European Centre for Environment & Human Health

Oceans and Human Health Center

An Overview of Harmful Algal Blooms and Human Health

Lora E Fleming MD PhD MPH MSc

European Regional Development Fund
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convergence
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University of Exeter Medical School

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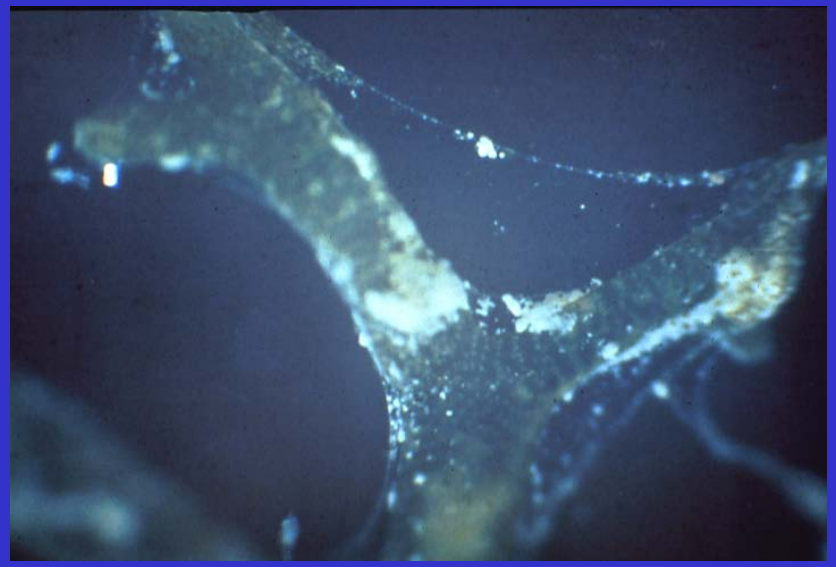
Science
31 August 2007 | $10
AAAS

Harmful Algal Blooms (HABs)

Definition:

- **"Red/Brown/Yellow/etc Tides"**
- **Proliferation of microscopic organisms**
- **Marine, fresh & estuarine waters**
- **☠ Potential danger to:**
  - **Environment**
  - **Wildlife**
  - **Humans**

Harmful Algal Bloom



Our Filthy Seas

Causes of HABs?

DEPENDS on Individual Organism!!!!

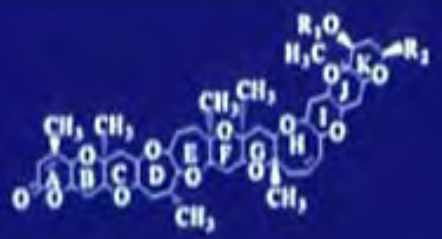
- **Environmental/Biological factors**
- **?Anthropogenic Factors**
  - **?Human Interactions**
  - **?Pollution & Nutrients**
  - **?Global Change**

Causes of HABs

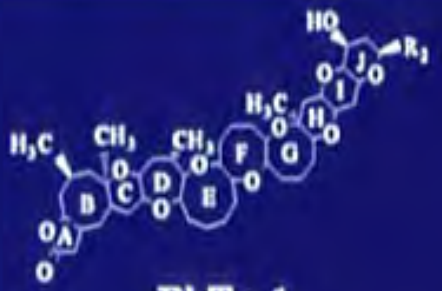
- Microscopic organisms
- "Harm" =
  - Oxygen deprivation
  - Natural Toxin-production

HAB Toxins

- Natural Toxins
  - Harmful in minute (picogram) doses
- Can NOT be
  - detected
    - No taste or smell
  - eliminated
    - Heat and acid stable
    - Cleaning, storage, cooking
- Work at cellular level



PbTx-2



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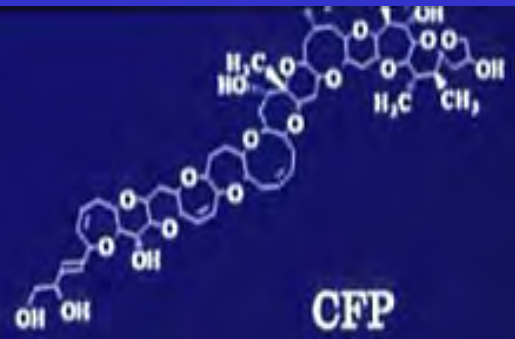
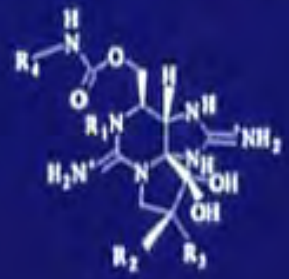


CFP

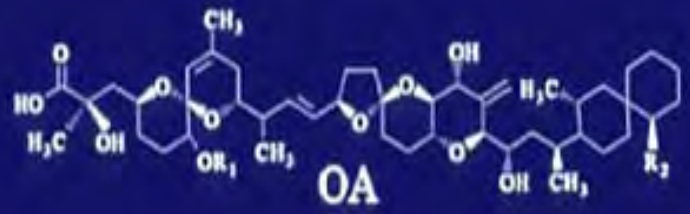
Marine Toxins Affecting Man

DA



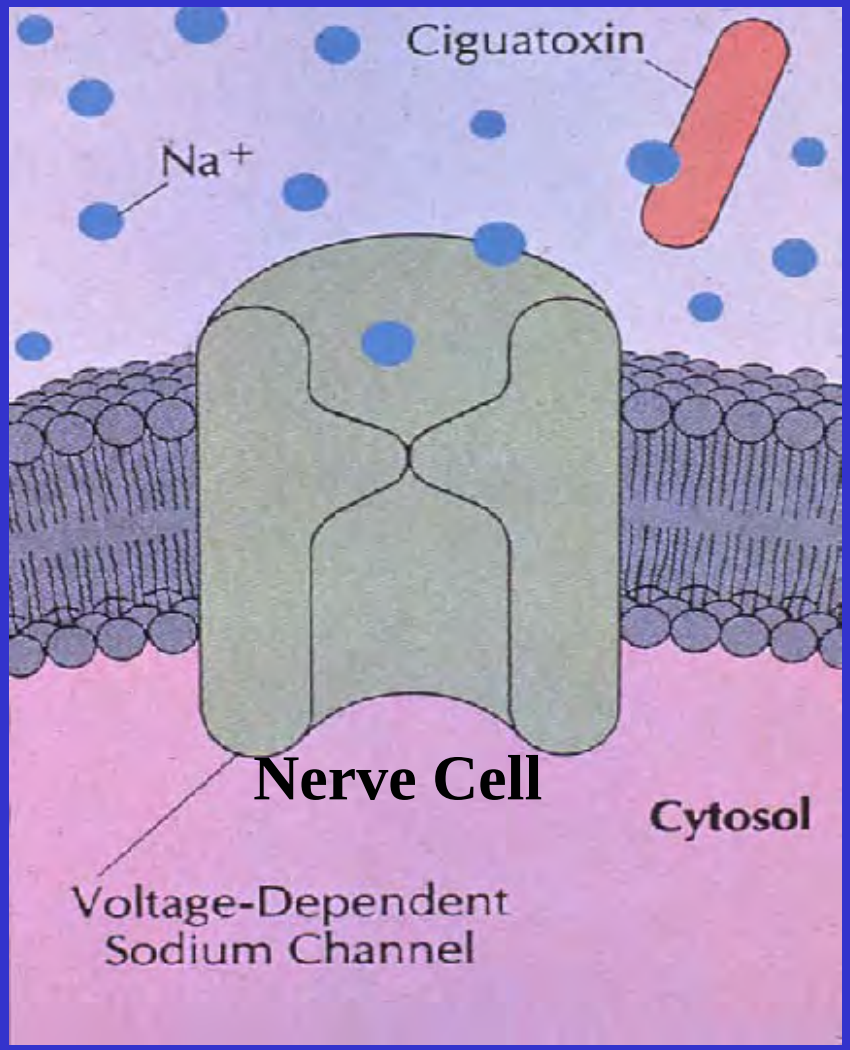
STX

TTX



OA

Ciguatoxin Effects on the Sodium Channel in Nerve Cells



Sentinel Species

Economic Costs of HABs

US 1987-1992: > $449,291,987

- Public Health
- Commercial Fisheries
- Recreation & Tourism
- Monitoring & Management
  - Anderson, Hoagland et al (2000/2002)

HAB Human Diseases: Routes of Exposure

TOXIC CARNIVORE

TOXIC HERBIVORE

EATEN BY CARNIVORE

HERBIVORE INGESTS TOXIC DINOFLAGELLATES

EATEN BY MAN

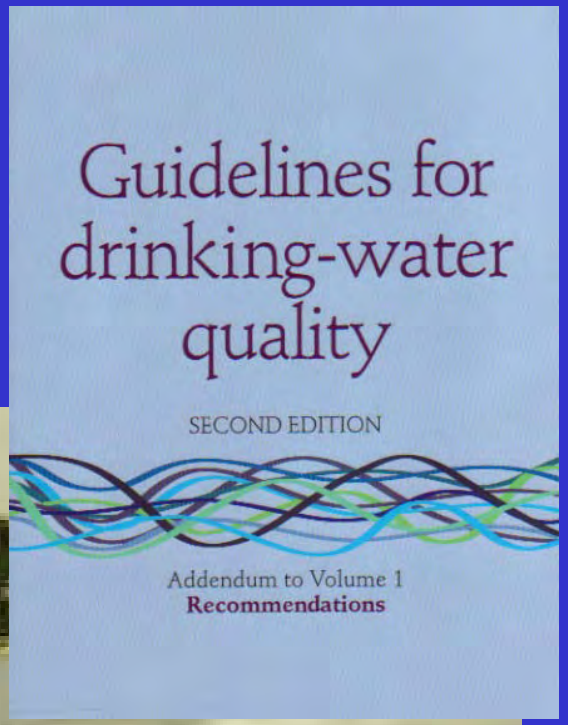
TOXIC HERBIVORE

TOXIN PRODUCING DINOFLAGELLATES

Seafood Consumption

- **Conflicting Health Advice & Data**
- **Bivalve Consumption (FAO 2004)**
  - **France & Norway 35% consume 1-11x/yr = 4.2 “eating occasions”/yr**
  - **US 8.6 “eating occasions”/yr**
- **Seafood Consumption (NAS 2007)**
  - **US > 16 lbs/person/yr**
-  **Subpopulation & Individual Variability**

HAB Human Diseases: Air/Water Exposure



HAB Known Human Diseases

HAB Known Human Diseases

- Paralytic Shellfish Poisoning (PSP)
- Neurotoxic Shellfish Poisoning (NSP)
- Diarrheic Shellfish Poisoning (DSP)
- Amnesiac Shellfish Poisoning (ASP)
- Azaspiracid Z/Shellfish Poisoning (AZP)

- Ciguatera Fish Poisoning
- Pufferfish “Fugu” (Tetrodotoxin)/(Saxitoxin)
- ?Brevetoxin Fish Poisoning

- Aerosolized (Brevetoxin) Red Tide
- Blue Green Algae/Cyanobacterial
- ??*Pfiesteria*/PEAS
- ??Ovatoxin/Ostreopsis
- OTHER?

HAB Human Diseases

Transvector	Disease
Shellfish	PSP
	NSP
	DSP
	ASP
	AZP
Fish	Ciguatera
	Fugu (Tetrodotoxin/Saxitoxin)
	?Brevetoxin Fish Poisoning
Water/Aerosol	(Brevetoxin) Red Tide
	Blue Green Algae/Cyanobacteria
	(*?Pfiesteria*/PEAS)
	?Ovatoxin/Ostreopsis

HAB Human Diseases : Clinical Epidemiology

Known Clinical Epidemiology

- **Onset**
- **Attack Rate = # ill/# Exposed**
- **Symptoms**
- **Fatality**
- **??Chronic Disease**
- **Treatment**
- **Other**

HAB Human Diseases

- Paralytic SHELLfish Poisoning (PSP)(Saxitoxin)
- PufferFISH "Fugu" (Tetrodotoxin)
- Acute Onset (5-30 min-hours; < 24 hrs)
- ?High Attack Rate
- Neurologic; GastroIntestinal, Respiratory
- Fatality (1-60%)
- ?Short Duration (days)
- ?Chronic Disease
- Supportive Rx; ?Other

Fugu=Pufferfish Poisoning
(Tetrodotoxin & Saxitoxin)

HAB Human Diseases

Diarrheic Shellfish Poisoning (DSP) (Okadeic Acid+)

- Acute Onset (30 min-3 hr; 24 hrs)
- ?High Attack Rate
- GastroIntestinal
- ?Short Duration (days)
- ?Chronic Disease: ?Cancer
- ?Supportive Rx

HAB Human Diseases

Neurotoxic Shellfish Poisoning (NSP) (Brevetoxin)

- Acute Onset (30 min-3 hr; < 24 hrs)
- ?High Attack Rate
- Neurologic; GastroIntestinal
- ?Short Duration (days)
- ?Chronic Disease: ?Neurologic?
- ?Supportive Rx

HAB Human Diseases

Amnesiac Shellfish Poisoning (ASP) (Domoic Acid)

- ?Onset: hours (?< 24 hrs)
- ?High Attack Rate
- Neurologic; ?Other
- ?Fatality (3%)
- ?Chronic Disease (yrs): ??Amnesia
  - Sea Lions
  - ?susceptible populations
- ?Supportive Rx

HAB Human Diseases

Azaspiracid Shellfish Poisoning (AZP) (Azaspiracid)

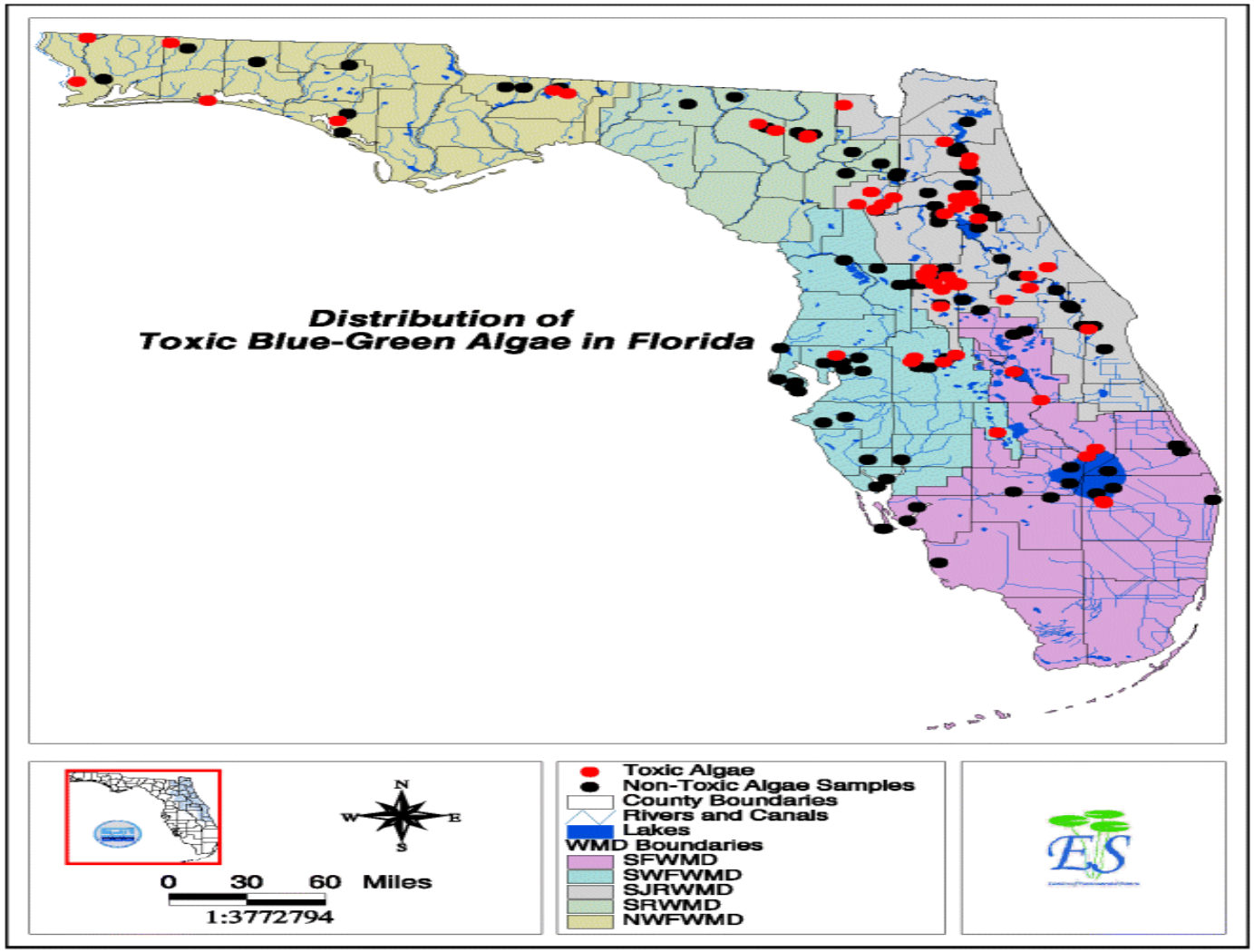
- ?Onset: hours (?<24 hrs)
- ?High Attack Rate
- Gastointestinal (Intestine, Liver)
- ?Fatality
- ?Chronic Disease (yrs): ?Cancer
- ?Supportive Rx

HAB Human Diseases

Blue Green Algae/Cyanobacteria (Multiple Toxins)

- ?Onset
- ?Attack Rate
  - ?Sensitive Subpopulations
- ?GastroIntestinal; ?Dermatologic; ?Hepatic; ?Renal; ?Neurologic; ?Respiratory; ?Other
- ?Fatality (0-20%)
  - Dialysis patients
- ?Chronic Disease (yrs): Hepatic, Cancer
- ?Rx

Florida Blue Green Algae Sampling: Surface Water



HAB Human Diseases

Ciguatera (Ciguatoxin; ?Maitotoxin, etc)

- Acute Onset (1-24 hr)
- ?High Attack Rate
- Neurologic; GastroIntestinal, Cardiovascular
- ?Fatality (0.1-12%)
- Long Duration (weeks to yrs)
- Chronic Disease: Neurologic, ?Chronic Fatigue, ?Other
- ?Rx: Supportive, Mannitol, ?TCA, ?Other

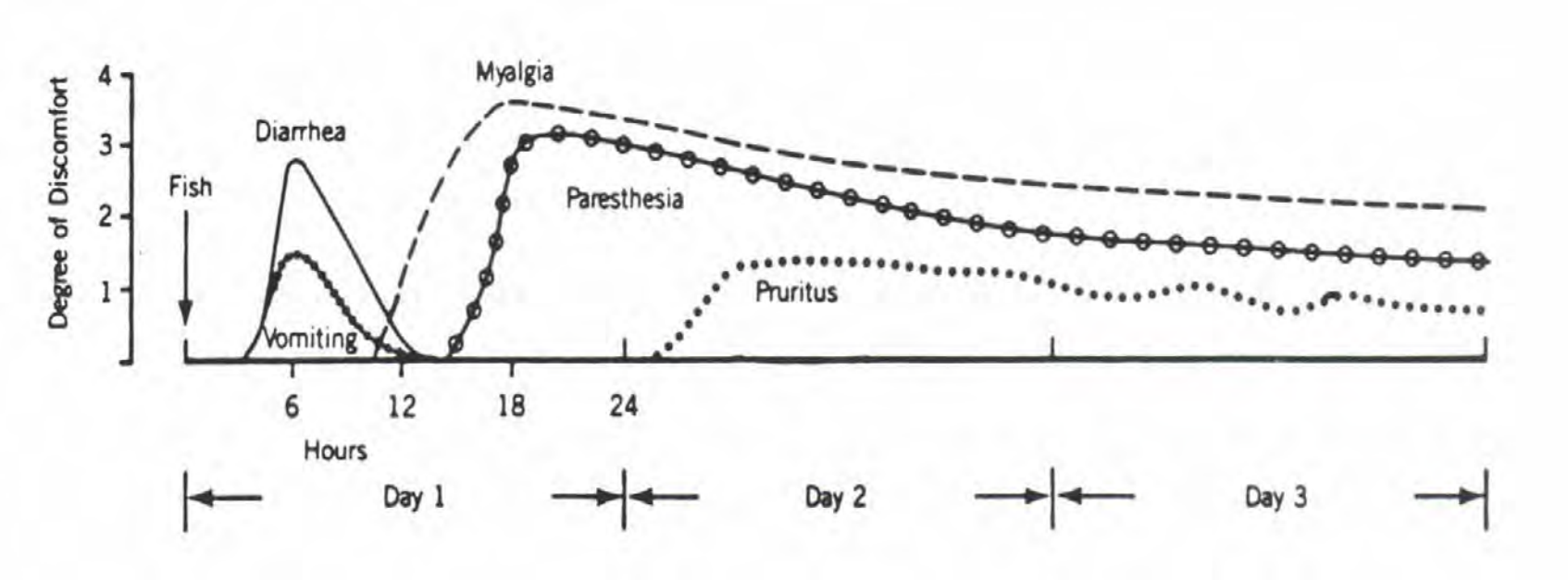

FABULOUS
FLORIDA
EVERGLADES
NATIONAL PARK
MIAMI
KENDALL
PERRINE
GOULDS
HOMESTEAD
KEY LARGO
PENNEKAMP
UNDERWATER PARK
FISHING CAPIT
BOCA CHICA
Y WEST
SADDLE
SNOOK
YELLOWTAIL
BONEFISH
SNAPPER
SAILFISH

Table 1 Reported Frequency of Clinical Symptoms of Ciguatera

Symptoms (reported by % frequency)	Region of Study Source of Data (Reference #) Number of Cases (n)									
	Caribbean (17) (n=442)	Caribbean (24) (n=57)	Caribbean (22) (n=47)	Caribbean (9) (n=129)	Caribbean (25) (n=16)	Caribbean (23) (n=80)	Caribbean (27) (n=6)	South Pacific Islands (26) (n=12,890)	Western Pacific (Australia) (1) (n=167)	South Pacific Isles (11) (n=3,009)
Gastrointestinal										
Diarrhea	78.7	77	81	76	56	83	66	72.6	49	70.6
Vomiting	42.5	37	40	68	69	69	66	38.8	50	37.5
Nausea		82				69	100	43.5	50	42.9
Abdominal pain	64.5	58	30		75	74	66	42.5	29	46.3
Neurological										
Arthralgia	78.7	75	34		31	60		85.9	29	85.7
Myalgia	79.0	75	34	86	94	56		85.3	38	81.5
Extremity paresthesia	81.0	79		71	38	36	50	89.0	82	89.2
Circumoral paresthesia	69.5	79	38	54	38	38	33	88.1	82	89.1
Temperature reversal	64.3	77	23		50	48	16	87.2	65	87.6
Headache		56	45	47	50	39		59.6	25	59.2
Dizziness/vertigo	50.0			47	56	33	16			42.3
Weakness		84		30	94	65.4		60.0	70	60.0
Chills/sweating			36	24				59.6		59.0
Other										
Dysuria	25.0				31			12.6		18.7
Pruritus	77.0		66	48	100	45	66	44.0	5	44.9
Dental pain or "looseness"	32.1	23	13		19	11		20.7		24.8
Dyspnea								12.1		16.1
Skin rash	32.1				31					20.5

Stinn et al 2001

Symptom Course of Sub/Chronic Ciguatera



Lawrence et al 1980

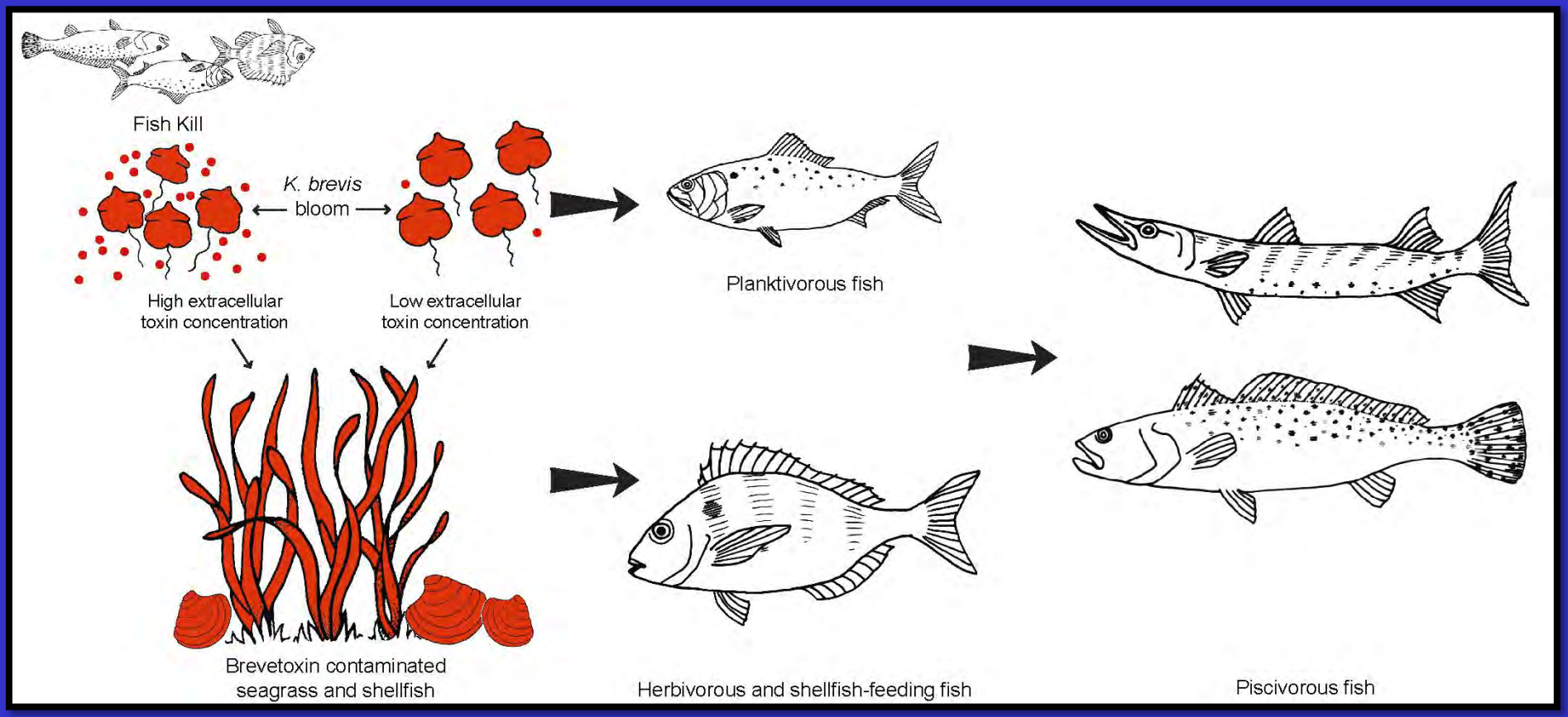
?Brevetoxin Fish Poisoning

Red tides and marine mammal mortalities

Unexpected brevetoxin vectors may account for deaths long after or remote from an algal bloom.

Flewelling et al. Nature 2005

?Brevetoxin Fish Poisoning New Pathway!



Naar, Flewelling, et al

Chronic Low Dose Exposures??

Aerosolized (Brevetoxin) Florida Red Tide

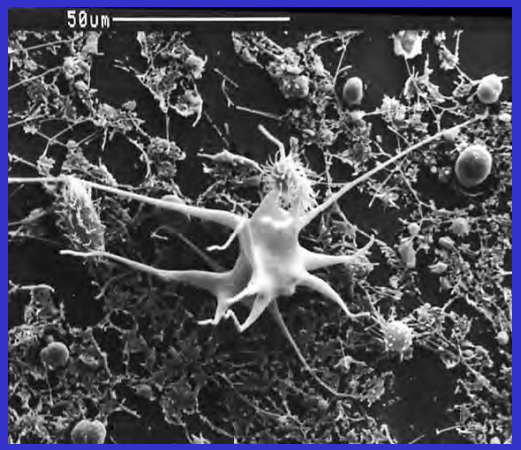
Conclusions: Humans

- **Emergency room visits GI & Respiratory**

- **Acute Respiratory Effects**
  - Symptoms in Asthmatics & Occupational
  - PFTs in Asthmatics
- **Sub Acute Respiratory Effects**
  - Symptoms & PFTs Asthmatics
  - Increased ER Respiratory Admissions
- **Chronic Respiratory Effects**
  - ?None in stable asthmatics; ?Unstable
  - ?Pneumonia, Bronchitis increased risk

Pfiesteria piscicida / PLOs???

Pfiesteria piscicida



Cryptoperidiniopsoid Dinoflagellate

New HAB Human Diseases?

- Geographic spread & new Locations
  - Ballast water, spat
- New transvectors
  - e.g. Brevetoxin FISH disease
- Known “Orphan” toxins
  - Cyclic imines
  - Pectenotoxins
  - Yessotoxins
  - Cyanotoxins
- New/Unknown toxins
  - ?Ovatoxin
- Mixtures???????

Shellfish Safety – Algal toxins

EU working group on emerging toxins (May 2012)

1. Ciguatoxins → Emerging in southern European waters
2. Ovatoxins → Emerging in Mediterranean
3. Cyclic Imines → Spirolides everywhere, others sporadic
4. TTX → Gasteropod (PT) & fish in Mediterranean


25. 5. 2001 08 : 04

Ciguatera:
Reported Lifetime Prevalence

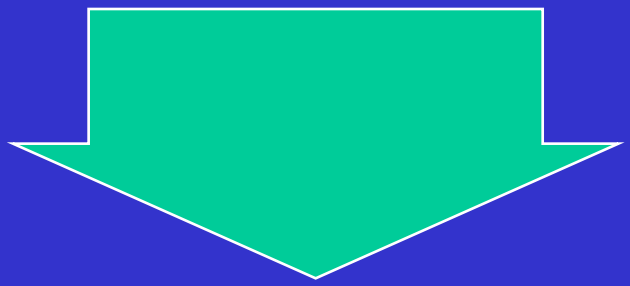
4.4%	St Thomas	McMillan 1980
7.0%	Puerto Rico	Holt 1984
8.5%	Tahiti	Bagnis 1979
43.0%	South Pacific	Rogers 1986
70.0%	Polynesian Isles	Lewis 1986

Ciguatera: Reported Annual Incidence/10,000 py

0.3	Hawaii	Anderson 1983
0.8	Reunion Isles	Quod 1996
3.0	Queensland	Gillespie 1986
5.0	Dade Ct, FL	Lawrence 1980
30.0	Guadeloupe	Czernichov 1984
40-75	Culebra (PR)	Azziz 2012
75.0	US Virgin Isles	Morris 1982
2820.0	Marshall Isles	Lewis 1986
5850.0	French Polynesia	Lewis 1986

Ciguatera Reporting

- Under-Diagnosis
- Under-Reporting
- Inadequate Cluster Follow-Up



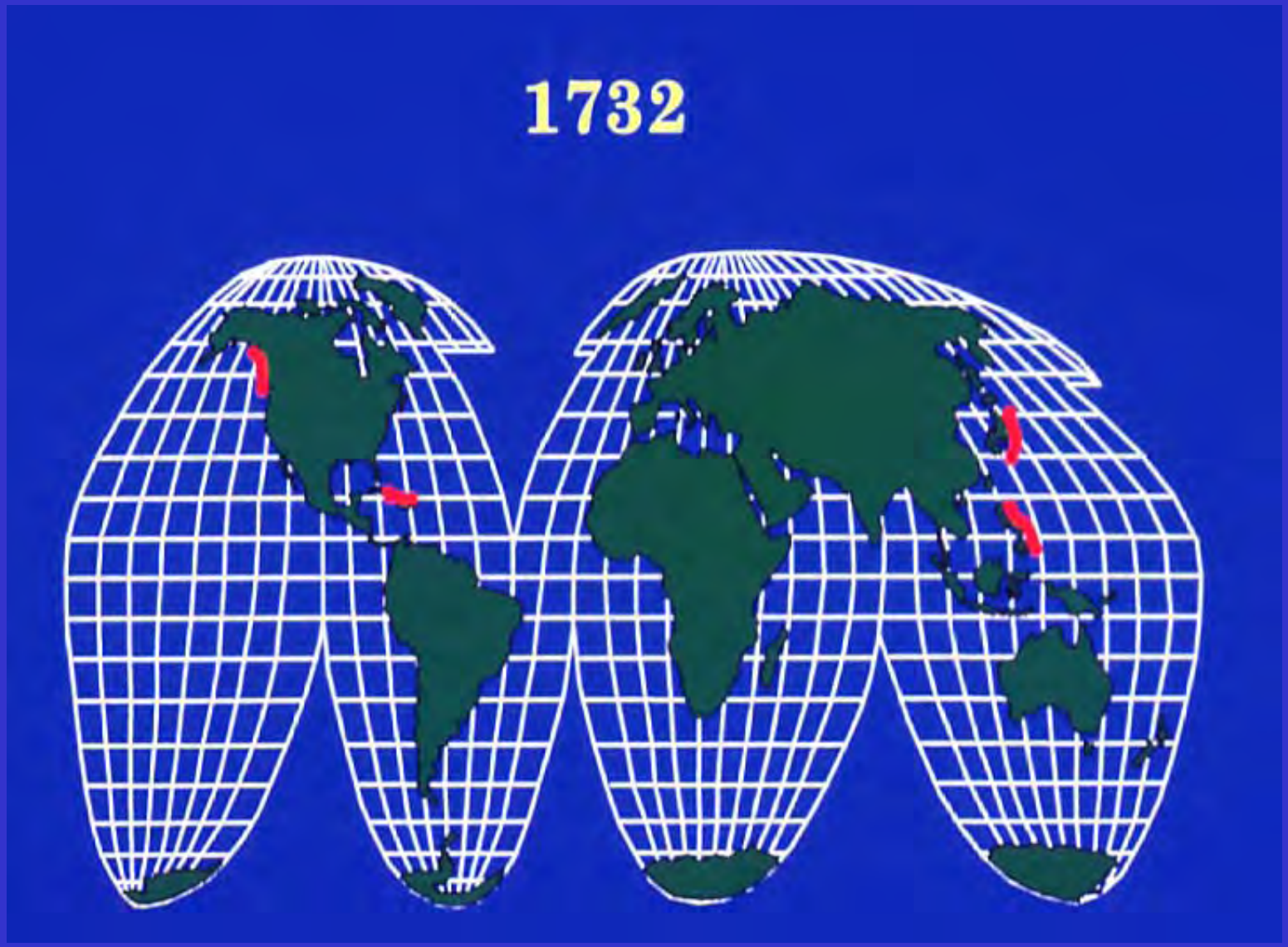
- 90-98% Ciguatera NOT Reported in US

Ciguatera Fish Poisoning Reporting by physicians in an endemic area

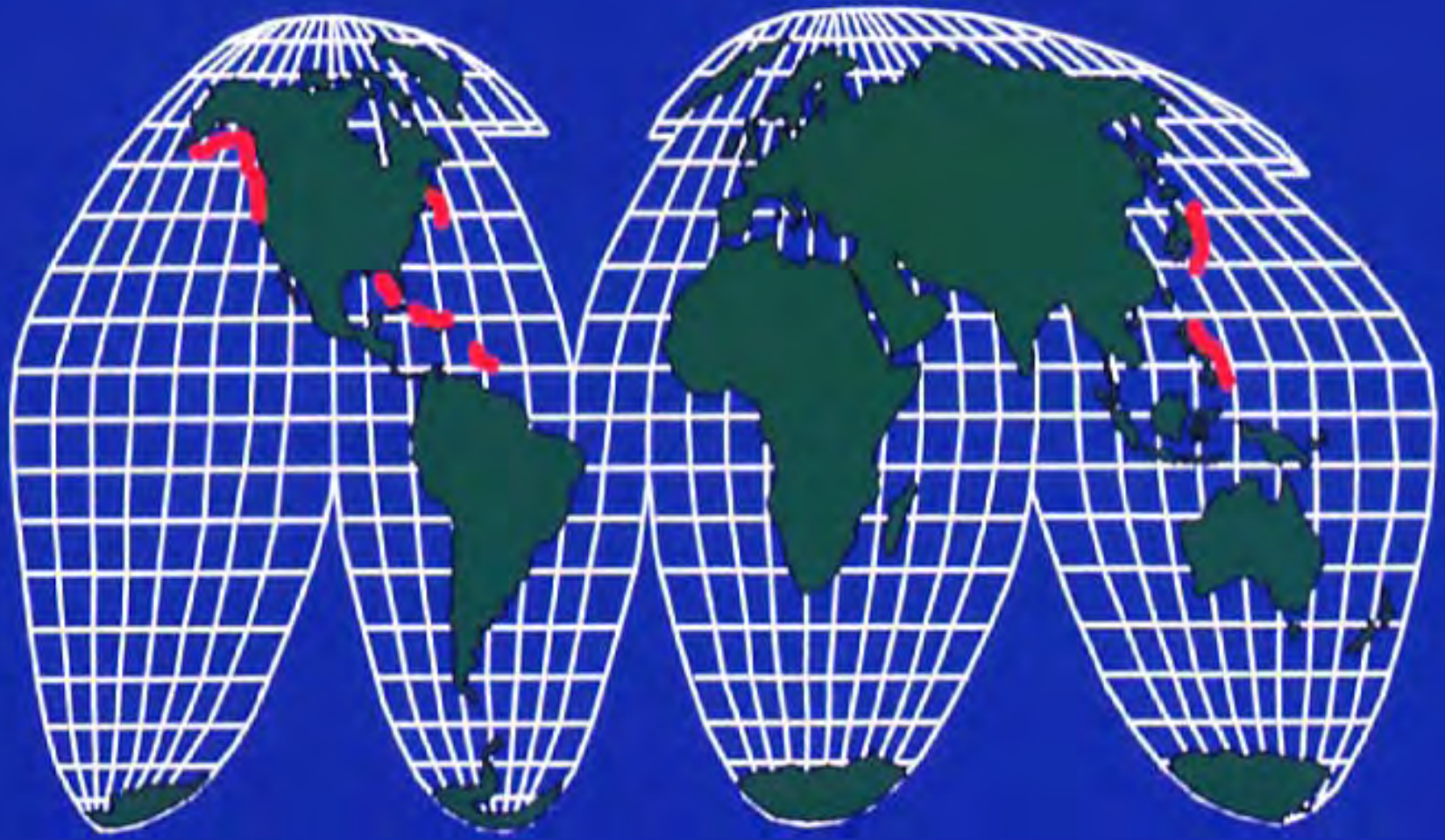
- **1^{O} Care Physicians in Miami-Dade County**
  - **Endemic Ciguatera**
- **Majority of Physicians NOT aware:**
  - **⬇ Diagnosis**
  - **⬇ Treatment**
  - **⬇ Reporting**
    - » (McKee et al 2001)

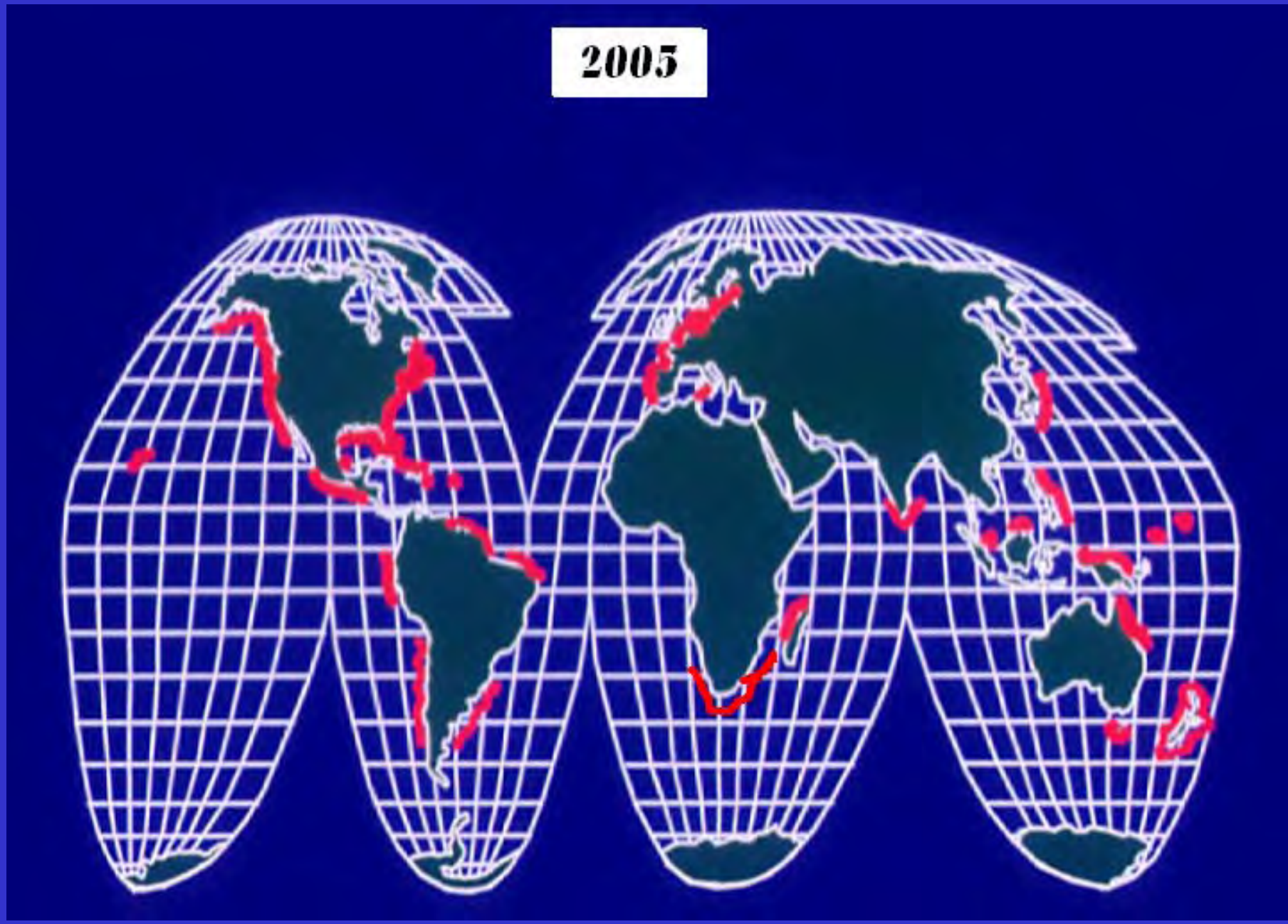
Harmful Algal Blooms Cause Human Illness
1544

1732



1945




2005

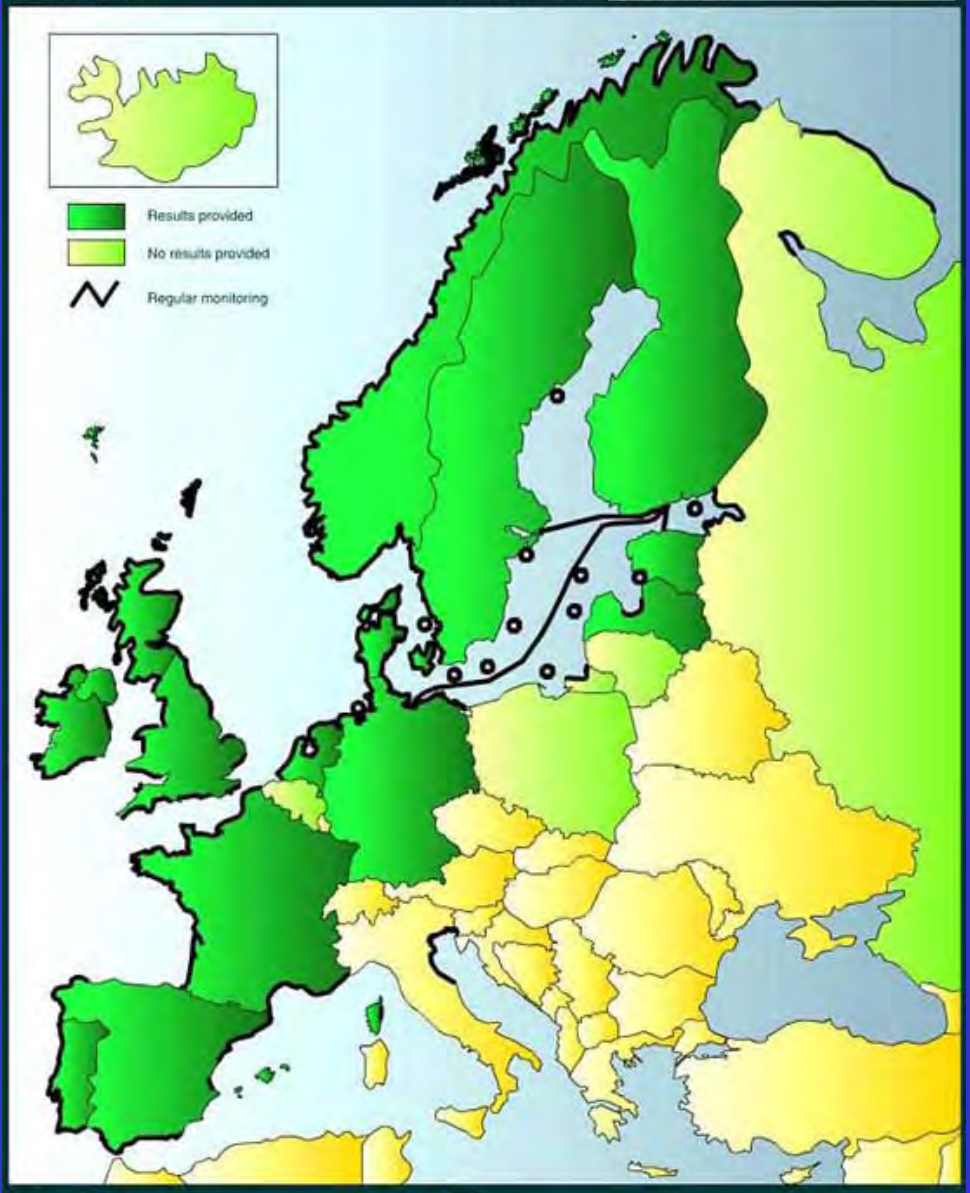
HAB Human Diseases: Current "Prevention" = Monitoring

Disease	Transvector
PSP	*Organism/Toxin Shellfish Bed Monitoring*
NSP	
DSP	
ASP	
AZP	
Ciguatera	*?Fish Monitoring*
Fugu (Tetrodotoxin/Saxitoxin)	
?Brevetoxin Fish	
(Brevetoxin) Red Tide	*?Water/Air Monitoring*
Blue Green Algae	
?Ovatoxin/Ostreopsis	

Regular monitoring
1991 - 2000

ICES countries

DISCLAIMER - WARNING
HAEDAT maps should be interpreted with caution regarding risk of intoxication by seafood products from the respective areas/regions/countries.
The IOC and ICES are not liable for possible misuse of this information.



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CIEM

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ICES
CIEM

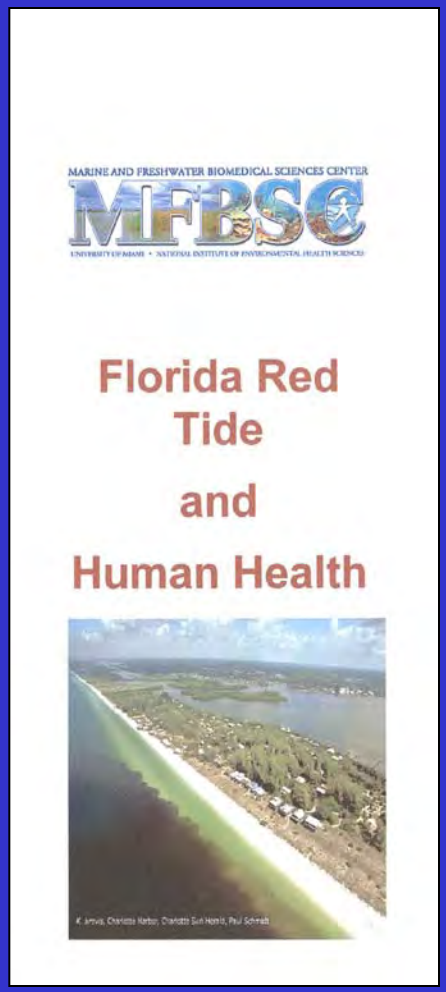
Ifremer

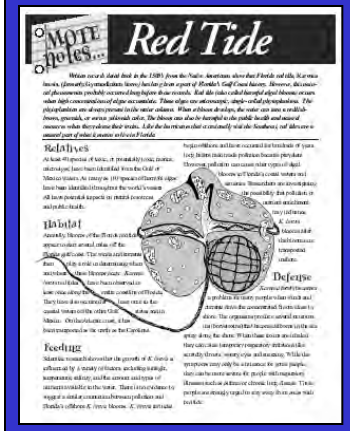
Outreach & Education

- Target Audiences
  - Seafood, Tourism, Water Industries
  - Public Health & Food Safety
  - Healthcare Providers & Patients
  - Consumers, General Public & Media
- Comprehensive & Usable
- Dissemination & Evaluation
  - Keeping Current
- Surveillance

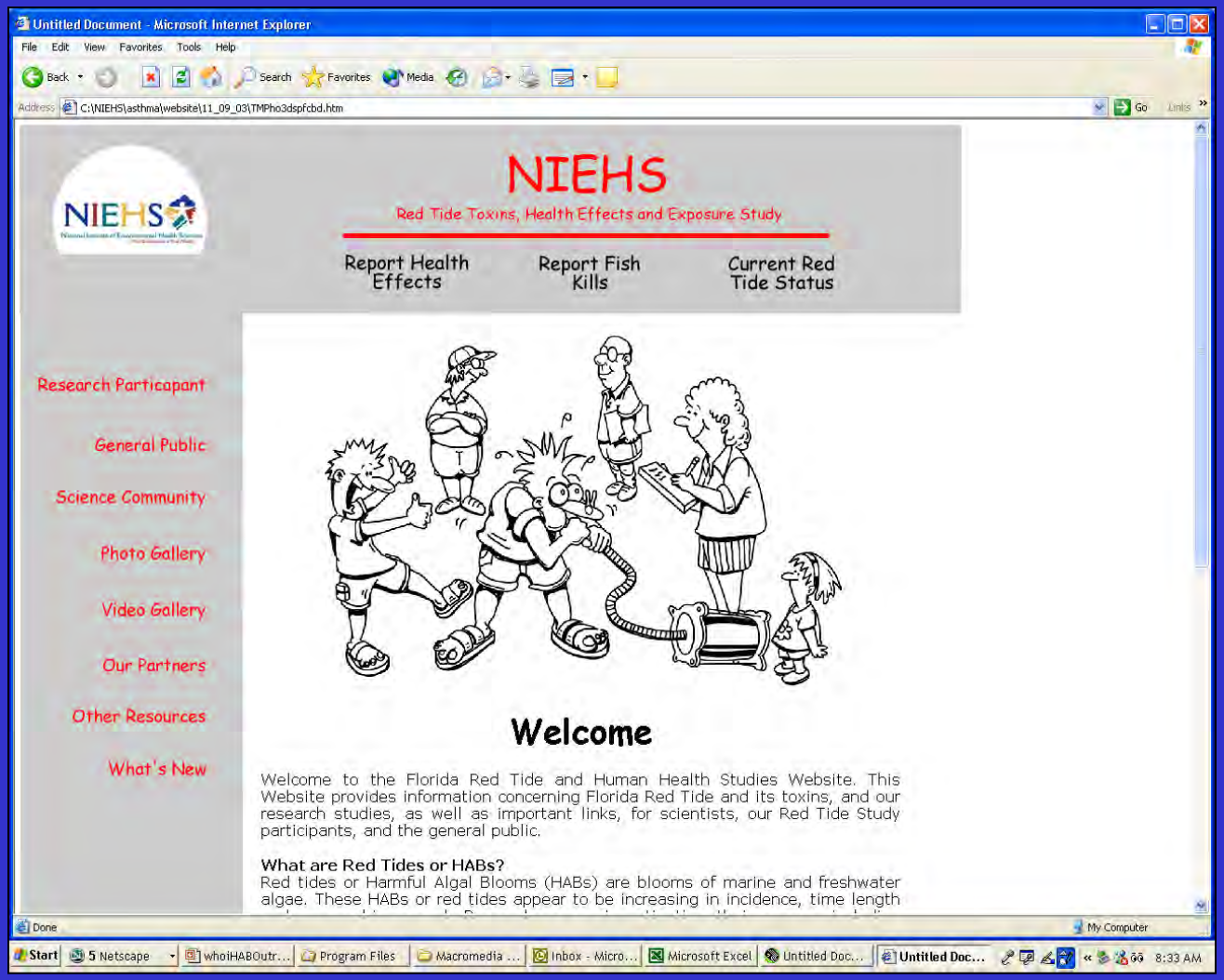
Florida Red Tide (Brevetoxins) & Epidemiologic Study Recruitment

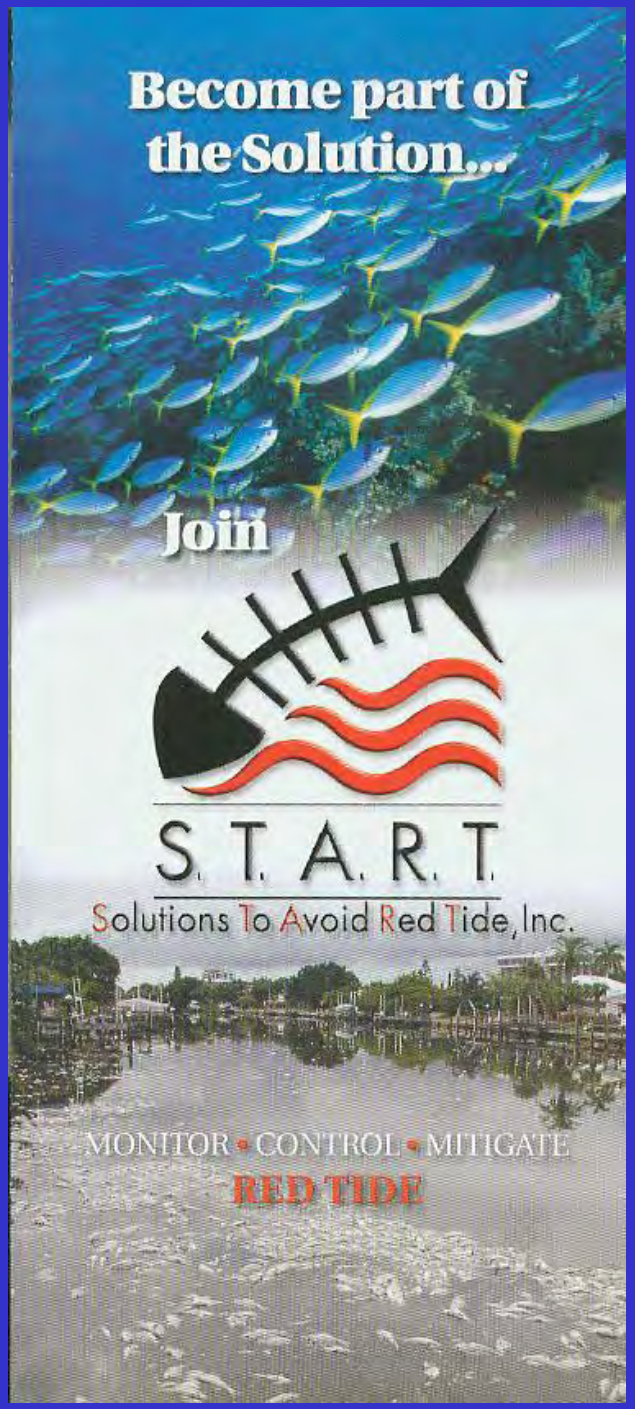
Outreach/Education





Visit our website at: www.mote.org/niehsredtidestudy





Hotels, Restaurants, Tourist Venues

Kirkpatrick, Reich, et al

FL DOH/CDC Medical Fact Sheets & CME

Medical Fact Sheet
Harmful Algae Bloom Series

Neurotoxic Shellfish Poisoning (NSP)

FLORIDA DEPARTMENT OF HEALTH

Environmental Health

CAUSATIVE AGENT: Neurotoxic Shellfish Poisoning (NSP) is caused by the consumption of molluscan shellfish (e.g. clams, oysters, coquinas, mussels, and other filter feeders) contaminated with natural toxins known as brevetoxins, which are produced by a marine dinoflagellate called *Karenia brevis*. *K. brevis* is principally distributed throughout the Gulf of Mexico, and occasionally along the mid- and south-Atlantic Coast. Commonly referred to as "Florida red tides," blooms of *K. brevis* most often occur during late summer and fall, but can be present any time of the year.

SIGNS/SYMPTOMS: Initial complaints typically include: abdominal pain, nausea, vomiting, and diarrhea accompanied by progressive paresthesias, which can affect areas of the mouth and extremities. Other common symptoms include: ataxia, myalgia, headache, and vertigo. Paradoxical temperature sensation (reversal of hot and cold sensations), as seen in Ciguatera Fish Poisoning, has also been reported in NSP. In more severe cases of NSP, acute respiratory depression and labile blood pressure may also be observed.

ONSET/DURATION: Onset of symptoms occurs within minutes to hours, definitely within 24 hours, of consuming brevetoxin-contaminated shellfish. Duration of the illness is generally short, lasting from a few hours to several days.

DIAGNOSIS: Diagnosis is generally based on a clinical evaluation of symptoms and recent food history. Mouse bioassay is the only technique accepted by FDA for testing samples for brevetoxins in shellfish; however the use of a brevetoxin ELISA test (to evaluate biological fluids such as urine) is experimental at this time.

TREATMENT: No specific antitoxin is available although a new natural antagonist known as brevenol may be useful in the future. Although not well researched, the illness appears to be self-limiting, and therapy is supportive and symptom-driven.

RISK GROUPS: All persons are susceptible to NSP. However, young children, the elderly and those individuals with underlying neurologic disease may be at increased risk.

PREVENTATIVE MEASURES: The contaminated shellfish are described as tasting delicious and the toxins cannot be removed from the shellfish by different preparation or storage methods. The Florida Department of Agriculture and Consumer Services closes shellfish harvesting areas when *K. brevis* cell counts exceed 5,000 cells per liter. In recent years most NSP cases have been the result of illegal harvesting of shellfish from closed areas. See www.floridaaquaculture.com/seas/seas_statusmap.htm for shellfish harvesting area status.

REPORTING REQUIREMENTS: NSP cases must be immediately reported to the local county health department pursuant to Section 381.0031 (1), Florida Statutes.

ADDITIONAL INFORMATION

Aquatic Toxins Hotline (Florida Poison Information Center): **1-888-232-8635**
The Florida Department of Health's Aquatic Toxins Program at www.myfloridaeh.com

AQUATIC TOXINS PROGRAM
Protecting Florida's citizens and visitors from Harmful Algal Blooms and related illnesses through
RESEARCH • SURVEILLANCE • EDUCATION

Neurotoxic Shellfish Poisoning

Reporting code = 98800
Case Report Form:
1. CDC 52.13 (9/89) *Investigation of Foodborne Illness*

Clinical case definition

Onset is within a few minutes to a few hours after consumption of epidemiologically implicated shellfish. Symptoms include tingling and numbness of lips, mouth, fingers, and toes; muscular aches; dizziness, reversal of hot and cold sensations; pupil dilation; and usually accompanied by diarrhea, vomiting and ataxia. Illness is self-limited and milder than paralytic shellfish poisoning; paralysis has not been documented. Duration is from a few minutes to a few hours or a few days at most.

Laboratory criteria for diagnosis

- Detection of toxin in epidemiologically implicated shellfish

Case classification

Confirmed: Clinically compatible illness that is associated with consumption of shellfish from areas where other toxic shellfish have been found.

From:
Surveillance Case Definitions for Select Reportable Diseases in Florida
Florida Department of Health
Bureau of Epidemiology
June 2003

Backer, Reich, Fleming, et al

Florida Aquatic Toxins Hotline

University of Miami School of Medicine

Poison Control Information Center

Sneezing? Coughing? Watery Eyes?

Your symptoms may be related to Florida Red Tide.

People with asthma or respiratory problems should avoid red tide areas especially when winds are blowing on shore.

S.T.A.R.T
Solutions To Avoid Red Tide, Inc.
www.redtideonline.com

To speak to a health professional anytime, call the Florida Red Tide Health Hotline

1-888-232-8635 toll free

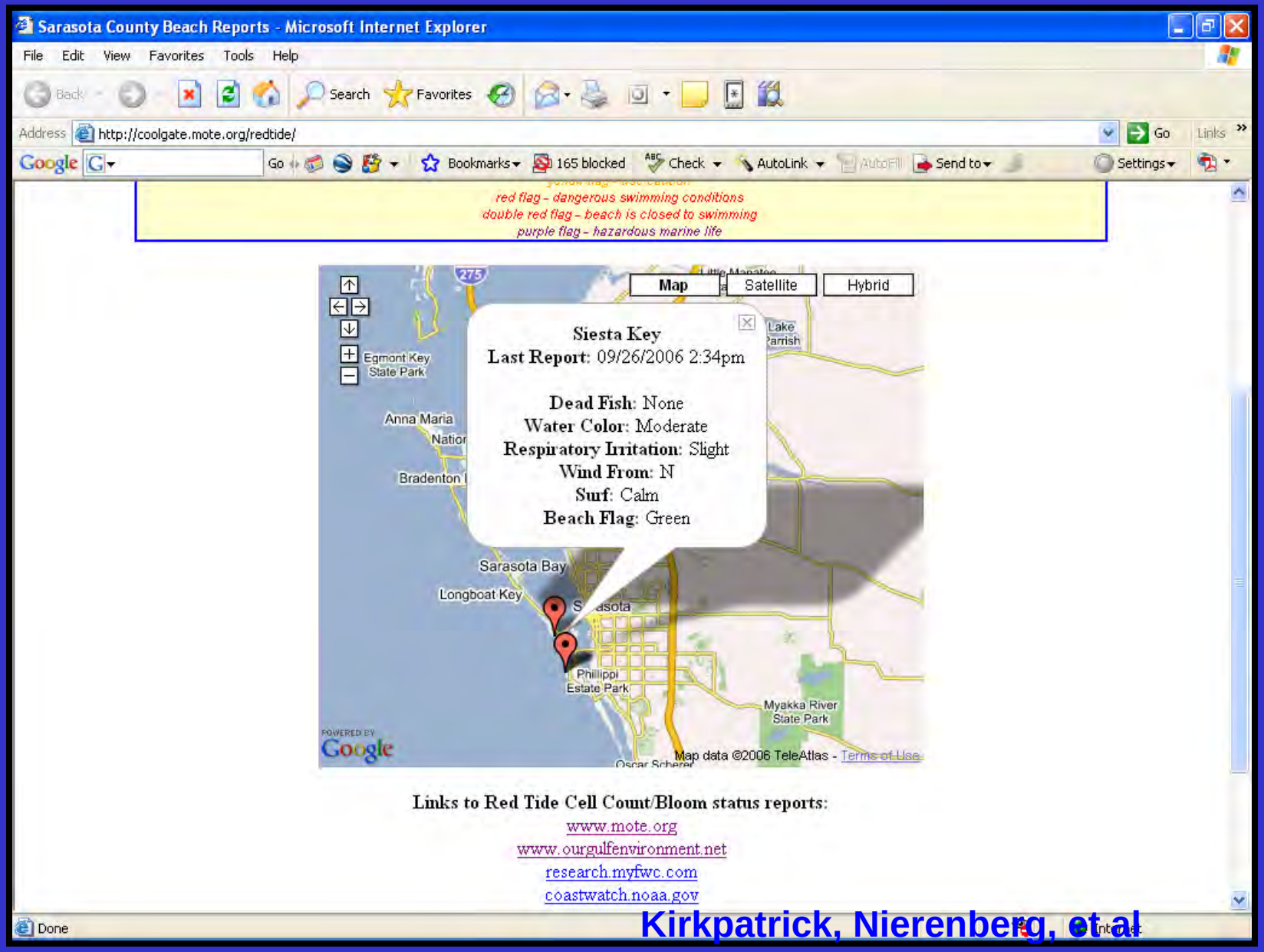
Breathe Easy During a Red Tide

This informational material was funded by the Florida Department of Health.

FLORIDA DEPARTMENT OF HEALTH

Stephan, Reich, Kirkpatrick,, et al

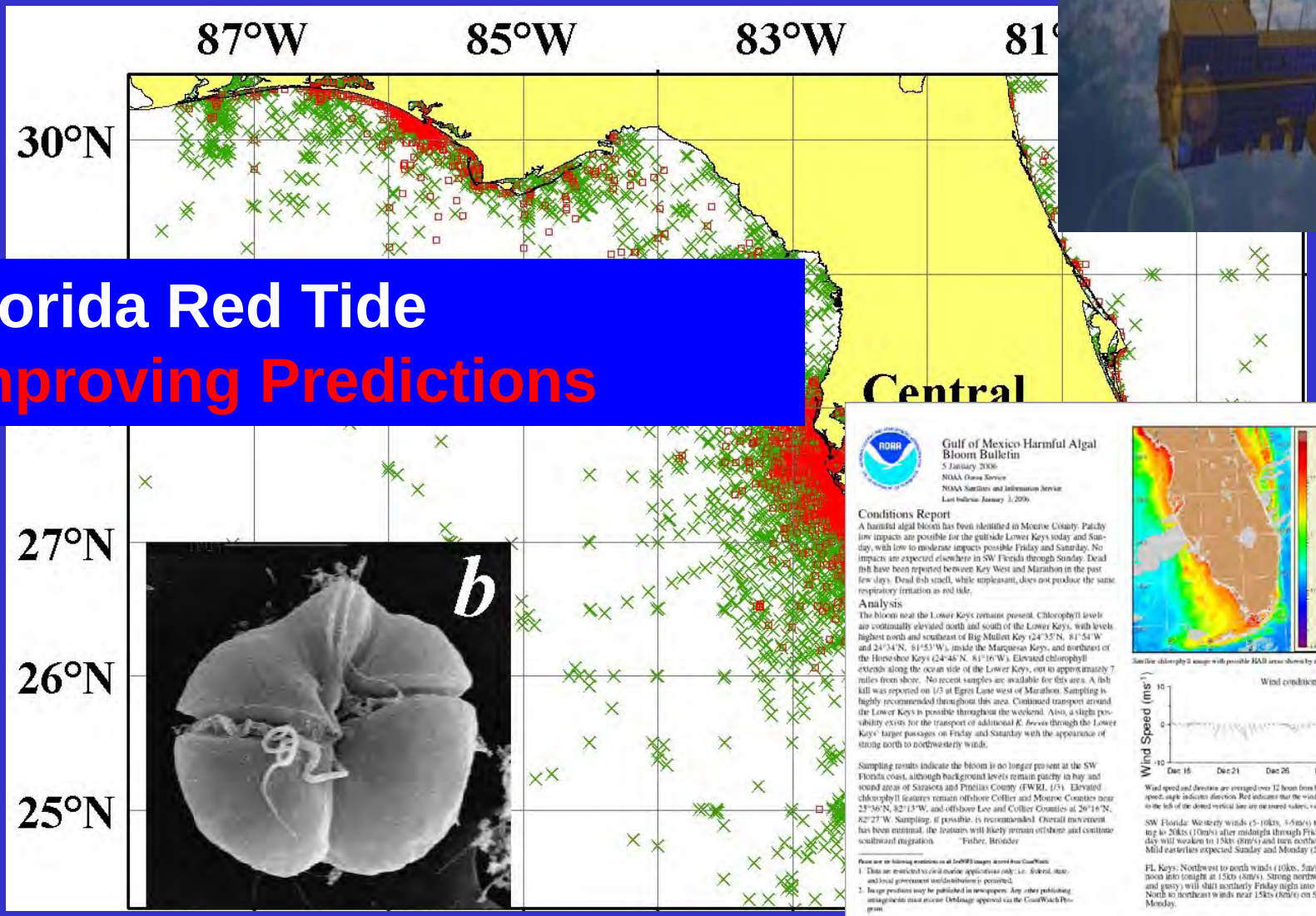
Mote Marine Beach Conditions Report



Kirkpatrick, Nierenberg, et al

Florida

Florida Red Tide
Improving Predictions



Gulf of Mexico Harmful Algal Bloom Bulletin

5 January 2006

NOAA Ocean Service

NOAA Satellites and Information Service

Last bulletin: January 3, 2006

Conditions Report

A harmful algal bloom has been identified in Monroe County. Patchy low impacts are possible for the gulfside Lower Keys today and Sunday, with low to moderate impacts possible Friday and Saturday. No impacts are expected elsewhere in SW Florida through Sunday. Dead fish have been reported between Key West and Marathon in the past few days. Dead fish smell, while unpleasant, does not produce the same respiratory irritation as red tide.

Analysis

The bloom near the Lower Keys remains present. Chlorophyll levels are continually elevated north and south of the Lower Keys, with levels highest north and southeast of Big Mullet Key (24°35'N, 81°54'W and 24°34'N, 81°53'W), inside the Marquesas Keys, and northeast of the Horseshoe Keys (24°48'N, 81°16'W). Elevated chlorophyll extends along the ocean side of the Lower Keys, out to approximately 7 miles from shore. No recent samples are available for this area. A fish kill was reported on 1/3 at Egret Lane west of Marathon. Sampling is highly recommended throughout this area. Continued transport around the Lower Keys is possible throughout the weekend. Also, a slight possibility exists for the transport of additional *K. brevis* through the Lower Keys' larger passages on Friday and Saturday with the appearance of strong north to northwesterly winds.

Sampling results indicate the bloom is no longer present at the SW Florida coast, although background levels remain patchy in bay and sound areas of Sarasota and Pinellas County (FWRI, 1/3). Elevated chlorophyll features remain offshore Collier and Monroe Counties near 25°36'N, 82°13'W, and offshore Lee and Collier Counties at 26°16'N, 82°27'W. Sampling, if possible, is recommended. Overall movement has been minimal. the features will likely remain offshore and continue southward migration. -Fisher, Bronder

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1. Data are restricted to civil marine applications only; i.e. federal, state, and local government use/distribution is permitted.
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Satellite chlorophyll image with possible HAB areas shown by red polygon(s).

Wind speed and direction are averaged over 12 hours from buoy measurements. Length of line indicates speed; angle indicates direction. Red indicates that the wind direction favors upwelling near the coast. Values to the left of the dotted vertical line are measured values; values to the right are forecasts.

SW Florida: Westerly winds (5-10kts, 3-5m/s) today will shift northwesterly, strengthening to 20kts (10m/s) after midnight through Friday. Continued northwesterlies on Saturday will weaken to 15kts (8m/s) and turn northeasterly Saturday night at 10kts (5m/s). Mild easterlies expected Sunday and Monday (5-10kts, 3-5m/s).

FL Keys: Northwest to north winds (10kts, 5m/s) today, becoming westerly this afternoon into tonight at 15kts (8m/s). Strong northwesterlies on Friday (up to 25kts, 13m/s and gusty) will shift northerly Friday night into Saturday, weakening to 15kts (8m/s). North to northeast winds near 15kts (8m/s) on Sunday. Northeast to east winds expected Monday.

NOAA HAB Bulletins

Forecast

Detailed Analysis

Infrared Satellite Imagery (Chlorophyll a)

Wind Speed Graph

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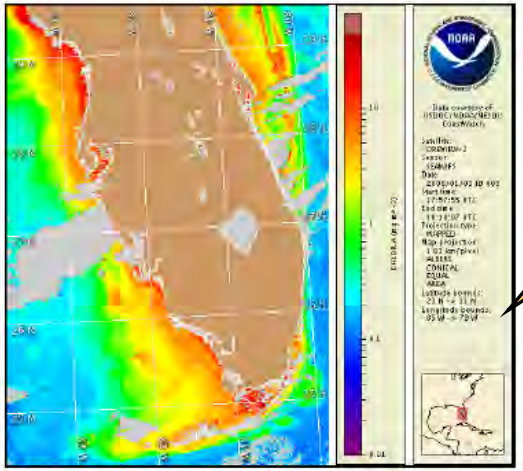

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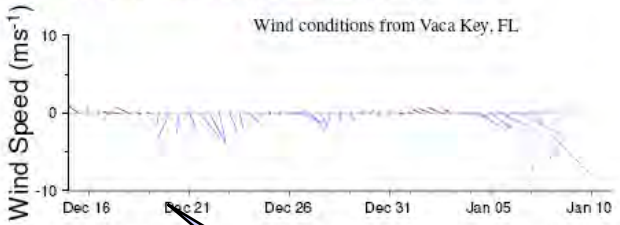

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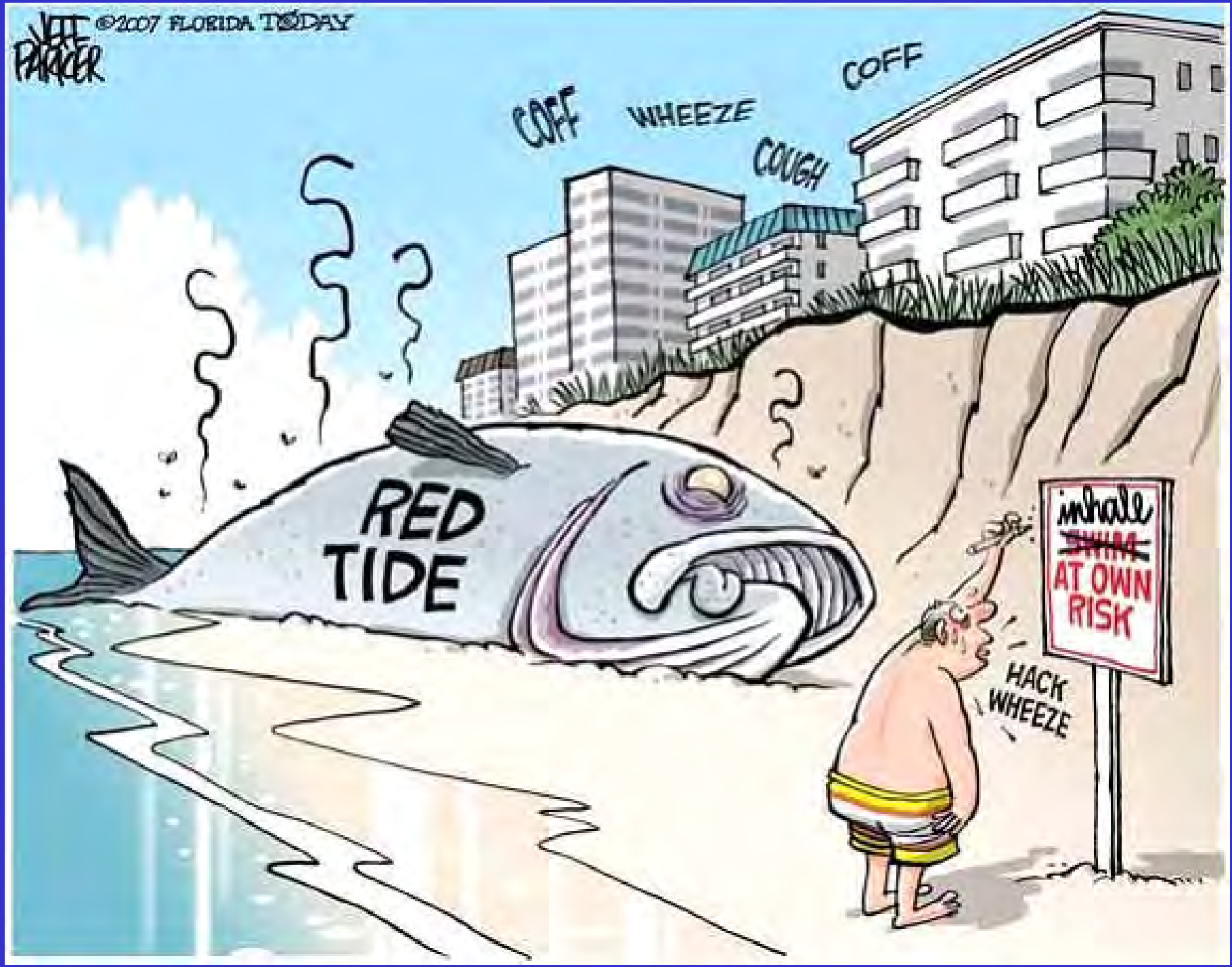
Stump, Kirkpatrick, et al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RED TIDE
inhale
~~SWIM~~
AT OWN RISK
HACK
WHEEZE

HAB Human Disease Issues

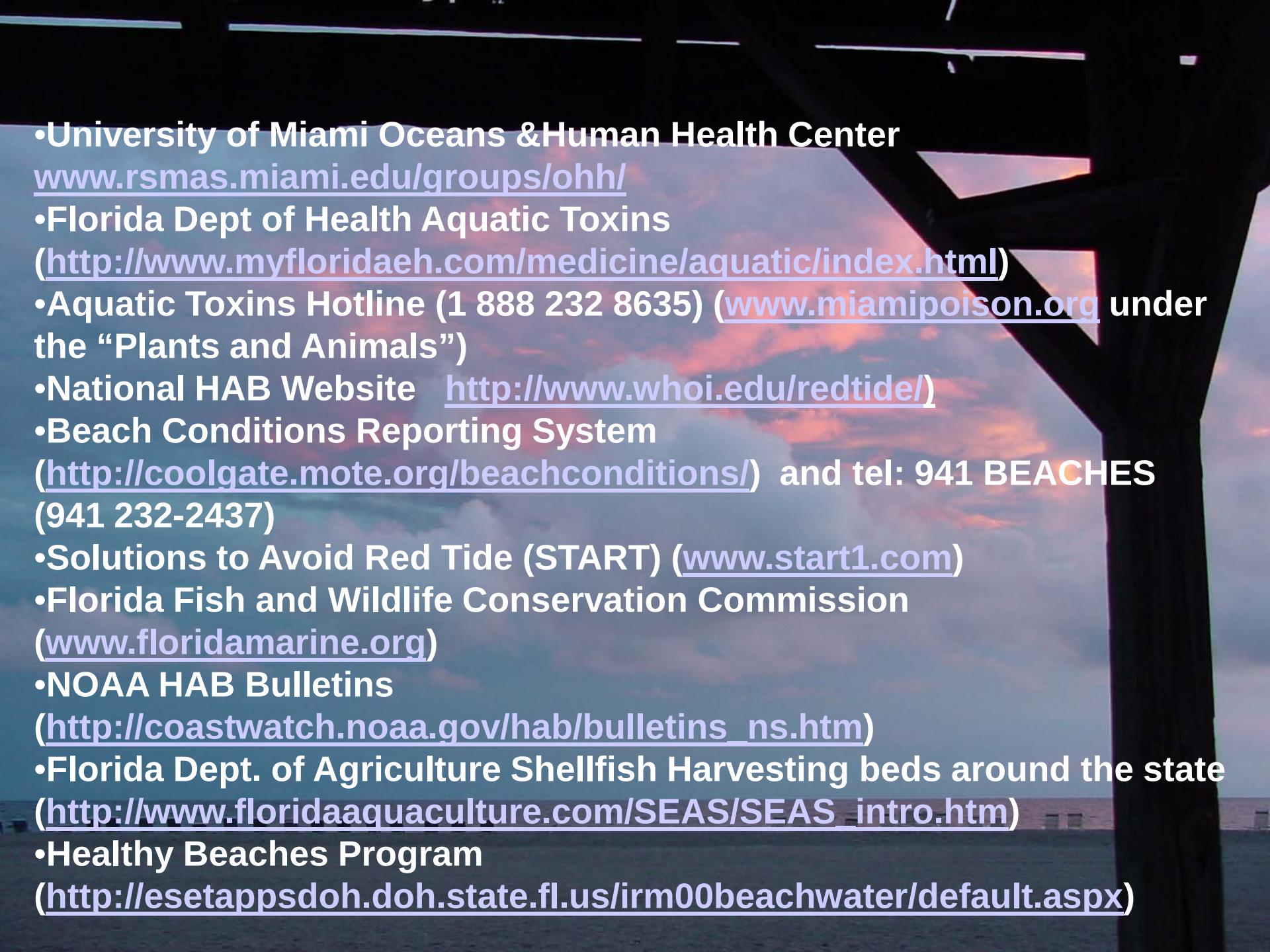
- Lack of Epidemiology
  - Clinical diagnosis
    - Biomarkers
    - More widely available transvector testing
  - Surveillance Lack
    - What is baseline? Is there an increase?
    - CDC HABISS (Dr Lorrie Backer NCEH)
  - Beyond Acute ??Sub/Chronic disease
    - Susceptible subpopulations
      - Chronic disease, Children, Pregnant/Lactating

HAB Human Disease Issues

- Appropriate Specific Treatments?
- Sub/chronic low dose exposure?
- Mixtures
  - Toxins
  - Microbes & Toxins
- Prevention
  - New Transvector, HAB Organism, Geography, Global Trade
- Outreach & Education

Grant Support

European Regional Development Fund (ERDF), European Social Fund (ESF), National Institute of Environmental Health Sciences (NIEHS) of the National Institutes of Health (NIH), National Science Foundation (NSF), Centers for Disease Control and Prevention (CDC), Florida Dept of Health, Florida Harmful Algal Bloom Taskforce



- University of Miami Oceans &Human Health Center www.rsmas.miami.edu/groups/ohh/
- Florida Dept of Health Aquatic Toxins (http://www.myfloridaeh.com/medicine/aquatic/index.html)
- Aquatic Toxins Hotline (1 888 232 8635) (www.miamipoison.org under the “Plants and Animals”)
- National HAB Website http://www.whoi.edu/redtide/)
- Beach Conditions Reporting System (http://coolgate.mote.org/beachconditions/) and tel: 941 BEACHES (941 232-2437)
- Solutions to Avoid Red Tide (START) (www.start1.com)
- Florida Fish and Wildlife Conservation Commission (www.floridamarine.org)
- NOAA HAB Bulletins (http://coastwatch.noaa.gov/hab/bulletins_ns.htm)
- Florida Dept. of Agriculture Shellfish Harvesting beds around the state (http://www.floridaaquaculture.com/SEAS/SEAS_intro.htm)
- Healthy Beaches Program (http://esetappsdoh.doh.state.fl.us/irm00beachwater/default.aspx)