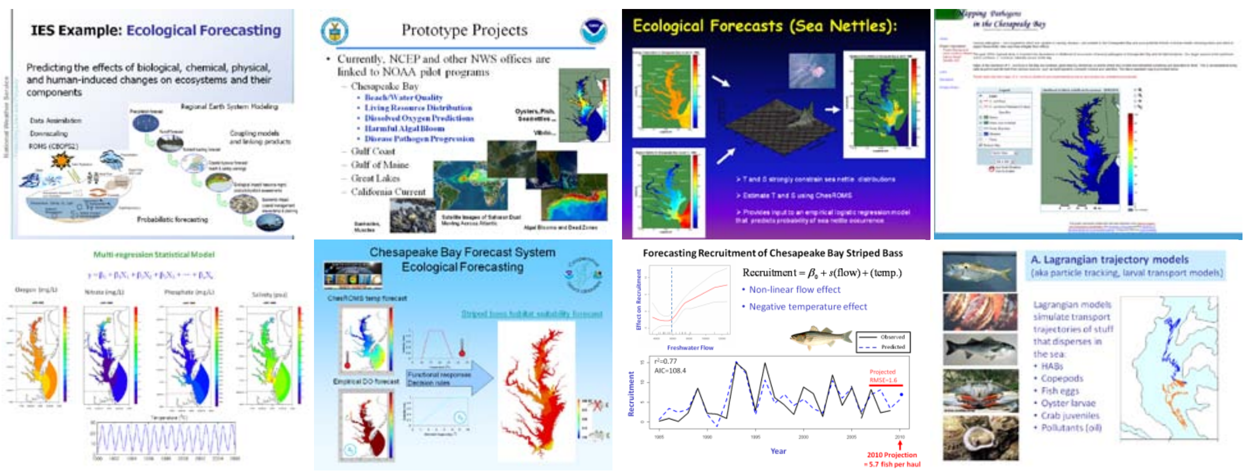
Report of the special session of “Chesapeake Bay Ecological Forecasting: Moving ecosystem modeling from research to operation” of the 2010 Chesapeake Modeling Symposium

Raleigh Hood, Robert Wood, David Green, Xinsheng Zhang



September 2010

NOAA Technical Memorandum NOS NCCOS 120

REPORT AUTHORS

Raleigh Hood
University of Maryland Center for Environmental Science
Horn Point Laboratory

Robert Wood
NOAA National Ocean Service
National Centers for Coastal Ocean Sciences
Cooperative Oxford Laboratory

David Green
NOAA National Weather Service
Office of Climate, Water, and Weather Services

Xinsheng Zhang
NOAA National Ocean Service
National Centers for Coastal Ocean Sciences
Cooperative Oxford Laboratory

Acknowledgments*:* On behalf of the conveners, we would like to thank all of the presenters and participants for supporting the "Chesapeake Bay Ecological Forecasting: Moving ecosystem modeling from research to operation" session. In particular, we are grateful to Kevin Sellner, Raghu Murtugudde, Ed Martino, Lowell Bahner, Doug Wilson, Howard Townsend, Heath Kelsey, Ruth Kelty, Mark Monaco, Rob Magnien, Alan Lewitus and Kevin McMahon for their assistance in preparing this report and/or supporting Chesapeake Bay Ecological Forecasting in general, and to Ruth Kelty for her efforts to synthesize information for this report. Staff at the Chesapeake Research Consortium, Inc. (CRC) provided excellent facilities and support. We thank the NCBO, EPA/CBP and NSF for partial funding to support this symposium.

This report should be cited as: R. Hood, R. Wood, D. Green, X. Zhang. 2010. Report of the special session of "Chesapeake Bay Ecological Forecasting: Moving ecosystem modeling from research to operation" of the 2010 Chesapeake Modeling Symposium. Special Report. NOAA NCCOS CCEHBR. Charleston, SC. 35 pp.

For more information contact: Xinsheng.Zhang@noaa.gov

Table of Contents

Executive Summary

Moving ecosystem modeling from research to applications and operations has direct management relevance and will be integral to achieving the water quality and living resource goals of the 2010 Chesapeake Bay Executive Order. Yet despite decades of ecosystem modeling efforts of linking climate to water quality, plankton and fish, ecological models are rarely taken to the operational phase. In an effort to promote operational ecosystem modeling and ecological forecasting in Chesapeake Bay, a meeting was convened on this topic at the 2010 Chesapeake Modeling Symposium (May, 10-11). These presentations show that tremendous progress has been made over the last five years toward the development of operational ecological forecasting models, and that efforts in Chesapeake Bay are leading the way nationally.

Ecological forecasts predict the impacts of chemical, biological, and physical changes on ecosystems, ecosystem components, and people. They have great potential to educate and inform not only ecosystem management, but also the outlook and opinion of the general public, for whom we manage coastal ecosystems. In the context of the Chesapeake Bay Executive Order, ecological forecasting can be used to identify favorable restoration sites, predict which sites and species will be viable under various climate scenarios, and predict the impact of a restoration project on water quality.

MAJOR FINDINGS

- Operational ecosystem modeling and ecological forecasting has great potential to facilitate and inform ecosystem research and management, and also help protect human health in Chesapeake Bay and other coastal systems.
- Modeling efforts are most successful when a small number of parameters (e.g. salinity and temperature) can explain and predict complex ecological processes. The most developed Chesapeake Bay forecasts are empirical models based upon logistic regression, neural networks and other statistical approaches. Ultimately the goal is operational implementation of a wide variety of models that will include fully mechanistic ecosystem and biogeochemical models that are, in turn, used to force multi-parameter empirical models of high order biological phenomenon.
- Within the Bay, the sea nettle forecast is the most advanced ecological forecast. It has begun to provide operational products and services and is ready to be transferred to operations by the National Weather Service (NWS). The pathogen forecast is the next most advanced along the continuum from research to applications and operations. Pathogen forecast products are being tested, and partners are planning the transfer to application or routine operation of the forecast. Fish habitat quality and recruitment are linked to critical environmental factors (e.g. dissolved oxygen and nutrients), and these more complex forecasts range in maturity from development to calibration and validation.
- Within NOAA, ‘Operational Forecast’ denotes a level of commitment and operation. The NWS will likely house the forecasts, and a rigorous process is in place to move forecasts from research and development to deployment, maintenance, and assessment of a 24/7 operational forecast.

- With the implementation of CBOFS2 and the Chesapeake Bay Sea Nettle forecasting model, Chesapeake Bay scientific and management communities will be uniquely positioned to lead the way nationally in the implementation of robust ecological forecasting models.

TRANSITIONING TO OPERATIONS

While there are multiple pathways to moving a forecast from research to applications and operations, the NWS has offered their Operations and Service Improvement Process (OSIP) as a standard, systematic, disciplined process to evaluate ecosystem forecasting needs and opportunities in the Chesapeake Bay. OSIP promotes sustainability of an operational model through critical review and systematic science, technology, service and budget evaluation. The transition process involves five stages: 1) data collection and model validation; 2) operational model concept exploration and definition; 3) applied research and analysis; 4) operational development; and 5) deployment, maintenance and assessment.

As of now, there are no operational forecasting models in the Chesapeake Bay. The sea nettle forecast is ready for transition, but has not yet gone through the rigorous approval and implementation process that NOAA requires. The term “prototype operational model” is therefore used in this report.

SESSION OVERVIEW

Presentations in this session ranged from reports from NOAA agencies on current efforts and prospects for implementing true, 24/7 operational ecological forecasting models in NOAA (Uccellini, Green and Brown), to prototype operational nowcast/forecast models (Friedrichs, Hood, Constantin de Magny, Jacobs, Wiggert and Long), and also new models that might be implemented operationally in the future (Zhang, Prasad, Evans, Bi, Martino, North and Kaushal). New developments include the transition of the Chesapeake Bay Sea Nettle forecast model to operational within NOAA (Brown), the formulation of new ecological forecasting models for pathogens like *Vibrio cholerae* and *Vibrio vulnificus* (Constantin de Magny and Jacobs) and emerging empirical and mechanistic models for forecasting biogeochemical properties like dissolved oxygen (Wiggert, Long, Prasad and Evans).

Sea Nettles

Sea nettles in Chesapeake Bay are strongly constrained by temperature (>20°C) and salinity (12 – 16 ppt). Temperature and salinity are calculated mechanistically using a Chesapeake Bay implementation of ROMS called ChesROMS (Decker, Brown et al. 2007, http://sourceforge.net/projects/chesroms/). The Chesapeake Bay Sea Nettle forecast model is an empirical logistic regression model that relates probability of occurrence of the jelly fish to temperature and salinity. The forecast has begun to provide operational products and services and is ready to be transferred to operations by the NWS.

Pathogens and Harmful Algal Blooms

Many pathogens (e.g. *Vibrio cholerae* and *Vibrio vulnificus)* are also constrained by temperature and salinity, and the developing pathogen forecasts follow the same empirical modeling approach as the sea nettle forecasts (Constantin de Magny, Long et al. 2009; Jacobs, Rhodes et al. 2010). Brown and Ramers et al. (2010) take a slightly different approach to predict presence or absence of the harmful algal bloom species *Karlodinium veneficum*. Their empirical neural network model incorporates time of year as well as temperature and salinity as the forcing variables. Kaushal is developing more complex models using forecasts of watershed nutrient and contaminant loadings to model bacterial loading and turbidity of drinking water supplies for human health applications. He is applying novel techniques, such as computational social science and social network computations. New frameworks that facilitate the development and comparison of these models are now available (Friedrichs).

Environmental Variables

Temperature and salinity are calculated mechanistically using a Chesapeake Bay implementation of ROMS called ChesROMS (Decker, Brown et al. 2007, http://sourceforge.net/projects/chesroms/). NOAA's Marine Modeling and Analysis Branch is working with the NWS to transition a Chesapeake Bay implementation of ROMS (the Chesapeake Bay Operational Forecast System or CBOFS2) to operations. The Chesapeake Bay Operational Forecast System (CBOFS2) is a mechanistic hydrodynamic model designed to predict temperature and salinity for a wide variety of empirical ecological and biogeochemical forecasting models. It is a Chesapeake Bay version of ROMS and has been validated.

Considerable effort has also been dedicated to developing models that can forecast oxygen concentrations because of its importance to pelagic and benthic species in Chesapeake Bay. Wiggert and Long are taking a mechanistic biogeochemical approach, predicting oxygen concentration by calculating air-sea exchange and biological oxygen production and consumption. This prognostic oxygen model is still being calibrated but looks promising. Prasad et al. (2010) take an empirical approach, using multiple linear regression models to predict oxygen concentration from temperature, salinity, and dissolved nutrients. The current assessment is that the empirical approaches are more mature and robust. However, operational mechanistic biogeochemical modeling holds great promise to provide short-term forecasts of not only oxygen, but additional biogeochemical and environmental properties, like nutrient and phytoplankton concentrations, and water clarity.

Fish Habitat and Recruitment

Improvements in hydrographic and other environmental forecasts enable advances in forecasts of fish habitat quality and recruitment (Bi, Martino, North and Zhang). Improved capabilities to forecast fish recruitments are being evaluated, and include using down-scaled seasonal climate projections to forecast fish year-class strength one to three years prior to entering Atlantic coast fisheries (Murtugudde, 2009; Martino and Houde, 2010). A suite of habitat suitability and bioenergetics models for striped bass and forage fishes based on species/life-stage-specific physiological requirements and allometric scaling have been developed and employed (Costantini et al. 2008; Ludsin, Zhang et al. 2009). Input variables to these models include observed and modeled temperature, plankton, and oxygen.

Session Objectives, Scope and Product

Session Lead: *Raleigh Hood*
Session Co-Lead(s): *Robert Wood, David Green, Xinsheng Zhang*
Date: *May 11, 2010*
Time: *8:30 am*
Room: *Coastal West*

Session Objectives
Despite decades of ecosystem modeling efforts, ecological models are rarely taken to the operational phase. As we endeavor to move towards ecosystem management it is essential that we acknowledge that, in the words of David Fluharty, "It is extremely important to avoid making perfect knowledge of the ecosystem the enemy of using the good knowledge we have." Operational modeling has great potential to educate and inform not only ecosystem management, but also the outlook and opinion of the general public, for whom we manage Chesapeake Bay and other coastal ecosystems. This session will focus on existing or developing ecological or ecosystem models that have great potential to become operational in the near future. We will also explore the challenges facing both scientists and managers in moving towards model operationalization and use.

Session Scope
Introduction with classic short presentation session focusing on scientific and management approaches, followed by panel/audience discussion.

Session Product
Based upon the presentations, feedback, and panel discussions of this session, a document will be produced that outlines an effective strategy towards developing and implementing operational ecological models to support Chesapeake ecosystem based management.

Presenters List

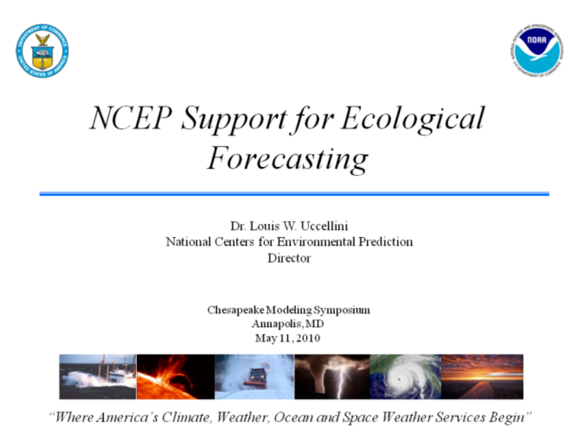
1. Louis W. Uccellini, NOAA/NWS/NCEP, Louis.Uccellini@noaa.gov
2. David Green, NOAA/NWS/OCWWS, david.green@noaa.gov
3. Carl Friedrichs, Virginia Institute of Marine Science, College of William & Mary, cfried@vims.edu
4. Raleigh Hood, Horn Point Laboratory, University of Maryland Center for Environmental Science, rhood@hpl.umces.edu
5. Christopher Brown, NOAA/NESDIS, Christopher.W.Brown@noaa.gov
6. John Jacobs, NOAA/NOS/NCCOS Cooperative Oxford Laboratory, John.Jacobs@noaa.gov
7. Xinsheng Zhang, NOAA/NOS/NCCOS Cooperative Oxford Laboratory, Xinsheng.Zhang@noaa.gov
8. Jerry Wiggert, University of Southern Mississippi, Jerry.Wiggert@usm.edu
9. Wen Long, Horn Point Laboratory, University of Maryland Center for Environmental Science, wenlong@hpl.umces.edu
10. Mary Anne Evans, University of Michigan, mevans@umich.edu
11. M. Bala Krishna Prasad, Earth System Science Interdisciplinary Center, University of Maryland, mbkp@umd.edu
12. Hongsheng Bi, Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, hbi@cbl.umces.edu
13. Ed Martino, NOAA/NOS/NCCOS Cooperative Oxford Laboratory, Ed.Martino@noaa.gov
14. Elizabeth North, Horn Point Laboratory, University of Maryland Center for Environmental Science, enorth@hpl.umces.edu
15. Sujay Kaushal, Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, kaushal@cbl.umces.edu

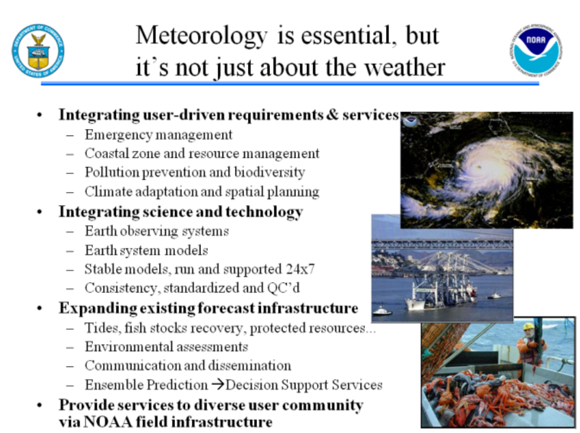
Abstracts and Representative Slides

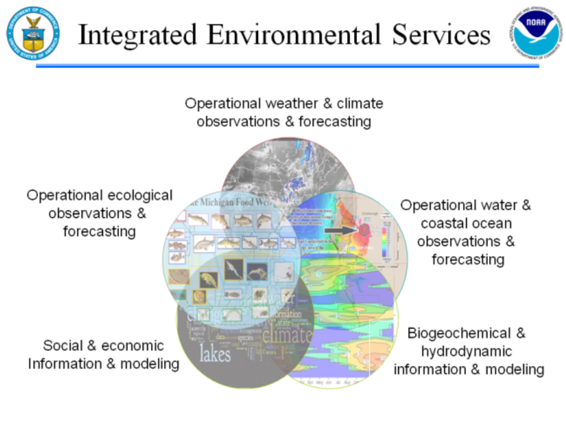
NCEP SUPPORT FOR ECOLOGICAL FORECASTING

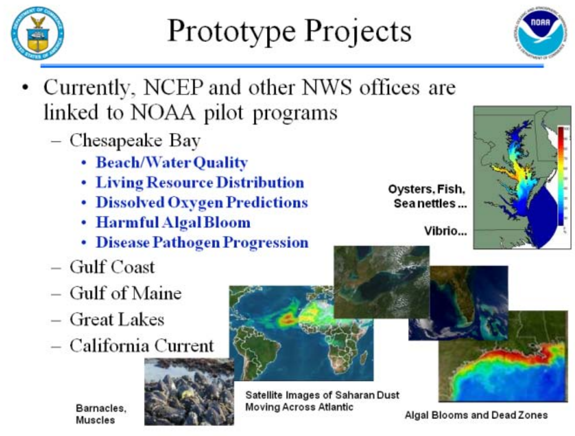
Uccellini, Louis
NOAA/NWS/NCEP, Louis.Uccellini@noaa.gov

This presentation will highlight how the National Centers for Environmental Prediction (NCEP) supply backbone capabilities for an operational ecological forecasting system. This includes support for applied research, technology transfer and implementation of a common modeling infrastructure. The NCEP is a recognized global leader delivering a seamless suite of operational environmental analysis, diagnostics and forecasts for a domain that now ranges from the sun to the sea, including weather, ocean, climate, water, and space weather prediction services. In order to address evolving user needs the NCEP is capitalizing on emerging scientific and technological advances and partnering with other agencies and institutions promoting ecosystem-based management. Recent efforts are targeting the transition of regional models and prototype ecological forecasts for the Chesapeake Bay and its tidal tributaries. The models rely on variables, including air temperature, wind speed, sea surface temperature, salinity, and solar radiation from NOAA forecasted data. The operational concept is to apply relevant observations and partner models to NCEP infrastructure and increase data availability, access and distribution of integrated environmental services through Weather Forecast Offices and other operational centers to state and local authorities. Specific challenges include scalability, data assimilation, and verification for short term forecasts, seasonal outlooks and climate projections.
Shared development, improvement in ocean and coastal models, hydrologic and land use models, and linkage with marine ecological and biogeochemical science are being advanced with an Earth System Modeling view. This presentation will focus on the continuing NCEP support for multidisciplinary activities required to transition ecosystem modeling from research to applications.







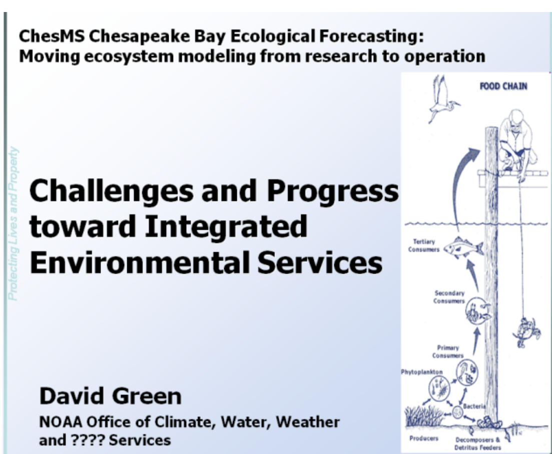


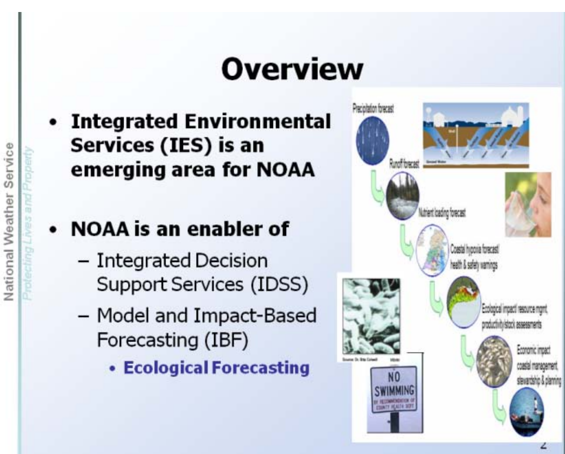
View presentation: http://www.chesapeakemeetings.com/ChesMS2010/sessions.php

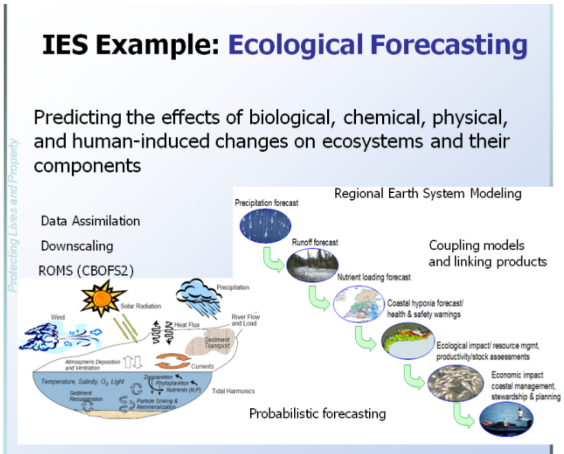
CHALLENGES AND PROGRESS TOWARD INTEGRATED ENVIRONMENTAL SERVICES

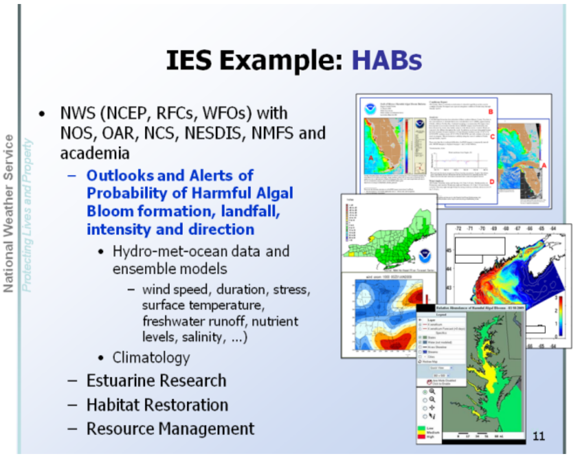
David Green
NOAA/NWS/NCWWS, david.green@noaa.gov

This presentation will identify the challenges and progress toward transitioning experimental model-based ecological forecasts into operational applications. NOAA has a long history of forecasting weather, tides, currents, floods, and fish stock through its various Line Offices and partnerships. In recent years the portfolio of experimental ecological models has matured and the infrastructure developed to tackle a broader suite of multidisciplinary and regional management issues. The lack of a robust framework and approach enabling transition of these models and derived forecasts, scenarios, and projections into sustained and durable environmental services limits the ability to meet user needs. The evaluation of requirements for service and operational improvement indicate that the integration of ecosystem and biogeochemistry models with existing climate, water and weather models is needed for ecosystem-based management and this shortfall presents unique development challenges. These include: understanding complex physical, biological, chemical, and behavioral interactions sufficiently to inform decision making over broad time and spatial scales; acquiring and assimilating adequate and representative observational and process data; testing and validating standard models; characterizing uncertainty in probabilistic forecasts; and providing adequate support to sustain operations. This presentation will provide examples of marine and coastal ecosystem model development and demonstration projects at NOAA and through regional partnerships that are contributing to a strengthened ecological forecast and warning system as a contribution to a broader integrated environmental service.







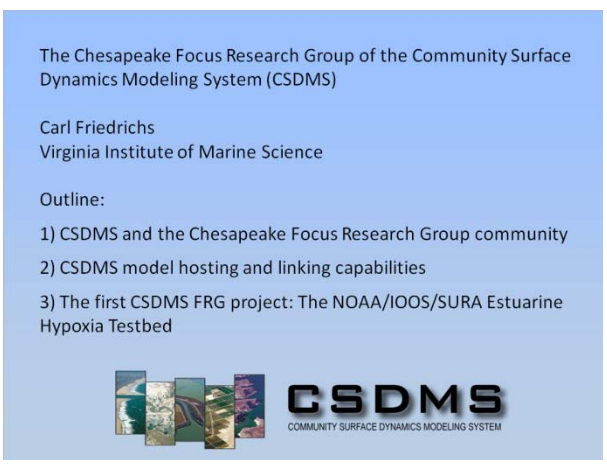


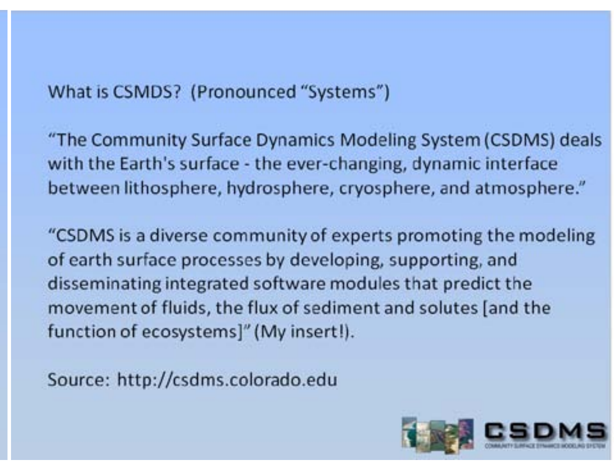
View presentation: http://www.chesapeakemeetings.com/ChesMS2010/sessions.php

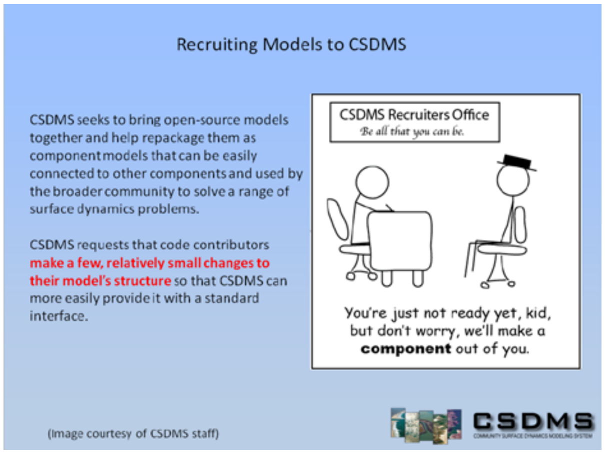
THE CHESAPEAKE FOCUS RESEARCH GROUP (FRG) OF THE COMMUNITY SURFACE DYNAMICS MODELING SYSTEM (CSDMS): A PATHWAY TO COMMUNITY OPERATION OF A MULTI-MODEL ECOLOGICAL FORECASTING TEST BED

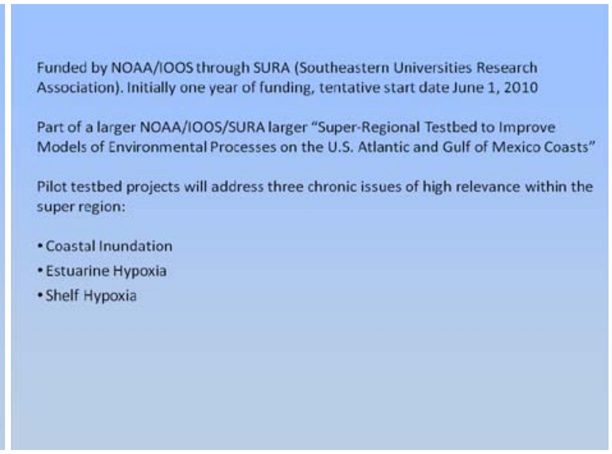
Carl Friedrichs
Virginia Institute of Marine Science, College of William & Mary, cfried@vims.edu

The Community Surface Dynamics Modeling System (CSDMS, pronounced "Systems") is a national facility funded by the National Science Foundation to provide community access to high performance computing (HPC) facilities, model linking software, and HPC expertise for the purpose of advancing the application and evolution of freely available, open source models of earth surface processes, including coastal and estuarine hydrology, hydrodynamics and ecosystem function. The Chesapeake FRG is CSDMS's first geographically-focused research group and has the specific goal of assembling a collection of interchangeable models and model components to address environmental processes within the Chesapeake region. The Chesapeake FRG is a partnership between CSDMS and the Chesapeake Community Modeling Program, which, in turn, is supported by the NOAA Chesapeake Bay Office, the EPA Chesapeake Bay Office, and the member institutions of the Chesapeake Research Consortium. This presentation provides additional background regarding the CSDMS Chesapeake FRG, its activities to date, and its short and long-term goals. At present, the Chesapeake FRG is seeking funding to establish a community accessible test bed at CSDMS to link, operate and interchange existing open-source Chesapeake Bay models for (1) land-use/hydrology, (2) hydrodynamics, and (3) water quality/ecosystem function. As part of this project, multiple existing open-source models would be interchanged and assessed against existing data sets. Ideally, a process would be developed by which multiple scientifically-vetted, open-source model suites could be formally recommended for ensemble operational use.





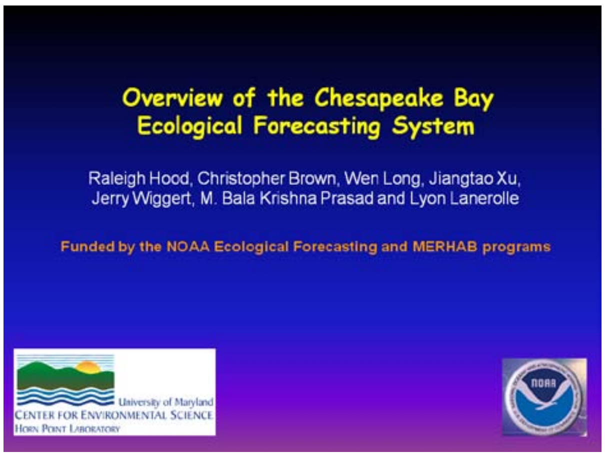


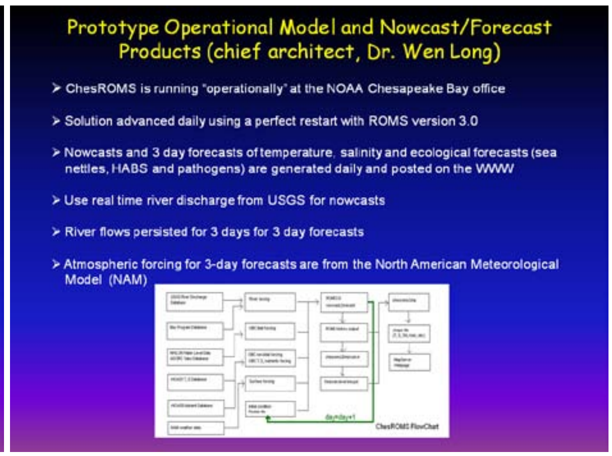


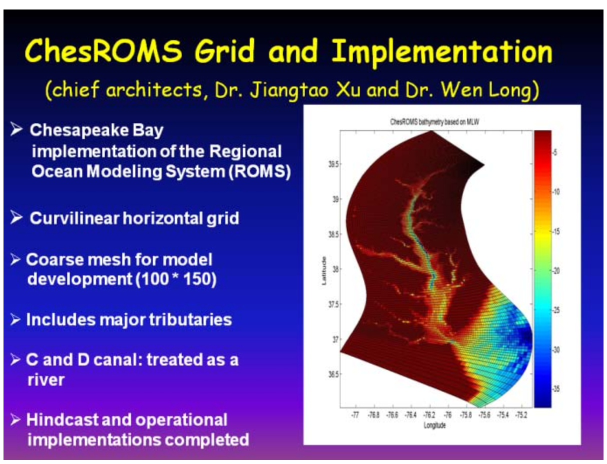
View presentation: http://www.chesapeakemeetings.com/ChesMS2010/sessions.php

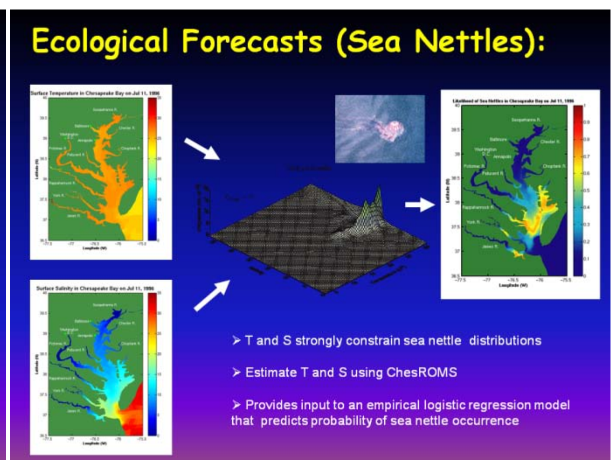
CBEFS: THE CHESAPEAKE BAY ECOLOGICAL FORECASTING SYSTEM
Raleigh Hood
Horn Point Laboratory, University of Maryland Center for Environmental Science, rhood@hpl.umces.edu

The Chesapeake Bay is an important recreational and economic resource that has been subjected to increasing stress due to anthropogenic impacts. These impacts include eutrophication and they have contributed to increased frequency of noxious bloom events that can negatively impact human health. In this presentation we give an introductory overview of the Chesapeake Bay Ecological Forecasting System (CBEFS), which provides prototype ecological nowcasts and shortterm forecasts of physical and biogeochemical properties as well as blooms of jellyfish, harmful algae and pathogenic microbes in the Bay.







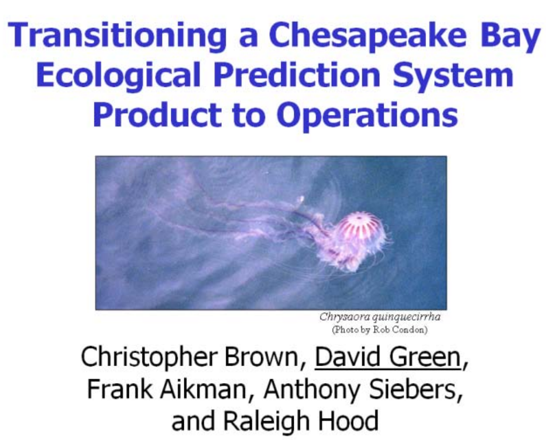


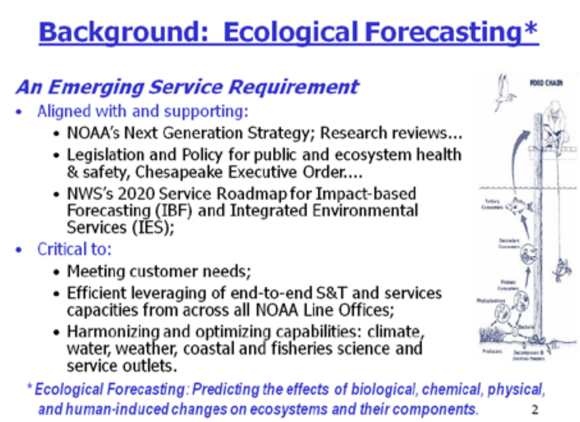
View presentation: http://www.chesapeakemeetings.com/ChesMS2010/sessions.php

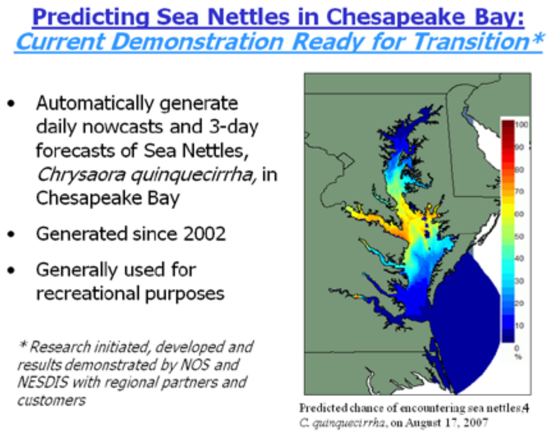
TRANSITIONING A CHESAPEAKE BAY ECOLOGICAL PREDICTION SYSTEM PRODUCT TO OPERATIONS

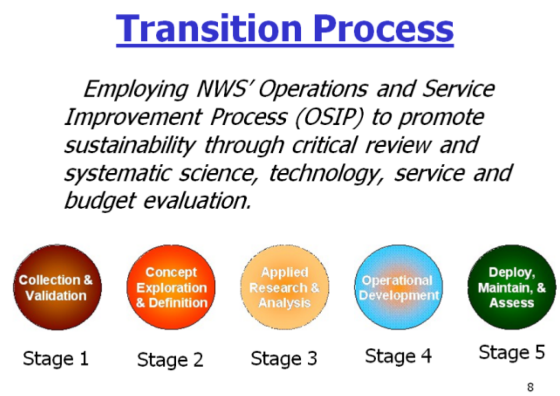
Christopher Brown
NOAA/NESDIS, Christopher.W.Brown@noaa.gov

NOAA is transitioning a prototype ecological system that predicts the probability of encountering sea nettles (*Chrysaora quinquecirrha*), a stinging jellyfish, in the Chesapeake Bay and its tidal tributaries, to operations. These jellyfish can negatively impact activities in the bay, and knowing where and when this biotic nuisance occurs may help to alleviate its effects. The bay-wide nowcasts and three-day forecasts of sea nettle likelihood are generated daily by forcing an empirical habitat model (that predicts the probability of sea nettles) with real-time and 3-day forecasts of sea-surface temperature (SST) and salinity (SSS). Importantly, this prediction system can be easily modified to predict the probability of other important target organisms, such as harmful algal blooms and water-borne pathogens, in the Chesapeake Bay. In the operational system, the SST and SSS fields will be generated by the Chesapeake Bay Operational Forecast System (CBOFS2), a 3-dimensional hydrodynamic model developed and operated by NOAA's Ocean Service and run at the NWS's National Centers for Environmental Prediction. It is anticipated that the operational forecasts will be disseminated and delivered through existing methods and portals, e.g. as digital images available via the World Wide Web and text-based messages included within NWS marine weather forecast products. This activity represents the first effort to leverage and strengthen NOAA-wide capabilities in order to transition a prototype ecological forecast product to NWS operations. The steps involved are consistent with NOAA Research to Operations Policy and adhere to the NWS Operations and Services Improvement Process (OSIP), the accepted requirements management process for bringing research results into the NWS operational environment. Consequently, in addition to operationalizing the sea nettle forecasts, the exercise will develop a framework for transitioning other ecological forecasts, promote an enterprise architecture and earth system management infrastructure, and improve delivery of knowledge-based products for integrated environmental decision support services.







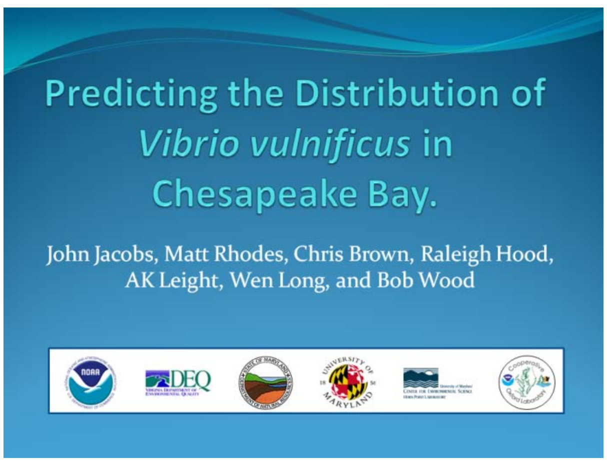


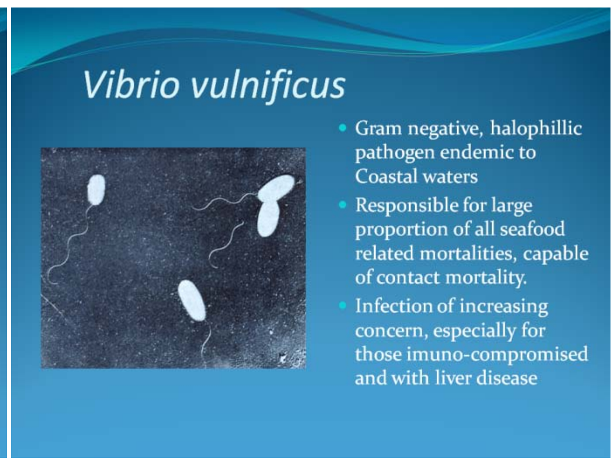
View presentation: http://www.chesapeakemeetings.com/ChesMS2010/sessions.php

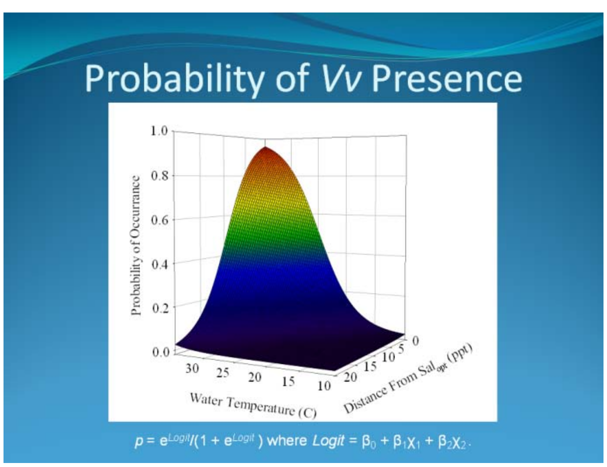
PREDICTING THE DISTRIBUTION OF *VIBRIO VULNIFICUS* IN CHESAPEAKE BAY

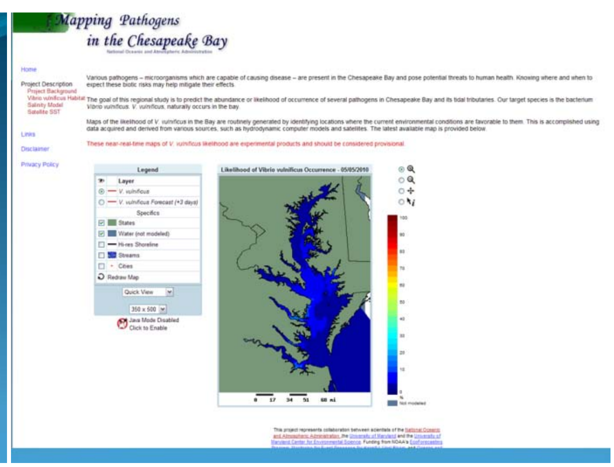
John Jacobs
NOAA/NOS/NCCOS Cooperative Oxford Laboratory, John.Jacobs@noaa.gov

Vibrio vulnificus is a gramnegative pathogenic bacterium endemic to coastal waters worldwide, and a leading cause of seafood related mortality. Because of human health concerns, understanding the ecology of the species and potentially predicting its distribution is of great importance. We evaluated and applied a previously published qPCR assay to water samples (n = 235) collected from the main-stem of the Chesapeake Bay (2007- 2008) by Maryland and Virginia State water quality monitoring programs. Results confirmed strong relationships between the likelihood of *Vibrio vulnificus* presence and both temperature and salinity that were used to develop a logistic regression model. The habitat model demonstrated a high degree of concordance (93%), and robustness as subsequent bootstrapping (n=1000) did not change model output (p >0.05). We forced this empirical habitat model with temperature and salinity predictions generated by a regional hydrodynamic modeling system to demonstrate its utility in future pathogen forecasting efforts in the Chesapeake Bay.







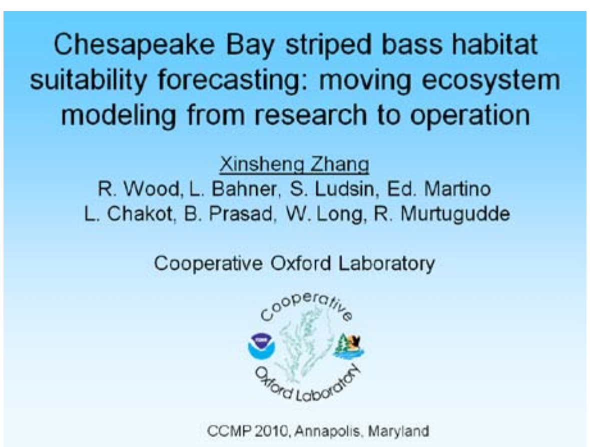


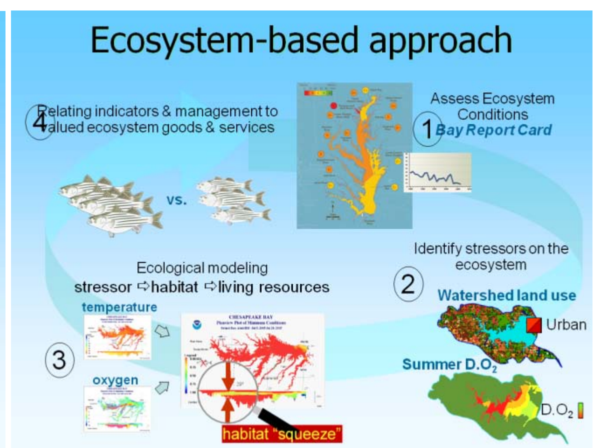
View presentation: http://www.chesapeakemeetings.com/ChesMS2010/sessions.php

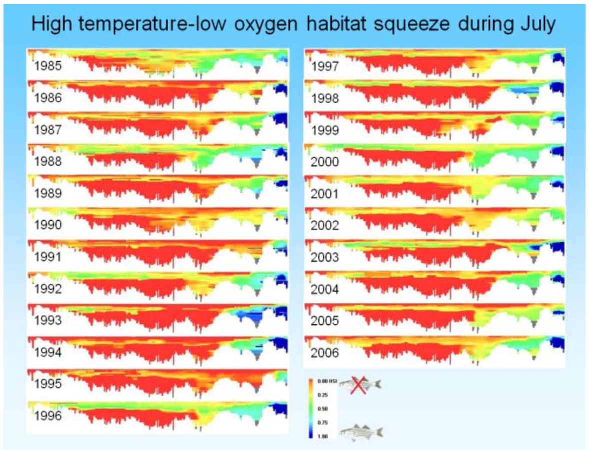
CHESAPEAKE BAY STRIPED BASS HABITAT SUITABILITY FORECASTING: MOVING ECOSYSTEM MODELING FROM RESEARCH TO OPERATION

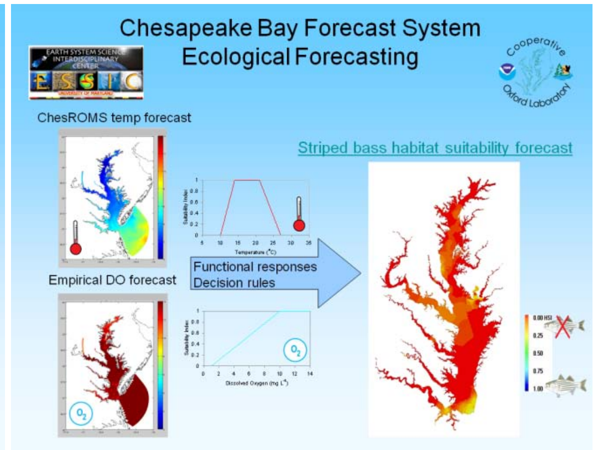
Xinsheng Zhang
NOAA/NOS/NCCOS Cooperative Oxford Laboratory, Xinsheng.Zhang@noaa.gov

Operational modeling offers the potential to educate and inform ecosystem management and the outlook and opinion of the general public for whom we manage coastal ecosystems. Striped bass (*Morone saxatilis*) supports important commercial and recreational fisheries in Chesapeake Bay. Improved understanding and forecasting of striped bass habitat suitability, and the interactions of striped bass and its prey are important from both scientific and resource management perspectives. We have developed a suite of life-stage-specific, striped bass habitat suitability models that can be used to evaluate and forecast how hydro-climate variability drives variability in habitat quality and quantity. Particular emphasis was placed on summer conditions, when the striped bass population is vulnerable to stress from warm temperatures and low dissolved oxygen. Model results suggest that Coutant's temperature-oxygen "squeeze" could affect striped bass in Chesapeake Bay through predator-prey habitat overlap/separation and encounter rates, and vulnerability to pathogens. These models have been integrated into the Chesapeake Bay Ecological Forecasting Modeling System, a joint NOAA-University of Maryland Earth System Science Interdisciplinary Center effort that links atmospheric, hydrodynamic, water quality, and living resources sub-models to produce operational and accessible models relevant to Bay restoration efforts. One ultimate objective is to provide managers with decision support tools for planning ecosystem-based fisheries management.







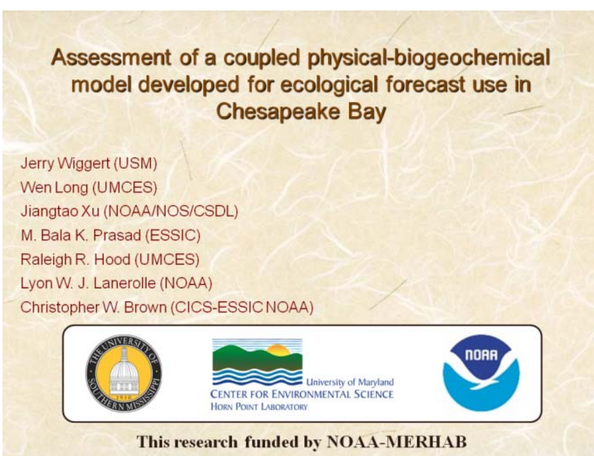


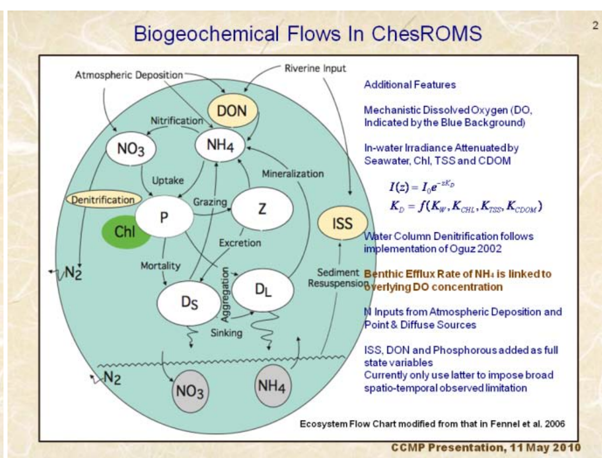
View presentation: http://www.chesapeakemeetings.com/ChesMS2010/sessions.php

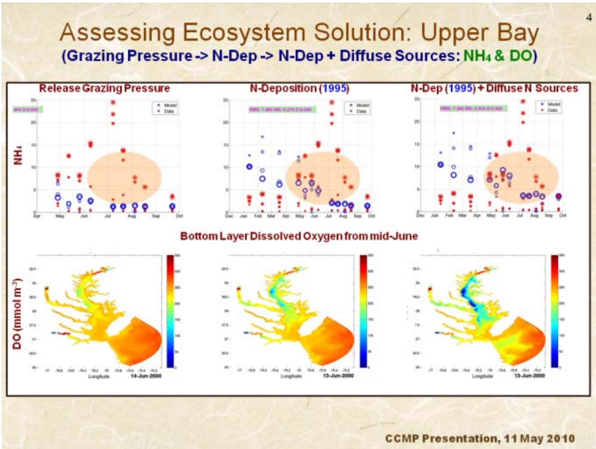
ASSESSMENT OF A COUPLED PHYSICALBIOGEOCHEMICAL MODEL DEVELOPED FOR ECOLOGICAL FORECAST USE IN CHESAPEAKE BAY

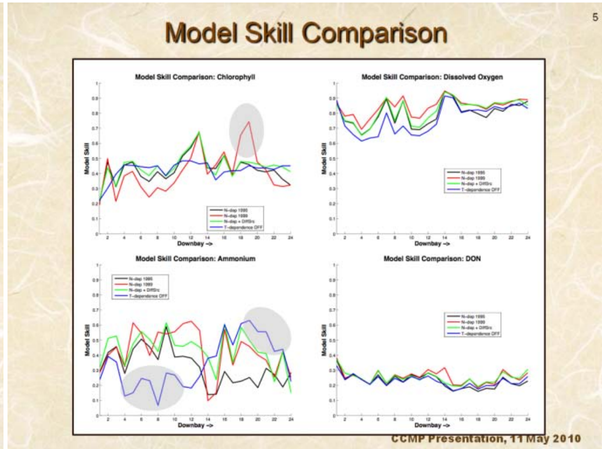
Jerry Wiggert
University of Southern Mississippi, Jerry.Wiggert@usm.edu

The Chesapeake Bay is a valuable recreational, ecological and economic resource that is commonly subject to harmful algal bloom (HAB) outbreaks that threaten its continued viability. With expanding knowledge of the conditions likely to promote HAB occurrence, forecasting these events is becoming ever more tenable. HAB triggers include both physical and biogeochemical environmental properties; therefore a fully coupled physical-biogeochemical numerical model that accurately simulates, and forecasts, the Bay's environment is well-suited for application as a means of generating nowcasts or forecasts of HAB occurrence. Attaining this technological capability has been a primary motivation for the development of the biogeochemical version of the Chesapeake Bay Regional Ocean Modeling System (ChesROMS), which incorporates Rutgers University's Regional Ocean Modeling System (ROMS) as the physical modeling engine. The ecosystem model has been modified from the standard Fasham-type formulation incorporated within the ROMS distribution to include components that explicitly accommodate the impact of river borne sediments, inorganic nutrients and dissolved organic matter. Nutrient inputs from diffuse land sources as well as those from atmospheric deposition are also taken into account. In addition, dynamic simulation of dissolved oxygen has been implemented, with the intent of resolving seasonally developing hypoxic conditions within the Bay and the accompanying transition to denitrification within the water column and underlying benthos. Here, simulations for the year 1999 will be presented and characterized with respect to in situ observations made available by the Chesapeake Bay Program. These results will highlight and assess the realism of model simulated phytoplankton bloom dynamics and the seasonal evolution of dissolved oxygen distributions in the Bay.







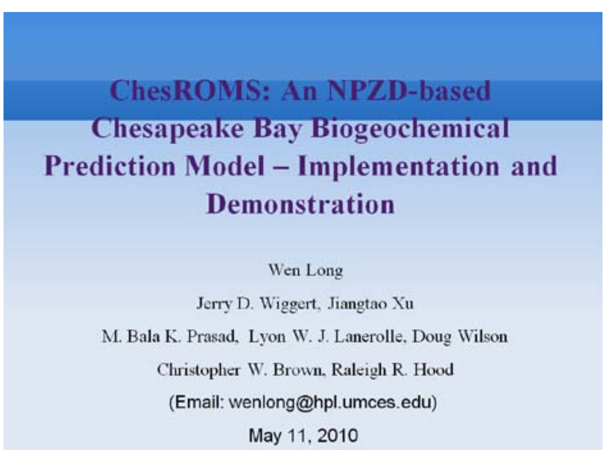


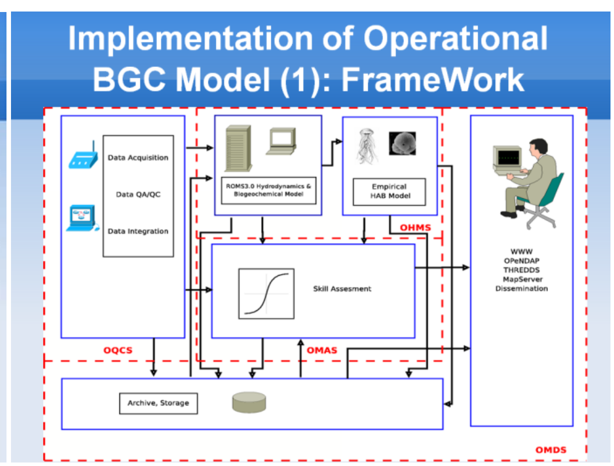
View presentation: http://www.chesapeakemeetings.com/ChesMS2010/sessions.php

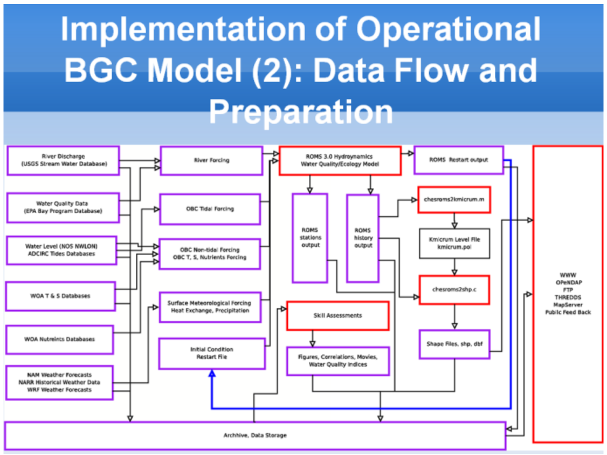
CHESROMS: AN NPZD-BASED CHESAPEAKE BAY BIOGEOCHEMICAL PREDICTION MODEL IMPLEMENTATION AND DEMONSTRATION

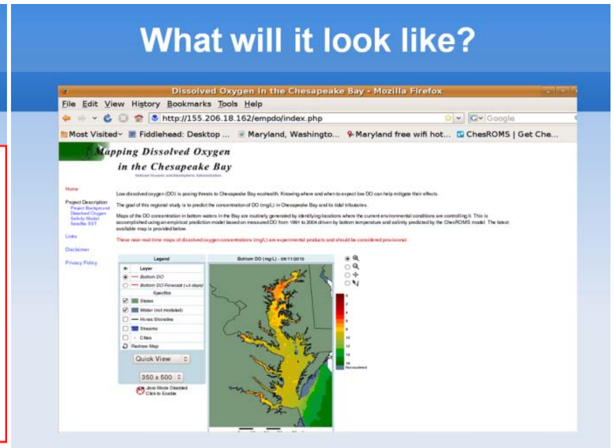
Wen Long
Horn Point Laboratory, University of Maryland Center for Environmental Science, wenlong@hpl.umces.edu

The presentation will provide an introduction to ChesROMS v1.2, an open source prediction model of the Chesapeake Bay that is based on the 3-D primitive equation numerical ocean circulation model ROMS (Regional Ocean Modeling System). The initial hydrodynamic implementation of ChesROMS has been employed to provide input to empirical harmful algal bloom (HAB) predictive models. Recently, ChesROMS has been extended to include a fully coupled Nitrogen-Phytoplankton-Zooplankton-Detritus (NPZD) type dynamic lower trophic level ecological component that simulates the Bay's biogeochemical cycles. The model framework provides necessary components for retrospective and near real time data acquisition and pre- and post- processing, which make it suitable for hindcasting, nowcasting and short term forecasting of bay-wide physical, ecological and water quality conditions. A web based GIS visualization system has also been developed for dissemination. Key aspects of the biogeochemical model include point and non-point (diffusive) nutrient inputs, atmospheric nutrient deposition, light attenuation by particulate and dissolved components, and mechanistic implementation of water column and benthic denitrification. The Bay's open boundary is relaxed to climatological nutrient and biomass concentrations and physical properties. The simulated biogeochemical state variables include nitrate, ammonia, phytoplankton, chlorophyll a, zooplankton, dissolved organic nitrogen, detritus, dissolved oxygen and inorganic suspended solids. An overview of the model components, strategies and implementation specifics will be presented. The system is initially deployed at the NOAA Chesapeake Bay Office for nowcasting and three-day forecasting with a daily updating cycle. An initial assessment of results from re-forecasting years 2008 and 2009 will be presented.







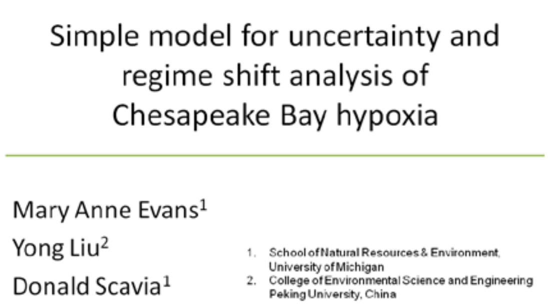


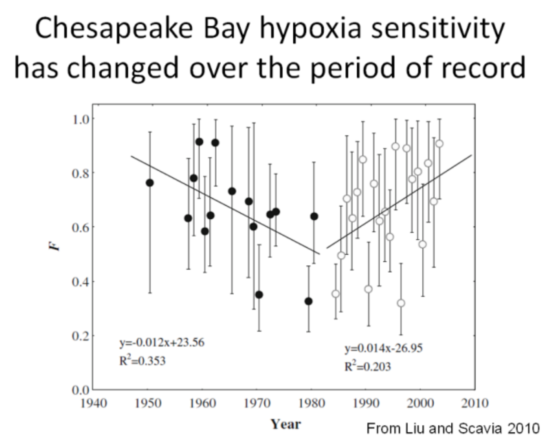
View presentation: http://www.chesapeakemeetings.com/ChesMS2010/sessions.php

SIMPLE MODEL FOR UNCERTAINTY AND REGIME SHIFT ANALYSIS OF CHESAPEAKE BAY HYPOXIA

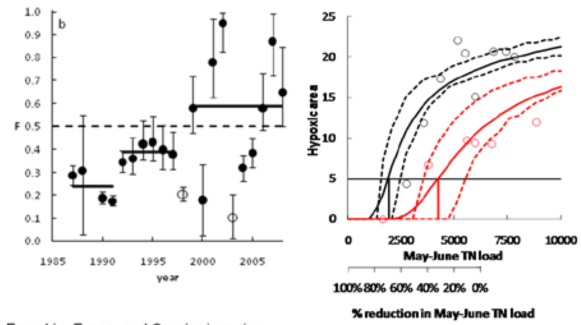
Mary Anne Evans
University of Michigan, mevans@umich.edu

Because all models are simplifications of natural systems it is desirable to use a variety of model constructs for any given natural system. More confidence can be placed in a result, such as the nutrient loading decreases needed to achieve a given reduction in hypoxic area, if this result is supported by multiple modeling approaches. We contribute to this diversity of modeling approaches with an implementation of the Streeter-Phelps river model for the bottom waters of Chesapeake Bay. This model is structurally simple, such that it can be parameterized with a minimum of field data, but retains enough mechanistic detail to allow validation against measured rate processes in the bay. Additional strengths of this model include explicit handling of parameter uncertainty and incorporation of multiple data types in parameterization and forecasting through Bayesian inference and Monte Carlo simulation. Results to date show (1) that Chesapeake Bay hypoxia is strongly influenced by total nitrogen (TN) loading but that the conversion efficiency of nitrogen to hypoxia varies from year to year, (2) specifically that this conversion efficiency has increased since 1980s, (3) that due to this increase in efficiency, TN load reductions of 35%, that previously would have returned the bay to hypoxic areas typical of the 1950s-1970s, would now be inadequate to return the bay even to the 1980s and 1990s hypoxic areas.





A similar sensitivity shift has been observed in the Gulf of Mexico



From Liu, Evans, and Scavia, *in review*

Comparison of Chesapeake Bay and Gulf of Mexico

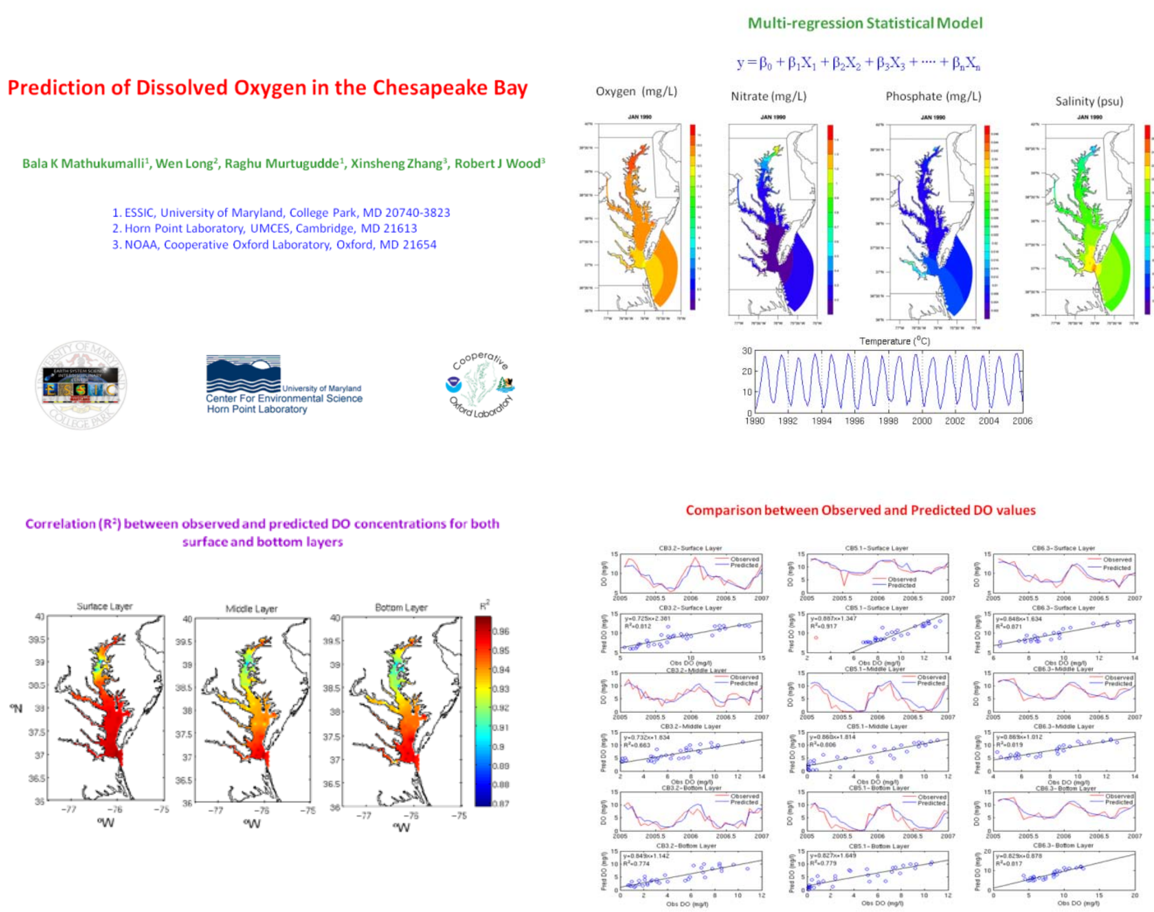
- Show similar patters of model performance saturation after 5 years of calibration data
- Overall model performance (accuracy) was better for the Gulf of Mexico
- Similar response of the "moving window" calibration in the Gulf of Mexico and Chesapeake Bay supports this as a robust method for dealing with shifts in system sensitivity

View presentation: <u>http://www.chesapeakemeetings.com/ChesMS2010/sessions.php</u>

ECOLOGICAL PREDICTION OF DISSOLVED OXYGEN IN THE CHESAPEAKE BAY

M. Bala Krishna Prasad
Earth System Science Interdisciplinary Center, University of Maryland, mbkp@umd.edu

The structure and dynamics of aquatic ecosystem are a function of set of biogeochemical properties and forecast of these biogeochemical properties is a critical step in the sustainable management of the aquatic ecosystems. Dissolved oxygen (DO) is a key parameter in the aquatic science research which not only controls the biological productivity but also regulated by the biological productivity. Nutrient pollution resulted from the increasing human activities alters the oxygen dynamics by reducing its concentrations to a critical level where the ecosystem cannot support the biological systems. The Chesapeake Bay is a largest estuary in the North America and is experiencing summer hypoxia/anoxia events due to the cultural eutrophication. Statistical step-wise multiple regression approach is applied to develop an empirical model to predict DO in Chesapeake Bay by using a longterm data (1990-2006) of water temperature, salinity, dissolved nutrients (N and P). The predicted DO concentrations correlated well with the observed values. The predicted DO values depict the current status of the Bay and are useful to develop several linked products by integrating results from other hydrodynamic physical models for the ecosystem conservation and management.

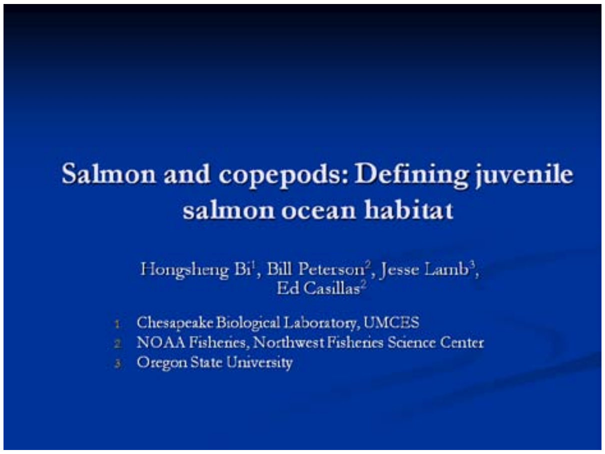


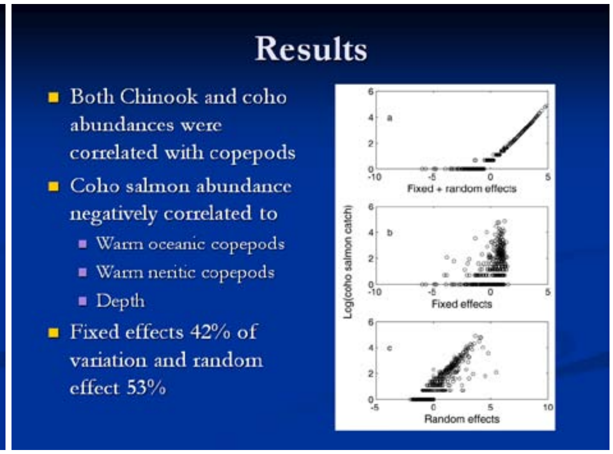
View presentation: http://www.chesapeakemeetings.com/ChesMS2010/sessions.php

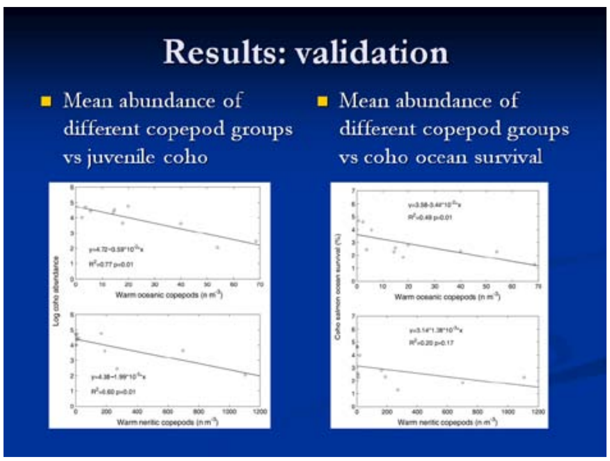
COPEPODS AND SALMON: FORECASTING SALMON SURVIVAL OFF WASHINGTON AND OREGON

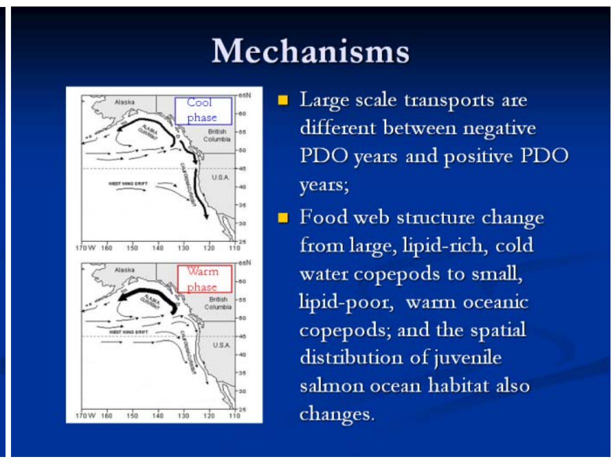
Hongsheng Bi
Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, hbi@cbl.umces.edu

The abundance of yearling Chinook (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) was sampled concurrently with physical (temperature, salinity, water depth) and biological variables (chlorophyll a concentration and copepod abundance) along Washington and Oregon coast in June 1998-2006. Copepods were divided into four different groups by their water-type affinities: cold neritic, subarctic, warm neritic and warm oceanic, and each group was used an independent environmental variable. Data collected in 1998- 2008 were used to perform nonparametric correlation and negative binomial loglinear mixed regression with a spatial random factor, and data collected in 2006 was used to validate the models. Yearling Chinook abundance was negatively related with temperature, and positively related to the density of cold neritic copepod, chlorophyll a concentration, and salinity. Yearling coho abundance was positively related with temperature, and negatively related with warm oceanic copepods, warm neritic copepods, and water depth. The two salmon species also showed different spatial patterns in most years. Yearling Chinook abundance showed significant spatial autocorrelations in 1999, 2000, 2002, 2004, and 2005, and yearling coho abundance showed significant spatial autocorrelations in 2000- 2002. The spatial random factor in the negative binomial loglinear mixed model was positively correlated with juvenile salmon abundance and showed similar spatial cluster patterns as juvenile salmon abundance for both species. Thus the occurrence of spatial autocorrelation could be attributed to the spatial random. Both annual mean abundance of yearling Chinook and the spring Chinook jack counts, a measurement of local population success, were positively correlated with cold neritic copepods. The annual mean abundance of yearling coho and the ocean survival rate were negatively correlated with warm oceanic copepods. The differences in how each species mapped onto habitat variable might be explained by the fact that yearling coho has relatively wider coastal distribution, and could feed on a relatively wider range of prey items than yearling Chinook. To address the spatial autocorrelation and the difference between two species, information on other physical processes, such as large scale transports, eddies and fronts, and biological processes such as prey and predator may be necessary.







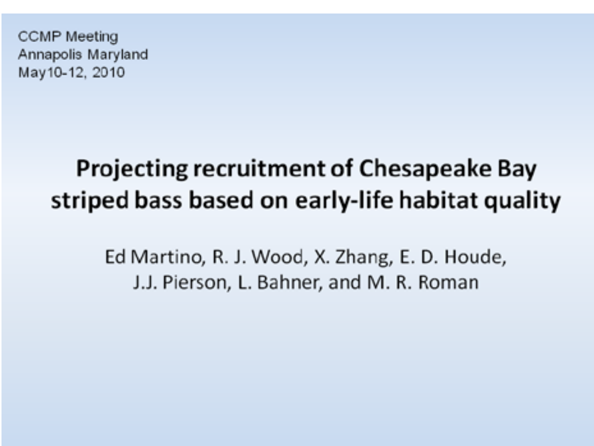


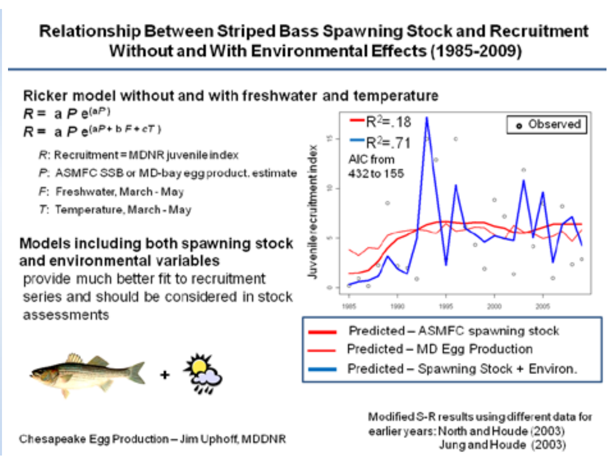
View presentation: http://www.chesapeakemeetings.com/ChesMS2010/sessions.php

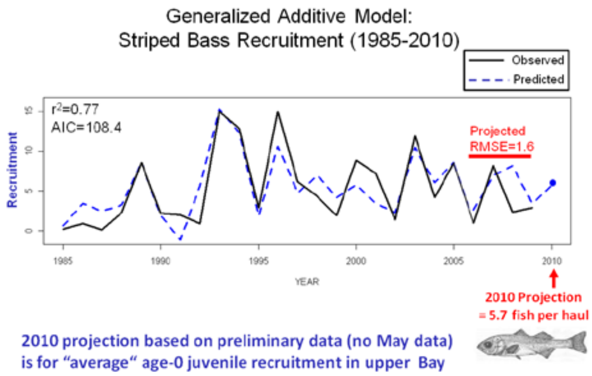
PROJECTING RECRUITMENT OF CHESAPEAKE BAY STRIPED BASS BASED ON EARLY-LIFE HABITAT QUALITY

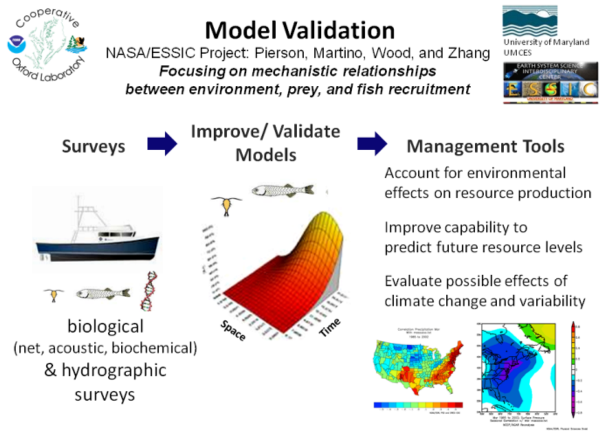
Ed Martino
NOAA/NOS/NCCOS Cooperative Oxford Laboratory, Ed.Martino@noaa.gov

Ecosystem-based approaches to fishery management require improved understanding of habitat requirements and how environmental variability affects stock dynamics. High variability (>20 fold) in age-0 juvenile recruitment is a common feature of Chesapeake Bay striped bass population dynamics. Spatio-temporal variability in zooplankton prey for striped bass larvae, controlled by synoptic-scale climatology and hydrological conditions, explains strong environmental controls of recruitment. In two spawning-nursery locations, Ricker stock-recruitment models were fit using stock biomass (SSB) alone and with freshwater flow to partition effects of SSB and hydrology on age-0 recruitments for years 1989-2008. Models including flow explained more variability in recruitments than models with SSB alone (AIC=507 to AIC=273). Regression models including freshwater flow and temperature explain a high proportion of variability (r^2=0.63) in age-0 recruitment. Modeling results indicate that environmental variability controls larval survival and the level of age-0 recruitment. Estimates of zooplankton abundance and distribution based on net and acoustic sampling coarsely depicts annual differences in prey availability, and indicates feeding conditions and potential survival of striped bass larvae. We also develop indicators of habitat quality and quantity based on isohaline location, and assess their ability to predict recruitment. After the larval stage, regulation occurs via density-dependent growth and size-selective overwintering mortality of age-0 juveniles. Age-1 juvenile abundance can be predicted in a regression model (r^2=0.82, p<0.001) using age-0 juvenile abundance, age-0 length attained, and winter temperature. Requirements of ecosystem-based fishery management are addressed by evaluating the potential to apply these findings to determine indicators and reference points of habitat suitability and reproductive success.



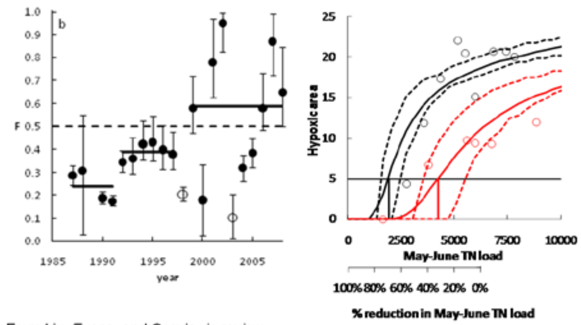






View presentation: http://www.chesapeakemeetings.com/ChesMS2010/sessions.php

A similar sensitivity shift has been observed in the Gulf of Mexico



From Liu, Evans, and Scavia, *in review*

Comparison of Chesapeake Bay and Gulf of Mexico

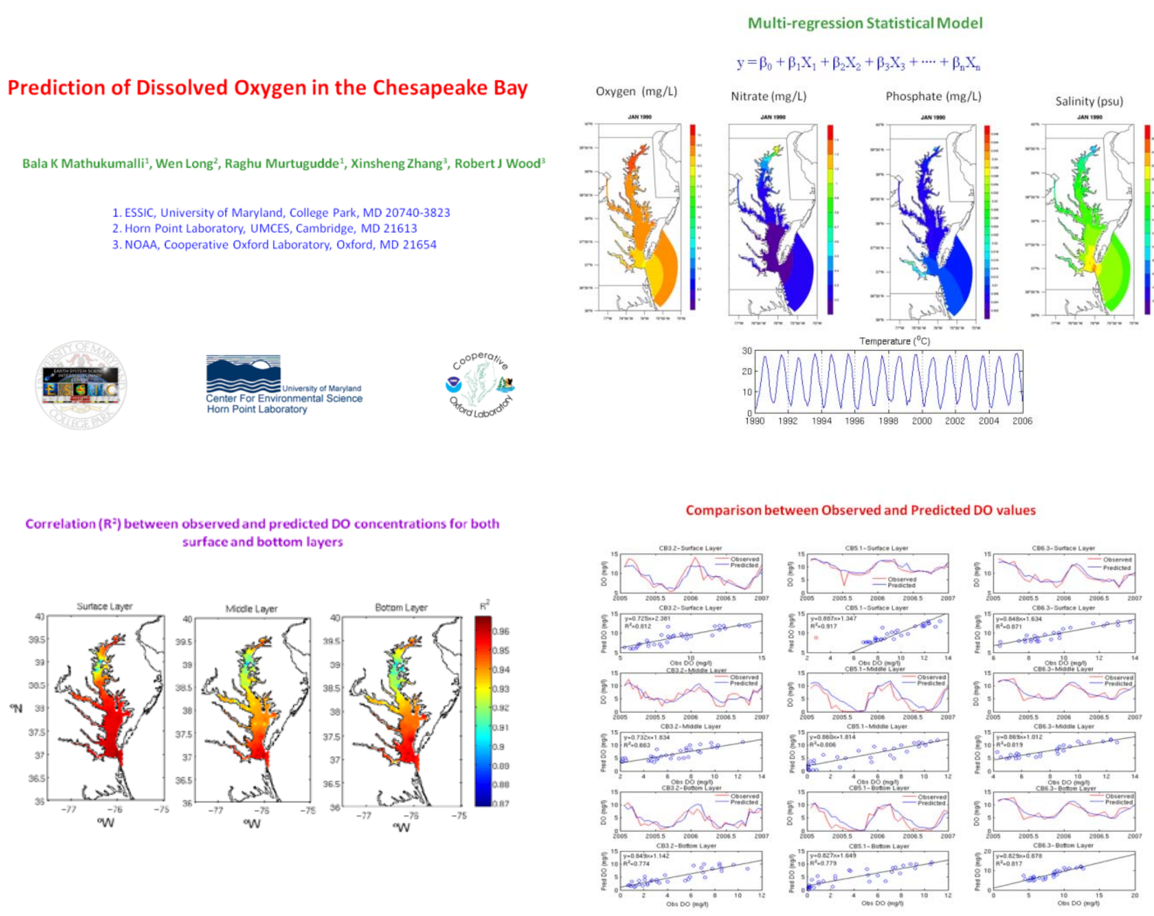
- Show similar patters of model performance saturation after 5 years of calibration data
- Overall model performance (accuracy) was better for the Gulf of Mexico
- Similar response of the "moving window" calibration in the Gulf of Mexico and Chesapeake Bay supports this as a robust method for dealing with shifts in system sensitivity

View presentation: http://www.chesapeakemeetings.com/ChesMS2010/sessions.php

ECOLOGICAL PREDICTION OF DISSOLVED OXYGEN IN THE CHESAPEAKE BAY

M. Bala Krishna Prasad
Earth System Science Interdisciplinary Center, University of Maryland, mbkp@umd.edu

The structure and dynamics of aquatic ecosystem are a function of set of biogeochemical properties and forecast of these biogeochemical properties is a critical step in the sustainable management of the aquatic ecosystems. Dissolved oxygen (DO) is a key parameter in the aquatic science research which not only controls the biological productivity but also regulated by the biological productivity. Nutrient pollution resulted from the increasing human activities alters the oxygen dynamics by reducing its concentrations to a critical level where the ecosystem cannot support the biological systems. The Chesapeake Bay is a largest estuary in the North America and is experiencing summer hypoxia/anoxia events due to the cultural eutrophication. Statistical step-wise multiple regression approach is applied to develop an empirical model to predict DO in Chesapeake Bay by using a longterm data (1990-2006) of water temperature, salinity, dissolved nutrients (N and P). The predicted DO concentrations correlated well with the observed values. The predicted DO values depict the current status of the Bay and are useful to develop several linked products by integrating results from other hydrodynamic physical models for the ecosystem conservation and management.

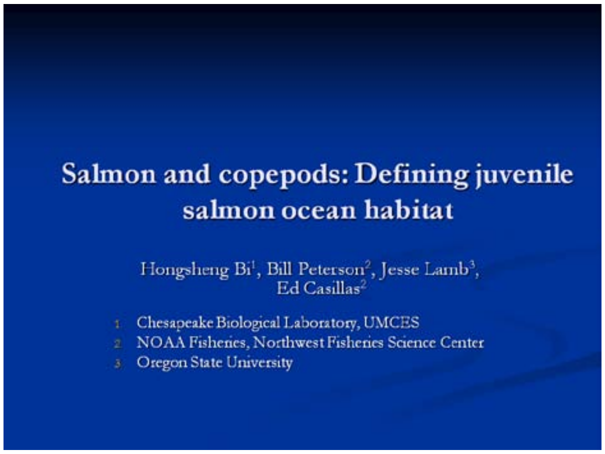


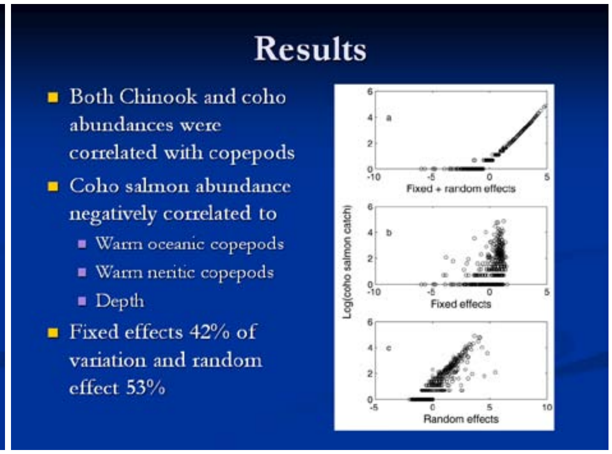
View presentation: http://www.chesapeakemeetings.com/ChesMS2010/sessions.php

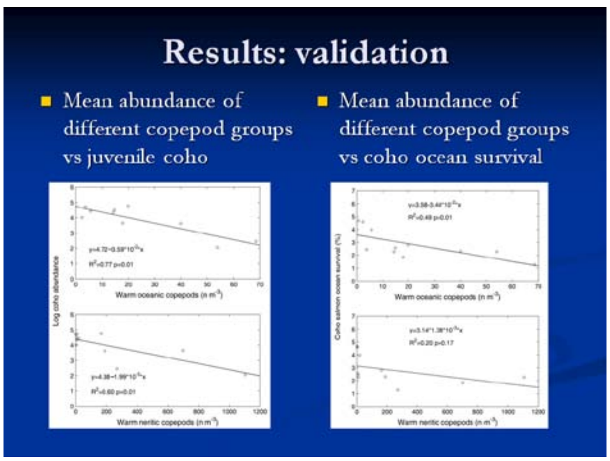
COPEPODS AND SALMON: FORECASTING SALMON SURVIVAL OFF WASHINGTON AND OREGON

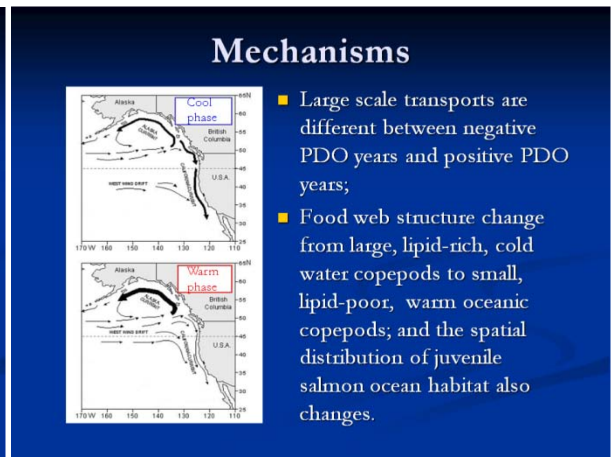
Hongsheng Bi
Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, hbi@cbl.umces.edu

The abundance of yearling Chinook (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) was sampled concurrently with physical (temperature, salinity, water depth) and biological variables (chlorophyll a concentration and copepod abundance) along Washington and Oregon coast in June 1998-2006. Copepods were divided into four different groups by their water-type affinities: cold neritic, subarctic, warm neritic and warm oceanic, and each group was used an independent environmental variable. Data collected in 1998- 2008 were used to perform nonparametric correlation and negative binomial loglinear mixed regression with a spatial random factor, and data collected in 2006 was used to validate the models. Yearling Chinook abundance was negatively related with temperature, and positively related to the density of cold neritic copepod, chlorophyll a concentration, and salinity. Yearling coho abundance was positively related with temperature, and negatively related with warm oceanic copepods, warm neritic copepods, and water depth. The two salmon species also showed different spatial patterns in most years. Yearling Chinook abundance showed significant spatial autocorrelations in 1999, 2000, 2002, 2004, and 2005, and yearling coho abundance showed significant spatial autocorrelations in 2000- 2002. The spatial random factor in the negative binomial loglinear mixed model was positively correlated with juvenile salmon abundance and showed similar spatial cluster patterns as juvenile salmon abundance for both species. Thus the occurrence of spatial autocorrelation could be attributed to the spatial random. Both annual mean abundance of yearling Chinook and the spring Chinook jack counts, a measurement of local population success, were positively correlated with cold neritic copepods. The annual mean abundance of yearling coho and the ocean survival rate were negatively correlated with warm oceanic copepods. The differences in how each species mapped onto habitat variable might be explained by the fact that yearling coho has relatively wider coastal distribution, and could feed on a relatively wider range of prey items than yearling Chinook. To address the spatial autocorrelation and the difference between two species, information on other physical processes, such as large scale transports, eddies and fronts, and biological processes such as prey and predator may be necessary.







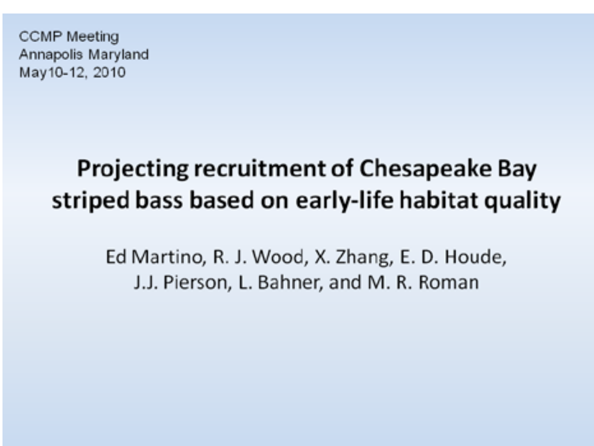


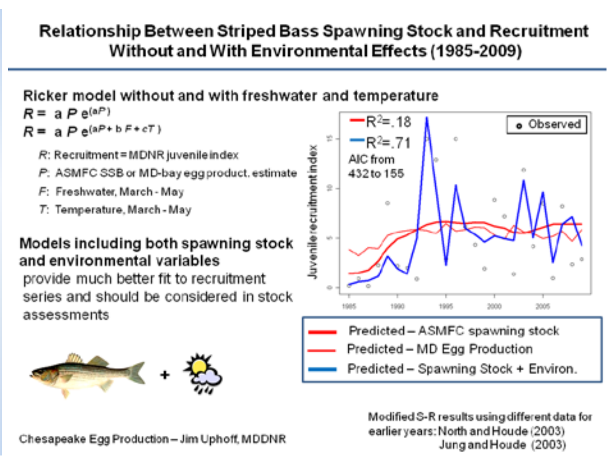
View presentation: http://www.chesapeakemeetings.com/ChesMS2010/sessions.php

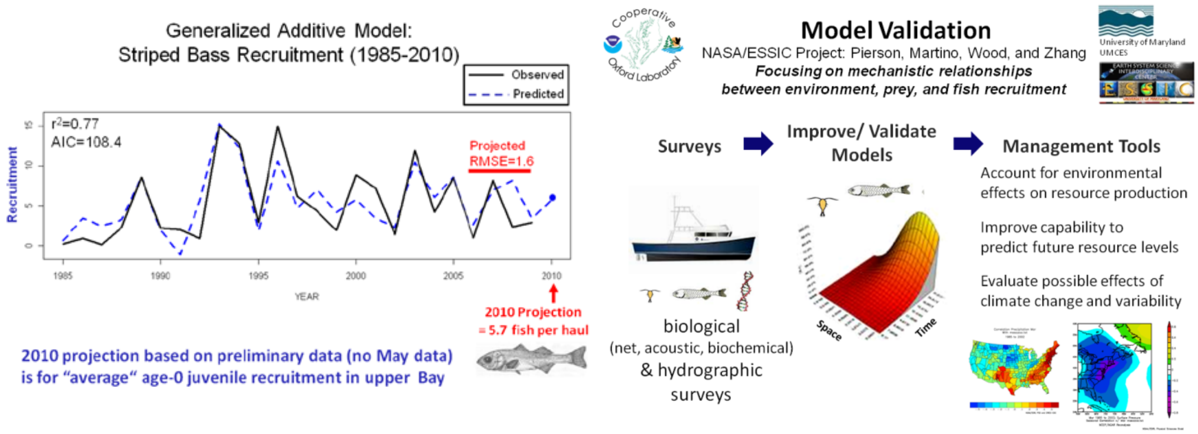
PROJECTING RECRUITMENT OF CHESAPEAKE BAY STRIPED BASS BASED ON EARLY-LIFE HABITAT QUALITY

Ed Martino
NOAA/NOS/NCCOS Cooperative Oxford Laboratory, Ed.Martino@noaa.gov

Ecosystem-based approaches to fishery management require improved understanding of habitat requirements and how environmental variability affects stock dynamics. High variability (>20 fold) in age-0 juvenile recruitment is a common feature of Chesapeake Bay striped bass population dynamics. Spatio-temporal variability in zooplankton prey for striped bass larvae, controlled by synoptic-scale climatology and hydrological conditions, explains strong environmental controls of recruitment. In two spawning-nursery locations, Ricker stock-recruitment models were fit using stock biomass (SSB) alone and with freshwater flow to partition effects of SSB and hydrology on age-0 recruitments for years 1989-2008. Models including flow explained more variability in recruitments than models with SSB alone (AIC=507 to AIC=273). Regression models including freshwater flow and temperature explain a high proportion of variability (r^2=0.63) in age-0 recruitment. Modeling results indicate that environmental variability controls larval survival and the level of age-0 recruitment. Estimates of zooplankton abundance and distribution based on net and acoustic sampling coarsely depicts annual differences in prey availability, and indicates feeding conditions and potential survival of striped bass larvae. We also develop indicators of habitat quality and quantity based on isohaline location, and assess their ability to predict recruitment. After the larval stage, regulation occurs via density-dependent growth and size-selective overwintering mortality of age-0 juveniles. Age-1 juvenile abundance can be predicted in a regression model (r^2=0.82, p<0.001) using age-0 juvenile abundance, age-0 length attained, and winter temperature. Requirements of ecosystem-based fishery management are addressed by evaluating the potential to apply these findings to determine indicators and reference points of habitat suitability and reproductive success.





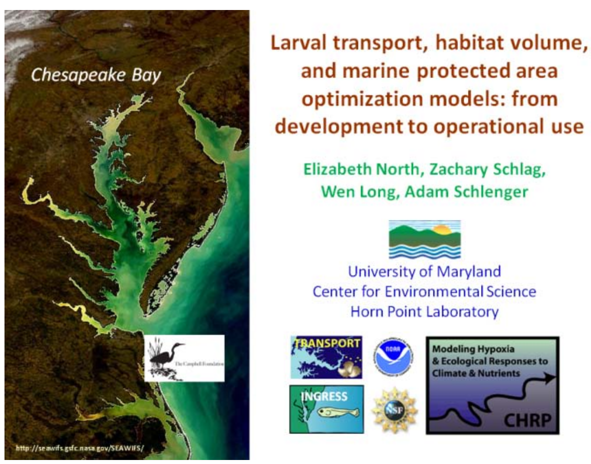


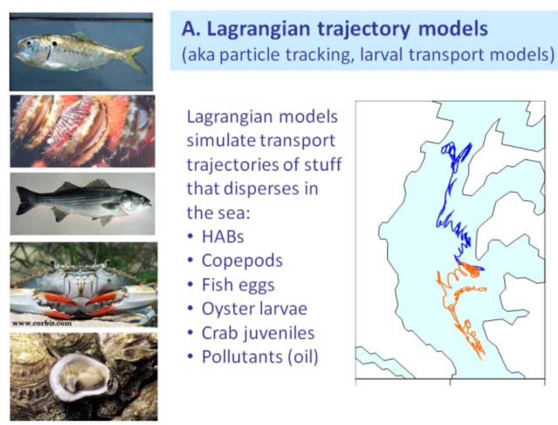
View presentation: http://www.chesapeakemeetings.com/ChesMS2010/sessions.php

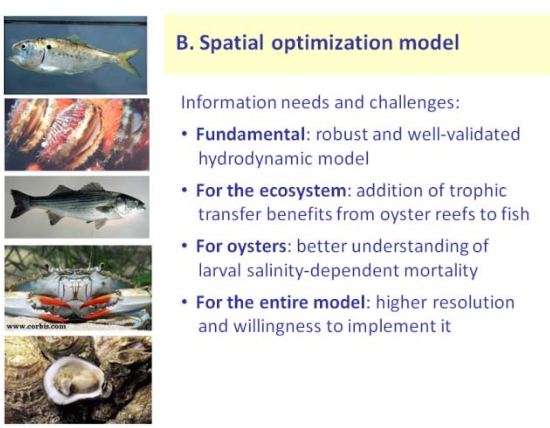
LARVAL TRANSPORT, HABITAT VOLUME, AND MARINE PROTECTED AREA OPTIMIZATION MODELS: FROM DEVELOPMENT TO OPERATIONAL USE

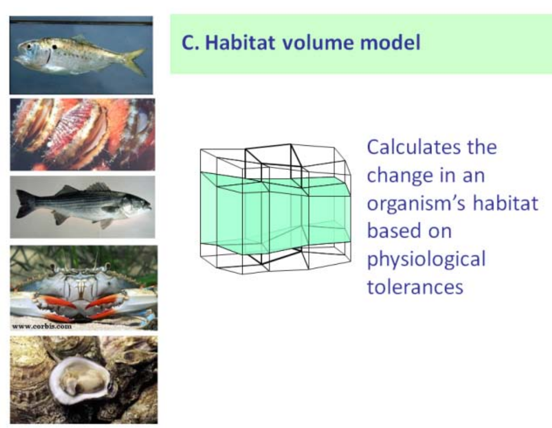
Elizabeth North
Horn Point Laboratory, University of Maryland Center for Environmental Science, enorth@hpl.umces.edu

Coupled bio-physical models are increasingly being used to inform fisheries and ecosystem management and restoration programs. We describe three types of coupled biophysical models and present case studies for three Chesapeake Bay species: 1) a larval transport model for blue crab (*Callinectes sapidus*), 2) a habitat volume model for juvenile Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), and 3) a marine protected area optimization model for oysters (*Crassostrea virginica*). The differences and similarities in these modeling approaches will be highlighted and used to illustrate the information needs and challenges in moving these types of models towards operational use.







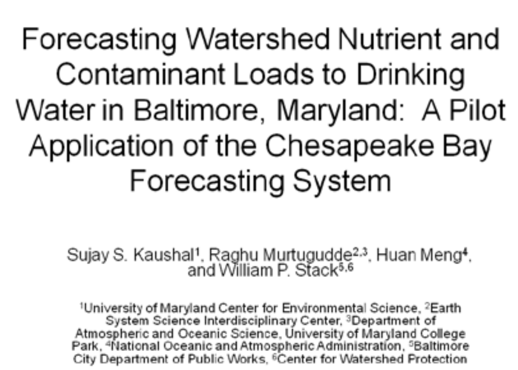


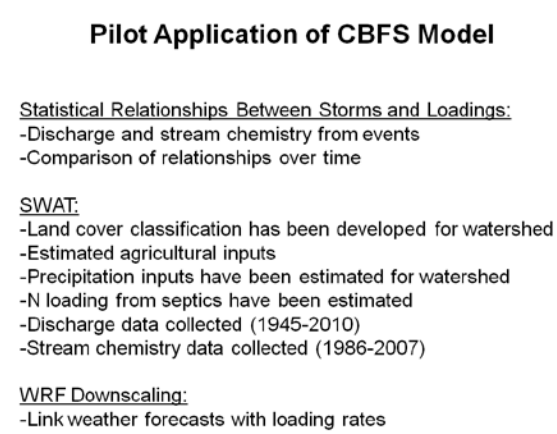
View presentation: http://www.chesapeakemeetings.com/ChesMS2010/sessions.php

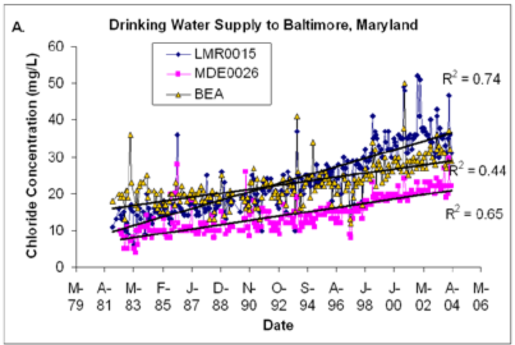
FORECASTING WATERSHED NUTRIENT AND CONTAMINANT LOADS TO DRINKING WATER IN BALTIMORE, MARYLAND: A PILOT APPLICATION OF THE CHESAPEAKE BAY FORECASTING SYSTEM

Sujay Kaushal
Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, kaushal@cbl.umces.edu

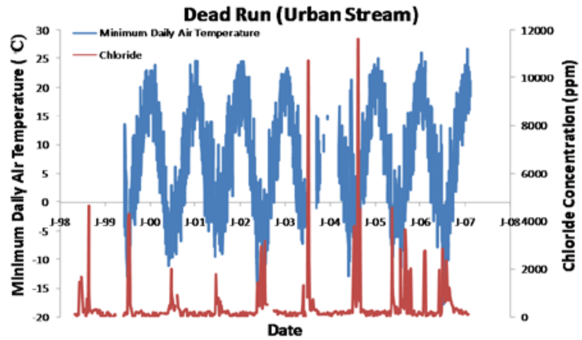
There have been increasing interactive effects of land use and climate change on water resources in Maryland. These interactive disturbances may have important effects on nutrient and contaminant loads to municipal drinking water supplies. Here, we develop and test a pilot application of the Chesapeake Bay Forecasting System regarding loadings of nitrogen, phosphorus, and road salt in the North Branch of the Patapsco River. The North Branch of the Patapsco River serves as a critical source of water to Liberty Reservoir, one of 3 major reservoirs operated by Baltimore City Department of Public Works that distribute an average of 265 million gallons of water per day to 1.8 million people in the Baltimore region. Analysis of long-term trends in the North Branch of the Patapsco River and nearby watersheds show increasing salinization due to road salt use, pronounced effects of record drought and wet years on nitrogen and phosphorus loads, and rising stream and river water temperatures. The objective of the pilot application involves collaboration with Baltimore City Department of Public Works to investigate and model the effects of extreme weather events and precipitation variability on the temporal distribution and magnitude of storm discharge rates and contaminant loadings. This information may be useful for informing watershed restoration strategies to increase resilience in ecosystem nutrient retention functions in response to extremes in precipitation, and as a potential support tool for predicting the quality of water withdrawals across different weather conditions. Application of the Chesapeake Bay Forecasting System may be useful in assisting efforts to predict and protect quantity and quality of water, and preliminary challenges and/or results from the pilot application will be discussed.







Kaushal et al. (2005)



Kaushal et al. (In Press)

View presentation: http://www.chesapeakemeetings.com/ChesMS2010/sessions.php

References

Brown, C. W., D. L. Ramers, et al. (Need all the authors). 2010. Predicting the abundance of the dinoflagellate Karlodinium veneficum in the Chesapeake Bay. Harmful Algae (*in preparation*).

Constantin de Magny, G., W. Long, C.W. Brown, R.R. Hood, A. Huq, R. Murtugudde and R.R. Colwell. 2009. Predicting the distribution of *Vibrio spp.* in the Chesapeake Bay: A *Vibrio cholerae* case study. Ecohealth 6: 378-389.

Costantini, M., S.A. Ludsin, D.M. Mason, X. Zhang, W.C. Boicourt and S.B. Brandt. 2008. Effect of hypoxia on habitat quality of striped bass *Morone saxatilis* (Walbaum) in Chesapeake Bay. Can. J. Fish. Aquat. Sci. 65(5): 989-1002.

Decker, M. B., C. W. Brown, R.R. Hood, J.E. Purcell, T.F. Gross, J.C. Matanoski, R.O. Bannon and E.M. Setzler-Hamilton. 2007. Predicting the distribution of the scyphomedusa, *Chrysaora quinquecirrha*, in Chesapeake Bay. Marine Ecology Progress Series 329: 99-113.

Jacobs, J. M., M. Rhodes, C.W. Brown, R.R. Hood, A. Leight, W. Long and R. Wood. 2010. Predicting the distribution of *Vibrio vulnificus* in Chesapeake Bay. NOAA Technical Memorandum NOS NCCOS. 112. 12 pp.

Ludsin, S.A., X. Zhang, S.B. Brandt, M.R. Roman, W.C. Boicourt, D.M. Mason and M. Costantini. 2009. Hypoxia avoidance by planktivorous fish in Chesapeake Bay: implications for food web interactions and their recruitment. J. Exp. Mar. Biol. Ecol. 381: S121-S131.

Martino, E. J. and E.D. Houde. 2010. Recruitment of striped bass in Chesapeake Bay: spatial and temporal environmental variability and availability of zooplankton prey. Marine Ecology Progress Series 409: 213-228.

Murtugudde, R. 2009. Regional earth system prediction: a decision making tool for sustainability? Current Opinion in Environmental Sustainability 1: 37-45.

Prasad M.B.K., L. Wen, X. Zhang, R. J. Wood, R. Murtugudde. 2010. Prediction of dissolved oxygen in the Chesapeake Bay. Aquatic Sciences (*Submitted*).