Proceedings of the Seminar on

REMOTE SENSING IN MARINE RESOURCES

Central Marine Fisheries Research Institute
Cochin

April 17-18, 1985

Edited by

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Foreword

The Space Research Programme in India is applications oriented and the decision to launch an Indian Remote Sensing Satellite IRS-1, in 1986, is a major step forward. India is a vast country, full of resources and it has been recognised that for the management of these resources timely information is an important factor. Space based remote sensing technique promises such timeliness and for a National Natural Resources Management System (NNRMS) it is envisaged to have a hybrid information system consisting of an optimum mix of remote sensing based system as well as conventional systems.

Marine resources development, specifically, Fisheries development is one of the major areas demanding immediate attention. In this field work carried out in other countries have shown that remote sensing can be successfully used in mapping and monitoring of ocean features like thermal fronts, eddies, upwelling, concentration of sediments and biomass. For locating probable areas in the ocean having fish schools such information is very useful. With this in view and for learning the use of remote sensing in marine fish resources a project was carried out in the early seventies, the UNDP/FAO/GOI Pelagic Fisheries Project.

When a decision was taken to plan for an Indian Remote Sensing Satellite, in 1979, a decision was also taken to conduct Joint Experiments with the actual users so as to provide data for optimising the sensor parameters for the IRS as well as jointly develop the operational methodology for different remote sensing applications in the country. One such Joint Experimental Project for Marine Resources and Fisheries Survey has been conducted, in a comprehensive manner, jointly by Central Marine Fisheries Research Institute (CMFRI) of the ICAR, Fishery Survey of India (FSI) of the Ministry of Agriculture and the Space Applications Centre (SAC) of ISRO. The present seminar is planned to discuss and review the results of this joint experiment to help in planning the future work for the utilisation of the IRS-1 data.

The results presented in this proceedings bring out the techniques and methodologies developed for the primary sea truth data collection and extraction and mapping of biological parameters from airborne and spaceborne sensors. Efforts have been made in the difficult area of developing models for atmospheric correction of Nimbus-7 Coastal Zone Color Scanner (CZCS) data to retrieve the phytoplankton pigment. Apart from the CZCS sensor, which is optimised for ocean colour sensing, efforts were also made in the use of Landsat satellite data, which is basically designed for earth resources survey, for fish resources survey.

It is hoped that a long term plan, mutually worked out by all agencies concerned with Marine Resources Survey, will evolve out of these efforts.

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April 11, 1985

Preface

The seminar proceedings on the role of Remote Sensing in Marine Resources is the outcome of the collaborative efforts between Indian Space Research Organisation, Indian Council of Agricultural Research and Ministry of Agriculture, as one of the projects under Joint Experiment Programme (JEP) (1979-1984). The objectives of this programme were to address the spaceborne sensor requirements under Indian Remote Sensing Programme for the application of detection and mapping locations of marine living resources and also to develop methodologies for the extraction of information related to marine living resources survey from remotely sensed data.

Seminar proceedings in all contain nine papers. These papers essentially cover the following topics in terms of our understanding about the role of remote sensing in marine resources survey:-

1. Biological productivity of the Indian Ocean, developments in fisheries technology and scope of remote sensing techniques in marine fish resources survey.

2. Methods in estimating the optical parameters and their relationship with oceanic/biological parameters.

3. Ocean colour mapping from airborne and spaceborne sensors

There are three overview papers which cover a detailed discussion on biological productivity of the Indian Ocean, role of remote sensing in fish resources survey and the scope of Indian Remote Sensing Programme in marine living resources. A detailed understanding of optical processes in remote sensing of ocean colour, relationship between optical and oceanic/biological parameters has been brought out using sea truth data collected during the period preceding South West monsoon i.e. October, November and December 1981 and November 1982 in oceanic waters off Cochin. This area is well known for the occurrence and abundance of pelagic shoals of **oil sardine** and **mackerel.** Role of airborne sensors and spaceborne sensors on **Landsat** and **Nimbus-7** satellites, have been discussed in detail towards extraction of information related to fish resources survey.

We are extremely grateful to Director, Space Applications Centre (SAC/ISRO) and Director General, Indian Council of Agricultural Research (ICAR) for their keen interest and support to this programme. Thanks are due to Shri D.S. Kamat, the then Programme Manager, JEP., Prof. P.D. Bhavsar, Associate Director, SAC and Chairman, RSA, SAC and Dr. Baldev Sahai, Associate Director, IRS-Utilisation Programme and Head, Aerial Surveys Ground Truth and Photointerpretation Division, SAC for their guidance and encouragement. Our sincere thanks to colleagues at SAC, Mrs. V. Sudha, Dr. M.B. Potdar and Dr. P.C. Pandey for their support extended to us in many ways. Thanks are also due to Assistant Director of Cochin base, Fishery Survey of India (FSI), Skippers and crew members of **Meena Sachatak, Meena Utpadak** (FSI Vessels), **Cadalmin I & IX** (CMFRI Vessels). NRSA's flight crew and ground truth team's efforts are also thankfully acknowledged. We would like to thank Shri K.H. Bharadiya and Shri R.V. Nair for drawings, Shri K.M. Bhavsar for photographic support and Shri Naresh Bhatnagar for secretarial assistance.

We are thankful to Shri N.K. Sharma, Librarian, SAC, Shri S.C. Raval and Shri F.N. Shaikh and colleagues for their excellent job in printing these proceedings.

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SEA TRUTH DATA COLLECTION: ESTIMATION OF DIFFUSE ATTENUATION COEFFICIENT IN OCEAN COLOUR MAPPING

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Abstract

Phytoplankton pigments in the ocean waters are the prime synthesizers in marine food chain which in turn terminate as pelagic or benthic nekton. They perform about half of the total global photosynthesis and comprise the upper consumption and production. These are the substances that have definite spectral characteristics and thereby govern the ocean colour. Through its correlation with various biological and physical processes, the quantification of chlorophyll concentration in the ocean waters provide information which is indirectly relevant to the management of fisheries. With the help of sea truth data, an attempt has been made to develop an algorithm for estimating diffuse attenuation coefficient, K at 490 nm and 520 nm of the sea water from the ratio of inherent upwelling radiances at 443 nm and 550 nm. Since K covaries with the pigment concentration present in ocean water, it can be used as an indirect measure of chlorophyll concentration. A least squares regression has been performed for K(490) and K(520) and chlorophyll concentration. The coefficients of determination and standard error of estimate for this analysis is presented. An estimation of K is useful in understanding the optical properties of ocean water types. A colour coded K-map was generated using K algorithm for ocean waters off Cochin. The sea truth data used in the present analysis, was collected preceding SW monsoon i.e., during October, November and December, 1981 and November 1982 in coastal waters over North of Cochin in the Arabian sea, which is well known for the abundance of pelagic shoals of oil sardine ***(Sardinella longiceps)*** *and mackerel* ***(Rastrelliger kanagurta)****.*

Introduction

The diffuse attenuation coefficient, K for upwelling/downwelling irradiance can be used to describe physically the optical properties of ocean waters, which makes it possible to determine marine pigment concentrations contained in the phytoplankton, (predominently chlorophyll-a). This in turn suggests the potential for obtaining rapid assessments of primary productivity over time scales required to link this productivity to commercially important fisheries. Smith and Baker (1978a) have used the spectral diffuse attenuation coefficient $K(\lambda)$ for optically classifying natural waters, whose dissolved and suspended materials are primarily of biogenic in origin in terms of the chlorophyll like pigment present in these waters. Smith and Baker (1978b) have defined 'bio-optical state' as a measure of the total effect of biological meterial on the optical properties of natural waters. It is this state of ocean waters that can be remotely sensed by means of airborne/spaceborne sensors. The bio-optical state can be suitably related to the concentration of chlorophyll-a and consequently to the primary productivity. The diffuse attenuation coefficient, K for downwelling irradiance, KE_d, is readily measured at sea and is found to be highly correlated with and dependent on the chlorophyll like pigment concentration. This pigment concentration and diffuse attenuation coefficient provide a measure of the fraction of radiant energy attenuated by phytoplankton. It may also be used as an index of primary productivity, which, in turn, indirectly give an idea of available fish stock.

The diffuse attenuation coefficient may also be used as a measure of water quality. It increases with biomass and decreases with non-algal turbidity. However, increased interception of underwater light by phytoplankton pigment causes a steepening of the light gradient and thus a reduction of the vertical extent of euphotic zone. Therefore, diffuse attenuation coefficient may be used to predict the depth of the euphotic zone (Tilzer, 1983). A relationship between the diffuse attenuation coefficient for irradiance and the chlorophyll like pigment concentration has been found with spectral irradiance data of sea water.

Methodology

Diffuse attenuation coefficient, K, for upwelling radiance L, was calculated using the following Equation (Austin and Petzold, 1981),

$$K_L = -\frac{1}{L}\frac{dL}{dZ} \tag{1}$$

with the assumption that K is a constant with depth, Z over the interval from Z_1 to Z_2, the above Equation can then be rewritten as

$$K = -\frac{1}{Z_2-Z_1}\ln\frac{L(Z_2)}{L(Z_1)} \tag{2}$$

Smith and Baker (1978a) have shown that the total diffuse attenuation coefficient, K_T for irradiance can be used to describe the 'bio-optical state' of ocean waters and can be expressed as

$$K_T = K_w + k_c \times C + K_x \tag{3}$$

where K_T (m^{-1}) is the total diffuse attenuation coefficient for irradiance, K_w (m^{-1}) is the diffuse attenuation for pure sea waters, k_c is the specific attenuation coefficient for irradiance due to plankton (chlorophyll-like) pigments, C (mg pigments m^{-3}) is the concentration of chlorophyll-a and phaeopigments in the water column, and K_x(m^{-1}) is the contribution due to attenuation not directly attributable to chlorophyll-like pigments.

Data Acquisition and Analysis

Surface and subsurface upwelling spectral radiance and downwelling spectral irradiance data were obtained using submersible Quanta Spectrometer (Techtum Instrument, Model **QSM-2500-UW**) at different stations with corresponding variation in depth in the coastal waters over North of Cochin during October, November and December 1981, and November 1982. Upwelling spectral radiance was measured at several depths and was used to calculate radiance ratios at different wavelengths. The resulting values were used to develop an algorithm for estimating diffuse attenuation coefficient, K. In addition to radiance measurements, data on Secchi disc depth or transparency and water samples for estimating chlorophyll-a (chl-a) concentration at various stations was collected.

Results and Discussion

78 data points were taken from different station depths during the period from October to December, 1981 and November, 1982. Values of K (λ) were computed for the wavelength 490 nm and 520 nm using Equation 2.

$$\log\,[K_T(490) - K_w\,(490)] \text{ was plotted against}$$

$$\log\left(\frac{L_u(443)}{L_u(550)}\right)$$

as shown in Figure 1, where K(490) is the value of total diffuse attenuation coefficient at 490 nm and $K_w(490)$ is the diffuse attenuation coefficient for pure sea water at 490 nm. A least squares fit was obtained from the total data set. Figure 1 shows 78 measured K(490) values plotted against $L_u(443)/L_u(550)$ along with the coefficients derived from the above regression analysis. Thus,

$$K(490) = 0.095\left(\frac{L_u(443)}{L_u(550)}\right)^{-1.419} + 0.022 \qquad (4)$$

where diffuse attenuation coefficient for pure sea water, $K_w(490) = 0.022$ (m^{-1}). The coefficients of determination, $r^2 = 0.90$ and standard error of estimate (S y.x) = 0.11.

In Figure 2 the log of calculated values of attenuation coefficient, K_c (490) [m^{-1}] are plotted against the log of the measured values of attenuation coefficient, $K_m(490)$ [m^{-1}]. The slope of the straight line is 0.90 which shows that the value estimated from the Equation 3 closely matches with the corresponding value of K obtained from measured upwelling radiance.

A similar type of information is obtained by plotting the measured K(520) values against $L_u(443)/L_u(550)$. Figure 3 shows the plot with the coefficients derived from the above regression analysis. Thus,

$$K(520) = 0.103\left(\frac{L_u(443)}{L_u(550)}\right)^{-1.299} + 0.044 \qquad (5)$$

with $r^2 = 0.95$ and S y.x = 0.13.

In Figure 4 the values of logarithm of calculated diffuse attenuation coefficient, K_c are plotted against the logarithm of measured diffuse attenuation coefficient, K_m values. Here the slope of the straight line is 0.97 which again shows that the estimated K values closely match with the corresponding measured values.

Relationship between Radiance Ratios

A large number of upwelling surface radiances and radiance ratios were calculated while analysing the data for developing the algorithms. An excellent correlation was found between these ratios. Figure 5 shows a plot of log $(L_u(443)/L_u(520))$ against log $(L_u(443)/L_u(550))$ for 99 points. A linear regrssion of the data yields the following relationship,

$$\frac{L_u(443)}{L_u(520)} = 0.848 \left(\frac{L_u(443)}{L_u(550)}\right)^{0.815} \qquad (6)$$

with $r^2 = 0.87$ and S y.x = 0.08.

Relationship between Chlorophyll-a and Secchi Disc Depth

Figure 6 shows the relationship between chl-a and Secchi disc depth which is expressed by the Equation for vertical attenuation of light in water (Carlson, 1977),

$$I_z = I_o e^{-1(K_w + K_b)Z} \qquad (7)$$

where I_z, is the light intensity at the depth at which Secchi disc disappears, I_o, is the intensity of light striking the water surface, K_w, is the coefficient for attenuation of light by water and dissolved substances. K_b, is the coefficient for attenuation of light by particulate matter and Z, is the depth at which the Secchi disc disappears. K_b is attenuation coefficient due to particulates and is mainly a function of chl-a concentration for open sea. Equation 7 can be rewritten as

$$Z = \left(\ln \frac{I_o}{I_z}\right)\left(\frac{1}{K_W + K_b}\right) \qquad (8)$$

The above equation has been rearranged to a linear form as

$$\left(\frac{1}{Z}\right) \quad \left(\ln \frac{I_o}{I_z}\right) = K_w + K_b \qquad (9)$$

According to the above Equation Secchi disc depth is inversely proportional to the sum of K_w and K_b. However, K_w is usually very small compared to K_b. Hence, from Equation 9 it is understood that attenuation coefficient K_b or chl-a concentration is inversely proportional to Secchi disc depth.

A plot of Secchi disc depth versus chl-a concentration given in Figure 6 was from the sea truth data over North of Cochin and shows this inverse relationship. The curve obtained is of hyperbolic nature. Figure 7 shows the plot of log-transformed ratios of Secchi disc data against chl-a concentration. The resulting Equation is

$$\ln SD = a - b \ln Chl\text{-}a$$

where SD (Secchi disc transparency) is in meters and chl-a concentration is in milligrams per cubic meter taken at various depths and in different stations. One possible explanation for this exponential relationship may be that as algal density increases, the algae concentration become increasingly light limited. In response to lower light per unit cell, more chlorophyll may be produced (Steele, 1962).

K Mapping

A colour coded K-map showing K distribution (m^{-1}) was generated using algorithm on a in-house COMTAL image processing system using Equation 4 (Figure 8). Grey values of the colour coded image after atmospheric correction of NIMBUS-7 CZCS data (Orbit 5570, Dec'l, 1979) correspond to different K values (m^{-1}). The higher grey levels in the image were flagged so as to correspond to either land/clouds. A relationship between K at 490 and 520 derived from the present data set with pigment data from sea truth is then useful in estimating pigment concentration directly from K (Figure 9). Since no synchronous sea truth data form CZCS (Orbit 5570, Dec'79) was available the chlorophyll concentration as derived from K to C relationship (Figure 9) was compared with chl-a data collected in the same area for Dec,, 15, 16, 1981. Assuming that the conditions were more or less similar during December for the year 1979 and 1981, it was found that in near shore waters chl-a value from K & C relationship was 3.0 mg m^{-3} as against the actually measured value from sea truth during December 1981 as 3.32 mg m^{-3}.

Conclusions

An algorithm for estimating diffuse attenuation, K has been developed using the data collected in ocean waters North of Cochin. The results closely match with the observations as made by Austin and Petzold (1981), employing data collected from a variety of ocean water types. The technique is useful in understanding the depth of euphotic zone which supports the plant life in the ocean. A relationship between Secchi disc depth with K is useful in employing simpler methods for estimating K on an operational basis, since K is a function of chl-a pigment concentration. By estimating K one can have an indirect estimate of chl-a concentration, which is indicative of fish stock through its conversion to other levels in the ocean food chain.

Upwelling radiance ratio after atmospheric correction could be substituted in K algorithm so as to map K values over the first attenuation length. A relationship between K at 490 nm and 520 nm with pigment concentration as shown in the present study and as well as by Austin and Petzold (1981) could then lead to estimating average chlorophyll concentration over the first attenuation length and also its distribution in euphotic zone. Apart from this it is noticed that the pigment concentration thus extracted gives a better estimate than the one obtained from the chlorophyll pigment algorithm (Gordon et. al., 1980) alone. Further details on chlorophyll mapping as derived using above mentioned pigment algorithm can be seen in another paper of this proceeding.

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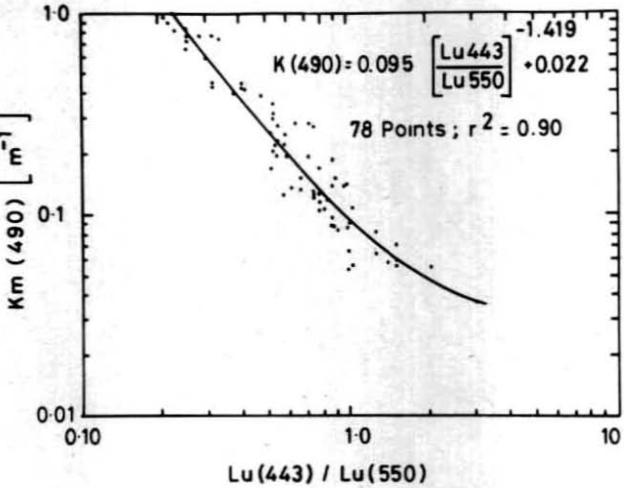

Fig. 1 Relationship between K(490) and ratio of the upwelling radiances at the ocean surface

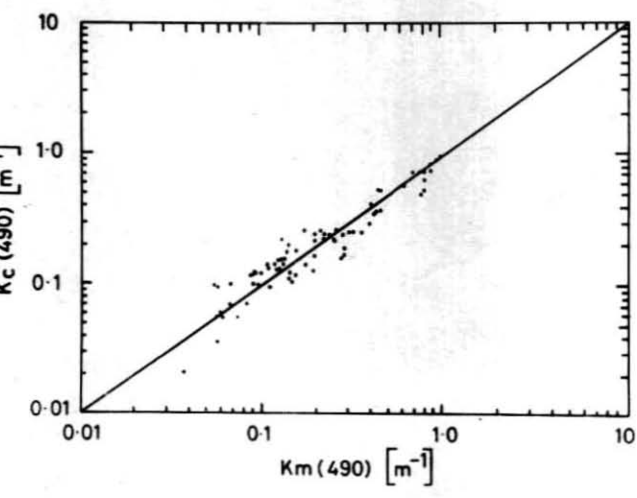

Fig. 2 Plot of calculated K(490) versus measured K(490)

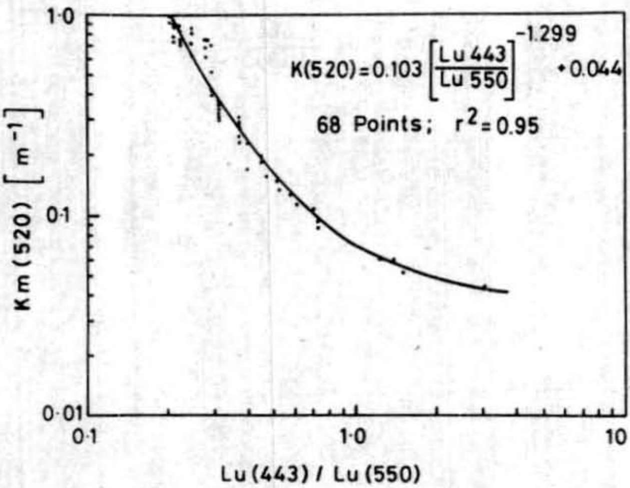

Fig. 3 Relationship between K(520) and the upwelling radiances at the ocean surface

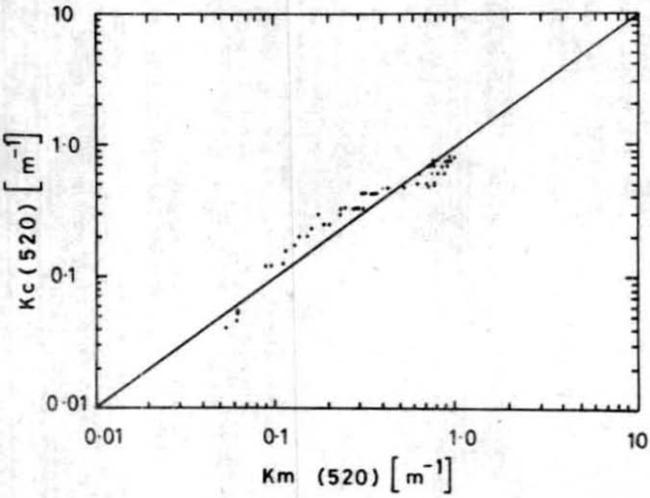

Fig. 4 Plot of calculated K(520) versus measured K(520)

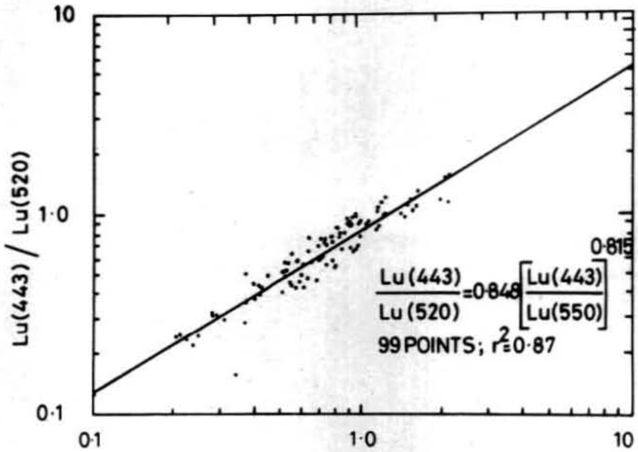

Fig. 5 Plot of the ratios of upwelling radiances

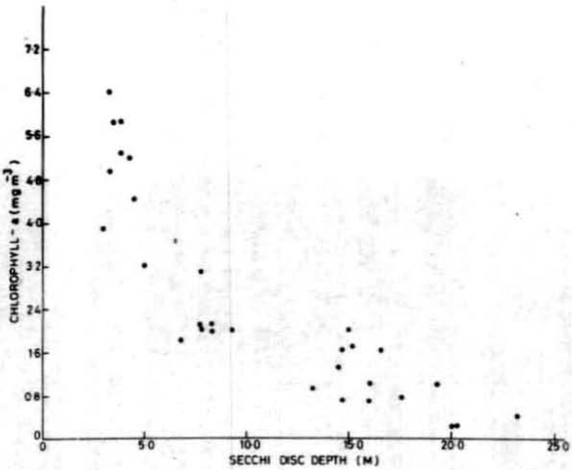

Fig. 6 Relationship between Secchi disc depth and chlorophyll-a concentration

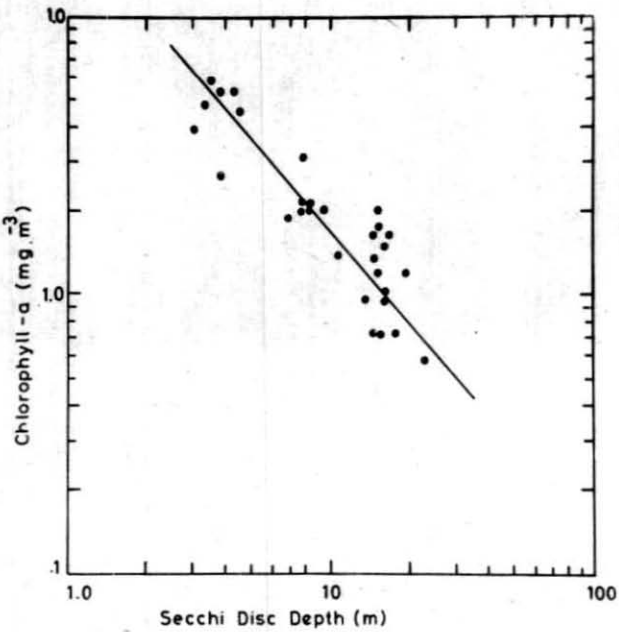

Fig. 7 Plot of log-transformed Secchi disc depth and chlorophyll-a values

Fig. 8 A colour coded K-Map showing K distribution (m^{-1}) in oceanic waters off Cochin from Nimbus-7 CZCS data (Orbit 5570, December 1, 1979)

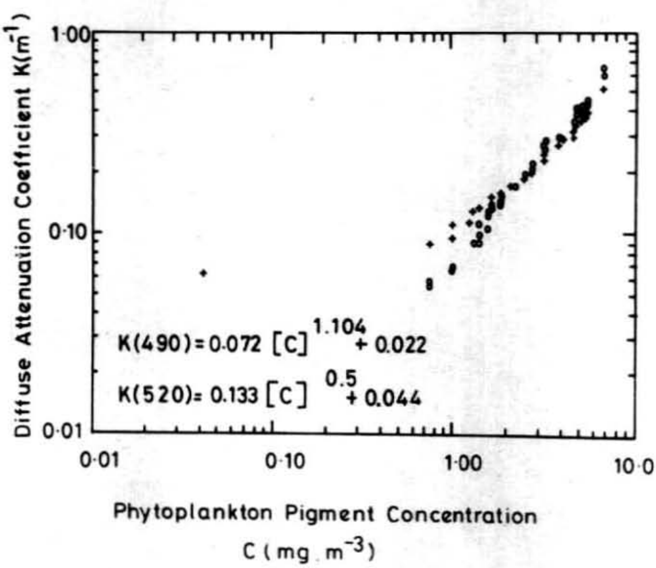

Fig. 9 Relationship between the diffuse attenuation coefficients K(490) and K(520) with phytoplankton pigment - C (chlorophyll-a) values