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Plant Sensory Systems

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Institute of Marine and Environmental Technology

Allen R. Place
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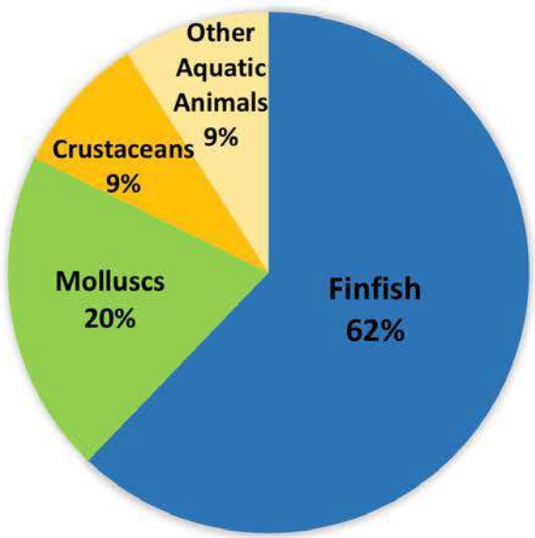
Baltimore, MD 21202

EMERGING GLOBAL FOOD THREATS – BIOTOXINS IMPEDIMENTS TO AQUACULTURE FEEDING THE WORLD

Allen R. Place, PhD, Institute of Marine and Environmental Technology, University of Maryland Center for Environmental Science, Baltimore, MD, USA 21202

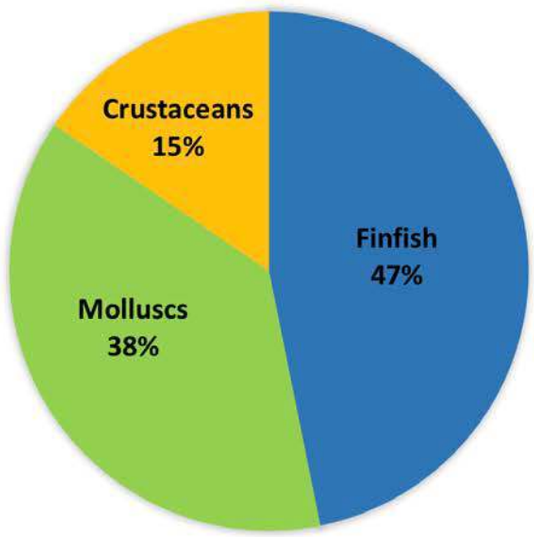
Global versus US Aquaculture Production

WORLD AQUACULTURE PRODUCTION



Total Production: 73.8 million tons
Value: $160.2 Billion

US AQUACULTURE PRODUCTION

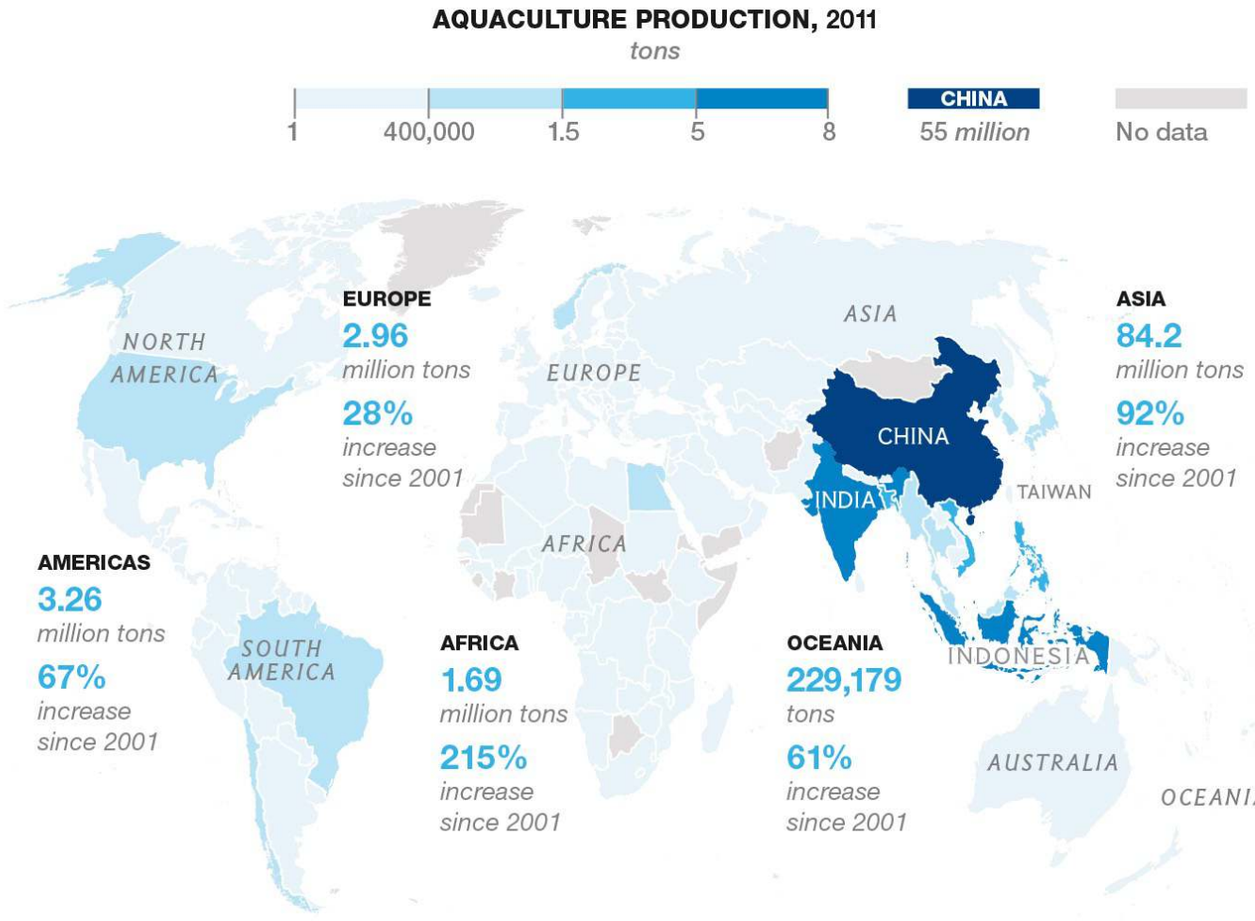


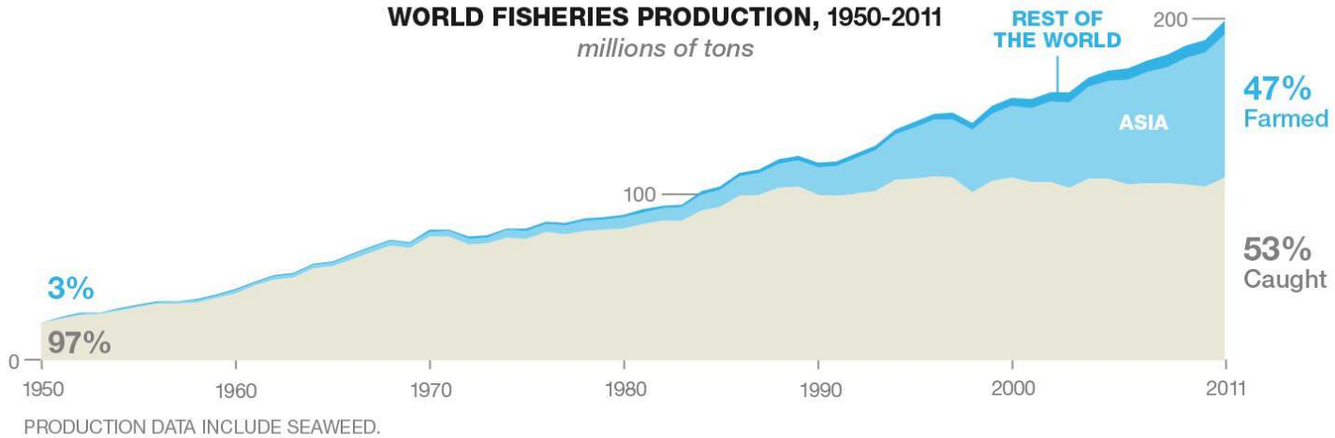
Total Production: 0.330 million tons
Value: $1.4 Billion

Seafood and Aquaculture:
The Crisis and the Promise

Farming Soars as Wild Catches Stall

With demand rising and many marine fish stocks already overfished, nearly half of all seafood now comes from aquaculture, which has grown at a double-digit clip for decades. Most of the growth is in Asia, home to 90 percent of fish farms. China, the world leader, imports additional fish to make fish oil, fish food, and other products.





PRODUCTION DATA INCLUDE SEAWEED.

At dawn on China's Fujian coast, seaweed farmers head out to tend their aquatic fields. Such farms help China grow 12 million tons of food a year with no soil or fresh water and no fertilizer except runoff from the land. Oceans cover 71 percent of Earth yet provide less than 2 percent of our food—for now.

PHOTOGRAPH BY GEORGE STEINMETZ

Aquaculture

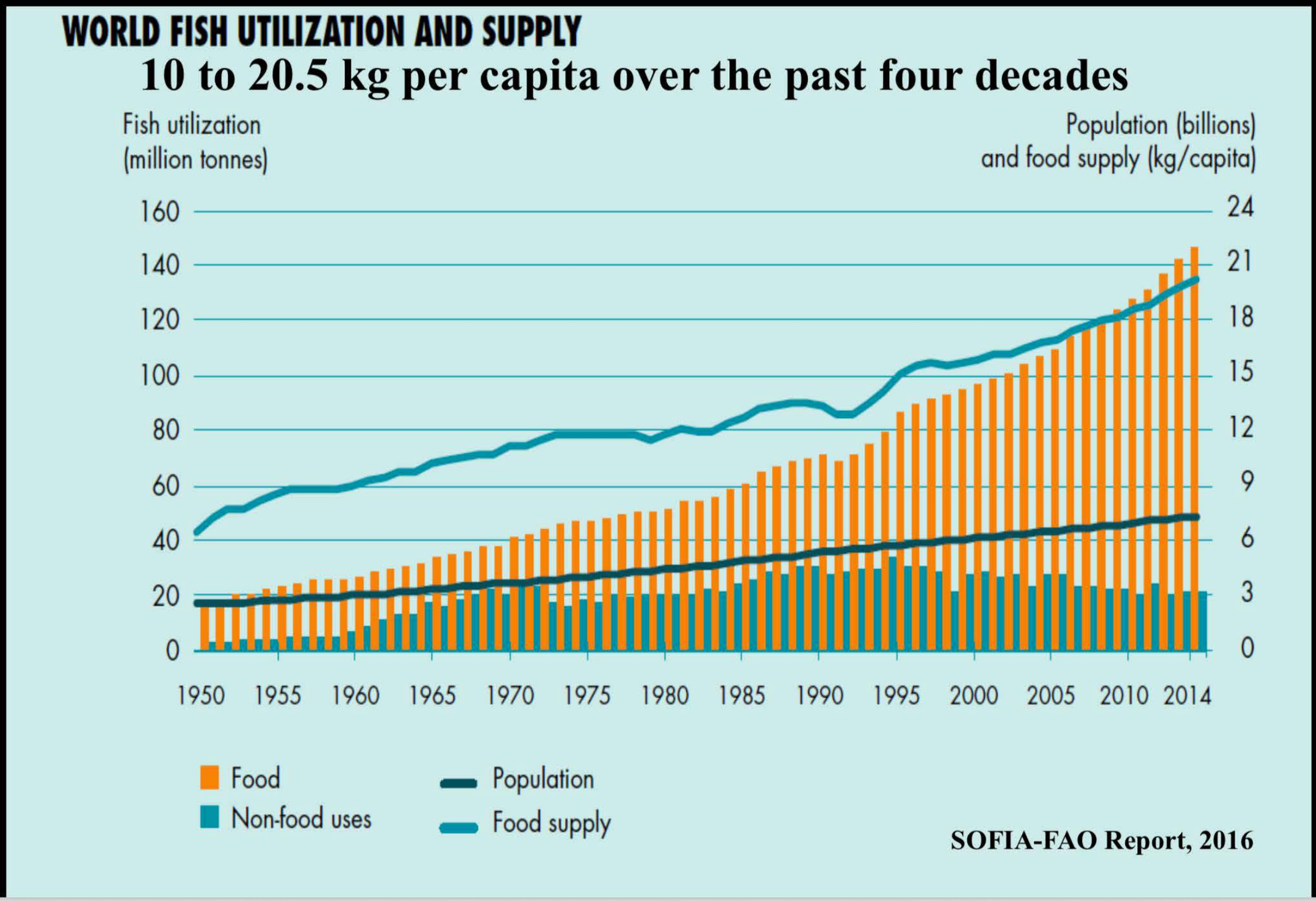
The World Bank

Aquaculture is projected to be the prime source of seafood by 2030, as demand grows from the global middle class and wild capture fisheries approach their maximum take. When practiced responsibly, fish (shellfish) farming can help provide livelihoods and feed a global population that will reach nine billion by 2050. But for an aquaculture system to be truly sustainable, it must have:

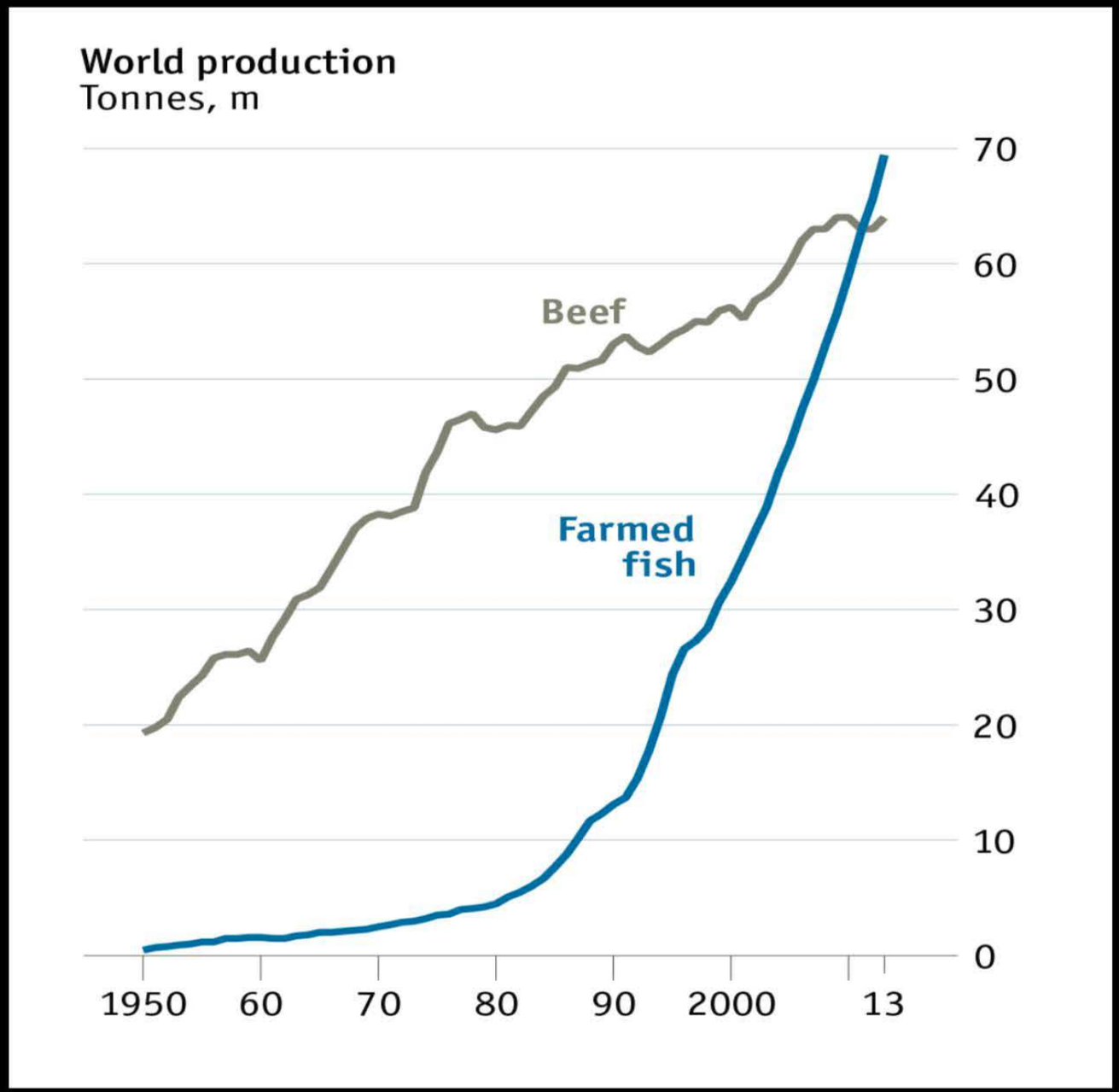
- **Environmental sustainability** — Aquaculture should not create significant disruption to the ecosystem, or cause the loss of biodiversity or substantial pollution impact.
- **Economic sustainability** — Aquaculture must be a viable business with good long-term prospects.
- **Social and community sustainability** — Aquaculture must be socially responsible and contribute to community well-being.

Sustainable aquaculture is a dynamic concept and the sustainability of an aquaculture system will vary with species, location, societal norms and the state of knowledge and technology.

More People Eat More Fish



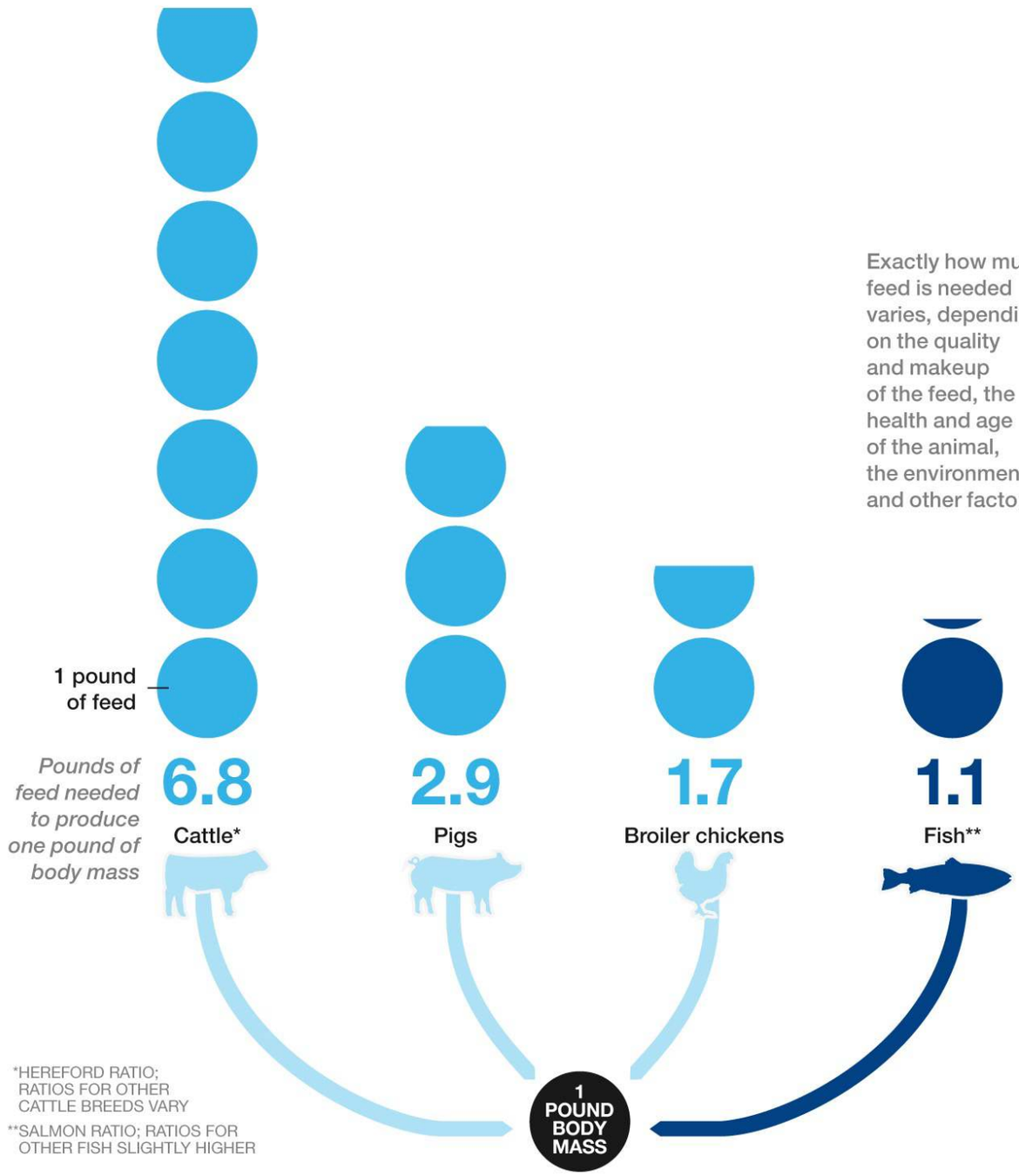
We now produce more fish than beef!



The Economist, June 2016

Pounds for Pound

Different sources of animal protein in our diet place different demands on natural resources. One measure of this is the "feed conversion ratio": an estimate of the feed required to gain one pound of body mass. By this measure, farming salmon is about seven times more efficient than raising beef.



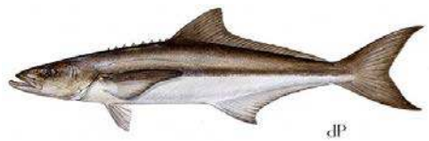
Exactly how much feed is needed varies, depending on the quality and makeup of the feed, the health and age of the animal, the environment, and other factors.

From National Geographic

Nutrition and Feeds: The Issues

- Feed cost accounts for 50% of growout expenses
- Aquaculture industry spends $40 billion/year on feed
- Aquaculture is the fastest growing segment of the animal feed industry (projection for 2030 = $70bn)
- Heavy dependence on fish meal/oil (1/3 of all fisheries; 8 mmt/year)

Source: USDA; FAO



FISHMEAL

Fillet Contaminants
PCB 5X Lower
Mercury 4X Lower
FCR 1.46

Sustainability: Challenges

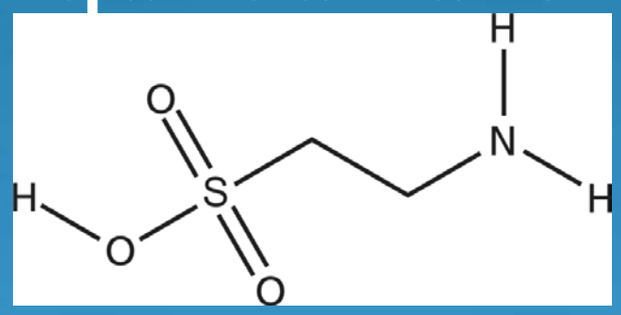
1. Complete independence from natural stocks through **DOMESTICATION**
2. Improved / more cost-effective **SEED PRODUCTION**
3. Better targeted **SPECIES SELECTION**
4. Development of more efficient stocks through **SELECTIVE BREEDING**
5. More **MICROBIAL MANAGEMENT** for more sustainable production
6. Better understanding of **IMMUNE SYSTEMS** in vertebrates and invertebrates
7. More **INTEGRATED PRODUCTION SYSTEMS** for plant and animal farming
8. **COASTAL AND OFF-SHORE FARMS** of food and energy
9. Full independence from fisheries stocks for **LIPID AND PROTEIN INGREDIENTS** in aquatic feeds
10. More attention for **INTEGRATION** of restocking activities with **FISHERIES** management
11. **SOCIETAL LEVERAGE:**
    1. multi-stakeholder interaction
    2. International cooperation on a win-win basis

Aquaculture, The Blue Biotechnology of the Future
Patrick Sorgeloos
World Aquaculture, 2013

Turning Carnivorous Fish into Vegetarians

http://www.gizmag.com/fishless-fish-feed/28615/

Taurine
The missing ingredient for development of fish free diets for aquaculture?



Supplement Facts Serving Size 8.0 fl.oz. (240 ml) Serving Per Container 3		
Calories	100	
Total Carb	27g	9%
Sugars	27g	
Vitamin B2	1.7mg	100%
Vitamin B3	20mg	100%
Vitamin B6	2mg	100%
Vitamin B12	6mcg	100%
Sodium	180mg	8%
Taurine	1000mg	
Panax Ginseng	200mg	
Energy Blend 2500mg L-Carnitine, Glucose, Caffeine, Guarana Inositol, Glucuronolactone, Maltodetrin		
Percent Daily Values are based on a 2000 calorie diet.		

Aaron Watson, Ph.D. Rick Barrows, Allen R. Place

Institute of Marine and Environmental Technology
University of Maryland Center for Environmental Science

A diver nets a ten-pound cobia for sampling before harvest in one of Open Blue's dozen offshore pens. Able to hold hundreds of thousands of fish, but less densely stocked and better flushed than nearshore salmon pens, they produce little pollution. Cobia contain as much healthy fish oil as salmon do.

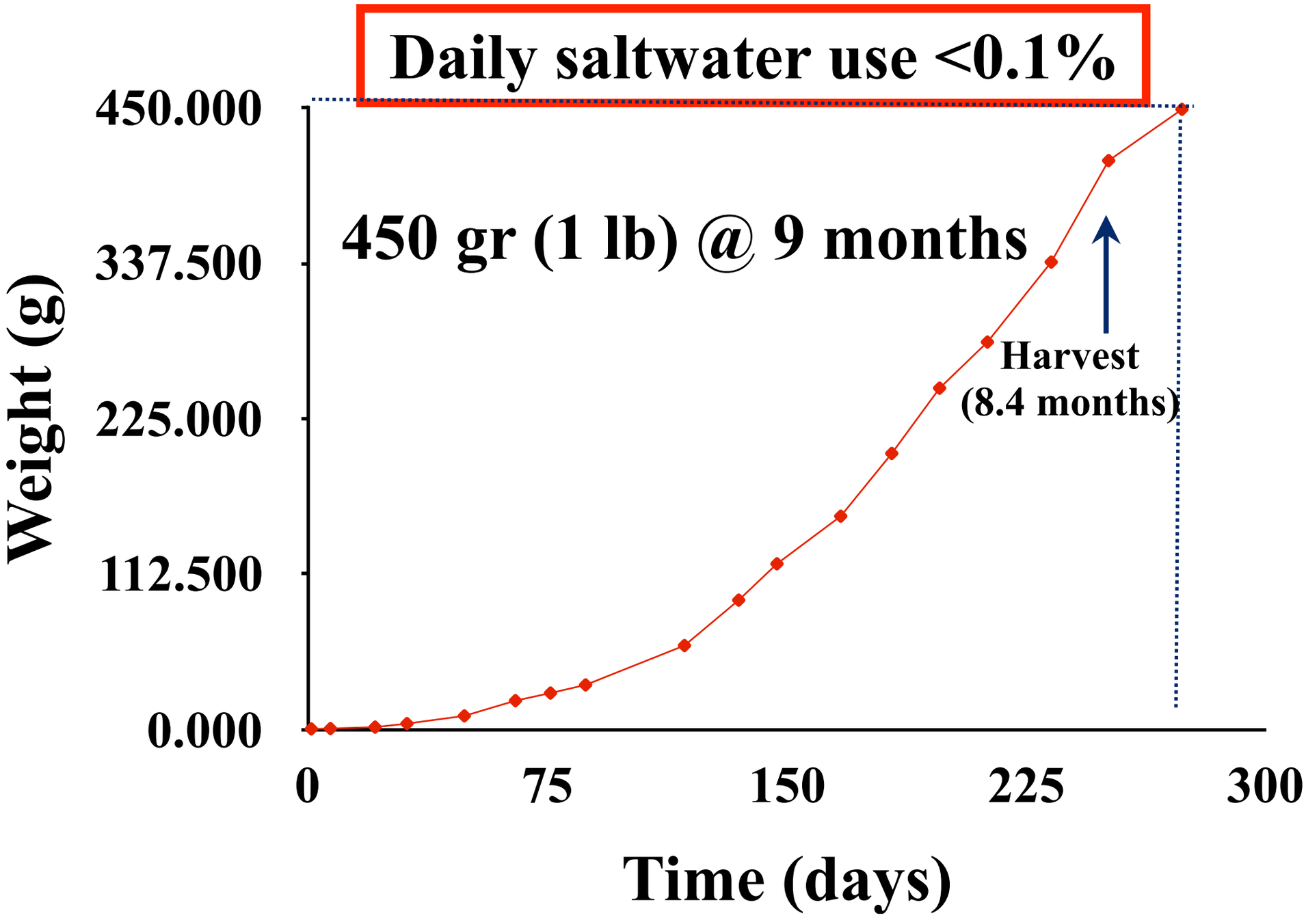
Growth rate of gilthead seabream in an urban recirculated mariculture facility

Daily saltwater use <0.1%

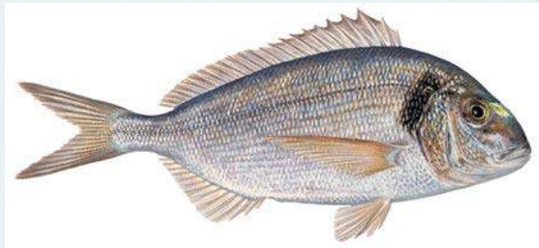
2 tons produced;
99% survival
Density:
73 kg/m³ =
0.61 lb/gal.

Average FCR: 1.2

Saltwater use:
16 liter/kg fish =
1.9 gal./lb fish



Sea Bream Performance on Experimental Feeds Prior to “Recovery” Phase

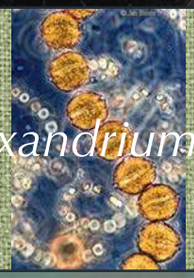


	Plant Protein: Fish Oil	Plant Protein: Microbial Single Cell	Plant Protein: Canola Oil + EFA
	Sea Bream	Sea Bream	Sea Bream
% Wt Gain (Final Wt)	696 (93)	786 (111)	680 (95)
Feed Conversion Ratio	1.36	1.27	1.37
Specific Growth Rate	2.36	2.48	2.36
Survival	100%	100%	100%
% Lipid (Fillet)	14.46 ± 3.93	15.28 ± 4.54	16.33 ± 4.50

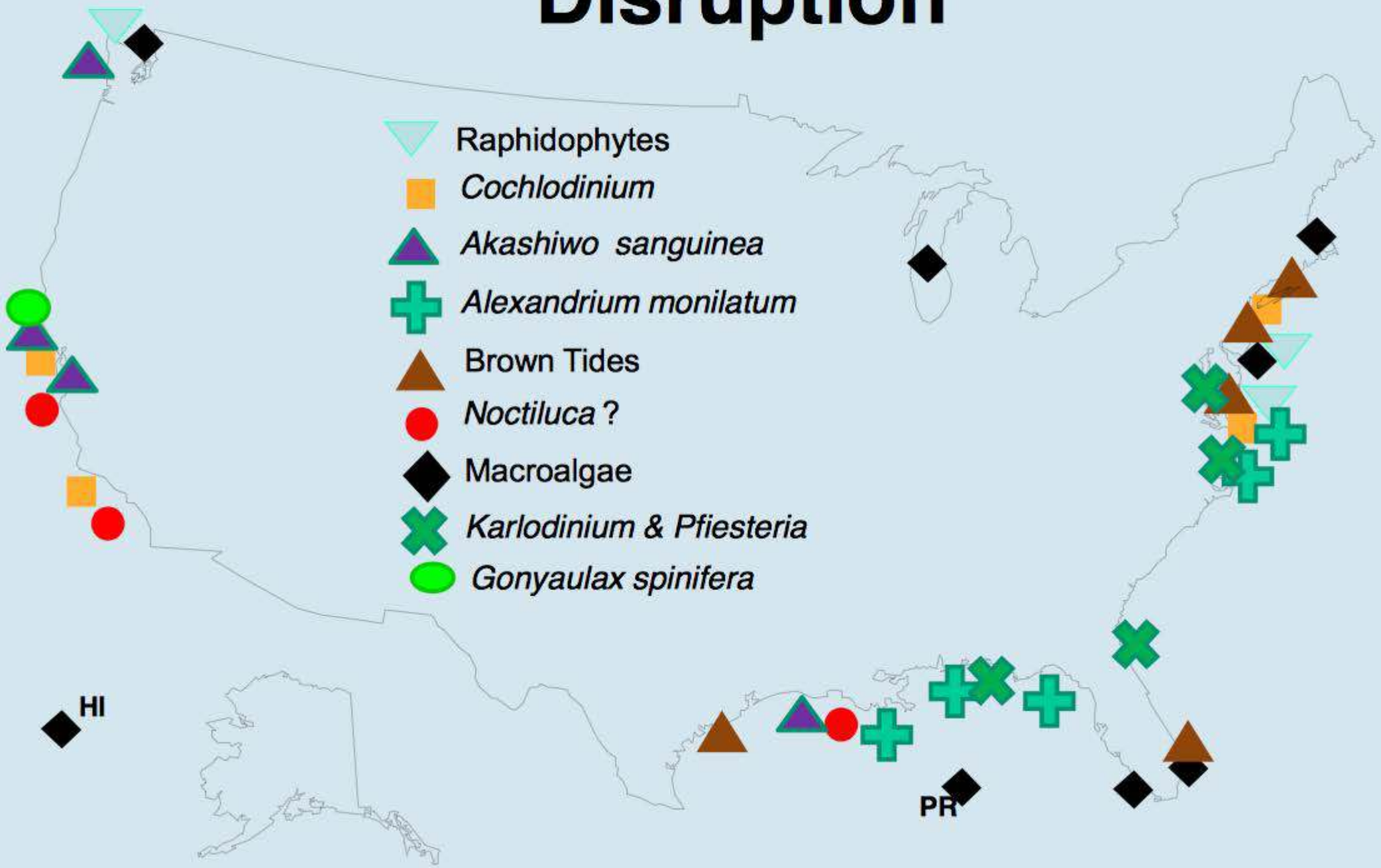
Feed Conversion Ratio = Food Fed/ Weight Gained
Specific Growth Rate = $((\ln BW_F - \ln BW_I) * (\text{days of growth trial}^{-1})) * 100$

Sea Bream trial ran 88 days prior to this sampling (starting weight 11g)

Tilapia pens in Laguna de Bay, the largest lake in the Philippines, are choked by an algal bloom they helped create. The overstocked lake produces large numbers of farmed fish, but excess nutrients trigger blooms that use up oxygen—and kill fish.

Human Health Impact	Toxigenic Phytoplankton	Toxin
Amnesic Shellfish Poisoning	 *Pseudo-ntizschia*	Domoic Acid
Neurotoxic Shellfish Poisoning	 *Karenia brevis*	Brevetoxin and congeners
Paralytic Shellfish Poisoning	 *Alexandrium* sp.	Saxitoxins and congeners
Diarehetic Shellfish Poisoning	 *Dinophysis* sp.	Okadaic Acid and congeners
Ciguatera Fish Poisoning	 *Gamiberdiscus* sp.	Ciguatoxin/Maitoxin

Coastal HABs
Animal Mortality/Ecosystem Disruption



Domoic Acid is Pervasive

From sanddab

domoic ac

Bulletin of Environ

January 2017, V

Domoic

Cetacean

Authors

S. M. Bengtson Nas

Article

First Online: 16 August 2016

12

https://doi.org/10.1016/j.hal.2007.05.008

Marine Bi

Prevalence of algal toxins in Alaskan marine mammals

ironment

ntington [c], Gay

el [f], Tracey

on [f], Verena Gill

ghts and content

Acute and chronic dietary exposure to domoic acid in recreational harvesters: A survey of shellfish consumption behavior

Bridget E. Ferriss [a], David J. Marcinek [b], Daniel Ayres [c], Jerry Borchert [d], Kathi A. Lefebvre [e]

Show more

https://doi.org/10.1016/j.envint.2017.01.006

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biotoxins in non-bivalve vectors

Pedro Reis Costa, Sara T. Costa, Ana Catarina Braga, Susana M. Rodrigues, Paulo Vale

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https://doi.org/10.1016/j.foodcont.2016.12.038

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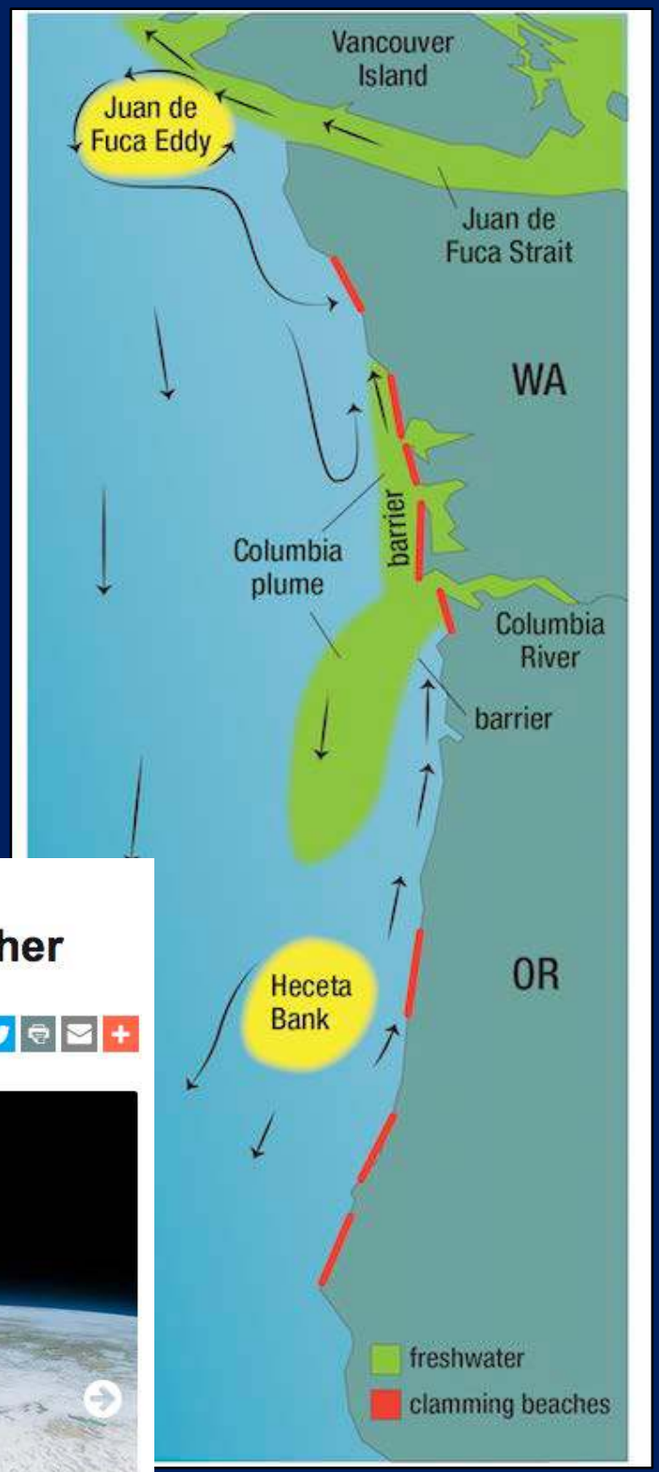
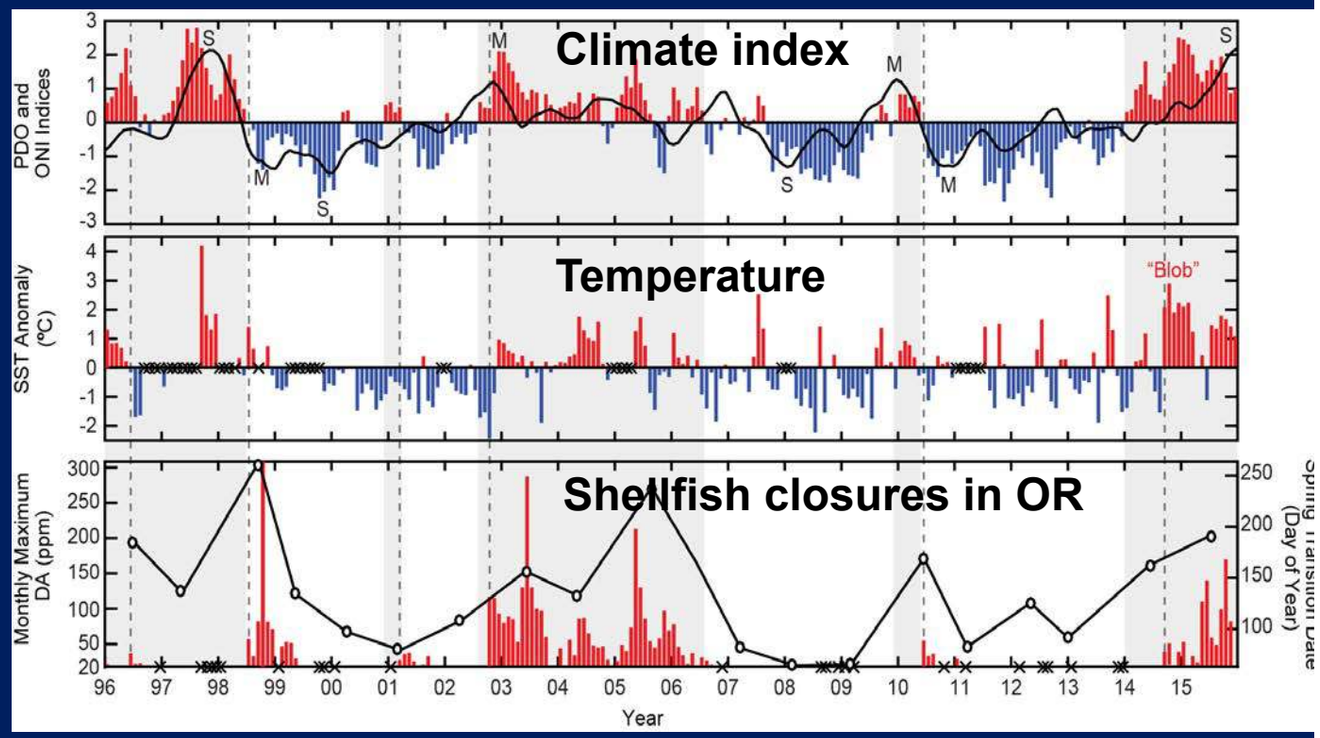
Vol. 237 (July 18 2002), pp. 209-216

Pseudo-nitzschia (domoic acid)

- Since first identified in 1991, periodic closures of shellfishing
- Severity of annual blooms highly variable but unprecedented coastwide closure in 2015
- Forecasting movement from “hotspots” important
- Linkage to warm ocean (Climate Change)





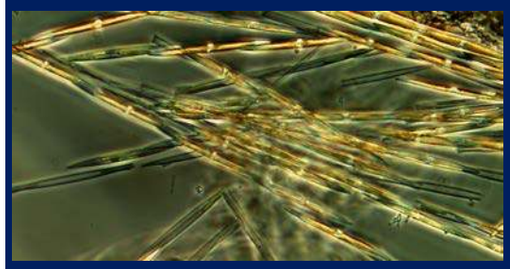
McKibben et al. 2017. PNAS

Scientists: Clam toxin, warmer ocean go together

Published on January 17, 2017 2:45PM

NASA PHOTO

Darker green colors near the West Coast of the U.S. reflect blooms of phytoplankton and high algal levels, some of which are toxic.



HABs Effects on Fisheries

By the numbers: Virginia leads nation in clam production

By **VIMS Staff** - May 27, 2017

Hard clams ready for market. (Courtesy K. Hudson/VIMS)

Virginia shellfish farmers sold $56.6 million in clams and oysters in 2016, with hard clam sales of $38.1 million and $18.5 million in oyster sales. Hard-clam production once again leads the nation and oyster production is tops among East Coast states.

FOOD FOR THOUGHT

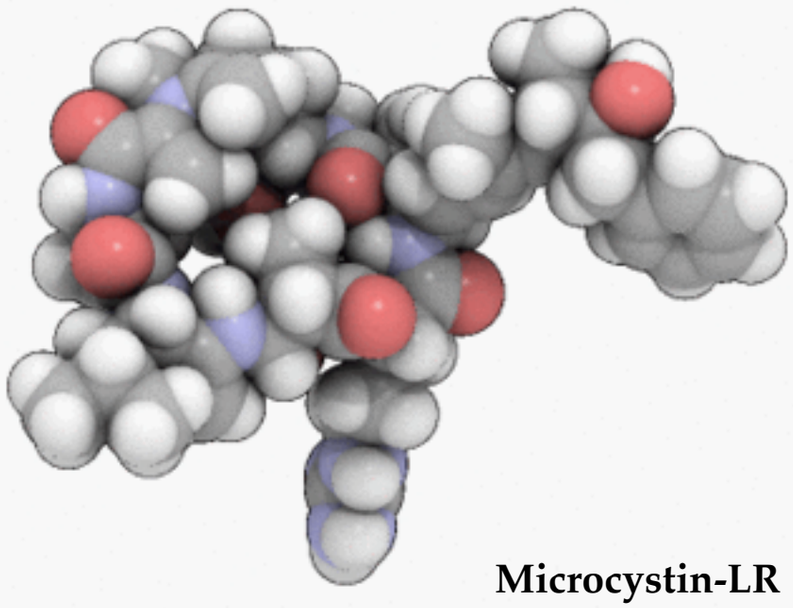
Shellfish Industry, Scientists Wrestle With Potentially Deadly Toxic Algae Bloom

January 4, 2018 · 2:36 PM ET

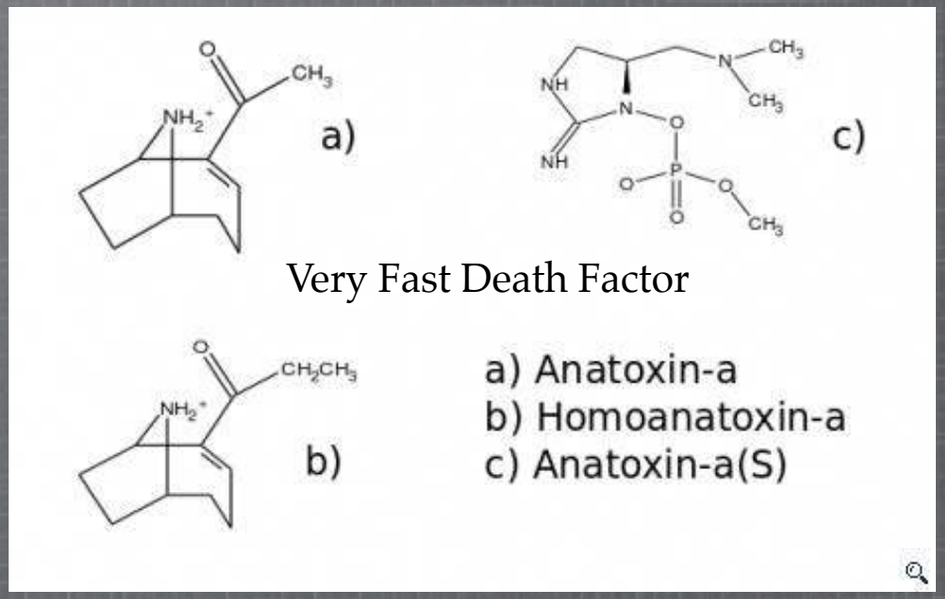
FRED BEVER

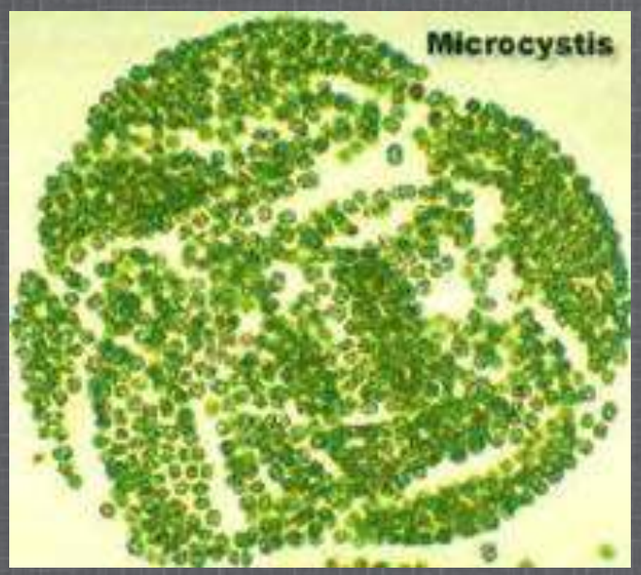
FROM maine public

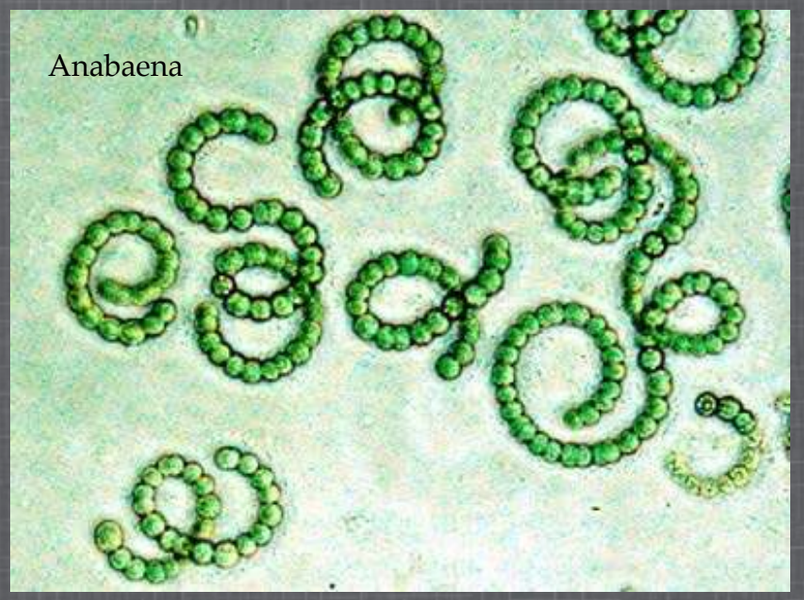
Feed the Players and The Toxins



Microcystin-LR







How Common are Toxic Cyanobacterial Blooms?

Thirty percent of lakes included in the 2007 EPA National Lakes Assessment had detectable microcystins.

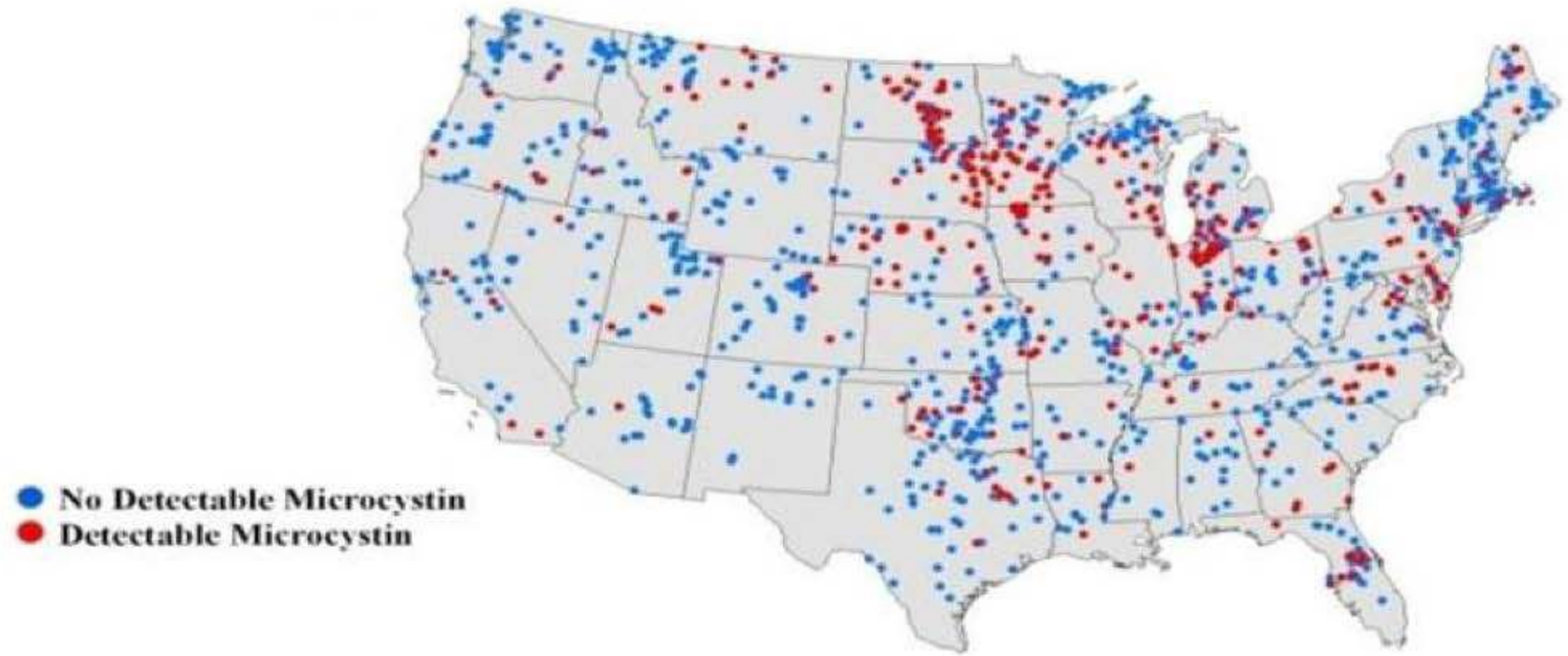
30% of lakes had detections (n=1,028)

Maximum concentration: 230 µg/L

Median: <0.10 µg/L (0.52 µg/L*)

Mean: 1.0 µg/L (3.0 µg/L*)

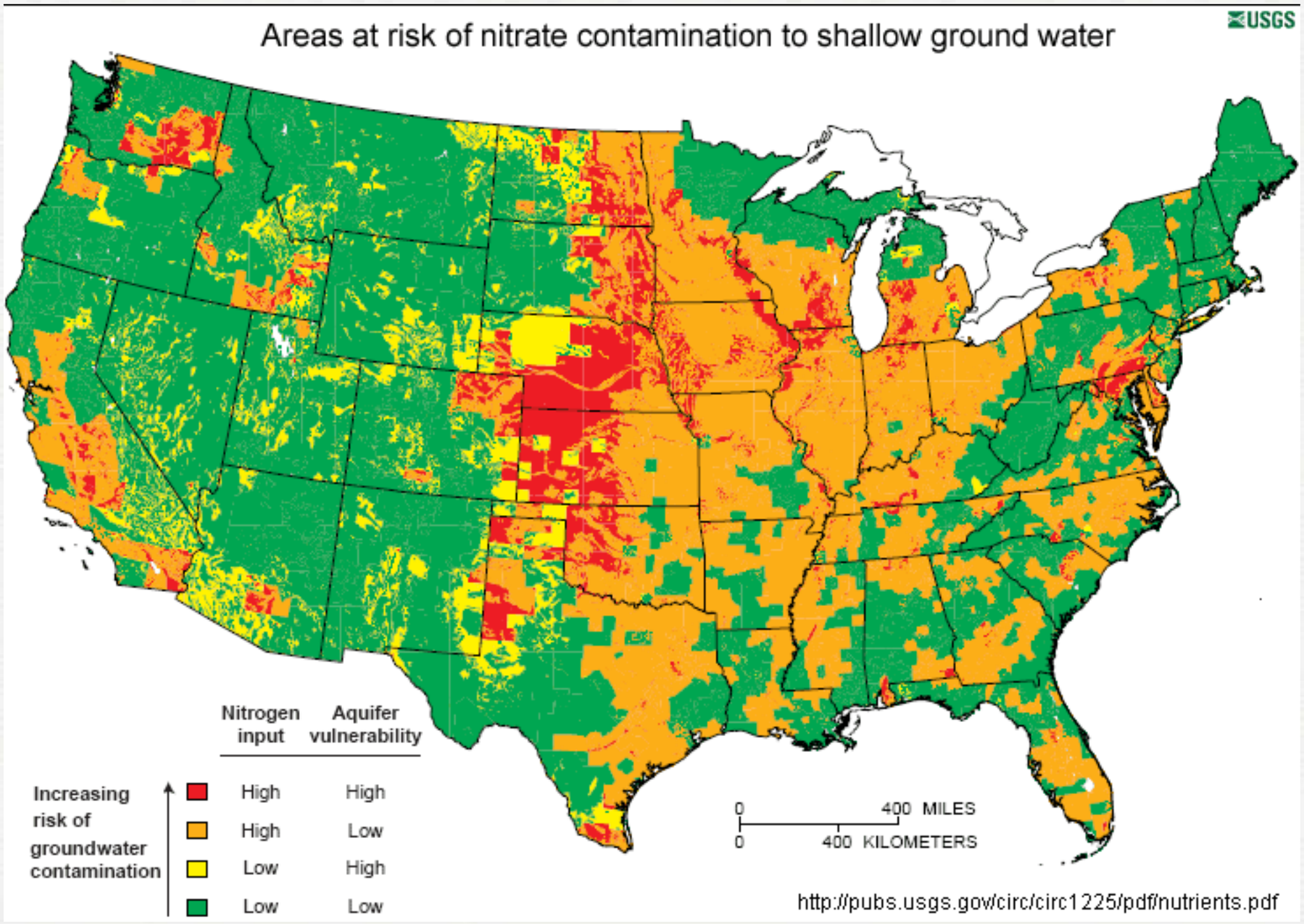
*Detections only



USGS science for a changing world

*Map generated by USGS using data from EPA 2007 National Lakes Assessment
http://water.epa.gov/type/lakes/lakessurvey_index.cfm

Too Much of A Good Thing



What Types of Toxins Do Cyanobacteria Produce?

- **Hepatotoxins (liver toxins)**
  - **Common toxins:** microcystins, cylindrospermopsins
  - **Symptoms of exposure:**
    - Vomiting
    - Diarrhea
    - Fever
    - Cramps
- **Neurotoxins**
  - **Common toxins:** anatoxins, saxitoxins
  - **Symptoms of exposure:**
    - Paralysis
    - Seizure
- **Dermatoxins**
  - **Common toxins:** lipopolysaccharides, lyngbyatoxin
  - **Symptoms of exposure:**
    - Irritation to eyes, ears, throat
    - Rashes
    - Skin Lesions

Photo courtesy of L. Merchant-Masonbrink

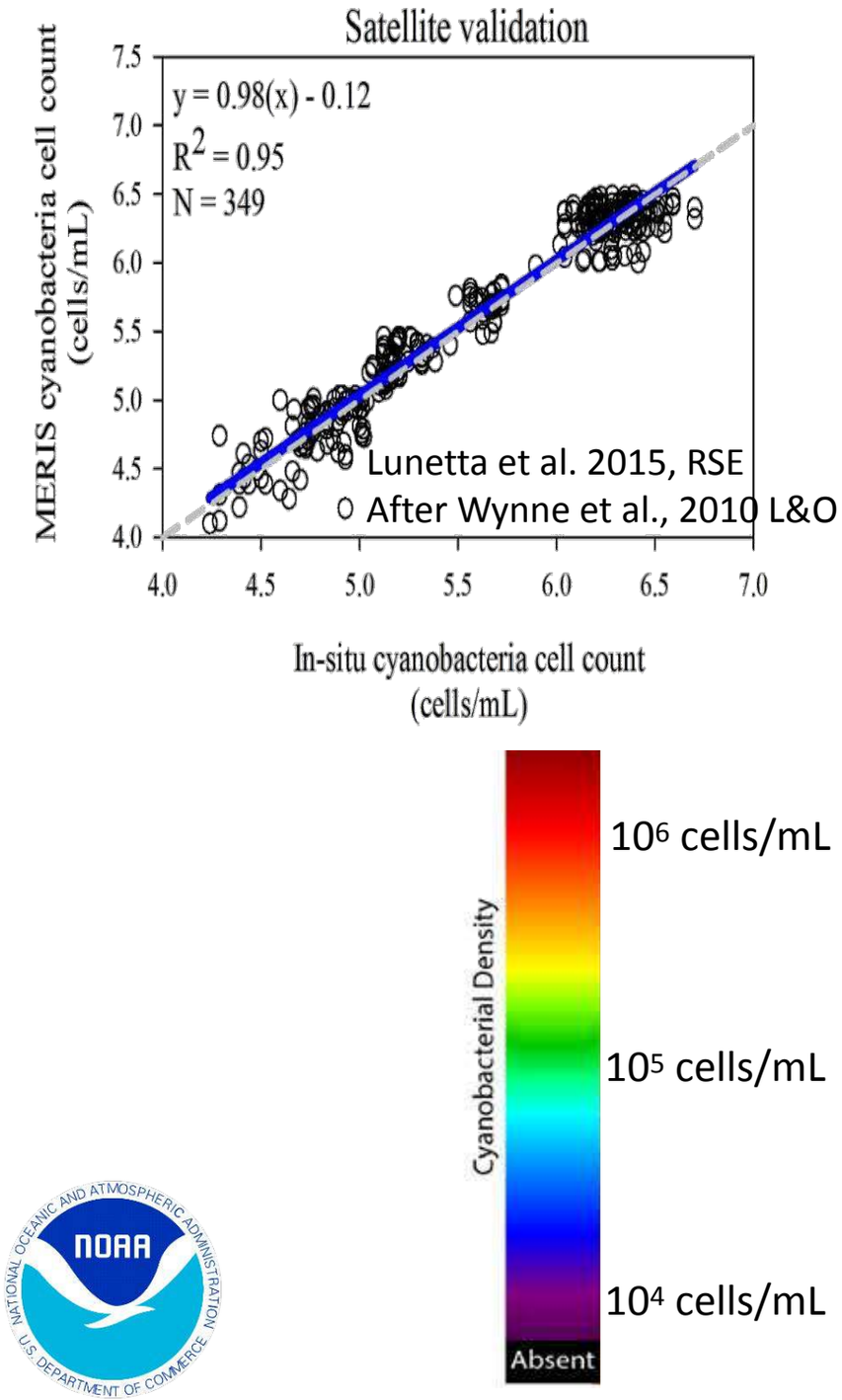
USGS science for a changing world

Remote Sensing to the Rescue

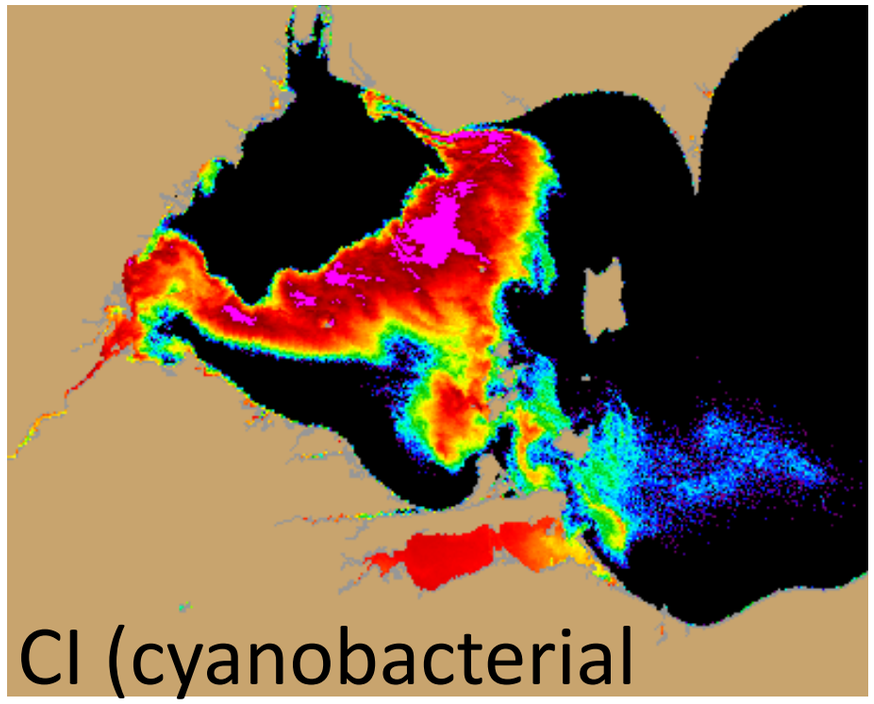
Examining and Forecasting Characteristics of the Annual Cyanobacterial Bloom in Lake Erie with a mechanistic model

R.P. Stumpf, E. Davenport, T.T. Wynne, M.C. Tomlinson
NOAA NOS Natl Centers for Coastal Ocean Science
D. Dupuy CSS-Inc.,
Laura Johnson Heidelberg U.

Cell abundance from satellite



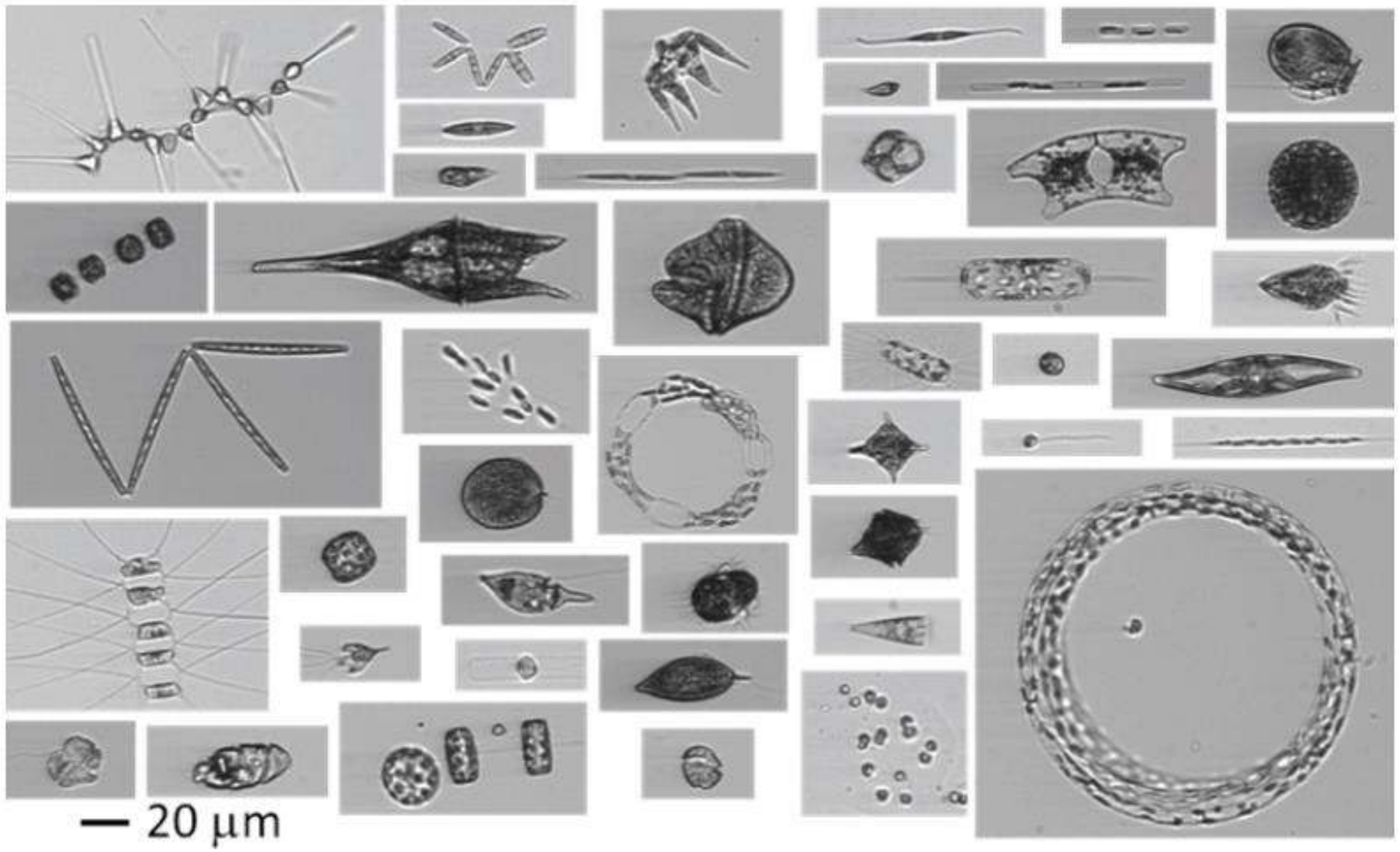
Sources
MERIS: 2002-2011
MODIS: 1999-2001, 2012-2017
Sentinel-3: 2017



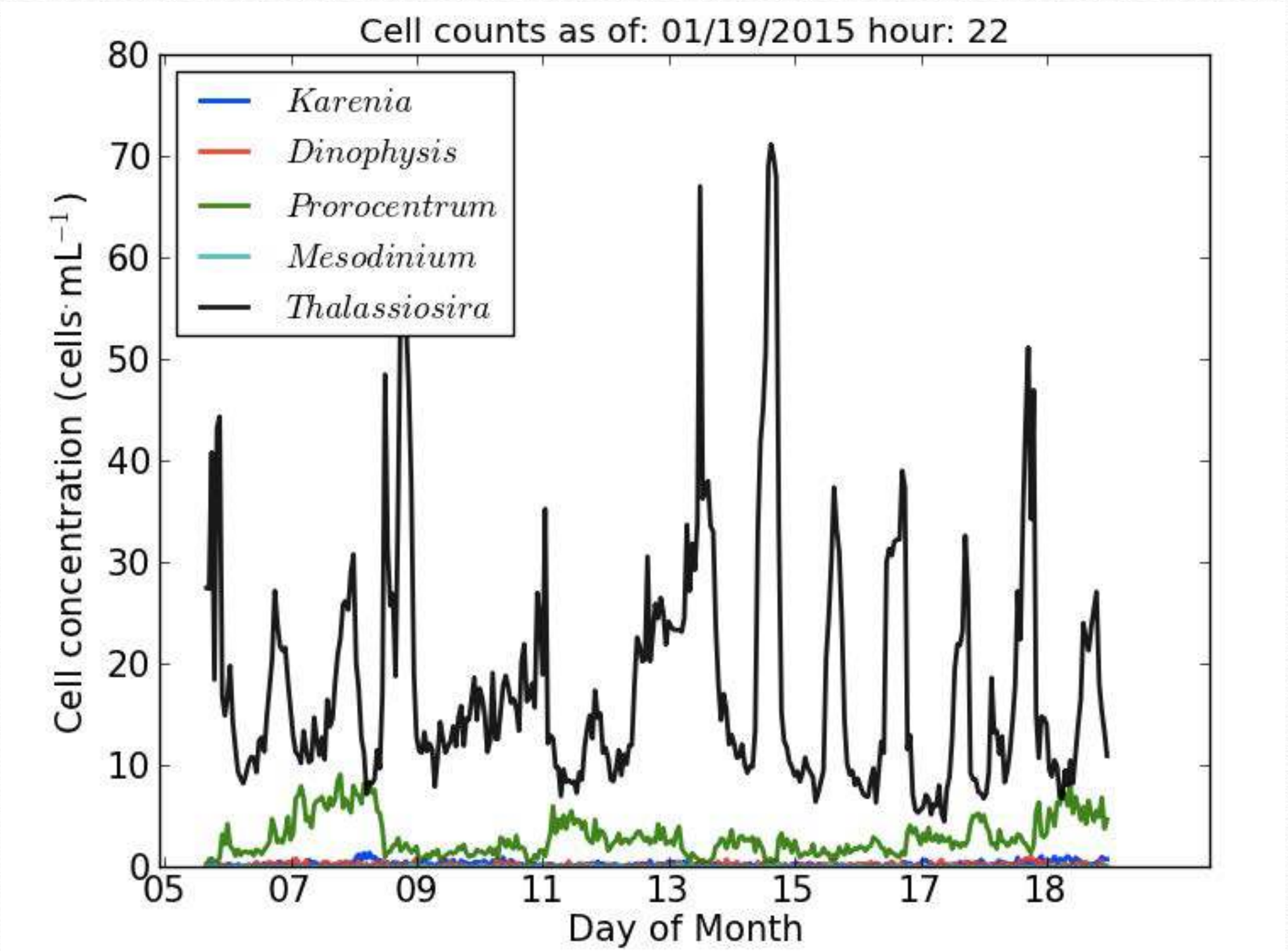
2017 Sep 22
Sentinel-3

Data derived from Copernicus Sentinel-3 provide by EUMETSAT

The IFCB to the Rescue!



The IFCB is essentially an automated microscope and image classifier


Cell counts as of: 01/19/2015 hour: 22
Karenia
Dinophysis
Prorocentrum
Mesodinium
Thalassiosira
Cell concentration (cells·mL⁻¹)
0
10
20
30
40
50
60
70
80
05
07
09
11
13
15
17
18
Day of Month

Take Home Lessons

- Aquaculture has the potential to feed the world
- Must be done in environmentally and economical sustainable manner
- Harmful Algal Blooms could prevent aquaculture from reaching its true potential

Limiting Resource