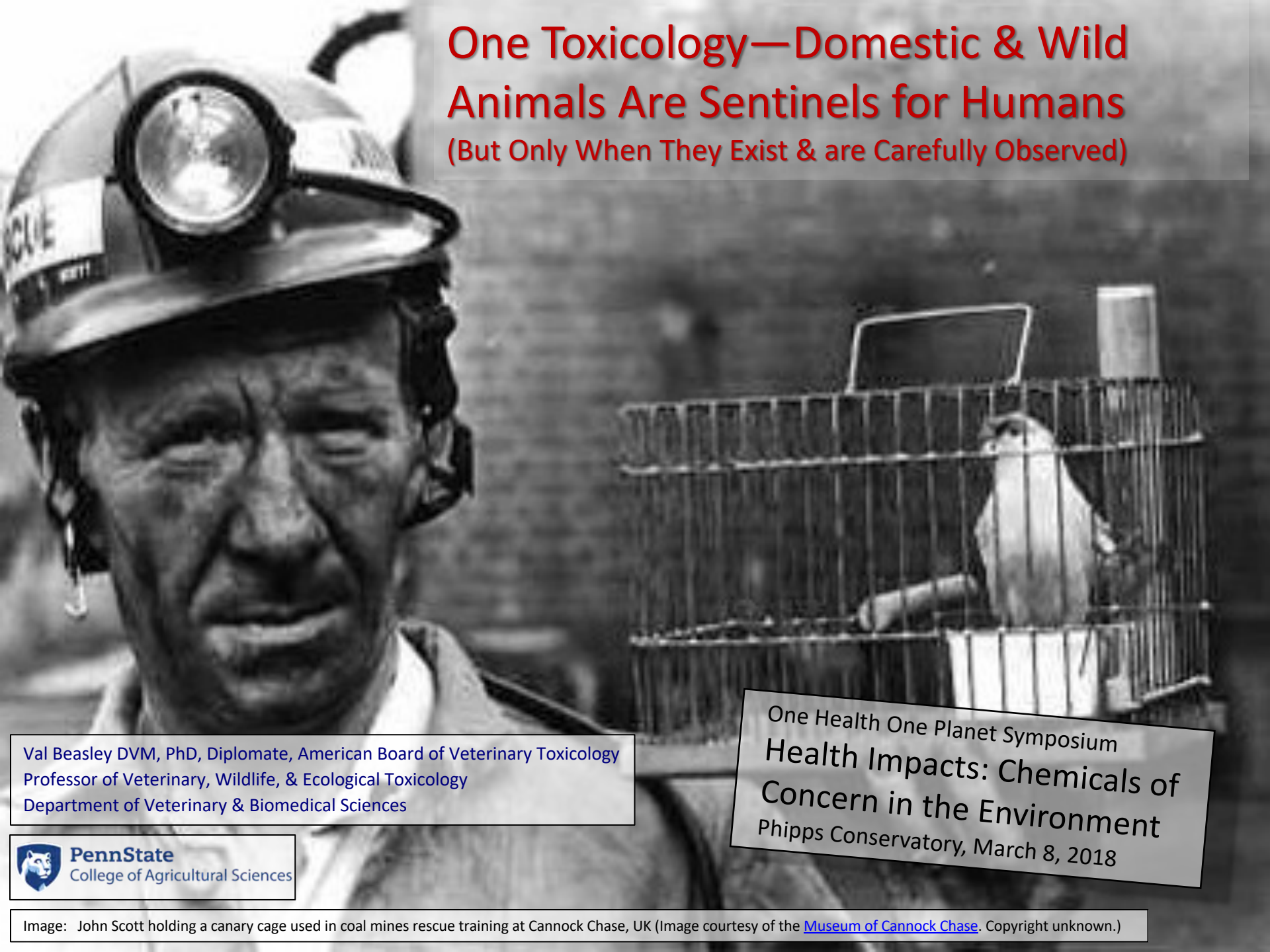
One Toxicology—Domestic & Wild Animals Are Sentinels for Humans

(But Only When They Exist & are Carefully Observed)



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PennState
College of Agricultural Sciences

One Health One Planet Symposium
Health Impacts: Chemicals of Concern in the Environment
Phipps Conservatory, March 8, 2018

Image: John Scott holding a canary cage used in coal mines rescue training at Cannock Chase, UK (Image courtesy of the Museum of Cannock Chase. Copyright unknown.)

Avian Respiratory Morphology & Physiology

Bidirectional airflow through the **trachea**,…..

……but **unidirectional airflow through** the **lungs**….

….& **birds** have a **very thin blood-gas barrier!**

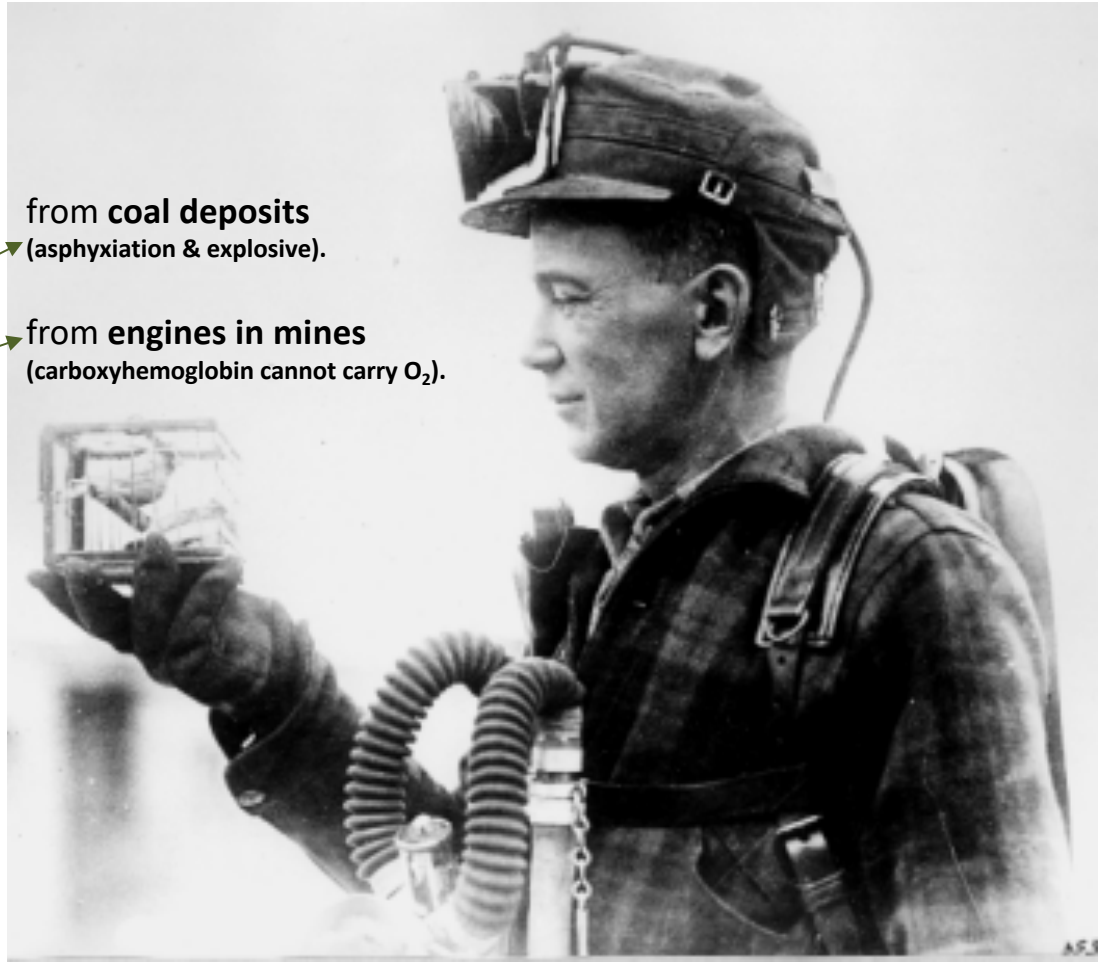
→ ***Absorb toxic gases faster than mammals!***

Historical 1890s-1986: Canaries in coal mines were sentinels of airborne toxicant exposures.

Methane,
carbon monoxide.

from **coal deposits**
(asphyxiation & explosive).

from **engines in mines**
(carboxyhemoglobin cannot carry O_2).



Tangible.
Immediate.
Shared fate.
Appreciated.

Data: https://en.wikipedia.org/wiki/John_Scott_Haldane
Image: Mining foreman, R. Thornburg, shows a small cage with a canary used for testing carbon monoxide gas in 1928. George McCaa, U.S. Bureau of Mines, https://www.smithsonianmag.com/smart-news/story-real-canary-coal-mine-180961570/

Today's World: The same airborne toxicants are important in homes – pet birds & families affected!

Methane,
carbon monoxide.

from **leaking gas lines or appliances.**

from **engines in garages & poorly-vented fossil-fuel heating systems.**

Tangible.
Immediate.
Shared fate.
Appreciated.

Birds also highly sensitive to other airborne toxicants:

- **Burning foods/overheating** cooking **oils, self-cleaning ovens.**
- Fumes & particulates from **overheated Teflon, Silverstone, & similar coatings, especially on drip pans.**
- **PAM spray.**
- **Second-hand tobacco smoke.**
- **Ammonia.**
- **Aerosol deodorants, perfumes, & hairsprays.**

Data: http://www.busybeaks.com/QA%20teflon.pdf, http://www.exoticpetvet.net/avian/topten.html, http://www.tandfonline.com/doi/full/10.1080/10807039.2017.1353902, https://www.poison.org/articles/2016-jun/hairspray (human)

TODAY

- One Toxicology.
- Three Examples.
  - Outdoor Insecticides.
  - Local to Global Mercury.
  - Indoor Flame Retardants.
- Take Home Messages.

One Toxicology

- **If we consistently protected domestic & wild animals** from **environmental, food, & household contaminants**, ***could we worry less about toxic impacts in humans?***

Thyroid Adenoma in Cat

”Fireproof Killer Whales”

See: http://www.nrcresearchpress.com/doi/pdf/10.1139/f05-244

Environmental pollution is most extreme in developing nations,
…..yet we do very little about it!

Images: Mr. Graeme Ellis, Dr. Mark E. Peterson, & Beasley Research Group.
Data: Beasley 2009. http://www.izs.it/vet_italiana/2009/45_1/97.pdf

One Toxicology

The Lancet Commission on Pollution and Health (2017)

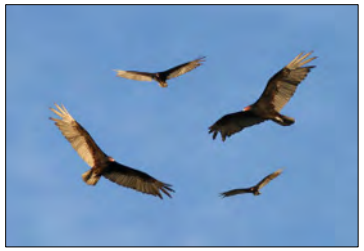
- **If we consistently protected humans** from **environmental, food, & household contaminants**, ***could we worry less about toxic impacts in domestic & wild animals?***

Images: Suchichi02 - Smog in Chaoyang, Beijing - https://commons.wikimedia.org/wiki/File:Smog_in_Chaoyang,_Beijing.jpg
http://www.prweb.com/releases/2015/07/prweb12854514.htm

Impacts Depend on Genomes, Biochemical Receptors, Metabolism, Physiology, Lifestyles, Diets, Locations, & Human Choices (Exposures)

- **All animals exposed to chemicals in their water, food, air, & soil.**
- **Domestic animals: Typically "stay home"** & have **"constant diets."**
  - **Pets:**
    - **Chemical exposures** come from **homes, yards** & **pet foods (e.g. melamine + cyanuric acid).**
    - ***Compressed lifespans*** relative to humans; **but *not enough are examined postmortem*.**
  - **Farm animals:**
    - **Chemical exposures** come from **farm buildings, pastures, foodstuffs & water.**
    - **Meat-producing** animals are **killed & inspected** *when still* ***young*.**
    - **Dairy & breeding animals** are **killed & inspected** *when* ***reproduction wains*.**

- **Wild animals: Diverse in form, function, habitats & exposures.**
  - **Game species (fish, birds, mammals) inspected by *people who fish & hunt*, & sometimes by *specialists* (e.g., deer at check stations examined by *veterinary pathologists*).**
  - ***Wildlife veterinarians* undertake *field studies* & sometimes examine *road-kills*.**
  - **Some = terrestrial; some = aquatic; & others = amphibious.**
  - **Mice range over a ~40 meter radius; Arctic terns & Swainson's hawks migrate >>20,000 miles each year.**
  - **Many eat plankton or plants… Many others are predators… & Some are top predators.**
  - ***Daphnia* live only 5-6 months; turkey vultures ~16 years; bowhead whales >200 years.**



***Few humans are examined at postmortem in the US*:** https://emedicine.medscape.com/article/1705948-overview

To Learn Enough to Protect Animals & People All At the Same Time

- **Examine animals (alive & those that die) & their environments:**
  - **Clinical signs, physiological parameters, blood, urine, feces.**
  - **Gross postmortem & histopathology.**
  - **Food, water, sediments & soils, & air.**
  - **Appropriate specimens collected, packaged, labeled, shipped, & examined for infectious agents & toxic chemicals.**

- **Undertake follow-up research to establish causation, mechanisms, impacts, diagnostic criteria, & effective therapies.**
  - **In laboratories with the same species, surrogate species, & cultured tissues or cells.**
  - **In the field: studies of free-ranging animals.**

Wild animals must be in peak condition to:

- **Be effective in finding & competing for food.**
  - Alertness, vision, smell, taste, coordination & strength, to find nutritious, "nontoxic" plants or to catch prey (milliseconds make a difference).
- **Avoid becoming prey** (milliseconds make a difference).
- **Compete for mates** (natural beauty, courtship behaviors).
- **Breed & reproduce successfully.**
- **Protect & feed offspring.**
- **Survive extreme weather.**
- **Resist infections** (without food handling training programs, hot water, detergents, disinfectants, refrigerators, stoves, facemasks, & vaccines).

Metals – Especially Mercury

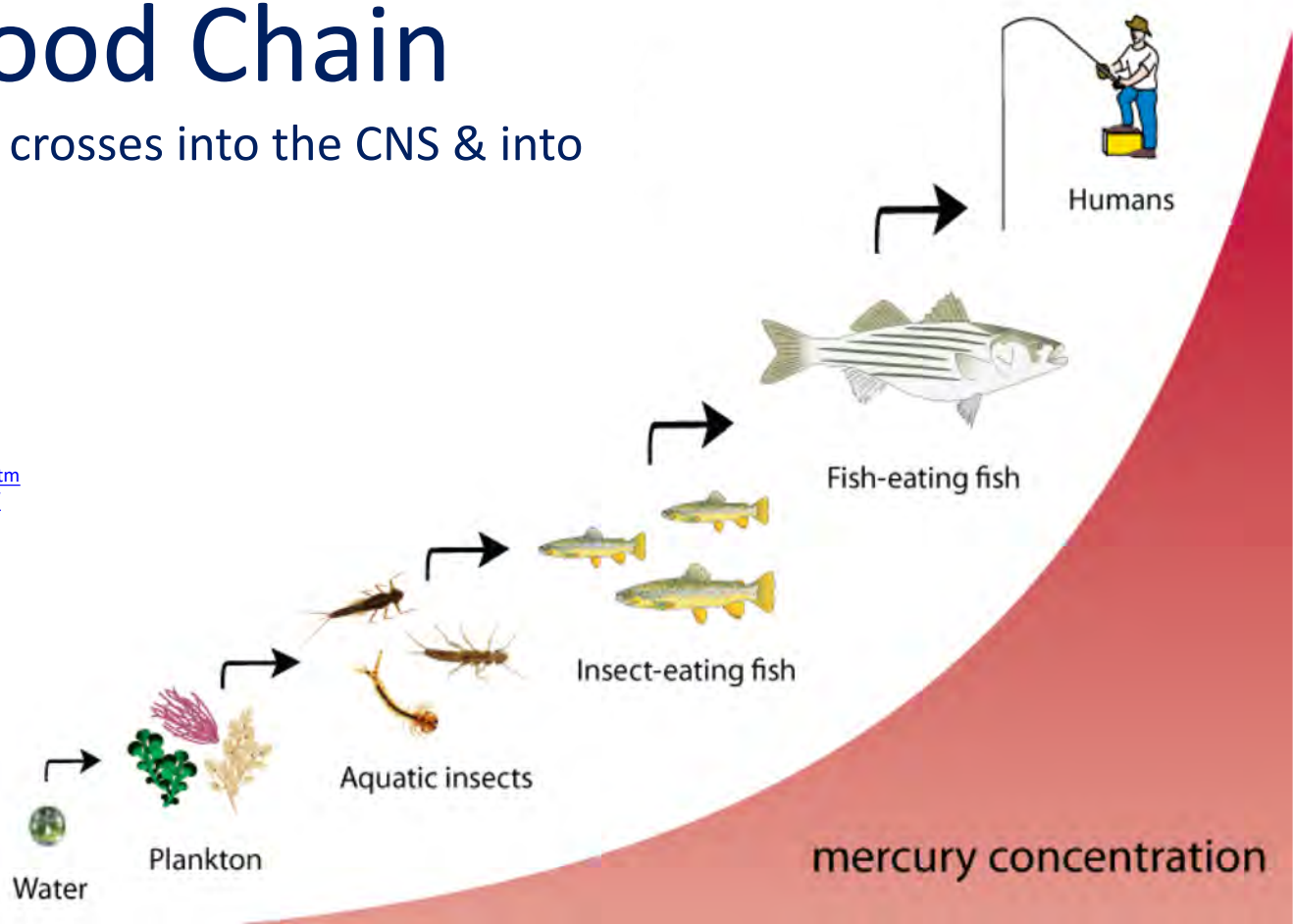
Methylmercury

(= MgHg = CH_3Hg^+)

Readily Biomagnified Up the Food Chain

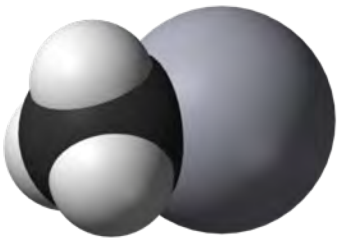
(= in muscle of fish, crosses into the CNS & into developing young)

Image: https://www.nps.gov/subjects/air/humanhealth-toxics.htm
Data: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3139210/



Mercury Then: Minamata, Japan

- In **1951, Chisso Chemical Company used mercury sulfate with a *new co-catalyst**** → **Directly produced MeHg → Released to Minamata Bay**.
- Soon, ***dead fish*** floated in the bay & catches by fishermen declined.
- In **1953**, ***seabirds & crows spiraled into the sea***… & that **same year...**



http://www.med.or.jp/english/pdf/2006_03/112_118.pdf

* Manganese dioxide changed to ferric sulfide.

Fish-eating, mercury-poisoned cats were very unsteady, such that they sometimes held their limbs wide apart to maintain their balance.

Some of the cats knuckled over their hind paws.

Some reports stated that affected cats *"danced in circles"* (seizured) ***& they "committed* suicide"** (some fell into the bay & drowned).

Methylmercury

- In **1956**, ***severe neurotoxicity*** in ***children*** associated with **eating fish & shellfish of Minamata Bay**.
- In **1957**, poisoning was ***reproduced in cats*** **fed fish from the bay.**
- **11 years later**, in **1968**, **Chisso** finally **stopped releasing MeHg**.
- By **2001**, **1,784 died** of ***2,265 humans diagnosed*** with MeHg poisoning; **& >10,000** were **compensated** after **lawsuits.**
- ***Life-long effects in survivors!***

Mercury Now:

Globally Important.

Hotspots Important.

Image: US Fish & Wildlife Service - https://usfwsnortheast.wordpress.com/2016/09/13/its-back-to-the-future-for-loons-in-massachusetts/
Data: https://www.netl.doe.gov/File%20Library/Research/Coal/ewr/air-quality-research/Mercury-Soils-AQ-V.pdf

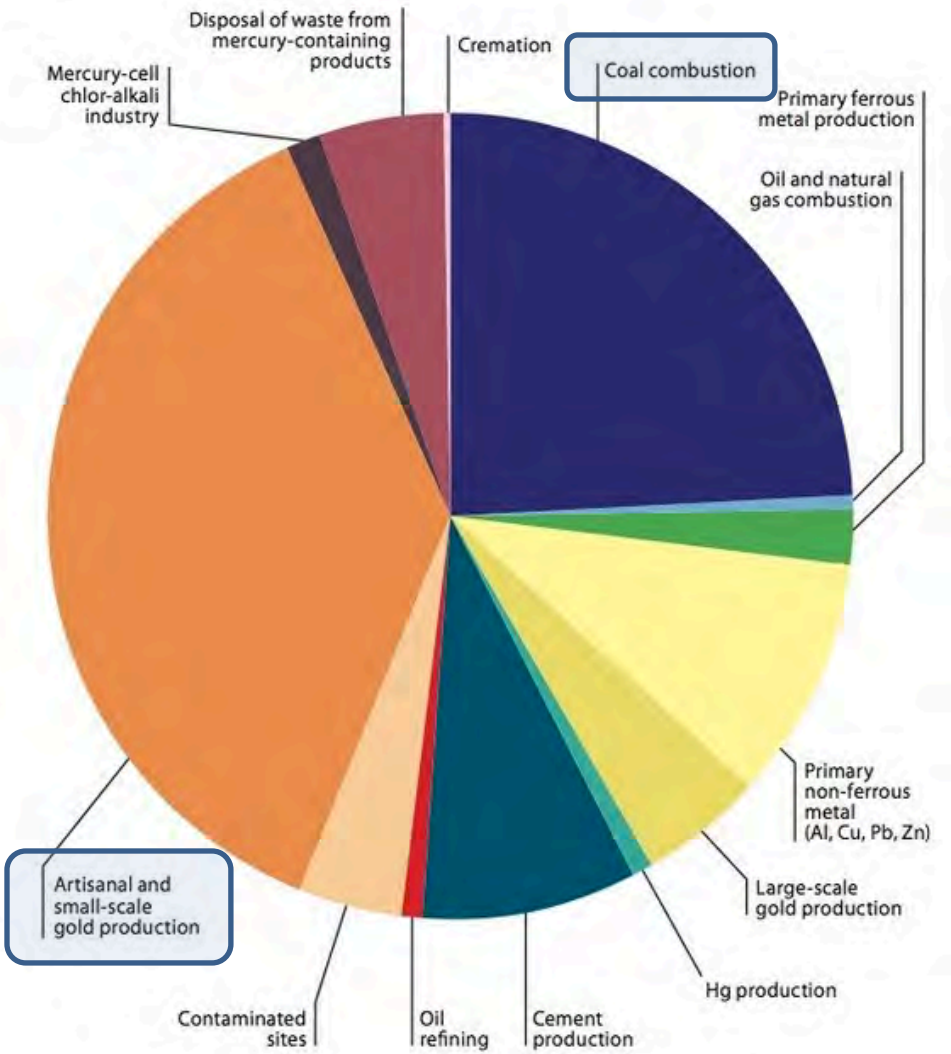
Mercury Now:

Globally Important.
Hotspots Important.

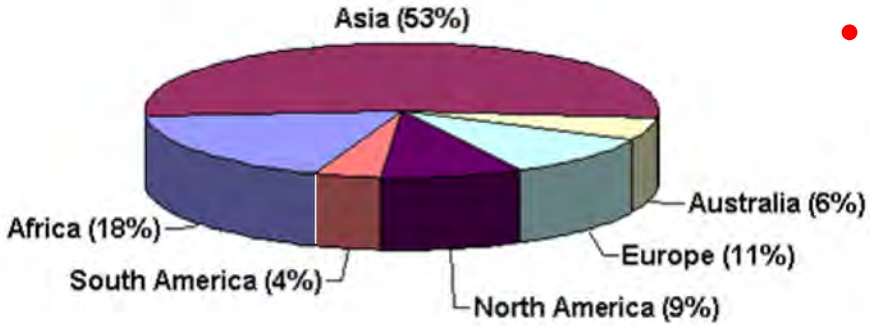
- **Australia, February 2018: MeHg mercury poisoning of dog** & **concerns for family members. → All were eating the same fish (seeking health benefits).**
- History: "The **dog was fed human-grade fish** including Coles and Aldi branded **Basa from Vietnam.**
  - Basa (*Pangasius bocourti*) is a **commonly cultivated catfish in Vietnam**. It also goes by the names, "pangasius", "bocourti", "panga", "river cobbler", "cobbler", "swai", or any of these with "catfish".
- The dog had **severe neurological signs** with **visual deficits, ataxia, tremors & mental dullness.**
- **Hair & blood analyses confirmed toxic concentrations of mercury.**
- **No other cause** for the dog's neurologic signs were found based after **MRI, CT, cerebral spinal fluid analysis, vit. B12 & thiamine analyses, & liver function testing.** (Thiaminase in raw fish may cause illness → but, thiamine deficiency was ruled out).

- **Historically: More Hg was sequestered in mineral deposits & coal.**
- **Human activity: Releases mercury & it circles the globe… deposition occurs in ~1 year.**
- **Coal burning was most important source, but now artisanal/small-scale gold = #1.**

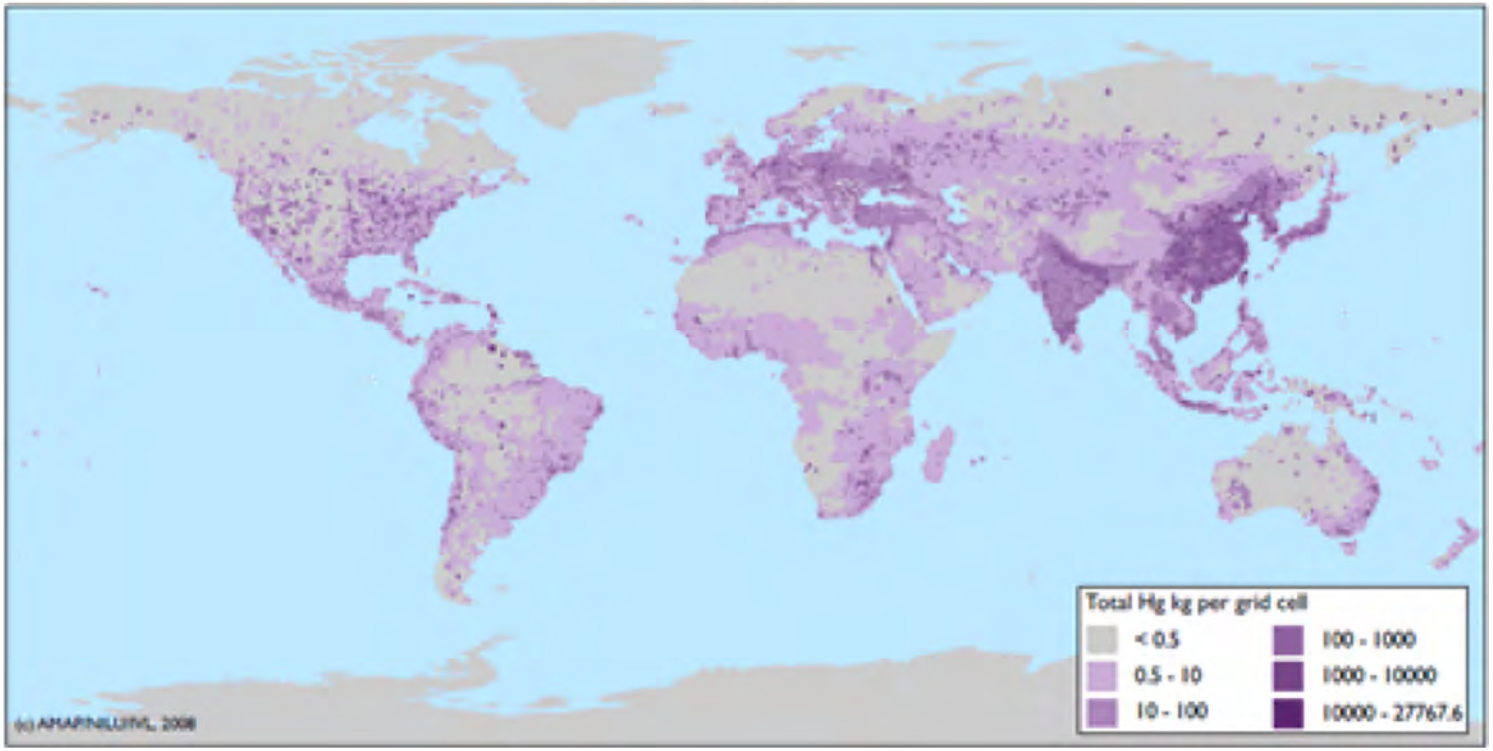
Anthropogenic sources of Hg in air.
(Reported 2010).



Data: Minamata Mercury Convention - http://www.mercuryconvention.org/Portals/11/documents/Awareness%20raising/FACT%20SHEETS/Minamata%20Convention%20on%20Mercury%20at%20a%20glance_COP1%202017.pdf, https://www.scientificamerican.com/article/new-catalyst-can-reduce-mercury-emissions/, http://www.wbcsdcement.org/pdf/MercuryReport%20Executive%20summary.pdf
Image - UNEP = United Nations Environment Programme: http://wedocs.unep.org/bitstream/handle/20.500.11822/7984/-Global%20Mercury%20Assessment-201367.pdf?sequence=3&isAllowed=y



- **Power plants in Asia alone release 860T/yr.**



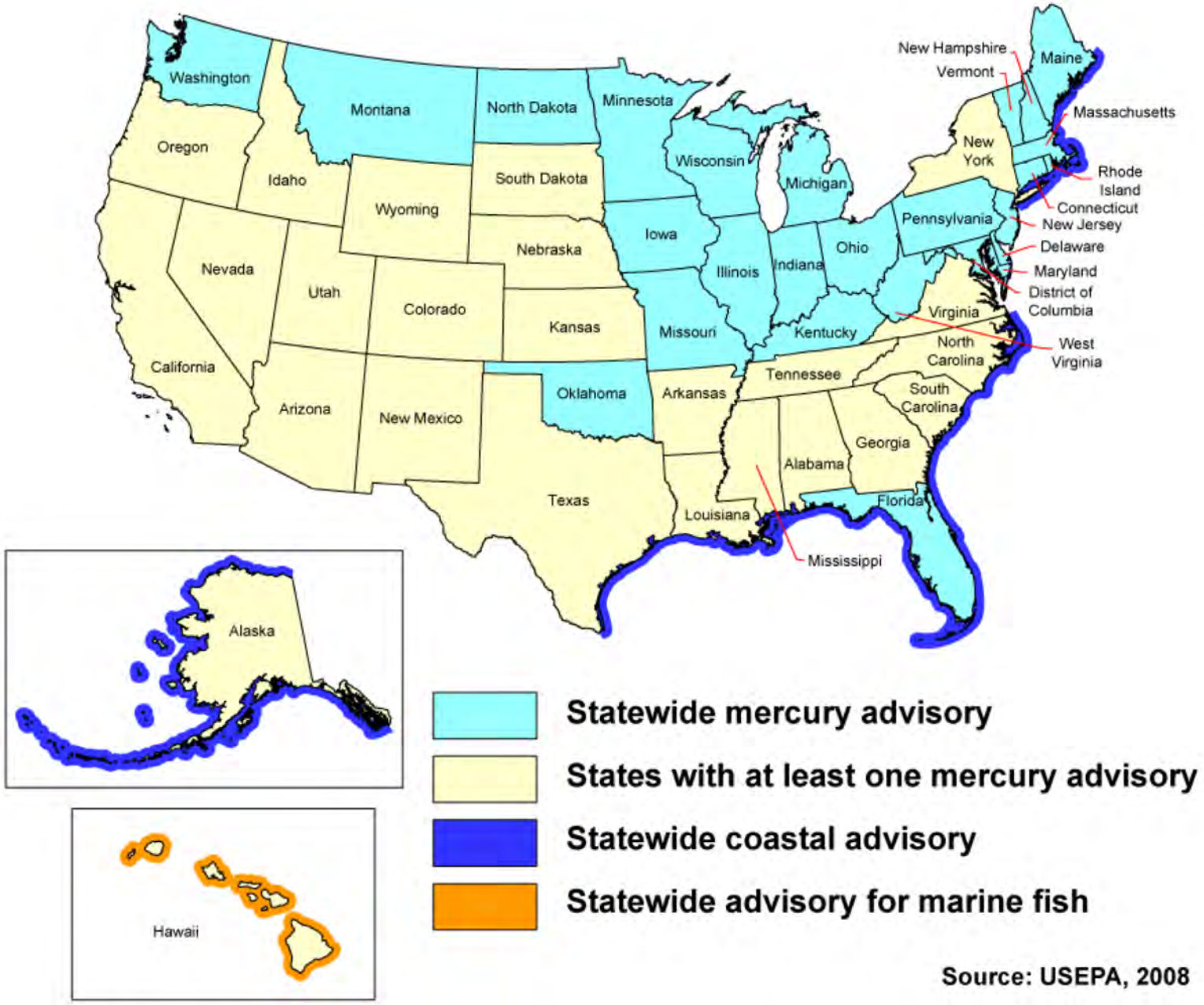
Recent loadings of mercury in the environment are most bioavailable.

Data: https://www.nrdc.org/sites/default/files/potential-cobenefit-mercury-control-power-plants-china.pdf

Images: Pie Chart - Pacyna & Munth. Mercury Workshop in Brussels, Mar 29-30, 2004

Map – United Nations Environment Programme, Global Atmospheric Mercury. Assessment: Sources, Emissions and Transport, 2008, using 2005 data, as presented by the Arctic Monitoring and Assessment Programme Secretariat.

Mercury Concentrations in Fish: A Public Health Concern



Zebra Finch: **Model for Avian Behavior**

- We **can't subject multiple species of wild animals to learning tests** as **they did with children of Faroe Island mothers who ate pilot whale meat.**

- **Captive zebra finches** given a **life-long diet** with **MeHg at 1.2 ppm** (**blood Hg ~8 to 25 ppm**) → **Ate less, lost weight, hyperactive, & impaired hearing & spatial memory**, lower **social hierarchy**, **hypersensitive to a predatory threat, delayed immunity & liver damage.**

Data: Swaddle et al., 2017 - http://jpswad.people.wm.edu/Swaddle%20et%20al%202017%20-%20Mercury%20and%20cognition.pdf,
Wolf et al., 2017 - https://link.springer.com/article/10.1007/s10162-017-0619-7,
Kobiela et al., 2015 - http://jpswad.people.wm.edu/Kobiela%20et%20al%202015.pdf
Also for loons & eagles, see Scheuhammer at al, 2008 - https://link.springer.com/article/10.1007/s10646-007-0170-0

Marilyn Spalding of the CVM of U Florida & Envirovet Students in 2010

Image: Beasley Lab Group

MeHg

Lethal to Great Egret Chicks

- **Florida historically had low Hg emissions:**
  - **Minor historical sources during droughts → Spontaneous oxidation of wetlands & Wildfires in wetlands.**
  - **Florida incinerated medical wastes 1983-1991 → Emissions spiked+++.**
    - **Sphygmomanometers, bougies, thermometers, switches, thermostats, fluorescent tubes.**
    - **In 1993, started autoclaving & landfilling medical wastes → Environmental Hg started downward.**
    - **Still, by 1998, largemouth bass contained Hg at ~2.5 ppm.**
- **In 2000, great egret chicks fed fish** containing **MeHg** at **0.5 or 5 ppm**:
  - **Ate less & growth was slowed.**
  - **Most high-dose birds died** *by* **week 12.**
  - **Growing feathers (important excretory route) had highest Hg.**
    - **At 5 ppm in diet, feathers (810 ppm), & brain (35 ppm), blood (93), & liver (140).**
- **Now: Because of the pollution controls, Hg in great egrets is markedly declining!**

Data: Atkeson et al, 2005 – https://link.springer.com/content/pdf/10.1007%2F0-387-24494-8_26.pdf ; Spalding et al, 2000 - http://www.jwildlifedis.org/doi/pdf/10.7589/0090-3558-36.3.411; https://www3.epa.gov/region9/waste/p2/projects/hospital/mercury.pdf Image: Rachel Faikner- http://blog.nwf.org/2012/04/photo-of-the-day-great-egret-chicks-feeding-time/

MeHg

Endocrine Disruption in White Ibis.

- **Reproduction has been low in Everglades crustacean- & fish-eating water birds**, including **white ibis.**
- **Nestling ibis** collected **from breeding colonies in Florida** were placed in **large aviary**.
  - Starting at 90-days-old, fed pelletized **diet containing MeHg** at **concentrations found in wild (0.05, 0.1 or 0.3 ppm)** (the high dose = 0.28 ppm Hg).
    - Controls fed clean diet.
  - After they matured, ~**13% of the nests of birds fed Hg at any level had no offspring &** at the **high dose** → **35% fewer fledglings.**
    - **Low testosterone.**
    - **Fewer offspring** in **heterosexual pairs.**
    - **Male/male pairings (55% of males at high dose).**
    - **High dose birds had mean blood Hg of ~4 ppm & mean feather Hg of ~37 ppm.**
    - **Low dose birds had mean blood Hg of ~0.7 ppm & mean feather Hg of ~7 ppm.**

Image: US Fish & Wildlife Service - https://upload.wikimedia.org/wikipedia/commons/6/69/White_ibis_%289151955161%29.jpg

Data: Frederick & Jayasena, 2011 - http://rspb.royalsocietypublishing.org/content/278/1713/1851, https://www.nps.gov/ever/learn/nature/upload/SecureWadingBirdReport2014.pdf.

For more on effects of Hg on wildlife, see: http://www.nwhc.usgs.gov/publications/field_manual/chapter_45.pdf, http://www.state.nj.us/dep/dsr/vol2-Chapter6.pdf

Arctic Ivory Gull Populations (Coastal Distribution)

(Report from 2015)

- **Feathers collected over 130 years** were analyzed.
- **Mercury increased almost 50-fold in that time.**
- **Current residues of MeHg feathers = 4.1 ppm.**
- ***Ivory Gull populations in Canada decreased 80% since the 1980s.***
- **Authors concluded** that **MeHg may be playing a role in the decline.**
- Mercury pollution **at high latitudes** is expected to **continue increasing**, in part, because of **ongoing emissions & climate change.**

Data: http://rspb.royalsocietypublishing.org/content/282/1805/20150032
https://royalsociety.org/news/2015/03/mercury-pollution-danger-for-arctic-ivory-gulls/

Climate Change: Melting Permafrost as a Source of Hg

Yukon River alone is releasing up to 5T of Hg/Year to Environment

Paul Schuster, of USGS:

- **"What has happened in the past 30 yr is unprecedented."**
- February 5, 2018: Schuster et al, in *Geophysical Research Letters:*
  - "**Permafrost soils store nearly twice as much Hg as all other soils, the ocean, & the atmosphere combined**, **& this Hg is vulnerable to release as permafrost thaws**…. "
  - **30-99% of Arctic's near-surface permafrost** is **predicted to thaw by 2100.**

Images: National Park Service - https://www.nps.gov/stateoftheparks/yuch/naturalresources/landcover.cfm & Alaska Department of Fish & Game - http://www.adfg.alaska.gov/static/fishing/chinookproject/images/yukon/yukon_map.jpg
Data: https://pubs.er.usgs.gov/publication/70006305 & https://www.scientificamerican.com/article/the-arctic-permafrost-holds-a-crazy-amount-of-mercury-mdash-and-thats-bad-news/

Report US FWS:

- **To protect sensitive species of birds that regularly consume fish & other aquatic organisms, <u>Hg in prey should not exceed 0.1 ppm</u>.**

How are we doing in Today's environment?

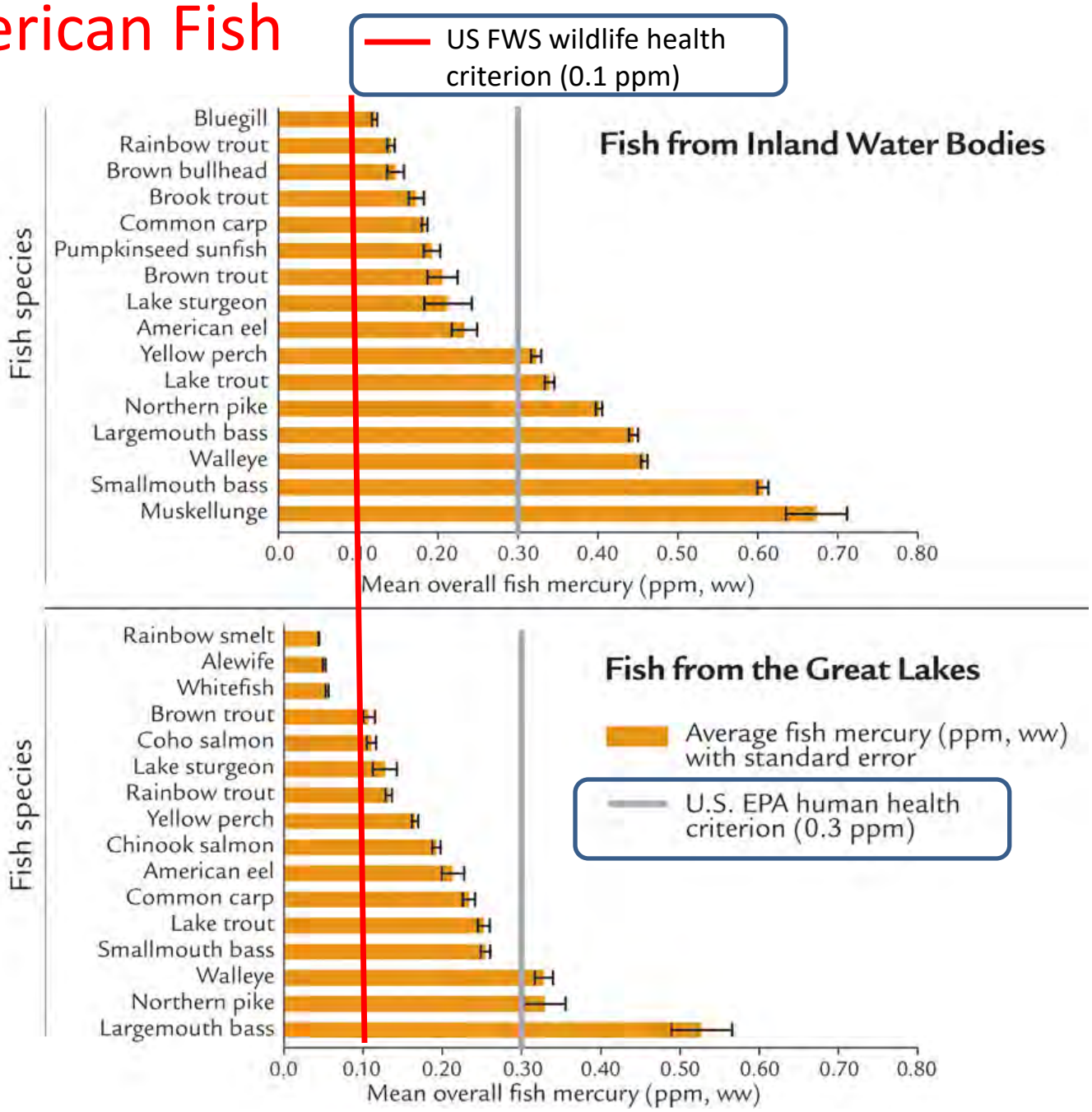
Image: Doug Racine, US Fish & Wildlife Service - https://commons.wikimedia.org/wiki/File:Great_egret_eating_fish_at_Montezuma_National_Wildlife_Refuge._(8578390264).jpg
Data: https://www.pwrc.usgs.gov/eisler/CHR_10_Mercury.pdf, Sørmo et al., 2011 - http://pubs.acs.org/doi/pdf/10.1021/es200478b, Cusack et al, 2017 - https://www.ncbi.nlm.nih.gov/pubmed/27928722

Hg in North American Fish

(In ppm - some spp. with high Hg)

Ocean Fish

- Tile fish (Gulf) (1.123)
- Swordfish (0.995)
- Shark (0.979)
- King mackerel (0.73)
- Tuna frozen–bigeye (0.689)
- Orange roughy (0.571)
- Marlin (0.485)
- Spanish mackerel (0.454)
- Grouper (0.448)
- Chilean bass (0.384)
- Bluefish (0.368)
- Tuna albacore (0.350)
- Croaker (0.287)
- Halibut (0.241)
- Mahi mahi (0.178)
- Saltwater bass (0.167)
- Snapper (0.166)
- Monkfish (0.161)
- Tuna skipjack (0.144)
- Atlantic tilefish (0.144)
- Other fish lower Hg.



Data: FDA https://www.fda.gov/food/foodborneillnesscontaminants/metals/ucm115644.htm Image on right: Adapted from Biodiversity Research Institute. http://www.briloon.org/uploads/images/template/74/Fig7-LA-01-x980.jpg & http://www.briloon.org/mercury-connections-landing-page/mercury-in-the-great-lakes-region

Some Regional Source of Mercury are "Fixable"

- In **much of** the **US, the UK, & Sweden**, concentrations **peaked around 1960**.
- **Hg in paints in the USA** was **banned** in **1990-1991.**
- **Hg being phased out in chloralkali plants.**
- **Current technologies** for **coal-burning power plants** have **reduced Hg emissions by ~90%.**
- **Artisanal gold: Methods** are available **to condense Hg in retorts**; **& better yet** are **concentration methods** that **capture heavy gold particles without Hg.**

Images: Amanda Boyd/US Fish & Wildlife Service, US Fish & Wildlife Service - https://www.recreation.gov/recreationalAreaDetails.do?contractCode=NRSO&recAreaId=1544
Data: https://www.nps.gov/ever/learn/nature/upload/SecureWadingBirdReport2014.pdf, , https://soils.ifas.ufl.edu/media/soilsifasufledu/sws-main-site/pdf/technical-papers/Howard-Nicole.pdf , http://www.artisanalmining.org/casm/sites/artisanalmining.org/files/files/Pg53-89Ch5GoldAmalgamation.pdf, https://www.export.gov/article?id=European-Union-Marking-Labeling-and-Packaging-Overview & https://www.epa.gov/international-cooperation/artisanal-and-small-scale-gold-mining-without-mercury

Some Regional Source of Mercury are "Fixable"

- **But,** with **A) current high prices for gold** → prompting **artisanal gold mining**, **B) burning more coal in old & new-but-obsolete-technology power plants**, **C) improper disposal of wastes** (household, commercial, dental & medical), & **D) global climate change** →

  People are still loading parts of the biosphere with Hg.

- **A Way Forward: STOP buying electricity & goods from producers who foul the world with Hg.**
- **Need universal ecolabeling & logos reflecting environmental stewardship (No Greenwashing).**

Images: US Fish & Wildlife Service - https://www.fws.gov/refuge/National_Key_Deer_Refuge/wildlife_and_habitat/birds/ & https://training.fws.gov/resources/course-resources/es-slideshow/IMAGES.html
Data: https://soils.ifas.ufl.edu/media/soilsifasufledu/sws-main-site/pdf/technical-papers/Howard-Nicole.pdf , http://www.artisanalmining.org/casm/sites/artisanalmining.org/files/files/Pg53-89Ch5GoldAmalgamation.pdf, https://www.export.gov/article?id=European-Union-Marking-Labeling-and-Packaging-Overview

Minamata Convention on Mercury

- **= A legally binding treaty: The US signed on in 2013. Currently 86 nations.**
- **Mercury uses & emissions must cover its life-cycle** & be integrated into **public health & environmental strategies** at the **local, regional, national & international levels** as **part** of the overall **pollution control agenda.**
- **All sectors of society must be involved with implementation, sharing the burden & benefiting from experience & expertise.**
  - **No new mercury mines, close control of mercury exports, rapid phase-out of mercury containing products.**
  - **Expert guidance on mercury handling, containment, disposal provided for energy & manufacturing sectors.**
- **Governments much reach out** to their **impacted communities.**
  - **Legislation needed to curtail illegal traffic in Hg (e.g. artisanal gold).**
  - **Artisanal gold mining communities** need to **know about, & be encouraged to use, alternatives.**
- **Transparency in national plans, sources, interim storage, disposal, & inventories of releases, & progress in reducing exposures.**

Data: http://www.mercuryconvention.org/Portals/11/documents/meetings/cop1/KTM%20FINAL%202909.pdf,
http://www.mercuryconvention.org/Portals/11/documents/Awareness%20raising/UNEP%20PPT/Overview%20of%20the%20Minamata%20Convention%20on%20Mercury%20EN.pdf
http://www.mercuryconvention.org/Portals/11/documents/Awareness%20raising/FACT%20SHEETS/Minamata%20Convention%20on%20Mercury%20at%20a%20glance_COP1%202017.pdf

Research Projects on Air Pollution, Birds (& Other Wildlife)

- **University** of Turku in **Finland** – **Research** groups studying **bats, birds, turtles, cell cultures due to exposures to effluents from metal smelters.**
  Publications 2015-present:

  - **Smelter workers had increased numbers of nasal, lung & stomach cancers.**
  - **Birds near the smelters—developed problems years before the people.**
    - **They suffered from direct toxicity & reduced food availability.**

  Pied flycatcher, *Ficedula hypoleuca*, had **severe breeding & egg shell problems but they largely recovered over time after a ~99% decrease in the emissions of metal dusts from the smelter.**

  - **Although wild birds are victims & sentinels for people, the effects of air pollution on wild or domestic birds are rarely studied.**

Image: Ken Billington, https://commons.wikimedia.org/wiki/File:Pied_Flycatcher_(Ficedula_hypoleuca)_(3).jpg & https://focusingonwildlife.com/news/author/ken-billington/
Data: https://www.utu.fi/en/units/sci/units/biology/research/projects/birds_and_pollution/Pages/home.aspx, http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0117071, https://www.sciencedirect.com/science/article/pii/S0269749115001037, http://www.audubon.org/news/what-can-birds-tell-us-about-air-pollution & https://www.researchgate.net/publication/309220917_Cancer_incidence_among_copper_smelting_and_nickel_refining_workers_in_Finland_Cancer_in_Nickel_Refinery_Workers_in_Finland

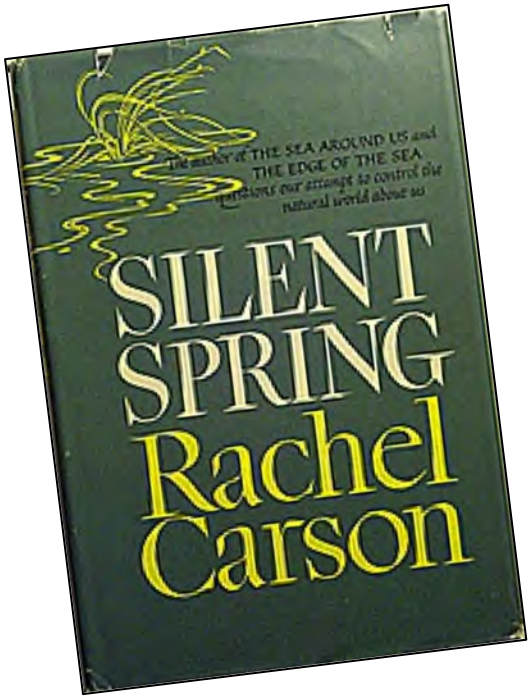
Anas platyrhynchos
Mallard duck

Outdoor Insecticides

Image: U.S. Fish & Wildlife Service - https://www.fws.gov/mississippiES/images/mallard%20takeoff%20FWS%20image.JPG

- ***S*ilent *Spring*** published **1962**, launched the **environmental movement** in the US.
- It described how **animals & people** were **heavily exposed** to **pesticides**, & documented links to **serious illnesses & deaths.**
- She was **attacked** by the **chemical industry** & some in **government** as an **"alarmist" & "hysteric."**
- **Testifying before Congress in 1963, she called for new policies to protect human health & the environment.**
- She **died in 1964** after a long battle with breast cancer.
- The **US EPA** was **founded in 1970** & most of the **laws** that **protect** the **environment today followed soon thereafter.**

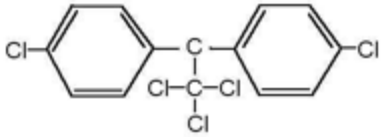
Homo sapiens
Rachel Carson

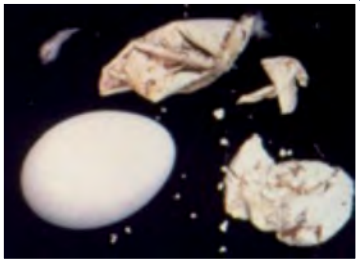


Insecticides Then: DDT

- Neurotoxic at Na^+ & K^+ channels.
- Inhibits calcification of eggshells.
- Estrogenic & anti-androgenic.

After WWII, massive amounts of **DDT & other organochlorine insecticides** used in **agriculture**, **mosquito control** & **households.**





Pelecanus occidentalis
Brown pelican

Haliaeetus leucocephalus
Bald eagle

Falco peregrinus
Peregrine falcon

Images:
David Pereksta for US Fish & Wildlife Service- https://www.fws.gov/cno/newsroom/featured/2016/Brown_Pelican_Survey/; US Fish & Wildlife Service - https://www.fws.gov/midwest/eagle/;
Mitch Urban for the National Park Service - https://www.nps.gov/media/photo/gallery.htm?id=092E2431-AE75-B2BB-BC2236A5C0D418BF

Image: McNary, US Fish & Wildlife Service

Pandion haliaetus
Osprey
Harmed by DDT

Simplified Version of the Food Chain of an Osprey

Osprey

Northern pike

Perch

Bleak

Freshwater shrimp

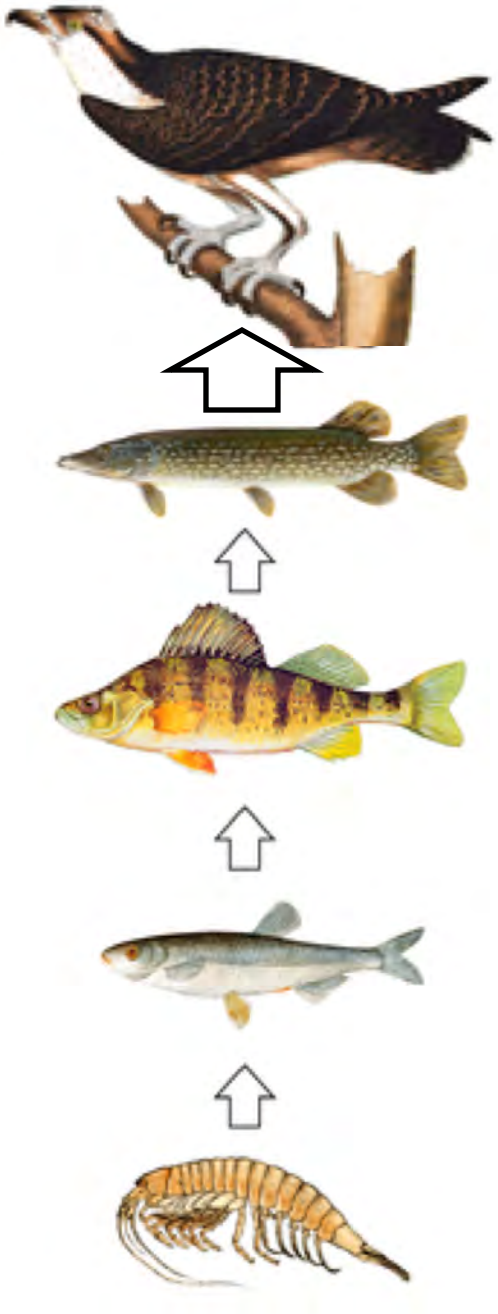


Image: Slightly modified from public domain - https://upload.wikimedia.org/wikipedia/commons/thumb/9/9f/Food_chain.png/160px-Food_chain.png

- **Slow biodegradation/metabolism** (***crowded halogen atoms inhibit metabolism***).
- **Uncharged (neutral) molecules → cross blood-brain barrier** & **into developing offspring** & **mammary gland.**
- When in an **anabolic** state → **Adipose (fat) depots**.
- But during **catabolic states** when **animals mobilize lipids** (e.g. **migrating, egg laying, pregnant, & lactating**). → **Risk of toxicity in adults &** ***Firstborn young of top predators*** *feeding in* ***contaminated aquatic food webs*** *are* ***often massively exposed.***

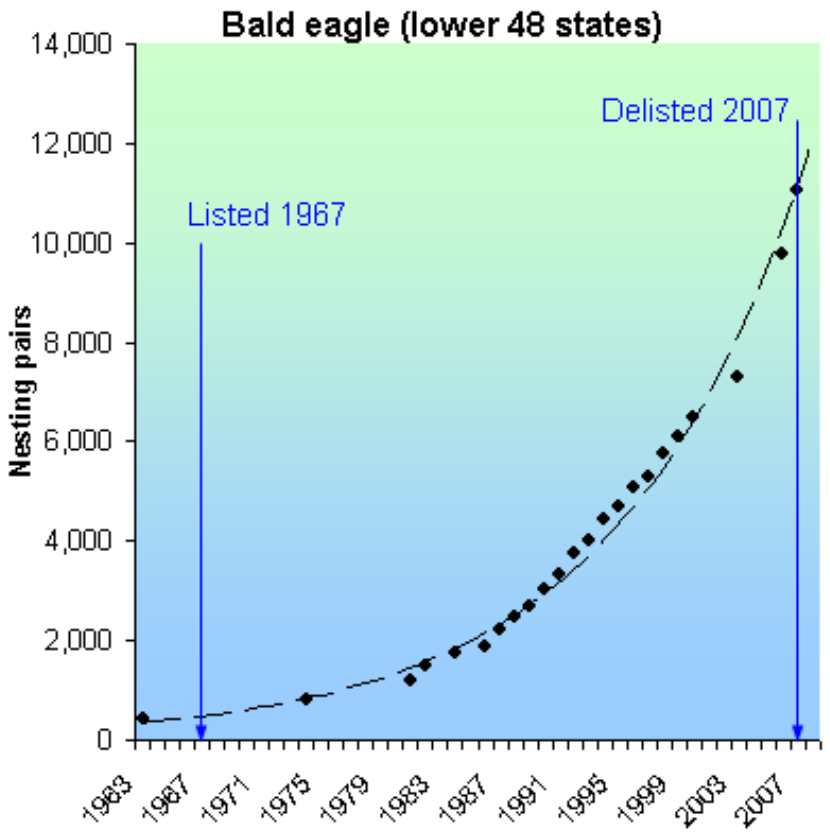
Data: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1568747/pdf/envhper00444-0018.pdf, http://www.nrcresearchpress.com/doi/pdf/10.1139/a06-005 & https://w3.marietta.edu/~biol/102/2bioma95.html

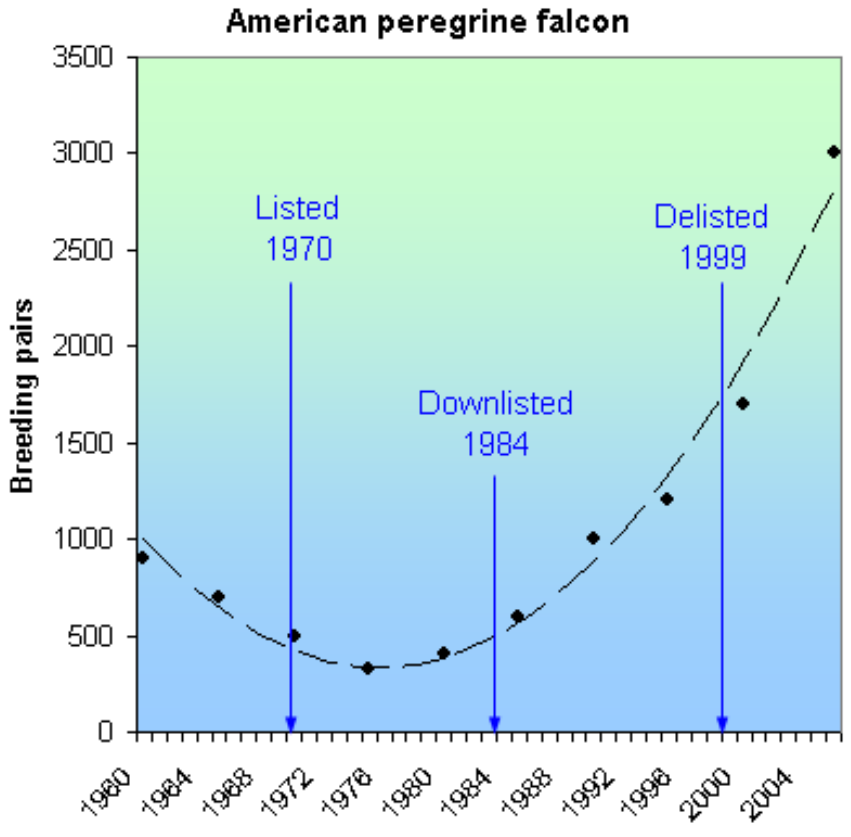
After Publication of “Silent Spring”…

…DDT & many other chemicals that **harmed wildlife populations *& harmed or seriously threatened human health*** were **banned** from most or all uses!

Bald Eagle & Peregrine Falcon Recoveries after DDT was banned in 1972

(Listing & Delisting as Endangered Species in the US)

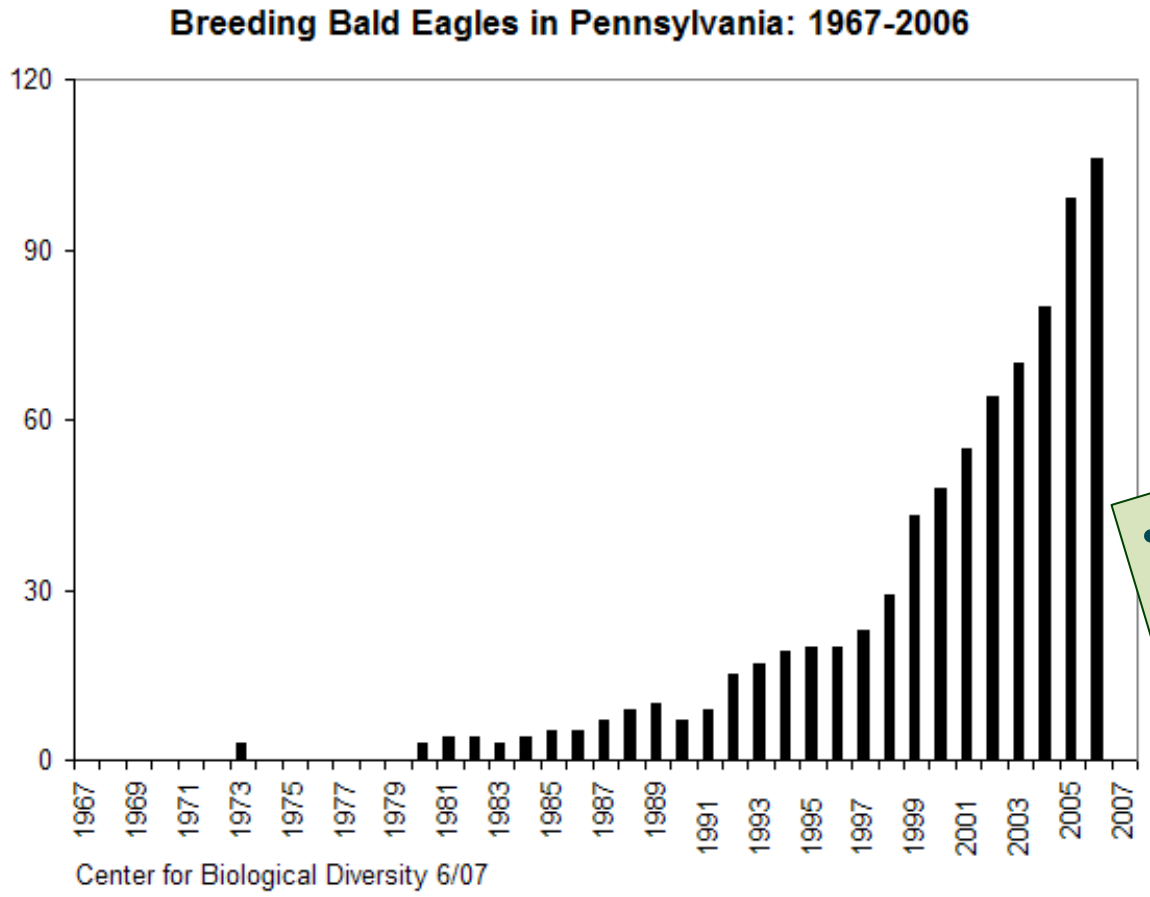




Images: http://www.esasuccess.org/nevada.shtml

Bald Eagle Recovery in Pennsylvania

- **History - Commonly nested near Lake E**rie but **by 1973, only 3 pairs remained in PA**.
- **Shooting, disturbance, & habitat destruction**, but **DDT was most important** in decline.
- **1983-1989: Pennsylvania released 92 Saskatchewan-born eaglets.**
- By **2006**, there were **106 nesting pairs** in **31 of the state's 67 counties.**



- In **2013**, there were **>270 nests.**
- **Bald eagles currently nest in 56 of Pennsylvania's 67 counties!**

Data: http://www.biologicaldiversity.org/species/birds/bald_eagle/report/#map & http://www.pgc.pa.gov/Wildlife/WildlifeSpecies/BaldEagles/Documents/Bald%20Eagle%20Management%20Plan.pdf

Unique Exposures & Sensitivities of Birds to Many Insecticides

- **High metabolic rates:**
  - **→ High intake of foodborne toxic chemicals.**

- **Rapidly lose body condition when feeding declines.**
  Insecticides directly & indirectly affect feeding:
  - **Direct: Neurotoxicity → Stop eating → Malnutrition or starvation** (any spp.)
  - **Indirect: Kill organisms in foodweb → Malnutrition or starvation** (many spp.)

- **Chronic Stress → Corticosterone → Immunosuppression → Infectious diseases.**

Data: http://eap.mcgill.ca/MagRack/JPR/JPR_14.htm Image: US Fish & Wildlife Service - https://www.fws.gov/refuge/Optima/contact.html

Insecticides Now:

Fipronyl & Neonicotinoids

Fipronil = an ion channel blocker.

Clothianidin = a neonicotinoid.

Imidacloprid = a neonicotinoid.

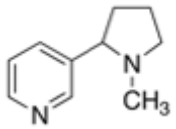
Avian Toxicology: **Fipronil**

Perdix perdix
Grey partridge

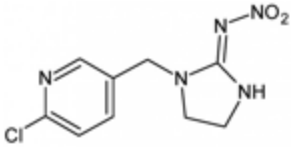
- **Not as highly biomagnified as older organochlorines & *more toxic to insects than birds*, but fipronil is *not selective enough* to avoid direct avian toxicity.**
- **Neurotoxic (dropped wings, tremors, seizures) & thyrotoxic.**
- **Lethal poisoning** from **eating pre-treated seeds**.
- **Sublethal poisoning from treated seeds**:
  - **Reduced body condition, cellular immunity, carotenoid-based coloration, & steroid hormone levels, & especially reproduction.**
    - **Surviving offspring** also have **reduced cellular immunity.**
- **Toxic to insects, & potentially fish, lizards, & small mammals → *Fewer of these prey* → Malnutrition, stress, impaired reproduction in predatory species.**
  - **More research on impacts on predatory birds is needed.**

Image: Marek Szczepanek, Creative Commons, https://commons.wikimedia.org/wiki/File:Perdix_perdix_(Marek_Szczepanek).jpg
Data: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4284370/, http://pubs.acs.org/doi/full/10.1021/acs.est.5b03822?src=recsys, http://pubs.acs.org/doi/abs/10.1021/es0600678?prevSearch=fipronil&searchHistoryKey, http://www.sciencedirect.com/science/article/pii/S0045653510014621?via%3Dihub https://link.springer.com/content/pdf/10.1007%2F978-1-4899-7283-5_1.pdf In Reviews of Environmental Contamination and Toxicology 176, 2003. George Ware, Ed.

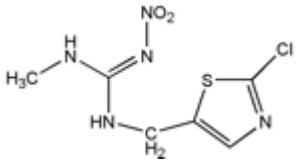
Avian Toxicology: **Neonicotinoids**



Nicotine



Imidacloprid



Clothianidin

- **Neonicotinoids** (e.g., **Imidocloprid & Clothianidin**) are **the most important & fastest growing insecticides** in the **market.**
- **Although they are unlikely to biomagnify, & are *less toxic to birds than insects*, neonicotinoids are *not selective enough*.**
- **Direct exposure from spraying → May kill sensitive spp. of birds.**
- **One to a few treated seeds → May kill granivorous birds.**

November 2016: Hundreds of red-winged blackbirds & other spp. died after eating imidacloprid-treated wheat seed that had been broadcast on a field in southern NJ.

- **Stimulation → Ataxia → Crash injuries (fractures, hemorrhages) & paresis, paralysis & apathy → vulnerable to predation.**

Image: Walter Siegmund, Creative Commons - https://commons.wikimedia.org/wiki/File:Agelaius_phoeniceus_0110_taxo.jpg
Data: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4284370/, http://biology-web.nmsu.edu/~houde/neonicotinoid%20insecticides.pdf,
Hallman et al Nature 2014: https://www.nature.com/articles/nature13531 & Mineau & Palmer 2015: https://abcbirds.org/wp-content/uploads/2015/05/Neonic_FINAL.pdf
https://www.sciencedirect.com/science/article/pii/S0045653514013848

Avian Toxicology: **Neonicotinoids**

- **At well below lethal doses: Genotoxicity & reduced immunity, growth, & reproduction.**
- **Deplete invertebrate prey base needed by many spp. of birds.**
- **In the Netherlands, areas with high imidocloprid use** are seeing average **declines** in **insectivorous bird populations of 3.5%/year!**

Motacilla flava
Yellow wagtail

Image: Frebeck, Creative Commons - https://commons.wikimedia.org/wiki/File:Wiesenschafstelze.JPG
Data: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4284370/, http://biology-web.nmsu.edu/~houde/neonicotinoid%20insecticides.pdf, http://www.sciencedirect.com/science/article/pii/S0045653510014621?via%3Dihub & Hallman et al Nature 2014: https://www.nature.com/articles/nature13531

Protecting bees might also protect birds from these insecticides.

- ***Neurotoxicity in bees*** **from fipronil & neonicotinoids:**

  (& bees seem to become addicted to neonicotinoids as people do to nicotine).

  - **Honey bees don't find way back to hives.**
  - **Bumblebees are especially susceptible.**
  - **Bees** have **fewer young.**

- **Neonicotinoids & fipronil increase infectious diseases in bees.**

- **2009: USEPA banned fipronil corn seed treatments.**
- **2013: Europe severely restricted neonicotinoids & fipronil.**
- **2015: Montreal, Canada banned neonicotinoids.**
- **2017: Europe banned fipronil in agriculture.**
- **2018: US neonicotinoids being reviewed under current EPA Administrator.**

Data: https://www.epa.gov/pollinator-protection/schedule-review-neonicotinoid-pesticides, https://www.nature.com/articles/srep24764, https://www.nature.com/articles/nature14414
https://pdfs.semanticscholar.org/1411/367f122c43218cca15d219025fac062b4367.pdf, http://onlinelibrary.wiley.com/doi/10.1002/ps.4489/full,
http://www.sciencedirect.com/science/article/pii/S2214574515000917, https://www.ncbi.nlm.nih.gov/pubmed/25703042,
https://ec.europa.eu/food/plant/pesticides/approval_active_substances/approval_renewal/neonicotinoids_en,
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0091686,
http://heinonline.org/HOL/Page?handle=hein.journals/sjel7&div=5&g_sent=1&casa_token=&collection=journals
Image: Lance Gheung, USDA - https://nifa.usda.gov/national-monitoring-plan-native-bees-stakeholder-and-public-listening-session
Advocacy group (NRDC) summary: https://www.nrdc.org/experts/jennifer-sass/neonicotinoid-pesticides-still-bad-bees-two-studies-nature-journal-add

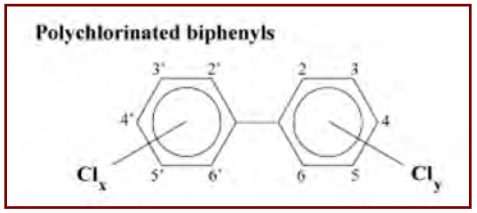
What if Fipronil & Available Neonicotinoids are **Withdrawn?**

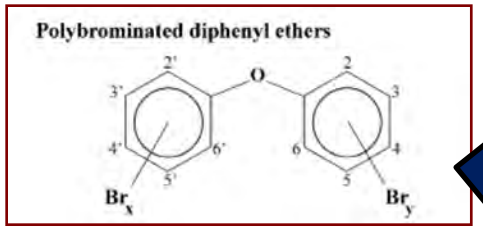
- Other (***currently available, potentially more toxic***) organophosphorus insecticides **may be used** instead.
- **Need more:**
  - ***Highly selective insecticides*** (to target pest insects, not insects that prey on them, & not birds, bats, or other spp.).
  - ***Integrated pest management*** **(IPM).**
  - ***Integrated biodiversity management*** **(to protect more species).**
    - Crop rotation & better selection of crop varieties.
    - Companion plantings to support life cycles of more predatory insects.
    - Insect traps, pheromones, & economic spray thresholds.
- **Scientists working, but an ongoing story & pressure + funding drive research, innovation, & protection….**

Data: https://www.epa.gov/pollinator-protection/schedule-review-neonicotinoid-pesticides, https://www.nature.com/articles/srep24764, https://pdfs.semanticscholar.org/1411/367f122c43218cca15d219025fac062b4367.pdf, http://onlinelibrary.wiley.com/doi/10.1002/ps.4489/full, http://www.sciencedirect.com/science/article/pii/S2214574515000917, https://www.ncbi.nlm.nih.gov/pubmed/25703042, https://ec.europa.eu/food/plant/pesticides/approval_active_substances/approval_renewal/neonicotinoids_en, http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0091686, http://onlinelibrary.wiley.com/doi/10.1002/ps.4715/full http://heinonline.org/HOL/Page?handle=hein.journals/sjel7&div=5&g_sent=1&casa_token=&collection=journals
Advocacy group (NRDC) summary: https://www.nrdc.org/experts/jennifer-sass/neonicotinoid-pesticides-still-bad-bees-two-studies-nature-journal-add

Halogenated Persistent Organic Pollutants (POPs)

PCBs & PBDEs

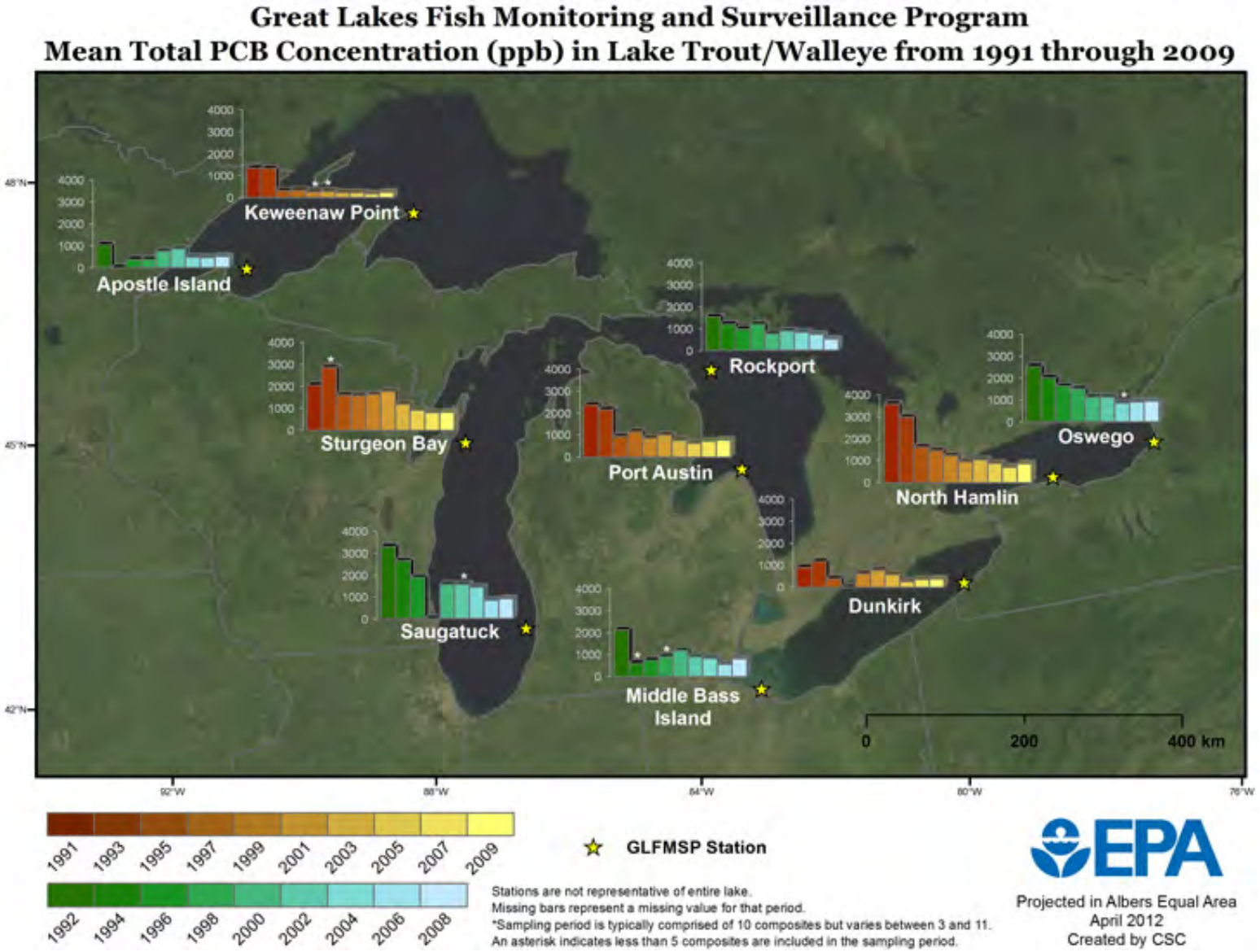




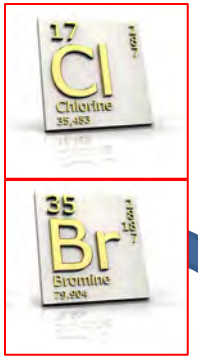
- **Humans, domestic animals, wildlife are exposed** from development of gametes & fertilized ova through death.
- **Biomagnification** → Food chain exposures important.
- **Thyroid** problems.
  - Weight loss.
- **Reproductive** problems.
- **Cancers**.
- **Developmental** disorders.
- **Learning** deficits.
- **Behavioral** problems.
- **Nephrotoxicity**.
- **Hepatotoxicity**.
- **Dermal** toxicity.

Similar structures. PBDEs may be somewhat less persistent than PCBs, but biomagnification is still a major concern.

PCBs: A Slow Success Story *in Progress*: Trends in Concentrations US Great Lakes Fish



PBDEs: A LESSON *RELEARNED*?



PERIODIC TABLE OF THE ELEMENTS

CENTRAL WASHINGTON UNIVERSITY

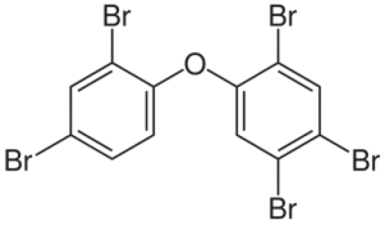
1A																	8A
1 H Hydrogen 1.00794	2A											3A	4A	5A	6A	7A	2 He Helium 4.00260
3 Li Lithium 6.941	4 Be Beryllium 9.01218											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.998403	10 Ne Neon 20.1797
11 Na Sodium 22.98977	12 Mg Magnesium 24.305	3B	4B	5B	6B	7B	8B			1B	2B	13 Al Aluminum 26.98154	14 Si Silicon 28.0855	15 P Phosphorus 30.97376	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Ar
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.9559	22 Ti Titanium 47.88	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.9380	26 Fe Iron 55.847	27 Co Cobalt 58.9332	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.9216	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.9059	40 Zr Zirconium 91.224	41 Nb Niobium 92.9064	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.9055	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.82	50 Sn Tin 118.710	51 Sb Antimony 121.757	52 Te Tellurium 127.60	53 I Iodine 126.9045	54 Xe Xenon 131.29
55 Cs Cesium 132.9054	56 Ba Barium 137.327	57 *La Lanthanum 138.9055	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.2	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.9665	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.9804	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium 226.0254	89 †Ac Actinium 227.0278	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (268)	110 (269)	111 (272)	112 (277)						

*Lanthanide Series	58 Ce Cerium 140.115	59 Pr Praseodymium 140.9077	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.965	64 Gd Gadolinium 157.25	65 Tb Terbium 158.9254	66 Dy Dysprosium 162.50	67 Ho Holmium 164.9303	68 Er Erbium 167.26	69 Tm Thulium 168.9342	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
† Actinide Series	90 Th Thorium 232.0381	91 Pa Protactinium 231.0359	92 U Uranium 238.0289	93 Np Neptunium 237.048	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (260)

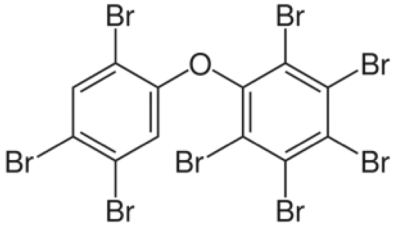
Image: Size of killer whale compared to a human.
Credit: Chris Huh, Creative Commons By-SA 3.0
http://marinesciencetoday.com/2013/11/22/oceans-toughest-predators-great-white-shark-vs-killer-whale/

What are PBDEs?

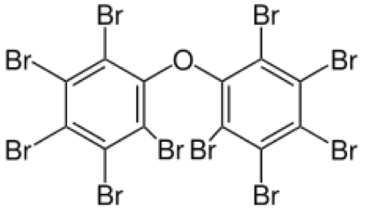
Polybrominated Diphenyl Ethers



A penta-BDE



An octa-BDE



Deca-BDE

Flame Retardants

209 Congeners

3 *Mixtures*: Penta, Octa, & Deca

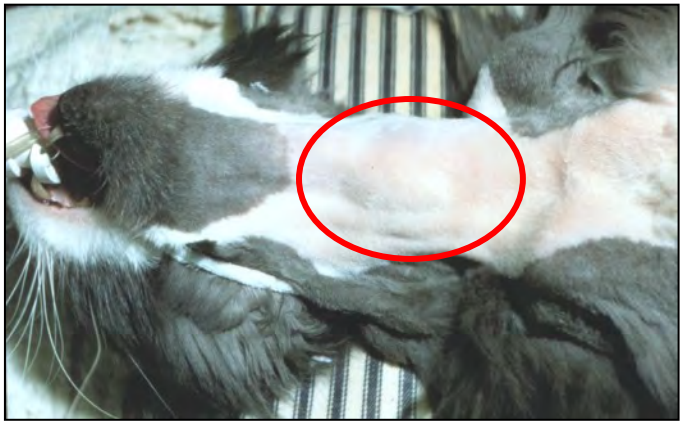
Made by:

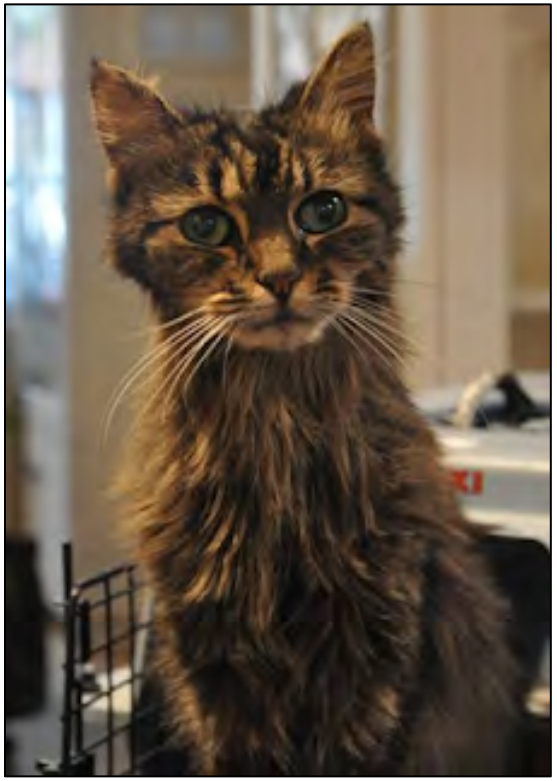
Dead Sea Bromine Group, Israel

Albemarle Corporation, VA

Great Lakes Chemical Corporation, West Lafayette, IN

Polybrominated Diphenyl Ethers (**PBDEs**): **Thyroid Adenomas** → Clinical **Hyperthyroidism** in **Cats**



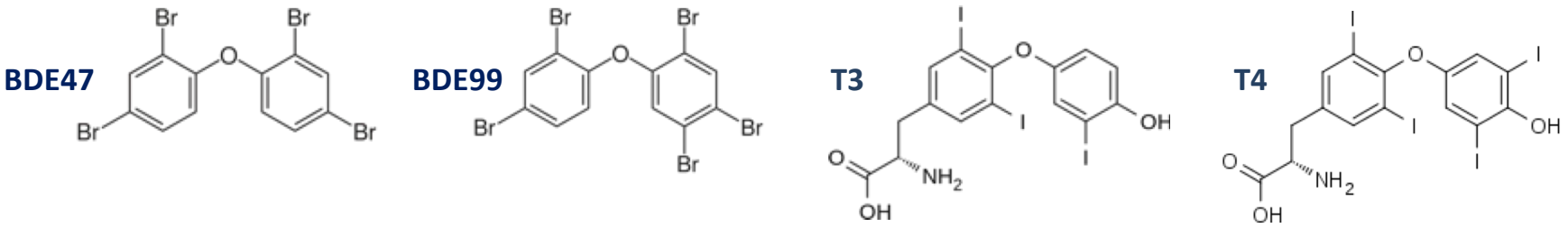


Hyperthyroidism in cats *<u>became</u>* an **important** cause of **morbidity & mortality.**

Images of hyperthyroid cats: Dr. Mark E. Peterson, Veterinary Endocrinologist

Are Cats Sentinels for Human Exposures & Effects of PBDE?

Are PBDEs a Cause of Feline Hyperthyroidism?



Structures of two common PBDE congeners compared to thyroid hormones (T3 & T4)

- **Many** house cats live **indoors ~100%** of the time, & **sleep** (a lot) on **warm objects, like padded furniture & electronic equipment.**
- PBDEs **first commercially produced** in **1970s.**
- **First case report** of feline hyperthyroidism published in **1979.**

- **Dye et al (2007)** examined **11 hyperthyroid** & **12 normal cats.**
  - **PBDE concentrations in cats were 20- to 100-fold those of U.S. adults.**
  - Cat food **(dry & canned) & house dust** (esp. BDE47 & 99, likely from penta mixture) contributed to **body burdens.**
  - **Cats *may be* sentinels of chronic human exposures & (perhaps) *adverse health effects from PBDEs.***

Image: Washington State University, hyperthyroid cat - posted at http://www.cat-health-guide.org/hyperthyroidismcat.html

Cats in Homes with High PBDEs in Dust More Likely to Develop Hyperthyroidism Mensching et al (2012)

- **Tested blood** from **62 owned cats** (with & without hyperthyroidism) & **10 feral cats.**
- **Obtained house dust** (from vacuum bags).
- **Feral cats** had **very low PBDE concentrations & T4s:**
  - **Their T4 values were ~1/2** of those of **indoor euthyroid cats & ~1/4** of those of **indoor hyperthyroid cats.**
- Total **PBDEs** in **canned cat food = 0.42-3.1 ppb**, but **dust** from **homes** of **hyperthyroid cats** had **1,100-95,000 ppb.**

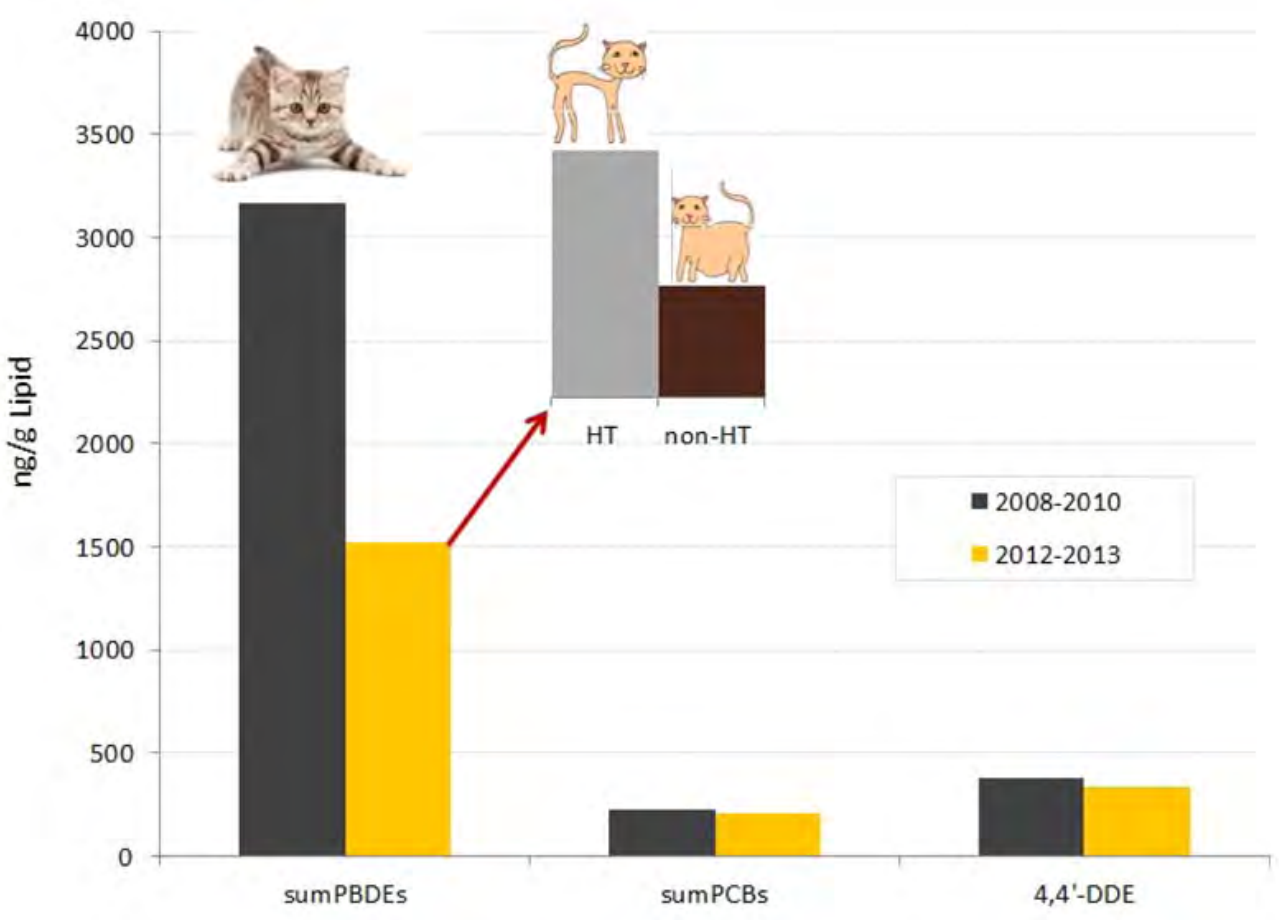
- One of the hyperthryoid **cats** had total **PBDEs at 51,000 ppb** in serum lipid (**highest found in any species?**).
- **PBDEs in dust** were **correlated** with abnormally **high T4 levels**.
- **Cats *may be*** sensitive **sentinels** for **PBDE exposures & risks** of **toxic nodular goiter in humans.**

Data: https://www.tandfonline.com/doi/abs/10.1080/15287394.2012.652054

Hyperthyroid Cats Have Higher PBDE Burdens Guo et al (2012; 2016)

- **11 hyperthyroid & 11 normal cats.**
- PBDE concentrations in **cats** were about **60-times higher than** in **humans.**
- Concentrations of **PBDEs in cats >> PCBs & DDE**.
- In addition to **PBDEs from living indoors, thyroid-disrupting compounds in water** & **BPA in cat food may be involved.**
- **Fortunately PBDE concentrations have declined in some homes (small N).**

Contaminants in Serum Lipid 2008-2010 vs. 2012-2013



Concentrations of PBDEs declined unlike PCBs & DDE.

Figure is from the article by Guo et al (2016)
Data: http://pubs.acs.org/doi/abs/10.1021/acs.est.5b04252

Hyperthyroid Cats Have Higher PBDE Burdens

- **Norrgran et al (2015): PBDE** concentrations in **cats** were **correlated** with **hyperthyroidism.**
- **Walter et al (2017): Hyperthyroid cats had higher concentrations of 4 PBDE congeners** than normal cats.
  - Total **PBDE** concentrations **in cats** were **50x higher than** in **humans** of a similar area, whereas PCB concentrations in cats & people were similar.

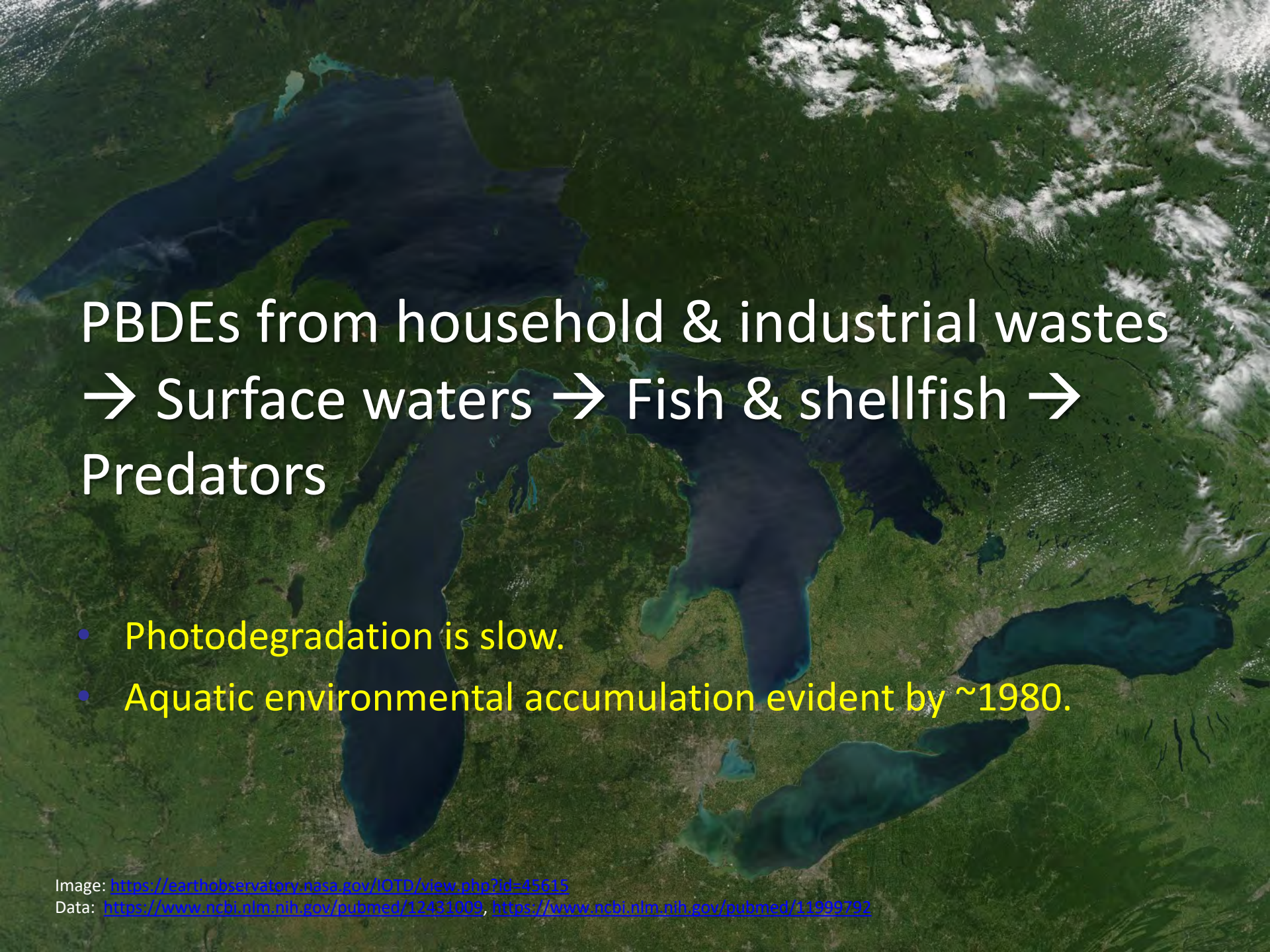
OVERALL:

- **Housecats = Sentinels for human exposure to PBDEs & possible thyroid disruption.**
- ***Challenge of funding 15-year-long studies in cats.***

Data: Norrgran et al. Environmental Science & Technology, 2015. http://pubs.acs.org/doi/abs/10.1021/acs.est.5b00234
Walter, Lin, Kass, Puschner. 2017. BMC Veterinary Research. https://www.ncbi.nlm.nih.gov/pubmed/28468659

PBDEs in Outdoor Environments

Image: Orca & Pilot whale – NOAA Photo Library, Peregrine falcon – Barb Baldinger, MDNR volunteer in http://www.mlive.com/news/flint/index.ssf/2013/05/endangered_falcons_making_a_ho.html
Data: http://www.noaanews.noaa.gov/stories2009/20090401_ecosystems.html, https://ehp.niehs.nih.gov/wp-content/uploads/2017/07/EHP2098.alt_.pdf, https://www.ncbi.nlm.nih.gov/pubmed/19680967 & http://deohs.washington.edu/srp/sites/deohs.washington.edu.srp/files/images/D_Rice_Agency_Seminar_SBRP_3-08.pdf

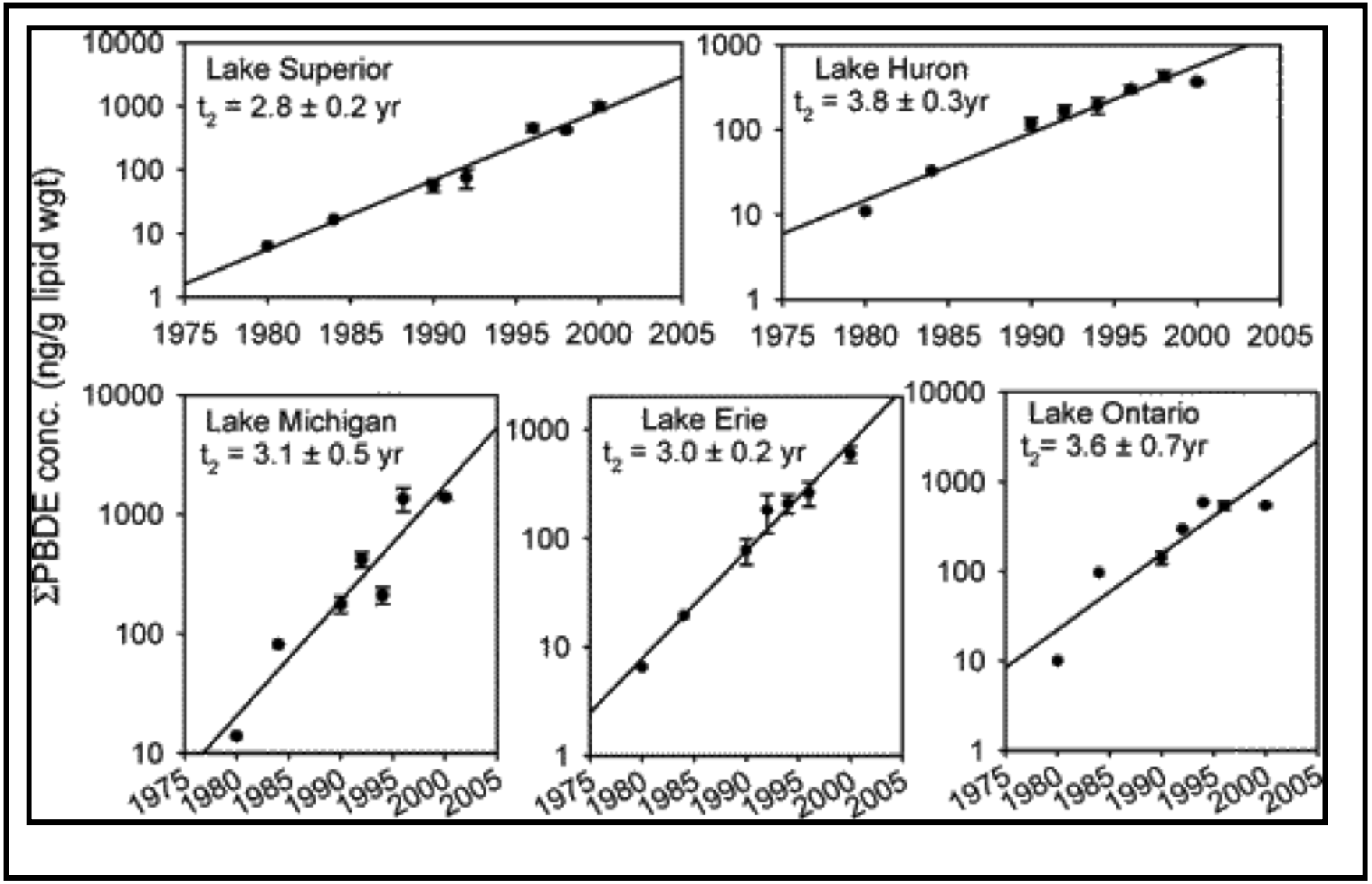


PBDEs from household & industrial wastes → Surface waters → Fish & shellfish → Predators

- Photodegradation is slow.
- Aquatic environmental accumulation evident by ~1980.

Image: https://earthobservatory.nasa.gov/IOTD/view.php?id=45615
Data: https://www.ncbi.nlm.nih.gov/pubmed/12431009, https://www.ncbi.nlm.nih.gov/pubmed/11999792

PBDE Trends in Great Lakes Trout & Walleye (1980-2000)



From Zhu and Hites, *Environ. Sci. Technol.,* 38 (10): 2779-84, 2004.

Species - PBDE Body Burdens

Chinook salmon (BC) 2.3 ppb w/w
Buffalo River (NY) carp 13-23 ppb w/w
Lake Superior smelt 150 ppb lipid
Lake Michigan salmonids 80 ppb w/w
Lake Huron trout 237 ppb lipid
Lake Ontario smelt 240 ppb lipid
Lake Ontario trout 545 ppb lipid
Polar bear 7.6- ~70 ppb lipid
Sperm whales (Dutch coast) ~100 ppb w/w
White-beaked dolphin (Dutch coast) >700 ppb w/w
Harbor seals (Dutch coast) >100 ppb w/w
Beluga whales (Quebec) 20- ~1000 ppb w/w
Pilot whales (Faroe Islands) 843-3160 ppb lipid
Orca/killer whale (Pacific NW) 8,560 ppb w/w
Peregrine falcon eggs (Sweden) 39,000 ppb lipid

Are PBDE-induced Thyroid & Neurologic Diseases a Wildlife Concern?

- Increased susceptibility to hypothermia, infections, failed reproduction?
- Impaired brain development & capacity to learn?
- Increased risk of predation?
- Decreased energy & concentration for the hunt?

Images: NOAA

PBDEs On the Legal Front

Companies & governments moving away from PBDEs
Stockholm Convention → Manufacture has fallen off.
Products still in homes & being discarded.

1970s: First manufactured.

1989: Voluntary cessation, Germany.

1998: Penta banned, Sweden.

2004: Penta & Octa banned, EU.

2004: Voluntary cessation of Penta & Octa by Great Lakes Chemical Corp., US.

2006: California phase out of Penta & Octa.

2008: California phase out all but Deca.

2008: All PBDEs phased out in EU.

2013: No manufacture or import of Deca into US.

Data: https://www.atsdr.cdc.gov/phs/phs.asp?id=1449&tid=183

PBDEs in Products: What can we do now?

- **Fix damaged upholstery.**
- Place **mattresses in covers** designed to **minimize exposures** to allergens.
- **Vacuum** often & thoroughly, preferably with a high-efficiency particulate air (HEPA) filter.
- Purchase **new furniture, fabrics**, etc. that have **no halogenated flame retardants.**
- Note:
  - **Disposing** of PBDE-containing materials → **Environmental contamination** + **Risks to workers in recycling facilities + Hand-off** of contaminants **to unsuspecting consumers (recycled carpet padding).**
    - Workers in recycling facilities need **Personal Protective Equipment (PPE).**
  - **Burning** PBDEs at low temperatures can produce **dioxins & dibenzofurans** (higher toxicity).
  - **Innovations** are **needed** to develop **safe disposal** methods!
  - The **US & Canadian governments** are just **getting underway in controlling emissions into the Great Lakes!**

Data: https://www.pharosproject.net/uploads/files/sources/1/e5ca3f715bb8c16764482235439a226273c140c0.pdf, http://ijc.org/files/publications/Polybrominated_Diphenyl_Ethers_Great_Lakes_EN.PDF & https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/polybrominated-diphenyl-ethers-pbdes

Take Home Messages

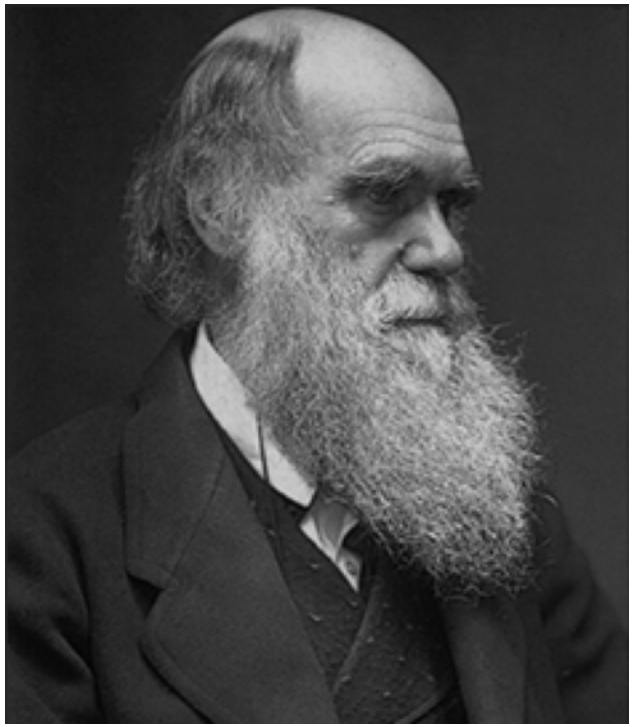
- **One Toxicology** is central to **One Health.**
- **Mercury** is an **important pollutant today.**
- **DDT devastated birds**, but **current insecticides can poison them & their foodwebs.**
- **Halogenated flame retardants will harm animals for decades to come.**
- ***More diagnoses, more careful usage & disposal, & more green chemistry are essential.***

Is This Fun or What?

Image: Beasley Lab Group

Image: Beasley Lab Group

Comparative Environmental Bioscience…



"The existence of groups would have been of simpler significance, if one group had been exclusively fitted to inhabit the land and another the water; one to feed on flesh, another on vegetable matter, and so on; but the case is widely different, for it is notorious how commonly members of even the same sub-group have different habits."

Charles Darwin
Origin of Species