigment concentration are reviewed with the help of relevant examples. The paper concludes with a look forward to the advances in the field of ocean color remote sensing and finally with a few recommendations for promotion of ocean color of remote sensing in Southeast Asia. We have also provided a brief list of literature on the subject for more comprehensive information

## 2.0 Principles of ocean color remote sensing

Ocean color remote sensing is based on the concept that particulate and dissolved substances suspended in the upper ocean interact with the incident sun light. Such interaction could either be absorption of light by substances such as phytoplankton pigments and dissolved organic matter or scattering of light by substances like inorganic suspended sediments. As water molecules scatter light similar to the way that atmosphere scatter light, where concentration of particulate matter and dissolved substances are negligible, ocean appears deep blue in color. The scattering and absorption processes alter this color. Chlorophyll, the photosynthetic pigment found in phytoplankton, absorbs strongly in the red and blue region of the visible light spectrum (Figure 1) and reflects in the green. As the concentration of phytoplankton increases, the color of the water appears increasingly green. The absorption of light by chlorophyll can be quantified to determine the concentration of chlorophyll in water allowing estimation of phytoplankton abundance in a given area. However, the relationship between light absorption and chlorophyll concentration leads to complication by the presence of light scattering inorganic particulate matter in the water. Concentration of such particulate matter is generally high in coastal waters. That makes the water color near the coast green to brown or reddish brown. Even though chlorophyll pigment present in high concentration in water near the coast, the presence of fluvial suspended load makes it difficult to extract the amount of light absorption solely attributable to chlorophyll. In order to differentiate the oceanic water where the phytoplankton is the major water constituents, from that of the coastal waters where the non-chlorophyll particulate matter is abundant, they are often respectively categorized as “case 1” and “case 2” waters in scientific literature. Besides, cocolithophores, a type of phytoplankton which form hard mineral shells that scatter light very effectively can make the ocean color milky white.

However measurement of pigment concentration from the remotely sensed signals received at a space-borne ocean color sensor involves correction from the noises inherent in the signals because of interference by atmospheric as well as under water optical process.

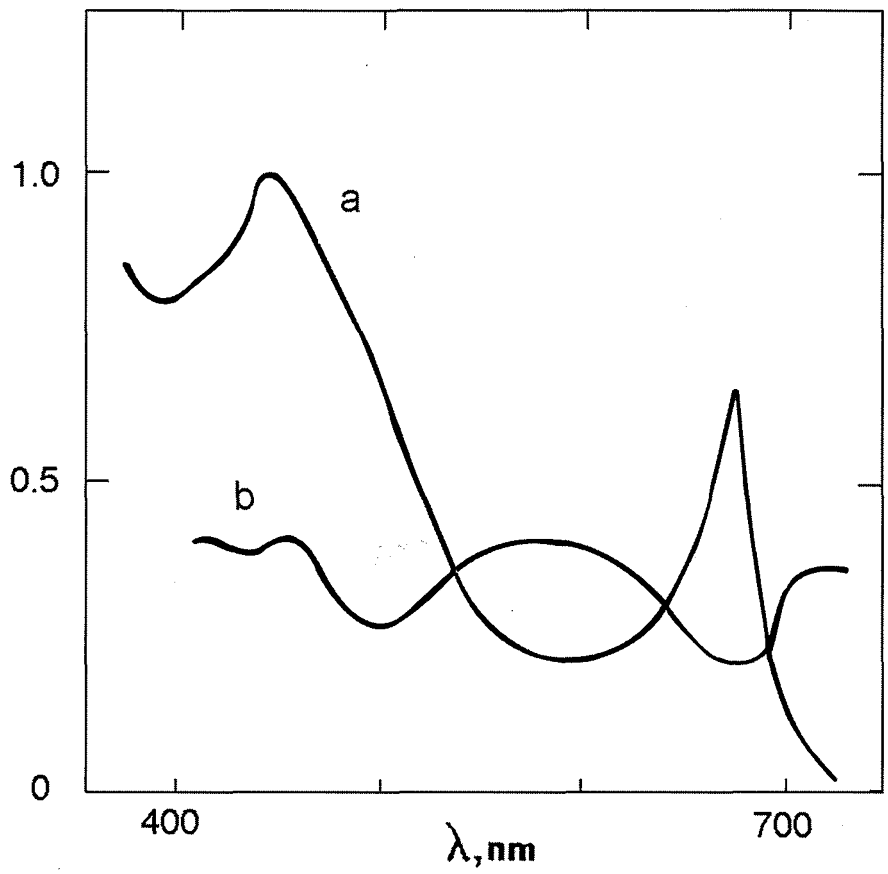


Figure 1: Spectral variation absorption (a) and backscattering (b) due to chlorophyll pigment.

## 2.1 Atmospheric correction

Remote sensing of the sea using visible wavelengths relies on the sunlight, which is backscattered from the sea to convey information about the optically active constituents of the seawater including phytoplankton pigments. In a typical scenario of ocean color remote sensing various optical paths of light particles (photon) between the ocean surface and remote sensors are illustrated in the Figure 2. Up to 80% or more of the light reaching at the sensor is atmospheric path radiance backscattered by molecular or aerosol particles in the atmosphere (ray C). In addition, not all the water leaving radiance reach the sensor since some of it absorbed or scattered (ray D) within the atmospheric column. To quantify the upwelling radiance for estimation of water constituents it is necessary to remove the undesirable signals received from the atmosphere. This is called atmospheric correction. Most recent standard procedures (Gordon and Wang 1994) are available for carrying out such correction on satellite derived image. Once the radiance signal has been corrected for atmospheric interference, the signal is then corrected for the solar zenith angle to derive normalized water-leaving radiance. Normalized water leaving radiance is subsequently used in algorithms meant for different water constituents for deriving the desired parameters.

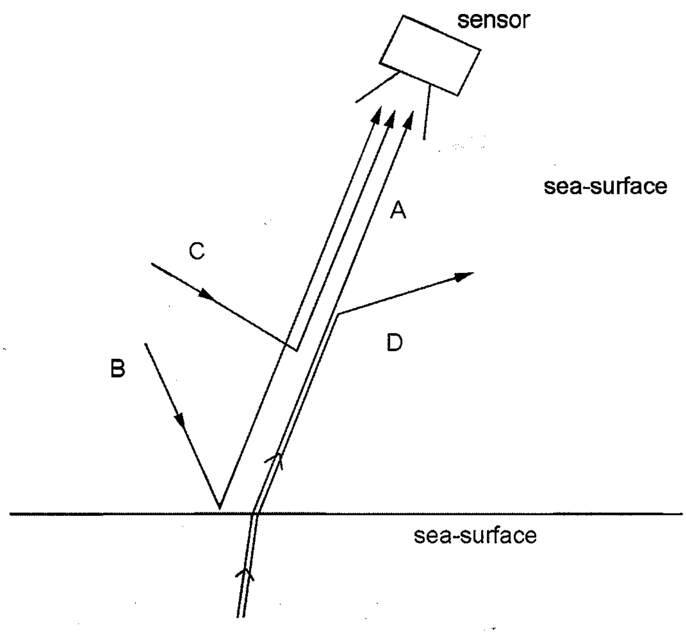


Figure 2: Light paths reaching an ocean colour sensor (A) leaving the water within the field of view; (B) reflected from the surface; (C) scattered by the atmosphere into the field of view; and (D) scattered aot of the field of view.

## 2.2 The underwater light field

Figure 3 illustrates the various components, which control the underwater light field in the upper ocean. These components determine the magnitude and spectral distribution of light leaving the sea, and ultimately define its apparent color. Photons from the sun reach the sea surface directly or are scattered in the atmosphere to reach the sea as skylight. They are refracted as they pass through the sea surface and then scattered or absorbed as they interact with the water and different constituents of water. The behavior of photons satisfies the probabilities, which can be expressed in term of inherent optical properties of seawater. The major optical properties are absorption coefficient, and the volume scattering function, which describes the directional distribution of the scattered light. Both of these vary with wavelength.

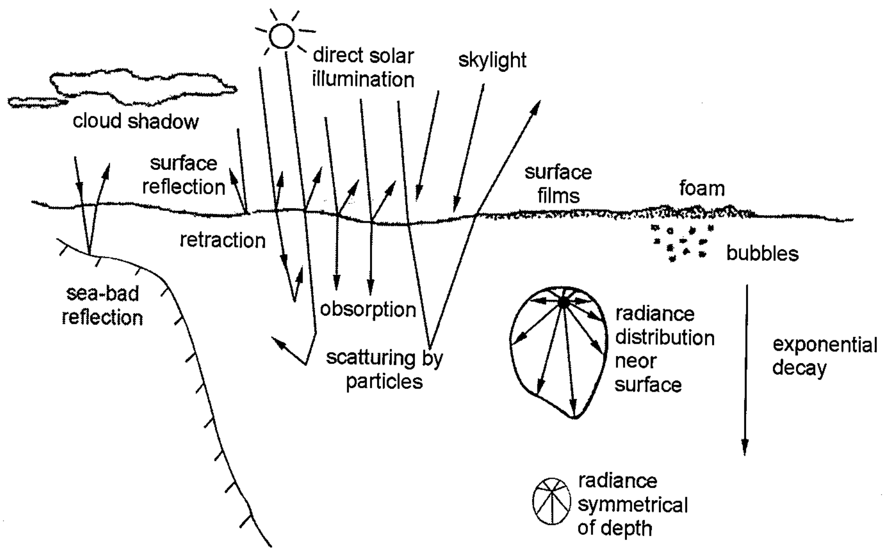


Figure 3: Different components, which control the incoming and outgoing light from the upper ocean.

The ratio of upward and downward irradiance is known as the subsurface irradiance reflectance ratio (R). Spectral variation of R (λ) depends on the ratio of backscatter and absorption coefficient. R (λ) varies in a complex way with changes in water constituents and it can be decomposed into ratio of backscatter and absorption coefficients attributed to different water constituents such as pigment, suspended matter etc. It is the ultimate goal of ocean color remote sensing to measure R (λ) in sufficient spectral detail that the concentration of chlorophyll, of the suspended sediment and the yellow substance can be determined with an acceptable level of accuracy. Theoretically it should be possible to distinguish between different species of phytoplankton if their pigment characteristics are sufficiently distinct. The response of R to different seawater compositions has been modeled, but in practice it is difficult to invert ocean color data to recover such information if more than one constituent is present. Hence ocean waters are classified under "case 1" and "case 2" categories. Case 1 waters mostly belong to oceanic region and dominated my phytoplankton. This category of waters has provided most success in calibration of the ocean color. This is because the strong absorption in the blue part of the spectrum by the chlorophyll a pigment ensures a good correlation between chlorophyll concentration and the ratio of R at 550 nm (green) and 440 nm (blue) as shown in Figure 4. Chlorophyll algorithm is developed using empirical relationship between in situ measurements of chlorophyll and ocean color signal at the sample locations. The same relationship is implemented for the entire image for pigment retrieval. However in case 2 waters, reliable calibration algorithms are yet to be developed (for global application), except in the limited case of sampling site specific models based on coincident in situ data.

Recently it has been suggested that oceans should be partitioned in to various oceanographic provinces based on regional absorption characteristics of phytoplankton pigments Such characteristics could then be used to improve algorithms for enhancement in accuracy of phytoplankton pigment estimates.

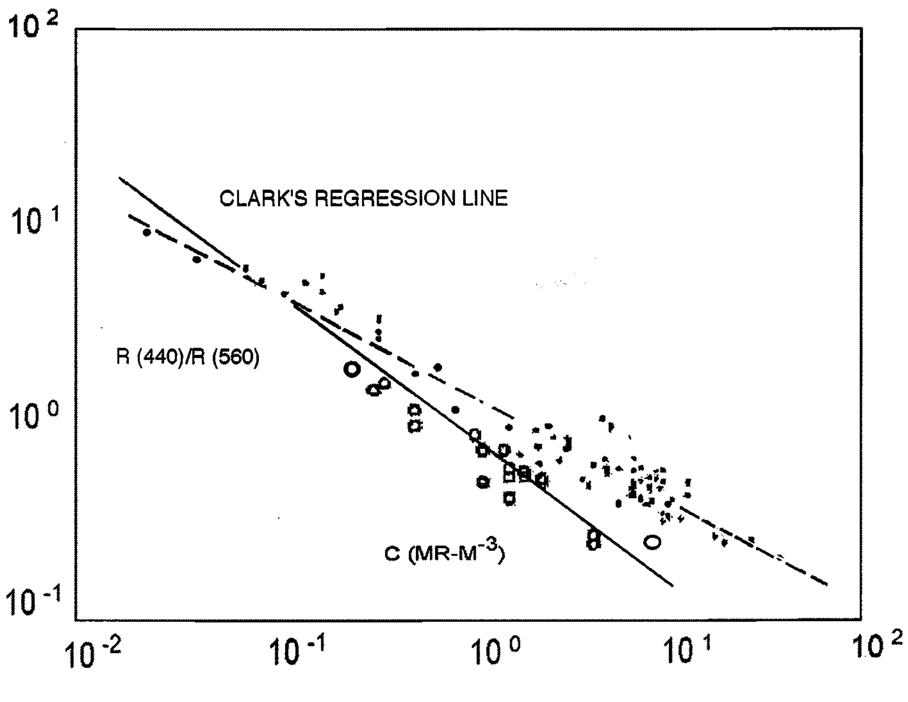


Figure 4: Correlationship between reflectance (R) ratio, R(441)/R(560), and chlorophyll pigment concentration (Gordon and Morel, 1983).

### 2.3 Other possible problems

When analyzing image data one has to ensure the image to be reasonably cloud free and also avoidance of the artifacts due to undesirable sea surface effect or sun glint effect as they can affect the radiance field in the area of interest. Besides sea foams, bubbles can also distort pigment estimates significantly. Moreover thick clouds also sometimes causes sensor overshooting. One has also to be careful while working with the images from shallow sea, because the variation of depth in shallow waters may cause changes in the ocean color.

## 3.0 Characteristics of Ocean color sensors

Remote sensors are mounted on a satellite vehicle and satellite should provide certain necessary facilities such as power supply, thermal control, aspect control and data handling system, for successful operation of the sensor in the orbit. Some of the important characteristics of ocean color sensors are presented in Table 1. They are mostly dependent on the orbital characteristics of the sensor/satellite. The type of orbit chosen for a satellite controls the spatial and temporal Earth coverage. Ocean color sensors are usually launched on polar-orbiting and sun synchronous satellites, which are different from the geostationary satellites, used for meteorological data collection. It takes about 100 minutes for a polar orbiting satellite to complete a sun-synchronous orbit. The usual local time of descending node is around noon for any location along the orbital path. So all ocean color images provide the noon time coverage of any given area. Some important characteristics of the ocean color sensors are discussed below to give an idea about their relevance in ocean color remote sensing. Such characteristics of all known historical, existing, and scheduled ocean color sensors are presented in Table 2.

### 3.1 Spectral resolution

The electromagnetic spectrum within the spectral range of 200 nm and 1m (Figure 5) is relevant for various ocean remote sensing applications. For ocean color study visible and near infrared spectral region (400-700 nm) is relevant. However, not the entire visible and near-IR part is useful. The atmosphere, including air, water vapor and aerosols present in the atmosphere absorb most radiation at certain wavelengths within the visible and near-IR part of the spectrum. This leaves only limited wavelengths, known as "atmospheric window", for inclusions in remote sensing channels of an ocean color sensor. The choice of channels is also governed by the application for which the sensors are developed. Some of the ocean color sensors include the thermal IR region (>900 nm) for simultaneous observation of sea surface temperature. Table 3 presents spectral characteristics of CZCS (Coastal Zone Color Scanner), OCTS (Ocean Color and Temperature Scanner) and SeaWiFS (Sea-viewing Wide Field-of-view Sensor). The CZCS and the OCTS were having both visible and thermal IR bands, however SeaWiFS is totally dedicated for ocean color measurements. The spectral channels with near-IR bands (at >700 nm) are meant for measuring aerosol radiance for atmospheric correction on the ocean color image.

| **Sensor Parameter** | **Range** | **Resolution (Smallest discernible element)** | **Spacing of smallest discernible element** |
|---|---|---|---|
| Spectral | Wavelength Coverage | Spectral bandwidth of Individual band | Spectral sampling frequency |
| Spatial | Total field of view for one image acquisition | Ground sampled distance, or instantaneous field of view | Spatial sampling frequency |
| Temporal | Time during which sensor can acquire image over a given location e.g. any time of day or just one time | Duration of acquisition time, integration, dwell or exposure time | Frequency with which image of feature can be acquired e.g. any day or only certain day |
| Radiometric | Dynamic range of radiance input | Noise equivalent reflectance difference | Always adjacent and determined by quantization |

Table 1: Some important characteristics of ocean color remote sensors.

| Satellite | Nimbus7 (USA) | ADEOS (Japan) | IRS P3 (India) | Priroda (Russia) | OrbView-2 (USA) | EOS AM-1 (USA) | IRS-P4 (India) | ROCSAT-1 (Taiwan) | ADEOS-2 (Japan) | ENVISAT-1 (Europe) | KOMPSAT (Korea) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sensors | CZCS • | OCTS/ POLDER • | MOS •• | MOS •• | SeaWiFS •• | MODIS MISR ••• | OCM ••• | OCI ••• | GLI/ S-GLI/ POLDER-2 ••• | MERIS ••• | OSMI ••• |
| Operation Date / Schedule | Oct.78- June 86 | Aug.96- July97 | Mar.96- | Apr. 96 | Aug.97 | June98 | Nov.98 | Apr.99 | June 2000 | Dec.99 | Aug.99 |
| Swath (km) | 1556 | 1400/ 2400 | 200 | 85 | 2806 | 2330/ 360 | 1420 | 690 | 1600 1600/ 2400 | 1150 | 800 |
| Resolution (m) | 825 | 700/ 6000 | 500 | 650 | 1100 | 1000/ 250 | 360 | 825 | 250/1000 750/ 6000 | 300/ 1200 | 850 |
| Number of Spectral Bands | 6 | 12/ 9 | 18 | 17 | 8 | 36/ 4 | 8 | 6 | 36 11/9 | 15 | 6 |
| Spectral Coverage (nm) | 433- 12500 | 402-12500/ 443-910 | 408- 1600 | 408- 1010 | 402-885 | 405-14385 446-867 | 402- 885 | 433-12500 | 375-12500 412-865 443-910 | 412-1050 | 400-900 |

• Historic •• Existing •••Scheduled

Table 2: Some important characteristics of ocean color remote sensing sensors.

## 3.2 Spatial resolution

The design of the sensor decides the angle of view from which the signal is received by the sensor at any one instant. This is called the instantaneous field of view (IFOV) or spatial resolution of the sensor. Spatial resolution of ocean color sensors have a resolution of around 1000m (Table 2), except the sensors such as POLDER (Polarization and Directionality of the Earth's Reflectance) which consist of an area array camera operating in snapshot mode covering a field of view of 6000 meters. The design of such sensors are altogether different from the conventional ocean color sensors. To produce an image of wide coverage around the Globe on each satellite orbit, the sensors are so designed to scan across the satellite tracking directions. For polar orbits the scan timing is arranged so that subsequent scans occur after the satellite has traveled a distance approximately equal to the IFOV projection on the satellite subtrack. The scanner samples at a rate so that the subsequent IFOVS just overlap along the scan direction and there are typically 2000 to 4000 samples along a scan line. In this way the whole area within a wide swath is efficiently sampled. The swath covered by a ocean color sensors are mostly more than1500 km, however, for the purpose of localized coastal data a few sensors have narrower swath width (Table 2).

| Sensor | CZCS | OCTS | SeaWiFS |
|---|---|---|---|
| Wavebands(nm) | | | |
| 1 | 433-453 | 402-422 | 402-422 |
| 2 | 510-530 | 433-453 | 433-453 |
| 3 | 540-560 | 480-500 | 480-500 |
| 4 | 660-680 | 510-530 | 500-520 |
| 5 | 700-800 | 555-575 | 545-565 |
| 6 | 10,500-12,500 | 655-675 | 660-680 |
| 7 | | 745-785 | 745-785 |
| 8 | | 845-885 | 845-885 |
| 9 | | 3.55-3.85 micron | |
| 10 | | 8.25-8.75 micron | |
| 11 | | 10.3-11.3 | |
| 12 | | 11.5-12.5 | |

Table 3: Spectral bands of CZCS, OCTS and SeaWiFS

## 3.3 Temporal resolution

Increased swath width brings down the time interval for the sensor to cover the whole earth, which is also known as temporal resolution. Usual temporal resolution of most of the ocean color sensors is 2 days for the whole Earth and at middle to high latitudes once a day. However, practically cloud cover limits actual imaging of the entire ocean surface to approximately every eight days, which means that at least one cloud-free view of any area on the ocean surface can be obtained in an eight-day period. Coverage along the equator may be slightly degraded due to instrument tilt to avoid sun glint effect.

## 3.4 Radiometric resolution

The ocean color information measured by a sensor are generated as voltage or frequency signal corresponding to the measurements being made. The analogue form of the information are then converted into digital signal for transmission from the satellite to a receiving station at the earth. The digital signal should be noise-free for retrieval and necessary image processing. Monitoring of transmission of noise-free signal is achieved by running a standard voltage ramp through the system periodically. The digital encoding of remotely sensed images facilitate their storage, dissemination and analysis and enhancement by image processing computer. In binary coding, $n$ bits of information are required to represent a whole number in the range 0 to $2^{n-1}$. This is known as quantization level or radiometric resolution. Usually the sensitivity of ocean color sensors requires a 10-bit digitization (that is 0 to 1023).

## 4.0 Status of ocean color sensors

The CZCS launched in October 1978, on-board the Nimbus7 satellite, one of a series of experimental satellites of NASA, was the first space-borne ocean color sensor. Although originally designed to record data from coastal waters in mid-latitudes with moderate to high pigment concentration, CZCS had proven to be useful for a dynamic range of waters and could even resolve the pigment gradients in oligotrophic oceanic waters. However, being an experimental rather than operational sensor, CZCS was neither always switched on, nor was there a continuous archiving of data for local as well as global coverage. Nonetheless, the satellite had long over-lived its originally designed life and it was operational till June 1986 spreading over almost eight years after its launch. Presently an impressive archive of data is available for analysis and oceanographic interpretation at the Goddard Space Flight Center (GSFC) of NASA and the data are open for users along with data processing software to work on the historical CZCS image. There was a time lag of almost one decade before the next ocean color sensor the OCTS was launched, in August 1996 on-board the ADEOS satellite by National Space Development Agency (NASDA) of Japan. Unfortunately the satellite had gone out of operation from June 30, 1997 due to malfunctioning of the ADEOS satellite, after successful operation for about nine months. The OCTS was meant for receiving both ocean color and SST data. Despite its short life span, the data quality has been found to be very useful for many ocean color investigations and complimentary study along with SST, in seas around Japan and elsewhere. Earth Observation Research Center (EORC) of NASDA is still working on OCTS data to improve the processing algorithm with updated calibration. Presently data processing using version 4 calibration parameters is under progress.

There was also another ocean color sensor the POLDER developed by CNES, France that had been launched on the ADEOS satellite along with the OCTS. As it can be notices from the Table 2, the POLDER is a wide-field-of view (2400 km swath), moderate resolution (6×7 $km^2$ at nadir) multi-spectral imaging radiometer designed to collect global and repetitive observations of the solar radiation reflected by Earth-atmosphere-ocean system. It is highly useful for ocean color application. However, despite coincidence of two ocean color sensors on one platform, it has not yet been utilized much by the oceanographic community in the field of ocean color, mainly due to coarse resolution as well as lack of experience to work with such a unique ocean color sensor. However, CNES encourages scientists to carry out research on the POLDER data by providing data as well as image processing software.

The SeaWiFS, an eight-channel visible radiometer was launched by Orbital Science Corporation of U.S.A onboard the OrbView-2 (formerly "SeaStar") satellite in August 1997. It is considered to be the follow-on mission to the CZCS and predecessor to several ocean color sensors scheduled for deployment in the years 1998-2003. The SeaWiFS mission is a public private partnership between NRSA and the Orbital Science Corporation. Although the SeaWiFS spacecraft and data belong to the Orbital Science Corporation, NASA has purchased the rights to use data for scientific purpose. There are many High Resolution Picture Transmission (HRPT) data receiving stations located at various locations around World to collect the data from the local region. For South East Asian region there are around eight HRPT data receiving stations (Taiwan 4, China 3, and South Korea 1) apart from five stations at Japan which covers the seas around Japan and part of SE Asian region. One of the primary goals of the SeaWiFS mission is to achieve accuracy in chlorophyll *a* estimation within 35% over the range 0.05-50.0 mg $m^{-3}$. Ocean color scientists have been working on the SeaWiFS data at several places around the World and it has been proved to be an extremely successful ocean color mission, moreover an improvement to CZCS mission by having better spectral bands for atmospheric correction (Table 3). The improved atmospheric correction particularly aids estimation of chlorophyll in coastal region. Significantly the SeaWiFS has a spectral channel at violet wavelength (412 nm) which can be of immense use for coastal study besides oceanic chlorophyll *a* measurement. With the help of violet spectral band, concentration of the yellow substances, that is a characteristic of coastal water, can be estimated. After carrying out initial processing of the SeaWiFS data for seven months (February-August 1998), recently (since September 1998) SeaWiFS project has switched over to improved algorithms for reprocessing of the all images. These improvements include the modification in chlorophyll algorithm. Recent modification method is expected to produce more near-accurate estimates of chlorophyll *a* especially in the coastal waters. All SeaWiFS data are available from the Goddard Distributed Active Archive Center (DAAC) in Hierarchical Data Format (HDF). HDF is a "self describing" data format, that contains all the pertinent information necessary to examine data in a file, within one file. The SeaWiFS data are recorded in two forms: 1) 1 km resolution LAC (Local Area Coverage) data, 2) 5 km resolution GAC (Global Area Coverage) data. The GAC data are used for production of global dataset. Both GAC and LAC SeaWiFS data are processes from raw radiance to three levels (Level 1A, Level 2, and Level 3) at SeaWiFS Project and then transmitted to the Goddard DAAC for archiving and retrieval. The SeaWiFS data were available to the public without restriction initially for a few months (till March 11, 1998) after launching of

SeaWiFS. Following March 11 1998, the data are available only for scientific research to authorized users who have registered with the SeaWiFS project. Interested researchers have to be accepted by SeaWiFS Project as an authorized user. However this arrangement is restricted only for scientific users. For commercial application one has to contact the Orbital Science Corporation and buy the necessary data. Besides the German Modular Optoelectric Scanner (MOS) sensor was launched in 1996 aboard an experimental satellite the IRS-P3 of the Indian Space Research Organization (ISRO). Data from European coastal waters and part of the Arabian Sea are now available to the researchers. This sensor has also been found useful for coastal studies with specific sensors and also its high resolution data. There is also an identical MOS sensor on the Priroda satellite of Russia. This sensor has a smaller swath, lower resolution and less coverage than the one on the IRS-P3 (Table 2). However it's current status is not known.

Apart from these active sensors there are several ocean color sensors are in pipeline to be deployed in the years 1998-2003 (Table 2). Significant of them are the Global Imager (GLI) scheduled to be launched on the ADEOS-2 satellite in June 2000. Fifteen spectral bands of this sensor will be dedicated to ocean color. There are also two ocean color sensors the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Multi-angle Imaging Spectroradiometer (MISR) to be launched by NASA on the EOS AM-1 satellite. The MODIS will be receiving data at 36 spectral bands of visible and infrared region and 9 of those will be available for ocean color application. The MODIS ocean color products will be suitable to study phycobiliproteins, florescence, cocolithophores, chlorophyll and PAR (Photosynthetically Active Radiation). The data policy has been formulated for users to have free accessibility of data. The Medium Resolution Imaging Spectroradiometer (MERIS) is scheduled to be launched by the European Space Agency (ESA) onboard the ENVISAT-1 satellite. The primary goal of this sensor is bio-optical oceanography including estimation of pigments, yellow substances and suspended matter that would make it useful for both oceanic and coastal studies. Besides, India, Taiwan and Korea are scheduled to launch ocean color sensors. Indian Ocean color sensor, the Ocean Color Monitor (OCM) will be launched on Oceansat/IRS-P4 (India). The Taiwanese Ocean Color Imager (OCI) and the Korean Ocean Scanning Multispectral Imager (OSMI) are scheduled to be launched respectively on the ROCSAT-1 and the Korea multi-purpose satellite (KOMPSAT).

Cloud is the major limitation encountered by the investigators in the field of ocean color remote sensing. Cloudiness prevents deriving chlorophyll a concentration over about 60 percent of the ocean on a daily basis excluding that already lost due to high Sun glint. Hence launching of the above ocean color sensors by different countries within rather a short duration of five years is undoubtedly a welcome development as it would increase sampling frequency of ocean color data. It would further provide a unique opportunity to the satellite oceanographers to plan studies on large and meso-scale oceanographic processes in different part of the World Ocean. It would specifically help to study plankton processes, which vary rapidly over time and space. Finally these intensive research activities may lead to large scale operationalization of ocean color data.

## 5.0 Application of remotely sensed phytoplankton pigment concentration

Phytoplankton load, as revealed by ocean color can be attributed to mainly plant pigment, chlorophyll *a*. The CZCS-derived phytoplankton estimates are combination of both chlorophyll *a* and its covarying pigment, phaeopigment concentrations. As an improvement over CZCS it has been possible to derive concentration of only chlorophyll *a* from the recent sensors such as OCTS and SeaWiFS by adopting improved algorithms. With launching of MODIS it will be possible to measure chlorophyll fluorescence, thus better estimates of chlorophyll *a*.

## 5.1 Phytoplankton distribution as tracer to a dynamic ocean

Distribution of phytoplankton pigments can be used to trace oceanographic features such as currents, jets and plumes. An example of CZCS-derived phytoplankton pigment image for the northeastern coast of United States (Plate 1) reveals the high pigment concentrations along the coast and influence of Gulf Stream. The upper part of the color bar with violet color shows lowest pigment concentration and red color indicates highest level at the lower part of the bar. Several large Gulf Stream Warm Core Rings, prominent features of this western boundary currents, can be marked on this image with ring-shaped water pockets with very low level of phytoplankton pigment concentration. Higher productivity areas can also be marked near the Chesapeake and Delaware Bays on this image. Plate 2 shows an OCTS derived chlorophyll *a* imagery covering seas near Malaysia on June 13, 1997. Highly pigmented waters can be noticed near to coast however oceanic waters with very low level of chlorophyll *a* concentration. Plate 3 shows a series of six chlorophyll *a* images derived from SeaWiFS images covering the Kuroshio-Oyashio frontal area along east coast of Japan spreading over entire winter season (mid-December to mid-March). The images depict development of phytoplankton bloom during summer under the influence of the Kuroshio-Oyashio currents.

## 5.2 Phytoplankton as indicator of ocean production

Chlorophyll *a* concentration is a key input to the primary production taking place in ocean water. Moreover, since phytoplankton are the first link in the pelagic food chain, the success of most oceanic life is dependent on the success of phytoplankton. Since many countries are dependent on fish for food and commerce, the health and economies of many people especially in the developing World are also dependent on this first link. Therefore, understanding the process that affects phytoplankton is of importance from economic and conservational point of view. Phytoplankton distribution is controlled by the physical oceanographic processes. Their feeders such as zooplankton and fishes depend on them for food. Hence information on phytoplankton distribution in the context of their physical set up, are considered to be an important information to study the biological resource variability including those belong to higher trophic levels, over local and regional scale. The frontal areas such as Gulf Stream (Plate 1) and Kuroshio (Plate3) provide favorable habitat for pelagic fishes to congregate both due to favorable temperature gradient and food availability. The Gulf Stream area near Chesapeake and Delaware Bays (Plate 1) is a well known highly productive area and was well known for its Grand Banks cod fishery. However, in the recent decades there has been a total collapse of the cod fishery due to overfishing.

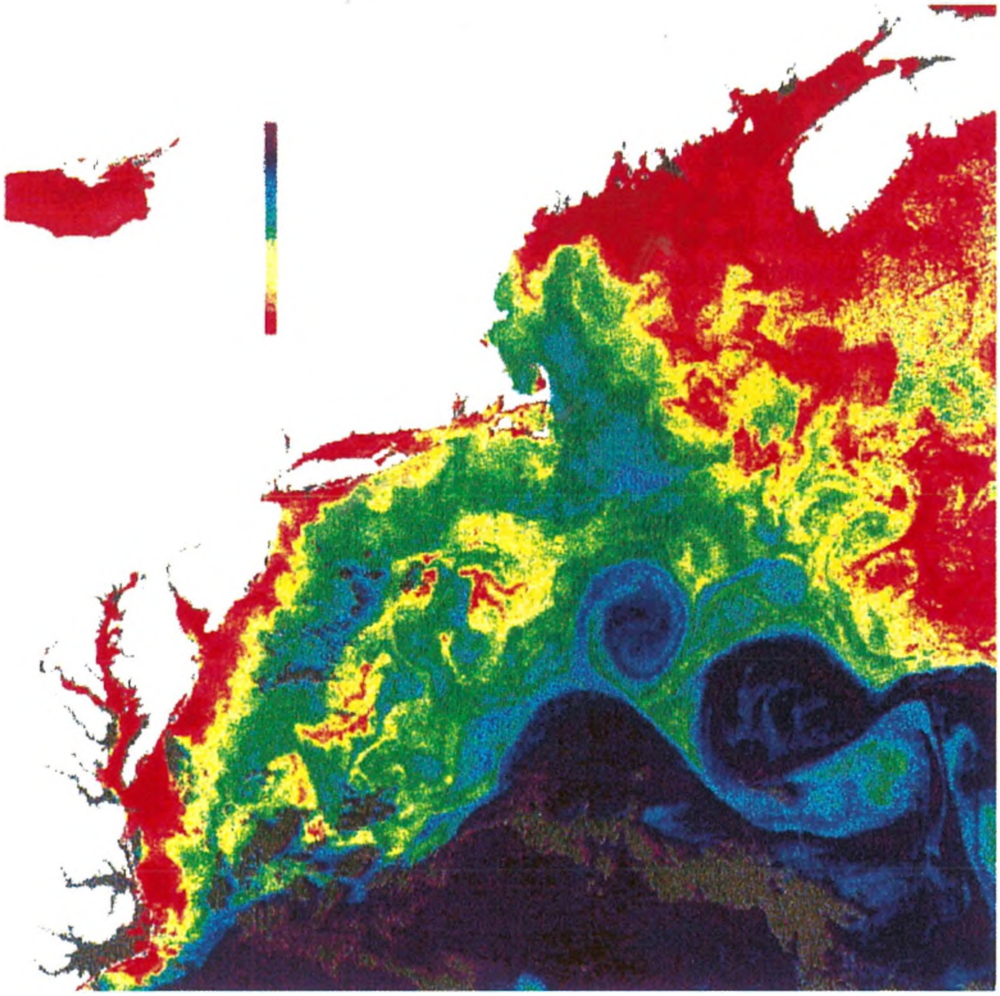

Plate 1: A daily CZCS phytoplankton pigment product covering coastal waters along northeastern coast of the United States shows the high pigment concentration along the coast and influence of the Gulf Stream.

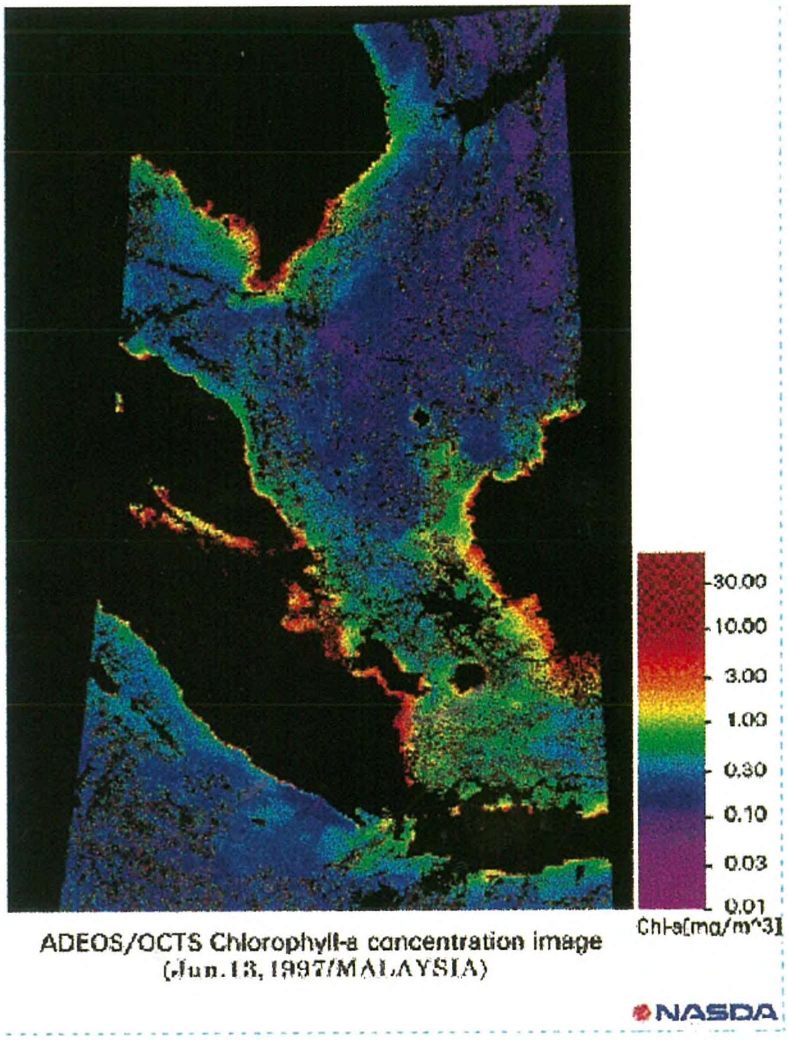


Plate 2: OCTS chlorophyll-a product of the seas near Malaysia shows highly pigmented waters along the coast and oceanic waters with very low pigment concentration.

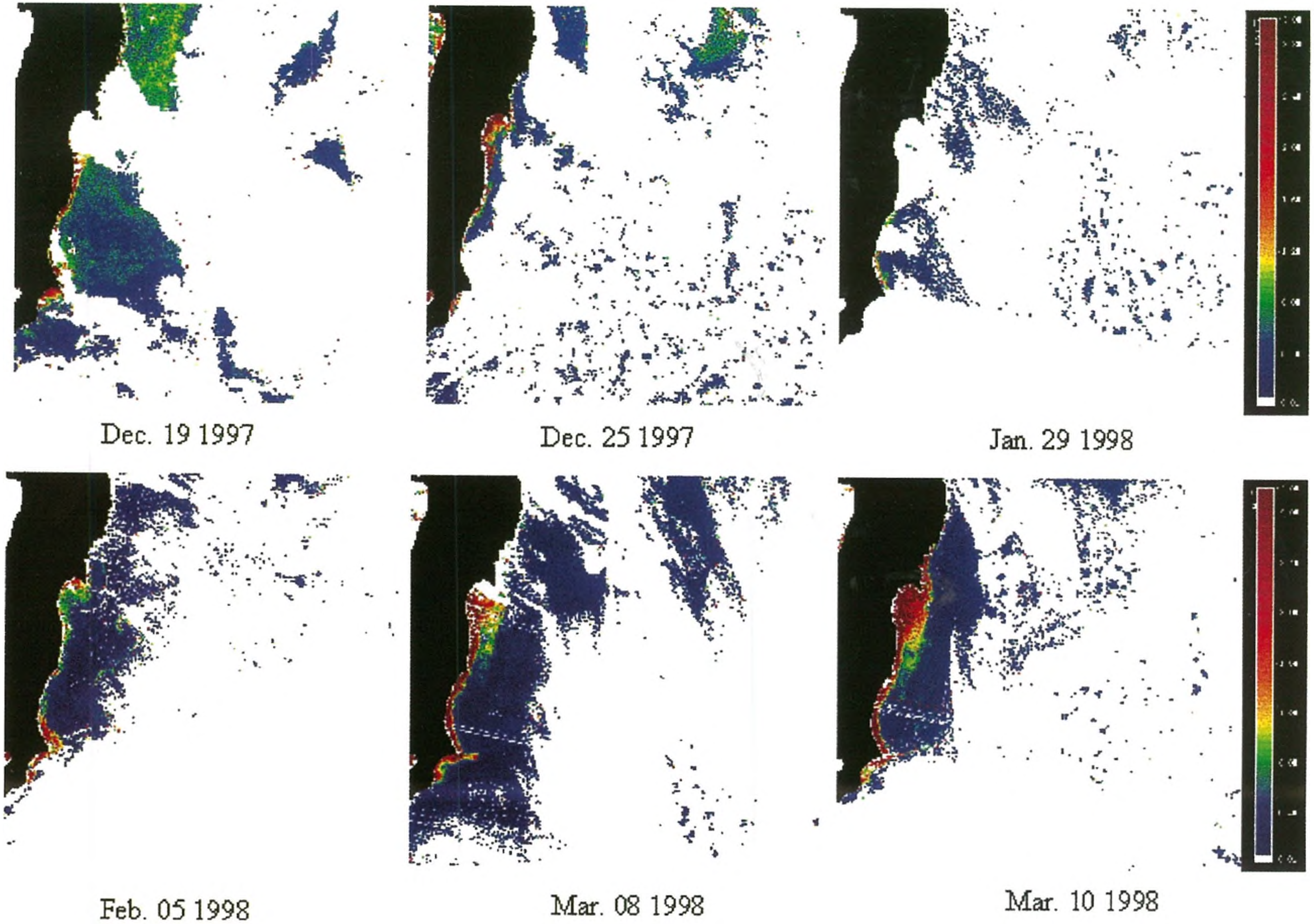


Plate 3: SeaWiFS derived chlorophyll-a distribution at the Kuroshio-Oyashio frontal region.

### 5.3 Coastal pollution:

The phytoplankton shows where coastal pollutants degrade the ocean ecosystem and prevent or alter the plant growth. They can further show subtle changes in phytoplankton distribution as a result of change in SST and salinity. Since phytoplankton depend upon specific oceanographic conditions for growth, they frequently become the first indicators of a change in their environment. Since most of the polluted regions belong to coastal waters, it is necessary to develop appropriate models/algorithms to successfully implement them on ocean color images to derive the desired information. With the specific spectral bands on SeaWiFS and the forthcoming sensors meant for coastal water studies it would be possible to assess the influence of coastal pollution on coastal ecosystem.

### 5.4 Carbon cycle and global climate study

Through photosynthesis, phytoplankton affects the Earth's climate by absorbing a significant portion of the World's carbon dioxide. When phytoplankton die, if their carbon is not consumed by other living creatures, it sinks to the ocean floor and eventually emitted back into the atmosphere again through volcanism; part of this process known as the carbon cycle (Figure 6). The carbon cycle has drawn considerable attention of the scientists in view of its effect on global climate. Before the industrial Revolution, the level of atmospheric carbon dioxide had remained nearly stable for thousands of years.

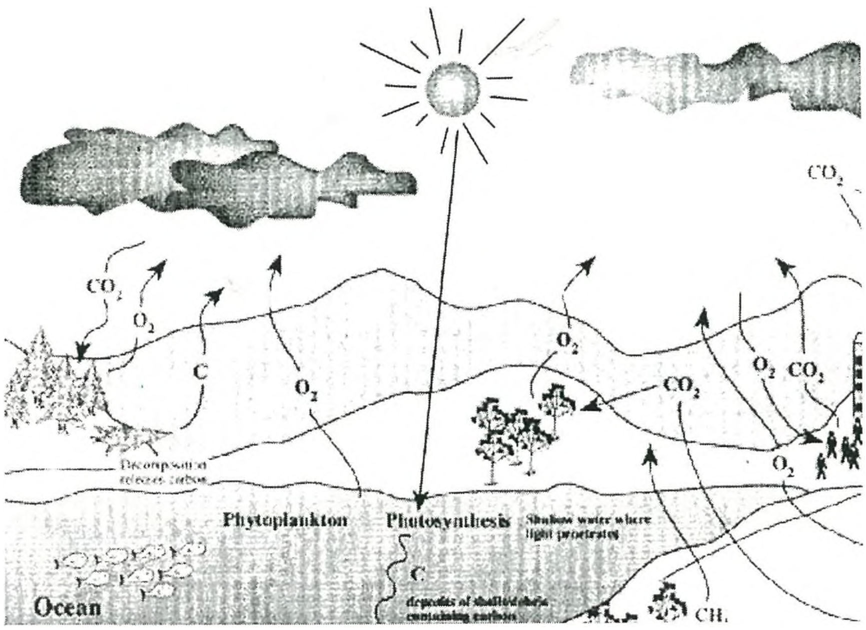


Figure 6: Pictorial depiction of the Carbon Cycle

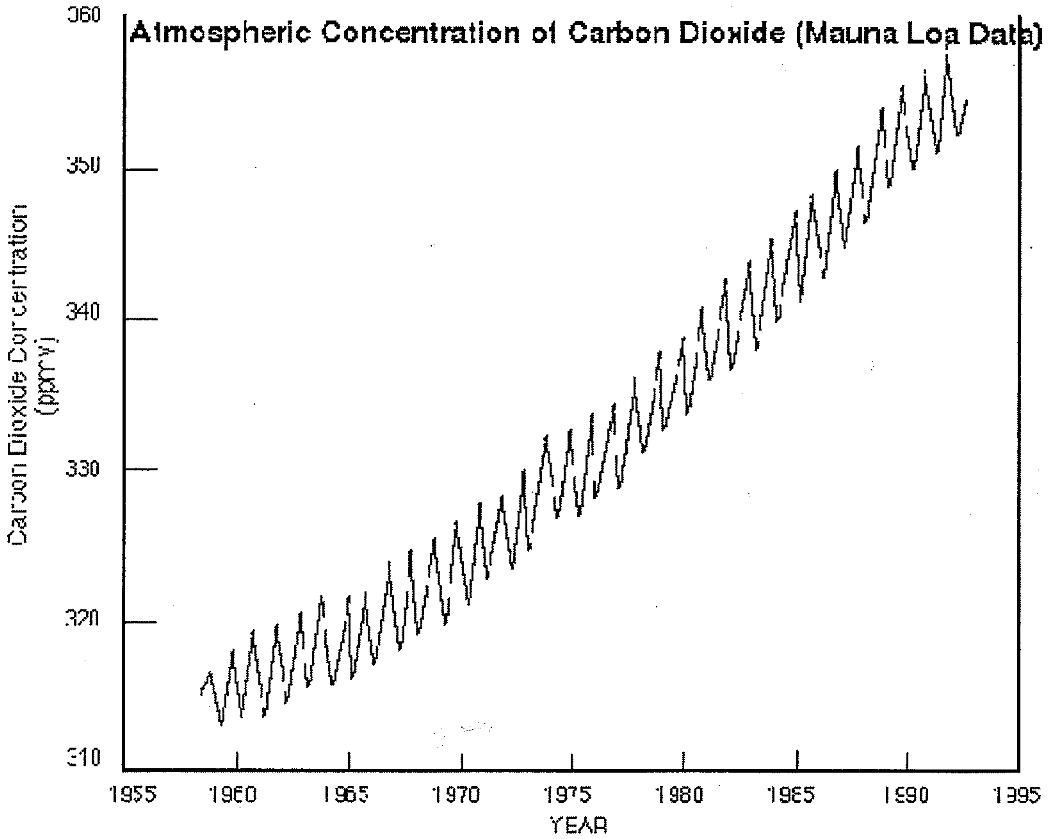


Figure 7: Increase in atmospheric carbon dioxide during 1965-1995

Since human beings developed a fossil fuel based global economy and life style, the amount of atmospheric carbon dioxide has increased dramatically as evident from the Fig.7. This increase means that less long-wavelength energy (temperature) emitted from the earth can escape to space. It is now being predicted if such trend continues this can lead to global warming. Primary production process in ocean can provide insight to carbon cycle and global climate. Ocean color or phytoplankton information is considered to be a good indicator to primary production, hence they can aid in monitoring the change in global climate and to assess how does such a change affects the living system.

Two vital issues are to be addressed in context of phytoplankton: 1. How does a change in phytoplankton (due to natural or artificial reason) affect global climate? 2. How does such a change affect the ocean's food supply? The first step towards answering these questions are: 1) estimating the level of primary production in the ocean with accepted level of accuracy, 2) finding out how variable (both spatially and temporally) is productivity and finally 3) determining if is there a long term trend. All of these questions can be answered through ocean color remote sensing if we have a reliable technique to achieve desired accuracy. Plate 4 shows the global ocean phytoplankton biomass within the upper layers of biomass from the CZCS. While this is an annual product, with the existing SeaWiFS and forthcoming ocean color sensors, it would be possible to provide comparable global coverage on a weekly to monthly

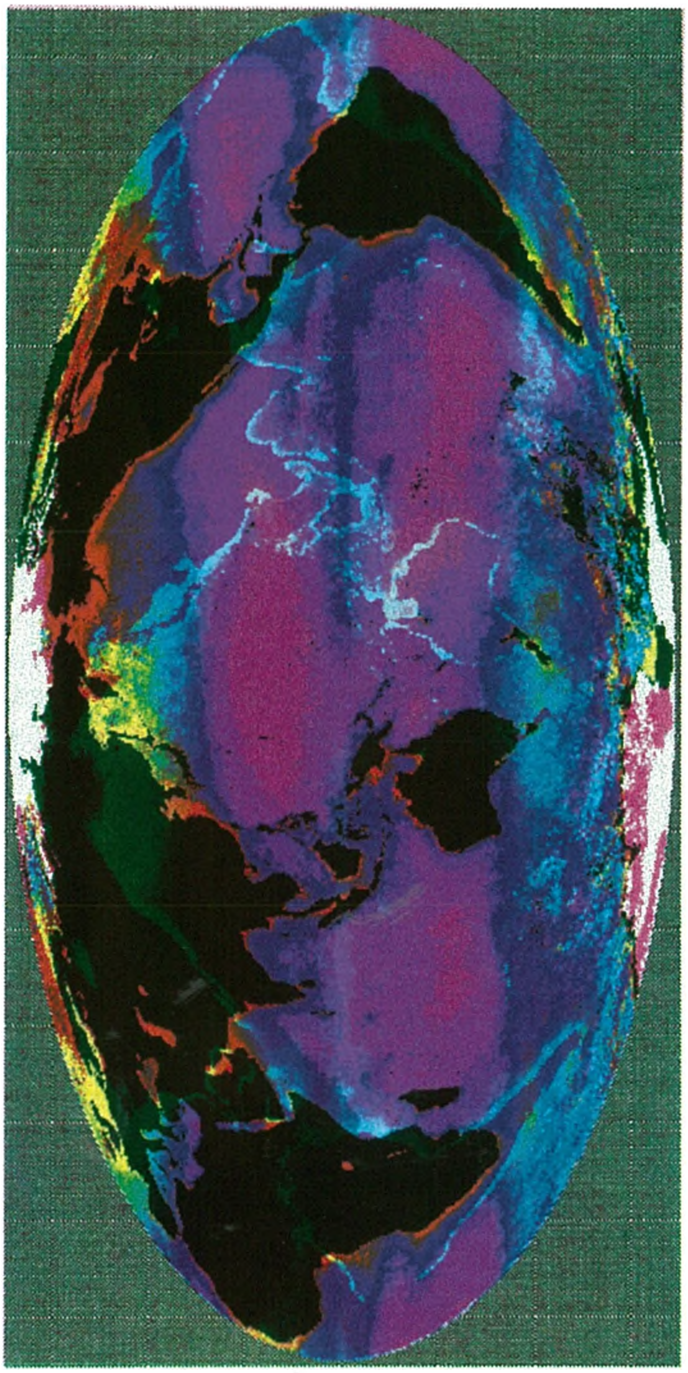

Plate 4: Global ocean phytoplankton biomass as revealed from annual CZCS binned product.

basis to enable scientists to study large-scale changes in marine ecosystems over weeks and decades. Currently scientists are exploring both statistical and semi-analytical models to estimate productivity using bio-geographical quantities such as phytoplankton pigments, SST, light levels etc, measurable using satellite remote sensing. Statistical models involve developing statistical relationships between satellite derived ocean color with primary productivity. This technique is found quite reliable for assessment of long-term, regional trends and estimating global productivity. In case of the semi-analytical mathematical models, physical processes are integrated into algorithms and they are most useful in calculating primary productivity for more over localized region.

## 6.0 Prospects of ocean color remote sensing in coming decade

During next five years there is an encouraging schedule for launching of ocean color sensors by the countries representing almost all regions of World. Assemblage of ocean color satellite systems through international efforts would lead to continuous global coverage of the World Ocean. However, it is a challenge before scientific community to achieve inter-calibration of the sensors and validate the data from different satellites for producing standard outputs. Moreover the envisaged missions provide a unique opportunity for development of techniques and methodology and refinement of the existing ones for successfully recovering ocean color information from satellite data. It would also lead to advances in the application of ocean color remote sensing to address problems related to local, regional and global ocean processes. Especially the coastal waters classified under "case 2" category, are expected to draw increased attention of the investigators as many of the countries located along the coastline are interested in assessing coastal oceanographic processes.

In the context of Southeast Asia, where most of the countries are surrounded by ocean and exposed to global climatic phenomena such as El Nino, remotely sensed phytoplankton pigment information could be an efficient tool for understanding and assessment of the impact of such phenomena on marine ecosystem. Besides most of the Southeast Asian countries have interest in development and management of their coastal region for commercial activities such as fishing and coastal aquaculture, hence they need efficient sustainable management strategy to protect the coastal environment from further degradation. Ocean color information can help immensely to aid in such efforts. In view of anticipated launching of a number of ocean color sensors in the coming years, especially three sensors by the nearby countries, there is a major scope for the scientists from this region to undertake research programs related to ocean color remote sensing in their respective areas of interest. Joint efforts by scientific community from this region and those from the countries already exposed to ocean color remote sensing technology can help development of appropriate techniques and methods to address the research and application needs of Southeast Asia.

## 7.0 Conclusions and recommendations

In this status paper we have tried to present the principle of phytoplankton remote sensing, characteristics of the ocean color sensor systems and various applications of the remotely sensed phytoplankton pigment data in a simple language, without citing equations, so that it would be easier to appreciate for the resource scientists, especially those who are new to remote sensing technology. We have attempted to clarify the potential and limitations involved with the technology, so that the prospective users can appreciate such aspects. In addition we have touched upon a few important images to depict capability of remote sensing technique in understanding ocean process and ecosystem.

In our recommendations we would urge the scientific community in the fields, relevant to ocean color remote sensing, to evolve a program for technical collaboration with their counterparts in the countries where they have been exposed to ocean color remote sensing, especially in nearby countries in Asia. It appears more relevant in view of scheduled launching of ocean color sensors by four countries near to the region (Japan, Korea, Taiwan, and India). To start with, a forum such as joint working group of scientists and technocrats can be formed for frequent interaction between them and identifying areas of common interest. Scientists from the countries those who are involved in development of ocean color sensors and techniques for application of remotely sensed data can provide the data and share their experience with their colleagues from Southeast Asian countries. Moreover it is also very important on the part of these countries to generate more trained manpower in this field to meet the research interests of the respective countries in this emerging field of science.

**Acknowledgement**

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Goddard DAAC Home page (http://daac.gsfc.nasa.gov/)
EORC Home page (http://www.eorc.nasda.go.jp/ADEOS)

# ANNEX 6

THE MFRDMD/SEAFDEC FIRST REGIONAL WORKSHOP ON
REMOTE SENSING OF PHYTOPLANKTON

Kuala Terengganu, Malaysia, 17-18 November, 1998

SEAFDEC/MFRDMD/WS/98/CR. 1

# COUNTRY STATUS REPORT

# INDONESIA

## REMOTE SENSING TECHNOLOGY FOR UTILIZING FISHERY RESOURCES IN INDONESIA

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## 1.0 Introduction

Geographically, Indonesia, which is located at the equator consists of two-third of marine area. This tropical country comprises of 17,508 islands. It has a very large and complex biodiversity such as many kinds of fish species.

To utilise these potential fish resources, traditional fishing gears that are suitable for this area and species are often used. Traditional fishing gears are mostly used by the fishermen to catch fish in coastal areas. The modern technology, such as purse seines, gill nets, and fish nets are operated in the off shore waters in Indian Ocean, North Irian Jaya Sea, South China Sea, and Arafuru Sea.

Nowadays, remote sensing technology has been developed for detecting fishery resources. Its application in Indonesia is still limited. This technology still cannot be used to track the migration of pelagic fish from one area to another area.

The application of remote sensing technology for fishery in Indonesia is still on trial. Hopefully that this technology could be used in utilizing the marine fish resources in the future.

## 2.0 Fisheries Development in the South China Sea

In Indonesia, the East Coast of Sumatra which bordering the Malacca Straits, also referred to as the South China Sea. Northern area is Exclusive Economic Zone (EEZ) of Indonesia, while in the south there is coastal area of Sumatra.

### 2.1. Fisheries Production

The quantity of the fish captured is depended on various factors such as type and effectiveness of catching equipment, the size of fishing area, fishing intensity and season.

Total marine fish captured was 220,587 tons in 1994. In 1996, the production was 260,584 tons. The annual increment was 1.08%.

### 2.2. Fishing boats.

In terms of fishing units, the number of fishing boats was risen from 21,066 units in 1994 to 21,324 units in 1996, with an average annual increment of 1.22%.

### 2.3. Equipment and Technology

The statistics of the Fishery Service of East of Sumatra mentioned that in the years of 1995 to 1996 the number of boats and fishing equipment in South China Sea are as in Table 1.

| Types | 1994 | 1995 | 1996 |
|---|---|---|---|
| Boats | | | |
| 1. Non-power boat | 8,526 | 8,234 | 8,359 |
| 2. Out board engine | 3,630 | 3,687 | 3,979 |
| 3. In board engine | 9,373 | 8,662 | 8,966 |
| Fishing equipment | | | |
| 1. Seine nets | 2,107 | 2,603 | 2,684 |
| 2. Purse seine | - | - | - |
| 3. Gill nets | 6,386 | 6,461 | 6,928 |
| 4. Lift nets | 6,122 | 6,832 | 6,607 |
| 5. Hook and line | 7,916 | 8,271 | 8,672 |
| 6. Traps | 4,580 | 4,511 | 4,811 |
| 7. Others | 180 | 107 | 199 |

Table 1: Number of boats and fishing equipment, 1994 – 1996

The total number of marine fishing units in South China Sea was 29,899 units in 1996.

### 2.4. Fisheries Resources in the South China Sea

The potential of fishery resources in the South China Sea is about 1,210,662 ton (1987). The resources include demersals, pelagics, penaeids, lobsters, coral fishes, and squids (loligo). Table 2 below shows the potential of fishery commodities.

| No | Commodities by group | Ton per annual |
|---|---|---|
| 1 | Pelagics | 513,000 |
| 2 | Demersals | 656,000 |
| 3 | Penaeids | 11,000 |
| 4 | Lobsters | 400 |
| 5 | coral fishes | 27,565 |
| 6 | squids (loligo) | 2,697 |
| | Total | 1,210,662 |

Table 2: The potential of marine fisheries in South China Sea:

The types of fish that are common in Indonesia are listed in Table 3.

| No | Indonesian name | Scientific name |
|---|---|---|
| 1. | Manyung | *Trychyurus* spp. |
| 2. | Gerot-gerot | *Pomadasys* spp. |
| 3. | Bambangan | *Lutjanus* spp. |
| 4. | Kerapu | *Epinephelus* spp |
| 5. | Lencam | *Lithinus* spp |
| 6. | Kakap | *Lates calcalifer* |
| 7. | Ekor kuning | *Caesio* spp |
| 8. | Gulamah | Scianidae |
| 9. | Cucut | Spyrinidae |
| 10. | Pari | Trigonidae |
| 11. | Bawal hitam | *Formio niger* |
| 12. | Layang | *Decapterus* spp |
| 13. | Selar | *Selaroides* spp |
| 14. | Kuwe | *Caranx* spp |
| 15. | Tetengkek | *Megalaspis cordyla* |
| 16. | Daun bambu | *Chorinemus* spp |
| 17. | Belanak | *Mugil* spp |
| 18. | Kuro/Senangin | *Polynemus* spp |
| 19. | Teri | *Stolephorus* spp |
| 20. | Tembang | *Sardinella fimbriata* |
| 21. | Golok-golok | *Chirocentrus* spp |
| 22. | Kembung | *Rastrelliger* spp |
| 23. | Tenggiri | *Scomberomorus guttatus* |
| 24. | Tongkol | *Euthynus* spp |

Table 3: Common marine fish species in the South China Sea is listed below.

## 3.0 Remote Sensing Technology for Fishery

Directorate General of Fisheries Indonesia has been implementing research on the application of remote sensing technology using NOAA AVHRR data for fisheries in cooperation with LAPAN. The study is focused on analysis of physical oceanographic phenomena such as distribution of sea surface temperature for detecting movement of pelagic fish. The sea surface temperature of Sunda Strait or Sunda Shelf (south of Java) was about 29°C to 30°C. This temperature range covers quite large areas, and has a significant relationship with fish production. For example, the total fish landed at Labuhan (normal sea surface temperature of 29°C) is high, while in the other areas, which have a sea surface temperature of around 30°C to 32°C, the total fish landed is low. Therefore, we conclude that the sea surface temperature of around $29^0$C provides suitable habitat for small pelagic fish such as scads (*Decapterus* spp).

## 4.0 Remote Sensing Technology for Fish Stock Assessment

Remote sensing technology is used to investigate stock of fisheries resources. A working group has been established to assess the stock as well as to implement detailed study for analysing fish stock.

Currently, the remote sensing technology for detecting phytoplankton distribution has yet to be implemented in Indonesia. Indonesia doesn't have "satellite sea watch" program for monitoring of phytoplankton and fish resource.

# ANNEX 7

THE MFRDMD/SEAFDEC FIRST REGIONAL WORKSHOP ON REMOTE SENSING OF PHYTOPLANKTON

Kuala Terengganu, Malaysia, 17-18 November, 1998

SEAFDEC/MFRDMD/WS/98/CR. 2

# COUNTRY STATUS REPORT

# JAPAN

## ACTIVITY ON THE REMOTE SENSING OF PHYTOPLANKTON IN JAPAN

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## 1.0 Current marine remote sensing application in Japan

The fishing ground of many useful fish (sardine, anchovy, saury, skipjack tuna, etc.) locates the special temperature zone or the temperature gradient zone near Japan. It is important matter for fisheries to forecast oceanographic conditions. There is two types of oceanographic conditions forecasting for fishery in Japan. First one is the long term, 2 to 4 months forecasting and the second one is near future forecasting or quick report. When making the long term forecasting, we use many types of oceanographic items like current meter records, NOAA SST map, 100 m depth temperature map. Quick report for fisheries are published by JAFIC and many prefectural fisheries experimental stations. These reports are mainly SST mapping by the SST data from fishing boats and satellite infrared images (GMS and NOAA).

There are two main research frameworks for ocean color remote sensing for fisheries in Japan. Forst one is the joint research agreement between NASDA and JAFIC for putting the ocean color images to quick report for fishing ground. Second one is the joint research agreement between NASDA and NRIFS for ocean color validation and tuning up in-water algorithm for chlorophyll-a and primary production since 1996.

## 2.0 Research findings of phytoplankton blooms

There are a lot of chlorophyll-a shipboard observations near Japan in winter and spring around fish spawning season, but there are not many data in other seasons. Only CZCS pigment images can clarify the annual change of phytoplankton. In the Kuroshio region there are 'spring bloom' in December and January. There occurs phytoplankton bloom in January and February in the inner region of the Subtropical Gyre. The blooming is occurred from south to north of the Kuroshio. This bloom movement is similar to the movement of fish group like sardine, anchovy and saury.

## 3.0 Monitoring of coastal sea environment using remote sensing techniques.

It is not easy for short term monitoring coastal area from satellite, because the frequency of observation is low. My group succeeds in detecting the red clay discharge in coral reef area using LANDSAT-TM data. There are a lot of red tide reports by airborne observations.

## 4.0 Problem encounters

1. Establishing CASE 2 water algorithm
2. Packaging effect

Research needs and proposals of member countries and the region
1. Establishing the validation system
2. Creating local in-water algorithm

# ANNEX 8

THE MFRDMD/SEAFDEC FIRST REGIONAL WORKSHOP ON REMOTE SENSING OF PHYTOPLANKTON

Kuala Terengganu, Malaysia, 17-18 November, 1998

SEAFDEC/MFRDMD/WS/98/CR. 3

# COUNTRY STATUS REPORT

# MALAYSIA

## STATUS OF MARINE REMOTE SENSING APPLICATIONS IN MALAYSIA

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## 1.0 Introduction

The ability of remote sensing technology to monitor sea conditions is undoubtedly a very valuable and necessity tool for routine environmental monitoring. Accurate and dependable information about the sea conditions is needed to protect human lives from danger, to protect natural ecosystems from pollution such as oil spills and to facilitate economic activities through fishing.

The application of remote sensing technology to monitor the marine environment in Malaysia is rather new. Apart from few researches conducted by local universities such as the University of Technology Malaysia (UTM), University Putra Malaysia (UPM) and University of Science Malaysia (USM), there has been little work done by the Department of Fisheries. Following the Department of Fisheries concern to increase fish production through aquaculture, remote sensing techniques have recently been used to determine the distribution and magnitude of water bodies in the country. Many of the applications are associated with inventorying by updating landuse maps and identifying potential aquaculture sites in the country.

This paper provides an overview on the application of remote sensing techniques on marine environment in Malaysia. It also highlight some projects that are in progress and the results and problems faced in a number of studies. Participating agencies involved in the application and development of remote sensing techniques in Malaysia are also mentioned. A brief information on some research findings on algal blooms in Malaysia is also given.

## 2.0 Participating agencies in the application and development of remote sensing technology in Malaysia

### 2.1 Co-ordinating agency

The development of remote sensing technology in Malaysia is implemented under the National Remote Sensing Programme (NRSP). The program is co-ordinated by the Malaysian Centre for Remote Sensing (MACRES) which was established in August 1988 in full operation in January 1990. The centre is equipped with computer hardwares and softwares for satellite image processing and geographic information system (GIS). It is responsible for the national operationalisation of remote sensing technology through the user, ground and space segments.

In the user segment, the development of trained and skilled manpower was given emphasis by MACRES in order to operationalise the remote sensing technology especially on the resource and environmental management and strategic planning of the country. This entails several collaborative research programmes with user agencies in Malaysia such as research institutes and institutes of higher learning in the country. Currently, MACRES is building up a database at the national level for the National Resource and Environmental Management Programme (NAREM) of Malaysia. The input data are sourced mainly from satellite and data from various user agencies from existing databases on agriculture, forestry, geology & mineral, fishery & marine, coastal zone management, environment, topography and socio-economic.

These databases will be used to assist in the planning, modelling and decision-making process of the country.

As for the ground segment, MACRES is constructing a ground receiving station in order to facilitate real time reception of data. This is to meet the increasing demand of national needs for a more effective environmental monitoring and natural resources management. The space segment focuses on the acquisition of technological capabilities in satellite design and integration, sensor development, altitude and orbit control, tracking, telemetry and command.

### 2.2 User agencies involved in the application of remote sensing technique on the marine environments

#### 2.2.1 Fisheries Research Institute (FRI), Penang

The Remote Sensing and Geographic Information System (RS & GIS) applications team has been established in 1993 after the procurement of nearly a half million *Ringgit Malaysia* worth of remote sensing and GIS set-up. The set-up is made up two units; workstations and image processing software of ERDAS - Imagine for RS and operating softwares of ArcInfo and Arcview for GIS with several other support equipment. The RS & GIS team of FRI is responsible for research on the application of RS and GIS techniques on water bodies in Malaysia. The unit is manned by few researchers who showed keen interest on using remote sensing/GIS techniques as one of the tool to conduct research.

#### 2.2.2 Marine Fishery Resources Development and Management Department (MFRDMD) of the Southeast Asian Fisheries Development Center (SEAFDEC)

The remote sensing unit of MFRDMD/SEAFDEC was established in 1994. The unit was initiated in order to use remote sensing technique in the feasibility study of locating fish schools for exploitation as well as oceanography and marine resource management. It has planned to conduct regional programmes for the benefit of member countries initially bordering the South China Sea in the Southeast Asian region.

The RS unit is equipped with the High Resolution Picture Transmission (HRPT) system developed by Dundee Satellite System, United Kingdom. The HRPT system was installed in order to receive data from the Advance Very High Resolution Radiometer of the National Oceanic and Atmospheric Administration (NOAA AVHRR) satellite. It is able to acquire and track the NOAA satellite automatically and provides real time image display on the monitor. The system is supported with an image processing software developed by SeaScan Star of Canada. The satellite data is processed to provide the sea surface temperature (SST) distribution. The NOAA AVHRR data received by the system will automatically stored in hard disk before copied to Exatape for long-term storage.

The system was selected since the data received would have channels in the visible and infrared regions of the electromagnetic spectrum which is suitable for studies of sea surface temperature. The area of coverage extends from Indian Ocean to

Philippines waters and from Mekong watershed to South Java. The system is able to receive signal from NOAA - 12 and NOAA - 14 satellites at 1698 MHz and 1707 MHz respectively. With the swath area of 2400 km, ground resolution of 1.1 km at nadir and repetition frequency of few hours, the NOAA satellite is capable of providing the information on the oceanographic features of the Southeast Asian waters.

The Oceanographic laboratory is equipped with oceanographic survey equipment such as water sampler, plankton nets, fish larvae nets, a CTD, field fluorometer, nutrient analyser, chemicals as well as glasswares and microscopes. The equipment could be used in the sea truthing works.

### 2.2.3 University of Technology Malaysia (UTM)

The Centre for Remote Sensing was established in October 1986 under the Faculty of Geoinformation Science and Engineering. The objective of the centre is to provide education, research, consultation activities and training infrastructure that would facilitate development and acceptance of remote sensing technology by users in both government, semi-government and private sectors. The centre is equipped with several image processing system such as ERDAS-Imagine, ErgoVista, PCI EASI/PACE, ER MAPPER & ER RADAR and operating softwares for GIS such as ESRI Arc Info and ESRI ArcView.

### 2.2.4 University of Science Malaysia (USM)

The remote sensing and GIS team of USM has been established since 1992 under the School of Humanities. The team specialises in interdisciplinary research with emphasis on promoting GIS and remote sensing research and teaching at USM as well as establishing external linkages. The team is equipped with several image processing systems such as ERDAS – Imagine, PCI and Idrisi for window.

## 3.0 Applications of remote sensing techniques on marine environment in Malaysia

Some of the research works on marine environments that use remote sensing techniques are listed below according to the user agencies.

### 3.1 Fisheries Research Institute, Department of Fisheries Malaysia

The FRI remote sensing team conducted studies on the following subjects:

a. Water resources inventories using Landsat TM data.
b. Mapping of salinity pattern for potential brackish water aquaculture sites.
c. Mapping of water quality pattern for open sea cage culture.
d. Change detection on the disappearance of coastal mangroves areas of west coast Peninsular Malaysia
e. Mapping of coral reefs in marine parks.

The completed studies are listed below:

a. Salinity mapping for potential brackish water aquaculture sites. (Mahyam, *et. al.* 1993).
b. Change detection on the disappearance of coastal mangrove forest in Merbok. (Ahmad-Husin and Fahrurrazi, 1996).
c. Mapping of coral reefs in marine parks. (Aikanathan and Wong, 1994).

### 3.2 Marine Fishery Resources Development and Management Department (MFRDMD) of the Southeast Asian Fisheries Development Center (SEAFDEC)

Below are some of the projects that had been conducted by the remote sensing team of MFRDMD/SEAFDEC.

a. Mapping of ocean colour for determining potential fishing grounds. Collaborated with UTM.
b. Mapping of sea surface temperature in the South China Sea.
c. Phytoplankton distribution. Collaborated with UTM

### 3.3 University of Technology Malaysia (UTM)

Below are some of the research works that are completed by the RS centre of UTM on the application of remote sensing technique on marine environments in Malaysia:

a. Bathymetry of clear and turbid waters from satellite remotely sensed data. (Mohammed, 1994).
b. Sea bottom features mapping from remote sensing data. (Mohammed - Ibrahim *et. al.* 1995).
c. Suspended sediment concentration studies using remote sensing data. (Adeli, 1992).
d. Sea surface temperature studies from Landsat TM and NOA - AVHRR data. (Adeli, 1992; Shattri *et. al.* 1997).
e. Seagrass and coral reef mapping using Landsat TM data.(Abdul-Wahid and Mazlan, 1997; Mazlan, *et. al.* 1997).
f. Plankton distribution (Adeli and Mazlan, 1997).
g. Ocean colour mapping (Mazlan, et. al. 1997).

### 3.4 University Putra Malaysia (UPM)

Some of the completed studies that had been conducted by UPM on the application of remote sensing technique on marine environments are listed below:

a. Coastal zone management. (Mohammed and Ibrahim, 1991).
b. Monitoring on development impacts of coastal resources. (Mohammed and Yusoh, 1992).
c. Development impacts on marine parks in Malaysia. (Mohammed and Japar - Sidik, 1992).
d. Environmental monitoring of coastal zone. (Mohammed, 1992).
e. Coastal resources mapping. (Mohammed *et. al.* 1991).

### 3.5 University of Science Malaysia (USM)

The remote sensing team of USM has involved in the following projects:

a. Meteorological and oceanographic studies in Malaysia (Khiruddin, 1998).
b. Geophysical and biological aspects of coastal waters.
c. Sediments dynamics and water quality in coastal waters.

## 4.0 Research findings of phytoplankton/algal bloom in Malaysia

Algae are tiny, single celled plants that live in the sea. Like plants on land, the algae capture and use the sun's energy to grow and serve as the energy producer. The growth of algae is an essential life process and it is the first step in transferring solar energy into aquatic food webs.

The algae thrive and multiply in response to increased light intensity, favourable levels of salinity and nutrients in the ocean. Occasionally, the algae grow very fast or bloom and each single algae cell may replicate itself by one million times in two to three weeks. During the reproductive riot of the bloom, the algae will accumulate into dense, visible patches near the surface of the water. Most species contributing to the algal blooms are harmless. Unfortunately, a small number of species produce potent toxins that can be transferred through food web. The harmful algal bloom, commonly called 'red tides' or HABs cause serious economic and public health problem throughout the world. The toxins tend to affect and even kill the higher forms of life such as zooplankton, shellfish, fish, birds, marine mammals and human being that feed upon them directly or indirectly.

Some of the published research findings on phytoplankton/algal blooms in Malaysia are listed below:

a. *Identification of species and effect of red tide occurrence in Sabah (Roy, 1977; Maclean, 1979).*
Sabah was one of the first regions in Southeast Asia to face the problem of red tide with its first outbreak occurred in 1976. Dense patches of algae were seen near Kota Kinabalu with 186 victims reported to be suffering from food poisoning. The species of algae that causes the 'red tides' bloom was identified as *Pyrodinium bahamense* var. *compressum*. It causes paralytic shellfish poisoning (PSP).

b. *Comprehensive report on the first outbreak of red tide in Sabah (Wong and Ting, 1984).*
The study largely reported on the number of human fatalities and food poisonings. Places of occurrence were also highlighted in the study.

c. *Report on the outbreak of red tide in west coast Peninsular Malaysia (Jothy, 1984).*
The study focused on the occurrence of red tide blooms in Penang and Johore. A decline in catches was reported due to the occurrence of red tide blooms.

d. *Report on the occurrence of heavy mortality of shrimp in cultured ponds as well as fish and crabs along the Straits of Johore (Khoo, 1985).*
The study reported several occurrences of red tides along the Straits of Johore in 1983, which resulted to mass mortality of shrimp in cultured ponds as well as fish and crabs along the coast.

e. *Laboratory and environmental observations on the occurrence of 'red tides' in Sabah (Usup et. al. 1989).*
The studies on red tide occurrence in Sabah had been carried out since 1985 (Usup *et. al.* 1987, 1988). The biology and ecology of *Pyrodinium bahamense* var. *compressum* conducted by Usup *et. al.* (1989) reported that the onset of the red tide outbreaks coincided well with the onset of Northeast and Southwest monsoons. However, periods of heavy rainfalls have negative effect on the occurrence of the red tides. Based on the laboratory observations, *Pyrodinium bahamense* var. *compressum* was aggregatory, underwent vertical migration and emitted fluorescence.

f. *Management on the occurrence of red tides in Sabah (Wong and Thian, 1989).*
The study was based on fortnightly monitoring of toxin levels in shellfish and plankton samples for the causative dinoflagellate of *Pyrodinium bahamense* var. *compressum.* Because of the danger of red tides outbreaks, some precautionary measures were discussed which includes red tides monitoring, public warnings and education.

g. *Red tide working group under ASEAN – CANADA CPMS –11.*
Organised surveys of nearshore organismal distribution begun during the last few years under the auspices of the ASEAN - CANADA projects. As is usually the case, studies have started with a broad characterisation of organisms in terms of general taxonomic groupings and their possible relations with the occurrence of fish mortality and food poisoning.

Following are some of the studies that had been conducted:

1. *GIS base marine mapping. Project No. WBS#131-6RT.*
A digital map, which illustrated the HAB location in ASEAN waters at the scale of 1:1,000,000 was completed. The paper also outlined five datasets used in the red tide work. (Seagel, 1996).

2. *Monitoring and toxicology of HAB in Peninsular Malaysia. Project No. WBS#131-18).*
Monthly plankton sampling was carried out in Malacca for a 2-year period (1993 and 1994). Fluctuations in the densities and spatial distribution of HAB species in the water column were identified. Baseline data on the environmental factors was also collected in order to understand the cause and predict the occurrence of HAB species. (Anton and Mohamad-Noor, 1996).

3. *Baseline study of HAB organisms in Sarawak. Project No. WBS#131-19.*
Preliminary baseline study of waters near the shellfish growing areas of Kuching was carried out in order to detect the presence of toxic

dinoflagellate (*Pyrodinium bahamense* var. *compressum*). The result showed that the percentage composition of dinoflagellate was higher in Brunei Bay than in Kuching bay. The need for the routine phytoplankton monitoring in Sarawak's waters was emphasised. (Yong, 1996).

h. *Mapping of coastal plankton distribution using remote sensing technique (Adeli and Mazlan, 1997).*
The spatial distribution pattern of coastal plankton in Malaysia was identified using Landsat TM data.

## 5.0 On-going monitoring of coastal sea environment

The following are some of the on-going research projects that are being conducted by government scientists or universities lecturers in collaboration with industry.

### 5.1 FRI – MACRES

a. Setting up database on water resources inventories.
b. Coastal monitoring of water quality.
c. Mapping of cockle spatfall areas along the coastal line of west coast Peninsular Malaysia.
d. Use of remote sensing and GIS techniques on the impacts of brackish water aquaculture activities on the coastal environments.
e. Change detection on mangroves areas disappearance and its impacts on the coastal environments.

### 5.2 MFRDMD/SEAFDEC

The on-going projects undertaken by the remote sensing team of MFRDMD/SEAFDEC are listed below according to the collaborating agencies:

#### 5.2.1 MFRDMD/SEAFDEC – UPM

a. *Application of remote sensing and GIS techniques for fish forecasting.*
The project is funded under the national Intensification of Research in Priority Areas (IRPA) scheme. The project involves sea surface temperature (SST) and oceanographic ground truthing experiments. The SST of the South China Sea is analysed using NOAA AVHRR data and correlated with fish distribution and abundance. The ocean colour from Landsat TM, ADEOS OCTS and SeaWiFS will also take into account as part of potential fishing grounds forecasting.

#### 5.2.2 MFRDMD/SEAFDEC - UTM

a. *Ocean colour and seagrass studies from remote sensing techniques for application in fisheries.*
The project is funded under national IRPA scheme. The project is using Landsat - TM satellite and covers Terengganu waters and Langkawi Island. The satellite image is used to map the seagrass distribution along the study areas. The satellite data will also be used to map plankton distribution.

### 5.2.3 MFRDMD/SEAFDEC - MACRES

a. *Oceanographic study using NOAA - AVHRR and Landsat - TM data for fisheries industry in Kuala Terengganu.*
   It is a 3 - year project (1997 - 1999) and covers among others mapping of water depth, sea surface temperature, chlorophyll-a concentration and plankton distribution.

### 5.2.4 MFRDMD/SEAFDEC

a. *Airborne video remote sensing of suspended sediment in coral reef.*
   The project includes the construction of air-balloon platform to be used in aerial photography of coral reef mapping. A field spectroradiometer will be used to measure the reflectance of the plumes laden with suspended sediments.

b. *Total suspended solids mapping using NOAA AVHRR.*
   A total suspended solids pattern is mapped for the whole Malaysian waters for fisheries management using NOAA AVHRR.

## 5.3 University of Technology Malaysia

a. Oil slick studies from remote sensing.
b. Ocean colour and seagrass mapping for fisheries application.
c. Pollution and sedimentation studies using satellite and airborne remote sensing.
d. Coastline variations mapping.
e. Water depth mapping.
f. Sea surface temperature mapping.
g. Coral reefs mapping.

## 5.4 University of Science Malaysia (USM)

Some of the on-going researches conducted by the remote sensing team are listed below:

a. *The uses of ADEOS data in studying geophysical and biological aspects of coastal waters. ESCAP / UNDP Grant.*
   Team members: Dr. Khiruddin Abdullah, Dr. Ruslan Rainis, Moh Zubir Mat Jafri, Nasirun Mohamed Salleh, Yusuff Mahamod and Tajudin Khader.

b. *The uses of in-situ oceanographic and remote sensing data in studying sediments dynamics and water quality in coastal waters. IRPA Research grant*
   Team members: Dr. Khiruddin Abdullah, Dr. Ruslan Rainis and Dr. Zubir Din.

## 6.0 Problems associated in the application of remote sensing technique on marine environments.

Listed below are some of the problems encountered during the implementation of research using remote sensing technique on marine environments in Malaysia:

a. High degree of cloud cover over study areas. Acquisition of cloud free image is preferable for any analysis to be carried out. One of the main hindrances for efficient analysis to be carried out is due to the high degree of cloud cover over the study areas.

b. Acquisition of cloud free remotely sensed data synchronised with the time of ground truthing sampling.

c. Lack of highly skilled personnel at the Department of Fisheries. The expertise is needed especially on image processing, computer programming and data gathering.

d. Lack of capital for ground truthing sampling. The cost of conducting ground truthing sampling in the marine environment is expensive especially when boats and personnel are needed for the collection of samples. Condition of the sea is very dynamic and always fluctuates according to the environmental and weather conditions. Several repetitive sampling schemes need to be carried out in order to obtain an accurate and non-bias data information. But, this can only be achieved with high capital investment and repetitive sampling strategies.

e. Marine remote sensing is difficult since there are several parts of the study, namely, oceanography, atmospheric science, electromagnetic physics, as well as image processing. The researchers involve in this study should have excellent knowledge on oceanic processes, method of marine sample analyses, image processing as well as atmospheric science.

f. Since the sea / water reflect just 10-20 percent of the electromagnetic radiation, and the remaining is reflected by the atmosphere, detail analysis should be carried out to eliminate the atmospheric effects. This factor should be taken into consideration if anyone would analyse marine environment quantitatively using remote sensing techniques.

## 7.0 Research needs and possible collaborative research program

Possible collaborative research programmes are listed below:

a. Monitoring of water quality changes and its relationship with the occurrence of 'red tides' bloom in the marine environment of all member countries.
Develop a procedure for using remote sensing data in detecting, identifying and quantifying any occurrence of algal blooms so as to give forewarning to all member countries.

b. Monitoring of shrimp resources in the coastal waters of east coast during Northeast monsoon.

High occurrence of shrimp resources was reported during the Northeast monsoon. Therefore, the objective of the study is to detect and find the reason for sudden occurrence of shrimp resources in the coastal water of east coast Peninsular Malaysia during Northeast monsoon. Raja-Nordin and Ku-Kassim (1997) developed a hypothesis that the shrimp resources found in east coast Peninsular Malaysia during north-east monsoon originated from Southern Vietnam. They suggested that NOAA -AVHRR data to be used in determining the extend of estuarine plume in the Mekong river which might influence the emigration of shrimp resources out of Vietnamese waters.

Kawamura (1986) made a preliminary study on the oceanographic features (SST and current movement) of Terengganu waters using NOAA - APT. The images showed that there were two different types of water flows in Terengganu waters. They were gulf waters flowing down southward from Gulf of Thailand and offshore waters going northwards. The presence of gulf water indicates that the fishery in Terengganu waters might be affected by the movement of gulf water and the marine resources tend to migrate or move with or within the water mass.

Possible collaborative countries for this study are Thailand and Vietnam.

c. Detecting changes in sea surface temperature (SST) - isothermic mapping and its relationship with plankton distributions and pelagic fish abundance such as baitfish and tuna resources.
The NOAA-AVHRR had proven to be a useful tool in mapping the daily distribution of SST. Study conducted by Yang *et al.* (1995) showed that the location of Japanese pilchard (*Sardinops melanosticta*) in the Huanghai Sea and East China Sea could be predicted up to 91.3% accuracy with the SST of the location between 15 to 17 °C. This information allows the Japan Fisheries Information Service Centre (JAFIC) to produce and distribute satellite aided oceanographic condition charts with NOAA - AVHRR data to fishing vessels for fishing ground forecasting.

Possible collaborative countries for this study are all member countries that share similar territorial waters of the South China Sea.

d. Ocean colour study for detection of phytoplankton blooms could be conducted for large scale satellite data such as NOAA AVHRR and SeaWiFS. With this data as well as SST data, potential fishing ground could be predicted, for at least daily or weekly.

e. Sediment transport studies would be carried out to quantify the sediment load into the waters for monitoring of water quality and locating suitable sites for cage cultures.

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# ANNEX 9

THE MFRDMD/SEAFDEC FIRST REGIONAL WORKSHOP ON REMOTE SENSING OF PHYTOPLANKTON

Kuala Terengganu, Malaysia, 17-18 November, 1998

SEAFDEC/MFRDMD/WS/98/CR. 4

# COUNTRY STATUS REPORT

# PHILIPPINES

## STATUS OF MARINE REMOTE SENSING APPLICATIONS IN THE PHILIPPINES

By:

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## 1.0 Introduction

Philippines interest in participating in the First Regional Workshop on Remote Sensing of Phytoplankton is due to the recognized need of fishery scientists to gain awareness on the application of marine remote sensing and to be involved in this regional initiative to determine research priorities.

The Philippine fisheries scientific community recognizes that the remote sensing is a tool in resource and environmental assessment. This technology would farther advance their capacity to undertake more precise data and information of their fishery resources and oceanographic conditions, which would provide assistance in their programs on resource conservation and management.

## 2.0 Application of marine remote sensing

Most applications of remote sensing have been on coastal zone resources. In the Philippines, a multi-disciplinary program on conducting pilot studies for coastal resources and environment using LANDSAT MSS data have been completed. The program has focused on the information generation capacity of existing LANDSAT system for the fisheries and aquatic resources, forestry and vegetation, geology and hydrology, and land use sectors of the pilot study areas in Lingayen Gulf, Northern Luzon. These multi-disciplinary informations are being used for the integrated coastal zone management program of the government.

Multi-level remote sensing had been applied to provide different levels of information needed for specific mangrove related management decisions. The mangrove management program of the government had used LANDSAT data in its assessment studies. In one such study on mangrove assessment the remaining mangrove forests were grouped according to their proximity to the nearest fishing grounds on the assumption that mangroves play important ecological roles in the marine productivity of the out-laying bodies of water. The boundary of each fishing ground was delineated using surface current data.

Remote sensing had been used in the assessment and mapping of the corals on Apo Reef. Digital analysis of LANDSAT MSS data was used. The major physiographic zones and bottom cover of Apo Ref in Mindoro Island, were categorized and mapped out, using combinations of unsupervised (without ground truth) and supervised (with extensive ground truths using transects, bounce dives, under water sled transects, and shallow surface reconnaissance) techniques of digital processing, using interactive computer-assisted processing systems.

Before conducting a detailed mapping of coral reefs, the major bottom and bathymetric variations of the reefs surface were first determined and mapped to arrive at more detailed categories and also to provide quantitative and qualitative information on the reef's major structures.

The actual stratification and classification of submerged features of a coral reef can be a difficult and tedious process. Reflectance features defining coral reefs represent a summation of signals due to bottom reflection, signals due to sea surface and atmospheric influences.

The oceanographic and marine biological studies conducted were mainly in the Lingayen Gulf areas. They were aimed at maximizing the use of LANDSAT imageries for detecting and monitoring dynamic processes. Water movement, changes in water quality, bathymetric configuration and siltation were monitored. The extent of the effects of suspended sediments coming from mine tailing on marine life was determined. Mapping of major biotic communities in shallow waters was also of particular interest since such information have been useful in delineating areas for mariculture and in assessing our marine resources. The different studies conducted under this sector have as a whole established a methodology on the future characterization of the saltwater bodies in the project areas, from mapping the bottom of shallow waters to determining the quality of the water above it.

The botanical studies were mainly concerned with the mapping of natural vegetation using LANDSAT MSS data in contrast with cultivated crops, discriminating major plant communities and determining their growth conditions and studying the effects of the seasonal changes in the spectral signatures of natural vegetation. Both aerial photographs and LANDSAT imageries were used in these activities.

The fishery resource studies involved the discrimination and delineation of various types of fishponds for inventory purposes using LANDSAT imageries and correlating LANDSAT spectral properties of sea water with planktonic production for possible use to fish stock assessment. Also included is the integration of all parameters detectable from LANDSAT imageries to predict the fishery potentials of selected coastal sites.

## 3.0 Monitoring of Coastal Environment

Brackishwater fishponds are scattered in the major islands of the Philippines. Pond culture, the improved technology, as one of the fish production industry in the Philippines, has been contributing significantly to the total annual fish production. However there is a need to monitor fishponds operation and development and assess changes in development. LANDSAT remote sensing data have been used to determine important information. Visual interpretation of LANDSAT photo products has indicated that these two important parameters can be extracted using properly selected date of coverage.

Changes in the country's bay areas are being monitored using remote sensing data. Multidate imageries are being used to study and measure environmental changes. In Manila Bay, extensive areas have been reclaimed and filled and are now occupied by hotels, business offices, trading sites, recreational facilities and others. LANDSAT data are being used to determine the extent of the reclaimed land in the bay area.

In the Philippines, soil erosion has been identified as a critical environmental problem. Soil erosion contributes to the siltation/sedimentation of our bay caused mainly by intensive farming, mining, deforestation and other forms of human activities. Analysis of LANDSAT imagery of Manila Bay and surrounding area taken during the rainy season at the time of heavy rainfall showed the heavy load of silts being carried by the waters into the Bay.

## 4.0 Proposals from the Philippines

1. Acquisition of archive data for the Philippines from NOAA and agencies of countries which have satellite data.

2. Training of personnel on the following fields:

   - Computerized image processing systems for oceanographic application
   - Software system for oceanographic applications.

3. Acquisition of computerized image processing systems for relevant agencies and institutions, like BFAR (Bureau of Fisheries and Aquatic Resources)

4. Establishment of data communication network among institutions engaged in oceanographic studies.

5. Establishment of receiving station for the Philippines

# ANNEX 10

THE MFRDMD/SEAFDEC FIRST REGIONAL WORKSHOP ON
REMOTE SENSING OF PHYTOPLANKTON

Kuala Terengganu, Malaysia, 17-18 November, 1998

SEAFDEC/MFRDMD/WS/98/CR. 5

# COUNTRY STATUS REPORT

# THAILAND

## STATUS OF MARINE REMOTE SENSING APPLICATIONS IN THAILAND

By:

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## 1.0 Status of marine remote sensing applications in Thailand

Thailand administers 1,840 kilometers of coastline of the Gulf of Thailand and 865 kilometers of Andaman Sea coast with jurisdiction out to the territorial water limits. As a country where fish plays a major role as a prime ingredient in the national diet, Thailand is extremely aware of the part played by the primary production and the marine food chain in maintaining fish stocks. It is also well aware of the profound link between phytoplankton and the environment. Over many years the fisheries authorities have measured the abundance of phytoplankton using standard TM methods, however, the authorities are open to alternative methods of assessment that define the cyclic extent of this resource in Thai waters.

One area of investigation and assessment has been satellite remote sensing. Extensive use is made of the satellite receiving station set up by the Government of Thailand. Participation in the remote sensing program of the United States has been under way and active since 1972. Since 1982 there has been direct access to signals from the NOAA, LANDSAT 2 and LANDSAT 3 data. In 1984 the station was upgraded to access LANDSAT 4 and LANDSAT 5, and SPOT. A separate antenna to receive MOS was installed in 1988. There is, as yet, no provision for accessing data from SeaWiFS launched by NASA in 1997, this satellite holds the most promise for sea colour linking for phytoplankton assessment.

The use made of the remote sensing program has been extensive in terms of land use and relevant disciplines including forestry, land development, crop-mapping, water resources, soil erosion, estuarine studies and geology. The program for these spheres of interest is ideal, simply because the establishment of "ground truth" is easy and the time span for "ground truth" longevity is extended, with a slow rate of change. Although sedimentary movement, distribution and changes in pattern around Phuket and the rivers in the upper Gulf have been the subject of remote sensing, together with some observations of turbidity, little use has been made in the marine field. During a period in 1993 to 1994 some use was made of LANDSAT 5 TM data to study chlorophyll distribution in the Gulf of Thailand. In this project the logistics of the establishment of a "sea-truth" was found to be problematic and cloud radiance and cloud edge diffusion also presented difficulties. The data resulting from this work bore a correlation with turbidity rather than chlorophyll. The use of remote imagery in the marine environment has several unsolved constraints with little hope of problem resolution in the immediate future. As a result of these constraints Thailand does not use satellite imagery or remote sensing in its phytoplankton program, but keeps an active watching brief on developments in both the hope and expectation that the present problems will eventually be solved.

There are three major factors that militate against the use of remote sensing for fisheries resources management in Thailand, the first is one that is common to the marine environment throughout the world and that is the establishment of a "sea-truth". The temporal nature of sea characteristics makes the reference baseline difficult to achieve. Although it does not influence Thailand, recently, NASA and MOBIS have deployed a marine optical sensing buoy off the coast of Lanai Island, Hawaii, with the objective of providing light absorption and water radiance correctional data to the SeaWiFS program. This after only ten months operation speed and direction. The light band discrimination should help to give baseline conditions of water light colour absorbency and indirectly chlorophyll determination.

Phytoplankton abundance is monitored through shipboard sampling, the opportunities for this are many, but they are not regular, or to any schedule. Algal blooms are monitored in co-operation with other government departments who organise volunteer aircraft from the private sector to over-fly various sea areas to observe anomalies in sea conditions including red tide phenomena sightings.

Other methods of plankton collection have been looked at by Thailand including the SAHFOS plankton continuous collection project. This system is effectively a towed array of silk-screening subsequently subjected to entrapped plankton abundance analysis. The array is towed behind commercial vessels, the SAHFOS term for this is a "ship of opportunity" plying between ports on specified routes. This is an innovative method showing some promise of being a viable practice. A shortcoming of the system is that only the shipping lanes are explored and take little account of other sea areas.

In closing this country report for Thailand, I should like to reiterate that any tool that may be successfully used for fisheries resource management is of interest to the country and that where regional considerations are concerned information and experience will be readily discussed.

## 2.0 Comment on the proposals for a network of fisheries remote sensing technologists

The objective to form a core-expert group is a good idea, but discussion among colleagues seems to indicate that the specified "fisheries remote sensing" discipline may be too limited in its remit. It seems to us that whereas remote sensing may be good for hydrology and oceanographic conditions it may be limited in its application to fisheries management. It is thought that the disciplines of the core-experts should be closer to participants in fisheries management with remote sensing knowledge rather than fisheries remote sensing alone, as specified. Remote sensing is a tool to be used in, rather than the purpose of, fisheries management. In other words, the primary objective in fisheries management seems more aligned with fisheries, starting with primary production rather than wholly with its measurement.

## 3.0 Suggested areas of collaborative research in remote sensing within the Southeast Asian Region.

- While Thailand cannot successfully use remote sensing for phytoplankton abundance assessment at this time, this does not mean that it is not an effective tool for the rest of the region. Thus, as far as collaborative regional research is concerned it is proposed that fundamental research be conducted to establish a synoptic regional baseline "sea truth" within the periphery of the satellite footprint. This would be essential before meaningful remote sensing can be undertaken. This may be achieved by multiple shipboard sampling on a regulated basis, or by the deployment of MOBIS type buoys that monitor light absorption and water radiance on a continuous basis. The essential parameter is that the readings be taken simultaneously while the satellite is covering the region.

displayed degradation of spectral response varying between 3 and 5% on several of the discriminating bands employed. The buoy data will be used to modify the algorithms used for baseline sea colour. This buoy deployment will provide another step in the progress toward consistency in data accuracy and since the buoy deployment is in clear water it may provide a reference that has a bearing on the waters with which Thailand in concerned. Even so, this does not solve another major difficulty afflicting particularly the Gulf of Thailand, the problem here is turbidity. NASA themselves admit this problem exists, and I quote, "Over turbid waters atmospheric correction yields noticeably non-uniform aerosol radiances, epsilons etc., which impact the pigment products. This is not surprising as the NIR reflectance in these waters may deviate from zero. Schemes may be envisioned which either correct for the near infrared reflectance somehow or extrapolate the atmospheric correction parameters from near-by non-turbid waters, but the project does not have a methodology in place for addressing this situation." This leaves Thailand with a difficulty in using data from SeaWiFS, on the grounds that the Gulf of Thailand is turbid with run off from rivers and mining activities and the entrained silt generated. This makes the use of remote sensing in Thai waters of doubtful value. This is also true to a lesser degree, of the waters of the Andaman Sea. Another problem besetting coastal sea areas like the Gulf of Thailand is the entrained atmospheric dust. Thailand is afflicted by relatively high and variable concentrations of Æolian dust. This absorbs in the visible light bands resulting in unreliable readings. The present set of atmospheric models does not include any models for dust primarily because the phase function and indices of refraction are not well known. High concentrations of dust trigger the cloud mask in the SeaWiFS equipment, but low concentrations are processed leading to erroneous derived products, e.g. high pigment estimates. There is no method for flagging dust contaminated pixels, let alone correcting for them. NASA recognizes this fact.

Because of the lack of technical facility and a paucity of funding, it is not possible for Thailand to generate its own scientific satellite program. Even if it did, it would be faced with the same problems that NASA presently face and which, despite their overwhelming competence, have not yet been able to solve.

Although Thailand does not presently use satellite imagery for its routine phytoplankton studies, this does not discount its use at a later date. In the interim it has involved itself with the SEAWATCH system of oceanographic data buoys, eight of which are deployed around and in the Gulf of Thailand and elsewhere. While this buoy system does not constitute remote sensing in the satellite meaning of the word, it is remote sensing in the sense that data derived is constantly updated in remote, that is unmanned, conditions. The readings of the instrumentation are sent to the INMARSAT satellite and retrieved from a ground station. The system installed under the auspices of National Research Council of Thailand (NRCT) and the Norwegian Company, Oceanor, has suffered many problems in terms of sensor failure and unreliability. This is hardly surprising, as the sea is an extremely hostile environment for electronics in any form. Civilian persons, possibly fishermen, have also, it is suspected, tampered with the buoys. The results of this program are not as conclusive as it was hoped and expected they would be. Having said that, some readings taken by the buoys show some anomalous conditions that are not yet satisfactorily explained. The parameters the buoys report are: current velocity and direction, wave height and period, red, green and blue light band absorbency, salinity, sea temperature and wind

- Other areas for research may well lie in the Carbon Dioxide levels in the atmosphere, the global warming effect and the level of conversion of Carbon Dioxide by phytoplankton. Does the increased level of Carbon Dioxide presage an increase in phytoplankton abundance? What is the Carbon Dioxide saturation level of phytoplankton and how would phytoplankton abundance equate between increased levels of Carbon Dioxide and the predation of decreasing numbers of pelagic species. Such research involves both remote sensing in oceanography linked to laboratory research.

# ANNEX 11

THE MFRDMD/SEAFDEC FIRST REGIONAL WORKSHOP ON
REMOTE SENSING OF PHYTOPLANKTON

Kuala Terengganu, Malaysia, 17-18 November, 1998

SEAFDEC/MFRDMD/WS/98/CR. 6

# COUNTRY STATUS REPORT

# VIETNAM

## STATUS OF MARINE REMOTE SENSING APPLICATIONS IN VIETNAM

By:

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## 1.0 Applications of remote sensing in marine fisheries research.

Since 1980s, the remote sensing technique has been introduced in different fields. However, remote sensing application in marine research is still limited only in several studies such as:

- Sea surface temperature distribution mapping.
- Shallow sea bathymetric study.
- Coral reefs distribution mapping.
- Development of accumulative areas and changes of navigation channels mapping.
- Spatial structure of the storm and typhoon systems at the South China Sea analyses.

## 2.0 Status of phytoplankton research in seawaters of Vietnam.

As we know, plankton and zoo-benthos are the food sources of the fish in the sea. Knowledge in the rules of distribution and dynamic of biomass of those will give considerable contribution to the study of the distribution and dynamic of the marine fishery resources.

According to Nguyen Tien Canh (1994), there were 537 species of 4 phylum of algae in Vietnam waters, namely:

- Silicoflagellata with 2 species, constitutes 0.37%
- Cyanophyta with 3 species, constitutes 0.56%
- Pyrrophyta with 184 species, constitutes 34.26%
- Bacillariophyta with 348 species, constitutes 64.80%

In the Tonkin Gulf, 318 phytoplankton species were found, of which 1 species was of Silicoflagellata, 3 of Pyrrophyta and 230 of Bacillariophyta, taking 59.22% of the total species found in Vietnam seawaters.

In Central Vietnam, West and East of South Vietnam waters, there were 468 phytoplankton species of which 2 species was of Silicoflagellata, 3 of Cyanophyta, 159 of Pyrrophyta and 304 of Bacillariophyta, comprising of 87.15% of the total species found in Vietnam seawaters.

Vietnam waters is composed mainly of two seawater zones: The near shore water zones with low salinity, often less than 32.5‰, and the off shore water zones with high salinity, often higher than 33.5‰. Between them is a mixed water zone with the salinity of 32.5‰ - 33.5‰.

As few rivers come in near shore water of the Central Sea, water in this area has high salinity and many features of the offshore water to make it different from features of near shore waters in Tonkin Gulf, East of Southern Sea and West of Southern Sea.

Most of phytoplanktons in Vietnam seawaters are euryhaline and eurythermal, but some others distribute only in high or low salinity waters. Based on the distribution of phytoplankton in different seawaters, they can be classified as follows (Nguyen Tien Canh, Truong Ngoc An and Nguyen Van Khoi, 1986):

a. Species live in brackish water at the estuaries:
*Chaetoceros abnormis, Schmackeria speciosus, Acartia sinensis, A.bifilosa*

b. Species prefer low salinity, represent those living in near shore waters:
*Skeletonema costatum, Ditylum sol, Thalassiothrix frauenfeldii, Hemidiscus hardmanianus, Hemiaulus indicus*

c. Species prefer high salinity, represent those living in offshore waters with high salinity and high temperature:
*Chaetoceros messanensis, Ch. alanticus, Coscinodiscus excentricus* (Bacillariophyta). Those species are also apparent in the Tonkin Gulf, where currents drive them in from offshore.

d. Species distribute in the mixture of two above water masses, including both of euryhaline and eurythermic species such as:
*Chaetoceros coartatus, Ch. diverrus, Planktonniella sol, Coscinodiscus nobilis* (Bacillariophyta) and species only living in near shore waters such as:
*Thalassionema nizschioides, Rhizosolenia imbricata, Hemidicus hardmanianus, Stephanopyxis palmeriana* (Bacillariophyta).

The highest densities of phytoplankton observed in Vietnam seawater were:

- 125,892,000 cells/$m^3$ observed in the Tonkin Gulf in September 1960
- 14,800,000 cells/$m^3$ observed in Central Sea in September 1979
- 45,318,000 cells/$m^3$ observed in East Southern Sea in May 1984
- 98,900,000 cells/$m^3$ observed in West Southern Sea.

The phytoplankton density in Vietnam waters ranged between 437,000 - 5,549,000 cells/$m^3$ (Table 1).

| Area | Density ($10^3$ cells/$m^3$) |
|---|---|
| Tonkin Gulf | 1962 |
| Central Sea | 437 |
| East of Southern Sea | 872 |
| West of Southern Sea | 5549 |

Table 1: Average density of phytoplankton in Vietnam seawaters
*(Source: MOFI, 1996. Fisheries Resources of Vietnam)*

In comparison with the other seas, the density of the phytoplankton in seawater of Vietnam is rather higher. According to the surveys conducted by Zenrnova (1962) in north of Indian Ocean, the maximum average density was only 6,100 cells/$m^3$ (in Andaman Sea); 3,600 cells/$m^3$ (in Aden Gulf) and 1,200 cells/$m^3$ (in Arabian Sea).

Kabanova's study on this ocean (1964) also gave the same results, i.e., 10,000 cells/m$^3$ (in Andaman Sea), and 500 - 1,000 cells/m$^3$ (in Bengal Gulf and in Arabian Sea).

According to Athan (1970) in his study in Singapore, the maximum average density was 1,600,000-1,700,000 cells/m$^3$ observed respectively in April and May, almost less than 500,000 cells/m$^3$ in other months. The average density for the whole year was only 575,000 cells/m$^3$ (equal to that in Central Sea and East of Southern sea of Vietnam).

One of the special features of phytoplankton distribution in the Vietnam seawaters is that they often concentrate in near shore waters in the north or west of the Tonkin Gulf and Southern Sea. Those areas are near to the estuaries, with salinity of less than 32.4 ‰ and rich in nutrients, a good environment for phytoplankton to grow. Moreover, due to the influence of the upwelling water (in Central Sea, Tonkin Gulf), water from bottom layers is driven up to upper layers bringing also nutrients for phytoplankton.

Table 2 shows the average densities of phytoplankton in different seasons in four areas. The t-Student test has proven the difference in density of phytoplankton in different seasons and in different seas. The results of analyses showed that, in the Tonkin Gulf the density of phytoplankton in winter is higher than that in spring, much higher than that in summer and not much different in autumn. The density of phytoplankton in spring is not different from that in summer but lower than that in autumn.The highest density of phytoplankton is during summer in Central Sea and East of Southern Sea. In other seasons it is unclearly observed.

| **Sea area** | **Season** | **$10^3$ cells/m$^3$** |
|---|---|---|
| | Winter | 2,694 |
| Tonkin Gulf | Spring | 1,149 |
| | Summer | 1,654 |
| | Autumn | 2,207 |
| | Winter | 60 |
| Central Vietnam | Spring | 22 |
| | Summer | 1,468 |
| | Autumn | 306 |
| | Winter | 800 |
| East of Southern Sea | Spring | 700 |
| | Summer | 1,468 |
| | Autumn | 340 |
| | Winter | 5,288 |
| West of Southern Sea | Spring | 5,809 |

Table 2: Average density of phytoplankton at the water layer of 0-100 m depth in Vietnam seawaters. *(Source: MOFI, 1996. Fisheries Resources of Vietnam)*

## 3.0 Needed research activities and Recommendation

- To obtain and analyse NOAA, SPOT and LANDSAT images to map the temperature distribution at the sea.
- To analyse images to study distribution and biomass of phytoplankton.
- To attend in training on methodology of satellite images processing to apply for fisheries.
- To participate in workshops, conferences both regional and international on the issues of applying remote sensing in marine fisheries.

## 4.0 Possibility of collaboration and research programs between Vietnam and other countries, and especially RIMP and SEAFDEC.

Research Institute of Marine Products (RIMP) has acquired equipment and software to analyse satellite images in marine fisheries research. The institute is still looking for sources of satellite images for research purposes. RIMP is willing to collaborate with organizations and nations in the region and in the wold, and especially with SEAFDEC, in marine fisheries research in general and in application of remote sensing in marine fisheries in particular.

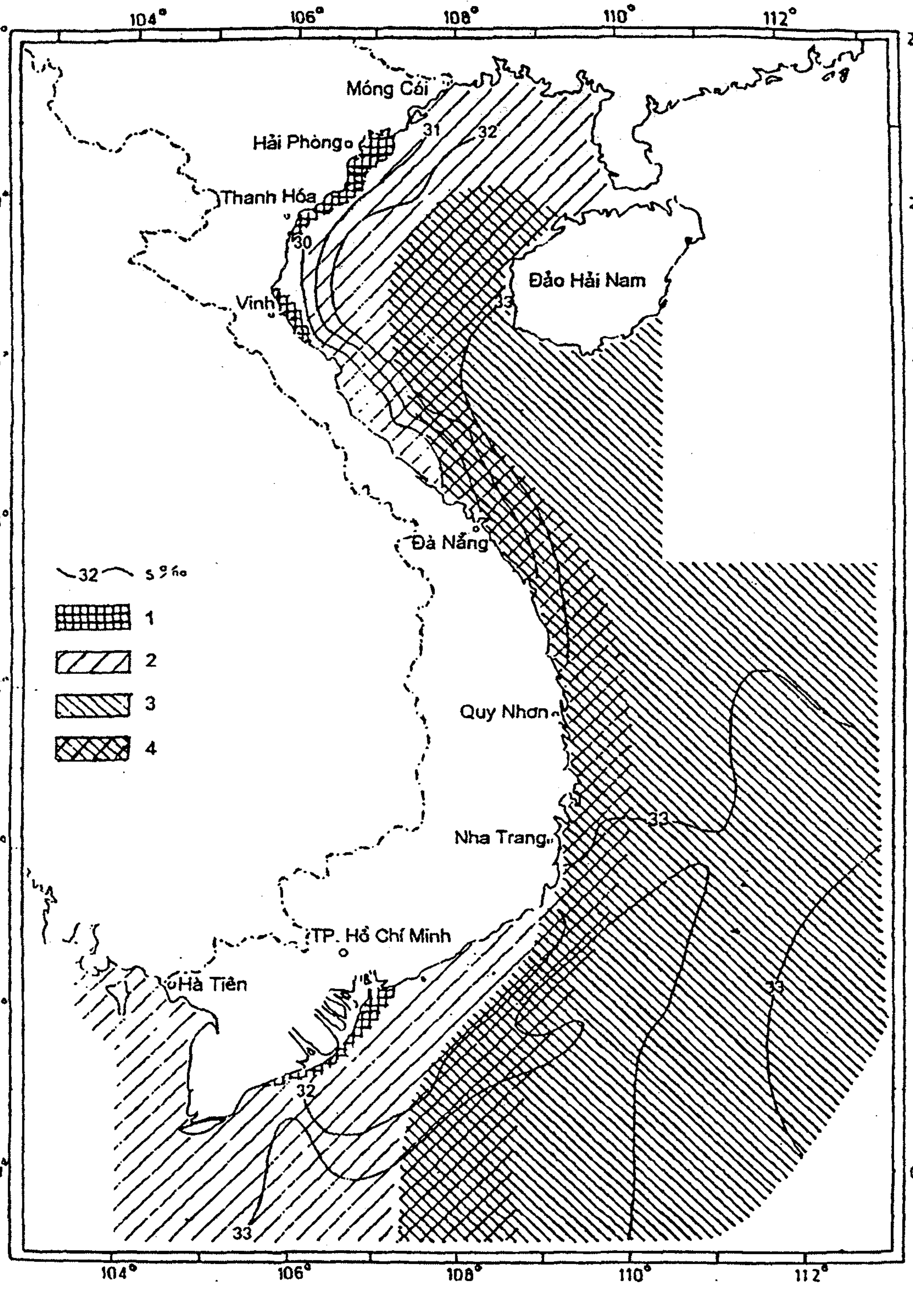


Figure 1. Distribution of phytoplankton species:
(Nguyen Tien Canh, 1989):

Near estuaries (1)
Low salinity, near shore seawater (2)
High salinity, off shore seawaters (3) and
Zone of mixture (4)

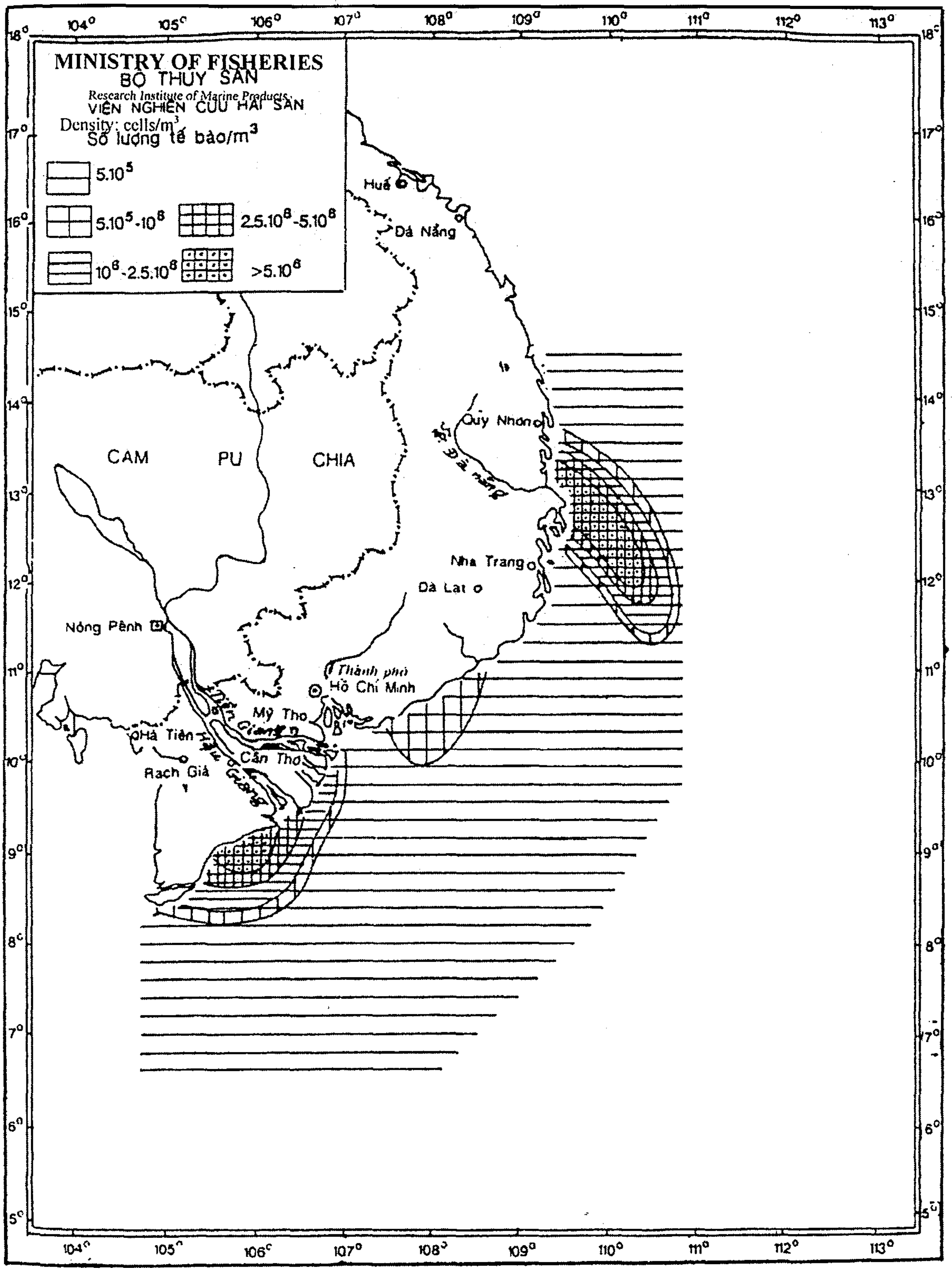


Figure 2. Distribution of phytoplankton in June 1979 in the Central Vietnam and East of Southern Sea (Nguyen Tien Canh, 1981)

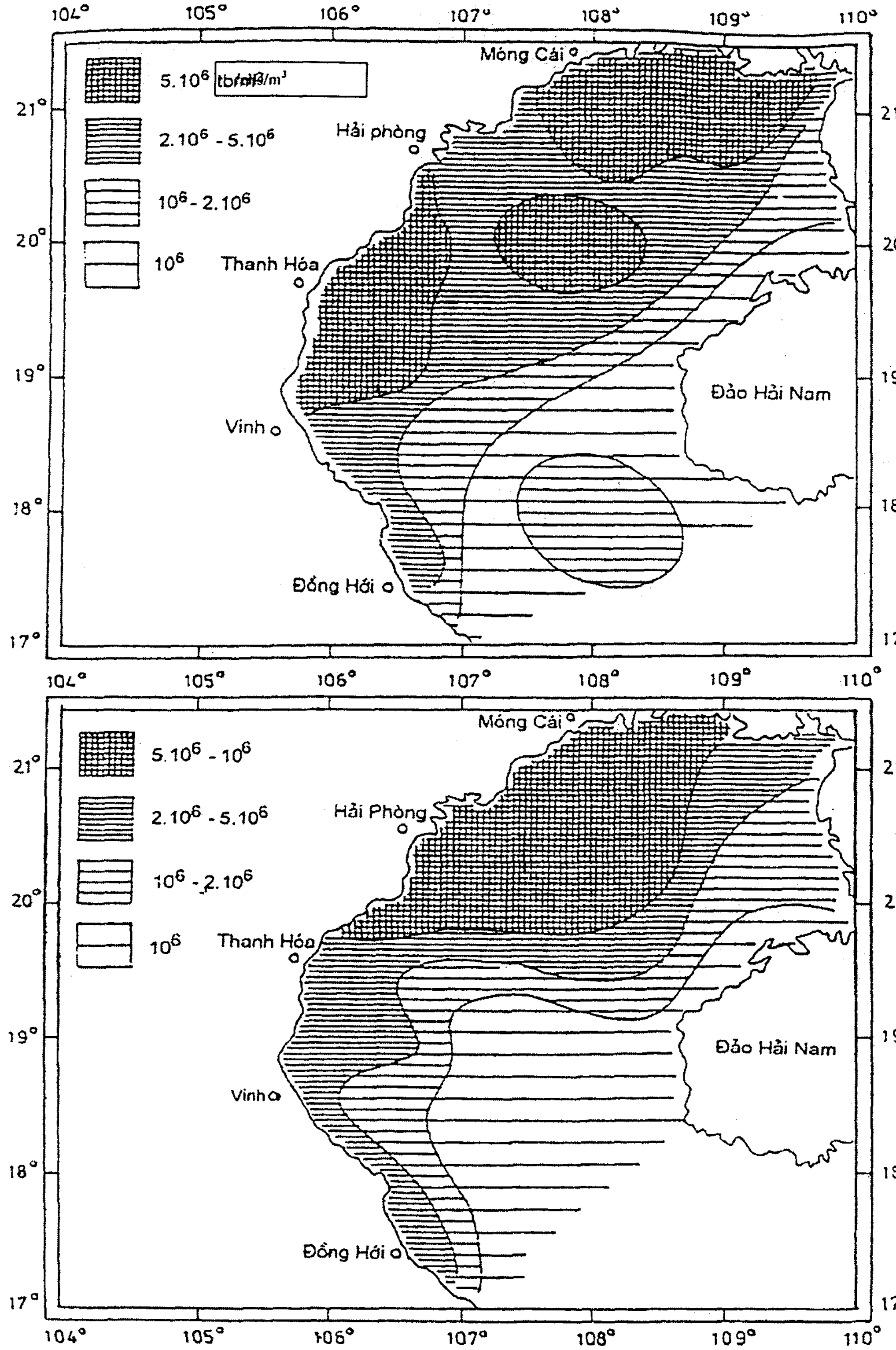


Figure 3: Distribution of phytoplankton cells in the Tonkin Gulf in the South West monsoon (1) and North East monsoon (2) (Nguyen Van Khoi, 1985)

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**List of aronym**

| | |
|---|---|
| RIMP: | Research Institute of Marine Products. |
| MOFI: | Ministry of Fisheries. |
| SEAFDEC: | The South Eàst Asian Fisheries Development Center |
| NOAA: | The National Oceanic and Atmospheric Agency |

# ANNEX 12

THE MFRDMD/SEAFDEC FIRST REGIONAL WORKSHOP ON
REMOTE SENSING OF PHYTOPLANKTON

Kuala Terengganu, Malaysia, 17-18 November, 1998

SEAFDEC/MFRDMD/WS/98/WP. 2

# TECHNICAL REPORT

## BACKGROUND OF PLANKTON I: BIOLOGY OF PLANKTON

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CRUISE 1 & 2

**Summary of the results of the MV SEAFDEC Survey Cruise: Sept/Oct 1995 (Pre-monsoon) – Apr/May 1996 (Post-monsoon); Gulf of Thailand and East Coast of Peninsular Malaysia.**

- **Bloom/Red Tide:** Single species dominant/diffuse/occurrence unpredictable.
- **> 290 taxa:** 2 genera (2 species) blue green algae; 45 (110) diatoms; 25 (70) dinoflagellates.
- **Pre monsoon:** 9 species dominant:
  Blue green algae (1):
  - *Trichodesmium (Oscillatoria) erytharaeum*

  Diatom (8):
  - *Chaetoceros lorenzianum,*
  - *C. pseudocurvisetum*
  - *C. compressum*
  - *Thalassionema frauenfeldii*
  - *T. nitzschoides*
  - *Coscinodiscus jonesianus*
  - *Bacillaria paxillifera*
  - *Bacteriastrum comosum*
- **Post monsoon:** 15 species dominant:
  Diatom :
  - *Chaetoceros* spp. (7)
  - *Th. frauenfeldii*
  - *Pseudosolenia calcal-avis*
  - *Bacteriastrum comosum*
  - *Proboscia (Rhizosolenia) alata*
  - *Pleurosigma*
  - *Skeletonema costatum*
  - *Cylindrothecca (Nitzschia) closterium*

  Blue green algae:
  - Trichodesmium erythareum

  Dinoflagellates:
  - *Ceratium fusus*
  - *Alexandrium tamarense/famiyanicai* (17-20 cell per litre in the Gulf of Thailand)
  - *Amphisolenia bidentata*
  - *Dinophysis hastata*
  - *Gymnodinium / Gyrodinium / Kofoidinium / Noctiluca*
  - *Ornithocercus magnificus / Oxytoxum / Phalacroma*
  - *Prorocentrus / Protoperidinium / Pyrophacus / Scripsiella trochiodea*
  - *Pyrodinium bahamense*

Nanodiatom

- 150 species (< 20μm) 10 genera ?new record
- Dominant species *Minidiscus comicus* Takano; *M. trioculatus* Hasle; *Navicula climacospheniae* Booth; *Thalassiosira tenera* Proschkinae-Larenko
- Size fractionated nanodiatom biomass/productivity 60-75%/40-60% respectively.
- 6-8 x $10^4$ cell/l at depth 30m.

(B.Huang et al. 15th IDS Perth Australia)

**Diatom – Ship Ballastwater**

- Global transport (ballast water) 10 billion tonnes/year
- Transfer harmful bacteria/toxic diatom-dinoflagellate / seaweed / molluscs etc.
- Nonindigenous => ecological/environmental damage worldwide.
- Cultural ballast species => *Chaetoceros, Detonula, Ditylum, Heptocylindrus, Skeletonema, Thalassiosira* (have resting spores).
- Similarly small pennate *Amphora, Navicula, Nitzschia* survive in dark (5 weeks), spores.
- Pseudo-nitzshia, amnestic shellfish poisoning (ASP), paralytic shellfish poisoning (PSP)
- *P. fraudulata/lineata/turgidula/subpacifica* – toxic?
- *P. multiseries / P.australis / P.seriata / P. pungens / P. pseudodelicatisoma / P. cuspidata*

**Phytoplankton classification**

- Bloom / Red Tide – single species dominant / diffuse or patch / occurance unpredictable.
- *Skeletonema costatum* bloom $10^6$ cell/l => 1 mg chlorophyll a.
- Oceanic / neritic plankton
- Meroplankton – temporarily members of plankton community (e.g. Bivalves)
- Holoplankton – permanent
- Euryhaline / Stenohaline
- Allochthonous – imported into ecosystem; Autochthonous – within.
- Nutrient availability – eutro/meso/oligotrophic
- Pelagic/open sea plankton
- Epipelagic (0-150 m) / meso (150-1000 m) / bathy (1000-4000 m) / abyssopelagic (4000-6000).
- Microphytoplankton and microzooplankton – 20-200 μm
- Macroplankton (200-2000 μm) / megaplankton (>2000 μm)
- Nanoplankton – 2-20 μm / Ultrananoplankton (<2 μm)
- Maximum photosynthetic activity occurred among 5-50 μm species.

**Statistical analyses**

Shannon-Wiener (Diversity) Index (H); Species richness

$H = \sum P_i \log2 P_i$

$P_i = n_i / N$, where $n_i$ = number of individuals of ith species

Species Evenness Index (J)

$J = H / \log_2 S$

Similarity Index (C)

Jaccard, $Cj = j / (a+b-j)$
Sorensen, $Cs = 2j / (a+b)$

Species assemblages / association in cluster analysis

- According to their preference on environmental conditions using UPGA (unweighted pair group average).

Cannonical correspondence analysis (CCA)

- Species-environment correlation measures the strength of the relationship bet the environmental variables and species for each ordination.
- End of each vector is related to high values for the quadrant adjacent to pH axis, acidic furthest away.

Seawater properties of Southeast Asia

1 W / m2 = 5 µmol/$m^2$/$s^2$ = 250 lux; Fluorometer F; Chl a = 0.0146 F + 0.0037

| No. | Parameters | Gulf of Thailand | Johore offshore South China Sea | Sarawak Water (SCS) |
|---|---|---|---|---|
| 1 | Chl a mg/$m^3$ | 0.11 | 0.13 | 0.12 |
| 2 | $NO_3$ µg at/l | 0.069 | 0.21 | 0.18 |
| 3 | $PO_4$ µg at/l | 0.066 | 0.51 | 0.47 |
| 4 | $NH^+_4$ µg at/l | 5 | 4 | 6 |
| 5 | Light µmol/$m^2$<br>Surface<br>5 m<br>50 m | <br>8.2<br>1.2<br>0.2 | <br>10.0<br>4.0<br>0.4 | <br>9.0<br>3.5<br>0.3 |
| 6 | Net PS gC/$m^2$/y | 120 | 170 | 150 |
| 7 | Chl max. layer (CML) (meters) | 3 | 10 | - |
| 8 | Max depth | 51 | 70 | 300 |
| 9 | $O_2$ ml/l | 4.4 | 4.2-4.5 | - |
| 10 | Temp./Salinity | 28.9 (32.9) | 28-29 (28.4) | - |
| 11 | PH/alkalinity | 8.12 (8.1 meq.) | 8.07 (8.05) | - |
| 12 | DIC MM/l | 1.9-2.0 | 1.96 | - |

CRUISE 3 & 4

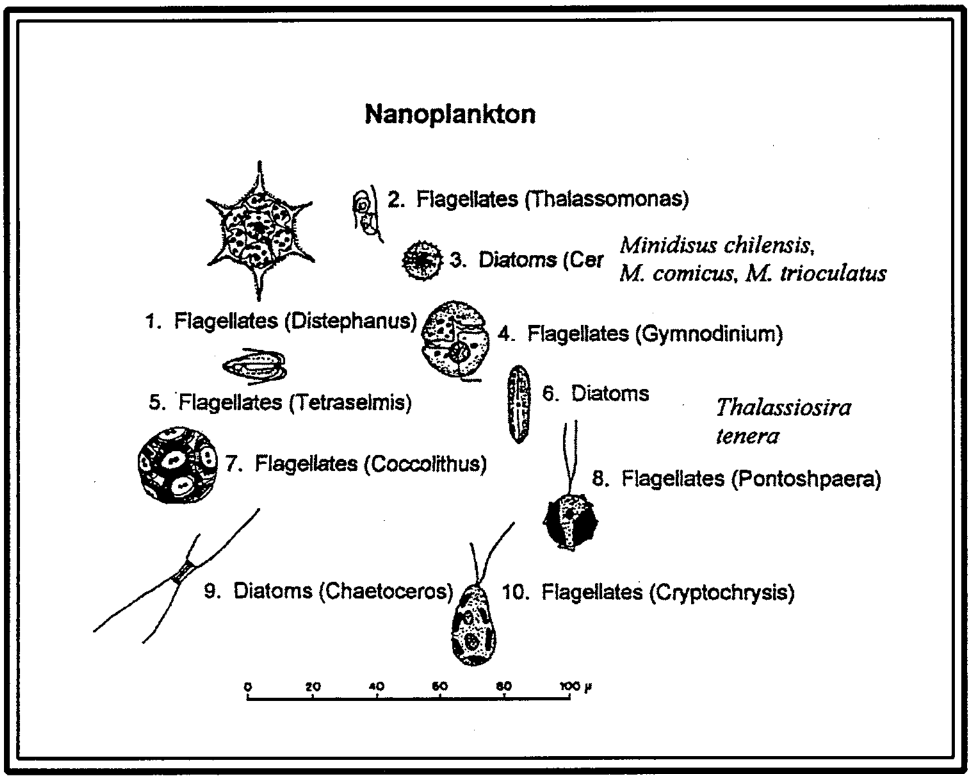
Sarawak-Sabah-Brunei Waters

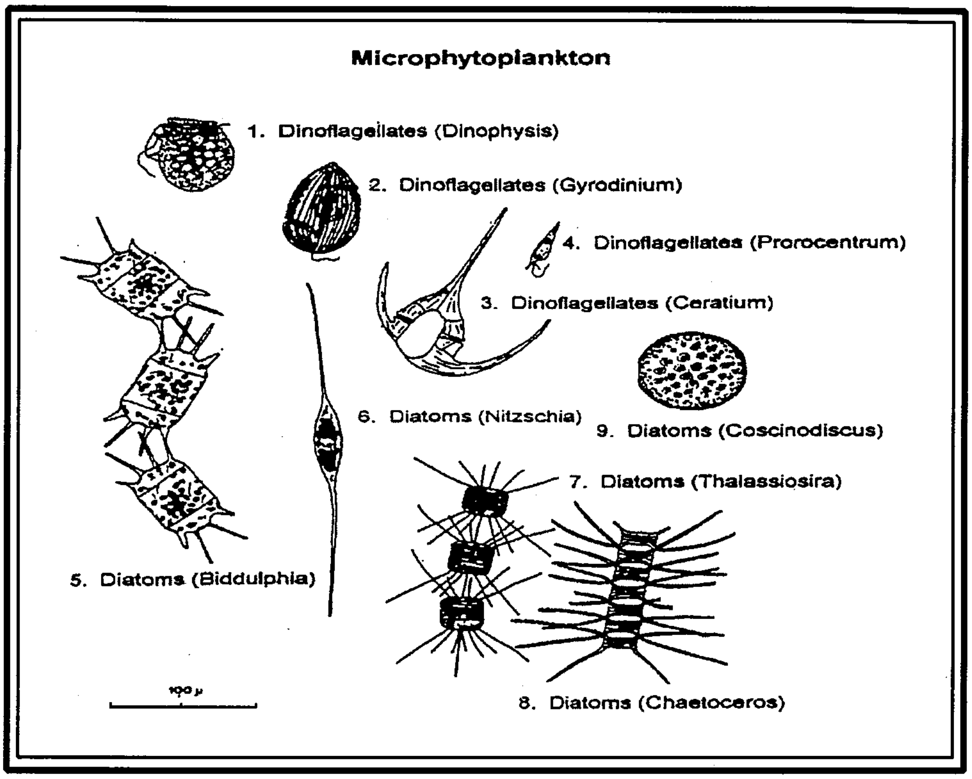
Dinoflagellate

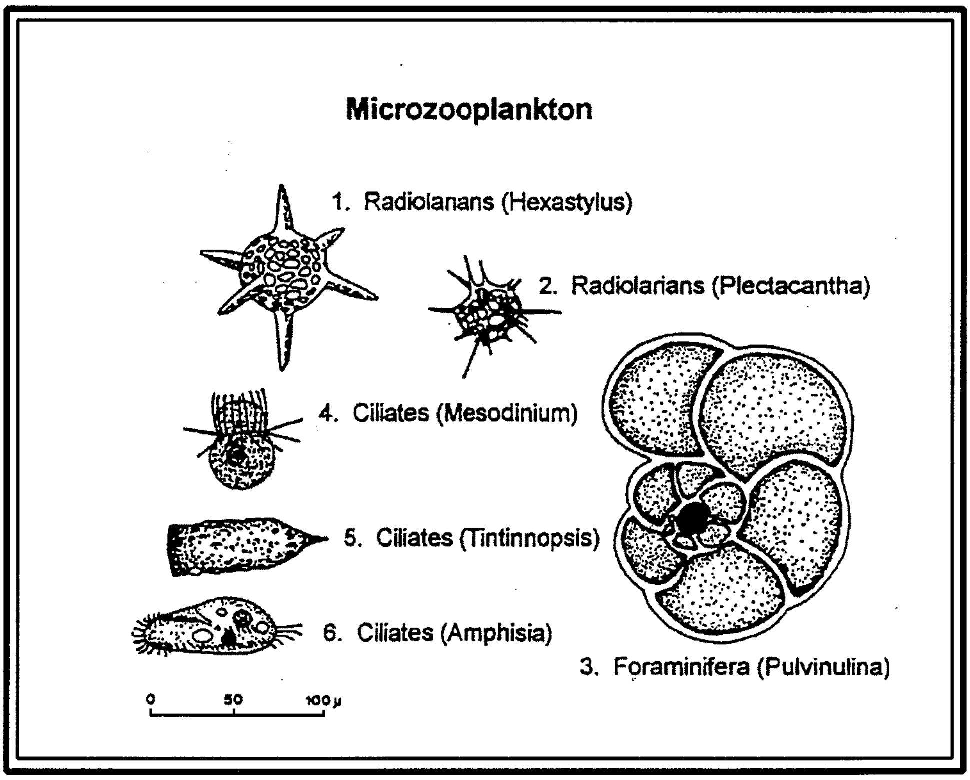
- Gymnodiniale
  *Amphidinium / Gymnodinium / Glenodinium*
- *Alexandrium*
- *Amphisolenia bidentata*
- Dinophysiaceae
  *Ceratocorys horrida / Dinophysis monunculus / Mitra*
- *Prorcentrum*
- *Pyrocystis fusiformis / lunula / noticula*
- Peridinales
  *Ceratium fusus / furca / gibberum / macroceros / tripos*
  *Peridinium depressum / pentagonum / sphaericum*
  *Phalacroma* sp.
  *Podolampas bipes*
  *Protoperidinium inflatum / tenuissinum*
  *Pyrophacus horologium / stenii*
  *Triposolenia truncata*

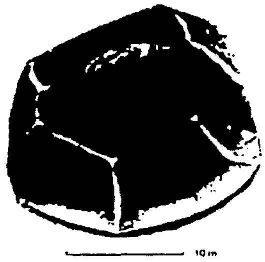
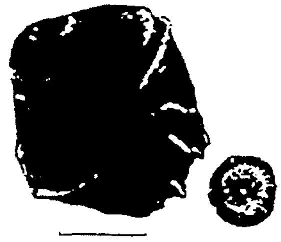
Others

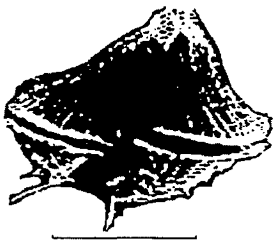
- Cyanophyceae, Family: Oscillatoriaceae
  *Richelia intracellularis / Trichodesmium (Oscillatoria) erythraeum / thebautii*
- Chrysopyceae
  *Dictyocha*
- Foraminifera
- Globigerinidae
  *Globigerina bulloides / Globigerinella / Globigerinoides conglabata Sphaeroidinella / Tretomphalus bulloides*

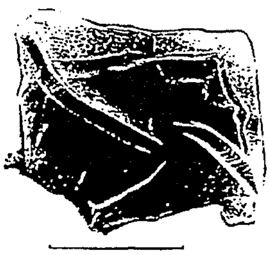
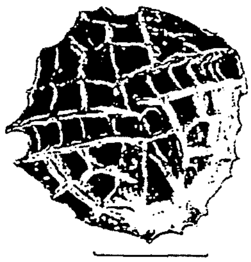


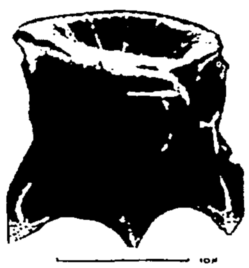
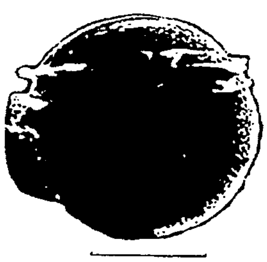
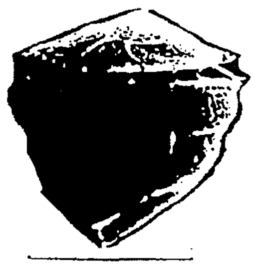

Microphytoplankton
1. Dinoflagellates (Dinophysis)
2. Dinoflagellates (Gyrodinium)
4. Dinoflagellates (Prorocentrum)
3. Dinoflagellates (Ceratium)
6. Diatoms (Nitzschia)
9. Diatoms (Coscinodiscus)
7. Diatoms (Thalassiosira)
5. Diatoms (Biddulphia)
100 µ
8. Diatoms (Chaetoceros)


Microzooplankton
1. Radiolanans (Hexastylus)
2. Radiolarians (Plectacantha)
4. Ciliates (Mesodinium)
5. Ciliates (Tintinnopsis)
6. Ciliates (Amphisia)
3. Foraminifera (Pulvinulina)
0 50 100 µ

| GONYAULACACEAE | GONYAULACACEAE | GONYAULACACEAE |
|---|---|---|
|  |  |  |
| 1. *Pyrodinium bahamense* Plate | 2. *Gonyaulax polyedra* Stein | 3. *G. polyramma* Stein |

| GONYAULACACEAE | GONYAULACACEAE | PERIDINIACEAE |
|---|---|---|
|  |  |  Po 3' 2a 7" 5c s 5''' |
| 4. *Gonyaulax* sp | 5. *Protogonyaulax tamarensis* Taylor | 6. *Protoperidinium quinquecorne* Abe |

| PERIDINIACEAE | PROTOCENTRACEAE | CERATOCERACEAE |
|---|---|---|
|  |  |  |
| 7. *P. pentagonum* Gran | 8. *Protoceratium spimilosum* Schiller | 9. *Ceratocorys horrida* Stein |

| PERIDINIACEAE | PROTOCENTRACEAE | CERATOCERACEAE |
|---|---|---|
|  |  |  |
| 10. *Ornithocercus magnificus* Stein | 11. *Dinophysis* sp. | 11. *Orytoxum* sp. |

# ANNEX 13

THE MFRDMD/SEAFDEC FIRST REGIONAL WORKSHOP ON
REMOTE SENSING OF PHYTOPLANKTON

Kuala Terengganu, Malaysia, 17-18 November, 1998

SEAFDEC/MFRDMD/WS/98/WP. 3

# TECHNICAL REPORT

## BACKGROUND OF PLANKTON II: HARMFUL ALGAL BLOOMS (HABs) - POSSIBLE CAUSES

By:

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## 1.0 Introduction

There is evidence to indicate that HABs have increased in occurrences (temporal and spatial) worldwide over the last decade. The blame inevitably is always put on eutrophication of coastal wafers from human activities. Despite years of research in several countries, we are still far from understanding the exact causes for these blooms, and to expect that a common cause function in all blooms would be naive. It might be possible, however, to identify a set of most probable factors that promote HABs in a particular location and close monitoring of these factors may provide some degree of certainty to predict HAB occurrences in that location.

## 2.0 HAB cycle

Most HABs do share some common properties, which are listed below.

1. HABs are often detected after cell densities get high enough to discolor the water (red tides) or cause seafood toxicity.
2. The blooms are often patchy vertically and horizontally, the patches persisting for several days.
3. At its peak the blooms are almost monospecies.
4. Both the appearance and disappearance of the bloom are abrupt events.

In many ways, the development of these HABs resembles the development of microbial populations in batch cultures (Figure 1). The challenge for researchers is to explain the processes involved in each phase. Currently, some of the phases are better understood than others.

### 2.1 Seed population and bloom initiation

In temperate waters explanation of bloom initiation is relatively straightforward. Over-wintering cysts germinate once temperature and light regime becomes favorable. In northeastern United States, for example, areas *Alexandrium* cyst accumulation have been identified. In this case the occurrence of HABs can be predicted with some certainty.

In tropical waters the seeding of HABs is not so clear cut. Most tropical dinoflagellates, including the toxic *Pyrodinium bahamense,* do form resting cysts. More interestingly, we have found that *P. bahamense* cysts have an obligatory quiescence phase of ca. 90 days. It is still not known how this obligator phase relates to environmental cues, since light and temperature vary over a narrow range.

The importance of resting cysts in the initiation of blooms of *P. bahamense* is open to question. On the West Coast of Sabah we have not been able to identify areas where cysts accumulate. On the other hand it is common to and a few vegetative cells of *P. bahamense* in the water column year round in protected bays and lagoons. It is thus likely that blooms develop from these background populations. In Manila Bay (Philippines), however, there is evidence that *P bahamense* blooms may originate from cyst beds in the Bataan and Cavite region (Figure 2). Clearly, the question of source population is an important issue that should be addressed, especially in tropical systems. This information is important in determining suitable locations for shellfish aquaculture projects and the setting up of an efficient HAB monitoring network.

## 2.2. Bloom growth

For several reasons, this is the most important phase of a HAB development. Unfortunately, it is also a phase that is least understood. Vegetative cells that germinate from cysts, or present in the plankton, will not form blooms unless conditions are conducive. What are the factors that may determine whether or not blooms develop? These could be:

1. competitive advantage
2. release from nutrient limitation
3. favorable hydrographic conditions
4. release from predation

Since HAB events are generally not continuous events, it follows that favorable combinations of these control factors for the HAB species are also episodic in nature.

## 3.0 Nutrients and Species Competition

Macronutrients

Nutrient discharges into coastal waters usually have an N:P ratio that differs from the receiving water. This could cause shifts in species composition. HABs are known from both P- and N-controlled environments, indicating that the apparent global increase HABs is not related to a general shift in supply ratios. In other words, there is no evidence at present that P-limitation leads to a higher frequency of HABs than N-limitation, or *vice versa.* Generally though N- and/or P-enrichment is normally not accompanied by Si-enrichment. Thus if the increase in HAB occurrence is related to a macronutrient enrichment-induced increase in phytoplankton biomass, non-diatoms will be favored, providing that light and temperature are not limiting growth.

Competition experiments with mixtures of dinoflagellates, haptophytes and diatoms generally indicate that dinoflagellates are poor competitors compared to haptophytes. If sufficient silicate is available, diatom will always outcompete non-diatom under nutrient- and/or light-limiting growth conditions. A model of the relative niche of major phytoplankton groups is shown in Figure 3. When light is limiting (center of diagram), diatoms are the fastest growing organisms. Under saturating light conditions (around the center of the circle), the nature of the growth-limiting nutrient will determine species composition.

Dominance of a particular phytoplankton species may also result from the dominant form of nutrients available at a particular time. This is particularly true of nitrogen, which can exist in a wide variety of forms. In coastal waters, for example, organic nitrogen may at times form the dominant fraction. Phytoplankton species vary in their capability to utilize these various forms of nitrogen and this could lead to dominance of a certain species. An example of how different phytoplankton species respond to various forms of nitrogen enrichment is shown in Figure 4.

Micronutrients

Trace metals have been widely studied in relation to HABs. In growth experiments of *P. bahamense* it was found that the species has a high requirement for selenium (Figure 5). This is an element that is not naturally found in high concentration in marine environments. Most f the input originates from terrestrial sources. It could be delivered into coastal waters through land runoff. Also interesting the fact that P. *bahamense* could only utilize selenium as selenite or organic selenide. Thus not only supply is important, but also be speciation. Other trace elements considered to be important for the growth of HAB species are shown in Table 1. While experimental evidence for the influence of Fe, Se, Co, and Cu on the growth of harmful algal species exist, the exact role played by trace elements and chelators in the initiation and maintenance of most HABs remain unknown. The over-riding question is not if the harmful organism has a general requirement for a particular metal. The nutritional physiology of HAB species is often very similar to their non-toxic counterparts. Trace elements are essential for the growth of all phytoplankton. The question is whether HAB species have unique trace element requirements, physiology, and uptake or detoxication mechanisms that would allow them to dominate non-toxic species.

## 4.0 Hydrography and physiology

Most observations on HAB events show that dinoflagellate blooms occur under stratified stable water column conditions. It is also an established fact that generally dinoflagellates do not like turbulence, as opposed to diatoms which thrive under such conditions. This fact was recognized many years ago by Margalef (Figure 6), although the scientist basis for this observation was not known until recently. It is now known from experimental evidence that strong shear inhibits DNA replication in dinoflagellates, especially if the shear is experienced during certain stages of the cell cycle. It is thus not surprising that in vertically well-mixed upwelling systems such as the Benguela current, Peru, and California, diatoms often dominate algal blooms. However, once turbulent energy decays, dinoflagellates can take advantage of the upwelled nutrients and form blooms. This, for example, is the case for *Dinophysis* and *Gymnodinium* blooms in the rias of Spain.

Turbulent events can also result in the abortion of blooms. On the west coast of Sabah, for example, we have often found that *P. bahamense* blooms abort (indicated by cell density) following strong winds. An even more pronounced example is bloom development in the northeastern United States. Here bloom events starts with germination of *Alexandrium* cysts from the mouth of the Kennebec River in Maine in early spring. These cells will then be transported by the plume of less dense water southwards, closely hugging the coastline. Since this plume of warmer water floats over the colder, denser water of the Atlantic, its movement can be easily tracked from SST images provided by NOAA satellites every four hours. Occasionally, winds from the south can blow for a period of time, enough to cause upwelling of cold Atlantic water. This will result in the destruction and dispersion of the plume offshore. In this case the blooms will die off. One thing that is still not clear in these events is whether the dinoflagellate cells actually die or whether they just get dispersed.

Life in a stratified water column presents its own problems to phytoplankters, especially if the nutrient is deep. It is likely that in a bloom patch the nutrient pool will rapidly become exhausted and recycling would not be fast enough to sustain a dense population (can reach ca. $10^6$ cells $L^{-1}$). Laboratory experiments in plankton towers showed that dinoflagellates overcome this problem through vertical migration. Dinoflagellates are motile and vertical migration could be further enhanced by buoyancy regulation, for example through changes in lipid composition.

What is the physiological status of cells in these blob patches? Is the high density of cells in bloom due to enhanced in-situ growth rate or is it due to accumulation by physical forces? These are very important questions that need to be addressed. Most growth experiments in the laboratory indicate that the maximum growth rate achieved by the dinoflagellate were 0.3 - 0.5 divisions $day^{-1}$. At these rates, a reasonable inoculum density (ca. 100 cells $mL^{-1}$) would actually be able to yield typical bloom densities within a period of 10 - 12 days, assuming minimum cell loss. It is thus possible to explain bloom formation just on the basis of passive accumulation, without invoking greatly enhanced growth rates. It would still be desirable though to be able to measure *in situ* growth rates in order to gain a better understanding of bloom formation. However this aspect is still very much limited by lack of suitable technology. It would also be desirable to know the nutritional status of these cells since this can have significant impact on cellular contents of toxins and photopigment.

## 5.0 Predation

In order for blooms to fully develop, population increase has to greatly exceed loss. Population loss can occur through physical dispersion, cell sinking, death, and predation. The persistence of a bloom patch is an indication that dispersal is not significant. Not much is known about sinking, although this could be significant during the later part of the bloom when resting cysts are formed. Ditto for natural cell death. Predation is an interesting aspect, not least because these cells are toxic. Experiments that have been carried out have been inconclusive. While some copepod species have been shown to avoid toxic cells, other predators such as the tintinnid *Favella* seem to feed on these toxic cells without adverse effects. The bottomline is that it is still not known how much impact predation, or the lack of it, has on HAB development.

## 6.0 Conclusion

HABs are, without doubt, becoming increasingly important in coastal waters worldwide. It is a very interesting phenomenon simply because most of the species involved are those that are not normally dominant in the plankton. Even over decades of research, still a lot is not known on the causative factors for these HABs. While increased nutrient loading undoubtedly increase the standing crop of phytoplankters in coastal waters, the relationship between eutrophication and HAB events is not always straightforward. In most cases we still do not know which species will benefit most from increased nutrient inputs. Treatment of effluents prior to discharge can reduce the amount of macronutrients that enter the sea, but at the same time this can also alter nutrient ratios. Experience in certain countries, for example in Japan and Scandinavia show that alteration of nutrient ratios can have quite unexpected outcomes on the phytoplankton assemblage. More studies, especially *in situ,* have to be conducted in order to better understand HAB events.

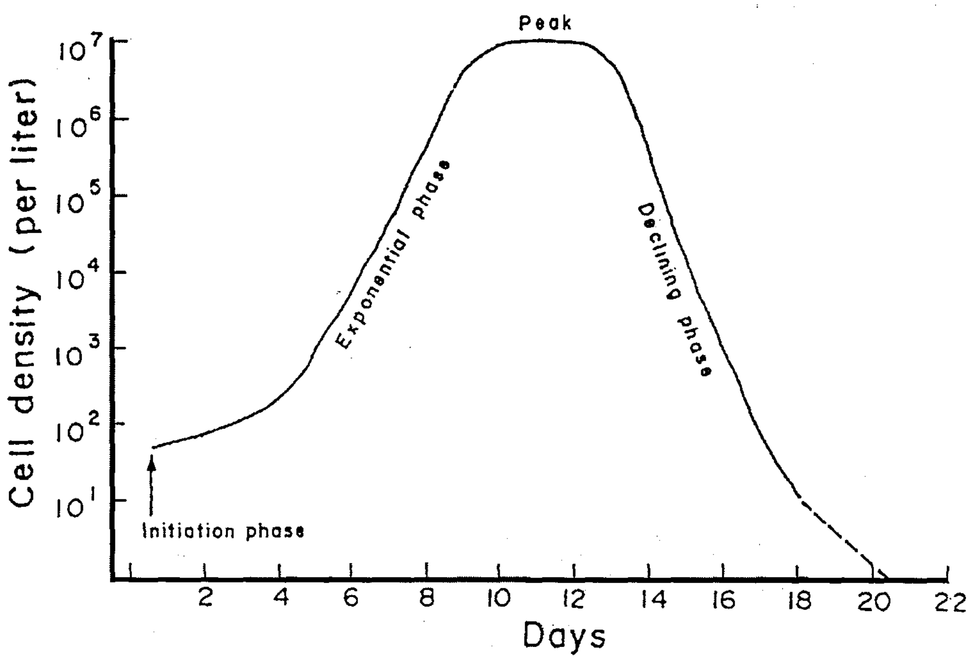



Figure 1: An idealized growth curve of a typical *Pyrodinium bahamense* var. *Compressum* red tide on the West Coast of Sabah.

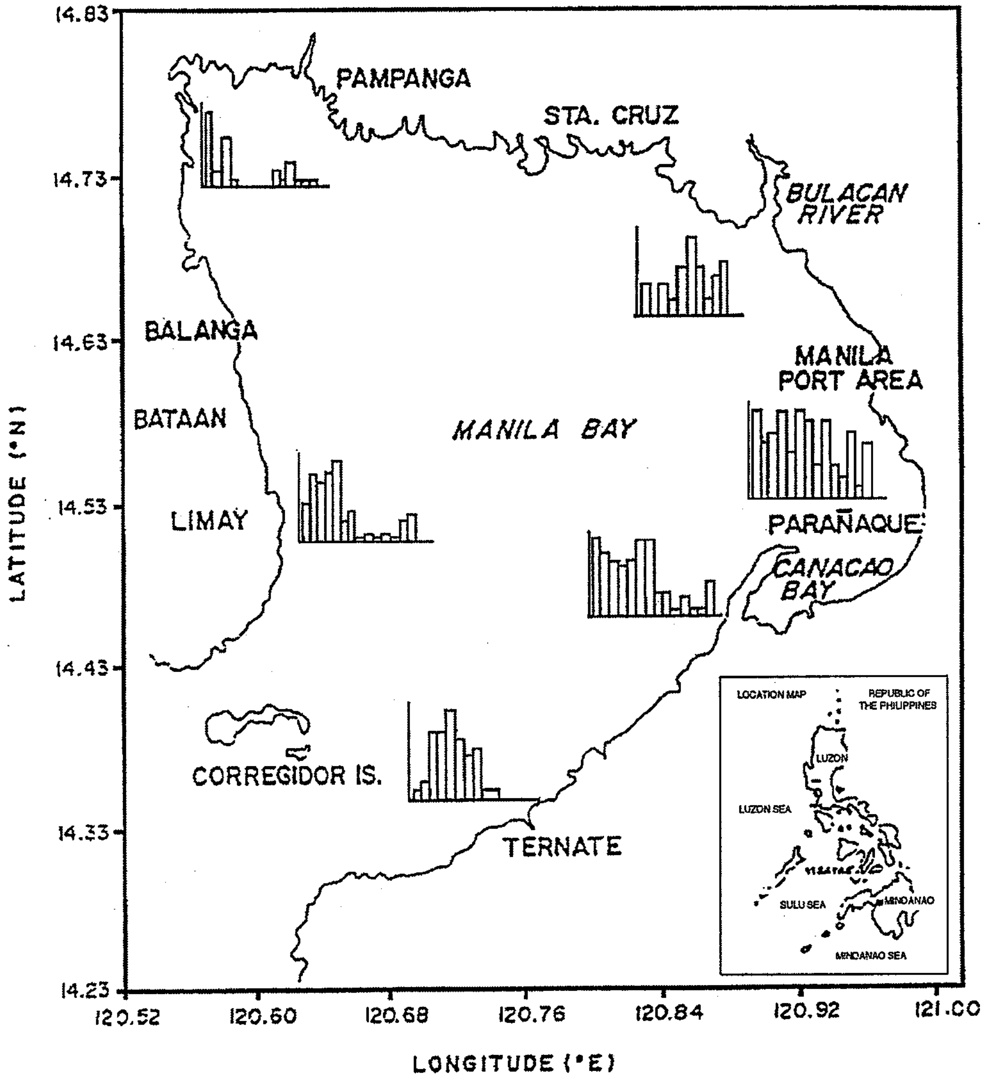



Figure 2: The distribution of *Pyrodinium bahamense* resting cysts in the surface sediment of Manila Bay from August 1993 to May 1994. Cyst densities (cysts $cm^{-3}$ sediment) for each region were as follows: Bataan 0-450; Pampanga 0-70; Bulacan 0-40; Paranaque 0-60; Canaco 0-300; Ternate 0-80. (from Corrales and Crisostomo, 1996).

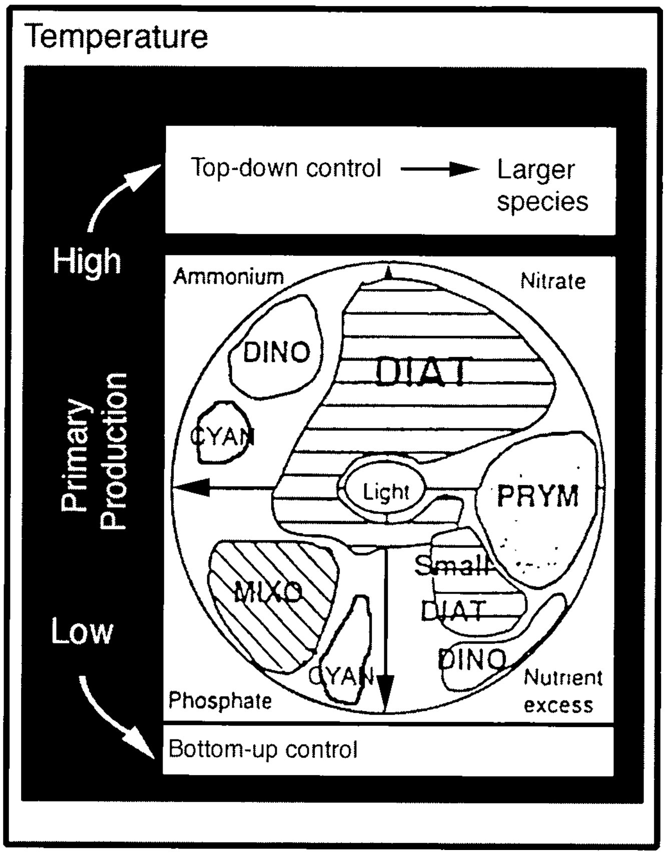



Figure 3: Ecological niche of dinoflagellates (DINO), diatoms (DIAT), haptophyceae (PRYM), cyanobacteria (CYAN) and mixotrophic algae (MIXO), according to their performance in competition experiments as described in Riegman *et al.* (1996). Centre of circle indicates light limiting conditions; border of circle indicates saturating irradiance levels and nutrient limitation or nutrien excess. Within the indicated taxonomical groups, primary production in the ecosystem may have, depending on its magnitude, its effect on species composition *via* top-down and corresponding size selective grazing.

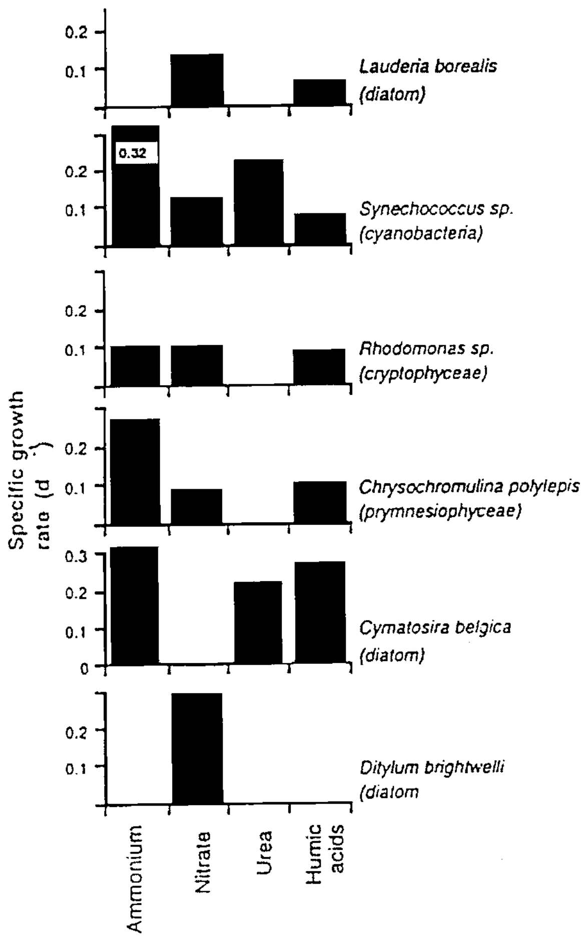
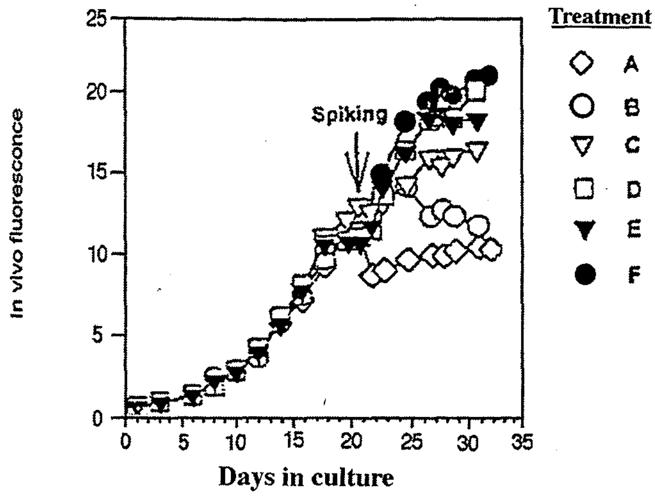



Figure 4: Response of different algae to different nitrogen sources under N-limiting growth conditions, in discontinuously diluted mixed algal cultures at a dilution rate 0.1 $d^{-1}$.



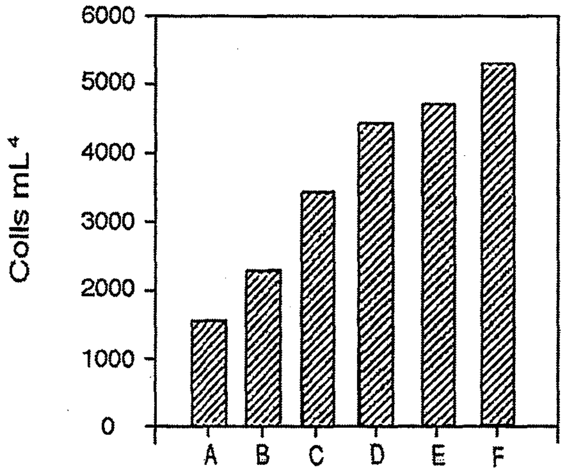




Figure 5: Effect of selenite supplement on *P. bahamense* var. *compressum* growth. Upper panel – *in vivo* fluorescence profiles of batch cultures spiked at early stationary phase with various nutrient combinations. Lower panel – highest yields obtained from the cultures. Spiking combinations were: A-no spiking; B-10 ml $L^{-1}$ modified ES medium nutrient mix; C-4 mL $L^{-1}$ soil extract; D-$10^{-7}$ M selenite; E-$10^{-7}$ M selenite, 200 mg bicarbonate, 10 mL $L^{-1}$ medium nutrients mix; F-$10^{-7}$ M selenite, 10 ml $L^{-1}$ medium nutrient mix. (From Usup, 1995).

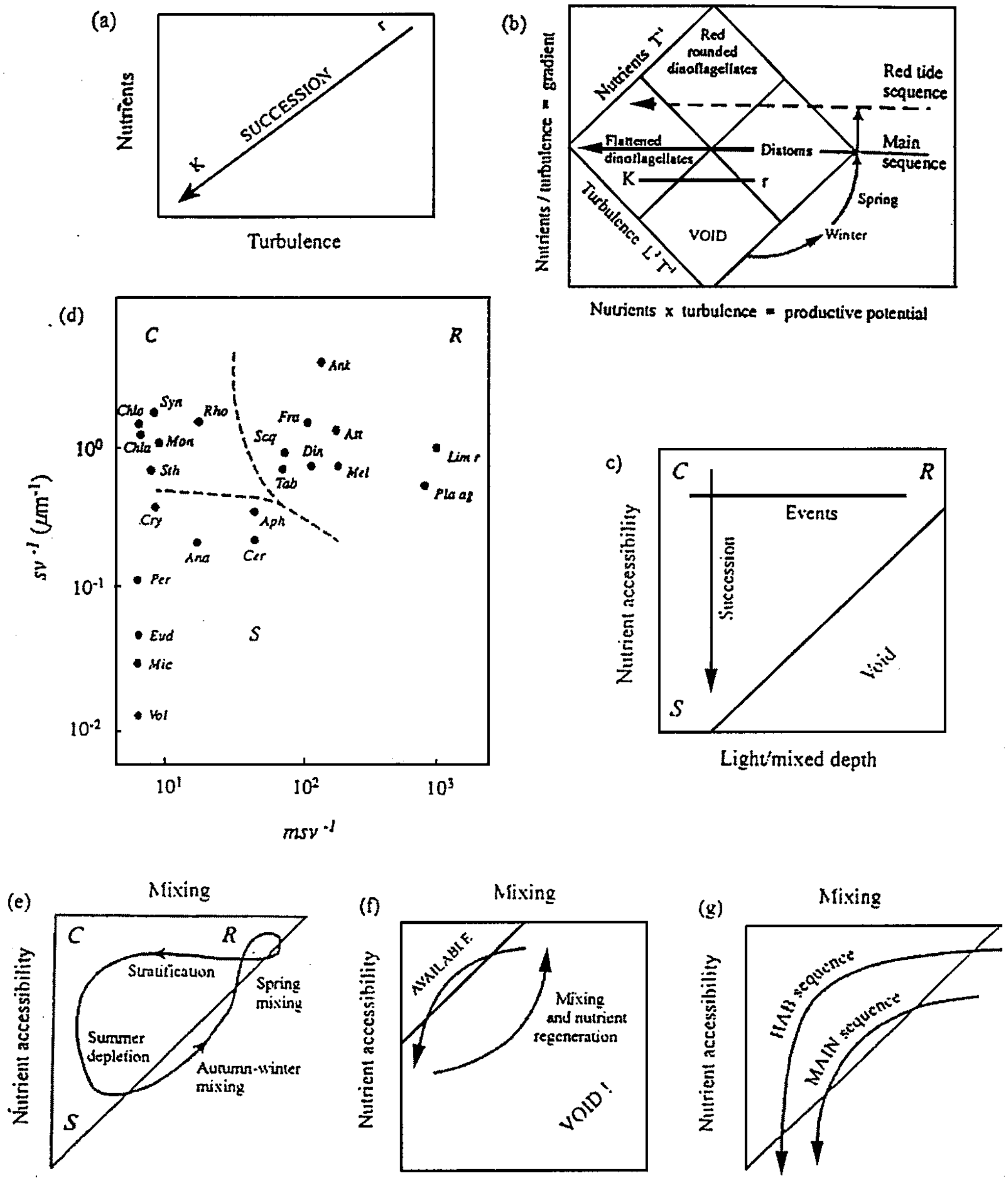


Figure 6: (a) Margalef's matrix summarising the sequence of phytoplankton (the main sequence) as a function of diminishing 'turbulence' and nutrient availability; (b) the Mandala of Margalef *et al.*, developed from (a) and including a 'red-tide', or HAB, sequence; (c) Reynolds' distinction of trajectories attributable to autogenic successional processes and allogenic forcing. and the selection of appropriately-adapted (C, *S* or R) species, which behaviour is influenced more by morphology than phylogeny; (e) ideal year-long trace of the selective trajectory imposed by (temperate) seasonal habitat variability; (f) diminished opportunities in the sea, which is mostly too nutrient- and light-deficient to support phytoplankton growth; (g) top left-hand corner of (f) showing how the main sequence (literally) skirts the edge but, with more nutrients available, trajectories pass more deeply to select more strongly for C-strategist algae.

| Metal | Species | Reference |
|---|---|---|
| IRON | *Alexandrium tamarense* | Wells *et al.* 1991a |
| | *Aureococcus anophagefferens* | Gobler 1995 |
| | *Chatonella antiqua* | Okaichi *et al.* 1989 |
| | | Nakamura 1990 |
| | *Gymnodinium breve* | Ingle and Martin 1971 |
| | | Kim and Martin 1974 |
| | *Gymnodinium sanguineum* | Doucette and Harrison 1990, 1991 |
| | *Haterosigma sp.* | Yamochi 1983; 1989 |
| COPPER | *Alexandrium tamarense* | Anderson and Morel 1978 |
| | | Schenck 1984 |
| | *Chatonella antiqua* | Nakamura *et al.* 1987 |
| | | Nakamura 1990 |
| | *Gymnodinium breve* | Martin and Olander 1971 |
| | *Gymnodinium sanguineum* | Robinson and Brown 1991 |
| | *Prorocentrum minimum* | Graneli *et al.* 1986 |
| SELENIUM | *Aureococcus anophagefferens* | Cosper *et al.* 1993 |
| | *Chattonella verruculosa* | Imai (this volume) |
| | *Chrysochromulina polylepis* | Dahl *et al.* 1989 |
| | *Gymnodinium nagasakiense* | Koike *et al.* 1993 |
| | | Ishimaru *et al.* 1989 |
| | *Pyrodinium bahamense* | Usup and Corrales (this volume) |
| COBALT | *Chrysochromulina polylepis* | Graneli *et al.* 1993 |
| | | Graneli and Risinger 1994 |

Table 1: Trace metals implicated in the growth of harmful algal species.

# ANNEX 14

**THE MFRDMD/SEAFDEC FIRST REGIONAL WORKSHOP ON REMOTE SENSING OF PHYTOPLANKTON**

**Kuala Terengganu, Malaysia, 17-18 November, 1998**

SEAFDEC/MFRDMD/WS/98/WP. 4

# TECHNICAL REPORT

## REMOTE SENSING TECHNOLOGY FOR PHYTOPLANKTON

By:

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## Remote Sensing Technology

Fundamental principles:

- The characteristics and interaction of the electromagnetic radiation (EMR) as its propagates from source to sensor.

Description:

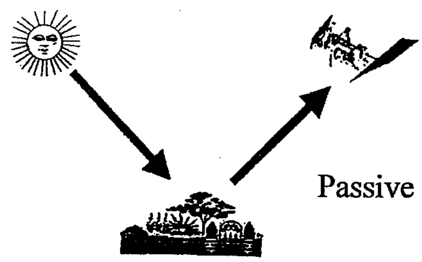
- The source of energy and the type and amount of energy it provides.
- The absorption and scattering effects of the atmosphere EMR.
- The mechanisms of EMR interaction with the earth surface features.
- The nature of sensor response as determined by the type of sensor.

Remote Sensing System

Passive sensor:

Use ambient radiation (what is around us to measure)

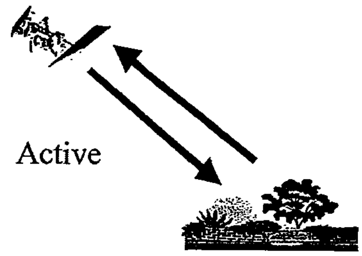
- Sunlight
- Heat from earth's surface
- Other microwave radiation



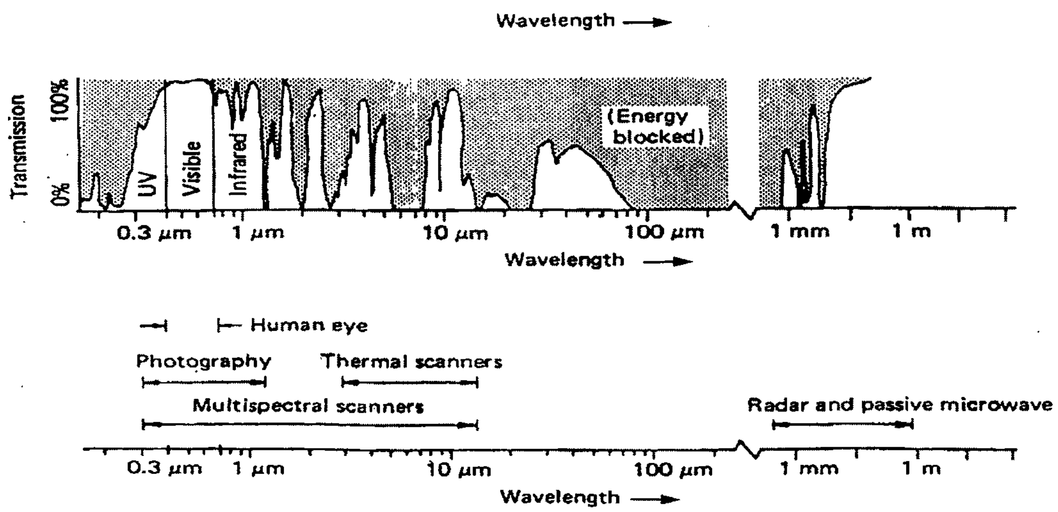

Active sensor

Illuminates a scene with some form of radiation

- Microwave – Radar, Altimeter, SAR
- Laser, altimeter, LIDAR




## Electromagnetic Radiation (EMR)

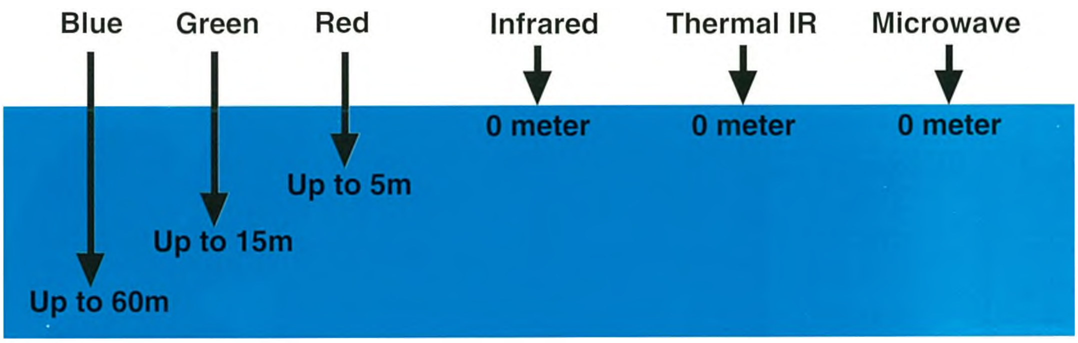


**Remote Sensing Wavelength**

Wavelength in remote sensing:

Passive:
- Visible
- Infrared
- Thermal infrared

Active:
- Microwave




Why Do We Use Satellite Remote Sensing?

- Repetition
  Repetition of data capture is consistent

- Coverage
  Coverage of large area in shortest time is suitable for dynamic phenomena

- Cost effective
  Cost per $km^2$ is low

Ideal remote sensing system

- Real-time imagery
- High spatial resolution
- High radiometric resolution

Current limitation

- Number of detector in sensor (now ~6000 detector)
- Satellite orbit and height

**Remote Sensing for Phytoplankton Detection**

Parameter that can be used for phytoplankton detection either direct or indirect:

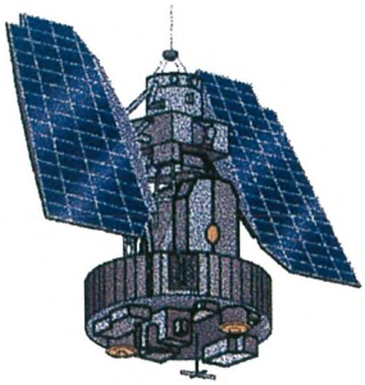
- Chlorophyll
- Ocean color
- $CO_2$
- Nutrient
- Sunlight in water

**Remote Sensing Satellites**

Archive data available

*Nimbus-7*

Sensor: Coastal Zone Colour Scanner (CZCS)



| Band | Wavelength (nm) | Colour |
|---|---|---|
| 1 | 455-453 | Visible blue |
| 2 | 510-530 | Visible green |
| 3 | 540-560 | Visible yellow |
| 4 | 660-680 | Visible orange/red |
| 5 | 700-800 | Very near infrared |

**Currently available**

*SEASTAR*

Sensor: SeaWiFS
(= Coastal Zone Colour Scanner)

| Band | Wavelength (nm) | Bandwidth (nm) | Colour | Measurement |
|---|---|---|---|---|
| 1 | 412 | 20 | Violet | Dissolved organic matter (violet absorption) |
| 2 | 443 | 20 | Blue | |
| 3 | 490 | 20 | Blue/Green | Chlorophyll (blue absorption) |
| 4 | 510 | 20 | Green | Chlorophyll (blue/green absorption) |
| 5 | 555 | 20 | Green/Yellow | Chlorophyll (green absorption) |
| 6 | 670 | 20 | Red | Chlorophyll (green reflection) |
| 7 | 765 | 40 | Near Infrared | Atmospheric aerosols |
| 8 | 865 | 40 | Near Infrared | Atmospheric aerosols |
| | | | | Atmospheric aerosols |

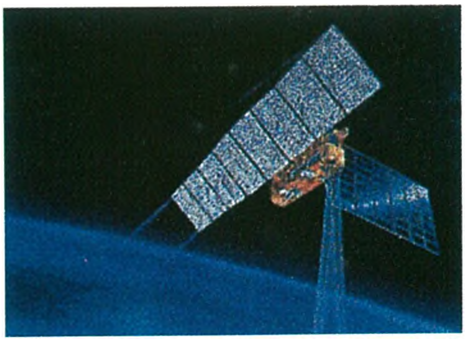
*ADEOS*

Sensors:

- Ocean Color and Temperature Scanner (OCTS) by NASDA Japan
- Advanced Visible and Near Infrared Radiometer (AVNIR) by NASDA Japan
- NASA Scatterometer (NSCAT) by NASA America
- Total Ozone Mapping Spectrometer (TOMS) by NASA America
- Interferometric Monitor for Greenhouse Gases (IMG) by IMG Japan
- Polarization and Directionality of the Earth's Refrectance (POLDER) by CNES France
- Improved Limb Atmospheric Sounder (ILAS) by MITI Japan
- Retroreflector In Space (RIS) by IMG Japan

*JERS*

Sensor : Optical Scanner (OPS)



Main specifications of OPS

- Swath width: 75 km
- Resolution: 18m x 24m
- Bands: Visible & near infrared (3)<br>Shortwave infrared (4)<br>Stereoscopic (1)
- High in noise, unsuitable for use

*NOAA*

Sensor: Advance Very High Resolution Radiometer (AVHRR)

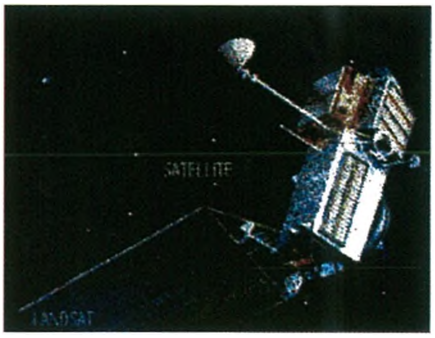
AVHRR characteristics:

| Band | Wavelength (μm) | Primary use |
|---|---|---|
| 1 | 0.58-0.68 | Daytime cloud/surface mapping |
| 2 | 0.725-1.10 | Surface water delineation, ice and snow melt |
| 3A | 1.58-1.64 | Snow / ice discrimination (NOAA K,L,M) |
| 3 | 3.55-3.93 | Sea surface temperature, nighttime cloud mapping |
| 4 | 10.3-11.3 | Sea surface temperature, day and night cloud mapping |
| 5 | 11.5-12.5 | Sea surface temperature, day and night cloud mapping |


*LANDSAT 4 & 5*

Sensor : Thematic Mapper

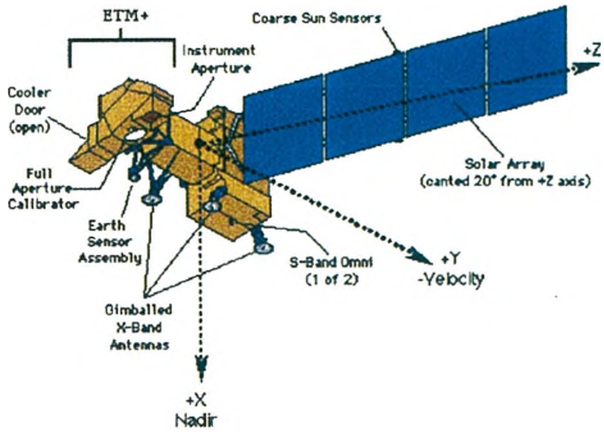
| Band | Wavelength (μm) | Spectrum |
|---|---|---|
| 1 | 0.45-0.52 | Blue-green |
| 2 | 0.52-0.60 | Green |
| 3 | 0.63-0.69 | Red |
| 4 | 0.76-0.90 | Near Infrared |
| 5 | 1.55-1.75 | Infrared |
| 6 | 10.4-12.5 | Thermal Infrared |
| 7 | 2.08-2.35 | Far Infrared |



## Future Satellite

*LANDSAT 7*

| Band | Wavelength (nm) |
|---|---|
| 1 | 450-515 |
| 2 | 525-605 |
| 3 | 630-690 |
| 4 | 750-900 |
| 5 | 1550-1750 |
| 6 | 10400-12500 |
| 7 | 2090-2350 |
| Panch. | 520-900 |




*ADEOS II*

<u>Sensor</u> same as ADEOS I, with 5 additional sensors:

- Advanced Microwave Scanning Radiometer (AMSR)
- Global Imager (GLI)
- Sea Winds (SeaWinds)
- Polarisation and Directionality of the Eatrh's Reflectances (POLDER)
- Improved Lomb Atmospheric Scatterometer-II (ILAS-II)


## Research at Remote Sensing Centre, UTM

<u>Oceanography:</u>

- Bathymetry
- Seagrass
- Coral reefs
- Suspended Sediment Concentration
- Sea Surface Temperature
- Sea Bottom Features
- Wave height and direction
- Wind speed and direction

# ANNEX 15

THE MFRDMD/SEAFDEC FIRST REGIONAL WORKSHOP ON REMOTE SENSING OF PHYTOPLANKTON

Kuala Terengganu, Malaysia, 17-18 November, 1998

SEAFDEC/MFRDMD/WS/98/WP. 5

# TECHNICAL REPORT

## PRODUCTION AND DISTRIBUTION OF PHYTOPLANKTON OBSERVED BY ADEOS: APPLICATION OF SATELLITE IMAGERY FOR FISHERIES

By:

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## 1.0 Introduction

The Japan Fisheries Information Service Center (JAFIC) was established 1972 as a result of request of fishermen and the local communities. JAFIC offers fisheries information to users around Japan. Main information is a prompt report of fishing condition and mapping of the sea surface temperature. The information is provided in co-operation with fishing vessels and researchers located around Japan. The remote sensing technology is also used to process the information and then to come out with the maps. The conventional technique consumes a lot of time, from collecting the water temperature data from the sea to thermal map production. By using the satellite data, this time could be reduced to just a few hours instead a few days using conventional technique. Moreover satellite could provide short-term variation and detail structure in the ocean.

Recently the satellite sensors could observe ocean color not only the temperature, but also phytoplankton distribution. We will provide knowledge, and expect some solution of phytoplankton production system in the South China Sea.

## 2.0 Advanced Earth Observing Satellite (ADEOS)

ADEOS was expected to acquire data on worldwide environmental changes in order to contribute to international earth observation and systematic environmental monitoring. The National Space Development Agency of Japan (NASDA) successfully launched the ADEOS on 17 August 1996 (JST). ADEOS is also called "*midori*" in Japanese, which mean "green" of phytoplankton. However it had acquired global observation data for 10 months only, before experienced a major failure of its solar panel, and operation was terminated in June 1997.

ADEOS Characteristics

| | |
|---|---|
| Altitude: | 797 km |
| Orbit degree: | 99 |
| Recurrent period: | 41 days days (solar-synchronous sub-recurrent orbit) |
| Sensors: | • Ocean Color and Temperature Scanner (OCTS) by NASDA Japan<br>• Advanced Visible and Near Infrared Radiometer (AVNIR) by NASDA Japan<br>• NASA Scatterometer (NSCAT) by NASA America<br>• Total Ozone Mapping Spectrometer (TOMS) by NASA America<br>• Interferometric Monitor for Greenhouse Gases (IMG) by IMG Japan<br>• Polarization and Directionality of the Earth's Refrectance (POLDER) by CNES France<br>• Improved Limb Atmospheric Sounder (ILAS) by MITI Japan<br>• Retroreflector In Space (RIS) by IMG Japan |

| Bands (μm) | Observation data | on ground solubility | observation wide |
|---|---|---|---|
| 0.402-0.442 | Yellow matters | | |
| 0.433-0.453 | Chlorophyll maximum absorption | | |
| 0.479-0.501 | Chlorophyll minimum absorption | local area coverage data | |
| 0.511-0.529 | Reference band | 680 m | |
| 0.555-0.575 | Chlorophyll maximum absorption | | |
| 0.660-0.680 | Chlorophyll minimum absorption | global area | |
| 0.745-0.785 | Revision atmospheric | coverage data 4km | 1400km |
| 0.845-0.885 | influence | | |
| 3.55-3.85 | sea-surface temperature | direct transmission for | |
| 8.25-8.80 | / revision atmospheric | local users 7 km | |
| 10.3-11.4 | influence | (4 bands) | |
| 11.4-12.7 | | | |

Table 1: The OCTS bands characteristics (JARS, 1996).

## 3.0 Distribution of chlorophyll in the South China Sea

In a mid-latitude area such as Japan, seasonal climate causes variation in plankton production and species composition for example "spring bloom of phytoplankton". Phytoplankton production is limited by nutrient supply in the tropical ocean. Northeast monsoon and Southwest monsoon are seasonal characteristic in South China Sea. These two monsoons develop currents in the sea. The OCTS monthly average image data of both monsoons show us some characteristic of chlorophyll distribution.

## 4.0 Spring bloom of phytoplankton in the Japan Sea

The OCTS data has shown an interesting spring bloom of phytoplankton phenomenon in the Japan Sea. Weekly average image data from April to May 1997 show us the bloom migration. During this period, the sea surface water was warmer in Japan Sea. The bloom migration veracity was equivalent to warmer velocity. We could observed the phytoplankton bloom in 8-13°C area (JAFIC, 1997).

## 5.0 Distribution of chlorophyll off Tohoku, Japan

The Northeast Pacific, off Tohoku is a main fishing area in Japan as well as in the world. We expect high production supports high catch volume. The area is characterised by the mixing of Kuroshio warm water and Oyashio cold water. Many fronts are developed well. Recently the remote sensing satellite has observed detail structure that we could not observe by a ship. Warm streamer exists from warm core ring. Observation made by the research vessels, aircraft and satellite evidenced that warm streamer is important route of fish school migration and feeding ground of fishes (Tameishi, 1998).

## 6.0 Forecast of fish ground area in use OCTS data.

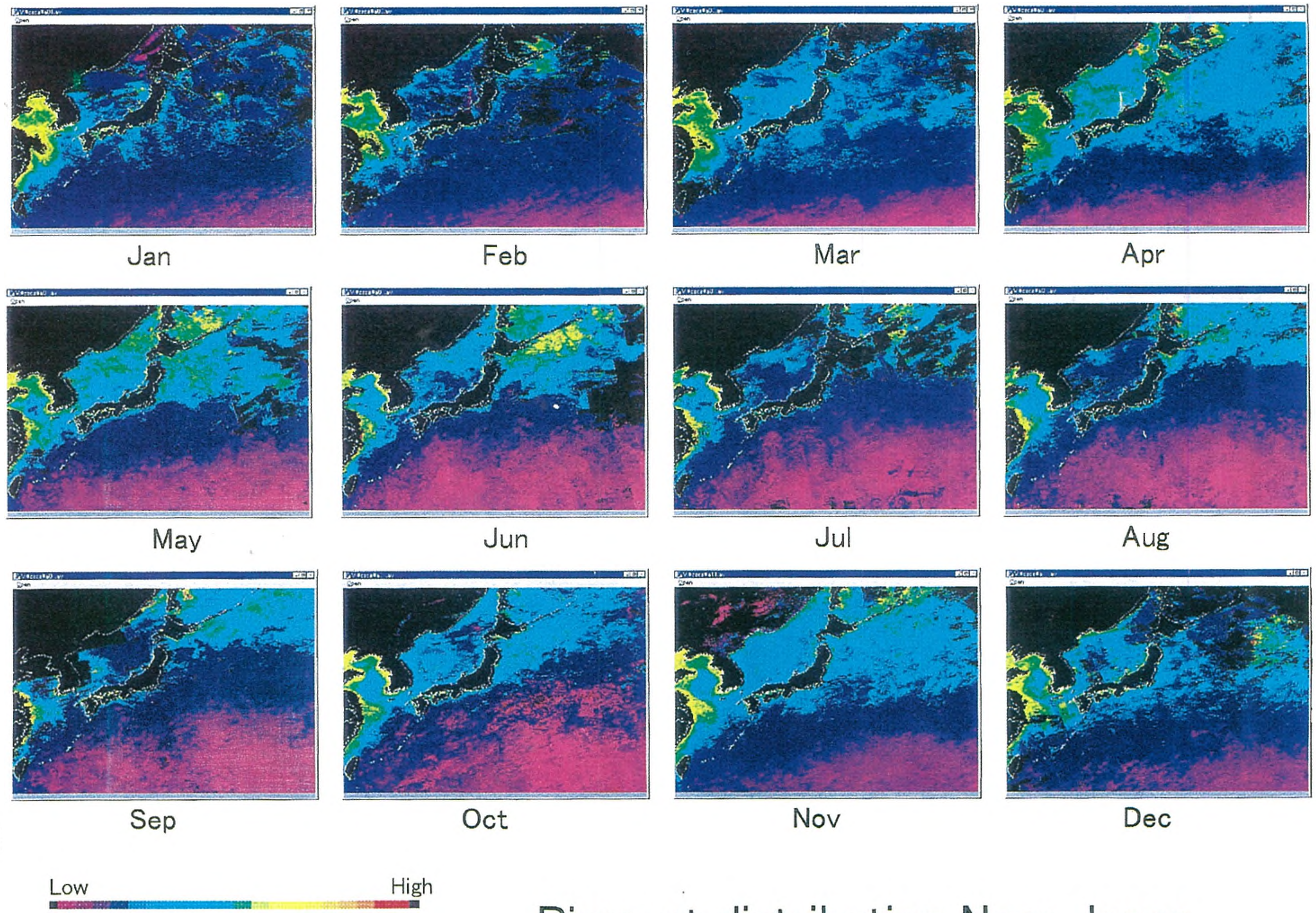
Each fish species has their favorite temperature range. Most of the fishermen interested with ocean temperature information. Food availability also could not be ignored as fish school gathering factor. JAFIC have mapped favorable temperature and favorable ocean color for mackerel, and determined the fishing ground area (JAFIC, 1997)

### References

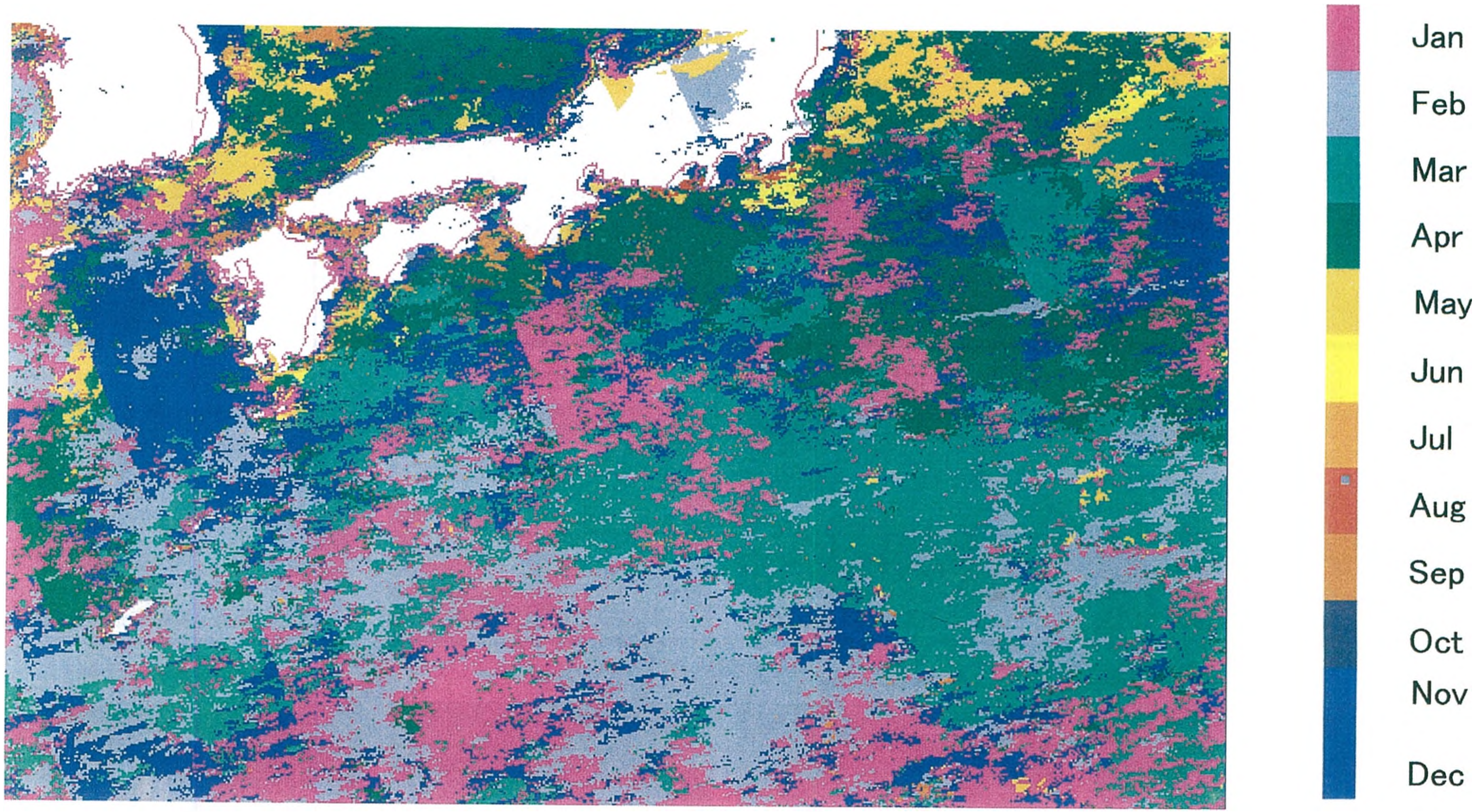
JARS. 1996. Japanese Earth observing satelites. Remote sensing and geographical information system, NASDA 2 (5) 52-55

Tameishi, H. 1998. Studies on the roles of warm cores and warm streamers in fish migration and fishing ground formation. Kaiyo monthly, extra 13, 103-109

JAFIC.1997. Report of develop high analytical system against satellite data 1997. 104-119




Pigment distribution Near Japan




Month of Maximum Pigment Value

# ANNEX 16

THE MFRDMD/SEAFDEC FIRST REGIONAL WORKSHOP ON REMOTE SENSING OF PHYTOPLANKTON

Kuala Terengganu, Malaysia, 17-18 November, 1998

SEAFDEC/MFRDMD/WS/98/WP. 6

# TECHNICAL REPORT

## PHYTOPLANKTON DISTRIBUTION MAPPING USING NOAA AVHRR SATELLITE DATA

By:

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**Abstract**

This research paper reports the result of mapping phytoplankton distribution using NOAA AVHRR satellite data of Malaysian waters. Phytoplankton is one of the important elements to identify fish breeding habitats and fishing grounds forecasting. The type of phytoplankton extracted from NOAA AVHRR satellite data was the microphytoplankton (>58 um). Visible band (band 1) and near-infrared band (band 2) of NOAA AVHRR were used in this study. Both bands were corrected for atmospheric effects for removing the Rayleigh and Aerosol scatterings. In-situ measurements collected during satellite overpass were used to regress the relationship between the reflectance and phytoplankton densities. In this study, non-linear regression technique was used. The best correlation coefficient was determined to extract the distribution of phytoplankton.

## 1.0 Introduction

NOAA AVHRR satellite data have been used in various coastal marine applications. As one of the large-scale satellite data, NOAA AVHRR satellite data can map the distribution of phytoplankton over entire Malaysian waters. Distribution of phytoplankton can be determined by the interaction of the incident light and particles present in the water, which will produce colour to satellite data. The NOAA AVHRR consists of five bands which are band 1 (visible), band 2 (near infrared), band 3 (near infrared), band 4 and band 5 (both thermal infrared). Bands 4 and 5 are used for mapping of surface temperature of the ocean. Band 1 and band 2 are used for vegetation mapping, as well as to study plankton distribution in the sea. The bandwidth for band 1 is 0.58 um to 0.68 um, while for band 2 it is 0.725 um to 1.10 um. The data is in 10-bit precision (1024 grey levels).

## 2.0 Materials and Method

There are two parts of the study, firstly, phytoplankton sampling and analyses, and secondly NOAA AVHRR mapping.

*Phytoplankton sampling and analyses*

Phytoplankton sampling was conducted once NOAA-14 AVHRR overpass. The sampling was conducted in the surrounding waters of Pulau Langkawi in Kedah on 19 March 1998. The area was used to obtain *in-situ* data that will be utilized to map distribution of phytoplankton covered the whole Peninsular Malaysia waters (Figure 1). During sampling the twin engines speedboats were used. The details of NOAA-14 AVHRR pass are shown in Table 1 below.

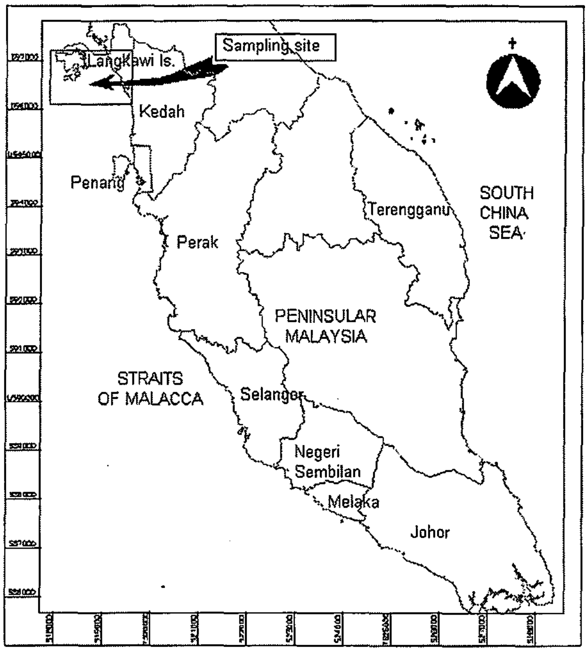


Figure 1: Peninsular Malaysia map showing sampling locations.

| | |
|---|---|
| Date | 19 March 1998 |
| Time | 11h 53m 00s GMT |
| Swath width | 2400 km |
| Resolution at nadir | 1.1 km |

Table 1: NOAA-14 AVHRR overpass during sampling in Kedah

Phytoplankton sampling was done using a 58-μm mesh-size plankton net, with the opening diameter of 0.45 m. A net was towed vertically from the depth of about 5 meters to the surface at a constant speed of 0.5 m per second. Sampling location, time, weather condition, current direction and velocity was also measured. The sample was preserved in 5% formalin. Phytoplankton counting was done in SEAFDEC Laboratory, using a microscope. Firstly, the sample was centrifuged for 10 minutes at 2500 rpm. The supernatant was siphoned off from the tube, while the remaining plankton solution was gently kept in a test tube. Distilled water was added to the solution to make it 50 ml. Then, one drop of plankton sample was taken from the test tube, and phytoplankton counting was done using inverted microscope. For one sample, 5 replicates were done, and then averaged for representing number of cell per one drop. One drop of sample was identified to be 0.05 ml. This value was used for estimating phytoplankton density in 50 ml solution.

*NOAA AVHRR Data Processing*

The raw image of NOAA AVHRR during sampling works is shown in Figure 2 below. The image shows that Peninsular Malaysia is cloud free during sampling. The image was retrieved from MFRDMD SEAFDEC archive. The remote sensing facility in MFRDMD is able to receive NOAA AVHRR data using the High-Resolution Picture Transmission (HRPT) system.

Figure 2: NOAA-14 AVHRR raw data on 19 March 1998.

Atmospheric correction was made to rectify the image affected by the atmospheric components such as Rayleigh and Aerosol components. Correction was made to the satellite data based on algorithm by Jensen (1996) (Equation 1.0). LOWTRAN-7 developed by Kneiyz et al. (1989) was used to compute the transmittance value.

The algorithm is given as:

$$L_s = \frac{1}{\pi}\left(R_i T_{\theta v} E_g\right) + L_p \qquad (1.0)$$

where

$L_s$ : total radiance at the sensor ($Wm^{-2}sr^{-1}$)

$\pi$ : 3.141592654

$R_i$ : average target reflectance

$T_{\theta v}$ : atmospheric transmittance at an angle θ to the zenith

$E_g$ : global irradiance incident on the surface ($Wm^{-2}$)

$L_p$ : path radiance resulting from mutiple scattering ($Wm^{-2}sr^{-1}$)

The NOAA AVHRR image was masked to remove cloud and land areas and hence leaving the water area which is the subject of the study. Band 2 of AVHRR (near IR) was used for masking since the difference between land and water were clearly visible. Geometric correction was made to enable registration of satellite image onto "Rectified Skewed Orthomorphic" coordinate (topographic mapping in Peninsular Malaysia). The image was corrected using second degree polynomial equation (7 sampling points).

*Phytoplankton Extraction*

Non-linear regression technique was applied between reflectance values (band 1, band 2, $\frac{band1}{band2}$ and $\frac{band2}{band1}$) and phytoplankton concentration samples from in-situ sampling. The best correlation coefficient ($r^2$) would be used to extract the distribution of phytoplankton.

## 3.0 Results and discussion

The phytoplankton density results are shown in Table 2 below. Table 3 shows reflectance value extracted from NOAA AVHRR data of the sampling station. The lowest density is at station 8 which is $1.61 \times 10^2$ cell per litre while the highest is at station 6 which is $4.93 \times 10^4$ cell per litre.

The data were analysed for linear and non-linear regression. It was found that the non-linear regression has given the best results as indicated in Table 4. The result listed in the table shows that band $\frac{band2}{band1}$ produced the highest correlation coefficients (which is the best in describing correlation between one factor to another independent factor).

| Sampling Station | Location | | | | Phytoplankton density (cell/l) |
|---|---|---|---|---|---|
| | RSO | | WGS84 | | |
| | N (m) | E (m) | N | E | |
| 1 | 699460.0 | 206099.0 | 6°18'57.00" | 99°50'4.91" | $1.50 \times 10^4$ |
| 2 | 693398.0 | 197460.0 | 6°15'38.72" | 99°45'24.96" | $1.11 \times 10^4$ |
| 3 | 694303.0 | 190909.0 | 6°16'6.88" | 99°41'51.62" | $8.70 \times 10^3$ |
| 4 | 685102.0 | 191951.0 | 6°11'7.53" | 99°42'27.36" | $2.17 \times 10^4$ |
| 5 | 681154.0 | 196983.0 | 6°8'59.98" | 99°45'11.84" | $4.63 \times 10^4$ |
| 6 | 682725.0 | 205011.0 | 6°9'52.68" | 99°49'32.71" | $4.93 \times 10^4$ |
| 7 | 686659.0 | 212172.0 | 6°12'2.13" | 99°53'24.94" | $1.64 \times 10^3$ |
| 8 | 690313.0 | 215289.0 | 6°14'1.68" | 99°55'5.68" | $1.61 \times 10^2$ |
| 9 | 698599.0 | 214631.0 | 6°18'31.34" | 99°54'42.73" | $1.33 \times 10^4$ |
| 10 | 703626.0 | 291326.0 | 6°21'27.61" | 100°36'17.97" | $2.46 \times 10^4$ |
| 11 | 697621.0 | 213897.0 | 6°17'59.36" | 99°54'19.02" | $1.83 \times 10^4$ |
| 12 | 697812.0 | 224062.0 | 6°18'7.45" | 99°59'49.78" | $1.74 \times 10^4$ |
| 13 | 694847.0 | 228506.0 | 6°16'31.71" | 100°2'14.93" | $2.28 \times 10^4$ |
| 14 | 691226.0 | 232114.0 | 6°14'34.45" | 100°4'12.98" | $3.54 \times 10^4$ |
| 15 | 689046.0 | 235482.0 | 6°13'24.06" | 100°6'2.95" | $2.59 \times 10^4$ |
| 16 | 686905.0 | 238787.0 | 6°12'14.92" | 100°7'50.85" | $1.42 \times 10^4$ |
| 17 | 685235.0 | 241876.0 | 6°11'21.07" | 100°9'31.65" | $1.85 \times 10^4$ |
| 18 | 682730.0 | 244670.0 | 6°9'59.98" | 100°11'2.97" | $1.83 \times 10^4$ |
| 19 | 680027.0 | 247386.0 | 6°8'32.42" | 100°12'31.79" | $2.31 \times 10^4$ |

Table 2: Plankton density in Kedah waters.

| Sampling Station | Reflectance | | Sampling Station | Reflectance | |
|---|---|---|---|---|---|
| | Band 1 | Band 2 | | Band 1 | Band 2 |
| 1 | 27 | 29 | 11 | 11 | 4 |
| 2 | 24 | 15 | 12 | 18 | 8 |
| 3 | 14 | 6 | 13 | 19 | 9 |
| 4 | 24 | 12 | 14 | 23 | 11 |
| 5 | 24 | 15 | 15 | 23 | 11 |
| 6 | 16 | 6 | 16 | 22 | 11 |
| 7 | 22 | 9 | 17 | 24 | 11 |
| 8 | 17 | 15 | 18 | 24 | 12 |
| 9 | 25 | 17 | 19 | 25 | 11 |
| 10 | 10 | 3 | | | |

Table 3: Reflectance value of NOAA AVHRR at each sampling point.

| Band analysed | band 1 | band 2 | $\frac{band1}{band2}$ | $\frac{band2}{band1}$ |
|---|---|---|---|---|
| $r^2$ | 0.4076 | 0.2438 | 0.7000 | 0.7017 |

Table 4: Correlation coefficient ($r^2$) between phytoplankton density and reflectance

Figure 3 shows the phytoplankton distribution over Peninsular Malaysia waters which was calculated using non-linear equation of $\frac{band2}{band1}$. In Figure 3, the density of phytoplankton is high in the Straits of Malacca compared to the South China Sea. The highest phytoplankton density areas are between 10 – 50 km off the shore, and located mainly off Perak. Northern area is higher phytoplankton density than the southern. Chua and Chong (1973) reported that the northern straits is low in phytoplankton content compared to other areas, and becoming high towards the south. Meanwhile, Abdul-Hamid and Abdul-Talib (1994) reported that there was high phytoplankton content in the northern areas. They also reported that phytoplankton density is as high as $9 \times 10^4$ cell/litre (or $9 \times 10^7$ cell/m$^3$) in the Straits of Malacca, compared to the highest $3 \times 10^0$ cell/litre ($3.25 \times 10^3$ cell/m$^3$) in the South China Sea. In terms of number of species, they reported that the South China Sea consisted of 20 species while 120 in the Straits of Malacca.

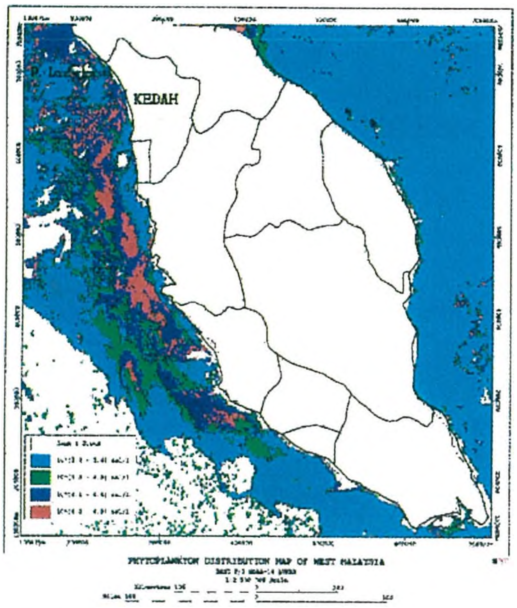


Figure 3 : Phytoplankton distribution map over Kedah sea area (Band 2/1 NOAA-14 AVHRR)

## 4.0 Conclusion

The remote sensing technique has been used widely in mapping of the distribution of phytoplankton. This study showed that NOAA-14 AVHRR satellite data is capable in mapping of distribution of phytoplankton using band 1 and band 2. The ratio of $\frac{band2}{band1}$ is the best technique for extracting phytoplankton information. The output of this study indicated that NOAA-14 AVHRR satellite data can be used as source of data acquisition in mapping techniques of phytoplankton information over large area at a low cost. Further studies should be conducted using more sampling points in every monsoon seasons to get basic ideas on the distribution of phytoplankton in the region, seasonally.


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# ANNEX 17

THE MFRDMD/SEAFDEC FIRST REGIONAL WORKSHOP ON
REMOTE SENSING OF PHYTOPLANKTON

Kuala Terengganu, Malaysia, 17-18 November, 1998

SEAFDEC/MFRDMD/WS/98/WP. 7

# GENERAL INFORMATION

## REMOTE SENSING UNIT OF MFRDMD

By:

**KU KASSIM KU YAACOB**

Marine Fishery Resources Development and Management Department
Southeast Asian Fisheries Development Center
21080 Kuala Terengganu, MALAYSIA.

**Remote Sensing Unit of MFRDMD**

- Formalized in 1993, when a Japanese remote sensing expert started the activities of the unit.
- NOAA AVHRR ground receiving system was installed (HRPT system).
- Organized by 3 staffs.

**Equipment**

**Installation (1994)**

- NOAA AVHRR HRPT Receiving system, developed by Dundee Satellite System, United Kingdom.
- Image processing system, SEASCAN, developed by SeaScan Inc. Canada.
- The system is MS-DOS based.
- Data reception :-
    - MS-DOS 6.2
    - CPU 486DX2, 16MB RAM, 2GB HDD
    - 21 inches SVGA monitor.
    - Software : Satellite Tracking System Ver 9, developed by DSS.
- Data storage :- EXABYTE Tape 8".
- Data processing : SeaScan STAR.
- Image output : SEIKO color printer

**Expansion (1997 and 1998)**

Image processing system

- New Pentium-PRO 200 PC for Image Processing.
- Windows 95
- 64MB RAM, 4MB VRAM, 2GB HDD
- Multimedia, internet ready
- Connected to LAN
- Accessories
- One unit of EXABYTE Tape Drive (8")
- One unit SONY MO Drive (2.6GB)
- One unit HP CD-Writer
- Software: PCI EASI/PACE Version 6.2
- EPSON STYLUS Colour Printer

**Maintenance**

- Since November 1997, the maintenance works are done by MFRDMD, with minimum supervision from DSS.

## Data

- NOAA AVHRR data since 1994.
- The data are stored in EXATAPE 8mm, 112m.
- One tape occupies about 20 AVHRR data.
- Each data is about 133 MB in size.

## Research

- Fish forecasting (joint venture with Universiti Putra Malaysia)
- Seagrass and ocean colour study (joint venture. with Universiti Teknologi Malaysia)
- Etc.

## Future development

### Upgrading of HRPT system to also receive SeaWiFS data

- The proposal was sent to NASA in July 1998.
- Accepted and verified on 1 September 1998.
- MFRDMD is waiting for permission from Malaysian government.
- Dundee Satellite System has been contacted for upgrading.
- Total cost will be RM100,000.00 (~USD27,000.00)
- The upgrading will include these items :-
  - Extra channel for HRPT receiver (1702.5 MHz)
  - Decryption box (given by OSC)
  - New PC for SeaWiFS data receiving and handling software.
  - SEADAS data processing software
  - SUN Workstation for SEADAS.
  - Networking for data transfer.
  - Internet ready

### SeaWiFS validation system

- The SeaWiFS Profiling Multichannel Radiometer (SPMR) will be purchased for seatruthing works.

### Training

- Once the upgrading is completed, MFRDMD will conduct training on "SeaWiFS data processing and research methodology" in 2000, for young scientists in the region.

*Dicetak oleh:*
PERCETAKAN YAYASAN ISLAM TERENGGANU SDN. BHD.
Gong Badak, 21300 Kuala Terengganu, Terengganu.