Marine plastic pollution : chemical threat to marine ecosystem

Shige Takada

(Tokyo University of Agriculture and Technology)

Topics

Anthropocene : Plastic age

Plastic pollution in organisms, Water, Sediment core

Hazardous chemicals in marine plastics

International Pellet Watch

Transfer and accumulation of hazardous chemicals from ingested plastics to biological tissue

Hazardous chemicals in microplstics

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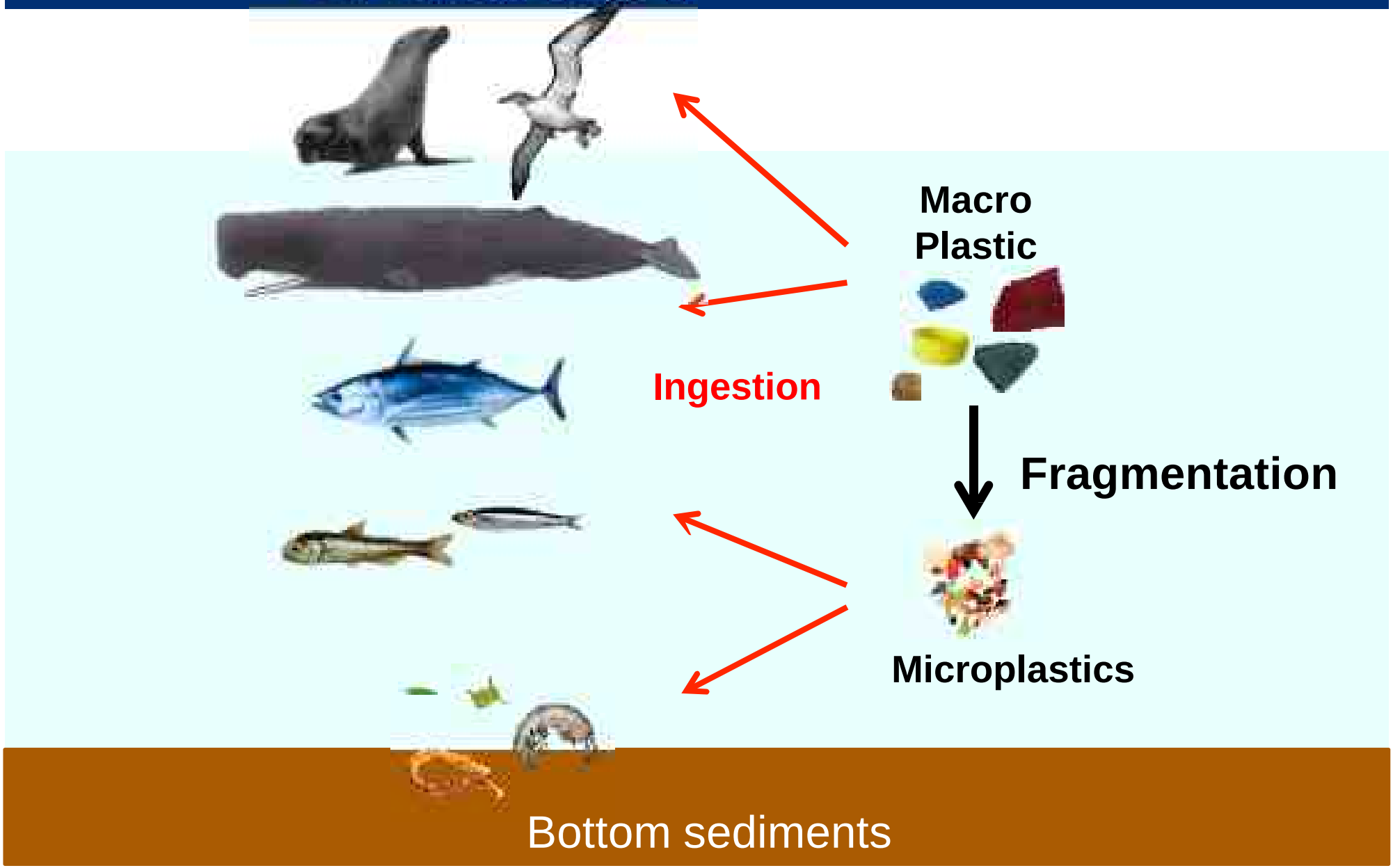
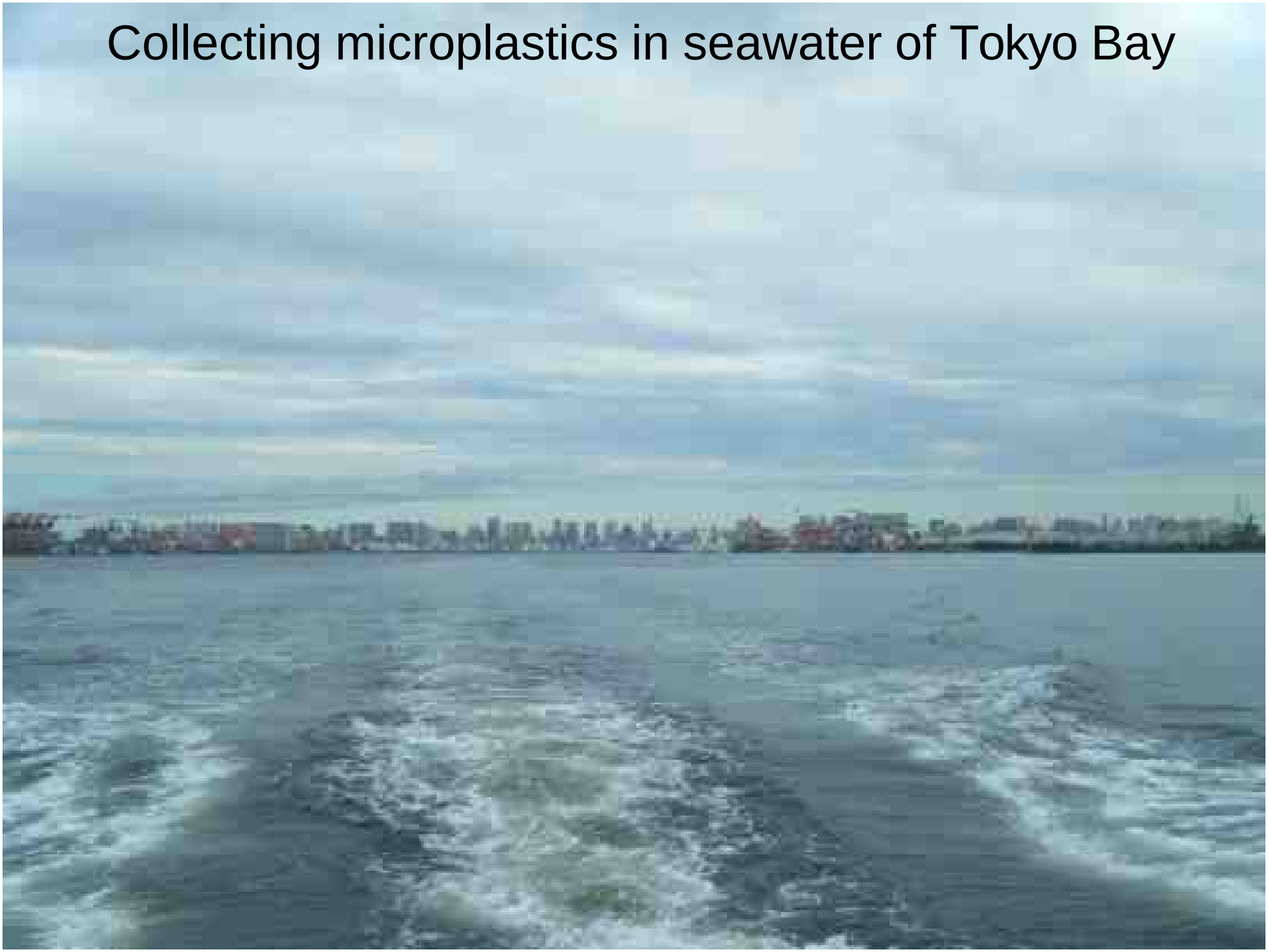
Plastics are fragmented into smaller particles (i.e. microplastics) and various sizes of marine plastics are ingested by various sizes of marine organisms



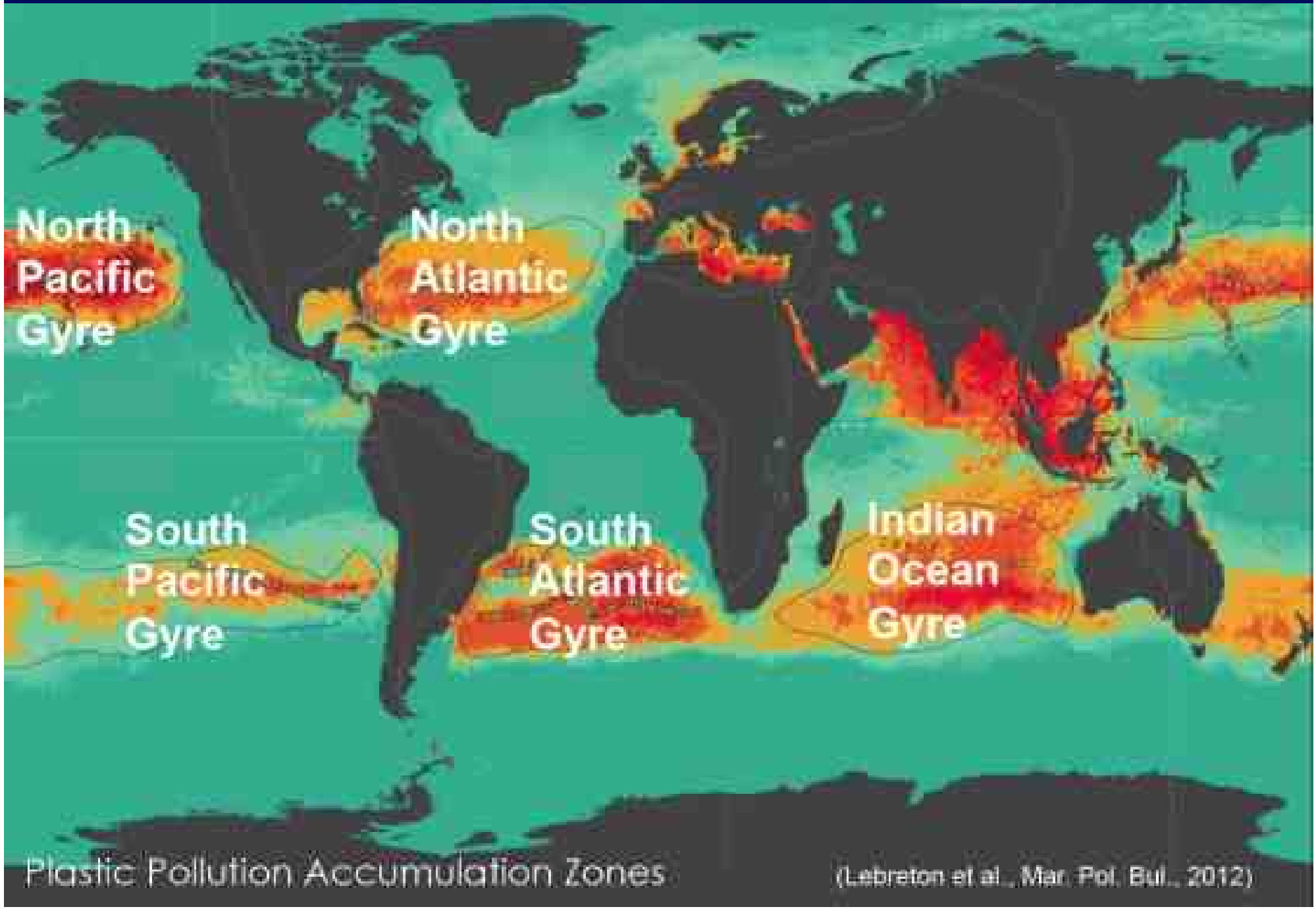
Collecting microplastics in seawater of Tokyo Bay



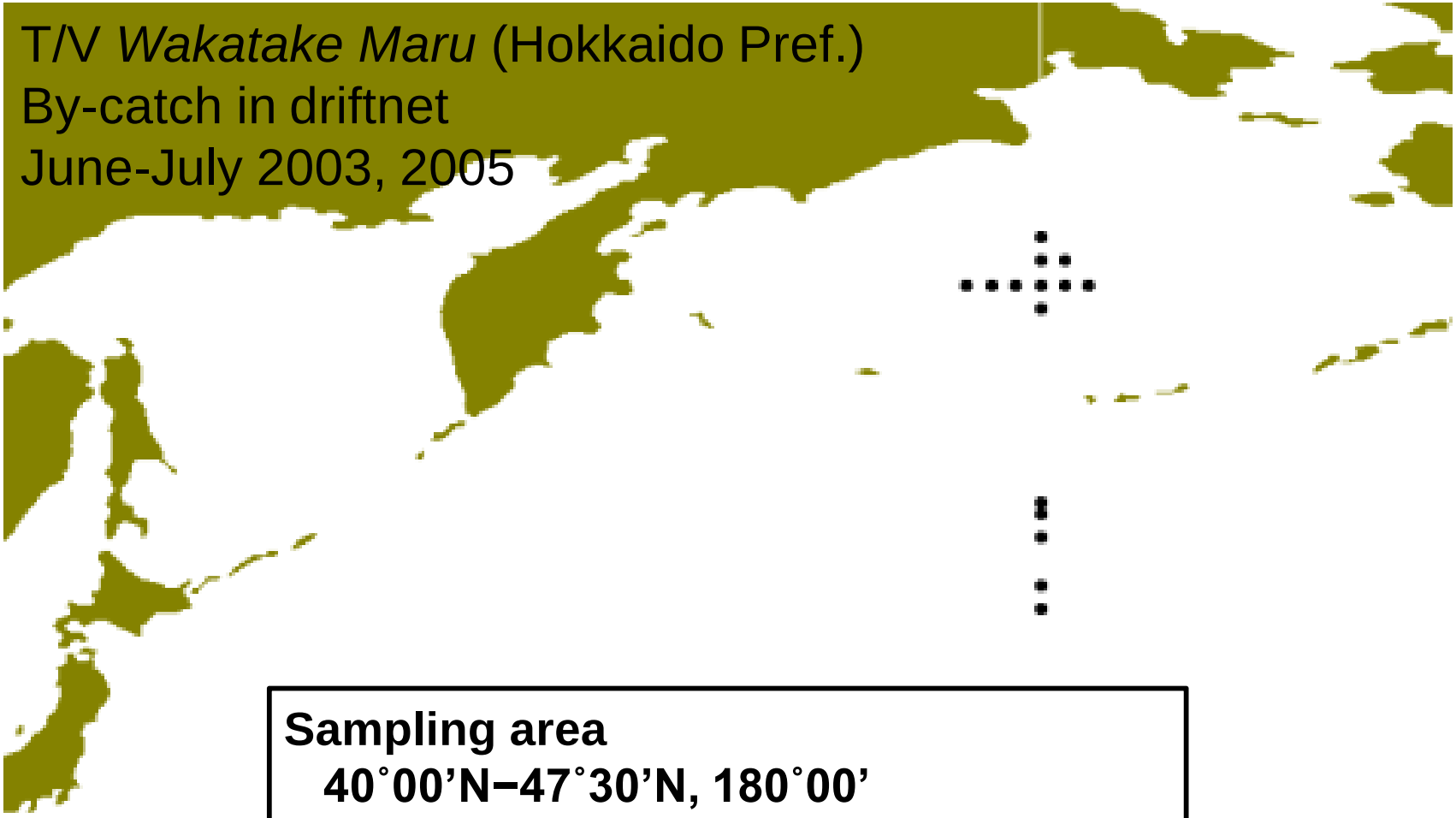
Collecting microplastics in seawater of Tokyo Bay

Microplastics in seawater of Tokyo Bay

0.27 millions ton of plastics floating on world ocean

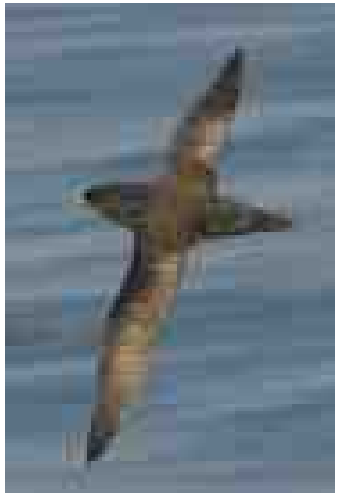


Short-tailed shearwater from Northern pacific

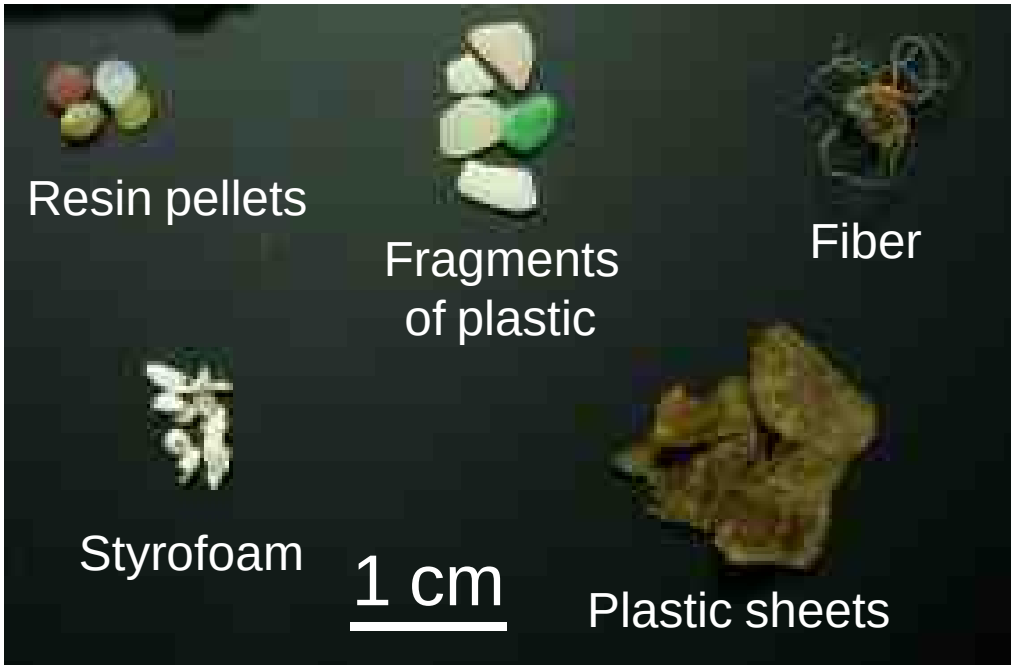


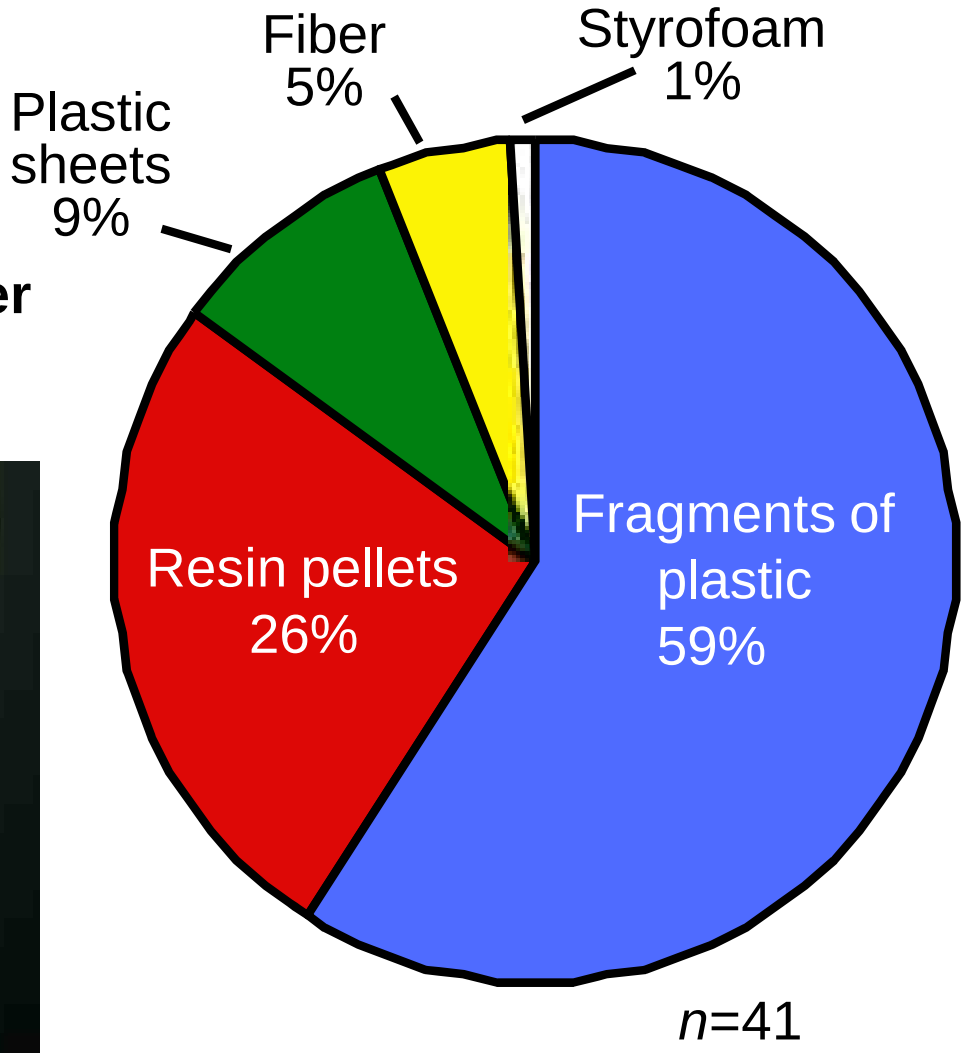
Sampling area
40˚00'N–47˚30'N, 180˚00'
55˚30'N–58˚30'N, 178˚00' E–178˚00'W

Plastics found in digestive tracts of the seabirds



Short-tailed shearwater
Puffinus tenuirostris





Type and composition of plastics found in the stomachs of short-tailed shearwater.

Yamashita et al. 2011

Short-tailed shearwater from Northern pacific

Plastics detected in digestive tract of short-tailed shearwater

Plastics detected in digestive tract of short-tailed shearwater

0.1 g – 0.6 g per an individual

Marine organisms ingest plastics

More than 180 species of animals are known to have ingested plastic debris, including birds, fish, turtles and marine mammals.

Physical impacts of the ingested plastics have been reported for many species of organisms (Wright et al., 2013).

Plastics in Seabird

Plastics in Sea Turtle

Microplastics in lower-trophic-level organisms

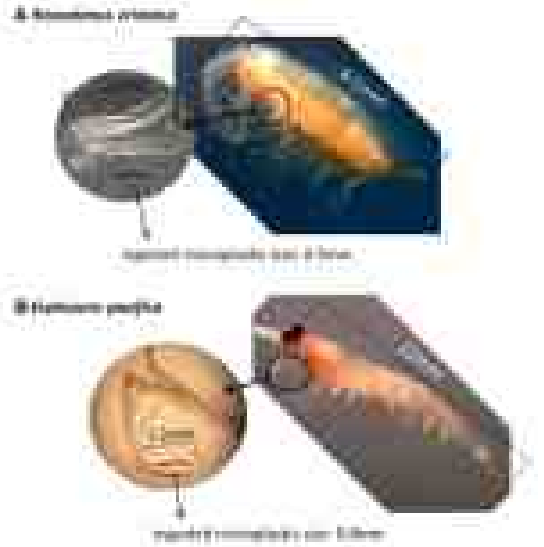
Microplastics in bivalves cultured for human consumption

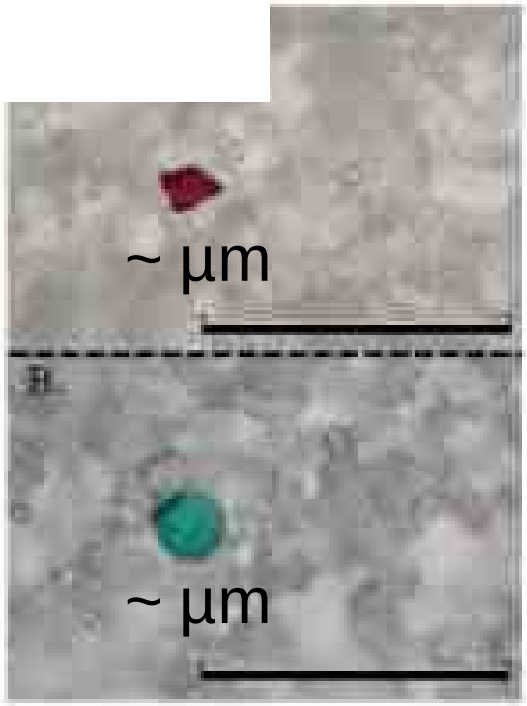
Lisbeth Van Cauwenberghe*, Colin R. Janssen

Ghent University, Laboratory of Environmental Toxicology and Aquatic Ecology, Jozef Plateaustraat 22, 9000 Ghent, Belgium

Ingestion of Microplastics by Zooplankton in the Northeast Pacific Ocean

Jean-Pierre W. Desforges[1] · Moira Galbraith[2] · Peter S. Ross[1]





OPEN

Anthropogenic debris in seafood: Plastic debris and fibers from textiles in fish and bivalves sold for human consumptio

received: 20 April 2015
accepted: 29 August 2015
published: 29 September 2015

Chelsea M. Rochman[1], Akbar Tahir[2*], Susan L. Wilia
Jeffrey T. Miller[3], Foo-Ching Tehi[3], Shinta Werorilan

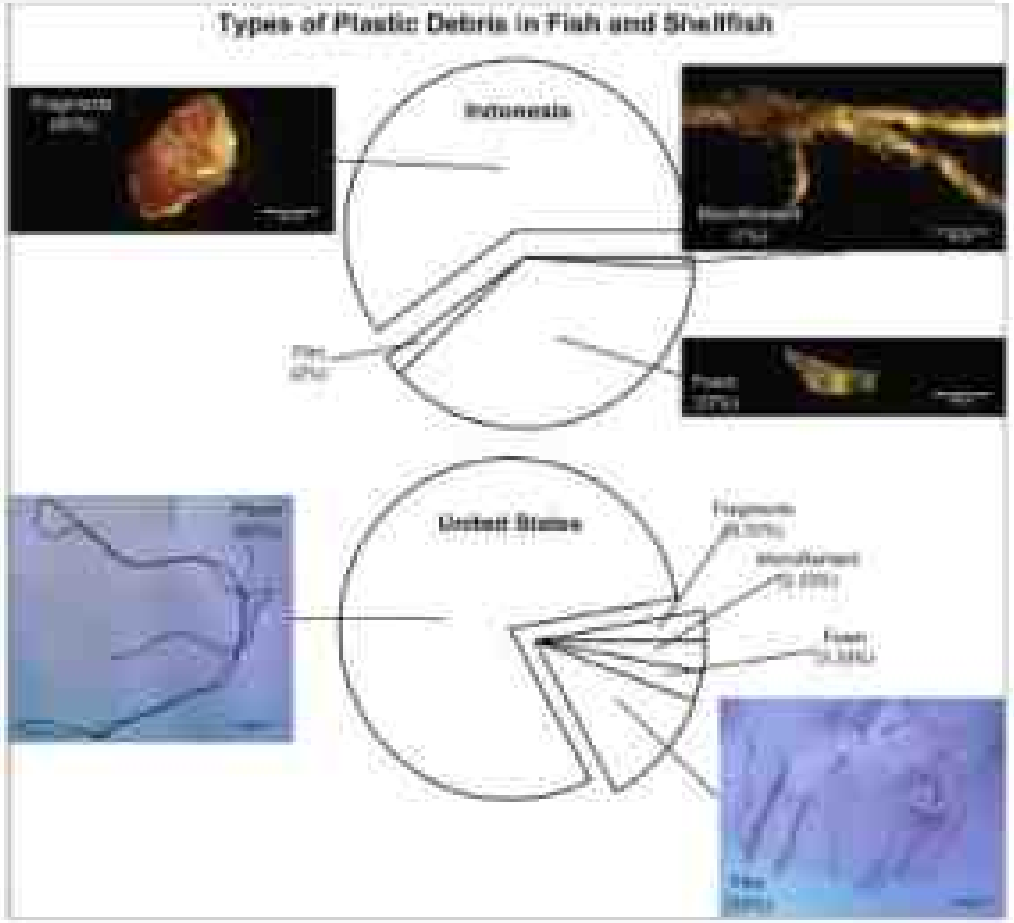
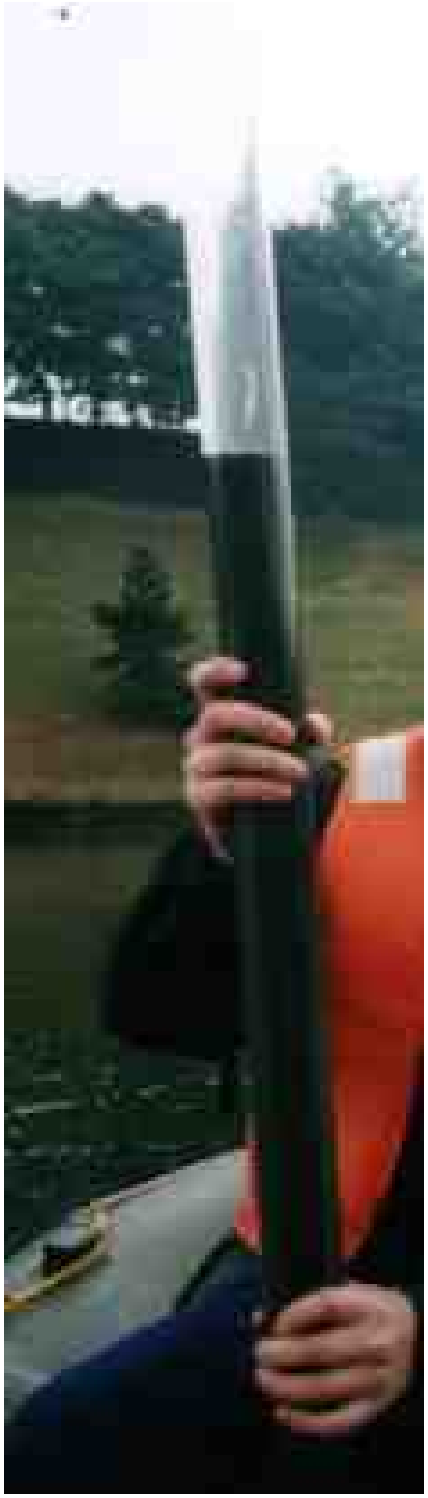


Figure 3. Types of anthropogenic debris in market fish products sampled from Indonesia and the United States. The pie charts above show the percentage of each type (i.e. plastic fragments, fibers, plastic film, plastic foam and plastic monofilament) of anthropogenic debris found across all fish sampled from Indonesia (top) and the United States (bottom). Images show examples of each type of debris found. Scale

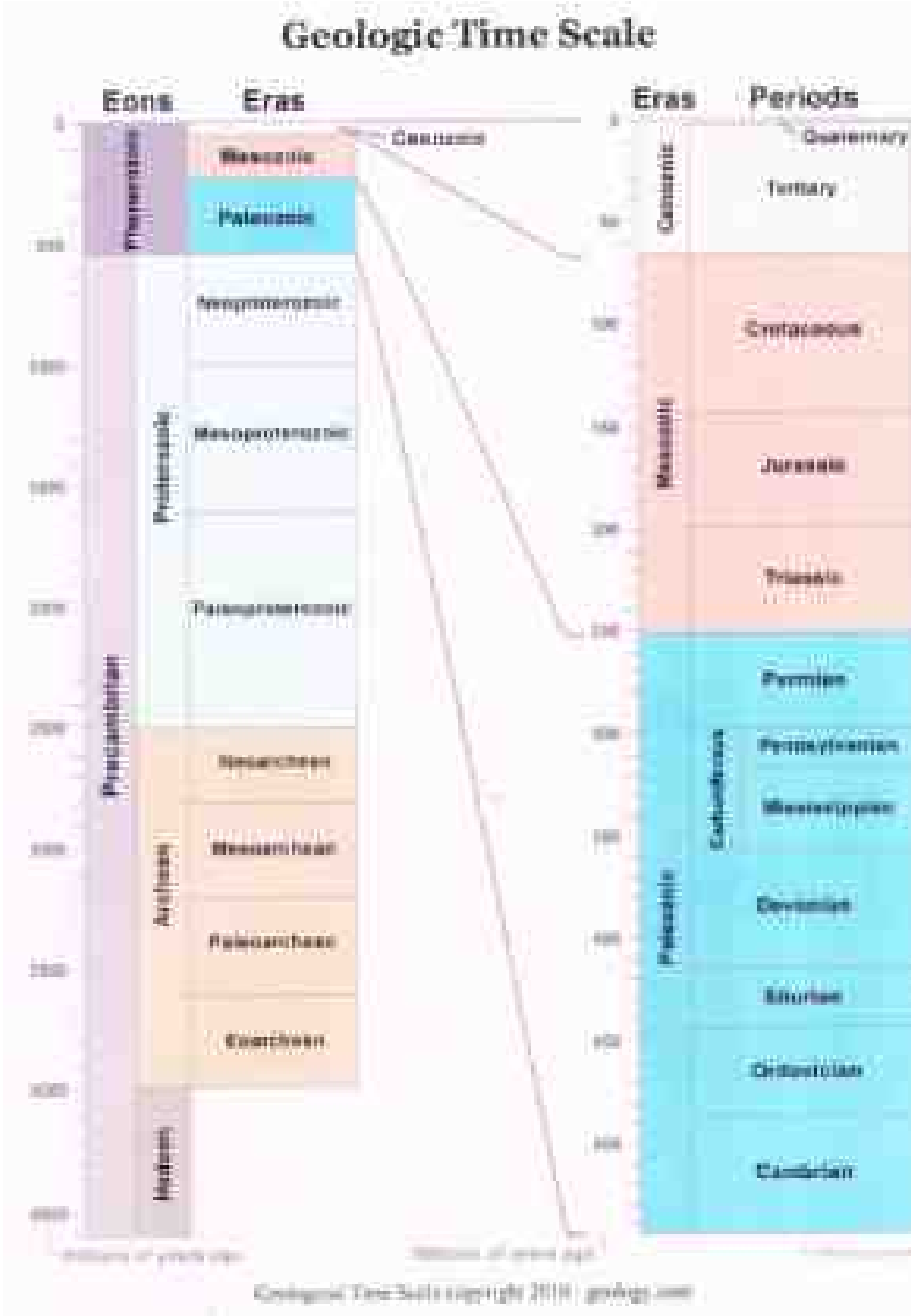
SCIENTIFIC REPORTS

Microplastics were detected in 49 of 64 anchovies



Microplastics in sediment core from Sakurada moat showed increasing trend from 1950s to 2000s, though no plastics were detected in 1600s.

Sedimentary microplastics showed increasing trend in Asia and African coasts.

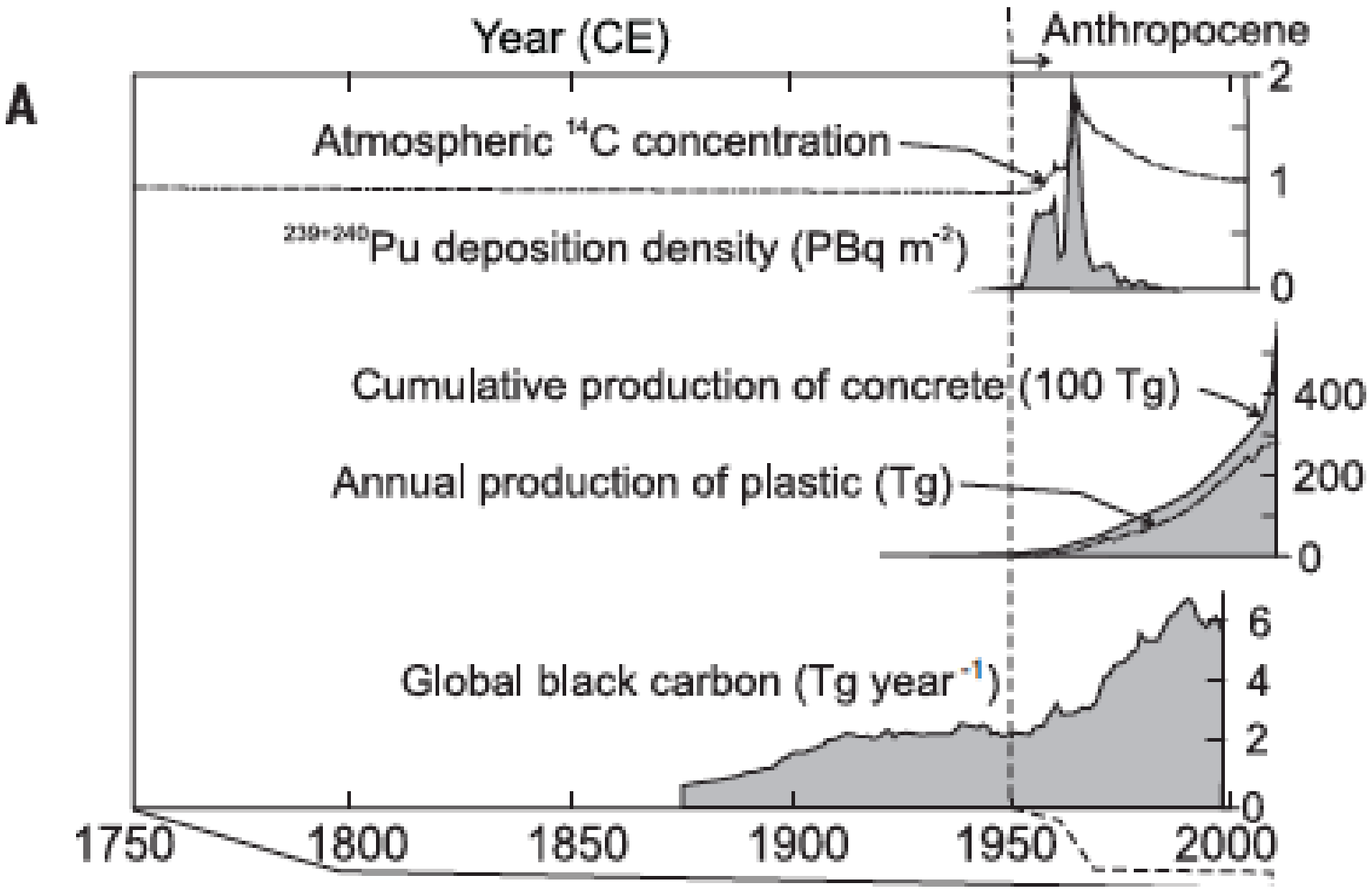


Anthropocene

EARTH HISTORY

The Anthropocene is functionally and stratigraphically distinct from the Holocene

Colin N. Waters,[1*] Jan Zalasiewicz,[2] Colin Summerhayes,[3] Anthony D. Barnosky,[4] Clément Poirier,[5] Agnieszka Gałuszka,[6] Alejandro Cearreta,[7] Matt Edgeworth,[8] Erle C. Ellis,[9] Michael Ellis,[1] Catherine Jeandel,[10] Reinhold Leinfelder,[11] J. R. McNeill,[12] Daniel deB. Richter,[13] Will Steffen,[14] James Syvitski,[15] Davor Vidas,[16] Michael Wagreich,[17] Mark Williams,[2] An Zhisheng,[18] Jacques Grinevald,[19] Eric Odada,[20] Naomi Oreskes,[21] Alexander P. Wolfe[22]


A
Year (CE)
Anthropocene
Atmospheric ^{14}C concentration
$^{239+240}Pu$ deposition density (PBq m^{-2})
2
1
0
Cumulative production of concrete (100 Tg)
Annual production of plastic (Tg)
400
200
0
Global black carbon (Tg $year^{-1}$)
6
4
2
0
1750
1800
1850
1900
1950
2000

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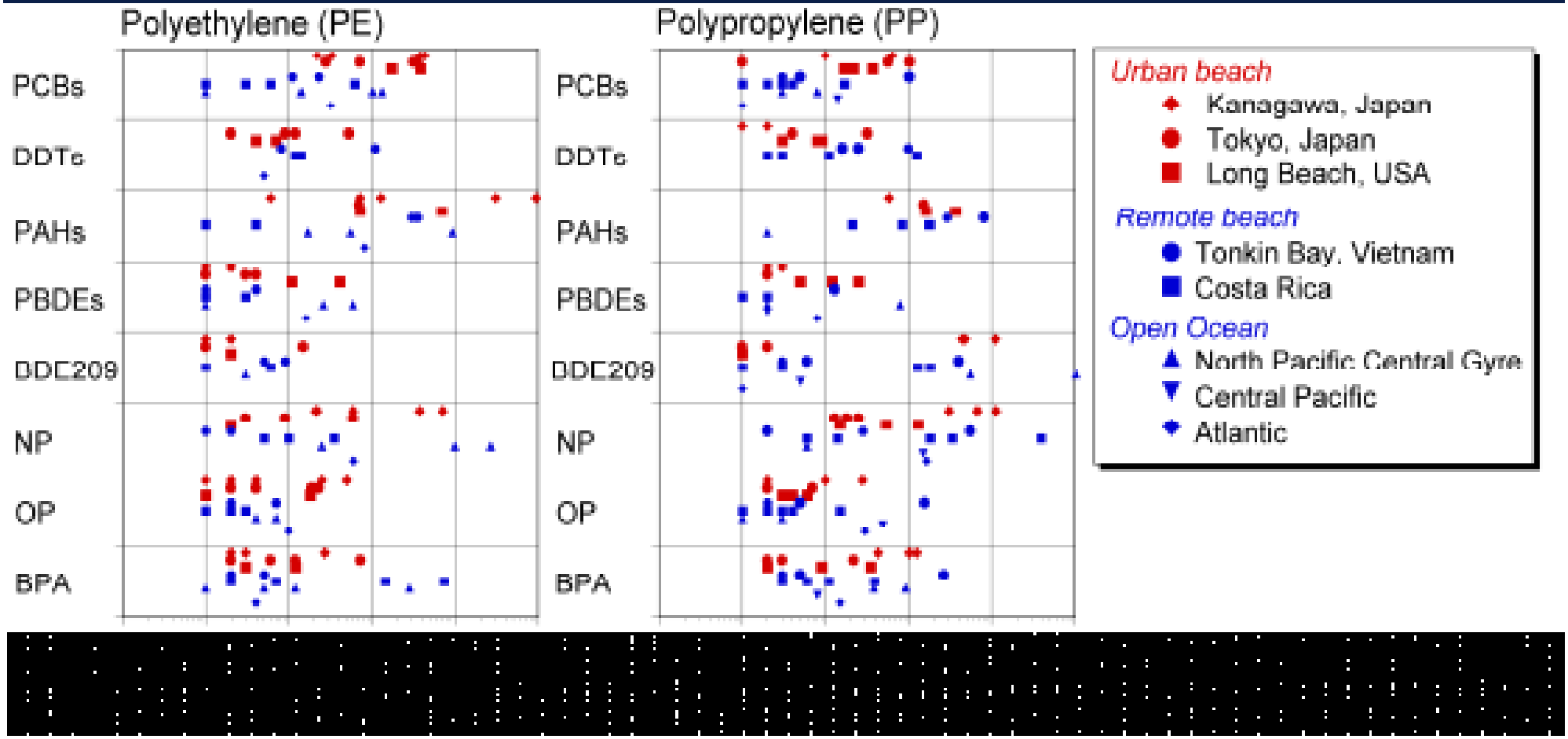
Hazardous chemicals in microplstics

Sampling locations of plastic fragments

Urban beach
Rural beach
Open ocean

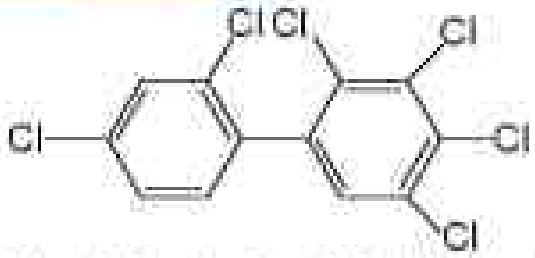
Detection of various hazardous chemicals in marine plastic fragments



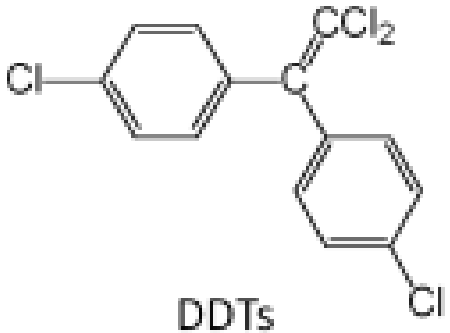
- chemicals ranging from 1 to 10,000 ng/g
- Large variability among the fragments

Plastics carry two types of chemicals in marine environment

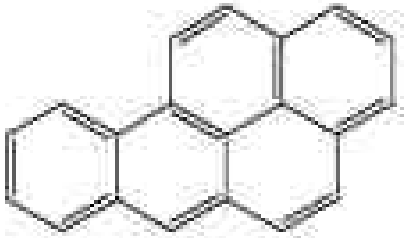
Sorption from ambient seawater



Polychlorinated biphenyl (PCBs)

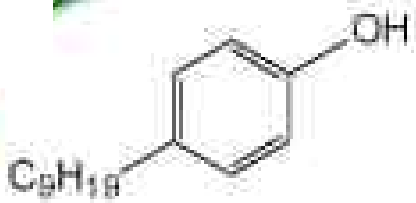


DDTs

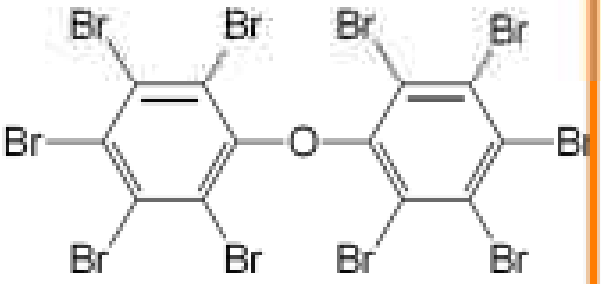


Polycyclic aromatic hydrocarbons (PAHs)

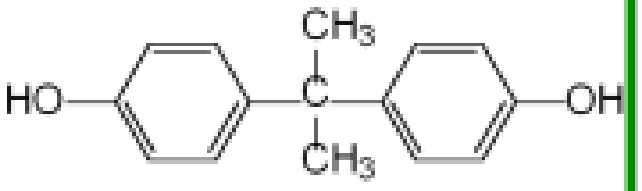
Additive-derived chemicals



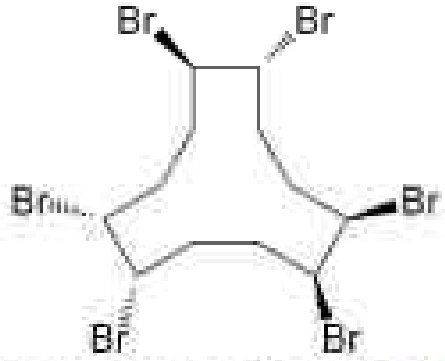
Nonylphenol



Polybrominated diphenyl ethers (PBDEs)

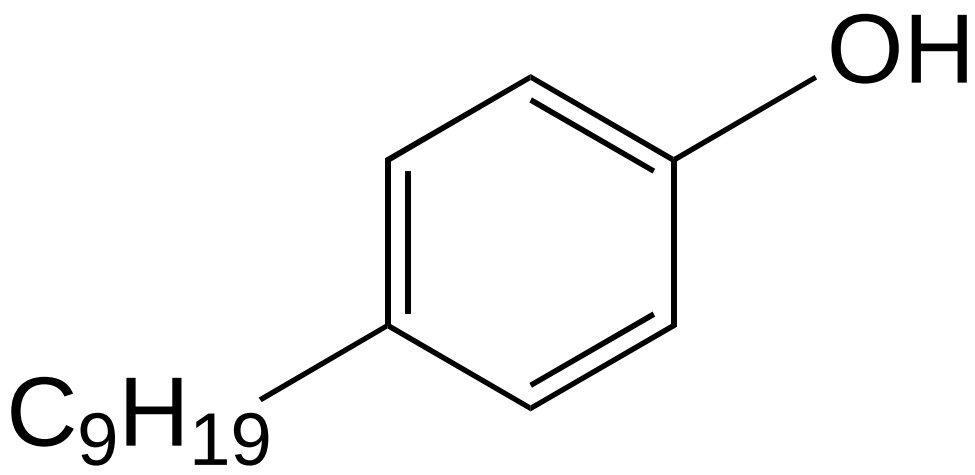


Bisphenol A



Hexabromocyclododecanes (HBCDs)

Nonylphenol : Endocrine disrupting chemicals

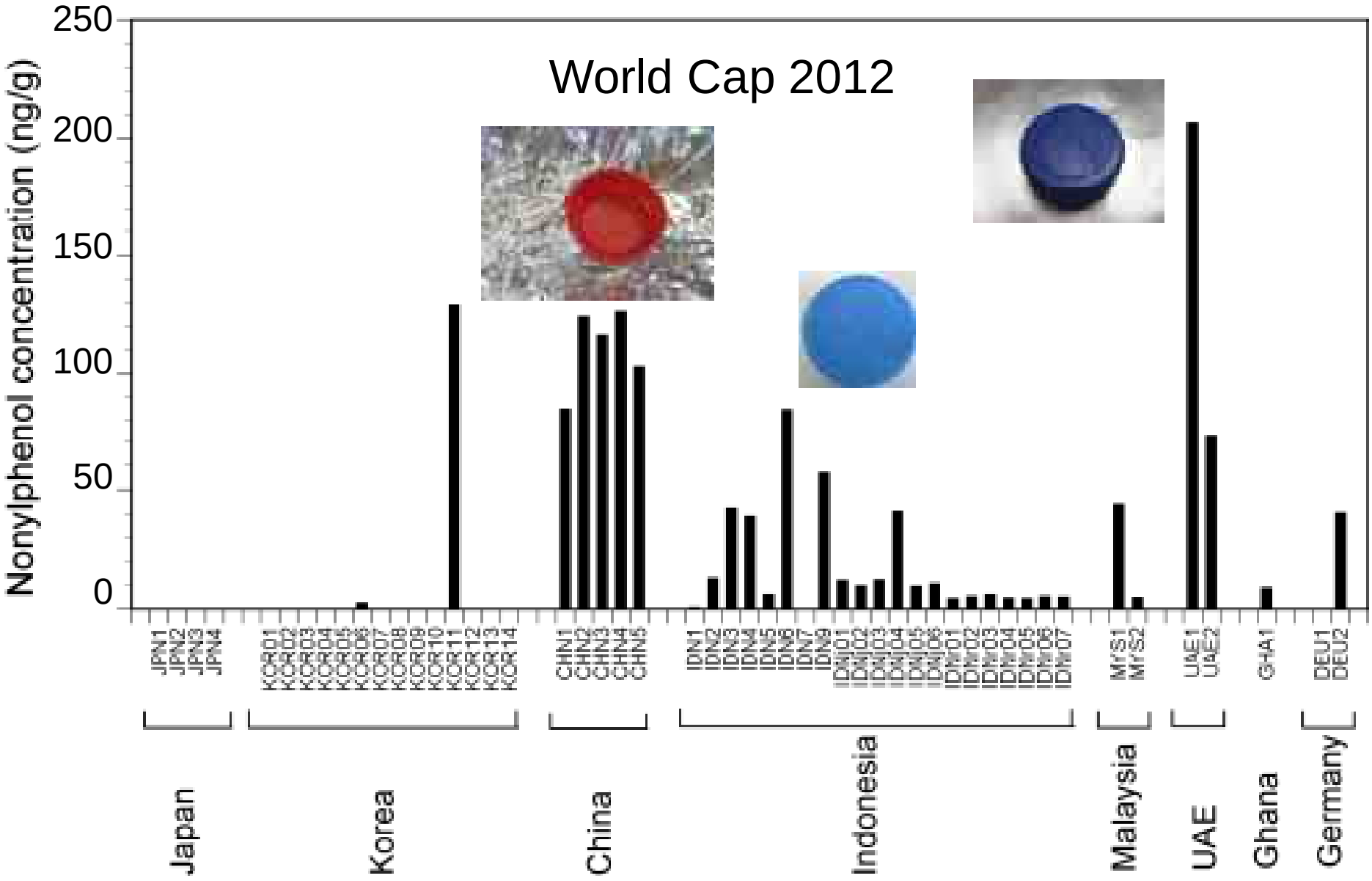


Additives to plastic

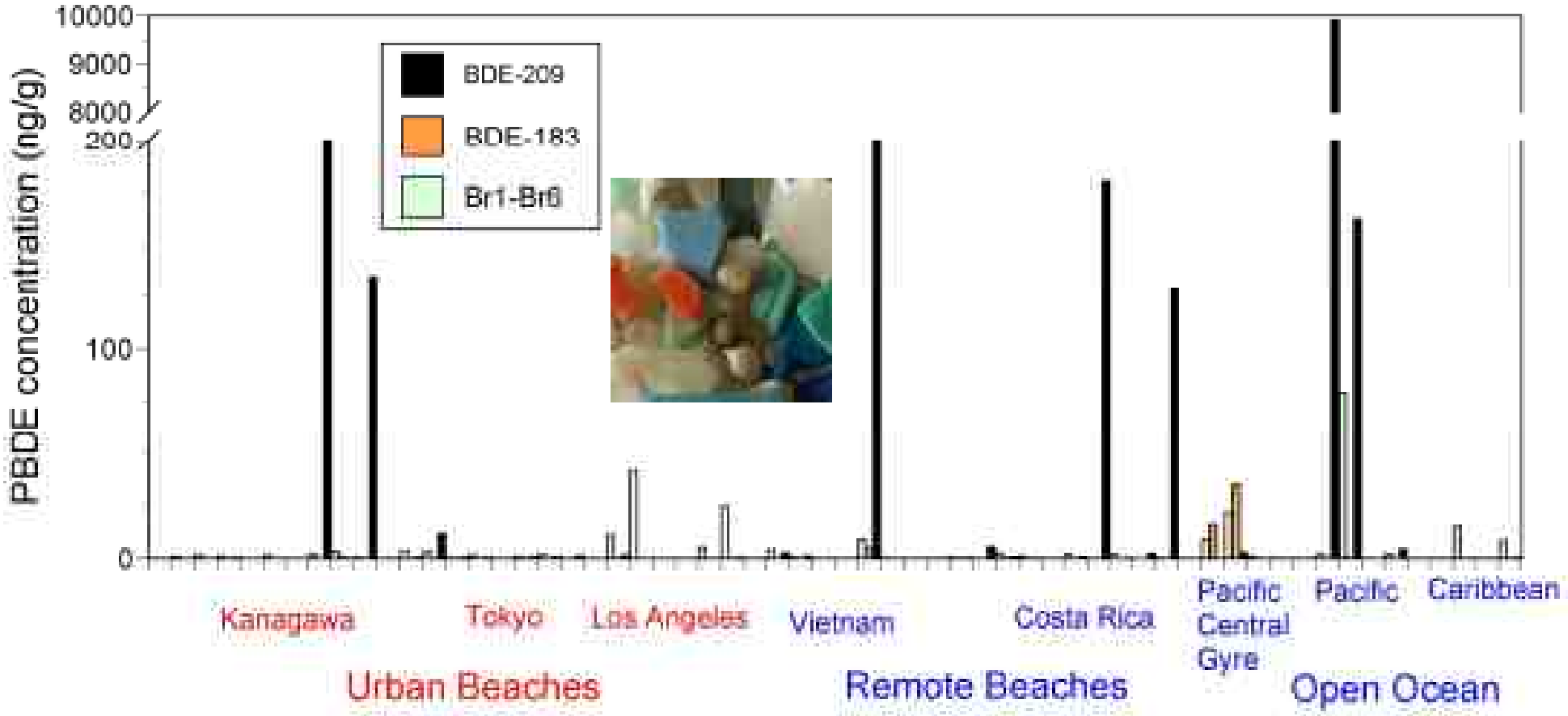
Antioxidants
Antistatic agents

- disorders in the reproductive system
- vaginal clear cell adenocarcinoma
- decreased ability to reproduce

Endocrine disrupting chemicals released from plastic caps of mineral water bottles



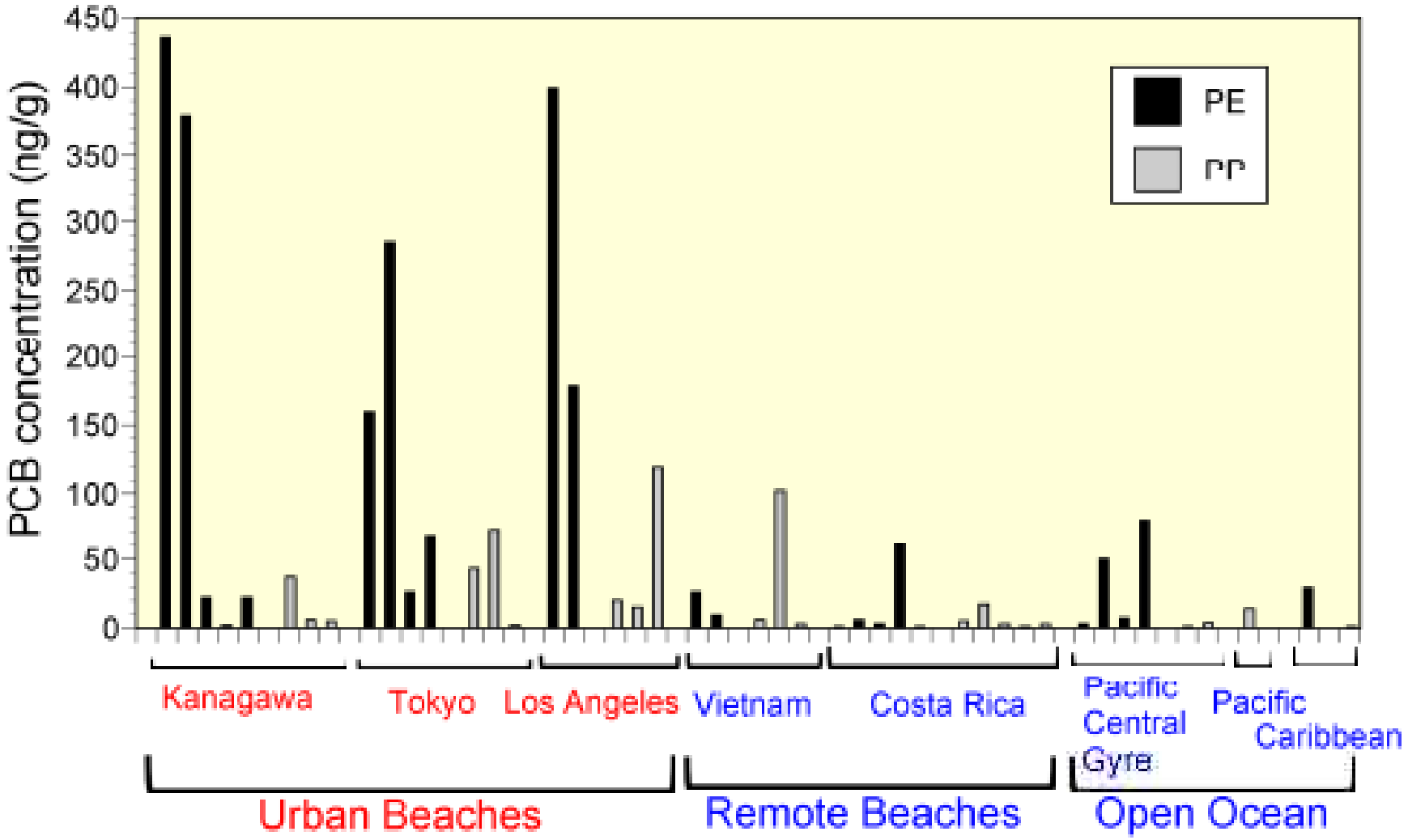
Distributions of PBDE congeners in marine plastic fragments



- BDE209 and BDE183 were sporadically detected in marine plastics even from open ocean

Hirai et al., 2011

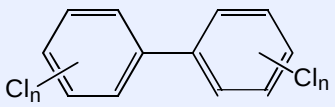
Distribution of PCBs in plastic fragments



Sporadic high concentrations of PCBs were detected even in remote beaches and open ocean

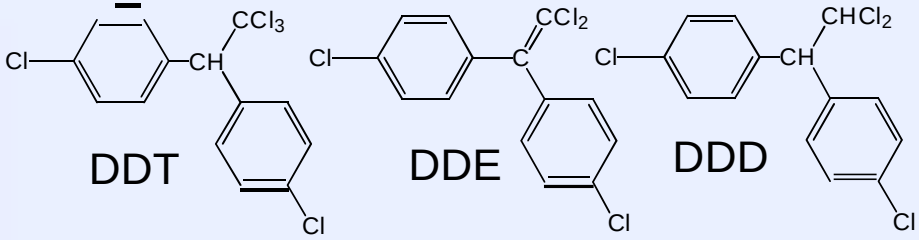
Pellets accumulate POPs from seawater

PCBs



- Industrial products for a variety of uses including dielectric fluid, heat medium, and lubricants.
- Endocrine disrupting chemicals

DDTs

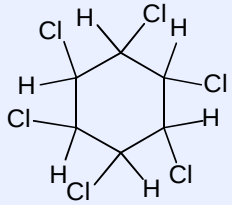


- DDT and its metabolites such as DDE and DDD.
- DDT was used as insecticides
- Endocrine disrupting chemicals

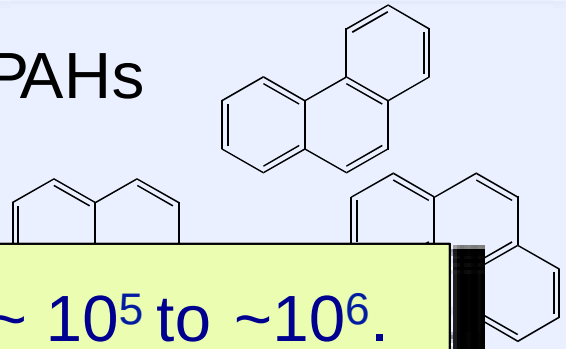
adsorption from ambient seawater

Plastics

HCH



PAHs



Concentration factor is estimated to be ~ 10^5 to ~10^6.

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International Pellet Watch

Global Monitoring of Persistent Organic Pollutants (POPs) Using Beached Plastic Resin Pellets

Since 2005

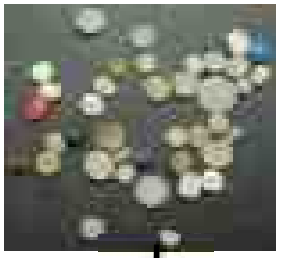
More than 50 pieces (~ 100 pieces)
per one location

Air Mail

Laboratory of Organic Geochemistry, Dr. Hideshige Takada,
Tokyo University of Agriculture and Technology,
Fuchu, Tokyo 183-8509, Japan

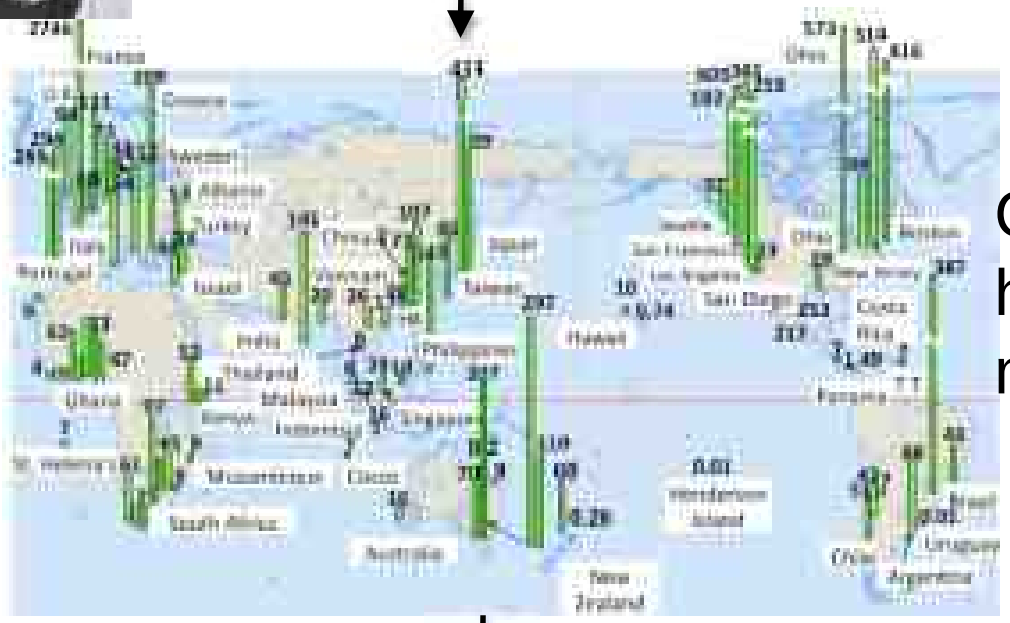
Plastic resin pellet from various areas in the world

Analysis for persistent organic pollutants (POPs)



Chemical Analysis

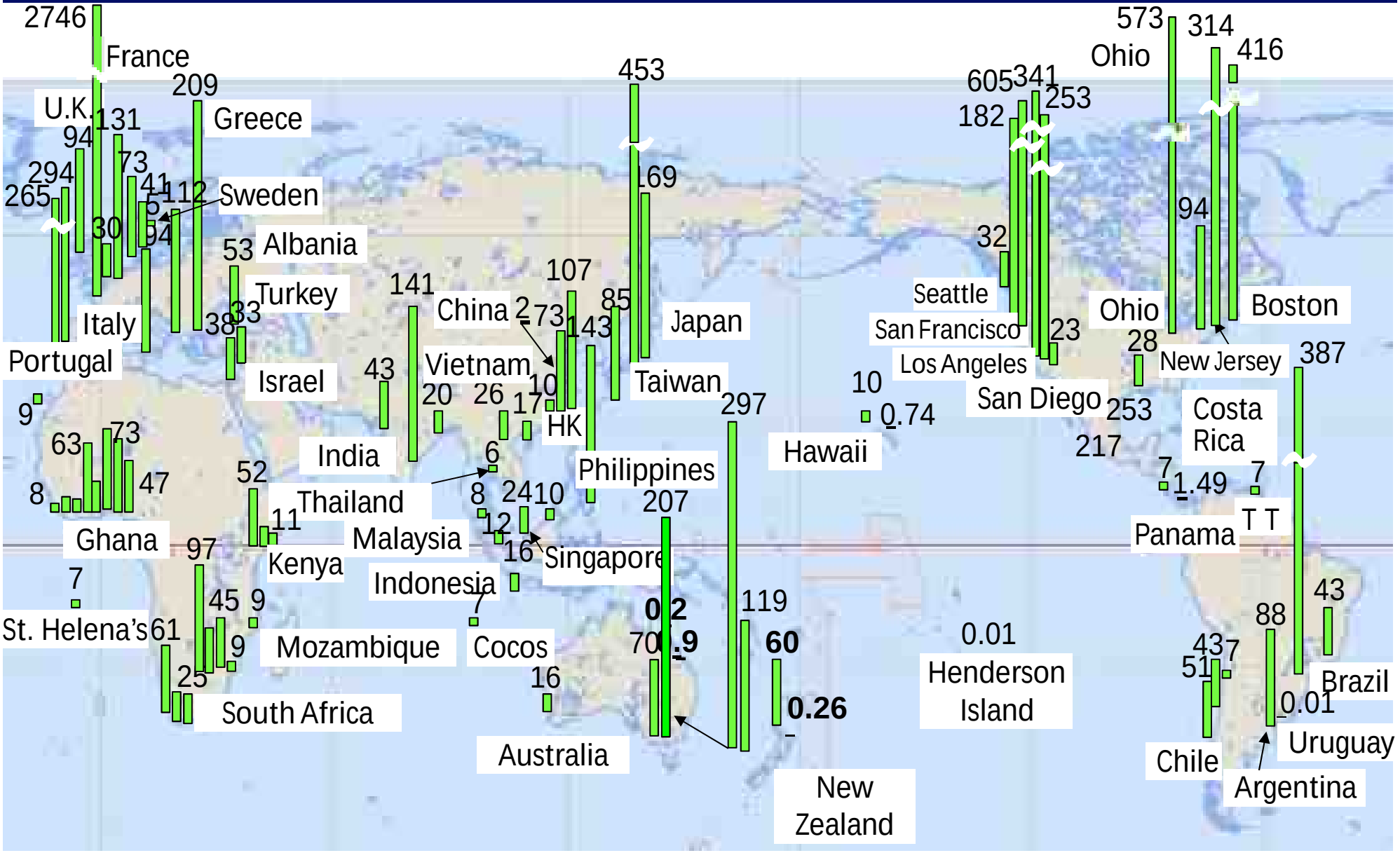
Status of Global pollution



Chemical hazardousness of marine plastics

- **Feed the data** back to the collaborators via e-mail
- **Releasing** the results on **web** http://**www.pelletwatch.**[3]**o**[6] **rg/**

International Pellet Watch : monitoring of POPs
Plastics carry hazardous chemicals in marine environments



Concentration of PCBs* in beached plastic resin pellet (ng/g-pellet)

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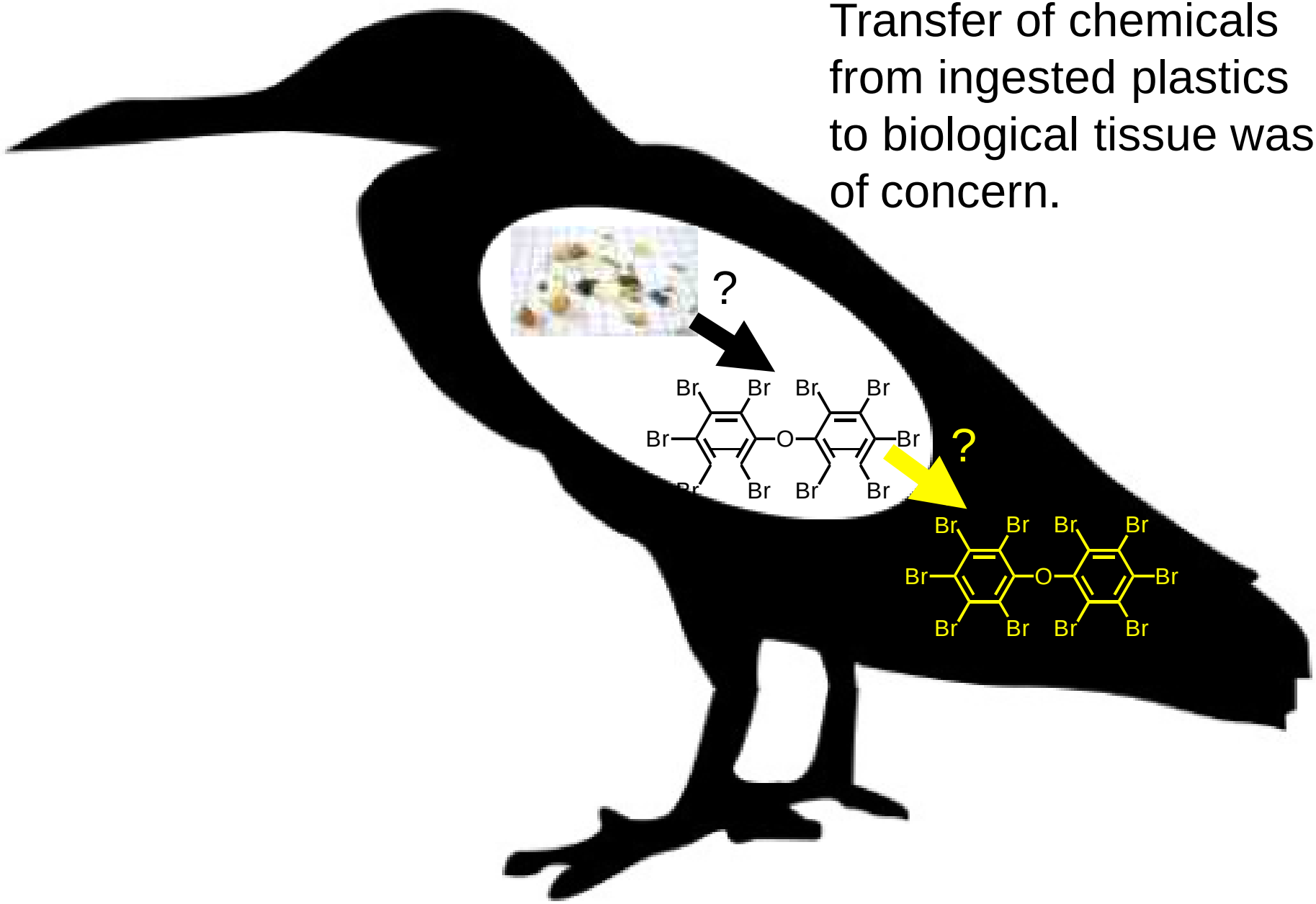
Transfer of chemicals from ingested plastics to biological tissue



Transfer of chemicals from ingested plastics to biological tissue was of concern.

Marine Pollution Bulletin 62 (2011) 2845–2849

Contents lists available at SciVerse ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Baseline

Edited by Bruce J. Richardson

The objective of BASELINE is to publish short communications on different aspects of pollution of the marine environment. Only those papers which clearly identify the quality of the data will be considered for publication. Contributors to Baseline should refer to 'Baseline—The New Format and Content' (*Mar. Pollut. Bull.* 60, 1–2).

Physical and chemical effects of ingested plastic debris on short-tailed shearwaters, *Puffinus tenuirostris*, in the North Pacific Ocean

Rei Yamashita[a,c,*], Hideshige Takada[a], Masa-aki Fukuwaka[b], Yutaka Watanuki[c]

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[b] *Hokkaido National Fisheries Research Institute, Fisheries Research Agency (FRA), 116 Katsurakoi, Kushiro, Hokkaido 085-0802, Japan*
[c] *Graduate School of Fisheries Sciences, Hokkaido University, 3-1-1 Minato, Hakodate 041-8611, Japan*

Faculty of 1000

Marine Pollution Bulletin 69 (2013) 219–222

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Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Baseline

Accumulation of plastic-derived chemicals in tissues of seabirds ingesting marine plastics

Kosuke Tanaka[a], Hideshige Takada[a,*], Rei Yamashita[a], Kaoruko Mizukawa[a], Masa-aki Fukuwaka[b], Yutaka Watanuki[c]

[a] Laboratory of Organic Geochemistry (LOG), Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183-8509, Japan
[b] Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Kushiro, Hokkaido 085-0802, Japan
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ARTICLE INFO

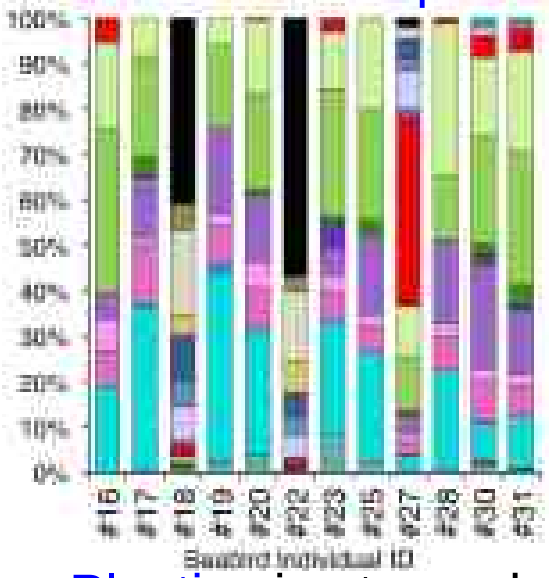
Keywords:
Polybrominated diphenyl ethers (PBDEs)
Plastic debris
Additives
North Pacific Ocean
Short-tailed shearwater
Bioaccumulation

ABSTRACT

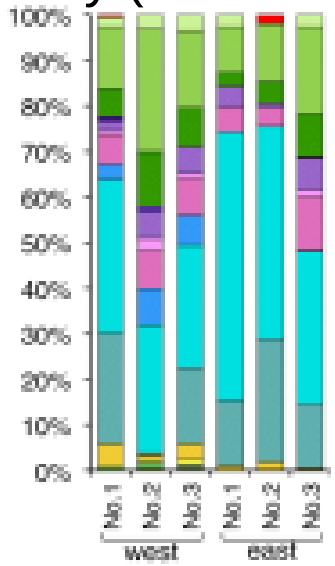
We analyzed polybrominated diphenyl ethers (PBDEs) in abdominal adipose of oceanic seabirds (short-tailed shearwaters, *Puffinus tenuirostris*) collected in northern North Pacific Ocean. In 3 of 12 birds, we detected higher-brominated congeners (viz., BDE209 and BDE183), which are not present in the natural prey (pelagic fish) of the birds. The same compounds were present in plastic found in the stomachs of the 3 birds. These data suggested the transfer of plastic-derived chemicals from ingested plastics to the tissues of marine-based organisms.

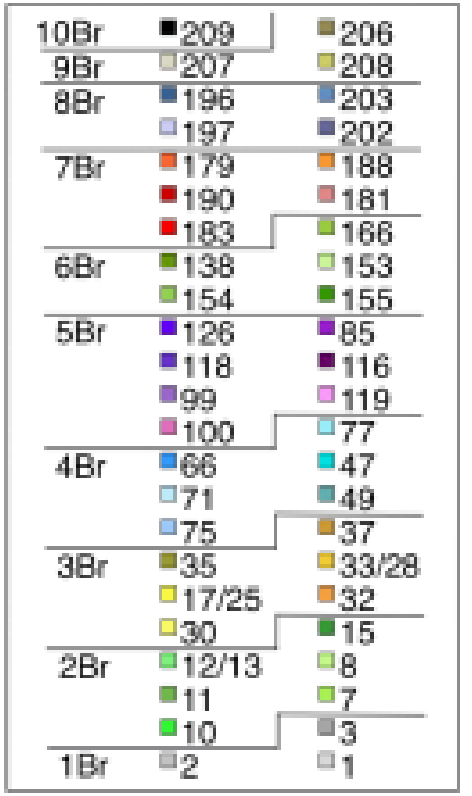
Composition of BDE congeners in seabird adipose, plastics in the stomachs, and their prey.

Abdominal adipose

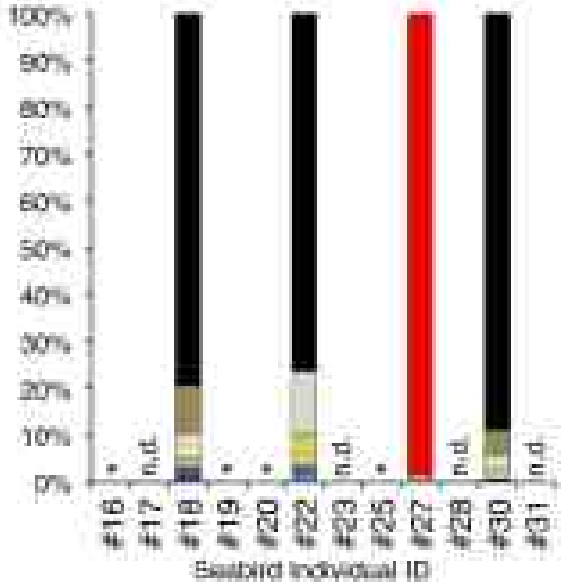


Prey (lantern-fish)





Plastics in stomach



Higher brominated congeners were derived from ingested plastics, whereas lower brominated congeners were derived from natural prey

ENVIRONMENTAL Science & Technology

Article

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Facilitated Leaching of Additive-Derived PBDEs from Plastic by Seabirds' Stomach Oil and Accumulation in Tissues

Kosuke Tanaka,[†] Hideshige Takada,[*,†] Rei Yamashita,[†] Kaoruko Mizukawa,[†] Masa-aki Fukuwaka,[‡] and Yutaka Watanuki[§]

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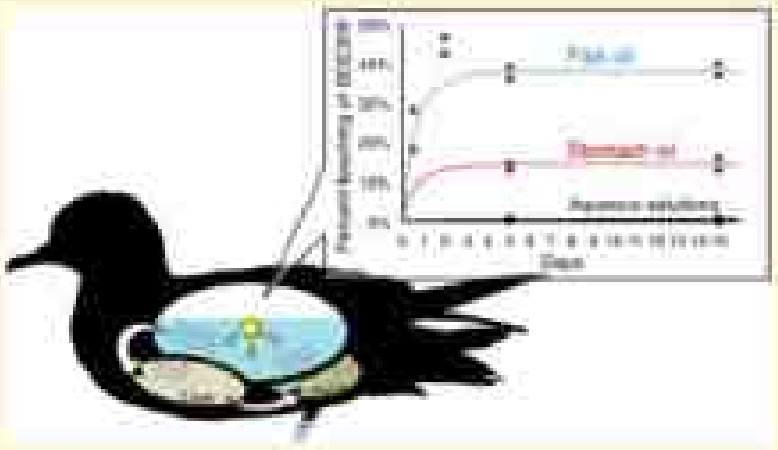
[‡]Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Kushiro, Hokkaido 085-0802, Japan

[§]Faculty of Fisheries, Hokkaido University, Hakodate, Hokkaido 041-8611, Japan

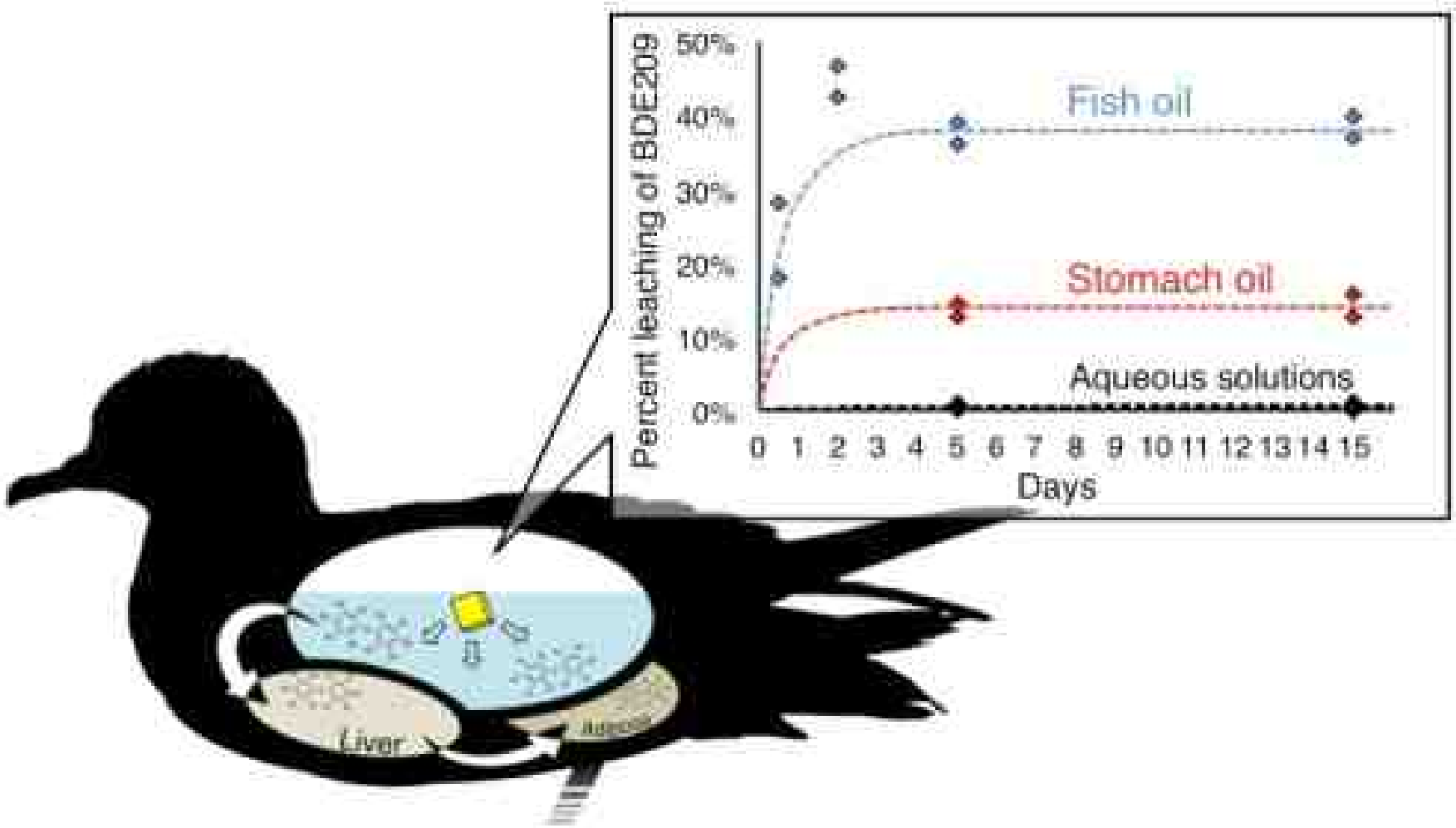
Supporting Information

ABSTRACT: Our previous study suggested the transfer of polybrominated diphenyl ether (PBDE) flame retardants from ingested plastics to seabirds' tissues. To understand how the PBDEs are transferred, we studied leaching from plastics into digestive fluids. We hypothesized that stomach oil, which is present in the digestive tract of birds in the order Procellariiformes, acts as an organic solvent, facilitating the leaching of hydrophobic chemicals. Pieces of plastic compounded with deca-BDE were soaked in several leaching solutions. Trace amounts were leached into distilled water, seawater, and acidic pepsin solution. In contrast, over 20 times as much material was leached into stomach oil, and over 50 times as much into fish oil (a major component of stomach oil). Analysis of abdominal adipose, liver tissue, and ingested plastics from 18 wild seabirds collected from the North Pacific Ocean showed the occurrence of deca-BDE or hepta-BDEs in both the tissues and the ingested plastics in three of the birds, suggesting transfer from the plastic to the tissues. In birds with BDE209 in their tissues, the dominance of BDE207 over other nona-BDE isomers suggested biological debromination at the meta position. Model calculation of PBDE exposure to birds based on the results of the leaching experiments combined with field observations suggested the dominance of plastic-mediated internal exposure to BDE209 over exposure via prey.



Stomach oil facilitates release of additive-chemicals to digestive fluid

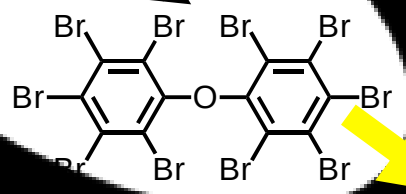
Trojan Horse

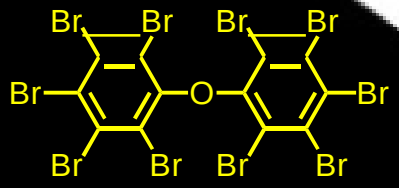


Transfer of chemicals from ingested plastics to biological tissue

Transfer of chemicals from ingested plastics to biological tissue has been confirmed.

Trojan Horse





Biological effects concerned

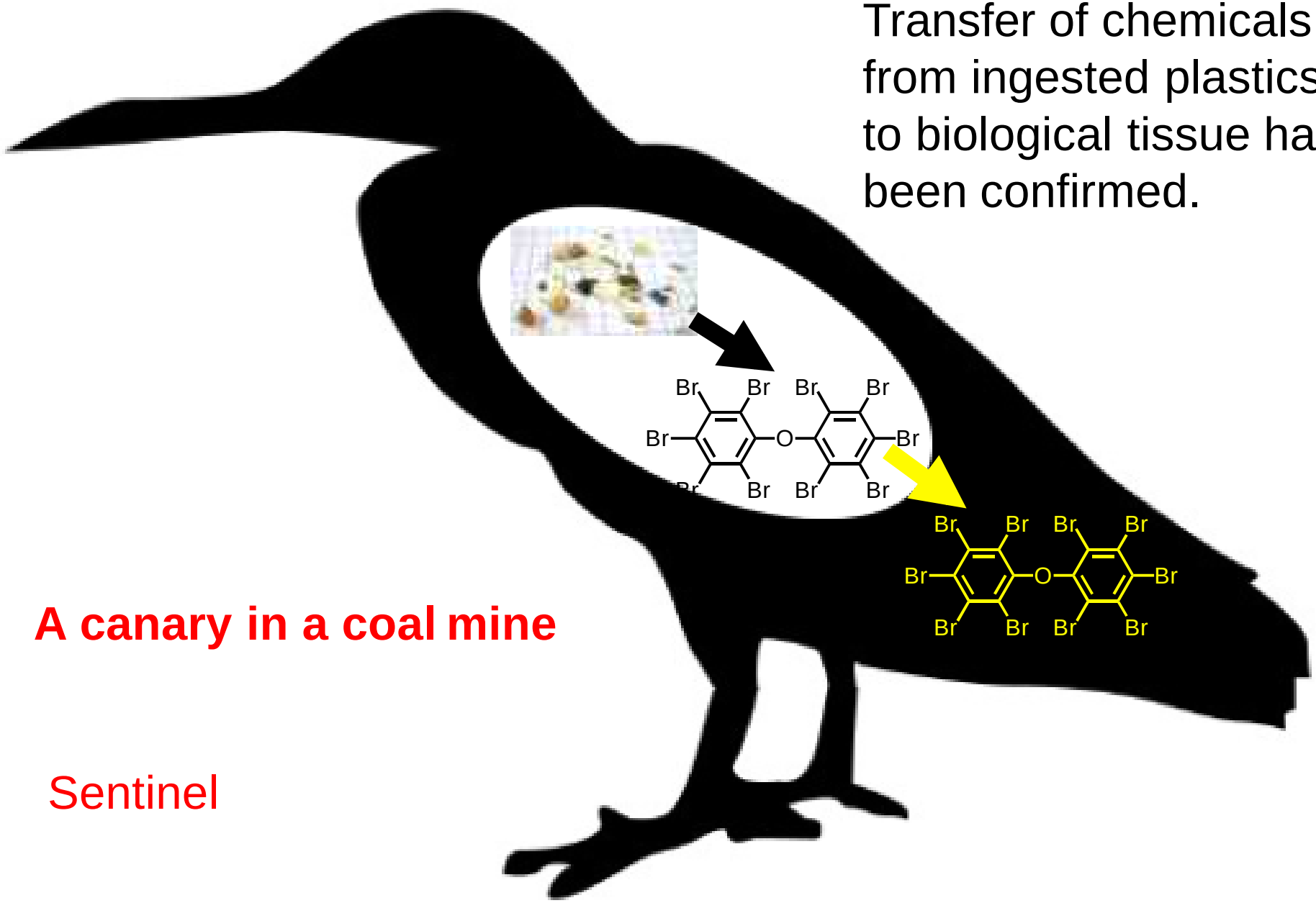
e.g., endocrine disruption

reproductive failure

decline of species

Transfer of chemicals from ingested plastics to biological tissue

Transfer of chemicals from ingested plastics to biological tissue has been confirmed.



A canary in a coal mine

Sentinel

Topics

Anthropocene : Plastic age

Plastic pollution in organisms, Water, Sediment core

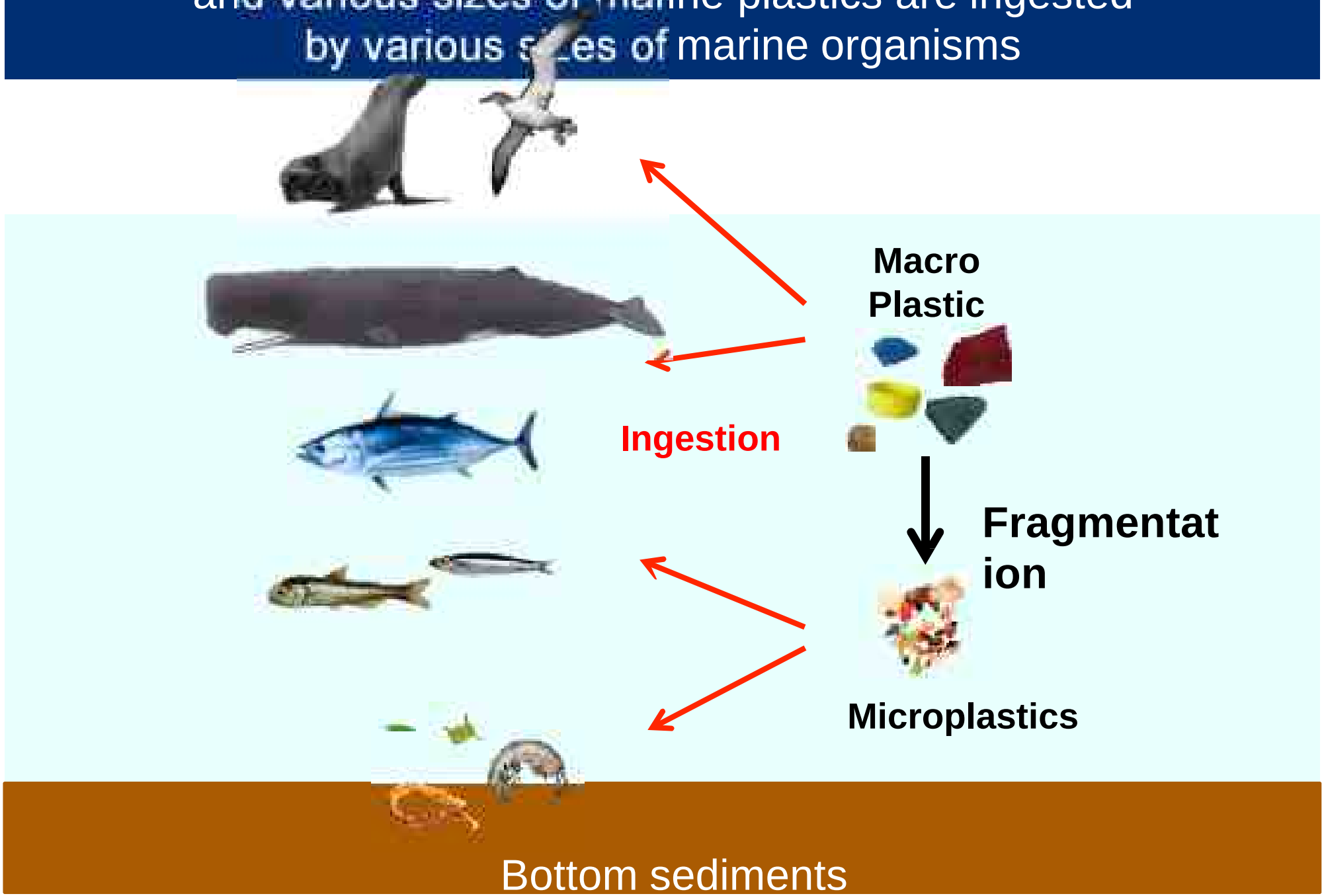
Hazardous chemicals in marine plastics

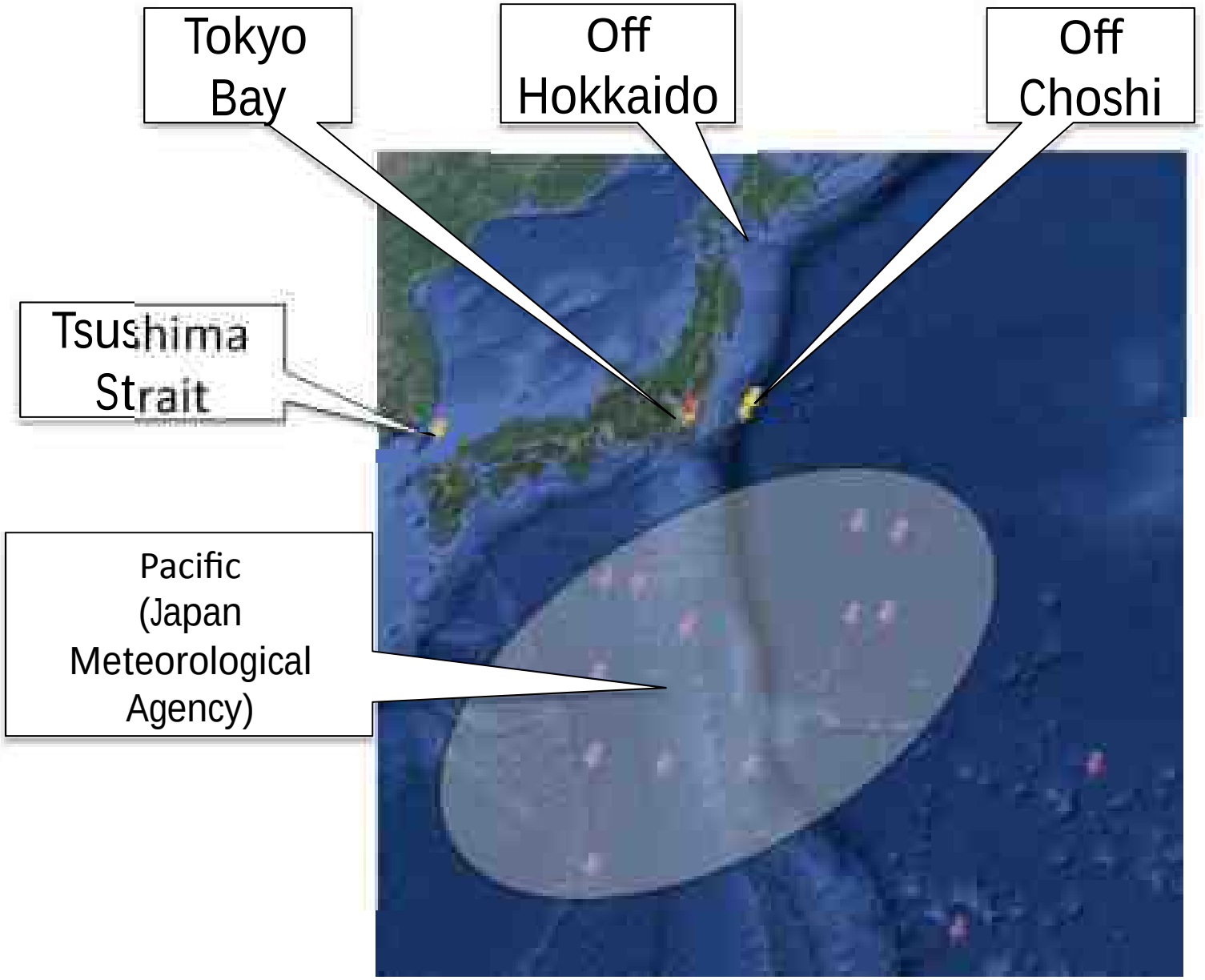
International Pellet Watch

Transfer and accumulation of hazardous chemicals from ingested plastics to biological tissue

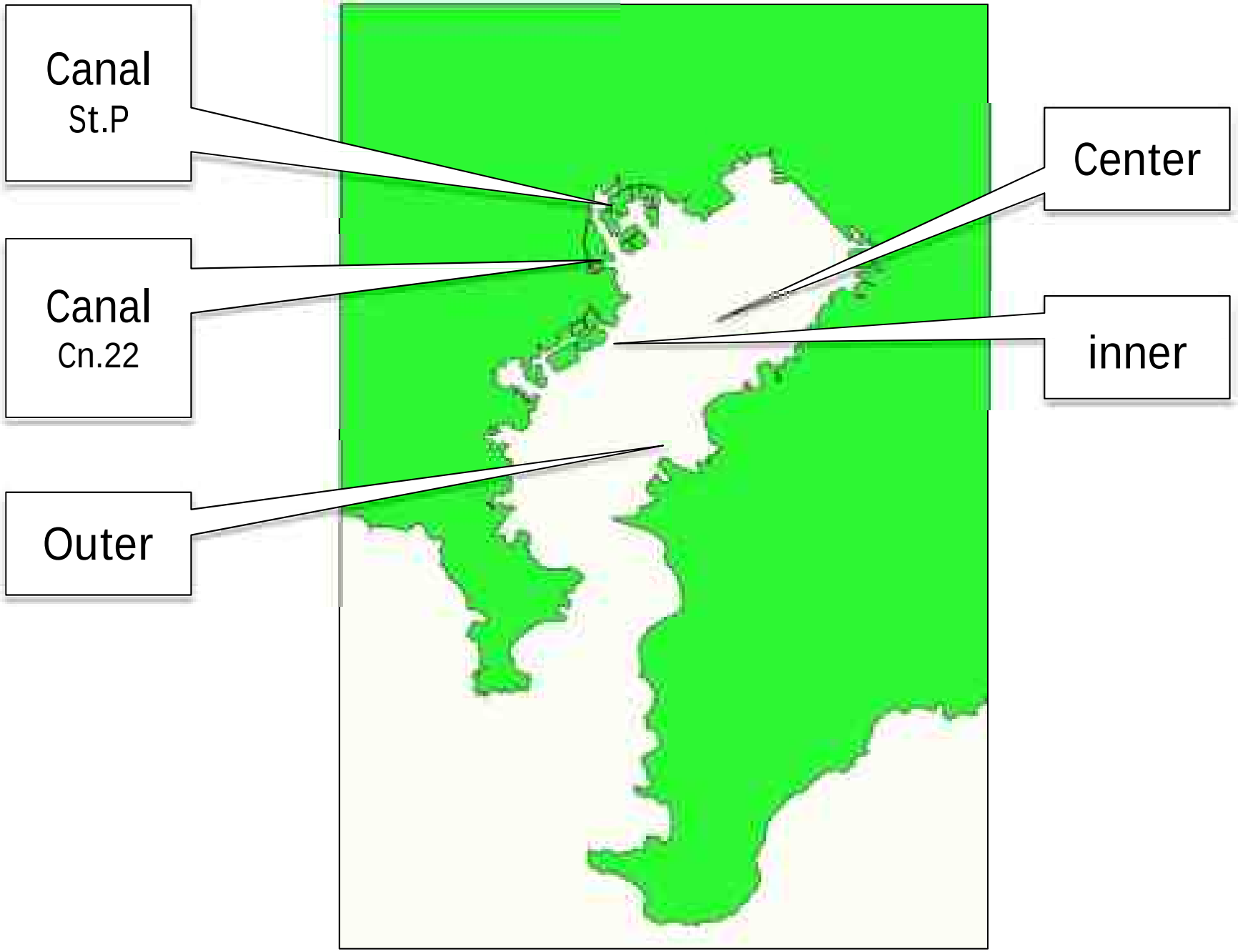
Hazardous chemicals in microplstics

Plastics are fragmented into smaller particles (i.e. microplastics) and various sizes of marine plastics are ingested by various sizes of marine organisms



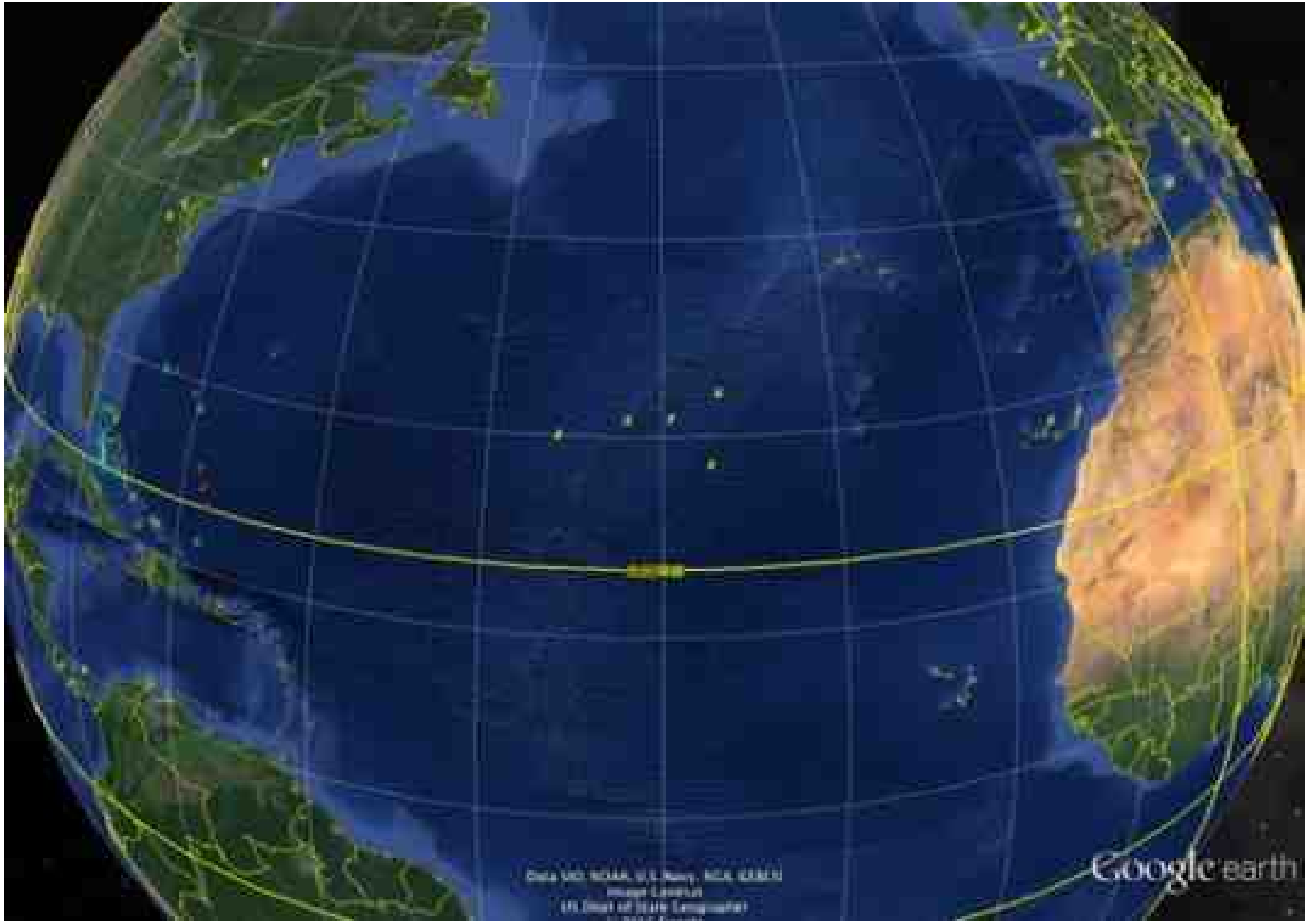

Tokyo Bay
Off Hokkaido
Off Choshi
Tsushima Strait
Pacific (Japan Meteorological Agency)

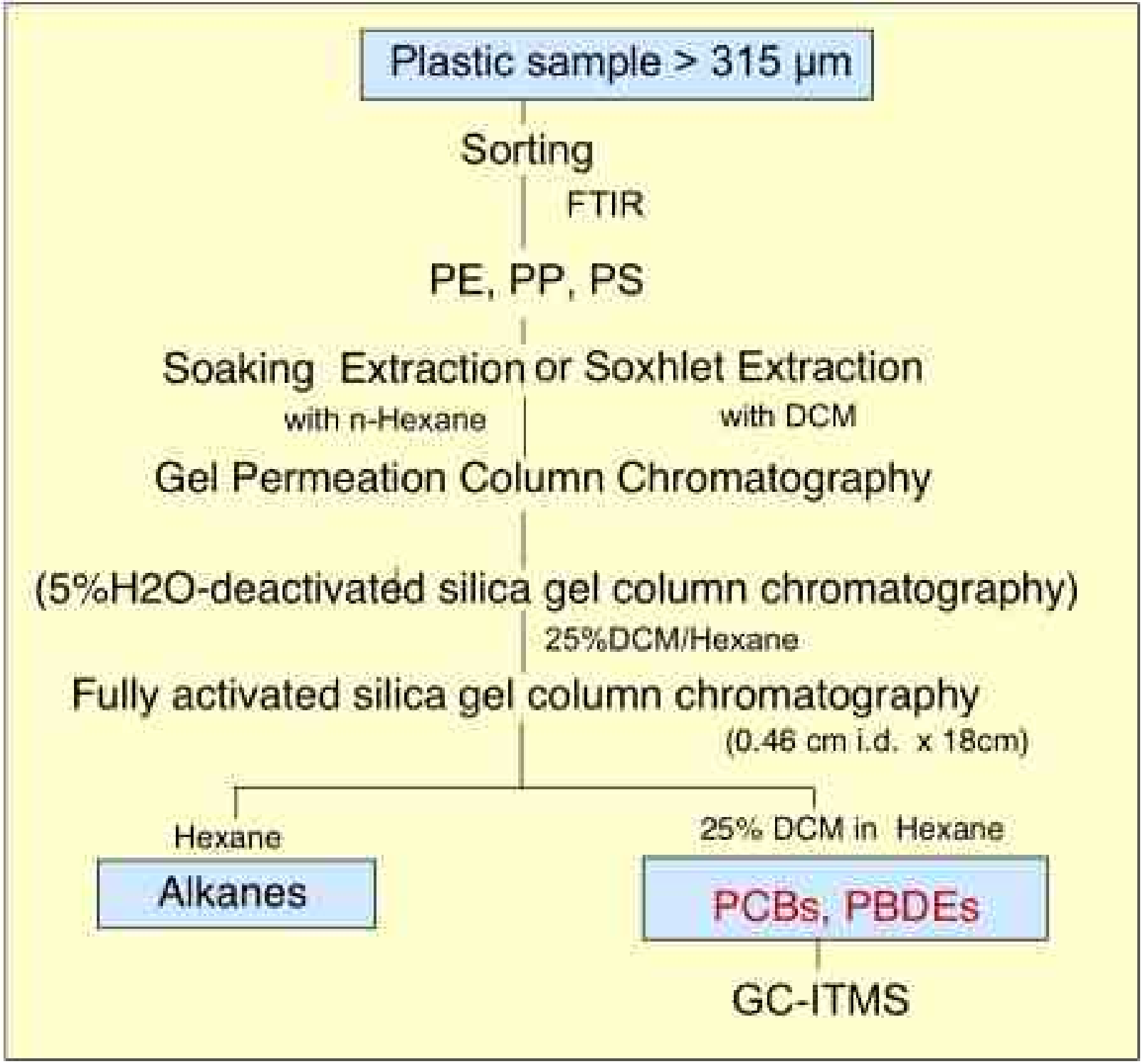
Tokyo Bay

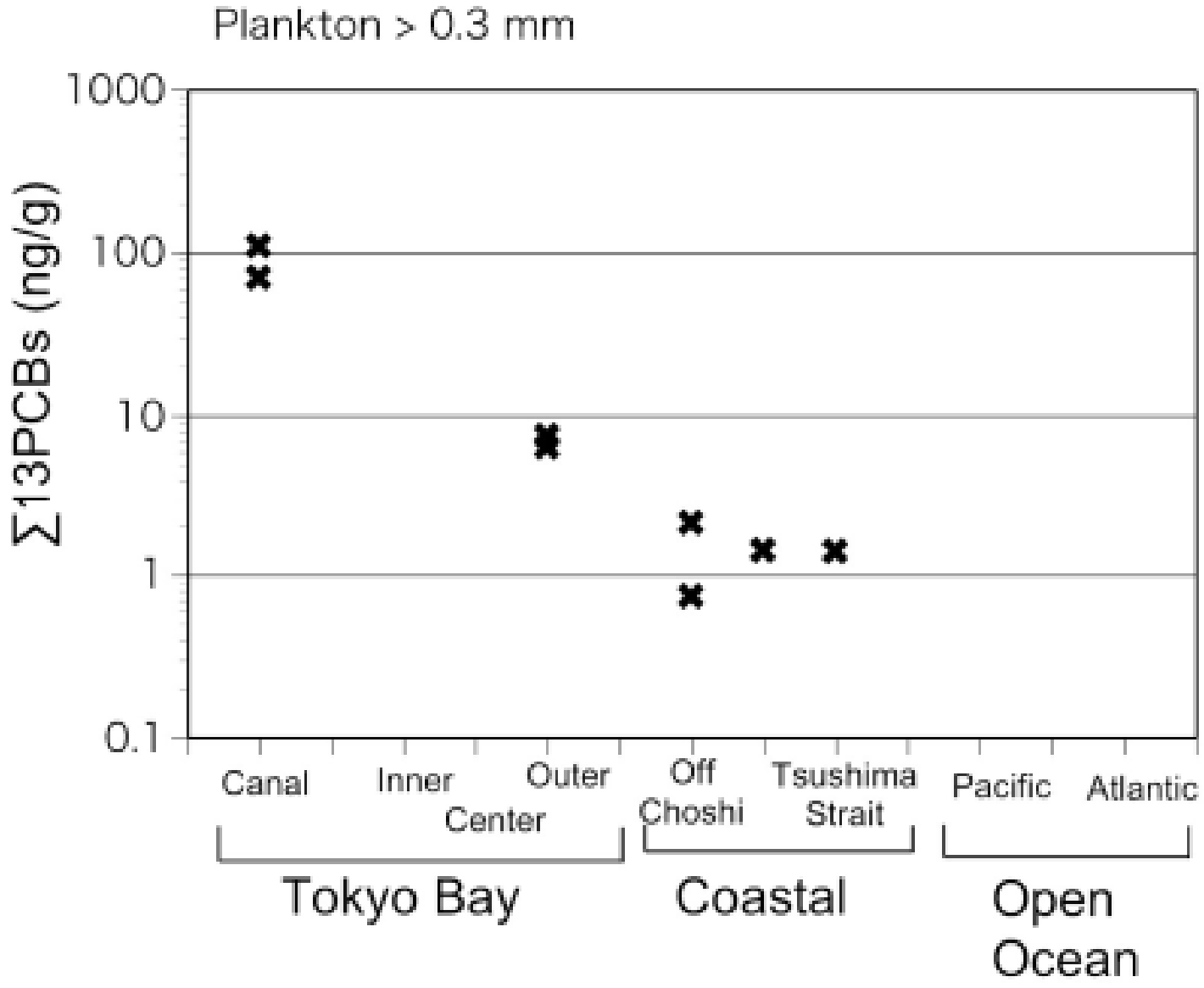


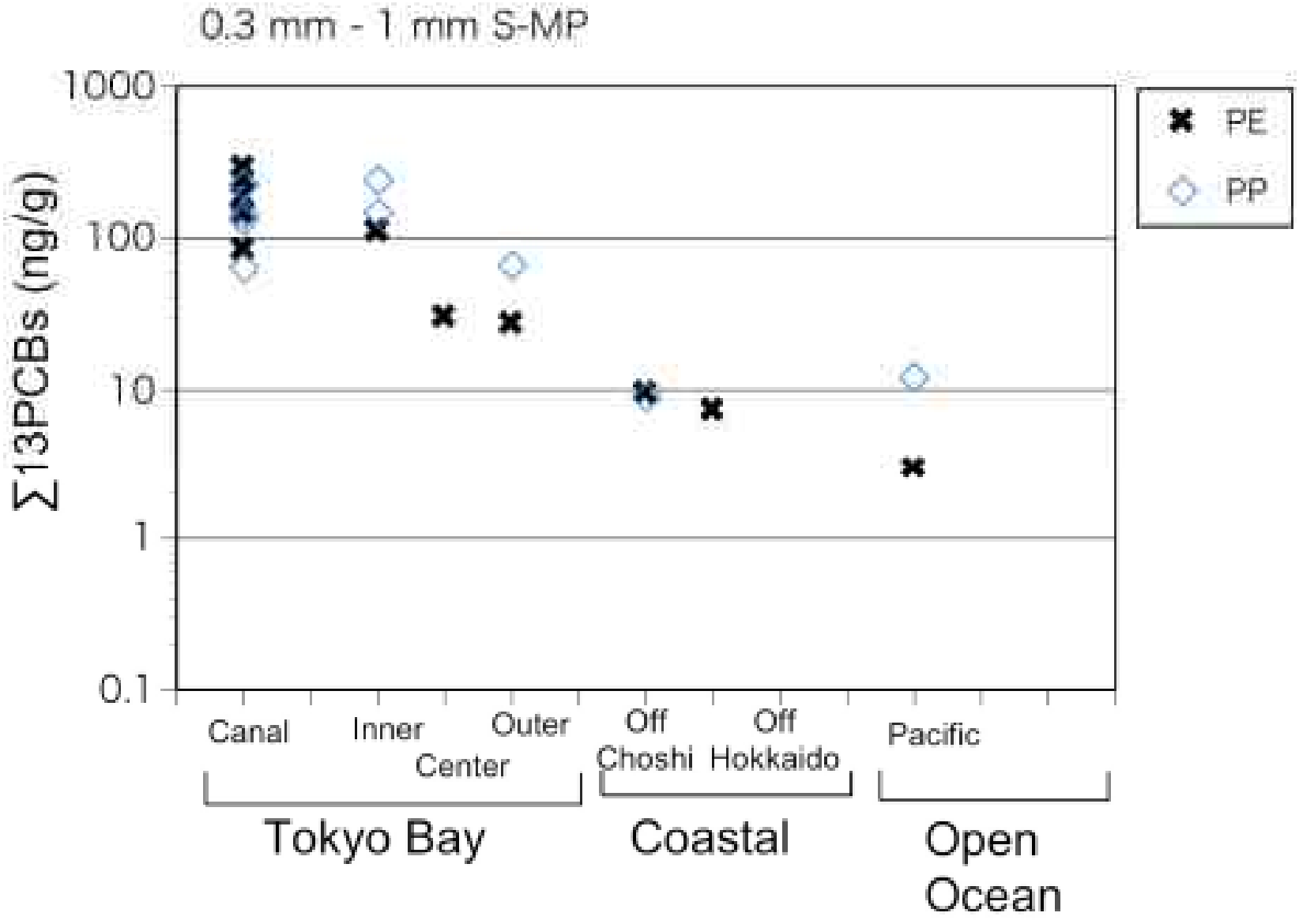
Microplastic samples from Pacific (Japan Meteorological Agency)

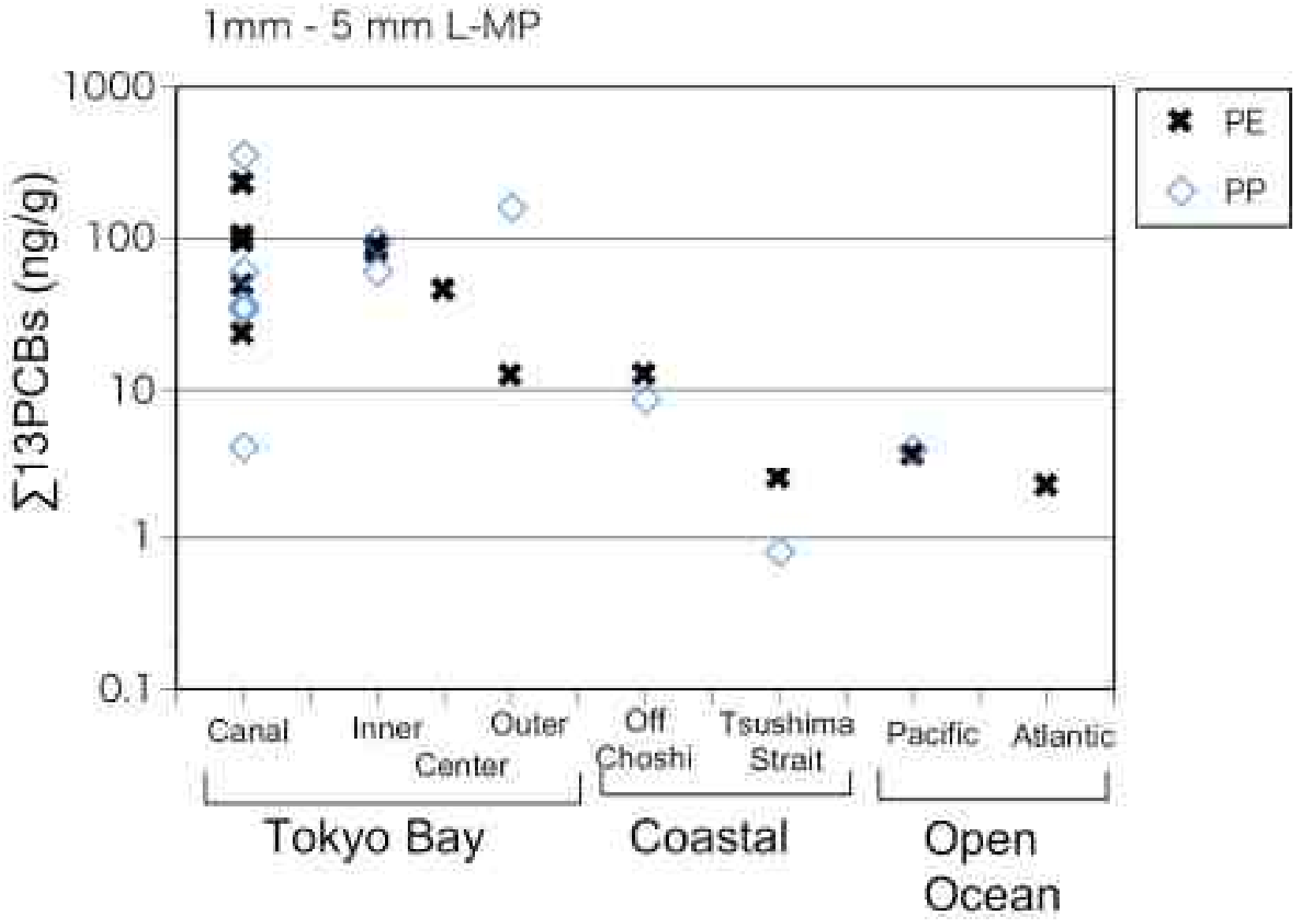
Microplastic samples from Ms. Nicole Trenholm: Ocean Research Project




Plastic sample > 315 µm
Sorting
FTIR
PE, PP, PS
Soaking Extraction or Soxhlet Extraction
with n-Hexane
with DCM
Gel Permeation Column Chromatography
(5%H2O-deactivated silica gel column chromatography)
25%DCM/Hexane
Fully activated silica gel column chromatography
(0.46 cm i.d. x 18cm)
Hexane
25% DCM in Hexane
Alkanes
PCBs, PBDEs
GC-ITMS


Plankton > 0.3 mm
1000
100
10
1
0.1
Σ13PCBs (ng/g)
Canal
Inner
Center
Outer
Off
Choshi
Tsushima
Strait
Pacific
Atlantic
Tokyo Bay
Coastal
Open
Ocean


0.3 mm - 1 mm S-MP
1000
100
10
1
0.1
∑13PCBs (ng/g)
PE
PP
Canal
Inner
Center
Outer
Off Choshi
Off Hokkaido
Pacific
Tokyo Bay
Coastal
Open Ocean


1mm - 5 mm L-MP
1000
100
10
1
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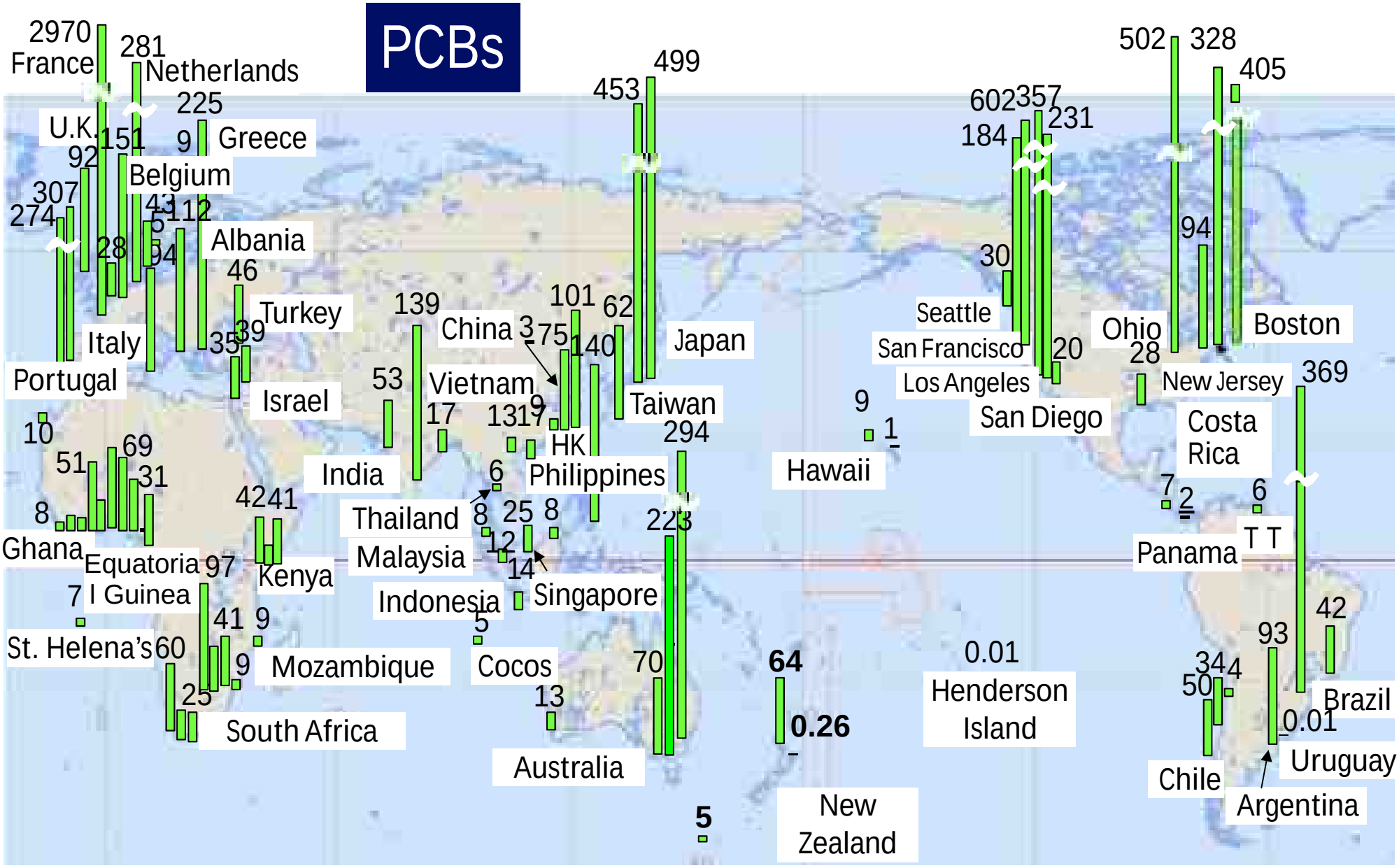
Σ13PCBs (ng/g)
PE
PP
Canal
Inner
Center
Outer
Off
Choshi
Tsushima
Strait
Pacific
Atlantic
Tokyo Bay
Coastal
Open
Ocean



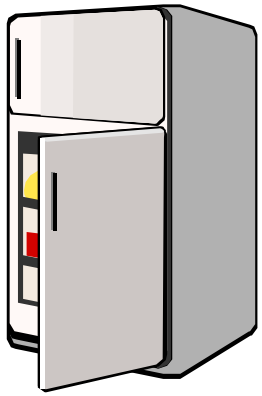
Concentration of PCBs* in beached plastic resin pellet (ng/g-pellet)

*sum of concentrations of CB#66, 101, 110, 149, 118, 105, 153, 138, 128, 187, 180, 170, 206

Measured by Polaris Q (Thermo Fisher Scientific)

PBDEs : Flame retardants

applied in various electric products and fabrics.

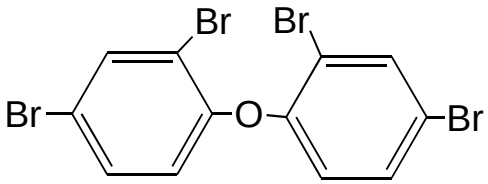



Lower brominated

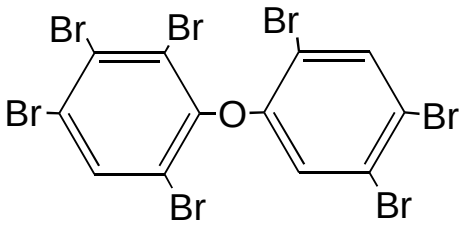
(Br4, Br5)

Higher brominated

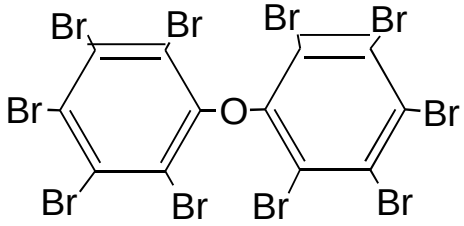
(Br7 – 10)



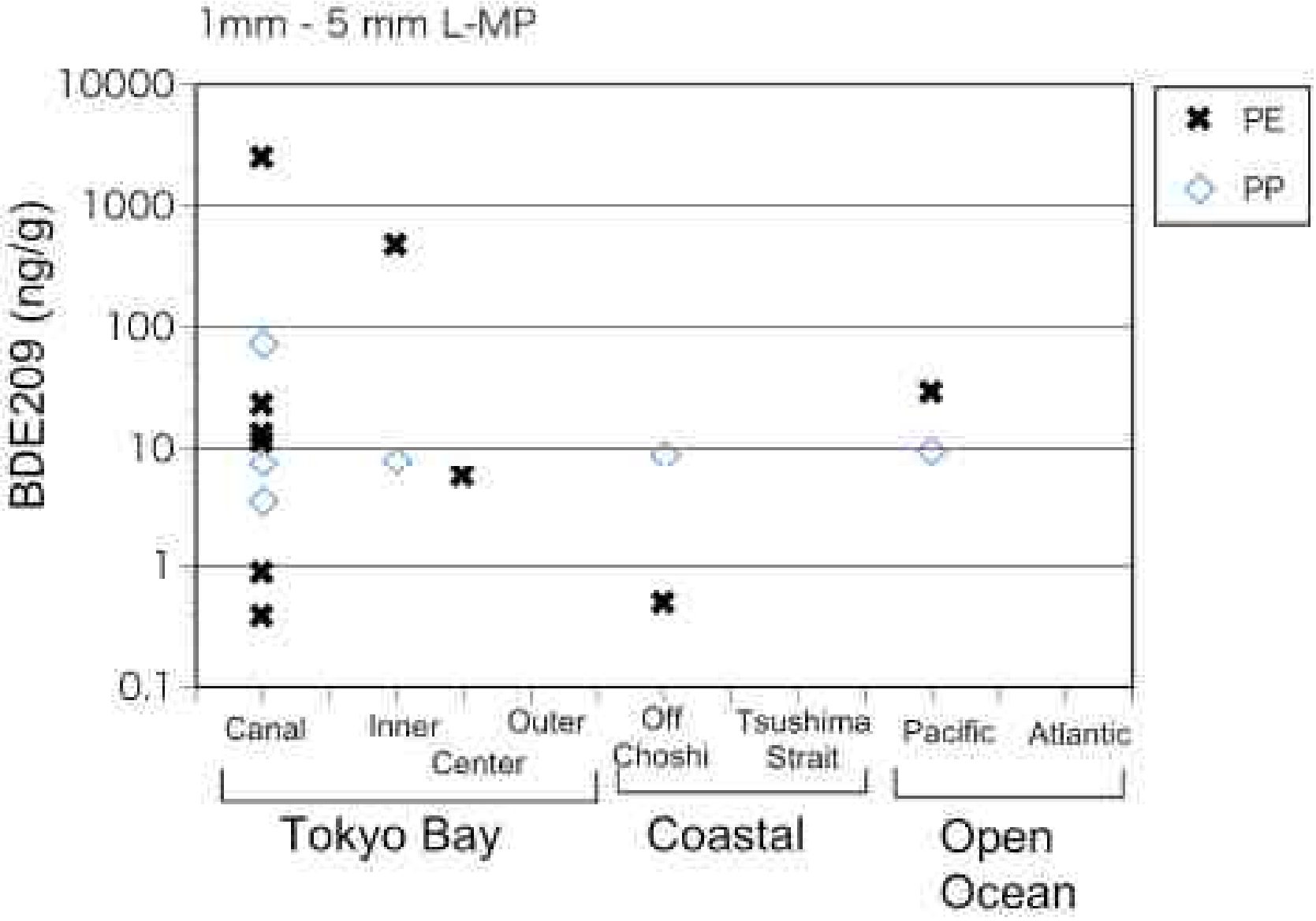
BDE47

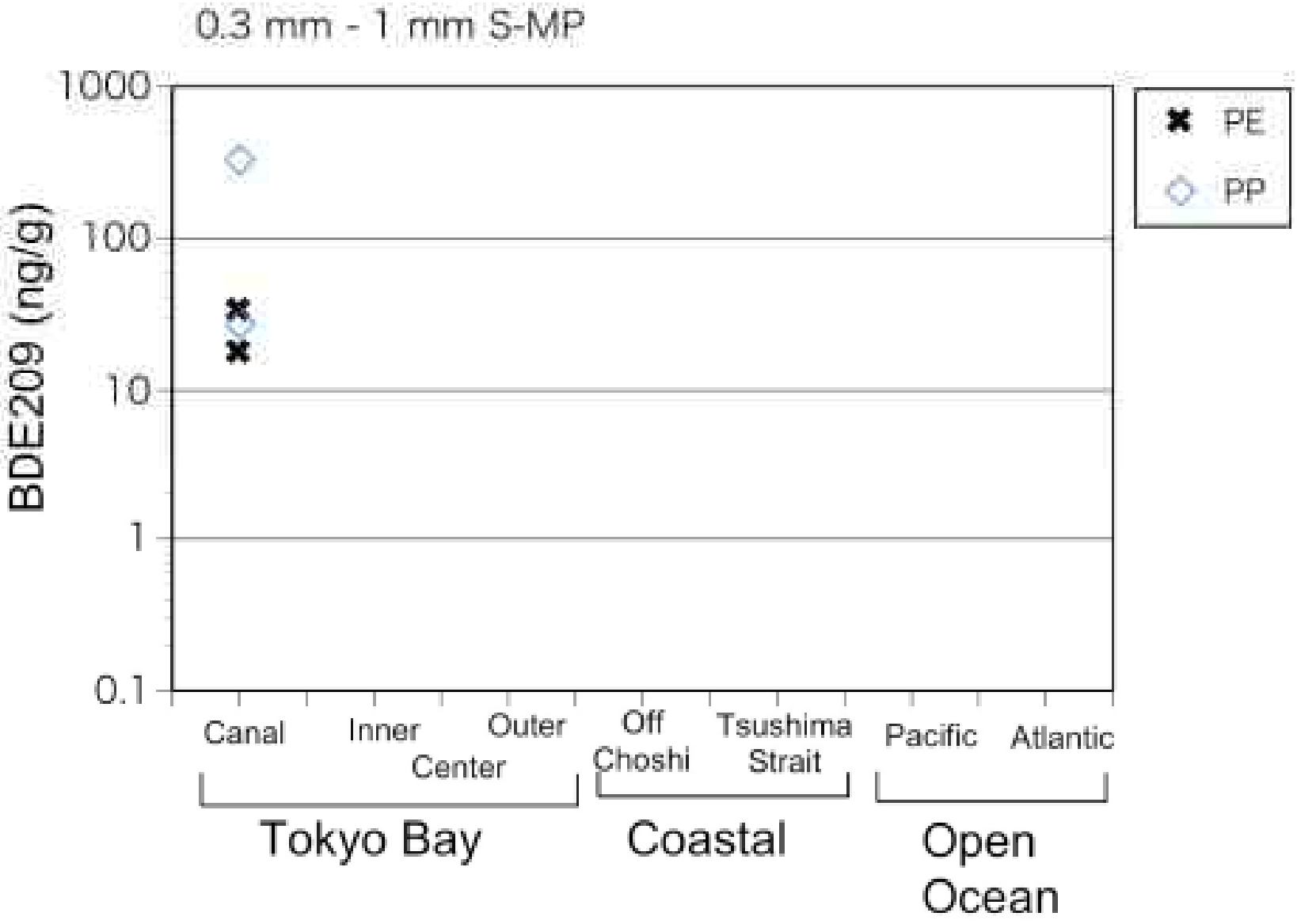


BDE183

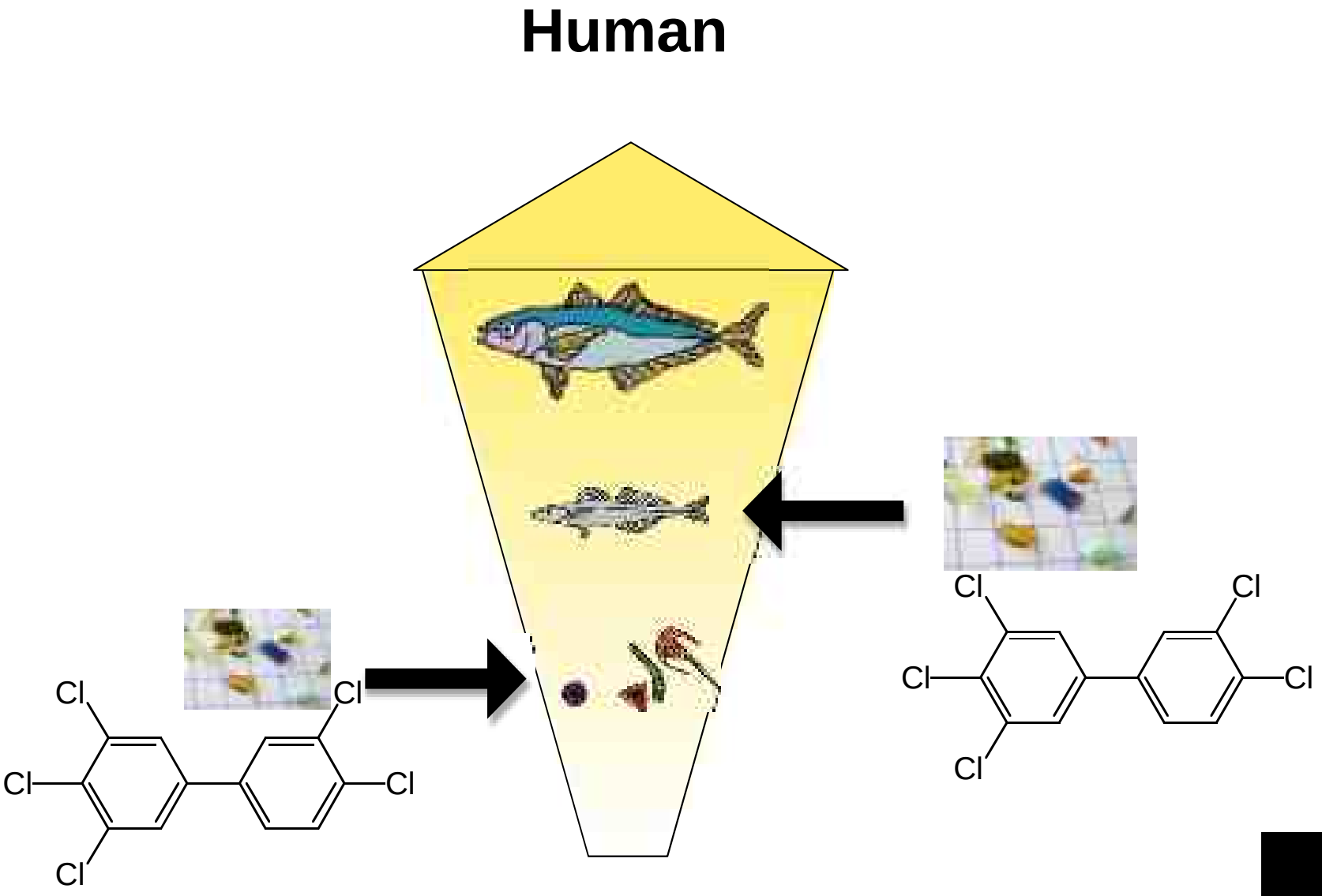


BDE209


1mm - 5 mm L-MP
BDE209 (ng/g)
10000
1000
100
10
1
0.1
PE
PP
Canal
Inner
Center
Outer
Off
Choshi
Tsushima
Strait
Pacific
Atlantic
Tokyo Bay
Coastal
Open
Ocean


0.3 mm - 1 mm S-MP
BDE209 (ng/g)
1000
100
10
1
0.1
PE
PP
Canal
Inner
Center
Outer
Off
Choshi
Tsushima
Strait
Pacific
Atlantic
Tokyo Bay
Coastal
Open
Ocean

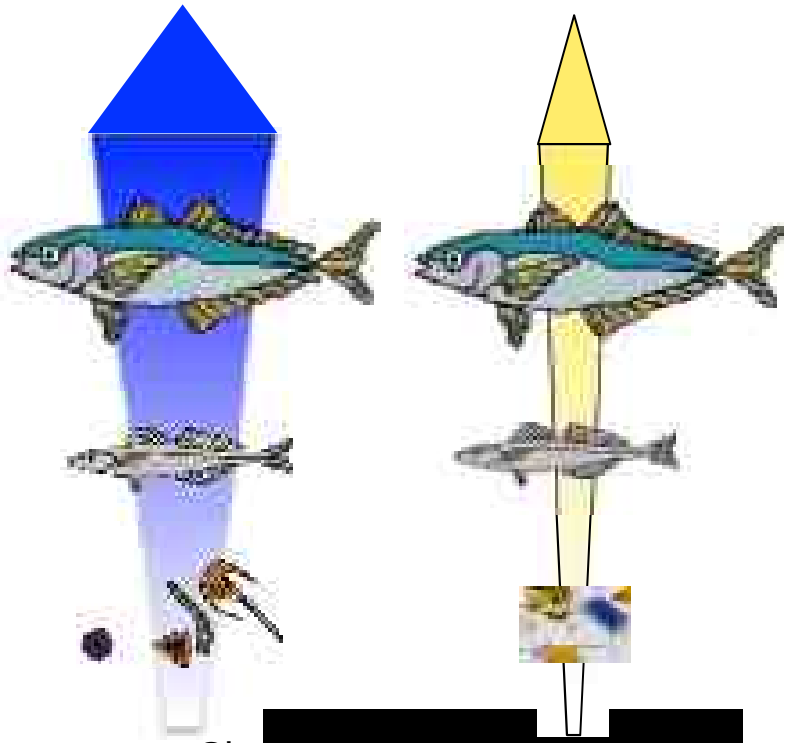
Invasion of plastics and associated chemicals to ecosystem

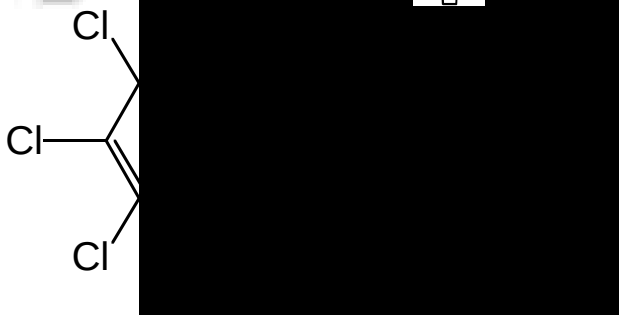


Marine organisms are exposed to hazardous chemicals through their natural prey and microplastics

[redacted]

Human





Plastic waste inputs to the sea will increase by a factor of **10 in coming 20 years**,if no action will be taken.

Plastic waste inputs from land into the ocean

Jenna R. Jambeck,[1]* Roland Geyer,[2] Chris Wilcox,[3] Theodore R. Siegler,[4] Miriam Perryman,[5] Anthony Andrady,[6] Ramani Narayan,[7] Kara Lavender Law[3]

Plastic debris in the marine environment is widely documented, but the quantity of plastic entering the ocean from waste generated on land is unknown. By linking worldwide data on solid waste, population density, and economic status, we estimated the mass of land-based plastic waste entering the ocean. We calculate that 275 million metric tons (MT) of plastic waste was generated in 192 coastal countries in 2010, with 4.8 to 12.7 million MT entering the ocean. Population size and the quality of waste management systems largely determine which countries contribute the greatest mass of uncaptured waste available to become plastic marine debris. Without waste management infrastructure improvements, the cumulative quantity of plastic waste available to enter the ocean from land is predicted to increase by an order of magnitude by 2025.

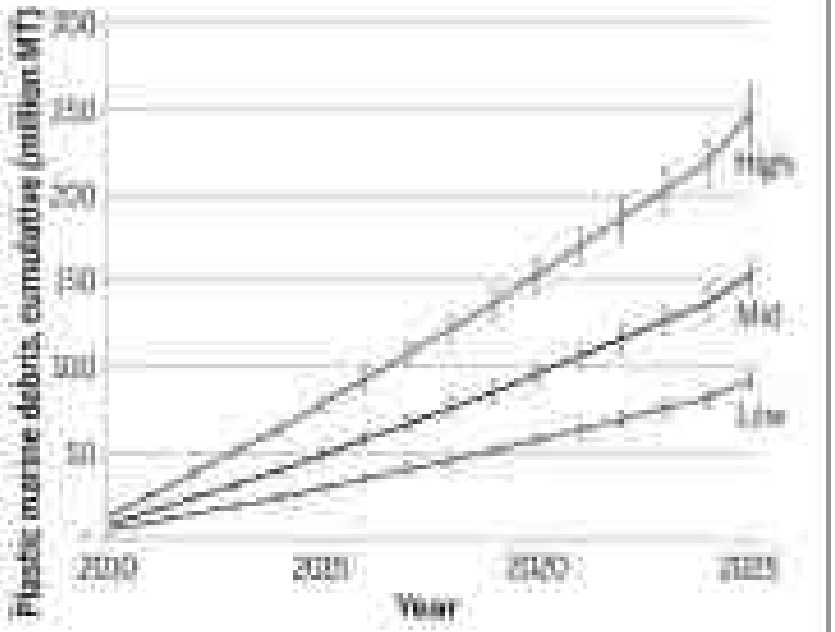
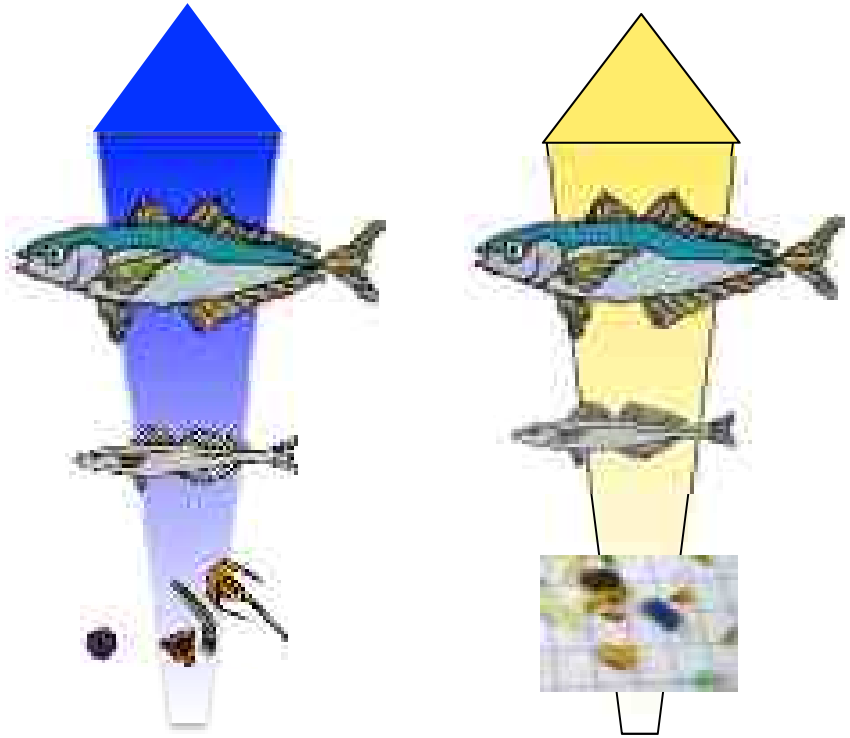


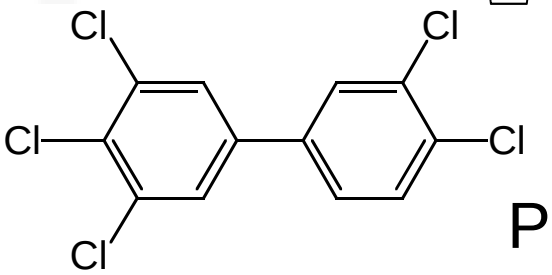
Fig. 2. Estimated mass of mismanaged plastic waste (millions of metric tons) input to the ocean by populations living within 50 km of a coast in 192 countries, plotted as a cumulative sum from 2010 to 2025. Estimates reflect assumed conversion rates of mismanaged plastic waste to marine debris (high, 40%; mid, 25%; low, 15%). Error bars were generated using mean and standard error from the predictive models for mismanaged waste fraction and percent plastic in the waste stream (12).

Jamebeck et al. (2015), Sceince

Marine organisms are exposed to hazardous chemicals through their natural prey and microplastics

Human





PCBs

Nature, vol. 494, p.169-171, 2013


COMMENT

Policy : Classify plastic waste as hazardous

Rochman, Chelsea M.; Browne, Mark Anthony; Halpern, Benjamin S.; Hentschel, Brian T.; Hoh, Eunha; Karapanagioti, Hrissi K.; Rios-Mendoza, Lorena M.; Takada, Hideshige; Teh, Swee; Thompson, Richard C.

No single-use plastics

Majority of plastics in marine environment is land-based.
Disposable packaging is dominant item.

Reduction of input of single-use plastic from land is necessary.

3R

Reduce

Reuse : non-reusable plastics

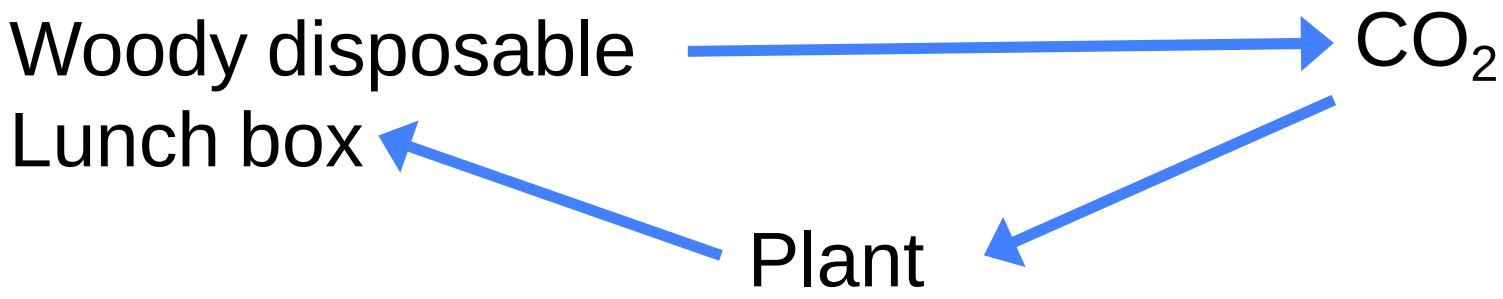
Recycle : consumes energy and emits CO_2

unanticipated detection of toxic additives
due to recycling of hazardous additives.

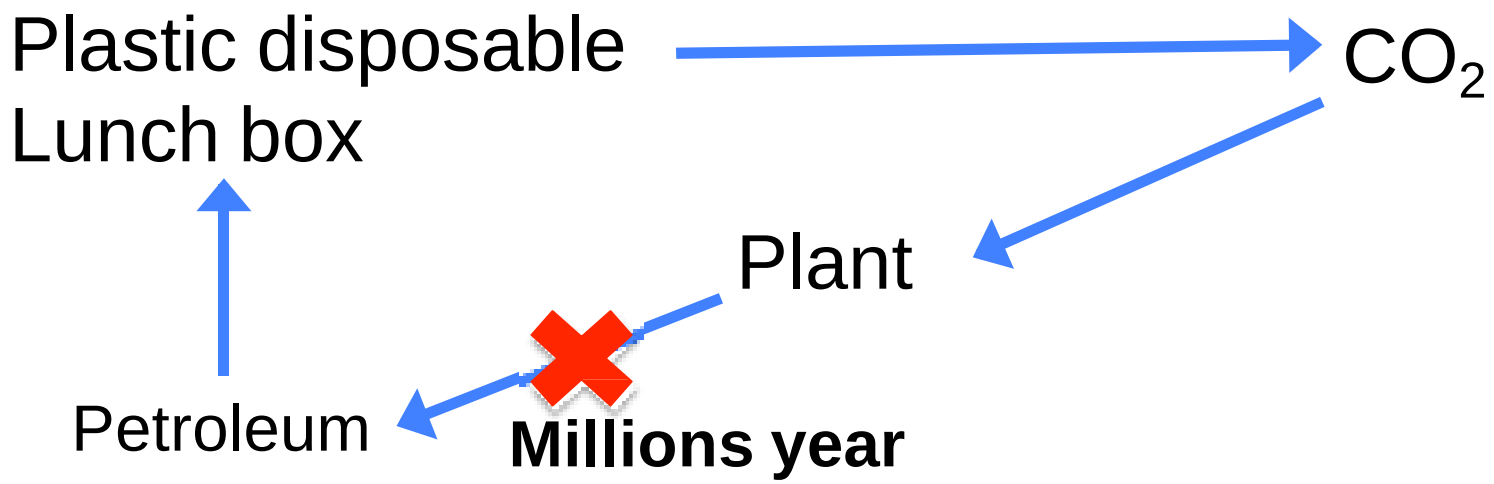
No single-use plastic!

Governmental regulation to reduce excessive plastic packaging is required .

Sustainable



One way, non-sustainable



Stone Age

Bzonze Age

Iron Age

Plastic Age

Smart Age