Southeast Atlantic Marine Monitoring and Prediction Center:

2001-02 Coastal Ocean Research and Monitoring Program (CORMP)

University of North Carolina at Wilmington
NOAA Award # NA16RP1460
Semi-Annual Progress Report, 1 Feb 2002 to 31 July 2002

Submitted by:

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This project report is for NOAA grant #NA96RP0259 and is for the period 1 February, 2002 to 31 July, 2002. The last progress report was for the period 1 August, 2001 to 31 January, 2002.

The previous report (1 Aug 2001-31 Jan 2002) contained a detailed discussion of the program's general objectives, milestones and accomplishments. In addition, that report contained similar discussions for each of eight pieces of the program that, when coupled, give a consistent, well integrated overall monitoring program in our coastal environment. Specifically, these individual pieces (see Table 1 below) contained sub-categories that included the sub-project description, objectives, tasks committed to, collaborations and user groups, milestones for the year's program, and products and future plans. This project report will not repeat this detailed information, but will concentrate on bringing this earlier report up-to-date as of 1 August, 2002. Details are given mostly in Appendix A. Currently, the grant is still underway through a no-cost extension.

The University of North Carolina at Wilmington began a Coastal Ocean Monitoring Project in September 1999. This program, now known as the Coastal Ocean Research and Monitoring Program (CORMP), is a multi-disciplinary research and monitoring effort focused on the coastal ocean off southeastern North Carolina. In addition to sustained sampling and measurement of basic oceanographic parameters, CORMP conducts process-oriented research on such issues as ecological responses to storm events, chemical and biological effects of the Cape Fear River's plume on the coastal ocean, and larval fish recruitment. Permanent monitoring stations have been established in the Cape Fear River plume and Onslow Bay, and they now provide baseline data and address user-driven research opportunities out to the continental shelf.

	Title	Issue(s)
A.1	*Characterization of the Colored Dissolved Organic Matter (CDOM) in the Waters of Onslow Bay, the Cape Fear River Plume and Coastal Southeastern North Carolina*	Water Quality, Productivity
A.2	*Optical Characterization of the Waters of Onslow Bay, the Cape Fear River Plume and Coastal Southeastern North Carolina*	Water Quality, Productivity
A.3	*Fisheries Recruitment Oceanography: Abundance and Diversity of Ichthyoplankton in Onslow Bay, North Carolina, in Shelf and Gulf Stream Water Masses*	Fisheries Oceanography
A.4	*Storm Impact on Sediment Mobility and Biotic Response in Onslow Bay, NC*	Sediment Movement & Shoreline Stability
A.5	*Ecological Impacts of The Cape Fear River Plume*	Water Quality
A.6	*Coastal and Estuarine Physical Oceanographic and Meteorological Observational Network and Coupled Model System*	Cross-Cut: Ocean Circulation
A.7	*Connections between Coastal Ocean Processes and Estuarine-Dependent Fisheries*	Fisheries Oceanography, Productivity
A.8	*Determination of Cross-Shelf Dispersion in Onslow Bay Using Radium Isotope Distributions*	Cross-cut: Ocean Circulation
A.9	*The distribution of phytoplankton in Onslow Bay*	Productivity

Table 1. Active CORMP research and monitoring projects during period

Administratively and management wise, several issues need addressing in this introductory section. These issues are 1) data management and 2) partnerships that have been extensively worked. In this latter category, explicitly discussed below are: 1) the new Caro-COOPS centered at the University of South Carolina; 2) a $4.8 million proposal to NSF that, if funded, would compliment CORMP in major and significant ways; 3) a program in the process of being established in conjunction with ocean and environmental needs at Camp Lejeune (UNCW's northern coastal neighbor) that involves the Office of Naval Research, and DoD and DoE's Strategic Environmental Research and Development Program (SERDP); and 4) the Coastal Observation Technology system (COTS).

Data Management: In accordance with a strong emphasis in NOAA Headquarters and NOAA laboratories, significant emphasis in CORMP is placed on data management. We have worked extensively with data managers of the NOAA supported Caro-COOPS program at the University of South Carolina and the Baruch Laboratory, as well as data management personnel at NOAA's Coastal Service Center in Charleston. Two data management specialists from the University of South Carolina spent several days with CORMP personnel at UNCW regarding the issues of CORMP data and instrumentation QA/QC, long-term data storage and regional data issues. Other persons from the Baruch

Laboratory met at UNCW with all CORMP personnel regarding the general issue of meta-data, what must be done to comply with best procedures and federal regulations, and setting up meta-data files and protocols per se. Dr. Madilyn Fletcher, Professor at USC and PI of the Caro_COOPS program, has shared resources regarding meta-data, as well as data management itself, generously with us. CORMP will be using the Baruch Laboratory's "CAST-NET" tools, and use CAST-NET as a metadata clearinghouse. Currently we are finishing CAST-NET data files for all parts of the CORMP program.

Further, senior CORMP administrators spent two days at a data management workshop at NOAA's Charleston Coastal Services Center. CORMP is also actively participating in the Charleston Coastal Service Center COTS program, and CORMP program materials exist on the COTS website.

Partnerships: CORMP management has actively motivated partnerships which would provide significant leverage to our NOAA program as well as those of other NOAA or federal agencies. Foremost among these is perhaps the history of CORMP assistance in the early initiation of the Caro-COOPS program. Since that time, CORMP has moved to assist PI Dr. Madilyn Fletcher in any way possible as Caro-COOPS became established. Numerous support meetings have been held. During this period, negotiations were underway for a sub-contract to CORMP from Caro-COOPS for coastal ocean operational support.

During the period May 2002-July2002 CORMP PI Dr. Marvin Moss led a UNCW effort to develop a proposal of some $4,800,000 for buoyancy driven transport processes in the Cape Fear River plume. This proposal was in response to a National Science Foundation request for proposal in the area of fresh-water input to coastal oceans. The proposal included UNCW CORMP investigators and well as modelers from NCSU and VMI. CORMP investigators involved were Bingham, Cooper, Durako, Grindlay, Leonard, Lankford, Mallin, and Posey. The proposal was submitted to NSF on July 24 after the CORMP proposal for 2002-03 had been successfully submitted. The rational for the proposal was that, if funded, the NSF program would significantly complement ongoing CORMP studies by providing resources, instruments and funds for additional graduate/undergraduate students working in the general areas that CORMP has defined. Of the eleven investigators involved in this NSF initiative, nine were major players in the CORMP program. The denouement of this proposal was expected to be known late in the 2002 calendar year.

Further, CORMP PI Marvin Moss has played a major role in assisting a dialogue and several meetings with personnel at the Camp Lejeune Marine Base in Jacksonville, N.C, located on the Atlantic coast about fifty miles to the north of UNCW. The New River runs through Camp Lejeune, and CORMP fixed moored instruments already exist both to the north and to the south of the area where the New River empties into the coastal Atlantic Ocean. Lejeune personnel need more instruments in and around this river outflow for a number of environmental and homeland defense strategic reasons. CORMP personnel Moss and Ihnat have remained digilent in assisting the Marine Corps in preparing for possible submission of a proposal of around $2-3M. This proposal, if it goes forward and is funded, would include funds to expand fixed moorings in the already partially instrumented Onslow Bay coastal ocean. In particular, CORMP management is looking to this opportunity potentially to bring funding for at least one, real-time mooring array within the CORMP program. Such an array, although costly, would add a major new dimension to the CORMP program, making it relevant to a wider base of users as well as providing an important extension to future potential modeling efforts.

Through the Coastal Observation Technology System (COTS), put together by the Charleston Coastal Services Center, CORMP personnel are interacting with other coastal observing systems around the coast of the United States. This includes centers at the University of California, California State University Laboratories, ACE at the University of Maryland, Caro-COOPS at the University of South Carolina, University of New Hampshire, and Louisiana State University. This alliance, under the direction of the Coastal Center Director, Dr. Margaret Davidson, is investigating new methods for accessing, integrating, and sharing data and information obtained from coastal observation systems. More information is available at www.csc.noaa.gov/cots.

Details of all work during this reporting period are presented and discussed at Appendix A. Appendix A follows the outline given in Table 1 above where the A.1-A.9 sections represent separate entrees but, overall, intimately related works pertaining to this interdisciplinary coastal ocean program

We note that the elements of Appendix A were possible through CORMP's experienced at-sea operational support staff. Details of missions, deployments, instrument recovery through diving, data downloading and archiving, and maintenance by this support staff will be delineated for the 2002-03 program in the next progress report.

Southeast Atlantic Marine Monitoring and Prediction Center:

2001-02 Coastal Ocean Research and Monitoring Program (CORMP)

Appendix A

A.1 Characterization of the Chromophoric Dissolved Organic Matter (CDOM) in the Waters of Onslow Bay, the Cape Fear River Plume and Costal Southeastern North Carolina

Description

Biological and chemical processes in surface ocean waters are in part controlled by the optical properties of the water. The organic carbon component is a major factor that determines the optical properties of natural waters. The uncharacterized organic carbon fraction in surface waters can be divided into two groupings, transparent (in the 300 - 800 nm wavelength range) and light absorbing. The absorbing fraction, historically referred to as gelbstoffe or humic matter (and other names) is the primary absorber of sunlight and is responsible for a majority of the photochemically mediated processes in surface waters. More recently the term chromophoric (colored) dissolved organic matter or CDOM, has been used because of increasing interest in: 1) remote sensing of ocean color, related to organic carbon cycling; 2) remote sensing of chlorophyll, as an indicator of primary productivity, and the potential interference in its measurement by CDOM; 3) air-sea exchange of important trace gases, namely CO, CO_2 and COS; 4) as a tracer of riverine input of organic carbon to the ocean; 5) carbon cycling in coastal waters, and; 6) attenuation of ultraviolet light in surface waters.

Although CDOM is principally responsible for the attenuation of light in surface waters, the exact chemical structure of CDOM is unknown. It is characterized using different measurements; for example, dissolved organic carbon (DOC), electronic absorption spectra (usually in the range of 200 – 800 nm), and fluorescence spectra. CDOM has been characterized in the surface waters of the Middle Atlantic Bight with respect to terrestrial inputs and photooxidation. However, little has been done in the South Atlantic Bight and its coastal environments. And, the Cape Fear River watershed delivers more dissolved organic carbon to the coastal ocean than any other system on the U.S. east coast.

One continuing contribution of this project, especially in conjunction with Durako's work, is providing data for use in refining algorithms for remote sensing of ocean color (SeaWiFS satellite) and resulting improved estimates of primary production. Such rapid, regional scale estimations have dramatic consequences for many applied issues, such as fisheries production, harmful algal blooms (HABs), and the health of coastal ocean ecosystems.

Objectives, July 2001 - July 2002:

This project is closely aligned with Durako, who will provide light attenuation data at same times and places. The primary goal of this project will be to better characterize the CDOM in Onslow Bay and the Cape Fear River Plume. Specific objectives include:

- to characterize the spatial and temporal variability of the CDOM in Onslow Bay, from near shore to the shelf break, and in the Cape Fear River Plume

- to determine whether CDOM can be used as a tracer of cross-shelf water mass transport and plume dynamics
- to equip the RV Cape Fear with an on-line fluorescence system that will provide a continuous signal for tracking CDOM in the Cape Fear River Plume and adjacent waters.

Tasks, Feb. 2002 - July 2002:

- *Water Samples:* Surface water samples (CTD/Rosette) have been collected at all of the plume and shelf stations sampled; refrigerated and returned to the laboratory, filtered through 0.2 µm filters prior to analysis.
- *UV/visible Absorption Spectra:* Electronic absorption spectra obtained using the Cary 100 spectrophotometer; spectra recorded from 200 to 800 nm; data transformed to ln A to determine the slope coefficient (S) of the waters as another indicator of photobleaching of CDOM; purified water from Milli-Q system used as reference.
- *Fluorescence Measurements:* Single wavelength fluorescence measurements made using a Turner Designs Model 10 spectrofluorometer standardized with quinine sulfate; 3-D synchronous spectra obtained using a SPEX FluoroMax III; Turner Designs Model 10 spectrofluorometer also used in flow through mode for continuous single wavelength fluorescence data collection at sea.
- *Dissolved Organic Carbon (DOC):* water samples analyzed using Shimadzu 5000A DOC analyzer according to standard methods accepted for oceanic measurements.

Collaborations and User Groups:

CORMP:

- **Mallin, *Ecological Impacts of the Cape Fear River Plume on the Coastal Ocean*: provides water quality data (suspended sediments, nutrients, pigments) on Onslow Bay transect and CFRP needed to characterize plume and partition absorbance factors**
- Durako, *Optical Characterization of the Waters of Onslow Bay, the Cape Fear River Plume (CFRP) and Coastal Southeastern North Carolina*: obvious linkage as CDOM is most significant absorber of light and must be accounted for in order to achieve ultimate goal—better algorithms for estimation of primary production using ocean color data from satellites
- Posey and Lankford, *Connections between Coastal Ocean Processes and Estuarine-Dependent Fisheries*: they hypothesize that recruitment is controlled in part by water quality factors (color and productivity) which serve as cues to larval ingress from the ocean to the estuaries; their sampling is correlated with patterns seen in this study
- Cahoon, *Development project-- primary productivity*: will begin measuring primary productivity *in situ* using fluorescence during 2002 cruises; CDOM may be a major source of carbon for microbial communities.

Milestones, Feb – Jul 2002:

- Onslow Bay cruise samples have all been analyzed for 3-D fluorescence for all of the cruise during this period (e.g. Figure 1)
- Cape Fear River Plume samples have all been analyzed for 3-D fluorescence spectra (Figure 2)
- DOC samples continue to be analyzed (Figure 3)
- Linux server purchased (from other funding sources) to process SeaWiFS level 2 imagery
- Development of flow-through system is on hold until we can purchase a dedicated spectrofluorometer and flow-through cell.

Results:

The UV/vis and 3-D fluorescence spectral data are proving to be very useful in obtaining a better understanding of the character and fate of the dissolved organic matter in the coastal waters. Figure 1 provides a representative view of the changes that occur in the absorption of light by the organic matter in the CFR Plume.

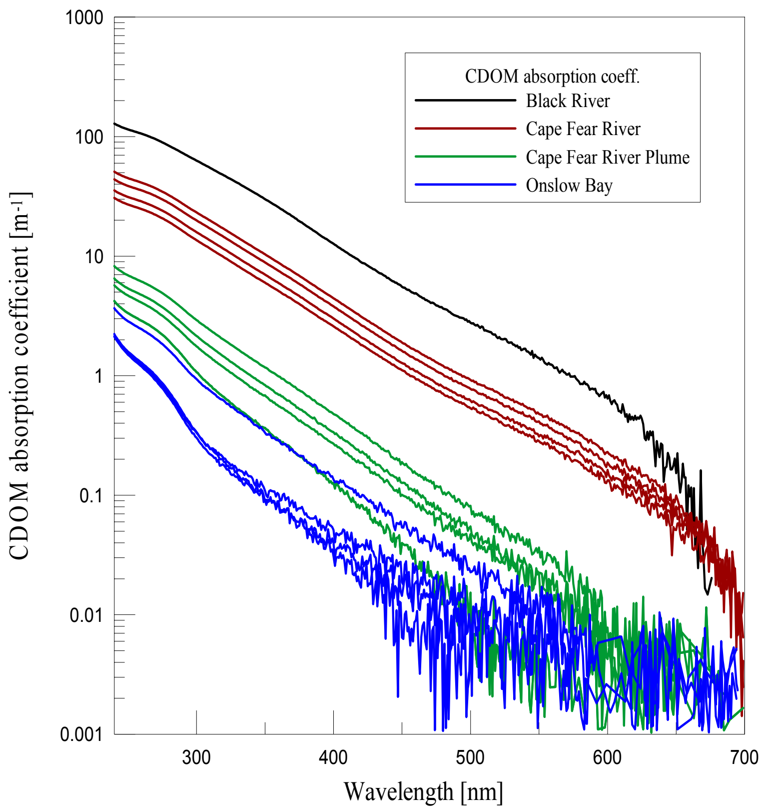


Figure 1. Absorption coefficients of water samples from the Cape Fear River system.

Table 1 summarizes the data shown in Figure 1. It is clear from this data set that the different "regions" of water are distinguishable; however, this is not sufficient to provide insight into the processes that are responsible for the changes.

Table 1. CDOM absorption characteristics of water sampled during 2001/2002 crises.

Water	Absorption Coefficient (a_y(400) m^{-1})	S (Slope Coefficient (nm^{-1}))
Black River	12.7	0.015
Cape Fear River (mean, n = 4)	3.46	0.015
Cape Fear River Plume (mean, n = 21)	0.71	0.018
Onslow bay (mean, n = 27)	0.088	0.024

Excitation-emission matrix fluorescent spectra were also obtained from the samples through out the system. Figures 2 to 5 provide a visualization of the fluorescent spectra (excitation-emission) of the end members of the system.

The "A" peak is associated with terrestrial humic acids; "C" peak, the terrestrial fulvic acids; "M" peak, marine fulvic acids; and the "T" peak, the proteineous substances (generally thought to be tryptophan and tyrosine amino acids in the protein). It is obvious from Figures 2 and 3 that the A and C peak dominate the spectra from the Black River and that the fluorescence of the Gulf Stream is approximately 500 fold less than the freshwater end member.

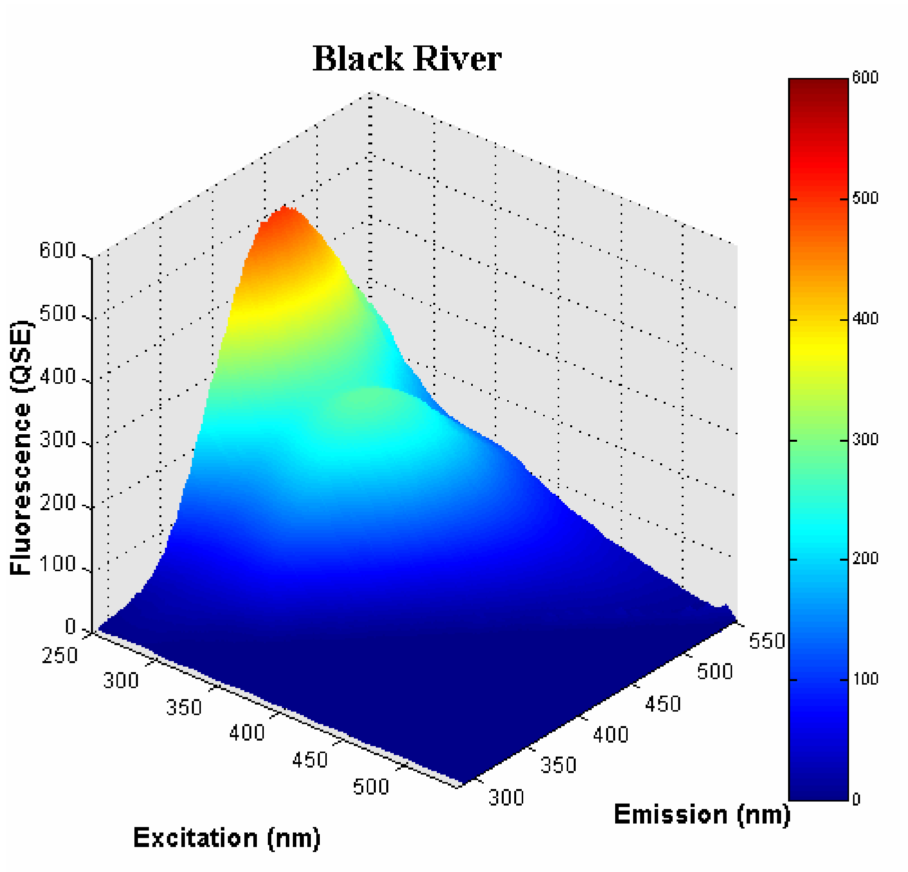


Figure 2. Excitation-emission Matrix Spectra (3-D fluorescence) of the Black River, the fresh water end member of the Cape Fear River system. (QSU are a relative measure of fluorescence based on quinine sulfate as a standard.)

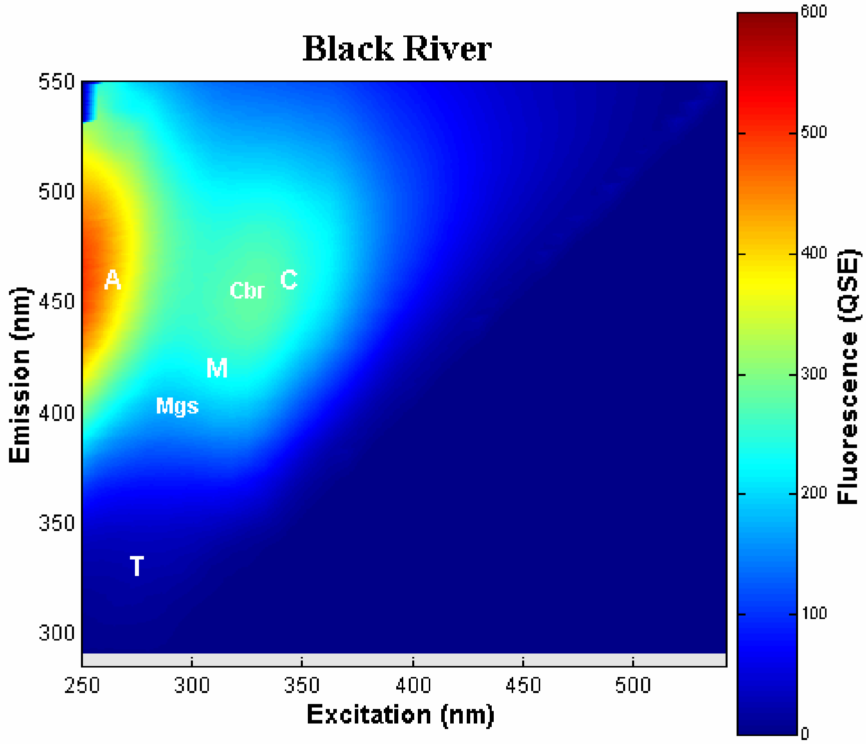


Figure 3. Top view of the excitation-emission Matrix Spectra (3-D fluorescence) of the Black River, the fresh water end member of the Cape Fear River system.

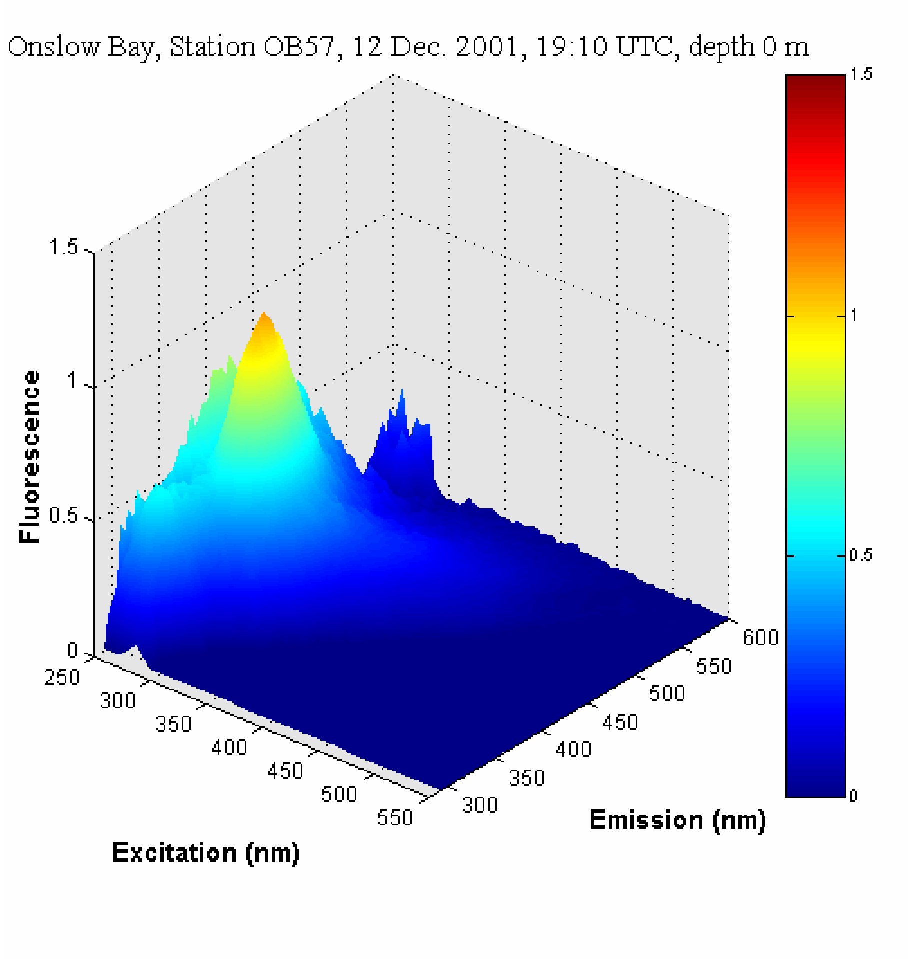


Figure 4. Excitation-emission Matrix Spectra (3-D fluorescence) of the Gulf Stream, the oceanic water end member of the Cape Fear River system. (QSU are a relative measure of fluorescence based on quinine sulfate as a standard.)

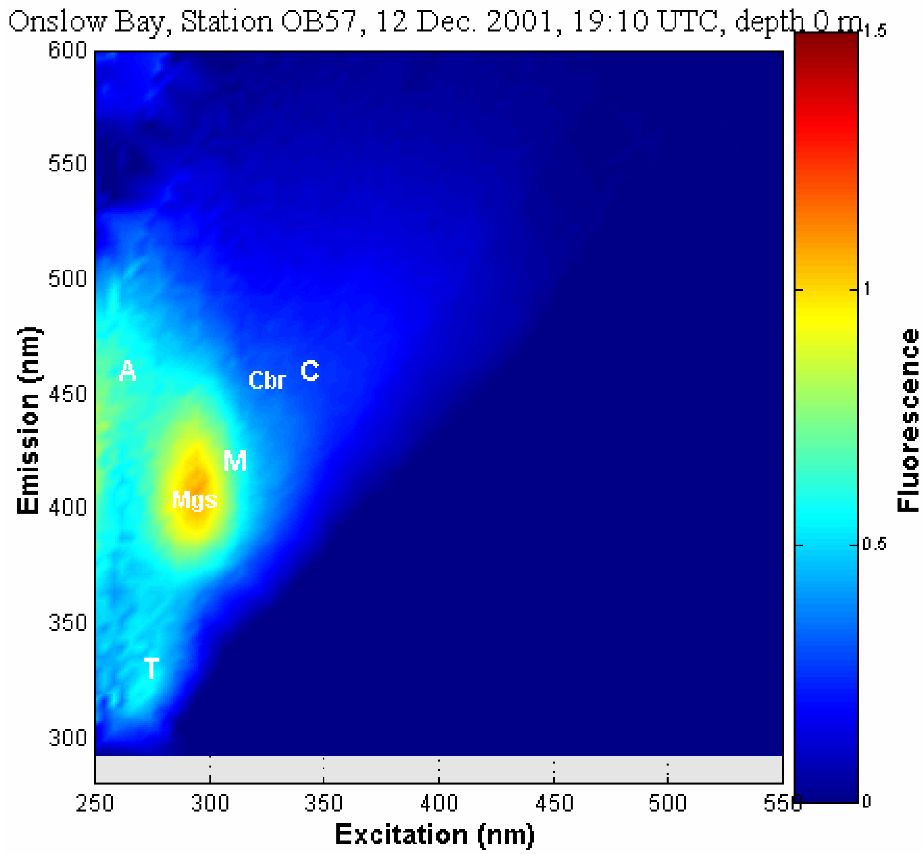


Figure 5. Top view of the excitation-emission Matrix Spectra (3-D fluorescence) of the Gulf Stream, the oceanic water end member of the Cape Fear River system.

If the absorptivity data are plotted against salinity (Figure 6), it appears that the changes in CDOM in the CFR Plume are conservative (the only process is mixing). However, by examining the fluorescent spectra carefully, that is integrating the peaks, it is possible to observe subtle changes in the fluorescent matter as the salinity approaches 35 o/oo (Figure 7). In the samples where the salinity is approaching 35 o/oo three of the four peaks appear to have been "bleached" with respect to the total spectra. By bleaching we infer processes that have resulted in a less efficient photo-process occurring in the organic carbon molecules. While in the peak associated with proteins there is a relative increase in its concentration.

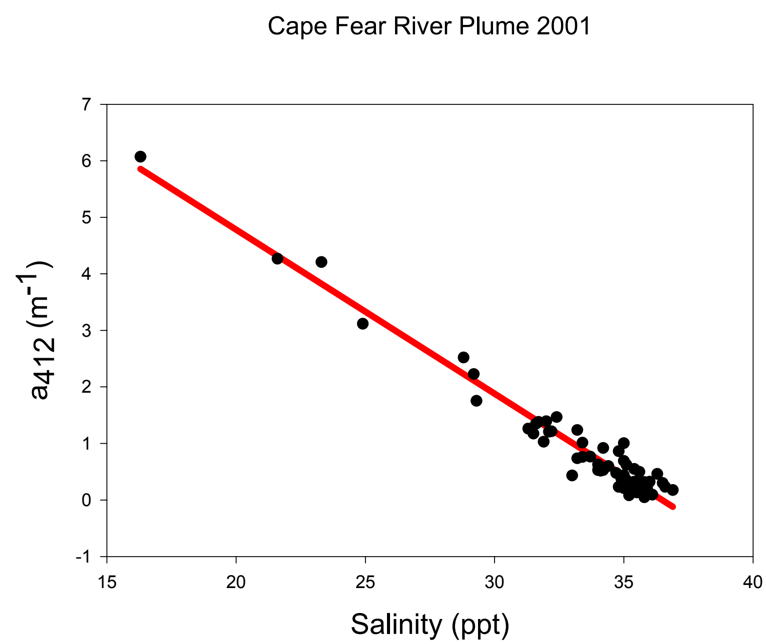


Figure 9. Absorption coefficient at 412 nm with increasing salinity in the Cape Fear River Plume.

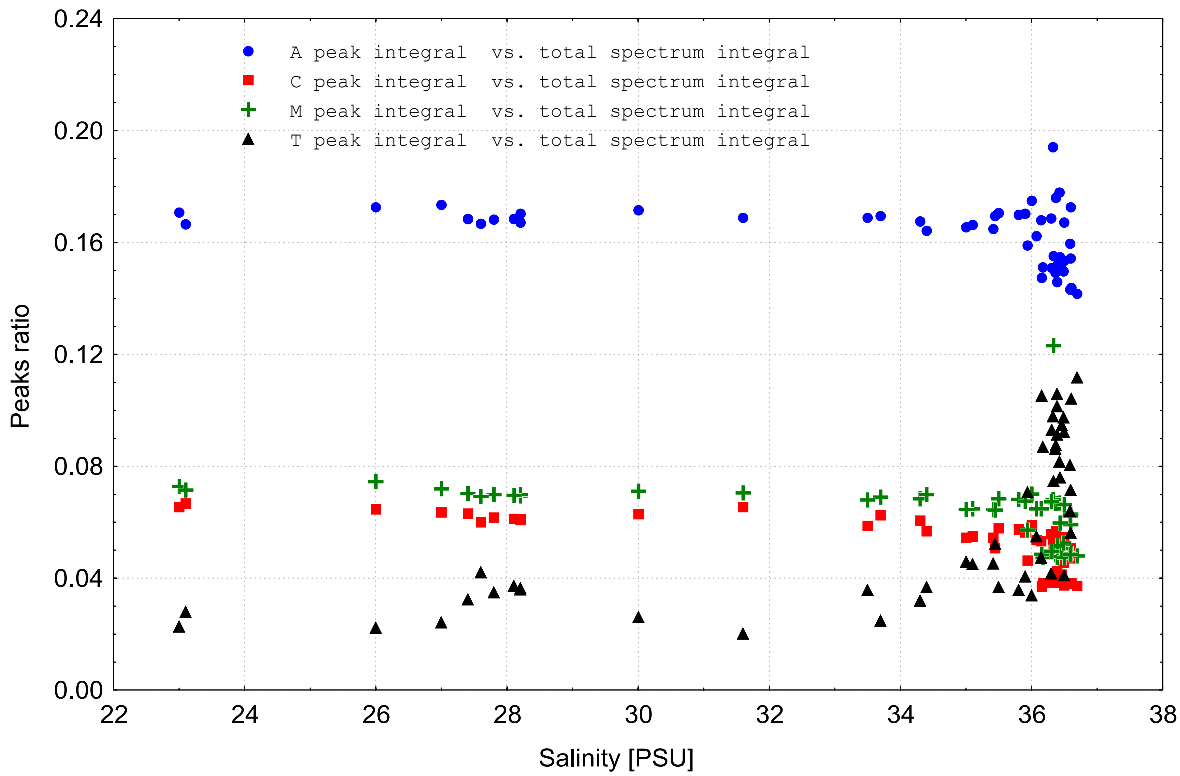


Figure 7. Ratios of peak area from the different fluorescent peaks associated with the different CDOM portions of the water.

The A, C, and M peaks all appear to decrease dramatically at the higher salinity. However, the T peak increase relative to the overall fluorescence. We believe that this may indicate that the T peak is either recalcitrant or that it is of formation processes in the open ocean.

We are in the process of interpreting the entire data set and hope to add to this initial set in the fall of 2002.

Products:

- Presentation of results at the American Society of Limnology and Oceanography, July 2002

Future Plans:

- Expand plume and shelf sampling out into Long Bay and SC coastal ocean
- Expand the analytical characterization of the biological contribution to absorption by isolating and analyzing accessory pigments in the Cape Fear River Plume
- Expand analysis to include total suspended solids and particulate organic matter
- Continue sampling into years with normal to above average rainfall

Dr. William Cooper, UNCW
Dr. Michael Durako, UNCW
Dr. Piotr Kowalczuk, UNCW

A.2 Optical Characterization of the Waters of Onslow Bay, the Cape Fear River Plume (CFRP) and Coastal Southeastern North Carolina

Objectives:

1. Conduct inter-calibration exercises between CORMP and EPA's National Health and Environmental Effects Laboratory (NHEERL) during the analysis of CDOM from the CFRP and Onslow Bay in order to quality assure (QA) the integrity of data produced by both programs.
2. Use field and laboratory optical measurements of pigments, CDOM and suspended sediments from Onslow Bay and the Cape Fear River plume as inputs into bio-optical models developed by EPA to simulate chlorophyll *a* content.
3. Process SeaWiFS satellite (Level 2) imagery from the South Atlantic Bight including Onslow Bay and the Cape Fear River and compare satellite derived spectral data to ground-based data.
4. Relate the temporal and spatial variability in chlorophyll distributions and optical properties in Onslow Bay and the Cape Fear River plume to changes in freshwater input and nutrient loading from the Cape Fear River watershed, the largest watershed in North Carolina.

Progress Towards Objectives:

- We have had to abandon both objectives #1 & 2, because there has been no progress in establishing an MOU with the EPA NHEERL. Repeated efforts to get the MOU in place have been futile.

- Objective 3 has been largely completed for cruises over the period from October 2001 to April 2002. The data for comparisons between ship-based and SeaWiFS radiometric measurements were obtained from monthly cruises from October 2001 to April 2002 using two Satlantic radiometric systems (Fig 1): MicroPro, developed for measurements of vertical profiles of downwelled irradiance and upwelled radiance, and MicroSAS,

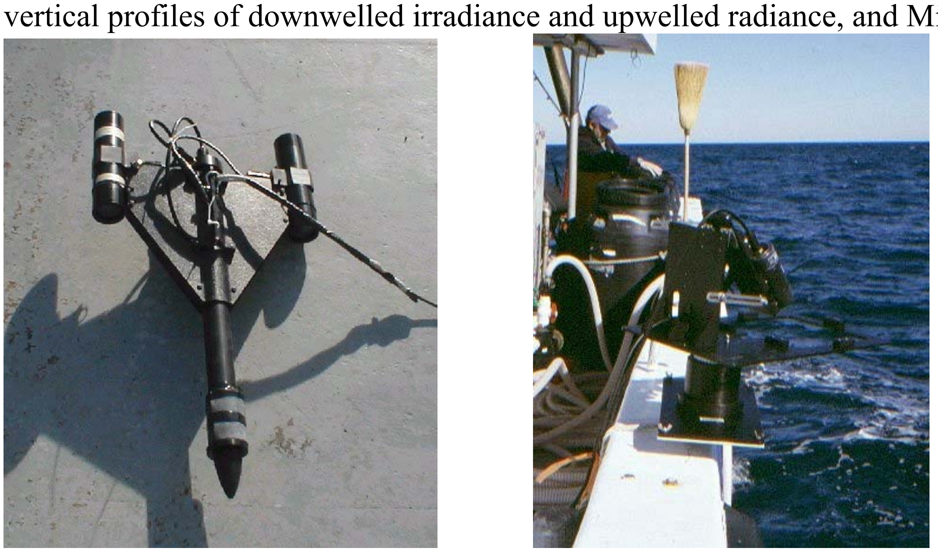


Figure 1. MicroPro (left) and MicroSAS (right) instruments.

designed to measure the spectral reflectance above the water surface. Measurements were taken in clear oceanic water at the costal shelf in Onslow Bay (optical Case I waters) and in turbid Cape Fear River plume waters (optical Case II waters), containing a high concentration of chromophoric dissolved organic matter (CDOM). Sample data were obtained under a range of environmental conditions that included calm and rough seas, and, clear and cloudy skies. Remote sensing reflectance was calculated at four wavelengths 412, 443, 490, and 555 nm, and the results from the two instruments were compared. The spectrally averaged unbiased percent difference between remote sensing reflectance, derived from these two instruments, is 9.8 % (Fig. 2). The largest difference between the two methods is observed at 555 nm (11.08 %) and the least at 490 nm (7.90 %). There was a significant reduction in differences when only celar sky data were compared (Fig 2B). Radiometric quantities derived during field measurements, e.g. downwelling irradiance, diffuse attenuation coefficient at 490 nm, spectral remote sensing reflectance and spectral values of normalized water leaving radiances, were compared for available estimates from SeaWiFS images obtained from the same periods as the cruises. The biggest random mean square root error between field measurements and SeaWiFS estimates of the remote sensing reflectance has been calculated for 412 nm wavelength (41.4 %) and the least for 555 nm waveband (15.4 %). The RMSE range calculated between field measurements and SeaWiFS estimates, of normalized water leaving radiances, was 52.3 % for 412 and 23.9 % for 555 nm. The RMSE calculated between field measurement and SeaWiFS estimates of K_d490 was 37.4 %.

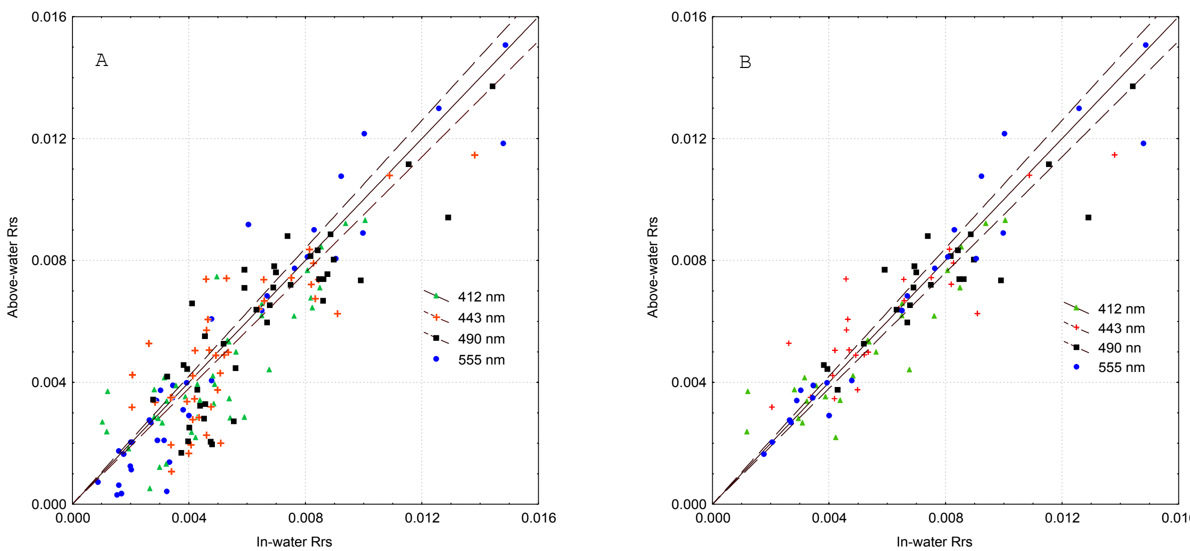


Figure 2. Comparison of in-water and above-water spectral remote sensing measurements for all data (A) and for clear sky conditions (B). The line represents 1:1 correspondence.

- We have made good progress on Objective #4. Analysis of the bio-optical data from CORMP indicate that the absorbance properties of CDOM within the plume may provide a means of describing how river discharge affects carbon sources and transformations in the nearshore waters of the Cape Fear River plume. CORMP bio-optical data also indicate that within the CFR plume, inherent optical properties such as a_{PAR} reflect changes in source, distribution, and transformations of dissolved and particulate constituents within the plume. During periods of high flow (March 2001), the spatial distribution and abundance of CDOM and TSS in the plume clearly reflect riverine inputs, while pigment distributions and low levels suggest little plume effect or possibly even a dilution effect (Fig. 3). During periods of low flow (January 2002), the

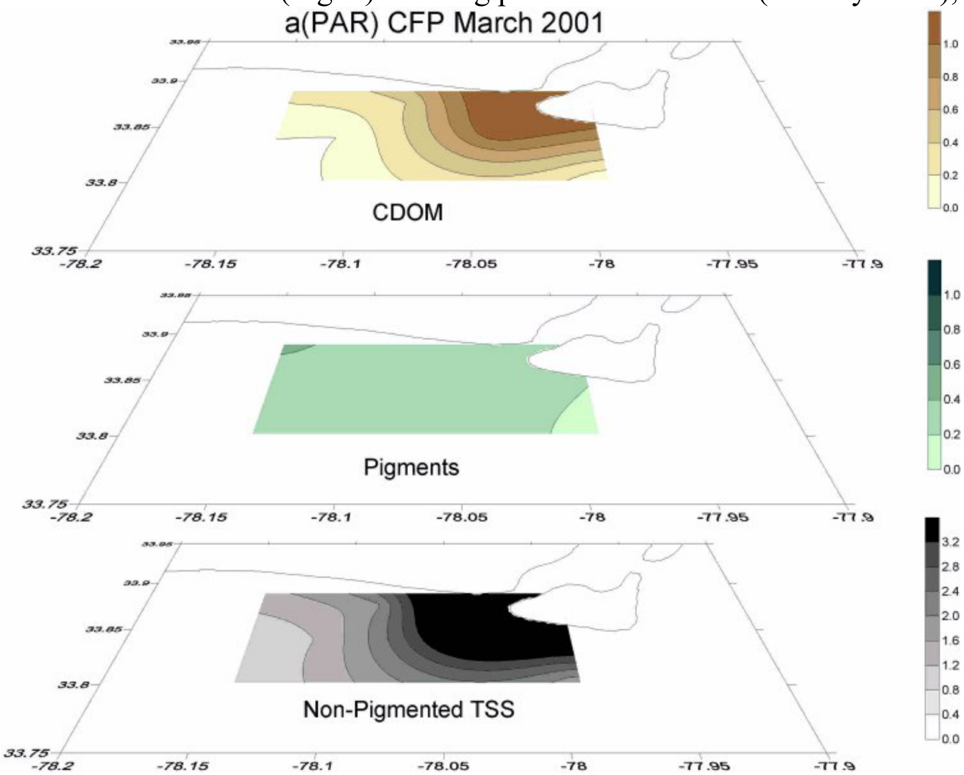


Figure 3. Spatial distribution of absorption coefficients for PAR partitioned by CDOM, pigments and non-pigmented TSS in the Cape Fear River plume, during high-flow conditions in March 2001.

plume effect on CDOM and TSS is much less defined and more restricted spatially (Fig. 4). The relatively higher pigment levels in the plume area, during the low discharge period, may reflect both the increased water transparency and a nutrient "memory" effect (remineralization of nutrients from river-deposited sediments) or effect of increased residence time of the plume area water mass. Thus, bio-optical data, in conjunction with other water-column measurements, may be used to quantify the relative contributions of terrestrial inputs versus coastal marine processes to the plume-influenced area. Within this plume system, the dominant contributors to bio-optical water quality are: 1) detrital particles and CDOM, predominantly originating from the Cape Fear River; and 2) pigments from phytoplankton blooms that may originate within the plume.

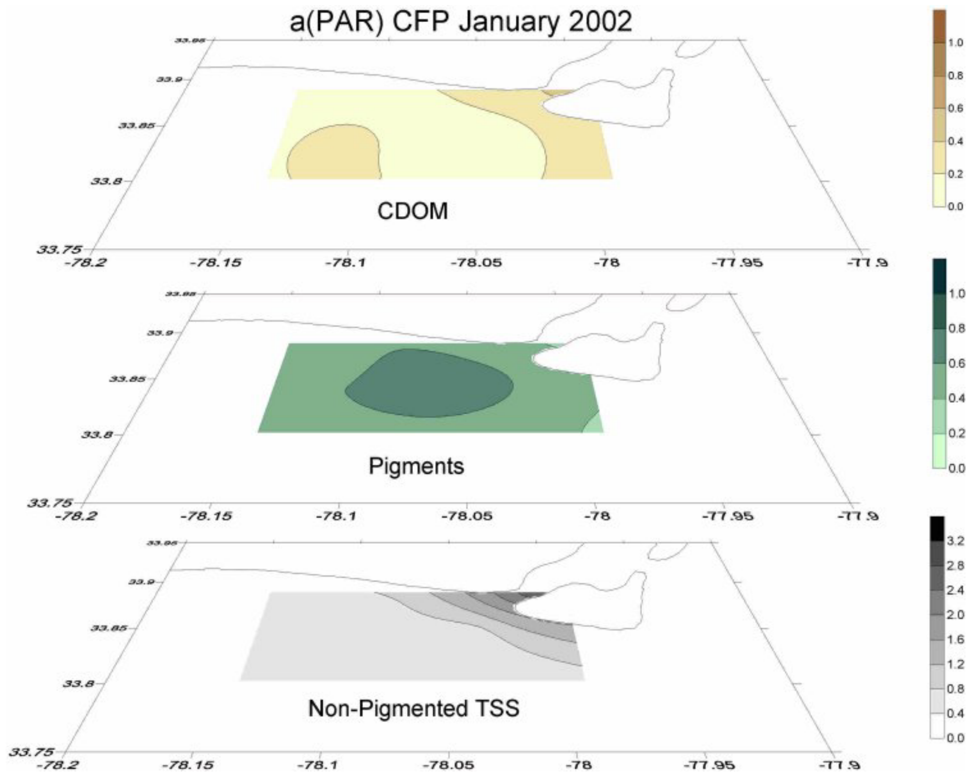
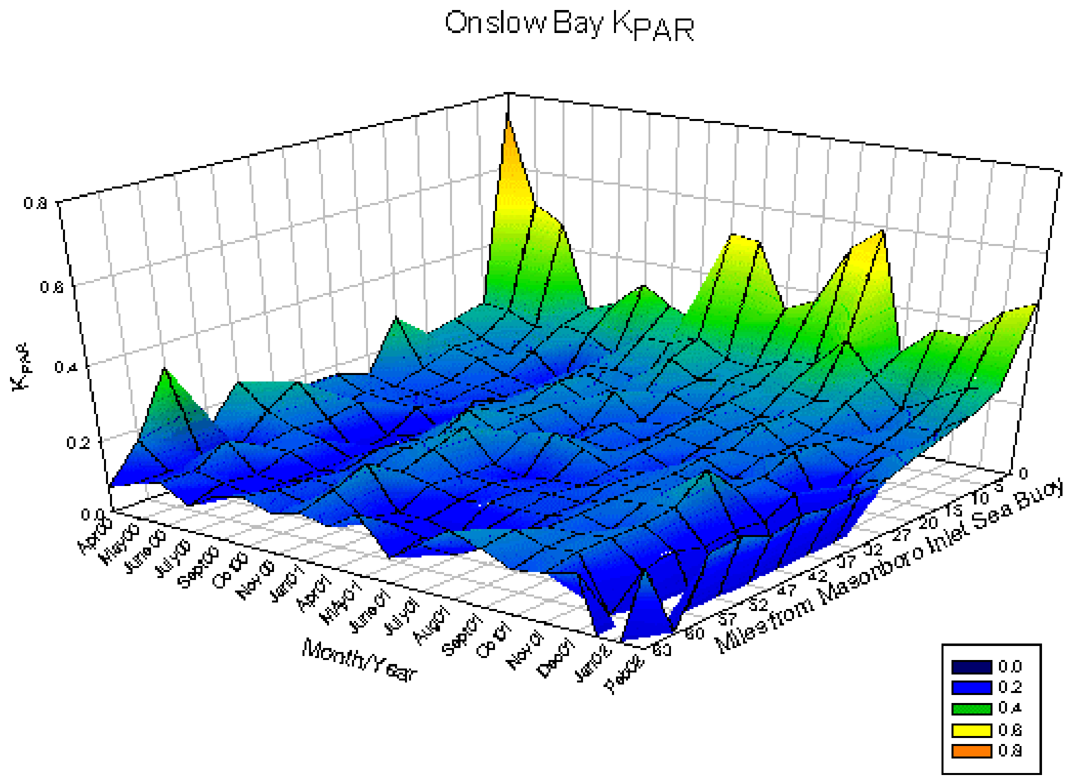


Figure 4. Spatial distribution of absorption coefficients for PAR partitioned by CDOM, pigments and non-pigmented TSS in the Cape Fear River plume, during low-flow conditions in January 2002.

Products:

- Data from monthly transects in Onslow Bay (Fig. 5) and the CFRP (Fig. 6) on attenuation of incident light from the LiCor PAR scalar quantum sensors, and spectral attenuation partitioning by various water components have continued to be posted on the CORMP web site (http://www.uncwil.edu/cmsr/comp/biooptical/biiopticalindex.htm).
- Durako, M. J., Kowalzcuk, P., Souza, J. Malim, M., McIver, M. 2002. Spatial and temporal variation in CDOM in a coastal blackwater river plume. Ocean Optics XVI, Santa Fe, NM.
- Kowalzcuk, P., Durako, M. J., Cooper, W. J. 2002. Comparison of radiometric quantities measured in water and above water and derived from SeaWiFS imagery in Onslow Bay and Cape Fear River plume area. Ocean Optics XVI, Santa Fe, NM.



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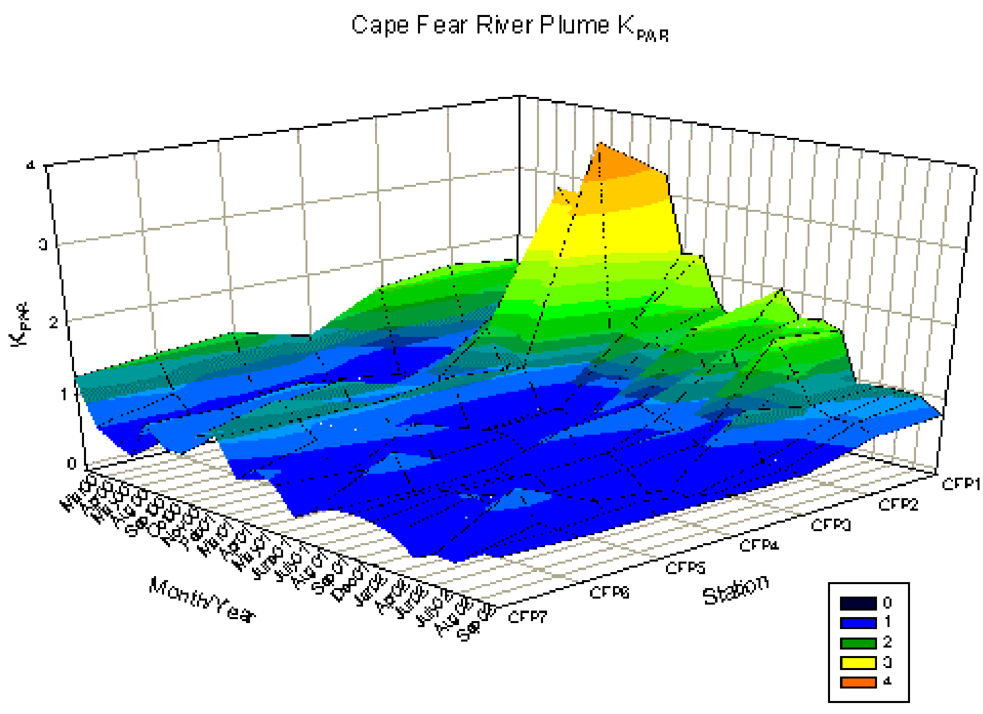

Figure 6. Diffuse attenuation coefficients in the Cape Fear River plume from March 2000 to September 2002.

A.3 Distribution of Larval Fishes in Shelf and Gulf Stream Waters in Onslow Bay, North Carolina

Milestones, February 2002-July 2002:

Monthly ichthyoplankton sampling was completed in December 2001.

Sorting and taxonomic identification of all ichthyoplankton samples were completed in February 2002. Approximately 25,000 larval fishes have been collected across water masses in Onslow Bay

Statistical analyses and interpretation began in March 2002 and were completed in July 2002

Products:

UNCW master's student Andrea Quattrini completed and defended her thesis, "Distribution of Larval Fishes in Shelf and Gulf Stream Waters in Onslow Bay, North Carolina", in September 2002 (copy of thesis available upon request).

Her thesis project was to examine data from a set of moorings deployed in Onslow Bay during 1999. She first gave an overview of the atmospheric and oceanic conditions before, during and after a series of hurricanes that passed over the North Carolina continental shelf that year. She is also calculated the heat balance in the water column using the moored temperature data, and NCEP model output. Her findings indicate the strongest oceanic response was from hurricane Dennis, as opposed to Floyd or Irene. This is an unexpected result given that Dennis passed over Onslow Bay with the moorings on its left hand side. Reasons for this are still being analyzed.

This work proceeded by collecting larval fishes with bongo and neuston nets in different water masses during the period April 2000-December 2001. This data was used to test the hypothesis that the Gulf Stream may be a source of larval fishes to the Onslow Bay region. The pelagic egg and larval stages of fishes are subjected to oceanographic processes that may cause larvae to become entrained into current regimes and dispersed from their local populations. Water masses were identified as shelf, Gulf Stream/shelf mixture, Gulf Stream front, or Gulf Stream with the use of conductivity-temperature loggers, advanced very high resolution radiometry (AVHRR) images, and acoustic doppler current profiler (ADCP) data. Certain fish families were abundant in different water masses collected with different gear. Familial diversities, measured as Shannon-Weaver indices, were generally greater in Gulf Stream and Gulf Stream front water masses than in shelf waters. Concentrations of most taxa were relatively low in the Gulf Stream and higher in shelf waters. Low concentrations of these taxa in shelf waters compared to Gulf Stream waters suggest the Gulf Stream is a source and may provide a mechanism for cross-shelf transport. These patterns in distribution can serve as an indicator for other species distribution patterns.

Ichthyoplankton samples have been archived and entered into UNCW's fish collection as a larval fish database. These samples will provide valuable reference material for investigators at UNCW and will be made available to researchers at other institutions worldwide.

Final results of this project will be presented at the 2002 American Fisheries Society's Southern Division meeting in February 2003. At least one manuscript is currently being prepared for publication in a peer-reviewed scientific journal.

A.4 Storm Impact on Sediment Mobility and Biotic Response in Onslow Bay, NC

Progress toward stated objectives:

We are making excellent progress meeting our objectives as stated for the August 2001-July 2002 time period. At this time we have:

- Identified key events leading to significant mobilization at the OB27 site and have identified events associated with both storm related and non-storm related phenomena,
- Associated significant sediment resuspension at OB27 with specific types of wind events and related the impact of these events on the substrate to sea floor morphology and substrate granulometry,
- Identified changes in the sedimentary structure of cores collected prior to and following small storm events, and;
- Identified areas where large changes in sediment texture have occurred using side scan sonar mapping techniques.

We have had less success meeting "storm-related" objectives because we still have not been impacted by a significant storm event (i.e., hurricane or large nor'easter).

Progress toward meeting stated tasks:

Over the reporting period we have:

- Continued to collect sediment box cores, surface sediment grab samples, benthic cores, and physical (current, temperature, and seafloor altimetry) data at OB27. These data continue to be collected (roughly) at six-week intervals.
- Continued to process box cores. This procedure includes: creation of sediment peels, X-ray imaging of cores, grain size analysis of subsamples, and description of sedimentary structures. All cores collected to date have been completely processed and described.
- Processed and archived benthic cores.
- Digitized and compared boundaries between areas of distinct seafloor reflectivity in 12/1999 and 12/2000 sidescan sonar mosaics to monitor bedform change.
- Performed pixel to pixel comparison of seafloor reflectivity between 12/1999 and 12/2000 sidescan sonar mosaics to monitor bedform change.
- Reviewed NURC archived digital video footage of OB27 site and vicinity to further ground truth sidescan sonar imagery.
- Completed initial processing of sidescan sonar imagery at OB5 site.
- Continued incorporating data into GIS database for OB27 site, including establishing a metadata template.
- Established an inner shelf station at OB5. An upward looking ADCP with wave upgrade has been deployed at this site and is collecting data. A Wetlabs Eco-sb turbidity sensor has been ordered and should be deployed by the next reporting period.

- Acquisition of Grant-Madsen MATLAB code to calculate bottom shear stresses resulting from wave-current interaction.
- Acquisition of code from Dr. Courtney Harris (VIMS) to quantify sediment flux (transport).
- Continued development of other MATLAB programs for data specific processing tasks; including determination near bottom wave orbital velocities
- Established N-S and E-W and sampled metered transect lines near OB27 site.

Products:

- Updated website with imagery and data
- OB5 (inner shelf site) established with upward looking ADCP; preliminary surface sediment survey conducted. This work is a joint effort between this component of CORMP and researchers at NCSU.
- Sidescan sonar survey of the OB5 site conducted.
- Collected underwater video of both the OB27 and the new OB3 site.
- Submitted proposal to NSF with Durako, Posey, Bingham, and other CORMP researchers to examine buoyancy driven processes in the Cape Fear River Plume region.
- Incorporation of CORMP data into educational curriculum at UNCW. Examples include use of PC-ADP near-bottom current data in GLY555--Sediment Dynamics, use of box cores and sediment samples in GLY591--Grain Size Analysis by Laser Diffraction, side scan imagery in GLY550—Marine Geology, benthic infaunal data in BIO434—Marine Ecology.
- One undergraduate Directed Independent Study student (Maverick Raber) completed a CORMP related project in Spring 2002.
- The research of one M.S. student and one Ph.D. student are supported by this component of CORMP.
- Benthic infaunal data from OB27 utilized in presentation to the North Carolina Coastal Resources Commission (identified user-group) on offshore borrow areas for beach renourishment in May 2002.
- Published Abstracts:

  Head, M., Grindlay, N., and L. Leonard; 2002. Using high-resolution side scan sonar to map and monitor sedimentary features at 23-Mile Site, Onslow Bay, NC, Southeastern GSA Meeting Abstracts with Programs, 34: A-13.

- Abstracts In press:

Head, M., Grindlay, N.R., and L. Leonard. 2002. Mapping and monitoring bedforms on the mid-continental shelf: 23-mile site Onslow Bay, NC. *Eos Trans. AGU, 83*(47), Fall Meet. Suppl., Abstract OS713-0292, 2002.

Wren, A., and L. Leonard. 2002. Physical Processes and Sediment Transport in Onslow Bay, NC. *Eos Trans. AGU, 83*(47), Fall Meet. Suppl., Abstract OS52F-12, 2002.

A.5 Ecological Impacts of the Cape Fear River Plume

Progress toward stated objectives:

- We are continuing to collect plume samples for physical parameters, nutrients, chlorophyll *a* and plankton. Samples were collected in April, June and July 2002. Severe weather in the other months precluded small boat sampling of the plume. A spatial pattern was continued of highest nutrient and chlorophyll concentrations at station 1 in the lower estuary, followed in turn by station 2 in the estuary mouth, station 6 in the plume, station 7 sometimes in the plume, station 5 sometimes in the plume, station 4 rarely in the plume, and station 3, the control station outside the plume influence. Turbidity and light attenuation, however, were similar at the control station and plume stations because of elevated turbidity caused by suspended sediments entrained in the water column at station 3 over the shoals. Dissolved oxygen tends to increase away from the estuary and estuary mouth, due to the low dissolved oxygen concentrations often seen in the Cape Fear River.
- We are continuing to accumulate baseline data for the plume that can be compared with future event-driven situations. The past two years have been dry periods and will provide an excellent data base against which to compare wet periods and/or hurricane and tropical storm events.
- We are in the early stages of modeling a system that we suspect is strongly driven by meteorological periodicity rather than strictly seasonal progressions. Our preliminary statistics show that rainfall-driven river flow leads to enhanced chlorophyll concentrations in the plume, and enhanced nitrate concentrations at the plume's outer edges. Because of these findings, we have initiated the following nutrient/primary production study:

A set of exciting experiments was initiated in June 2002 that entailed assessing what nutrients limit the growth of phytoplankton in and outside of the Cape Fear River plume. This was a student project performed by Sarah Kehoe, a senior. Another senior, Trent Johnston, is continuing nutrient limitation experiments this fall. In these experiments water from plume station 6 and control station 3 is collected, returned to the laboratory, and placed in 4 L cubitainers. The samples are spiked with different nutrients (nitrate, phosphorus, iron) incubated in flow-through systems outdoors, and sampled for chlorophyll *a* as the response variable. The experiments are showing consistent nitrogen stimulation of phytoplankton growth, with no phosphorus stimulation and rare iron stimulation. Chlorophyll yield in N-spiked treatments was 3-7X that of control. Since our data are establishing that nitrate delivery to the plume is controlled by rainfall and runoff far upstream in the Cape Fear River, the magnitude of the food base for the plume food chain may thus be strongly dependent upon weather variations and land use in the upper watershed.

Products:

- The following presentation was given based on plume data and experiments conducted in summer 2002:

Mallin, M.A., S.W. Kehoe, M.R. McIver and D.C. Parsons. 2002. "Summer nutrient limitation of phytoplankton in the Cape Fear River plume." Meeting of the Southeastern Estuarine Research Society, Conway, S.C.

- Submitted research proposal to NSF with several UNCW researchers and collaborators from other institutions to examine buoyancy driven processes in the Cape Fear River plume region.
- One undergraduate student (Sarah Kehoe) completed a Directed Independent Study project on plume nutrient limitation
- A second undergraduate student (Trent Johnson) is currently involved in the project.
- Data from the plume is being incorporated into an educational hands-on website currently under construction at UNCW Watson School of Education called Ocean View.
- Data collected during spring 2002 are being incorporated into our files for future modeling studies.

A number of Marine Biology and Marine Science students are obtaining field experience for credit by going out on plume sampling cruises and performing sample collections and data acquisition.

A.6 Coastal and Estuarine Physical Oceanographic and Meteorological Observational Network and Coupled Model System: North Carolina State University Component of CORMP

Observational Field Equipment Refurbishment and Recalibration:

NCSU brought equipment to the CORMP program whose value is in excess of $300,000-$400,000. The first priority was to ensure that all equipment was in a ready and advanced state for the monitoring requirements of CORMP.

In August 2001, NCSU received notice of intent of project initiation. To minimize delays and in preparation for instrument, refurbishing, servicing and up-fits, instruments were sent to original manufacturers. Three WorkHorse Acoustic Doppler Current Profilers, ADCPs, were sent from NCSU to RDInstruments, Inc. This included two 300 kHz units and one 1200 kHz unit. Upgrades included a 50 meter pressure sensor, 96 Megabyte memory card, and firmware/software for directional wave measurement capability. One of the WorkHorse ADCP's also had to undergo a transducer refurbishment. Three Narrowband ADCP's were also shipped to RDInstruments for refurbishment. This included 150 kHz, 300 kHz, and 1200 kHz units. Fifteen Sea-Bird Electronics SBE-16 Seacats and four SBE-37 Microcats were sent to Sea-Bird Electronics for calibration. Nine 7500RC glass ball transponding acoustic releases and ten 8242 acoustic transponding releases were sent to their manufacturer, Edgetech, for servicing and refurbishment.

Some equipment refurbishment, recalibration and upgrades were completed as early as September 2001. Other serviced equipment and mooring supplies were received at NCSU over the period 10/01/01-03/01/02, with most received by mid- January.

Mooring and Array Design:

Given the size of the A-frame on the Research Vessel CAPE FEAR and the available deck space, existing cages used to house ADCPs were deemed too large for deployment and recovery from the vessel. So a smaller, cost efficient bottom mount cage was required. A trawler-proof cage, also diver accessible, was designed for the WorkHorse ADCP's by NCSU technical staff. The new cage, shown in Figure 1, has an outer dimension, foot print, of only 66 inches by 50 inches. The design also includes a storage and mount for a pop-up acoustic release system. The cage was also equipped with a diver accessible mounting bracket for an SBE-16 Seacat. An in-pool test of the cage and release system was conducted on November 16, 2001 at the NCSU university pool. The remaining three cages were constructed over the following two months.

The locations of the moorings and the designs for each of the seven taut-wire and five bottom mounted moorings were determined by NCSU personnel, after conferring with UNCW. All hardware minus the bottom weights was provided by NCSU for these moorings. A mounting adapter was designed to allow a SBE-37 Microcat to be used in an existing SBE-16 Seacat mounting bracket. One narrow band ADCP was mounted in a bridle.

Geographical location and depths of all moorings were determined with reference to future modeling efforts of this coastal region as, for example, for storm surge.

Figure 1: NCSU trawler proof ADCP cage

Equipment, Delivery and Deployment:

The majority of the equipment used in the moorings was subsequently delivered by NCSU personnel to the Center for Marine Science (CMS) at UNCW on 03/18/02.Table 1 provides a list of that equipment and supplies.

SBE-16 Seacats:	Edgetech 7500RC Releases:	Edgetech 8242 Releases:	Mooring Equipment:
2010	18776	18677	4 trawler proof ADCP cages
2011	18779	18678	1 central portion of large ADCP cage
2012	18780	18679	9 Seacat mounts
2013	18781	22418	5 30" Subsurface Floats
2014	18782		84 Shackles
2016	18784		50 sling(pear) links
2021			6 1.3 meter lengths of ½" anchor chain
2023			5 1.0 meter lengths of ½" anchor chain
2025			6 6.1 meter lengths of 5/16” wire rope
2026			3 13.6 meter lengths of 5/16” wire rope

Table 1: Serial numbers of instruments and equipment delivered to CMS on 03/18/02.

In April, 2002, three WorkHorse ADCP's and four SBE-37 Microcats were programmed, readied for deployment, and delivered to the CMS at UNCW. NCSU technicians accompanied UNCW crew and divers on the Research Vessel CAPE FEAR for the deployment of three bottom mounted moorings and two taut-wire moorings in Onslow Bay.

In June 2002, three more 8242 acoustic/transponding releases, a 45" syntactic foam float, and a 300 kHz Narrowband ADCP were delivered to UNCW. A taut-wire mooring and a bottom mounted mooring were deployed by UNCW crew and divers with NCSU technicians aboard the CAPE FEAR. This also took place in Onslow Bay on June 11, 2002. In late June another Narrowband ADCP, 150 kHz, was delivered and prepared for deployment by NCSU technicians. This instrument was deployed by UNCW crew and divers in Long Bay along with two more tautwire moorings on July 1, 2002. In mid-July 2002 the three WorkHorse ADCP's in Onslow Bay were recovered by UNCW. Data was recovered from these units and they were readied for redeployment.

Water Level Recorder at Wrightsville Beach, North Carolina:

An Aanderaa Water Level Recorder was deployed at the Wrightsville Beach Coast Guard Station near Masonboro Inlet. On August 13, 2001 data was retrieved from the instrument for the period June 19-August 13. The instrument was then redeployed and again recovered on October 3, 2001. Again data was retrieved and the water level recorder redeployed until January 15, 2002. The instrument was redeployed on July 17, 2002 and is scheduled to be recovered on October 18 2002.

A.7 Connections Between Coastal Ocean Processes and Estuarine-Dependent Fisheries

Progress:

We are investigating the influence of the Cape Fear River discharge plume on recruitment and production of fishery resource species. Our project represents one of several components of UNCW's NOAA-supported "Coastal Ocean Monitoring Program". Associated components (physical, chemical) are generating core data to assist our fisheries component, which is addressing 1) the utilization of the plume environment by larval fishes and crustaceans relative to that of adjacent coastal ocean and estuarine habitats, and 2) the impact of biotic and abiotic conditions within the plume on the physiological condition (feeding, growth) of larvae. We are thus testing two important hypotheses regarding plume function: "aggregation/utilization" and "trophic enhancement". Our goal is to develop an understanding of the role of discharge plumes in coastal fisheries production and the implications/consequences of plume variability for sustainable resource use. We are also utilizing larval samples to develop and test molecular genetic markers for distinguishing larval blue crabs from related portunid crabs. The marker will permit accurate indexing of blue crab recruitment and abundance during the larval stage.

Scientific Results:

A Effects of plume environment on larval aggregation and abundance

Ship-based plankton sampling for fish and crustacean larvae was conducted successfully from February through July at CORMP plume stations (3 depths per station: surface, 1m and bottom) representing plume, coastal and estuarine sites. Sorting of larvae has been completed through July 2002. Taxonomic identification of larvae has been completed through June 2002. Preliminary findings indicate that overall abundances of commercially-important taxa (e.g., blue crab, penaeid shrimp, spot, croaker, seatrout, red drum) were quite low during Spring 2002, presumably due to drought conditions and extremely reduced river discharge (USGS flow gauge data indicate that annual mean freshwater discharge from the Cape Fear River for 2002 appears to be at a 20-year low). Preliminary analyses suggest that the CFR discharge plume aggregates fish and crustacean larvae, at least during certain seasons. Despite unusually low river discharges for most of 2001/2002, fish and crustacean larvae were observed at higher densities inside the plume compared to oceanic stations during most months.

B Assessment of plume impacts on physiological condition of larvae

The impact of the plume on the physiological condition of larvae (trophic advantage hypothesis) is currently being examined. Collections of fish and crab larvae for biochemical assays is continuing. Although we have been able to archive some sample material at –80C, additional samples are needed. Due to low recruitment of finfish and crabs, we are continuing to collect additional samples.

C Development of molecular genetic markers for larval blue crab identification

We have isolated two genetic markers capable of distinguishing between *C. sapidus* and *C. similis*. The first of these is based on a 700 base pair fragment of the cytochrome c oxidase I gene (COI) located in the crab's mitochondrial genome. We isolated this fragment using the polymerase chain reaction (PCR) and a set of primers reported in Folmer et al., 1994). There is a considerable amount of difference between the two species (~15% sequence divergence), and consequently we chose this region as the basis of our species identification assay.

We also have sequenced a number of *C. sapidus* and *C. similis* for a second mitochondrial gene. *C.sapidus* and *C. similis* also differ in the sequence coding for the 16s ribosomal subunit. The degree of differentiation between species is less (~7%) but this provides us with an alternate tool for species identification.

We have also collected sequence data on additional species of Portunid crabs. We have used this data to refine our identification process and ensure against incorrectly identifying larvae of other swimming crabs as *C. sapidus*.

In order to efficiently utilize these genetic differences to characterize the composition of larval samples we have been developing rapid assay protocols. We are currently employing a modified DNA extraction technique that involves sonication of the individual larvae to disrupt cellular components and then subsequent isolation of the DNA. This technique has proved to be relatively reliable for recovering DNA suitable for PCR (about 75% are sufficient quality). We are still working to further refine this technique to increase the success rate and efficiency. Our initial attempts at PCR after disruption (without extraction) were not successful, but we will continue to explore this (and other) simple approaches as such a modification will reduce the time and expense of processing individual larvae.

Our second task under this objective is to develop a simple assay that can provide definitive identification of larvae. We have developed a multiplex PCR technique that does just that. Typically, in PCR, a single set of primers specific to a particular target are added to the reaction, and billions of copies of a single product DNA is produced. Multiplex PCR is different in that involves the addition of multiple sets of primers that target different regions. Our assay involves two sets of primers, one specific for the *C. sapidus* COI gene and specific to the *C. similis* COI gene. When we add the DNA of an unknown crab larvae to the reaction we get one three outcomes. If the larvae is a *C. sapidus* we get the amplification of a ~600base pair fragment of the COI gene, and if the larvae is a *C. similis* we get a ~350 base pair fragment. The different sizes of these two fragments make identification an easy task following the electrophoresis of the PCR products. The third possible outcome of the multiplex PCR is absence of amplification (no product). No amplification can result from insufficient DNA extract quality, or from the analysis of non-target larva (not *C. sapidus* or *C. similis*).

The application phase of this project will be undertaken shortly. The samples collected as part of the CORMP cruises to study the Cape Fear River Plume have undergone their initial sort and morphological identifications are being made. These samples will be made available to us soon.

Preliminary trials using preserved larvae collected as part of the NSF-CRUI project in the Cape Fear River have shown that the genetic assay confirms the identification of megalopae previously identified as *C. sapidus*, 65% of the time (72/111). The other 35% (39 larvae) produced no amplification product with the multiplex assay, which prevented the identification of these larvae. We have subsequently amplified 9 of these larvae for the second marker (16s), which identified them as *C. sapidus*. This indicates that the assay as currently implemented is not 100% effective. We are currently working on modifications that will increase the accuracy of the assay.

Interestingly, we have not identified any field caught larvae as *C. similis*; however, these samples were collected in the river during months when *C. similis* is not thought to be recruiting to the estuary. Further, the *C. similis* larvae may have been correctly discarded in the morphological sorting process. We are including all Portunid larvae in our future analysis to investigate whether this absence of *C. similis* from the river is a biological fact or an artifact of sample processing.

Benefits:

The first year of larval studies has coincided with unusual drought conditions and very low freshwater discharge from the Cape Fear River. Hence, we have obtained an extremely valuable dataset on finfish and crustacean larval responses to plume environments under low-flow conditions. We hope to continue this sampling program such that a comparable dataset can be collected for normal or above normal flow conditions.

The project has provided valuable data to permit the comparison of larval abundances and diversities between the Cape Fear River plume and a smaller discharge plume at Masons Inlet. Masons Inlet was relocated recently. We were awarded a Pilot Project grant from the UNCW Center for Marine Science to conduct a similar study of the ingress of larval fishes and crustaceans through the recently relocated Masons Inlet. Our NOAA CORMP-funded research in the CFR plume is thus providing valuable data on larval ingress (seasonality, concentration & diversity) through this large inlet for comparison with the much smaller Masons Inlet.

CORMP support has also been instrumental in enabling the collection of larval portunid crabs from the CFR plume and adjacent ocean to complement our project "A New Method for the Evaluation of the Spatial and Temporal Dispersal Patterns of Blue Crab (*Callinectes* spp.) larvae in the Cape Fear River Plume" (funded by the NCSG Blue Crab Program). This project has resulted in the development of genetic markers for species-level identification of several species of larval portunid crabs. These genetic markers are currently being applied to identify larval portunids from the CFR plume to better understand recruitment patterns of blue crabs and other portunid species.

CORMP funding has also facilitated the collection of data to support our preparation and submission of the proposal "**Buoyancy-Driven Transport and Transformation of Materials (BD-TRANSOM) Within The Cape Fear River Plume System"** to the National Science Foundation to continue and expand upon our investigation of plume impacts. If funded, this 5-year project will permit additional sampling and permit us to further investigate the effects of interannual variability in freshwater discharge and associated plume characteristics on fisheries production.

Sharing:

* Presentation to Mr. Gene Smith (NOAA Program Officer), “Overview of Living Marine Resources Component, UNCW CORMP”.

* Poster Presentation, “Coastal Ocean Monitoring Program at the University of North Carolina at Wilmington”. 2002 AGU Ocean Sciences Meeting.

* A presentation will also be given at the American Fisheries Society’s Southern Division Meeting to be held in Wilmington, North Carolina, in February 2003.

Presentations on the genetic component were given at national scientific meetings: Hoffman, GG and AEWilbur. 2002. A single-step multiplex PCR identification assay to distinguish megalopae of *Callinectes sapidus* from *Callinectes similis* in plankton samples. Society for Integrative and Comparative Biology January 2-6 Anaheim CA
* presented by student

Hoffman, GG, AEWilbur, MHPosey and TDALphin. 2002. A single-step multiplex PCR identification assay to distinguish megalopae of *Callinectes sapidus* from *Callinectes similis* in plankton samples. National Shellfisheries association Meeting April 14-18 Mystic CT

Graduate Students:

Mr. Walter C. Markovsky joined the project in January 2002 as a graduate research assistant and has become involved in monthly field sampling, sorting and taxonomic identification of larvae, as well as data management/analysis. The project is forming the basis of Mr. Markovsky’s master’s thesis. In addition, 3 graduate students and 7 undergraduate students at UNCW have gained research experience on this project by assisting with field collections, sample processing, taxonomic identifications and/or molecular genetic analyses.

A.8 Summary of Ra Measurements and Eddy Diffusivity Determinations

The objective of determining Ra activities was to determine effective cross-shelf eddy diffusivities and cross-shelf water exchange rates in Onslow Bay. The term "effective eddy diffusivity" is used to formally recognize that dispersion is a result of both true turbulent eddy fluxes as well as various types of shear dispersion and that the net actual dispersion can be modeled by a single parameter that is mathematically equivalent to a true eddy diffusivity.

Between April 2000 and April 2002 fourteen transects of Ra samples were collected. All of the samples have been successfully analyzed for ^{223}Ra. The data are presented in Table 1. In addition, contoured temperature and salinity transects have been completed as well as contoured density transects based on CTD data.

For each transect, an eddy diffusivity was calculated based on the following procedure that is briefly outlined.

1. Create a salinity, temperature and density transect from collected CTD data (see example,Ffigure 1).
2. Use these transects to identify cases of apparent upwelling driven by offshore advection and whether water column is stratified or well mixed. If there is no apparent offshore advection, proceed with the following steps.
3. Fit a second order polynomial to ln Ra activity vs. distance from shore using least squares minimization to determine a best estimate of Ra activities at the transect endpoints (determination of boundary conditions).
4. Determine the best-fit value of the eddy diffusivity using a numerical solution to the diffusive continuity equation using the above boundary conditions that includes consideration of whether water column is stratified (example in Figure 2).
5. Identify Ra transects that produce a statistically significant eddy diffusivity.

Of the fourteen Ra profiles collected between April 2000 and April 2002 (Table 1) eleven effective eddy diffusivities were calculated that are statistically significant (Table 2). They ranged from 110 to 1900 m^2/sec. However, eight of the eleven values were between 110 and 400 m^2/sec. This is consistent with a larger data set we have for Onslow and Long Bays that show a predominance of values in this range. It is not clear, at this point, if the few higher values represent actual increases in eddy diffusivity or are either driven by uncertainties associated with the distribution of large eddies or time-dependent advection.

These effective eddy diffusivities can be used to calculate a characteristic cross-shelf water exchange time for Onslow Bay. The exchange time is given by rearranging the Einstein-Smoluchowski equation to get, $T=L^2/2K$, where L is the cross shelf distance of the Bay and K is the eddy diffusivity. Based on the predominant range of our calculated eddy diffusivities (110 to 400 m^2/sec), characteristic water exchange times typically vary between approximately 150 to 500 days.

Station	Distance offshore (km)	Apr.,2001 Ra-223 (dpm/100 l)	May,2001 Ra-223 (dpm/100 l)	June,2001 Ra-223 (dpm/100 l)	July,2001 Ra-223 (dpm/100 l)	Aug.,2001 Ra-223 (dpm/100 l)	Sep.,2001 Ra-223 (dpm/100 l)	Oct.,2001 Ra-223 (dpm/100 l)	Nov.,2001 Ra-223 (dpm/100 l)
OB SB	1.61E+00	9.20E-01	2.08E+00	1.45E+00	7.59E-01	8.62E-01	1.45E+00	2.25E+00	1.00E+00
OB 05	8.05E+00	8.20E-01	8.40E-01	9.20E-01	5.25E-01	5.22E-01	8.41E-01	8.04E-01	7.79E-01
OB 10	1.61E+01	8.90E-01	7.51E-01	5.10E-01		4.16E-01	8.86E-01	1.00E+00	9.49E-01
OB 15	2.41E+01	7.80E-01	1.21E+00	5.20E-01	6.32E-01	3.33E-01	6.88E-01	6.00E-01	6.36E-01
OB 20	3.22E+01	7.50E-01	8.11E-01	5.30E-01	6.71E-01	2.86E-01	4.20E-01	5.72E-01	4.55E-01
OB 27	4.35E+01	4.50E-01	7.14E-01	2.80E-01	5.30E-01	2.69E-01	4.09E-01	4.03E-01	3.41E-01
OB 32	5.15E+01	5.60E-01	3.43E-01	3.90E-01	2.73E-01	2.48E-01	3.33E-01	no sample	3.24E-01
OB 37	5.95E+01	3.30E-01	2.20E-01	5.60E-01	2.66E-01	2.20E-01	3.23E-01	no sample	3.79E-01
OB 42	6.76E+01	2.20E-01	7.04E-02	9.00E-02	2.71E-01	1.79E-01	3.73E-01	3.62E-01	2.35E-01
OB 47	7.56E+01	9.00E-02	5.69E-02	9.00E-02	2.67E-01	1.37E-01	3.27E-01	1.74E-01	2.75E-01
OB 52	8.37E+01	1.80E-01	6.18E-02	7.00E-02	3.06E-01	1.04E-01	1.98E-01	1.52E-01	3.06E-01
OB 57	9.17E+01	6.00E-02	4.93E-02	5.00E-02	7.92E-02	8.66E-02	1.95E-01	9.80E-02	2.14E-01
OB 63	1.01E+02	9.00E-02	6.45E-02	6.00E-02	7.66E-02	8.19E-02	1.47E-01	5.86E-02	6.63E-02

Station	Distance offshore (km)	Jan.,2002 Ra-223 (dpm/100 l)	Feb., 2002 Ra-223 (dpm/100 l)	Apr.,2002 Ra-223 (dpm/100 l)
OB SB	1.61E+00	9.90E-01	2.69E+00	no sample
OB 05	8.05E+00	5.10E-01	7.41E-01	no sample
OB 10	1.61E+01	6.60E-01	1.41E+00	no sample
OB 15	2.41E+01	7.00E-01	2.00E+00	no sample
OB 20	3.22E+01	4.80E-01	9.89E-01	no sample
OB 27	4.35E+01	4.50E-01	1.16E+00	no sample
OB 32	5.15E+01	no sample	4.56E-01	5.00E-01
OB 37	5.95E+01	no sample	1.65E+00	4.50E-01
OB 42	6.76E+01	no sample	2.18E-01	3.90E-01
OB 47	7.56E+01	no sample	3.24E-01	2.80E-01
OB 52	8.37E+01	no sample	no sample	1.72E+00
OB 57	9.17E+01	no sample	no sample	1.12E+00
OB 63	1.01E+02	no sample	no sample	1.40E-01

distance_offshore(km)	June,2000 Ra-223 (dpm/100 l)	Nov,2000 Ra-223 (dpm/100 l)
3.24E+00	3.90E-01	1.62E+00
1.12E+01	5.70E-01	1.27E+00
1.91E+01	6.00E-01	6.75E-01
2.72E+01	7.80E-01	8.36E-01
3.51E+01	4.60E-01	8.57E-01
4.15E+01	3.70E-01	5.43E-01
4.74E+01	4.80E-01	4.80E-01
5.05E+01	4.50E-01	7.13E-01
6.68E+01	3.40E-01	7.36E-01
7.10E+01	4.60E-01	7.55E-01
7.78E+01	5.60E-01	6.35E-01
8.46E+01	4.00E-01	2.06E-01
9.44E+01		1.92E-01

distance_offshore(km)	Apr., 2002 Ra-223 (dpm/100 l)
1.50E+00	1.68E+00
1.02E+01	6.90E-01
1.95E+01	6.20E-01
2.89E+01	5.70E-01
3.81E+01	4.70E-01
4.74E+01	4.90E-01
5.60E+01	4.30E-01
6.53E+01	2.90E-01
6.71E+01	3.70E-01
7.26E+01	4.00E-01
7.84E+01	2.00E-01
8.45E+01	7.00E-02
1.04E+02	4.00E-02

Table 1. Ra-223 activities for Onslow Bay Transects.

Date	Eddy Diffusivity (m2/sec)
Apr-00	400
Jun-00	*
Nov-00	200
Apr-01	150
May-01	130
Jun-01	812
Jul-01	*
Aug-01	1250
Sep-01	110
Oct-01	270
Nov-01	130
Jan-02	160
Feb-02	1900
Apr-02	*

Table 2. Effective Eddy diffusives.

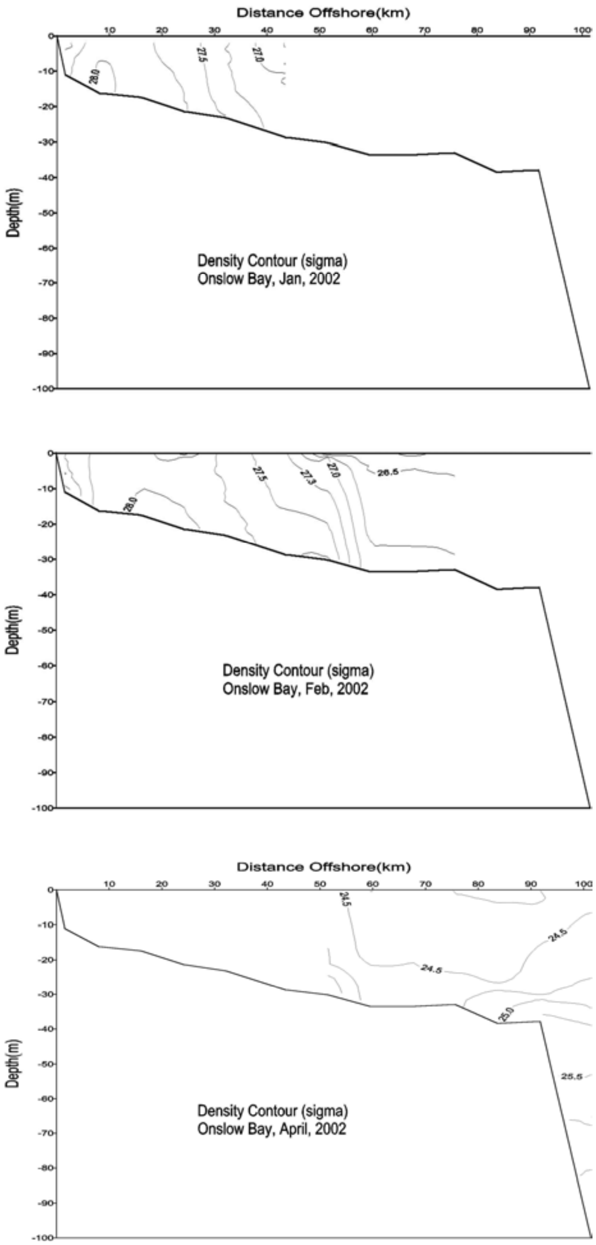

Fig 1. Example Density Contours.

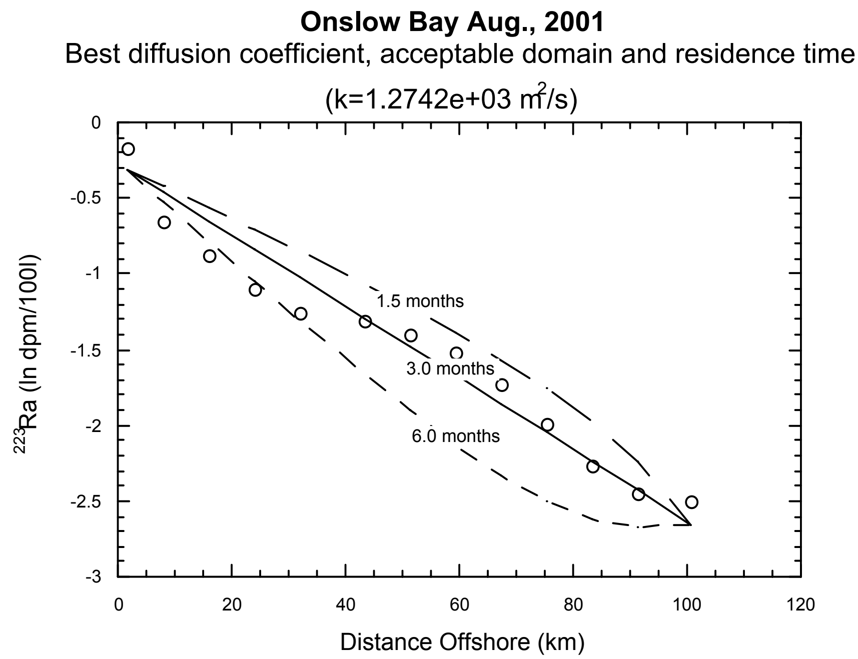

Fig 2. Ra transects and model fits

A.9 The distribution of phytoplankton in Onslow Bay

Description:

Numerous studies of phytoplankton biomass in Onslow Bay, a portion of the North Carolina continental shelf approximately 100 km wide and up to 55 m deep, show that a near-bottom chlorophyll a maximum (bottom concentrations often 2-3x higher than surface) is a frequent feature across much of the shelf. Chlorophyll a data from year I of UNCW's COMP show a similar result. Three explanations for this pattern can be considered: 1) Light flux to the bottom coupled with nutrient fluxes from the sediment may stimulate near-bottom production in a manner similar to the processes creating open ocean deep chlorophyll maxima; 2) Settling of phytoplankton to the bottom under calm conditions may create a near-bottom maximum by accumulation; or 3) Suspension of benthic microalgae may create an apparent "phytoplankton" maximum near the bottom.

We want to know if and under what conditions near-bottom chlorophyll maxima are formed by physical or other processes, as these maxima represent the bulk of the total phytoplankton in the water column much of the time and represent a significant food source for benthic and planktonic animals.

Cahoon et al. (1990), Cahoon and Cooke (1992) and Cahoon and Laws (1993) demonstrated the high biomass, high production, and taxonomically distinct character of the benthic microalgae in Onslow Bay. Approximately 80% of the chlorophyll a and 50% of the primary production in Onslow Bay are contributed by benthic microalgae.

References:

Cahoon, L.B., R.L. Redman, and C.R. Tronzo. 1990. Benthic microalgal biomass in sediments of Onslow Bay, North Carolina. Estuarine, Coastal, and Shelf Science 31:805-816. CMSR #011
Cahoon, L.B., and J.E. Cooke. 1992. Benthic microalgal production in Onslow Bay, North Carolina. Marine Ecology (Progress Series) 84:185-196. CMSR #045
Cahoon, L.B., and R.A. Laws. 1993. Benthic diatoms from the North Carolina continental shelf: Inner and mid shelf. J. Phycology 29:257-263 CMSR #029

Objectives, January 2002 - July 2002:

The work proposed here addresses three questions related to the importance of benthic microalgal production in the shelf waters of Onslow Bay:

How much benthic microalgal chlorophyll a is suspended by physical processes (tidal currents, storm events, etc.)?
How does benthic microalgal chlorophyll contribute to total water column chlorophyll a over time?
Can the distributions of chlorophyll a in the water column (a dynamic mix of phytoplankton and benthic microalgae) be modeled in a way useful to remote sensing applications?

Tasks, January 2002 - July 2002:

The questions above will be addressed by the following tasks:

Collecting turbidity and fluorescence data by deploying underwater chlorophyll loggers (Turner SCUFA II units) on a bottom-mounted mooring at the 23-mile reef site (OB-27)
obtaining chlorophyll-depth profiles using a flow-through fluorometer on shipboard
ground-truthing of the loggers' fluorescence data and remote sensing algorithms' parameters
visual identification of the taxonomically distinct benthic and planktonic microalgae, and
evaluation of relative importance of storms in regulating exchanges of materials across the sediment-water interface, and
estimation of benthic microalgal biomass in sediment cores collected at the site.

Collaborations and User Groups:

CORMP:

Durako, Optical Characterization of the Waters of Onslow Bay, the Cape Fear River Plume (CFRP) and Coastal Southeastern North Carolina: seeks to develop better algorithms for estimation of primary production using ocean color data from satellites; Cahoon project provides direct measures of Chl a, will explore ability of remote sensing algorithms to quantify benthic contribution to water column chlorophyll a and production.
Leonard, Storm Impact on Sediment Mobility and Biotic Response in Onslow Bay, NC: Examines response of shelf sediments to storm events and other physical perturbations. Cahoon project relies on PC-ADP measurement of near-bottom flows and OBS measurements of turbidity to relate suspension of benthic microalgae to sediment movement and suspension.
Cooper, Characterization of the Colored Dissolved Organic Matter (CDOM) in the Waters of Onslow Bay, the Cape Fear River Plume and Costal Southeastern North Carolina: CDOM (and DOC) with parameters measured on Cahoon project provide broad characterization of the chemical and biological properties of the shelf waters, especially near-bottom environment, where organic matter production is concentrated.
Posey and Lankford, Connections between Coastal Ocean Processes and Estuarine-Dependent Fisheries: they hypothesize that recruitment is controlled in part by water quality factors that serve as cues to larval ingress from the ocean to the estuaries; their sampling is correlated with patterns seen in this study. Near-bottom production may be important as a food resource for larvae migrating cross-shelf.
Mallin, Ecological Impacts of the Cape Fear River Plume on the Coastal Ocean: provides water quality data (suspended sediments, nutrients, pigments) on Onslow Bay transect and CFRP that complement this project's data; they are measuring Chl a using water samples and can benefit from faster fluorometric techniques as well as an approach using moored instrumentation.

EXTERNAL:

Lower Cape Fear River Program: Cahoon has worked with Mallin, P.I. and research coordinator on LCFRP, on many related publications, including one on effects of Hurricane Floyd on the Cape Fear River Estuary and coastal ocean now in preparation.

South Atlantic Fisheries Management Council/ NC Division of Marine Fisheries: propose to use artificial reefs as MPAs, but need to consider adjacent soft substrate and benthic microalgal production. NC Ocean Resources Task Force recommended protecting a "halo" of productive soft bottom around hard bottoms and artificial reefs. Data from this project and concurrent physics data can be used to assess "transport distance" for near-bottom microalgae (food for reef-associated herbivores).
Remote Sensing (SeaWiFS and EPA): ecological models must consider that measuring primary production using remote sensing provides inadequate information on overall system productivity, since bottom microalgae are major contributors to production and not remotely sensed or adequately accounted for in algorithms.

Milestones, January-July 2002:

fluorometers deployed at OB27 (23-nm reef) for entire period of 7 months, less turnaround time (2-3 days, typically) with successful measurement of turbidity and fluorescence at 10-minute intervals at two depths,
one fluorometer now deployed at OB-5 site to complement array of physics instruments there,
samples collected for Chl a and taxonomic analysis of near-bottom microalgae,
additional fluorescence and Chl a profiles conducted,
data on wave period, height, and other wave-related parameters obtained from Frying Pan Tower station in Onslow Bay.
Data show several trends, e.g.:
turbidity and Chl a frequently, but not necessarily correlated, implying suspension events and other processes regulate near-bottom chlorophyll a maxima.
data corroborate that at OB27 mid-shelf reef near-bottom primary producer biomass in water column is highly variable, confirming analysis of prior data sets showing extensive and frequent near-bottom maxima,
analysis of data show responses of near-bottom fluorescence and turbidity to high values of wave-induced near-nottom velocity and stress.
Measurement of sediment chlorophyll a on six dates confirms pattern of biomass concentration at sediment-water interface, typically in the range of 40-80 mg chl a m^{-2}. These values are equivalent to values obtained in previous studies and greatly exceed integrated water column Chl a values.

Products:

Graduate student GianLuca Manes is making <u>highly</u> satisfactory progress on Master's thesis examining physical resuspension of sediment microalgae as a mechanism creating the near-bottom chlorophyll a maximum. Graduation date expected: December, 2002. One and possibly as many as three publications will result; two figures are appended to illustrate results;
Poster presentation submitted to AGU meeting (with other co-PIs) in December on overall results of the project to date;
Presentation planned for meeting of Duke-UNC Oceanographic Consortium in November on apparent detection of zooplankton vertical migration by multiple in situ sensors at OB-27 site.

Fig. 1. Data from SCUFA II fluorescence and turbidity sensors at OB-27. “Top” instrument at 2.4 m above bottom, “bottom” instrument at 1.0 m above bottom.

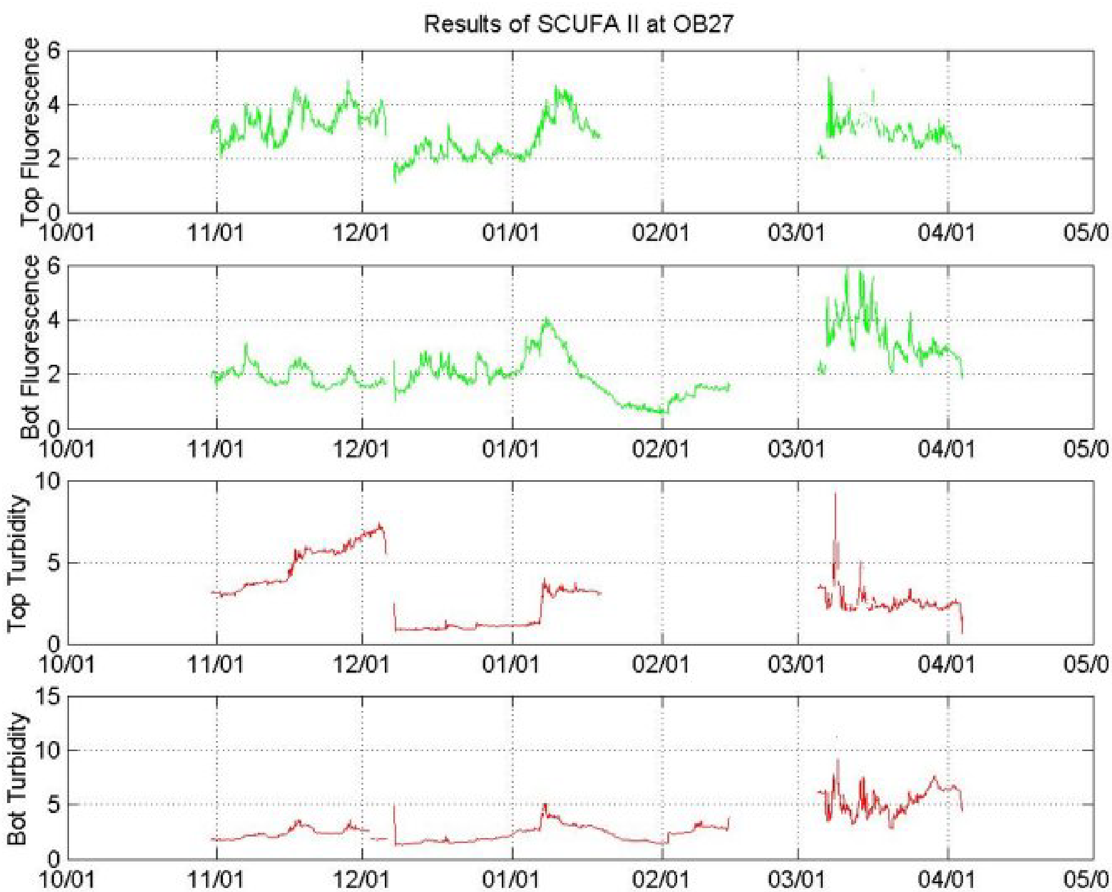

Fig. 2. Fluorescence, orbital velocity (calculated from wave data), and turbidity data from a storm event in January, 2002 at OB-27.