Variations of Light Attenuation and Relative Contributions of Water Quality Constituents in the Caloosahatchee River Estuary

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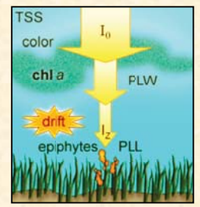
Abstract

Submersed aquatic vegetation (SAV) is an important valued ecosystem resource in the Caloosahatchee River Estuary (CRE). Light attenuation is a primary factor that controls SAV distribution and abundance. Multiple data sets collected over decades at locations throughout the estuary were compiled to examine the relationship between light attenuation (Kpar) and water quality constituents: Color, turbidity, phytoplankton [Chlorophyll a, Chl *a*] in the CRE. A statistical model was first developed to determine the relative contribution of each constituent to total light attenuation. The model was then used to assess the relative contribution of each constituent as a function of location in the estuary and magnitude of freshwater discharge at the S-79 to the estuary. On average, both color and turbidity contributed about 40% of light attenuation, while Chl *a* contributed about 10%. However, the relative contributions vary with freshwater inflows and regions of the estuary. Color was a main factor impacting light attenuation in the upper estuary and/or during the higher flow conditions. In contrast, turbidity became a major factor in the lower estuary and during lower flow conditions. The observed relative contributions of color, Chl *a* and turbidity and their variations with flow and location would be helpful with developing and assessing a restoration strategy in the system.

Introduction

- Submersed aquatic vegetation (SAV) is an important valued ecosystem resource in the Caloosahatchee River Estuary (CRE). Light attenuation is a primary factor that controls SAV distribution and abundance.
- Light is attenuated by three water quality constituents: Color, turbidity or total suspended solids [TSS], phytoplankton [Chlorophyll a, Chl *a*]. The concentrations of water quality constituents vary as a function of freshwater inflow and locations in the estuary.
- The goal of this study was to develop a light attenuation model and examine variations of light attenuation and relative contributions of water quality constituents and how they vary with freshwater inflows and locations in the estuary.



Methods

Fig. 1 Map of the Caloosahatchee River Estuary, showing segments, and water quality monitoring stations.

Table 1. Sampling stations in the four regions of the Caloosahatchee Estuarine System

Region of Estuary	Program			Km from
	ERD	CAL	CES	S-79
Upper	12,13	01,02,03,04	03,04	6-14
Middle	09,10,11	05,06,07,08	05,06	14-28
Lower	06,07,08	09,10,17	07,08	28-41
San Carlos Bay	03,04,05	18,11,12,13	na	41-49

- Water quality and light attenuation were taken at stations along the CRE (Fig. 1) collected from three programs spanning from 1995 to 2009. The Caloosahatchee Estuary (CAL) program sampled monthly water quality at 18 stations from 1994-1996. The Environment Research and Design (ERD) Program sampled 15 sites in the CRE on wet and dry seasons of each year (2000-2003). The Center for environmental studies (CES) program sampled 7 stations in the estuary and one station upstream of S-79 on monthly basis from 1999-2009. All data collected by the SFWMD or contactors working on behalf of the SFWMD. Data for CAL and CES programs are available on DBHYDRO. Data for ERD are available upon request. The CRE was divided into four regions: Upper, Middle, Lower estuary and San Carlos Bay (Table 1). Table 1 also shows associations of sampling stations with regions.
- Water quality constituents include salinity, turbidity, color, chlorophyll *a* (Chl *a*) that were sampled either at mid-depth or 0.5 m from the surface. If there were two or more samples at a station, then values were averaged. Vertical profiles of photosynthetically active radiation (PAR) were obtained at depth intervals of 0.25 m, and only PAR within 2 meters of the surface were used to calculate the light attenuation coefficient (Kd). The relationships between Kd and color, turbidity, Chl *a* were examined using multiple linear regression analysis (SAS 9.3). In the regression model, a forced intercept of 0.15 was specified. The value of 0.15 is the contribution of pure water to the total light attenuation coefficient at a depth of around 2 meters (Kelly Dixon, Mote Marine Laboratory, personal communication). The relative contributions of water constituents were calculated by dividing products of water quality concentrations and their respective linear regression coefficients by the estimated Kd.
- Average freshwater inflow (CFS) at S-79 for the 30 days prior to sampling was calculated from daily flow rate, and four flow categories (<450, 450-2800, 2800-4500 and >4500) were used to examine variations of Kd and contributions of water constituents.

Results

$$Kd = 0.15 + 0.014 \times Color + 0.049 \times Chl\ a + 0.14 \times Turbidity \quad \text{(CRE model)}$$

$$Kd = 0.3 + 0.014 \times Color + 0.024 \times Chl\ a + 0.062 \times Turbidity \quad \text{(M\&M model)}$$

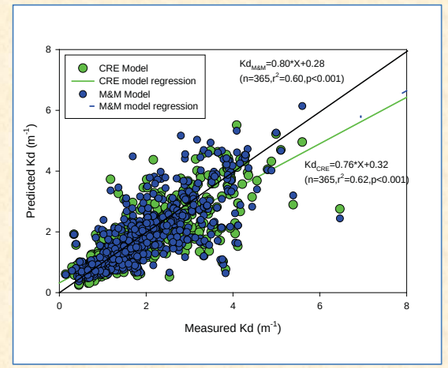


Fig. 2 Relationships between measured Kd and predicted Kd from linear regression model in this study (CRE model, green dots) and McPherson and Miller model (1994, M&M model, blue dots).

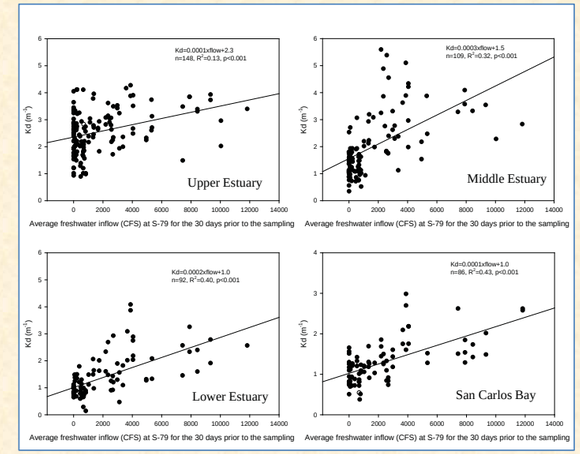


Fig. 3 Relationships between Kd and freshwater inflows in four regions. All regions show significant positive correlations. The strength of the correlations increase with distance downstream toward San Carlos Bay.

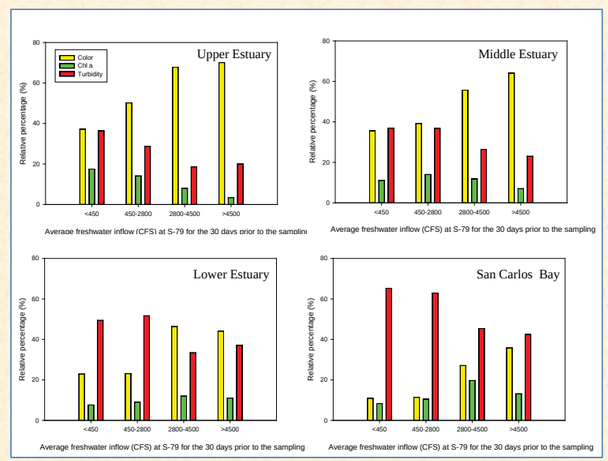


Fig. 4 Variations of contributions of color, Chl *a* and turbidity to light attenuation with flows and regions.

Table 2. Variations of contributions (%) of color, Chl *a* and turbidity to light attenuation with regions and flows

Water quality constitents	Flow < 450				Averages over regions
	Upper Estuary	Middle Estuary	Lower Estuary	San Carlos Bay	
Color	37.2	35.6	22.9	10.9	26.7
Chl *a*	17.5	11.0	7.6	8.3	11.1
Turbidity	36.4	36.9	49.4	65.3	47.0
450 <= Flows < 2800					
Color	50.2	39.2	23.1	11.4	31.0
Chl *a*	14.1	14.0	9.0	10.5	11.9
Turbidity	28.7	36.8	51.7	62.9	45.0
2800 <= flows < 4500					
Color	67.8	55.7	46.4	27.1	49.3
Chl *a*	8.0	11.8	12.0	19.7	12.9
Turbidity	18.6	26.4	33.4	45.4	31.0
Flows >= 4500					
Color	70.1	64.1	44.1	35.8	53.5
Chl *a*	3.4	7.0	11.0	13.1	8.6
Turbidity	20.0	23.0	37.1	42.5	30.7
Average over all regions and all flows					
Color	40.1				
Chl *a*	11.1				
Turbidity	38.4				

Highlights

- A new model linking light attenuation to water quality (color, Chl *a* and turbidity) was developed using 15 years' data. The model predicts Kd values comparable to those calculated using a previous model (McPherson and Miller, 1994).
- Light attenuation increased with increasing freshwater inflow in all regions. The significance of the correlations between Kd and flows increased from the upper to lower estuary.
- On average, both color and turbidity contributed about 40% of light attenuation, while Chl *a* contributed about 10%. However, the relative contributions vary with freshwater inflows and regions of the estuary. Color was a main factor impacting light attenuation in the upper estuary and/or during the higher flow conditions. In contrast, turbidity became a major factor in the lower estuary and during lower flow conditions. Chl *a* contributed the least with maximum percentage less than 20%.
- **While nutrient load reduction should improve water clarity, the degree or extent of improvement will be limited by the significant contributions of color and turbidity to light extinction.**

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