Forecasting and remote sensing of harmful algal blooms on the other coasts

Rick Stumpf
National Ocean Service
National Centers for Coastal Ocean Science
Hazards of Harmful Algal Blooms (HABs)

- Shellfish poisoning
- Economic
- Fish kills
- Marine mammals and birds
- Freshwater swimming
- Drinking water
- Clogging desal plants

*California sea lion undergoing stomach pumping after poisoning (photo courtesy Dr. Francis Gulland, Marine Mammal Center, Sausalito, CA)*
Why does HAB forecasting matter?

- Toledo, >$2 million economic loss from two-day bloom impact
  - Annually $11M for chemical treatment (nbcnews.com)
  - Methods will help with P reduction targets
- Florida tourism loss, $6M per month per county
  - Health, ER admissions 54% increase in respiratory, 40% increase in gastro-intestinal
- Gulf of Maine halo effect
  - 2005 $10’s millions lost seafood
Cyanobacterial (freshwater) HABs

Deaths at dialysis center in Brazil in 1996
Drinking water issue, cyano-toxins pose risk of liver & kidney damage

Toledo 2014

Toledo 2015, with no risk!

Tom Feran,
The Plain Dealer
Coastal HABS
Public Health Threats/Animal Mortality/Ecosystem Disruption
## Impacts Coastal HABs

<table>
<thead>
<tr>
<th>Name</th>
<th>Human &amp; Animal* Poisoning</th>
<th>Fish Kills</th>
<th>Water Discoloration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amnesic Shellfish Poisoning (ASP)</td>
<td>Yes**</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Ciguatera Fish Poisoning (CFP)</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Diarrhetic Shellfish Poisoning (DSP)</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Neurotoxic Shellfish Poisoning (NSP)</td>
<td>Yes**</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Paralytic Shellfish Poisoning (PSP)</td>
<td>Yes**</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Brown Tide</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>CyanoHABs</td>
<td>Yes**</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Golden Alga</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

* Mammals, birds, turtles, often protected species
** Can cause human or animal deaths
Some regions with chronic severe HABs

- Pacific NW
- CA
- TX
- FL/AL
- Erie
- C.Bay
- G.Main
HAB Operational Forecast System Concept: National Capability, Regional Implementation

**Inputs**
- Ocean Color, currents
- Public Health Data, *In situ* Observations
- Hydrodynamic Models
- Met Forecasts (Winds)
- Biological Models

**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

NOS Coastal Ocean Science
A harmful algal bloom has been identified in patches from southern Lee to central Collier County. Patchy very low impacts are possible ... today through Thursday.

Forecast with analyst interpretation:

“A harmful algal bloom has been identified in patches from southern Lee to central Collier County. Patchy very low impacts are possible ... today through Thursday."
Padre Island National Seashore Closes Park to Dogs (December 9, 2009)

http://tidesandcurrents.noaa.gov/hab
Gulf of Mexico Harmful Algal Bloom Operational Forecast System

Gulf of Mexico Harmful Algal Bloom Bulletin
Region: Southwest Florida
NOAA National Ocean Service
NOAA Satellite and Information Service
NOAA National Weather Service
Last bulletin: Thursday, March 30, 2017

Satellite chlorophyll a image with possible *K. brevis* HAB areas shown by red polygons, when applicable. Points represent cell concentration sampling data from March 24 to 31. Red (high), orange (medium), yellow (low), brown (low), blue (very low b), purple (very low a), pink (present), and green (not present). Cell count data are provided by Florida Fish and Wildlife Conservation Commission (FWC) Fish and Wildlife Research Institute. For a list of sample providers and a key to the cell concentration categories, please see HAB-OPS bulletin guide:

http://tidesandcurrents.noaa.gov/hab/hab_publication/habfs_bulletin_guide.pdf

Detailed sample information can be obtained through FWC Fish and Wildlife Research Institute at:

http://www.fwc.com/wildlifetours/

To see previous bulletins and forecasts for other Harmful Algal Bloom Bulletin regions, visit:

http://tidesandcurrents.noaa.gov/hab/bulletins.html

Gulf of Mexico Harmful Algal Bloom Bulletin
Region: Texas
NOAA National Ocean Service
NOAA Satellite and Information Service
NOAA National Weather Service
Last bulletin: Tuesday, October 11, 2016

Satellite chlorophyll a image with possible *K. brevis* HAB areas shown by red polygons, when applicable. Points represent cell concentration sampling data from October 3 to 11: red (high), orange (medium), yellow (low), brown (low), blue (very low b), purple (very low a), pink (present), and green (not present). Cell count data are provided by Texas Parks and Wildlife Department. For a list of sample providers and a key to the cell concentration categories, please see the HAB-OPS bulletin guide:

http://tidesandcurrents.noaa.gov/hab/hab_publication/habfs_bulletin_guide.pdf

Detailed sample information can be obtained through the Texas Parks and Wildlife Department at:

http://www.tpwd.state.tx.us/landwater/water/environconcerns/hab/redtide/status.shtml

Conditions Report
Not present to medium concentrations of *Karenia brevis* (commonly known as Florida red tide) are present along- and offshore portions of southwest Florida and not present in the Florida Keys. *K. brevis* concentrations are patchy in nature and levels of respiratory irritation will vary locally based upon nearby bloom concentrations, ocean currents, and wind speed and direction. The highest level of potential respiratory irritation forecast for Monday, April 3 through Thursday, April 6 is listed below:

**County Region: Forecast (Duration)**
- Southern Pinellas: Very Low (M-Th)
- Southern Manatee: Very Low (M-Th)
- Northern Sarasota: Low (M-Th)
- Southern Sarasota, bay regions: Low (M-Th)
- Southern Charlotte: Moderate (M-Th)
- Northern Charlotte, bay regions: Moderate (M-Th)

Gulf of Mexico Harmful Algal Bloom Bulletin
Region: Texas
NOAA National Ocean Service
NOAA Satellite and Information Service
NOAA National Weather Service
Last bulletin: Thursday, October 13, 2016

Satellite chlorophyll a image with possible *K. brevis* HAB areas shown by red polygons, when applicable. Points represent cell concentration sampling data from October 10 to 13: red (high), orange (medium), yellow (low), brown (low), blue (very low b), purple (very low a), pink (present), and green (not present). Cell count data are provided by Texas Parks and Wildlife Department. For a list of sample providers and a key to the cell concentration categories, please see the HAB-OPS bulletin guide:

http://tidesandcurrents.noaa.gov/hab/hab_publication/habfs_bulletin_guide.pdf

Detailed sample information can be obtained through the Texas Parks and Wildlife Department at:

http://www.tpwd.state.tx.us/landwater/water/environconcerns/hab/redtide/status.shtml

Conditions Report
*Karenia brevis* (commonly known as Texas red tide) ranges from not present to high concentrations along the Texas coast from the Corpus Christi Bay to Rio Grande region. *K. brevis* concentrations are patchy in nature and levels of respiratory irritation will vary locally based upon nearby bloom concentrations, ocean currents, and wind speed and direction. The highest level of potential respiratory irritation forecast for Thursday, October 13 through Monday, October 17 is listed below:

**County Region: Forecast (Duration)**
- Bay region-Corpus Christi Bay: Moderate (Th-M)
- Bay region-Upper Laguna Madre: Very Low (Th-M)
- Aransas Pass to PINS: Moderate (Th-M)
- Padre Island National Seashore region: Moderate (Th-M)
- Mustang Pass to Beach Access 6 region: Moderate (Th-Su), Low (M)
- Beach Access 6 to Rio Grande region: Moderate (Th-Su), Low (M)
- Bay region-Lower Laguna Madre to Laguna Vista: Low (Th-M)

All Other Texas Regions: None expected (Th-M)

Check http://tidesandcurrents.noaa.gov/hab/beach_conditions.html for recent, local observations. Over the past few days, reports of respiratory irritation and discolored water have been received from the Corpus Christi Bay region.

Analysis
*Karenia brevis* concentrations range between ‘not present’ and ‘high’ along the Texas coast from Aransas Pass to the Rio Grande (TPWD, 10/11-13). In the Corpus Christi Bay region, sampling this week continues to indicate up to ‘high’ *K. brevis* concentrations throughout the bay with corresponding reports of respiratory irritation and discolored water (TPWD, 10/11-12). Sampling from Texas A&M University’s Imaging FlowCytobot, located on the Port Aransas ship channel, continues to indicate up to ‘very low a’ *K. brevis* concentrations (TAMU, 10/11-12). Sampling in the Upper Laguna Madre detected a ‘very low a’ *K. brevis* concentrations where previous sampling indicated *K. brevis* was not present (TPWD, 10/12). Recent sampling in the Padre Island National Seashore region continues to indicate up to ‘low b’. *K. brevis* concentrations (TPWD, 10/12). New sampling around the Lower Laguna Madre to Laguna Vista region continues to confirm *K. brevis* concentrations have decreased in the last week with only ‘background’ concentrations detected on 10/10 (Texas Red Tide Rangers). Detailed sample information and a summary of impacts can be obtained through Texas Parks and Wildlife Department at:

http://www.tpwd.state.tx.us/landwater/water/environconcerns/hab/redtide/status.shtml

For information on area shellfish restrictions, contact the Texas Department of State Health Services.
Florida, developing improved respiratory forecast

Prototype forecast tool combining NDFD wind with cell concentrations.

Improved satellite data to direct beach sampling

HABscope developed to bring in volunteer networks

NOAA/NOS, GCOOS, Mote Marine Lab, NASA

Video frame of K. brevis cells
Addition of Flow Cytobot in Texas

Dinophysis detected 2008, Karenia in recent years

- Dinophysis detected in 2008 for first time in US
- Dinoflagellates produce the toxin okadaic acid and dinophysis toxins
- Causes diarrhetic shellfish poisoning (DSP)
- FlowCytobot has been critical for detection
Gulf of Maine Transition

4th year of cyst cruise led by NOAA, helped by WHOI

*Alexandrium* biological model now in ROMS “trunk”, evaluations of biology happening on NCEP computers, hydro model integration across NOS

Environmental Sample Processor (ESP) deployment - early warning to Maine

Multi-partnered investment (> $20M) across NOAA, with EPA, FDA, NERACOOS, NSF, Canada DFO, Maine DMR
Gulf of Maine Seasonal forecast

Gulf of Maine Red Tide Forecast Predicts Small Bloom for 2016

Posted on April 7th, 2016 (1 year ago) in Forecasting, Harmful Algal Blooms

This summer the Gulf of Maine red tide is predicted to be the smallest observed over the last eleven years, as forecast by researchers at Woods Hole Oceanographic Institution (WHOI) and North Carolina State University.


Conditions are ripe for another large bloom in New England waters; weather and ocean conditions will determine outcome

Courtesy:
Don Anderson, WHOI
Forecast Model types

- Gulf of Maine Cyst Map
- Lake Erie Satellite cyan index Sep 2011
- Lake Erie with POM model (3-D behavior in demonstration)
- Gulf of Maine Transport with ROMS 3-D model and biological response
Lake Erie Forecasts, run routinely since 2008

The Microcystis cyanobacteria bloom continues in the western basin. The bloom extends from west of West Sister Island, veering southward to the coast, then curving to the northeast through the islands toward the central basin and up to the Canadian coast.

Figure 1. Cyanobacterial Index from NASA’s MODIS-Terra data collected 24 July 2015 at 12:00 pm EDT. Grey indicates clouds or missing data. Black indicates bloom.

Figure 2. Nowcast position of bloom for 27 July 2015 using GLCFS modeled currents to move the bloom from the 24 July 2015 image.
Lake Erie Transition from NCcOS (Research) to CO-OPS (for operations)

Toledo increased monitoring because of bloom increase identified in bulletin.Bulletin forecasts twice per week post-Toledo.

Improved integration of GLERL field data, and using operational high res (FVCOM) model for transport.

-- Bulletin Aug 1 a.m.
-- Toledo water ban late Aug 1 (Fri)
-- Next bulletin issued Aug 4 (Mon) a.m.
Accomplishments:
Lake Erie ready for operations FY17

- 2016 was 8th season.
- 2000 subscribers + media distribution
- Stakeholder discussions
- Transition plan
- Research improvements now possible

One product for Lake Erie, location relative to intakes

-- Bulletin Aug 1, 2014 a.m.
-- Toledo water ban late Aug 1 (Fri)
-- Next bulletin issued Aug 4 (Mon) a.m.
Bulletin PDF images are geoPDF, check locations
New models being developed

3-D model for Lake Erie to predict blooms subsurface or surface
Annual assessment of blooms

Lake Erie peak cyanobloom severity: MERIS (ESA) and MODIS (NASA) data.
Comparison with Phosphorus Load

compare bloom biomass with total bioavailable phosphorus (TBP)
2016 Seasonal forecast milder than 2014 & 2015.

Correct, but several models overestimate internal loading from 2015.
From Lake Erie to rest of country, CyAN, Collaboration with EPA, USGS, NASA

- Testing “bulk” methods with time series analysis of FL, OH, and CA (2008-2011)
- Frequency maps and surface drinking water intake monitoring methods
Evaluation of other products

*Karlodinium veneficum* bloom (not fluorescing) in Chesapeake Bay (12/19/2016)

Maryland Dept of the Environment. Fish kill Dec 19, 2016. “*Karlodinium veneficum*, a toxin producing saltwater algae, pushed remarkably far into the freshwater end of the Chesapeake Bay estuary in 2016.”
NOAA’s Ecological Forecasting Roadmap

NOAA’s Ecological Forecasting Roadmap will:

• Leverage NOAA-wide capability
• Establish priorities and collaborations
• Build-on existing infrastructure and partnerships
• Improve quality and delivery of products and services

To achieve:

• Operational forecasts based on strong science
• Delivery of more consistent, efficient, reliable, and national forecasts (tailored to region-specific needs)

NOAA initial focus areas: Harmful Algal Blooms, Hypoxia, Pathogens
Biggest needs for modeling

Initializing operational models, we don’t have enough data on bloom location.

Scenario models, for most areas, insufficient data on initialization.

Validating operational model comparison (is one model “better”), we don’t have enough data on bloom location.
HAB Observing Networks: Development & Transition

Objective: promote development & transition to operations of regional & national HAB observing networks

Rationale: observations & measurements of HAB species & toxins are important for:

- support of forecasting
- validate satellite/airborne observations
- data assimilation for model correction
- early warning of HAB events
- assessing bloom toxicity (potential impacts)
- identifying drivers of HAB growth & toxicity
HAB Observing Networks: Where are we going?

Overall Aim: observing networks will be fully integrated as components supporting a national HAB forecasting infrastructure.

As we develop & deploy observing capabilities:
- identify & understand regional observing needs useful to managers & stakeholders
  - focus on ‘observations’ not ‘technologies’
- leverage existing infrastructure to provide contextual data (IOOS RAs, NDBC, NWS, etc.)
- plan for data dissemination & assimilation
Health: *Pseudo-nitzschia* in Pacific NW, Amnesic Shellfish Poisoning
California C-HARM
HINDCASTING *Pseudo-nitzschia*

- Focus on 2009 (Anderson et al. 2011)
- DINEOF reconstruction at 5-day intervals

2009 Hindcast versus Cell Counts, Santa Barbara

Red: Cell Counts
Blue: Predicted Probability
Five year vision

- Lake Erie, convert demonstration to true operations, FY17
- Gulf of Maine complete transition, FY18
- Improve Florida to public need, beach resolution FY19
- Transition California domoic acid to NOAA
- National cyano network (EPA, USGS, NASA)
- Implement Pacific NW, transition to NOAA
- Continue improvements, evaluate new areas

- Alaska, Puget Sound, Long Island Sound, Ciguatera, random events
“Emerging” problem areas

- Puget Sound
- Saginaw Bay
- Green Bay
- LI Sound
- IRL
- Caribbean
- Alaska
Detecting HABs in Freshwater Cyanobacteria Assessment Network

- Satellite monitoring in larger lakes and reservoirs, OLCI and MERIS
- Estimate human exposure to cyanotoxins
- Disseminate info → expedient public health advisories
- Decrease costs of monitoring
- Reduce exposures
- Create a standard approach for early HAB detection based on new satellite data (OLCI)
- Retrospective with MERIS
- Evaluate Landsat

EPA, NASA, NOAA, and USGS

Sentinel-3 satellite
Launched February 2016
CyAN. National scope

Red points are locations of water quality data.

MERIS tiles outlines in gray.

Insets are test MERIS files
CyAN objective of providing data, tools, and “bulk” analysis

EPA EnviroAtlas (Data dashboard)

Android mobile apps

RSTools (ArcGIS) support for CyAN data (developed for CA WaterBoard)
Northern Florida clear Scenes, MERIS to OLCI comparison