

Trophic Indicators of Ecosystem health in Chesapeake Bay (Houde, Harding, Boicourt and Roman)

Indices of Nutrient Enrichment in US Atlantic Estuaries from Remote Sensing of Ocean Color and Temperature (NASA-funded companion Grant, L. Harding, P.I.)

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Organizational (Institutional Partners):

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Objectives:

Develop indicators capable of determining plankton and fish community structure and function, i.e., indices of trophic transfer. Couple these indicators to physical-chemical and remote sensing assessments of ecosystem condition.

Progress Summary:

1. Remote Sensing and Bio-Optics

SAS III flights were conducted on a total of six occasions in Albemarle-Pamlico Sound from spring through fall in conjunction with the Chesapeake Bay flight series to measure chlorophyll and temperature distributions. The Chesapeake Bay remote sensing program (CBRS – <http://www.cbrsp.org>) is the more intensive part of this comparative effort,

consisting of >20 flights per year on the main stem Bay and 8-12 flights per year on two tributaries of focus, the Choptank and Patuxent Rivers. The former is linked to NASA and NOAA efforts and falls under the auspice of CBRSP that now spans 1989-2002; the latter continued a time-series from the EPA/NASA CISNet program that focused on the Choptank River (<http://www.cisnet-choptank.org>).

Shipboard bio-optical measurements were conducted on two sets of cruises as part of the Chesapeake Bay component of ACE INC. The first set gave coverage of the main stem Bay and adjacent coastal waters in collaboration with Bess Ward's Biocomplexity project; the second set gave coverage of the Choptank and Patuxent Rivers concurrent with surveys of physical properties (Boicourt), zooplankton sampling (Roman), and fish trawls (Houde). Bio-optical measurements on both sets of cruises supported the remote sensing efforts and included: (a) chl-a, (b) particulate absorption, (c) CDOM absorption and fluorescence; (d) seston; (e) HPLC pigment determinations; (f) in-water profiles of downwelling irradiance and upwelling radiance from a suite of instruments to recover remote sensing reflectance; (g) sun photometer measurements for atmospheric turbidity. The optical instruments for profiles included a Satlantic hyperspectral tethered radiometer buoy (TSRB) and two profilers, a Biospherical Instruments MER-2040 and a Satlantic MicroPro. Deployment of these instruments is supporting QA/QC of radiometry for ACE INC and comparisons with satellite and aircraft recoveries of key ecosystem properties.

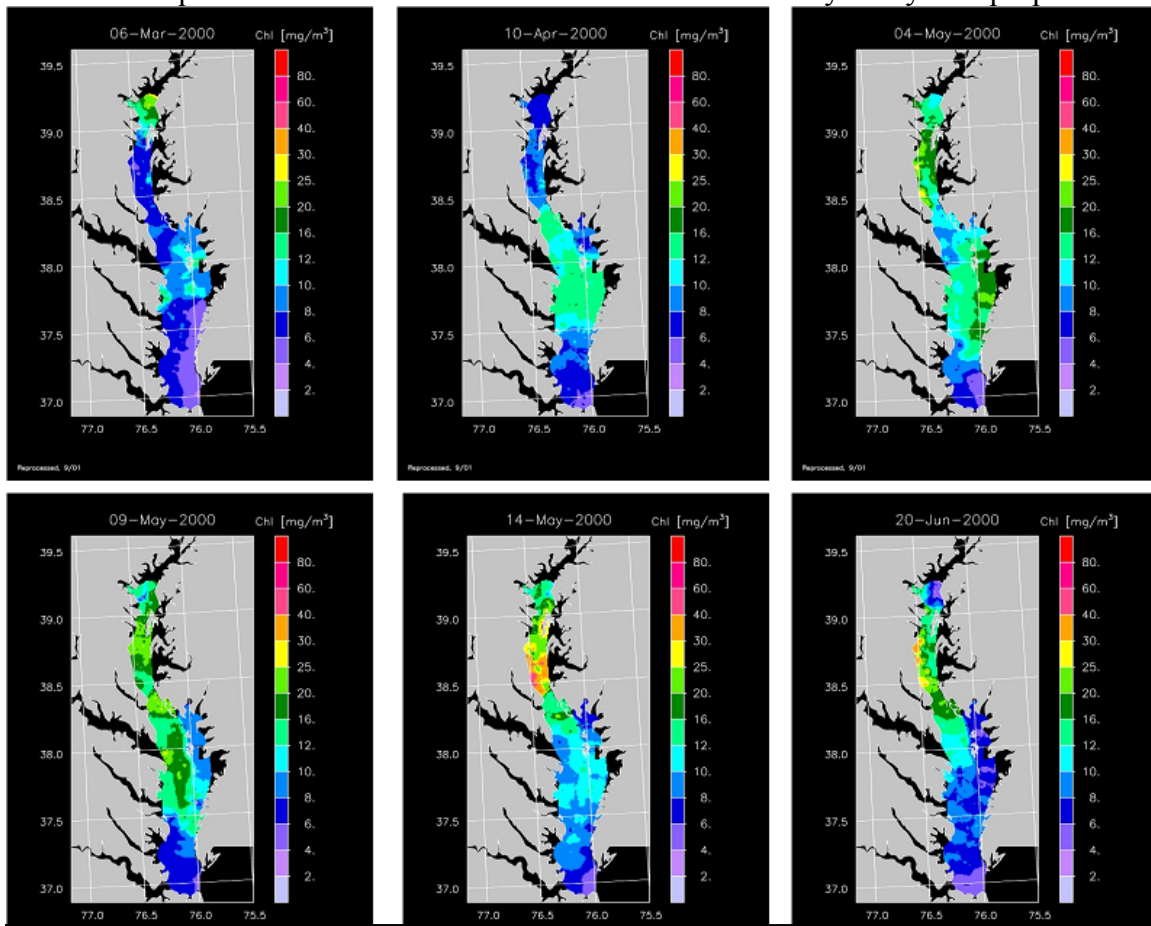


Figure 1. Chlorophyll (chl-a, mg/m^3) distributions in Chesapeake Bay from aircraft remote sensing of ocean color using SAS III for six dates in spring-summer 2000.

The Chesapeake Bay group has applied recently published models of primary productivity (Harding *et al.*, 2002) to the complete time-series of remote sensing data to generate spatially explicit outputs of PP for the main Bay. These data are now being analyzed to develop predictive capabilities for this integrative indicator of ecosystem function for the Bay. The specific approach combines data on freshwater input and nutrient loading to the estuary with the >400 time point data set developed from the remotely sensed data and models applied thereto. We reported on progress at an international symposium on primary productivity in the oceans in Bangor, Wales in March, 2002. Measurements of primary productivity on the main stem Bay and tributary cruises were conducted throughout 2002 to obtain validation data for model outputs and the data are now being processed and analyzed.

Future Activities:

Continuation of Y-2 Objectives and research schedule, with increased emphasis on applying indicators to other estuarine systems, including the Neuse-Pamlico Sound systems. Compare and cross-calibrate pigment-based indicators of phytoplankton functional groups as well as zooplankton and higher trophic-level indicators between Chesapeake and these systems.

2. Oxygen and Residence Time Component Indicators

Both field and analytical modeling efforts are being employed in the attempt to incorporate dissolved oxygen and residence time in meaningful indicators of estuarine health. For the field effort, we are focusing on the exchange dynamics and short-term oxygen variability of the Patuxent River and Choptank River estuaries, using shipboard axial surveys and moored sensors. These field measurements, while undertaking a comparative approach, also extend the time-series program in the Choptank that was initiated with our CISNet study. In addition to employing standard CTD surveys, a rapid sampling towed vehicle, the ACROBAT, was used to delineate the fine structure in the physical field, and the fine structure of oxygen, chlorophyll, and zooplankton distributions. The Stephens-Greenspan oxygen sensor was deployed in a variety of environments in the Choptank River and main stem Chesapeake Bay to test its ability to handle the deleterious effects of biofouling and hypoxia. This sensor maintained accuracy considerably longer (>1 month) than other probes under biofouling and hypoxic conditions. The performance was sufficiently stable that we acquired two units for deployment in spring 2003. We also acquired the new Aanderaa/PerSens Optode oxygen sensor for similar evaluation.

The field measurements were generally successful, although we encountered some difficulty in achieving stable flight performance with the ACROBAT with our heavy payload of sensors. This problem turns out to be common with this vehicle, but we now have acquired a new, more efficient control wing and have refined the trim settings and established reliable communications with the GPS and echo sounder. We expect to be fully operational for our spring 2003 cruise.

Analytical efforts have moved forward with the assembly and processing of historical oxygen data and the spinup of a simple advection-diffusion model for the tributary estuaries. Background geometrical data were developed for the model, and then the three-year CISNet time-series data were processed for evaluation of the exchange coefficients. The longitudinal structure of these coefficients included a marked maximum in mid-estuary, where the peak values were a factor of 5 greater than in adjacent regions. Further analysis revealed a confined region of elevated gravitational circulation located between the 1-layer circulation in the upper reaches and the pulsed, wind-driven circulation in the lower reaches. A similar structure has been discovered in the Pocomoke River estuary.

The advection-diffusion model was coded, debugged, and successfully run for the Choptank River. A strong advantage of this modeling approach is that it can provide an accounting of salt storage (and residence time) within the tributary estuary and significantly improved estimates of exchange between the tributary and the main stem estuary. A Sea Grant REU student, Kelley Kearney, participated in the construction of this model. Her contributions were recognized by an award from Sea Grant, who sponsored travel and a presentation at the Spring Meeting of the American Society of Limnology and Oceanography in Salt Lake City.

Future Activities:

The next procedures are to tune the coefficients, test the accuracy of the model on the ACE INC surveys, then apply the model to the Patuxent River and Pocomoke River estuaries. While residence time formulations are being developed for this model, we will expand our modeling activity to explore the utility of a two-dimensional model, which is expected to directly capture the gravitational circulation in key reaches of these tributaries.

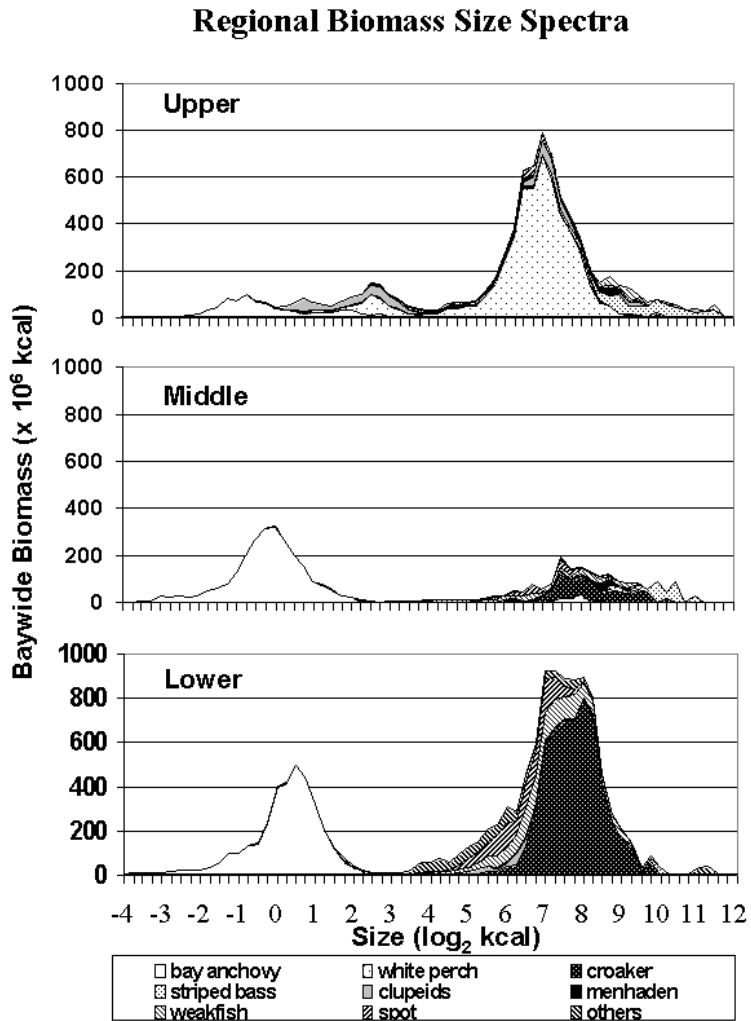
3. Integrated Physical and Biological Studies

Three research cruises (April, June, July), each of four days' duration, were conducted during 2002 in the Patuxent and Choptank Rivers, tributaries of Chesapeake Bay, to compare and characterize biological productivity and community structure. We have hypothesized that overall quality of habitat and productivity will differ between the two rivers, with healthier communities in the Patuxent, in response to reduced nutrient loading and improved water quality in that tributary in recent years. On these cruises we sampled phytoplankton (see above), zooplankton and fish using a variety of methods. Phytoplankton sampling centers on characterizing the distribution and abundance of chlorophyll (*chl-a*) as a measure of biomass, primary productivity using simulated in-situ sunlight incubations and ¹⁴C tracer techniques, pigment composition using HPLC, bio-optical measurements (inherent optical properties), and ancillary measurements of dissolved inorganic nutrients and suspended particulate matter. Zooplankton sampling includes optical plankton counter (OPC) and acoustic measurements, and traditional tow and pump sampling techniques. Optical and acoustic data are used to assess the size range and biomass of zooplankton in both systems for use in biomass size spectra. Tow

and pump samples are used to examine differences in species composition and abundance between the Patuxent and Choptank Rivers. Species composition may be affected by food availability, anoxia, freshwater input, etc. Fish data on abundances, sizes, feeding habits and age/size structure are being analyzed.

A one-day cruise specifically conducted to compare day and night variability in fish catches was conducted in August to allow adjustment of daytime trawl data for escapement and to improve the fish biomass size spectra that are being generated as part of ACE INC. The vulnerability of some species (*e.g.*, weakfish, Atlantic croaker, menhaden) increased at night, while other species (*e.g.*, bay anchovy, harvestfish) were equally vulnerable by day or night. Sizes of fish were similar in the day and night catches.

Biomass size spectra of fishes collected in CY 2003 research cruises and from earlier cruises that were part of the TIES Program are being developed and analyzed. The spectra are multi-modal, with two major modes that represent: 1) small forage fishes (*e.g.*, bay anchovy) that feed primarily on zooplankton, and 2) larger carnivorous fishes (*e.g.*, Atlantic croaker and white perch). The structure and variability in modal elevations and the slopes of the normalized spectra are being analyzed to evaluate these parameters as indicators of fish community structure. Spectra for the six-year



❖ Second dome is lower in the hypoxic, deep middle Bay.

Figure 2. Regional (upper, middle, and lower bay) biomass size spectra for fish in Chesapeake Bay, based on averaged regional estimates of trawlable biomass for the six-year period, 1995-2000.

period, 1995-2000, are now developed. A follow-up step is to link the fish biomass size spectra to those for zooplankton, and eventually to phytoplankton to produce integrated spectra that may be indicators of ecosystem status or health.

Jason Adolf, a recent Ph.D. from Horn Point Laboratory, joined the Harding group 1 December 2002. He is focusing on pigment reconstructions of taxonomic composition coupled with physiological and productivity measurements on phytoplankton. William Connelly, a Ph.D. candidate at the Chesapeake Biological Laboratory, joined the Houde research group in July 2002. He will conduct dissertation research on biomass size spectra (including overall spectra developed from primary producers, zooplankton and fish) as integrative indicators of estuarine health. Postdoc Sukgeun Jung is synthesizing available data on fish biomass size spectra, especially elements related to ecological scaling that distort spectra and produce multispectral peaks, making it difficult to interpret trophic relationships in the fish community.

Future Activities:

We convened an all-day meeting of Chesapeake Bay ACE INC participants at Horn Point Laboratory in January to discuss progress during the initial year of field sampling and coordinate our efforts for CY 2003. The meeting consisted of presentations on each of the major themes of our component, detailing progress toward developing integrative indicators from several perspectives. Assignments were made at the meeting to develop “theme area” statement for each of four themes, including: (1) phytoplankton composition / physiology (Adolf and Harding); (2) biomass size spectra (Houde, Kimmel); (3) dissolved oxygen (Jung, Boicourt); (4) influences of climate (Kimmel, Miller, Harding). These two-page summaries are being used to define products, including individual manuscripts in each of the theme areas, and to identify collaborative products within the Chesapeake Bay ACE INC component and with other members of ACE INC proper. We intend to expand the summaries by early summer and follow through on assignments for specific analyses and products.

4. Zooplankton as Indicators of Climate Change and Trophic Change in Estuaries

Spatial and temporal changes in zooplankton community composition and abundance have been observed in response to freshwater input in the Chesapeake Bay. In order to determine how freshwater flow directly impacts zooplankton species in the Chesapeake Bay, statistical models were constructed from long-term monitoring data. The purpose of the models was to identify how changing estuarine conditions that accompanied increases or decreases in freshwater input impacted zooplankton dynamics. Significant deviations from the models were found for particular time periods and correlated with water quality conditions. Time periods showing the strongest deviations from the model were typically “wet” or “dry” years. Therefore, we believe that zooplankton may be used as indicators of changes in estuarine condition that relate to freshwater discharge.

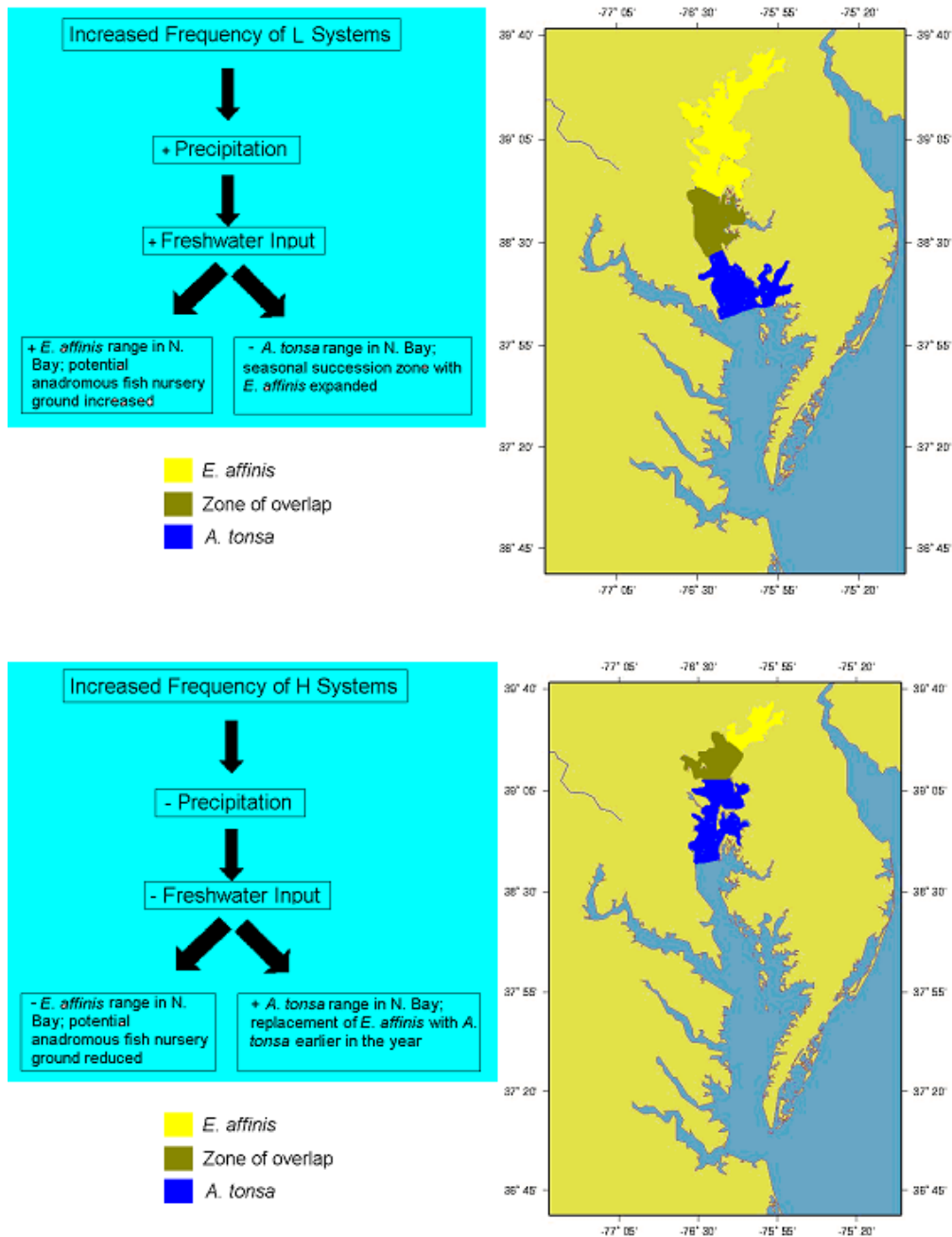


Figure 3. Winter weather patterns as indicators of shifts in the geographical distribution of mesozooplankton in Chesapeake Bay during spring: increase of low-pressure systems in winter (top panel); increase in high pressure systems (bottom panel).

Chesapeake Bay zooplankton co-varied with regional weather patterns calculated from data on sea level pressure. Particular weather patterns impacted the Chesapeake Bay region differently, causing variations in temperature, precipitation, cloud cover, etc. Weather pattern anomalies were calculated and correlated with shifts in mesozooplankton abundance and community composition. Winter-spring weather conditions appeared to influence the distribution of zooplankton in the spring and summer. Weather events, such as hurricanes and nor'easters, were found to significantly impact zooplankton dynamics. Depending on the magnitude of such events, zooplankton dynamics may be altered for significant time periods. Such events were often accompanied by strong freshwater input, therefore allowing our statistical models to predict their effects.

Zooplankton may be used as indicators of trophic and climate change in estuaries. Shifts in zooplankton abundance and species composition may indicate potential changes in the abundance and distribution of higher and lower trophic level organisms. Anadromous fish rely on abundant zooplankton prey in the spring as food for larvae. Shifts in the abundance or species of zooplankton prey may impact these fish negatively or positively. Zooplankton can be used to indicate whether the spring "trophic condition" is favorable or unfavorable for anadromous fish recruitment. It may also be possible to predict the spring zooplankton species composition and abundance in advance based on winter-spring weather patterns and abundance models. Zooplankton may also be used as indicators of climate change. Regional climate models based on CO₂ increases in the atmosphere can predict shifts in weather patterns. As shown above, these weather patterns are related to zooplankton dynamics in the estuary. A shift in distribution or abundance of particular species can be predicted from a change in weather and therefore be a useful indicator of climate change in estuaries.

Future Activities:

Essentially, Y3 objectives will remain the same as Y2. We will continue to analyze short and long-term zooplankton data sets in order to identify and potentially distinguish climatic from other drivers of community structure and function. In addition, efforts will be made to establish a comparative zooplankton community data set for the Neuse-Pamlico system in collaboration with H. Paerl and colleagues at UNC-CH Institute of Marine Sciences. A UNC-CH (Marine Science) graduate student (Amy Waggener) has been trained to initiate routine zooplankton data collection and analysis for the Neuse R. Estuary. This will form part of her MSc thesis.

Presentations:

Harding, L.W., Jr. 2002. Seasonal and inter-annual variability of primary productivity in Chesapeake Bay from remotely sensed aircraft observations. *Phytoplankton Productivity An Appreciation of 50 Years of the Study of Production in Oceans and Lakes*, Bangor, Wales, UK, Mar. 2002.

Jung, S. and E. D. Houde. 2002. Fish biomass production in Chesapeake Bay. Am. Fish. Soc. Annual Mtg., Aug. 2002, Baltimore, Maryland.

Jung, S. and E. D. Houde. 2002. Evaluating temporal and spatial variability in biomass, species assemblage and diversity of fishes in Chesapeake Bay, CoML. Int. Council Explor. Sea, Annual Science Conference, ICES CM 2002/L:13, Copenhagen, Sept. 2002.

Kimmel, D. G. and Roman, M. R. 2002. Influence of water quality parameters on Zooplankton abundance and community composition in the northern Chesapeake Bay: implications for climate change. Interdisciplinary Linkages in Aquatic Sciences and Beyond. American Society of Limnology and Oceanography. Victoria, British Columbia, Canada. June, 2002.

Jung, S. and E. D. Houde. 2003. Fish biomass size spectra as integrative indicators of ecosystem state and community structure in Chesapeake Bay. Feb. 2003, Salt Lake City, Utah.

Kearney, K., and W.C. Boicourt. 2003. A model for nutrient pathways in the Choptank River. ASLO Aquatic Sciences Meeting, Salt Lake City.

Kimmel, D. G. and Roman, M. R. 2003. Weather patterns as indicators of mesozooplankton dynamics in the Chesapeake Bay. The Earth's Eyes: Aquatic Sciences Through Space and Time: American Society of Limnology and Oceanography. Salt Lake City, Utah, USA. February 2003.

Publications:

Harding, L.W., Jr., M.E. Mallonee and E.S. Perry. 2002. Toward a predictive understanding of primary productivity in a temperate, partially stratified estuary. *Estuar. Coast. Shelf Sci.* 55:47-46.

Adolf, J.E., L.W. Harding, Jr., and M.E. Mallonee. 2003. The relationship of floral composition and primary productivity in Chesapeake Bay. *Mar. Ecol. Prog. Ser.* (in preparation).

Jung, S. and E. D. Houde. (in prep). Fish biomass size spectra and production in Chesapeake Bay. To be submitted to *Mar. Ecol. Prog. Ser.*

Kimmel, D. G. and Roman, M. R. 2003. Long-term trends in mesozooplankton abundance and community composition in the Chesapeake Bay USA: influence of freshwater input. (submitted to *Mar. Ecol. Prog. Ser.*).

Magnuson, A., L.W. Harding, Jr., and M.E. Mallonee. 2003. Bio-optical and remote sensing observations in Chesapeake Bay. *Estuar. Coast. Shelf Sci.* (submitted).

Seminars:

Harding, L.W., Jr. 2002. Recent advances in measuring primary productivity in estuaries using a combination of aircraft and shipboard observations. Horn Point Laboratory, University of Maryland Center for Environmental Science, Cambridge, Maryland, Feb. 2002.

Kimmel, D. G. Jan 2003. Weather patterns as indicators of mesozooplankton dynamics in the Chesapeake Bay. Invited Seminar: Maryland Dept. Nat. Resources. Oxford, Maryland.

Kimmel, D. G. Feb 2003. Weather patterns as indicators of mesozooplankton dynamics in the Chesapeake Bay. Invited Seminar: Chesapeake Biological Laboratory. Solomons, Maryland.

Kimmel, D. G. Mar 2003. Weather patterns as indicators of mesozooplankton dynamics in the Chesapeake Bay. Invited Seminar: Chesapeake Biological Laboratory. Solomons, Maryland.

Relevant Websites:

A website for the Chesapeake Bay ACE INC component has been developed (www.ACE-INC-UMCES.org/). This site features the Chesapeake Bay ACE INC research and is linked to other EaGLes and ACE INC websites. The theme area statements (see above) will be placed on the web site, together with reports, research plans, and results.

[The Chesapeake Bay Remote Sensing Program \(CBRSP\)](#)

[The EPA/NASA CISNet program - Choptank River](#)

Supplemental Keywords:

phytoplankton, zooplankton, fish, trophodynamics, size spectrum, bio-optics, remote sensing, primary production, HPLC, photopigments, dissolved oxygen, circulation, estuarine management, nutrients, regional scale indicators