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"Urbanization and Climate Change: A Recipe for Disaster without Effective Stormwater Management

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  Bryan Brooks

Urbanization in Coastal Ecosystems

- Globally > 55% of the world's population lives within 50 miles of the coast, 33 of the 50 largest cities in the world are located in coastal areas & more than 80% of world commerce is transported by ships (Dean, 1997)
- Half of the US population (>141 million people) reside within 50 miles of the coast, which occupies less than 11% of the land area of the lower 48 states (NOAA, 1999; 2005)
- U.S. population has increased by 33 million (28%) since 1980 and is expected to increase by anther 12 million by 2015 (Crossett et al.; 2004)
- **PEW COMMSSION:** 25% of all conversion of rural land into suburban/urban land use in the last 300 years for the U.S. has occurred in the 15 year period from 1982-1997 (NRI, 2000)

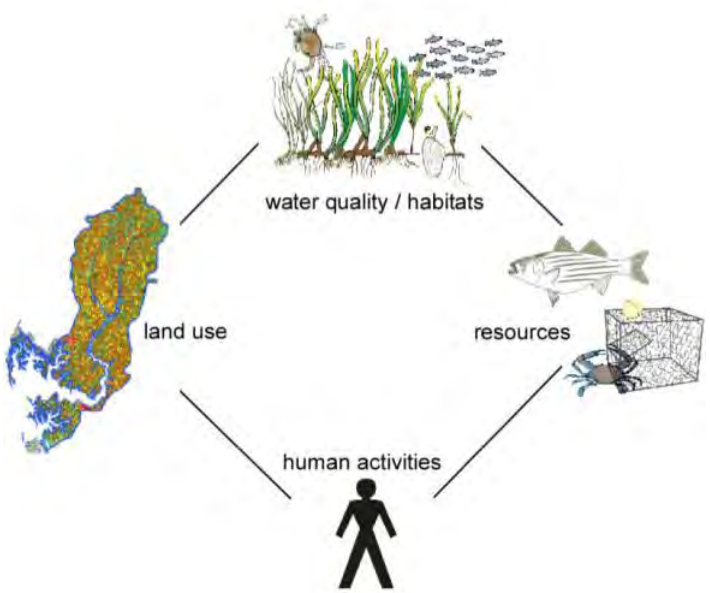
Consequences of Differences in Economic and Population Growth on the Coastal Zone

- Thus there is **5.19 times more commercial** development/land area in the coastal zone and **5.38 times more people/land area** in the coastal zone

- Both economic and urban development may result in increased emissions of air and water pollution.

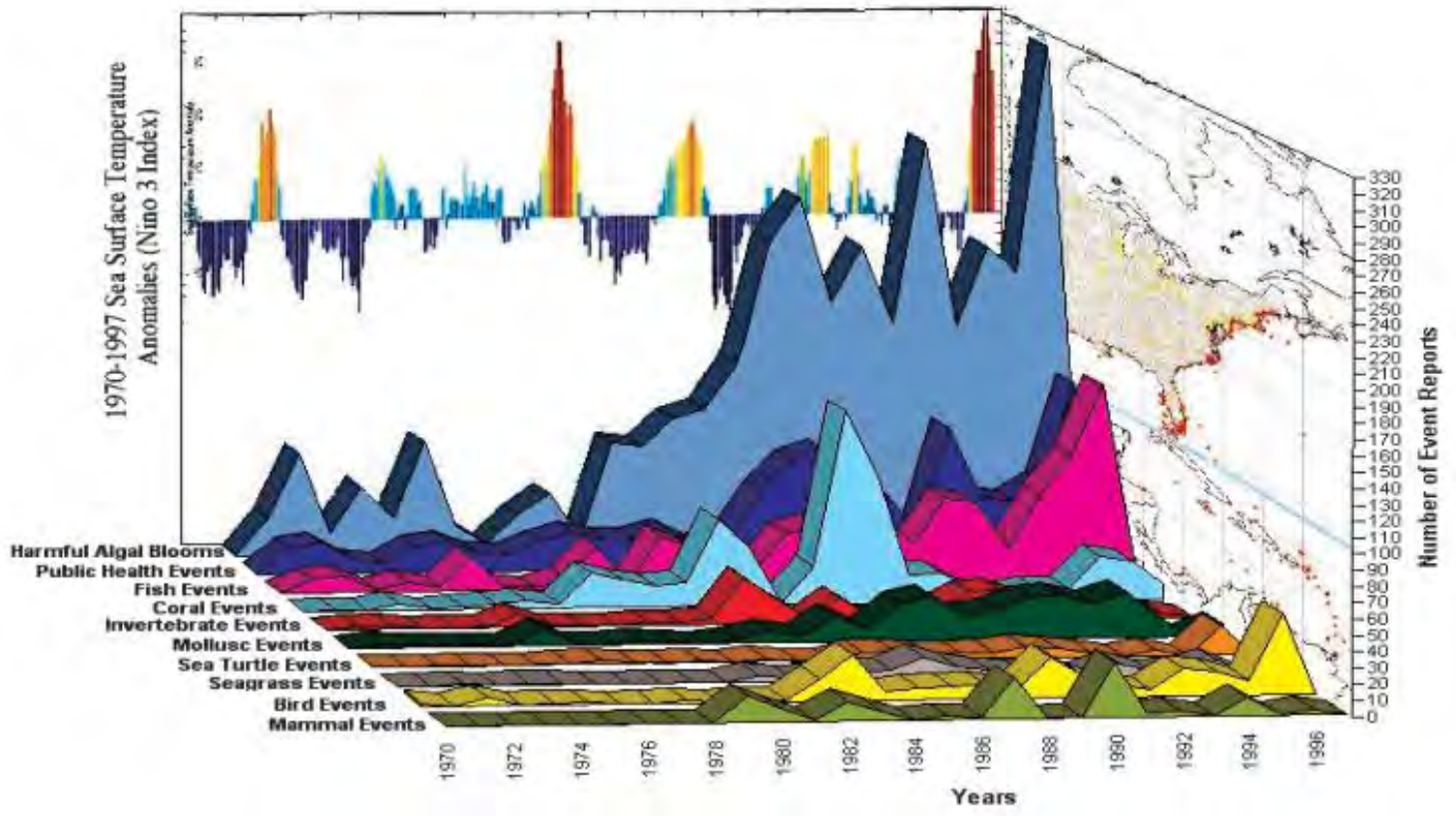
- Thus there will be increased impacts to the environment quality in coastal zone and coastal communities as a result = ***May Impact Both Ecosystem and Human Health***

Urbanization: Human Activity on Land Ultimately Affects Water Quality & Coastal Ecosystem Health



- **Land Use** activity may alter the **Landscape Ecology** → Increasing **Imperviousness** → Altering the **Hydrological Cycle** → Impacting **Water Quality**
- Altered or Impacted water quality may in turn impact ecosystem health and human health
- Impacts – Increased levels of Harmful Algal Blooms, Human Health Microbes, & Contaminants of Emerging Concern

Reported Major Marine Ecological Disturbances (1970-1996) — Labrador to Venezuela



Urbanization in Coastal Ecosystems

- **COASTAL CONDITION REPORT**: 44% of Estuarine Ecosystems were impaired primarily due to NPS pollution (EPA, 2012)
- **Bricker et al. (1999)** similarly has reported that 67% of our estuaries and bays in the U.S. are moderately or severely impacted by eutrophication
- **In 2005 > 35,000 beach advisories** or closures occurred in the U.S. (EPA, 2005)
- **> 40% of the shellfish beds in the U.S.** had harvest restrictions resulting from urban runoff, discharges from septic tanks, runoff from animal feedlots and wildlife pollution sources (EPA, 2001)

Fastest Growing Municipalities on the East Coast – Myrtle Beach, Charleston and Hilton Head

(Charleston Post & Courier 03/27/14)

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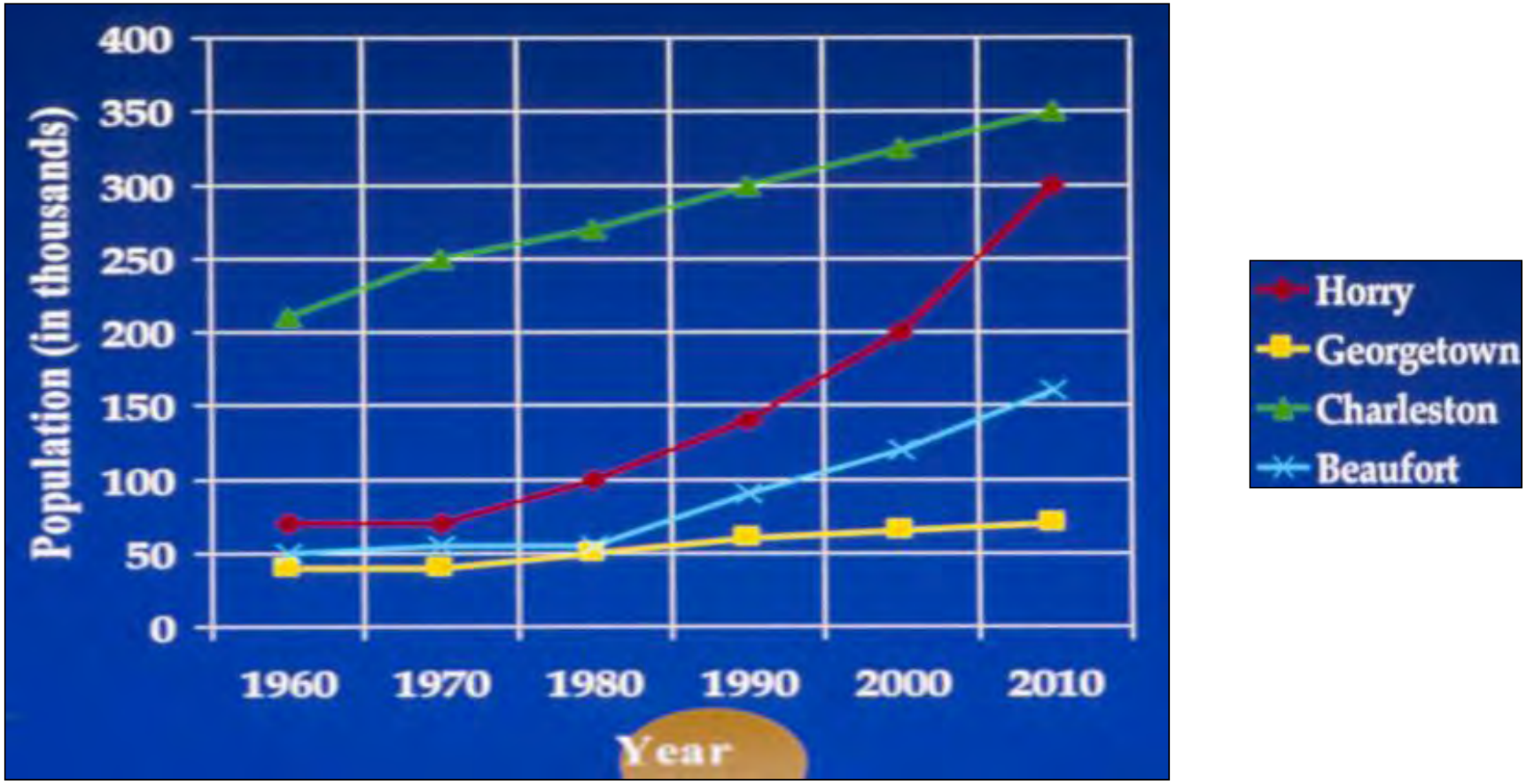
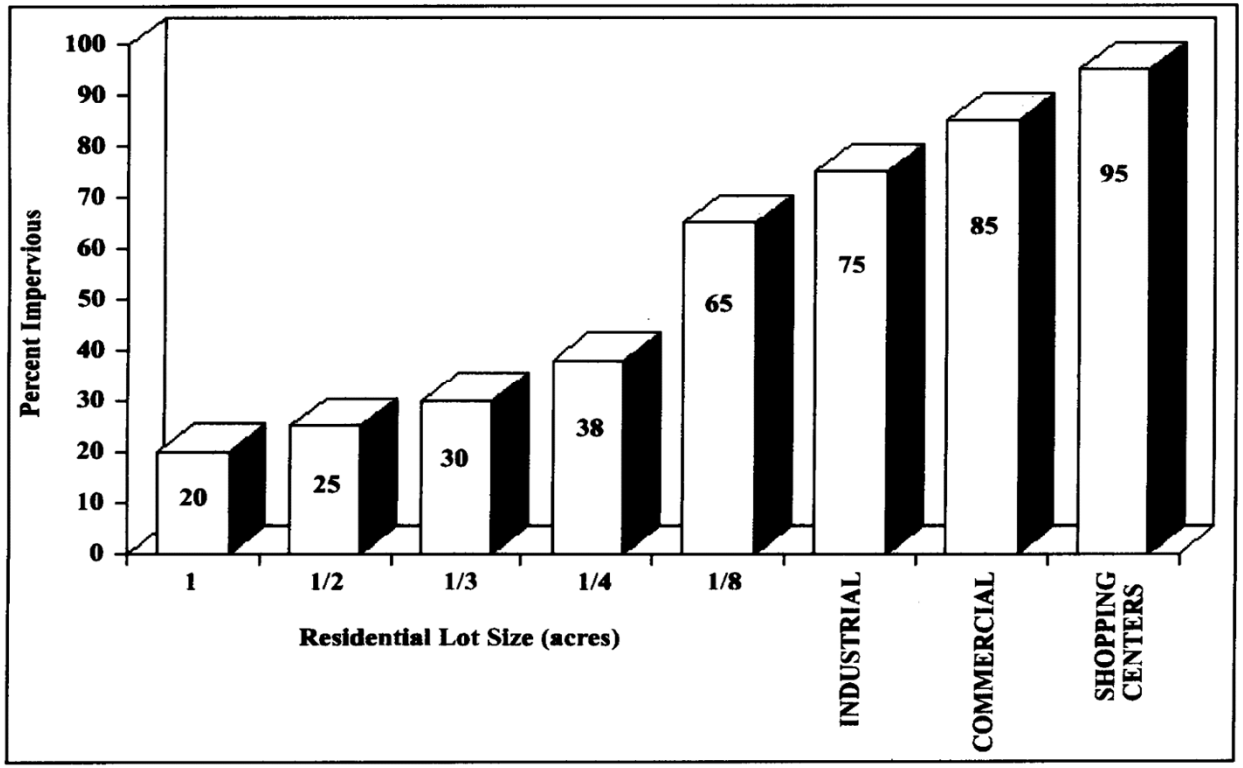
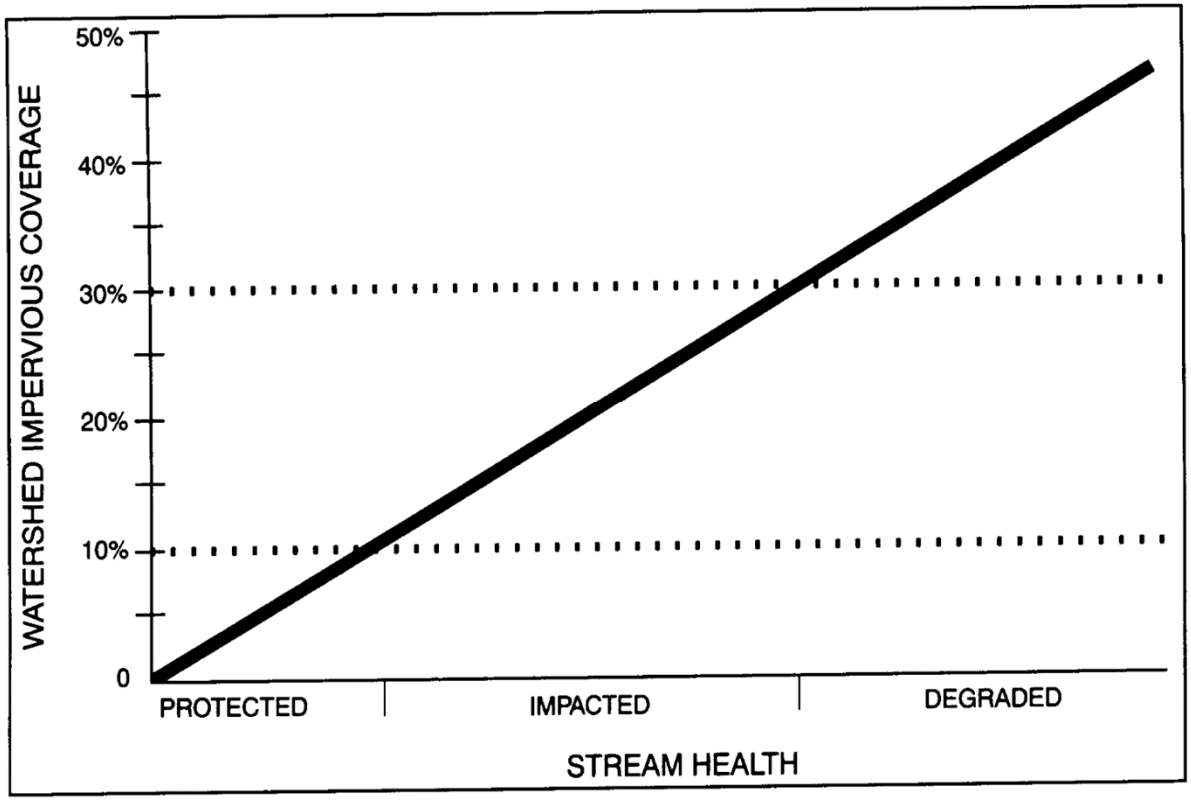
Population Trends Along the South Carolina Coast



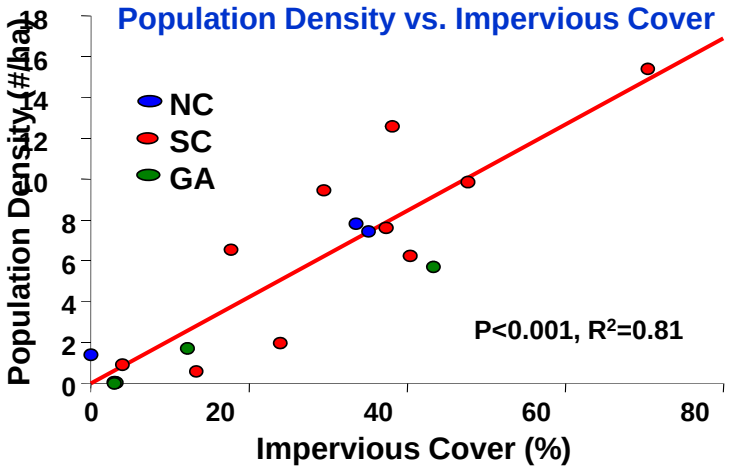
Effects of Lot Size on Imperviousness

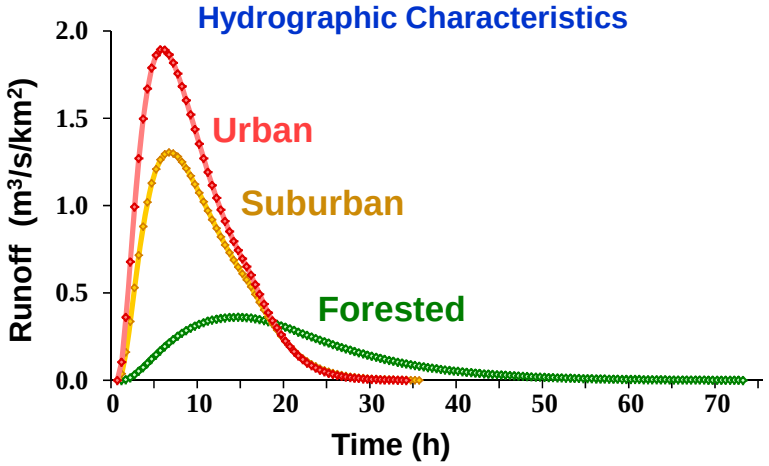


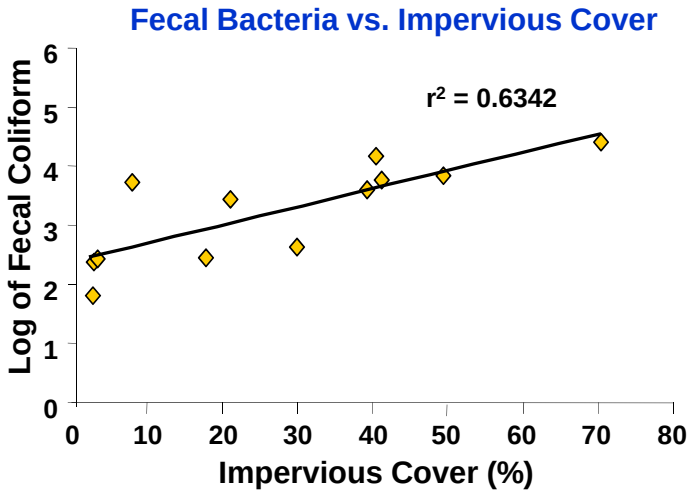
Effects of Imperviousness on Water Quality (Schuler et. al. 1992)

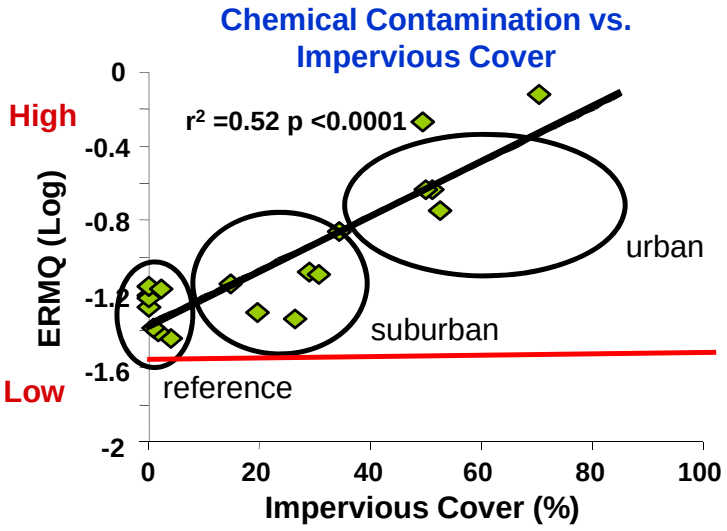


Summary: Urbanization Effects

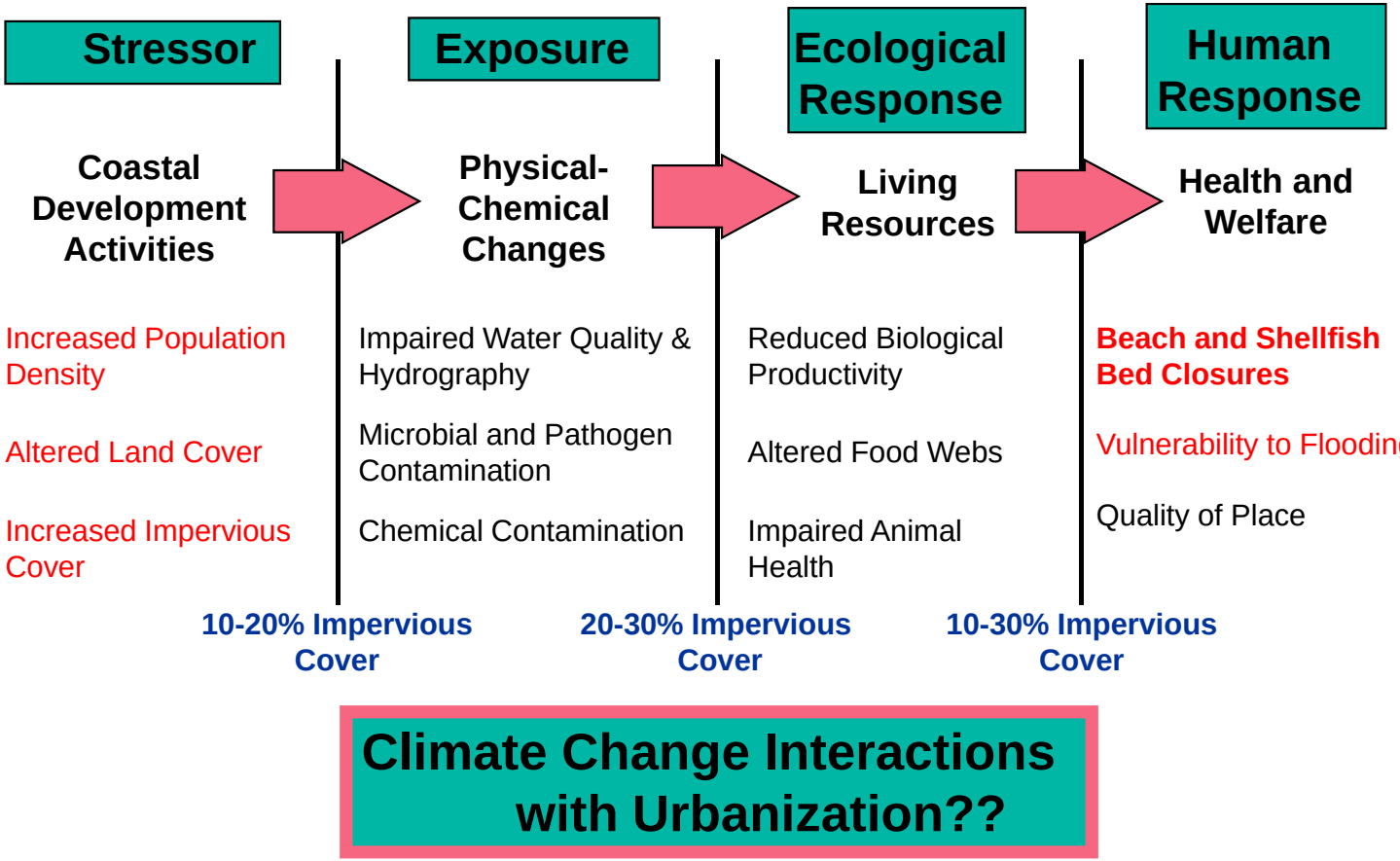








Urbanization Effects on Coastal Ecosystems



Climate Change Interactions with Urbanization??

Pollution Effects and Urbanization

Urbanization Effects

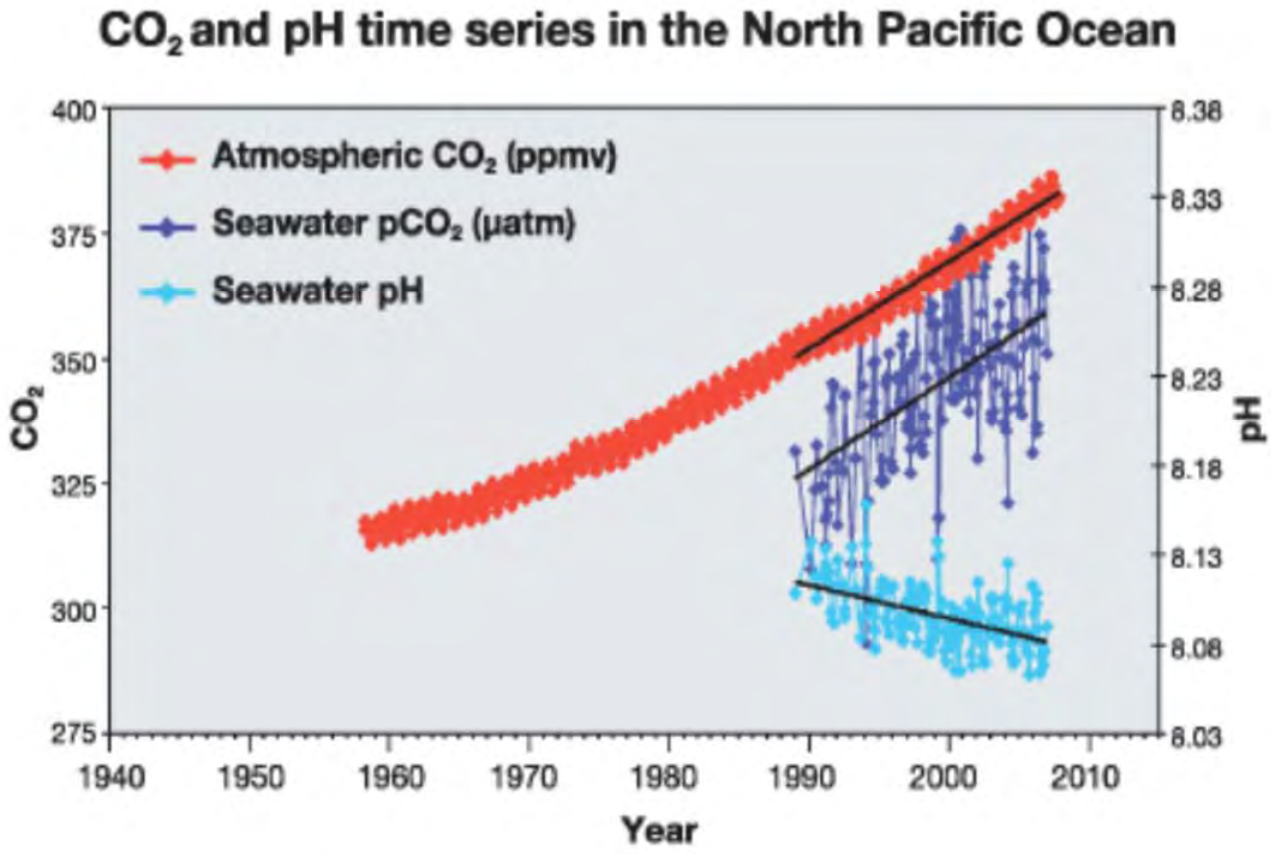
- **Hydrological Cycle**
- **Nitrogen Cycle**
- **Phosphorous Cycle**

Climate Change

- **Carbon Cycle**
- How Will Future Climate Change Effects Interact with Current Known Urbanization Effects?

Hypoxia (lack of oxygen) and Eutrophication (increased nutrients) are Common Results

NAS (2010) Monitoring Climate Change Impacts



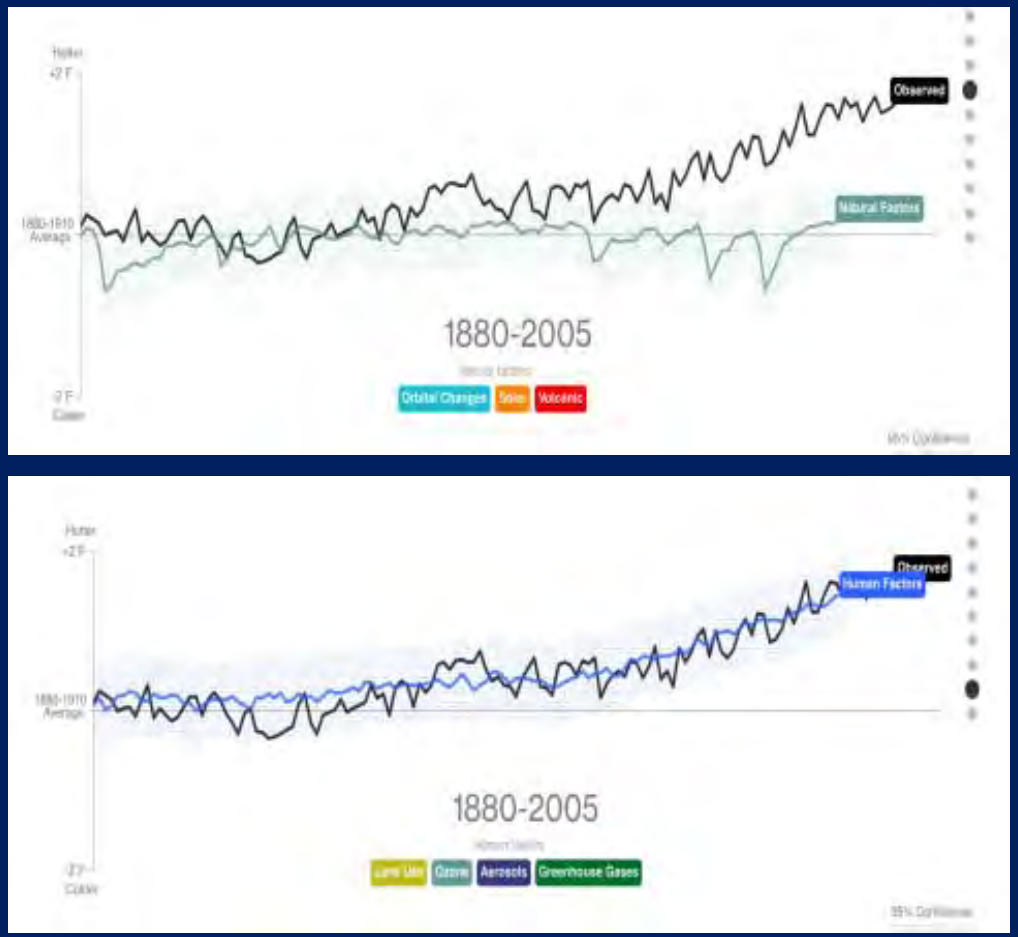
GLOBAL WARMING

- Present level of CO_2 are >400 ppm, which has increased by 25% since the start of the industrial revolution & has increased by 12% since 1960.

- This CO_2 increase has caused a 1 degree F increase in global temperatures during the 20^{th} century.

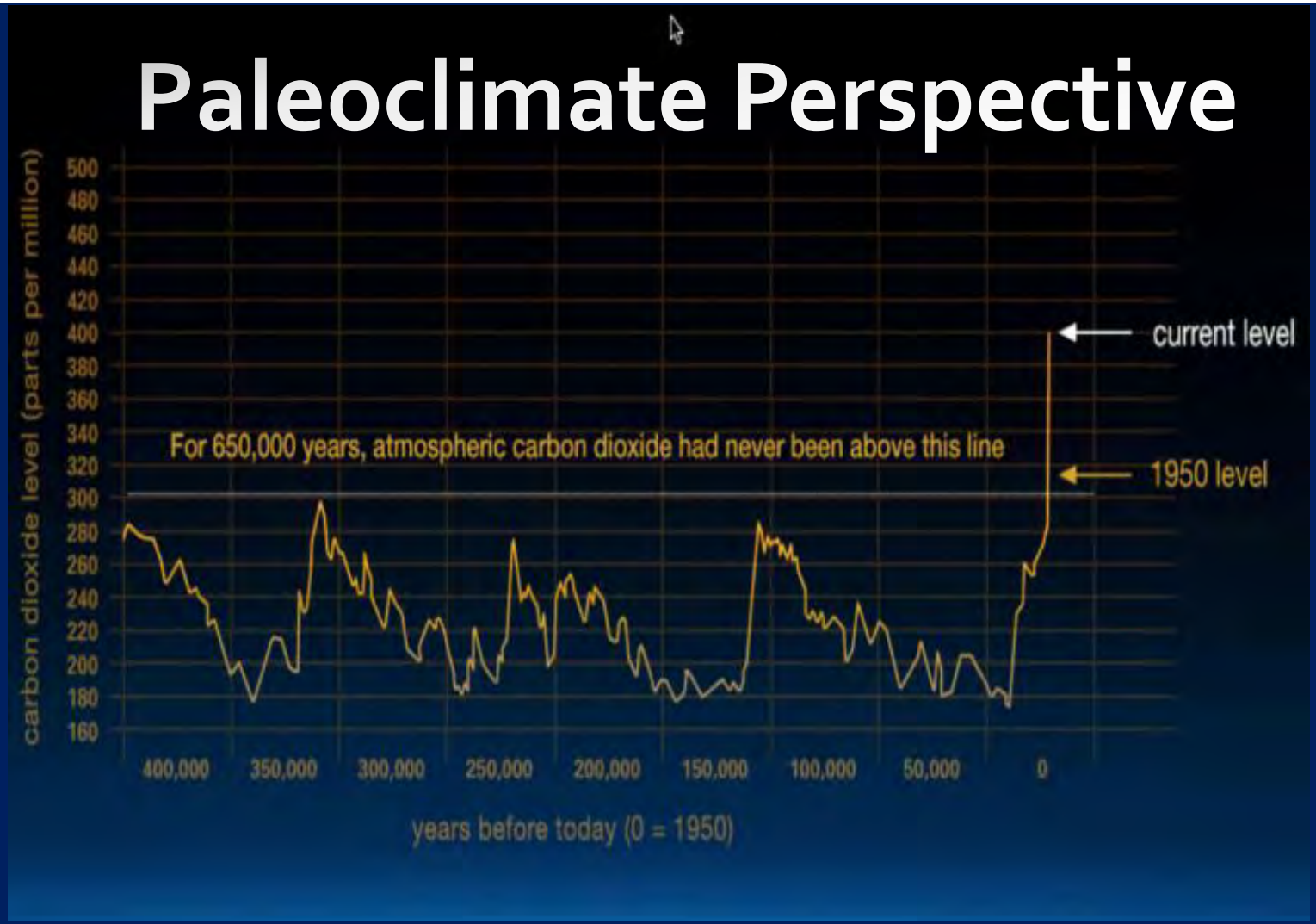
- Projections are for CO_2 levels to double by 2050 which will increase global temperatures by 1.5 - 4.5 degrees F.

Causes



Source: Roston, Eric and Blacki Migliozzi, 2015

Paleoclimate Perspective



Credit: Vostok ice core data/J.R. Petit et al.; NOAA Mauna Loa CO2 record

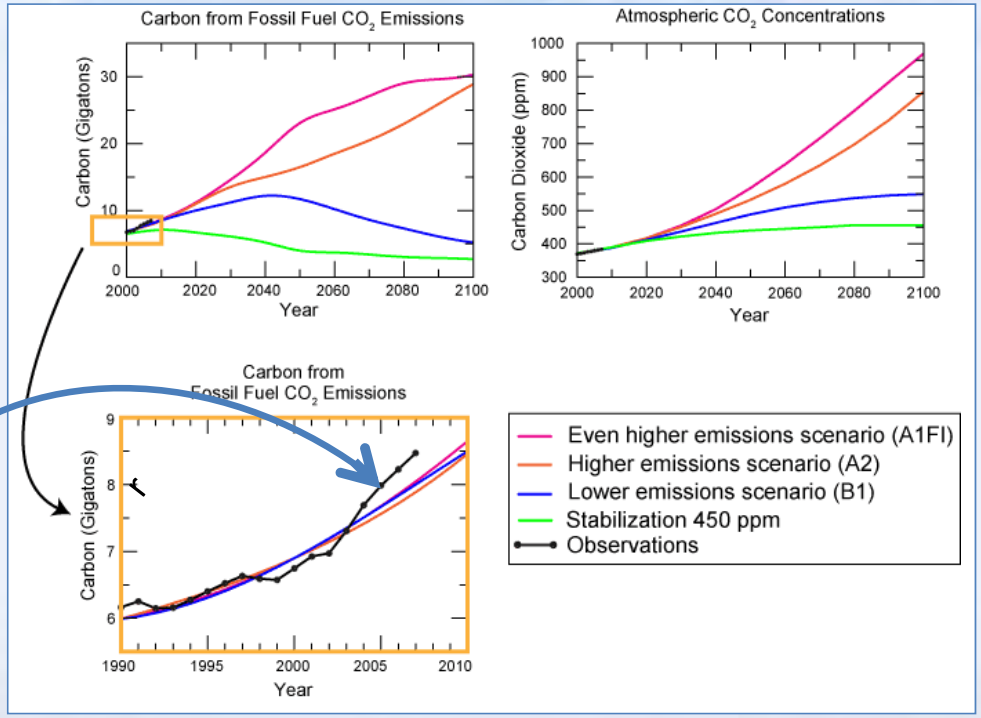
Sources of Information

(Dr. Thomas C. Peterson
NOAA's National Climatic Data Center)

- *Global climate change impacts on the United States*
  - June 2009 and 2014 Reports
  - Intense peer-review
  - Intense public-review
  - Available from
    - www.globalchange.gov/usimpacts

A bit about emission scenarios

- Recent carbon dioxide emissions are, in fact, above the highest emissions scenario developed by the IPCC



- About 1/3 of the CO_2 from fossil fuel burning remains in the atmosphere after 100 years
- About 1/5 of it remains after 1000 years

How May Climate Change Affect These Ocean Health Threats?

- Climate may directly affect growth, survival, persistence, distribution, transmission, and virulence of disease-causing organisms and harmful algal blooms and distribution and concentrations of chemical contaminants in coastal and ocean waters.
- Climate may also affect the distribution of disease vectors, including marine organisms.
- Major climate factors are temperature, precipitation (and associated drought, flooding, and runoff), sea level rise, salinity, extreme weather events, and ecological shifts.

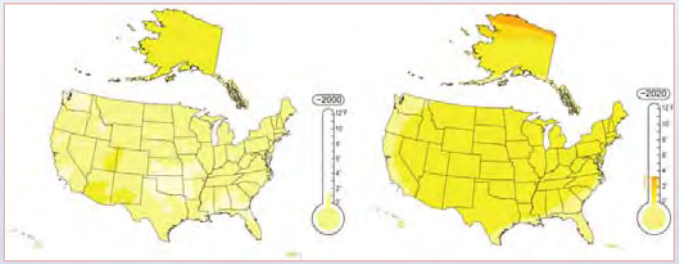
A tendency to have more warming in the middle of continents

Partly due to:

- More drying due to increased evaporation

Present-Day Change (1993-2007)

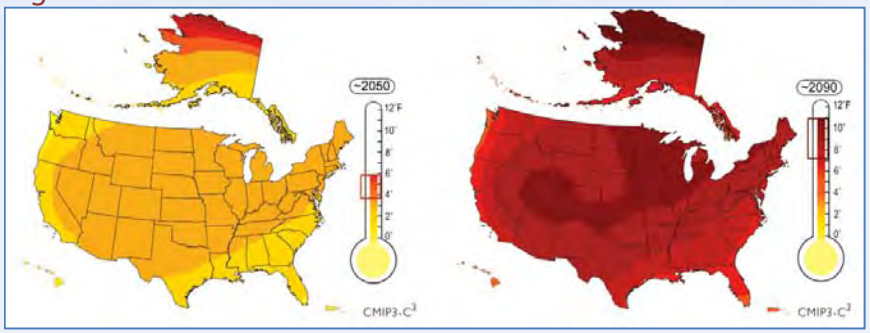
Near-Term Projected Change (2011-2029)



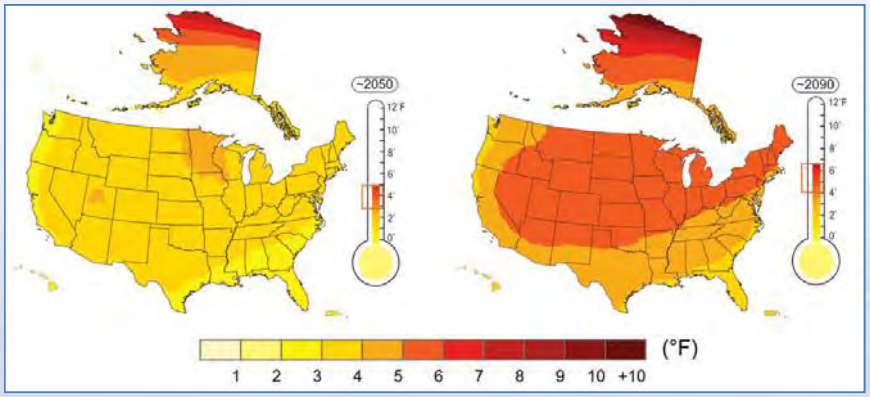
Projected Temperature Change (° F)
from 1961-1979 Baseline

Mid-Century (2041-2059 average) End of Century (2081-2099 av.)

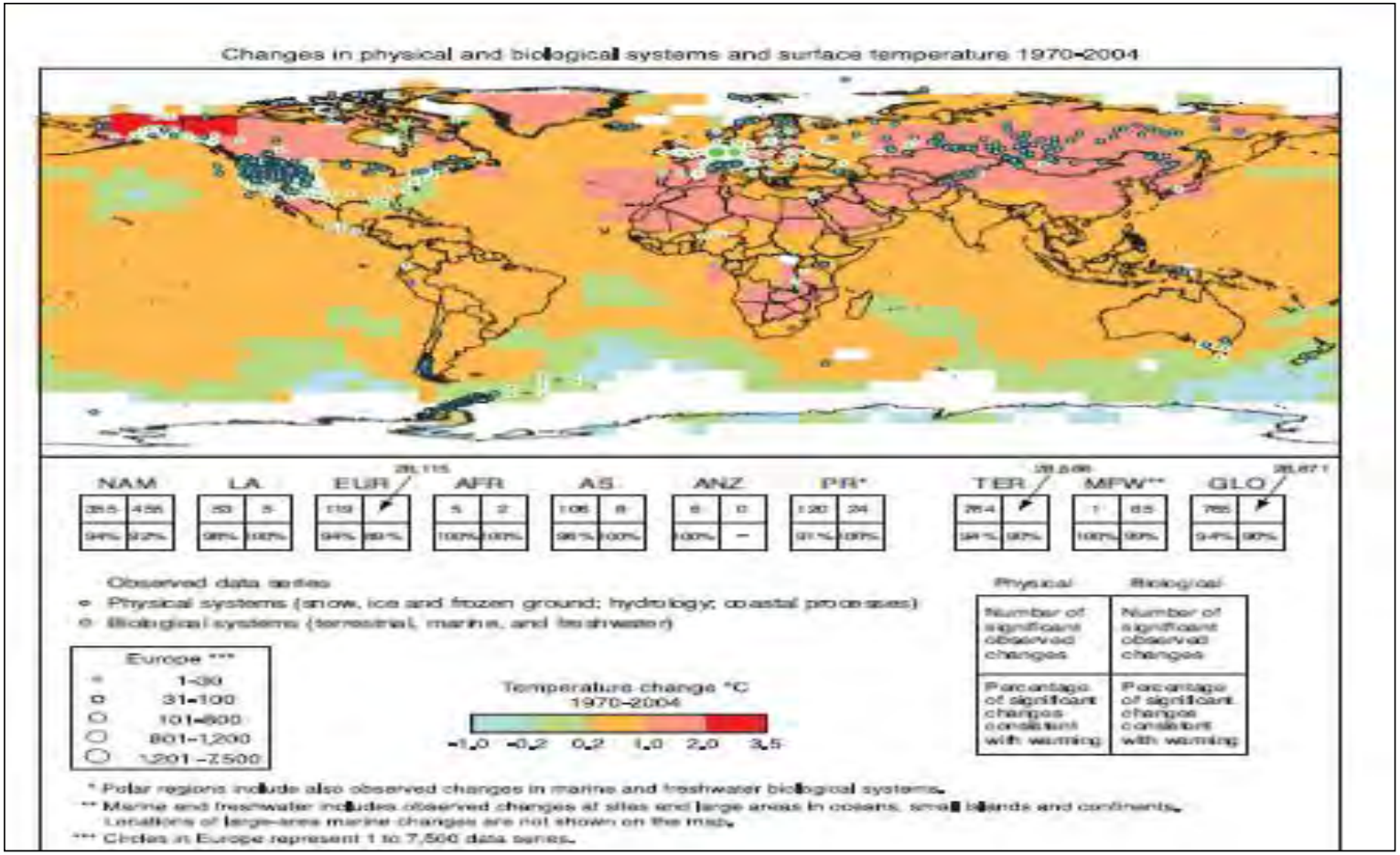
Higher Emissions Scenario



Lower Emissions Scenario



GLOBAL CHANGE IN SURFACE TEMPERATURES, 1970-2004

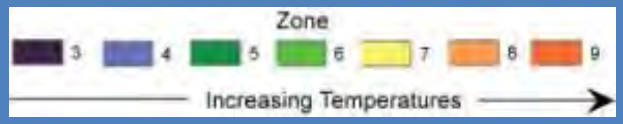


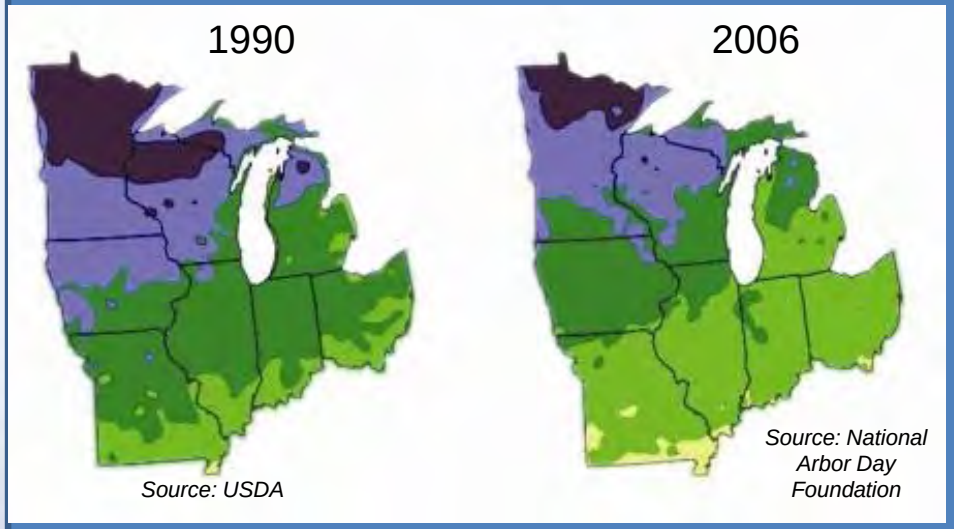
Increased Temperature

Global Warming Effects	Ecosystem/Ecological Response	Interactions with Known Coastal Urbanization Effects
Increased Temperature	Increased melting of polar ice	Increased release of Hg, Pb, DDT, and other contaminants into air and surface waters of boreal ecosystems
	Increased thermal stress	Enhanced toxicity of many emerging contaminants of concern (EECs) in combination with elevated temperatures
	Ecological shifts of marine organisms	Increased occurrences of marine animal diseases and human illness/diseases associated with microbes and harmful algal blooms

Climate change is already impacting plant hardiness zones

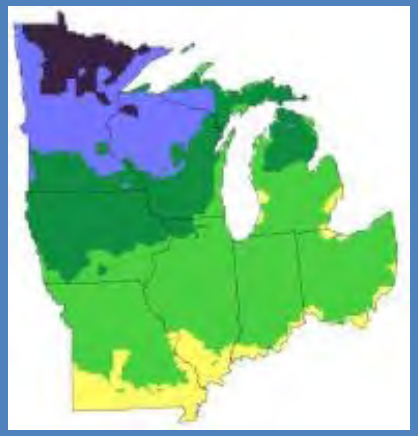
Observed and Projected Changes in Plant Hardiness Zones



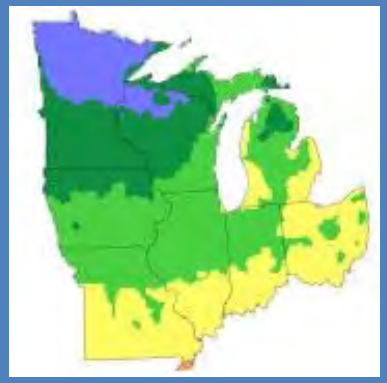


Source: USDA

Source: National Arbor Day Foundation



Lower Emissions Scenario by 2090



Higher Emissions Scenario by 2090

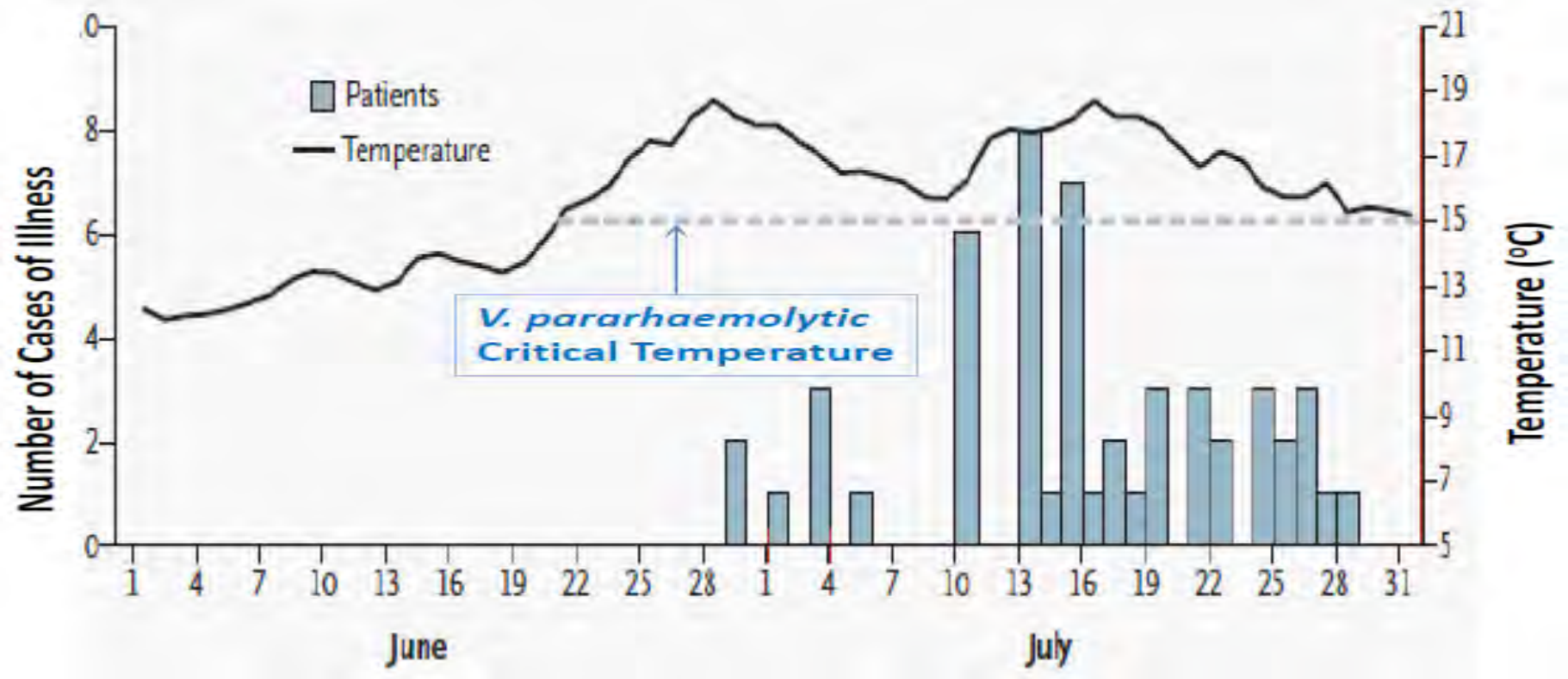
Vibrios: Naturally Occurring Harmful Bacteria

Vibrio cholerae

Vibrio parahaemolyticus (Vp)
Vibrio vulnificus (Vv)

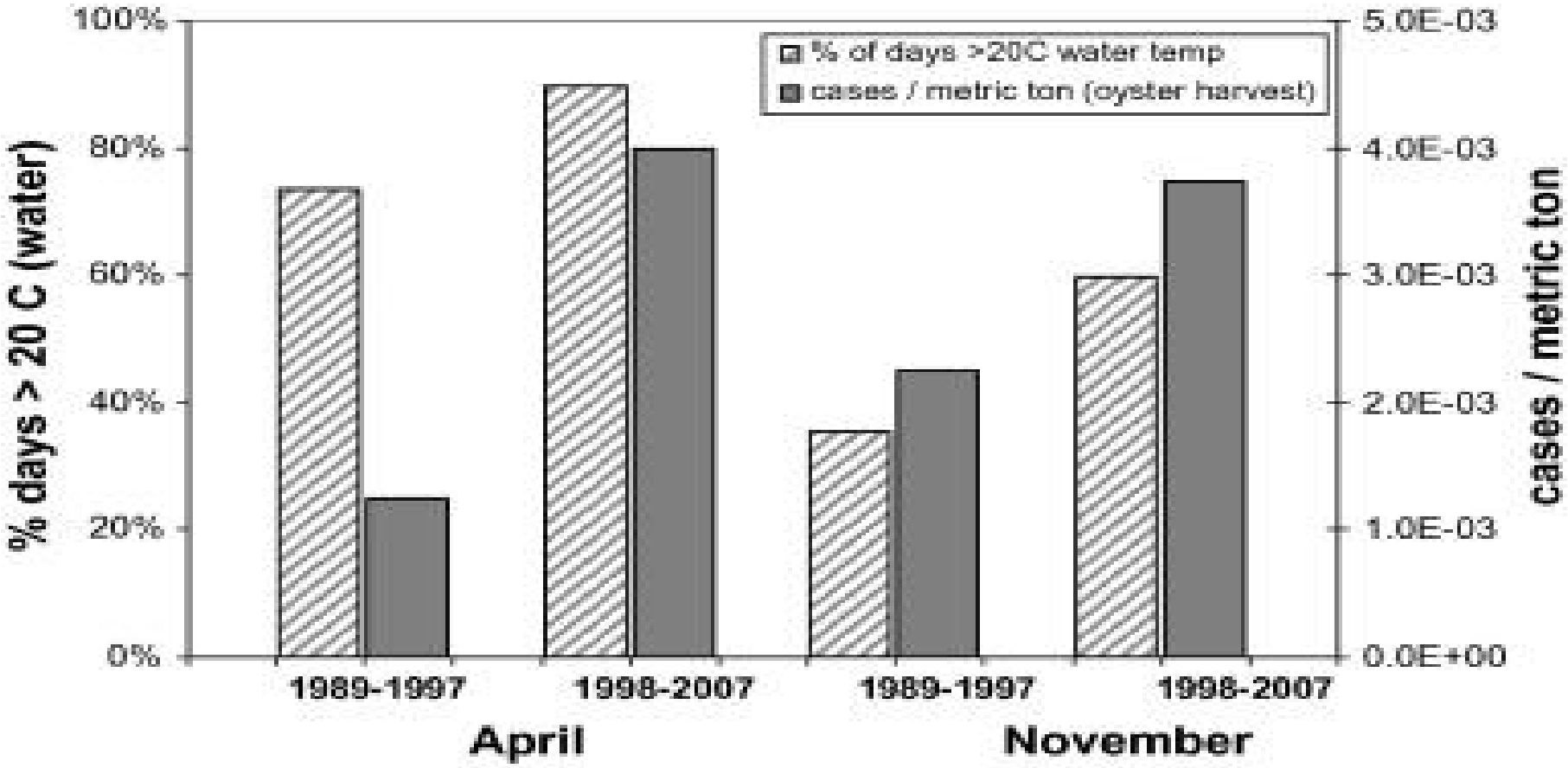
- ***V. cholerae* occurs in US waters too!**
- **Vp and Vv most common cause of seafood poisonings** - underreported, misdiagnosed and increasing
- **Vv can result in death** ~ 200 '89 - '04 & 5 confirmed deaths related to Katrina; associated with 95% of fatalities associated with seafood consumption. 50-60% fatality rate for susceptible individuals; wound infections kill 20-30% of healthy individuals affected.
- **Vp estimated at 8,000 cases per year**, but this is thought to be very low due to under reporting; Not Officially Reported to CDC until 2007; Outbreaks all over the US including 1st time in Alaska in 2004.
- ***Vibrio* infection rates have increased 41% over the last decade.**
- **Rate of Antibiotic Resistance in Vibrios has increased 31% over the past decade (Colwell et al, 2009)**

V. parahaemolyticus in Outbreak in Alaska

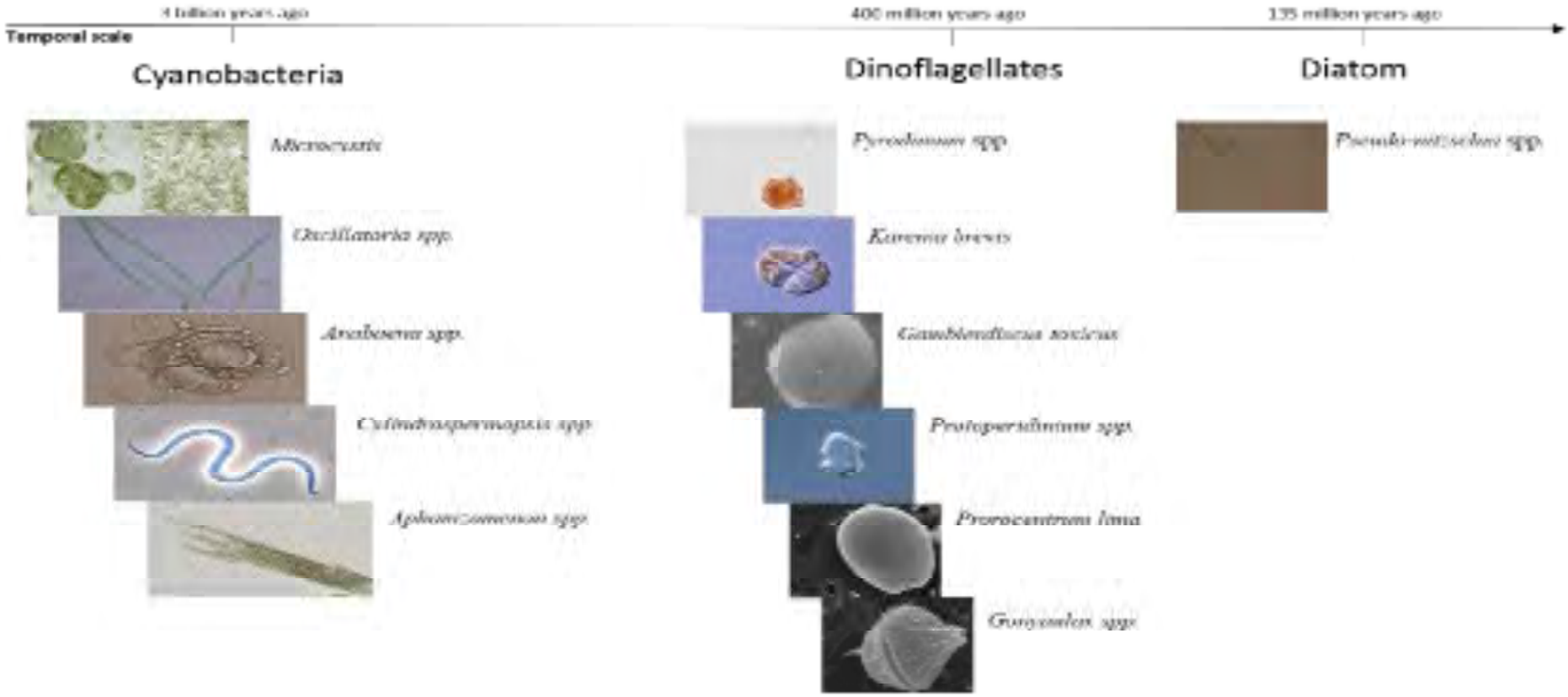


V. vulnificus Cases and Effects of Temperatures > 20°C

(Martinez et al. 2010. Food Research International, Volume 43 (7): 1780-1790)



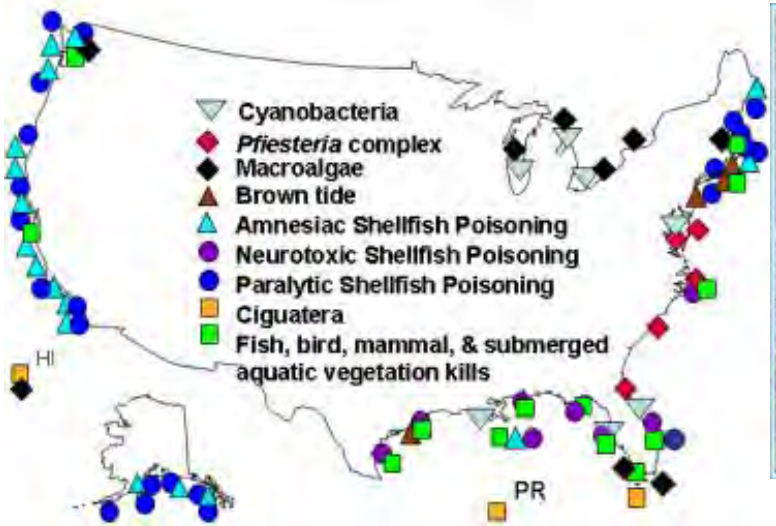
Major Types of Harmful Algae

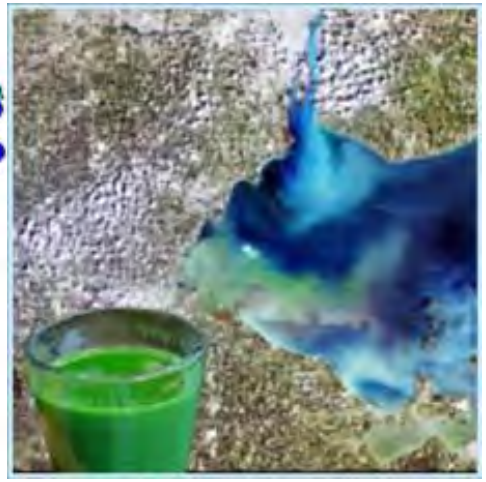


Freshwater HAB

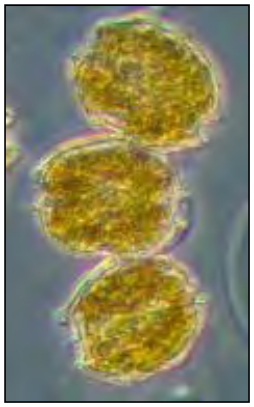
Marine HAB

Harmful Algal Blooms (HABs)





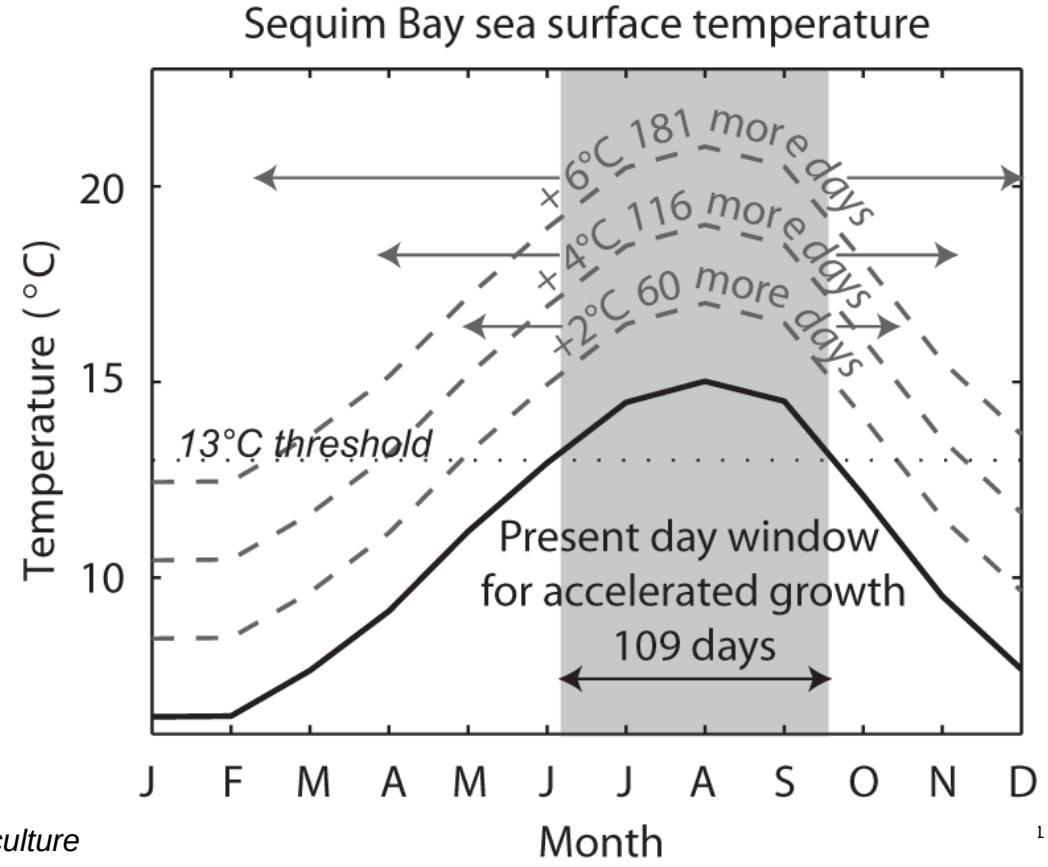
Case Study: Rising Temperatures Increase Window For HAB Growth In Puget Sound



Alexandrium catenella

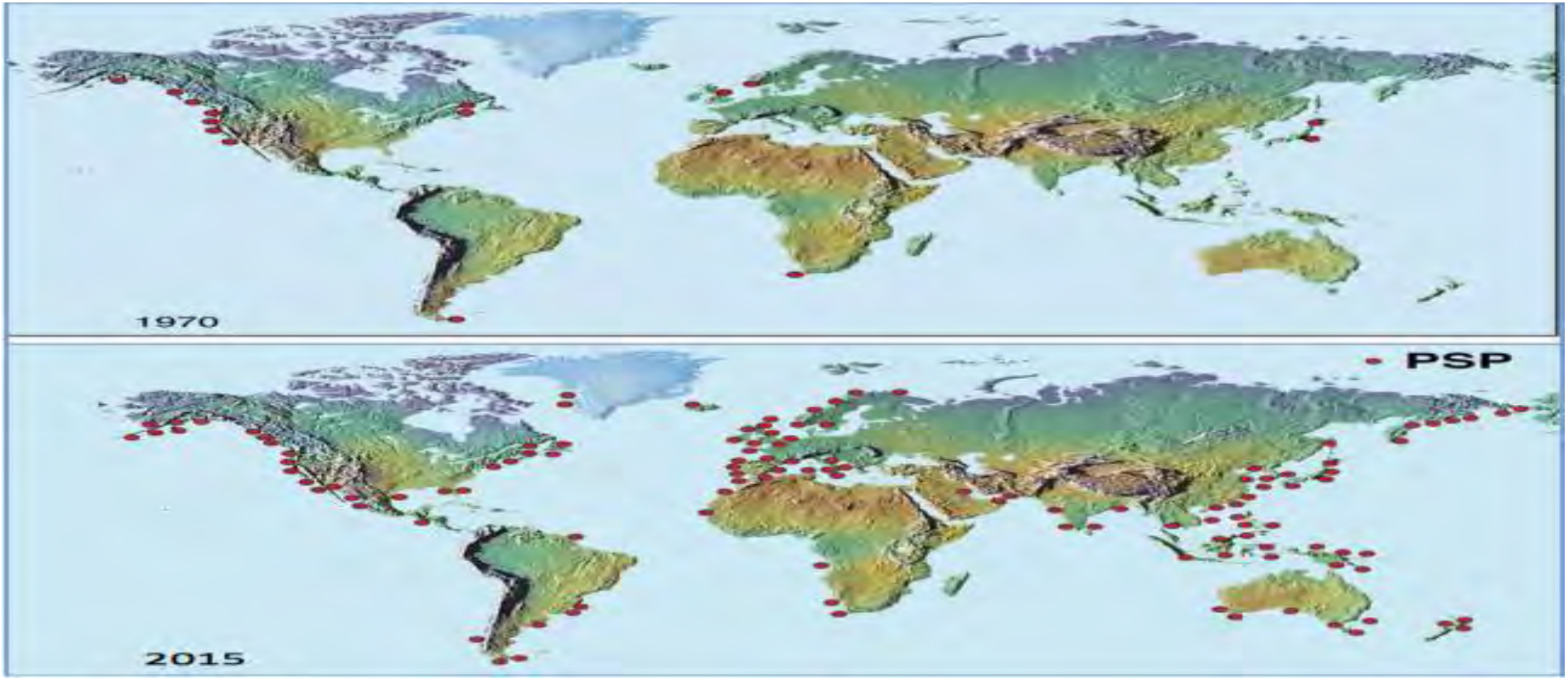
- Evidence for accelerated growth when water temperatures >13˚ C

Nishitani and Chew (1984): Aquaculture



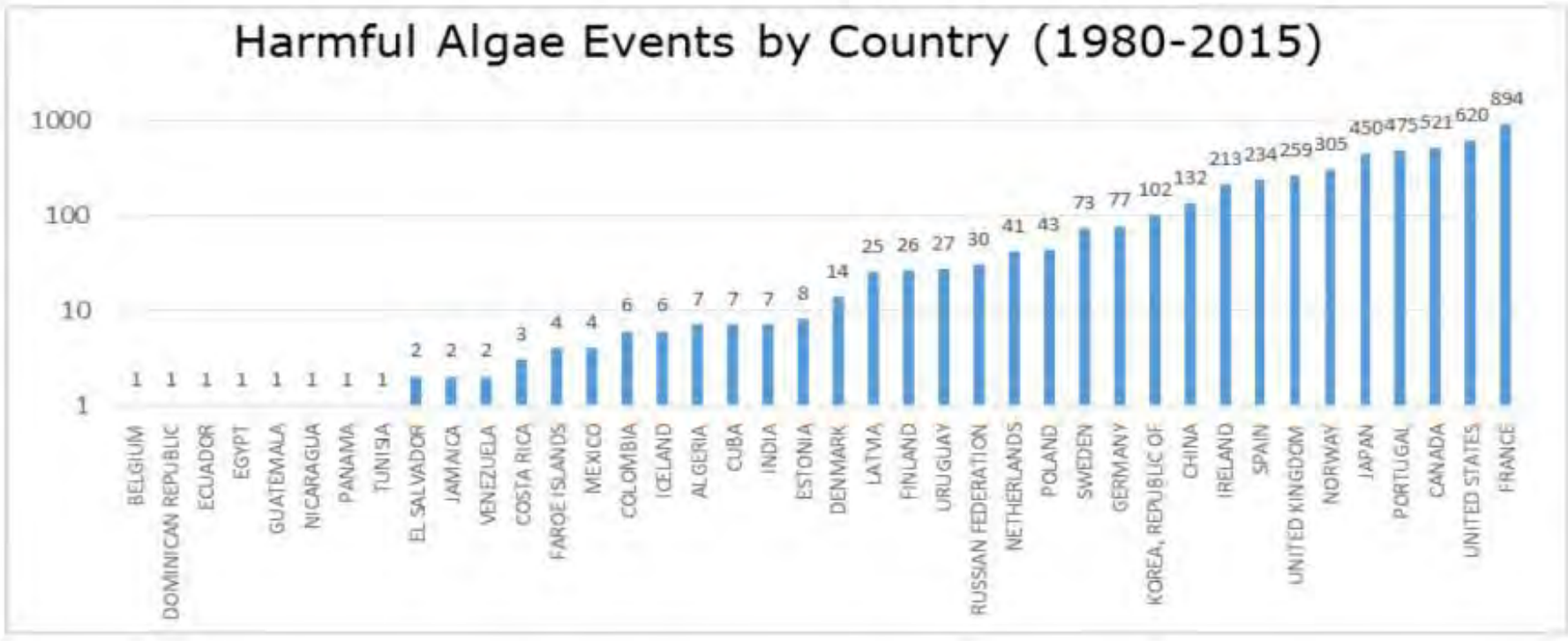
Moore et al. (in review): Environmental Health

Historical Comparison of PSP

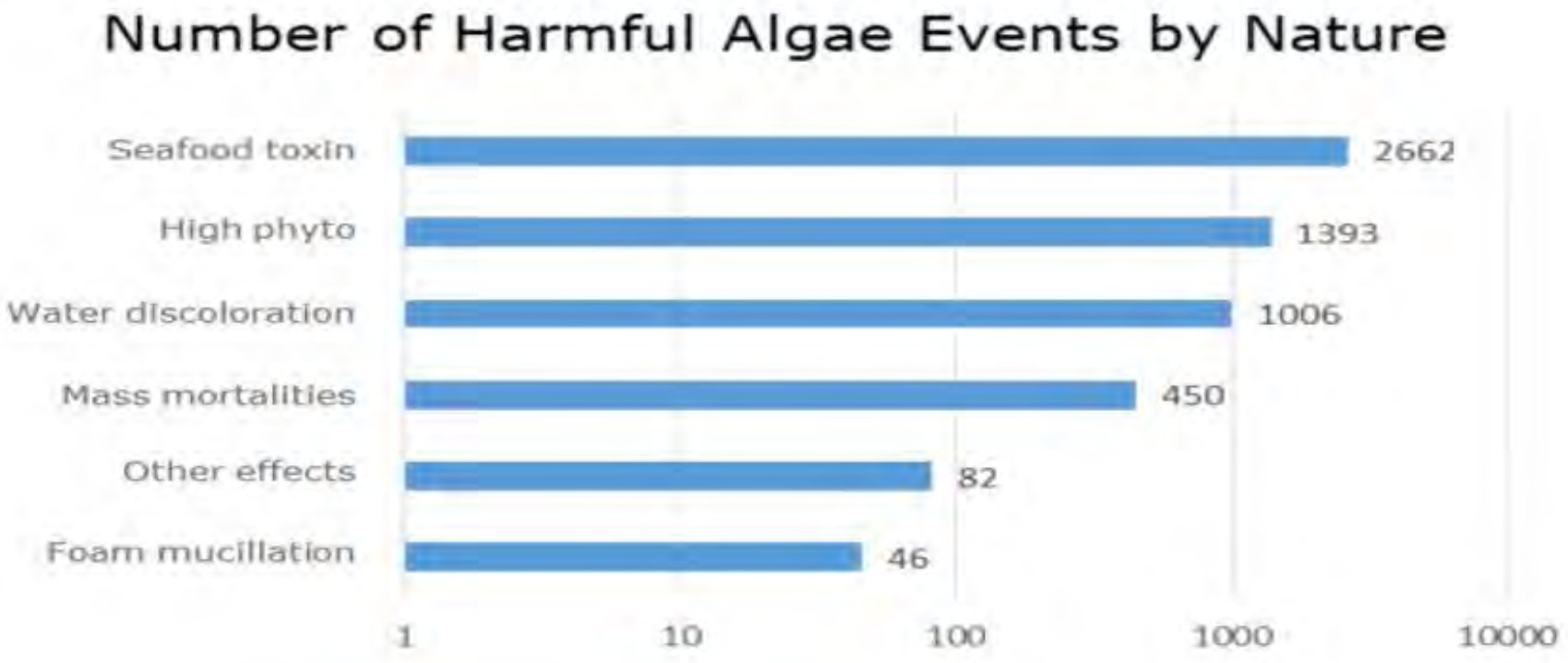


PSP = Paralytic Shellfish Poisonings

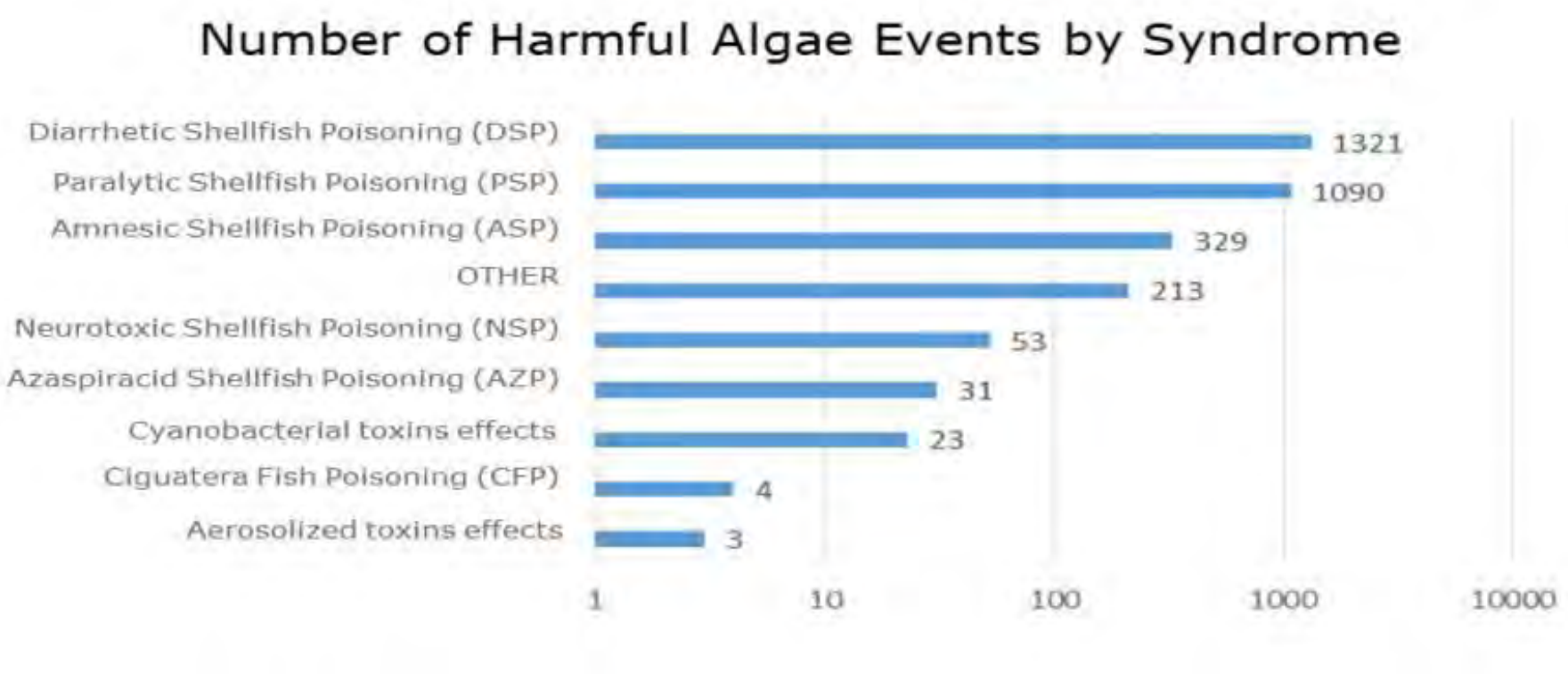
Harmful Algal Events Dataset (HAEDAT)



Sources of HAB Exposure and Effects HAEDAT 1980-2015



Number of Harmful Algal Events 1980-2015



Human Illness Measured in HAB Events in the US : 2007-2011 (HABISS)

Human Illness	Number of Cases (%)
Ciguatera fish poisoning	248 (54)
Rash from unknown organism or toxin	89 (19)
Illness from unknown organism or toxin	49 (11)
Microcystin poisoning	28 (6)
Other cyanobacteria- or algae-related illness not specified in HABISS	27 (6)
Paralytic shellfish poisoning (saxitoxins)	13 (3)
Neurotoxic shellfish poisoning (brevetoxins)	2 (<1)
Anatoxin poisoning	1 (<1)
Amnesic shellfish poisoning (domoic acid)	1 (<1)
Total	458

(**Source:** Backer at al. 2015. *Toxins 7*: 1048-1064)

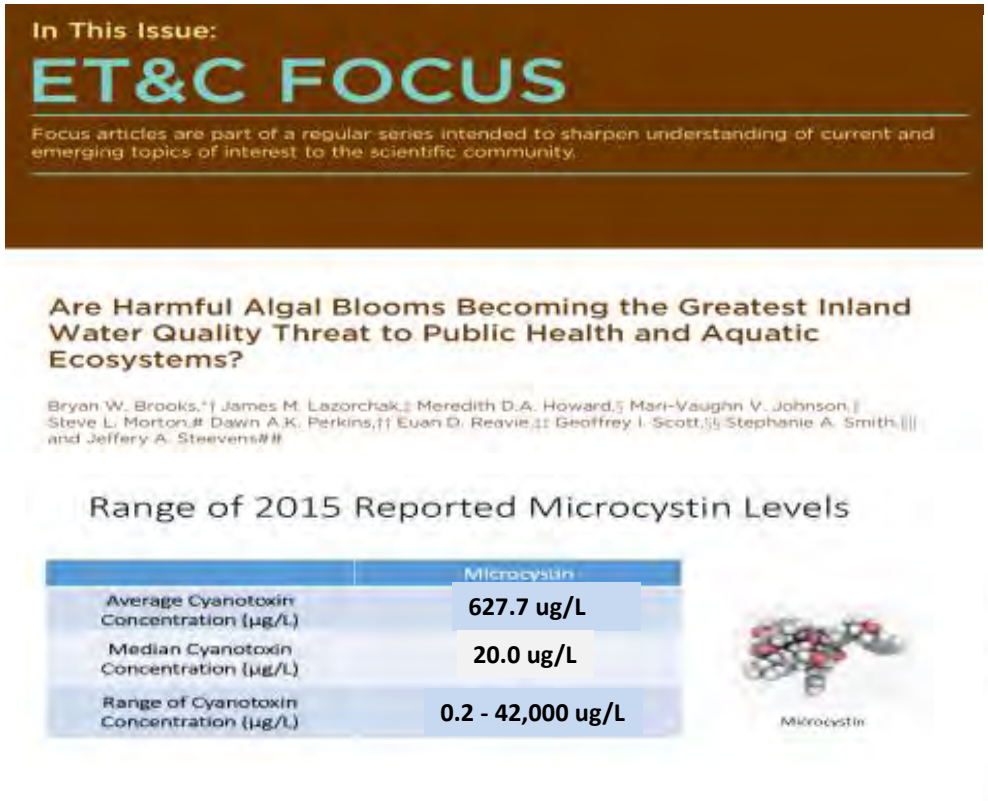
HABs in the US 2007-2011 Reported by CDC in HABISS

Toxin	Water Type				
	Fresh	Brackish	Marine	Unknown	Total (%)
Anatoxin	243	2	0	1	246 (7)
Azaspiracid	0	0	1	0	1 (<1)
Brevetoxoins	0	3	0	0	3 (<1)
Cylindrospermopsin	4	0	0	0	4 (<1)
Domoic Acid	0	0	31	0	31 (1)
Karlotoxins	0	3	1	0	4 (<1)
Microcytins Total	2629	35	2	10	2676 (81)
Microcytsin LR	21	0	0	0	21 (1)
Okadaic Acid	1	2	0	0	3 (<1)
Saxitoxins	296	1	11	3	311 (9)
Unidentified Toxin	0	1	0	0	1 (<1)
Total	3194	47	46	14	3301

96.7% of HABs occur in Freshwater

(Source: Backer et al. 2015. *Toxins* 7: 1048-1064)

Are HABs Becoming the Greatest Inland Water Threat to Public Health


In This Issue:

ET&C FOCUS

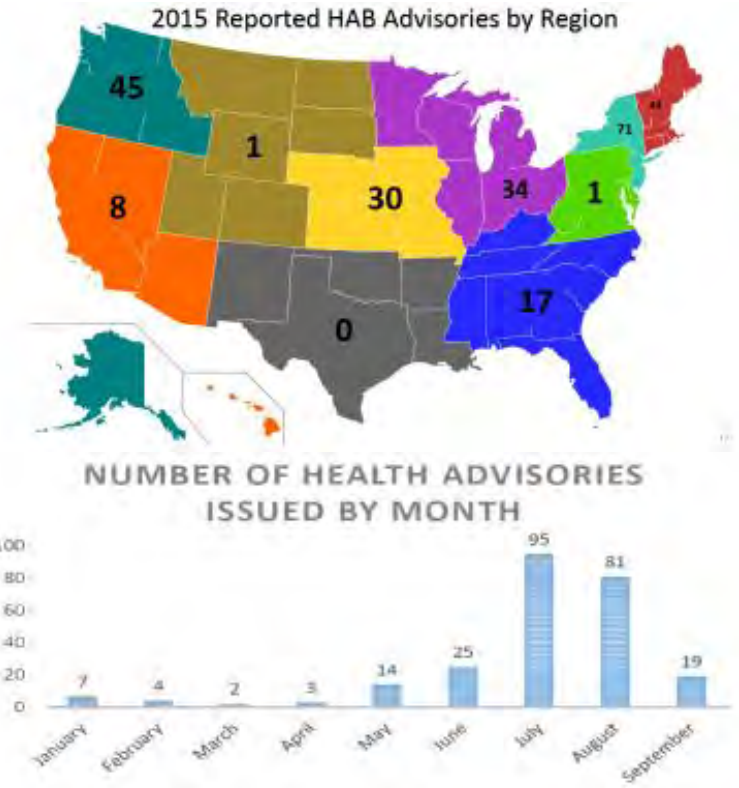
Focus articles are part of a regular series intended to sharpen understanding of current and emerging topics of interest to the scientific community.

Are Harmful Algal Blooms Becoming the Greatest Inland Water Quality Threat to Public Health and Aquatic Ecosystems?

Bryan W. Brooks,*† James M. Lazorchak,‡ Meredith D.A. Howard,§ Mari-Vaughn V. Johnson,‖ Steve L. Morton,# Dawn A.K. Perkins,†† Euan D. Reavie,‡‡ Geoffrey I. Scott,§§ Stephanie A. Smith,‖‖ and Jeffery A. Steevens###

Range of 2015 Reported Microcystin Levels

	Microcystin
Average Cyanotoxin Concentration (µg/L)	627.7 ug/L
Median Cyanotoxin Concentration (µg/L)	20.0 ug/L
Range of Cyanotoxin Concentration (µg/L)	0.2 - 42,000 ug/L



(Sources: Brooks et al. 2015. ETC; Ravencroft, J. 2016. Update on Development of Recreational WQC for Cyanotoxins. EPA Office of Water**)**

Toxic Algae in FL: May- July 2016

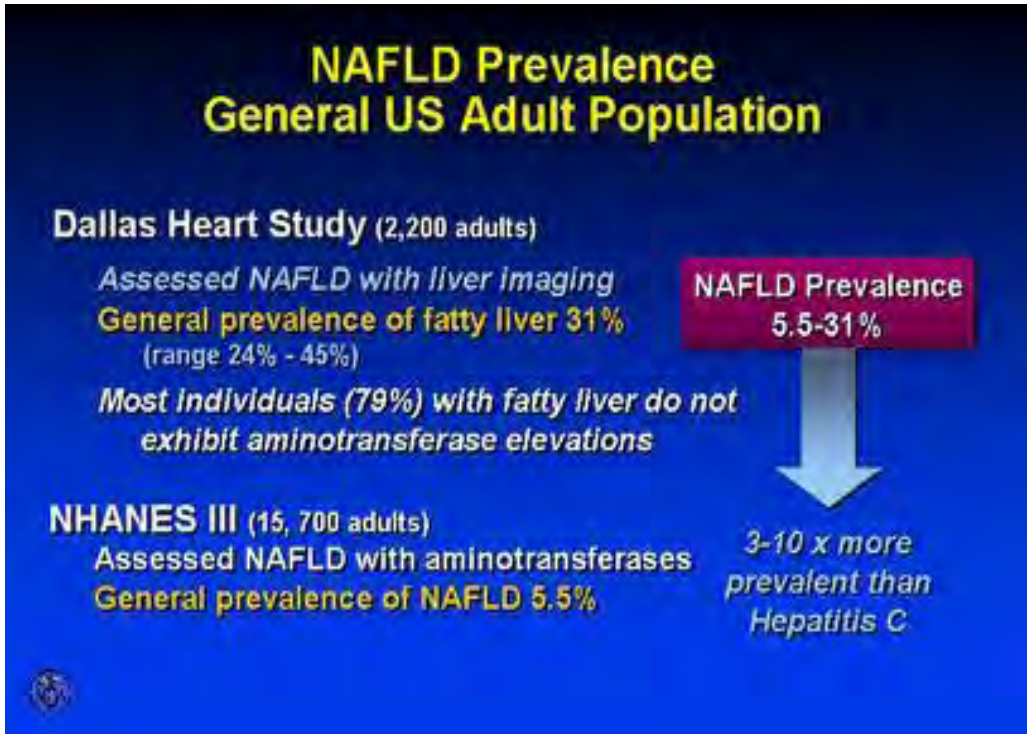
Toxic Algae in the St Lucie River in Stuart,FL: May-July 2

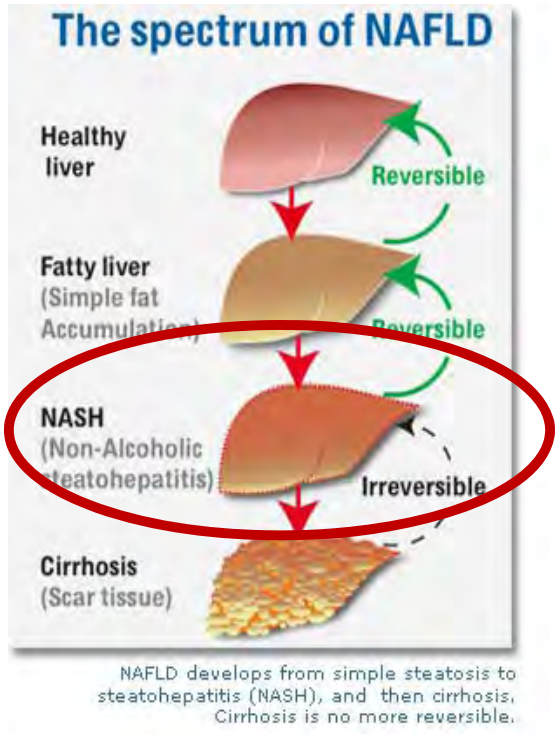
University of South Carolina

Red Tide Spread to Florida's Atlantic Coast Affecting Some of the Most Popular Beaches

- The red tide bloomed off the Florida east and west coasts for nearly 17 months, from November, 2017-February, 2019.
- Trey Claus, whose family has been commercial fishing off southeastern Florida for three generations, has never seen anything like it -- and neither has anyone he knows. "This might put a halt to our season, which is not a good thing," Claus, 30, said.
- In Miami-Dade County, public beaches that had been closed because of red tide announced Mayor Carlos Gimenez, who'd closed some beaches "in an abundance of caution."
- "Please bear in mind that the Florida Department of Health advises people with severe or chronic respiratory conditions, such as asthma, to avoid red tide areas," the mayor said in a statement.

NAFLD: Hepatic Manifestation of Metabolic Syndrome



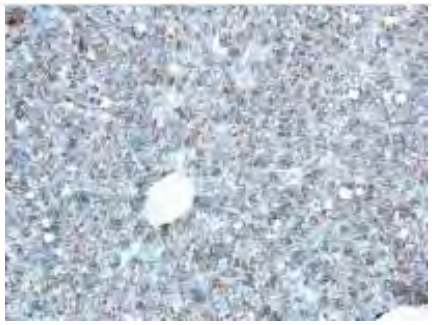


NAFLD develops from simple steatosis to steatohepatitis (NASH), and then cirrhosis. Cirrhosis is no more reversible.

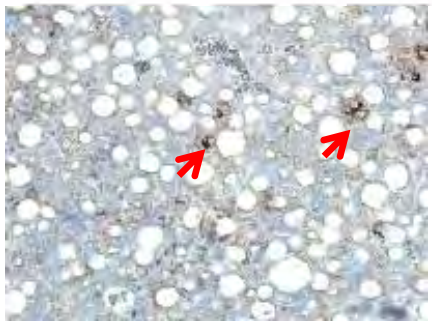
Source: American Gastroenterology Association, 2014

Microcystin-Exposure in NAFLD Mice Leads to Stellate Cell Activation in the Liver (Pre Fibrotic Stage)

Alpha-Smooth Muscle Actin (marker for activated stellate cells)

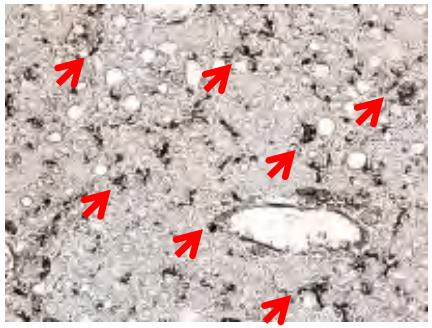


Healthy Controls



NAFLD

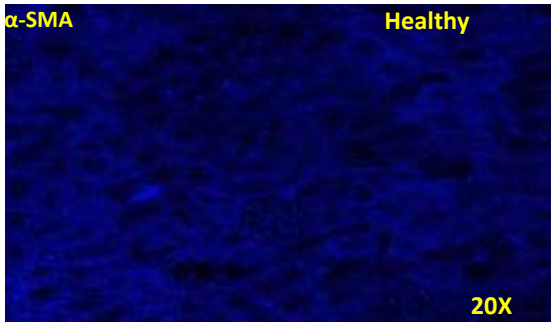
Healthy+ Microcystin

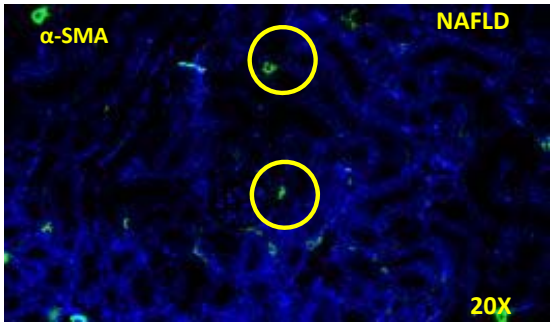


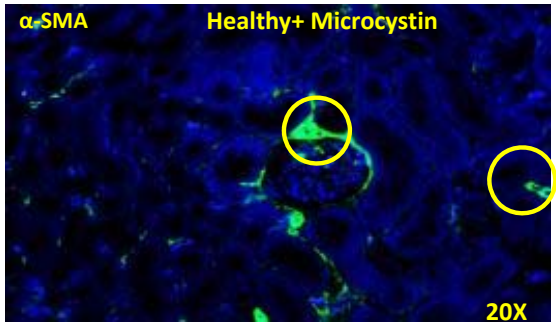
NAFLD + Microcystin

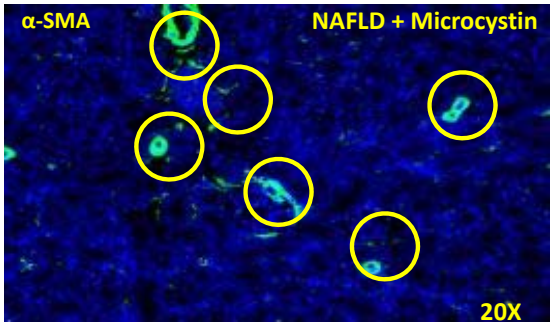
Microcystin exposure Leads to Increased Glomerular Inflammation in NAFLD-kidney

Alpha-SMA is a marker for mesangial cell activation crucial for glomerular inflammation





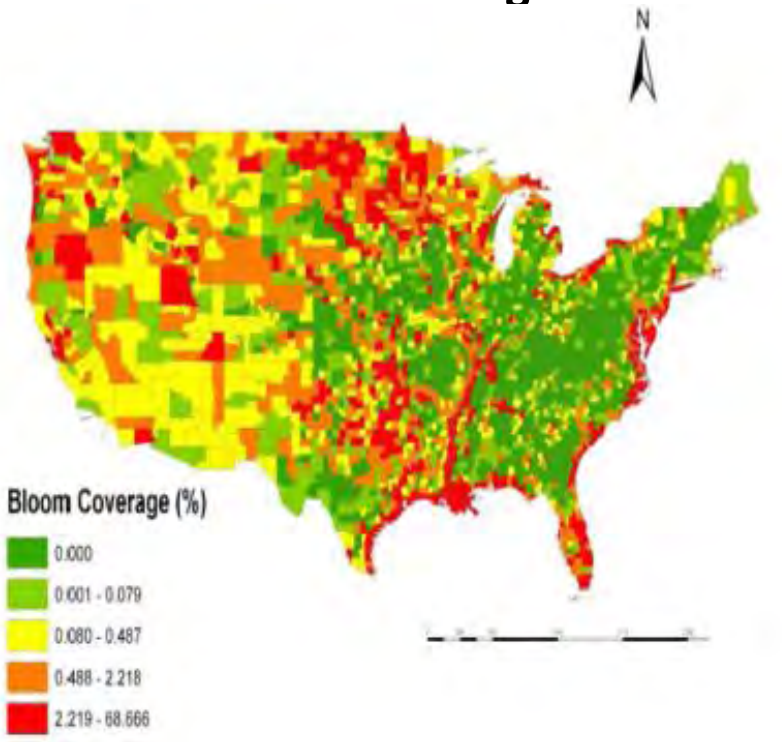




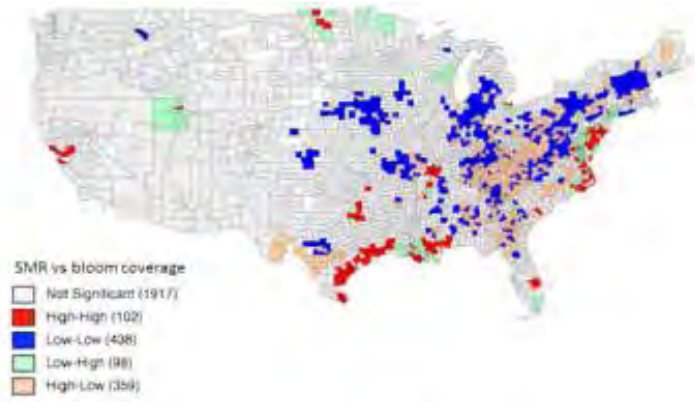
Correlation Between CHAB Blooms and Non-Alcoholic Fatty Liver Disease

(61% of US Counties Have CHABs and for Every 1% increase in CHABs Results in a 0.3% Increase in Non-Alcoholic Fatty Liver Disease)

CHAB Bloom Coverage



Fatty Liver Disease & CHABs



(**Source:** Zhang et al. 2015. Env. Health 14: 41-52)

Serum Microcystin Levels Positively Linked with Risk of Hepatocellular Carcinoma: A Case-Control Study in Southwest China

- Microcystins have been reported to be carcinogenic by animal and cell experimentation, but there are no data on the linkage between serum microcystins and hepatocellular carcinoma (HCC) risk in humans.
- In China a clinical case-control study was conducted to investigate the association between serum microcystins (MC-LR) and HCC risk after controlling several known risk factors, such as hepatitis B virus, alcohol consumption, and aflatoxin.
- The adjusted odds ratio for HCC risk by serum MC-LR was 2.9 (95% confidence interval [CI], 1.5-5.5) in all patients – establishing a clear relationship between MC-LR and HCC.
- Potential Additive Toxicological Interactions were investigated between MC-LR and hepatitis B virus infection (synergism index = 3.0; 95% CI, 2.0-4.5) and between MC-LR and alcohol (synergism index = 4.0; 95% CI, 1.7-9.5) = ***Suggesting Potential Synergism***

(Reference: Zheng et al, 2017. Hepatology 66(5):1519-1528. doi: 10.1002/hep.29310)

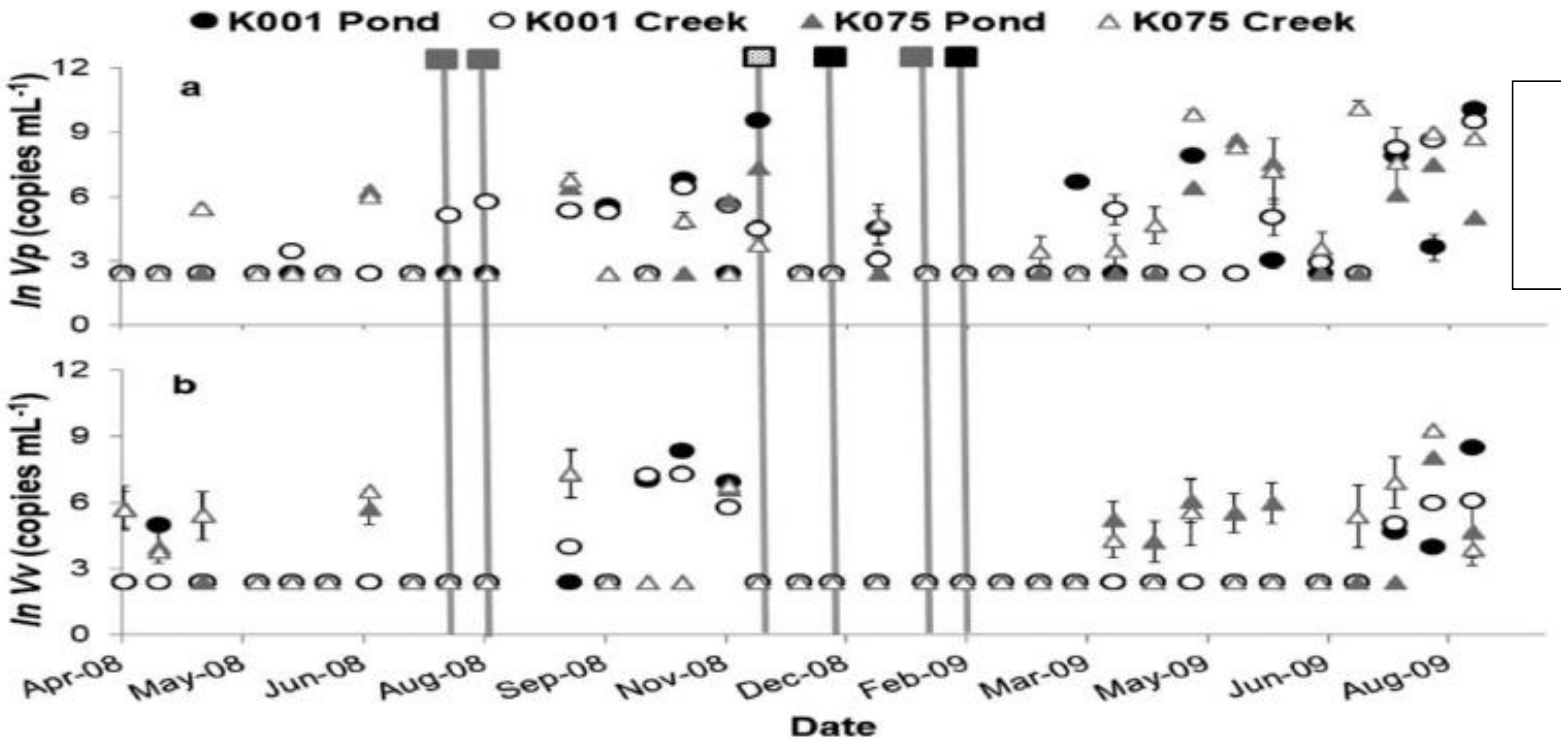
SC Sea Grant: Urbanization and Stormwater Ponds in SC

- To control the NPS pollution associated with this coastal urbanization, stormwater ponds have been constructed to collect runoff and reduce pollution loadings in estuarine tidal creeks.

- Many are constructed in urban areas associated with residential development.

- **SC** - 21,594 Ponds Total with a cumulative area of 29,395 acres of ponds (45.9 sq. miles) (Dr. Eric Smith, 2016)

Co-Occurence of Vibrios and HABs in Retention Ponds and Tidal Creeks

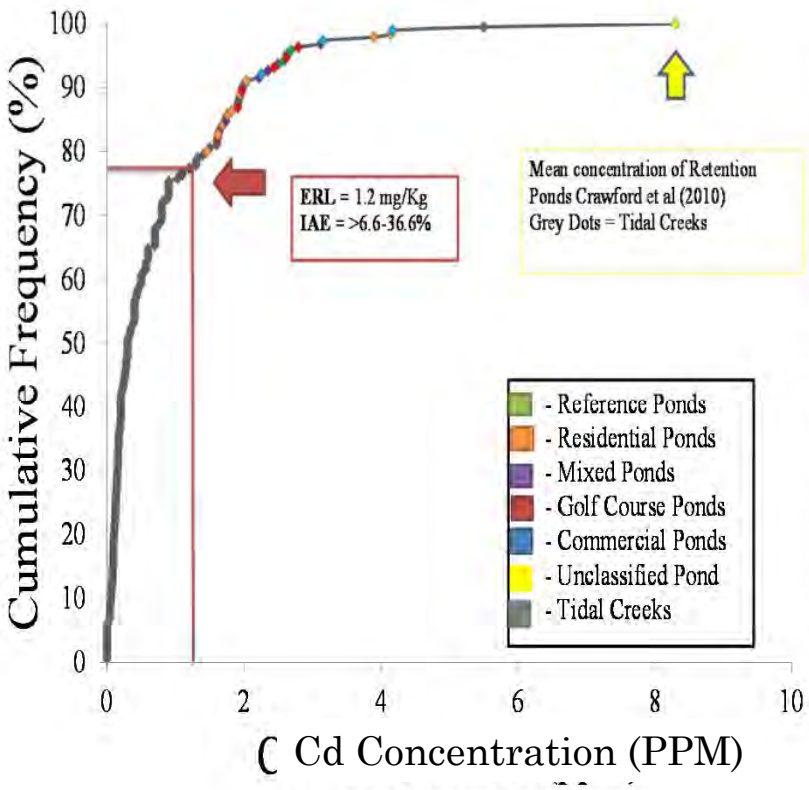


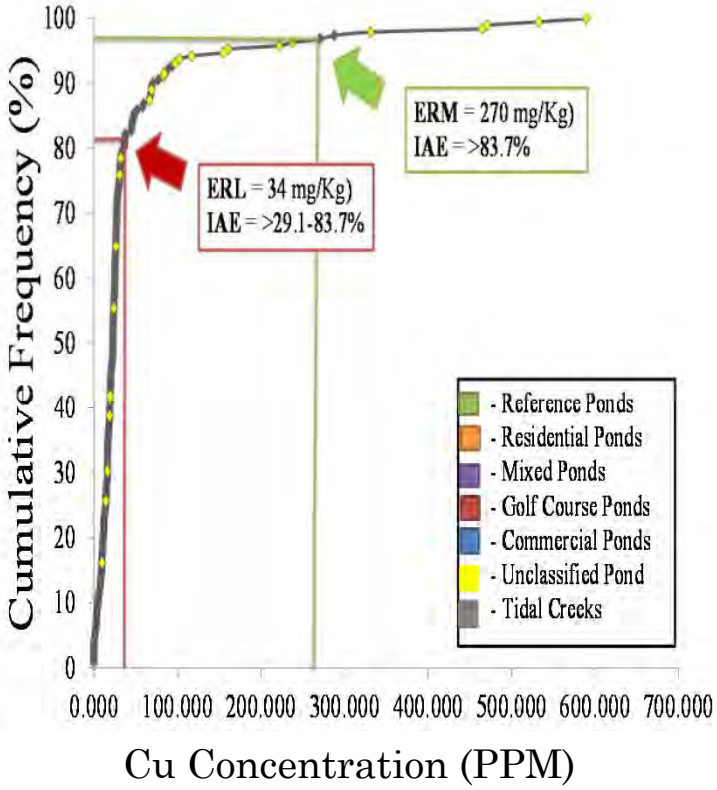
HABs Events (Cyanobacteria & Dinoflagellates)during warmer months (Aug- Nov) were followed by increased Vibrio abundances in both species while HAB events (dinoflagellates and euglenophytes) during cooler months(Dec-Feb) were not.

Vibrios Abundances were highly correlated with Temperature, DOM, and HAB Blooms!

(Source: Greenfield et al., 2017. GeoHeath10.1002/2017GH000094)

Cumulative Frequency Plots: Metals





Sediment Trace Metals

Trace Metal	≤ERL	> ERL	>ERM
Ag	100%		
As	35 %	65%	
Cd	77.8%	22.2%	
Cr	75%	23.9%	1.1%
Cu	75.8%	20.5%	3.7%
Hg	90.5%	9.5%	
Ni	69.1%	30.9	
Pb	91.3%	8.7%	
Zn	85.6%	12.8%	1.6%

Red = Retention Ponds had Highest Concentration
Orange = Retention Ponds had 2nd Highest Concentration
>ERL = As, Cd, Ni, Pb and Hg
>ERL & ERM = Cr, Cu and Zn

Trace Metal Pollution and Antibiotic Resistance

Resistance mechanism	Metal ions	Antibiotics	Refs
Reduction in permeability[b]	As, Cu, Zn, Mn, Co, Ag	Cip, Tet, Chlor, ß-lactams	[68,69]
Drug and metal alteration[c]	As, Hg	ß-lactams, Chlor	[70,71]
Drug and metal efflux[d]	Cu, Co, Zn, Cd, Ni, As	Tet, Chlor, ß-lactams	[72,73]
Alteration of cellular target(s)[e]	Hg, Zn, Cu	Cip, ß-lactams, Trim, Rif	[74,75]
Drug and metal sequestration[f]	Zn, Cd, Cu	CouA	[76,77]

[a]Abbreviations: Chlor, chloramphenicol; Cip, ciprofloxacin; CouA, coumermycin A; Rif, rifampicin; Tet, tetracycline; Trim, trimethoprim.

[b]Includes reduction of membrane permeability to metals and antibiotics.

[c]Includes drug and metal inactivation and modification.

[d]Includes rapid efflux of the metal and antibiotic.

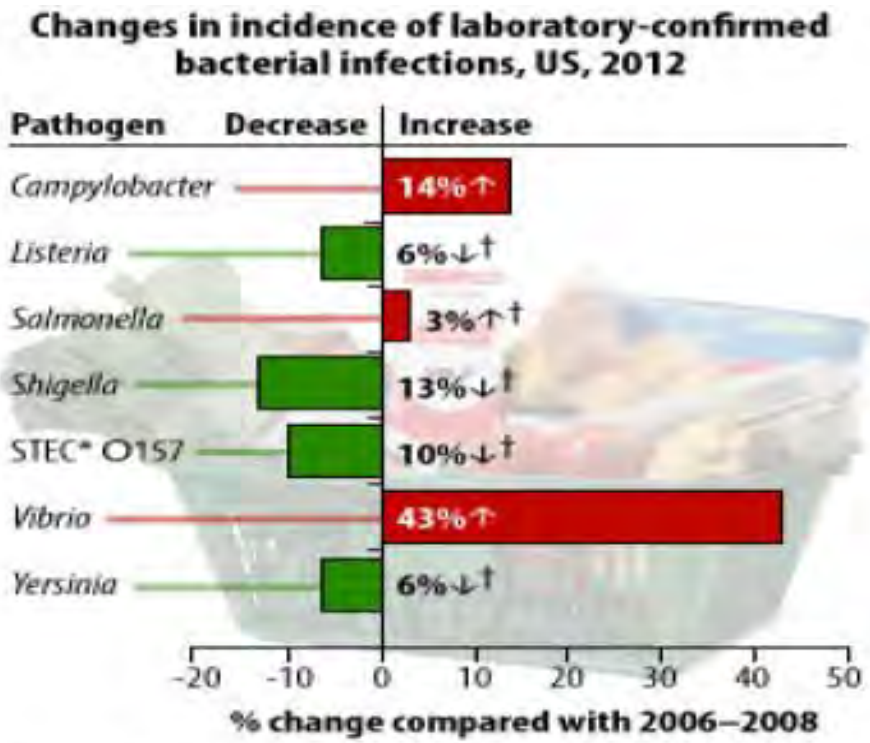
[e]Includes alteration of a cellular component to lower its sensitivity to the toxic metal and antibiotic.

[f]Includes drug and metal sequestration.

Retention Ponds had the Highest Concentrations of Cd, Cu, Cr, & Zn

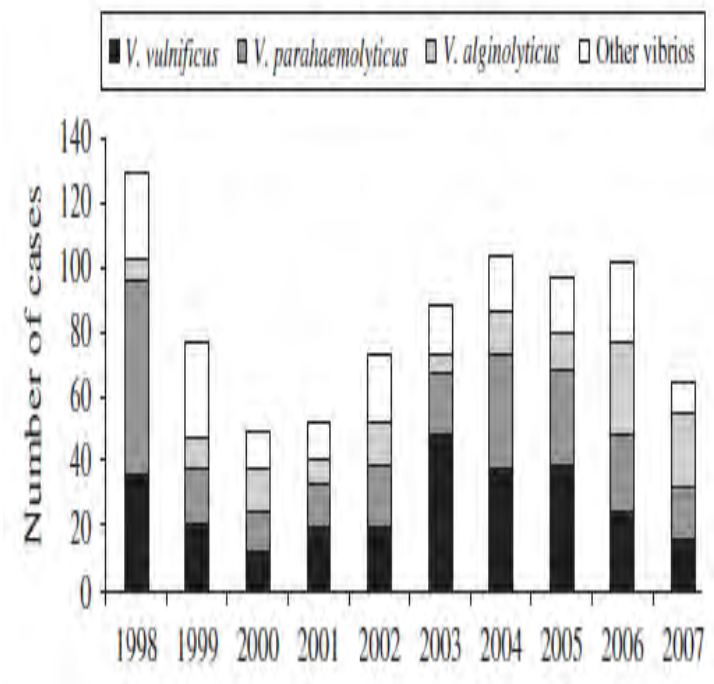
(Source: Baker-Austin et al. 2006. Trends in Microbiology 14(4): 176-182)

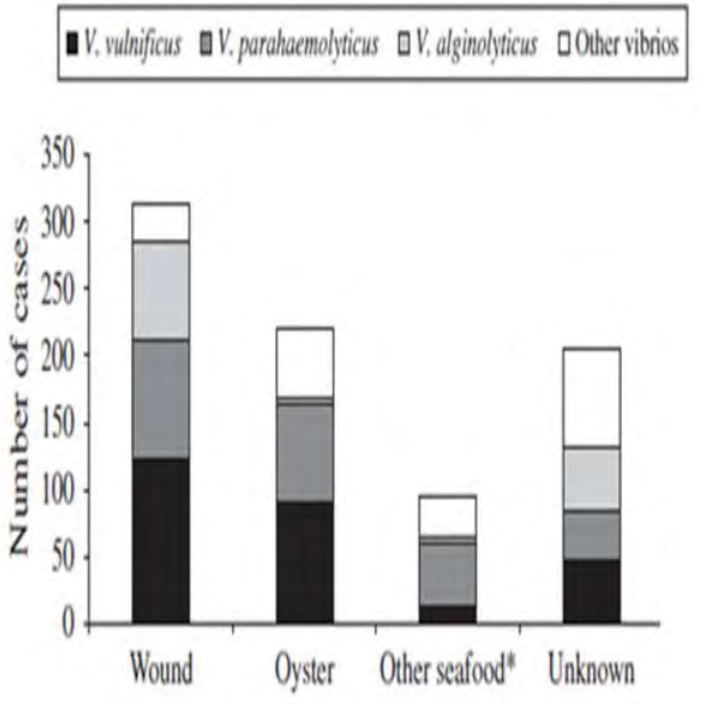
US Bacterial Illness Increase 2012 vs. 2006-2008



http://www.cdc.gov/features/dsfoodnet2012/figure1.html

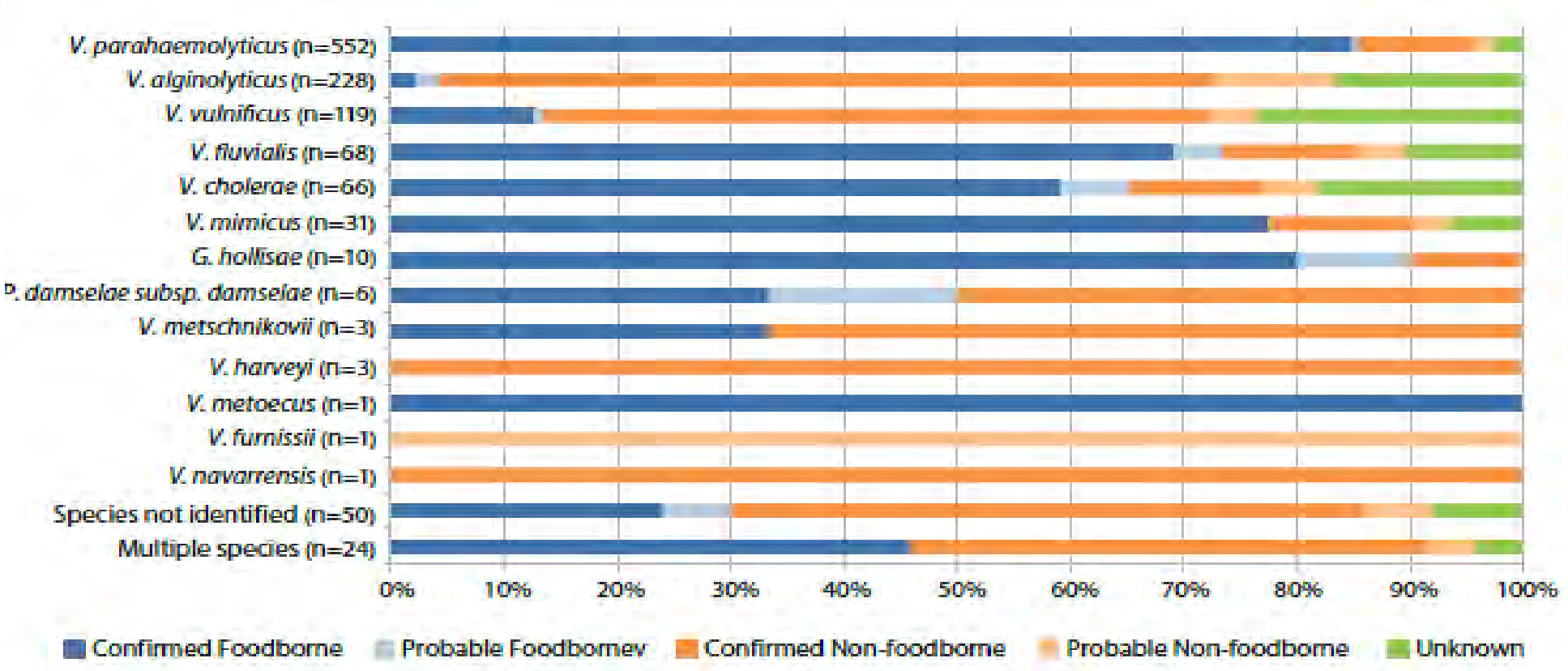
Vibrio Illnesses in FL, 1998-2007



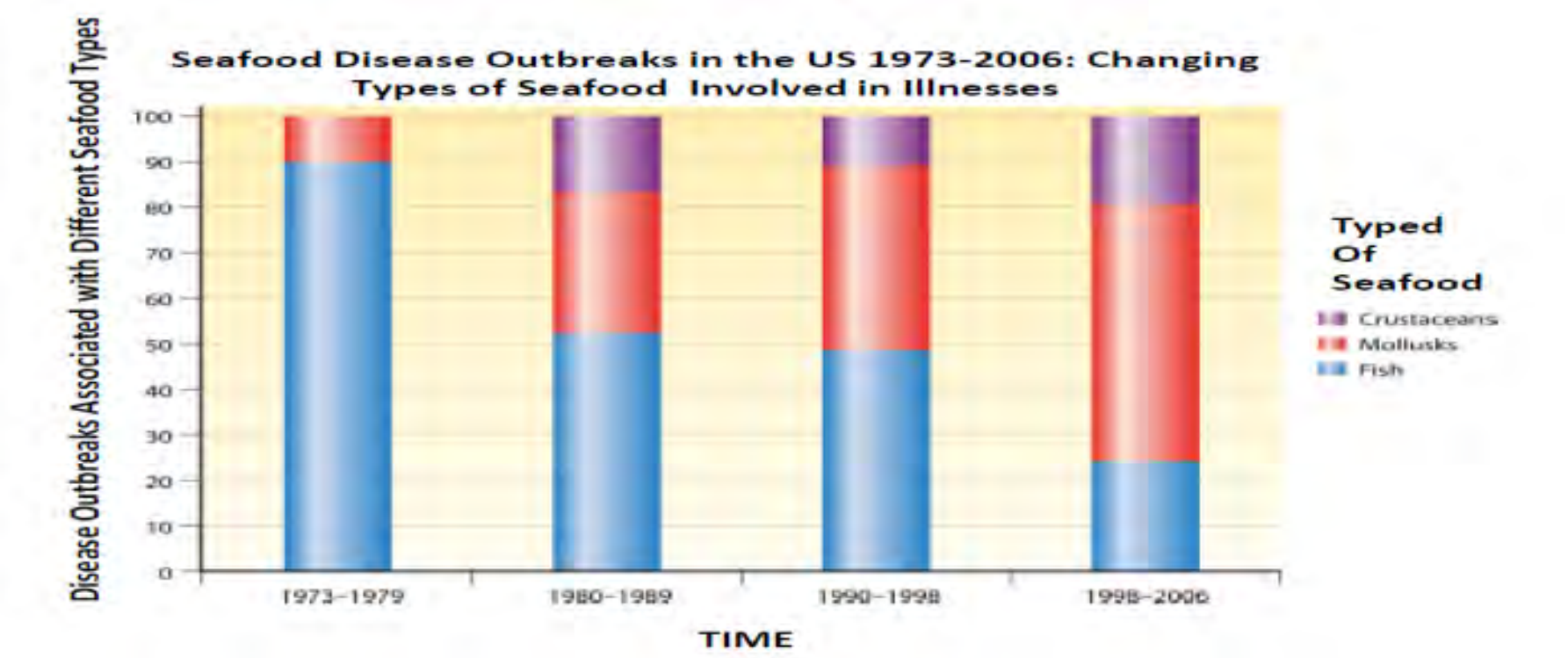


(Weis et al., 2011. Epidemiol. Infect. 139: 591-598)

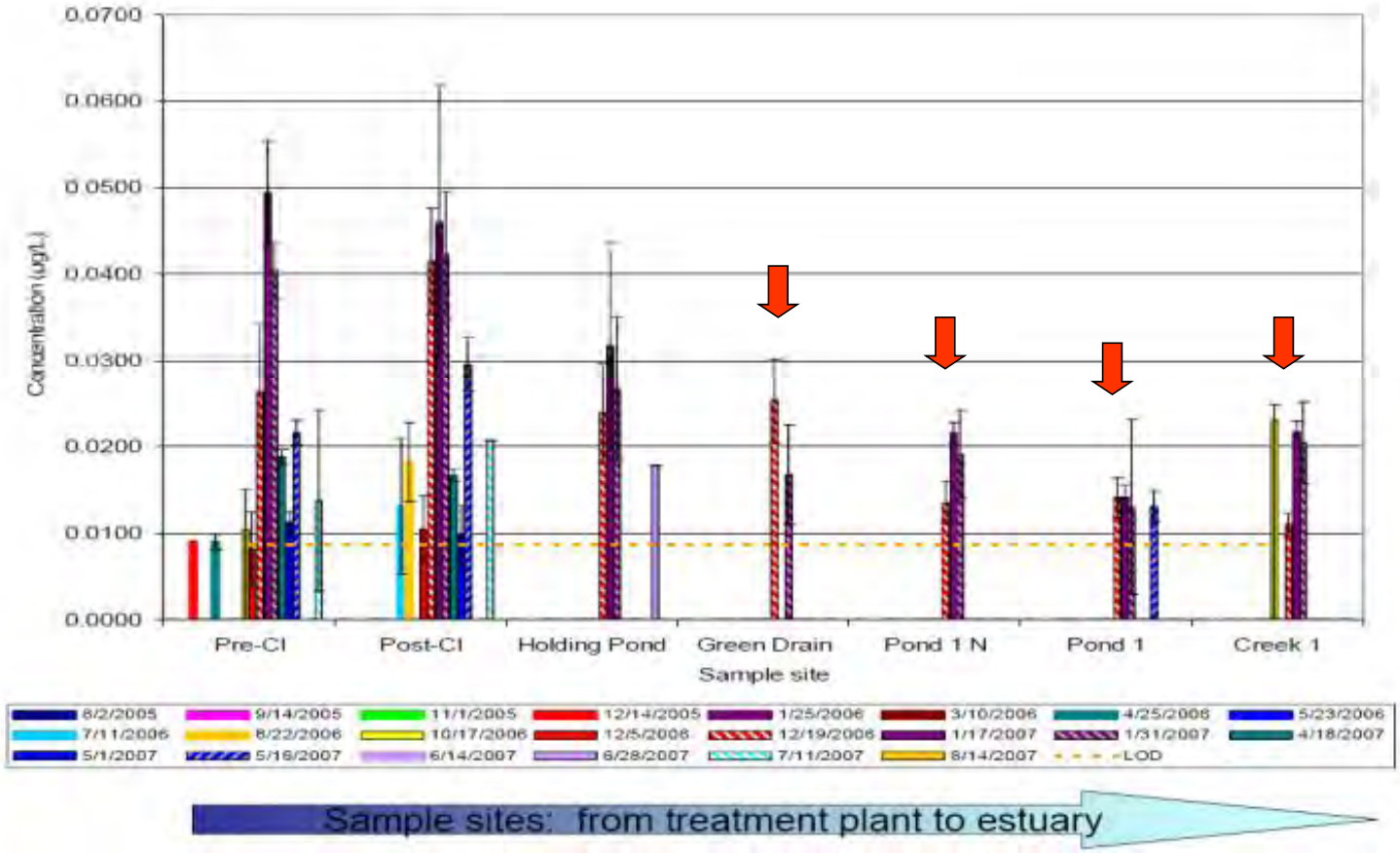
Vibriosis in the US 2014



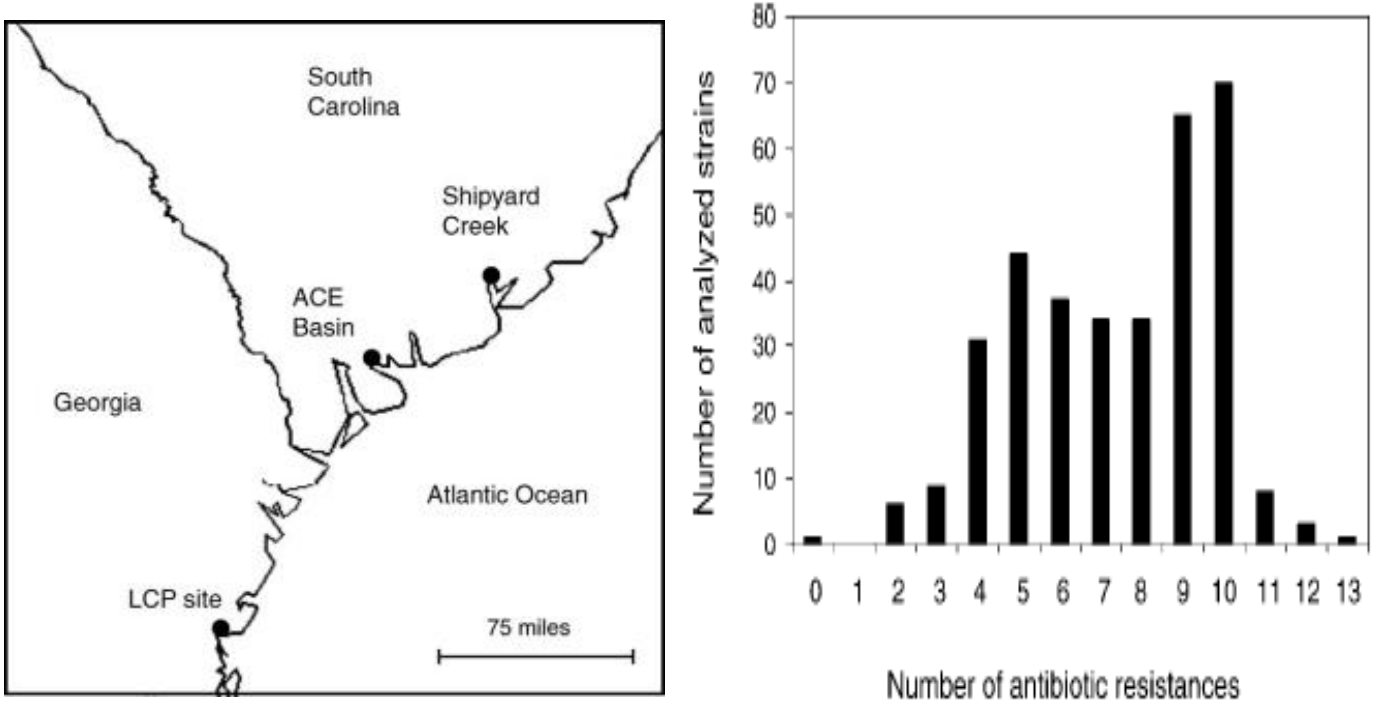
Changing Nature of Seafood Illness in the US: 1973-2006



Oxytetracycline Findings



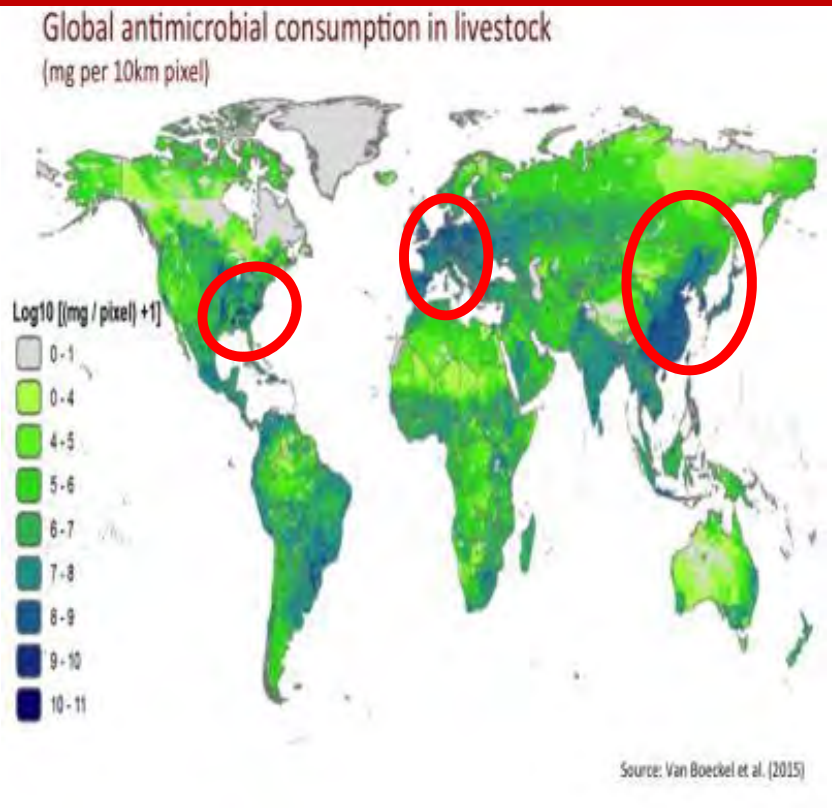
Antibiotic Resistance in *Vibrio parahaemolyticus*



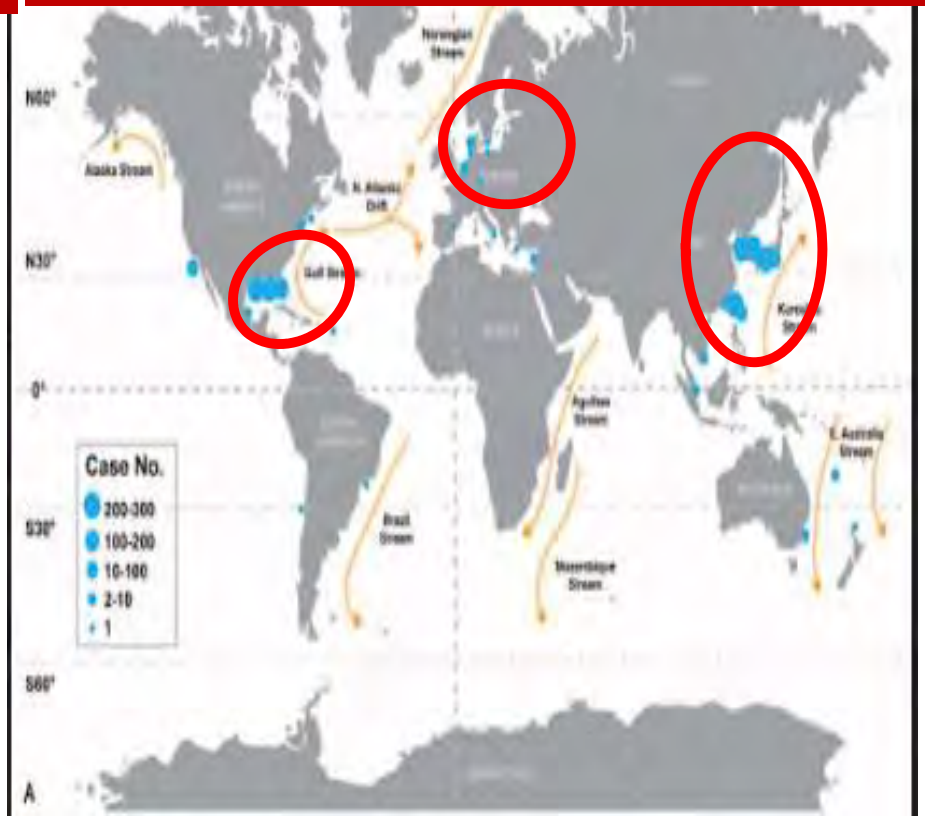
(Baker–Austin et al., 2008. Journal of Food Protection 71:2552)

A Comparison of Vibrio Illnesses and the Use of Antibiotics in Livestock

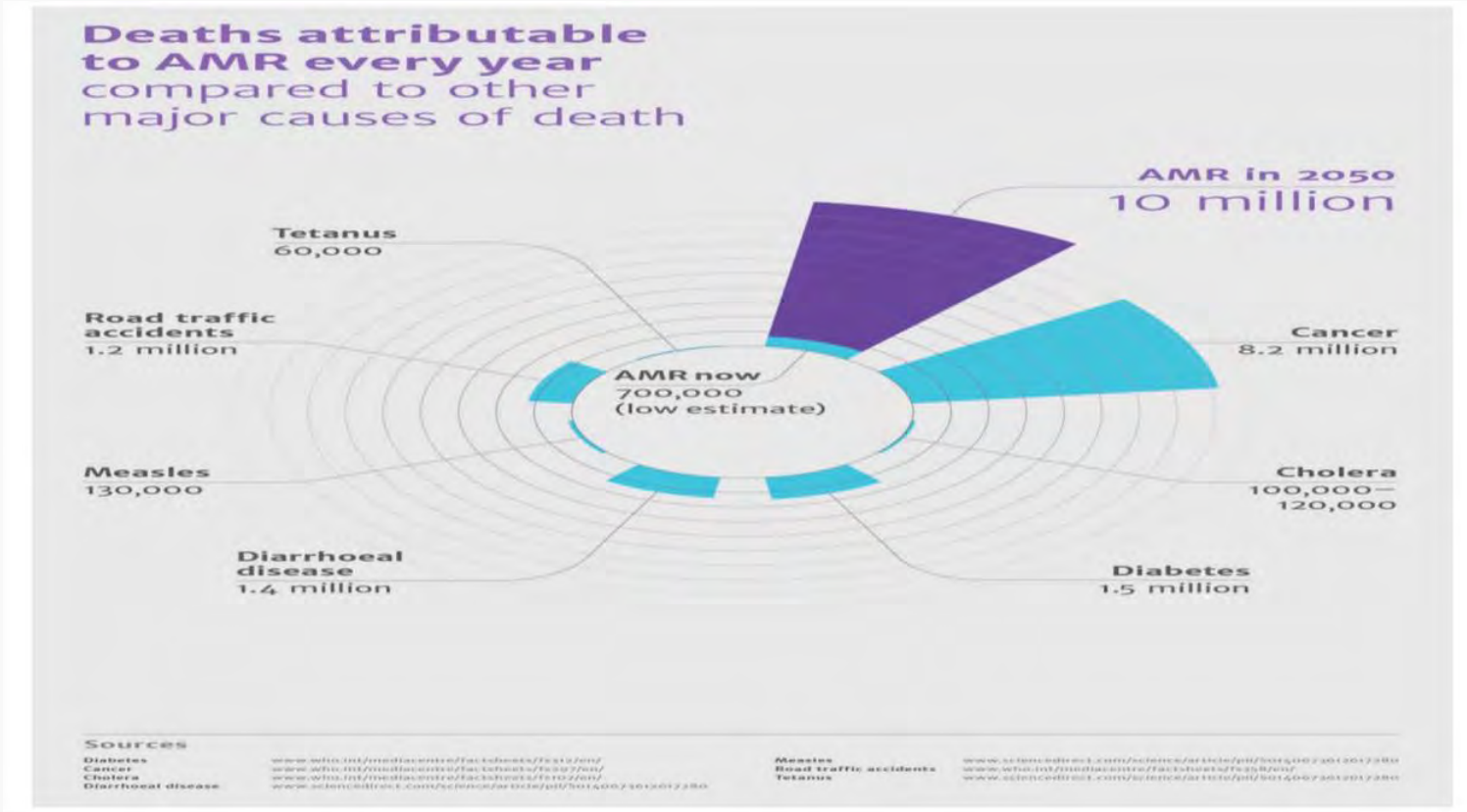
Antibiotic Resistance World- Wide



Vibrio Illnesses World-Wide



Deaths Due to Antibiotic Resistance (AMR) 2015 Versus 2050



(O'neill, J.2015. Antimicrobial Resistance: Tackling a crisis for the health and wealth of nations. Report to the Prime Minster of Great Britain)

Catawba River Basin and Lake Wateree

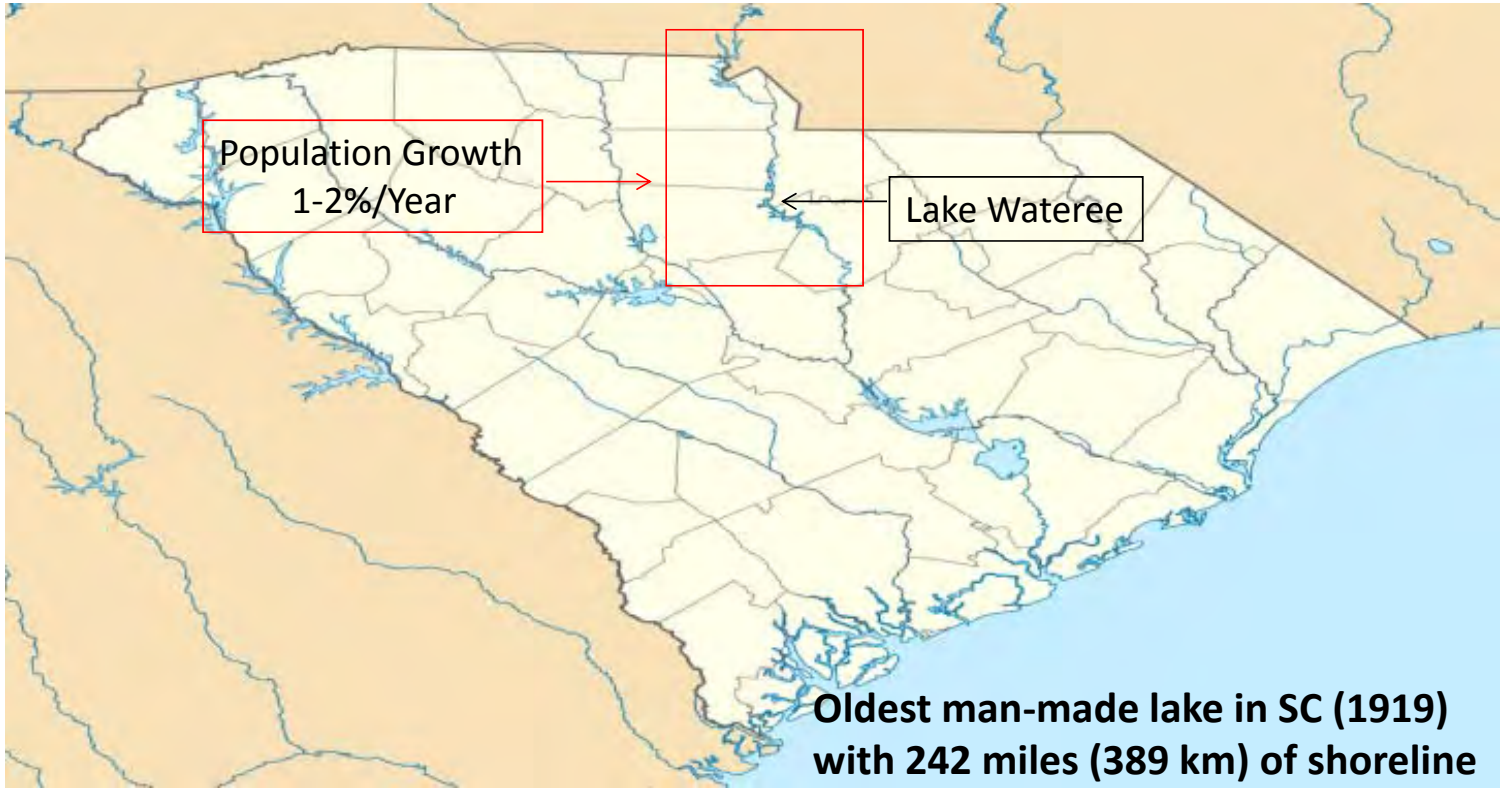
Source: Duke Energy (2007)

Catawba-Wateree River Basin

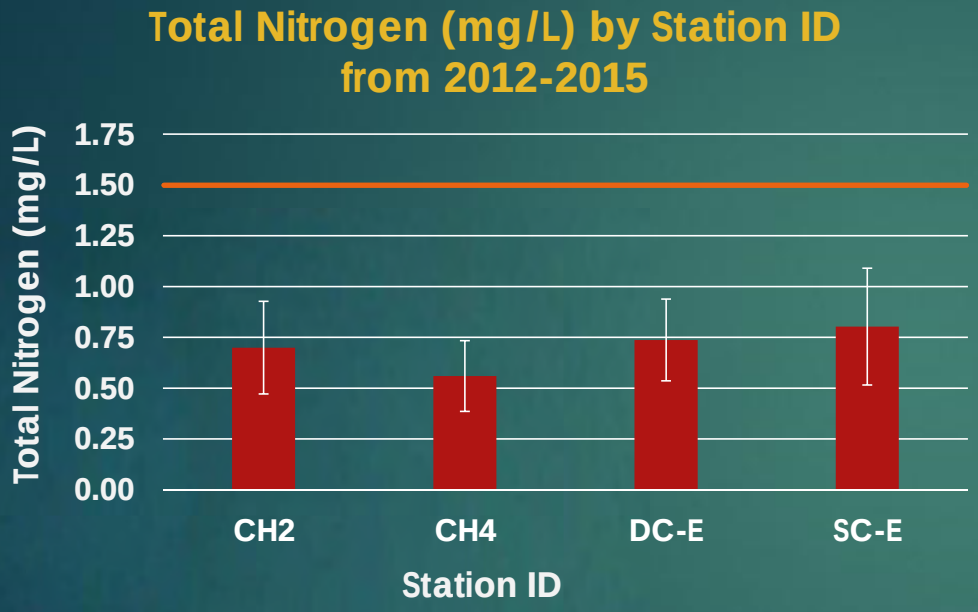
- **11 reservoirs, 14 dams and 5000 miles of waterways**
- **Supplies drinking water to approximately 2 million people.**
- **Most endangered river *(American Rivers, 2008)***
- **3rd most endangered river in SE U.S. *(Southern Environmental Law Center, 2012)***
- **4th most stressed river in the U.S. from power production *(Union of Concerned Scientists, 2011)***

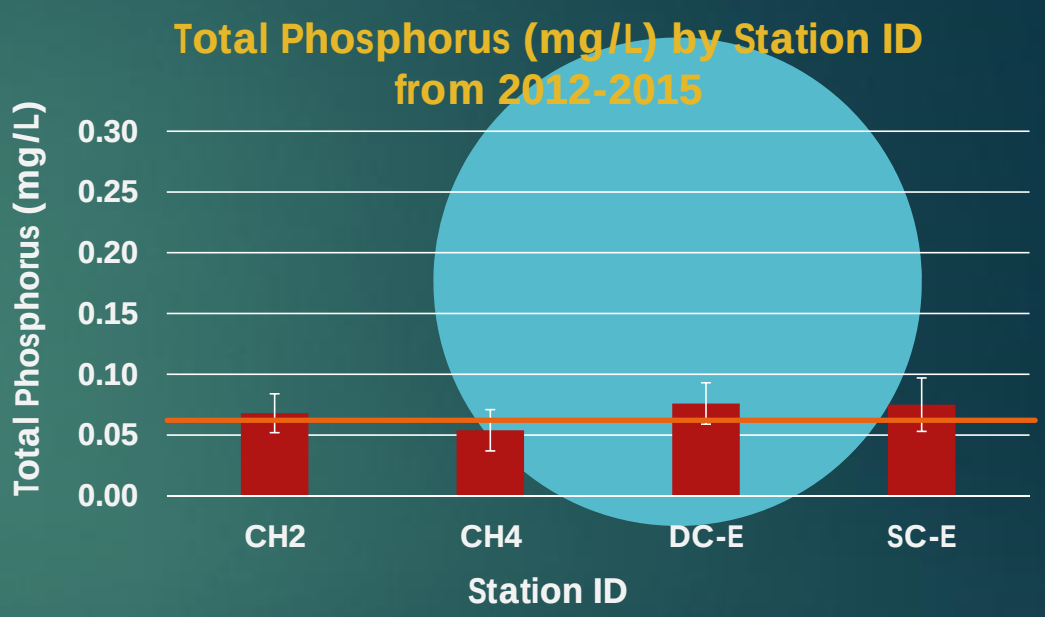
(Clyburn, K. 2019. Masters Thesis, USC)

Lake Wateree



Lake Wateree: Historical Average Total Nitrogen (mg/L) and Phosphorus (mg/L) Concentrations from 2012-2015





- Little variance by location
- TN lower than SCDHEC WQ standards (1.50 mg/L)
- TP higher than SCDHEC WQ standards (0.06 mg/L)

(Clyburn, K. 2019. Masters Thesis, USC)

Nutrient Limitation

- **The Redfield Ratio:** The molecular ratio of carbon, nitrogen and phosphorus in algae maintains that the balanced system of C:N:P molar ratio is 106:16:1 when nutrients are not limiting.

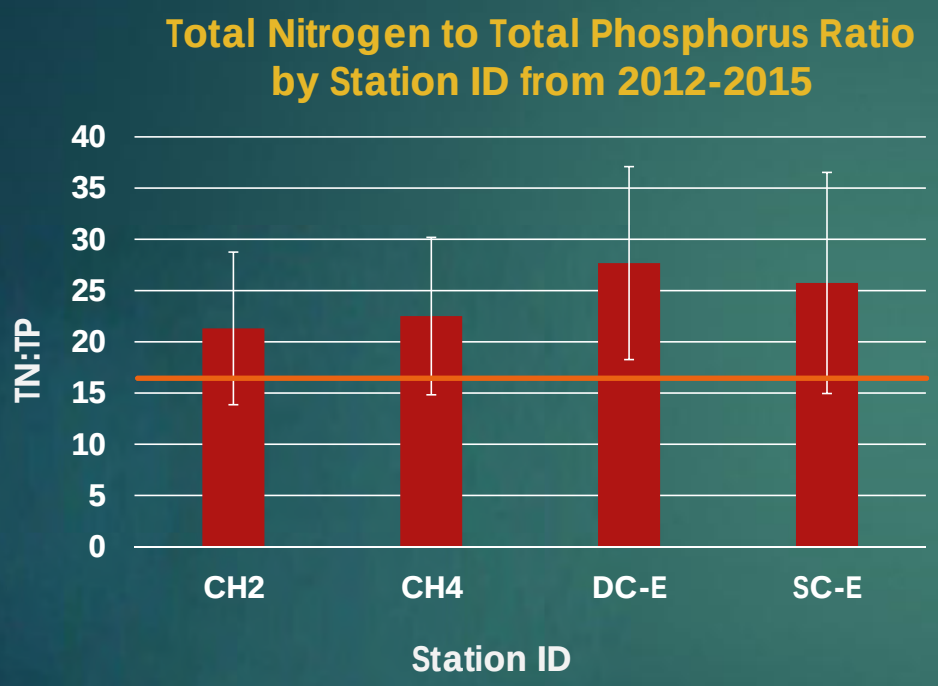
- A N:P molar ratio > 20:1 is typically phosphorus limiting (freshwaters)

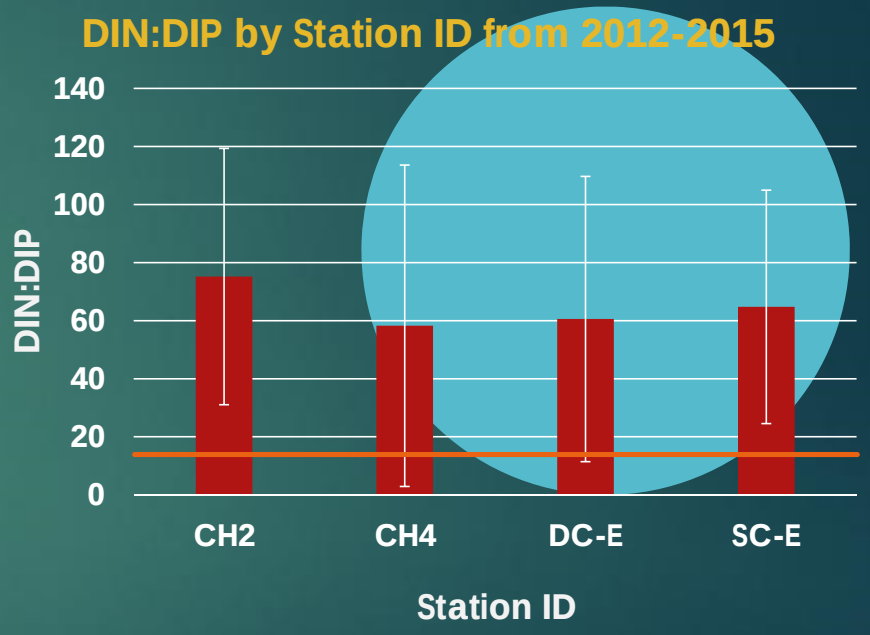
- A N:P molar ratio < 10:1 is usually nitrogen limiting (freshwater or seawater)

- Nutrient supply is relative to algae demand and may in part determine the types of algae observed.

(Clyburn, K. 2019. Masters Thesis, USC)

Historical Nutrient Ratios from 2012-2015





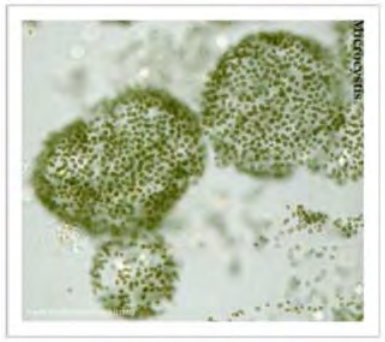
- (Clyburn, K. 2019. Masters Thesis, USC)

Cyanobacterial Harmful Algal Blooms (cyanoHABs)

Cyanobacteria, formerly called blue-green algae, are a type of photosynthetic bacteria.

Beneficial in that they can produce oxygen for the water and atmosphere.

When environmental conditions are ideal, cyanos can grow rapidly, or '**bloom**', forming thick surface scum layers. **Nutrient Enrichment** from point and NPS runoff can cause these blooms.



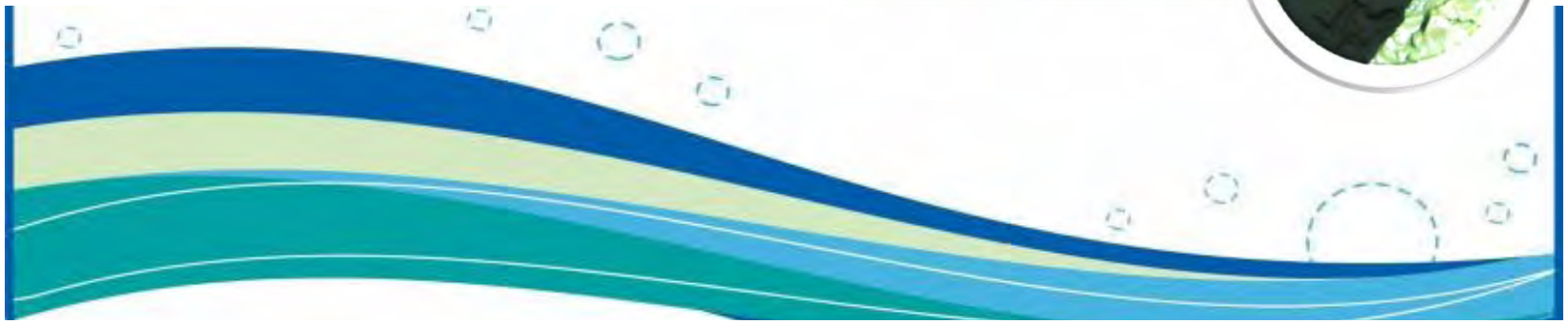
Cyano Harmful Algal Blooms (cyanoHABs)

Mounting evidence indicates global climate changes support increased frequency and geographic extent of HABs.

Each year the desire to live at lakeside and the reliance on large surface waters for recreation and drinking water puts more people and animals at risk for exposure to HABs and the toxins they can produce.

Lure Bar & Grill, Lake Petenwell, WI

Credits: NOAA



Lake Wateree also compensates for its high phosphorous and other nutrients by adding biomass – as *Lyngbya wollei*

Lyngbya wollei is a filamentous algae that is spreading through the lake. It is native to the Eastern US and grows very quickly in the presence of high levels of phosphorous.

It produces a number of noxious chemicals called taste and odor compounds, these give it a foul smell. It also produces at least six different neurotoxins including **Saxitoxins** and ***possibly*** some skin irritants.

When it’s growing off your shoreline it looks like (or old, emerging growth):

2017 LAKE WATEREE ALGAE STUDY

JUNE 29, 2017

SEPTEMBER 28, 2017

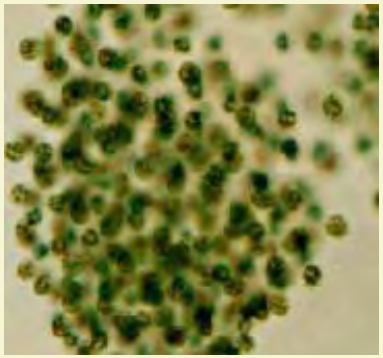
JUNE 2017

SEPTEMBER 2017

OVERLAP

(Stacie Gantz, 2018. MS Thesis)

Potentially Toxic Cyanobacteria



Microcystis aeruginosa

Lyngbya wollei

Anabaena circinalis

Anabaena spp.

Lake Wateree

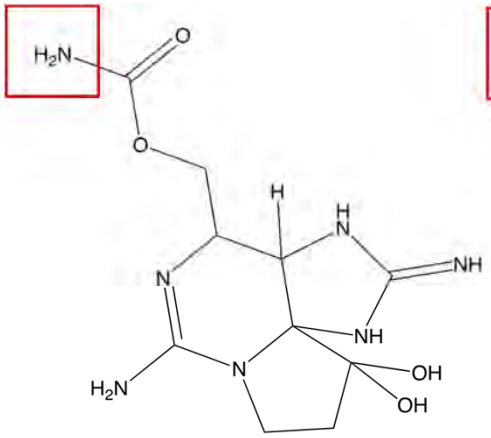
Cylindrospermopsis raciborskii

Raphidiopsis curvata

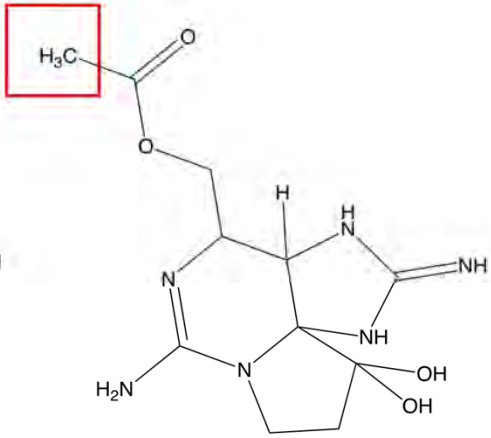
Cylindrospermopsis philippinensis

LMs: E. Allen

Toxin ID is ongoing (qualification and quantification)



Structure of saxitoxin



Structure of *Lyngbya Wollei* toxin 5 (LWT5)

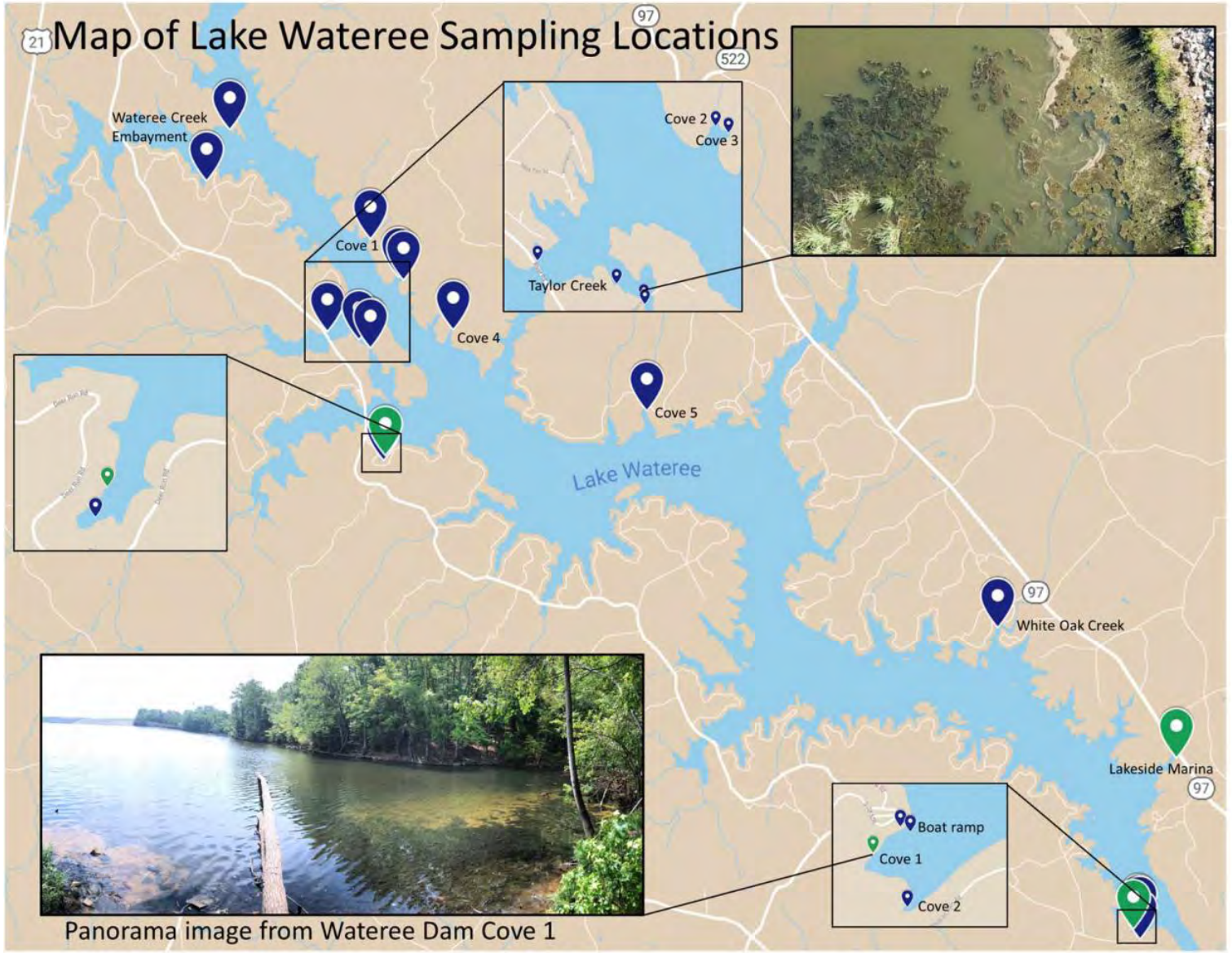
In lieu of a reference standard of LWT5, a reference standard of saxitoxin was used for quantitation of LWT5. Structurally, they are similar (replacement of N with C) therefore, their response on the UPLC-MS/MS is assumed to be similar.

Lyngbya wollei toxin 1,4,5, and 6 have been qualified and quantified vs saxitoxin

CyanoToxins

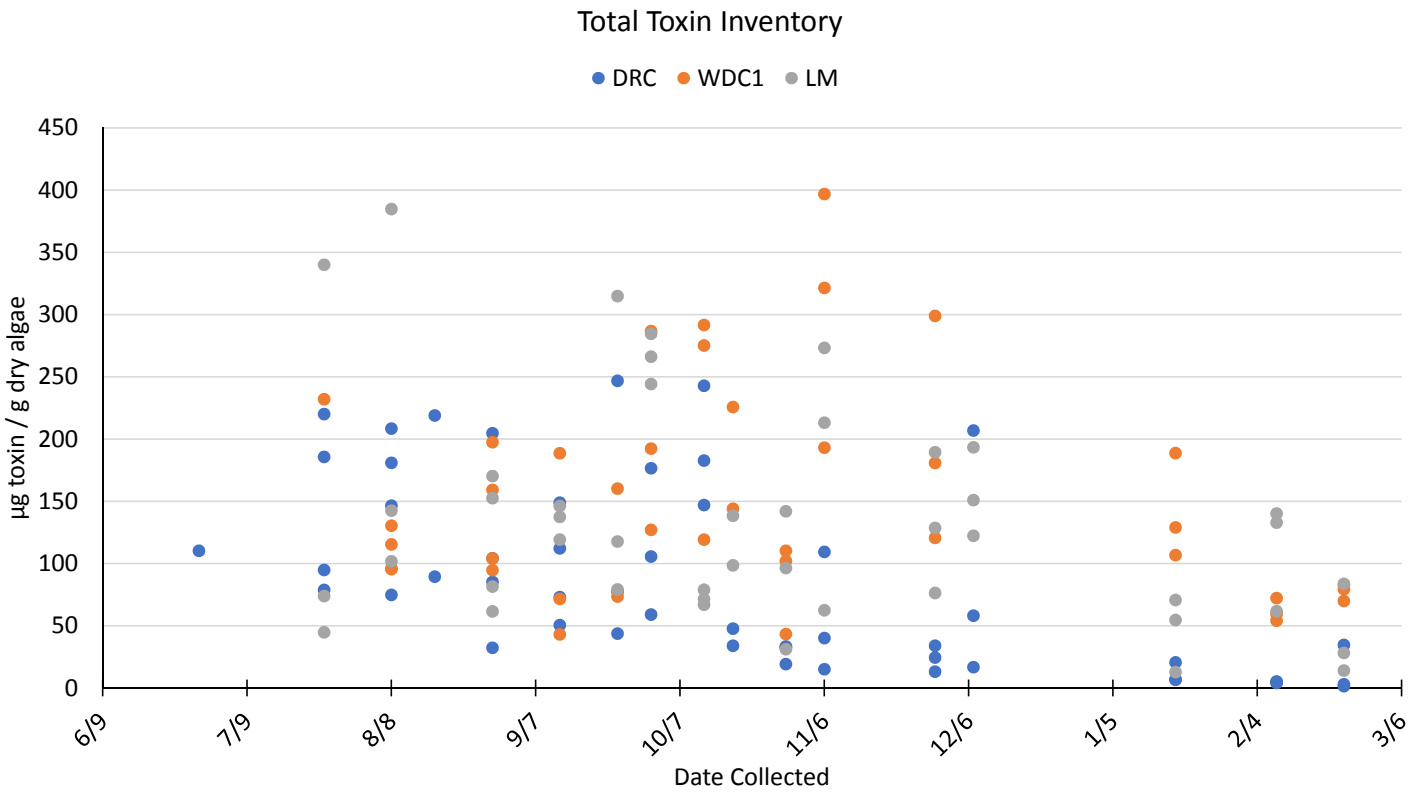
Toxins Produced	Type of Toxin	Target Organ	Onset of symptoms
Anatoxin-a **Saxitoxins**	Neurotoxins	**Nervous System** *Labored breathing, convulsions, numbness, paralysis and death* *Dog deaths caused by Anatoxin-a*	***Minutes to hours***
Microcystins	Hepatotoxin	**Liver** *GI symptoms, elevated liver enzymes in blood, death of cells, destruction of blood vessels*	***Hours to days***
Cylindrospermopsins	Hepatotoxin	**Liver and Kidneys** *Symptoms like food poisoning/Pos. kidney failure*	***Hours to days***

Map of Lake Wateree Sampling Locations



Panorama image from Wateree Dam Cove 1

Trends vs Time, ΣLWT



Natural Disasters 1950-2012

(Sandifer & Heyward-Walker. 2018. Frontiers in Public Health 6: 373)

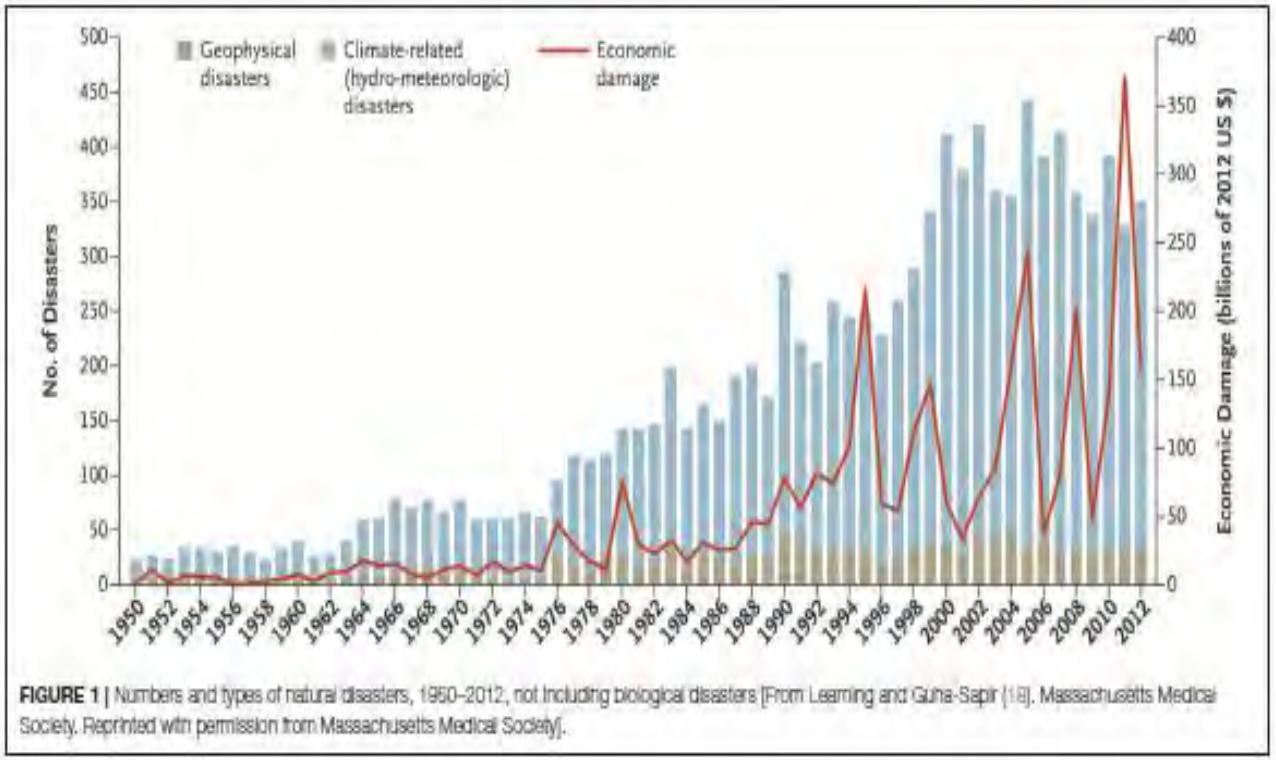


FIGURE 1 | Numbers and types of natural disasters, 1950–2012, not including biological disasters [From Leaming and Guha-Sapir [18]. Massachusetts Medical Society. Reprinted with permission from Massachusetts Medical Society].

U.S. has experienced 230 weather- or climate-related ("natural") disasters that each exceeds $1 Billion in damages since1980, with a total economic cost of $1.5 Trillion.

Note the Significant Increase in Climate Related Disasters since the 1970's

PHYTOPLANKTON MONITORING NETWORK (PMN)

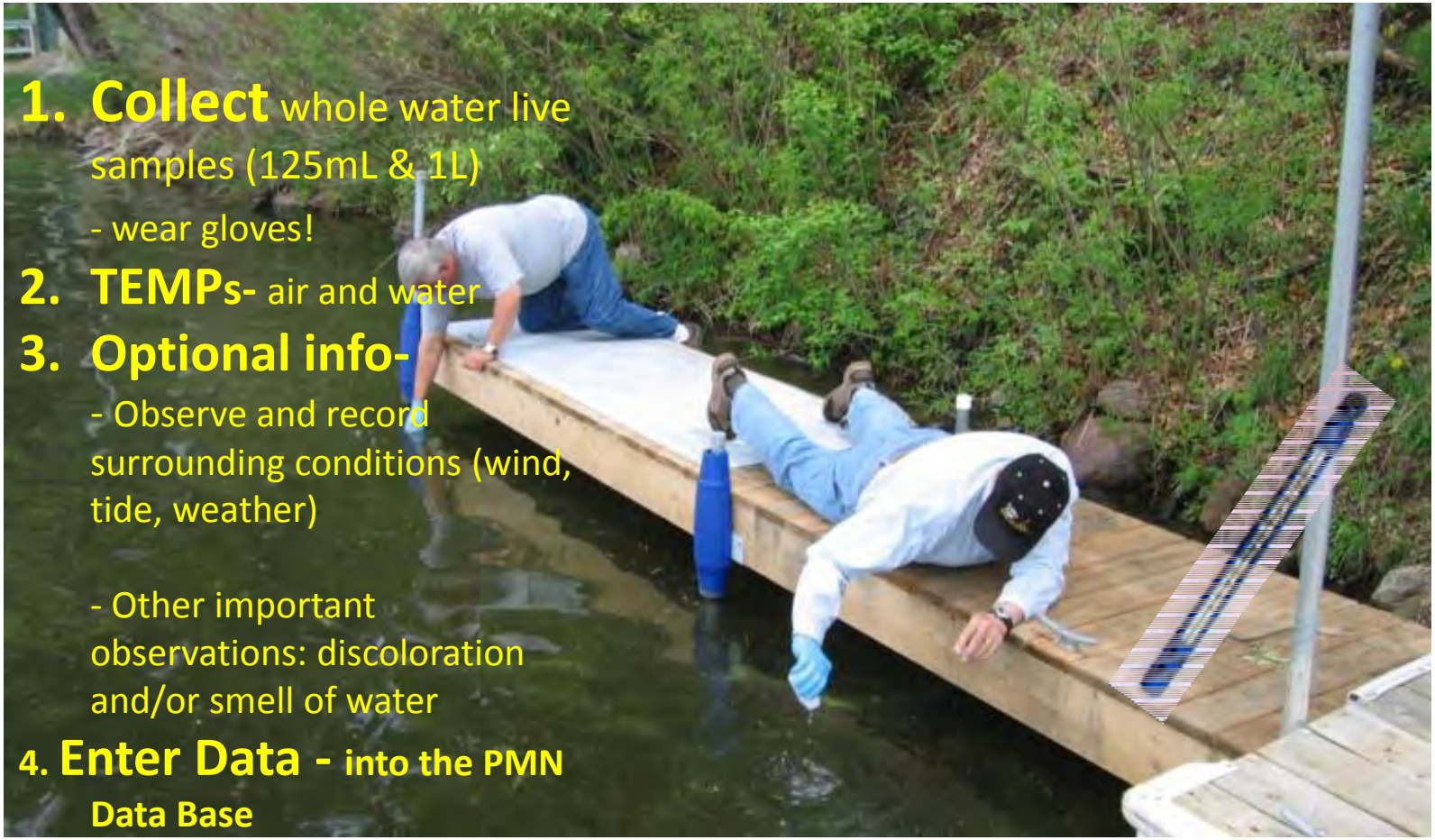
NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

Science Serving Coastal Communities

To educate the public on harmful algal blooms (HABs) while expanding the knowledge of phytoplankton that exist in coastal waters through research based monitoring.

- **PMN started in 2001 as part of Marine Biotoxins Program in Charleston, SC**
- **Over 100 active sites in 14 coastal states**

Field Sampling – Summary



1. **Collect** whole water live samples (125mL & 1L)
   - wear gloves!
2. **TEMPs-** air and water
3. **Optional info-**
   - Observe and record surrounding conditions (wind, tide, weather)

   - Other important observations: discoloration and/or smell of water
4. **Enter Data - into the PMN Data Base**

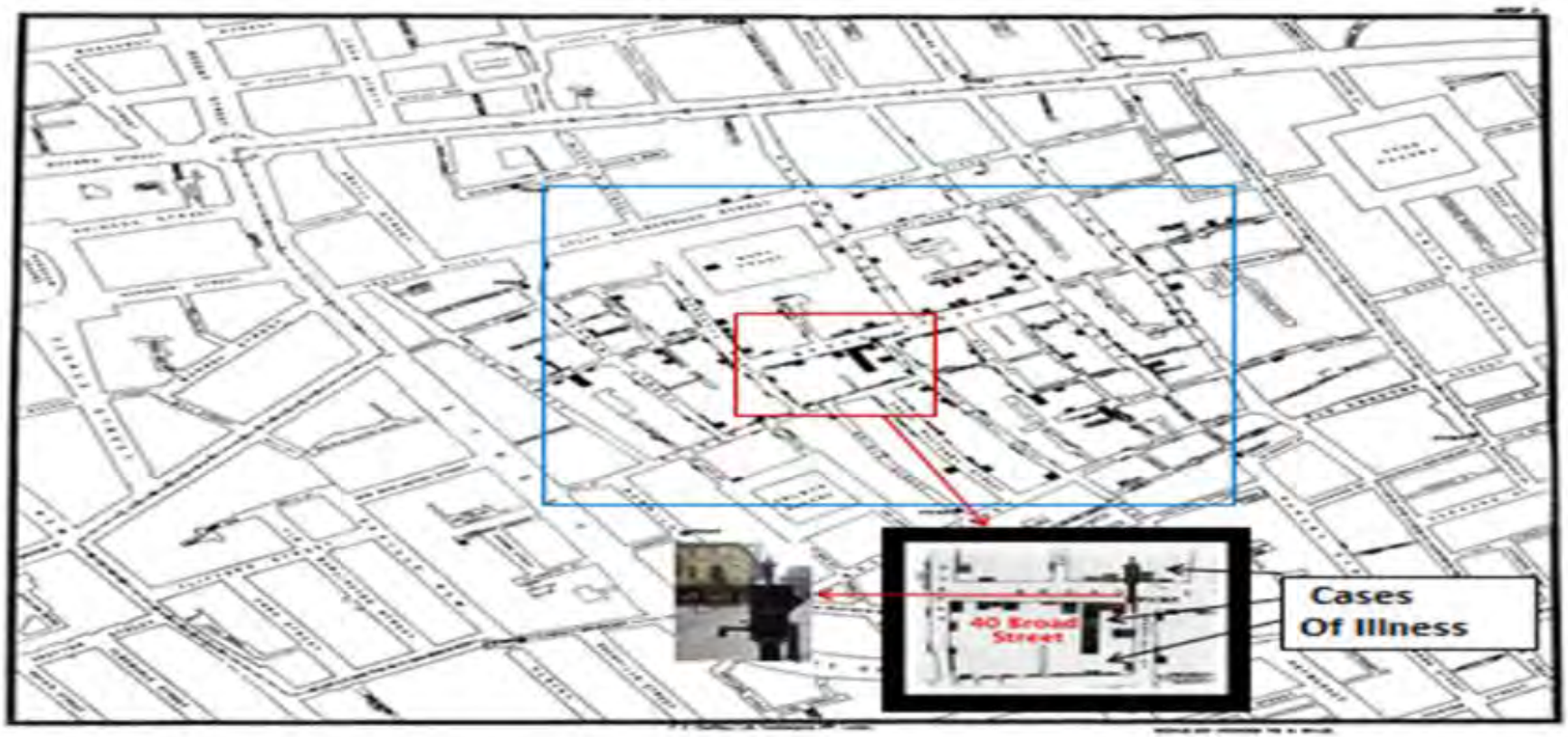
Participate in National HAB GRAB Day

- **HAB GRAB Day-** Participants grab samples using a standardized water collection method to identify and quantify HAB Species
- **2018** in Lake Erie the University of Bowling Green NSF/NIEHS OHH Center – estimated total Microcystin levels in Lake Erie.
- We would like for you to participate in this event in either July/August 2019 time frame at Lake Wateree and other lakes in the US

- **Focus: OHHC²I** 's main purpose will be to assess the effects of ocean health-related illness and disease and then to use this information to develop prevention strategies against ocean-related illness and disease to better protect public health.

- Our specific focus will be on climate change-related factors that may enhance the presence, abundance and virulence of ***Vibrio Bacteria*** and ***Freshwater Harmful Algal Blooms***

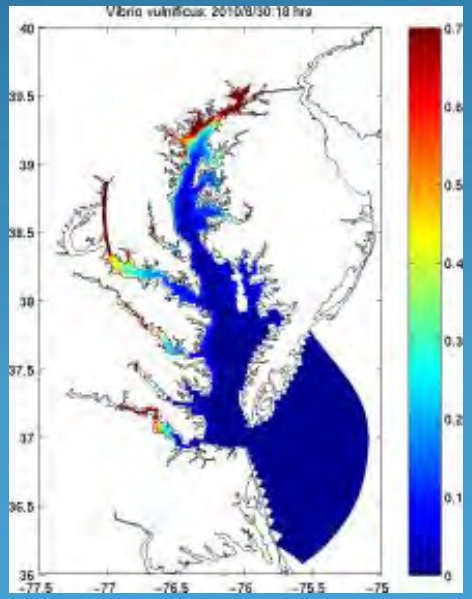
Sir John Snow: *V. cholerae* Outbreak In London 1854



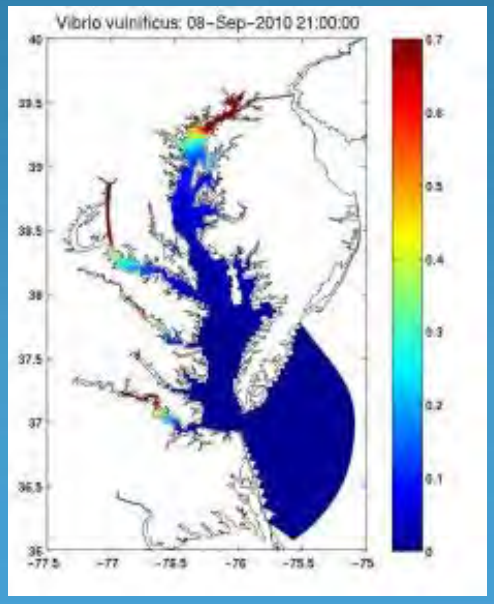
Current Experimental Vibrio Forecast Products

Forecasts and other Products

- Nowcasts and 3 day forecast – UMCES and NOAA
- 14 and monthly forecasts - UMD ESSIC



14 day



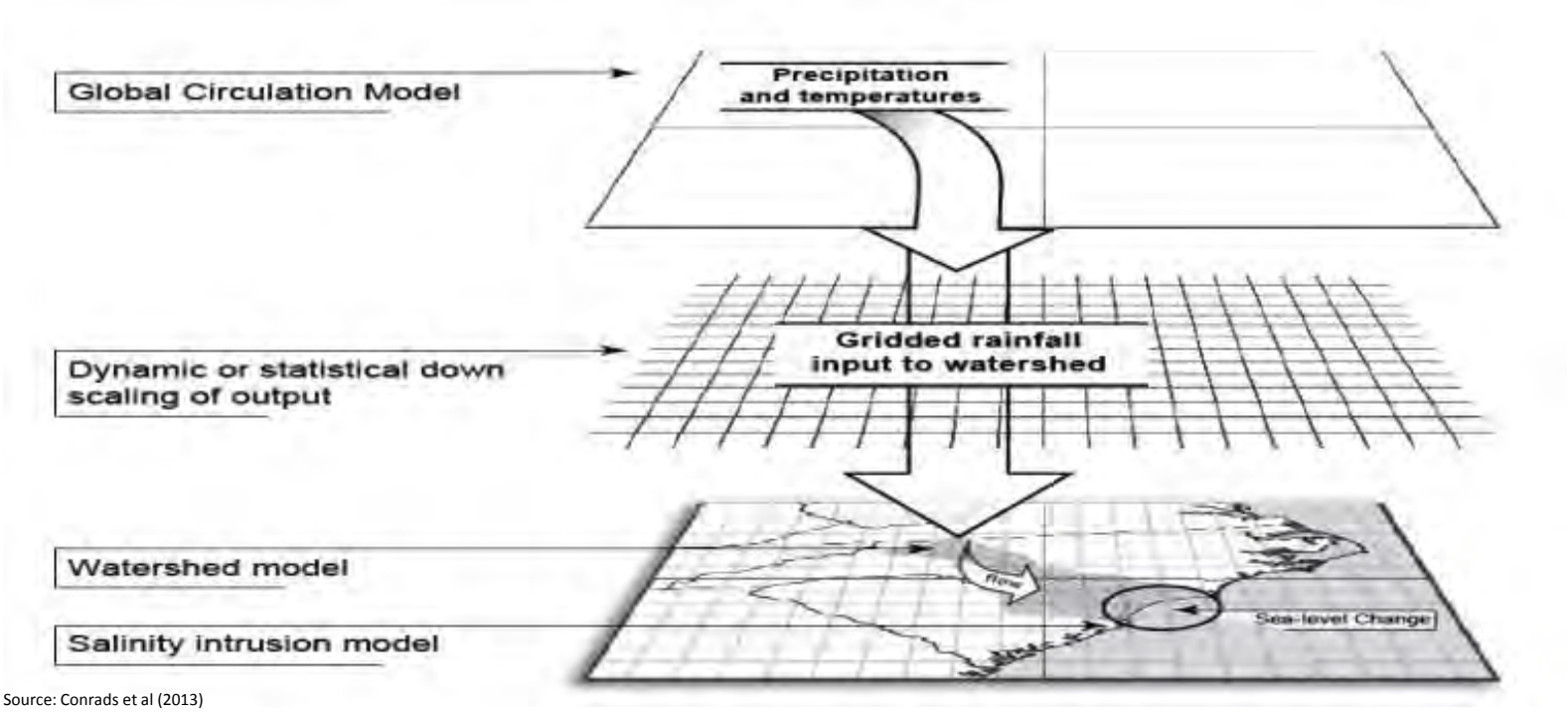
Monthly

OHH Center Research Will Evaluate the Effects of Climate Change Factors of Temperature, pH, and Salinity

and

Urbanization Effects of Trace Metals and CECs (Pharmaceuticals and Personal Care Products) On Antibiotic Gene Expression & Virulence In Vibrio Bacteria

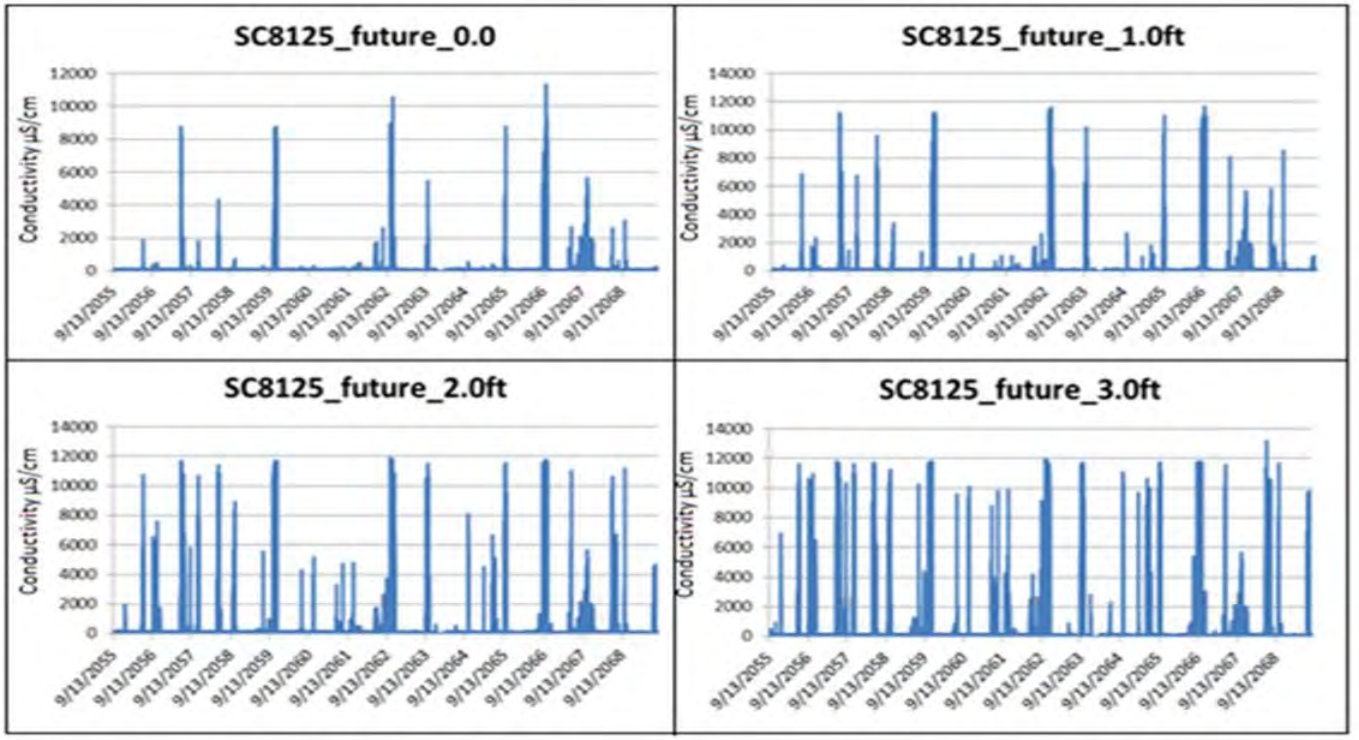
Climate Downscaling for the Watershed Model



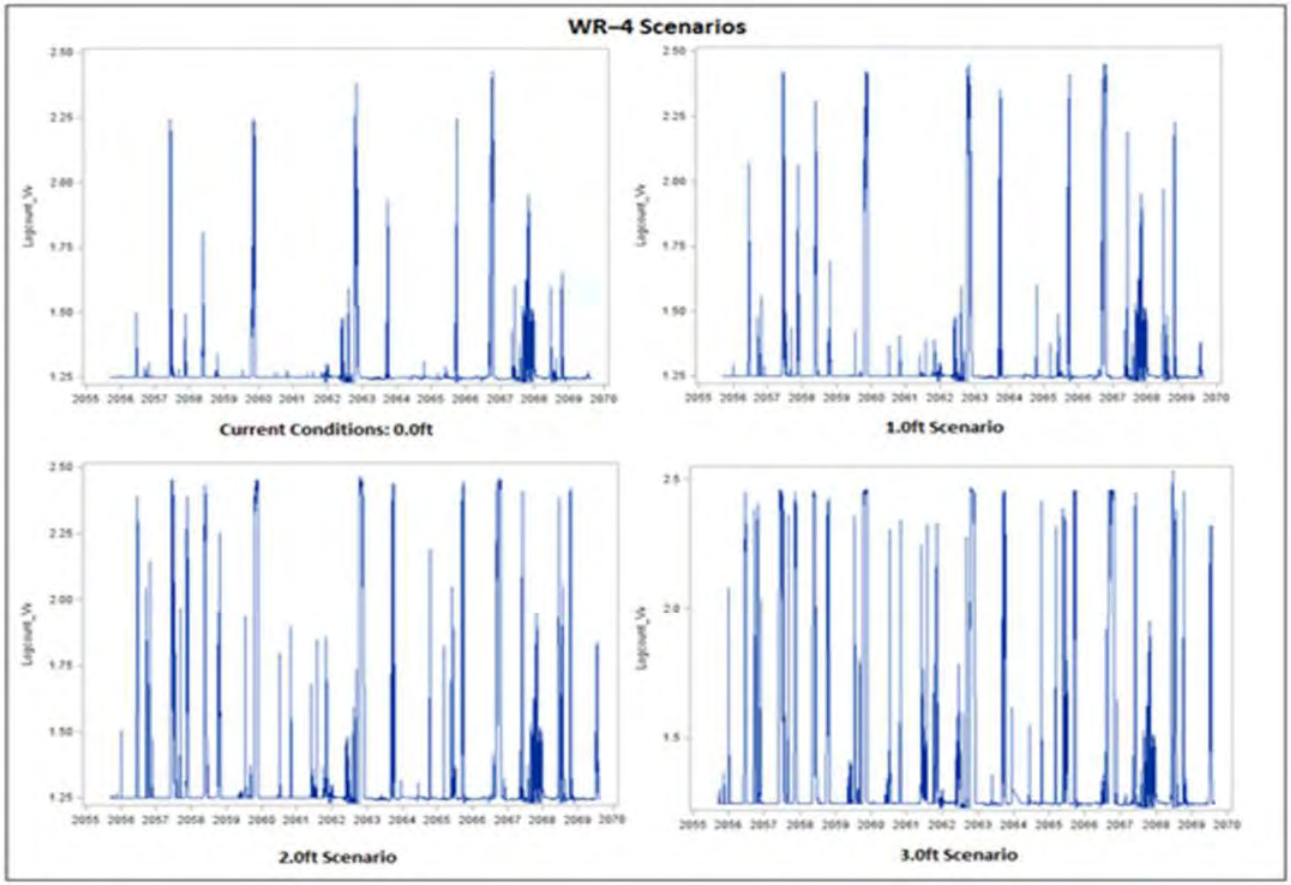
Source: Conrads et al (2013)

- We used five different GCMs – spanning a range of predictions
- Two simulation periods
  - Historic 1981 – 2010
  - Future 2041 – 2070

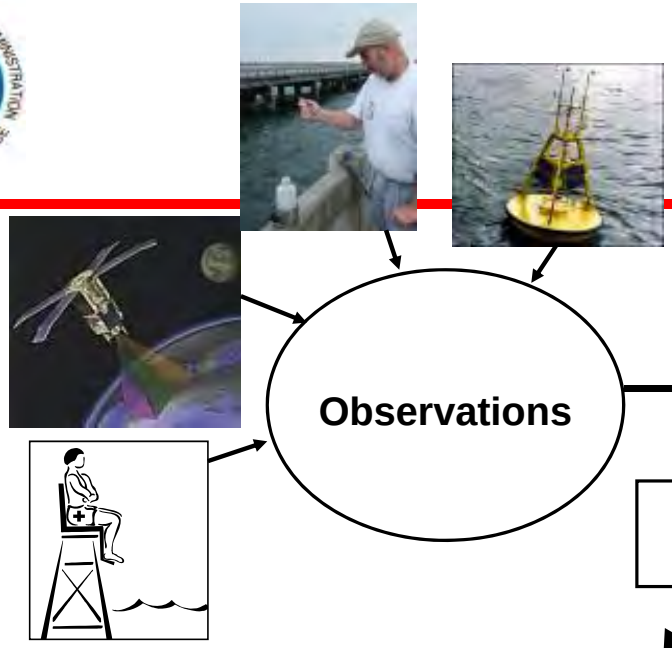
Predicted Increase in Specific Conductance in Winyah Bay with Sea Level Rise



Winyah Bay Station WR 4: Future *Vibrio vulnificus* Abundances with different Sea Level Rise Predictions



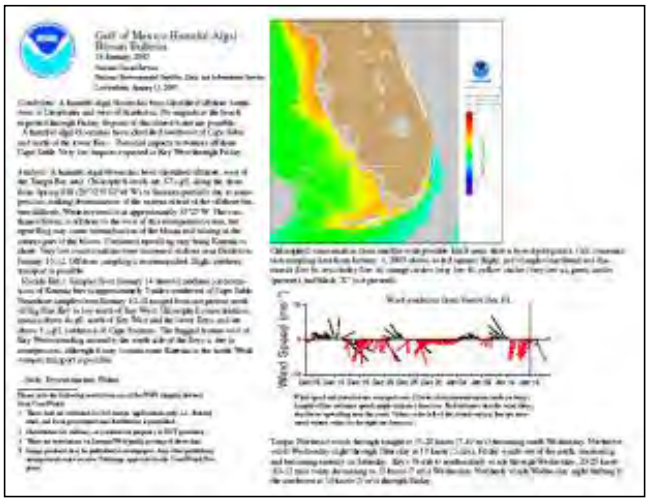
HAB Forecast System: Early Warning to Protect Human Health



Observations

Model Output

Synthesis and Analysis



A harmful algal bloom has been identified in patches from southern Lee to central Collier County. Patchy very low impacts are possible from southern Lee County to central Collier County today through Thursday. No other impacts are expected.

Conditions Report (public)

HAB Bulletin (managers)

http://www.csc.noaa.gov/crs/habf

Impacts of Pathogens and HABs on Health in the US

- Pathogens may cause disease in humans from consumption of food, drinking water and contact recreation, such as swimming. Effects may include gastrointestinal effects, upper respiratory illness and would infections.
- The health consequences due to **marine-borne pathogens in the USA** have annual costs on the order of **$900 million** (Ralston et al., 2011).
- This includes:
  - **$350 million** due to pathogens and marine toxins specifically identified as causing **food-borne disease**,
  - **$300 million** due to seafood-borne disease with **unknown etiology**,
  - **$300 million** due to gastrointestinal illness from **beach recreation** and
  - **$30 million** from direct exposure to the **Vibrio species** (Ralston et al., 2011).

Cost of Water Recreation Related Illnesses
=
$2.9 Billion per Year in the USA

90 million cases of **gastrointestinal, respiratory, ear, eye and skin-related illnesses per year** in the U.S. are associated to **swimming, paddling, boating and fishing**

The cost for recreational water related illness
per case **$9.5** to **$303,000**
(**mild illness** to **the most severe illnesses**)

Only **$10 million** per year allocated for beach protection

https://today.uic.edu/illnesses-caused-by-recreation-on-the-water-costs-2-9-billion-annually-in-the-us

Source: DeFlorio-Barker et al. 2018

Oceans and Human Health

NIEHS Center for Oceans and Human Health and Climate Change Interactions at the University of SC

- **Traditionally Ocean Health Assessments** – Man's Impact on the Environment of Marine Organisms
- If human impacts make the ocean environment unhealthy then we need to be concerned about **Human Health**
- **Oceans and Human Health –** Attempts to Complete the Full circle by Connecting Ocean Health & Human Health = **One Health Approach**