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Emerging Contaminants in the Gulf of Maine: Parallels with the Gulf of Mexico (2010 State of the Bay Presentation)

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Marine Environmental Research Institute (MERI)

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Emerging Contaminants in the Gulf of Maine:

Parallels with the Gulf of Mexico

Susan D. Shaw, DrPH
Director
Marine Environmental Research Institute (MERI)
Center for Marine Studies, Blue Hill, Maine USA

Casco Bay Estuary Partnership
State of the Bay 2010
Portland, ME October 21, 2010

Gulf of Mexico May 2010
Rig 313, east side of the Mississippi River from
the BP Deepwater Horizon oil well

Diving In

The New York

Op-Ed Contributor
MAY 28, 2010

Swimming Through the Spil

By SUSAN D. SHAW
Blue Hill, Me.

FOR the last few days, attention has under
shores of the Gulf Coast as oil has started
marshes. But last week I had the chance t
another perspective — when I dived into
Pass a Loutre wetlands in southern Loui
surreal, sickening scene beyond anythi

As the boat entered the slick, I had to
There were patches of oil on the gulf
mixed with an orange-brown puddin
gallons of a chemical dispersant cal
the spreading oil. Near Rig No. 31
stopped and I (wearing a wetsuit,
jumped in.

Only a few meters down, the nu
possible to make out tiny wisps
enveloped in dark oily droplet
the herring I could see feedin
Dispersants break up the oil
forming poisonous droplets

Bar Harbo

Blue Hill scientist dives

By Laurie Schreiber | Jun 16, 2010

(Courtesy of: Susan D. Shaw/Marine Environmental Research Institute) Dr. Susan Shaw, director of the Marine Environmental Research Institute in Blue Hill, took this picture recently of a patch of brown oil and dispersant in the Gulf of Mexico.

Blue Hill — Dr. Susan Shaw, director of the Marine Environmental Research Institute in Blue Hill and a marine toxicologist, returned recently from the Gulf of Mexico where, accompanied by a crew f The Times, she dove in the oil slick to get a first

Shaw traveled to the gulf in late May, when sh fishing boat to take them about 40 miles out to immediately hit by very strong fumes. The sur patches of viscuous brown sludge, she said. Sl the water where the oily sludge had broken up

"I'm one of few toxicologists who have gott

In a New Y dive, she s an orange 700,000 g 9500 that No. 313, and I (w exposed

"Only a few meters down, the nutrient-ri make out tiny wisps of phytoplankton, z droplets. These are essential food sourc gaping mouths on the oil and dispersant. Dispe

THE TIMES

What will be left after the oil spill?

Frank Pope
June 12

No dolphins... no whales... no bluefin tuna... no swordfish... no turtles... no coral beds... no plankton... The first man to dive below America's worst environmental disaster looks at the evidence

Thirty feet down in the Gulf of Mexico, the water suddenly goes dark. Above me, a ragged black silhouette of oil is eclipsing the sunlit circle that is the surface. I feel a familiar twinge in the back of my brain, the first warning that soon I need to get back up to breathe. With concentrated calmness, I pause and hang in the water, staring. Oil is above, around and beneath me; out of sight somewhere way below lurk yet more dark clouds of oil. This is now America's worst environmental disaster, according to the White House. The beaches are clogged not only with oil, but with clean-up workers, TV crews and politicians. But it is here, beneath the slick, that its destructive power will be most felt.

The silted tongues of the Mississippi river don't reach this far from shore, leaving the ocean clear. The familiar, cavernous blue of deep water stretches below, occasionally probed by a wavering beam of sunlight that has pierced the armour of the slick above. For as far down as I can see, there are tiny specks glinting in the shifting light, while others lurk as shadows behind.

Yellow-brown haloes surround the light when it appears from above, its fringes dotted as though by a swarm of motionless insects. Ten feet below this haze, I force my eyes to focus close to my mask. A shred of the slick hangs in the water in front of me, the size of

Photos: Julie Dermansky

Deepwater Horizon Oil Spill: Hidden Damage/ Long Term Impacts

180,000,000 gallons LA crude oil released at 5000 ft
1,800,000 gallons chemical dispersant
Dispersed oil in plumes, sediments, on the sea floor

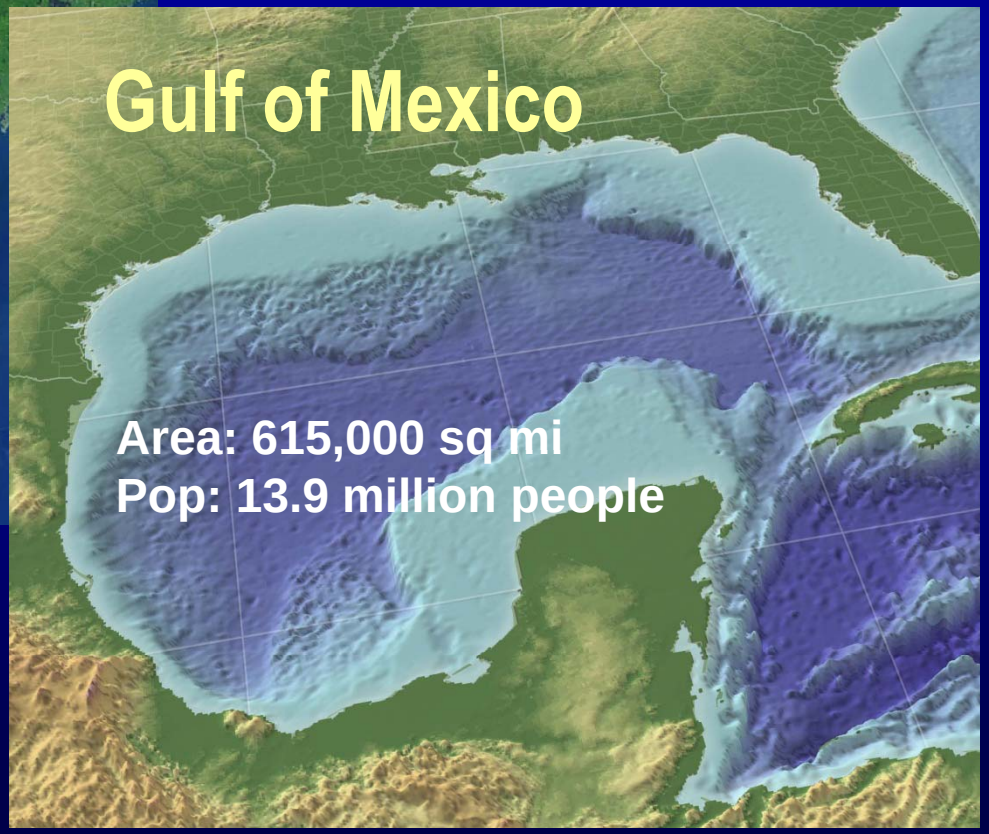
15,000 marine species in Gulf
600,000 sq mile area, 3000 mile coastline
14,383 ft at depth (average ~5300 ft)

DOI Strategic Sciences Working Group:

Scenarios/ Consequences/ Policy Actions to Lessen Stress, Accelerate Recovery

SSWG September 2010 New Orleans

Gulf to Gulf: Priority Concerns



Ecosystem Stressors

- Population pressure/ coastal development
- Fisheries depletion (overfishing)
- Destruction/ fragmentation of critical habitat
- Chemical and sewage pollution
- Coastal dead zones
- Species loss, regime shifts
- Oil and gas exploration, shipping, spills
- Lack of cohesive oceans/ toxics policy

Fisheries At Stake

Gulf of Maine

Total landings 530,000 mt
$900 million/ yr
Lobsters: ~ $600 million

Gulf of Mexico

Total landings 1.27 billion lbs
$659 million/ yr
Shrimp: 188 million lbs, $367 million

Gulf of Maine
$900 million/yr

Gulf of Mexico
$659 million/yr

Pollution

Chemical Contaminants (Industrial, Agricultural)

Oil and Gas

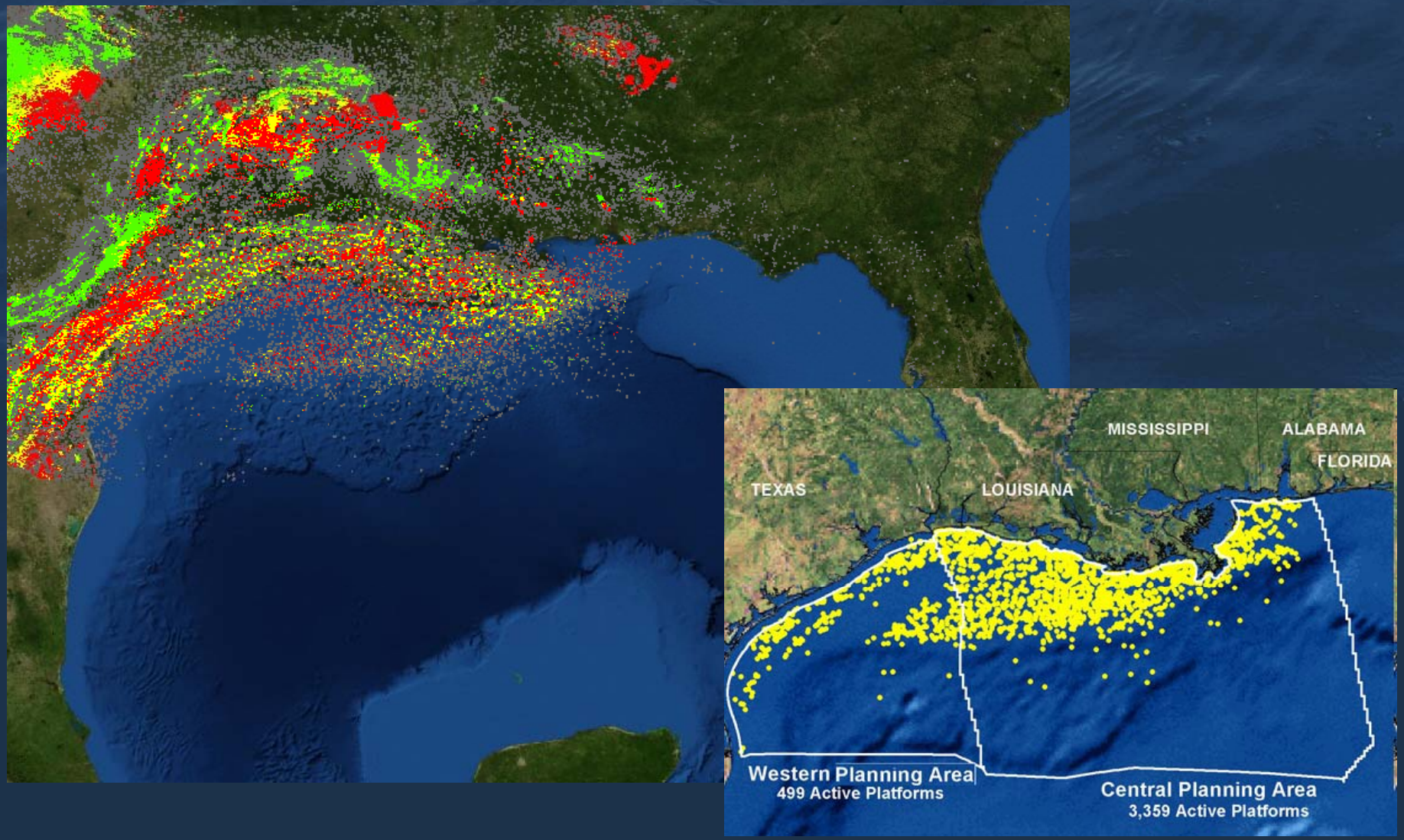
Coastal Dead Zones

Harmful Algal Blooms

Coastal Dead Zones

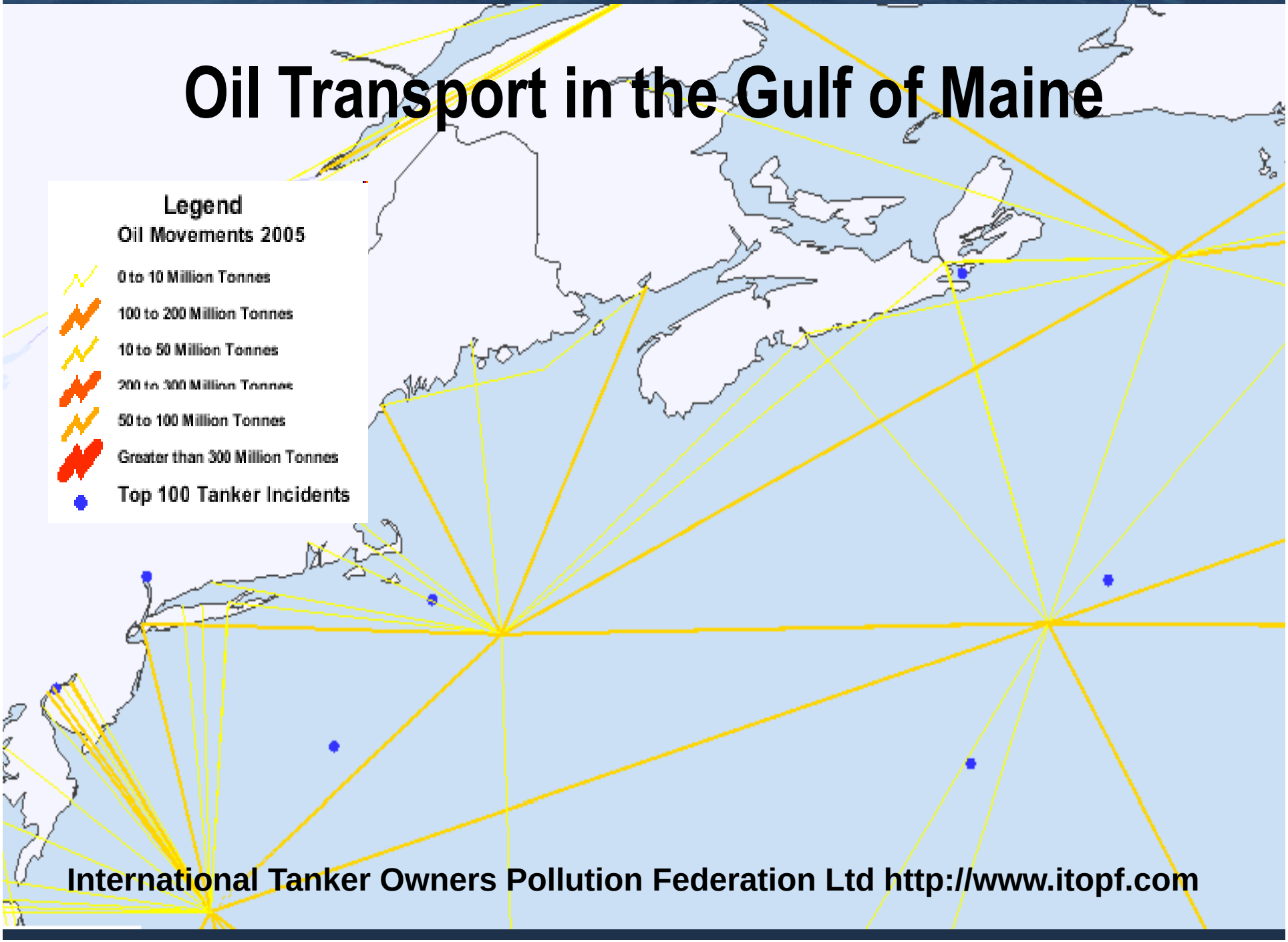
Diaz and Rosenberg 2008, Science

Oil and Gas in the Gulf of Mexico



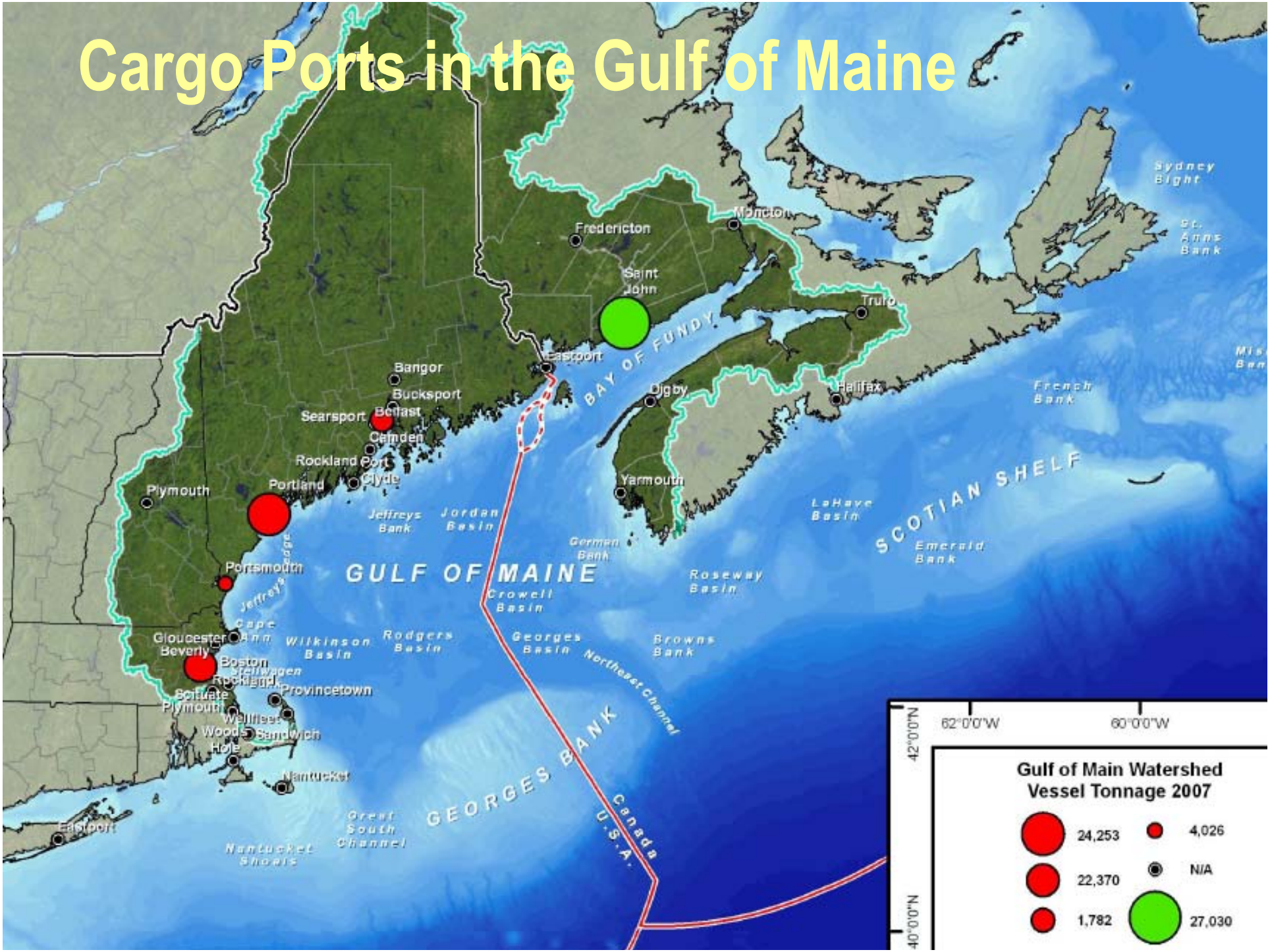
Source: NOAA Ocean Explorer, http://oceanexplorer.noaa.gov

Oil Transport in the Gulf of Maine



International Tanker Owners Pollution Federation Ltd http://www.itopf.com

Cargo Ports in the Gulf of Maine



Could This Happen Here?

Seals As Sentinels

Assessing Persistent Organic Pollutants in Seals and Fish in the NW Atlantic Marine Ecosystem (2000-2010)

- **First extensive region-wide investigation in marine mammals and commercial fishes**
- **Legacy and emerging contaminants in live and stranded seals and their prey fish**
- **Impacting toxics policy in the US and internationally**
- **Funded by NOAA since 2004**

Marine Environmental Research Institute (MERI) www.meriresearch.org

Legacy POPs

Persistent, bioaccumulative, toxic (PBT)

Legacy chemicals banned in 1970s – decreasing slowly

PCBs
Dioxins
Furans

Industrial chemicals/ biproducts

DDT
Dieldrin
Chlordanes
HCHs (lindane)
Mirex
Toxaphene

Pesticides

Cancers, endocrine disruption, immune suppression

Halogenated Flame Retardants, Perfluorinated Chemicals

Brominated flame retardants (BFRs)

Polybrominated diphenylethers (PBDEs*) – polyurethane foam
Hexabromocyclododecane (HBCD) - building materials
Tetrabromobisphenol-A (TBBPA) – plastics

Perfluorinated chemicals (PFCs)

PFOS**, PFOA**	Surfactants, non-stick
PFSAs, PFCAs	anti-stain fabrics
	fire-fighting foams

- *Phased out (PBTs, Stockholm Convention)

**Human carcinogens – banned

Flame Retardants (PBDEs)

Clothing, textiles, mattresses, upholstery, TVs, computers, plastics, electronics, house dust and food (fish)

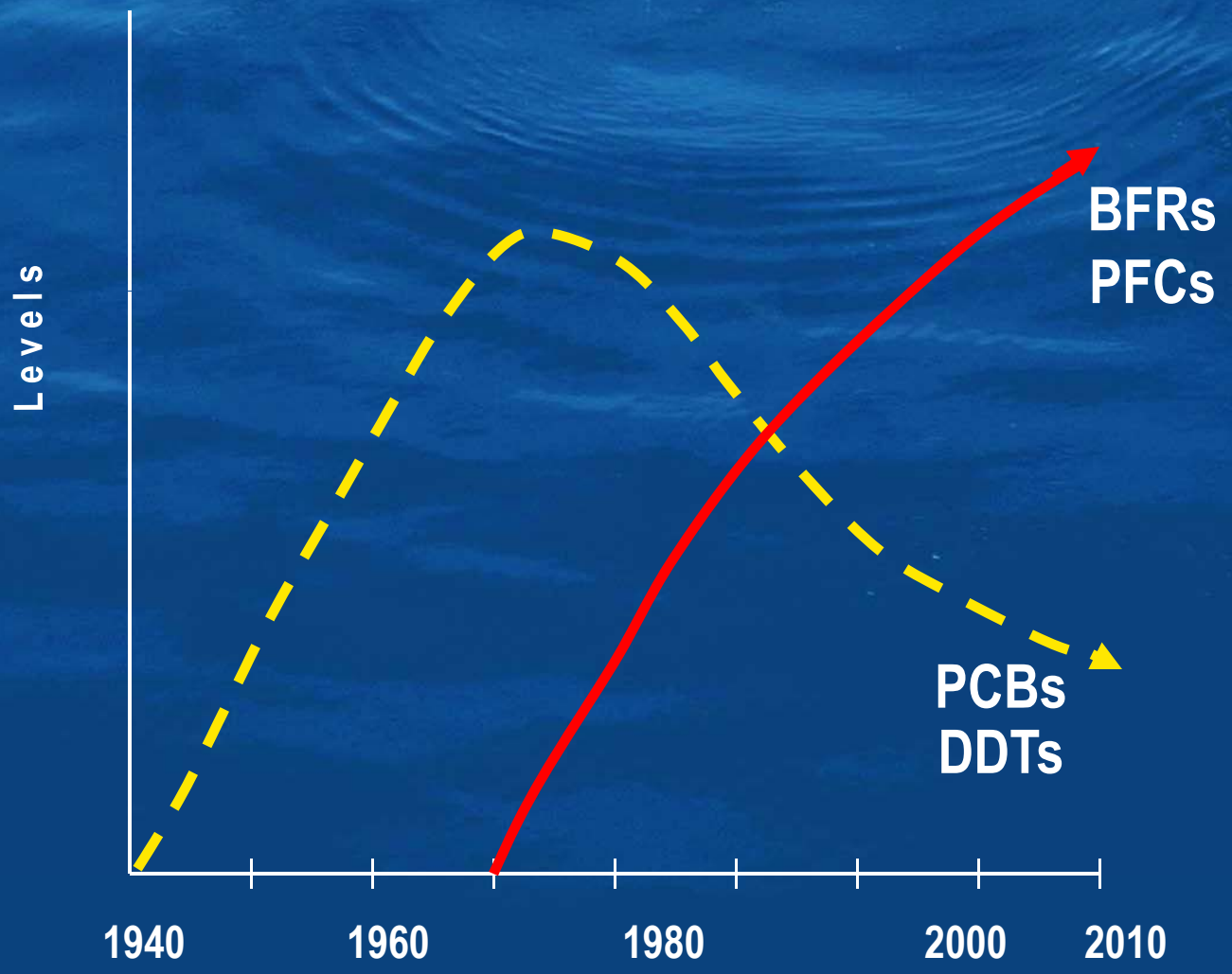
Endocrine disruptors (thyroid), developmental neurotoxins

Perfluorinated Chemicals (PFCs)

Food wrappers, stain-resistant fabrics, Scotchgard, Gortex, non-stick pans (Teflon), fire-fighting foams, drinking water

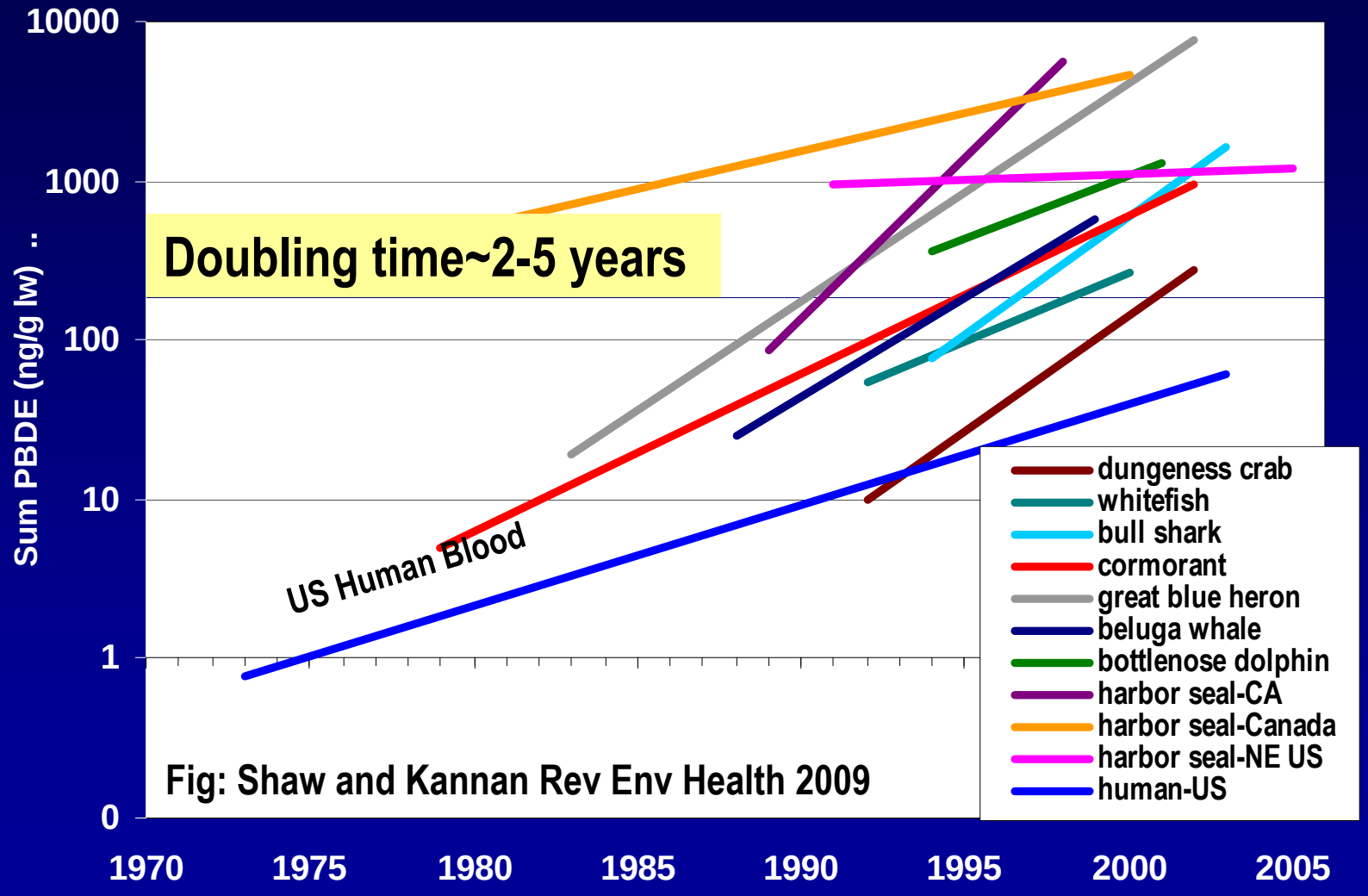
Endocrine disruptors (thyroid), P450 induction, cancer

Chemical Time Trends 1940-2010



PBDEs Increasing in North America

1970-2005



Data: Schecter et al. 2005, Ikonomou et al 2002, 2006, Rayne et al 2003, Johnson-Restrepo et al 2005, Elliott et al 2005, Lebeuf et al 2004, She et al 2002, Shaw et al 2008

Chemical Migration Indoor to Food Web (Oceans)

Atmosphere

Landfills

E-Waste

Wastewater

Treatment

HOME (80% dust)

Surface Waters

OCEANS
Final sink

Exposure

Oceans In Crisis

Ocean Dumping (chemicals, waste, sewage)

Runoff (pesticides, fertilizers, sewage wastes)

Plastic Debris,
Release of Chemicals

Oil Spills, Release of Carcinogens

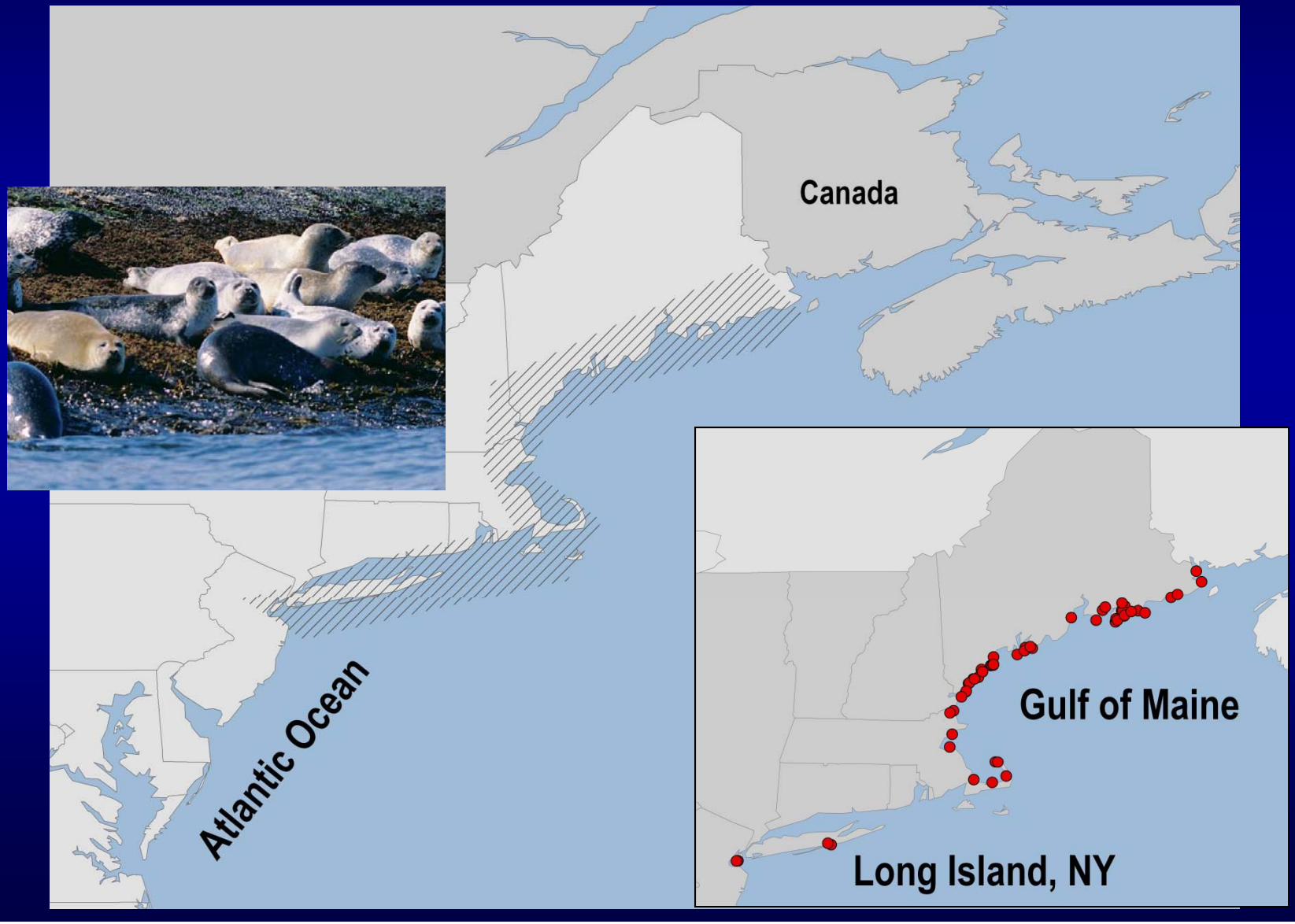
Marine Mammal, Seabird, Fish Die Offs

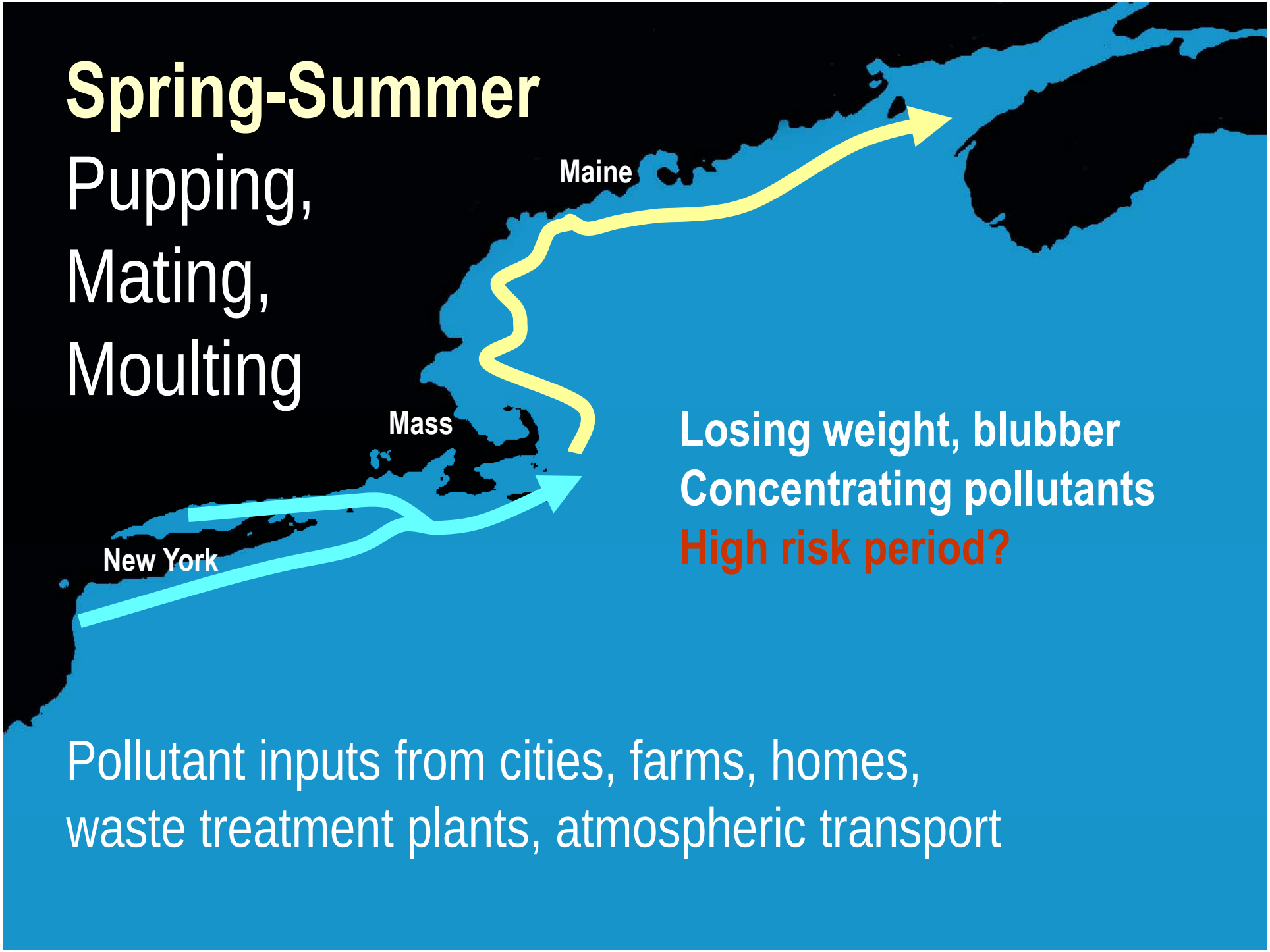
Dead zones Increasing Jellyfish, coral bleaching)

Collapse of global fisheries by 2053

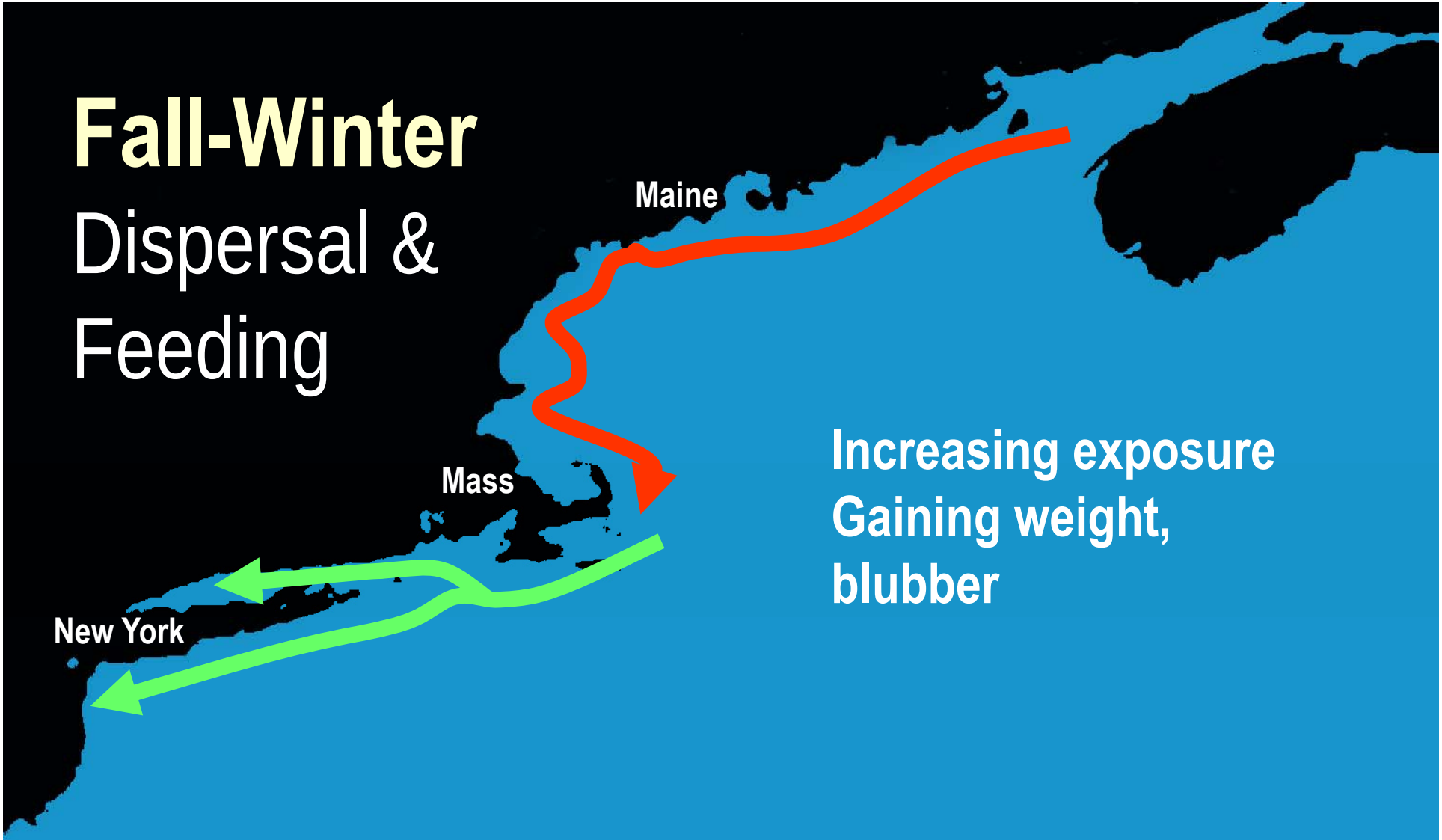
Ocean Acidification
CO_2, NO_2,

Seal Stranding Locations NE Region




Spring-Summer
Pupping,
Mating,
Moulting
Maine
Mass
New York
Losing weight, blubber
Concentrating pollutants
High risk period?
Pollutant inputs from cities, farms, homes,
waste treatment plants, atmospheric transport

Fall-Winter
Dispersal & Feeding



Increasing exposure
Gaining weight, blubber

Mass Bay and Long I Sound
"most polluted" in North America

Harbor Seal Food Chain

Trophic level

Atlantic mackerel
Piscivorous, pelagic

Silver hake
Piscivorous, semi-pelagic

Alewife
Piscivorous, anadromous

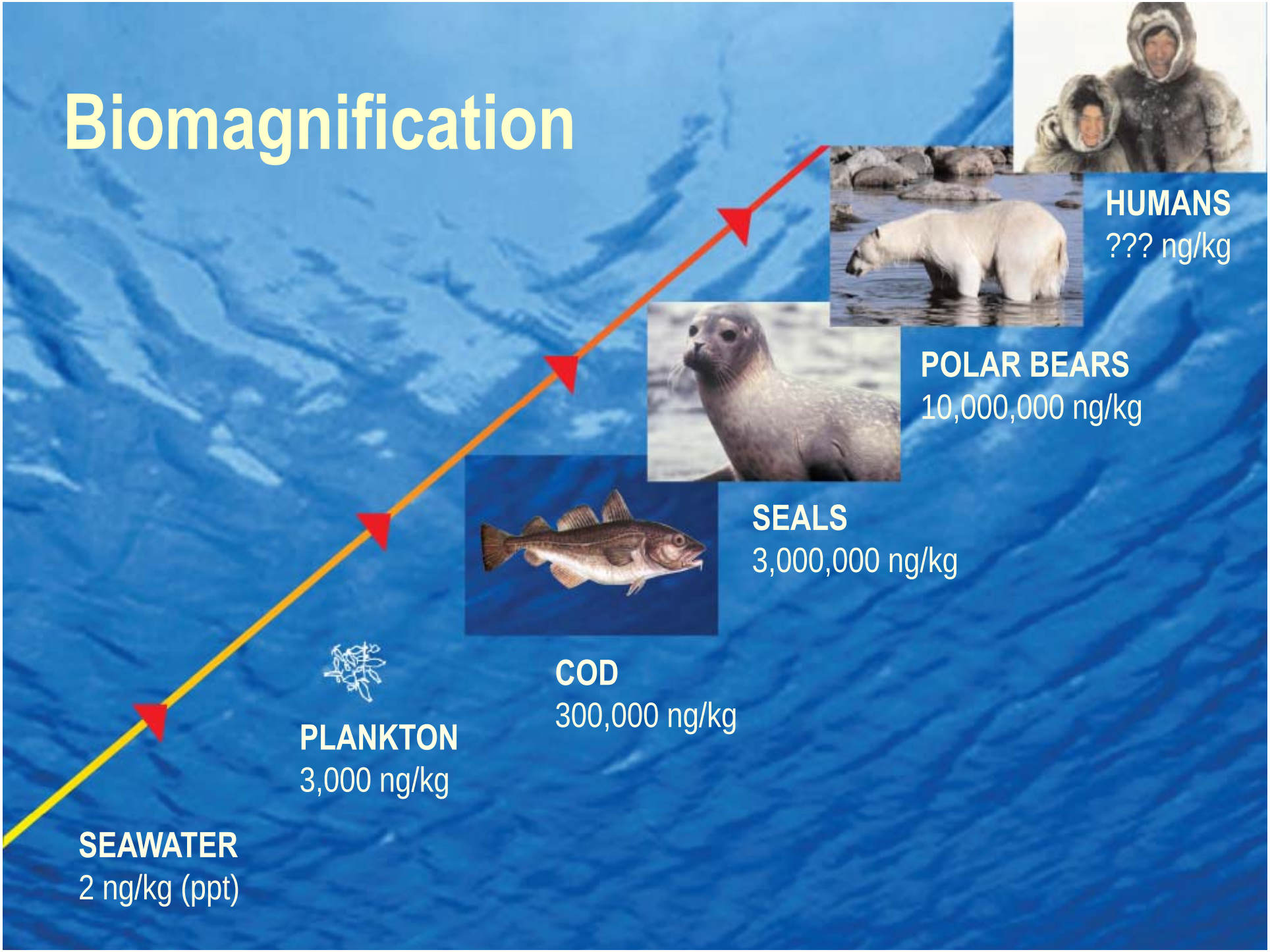
White hake
Piscivorous, bottom

Atlantic herring
Planktivorous

Winter flounder
Omnivorous bottom feeder

Amer. plaice
Omnivorous bottom feeder (echinoderms)

Biomagnification



Maternal Transfer to Pups

- Seal milk 50% fat - high in pollutants
- Mother downloads 15-80% of her body burden

Seals As Sentinels
RESULTS

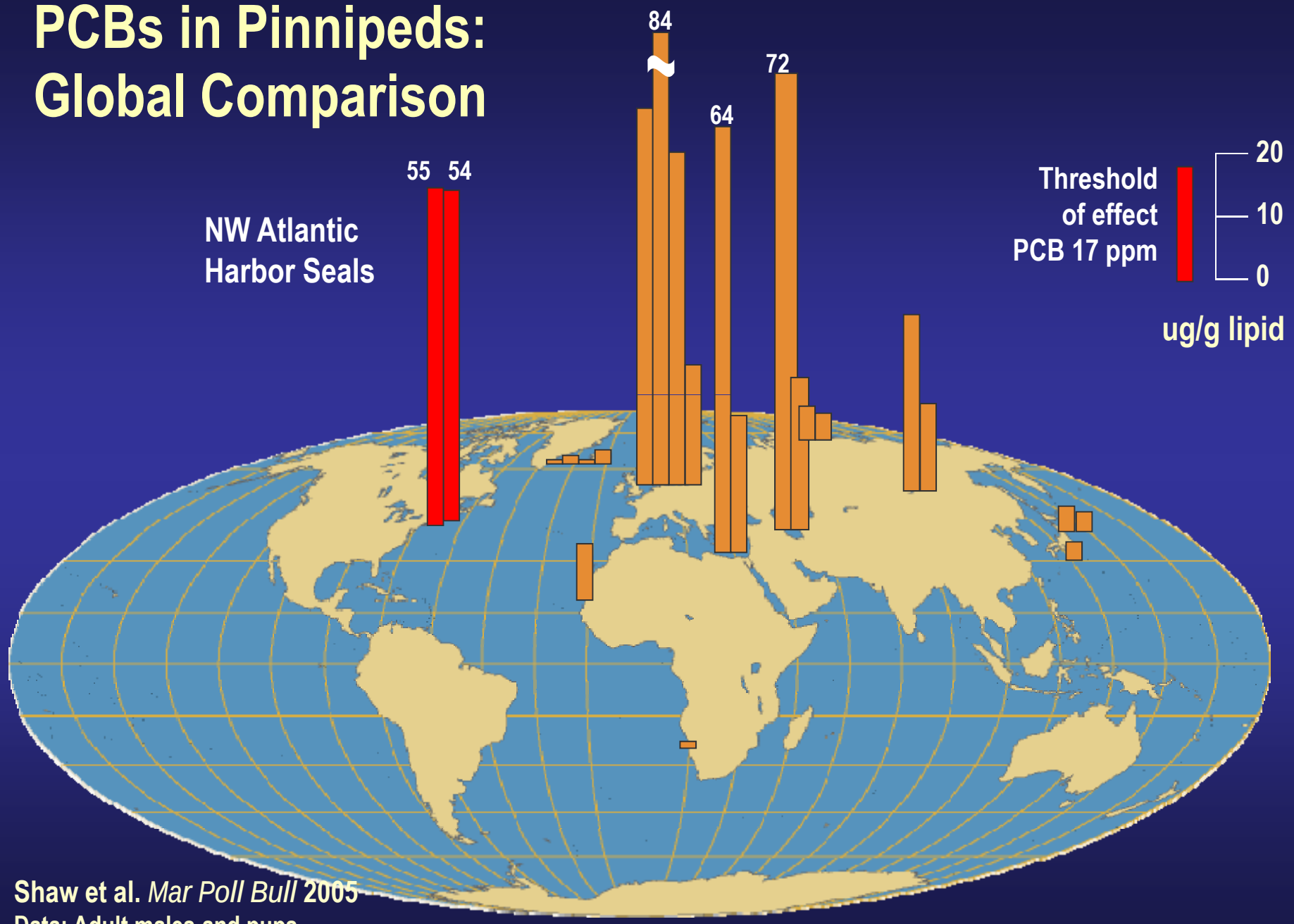
Analyzed ~400 Chemicals in 500 Tissues 181 Seals (Live and Stranded)

- PCBs, DDTs
- Hexachlorobenzene
- Chlordanes, HCHs
- PBDEs, OH-PBDEs
- HBCDs, OH-HBCDs
- PFOS, PFOA, PFNA, PFHS (PFSAs, PFCAs)

Analytic Labs:

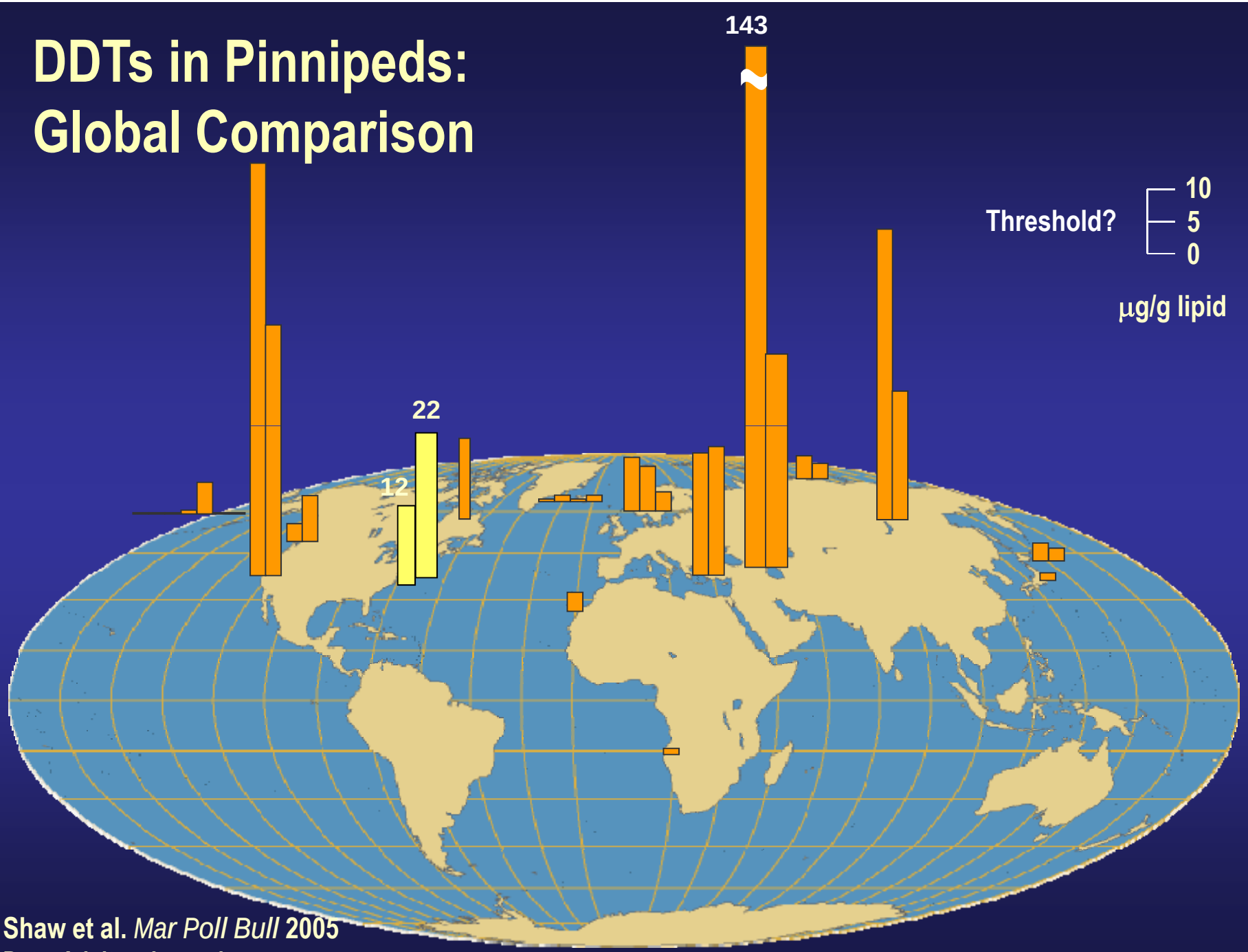
Wadsworth Lab (Kannan), NYS Dept of Health, Albany, NY
U. of Antwerp (Covaci), Belgium
Eurofins-ERGO, Hamburg, Germany

PCBs in Pinnipeds: Global Comparison



Shaw et al. *Mar Poll Bull* 2005
Data: Adult males and pups

DDTs in Pinnipeds: Global Comparison



Shaw et al. *Mar Poll Bull* 2005

Data: Adult males and pups

Flame Retardants (PBDEs) in Pinnipeds

Harbor seal *(Phoca vitulina)*
Shaw et al. 2008, Meng et al. 2009, Law et al. 2003

Sea lion *(Zalophus californianus)*
Meng et al. 2009, Stapleton et al. 2006

Gray seal *(Halichoerus grypus)*
Ikonomou & Addison 2008

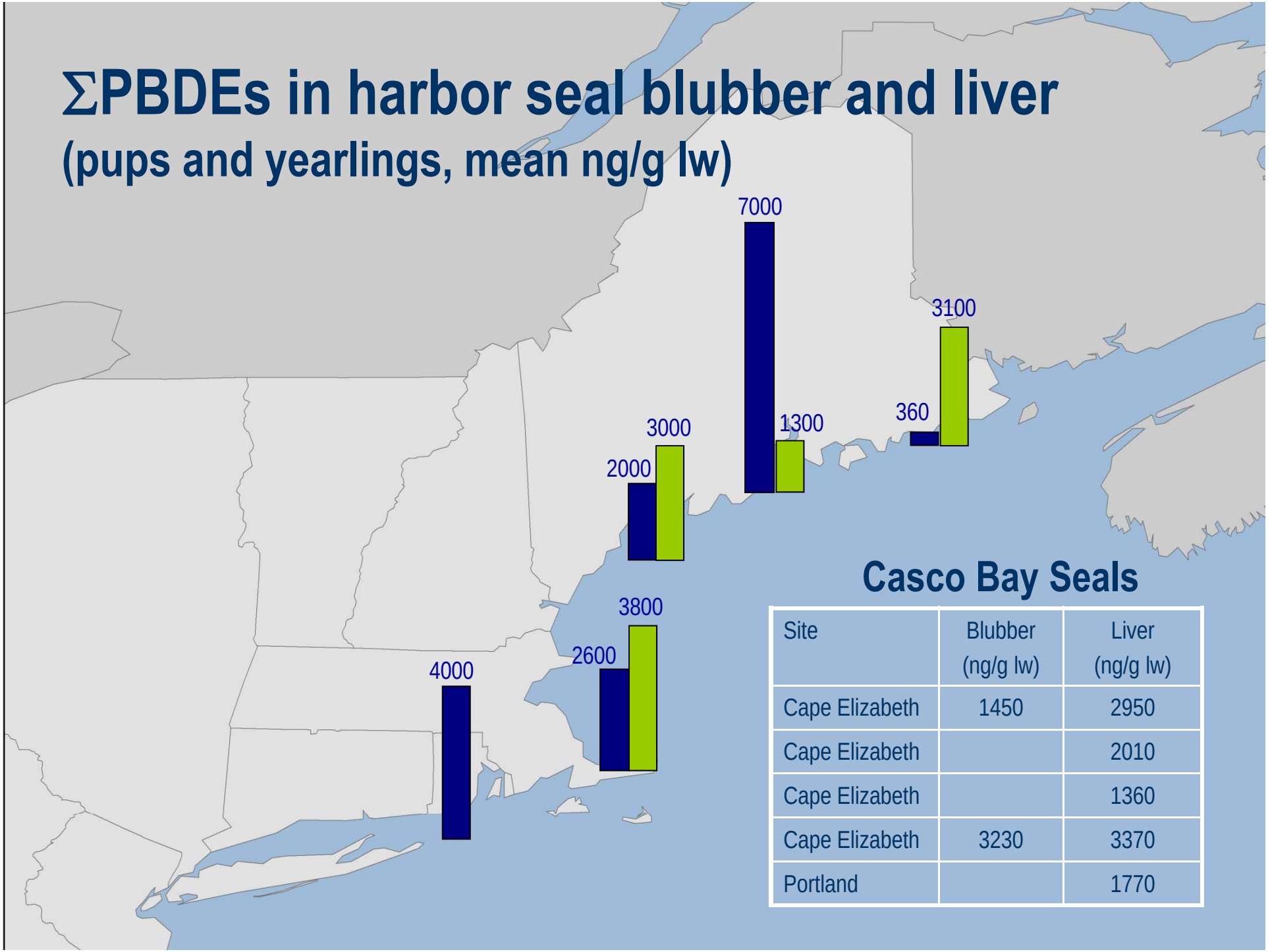
Ringed seal *(Pusa hispida)*
Riget et al. 2006, Johansen et al. 2004

No. elephant seal *(M. angustirostris)*
Meng et al. 2009

Harp seal *(P. groenlandica)*
Johansen et al. 2004

ΣPBDEs in harbor seal blubber and liver

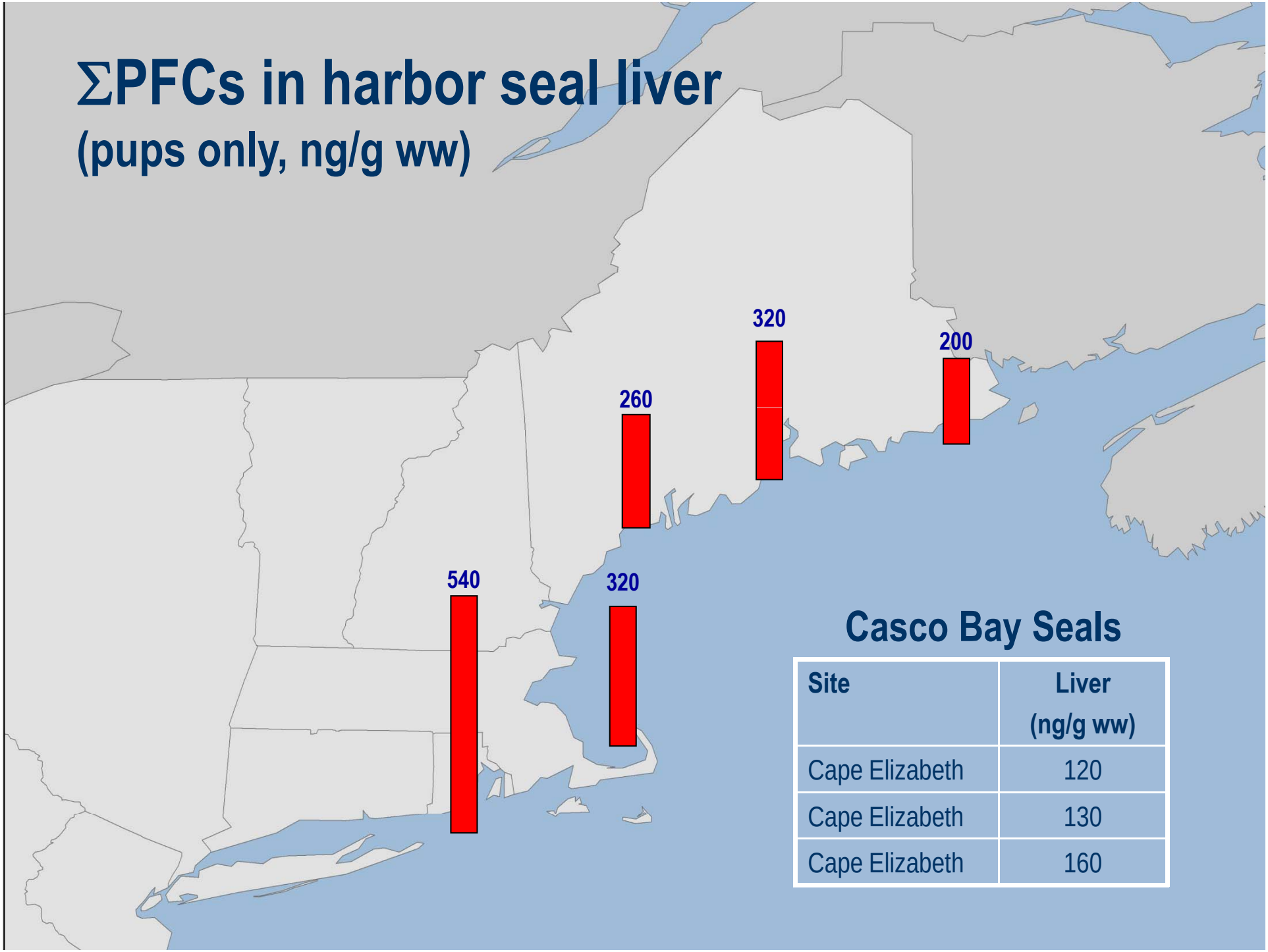
(pups and yearlings, mean ng/g lw)



Casco Bay Seals

Site	Blubber (ng/g lw)	Liver (ng/g lw)
Cape Elizabeth	1450	2950
Cape Elizabeth		2010
Cape Elizabeth		1360
Cape Elizabeth	3230	3370
Portland		1770

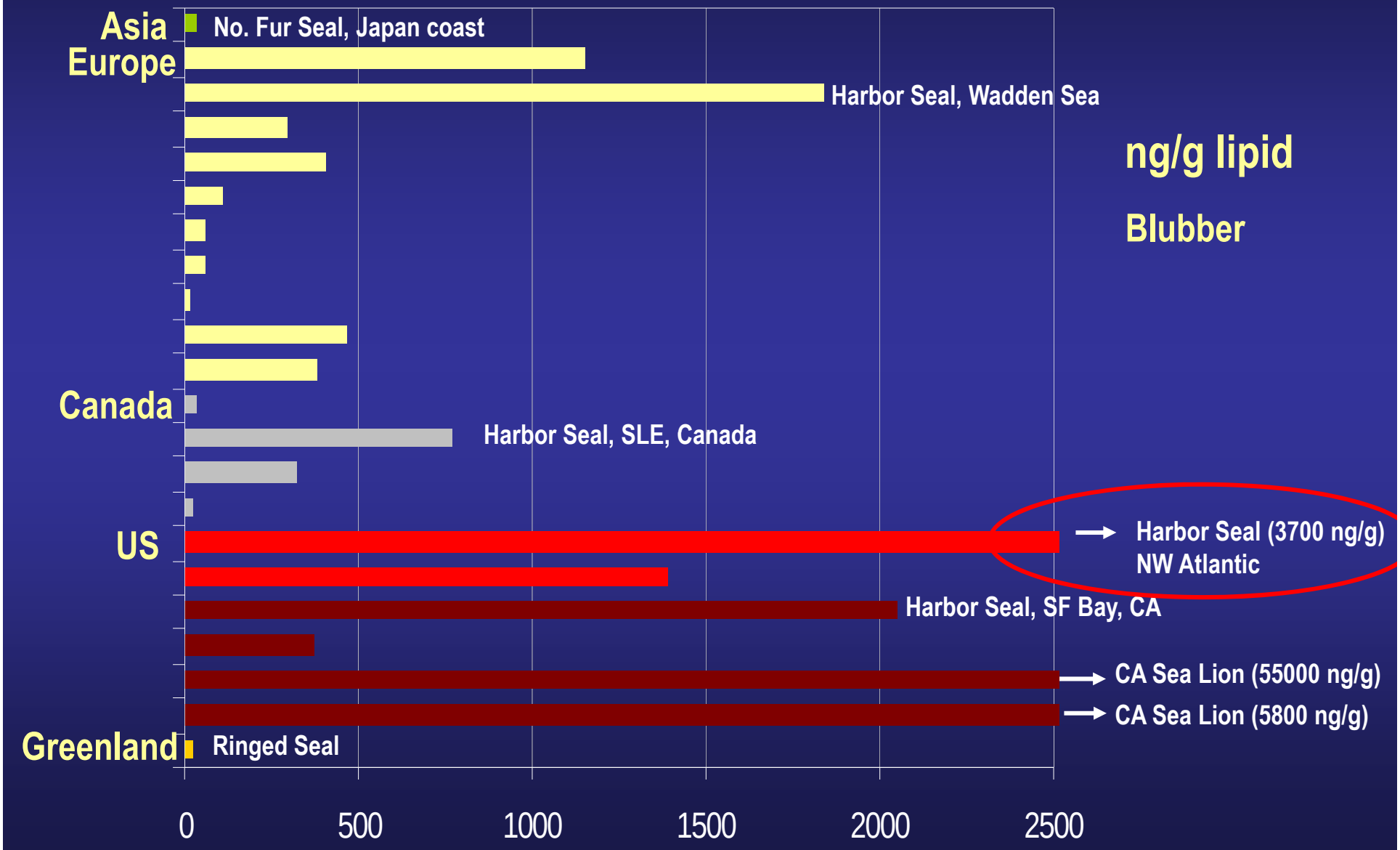
ΣPFCs in harbor seal liver
(pups only, ng/g ww)



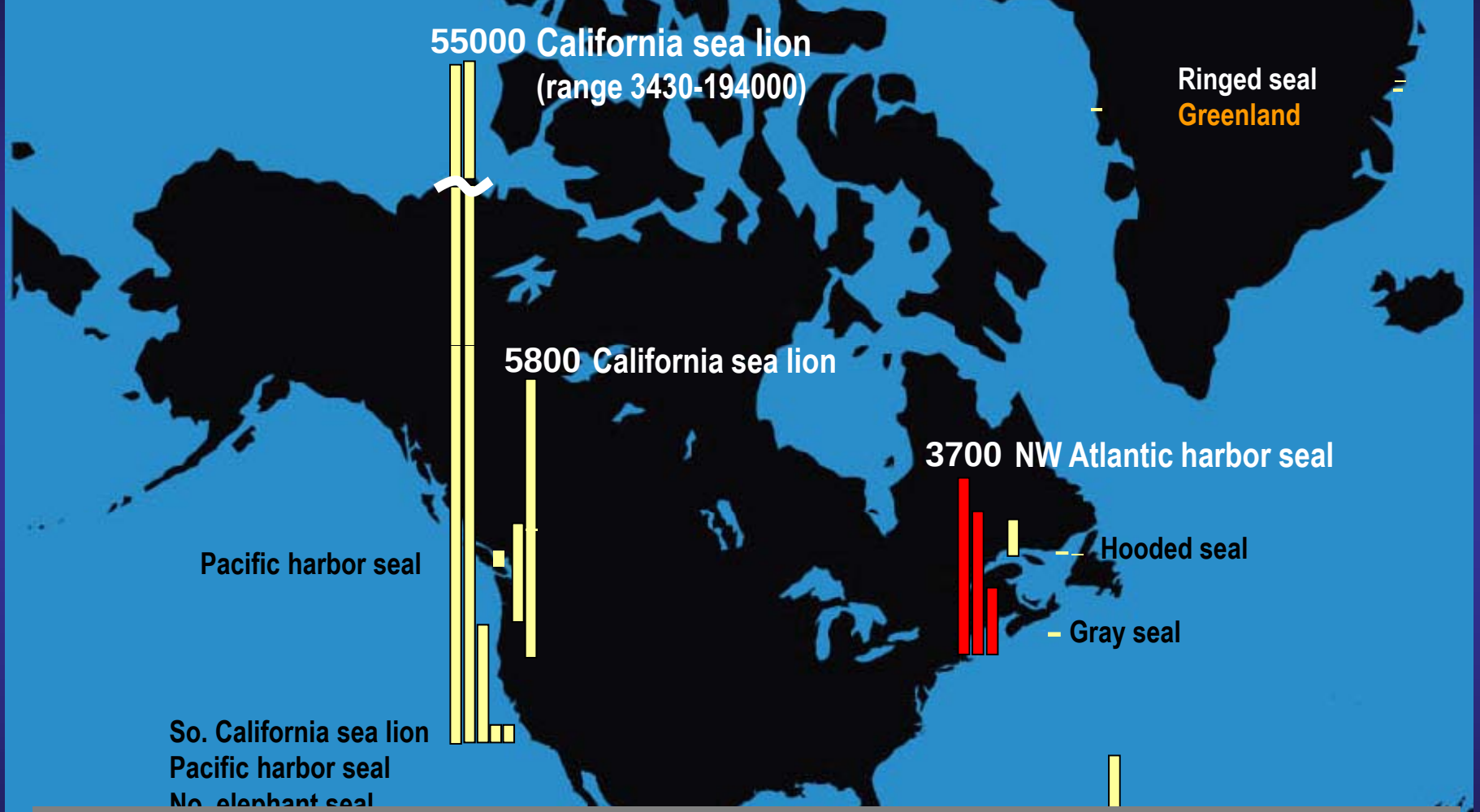
Casco Bay Seals

Site	Liver (ng/g ww)
Cape Elizabeth	120
Cape Elizabeth	130
Cape Elizabeth	160

Comparison of PBDE Levels in Pinnipeds



PBDEs in North American Pinnipeds



PBDE levels in California sea lions (mean 55 ppm lipid) highest reported in wildlife to date

Fireproof Harbor Seals?

Shaw et al. 2008 Chemosphere

NW Atlantic harbor seals highly contaminated (PBDEs)

First discovery of DECA flame retardant in seals

Recurring disease a concern in this population

Neurotoxic Flame Retardant Deca Banned

in Furniture, Baby Products, Shipping Pallets

State

Presque Isle shooting
Police investigating County incident **B5**

BANGOR DAILY NEWS

Section **B**

Experts find traces of deca in seals

COURTESY OF THE MARINE ENVIRONMENTAL RESEARCH INSTITUTE

Susan Shaw works as a marine toxicologist, director and senior scientist at the Marine Environmental Research Institute in Blue Hill.

BY KEVIN MILLER
OF THE NEWS STAFF

Scientists with a Blue Hill research organization have detected traces of a controversial chemical flame retardant in harbor seals found on the northeastern coast.

The discovery by scientists at the Marine Environmental Research Institute in Blue Hill is significant because, to date, the flame retardant deca rarely appears in marine mammals at measurable levels. MERI researchers said their findings, although preliminary, lend support to calls to ban deca in Maine.

"It's worrying that it's in wildlife to this extent," said Susan Shaw, a marine toxicologist and MERI's director and senior scientist.

Deca is the most common form of chemical flame retardant used in televisions, computers and other electronics as well as in some upholstered items.

But deca is coming under intense scrutiny from environmental and health advocates who claim the chemical is a potential neurotoxin that is showing up in humans and wildlife.

Inside
Washington leads fight against deca
Page B4

The Maine Legislature's Natural Resources Committee will hold a workshop this Tuesday on a bill, LD 1658, that would phase out the sale of many products containing deca.

Shaw and her team of researchers have been testing harbor seals for the presence of chemicals in the polybrominated diphenyl ether family for several years.

Until recently, the MERI team has tested for the presence of other PBDEs, including two known as octa and penta that were banned several years ago.

Shaw said researchers have found high levels of penta and octa in the seals' blubber. But they were alarmed recently to find traces of deca in four out of eight seals tested.

They plan to test blubber taken from more than 30 other seals that were found stranded from Maine to New York in recent years.

Representatives of the chemical industry defend deca by pointing out that the chemical, unlike its relatives octa and penta, rarely appears in mammals' fatty tissues. But Shaw said deca's presence in the four seals proves that the chemical does accumulate in marine mammals.

Shaw argued that deca is often difficult to detect because mammals break the chemical down into lower — and more dangerous — forms associated with octa and penta.

"It suggests that they are exposed to pretty high levels of deca, but they are breaking it down to these other congeners," said Shaw, who is presenting her findings at an international conference on brominated flame retardants in Amsterdam later this week.

MERI researchers believe the harbor seals likely are being exposed to deca through the food chain. They are working with several other international groups to test fish that seals eat for deca and other PBDEs.

Toxic Effects of PBDEs

Human Health Effects

Cryptorchidism

– Main et al, 2007

Hormone Effects

– Meeker et al., 2009 –
Decrease in Androgens and LH; Increase in FSH and Inhibin

– Meijer et al, 2008
Decrease in Testosterone

Reproductive Effects

-- Eskenazi et al., 2009
Low Birth Weight; Altered Behaviors

-- Harley et al, 2010
Increased time to pregnancy

Neurological Effects

– Herbstman et al, 2010
Decreased IQ

Decreased Sperm Quality

- Akutse et al, 2008

Diabetes

- Lim et al, 2008
- Turyk et al, 2009 (only in hypothyroid subjects)

Thyroid Homeostasis

- Herbstman et al, 2008 – decrease in TT4
- Turyk et al, 2007 – elevated T4
- Meeker et al, 2009 – elevated T4, TBG
- Dallaire et al, 2009 -Elevated T3 ~BDE47
- Eskenzai et al, 2009 – Low TSH

Courtesy, Linda S. Birnbaum, Director, NIEHS and NTP

Health Effects in Animals & Wildlife

- **Reproductive toxicity**: Abnormal gonadal development, reduced ovarian follicles, reduced sperm count
- **Neurotoxicity**: Decreased memory, learning deficits, altered motor behavior, hyperactivity
- **Endocrine disruption:** contributing to obesity & diabetes
- **Thyroid hormone alterations**
- **Cancers**

“Emerging Contaminants” - Replacements for Banned Chemicals

Replacements for Banned Flame Retardants

Chemical	Primary Uses
Hexabromocyclododecane (HBCD)	insulation, textiles, thermoplastics
Tetrabromobisphenol-A (TBBPA)	printed circuit boards, thermoplastics
Decabromodiphenylethane (DBDPE)	thermoplastics
1,2-Bis(2,4,6 tribromophenoxy) ethane (BTBPE)	thermoplastics
Pentabromoethylbenzene (PBEB)	textiles, adhesives, coatings, polyurethane foam
Hexabromobenzene (HBB)	thermoplastics?
Dechlorane Plus®	electrical wires/cables, computer connectors, plastic roofing materials
Firemaster 550®	polyurethane foam

New MERI Study:

Emerging Contaminants in the Northwest Atlantic Marine Food Web

- Novel chemicals marketed as replacements for banned flame retardants (PBDEs)
- Analysis: tissues of ≥40 harbor seals from the northwest Atlantic and their major prey fish
- Contamination status, trends

NOAA 2010-2011

Summary

- PBDEs, PFCs reaching the oceans; North American PBDE levels rivalling PCBs
- NW Atlantic harbor seals are highly contaminated by PBDEs and other POPs
- Biomagnification from prey fishes
- Replacement chemicals need further study to determine health and environmental risks

Publications

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Chemical Analysis: Dr. K. Kannan, Wadsworth Lab, NY State Dept of Health, Albany

Photography: MERI, Bowman Gray, Cynthia Stroud, John C. Fuller

MERI
Protecting the ocean environment and
human health through research and education
www.meriresearch.org