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

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COUNTRY STATUS REPORT

MALAYSIA

STATUS OF MARINE REMOTE SENSING APPLICATIONS IN MALAYSIA

By:

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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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References

Abdul-Wahid, R. and H. Mazlan. 1997. Mapping seagrass from satellite remote sensing data. Poster presented at the 18th Asian Conference on Remote Sensing, 20 - 25 October, 1997. Kuala Lumpur.

Adeli, A. 1992. Application of remote sensing techniques in marine information gathering. (In Malay). M. Sc. thesis. Fakulti Ukur, Universiti Teknologi Malaysia, Skudai, Johor.

Adeli, A. and H. Mazlan. 1997.Mapping of coastal plankton distribution using remote sensing techniques. Poster presented at the 18th Asian Conference on Remote Sensing, 20 - 25 October, 1997. Kuala Lumpur.

Ahmad-Husin, A. and A. Fahrurrazi. 1996. Change detection in Merbok areas over 22 years interval by GIS and remote sensing techniques. FRI Newsletter. Vol. 1 - No. 2. Department of Fisheries, Malaysia.

Aikanathan, S and F.H. Wong. 1994. Marine Park Island Management Conceptual Plan for Peninsular Malaysia. Report produced under Project MYS 256/93. July 1994. Department of Fisheries and World Wide Fund for Nature (WWF) Malaysia.

Anton, A. and N. Mohammad-Noor. 1996. HABs in Peninsular Malaysia: A reassessment of the issues and problems of PSP in the Malacca Straits. Paper presented at the ASEAN Marine Environmental Management: Quality criteria and monitoring for aquatic life and human health protection. Sheraton Hotel, Penang. 24 – 28 June, 1996. ASEAN-CANADA Cooperative Programme on Marine Science.

Jothy, A. A.. 1984. Status of shellfish toxicity and related problems in Malaysia. (pp. 33 - 34). In: A.W. White; M. Anraku and K.K. Hooi (eds.). Southeast Asian Fisheries development Centre, Singapore and International Development Research Centre, Ottawa.

Kawamura, G. 1986. A preliminary survey of the sea surface temperature in Malaysian waters and the Gulf of Thailand with the aid of a satellite data utilisation system. In: Mohsin, A.K.M.; Mohamed, M.I. and Ambak, M.A. (eds.). Ekspedisi Matahari 1985. A study on the offshore waters of the Malaysian EEZ. Faculty of Fisheries and Marine Science, Universiti Pertanian Malaysia. Occ. Publ. 3.

Khiruddin, A. 1998. Dual channel algorithms for retrieval of sea surface temperature from satellite thermal images. Poster presented at the 19th Asian Conference on Remote Sensing, 1998. Manila.

Khoo, E. W. 1985. Occurrences of 'red tides' along Johore Straits, resulted in heavy mortality of shrimp. World Mariculture Society. Society Newsletter.16 (1), 4.

Maclean, J.L. 1979. Indo-Pacific Red Tides. (pp. 173 – 178). In: D.L. Taylor and H.H. Seliger (eds.). Toxic dinoflagellate blooms. Proceedings of the Second International Conference on Toxic Dinoflagellate Blooms, Florida. Elsevier/ North Holland. New York, Amsterdam, Oxford.

Mahyam, M.I.; A. Fahrurrazi; A. Mohamad-Akhir and Y. Saniah. 1993. The use of remote sensing data in salinity mapping at Jubakar Lagoon, Tumpat, Kelantan. Paper presented at Seminar on Application of remote sensing data in the tropics. Universiti Kebangsaan Malaysia, 14 - 15 December, 1993. UKM, Bangi.

Mazlan, H.; A. Adeli and R. Abdul-Wahid. 1997. Integration of remote sensing techniques - GIS for mapping seagrass and ocean colour off Malaysian coasts. Paper presented at the 18th Asian Conference on Remote Sensing, 20 - 25 October, 1997. Kuala Lumpur.

Mohamad, Y. 1994. Study on sea depth using Landsat- 5 Thematic mapper (in Malay). M. Sc. Thesis. Fakulti Ukur, Universiti Teknologi Malaysia, Skudai, Johor.

Mohammed, M.I. and M. I. Ibrahim. 1991. Application of remote sensing in coastal zone management. In: Othman, B.H.R.; Mahadi, N.M.; Jaafar, A.B. and Tong, S.L. (eds.). The Marine Environment Challenges and Opportunities. Vol. 2. Ocean Studies and Management. Ensearch, Kuala Lumpur.

Mohammed, M.I. and M. Yusoh. 1992. Monitoring the development impacts on the coastal resources of Pulau Redang Marine Park by remote sensing. In: Chou, L.M. and Williams, C.R. (eds.). Proceeding 3rd. ASEAN Science and Technology. Vol. 6. Marine Science: Living Coastal Resources.

Mohammed, M.I. and B. Japar-Sidik. 1992. Application of remote sensing in the study of development impacts on marine park in Malaysia. In: Cracknell, A.P. and Vaughan, R.A. (eds.). Proceeding 18th Annual Conference of Remote Sensing Society.

Mohammed, M.I.; N. A. Hussein; M.I. Ibrahim and D. A. Kuchler. 1991. Coastal resources mapping of Besut (Terengganu coast), Malaysia using MicroBRIAN digital mapping technology and Landsat MSS satellite data. In: Proceeding Regional Symposium on Living Resources in coastal areas. Marine Science Institute, University of Philippines.

Mohammed, M. I. 1992. 1992. Remote sensing applications in the environmental monitoring of the coastal zone. In: Cracknell, A.P. and Vaughn, R.A. (eds.). Remote sensing and global climate change. Taylor and Frances, London.

Mohamad-Ibrahim, S.M.; A. Samsudin; A. Adeli and H. Kawamura. 1995. Satellite remote sensing for marine applications: Case studies on sea surface temperature and sea bottom features mapping. In: Snidvongs, A.; Utoomprukporn, W. and Hungspreungs, M. (eds.). Proceeding NRCT-JSPS Joint Seminar on Marine Science, December 2-3, 1993. Songkhla, Thailand.

Raja-Nordin, R.O. and K.Y. Ku-Kassim. 1997. NOAA images of the plumes in the South China Sea: Some preliminary observations. Poster presented at the 18 th Asian Conference on Remote Sensing, 20 – 25 October 1997, Kuala Lumpur.

Roy, R.N. 1977. Red tide and outbreak of paralytic shellfish poisoning in Sabah. Medical Journal of Malaysia. 31 (3): 247 – 251.

Seagel, G.C. 1996. Red tide database and GIS: An ASEAN-CANADA perspective. Paper presented at the ASEAN Marine Environmental Management: Quality criteria and monitoring for aquatic life and human health protection. Sheraton Hotel, Penang. 24 – 28 June, 1996. ASEAN-CANADA Cooperative Programme on Marine Science.

Shattri, M.; Quazi, K.H. and R. Abdul-Rahman. 1997. Surface temperature retrieval from satellite data over South China Sea. Poster presented at the 18th Asian Conference on Remote Sensing, 20 - 25 October, 1997. Kuala Lumpur.

Usup, G.; A. Ahmad; N. Ismail and G. Ismail. 1987. The red tide phenomenon in Sabah. Sabah Society Journal III (3): 320 – 328.

Usup, G.; J. Salimon; A. Ahmad and N. Ismail. 1988. Red tides in Sabah waters. (pp. 33 – 50). In: A. Sasekumar; R.D. Cruz and S.L.L. Hong (eds.). Proceedings of the 11 th. Annual Seminar, Malaysian Society of Marine Science, Kuala Lumpur, Malaysia.

Usup, G.; A. Ahmad and N. Ismail. 1989. Pyrodinium bahamense var. compressum red tide studies in Sabah, Malaysia. (pp. 77 – 110). In: G.M. Hallegraeff and J.L. Maclean (eds.). Biology, epidemiology and management of Pyrodinium red tides. ICLARM Conference Proceedings 21, 286 p. Fisheries Department, Ministry of Development, Brunei Darussalam and International Centre for Living Aquatic Resources Management, Manila, Philippines.

Wong, J.T.S. and T.M. Ting. 1984. Red tide and paralytic shellfish poisoning in Sabah, Malaysia. (pp. 35 - 42). In: Toxic red tides and shellfish toxicity in Southeast Asia. In: A.W. White; M. Anraku and K.K. Hooi (eds.). Souteast Asian Fisheries development Centre, Singapore and International Development Research Centre, Ottawa.

Wong, J.T.S and M.T. Thian. 1989. Management of red tides in Sabah, Malaysia. (pp. 135 - 139). In: G.M. Hallegraeff and J.L. Maclean (eds.). Biology, epidemiology and management of Pyrodinium red tides. ICLARM Conference Proceedings 21, 286 p. Fisheries Department, Ministry of Development, Brunei Darussalam and International Centre for Living Aquatic Resources Management, Manila, Philippines.

Yang, J.; C. Gu; L. Li; J. Li; C. Gao and W. Li. 1995. Satellite remote sensing prediction of Japanese pilchard fishing ground in the Huanghai Sea and the East China Sea. SCI.-CHINA-B-CHEM.-LIFE-SCI.-EARTH-SCI. 1995 vol. 38, no. 3, pp. 336-344

Yong, A. H. 1996. Baseline study of harmful algal bloom organisms in Kuching and Brunei Bay. Paper presented at the ASEAN Marine Environmental Management: Quality criteria and monitoring for aquatic life and human health protection. Sheraton Hotel, Penang. 24 – 28 June, 1996. ASEAN-CANADA Cooperative Programme on Marine Science.