

Determining the Maximum Depth of Seagrass Beds along the Southern Outer Banks with an Optical Model



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Abstract

The goals of this project are to develop a long-term record of seagrass bed extent, focusing primarily on the historical changes that have occurred to the deep-edge, and tie this in with historical changes in water-quality. The data gathered from this internship project will be used to calibrate a model of light attenuation for seagrass habitat requirements. This model is being developed as a tool to assist managers with monitoring water-quality to protect seagrasses, a critical estuarine habitat in North Carolina.

ArcMap was used to create maps that show how Chlorophyll a, TSS, and CDOM affect water quality. Pathfinder Office was used to locate the deep-edge sites, and to put the site locations into ArcMap. Each map showed how one component's value affected water quality for one day. These raster layers were then combined using the spatial analyst extension in ArcMap to form a raster layer that gave important information on how predefined thresholds were being exceeded. The thresholds are the highest values of CDOM, TSS, and Chlorophyll that can be present and still allow enough sunlight to get to the seagrass. Areas where the thresholds were exceeded are unfavorable for seagrass growth.

Future developments for this model aim to include remote-sensing information in near-real time to enable timely and appropriate management actions to be made.

Introduction

What are Seagrasses

Seagrasses are vascular plants that grow completely underwater. They are a part of a larger group of underwater plants called SAV (Submerged Aquatic Vegetation). SAV have special adaptations to help them survive in the aquatic environment. The leaves and stems lack the waxy cuticle that is characteristic of most terrestrial plants to allow for easy exchange of gasses and nutrients between the plant and surrounding water. Specialized air-filled cells, called aerenchyma, are present in the leaves and stems and provide the plant with additional buoyancy and support. Seagrasses are distinguished from other SAV because seagrasses require a certain amount of salinity to survive.

Importance of Seagrass

There are many important ecological roles of seagrass in the aquatic environment. They provide food and habitat for waterfowl, fish, shellfish, and invertebrates. The seagrasses serve as nursery habitat for many species of fish, such as young spot and striped bass,

which seek refuge from predators in the grass beds, blue crabs also hide in seagrass. Seagrasses provide oxygen in the water column as part of the photosynthetic process. Seagrasses filter and trap sediments that can cloud the water and bury bottom-dwelling organisms, such as oysters. They protect shorelines from erosion by slowing down wave action, and they remove excess nutrients such as nitrogen and phosphorous, that could fuel unwanted growth of algae in surrounding waters. These nutrients are also required for seagrass growth and reproduction, but in much lower water-column concentrations.

Common types of Seagrass

The two types of seagrasses along the Southern Outer Banks are eelgrass (*Zostera marina*), and shoalgrass (*Halodule wrightii*). Eelgrass is the most common seagrass in this area and it is more prevalent in temperate climates. Hot weather puts stress on this species of seagrass. Shoalgrass is a more tropical seagrass and is more prevalent during the summer months on the Outer Banks. Both of these species of seagrass are normally found in the same grass beds.

Figure 1 shows when the two seagrasses occur during the year.

Phenology of 2 species in N.C.

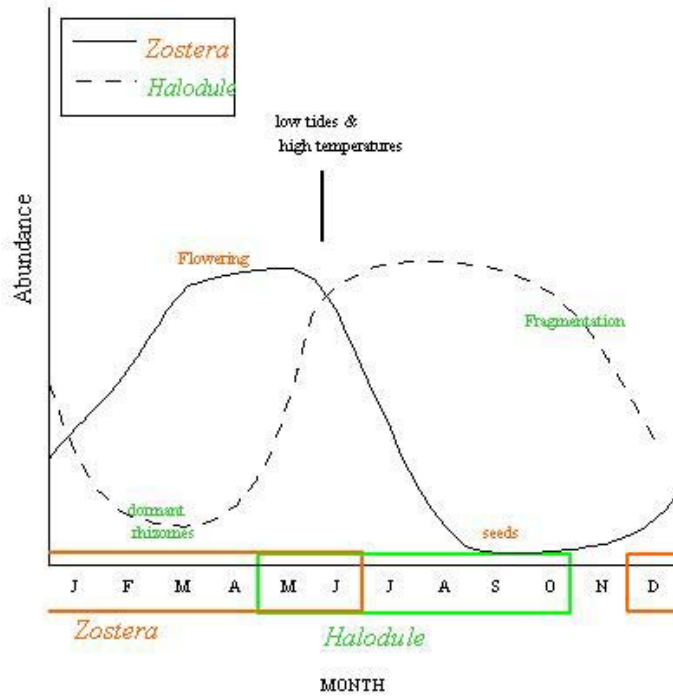


Figure 1: Abundance compared to the time of the year for both *Zostera* and *Halodule*.

Factors Effecting the Health of Seagrass

There are many factors that affect the health of seagrass, but light levels that reach seagrasses are the single most important factor determining their growth and survival. The amount of light is affected by water quality, and depth. Total suspended solids, algae, epiphytes, and nutrients that are present in the water column affect the water clarity. High sediment levels result from erosion off the land, often due to construction, forestry, and agricultural practices. Sediment levels are measured through monitoring activities. Chlorophyll can contribute to

phytoplankton and epiphyte growth that further blocks light from reaching the seagrass leaves. High nutrient levels are caused by the excessive use of fertilizers, runoff from livestock operations, and outflow from sewage treatment facilities. Nutrients allow excessive algal growth further blocking necessary light to the seagrass. The aims of this project were to:

1. Create raster layers in a GIS that show the distribution of Chlorophyll a, TSS, and CDOM in North River, NC.
2. Create maps composed of the query output from several raster layers to give managers a tool to

help manage water quality conditions for seagrass.

Methods

Validation of Deep Edge Points

Points were collected that represented the distribution of the seagrass beds in the North River, NC in 1992. The 1992 map was generated from aerial photographs, and this map was used as a starting point or reference in this project. From the distribution map, multiple points were selected along the deep-edge of the seagrass bed at 5 locations in the North River. These points were visually verified on June 2, 2004 (Figure 2) and the spatial coordinates of the existing deep-edges were collected using a Trimble GPS and then displayed in Pathfinder Office ver.2.9. The settings and procedures were as follows:

1. Data representing the edge of seagrass was loaded into a hand held Trimble GPS device.
2. The device was turned on.
3. The GPS device searched for a signal from satellites and a differential correction signal tower from a near by Coastguard station (Ft. Macon).
4. The Navigate menu was pressed on the display, and then the Target menu.
5. Visual verification took place once the first coordinate was loaded into the GPS.

In the field, we used a small powerboat to navigate to the saved coordinates and started to look for dark patches in the water, these were the seagrass beds. A new seagrass edge was recorded using

the GPS device. The settings and procedures for this were as follows:

1. The Data Collection menu was pressed.
2. The file was named BRP1 for Bottle Run Point 1.
3. The record button was pressed to record a line.
4. The boat was moving down the line as the GPS was recording.

The GPS recorded spatial coordinates continuously along the deep edge until a minimum of 50m had been mapped. These two procedures were repeated for Bottle Run Point B, and Goose Bay points 1, 2, and 3. The points collected were loaded onto Pathfinder Office by the following procedure:

1. The icon for Pathfinder Office was selected.
2. The GPS device was connected to the CPU by USB cable.
3. A new project was selected in Pathfinder Office.
4. The GPS was turned on.
5. The utilities menu was pressed on Pathfinder Office
6. The Data transfer menu was pressed on Pathfinder Office
7. The file manager menu was pressed on the GPS and the files were transferred.

Once the files were put into Pathfinder Office they had to be saved as shape files so they could be added as layers in ArcMap. Once added into ArcMap the points for the 1992 seagrass edges were compared to the points recorded on June 2, 2004, and they were found to be almost identical.

9 Sites

- Turbidity/Color gradient
- 3 regions along gradient
Middle + Lower region has seagrass
- 3 Stns per region
Sampled 1 day/mo.
Water - chl a/TSS/C-DOM
LiCor+YSI profile (0.5m inc.)
Secchi depth

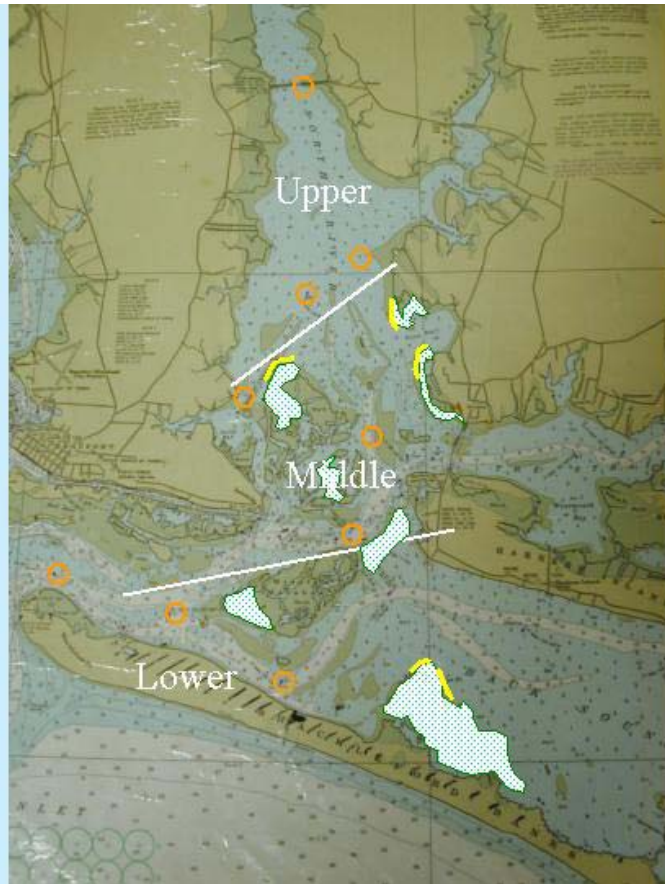


Figure 2: The orange circles represent the nine water quality testing sites. The green patches represent the seagrass beds from an aerial photograph in 1992, and the yellow lines represent the measurements of the five deep edge sites that were recorded on June 2, 2004.

Creation of a Base Map for Nine Water Quality Sites

The focus of this project was on the North River. Nine sites were tested for their CDOM (Color Dissolved Organic Matter), Chlorophyll, and Turbidity

levels in the North River. Three sites were tested in the upper region, three in the middle region, and three in the lower region of North River (Figure 2).

ArcMap was the program used to complete this project. ArcMap is a desktop application in ArcGIS, and it was used along with the Spatial Analyst Extension to ArcMap to visually represent the data in this project. A base map was created using three layers in ArcMap (Figure 3).

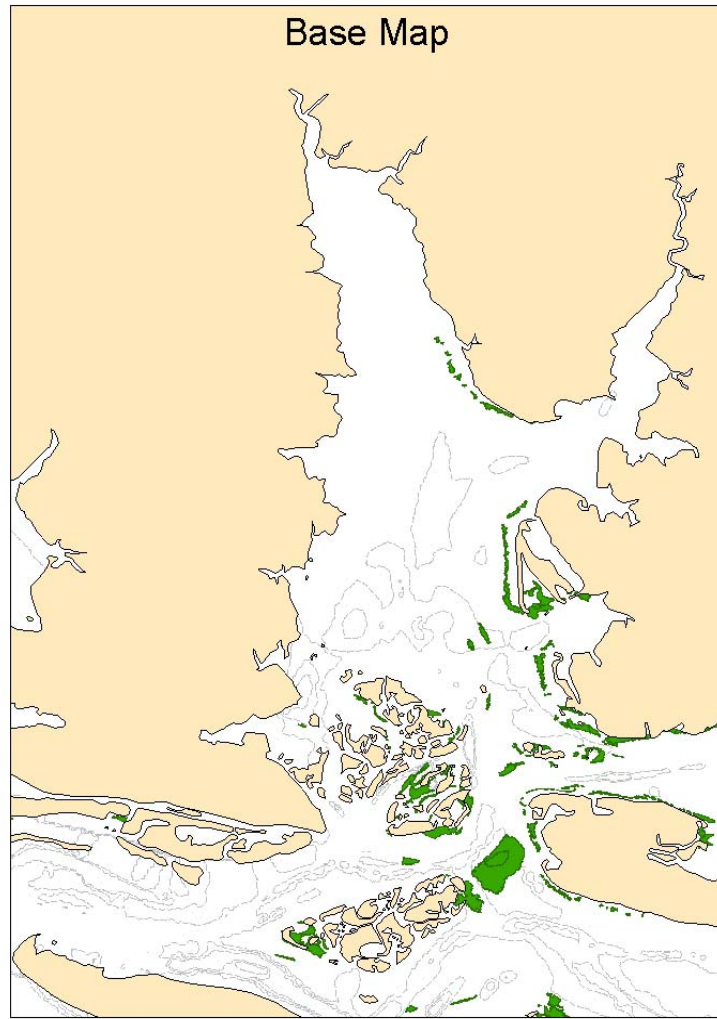


Figure 3: The tan land surface is the North River Layer. The green patches represent the seagrass layer, and the gray lines are the depth-contours layer.

The North River Layer, and the seagrass layer came from a 1992 map created from aerial photographs. The depth-contours layer came from a NOS (National Oceanographic Service) hydrology survey conducted in 1930 (Figure 4).



Figure 4: CSV point data from 1930 NOS hydrology survey used to create the depth-contours.

These three layers remained constant and were overlaid over a fourth layer, composed of components of water quality, to visually represent the distribution of each component of water quality (Figure 5).

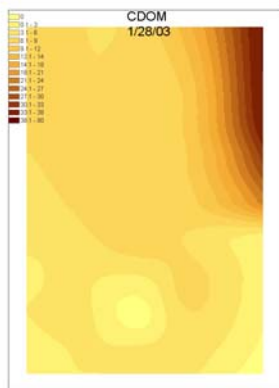


Figure 5: One of the fifteen CDOM layers

The Creation of CSV files

The data used to create the contour lines and the data used to create the water quality layers were CSV (Comma Separated Value) files. These files were created in Microsoft Excel to import spatial data points and attributes (e.g., depth, water-quality) into ArcMap.

CSV files were used because they were compatible with ArcMap. The files contained latitude, longitude, the sites sampled, and a value for each site. The CSV files were input into ArcMap by this process:

1. The data was taken from the NOS hydrology survey or the water quality results and put into a separate CSV file and saved.
2. In ArcMap the add layer button was pressed.
3. The location where the CSV file was saved was selected and the file was selected.
4. The CSV file appeared in the ArcMap table of contents.
5. The CSV file in the ArcMap table of contents was selected by right clicking the mouse and then add XY data was pressed.
6. The latitude and longitude was selected as the X and the Y coordinate, and the points appeared as a layer in the ArcMap Data Frame.

The Creation of Raster Layers and the Contour Layer

The entire NOS bathymetry survey was used for the contour lines and a separate layer was created for each day of water quality results for each component. The data from the NOS survey was turned into a raster layer and then into a contour layer using this procedure:

1. Under Spatial Analyst selected interpolate to raster.
2. Selected Inverse Distance Weighted. (For points of 100 or more.)

3. Z value was depth
4. Selected 2 for the power.
5. Input type was bathy.csv
6. Search radius type was variable.
7. Search radius was 12
8. Output cell size was .000588796
9. Output Raster was temporary
10. The OK button was pressed
11. Under Spatial Analyst surface analysis was selected.
12. Contour was then selected.
13. The input surface was IDW of Bathy
14. The contour interval was 1
15. The base interval was 0
16. The Z factor was 1
17. The OK button was pressed.

The contour lines for the NOS bathymetry data were put on the ArcMap Data Frame as a separate layer. The data for the water quality components were turned into a raster layer by this procedure:

1. Under Spatial Analyst selected interpolate to raster.
2. Selected the Spline Method. (For points of 100 or less.)
3. Input type was the CSV file for one of the components for one of the days the sample was collected.
4. The Z value was the date the sample took place.
5. The Spline type was regularized.
6. The weight was .1
7. Number of points was 3
8. Output cell size was .000588796
9. Output Raster was temporary
10. The OK button was pressed

Note that the Spline method of raster interpolation was used for points of 100 or less, and IDW was used for points of 100 or more. These two methods produced the best results for the given

number of data points. Additional data points were added to the water quality components CSV file in order to produce a better visual representation of the water quality data, because the original nine data points were not enough to produce a good spatial map. Additional data points were added to the North and South or East and West of the original sampling points, and they were assigned the same water-quality value as the original point.

Creation of Maps

Each of the 9 water-quality sites was sampled once a month from September 2002 to December 2003, with the exception of October 2002 and November 2002. October 2002 was sampled on the 17 and the 24, and November 2002 was sampled twice on the 7th. This resulted in fifteen layers for CDOM, seventeen layers for Chlorophyll, and seventeen layers for TSS. Each of these layers were added to the three base layers (Figure 3) to create forty-nine maps used in this project. CDOM had two less maps than the other two components because on September 12, 2002, and on December 12, 2002 the samples for CDOM were not analyzed. The general procedure followed to create the maps was as follows:

1. The raster layer for a water quality component was added to the base map for a given day of sampling.
2. The legend of the component was added to the data frame.
3. The title including the component and the day it was sampled was added at the top of the maps.
4. The maps were exported as JPEG files.

A legend was created for each component and was the same scale for each day of sampling, so the changes shown were consistent and based upon the same list of values.

RESULTS

Viewing the maps

Each map was put into Microsoft Power Point and set up as a slide show, to show the changes in each component over the 17-month time frame (Figure 6).

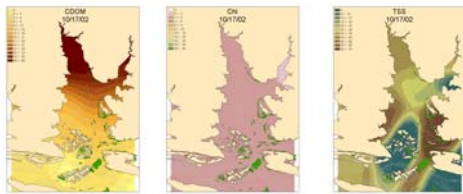


Figure 6: One day of data visually represented in a power point presentation.

This movie showed how the concentration of the components moved from month to month. A problem that occurred was that some areas of the maps were not interpolated to accurately represent the real world changes in water-quality. These areas are easy to point out because the high and low values are too close together.



Figure7: The high arrow is pointing to the dark color, which represents values of 0-5, and the light arrow is pointing to a light color, which represents values of 20-30. These values contrast too greatly to be so close together.

This inaccuracy was the result of not having enough points for the raster calculation. Even though points were added, there were still some areas of the maps where the gap between points was too great. In figure 7, if more points had been sampled the difference in values would not have been so steep. Further studies can decrease the map distortion by sampling more sites in the study area.

The Raster Calculator

The Spatial Analyst extension in ArcMap was used to create a map that cross-referenced the water quality components TSS and Chlorophyll.

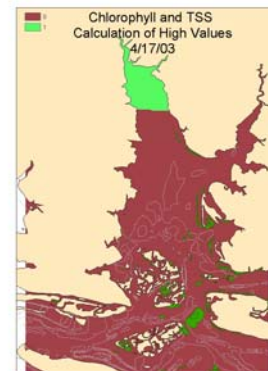


Figure 8: Calculation of high Chlorophyll and TSS regions in the North River.

The Raster Calculator feature was used to show how seagrass did not grow in areas with high concentrations both of chlorophyll and TSS on April 17, 2003 (Figure 8). The area in green is the area that is high in both Chlorophyll and

TSS, whereas the area in burgundy is not high in either Chlorophyll or TSS. The raster calculator can be used to perform a query on any 1 or more raster layers and output a single raster layer as a result. Each resulting raster layer can be added to the base map to create a more meaningful and useful map that interprets the interaction of multiple source layers. Predefined thresholds (Table 1) from January to December 2003 were used as a reference to create a query showing whether one of the components exceeded the predefined thresholds.

Depth(m)	Chl a (ug/L)	TSS(mg/L)	CDOM(1/m)
0.5	340.3	171.3	28.1
1.0	156.8	73.8	11
1.5	96.6	44	5.83
2.0	61.1	30.1	3.55
3.0	38.8	17.1	1.66

Table 1: Threshold concentrations for three water-quality components, calculated from measured optical properties in North River, NC in 2003.

Figure 9 is a map using these threshold values (Table 1). If the raster calculator receives a value that exceeds the threshold concentration for Chlorophyll, TSS, or CDOM at the corresponding depth or less, the area will be indicated in red on the output binary layer (Figure 9). All areas that do not exceed the threshold for any of the components will be indicated in blue.

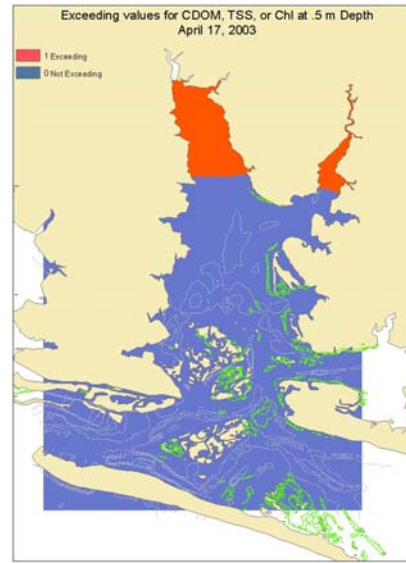


Figure 9: This map shows the areas exceeding threshold values for CDOM, TSS, or Chlorophyll at a depth of 0.5 meters or less in North River, NC.

Discussion

Increased sampling, both in space and time will produce a more accurate pattern of water-quality effects on seagrass. Areas where seagrasses do not currently grow and which are expected to be favorable for seagrasses, because water-quality does not exceed the threshold values, can be further evaluated. Either the threshold values can be changed or other factors can be implicated in why seagrasses are not growing in those areas. The resulting maps (e.g., Figure 9) can be used to show the water-quality conditions at the deep edges, and how much of each component is present at that depth. By cross-referencing all these factors, managers can then devise a plan to alter the components in the water (i.e., increase water clarity) so the seagrass beds can grow into deeper waters. Of the three components, CDOM exceeded the threshold values most often at all depths. Future projects could include a

series of maps querying only the CDOM raster layer, to see how often it exceeded its threshold values. If this was related to a certain time of the year, then that time of the year could be concentrated on as a target for managers to try and decrease the CDOM levels.

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References

1. Pathfinder Office Getting Started Guide, Version 2.50
July 1999, Trimble Navigation Limited
2. Pathfinder Office Release Notes, Version 2.51
October 1999, Trimble Navigation Limited
3. Hohl, P. and Mayo, B. ArcView GIS Exercise Book, Chapter 11 Spatial Queries
OnWord Press 1997
4. Ormsby, T., Napoleon, E., Burke, R., Groessl, C., and Feaster, L. Getting to know ArcGIS desktop, Chapter 4 Exploring ArcCatalog
ERSI Press 2001
5. Surfer 7 Users Guide, Contouring and 3D Surface Mapping for Scientist and Engineers, Chapter 6 Contour Maps. August 1999, Golden Software, Inc
6. Johansson, J.O.R, Publication: Water Depth (MTL) at the Deep Edge of Seagrass Meadows in Tampa Bay Measured by GPS Carrier-Phase Processing: Evaluation of the Technique Bay Study Group, City of Tampa.
7. Kenworthy, J., Thayer, G., Fonseca, M. The Ecology of Eelgrass Meadows of the Atlantic Coast: A Community Profile Fish and Wildlife Service 1984
8. Ferguson, R., Korfmacher, K. Remote sensing and GIS analysis of seagrass meadows in North Carolina, USA Elsevier Science B.V. 1997

