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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.

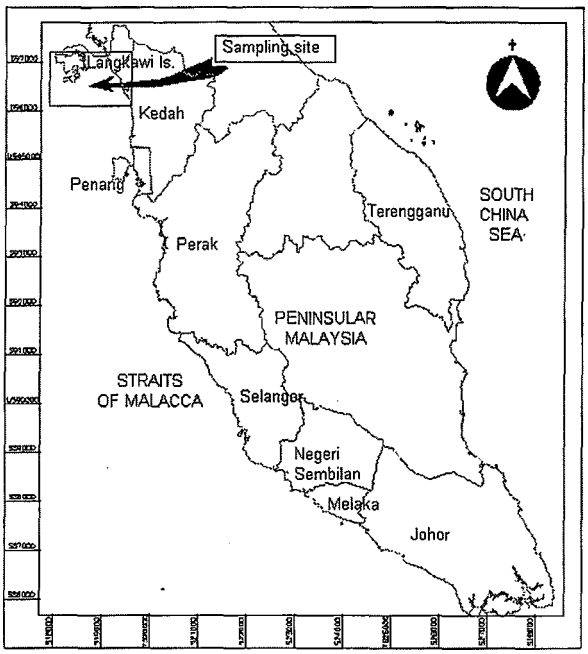

Figure 1: Peninsular Malaysia map showing sampling locations.

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 ($Wm^{-2}sr^{-1}$)
π : 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 1.61×10^2 cell per litre while the highest is at station 6 which is 4.93×10^4 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"	1.50×10^4
2	693398.0	197460.0	6°15'38.72"	99°45'24.96"	1.11×10^4
3	694303.0	190909.0	6°16'6.88"	99°41'51.62"	8.70×10^3
4	685102.0	191951.0	6°11'7.53"	99°42'27.36"	2.17×10^4
5	681154.0	196983.0	6°8'59.98"	99°45'11.84"	4.63×10^4
6	682725.0	205011.0	6°9'52.68"	99°49'32.71"	4.93×10^4
7	686659.0	212172.0	6°12'2.13"	99°53'24.94"	1.64×10^3
8	690313.0	215289.0	6°14'1.68"	99°55'5.68"	1.61×10^2
9	698599.0	214631.0	6°18'31.34"	99°54'42.73"	1.33×10^4
10	703626.0	291326.0	6°21'27.61"	100°36'17.97"	2.46×10^4
11	697621.0	213897.0	6°17'59.36"	99°54'19.02"	1.83×10^4
12	697812.0	224062.0	6°18'7.45"	99°59'49.78"	1.74×10^4
13	694847.0	228506.0	6°16'31.71"	100°2'14.93"	2.28×10^4
14	691226.0	232114.0	6°14'34.45"	100°4'12.98"	3.54×10^4
15	689046.0	235482.0	6°13'24.06"	100°6'2.95"	2.59×10^4
16	686905.0	238787.0	6°12'14.92"	100°7'50.85"	1.42×10^4
17	685235.0	241876.0	6°11'21.07"	100°9'31.65"	1.85×10^4
18	682730.0	244670.0	6°9'59.98"	100°11'2.97"	1.83×10^4
19	680027.0	247386.0	6°8'32.42"	100°12'31.79"	2.31×10^4

Table 2: Plankton density in Kedah waters.

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

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 x 10^4 cell/litre (or 9 x 10^7 cell/m^3) in the Straits of Malacca, compared to the highest 3 x 10^0 cell/litre (3.25 x 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.

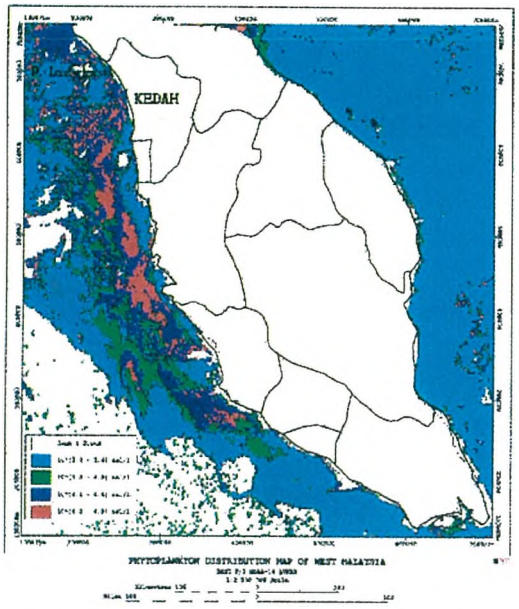

Figure 3 : Phytoplankton distribution map over Kedah sea area (Band 2/1 NOAA-14 AVHRR)

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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