NOAA's Ecological Forecasting Roadmap: Current Activities and Climate Linkages

Allison Allen

NOAA Ecological Forecasting Roadmap Portfolio Manager
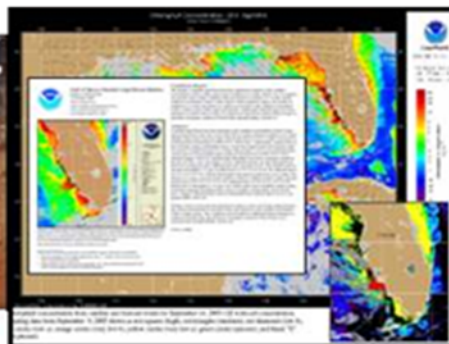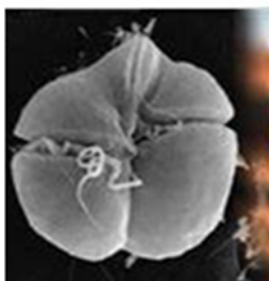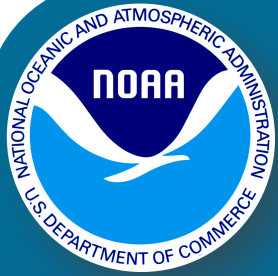
June 4, 2015

Princeton, NJ

Photo Credit: NOAA, WHOI, FWC FWRI, Charlotte (FL) Sun Herald

What Are Ecological Forecasts?

- Ecological forecasts predict likely changes in ecosystems in response to environmental drivers and resulting impacts to people, economies and communities.

- Ecological forecasts provide early warnings of the possible effects of ecosystem changes (e.g., harmful algal blooms, hypoxia, etc.) on coastal systems and human well-being with sufficient lead time to allow for corrective or mitigative actions.
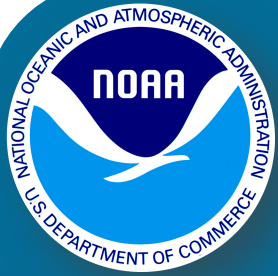
NOAA Ecological Forecasting Roadmap:
## Missions Supported

"Our job is to build an understanding of the Earth, the atmosphere, and the oceans to transform that understanding into critical environmental intelligence: timely, actionable information, developed from reliable and authoritative science, that gives us foresight about future conditions"

Dr. Kathy Sullivan
NOAA Administrator

WARNING MUSSELS CLAMS

Credit: NOAA

Legislation and Executive Mandates Pertinent to the Ecological Forecasting Roadmap

- NOAA Administrative Order 216-108 "Requirements Management"

- Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2014 (Public Law 113-124)

- Chesapeake Bay Executive Order

- The Coastal Zone Management Act

- Coral Reef Protection Executive Order/Coral Reef Conservation Act

- Magnuson-Stevens Fishery Conservation and Management Reauthorization Act

- Clean Water Act

- National Marine Sanctuaries Act

- Marine Mammal Protection Act
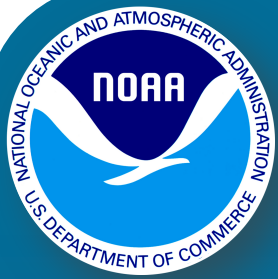
NOAA's Ecological Forecasting Roadmap: What we will achieve

- Strong science to enable delivery of forecasts

- Delivery of more products and services building on existing NOAA and partner capacity

- Delivery of more consistent, efficient, reliable, and national forecasts (tailored to region-specific needs)
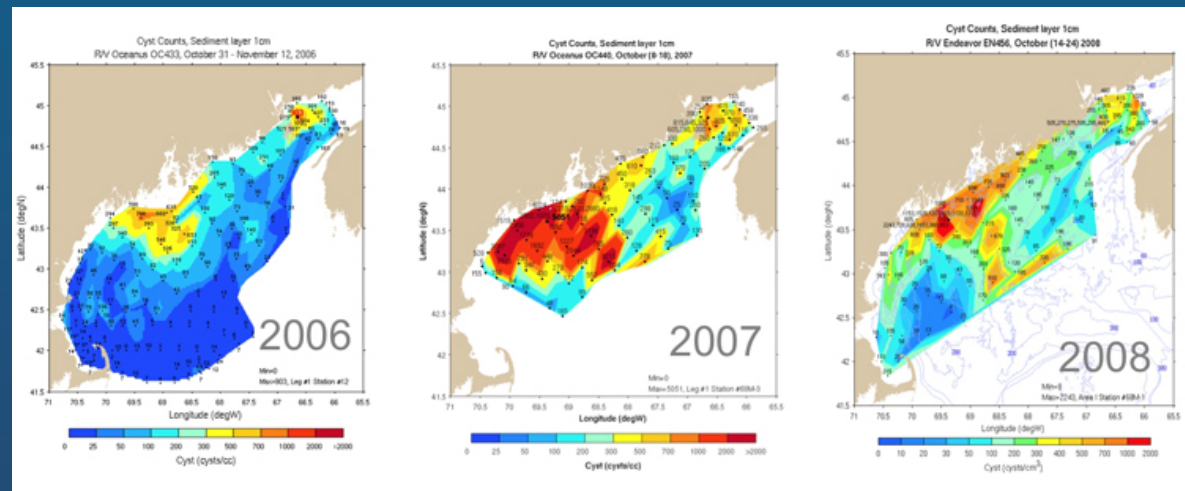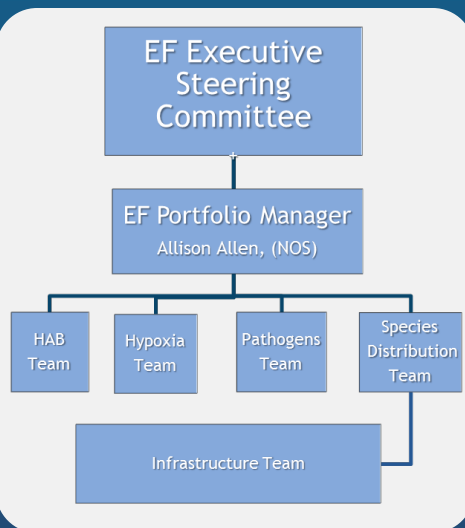
Ecoforecasting In Action: HABs

Toledo's water crisis

An algal toxin in Lake Erie contaminated the drinking water used by Toledo and many of its suburbs in August, 2014. It prompted a "do not drink" advisory for parts of three days and fueled public discussions about what created the problem and how to prevent it from happening again.

Saturday, Aug. 2: City issues 'do not drink' water advisory

Over a half million people impacted by "Do Not Drink Advisories" in Northwest Ohio and Southeast Michigan.
(August 1-3, 2014)
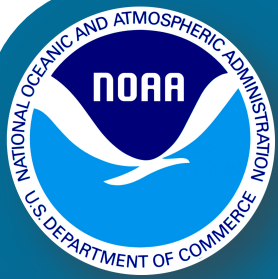
Harmful Algal Blooms in the U.S.

Cyanobacteria *(Microscystis)*

Paralytic Shellfish Poisoning *(Alexandrium)*

Amnesic Shellfish Poisoning *(Pseudo-nitzschia)*

Neurotoxic Shellfish Poisoning *(Karenia brevis)*

Hawaii

Alaska

Puerto Rico

ASP	
CFP	
DSP	
NSP	
PSP	
Brown tide	
CyanoHABs	
Golden alga	
Karlodinium	
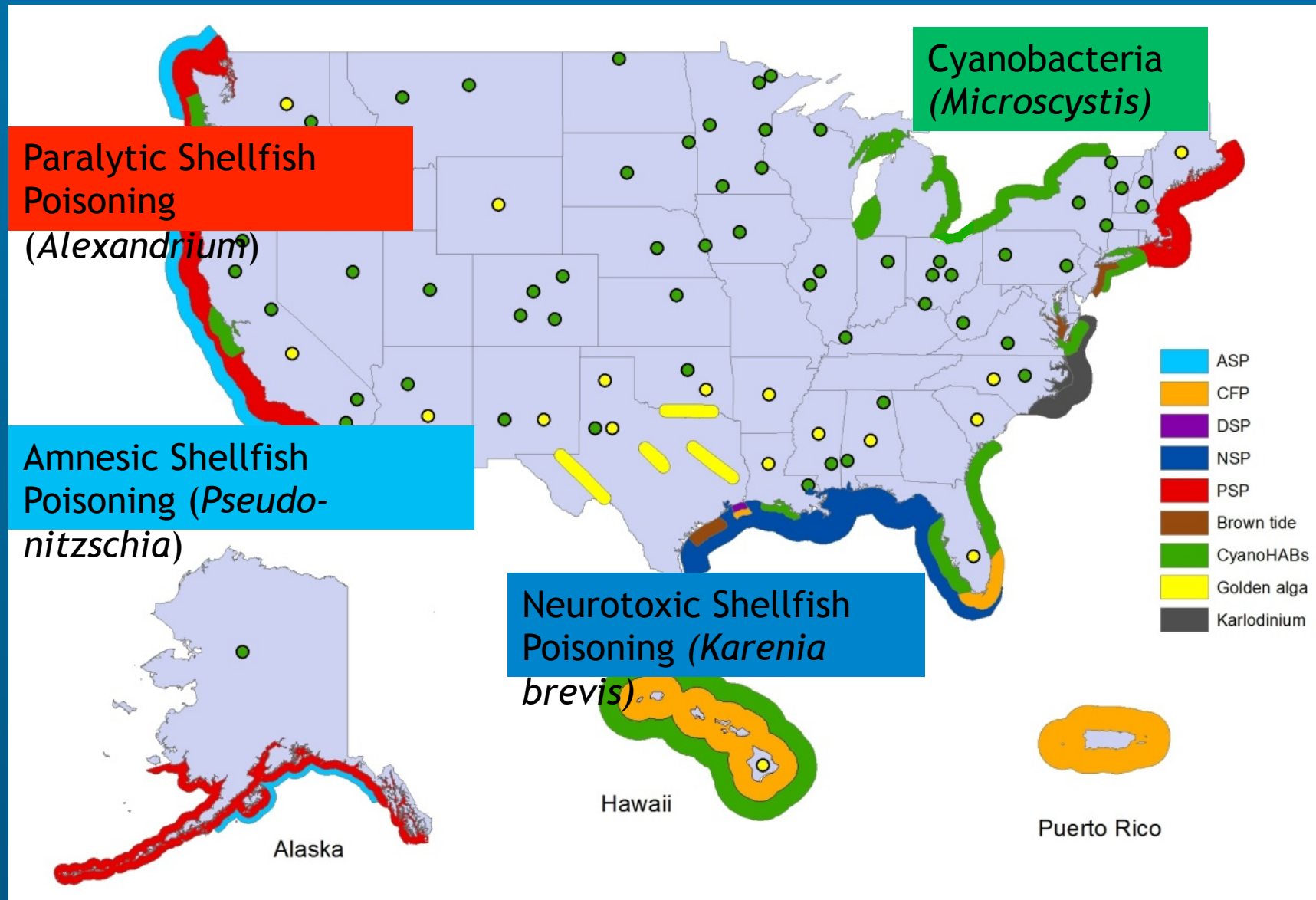
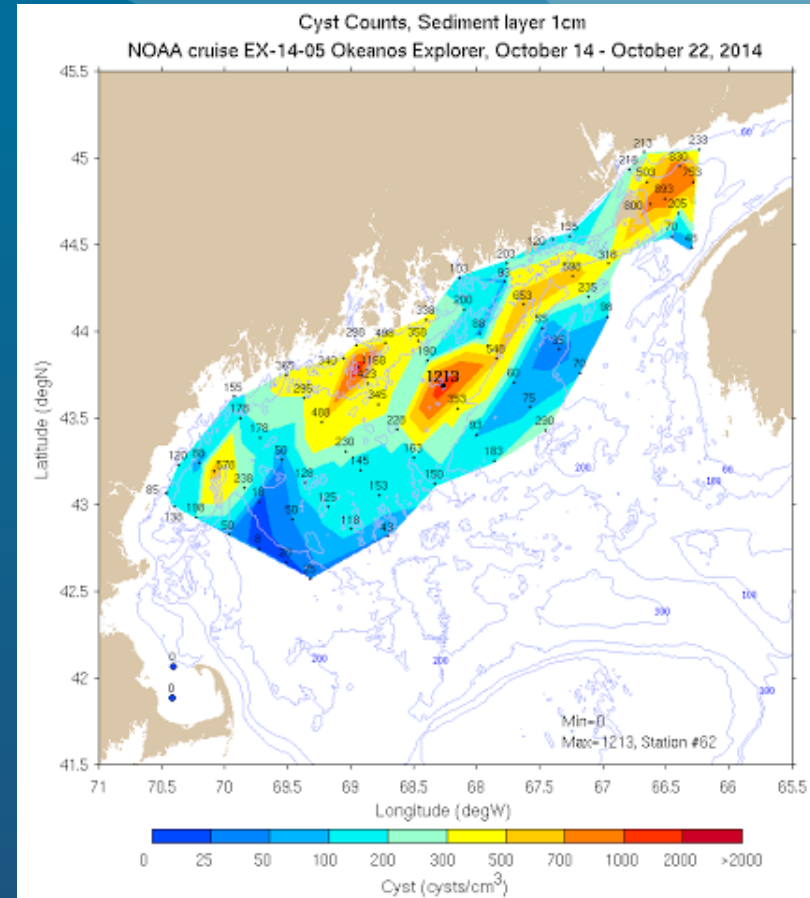Economic cost of HABs over the last decade is conservatively ~$1billion.
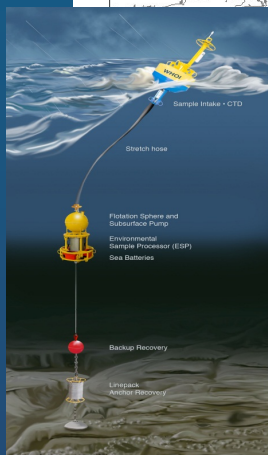
Status of a National HAB Forecast System
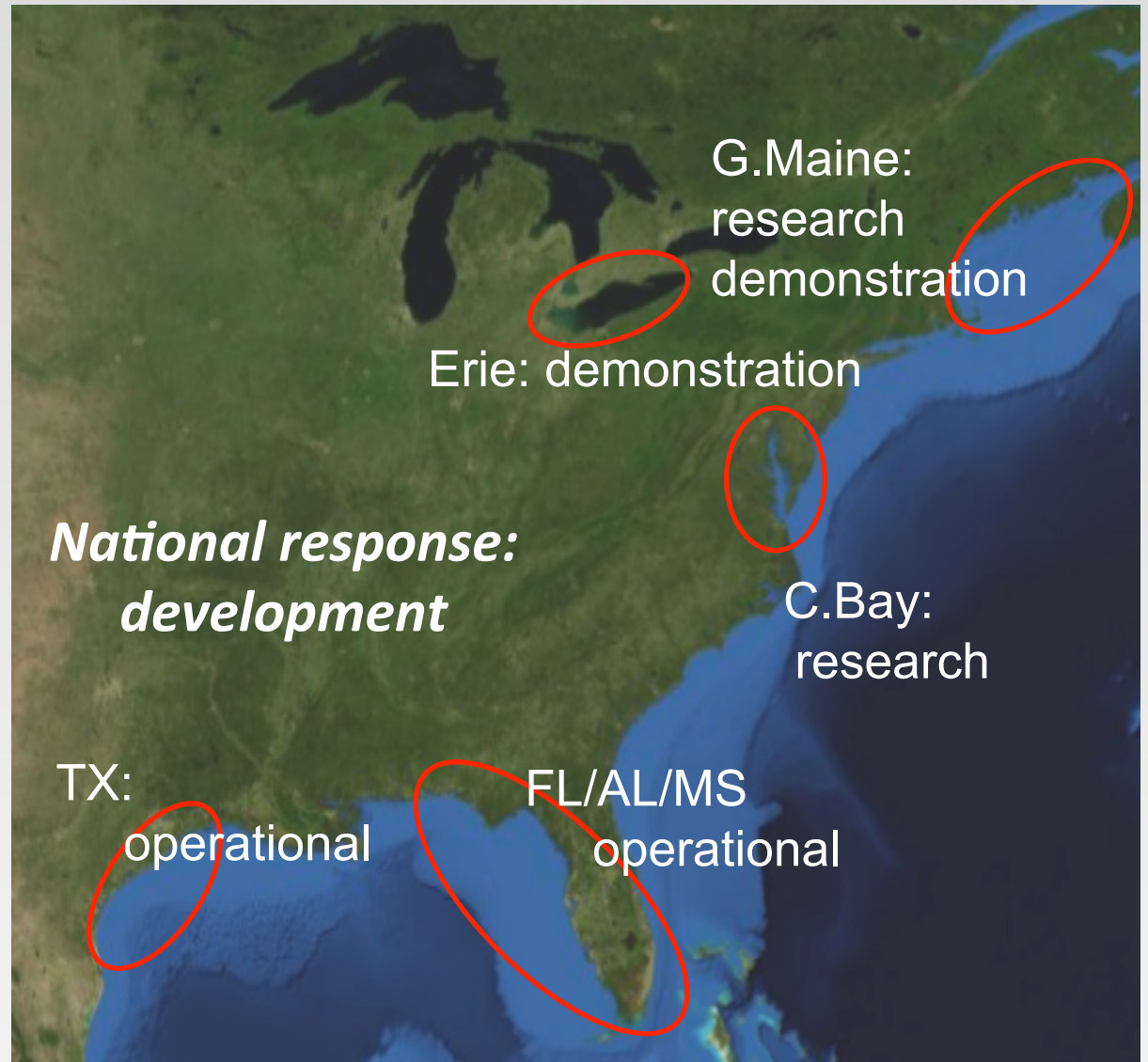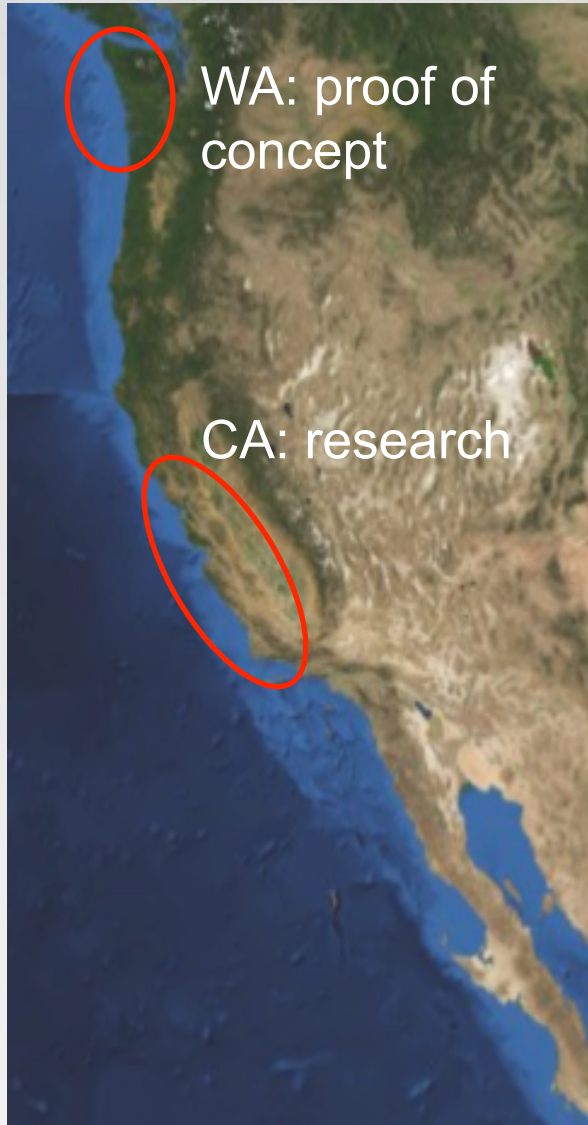
Gulf of Maine Seasonal HAB Forecast

Forecast: New England's spring and summer red tides will be similar in extent to those of the past three years.

Surface Wind Stress and Modeled A. Fundyense Bloom

12 May-27-2015
max cell #: 195

Cyst Counts, Sediment layer 1cm
NOAA cruise EX-14-05 Okeanos Explorer, October 14 - October 22, 2014

Min=0
Max=1213, Station #62

Cyst (cysts/cm^3)
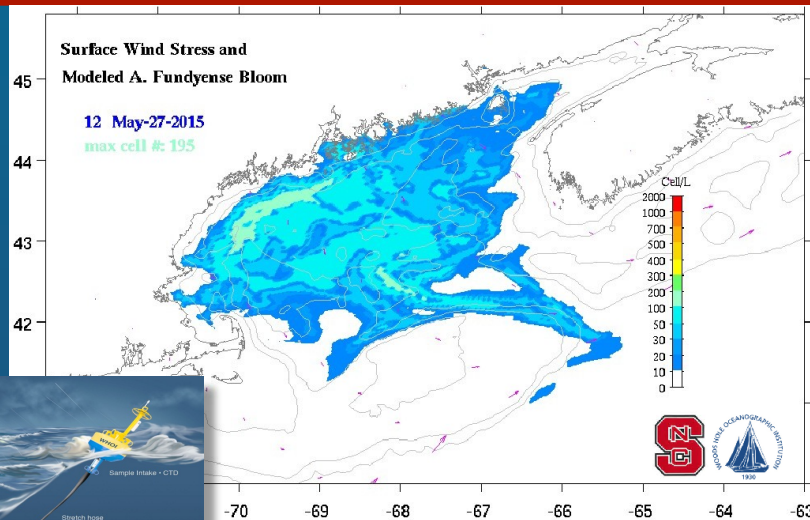
"This partnership on the Gulf of Maine seasonal HAB forecast and use of ESPs to detect toxic red tide offshore are examples of NOAA's role in improving ecological forecasting capabilities along our coasts,"
-Holly Bamford, Ph.D., Acting Assistant Secretary of Commerce for Conservation and Management

Lake Erie HAB Bulletin, 29 Aug 2014

Created since 2009 from Satellite Data + Current Models
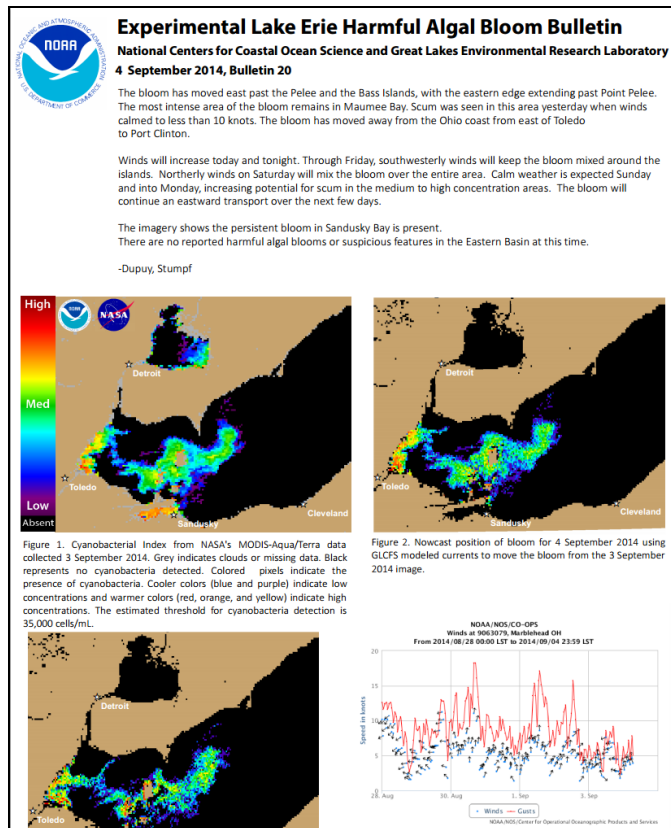
>1100 email subscribers plus many who access web version only
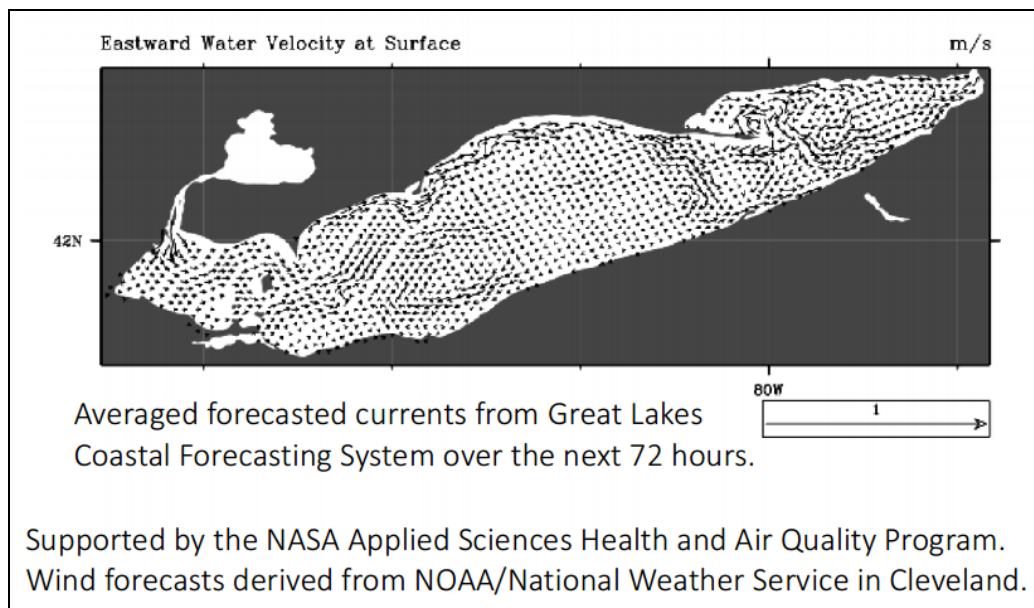
…also ground-truth sampling and toxin testing

Daily nutrient load data into Lake Erie

2014 forecast

Merged NOAA-U.Toledo severity index

Bloom Severity

significant

mild

forecast

range of models

2014 Ensemble Includes U.Michigan trial model

Lake Erie Harmful Algal Bloom Early Season Projection

NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE AND THE NATIONAL CENTER FOR WATER QUALITY RESEARCH
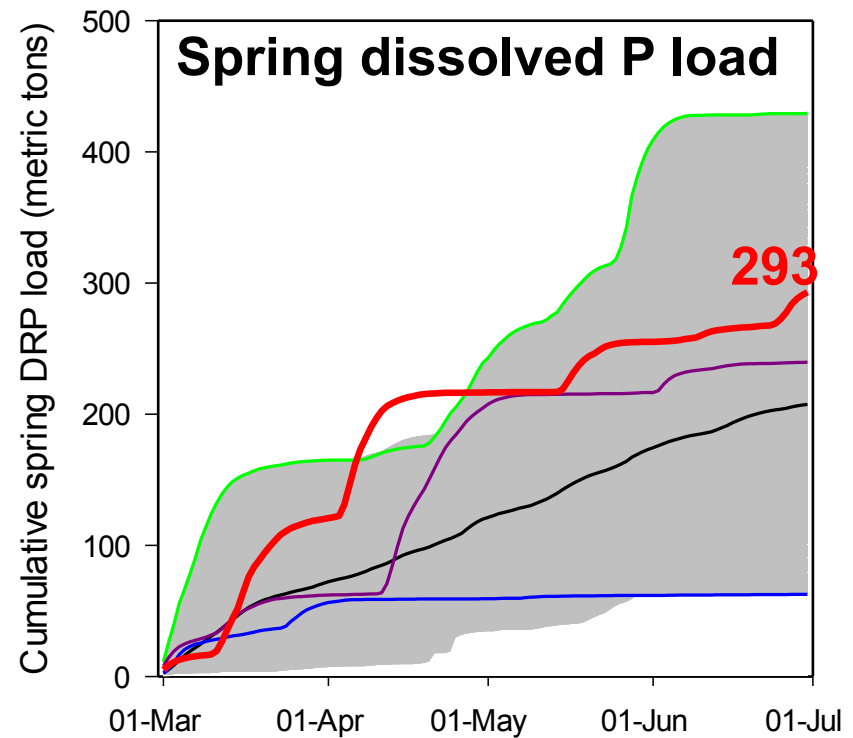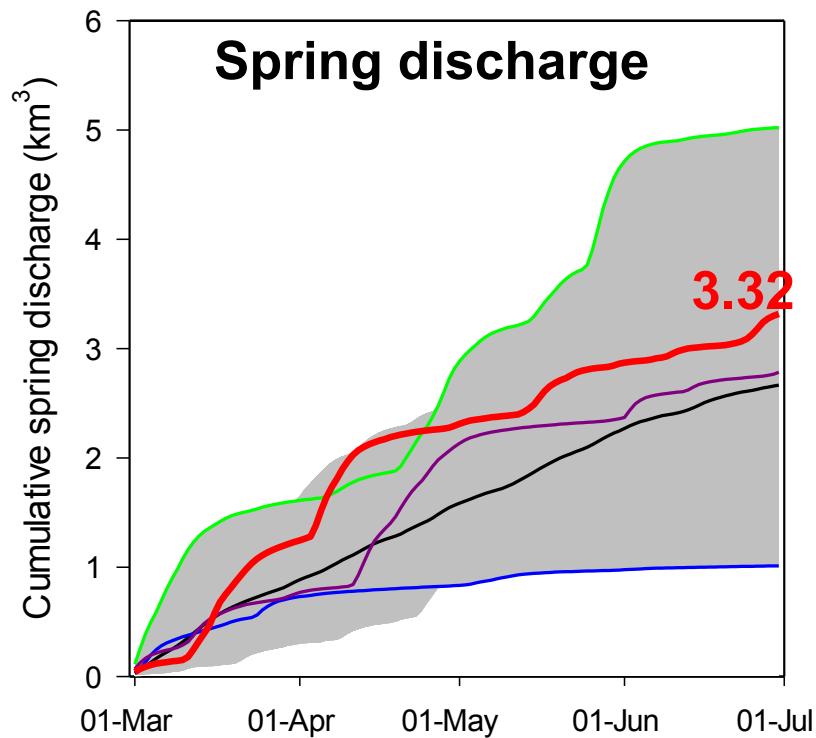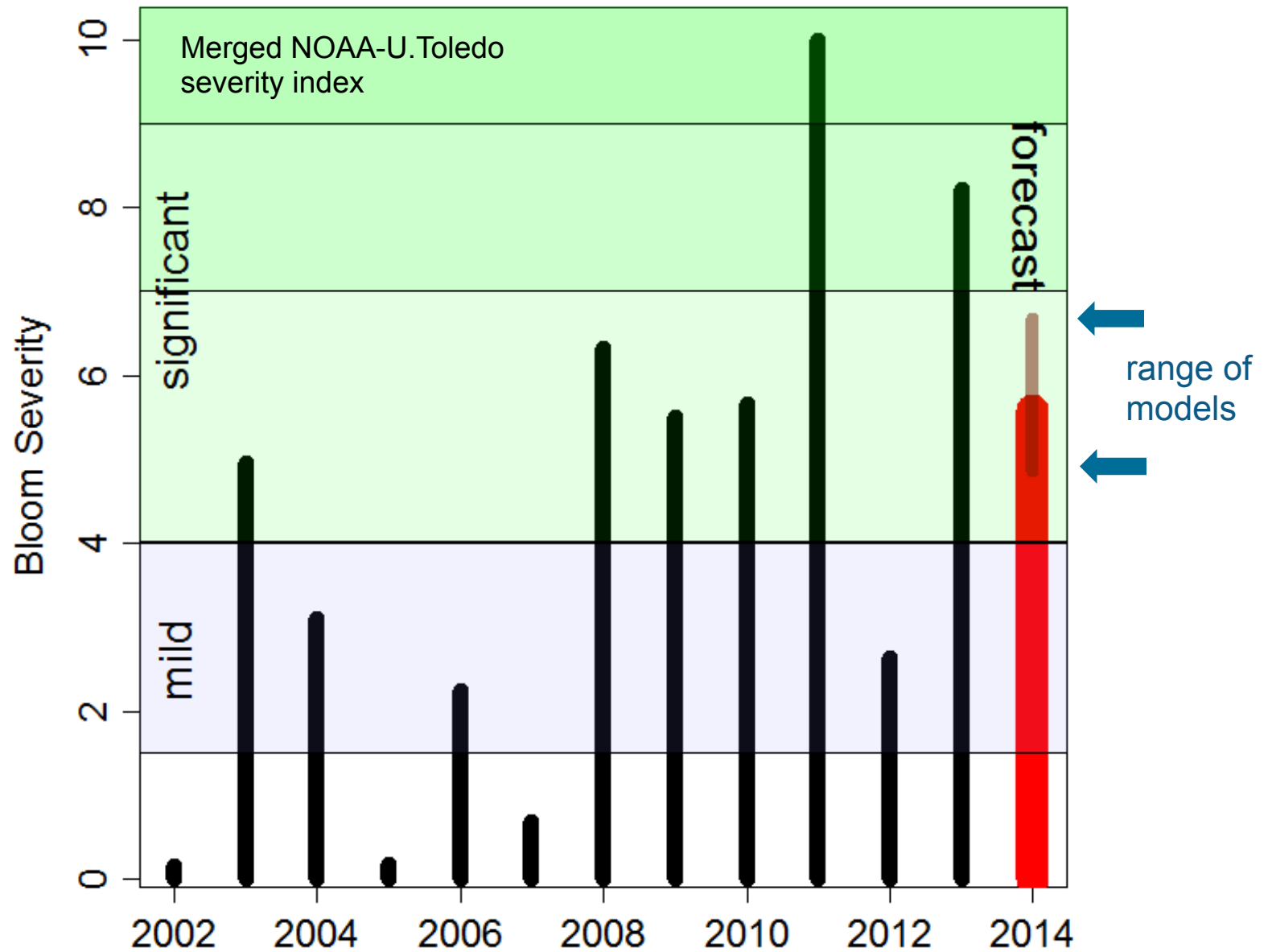3 June 2015, Projection 03

The severity of the western Lake Erie cyanobacterial harmful algal bloom (HAB) is dependent on phosphorus inputs from March 1st through July 31st, henceforth the loading season. This new product projects the bloom severity based on the combination of current measurements of phosphorus loading from the Maumee River for the season to date with historical records from past years to estimate the remainder of the loading season.

Based on data from March 1 to this week, the extensive severe blooms observed in 2011 and 2013 are not projected to occur this year. So far, this spring has been relatively dry, resulting in less discharge and lower phosphorus loads into the western basin. Heavy rains on May 31 have caused relatively small adjustments in the projection based on the NOAA River Forecast Center projection through June 6. The range of uncertainty continues to decrease.

The uncertainty will decrease over time as the loading season progresses.

This experimental product involves the Maumee River phosphorus load data from Heidelberg University's National Center for Water Quality Research and the western Lake Erie bloom severity models by NOAA's National Center for Coastal Ocean Science.

The downward trend reflects relatively low load from the Maumee River so far.
For more information visit: http://www.heidelberg.edu/academiclife/distinctive/ncwqr/ or http://coastalscience.noaa.gov/research/habs/forecasting/
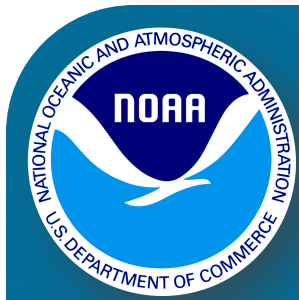
"Based on data from March 1 to this week, the extensive severe blooms observed in 2011 and 2013 are not projected to occur this year. So far, this spring has been relatively dry, resulting in less discharge and lower phosphorus loads into the western basin. Heavy rains on May 31 have caused relatively small adjustments in the projection based on the NOAA River Forecast Center projection through June 6. The range of uncertainty continues to decrease."

HAB National Strategy

- Vision – national operational forecast network
  - Within 5 years:
    - operational forecasts in Gulf of Maine, Gulf of Mexico (FL, TX), Chesapeake Bay, Lake Erie, PNW, California;
    - Progress towards establishing operational systems in NY (Long Island Sound), Alaska, Caribbean, other regions
    - Capacity for National Forecast and Early Warning for Event Response to HABs (FEWER HABs)
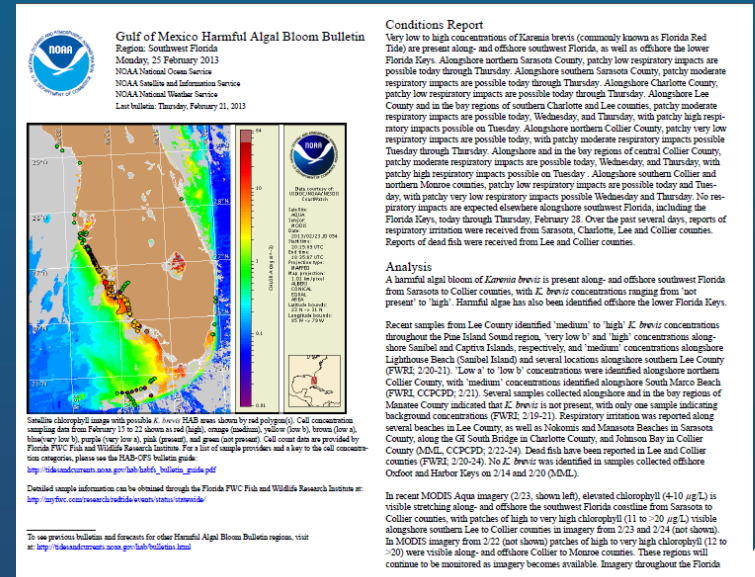
Valerie Davidson
Commissioner
P.O. Box 110601
Juneau, AK 99811-0601
dhss.alaska.gov

SEAL OF THE ST... OF ALASKA

STATE OF ALASKA
DEPARTMENT OF
HEALTH AND SOCIAL SERVICES

Press Release

COMMISSIONER'S OFFICE

FOR IMMEDIATE RELEASE: May 1, 2015

State cautions against eating recreationally harvested shellfish from Alaska beaches

Confirmed case of paralytic shellfish poisoning near Ketchikan is reminder of danger

ANCHORAGE ─ A confirmed case of paralytic shellfish poisoning last week has prompted epidemiologists with the Alaska Department of Health and Social Services to remind Alaskans and visitors about the risk of paralytic shellfish poisoning, or PSP, when consuming recreationally harvested Alaska shellfish. All shellfish─ including clams, mussels, oysters, geoducks and scallops ─ can contain paralytic shellfish poison. Crabmeat is not known to contain the PSP toxin, but crab guts can contain unsafe levels of toxin and should be discarded. Commercially harvested shellfish are tested and considered safe.

Although clam diggers often look for signs of a "red tide," there is no way to tell if a beach is safe for harvesting simply by looking at it. The toxins that cause PSP can be present in large amounts in shellfish even if the water looks clear and no algae bloom is present. Additionally, PSP cannot be cooked, cleaned or frozen out of shellfish.

HAB Operational Forecast System Concept: National Capability, Regional Implementation

Inputs

- Ocean Color, HF Radar
- Public Health Data, In Situ Observations
- Hydrodynamic Models
- Met Forecasts (Winds)
- Biological Models
- Climate Predictions

Analysis & Interactive GIS Portal

- Web Services, Web Mapping Services
- Can ingest all formats (ASCII, GRIB2, netCDF, etc)
- Export mapping tools for multiple formats (.shp, .kml, .geotiff, etc)

Output Products

- Regionally Specific Operational Products
- Web Updates
- Skill Assessments
- Research and experimental products

Continuing Research to Refine Integration

SOP's, Expert System Rules

What are Dead (Hypoxic) Zones?

Coastal waters with unusually low dissolved oxygen that can kill fish and destroy critical habitat

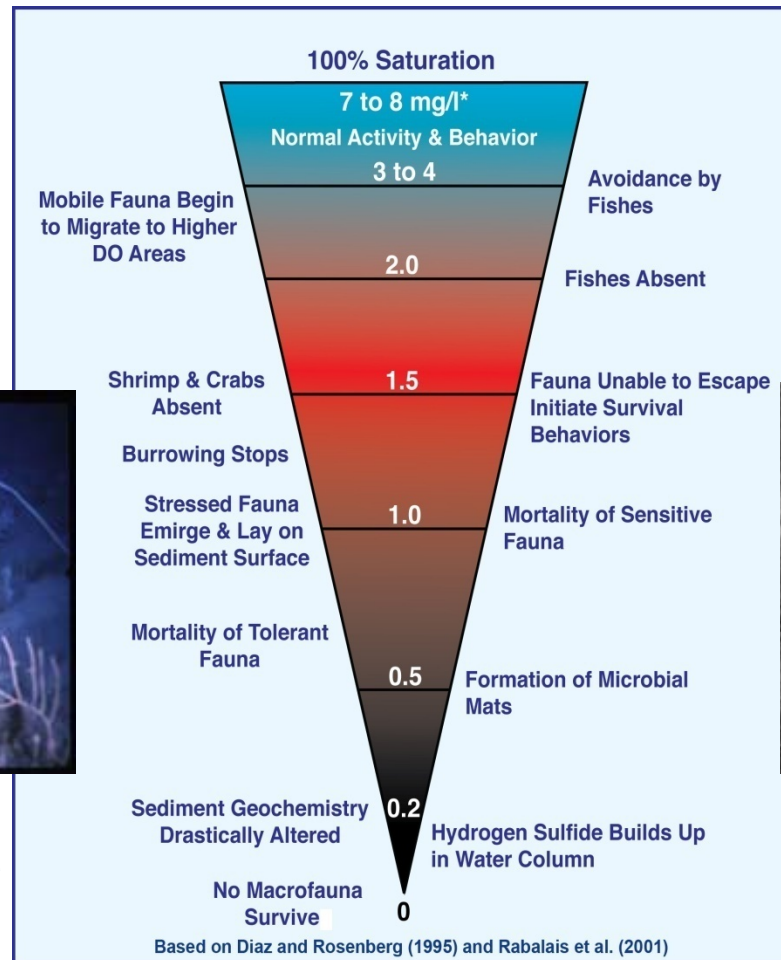**Hood Canal, WA**

Corsica R., MD

100% Saturation
7 to 8 mg/l*
Normal Activity & Behavior

3 to 4 — Avoidance by Fishes

Mobile Fauna Begin to Migrate to Higher DO Areas

2.0 — Fishes Absent

Shrimp & Crabs Absent

1.5 — Fauna Unable to Escape Initiate Survival Behaviors

Burrowing Stops

Stressed Fauna Emirge & Lay on Sediment Surface

1.0 — Mortality of Sensitive Fauna

Mortality of Tolerant Fauna

0.5 — Formation of Microbial Mats

Sediment Geochemistry Drastically Altered

0.2 — Hydrogen Sulfide Builds Up in Water Column

No Macrofauna Survive

0

Based on Diaz and Rosenberg (1995) and Rabalais et al. (2001)

Healthy bottom community - habitat and food for fish

Dead Zone – most higher forms of life absent

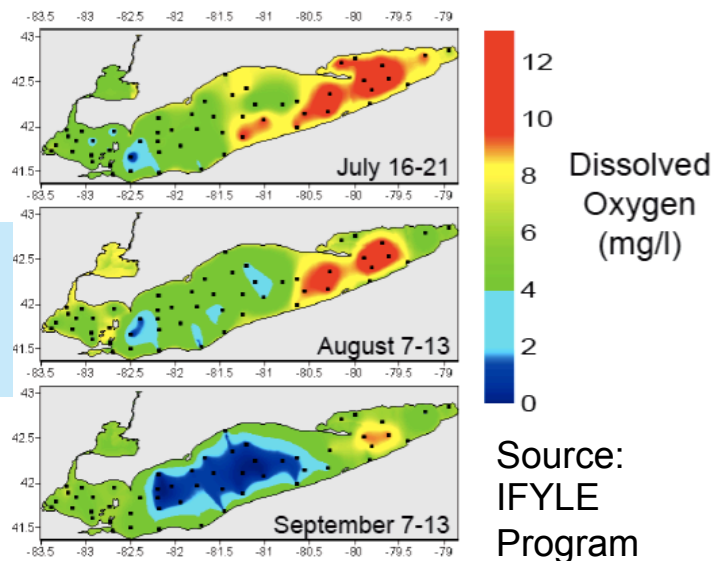Source: by Rochelle Seitz, VIMS

Three Largest Hypoxic Zones in US

Gulf of Mexico
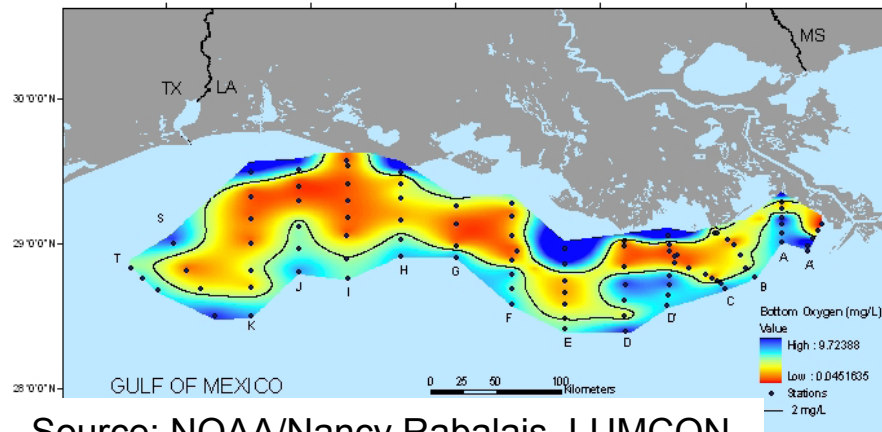
Source: NOAA/Nancy Rabalais, LUMCON

Chesapeake Bay

Mean Summer Bottom DO - 2006

Source: Chesapeake Bay Monitoring Program

Lake Erie

Source: IFYLE Program
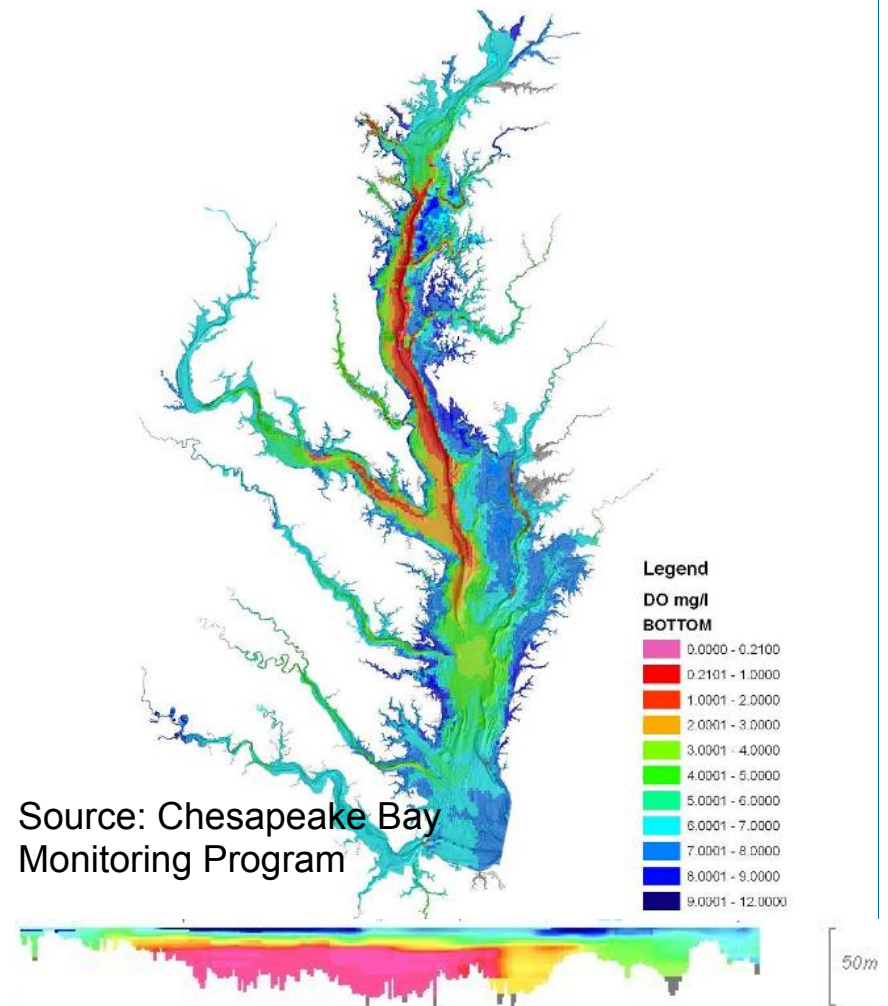
Hypoxia Forecasting Next Steps

Transition experimental Hypoxia forecasting *(e.g. Finite Volume Coastal Ocean Model + Texas A&M Hypoxia Module)*

Implement Gulf of Mexico Hypoxia Monitoring Plan – new technology

Link monthly/seasonal hydrology and precipitation forecasts to hypoxia models

Explore concept of operations for scenario forecasting
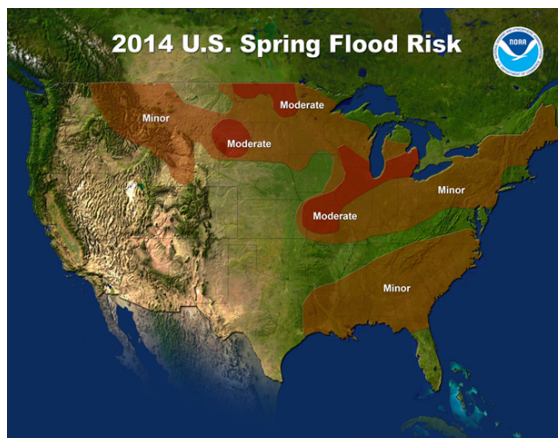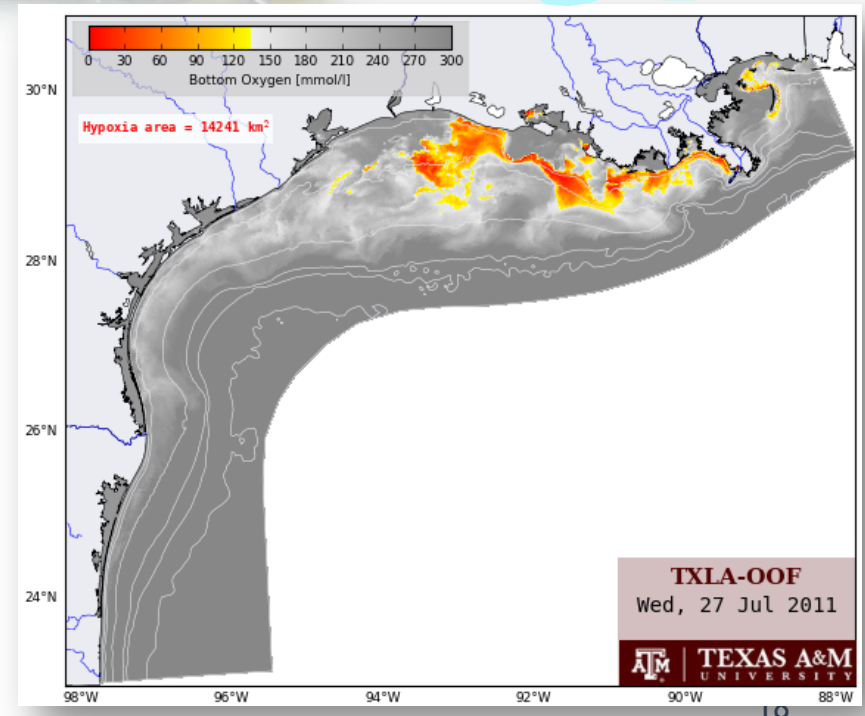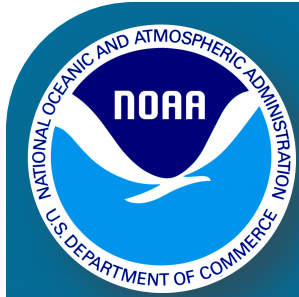
Vibrio

Vibrio cholerae

Vibrio parahaemolyticus (Vp)
Vibrio vulnificus (Vv)

- Naturally occurring bacteria in coastal waters

- *Vv* responsible for 95% of all seafood related mortality

- *Vp* estimated at 80,000 cases per year

- Over $300 million annually in health care costs alone.

Vibrio Risk Prompts Oyster Recalls, Bed Closures Far North Of The Gulf Of Mexico

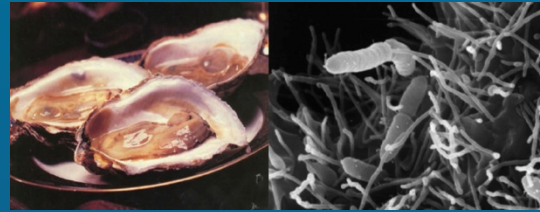The Huffington Post | By Joe Satran | Posted: 09/03/2013 5:00 pm EDT | Updated: 09/03/2013 5:57 pm EDT

For Immediate Release - August 30, 2013

Department of Public Health and Division of Marine Fisheries Announce Closure of Oyster Beds in Plymouth, Kingston, Duxbury, And Marshfield

Several cases of Vibrio linked to consumption of oysters harvested from the area

FOOD RECALL ADVISORY: Norwalk/Westport Area Shellfish Bed Closures Due to Vibrio
...dborne Illnesses; Recall of Clams and Oysters

Food Recall Advisory

...isory: On August 3, 2013 The Department of Agriculture Bureau of Aquaculture (DA/BA) has ...luntary closure of shellfish beds in the Norwalk Westport area due to a number of illnesses ...arahaemolyticus, a naturally occurring bacterium associated with shellfish harvested from ...areas. The closure affects commercial areas in Norwalk and Westport and recreational ...Westport, and Darien. Oysters and clams harvested from these areas between 7/3/13 and ...called.

Food Safety News
Breaking news for everyone's consumption

Home | Foodborne Illness Outbreaks | Food Recalls | Food Politics | Even...

Vibrio Closes Some Oyster Beds in Washington

BY NEWS DESK | SEPTEMBER 8, 2011

Several people who ate raw oysters from Washington state's Samish Bay and Hood C...
from Vibrio parahaemolyticus bacteria.

PLYMOUTH

Oyster bed closures leave aquaculturists reeling

By Emily Sweeney | GLOBE STAFF   SEPTEMBER 19, 2013

Shellfish bed closures raise climate change questions

By Jan Ellen Spiegel
Monday, August 5, 2013
Email Follow @janellens

2 Comments

BAY JOURNAL

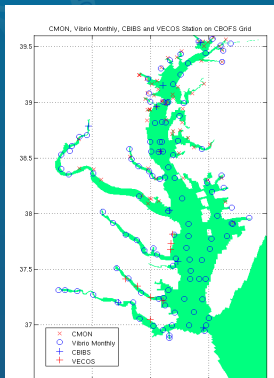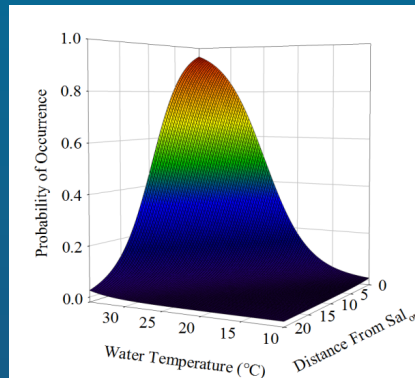**Health officials struggle with how to react to Vibrio cases**

Publicizing serious-yet very rare-infection could cause a panic and hurt tourism

Approach

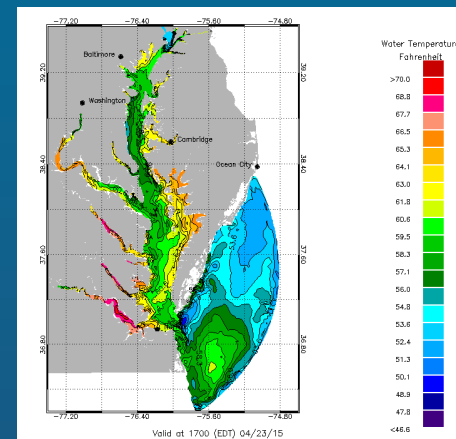Environmental Observations…

..to develop and assess statistical models….

..driven with existing OFS model output…

Or…

Existing algorithms

Probability(%) of Vibrio vulnificus in the Chesapeake Bay
CBOFS Model Run:20130709/0000 Daily Forecast for:20130709
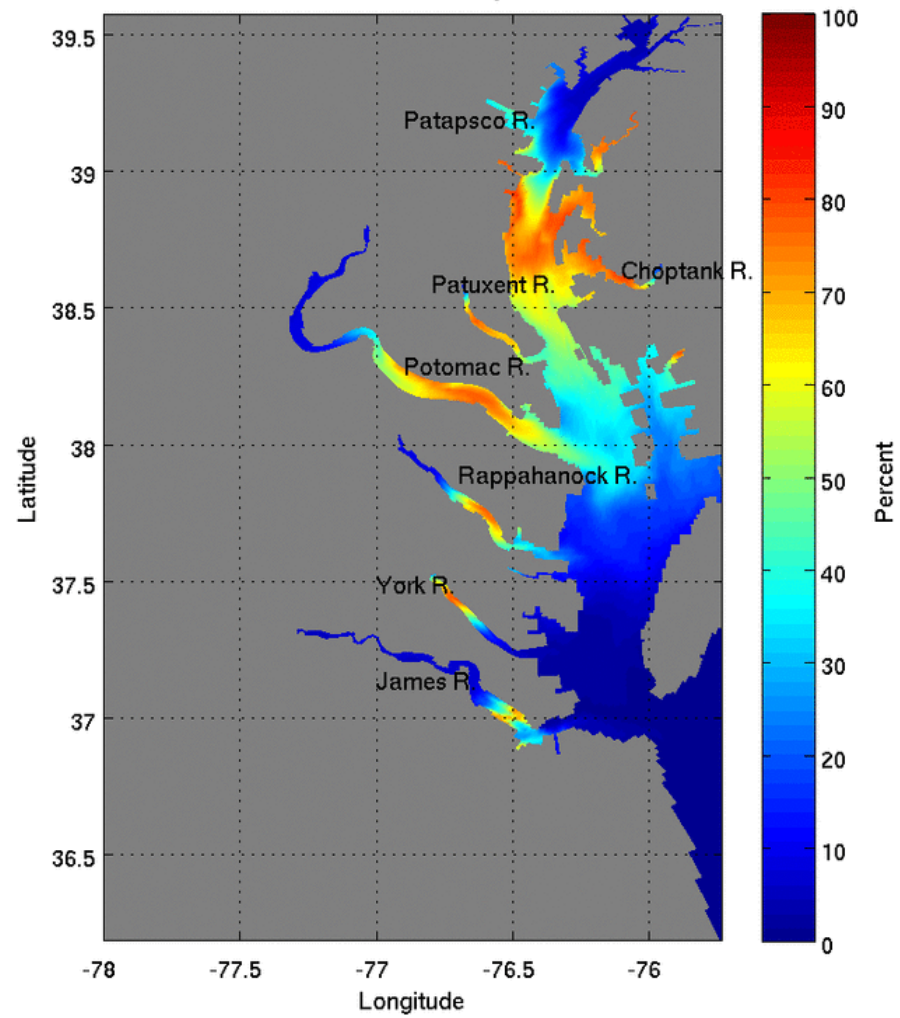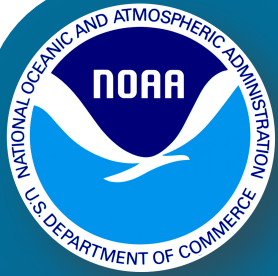
FY 15 Pilot Project

- **Key Targets of FY15 Project**

  - *Towards an operational forecast for Chesapeake Bay*

    - Publish concept of operations for *Vibrio vulnificus* (Vv) model in Chesapeake Bay

    - Complete model skill assessment for Chesapeake Bay occurrence of *Vv* in water

  - *Supporting FDA and the shellfish industry*

    - Finalize development of specific guidance models with FDA

    - Make operational a webpage of Vibrio guidance and weather tools for shellfish harvesters and regulators

  - *Assessing user needs and requirements*

    - *Stakeholder workshops for Puget Sound and Mid-Atlantic*
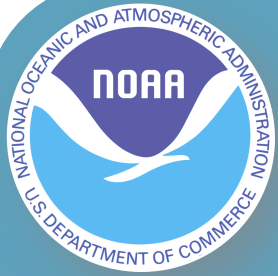
Why Produce Ecoforecast for Habitat & Species Distributions?

I. Identify priority habitat restoration areas based on higher probability of success (e.g., resiliency)

II. Forecast and understand species responses to climatic changes (e.g. increased water temps; changes in salinities)

III. Forecast gain/losses in ecosystem services provided by habitat and animals (e.g., coastal protection)

IV. Forecast ecological hotspots for protected species

V. Define & evaluate survey design (e.g., adaptive sampling)

Habitat Science and EcoForecasting

- Purpose: To understand & forecast how changes in benthic & water column habitats impact species' distribution & abundance.

- Requires focused efforts on scenario-based forecasting across multiple spatial & temporal scales due to the magnitude & complexity of habitat modifications.

- Utilize NOAA investments in computational capacity to develop models and to store and deliver results.
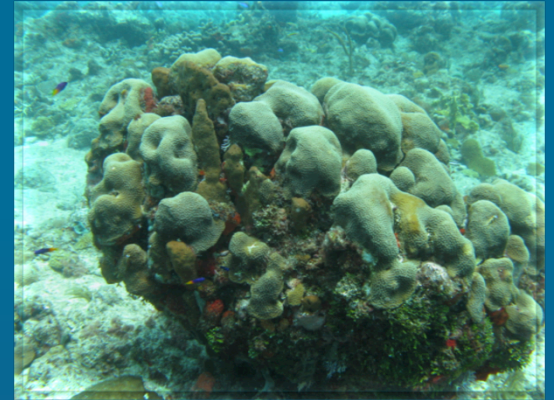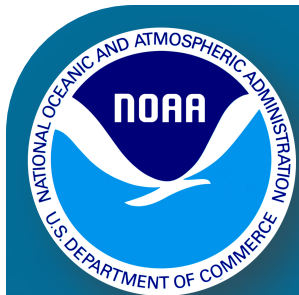
Statistical Downscaling and Coastal Environments

- Estuaries and nearshore coastal environments are closely linked to climate variability
  - Potential for strong response to climate change

- Global climate models are too coarse to resolve local dynamics, so must be downscaled to the area of interest
  - Statistical downscaling: relies on present-day relationships between regional and local-scale processes

- Procedure:
  1. Locate long-term, historical *in situ* time series
  2. Extract global climate model historical and future projections for same location
  3. Use regression, quantile mapping or other mathematical techniques to replicate past variability
  4. Apply to future projections

GFDL CM2.1 Global Climate Model

Saba et al.

Bottom ocean temperature change (°C)
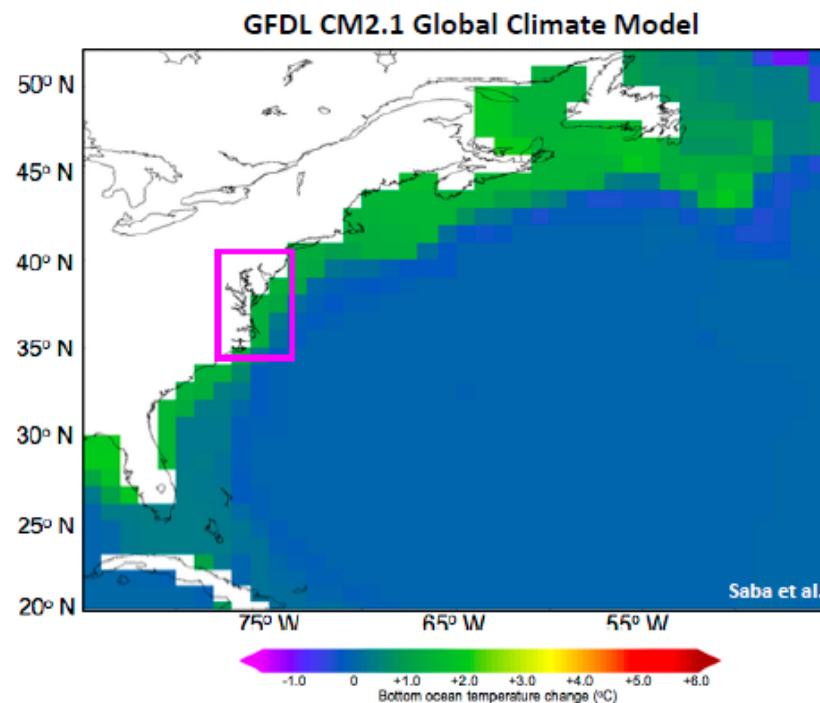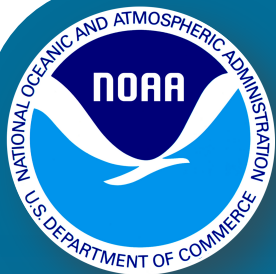
Wide Range of Space and Time Scales, Linked to Different NOAA Information Needs

MANAGEMENT INFORMATION NEEDS:

Operations; Response; Impact-avoidance

In-season regulations Adaptive management

Management Design & Review Processes

National policy & legislation

Global policy and change

SPACE SCALE

Global — 10^4 km
Basin — 10^3 km
Region — 10^2 km
Local — 10 km — 1 km
Site — 0.1 km

IPCC climate scenario-driven models

Coral bleaching events

Food web change forecasts

Ocean acidification effects on fish and habitat (coral, submerged vegetation)

Pelagic fish distribution forecasts

HAB event impacts on fish and habitat

Fish population and yield forecasts

Fish larval dispersal & recruitment forecasts

Coral bleaching long-term impact scenarios

Downscaled climate scenario forecasts for bays and estuaries

Fish Habitat/Distribution

Deep-sea coral HSD

Marsh/estuarine water quality impacts

Sea Level Rise

Hours — Days — Months / Seasons — Years — Decades — Centuries

Acute; Event-scale

Seasonal-to-interannual scale

Chronic; Climatological-scale

TIME SCALE

Operational ... Framework

Input:

Uses & Users

En...

(may ... hy... othe...)

Mo...
(inpu...)

O...

Prototype/
Test Beds

Users &
Stakeholders
Public & Private,
Local, State &
Federal Gov.,
NGOs, Academia

R & D

Variable	Ecological Forecasting Themes		
	HABs	Pathogens	Hypoxia
Temperature	X	X	X
Salinity	X	X	X
Dissolved Oxygen		X	X
Chlorophyll Concentration and its Anomaly	X	X	
Remote sensing reflectances	X		
Attenuation Coefficient		X	
Nutrient Concentration (NO3, PO4)		X	X
River Flow			X
pH		X	
Current velocity	X		
Upwelling Potential	X		
River plume location	X		
Species counts/biomass & toxicity / virulence	X	X	
Forcing for Atmospheric, Hydrodynamic, or BGC models	X	X	X

NOAA's Ecological Forecasting Roadmap

Ecological Event Outlook

Ecological Event Prediction

Ecological Event Forecast

Ecological Event Warning

FORECAST LEAD TIME

Years

Seasons

Months

Weeks

1 week

Days

Hours

Minutes

Forecast Uncertainty

IMPACT-BASED DECISION SUPPORT

Recovery

Planned Response

Preparation: to Avoid, Control, Mitigate, Recover

Impact of Climate Change on Human Health

Injuries, fatalities, mental health impacts

Asthma, cardiovascular disease

Heat-related illness and death, cardiovascular failure

Malaria, dengue, encephalitis, hantavirus, Rift Valley fever, Lyme disease, chikungunya, West Nile virus

Forced migration, civil conflict, mental health impacts

Respiratory allergies, asthma

Malnutrition, diarrheal disease

Cholera, cryptosporidiosis, campylobacter, leptospirosis, harmful algal blooms

Severe Weather

Air Pollution

Extreme Heat

Changes in Vector Ecology

Environmental Degradation

Increasing Allergens

Water and Food Supply Impacts

Water Quality Impacts

RISING TEMPERATURES

MORE EXTREME WEATHER

INCREASING CO_2 LEVELS

RISING SEA LEVELS

Source: USGCRP Climate & Health Assessment
http://www.globalchange.gov/health-assessment

Components of an Early Warning System—for multiple time scales

Population Demographics, Transportation and Migration

Epidemiological Surveillance

Ocean, Climate and Environmental Observation, Monitoring and Forecasts

Social and Behavioral Factors

Expert Assessment

Additional Sampling, Sensing

Predictive Models

Risk Analysis, Vulnerability Assessment

Disease Watch Early Warning

Response Strategy

Communication and Action

Evaluation and Feedback

Trtanj, J., J Davis and T. Collier 2013

Alaska Vibrio Outbreak

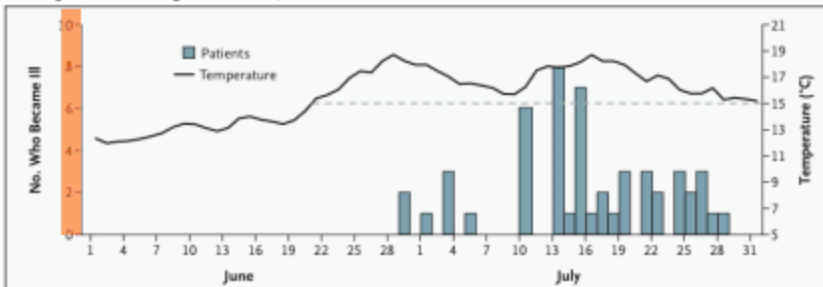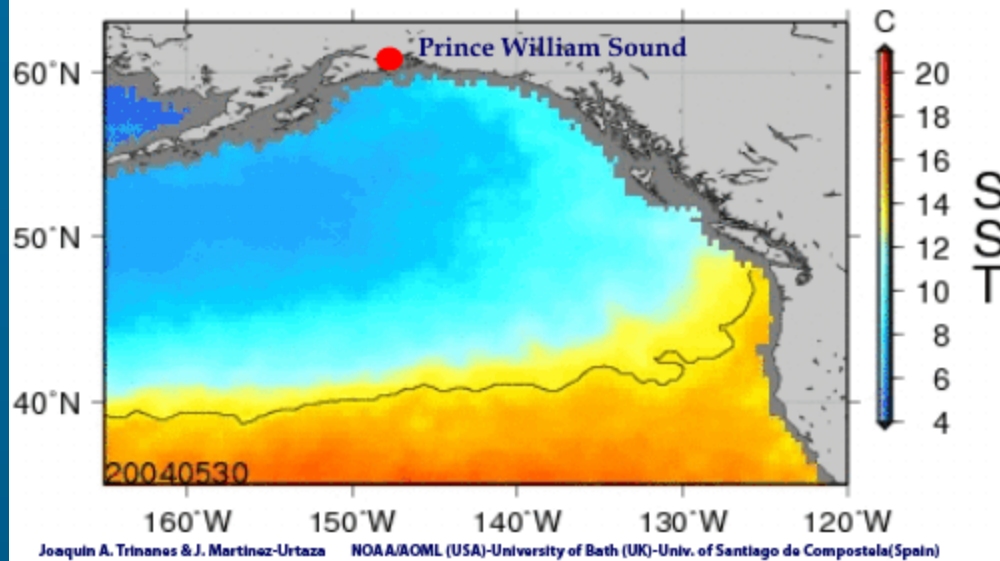

McLaughlin et al. N Engl J Med 2005;353:1463-70

Figure 3. Number of Patients with *Vibrio parahaemolyticus* Infection Associated with Oysters from Farm A, According to the Harvest Date, and Mean Daily Water Temperatures at Farm A.
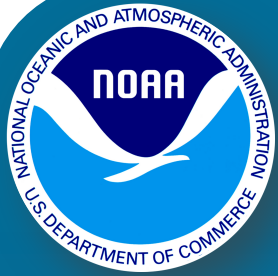
Joaquin A. Trinanes & J. Martinez-Urtaza   NOAA/AOML (USA)-University of Bath (UK)-Univ. of Santiago de Compostela (Spain)

- 2004 – 62 cases associated with shellfish consumption.

- *Vp* O:4 K:12 – transported from Puget Sound

- High proportion tdh+

Martinez-Urtaza, Bowers, Trinanes, and Depaola (2010) Food Research Int.
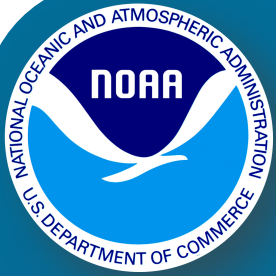
Some Climate Priorities...

- Higher resolution in coastal and near shore environments
  - Air temp used as a proxy for SST in Chesapeake and AK

- Preferred time scale is for vibrio and HABS:
  - 2-3 month lead time for seasonal prediction to manage harvest
  - decadal shifts in SST and salinity to manage placement and human exposure with changing seasonal windows and changing geographic shifts based on sst and salinitiy (ie moving into AK, ciguaterra moving out of caribbean but moving northward)

- For hypoxia: climate predictions on both seasonal and decadal time scales
  - Seasonal for for near-term marine resource management
  - Decadal for policy/planning

Questions?
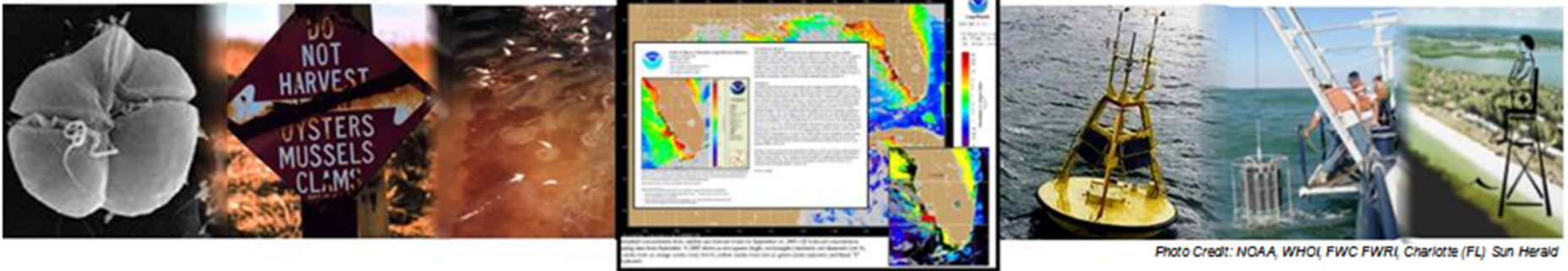
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Photo Credit: NOAA, WHOI, FWC FWRI, Charlotte (FL) Sun Herald