

Establishing an Ecological Forecasting System: Predicting Sea Nettle in the Chesapeake Bay

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CICS - ESSIC

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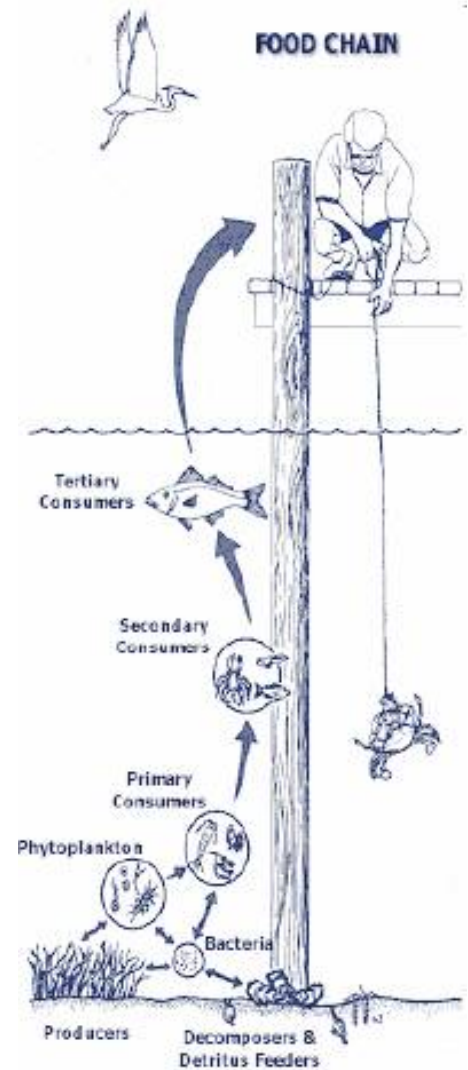
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Raleigh Hood and Wen Long (UMCES HPL)
Ragu Murtugudde (UMCP)
Nettle IWT Members (NOAA)

Background

Ecological forecasting*

- Is an emerging requirement for NOAA environmental prediction services;
- Identified as a pivotal issue to be addressed by NOAA to meet emerging ecosystem management challenges;
- Remains primarily in a research mode at NOAA; and,
- No comprehensive, coordinated and systematic approach exists to transition research advancements to stakeholders and beneficiaries.

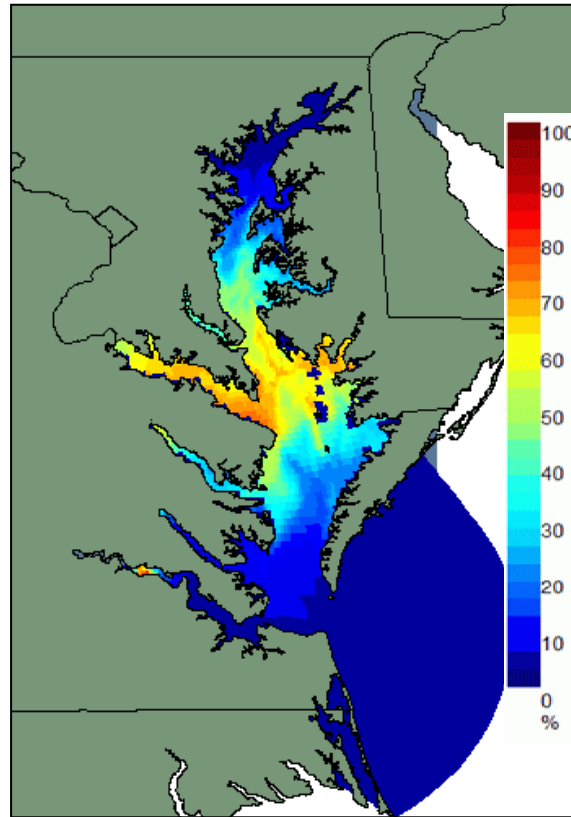


** Ecological Forecasting: Predicting the effects of biological, chemical, physical, and human-induced changes on ecosystems and their components.*

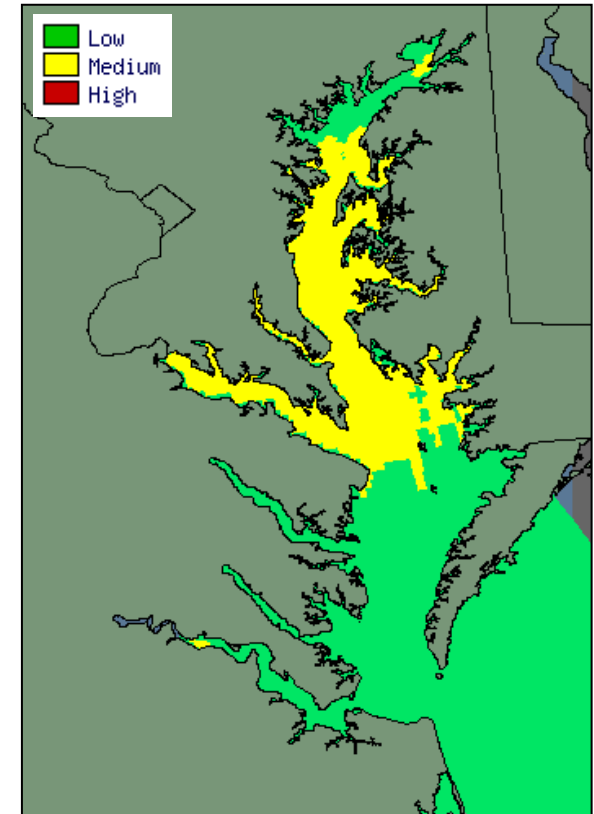
Ecological Prediction in Chesapeake Bay: *Current Demonstrations*

Generate daily
nowcasts and 3-
day forecasts of:

- *Chrysaora quinquecirrha*
(Sea Nettles)
- *Karlodinium veneficum*
- *Vibrio cholerae*



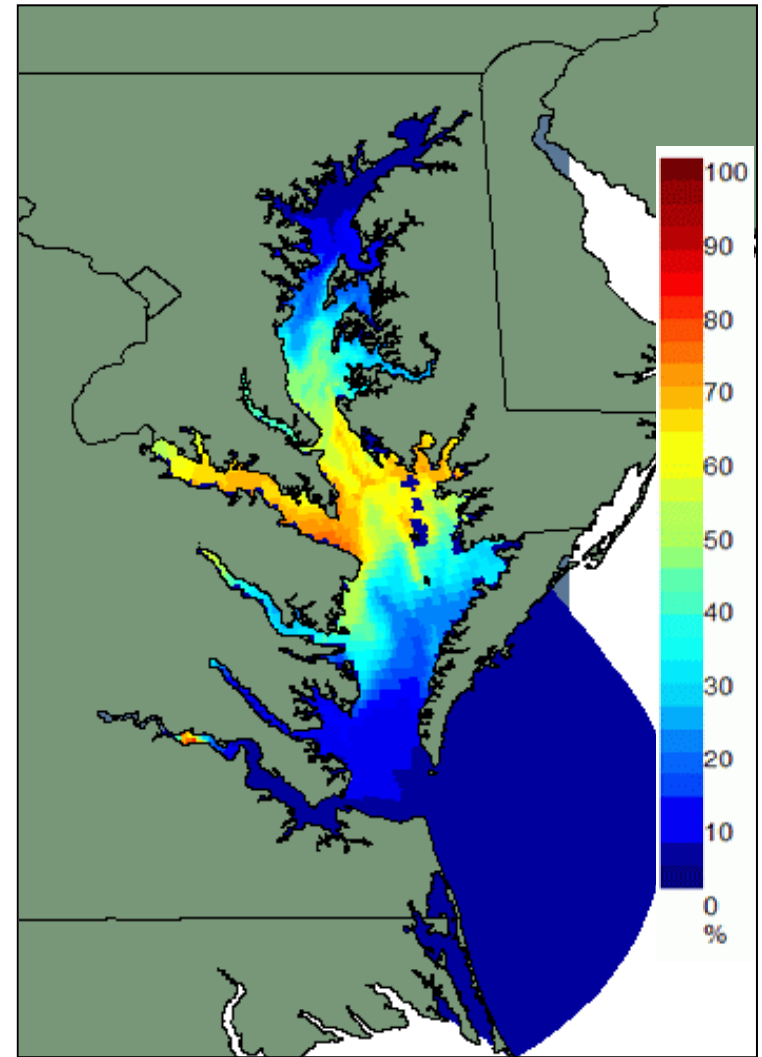
Predicted chance of encountering
sea nettles, *C. quinquecirrha*, on
August 17, 2007



Predicted relative abundance of
Karlodinium veneficum on
August 17, 2007

Project Objective

- Demonstrate the production of a prototype ecological product under the framework of NWS operations.
- Initiate the development of an operational ecological forecasting system at NOAA.



Predicted chance of encountering sea nettle,
C. quinquecirrha, on August 17, 2007

Forecasting Sea Nettle Distributions in Chesapeake Bay: An Overview



Chrysaora quinquecirrha
(Photo by Rob Condon)

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Predicting the distribution of the scyphomedusa *Chrysaora quinquecirrha* in Chesapeake Bay

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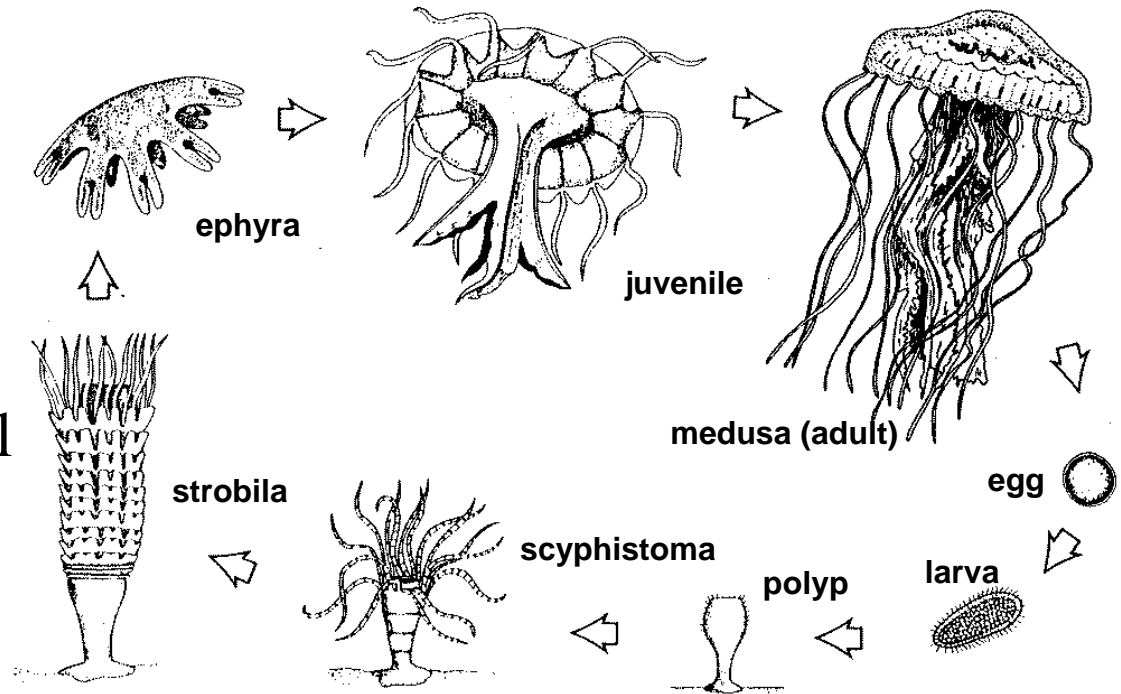
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Introduction: Sea Nettles

- *Chrysaora* ephyra and medusa seasonally populate Chesapeake Bay
- *Chrysaora* is biologically important and impacts recreational and commercial activities
- Knowing the distribution of *Chrysaora* would provide valuable information

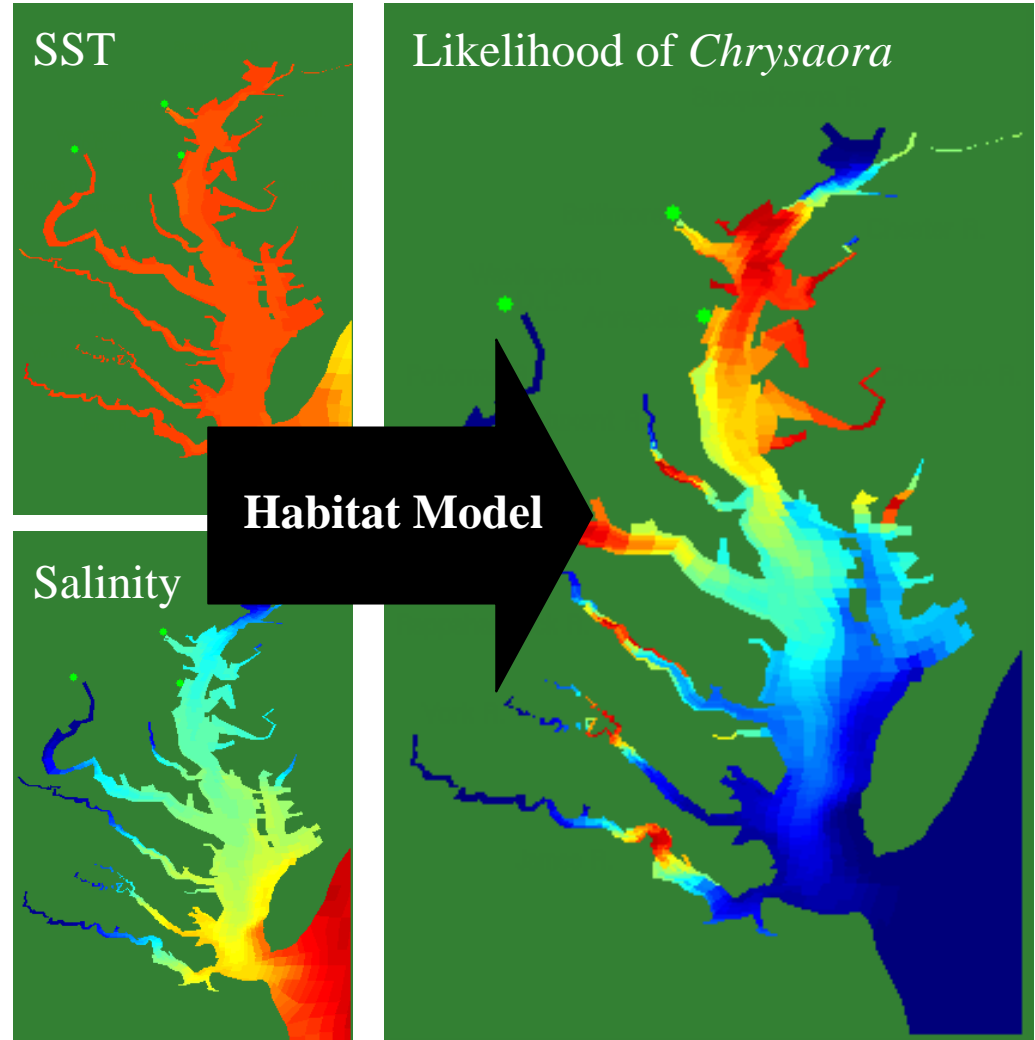


Life Cycle of *Chrysaora*

From: T.L. Bryant and J.R. Pennock (eds). 1988. The Delaware Estuary: Rediscovering a Forgotten Resource. University of Delaware Sea Grant College Program. Newark, DE.

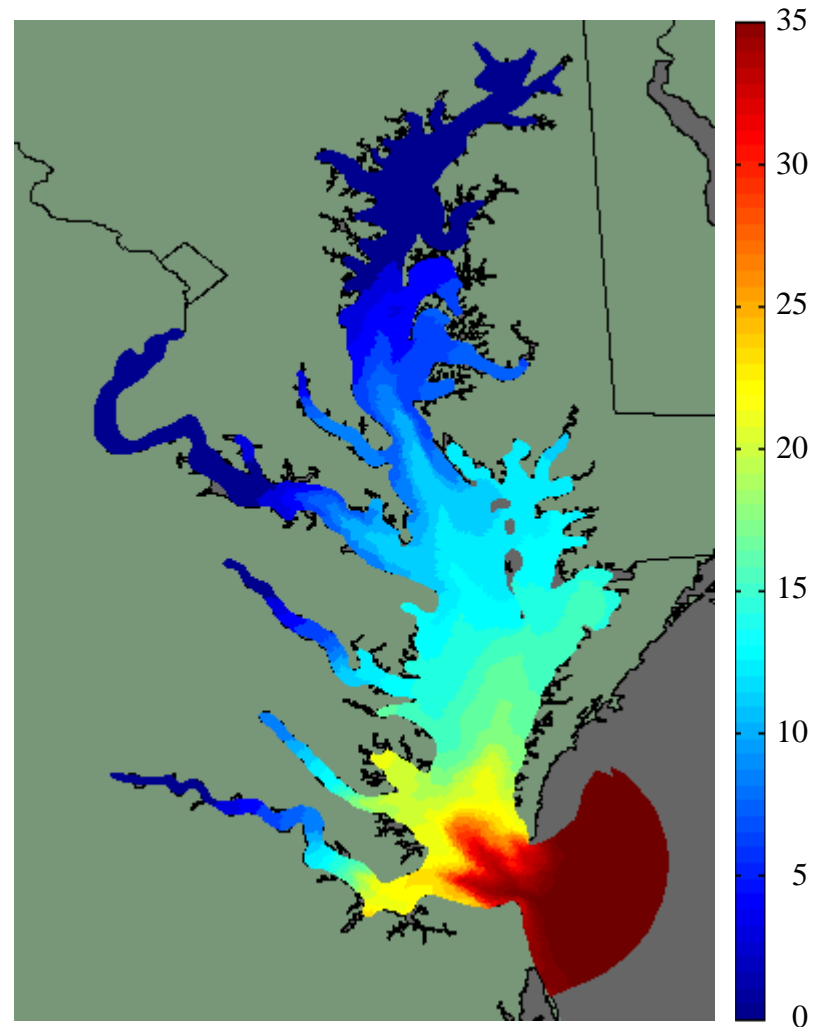
Sea Nettle Forecasting Procedure

1. Forecast surface salinity and temperature fields
2. Georeference salinity and SST fields
3. Apply habitat model
4. Generate image illustrating the probable distribution of sea nettles
5. Disseminate to users on WWW



Surface Salinity

- Generated using hydrodynamic model tuned for Chesapeake Bay (ChesROMS)
- Model forced using near-real time and forecast input
- Model attributes:
 - *Horizontal Resolution: 1-5 kilometers*
 - *Vertical Resolution: 1.52 meters*
 - *Error: 2 - 3 ppt*

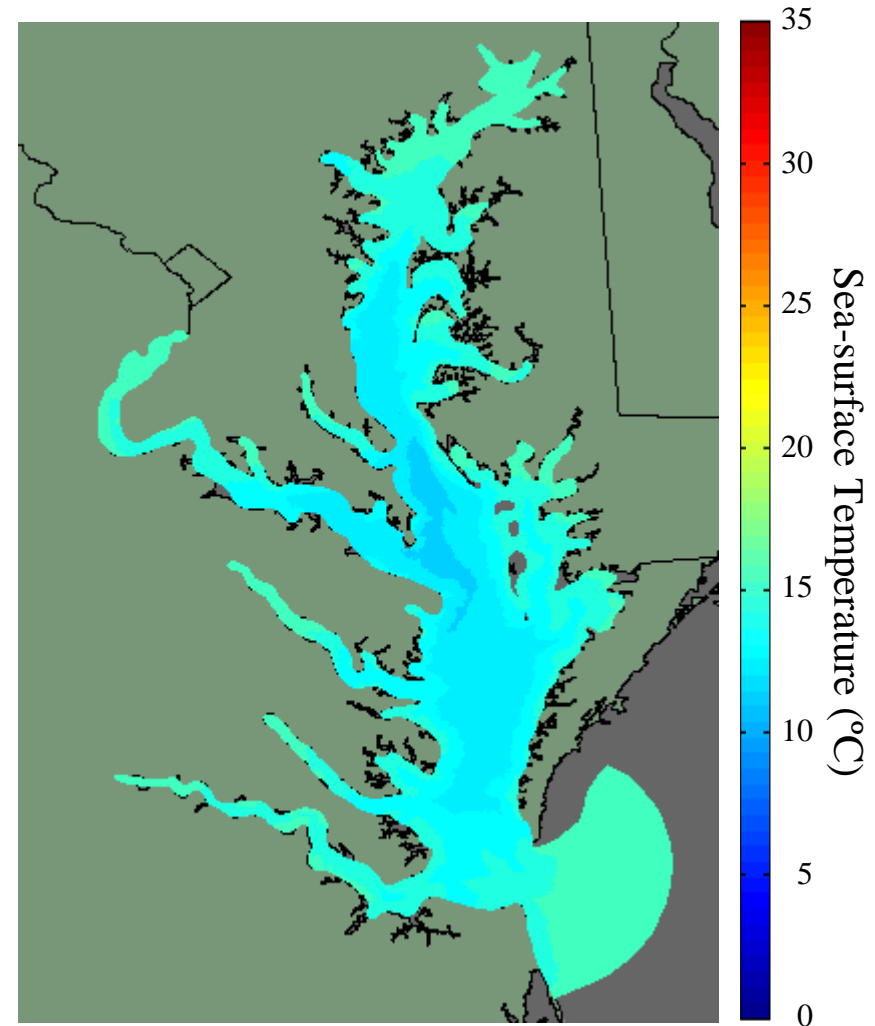


Model generated surface salinity in Chesapeake Bay for April 20, 2005

Sea-Surface Temperature

Two Sources:

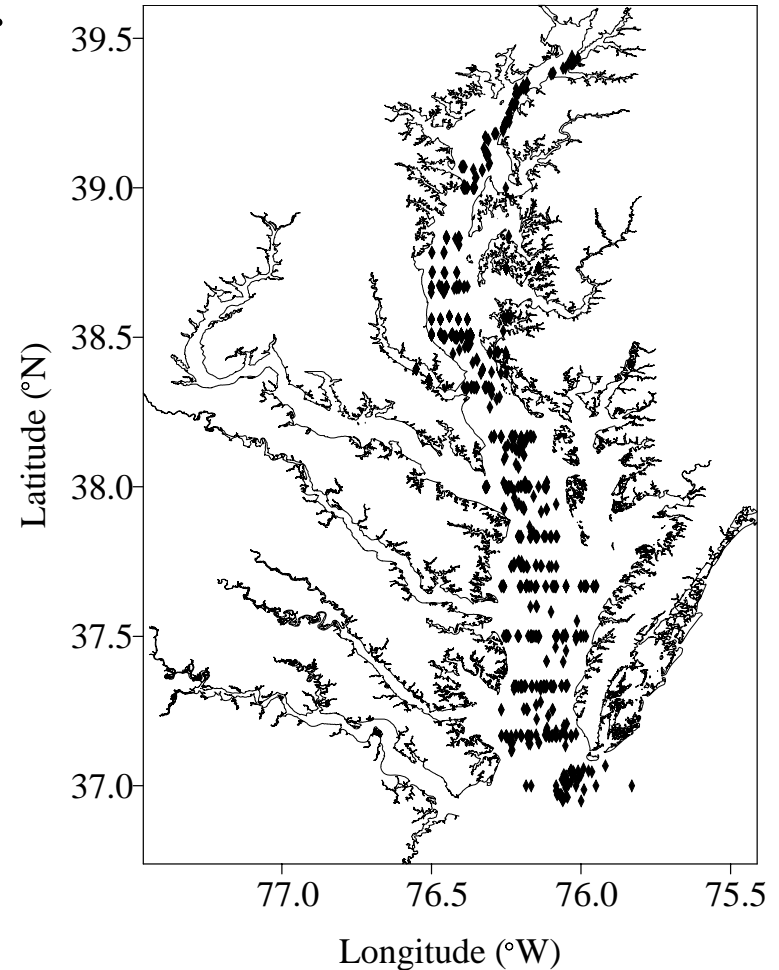
1. Generated by hydrodynamic model
 - *Error: 2 - 3 °C*
2. Derived from NOAA AVHRR satellite imagery
 - *Resolution: 1 km*
 - *Weekly composite*
 - *Bias: 0.5 °C; STD: 1.0°C*



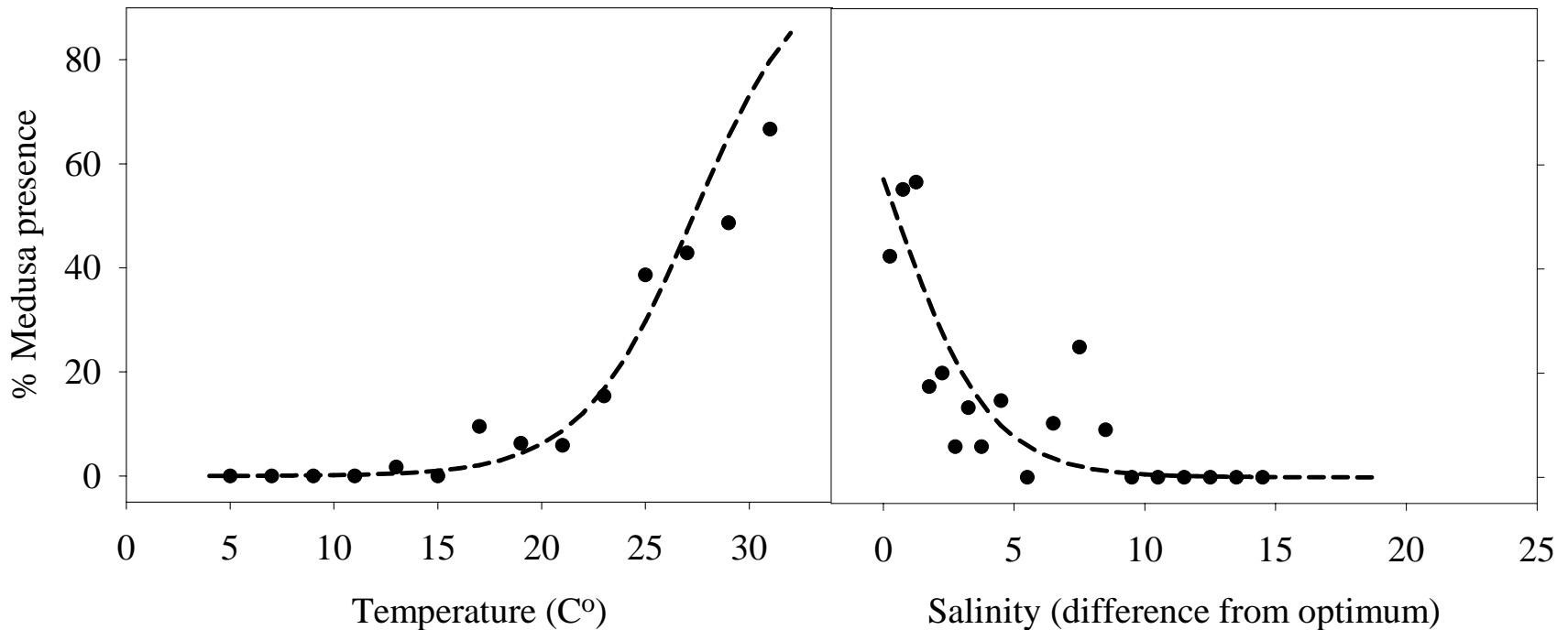
Model generated sea-surface temperature in Chesapeake Bay for April 20, 2005

Sea Nettle Habitat Model

- Models developed to predict:
 1. Probability of encountering *Chrysaora*
 2. Density of *Chrysaora*
- Analyzed relationship between *Chrysaora*, salinity and sea-surface temperature
- Samples collected in surface waters (0 –10 m) of Chesapeake Bay (n = 1064)
 - 2/3 model training
 - 1/3 model testing



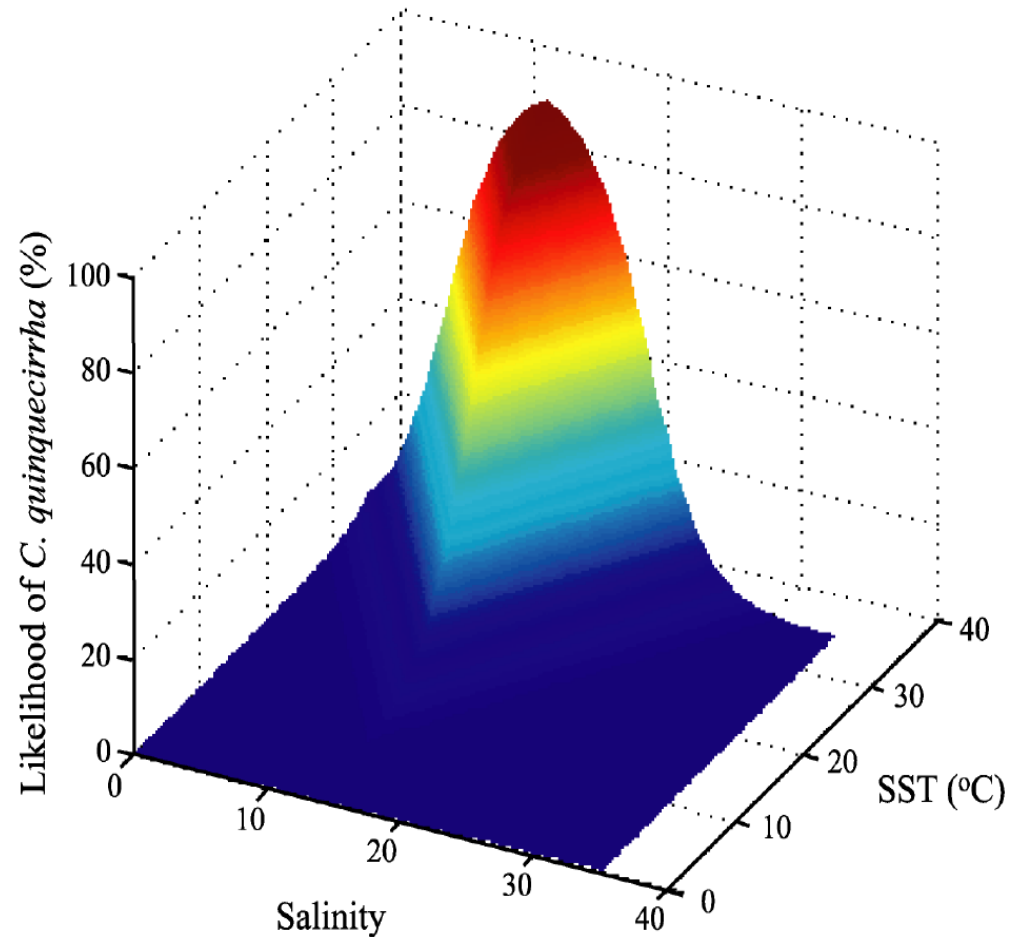
Sea Nettle Habitat

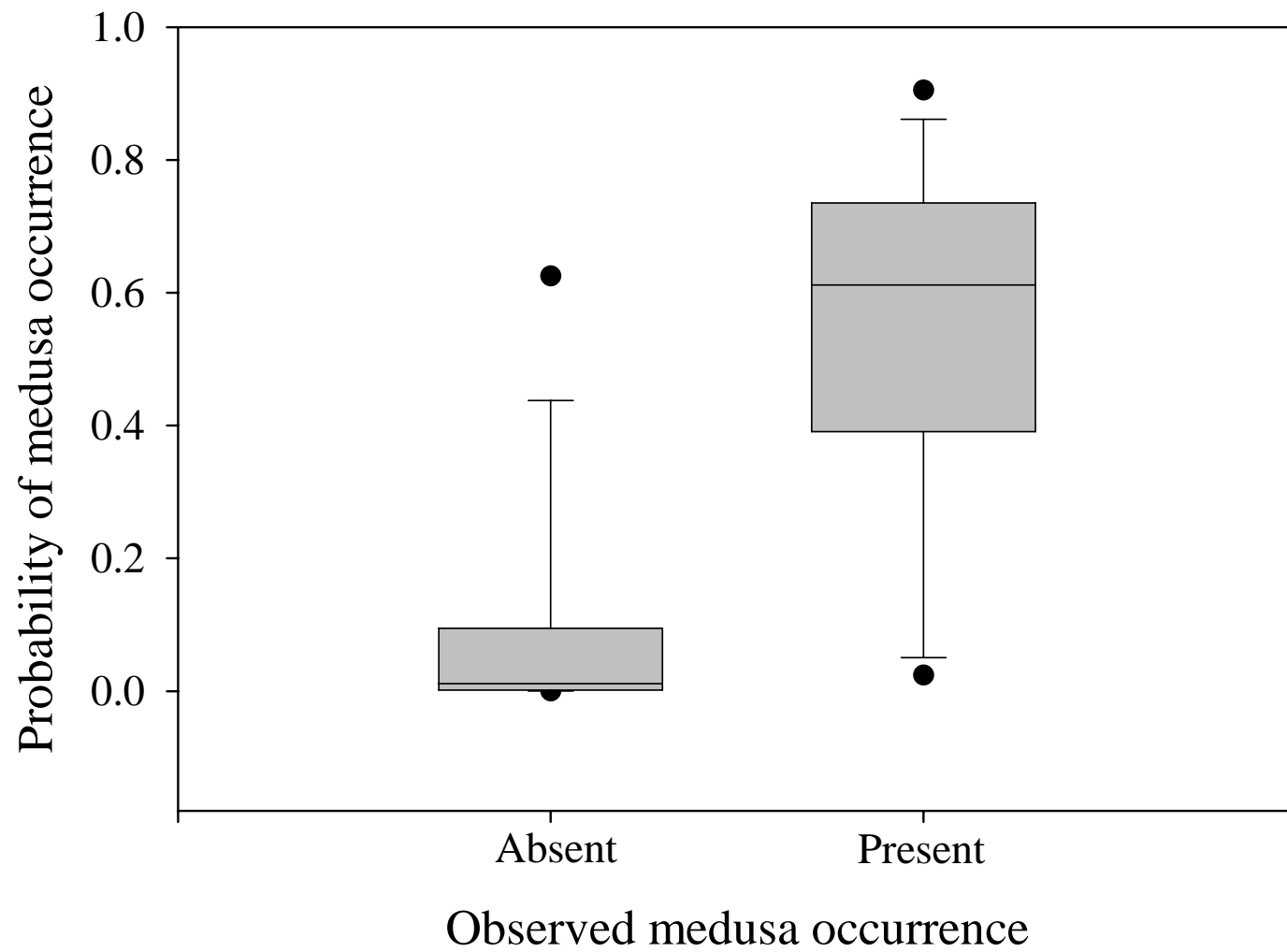


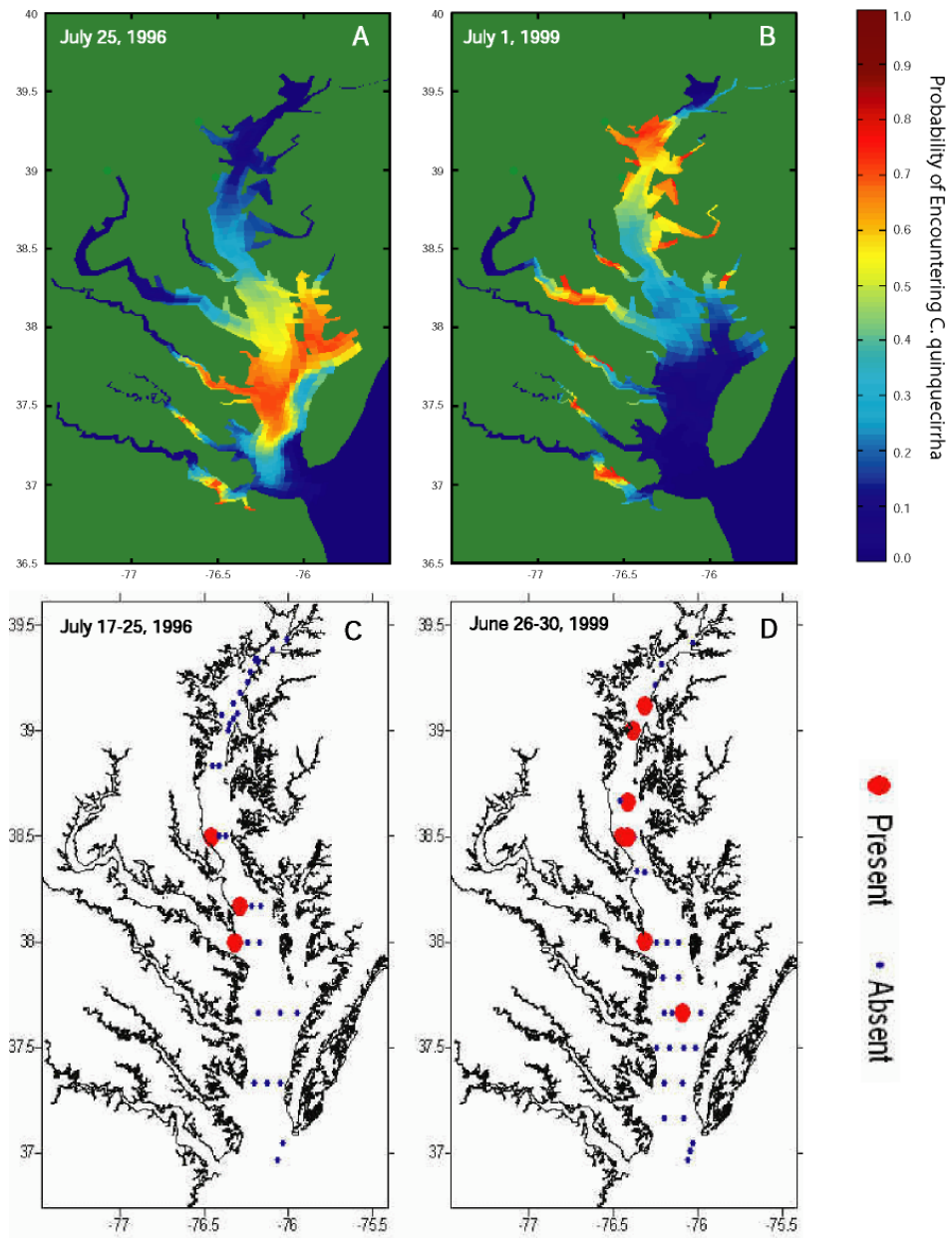
Nettle medusa occupy narrow temperature (26-31 °C) and salinity (10-16 PSU) range. Salinity optimum = 13.5.

Algorithm for Nowcasting Sea Nettles

- When $SST \leq 34^{\circ}\text{C}$:
 - $p = e^{\text{logit}} / (e^{\text{logit}} + 1)$,
where,
$$\text{logit} = -8.120 + (0.351 * SST) - (0.572 * |SAL - 13.5|)$$
 - Hosmer-Lemeshow Goodness of Fit $P = 0.493$
- When $SST > 34^{\circ}\text{C}$:
 - $p = 0$

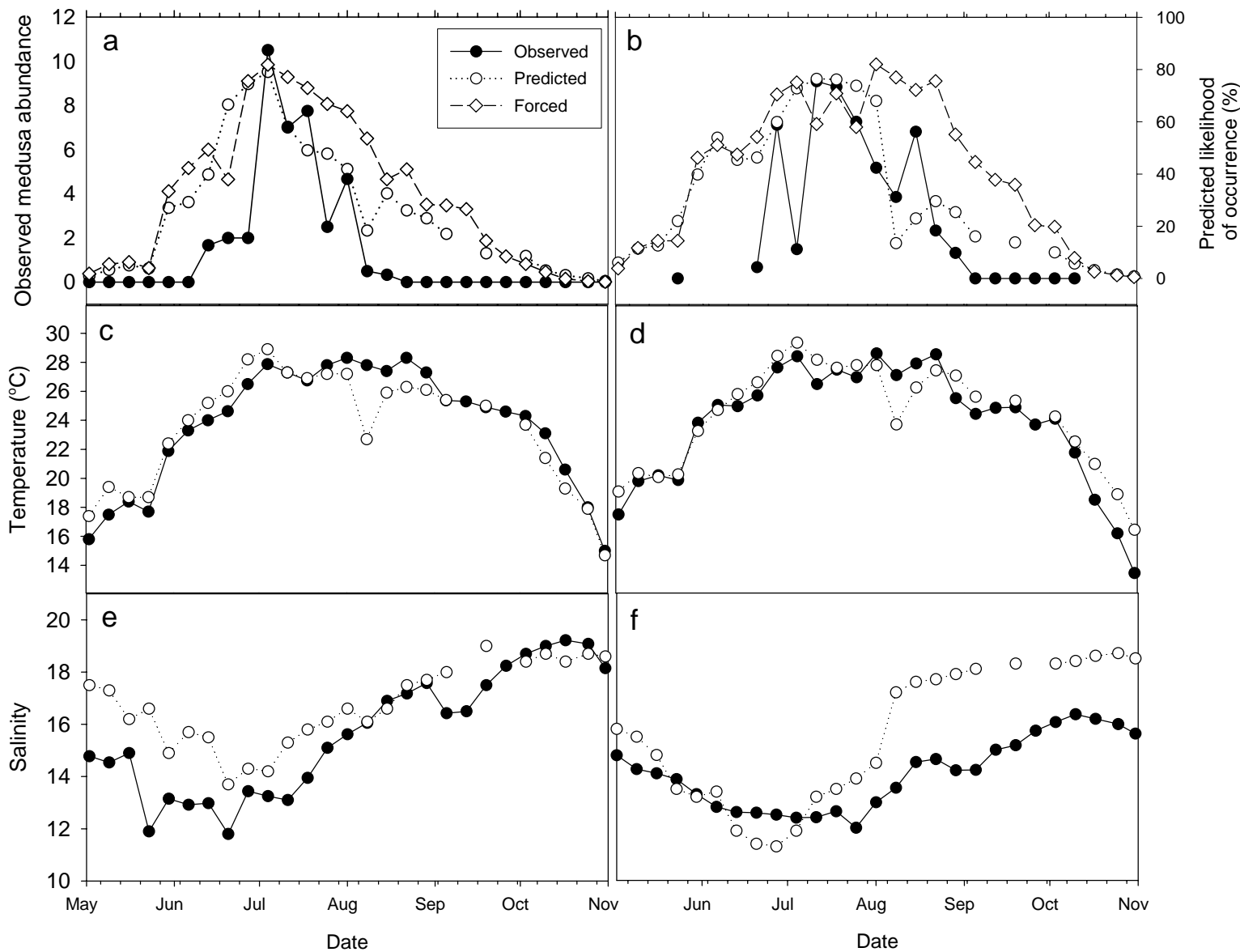






Chesapeake Bay Laboratory

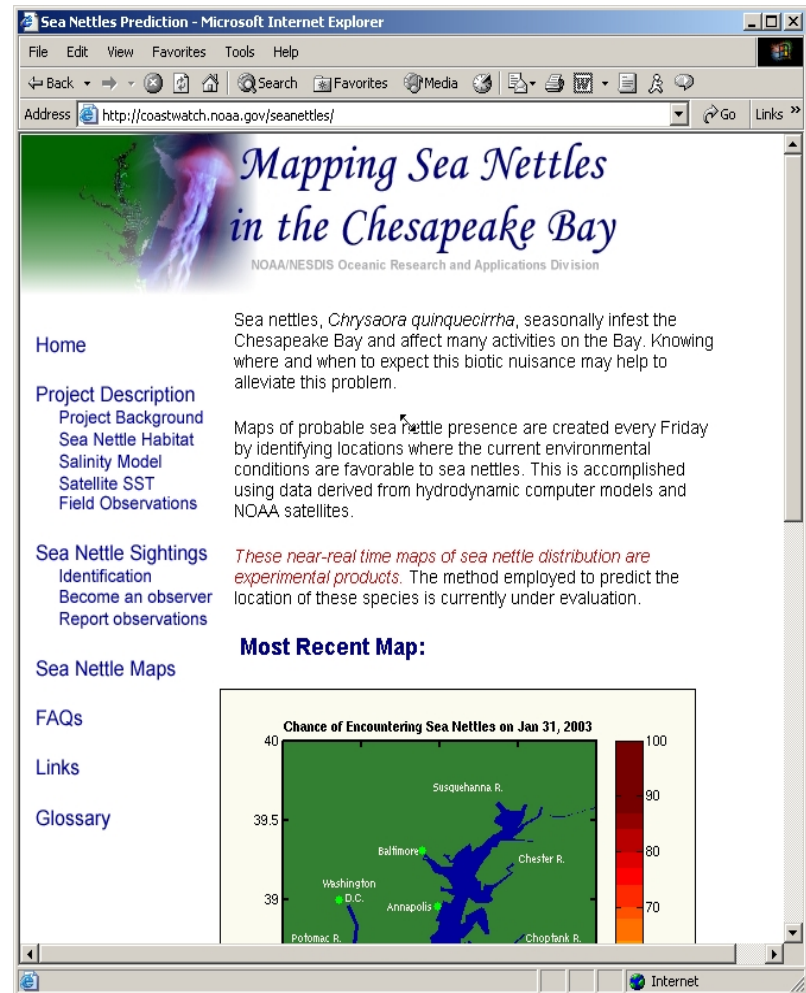
Horn Point Laboratory



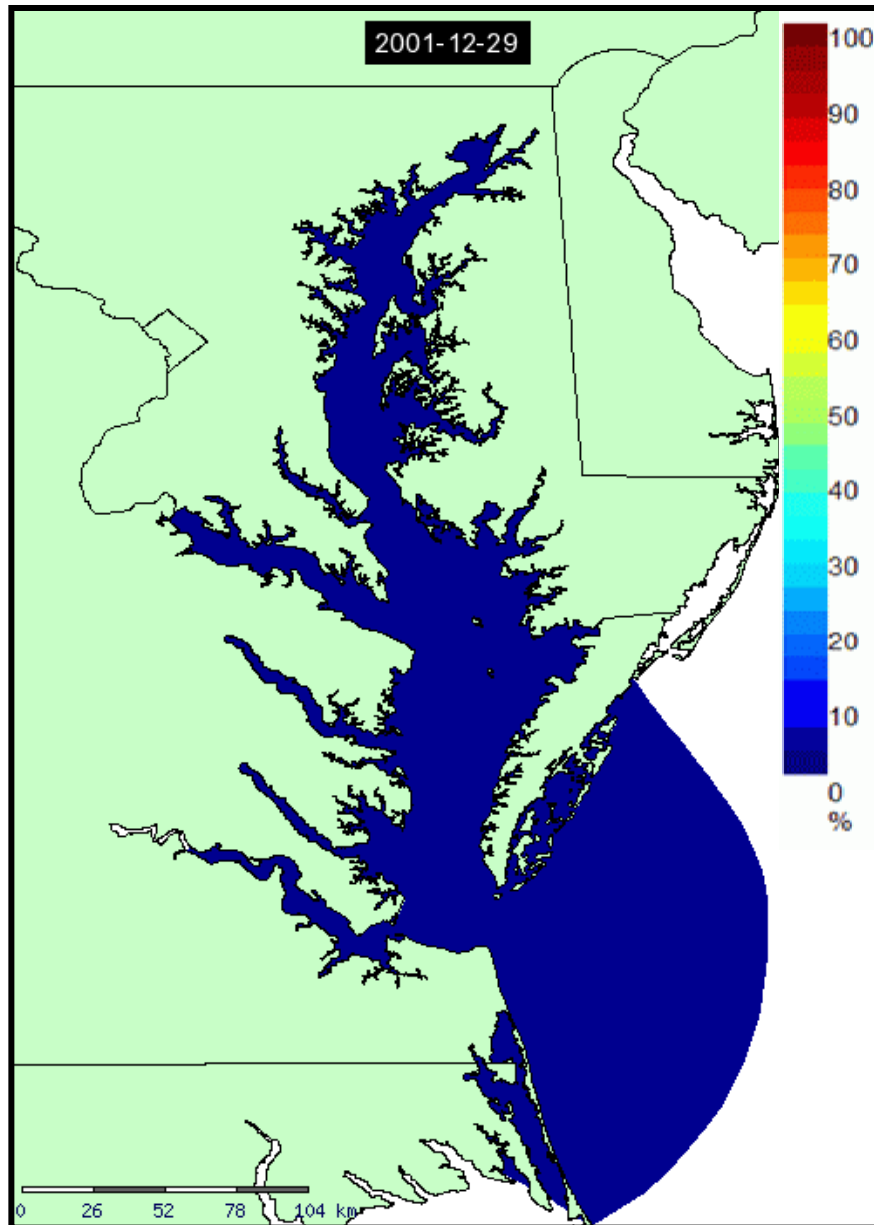
● Observed (closed circles)
○ Predicted (open circles)

Nettle Prediction WWW Sites

Predictions are generated daily and are available on the World Wide Web.

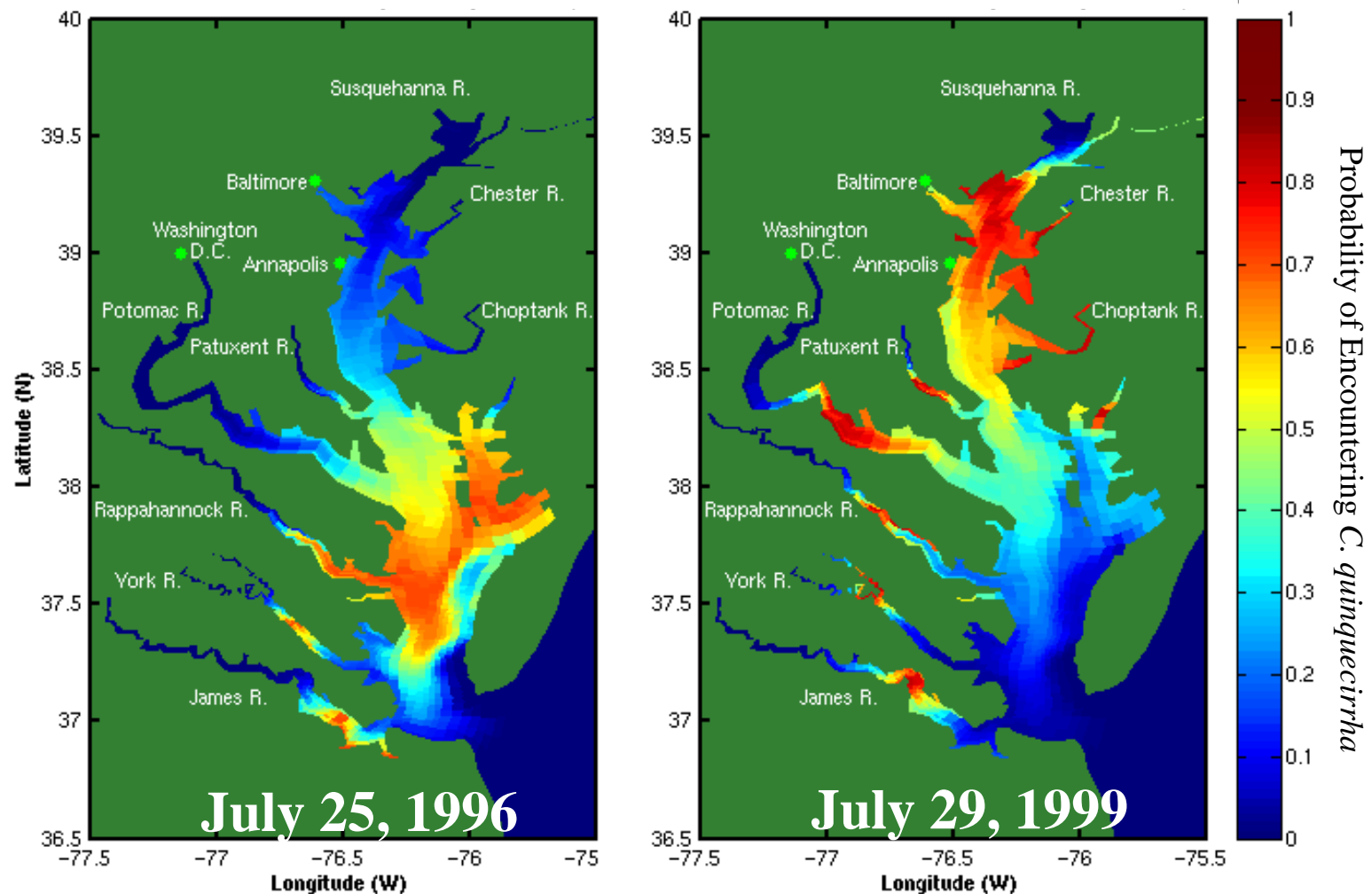


<http://coastwatch.noaa.gov/seanettles>



Animation of predicted likelihood of encountering the sea nettles (*Chrysaora quinquecirrha*) in Chesapeake Bay from December 29, 2001 – December 31, 2002.

Interannual Variability



Likelihood of Encountering *C. quinquecirrha*
in July 1996 and 1999

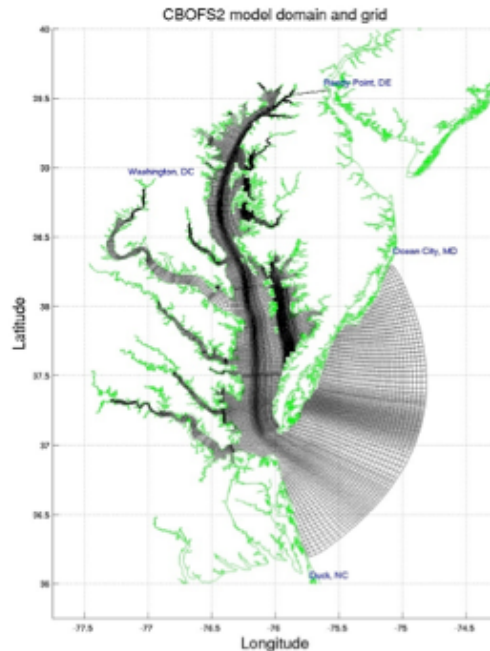
Transitioning Nettle Forecasts to Operations to NWS

- Vision
 - “Piggy-back” on NOS-supplied Chesapeake Bay Operational Forecast System (CBOFS2) model
 - Disseminate products through NWS
- Follow NWS’ Operations and Service Improvement Process
 - Assembling Integrated Working Team
 - Finalizing Statement of Need

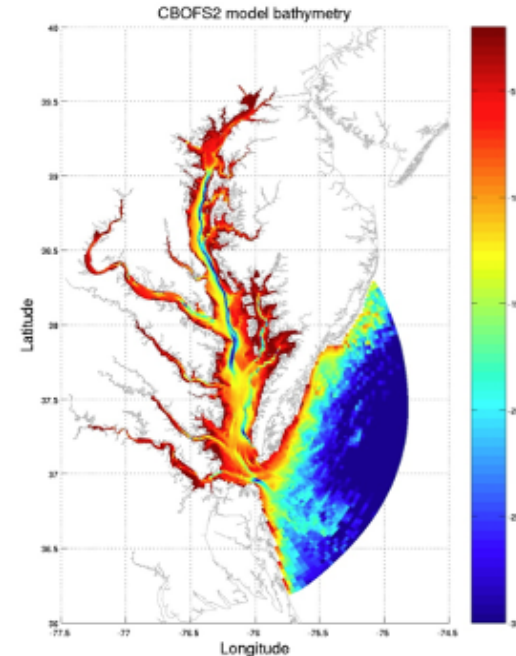


Employ NOAA's Operational Chesapeake ROMS

CBOFS2 model grid and bathymetry



- Extent – Susquehanna River reservoir (North), 100 m isobath & Duck – NC & Ocean City – MD (South), Washington DC (West) Reedy Point – DE (East along C & D canal)
- Grid is curvilinear and orthogonal
- Grid generated as local segments and pasted together within the DELFT3D grid generator



- Matlab script to go from DELFT3D format to ROMS NetCDF format
- 291 x 332 x 20 grid points; 20 vertical levels
- Resolution (m) : $34 \leq \Delta x \leq 4895$ and $29 \leq \Delta y \leq 3380$
- Vertical σ -grid with grid clustering at ocean surface and bottom
- Bathymetry interpolated from NOS soundings

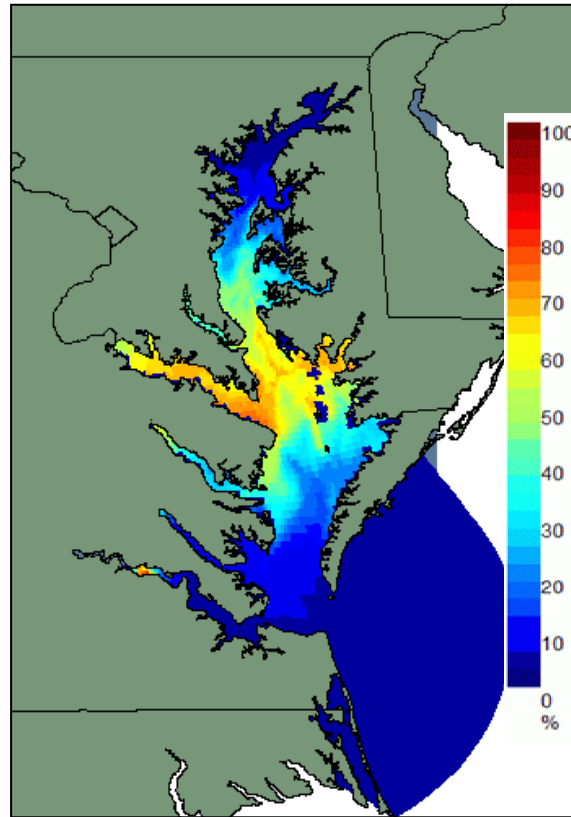
- o Propose to migrate our ecological forecasting models to CBOFS2
- o Allows better bathymetric representation
- o Improves simulation of physical processes (particularly salinity)
- o Provides more accurate forcing for our empirical and mechanistic models

Future Plans

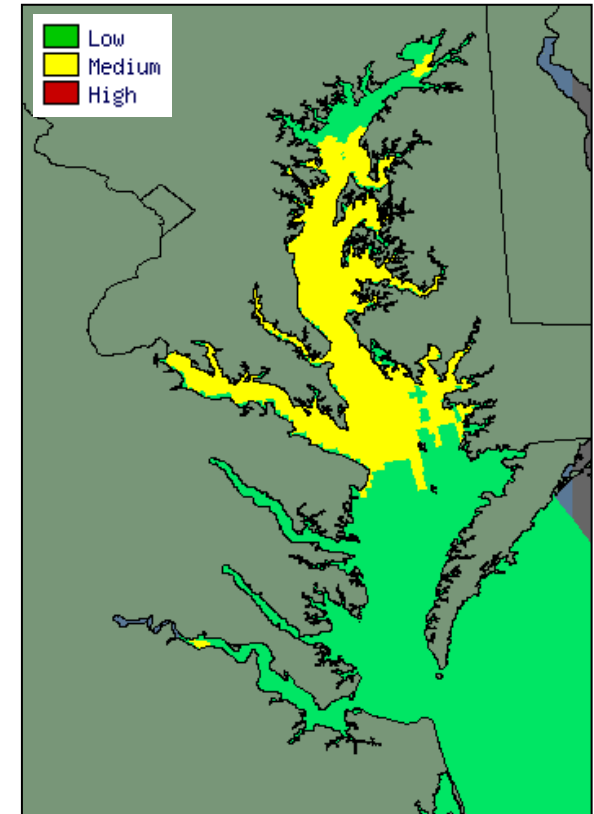
Ecological Prediction in Chesapeake Bay: *Future Operational Products*

Generate forecasts of:

- Sea Nettles
- Harmful algal blooms (HABs)
- Water-borne pathogens
- Hypoxia / Anoxia
- etc...



Predicted chance of encountering sea nettles, *C. quinquecirrha*, on August 17, 2007



Predicted relative abundance of *Karlodinium veneficum* on August 17, 2007

Chesapeake Bay Pilot Forecasts*

- Beach/Water Quality
- Living Resource Distribution
- Dissolved Oxygen [DO] Predictions
- Harmful Algal Bloom
- Disease Pathogen Progression (Climate Change)

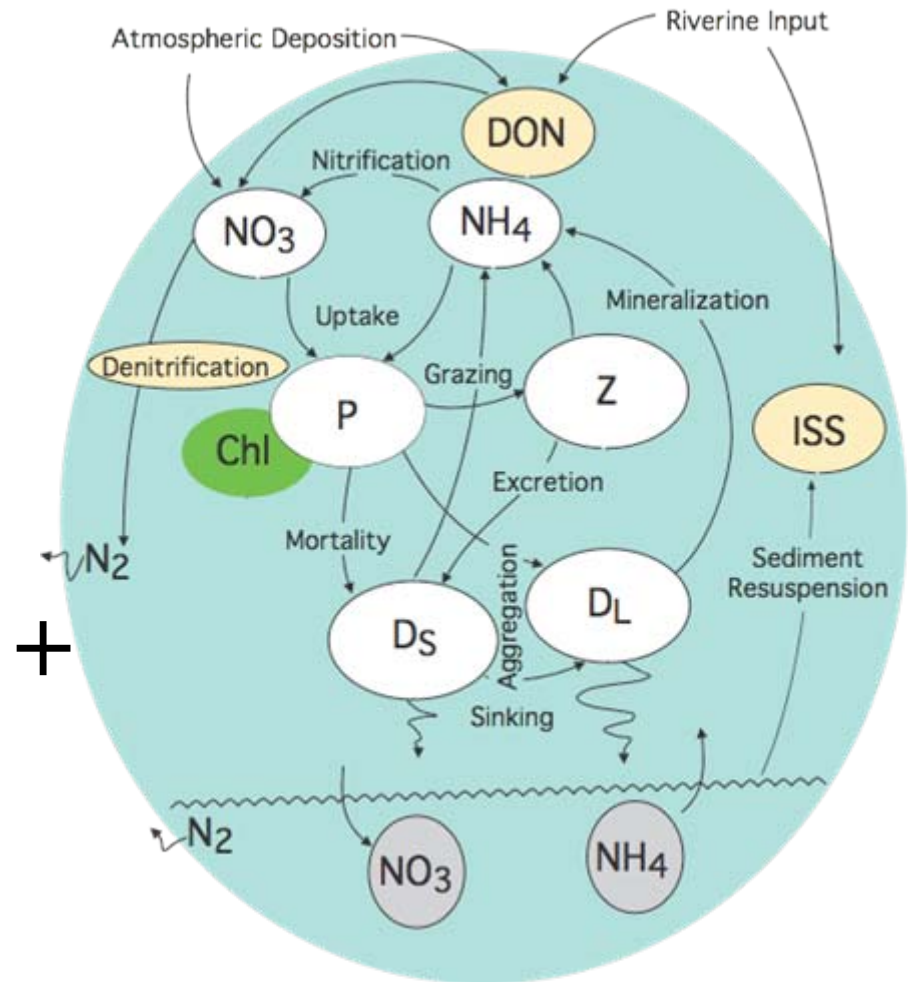
* Recommendation of regional scientists and information providers: *Chesapeake Ecological Forecasting Workshop*, Chesapeake Bay Office, Annapolis, Feb 27, 2009

Variables of Interest

- Temperature
- Salinity
- Current velocities
- Nutrient concentrations
- Dissolved oxygen concentration
- Biomass and productivity estimates and taxonomic information of organisms of various trophic levels

Biogeochemical Forecasting

- Couple biogeochemical / ecosystem model
- Generate biogeochemical / ecological forecasts
 - Chlorophyll concentration
 - Nutrient concentrations
 - Dissolved Oxygen
 - Zooplankton



Biogeochemical/ecological model

Regional Earth System Modeling

- **Objective:** Develop a fully integrated, bio-physical model of Chesapeake Bay and its watershed that assimilates *in-situ* and satellite-derived data.
- **Purpose:**
 - Near-Real Time Applications: Nowcasting and forecasting of marine organisms, ocean health, and coastal conditions
 - Climate Research: Estimating effect of climate change on the health of coastal marine ecosystems



SeaWiFS True-Color Image of Mid-Atlantic Region
from April 12, 1998.

Chesapeake Bay Forecast System

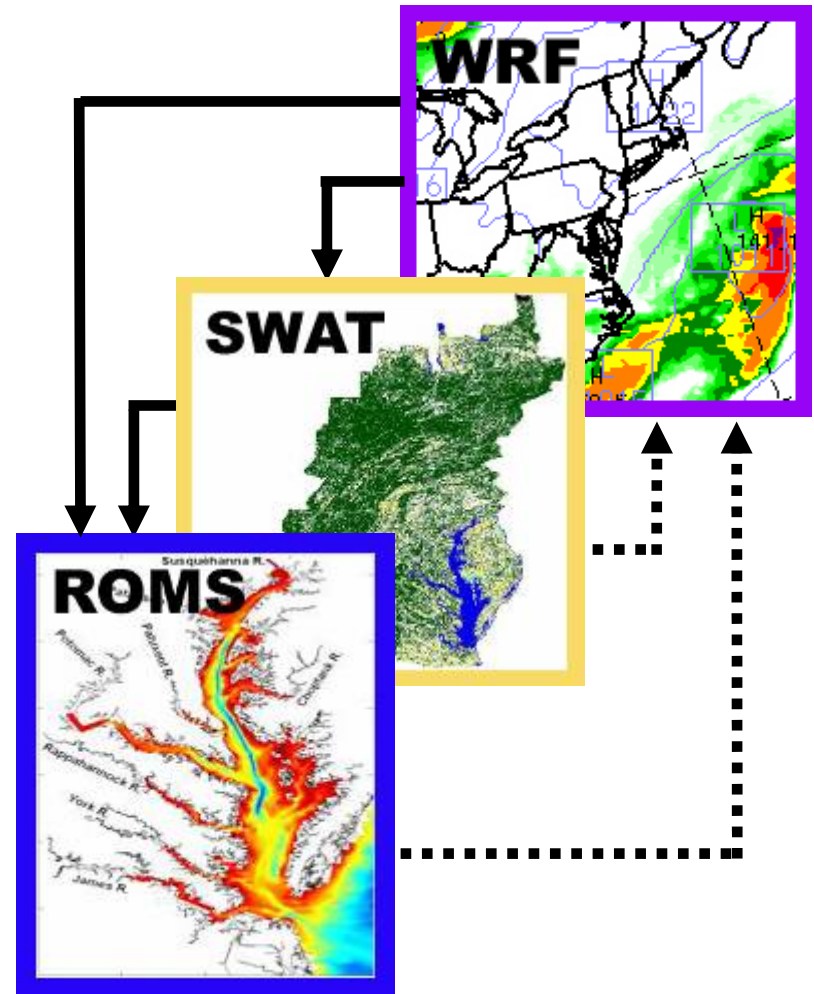
- **Objective**

- Develop a fully integrated, ecosystem model of the Chesapeake Bay and its watershed that assimilates *in-situ* and satellite-derived data by adapting and coupling existing models
- Consists of a coupled air / land / coastal ocean modeling system

- **System Components**

- **Air:** Atmosphere - Weather Research and Forecasting (**WRF**) Model
- **Land:** Land - Soil and Water Assessment Tool (**SWAT**)
- **Coastal Ocean:** Regional Ocean Modeling System (**ROMS**)

- **Partners:** UM System, NASA, NOAA



Expected Project Benefits

- Develop a framework and process for transitioning ecological forecasts to operations;
- Advance the proof-of-concept for a NOAA Ecological Forecasting System that is scalable and extensible; and
- Serve as test case for an integrated environmental service (IES) at NOAA.

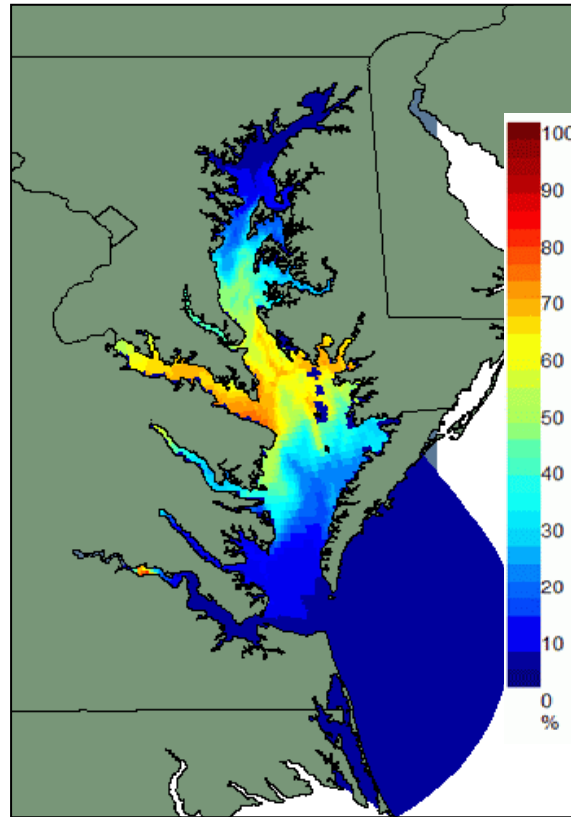


Thank You!

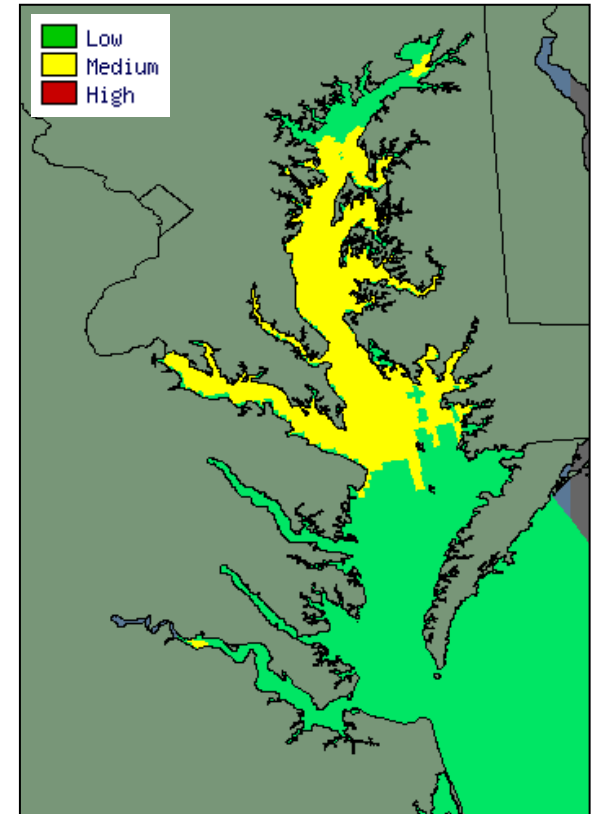
Backup Slides

Ecological Prediction in Chesapeake Bay: Current Capabilities

- Generate daily nowcasts and 3-day forecasts of
 - Sea Nettles
 - *Karlodinium veneficum*,
 - *Vibrio cholerae*
- Forecasts created by identify the locations where ambient conditions coincide with the preferred environment (= habitat) of the organism
- Forecasts of environmental conditions required



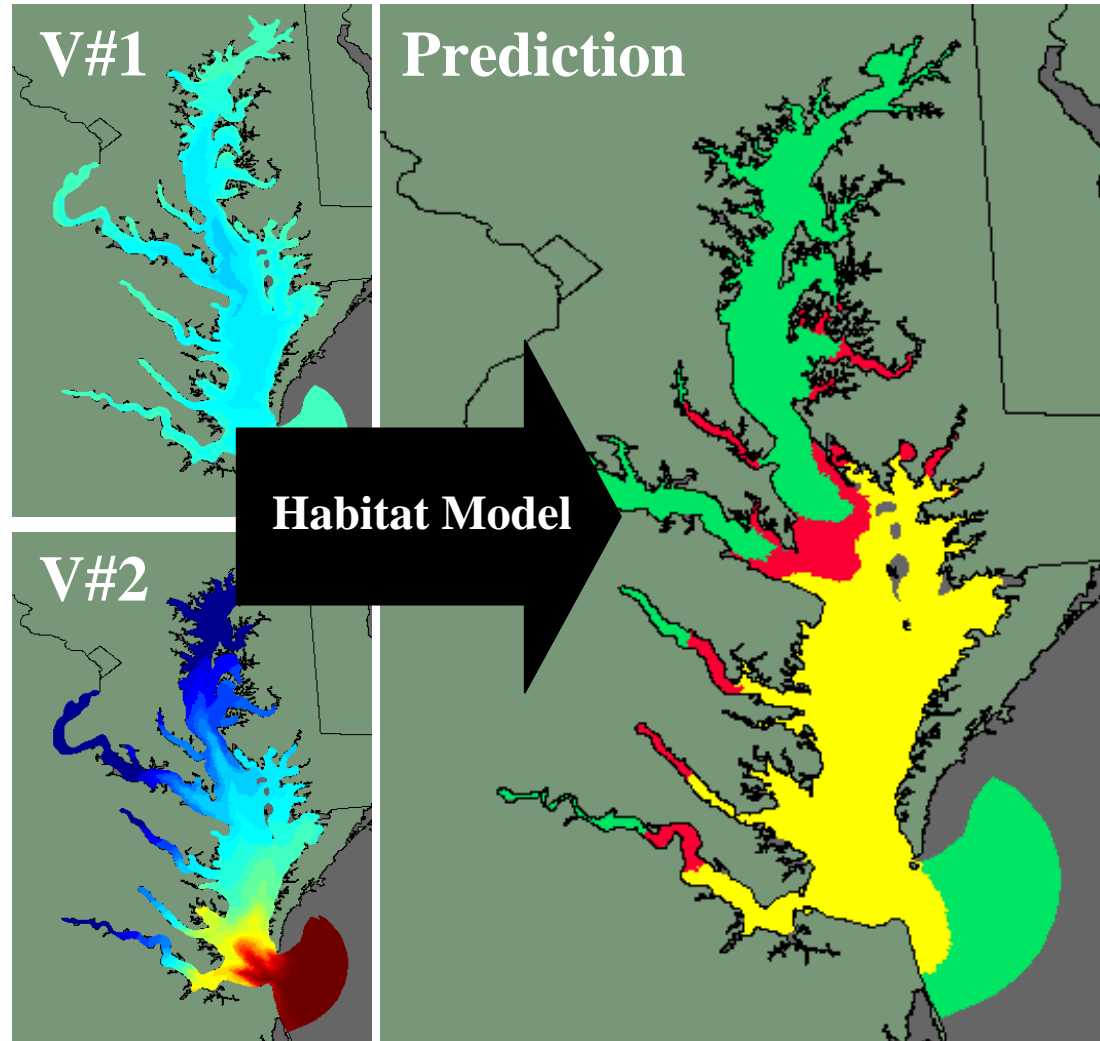
Predicted chance of encountering sea nettles, *C. quinquecirrha*, on August 17, 2007



Predicted relative abundance of *Karlodinium veneficum* on August 17, 2007

Statistical – Mechanistic Approach

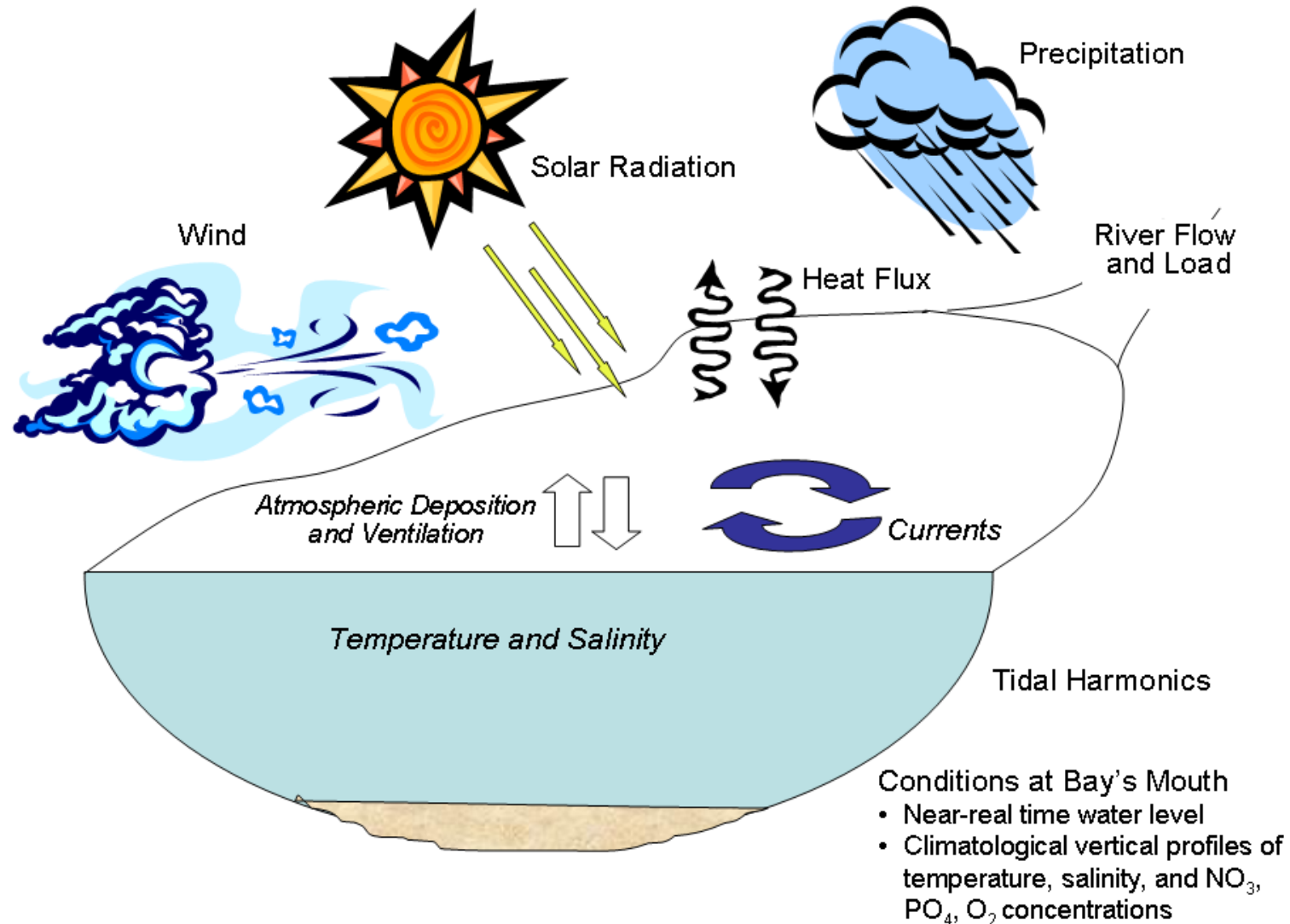
Using real-time and forecast data acquired and derived from a variety of sources and techniques to drive multi-variate empirical habitat models that predict the probability of the target species.

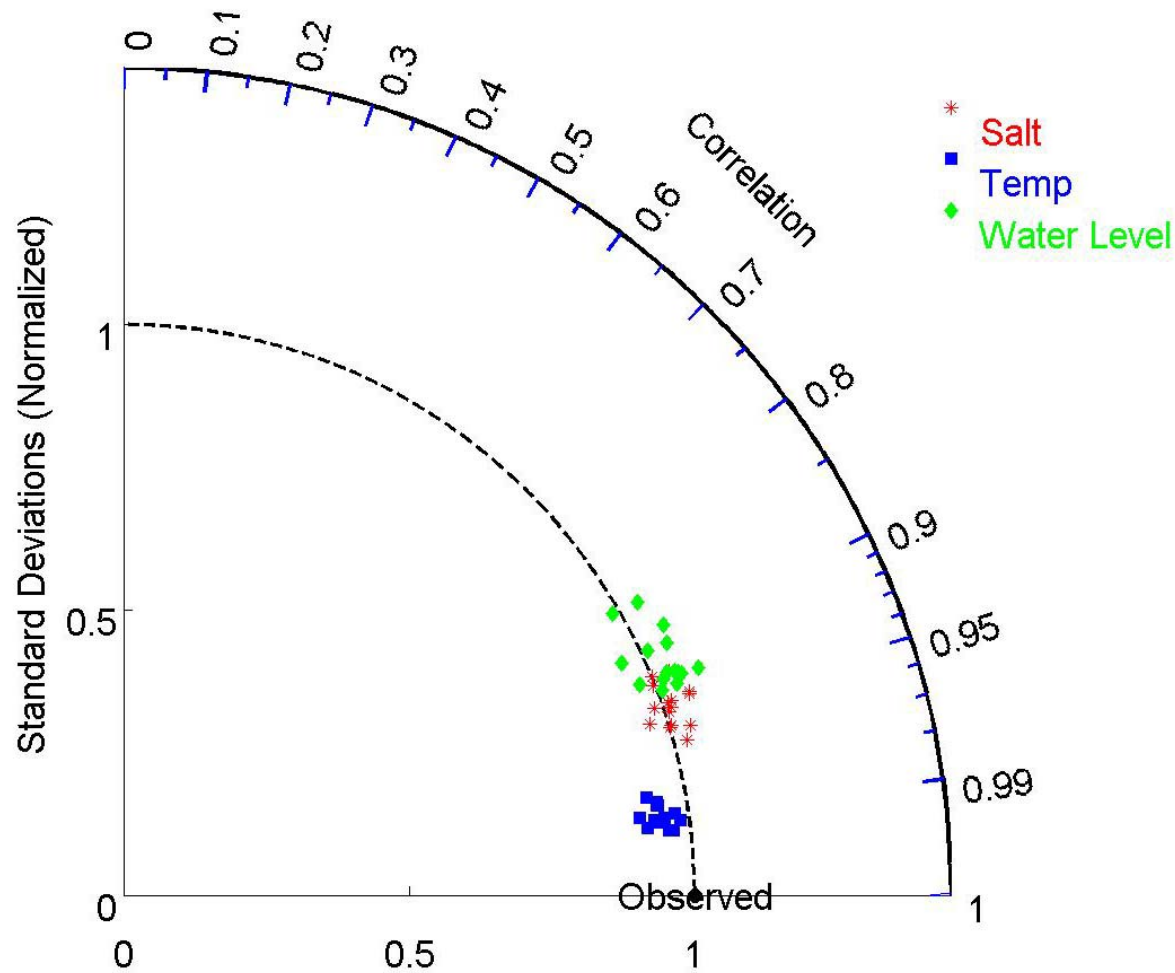


Issues With Empirical Approach

- Empirical models are specific for each location and population
- Development of empirical models require sufficient number of samples
- Species acclimate to environment, i.e. habitat model may change

Chesapeake Bay Regional Ocean Modeling System (ChesROMS)

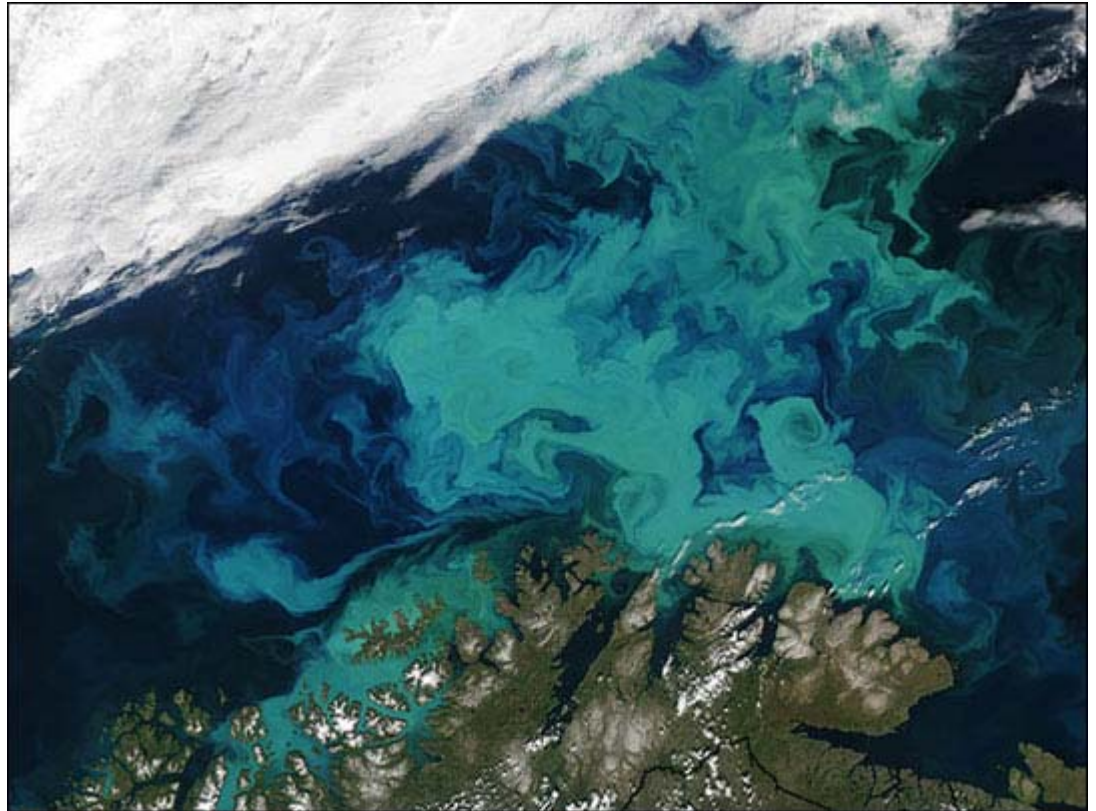




Taylor diagram of normalized standard deviations, correlations and RMSE of temperature (blue square), salinity (red star), water level (green diamond) for 1991-2005. Each points in one variable group corresponding to one year results.

Scientific Motivation for Study

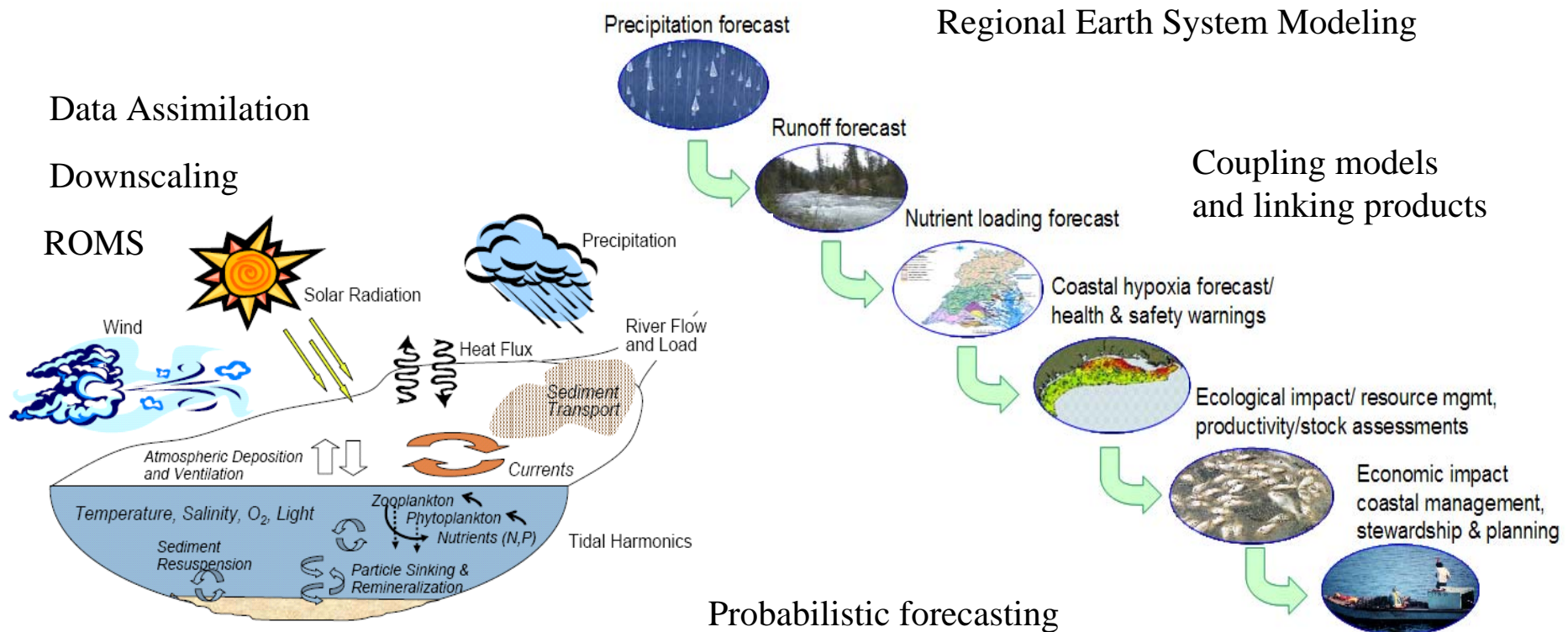
- Detect and predict distribution pattern of organisms that affect society, both beneficial and harmful
- Few existing methods work well and in near-real time



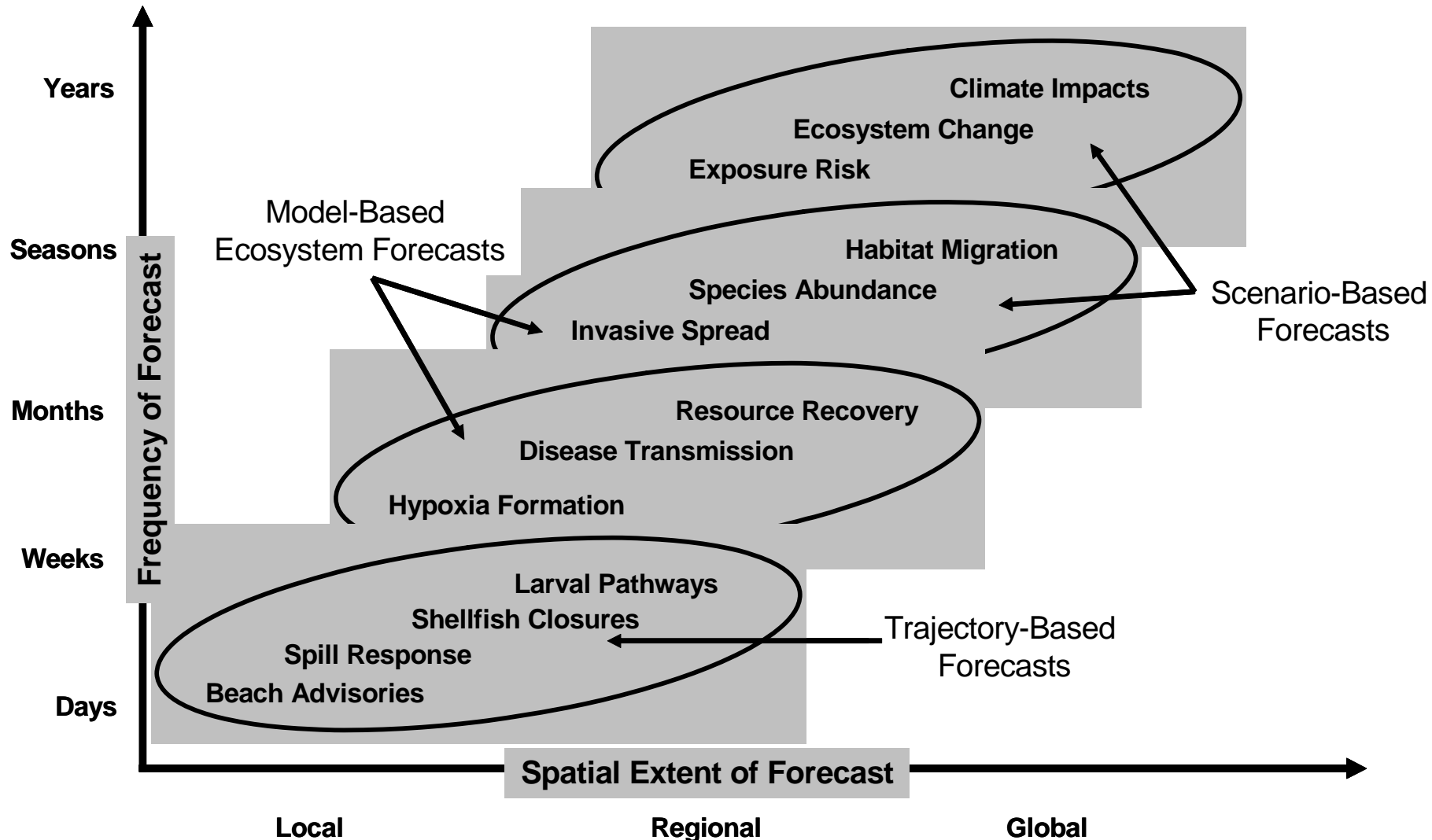
Bloom of the coccolithophorid *Emiliana huxleyi* in the Barents Sea in July 2003 in SeaWiFS imagery. *Image courtesy of NASA SeaWiFS Project and OrbImage.*

Ecological Forecasting

Predicting the effects of biological, chemical, physical, and human-induced changes on ecosystems and their components



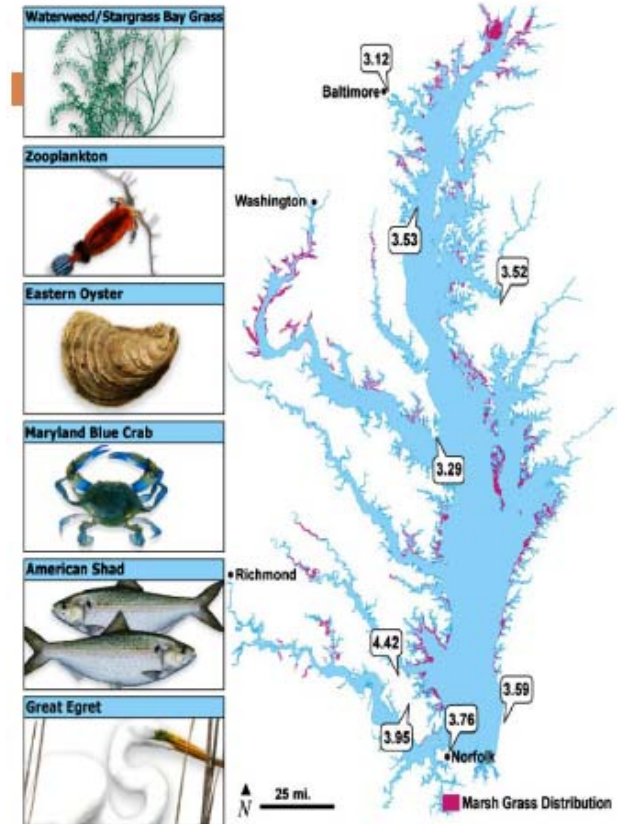
Building a “seamless suite” of model-based products and services over a backbone of existing infrastructure



Chesapeake Bay Prototype

Demonstrate:

- Regional collaboration (R2O)
- Dissemination of
 - Calendar-driven products
 - Near-real time applications
 - Climate projections
 - On-demand products/decision support tools



Biogeochemical and Ecological Forecasting

Prognostic State Variables:

- chlorophyll
- Nitrate
- Ammonium
- DON
- Oxygen
- Detritus
- Zooplankton

Biogeochemical/ecological forecasts

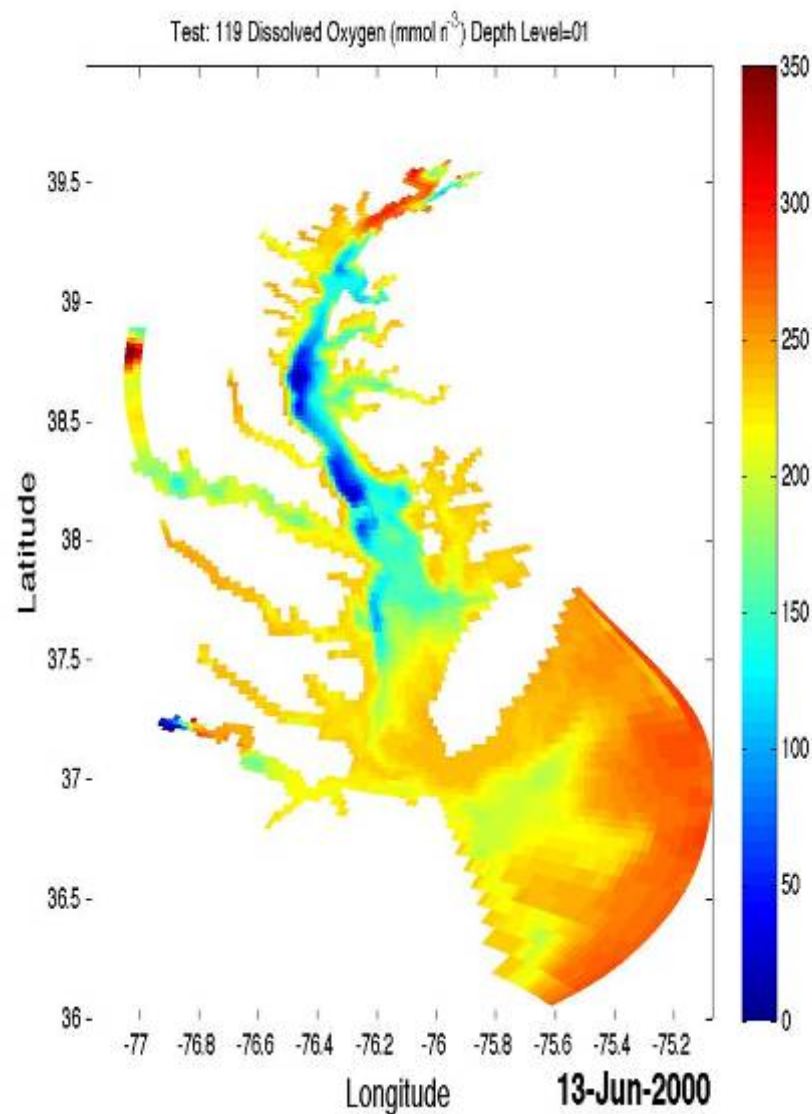
Additional forcing variables for
empirical habitat models



University of Maryland

CENTER FOR ENVIRONMENTAL SCIENCE

HORN POINT LABORATORY



ChesROMS modeled oxygen

The Need for High Performance Computing

- Our model development efforts (spin up, test and validation runs) are currently constrained by our computational resources
- Spin up, test and validation runs using CBOFS2 will require much higher performance computing capabilities
- Computational demand of running CBOFS2 operationally with a coupled biogeochemical/ecological forecasting model may also require HPC



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Microway 12 node (24 processor) cluster at Horn Point Laboratory currently used for ChesROMS spin up, test and validation runs

What do we need for a fisheries ecological forecasts in the Chesapeake?

- Operational backbone modeling suite to create forecasts of environmental variables
- Research and monitoring to provide data for developing and validating forecast models (statistical and process models to overlay on environmental variable forecast)
- Forecast office that works with regional management agencies and structure (e.g., Chesapeake Bay Program) to ensure utility of and support for forecast

