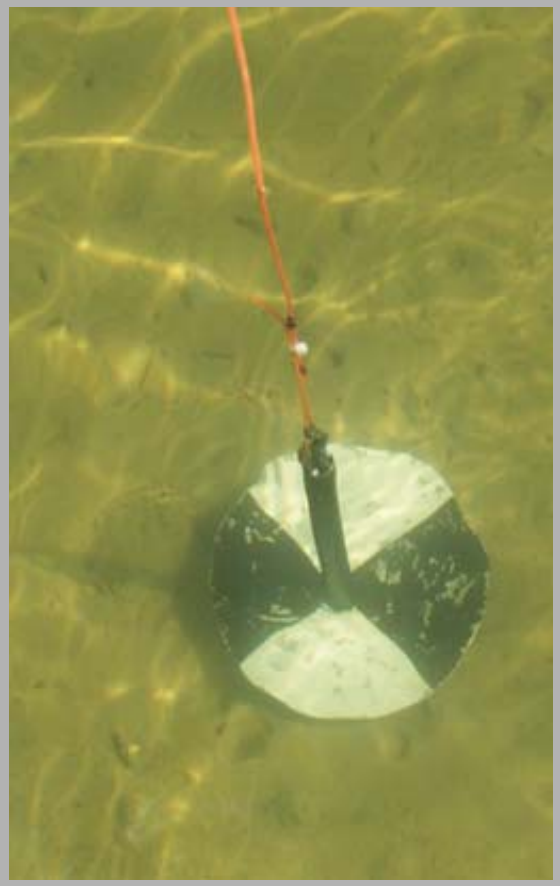
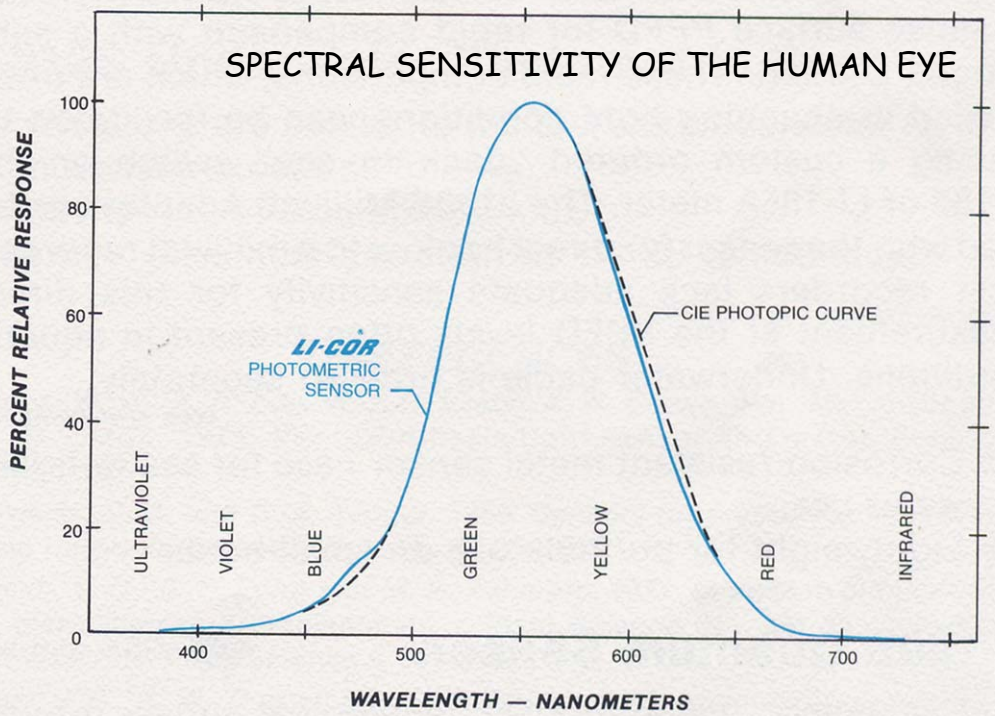
ISSUES OF SUBSURFACE LIGHT MEASUREMENTS IN ESTUARIES

PREPARED FOR RAMP MARCH 1 2006

J.O.R. JOHANSSON

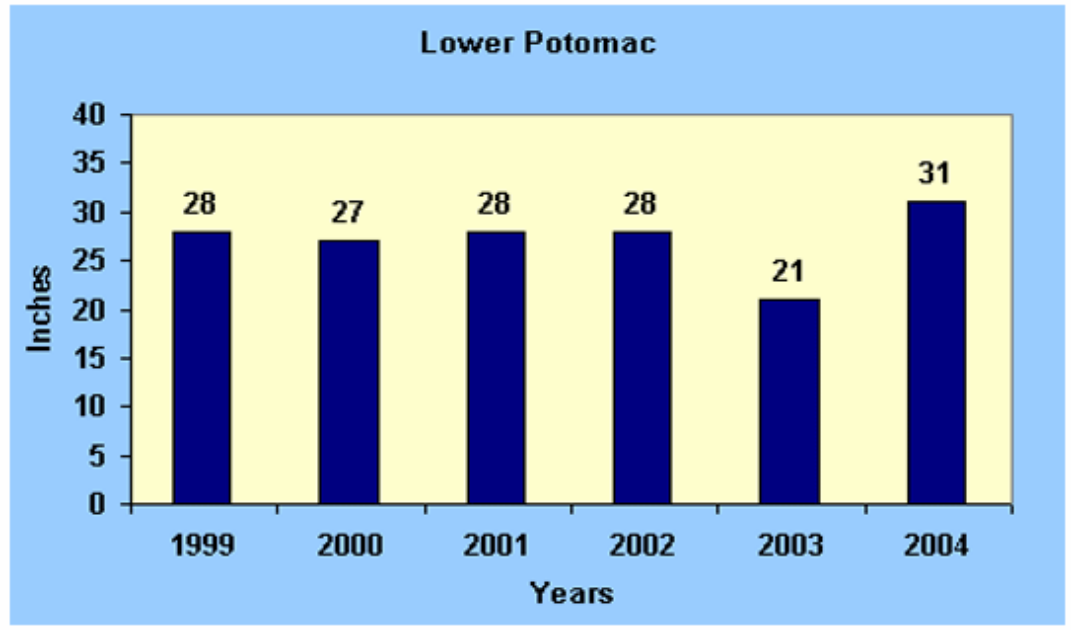
SECCHI DISK



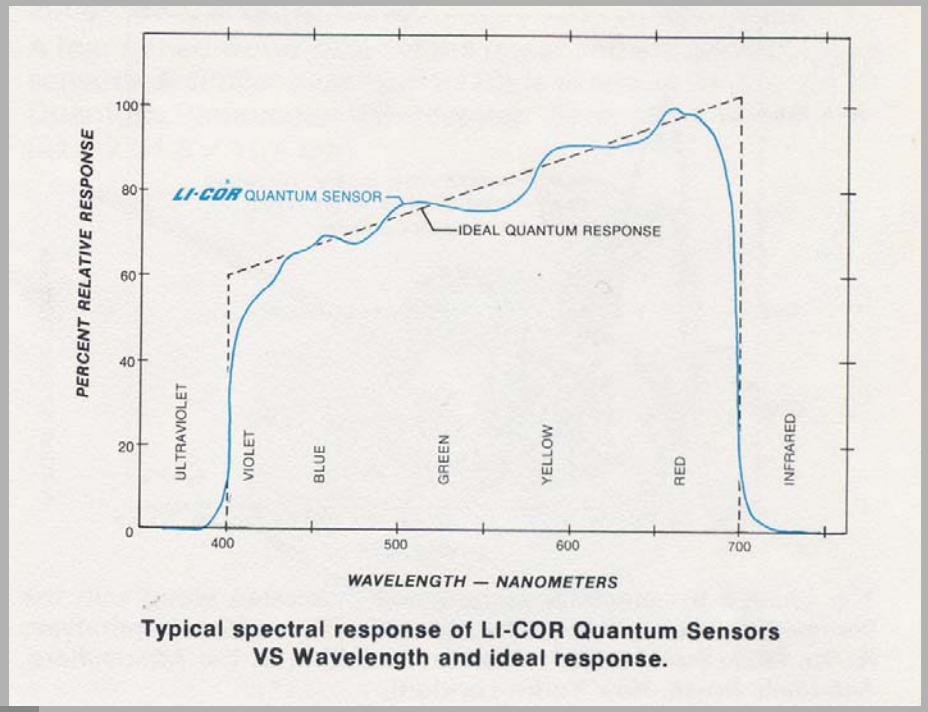


Typical spectral response of LI-COR photometric sensors vs. CIE photopic response curve. The spectral response introduces an error of less than 5% under most light sources.

Chesapeake Bay Annual Wade-In



UNDERWATER QUANTUM SENSORS



Typical spectral response of LI-COR Quantum Sensors VS Wavelength and ideal response.

Special Publication SJ93-SP13

PROCEEDINGS AND CONCLUSIONS OF WORKSHOPS ON: SUBMERGED AQUATIC VEGETATION INITIATIVE AND PHOTOSYNTHETICALLY ACTIVE RADIATION

Melbourne, Florida
July 16-17, 1992
and
January 7-8, 1993

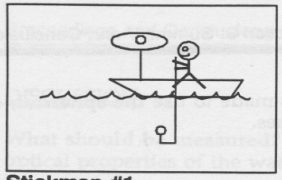
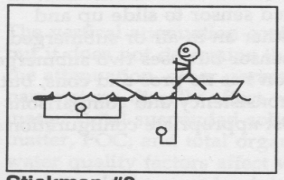
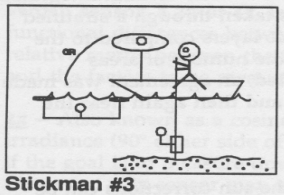
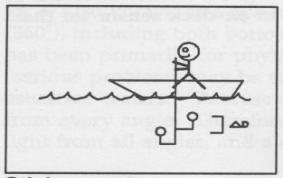
Edited by

Lori J. Morris
St. Johns River Water Management District
and
David A. Tomasko
Sarasota Bay National Estuary Program

Sponsored by

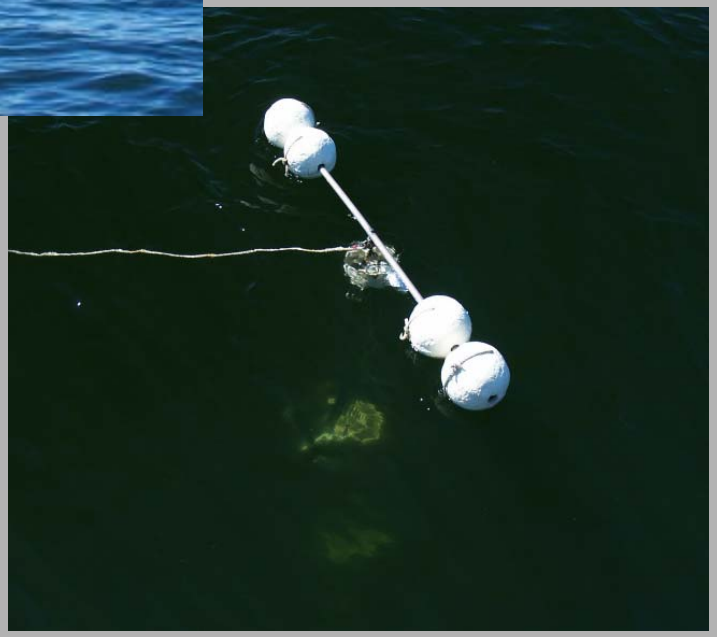
Indian River Lagoon National Estuary Program
Melbourne, Florida
St. Johns River Water Management District
Palatka, Florida
1993

Figure 1.

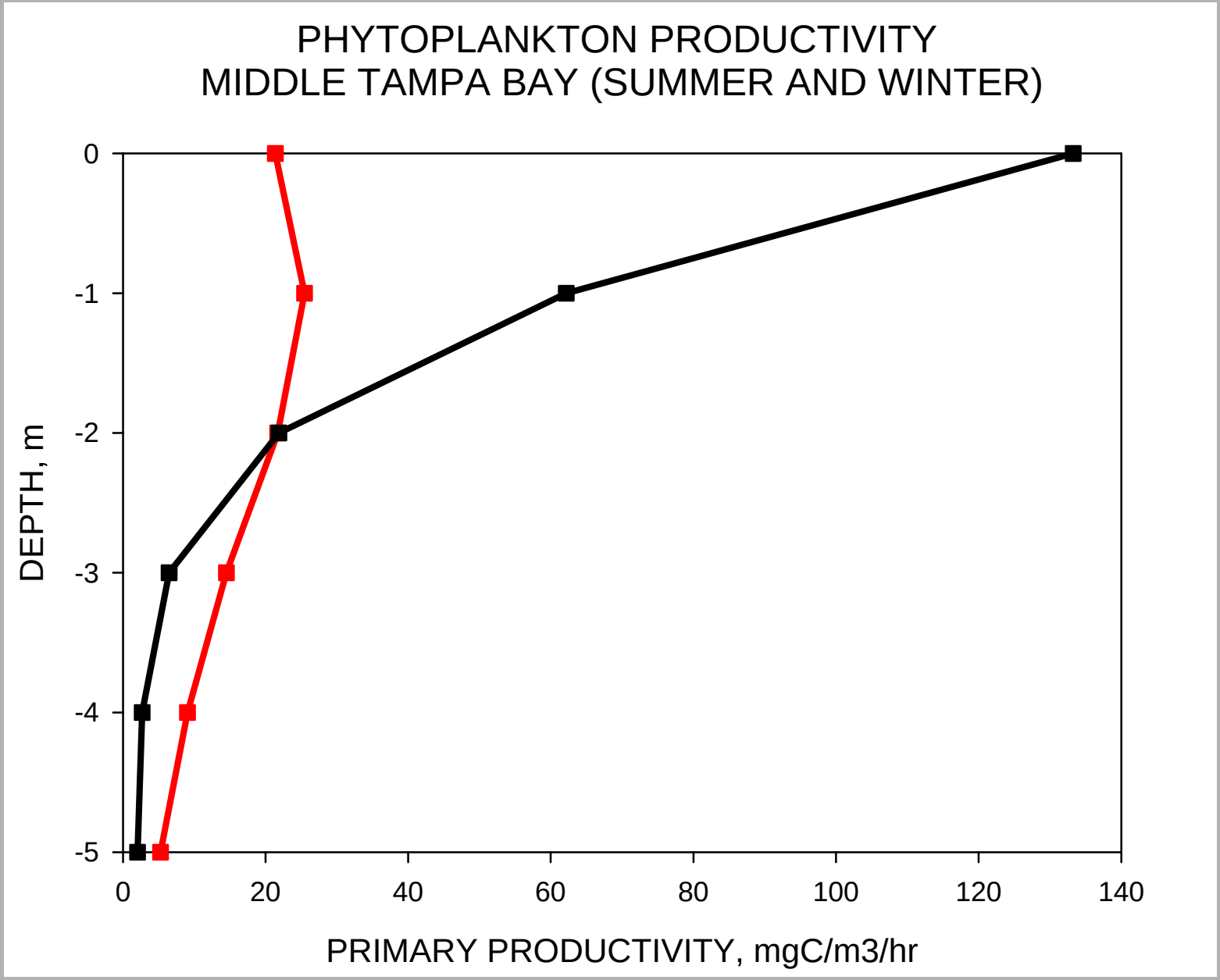
	PROS	CONS
 Stickman #1	Easily handled by one person.	Difficult to correct submerged sensor for cloud cover.
 Stickman #2	Stationary submerged reference sensor allows direct correction for cloud cover.	
 Stickman #3	Knowing exact depth of the sensor with relation to the bottom.	If boat is moving too much it will be difficult to hold the sensor steady.
 Stickman #4	Knowing fixed ΔD between the sensors at all times.	No correction for cloud or time of day. Unable to calculate K_d for integrated water column.

LIGHT POLE WITH PAR SENSORS AND TRANSMISSOMETER

PHYTOPLANKTON PRODUCTIVITY MEASUREMENTS

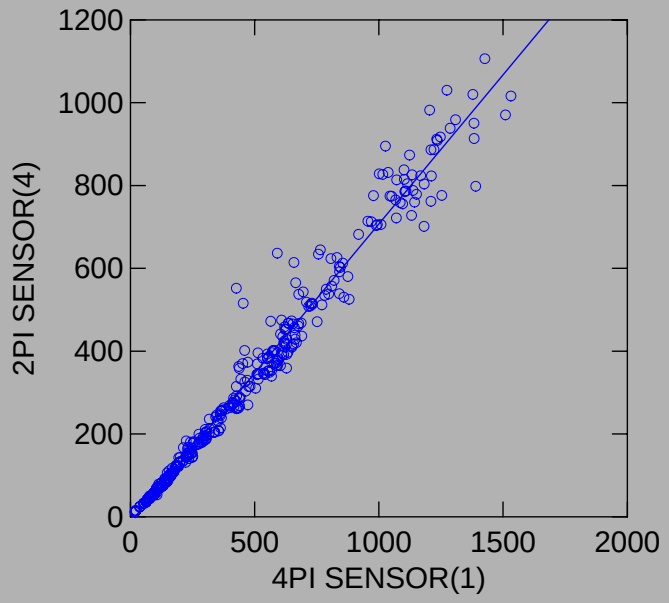


DEEP WATER LIGHT MEASUREMENTS


PHYTOPLANKTON PRODUCTIVITY
MIDDLE TAMPA BAY (SUMMER AND WINTER)
DEPTH, m
0
-1
-2
-3
-4
-5
0
20
40
60
80
100
120
140
PRIMARY PRODUCTIVITY, mgC/m3/hr

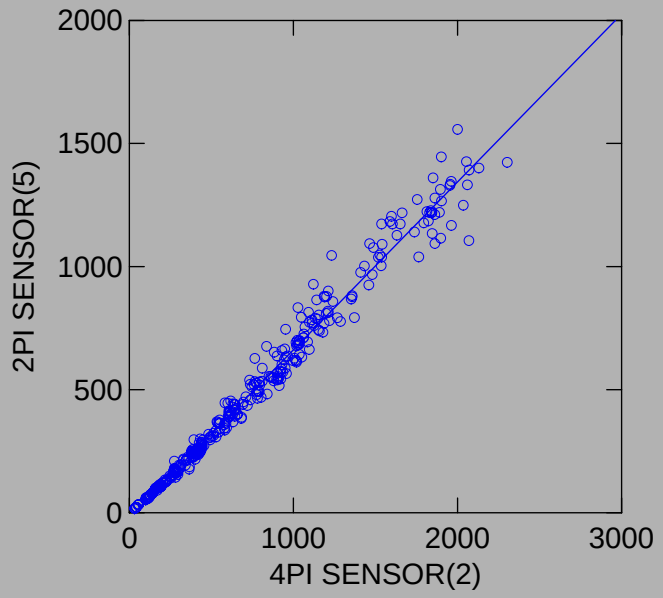
COMPARISON OF 2PI AND 4PI QUANTUM SENSORS

COMPARISON OF 4PI AND 2PI SENSORS



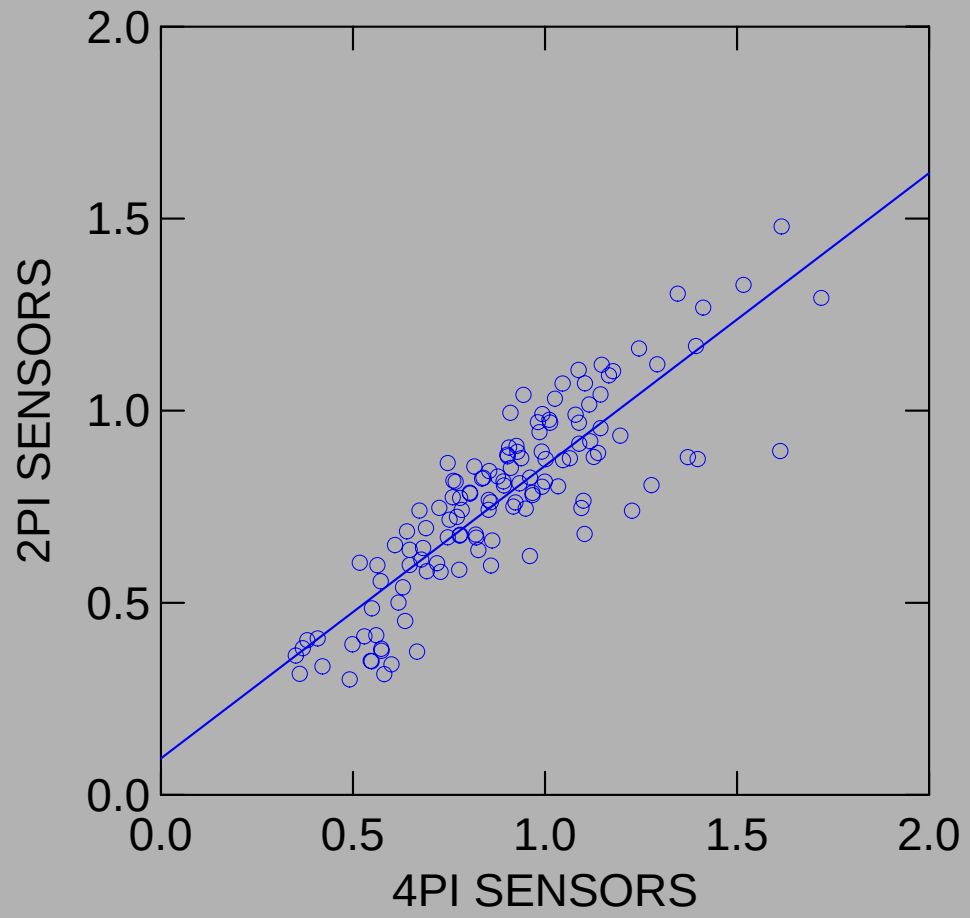
Dep Var: SENSOR1 N: 371 Multiple R: 0.988
Squared multiple R: 0.975

COMPARISON OF 4PI AND 2PI SENSORS



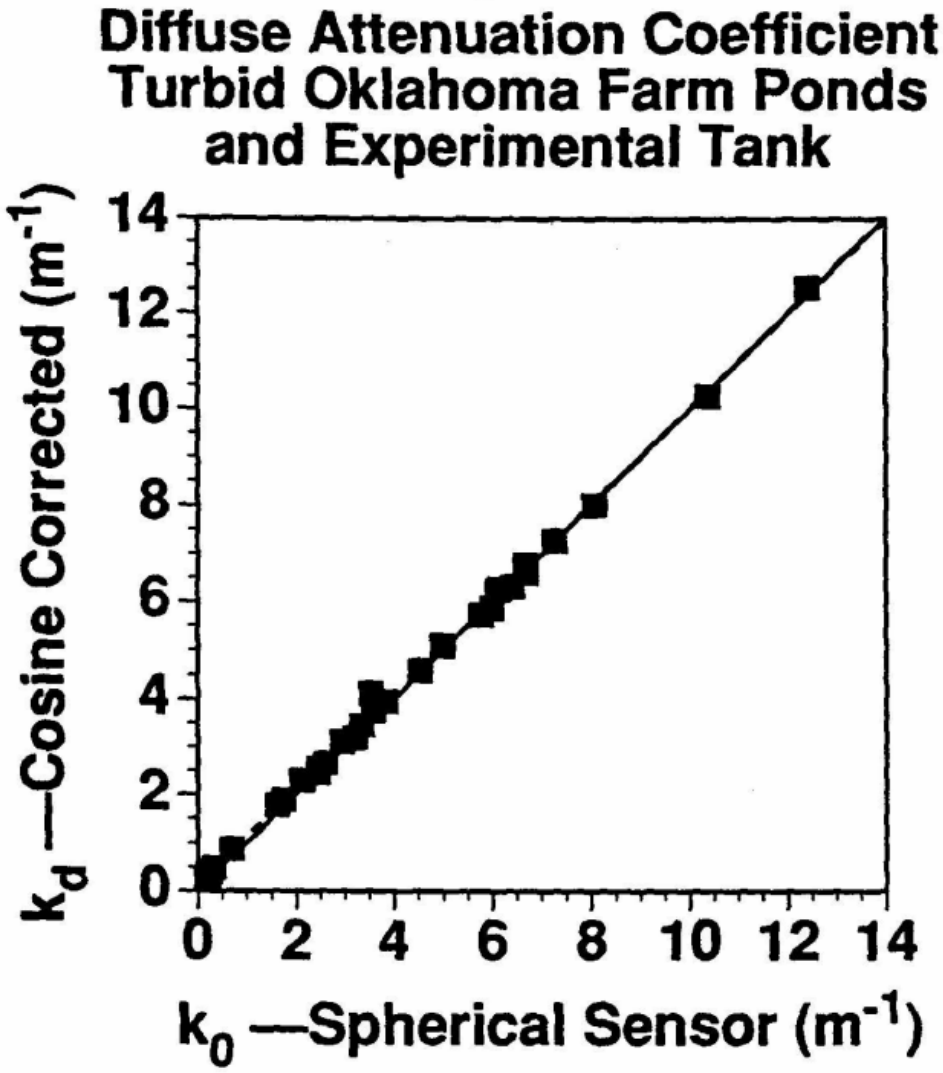
Dep Var: SENSOR2 N: 371 Multiple R: 0.992
Squared multiple R: 0.983

COMPARISON OF Kd FROM 2PI AND 4PI SENSORS



Dep Var: K12AVGP N: 127 Multiple R: 0.865 Squared multiple R: 0.748

Figure 7. Data taken in an experimental tank which started with tap water and followed the course of an induced algal bloom. There was a slight tendency for higher attenuation coefficients with the 2pi sensor.



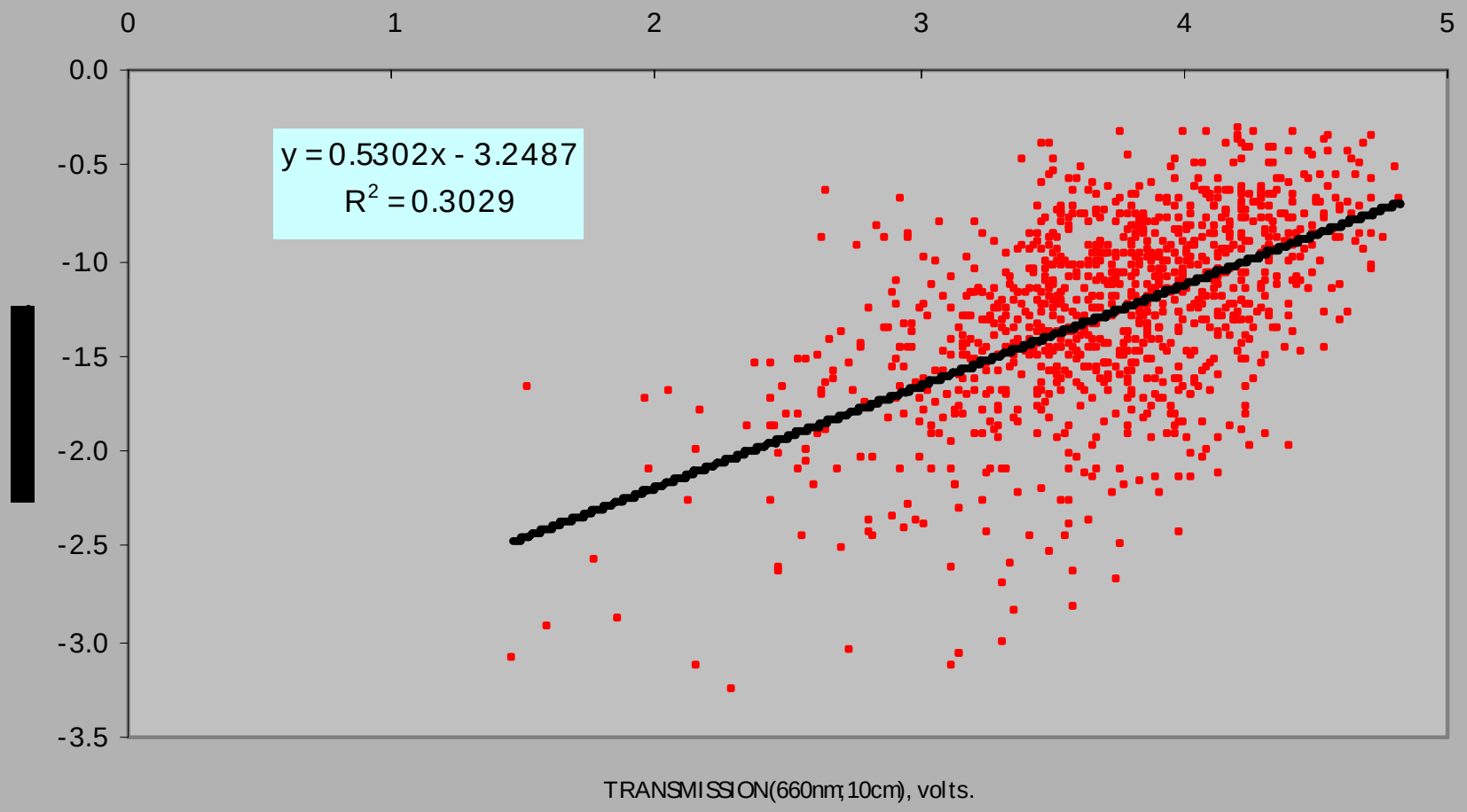
Gallegos 1993

SHALLOW WATER LIGHT MEASUREMENTS

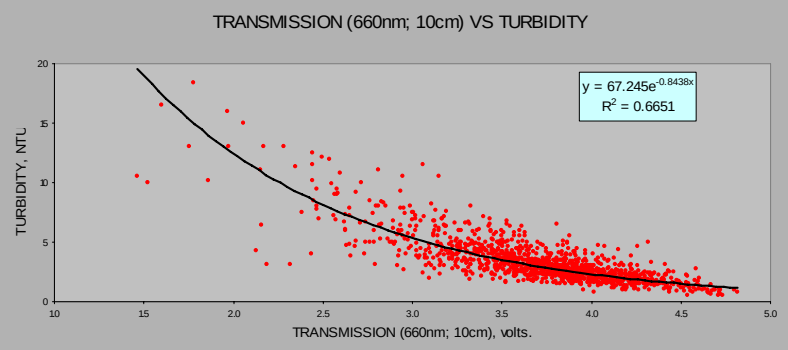
PAR SENSORS AND SD HAVE LIMITED USE IN SHALLOW AND CLEAR WATERS

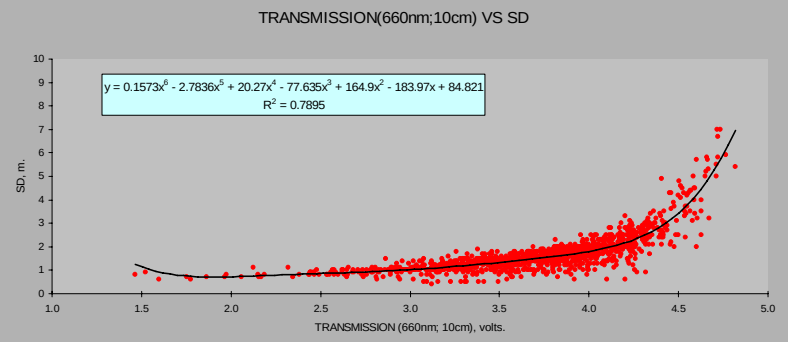
TRANSMISSOMETER (C-STAR 660nm 10cm)

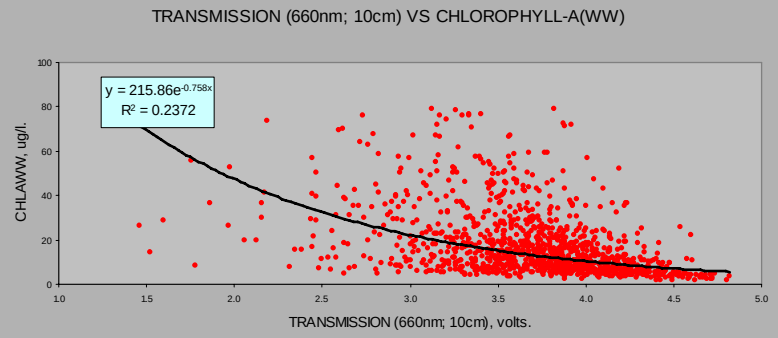
TRANSMISSION (660nm; 10cm) VS KD(PAR; 4PI)
NEAR SURFACE

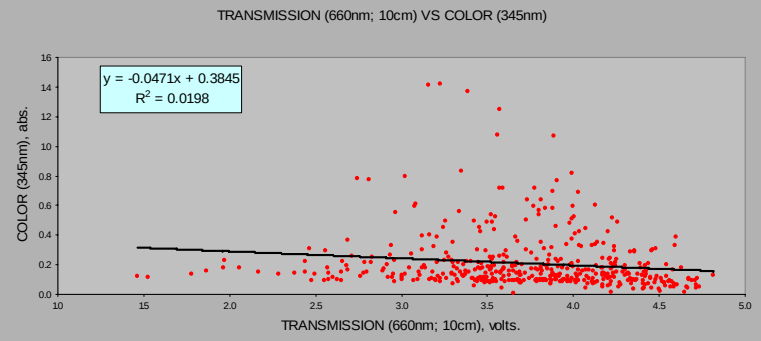


TRANSMISSION AND WATER QUALITY

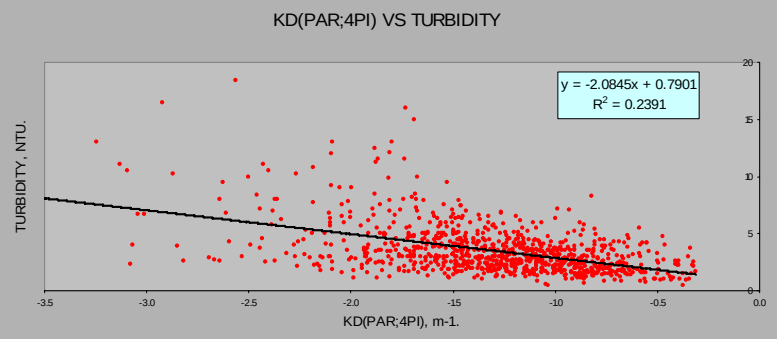


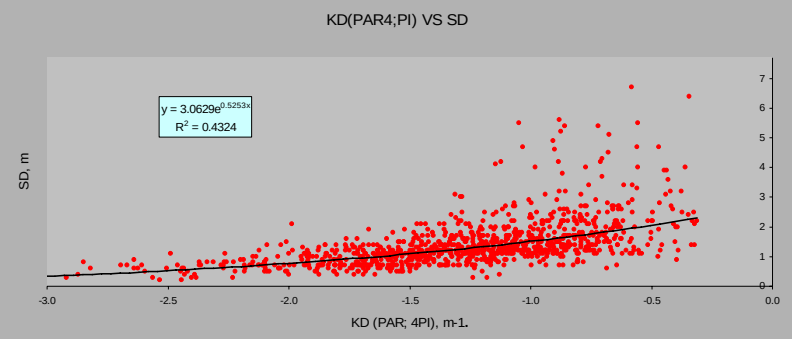


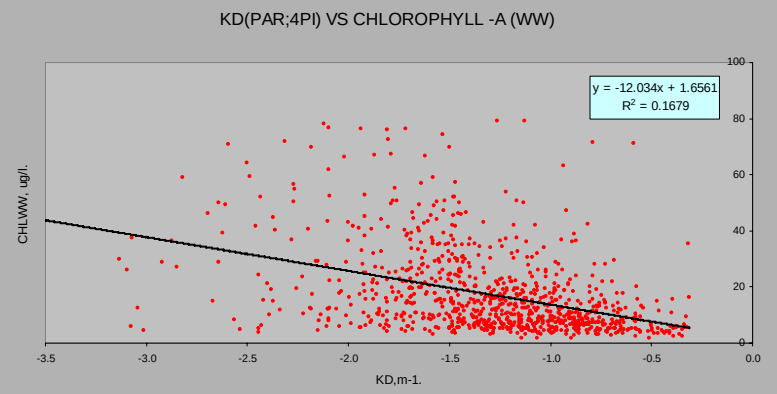


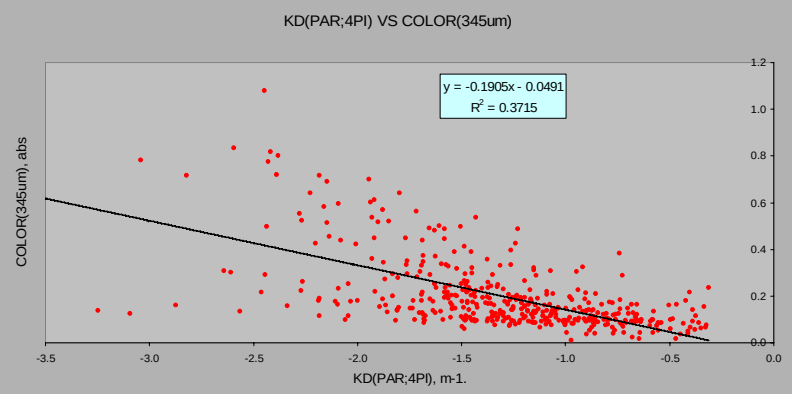


Kd(PAR) AND WATER QUALITY









EXAMPLES OF OPTICAL MODELS

DEVELOPMENT OF OPTICAL MODELS FOR PROTECTION OF SEAGRASS HABITATS [1]

by

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P. O. Box 28
Edgewater, MD 21037

Estuaries Vol. 28, No. 4, p. 572–580 August 2005

A Simple Empirical Optical Model for Simulating Light Attenuation Variability in a Partially Mixed Estuary

JIANGTAO XU*, RALEIGH R. HOOD, and SHENN-YU CHAO

Horn Point Laboratory, University of Maryland Center for Environmental Science, 2020 Horn Point Road, Cambridge, Maryland 21613

Phytoplankton (and macrophytes, if any), seston (nonphytoplankton particulate matter), and chromophoric dissolved organic matter (CDOM) contribute to light attenuation (Kirk 1994). $K_d(PAR)$ can be approximated as:

$$K_d(PAR) = K_w + K_p[PHY] + K_s[SES] + K_o[CDOM] \quad (3)$$

where K_w is the attenuation due to water, and K_p, K_s, and K_o are the specific attenuation coefficients of phytoplankton, seston, and CDOM, respectively.

Estimation of K_p, K_s, and K_o is quite challenging

Empirical Light Model Derived Using Secchi Depth

Secchi depth (SD) is routinely measured as a simple means of assessing water clarity in estuarine, coastal, and open ocean waters. It is measured by lowering a device called Secchi disc into the water and recording the depth at which it just disappears from view. In the Chesapeake Bay Program, it was measured much more often (along with water quality measurements) than the direct light measurements that we used in our analysis above. For 1995 and 1996, 3,428 SD measurements were made from 129 stations. It is tempting to use attenuation coefficients derived from these measurements for our optical model development, but the relationship between SD and attenuation coefficient is not fixed, i.e., it can vary by as much as seven fold in waters with large variations in CDOM and turbidity (Koenings and Edmundson 1991).

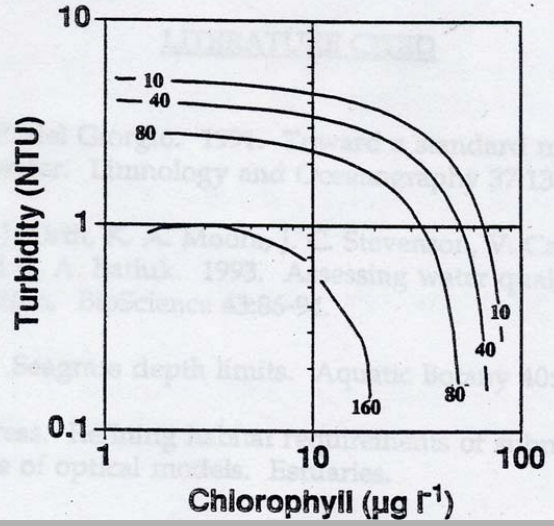
Xu et al. 2005

DEVELOPMENT OF OPTICAL MODELS FOR PROTECTION OF SEAGRASS HABITATS [1]

by

Charles L. Gallegos, Ph.D.
Smithsonian Environmental Research Center

Figure 6. Sensitivity of the 1 meter 20% penetration depth for PAR as predicted by optical model for Chincoteague Bay and Rhode River, MD, to changes in color as a function of chlorophyll and turbidity. Labels on contours indicate value of color (mg Pt.l^{-1}), which was held constant as chlorophyll and turbidity were varied.



Gallegos 1993

COLOR (CDOM) CONSIDERATIONS

Yellow Substance (Gelbstoff) and its Contribution to the Attenuation of Photosynthetically Active Radiation in some Inland and Coastal South-Eastern Australian Waters

J. T. O. Kirk

Division of Plant Industry, CSIRO, P.O. Box 1600, Canberra, A.C.T. 2601.

Aust. J. Mar. Freshwater Res., 1976, **27**, 61–71

Abstract

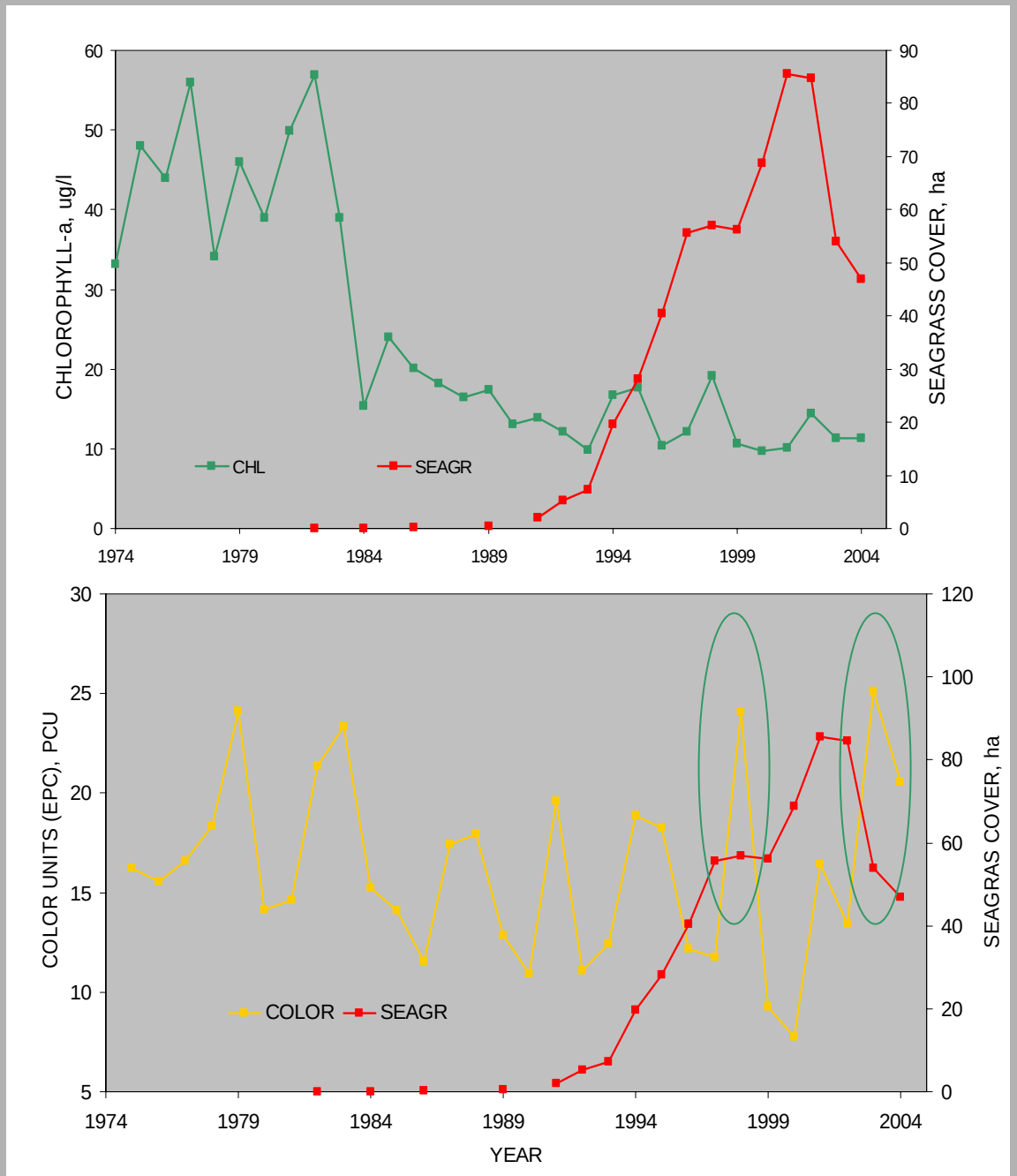
The absorption spectra relative to distilled water of samples from various inland and coastal waters in south-eastern Australia (New South Wales and the Australian Capital Territory) have been measured. Amongst the freshwater samples the level of dissolved yellow substance (gelbstoff) was found to vary seven-fold (the base-10 logarithm absorption coefficient at 440 nm ranged from 0·42 to 2·90 m^{-1}). In coastal sea water the concentration was much lower than in any of the freshwater samples (absorption coefficient 0·01–0·08 m^{-1} at 440 nm). Calculations have been carried out of the contribution made by yellow substance to attenuation of photosynthetically active radiation (PAR). In the inland waters yellow substance has a dominating influence on light attenuation, reducing the amount of PAR many-fold, and the blue region of the spectrum is abolished at quite moderate depths. In all cases except sea water it was calculated that most (60–80%) of the quanta captured are absorbed by yellow substance rather than by water.

An alternative name, 'gilvin' (Latin, *gilvus* = pale yellow), for the yellow pigments in natural waters, to replace 'yellow substance' or 'gelbstoff', is suggested.

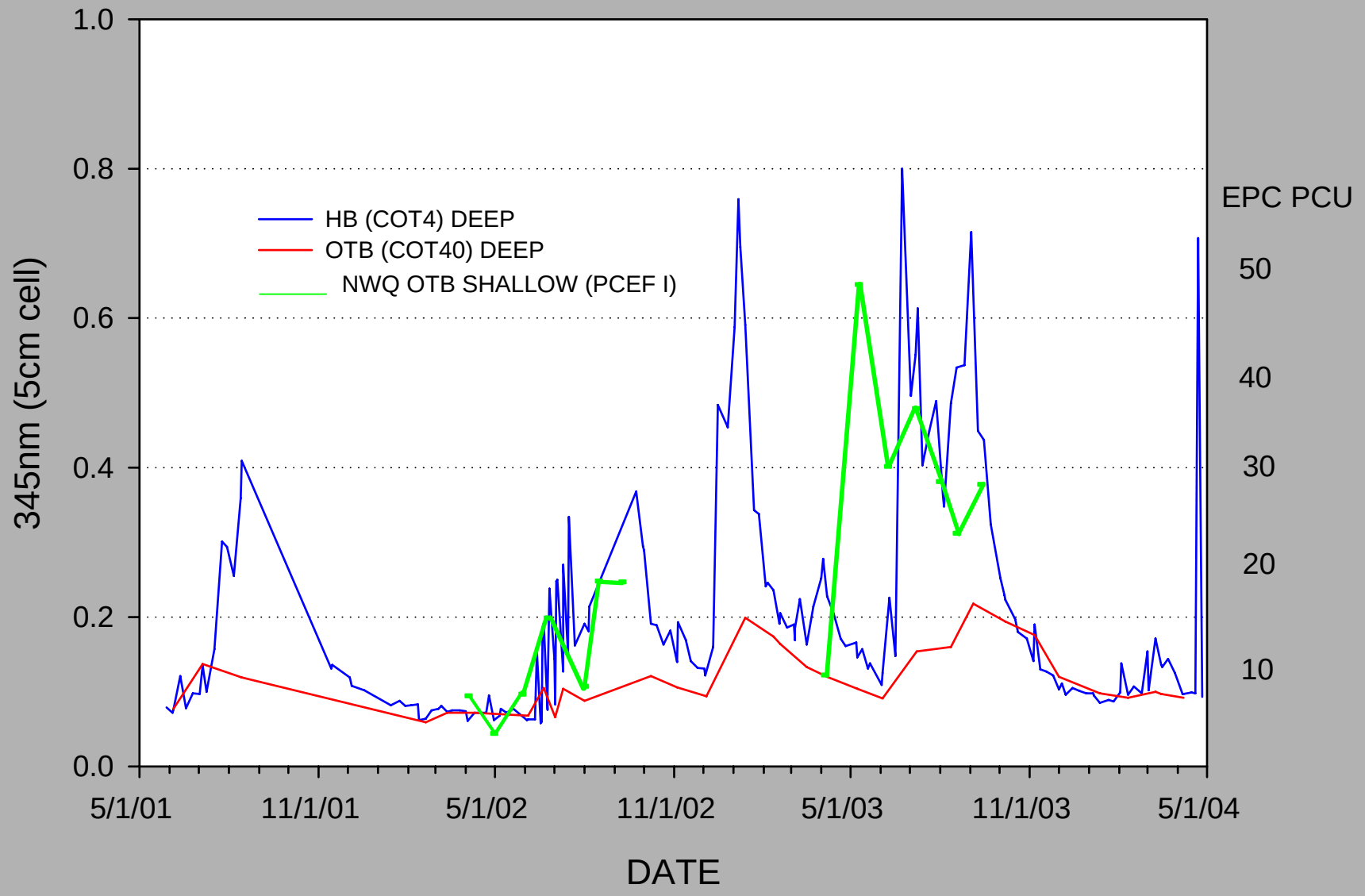
Introduction

Nearly all natural waters contain significant quantities of dissolved yellow substances which absorb light in the blue and ultraviolet (Hutchinson 1957; Kalle 1966; Jerlov 1968). These are commonly referred to collectively by the German term 'gelbstoff'. The chloroplast pigments of all algae and aquatic higher plants have absorption bands in the blue region of the spectrum (chlorophyll Soret band, carotenoid bands). The action spectrum of photosynthesis in the green algae, brown algae, diatoms and euglenas contains a broad and intense peak in the 400–500-nm region (Haxo and Blinks 1950; Mann and Myers 1968; Kirk and Reade 1970; Iverson and Curl 1973). The chlorophyll absorption bands at the red end of the spectrum are only of limited use in aquatic systems because of the rapid attenuation of red light by the water itself. Thus the ability of aquatic higher plants and many algae to photosynthesize and grow will be markedly affected by the availability of blue light which is in turn highly dependent on the concentration of yellow substance within the water.

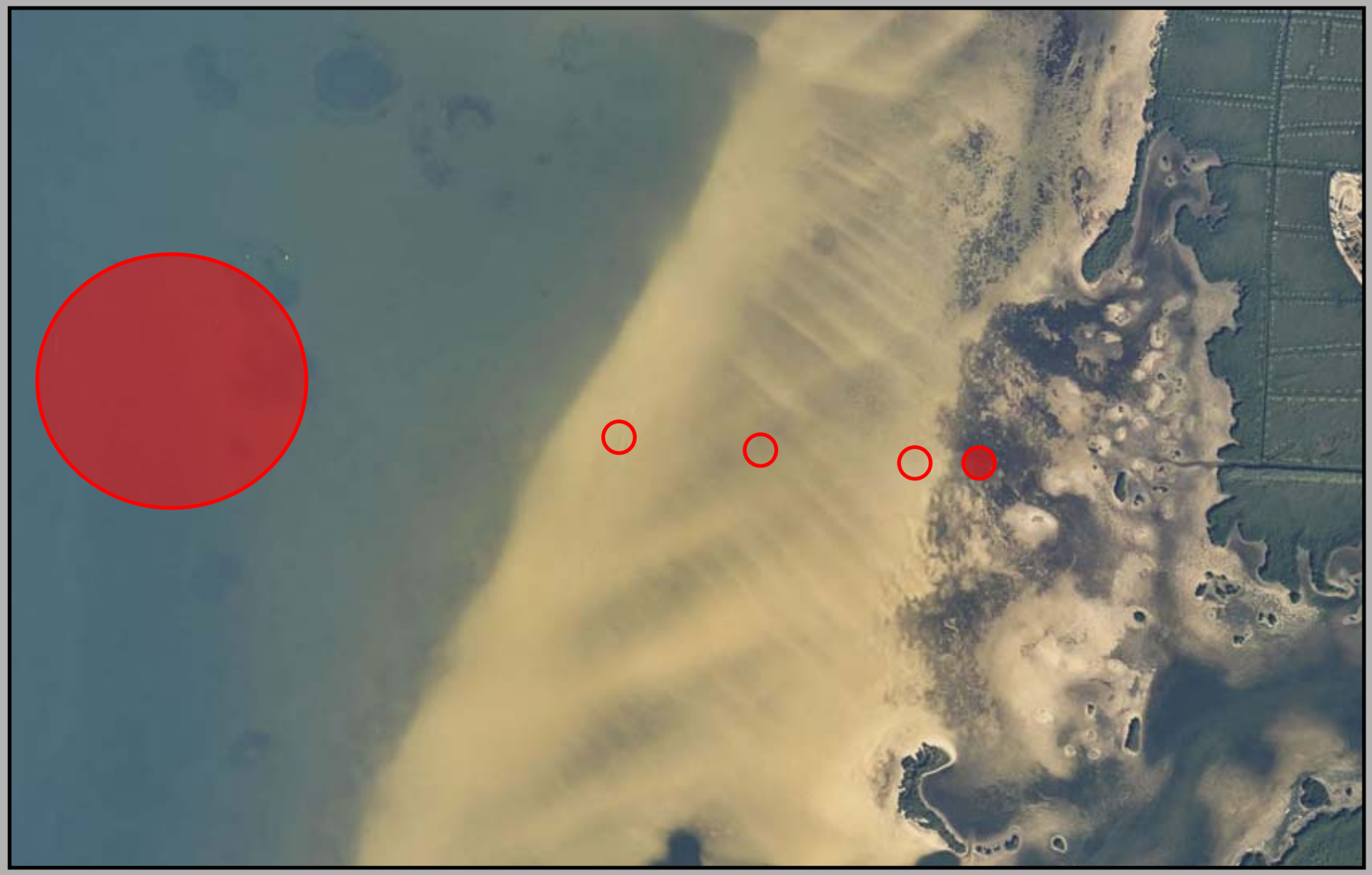
HILLSBOROUGH BAY SEAGRASS AND WATER QUALITY TRENDS



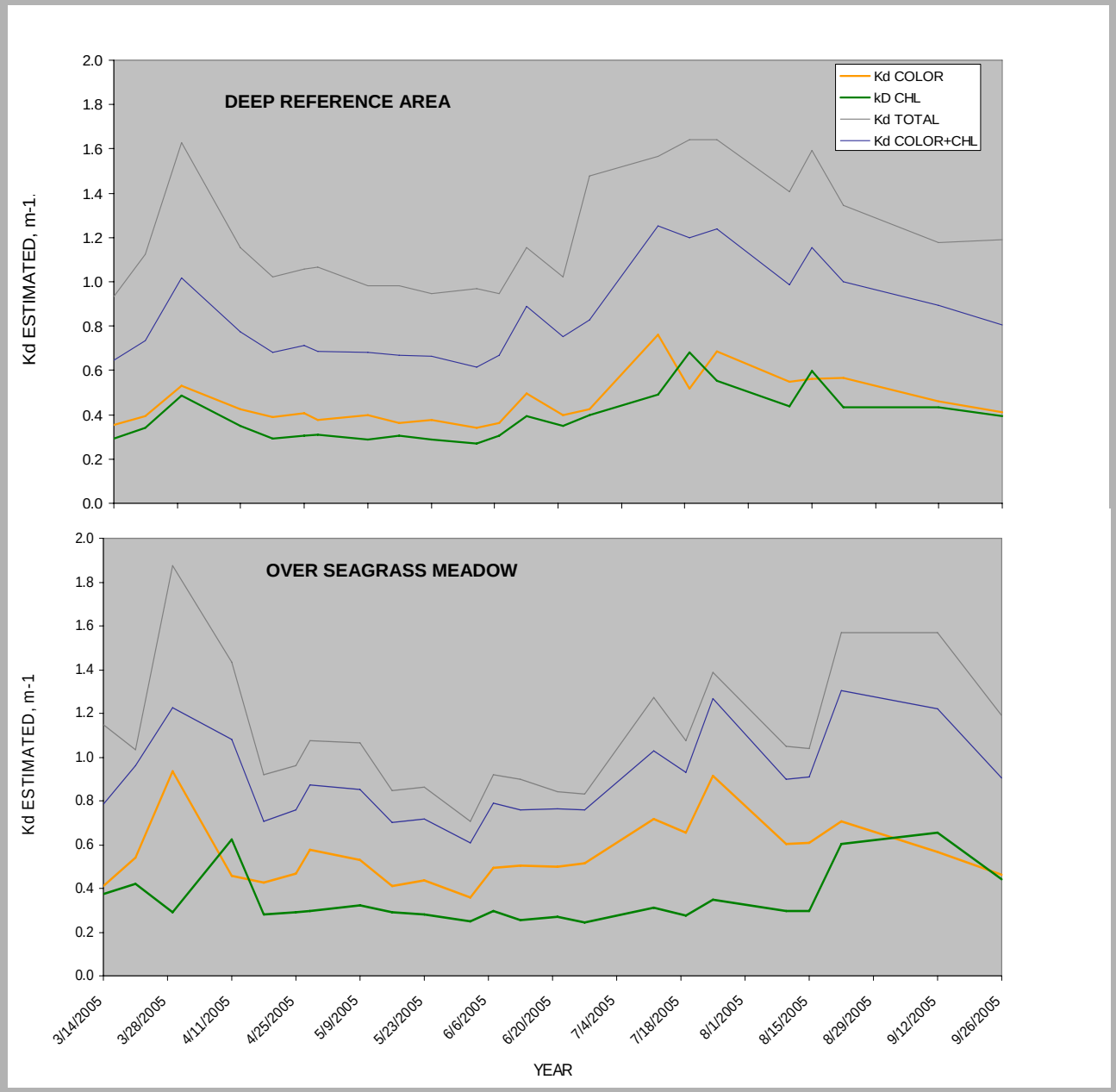
COLOR


1.0
0.8
0.6
0.4
0.2
0.0
345nm (5cm cell)
EPC PCU
50
40
30
20
10
HB (COT4) DEEP
OTB (COT40) DEEP
NWQ OTB SHALLOW (PCEF I)
5/1/01
11/1/01
5/1/02
11/1/02
5/1/03
11/1/03
5/1/04
DATE

DEEP AND SHALLOW WATER QUALITY MONITORING IN THE KITCHEN AREA OF HILLSBOROUGH BAY



ESTIMATED LIGHT ATTENUATION BY COLOR (CDOM) AND CHLOROPHYLL OVER THE SEAGRASS MEADOW IN THE KITCHEN (HB) AND AT THE DEEP REFERENCE AREA



SUMMARY

- SD and PAR sensors have limited use in shallow water.

- Transmissometers can measure wavelength specific beam attenuation (c) in shallow water, but c is not a substitute for Kd(PAR).

- The 660um transmissometer readings show strong correlations with turbidity and SD, and can provide a measure of apparent water clarity.

- Conversions of SD to Kd(PAR) may not be useful due to large variations in the relationship, specifically in waters with a large range in color (CDOM) content.

- Color has a dominating influence on light attenuation in the blue region of the of the PAR spectrum. Blue light is very important for photosynthesis in algae and higher aquatic plants. Therefore, light attenuation due to color should be accounted for in waters with high color content.

- Protection and restoration efforts of seagrass habitats should include water quality monitoring in shallow areas and the development and use of optical models which can account for light attenuation caused by turbidity, chlorophyll and color.