Coastal Ocean Monitoring Program
(formerly the Southeast Marine Monitoring and Prediction Center)

University of North Carolina at Wilmington

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Submitted by:

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Introduction

The University of North Carolina at Wilmington began a Coastal Ocean Monitoring Project (COMP) in September 1999 with funding appropriated through NOAA. This multi-disciplinary effort focused on ocean processes in the coastal ocean off southeastern North Carolina. In addition to sampling and measurement of basic oceanographic parameters, areas of investigation include responses to storm events, chemical and biological effects of the Cape Fear River's plume on the coastal ocean, storm impacts on benthic habitats, larval fish recruitment, and the biology of marine vertebrate populations. A major effort was also made to analyze the impacts of Hurricane Floyd on the coastal ocean in the region.

This is the final report for NOAA award # NA96RP0259, which funded COMP from September 1999 through May 2001. Previous semi-annual progress reports are posted on the program web site at http://www.uncwil.edu/cmsr/comp/results.htm. The following sections highlight results from the first long-term monitoring program in the coastal ocean of North Carolina.

Cape Fear River Plume (CFRP) Studies

This multi-investigator project is designed to assess the physical, chemical, and biological properties of the plume and how the properties interact. Sampling began in February 2000, with the goal of monthly sampling. Seven stations are currently being sampled. CFP1 is located in the lower estuary between Bald Head Island and Oak Island (see Figure 1 and map posted at http://uncwil.edu/cmsr/comp/cormppics/cfrplumestations.jpg). This station is about 5 km downstream of Station M18, sampled monthly by the non-Federally funded UNCW Lower Cape Fear River Program (http://www.uncwil.edu/cmsr/aquaticecology/lcfrp/). CFP2 is in the present ship channel about 6 km oceanward of CFP1. CFP3 is considered a control station out of the plume's influence and is located 5 km southeast of CFP2. CFP4 is located at the "sea buoy", the end of the ship channel about 7 km southwest of CFP2. CFP6 is about 5 km west of the ship channel, about 2 km offshore of Oak Island. CFP5 is about 12 km west of CFP2, and CFP7 is located between CFP4 and CFP5. Samples were collected on ebb tide.

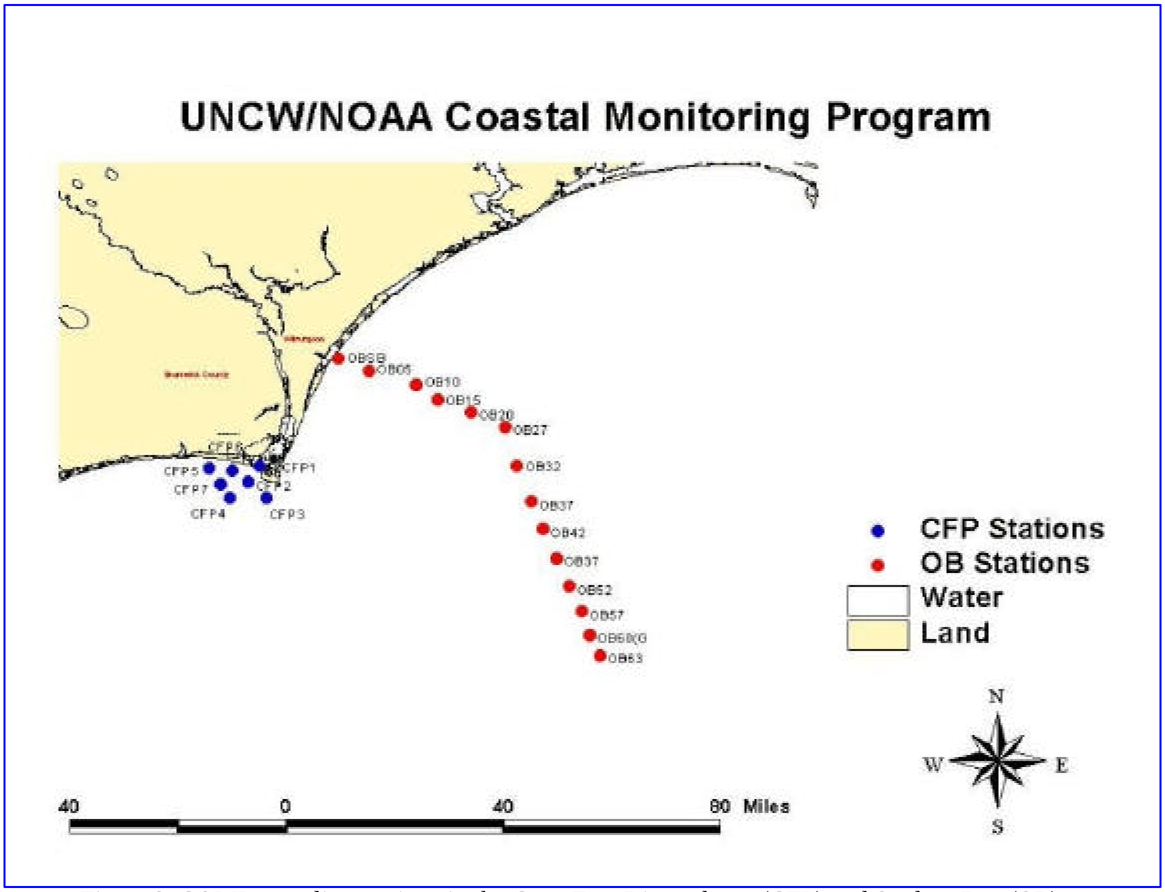

Figure 2. COMP sampling stations in the Cape Fear River plume (CFP) and Onslow Bay (OB).

Plume Water Quality

Table 1. Selected physical parameters (mean and standard deviation) for UNC Wilmington Center for Marine Science Coastal Ocean Monitoring Program (n = 7).

Sta.	Salinity (ppt)	Turbidity (NTU)	DO (mg/L)
CFP1	27.1±7.7	13±8	7.8±1.2
CFP2	31.2±4.1	10±5	7.6±1.3
CFP3	34.3±1.4	7±7	7.7±1.1
CFP4	33.6±2.1	4±5	8.0±1.3
CFP5	33.3±2.1	5±7	8.1±1.3
CFP6	32.7±1.6	6±6	7.7±0.8
CFP7	32.8±2.8	4±4	7.6±0.9

On station, vertical profiles of physical water quality parameters (water temperature, salinity/conductivity, dissolved oxygen, pH, and turbidity) were sampled using a YSI Model 6920 multi-parameter water quality instrument. Surface concentrations for some of these parameters are displayed in Table 1. Samples were also collected on-site for nutrient species concentrations. Total nitrogen, nitrate, total phosphorus, and orthophosphate have been stored frozen and wait to be analyzed. Ammonium, silicate, and chlorophyll *a* data are provided in Table 2.

As expected, average salinity was lowest in the estuary proper (CFP1) and just outside of the estuary (CFP2). It was only slightly higher at the control station CFP3. Highest averages were recorded at offshore stations CFP4 and CFP5 and just outside of the direct plume. Lowest salinities occurred in March, followed by September. Turbidity was highest in the estuary and just outside of its mouth, and slightly elevated at the control site CFP3, located in the Frying Pan Shoals to the east of the plume. Turbidity was highest in March, followed by September. Sites farthest offshore of the plume's direct influence (CFP4 and CFP5) appeared to yield the highest levels of surface dissolved oxygen. Temporally, dissolved oxygen showed an inverse relationship with water temperature, being highest in February (9.5 – 10.6 mg/L) and lowest in August (6.3 – 7.7 mg/L).

Table 2. Selected nutrient and biological parameters (mean and standard deviation) for UNC Wilmington Center for Marine Science Coastal Ocean Monitoring Program (n = seven cruises).

Sta.	Ammonium (µg/L)	Chlorophyll *a* (µg/L)	Silicate (µg/L)
CFP1	23±24	8.0±8.6	534.5±514.2
CFP2	18±17	5.0±3.7	280.9±292.7
CFP3	8±8	3.0±3.7	114.6±79.2
CFP4	10±11	3.0±2.9	184.3±149.2
CFP5	9±9	2.5±1.4	136.6±130.1
CFP6	13±15	2.9±1.5	231.7±124.2
CFP7	10±12	2.3±1.2	163.9±109.4

Ammonium concentrations were highest in the estuary and in the ship channel near the mouth (CFP1 and CFP2), followed by somewhat lesser concentrations in the plume as it curves to the west along-shore (CFP6). The control station CFP3 and the most ocean-ward station, CFP5, showed the lowest ammonium concentrations. Ammonium concentrations were highest throughout the station array in August (27 – 48 µg-N/L), elevated at CFP1 and CFP2 in March, and elevated at CFP1, CFP2, and CFP6 in August. Silicate was highest in the estuary (CFP1) and just outside of it (CFP2) and in the plume to the southwest (CFP6). Silicate was much lower at the control station CFP3, and at the most distant station CFP5. Silicate concentrations were highest in September, followed by March and October. Chlorophyll *a* concentrations were highest in the estuary and near the estuary mouth at CFP2, and displayed little difference among the other stations. Chlorophyll a was highest in February, with a peak of 24.6 µg/L at CFP1. A lesser bloom of 14.5 µg/L was recorded for CFP1 in August. To summarize, the effects of the plume can be seen in the spatial patterns of a number of physical and chemical parameters. Plume effects are most evident at Stations CFP1, CFP2 and CFP6, in that order, with the least effects at CFP3 and either CFP5 or CFP7.

Plume Optical Properties

Optical characteristics of the water column, including light attenuation (k_d) and spectral attenuation from the various sources contributing to (k_d) were also computed for each cruise. Spatial patterns in the diffuse attenuation coefficients (k_d) for PAR were uniform and values were low for February (Figure 2 and Table 3). The values increased dramatically during March with a pronounced turbidity plume extending along the ship channel from the Cape Fear River mouth to CFP2. The control station CFP3 had elevated (k_d) values in both February and March (Table 3). Overall calculated diffuse attenuation coefficients (k_d) values generally decreased from the high values of March, although August and September (k_d) values for CFP1 & CFP2 were relatively high. Values for May were the lowest yet measured for the offshore stations. A more diffuse turbidity gradient with a distinct plume was evident in April and May, including elevated values to the west at CFP6. In August, September, and October there was highest light attenuation around CFP1 and CFP2 in the Cape Fear River channel, followed by CFP6. Similar to many of the physical and chemical parameters, there is an overall pattern of highest (k_d) in and just outside of the estuary (CFP1 and CFP2), and in the west curving plume at CFP6; lowest values have been recorded at the sea buoy (CFP4) and to the west of the channel (CFP5 and CFP7). Light attenuation can be high at times at the control station CFP3, due to resuspension of sand from currents impacting the shoals that characterize this location.

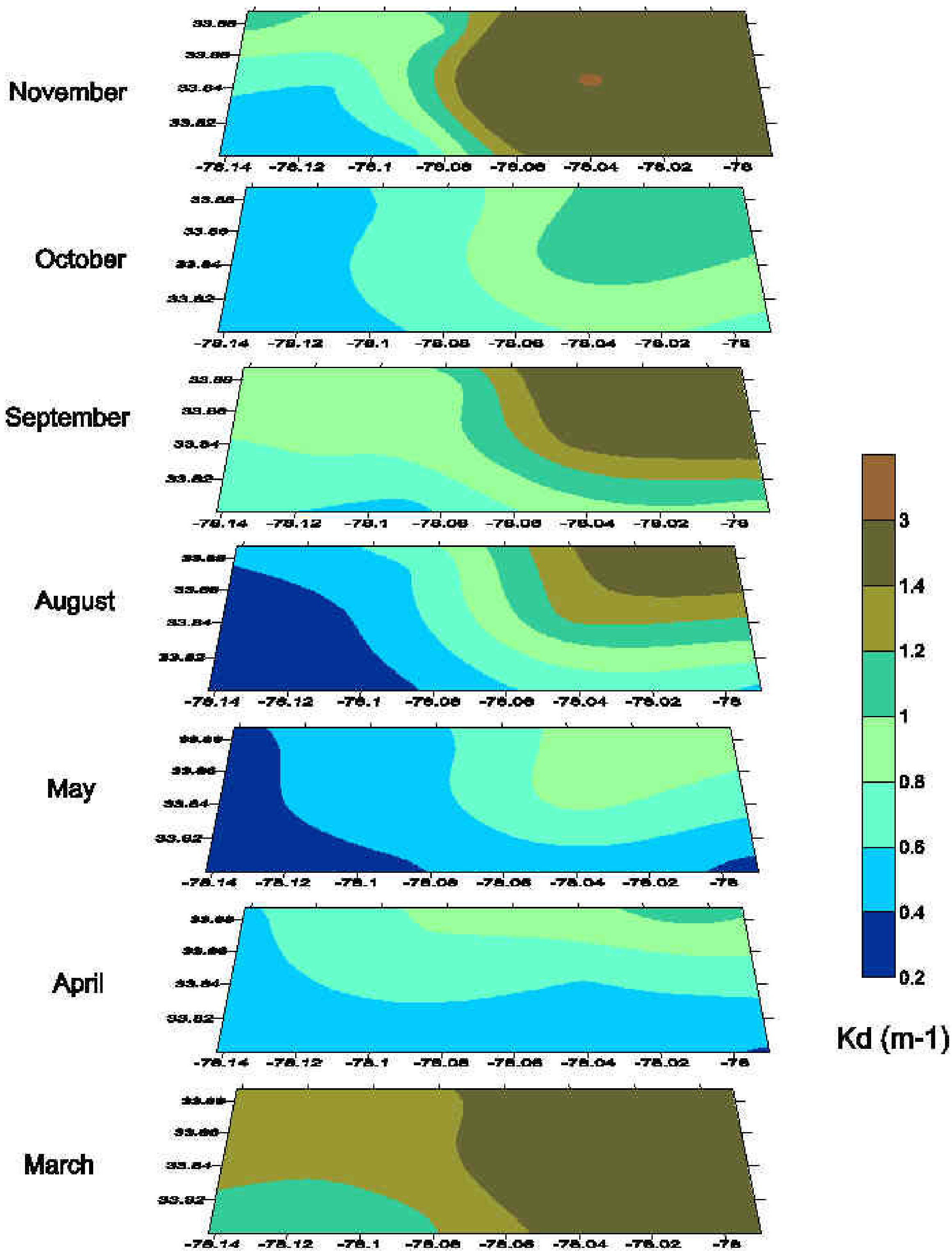

Figure 1. Light attenuation measurements (spectral diffuse attenuation coefficient Kd[lambda]total) in the Cape Fear River plume in CY 2000.

Table 3. Photosynthetically active radiation (PAR) light attenuation coefficients k_d from light profiles (see Figure 1).

Sta.	Feb	Mar	Apr	May	Aug	Sep	Oct	Avg.	Avg. less Oct.
CFP1	0.60	1.63	1.11	0.97	1.78	2.29	1.13	1.36	1.49
CFP2	0.60	1.74	0.61	0.90	1.29	1.56	1.15	1.12	1.21
CFP3	0.89	1.62	0.38	0.32	0.55	0.89	0.72	0.77	0.75
CFP4	0.78	1.12	0.54	0.37	0.37	0.55	0.60	0.62	0.59
CFP5	0.45	1.39	0.57	0.37	0.44	0.95	0.48	0.60	0.70
CFP6		1.32	0.82	0.51	0.64	0.83	0.66	0.80	0.80
CFP7		1.22	0.60	0.42	0.33	0.86	0.58	0.67	0.67
Total	0.66	1.43	0.66	0.51	0.77	1.13	0.76	0.85	0.89

Total, total suspended solids (TSS) and detrital spectral attenuation were all highest for CFP1 only in February and April. During the other months, CFP2 had the highest spectral attenuation for one or two of these fractions. Pigment and DOM spectral attenuation have been occasionally high for CFP2, although CFP1 usually had the highest spectral attenuation for these fractions as well. CFP3 and CFP5 have had the lowest spectral attenuation for most fractions. Total spectral attenuation was highest in September (also possibly March, but these data are unreliable due to backlighting problems-subsequently corrected); CFP2, CFP1, and CFP5 all had high attenuation and a similar spectral curves.

Data for August 2000 show that the dominant source of spectral attenuation is due to detrital particles in the total suspended solids (TSS) fraction. Phytoplankton contribute about 25-30% to the TSS attenuation overall, but they almost totally comprise the TSS attenuation peak around 663nm. Spectral attenuation from dissolved organic matter (DOM) has been highest at the shorter wavelengths and is generally highest at the Cape Fear River mouth (CFP1). The overall contribution of DOM to the total spectral attenuation is quite variable, being almost negligible in February to having values of over 50% of those for detritus. The high overall (k_d) values in March coincided with elevated field turbidity measurements throughout the station array. Likewise, high (k_d) values in August at CFP1 and September at CFP1 and CFP2 coincided with high field turbidity measurements.

Plume Dissolved Copper and DOC – Distribution and Complexation

Copper and dissolved organic carbon samples are collected quarterly at four locations (CFP1, CFP2, CFP3, and CFP5). Preliminary data suggests that the biogeochemical cycling of dissolved copper (Cu) in the Cape Fear plume is controlled almost exclusively by the transport and fate of strong organic complexing ligands. The data reveal that >99% of the total dissolved Cu is complexed by strong organic ligands with conditional stability constants $>10^{13}$. The free Cu^{+2} ion (reported to be the potentially toxic Cu species) has been measured at $<10^{-11}$ M (reported minimum toxicity level) in samples analyzed thus far. Riverine transport appears to be a major source of these strong complexing organic ligands to Long Bay as ligand concentrations are relatively constant at stations CFP1, CFP2, and CFP5, but typically much lower at the control site CFP3. Additionally, the data show a consistent presence of two distinct strong organic ligands. Future experiments are aimed at determining the specific sources and sinks of these ligands that may include *in-situ* biological processes and photochemical processes. Dissolved organic carbon (DOC) concentrations are very high (300 – 900 μM) in the Cape Fear plume. These data suggest that the high volume flow of the Cape Fear delivers a large concentration of riverine "humics" to the marine environment of Long Bay.

Fungal Respiration in the Plume

The objective of this sampling effort was to evaluate the metabolic activity of planktonic fungi relative to that of other planktonic microbes. The approach involved the use of anti-microbial compounds to inhibit either the bacterial or fungal components of the composite micro-biota. Bacteria were selectively inhibited either using chloramphenicol or a combination of penicillin and streptomycin sulfate. Amphotericin B was employed to selectively inhibit ergosterol-containing fungi (which probably represent in excess of 95% of the total planktonic mycoflora of the samples). Six BOD bottles (duplicates of three treatments) were filled with oxygen-saturated ambient water from each station for each sampling period-- two untreated controls, two with diluent (without anti-microbials) that was used to dissolve the anti-microbial compound in the "treated" replicates, and the remaining two with diluent in which was dissolved the particular anti-microbial compound(s). Dissolved oxygen concentrations in each bottle were determined on days 0, 5, and 20 using standard analytical protocols as a measure of microbial metabolism.

Results indicate that aerobic fungal metabolism, as measured by contribution to total oxygen utilization at each time interval, ranged between zero and five percent. These findings suggest that planktonic fungi, although present in plume water, are metabolically inactive throughout the year. Worthy of note is that bacterial respiration substantially increased at every sampling station and times in BOD bottles that received the diluent (without the anti-microbial compound). In other words, plume bacteria readily consume ethanol and dimethylsulfoxide, and apparently penicillin and streptomycin, and reflect this nutrient addition by more than doubling their dissolved oxygen utilization.

Plume Benthic Monitoring

The original scope of work for this project called for samples to be collected during two time periods - one during peak benthic faunal abundance and recruitment (March/April) and a time of lower benthic faunal abundance and high predation (July/August). Samples are collected at Stations CFP1, CFP2, CFP3, CFP4, CFP6 and CFP7. This distribution of sites allows us to examine the boundaries of the river-influenced benthic community and the communities more characteristic of near shore systems.

All the sampling outlined in the original proposal has been completed to date. We have also collected additional samples that we feel will enhance our understanding of the influence the Cape Fear River plume on the near-shore benthic community. We have collected samples from three additional near-shore stations that help to further bracket the river plume spatially as well as one additional station within the lower estuarine portion of the river itself. We have also increased our sampling to a quarterly format and increased replication from three samples per station to five samples per station. Currently we are processing all the samples that were outlined in the original proposal as high priority and all additional samples will be processed as both funding and time permit. Preliminary observation of a sub-set of samples shows there is some degree of overlap in the distribution of some river/ estuarine taxa in their distribution as we move from strictly river stations to near-shore areas.

In addition to looking at the distribution of benthic fauna we also outlined a study to examine the distribution and abundance of selected larval invertebrate taxa, in this case the blue crab *Callinectes sapidus*, at ten stations. These larvae will be sorted from the zooplankton monitoring samples monthly during times of expected peak abundance (April-November) and bimonthly for the remainder of the year. The processing of these samples is ongoing. Work from a separate study evaluating settlement within the Cape Fear River proper indicates that this year may have had an exceptionally high larval pool. This larval supply question has particular importance when looking at the interaction between oceanic and river systems.

Ongoing and Upcoming Research

In Autumn 1999, UNCW researchers were able to arrange and carry out post-Hurricane Floyd sampling cruises designed to measure the effects of the storm-induced river plume on the coastal ocean (see http://www.uncwil.edu/cmsr/comp/cahoonetal2001.pdf for a summary of results). The UNCW Cape Fear River Plume sampling component of the NOAA-sponsored COMP is providing a sound baseline against which the effects of Hurricane Floyd and future major storms can be measured. Besides the above parameters, the plume researchers are collecting other samples that are currently in the early stages of analysis. These include pigment samples to be analyzed by HPLC to obtain information on principal phytoplankton taxonomic groups residing in the plume station array, and zooplankton and meroplankton samples collected to obtain information on the plume food web. Contingent upon future funding, a fish sampling program is also being planned that will be coordinated with the water quality and plankton sampling efforts.

Onslow Bay (OB) Shelf Studies

This multi-investigator project was designed to assess: 1) cross-shelf distribution of physical, chemical, and biological properties, similar to parameters measured in the plume studies; 2) oceanographic conditions at outer and mid-shelf stations in order to describe shelf circulation patterns and Gulf Stream dynamics; 3) contribution of Gulf Stream events to recruitment at a mid-shelf “live bottom” reef; and 4) impacts of storms and chronic erosion on sediment transport and the health of “live bottom” reef communities. Sampling began in March 2000, with the goal of monthly sampling (see cruise logs for the Onslow Bay transects at http://www.uncwil.edu/cmsr/comp/results.htm). Figure 1 shows the sampling transect and stations. Two permanent stations (described below) on the transect included moorings with water column and seafloor instrumentation.

OB Physical Oceanography

Since June 2000, upward looking Acoustic Doppler Current Profilers (ADCPs) with Seabird MicroCat Conductivity-Temperature loggers (see mooring configuration at http://www.uncwil.edu/cmsr/comp/cormppics/mooring.gif) were maintained at two locations (27m and 92m depth) in Onslow Bay, with periodic cruises (see cruise logs at http://www.uncwil.edu/cmsr/comp/results.htm) to download, reconfigure and redeploy these instruments. The sites are mapped at http://www.uncwil.edu/cmsr/comp/cormppics/onslowbaymap.gif. Raw data from these deployments are plotted and plots are available at http://www.uncwil.edu/cmsr/comp/results.htm. A summary of 2000 results is presented at http://rover.phy.uncwil.edu/onslow/comp/compseminar/. Ongoing analysis of the data will focus on the tidal and synoptic time scales, where most of the interesting variability appears to be centered.

Beginning in 2001, COMP subcontracted with North Carolina State University (Dr. Len Pietrafesa and Dr. Lian Xie) to analyze data from three ADCP moorings NCSU maintained during the fall-winter of 1999-2000. These instruments were deployed along the shelf break in Onslow Bay and captured the sequence of hurricane events (Dennis, Floyd, and Irene) during fall, 1999. The downloaded, first pass-filtered data are being processed and will be published in 2002.

OB Chemical Oceanography

COMP is using high-resolution radium isotope data to quantify dispersion and develop an understanding of the processes controlling water exchange rates in Onslow Bay. The concentrations of radium isotopes (i.e., ^{223}Ra, ^{224}Ra, ^{226}Ra, ^{228}Ra) can be used to quantify the mixing of near shore and offshore waters as well as to determine horizontal kinematic eddy diffusivity. All of the radium isotopes that we measure are naturally occurring and are produced in either the ^{235}U, ^{238}U or ^{232}Th decay series, (^{223}Ra, ^{226}Ra and ^{224}Ra respectively). They are all radioactive with half-lives of 11.4 days, 3.64 days, and 1,600 years for ^{223}Ra, ^{224}Ra, and ^{226}Ra. Near-shore coastal waters contain elevated dissolved activities of these radium isotopes compared to the activities of their parent nuclides and offshore. These elevated activities arise through desorption of Ra from particle surfaces and the input of submarine groundwaters enriched in radium. The radium isotopes can thus be thought of as a dye or tracer with a near shore input. However, the two short-lived Ra isotopes (^{223}Ra and ^{224}Ra) decay before they reach the edge of the continental shelf while the long-lived isotope (^{226}Ra) is effectively conservative.

Three primary goals were accomplished during this grant period. First, alpha-particle counting equipment required for radium isotope analyses, both the static system for ^{226}Ra analyses and the re-circulating system for ^{223}Ra and ^{224}Ra analyses, were acquired, constructed and successfully tested. Precision and reproducibility is within the ranges expected based on counting statistics. Second, protocols and an operating manual were developed for radium sampling aboard the *R/V Cape Fear*. Third, radium analyses for five transects in Onslow Bay were completed in April, June and November 2000 and April and May 2001. These data, combined with radium isotope data from previous work by COMP investigators and others, show that flushing rates for the shelf waters of Onslow Bay can range from as little as 10 days to as much as nine months.

Water samples from Onslow Bay for analyses of nutrients have also been collected on nine cruises from April 2000 to May 2001, including triplicate samples from a combination of 19 stations and three depths at each station. Analyses for reactive silicate have been completed. Analyses of nitrate-nitrite, phosphate, total nitrogen, and total phosphate are pending. There are 636 samples to be analyzed as of this May 2001. Additional chemistry work is described in the Cape Fear River Plume report presented below.

OB Benthic Boundary Layer Study

This study examines the effects of storm-induced waves and currents on processes in the near-bottom zone, including sediment resuspension and effects of benthos. A quad-pod frame was deployed at a location in Onslow Bay, 27 miles off Wrightsville Beach, NC (OB27). A Sontek PC-ADP with an Optical Backscatter Sensor (OBS) has been deployed there since April. Box cores of sediment have been collected at this site seven times between April and December. Sediment peels and core X-radiographs have been created for six of these box core samples. Textural analyses of the sediment and identification of infauna are now in progress. A storm event in September 2000 was analyzed and the results presented at the Society of Engineering Conference in Charleston, SC, Oct. 23-25, 2000 (abstract at http://www.uncwil.edu/people/lynnl/comp/publications.html). Further data from the PC-ADP and OBS sensors and results of other analyses are presented at http://www.uncwil.edu/people/lynnl/bbl.html.

OB Larval Recruitment Study

The aim of this study was to examine the importance of the Gulf Stream as a source of larval recruits to shelf waters in Onslow Bay. Ichthyoplankton sampling along a transect across the Gulf Stream's western edge into Onslow Bay using a variety of nets, coupled with use of CT data and satellite imagery to delineate the edge of the Gulf Stream, has produced a large data set. Details of this data set are presented here and have been presented in posters presented at professional meetings (see http://www.uncwil.edu/cmsr/comp/results.htm under Fisheries).

Family Distribution

The numbers of fish larvae in each family caught during cruises CF01-CF03 (April through June 2000) and CF05 (September 2000) were calculated and the size ranges determined (Table 1). The total number of individuals caught was 7546 in 84 families. Non-reef fishes caught totaled 5209 individuals in 50 families. Reef fishes totaled 2337 individuals in 34 families. In shelf water, 624 reef fishes in 20 families and 612 non-reef fishes in 21 families were caught. In GS intrusions, 1464 individuals in 33 families of reef fishes and 3484 individuals in 42 families of non-reef fishes were caught. In the GS front, 188 reef fishes in 19 families and 906 non-reef fishes in 20 families were caught. In the GS axis, 61 reef fishes in 14 families and 182 non-reef fishes in 22 families were caught. Certain families appeared much more often in GS intrusions than in the other types of water masses (i.e. Apogonidae, Carangidae, Clupeidae, Holocentridae). Some families were much more prevalent in shelf water (e.g. Ophidiidae and Gobiidae). Some families were most abundant in GS front (e.g. Callionymidae). Others appear common to only GS axis waters (e.g. Acropomatidae and Caproidae). Finally some were common most to waters associated with GS, axis, front and intrusions, (e.g. Bothidae).

Ichthyoplankton Abundance

Ichthyoplankton concentrations and abundances were determined for the three gear types in each water mass for CF01-CF07 (April through November 2000). No significant differences were found (One way ANOVA, $P > 0.05$). However some trends can be seen as samples taken from the bongo net have a lower mean concentration for GS axis water, and highest for GS front (Figure 3). The neuston net collected the highest mean concentration in GS axis waters (Figure 4).

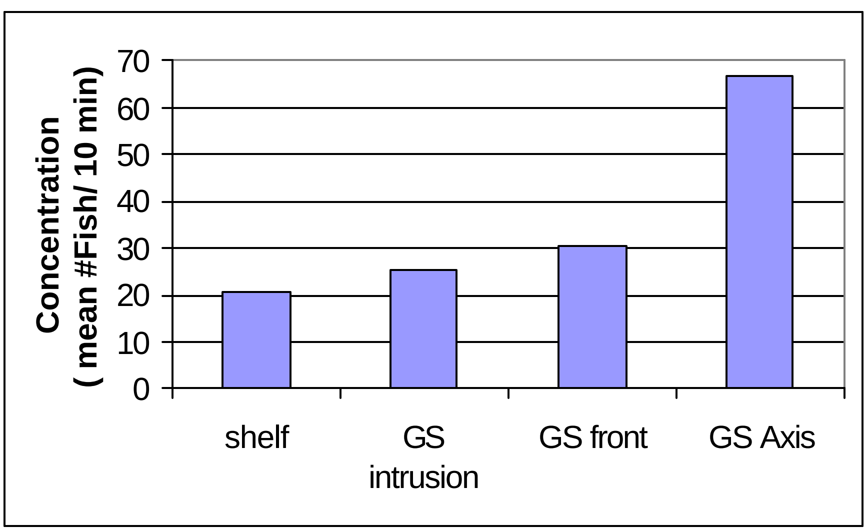

Figure 1. Concentrations of ichthyoplankton collected by the bongo net in four different water masses. No significant differences were found (One way ANOVA, P>0.05)

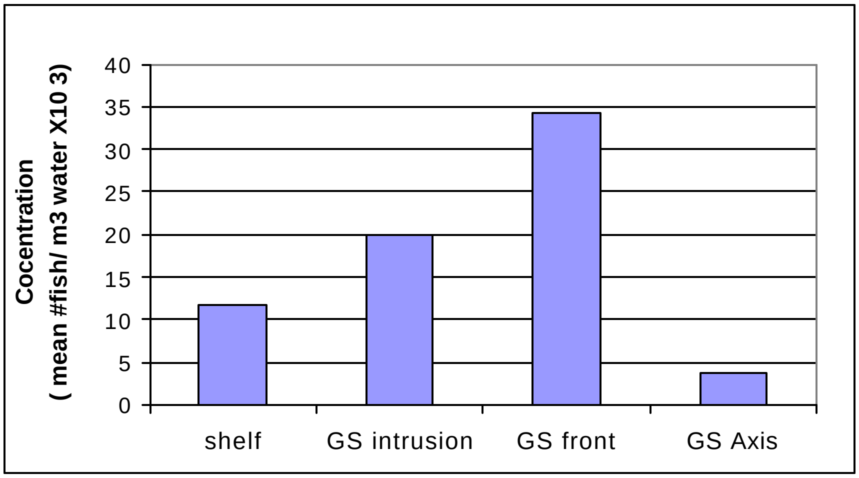

Figure 4. Concentrations of ichthyoplankton collected by the neuston net in four different water masses. No significant differences were found (One way ANOVA, P>0.05).

Biology of Marine Vertebrates

A goal of COMP is to determine the impact of severe storms and human activities on resources of the coastal ocean, including vertebrate species. Royal Terns and other seabirds may be used as ecological indicator species for marine and estuarine health in the coastal region. Marine mammals are apex predators in the offshore, coastal and estuarine environments of southeastern North Carolina. Their distributions are reliant upon both physical and biological features of these environments, thus, they represent "integrated" views of the ecosystem.

Seabirds

One focus of the work on marine vertebrates was an effort to census seabirds and determine their spatial distribution. Two species of seabirds, Royal and Sandwich Terns, were particularly interesting as they nested in the Cape Fear region in relatively large numbers. All sightings of Royal and Sandwich Terns in Onslow Bay Cruises occurred within 55 km of the Cape Fear Colony, in Carolina Coastal Water. Both species were less numerous further from shore, as would be expected by scattering (Royal, $\chi^2_{13} = 1.14$, P = 0.9; Sandwich, $\chi^2_{13} = 6.97$, P = 0.1). In the first transect (23-26 km from the colony), the apparent density of the Sandwich Tern was 3.6 times higher than that of the Royal Tern. Two Sandwich and 23 Royal Tern sightings occurred farther from the colony. In 135 total ocean sightings of these species, 66% were of the Sandwich Tern, and this is disproportionate to its population, which is only 30% that of the Royal Tern at the Cape Fear River Colony. Due to increasing ocean surface area in arcs (delimited by sampling stations) around the Cape Fear colony, and a decreasing number of surveys in the farthest transects, survey effort far offshore was insufficient to conclude that these species do not forage there. It is suspected that both species primarily feed close to shore due to the accessibility of fish in shallow water.

A related effort used stable isotope analyses to establish a base of information about the sources of foods for seabirds associated with different nesting sites in coastal North Carolina. Comparing species within colonies, significantly higher $\delta^{13}C$, $\delta^{15}N$ and $\delta^{18}O$ values occurred in the Sandwich Tern at the Cape Fear colony in 1999 ($\delta^{13}C$, $t_{18} = 2.76$, P = 0.01; $\delta^{15}N$, $t_{18} = 2.58$, P = 0.02; $\delta^{18}O$, $t_{18} = 3.73$, P = 0.002; Fig. 4a). No other significant isotopic differences were detected between Royal and Sandwich Terns within the same colonies in 1999. In 2000, the only significant interspecific difference within a colony occurred with a higher mean $\delta^{13}C$ value in the Sandwich Tern at Cape Lookout ($t_8 = 2.54$, P =

0.03). Four significant intraspecific, between-colony differences occurred in 1999, and one occurred in 2000. In the Sandwich Tern in 1999, mean $\delta^{13}C$ and $\delta^{18}O$ values were lower at Oregon Inlet than those of the other two colonies ($\delta^{13}C$, $F_{2, 27} = 14.5$, $P < 0.0001$; $\delta^{18}O$, $F_{2, 27} = 14.6$, $P < 0.0001$). Also in 1999, the mean $\delta^{18}O$ value in the Royal Tern at Oregon Inlet was lower than intraspecific values at the other colonies and the mean 1999 Royal Tern $\delta^{15}N$ values from Cape Fear and Oregon Inlet were lower than the mean intraspecific value for Cape Lookout ($\delta^{18}O$, $F_{2, 27} = 8.38$, $P = 0.002$; $\delta^{15}N$, $F_{2, 27} = 3.41$, $P = 0.048$). In 2000, the $\delta^{13}C$ value for the Cape Lookout Sandwich Tern was higher than those of Oregon Inlet and Cape Fear ($F_{2, 12} = 16.5$, $P = 0.0004$). Of the five hatched Royal Tern eggshells from Cape Fear in 1999, two analyzed that year had $\delta^{13}C$, $\delta^{18}O$ and $\delta^{15}N$ values that were the same as those from fresh eggs (standard deviations decreased slightly when these samples were included). Three 1999 $\delta^{15}N$ samples from hatched eggs tested in 2000, were 1‰ higher than the mean of fresh eggs tested in 1999. Most $\delta^{13}C$ and $\delta^{18}O$ values increased by 2-3‰ between 1999 and 2000, while all mean $\delta^{15}N$ values were 1-2‰ higher in 2000. Isotopic standards indicated that the mass spectrometer was calibrated the same in both years.

Since estuarine vs. oceanic salinity was most divergent in the Cape Fear area and salinity within the Cape Fear River itself was highly variable, this colony would be predicted to have the greatest divergence in $\delta^{18}O$ values between species, and between Royal Terns (estuarine foragers). 1999 results followed these predictions—ocean foraging Sandwich Terns had significantly higher $\delta^{18}O$ values in the Cape Fear Colony than did Royal Terns, and Royal Terns at this colony had a wide range of $\delta^{18}O$ values. Interspecific means were slightly higher in Sandwich Terns at the Cape Lookout and Oregon Inlet colonies, however, the differences were not significant. Distinct estuary (Royal Tern) and ocean (Sandwich Tern) signatures might become apparent with additional samples, as they followed the salinity gradient in 1999 for both habitat types. The higher $\delta^{18}O$ values in 2000 can not be explained without background isotopes, and ambiguous results may be due, in part, to the small sample size (half that of 1999).

Background values from different water masses and prey species would be necessary to interpret $\delta^{15}N$ and $\delta^{13}C$ values in eggshells, however, significant differences observed may reflect foraging differences. As with $\delta^{18}O$, the causes of higher $\delta^{15}N$ and $\delta^{13}C$ values and few significant inter- and intraspecific differences in 2000 are not known. These isotopes could provide abundant information on the Onslow Bay food web as more data are gathered.

A third effort employed genetic analyses to look for evidence of toxicants in the food chains supporting seabirds, particularly Royal Terns. During the spring and summer of 1999, small blood samples (10-40 μl) were collected from adult and juvenile Royal Terns from five breeding colonies in North Carolina. The colonies are located in three different estuaries systems (Core Sound – Sand Bag and Wainwright Islands, Pamlico Sound – Big Foot and Island L Islands, and Cape Fear River – Ferry Slip Island) that have variable contaminant loads. The blood was analyzed with the comet assay to determine levels of DNA strand breaks (SB). Comet assays have been used to assess DNA damage due to genotoxic exposure both in laboratory and field studies and on a variety of cell types (for a review see Fairbairn *et al*. 1995). Results from 1999 reveal that adult and juvenile terns from the Core Sound colonies (Sand Bag and Wainwright Islands) have significantly higher levels of apparent DNA damage than the remaining study sites (Figure 1). This was unexpected because previously published studies of sediment contaminants indicate that the Core Sound has lower pollutant loads than the other study areas (Hackney *et al*.1998). However, a study performed by Wickliffe and Bickham (1999) on Brown Pelicans from the Core Sound and Cape Fear River had similar results. To further assess these findings we collected additional blood samples during the spring and summer of 2000. These samples are currently being analyzed. We are especially interested in the results from year 2000 samples, as they may show effects from toxic materials that entered coastal waters as a result of flooding from the hurricanes of 1999.

Marine Mammals

COMP also helped support continuing efforts to document the population structure and residency patterns of Atlantic bottlenose dolphins (Figure 5) in coastal North Carolina waters. Stock structure of mid Atlantic bottlenose dolphins is highly complex, with offshore and coastal forms, as well as both migratory and resident individuals. Through support of COMP, the National Marine Fisheries Service, North Carolina Sea Grant, and the Wilmington Army Corp of Engineers, year round photographic surveys of Wilmington coastal waters help identify individual dolphins. Data collected in the past year, in addition to data from previous years, strongly indicate that some dolphins are resident year-round in SE North Carolina (Figure 6). Photos are archived in the NMFS centralized Mid-Atlantic Bottlenose Dolphin Photo-Identification Catalog.

Figure 5. Bottlenose dolphin surfaces in coastal ocean off Wrightsville Beach, NC. Similar photos are included in the NMFS centralized Mid-Atlantic Bottlenose Dolphin Photo-Identification Catalog.

The database shows that many dolphins in this area have been seen in northern sites such as Beaufort and Manteo, NC as well as in southern sites such as Myrtle Beach, SC. Continued work should help to elucidate the complex stock structure of mid-Atlantic bottlenose dolphins, which is essential to understanding the role that these top-level predators play in the overall Onslow Bay ecosystem.

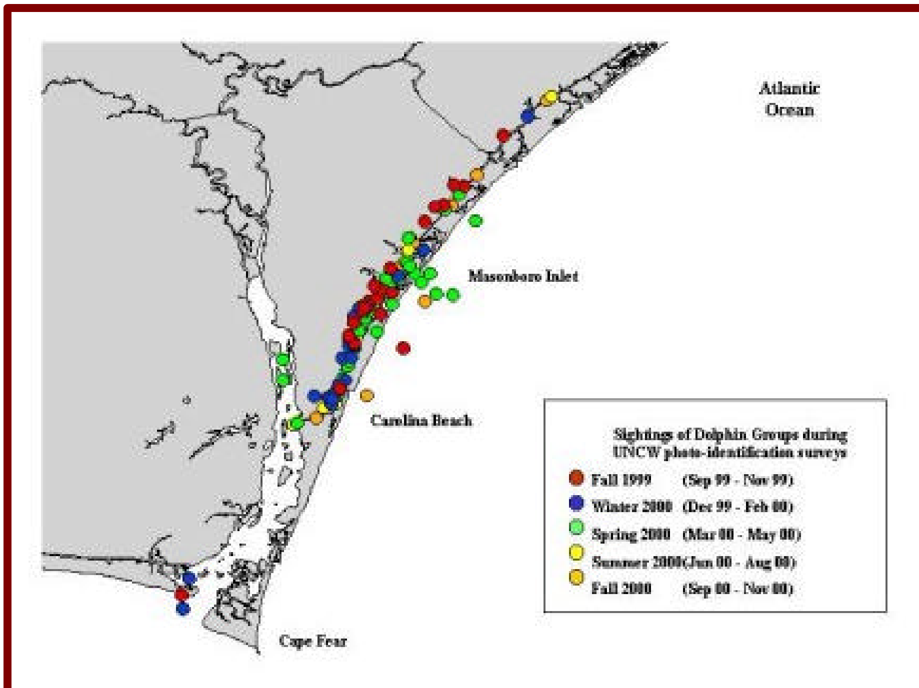

Figure 6. Dolphin sightings from 1999-2000 UNCW boat surveys, including offshore operations supported by COMP.