Marine plastic pollution : chemical threat to marine ecosystem

Shige Takada

（Tokyo University of Agriculture and Technology）

No Beer in PET bottle!

Topics

Anthropocene : Plastic age

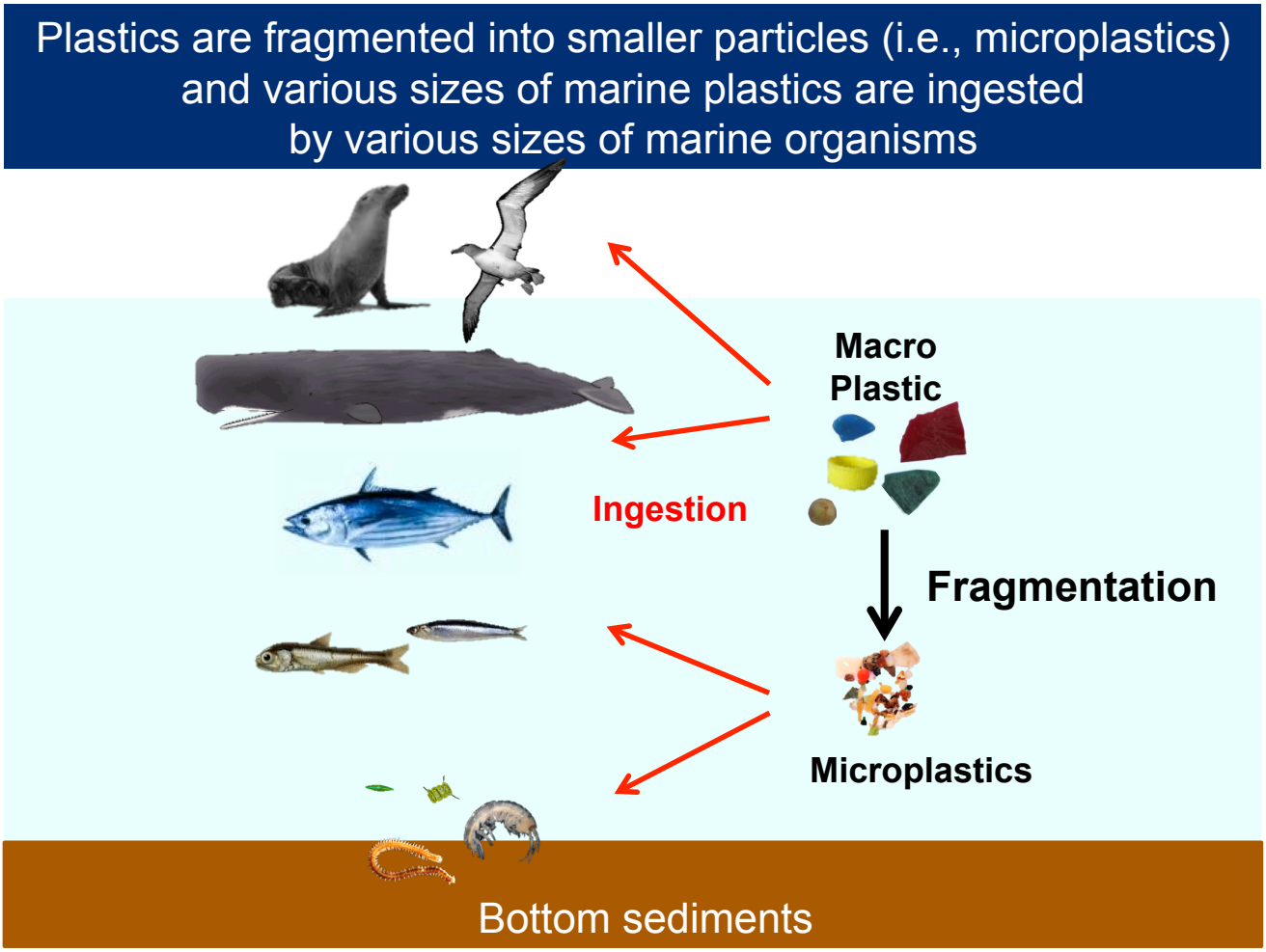
Plastic pollution in organisms, Water, Sediment core

Hazardous chemicals in marine plastics

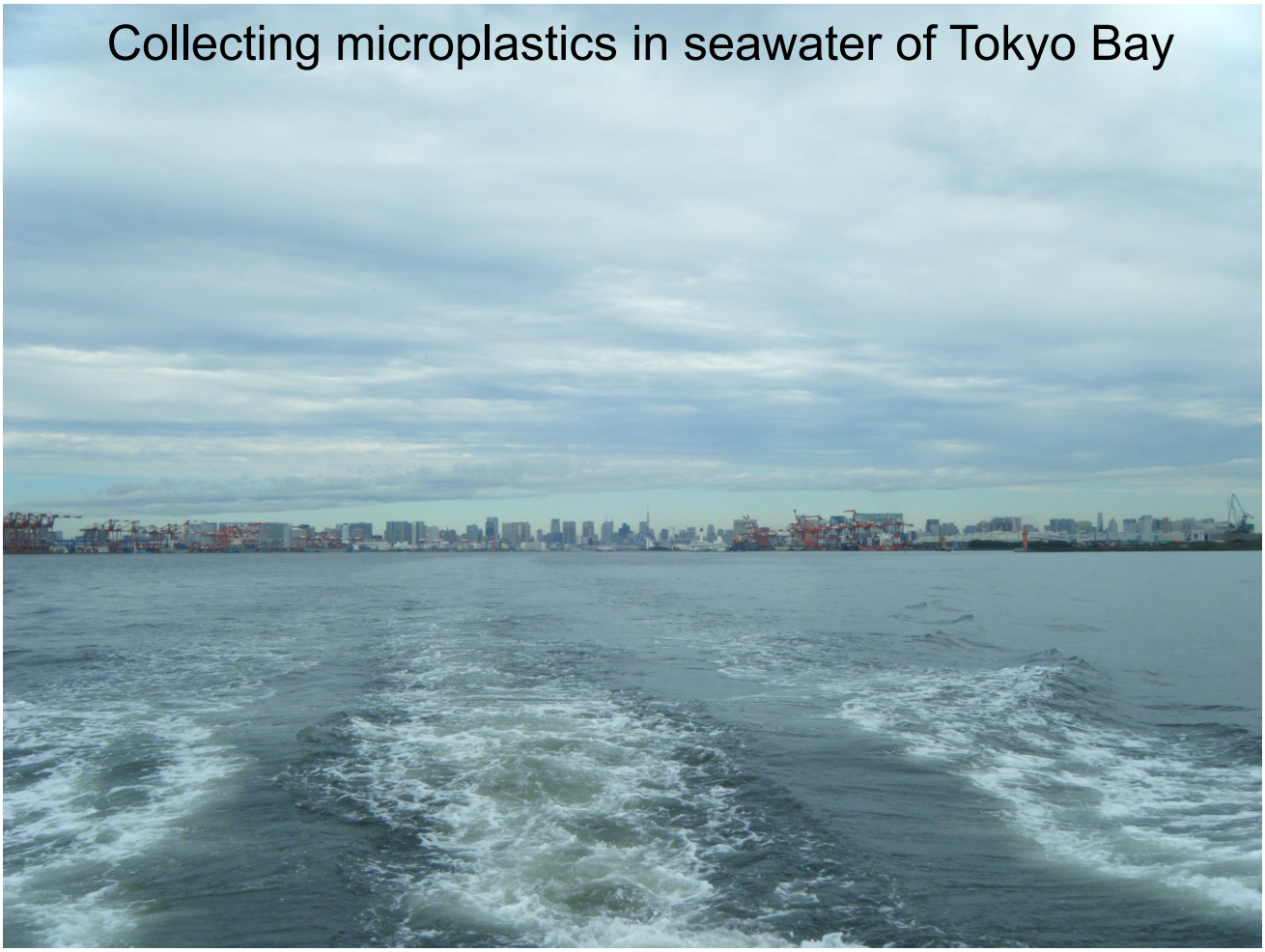
International Pellet Watch

Hazardous chemicals in microplastics

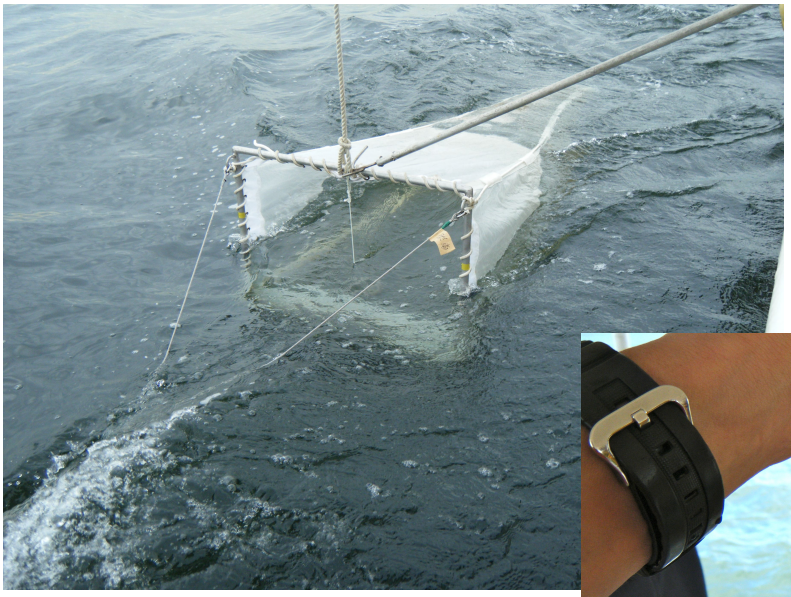
Transfer and accumulation of hazardous chemicals from ingested plastics to biological tissue



Collecting microplastics in seawater of Tokyo Bay



Collecting microplastics in seawater of Tokyo Bay



Microplastics in sand of Tokyo Bay

BREVIA

Lost at Sea: Where Is All the Plastic?

Richard C. Thompson,[1]* Ylva Olsen,[1] Richard P. Mitchell,[1]
Anthony Davis,[1] Steven J. Rowland,[1] Anthony W. G. John,[2]
Daniel McGonigle,[3] Andrea E. Russell[3]

838 7 MAY 2004 VOL 304 SCIENCE www.sciencemag.org

Microplastics in bottom sediment

Microplastics are coated with biofilm, resulting in higher density, which could facilitate sinking of microplastics into bottom sediments.

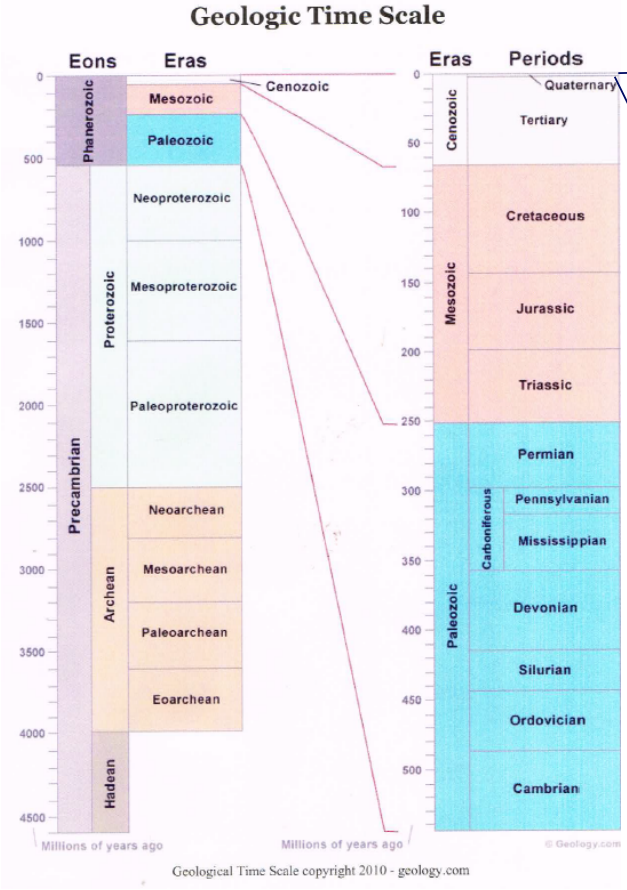
There have been several papers to report the presence of microplastics in bottom sediment.

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

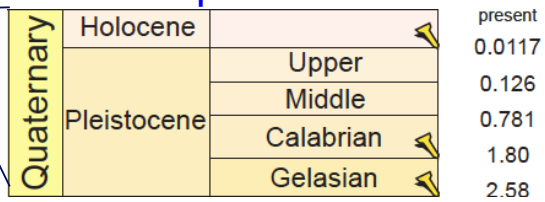
Collection of sediment cores from Asian and African coasts.

2005-2013

Plastics can be stored for geological time scale : Anthropocene



Anthropocene?



人新世

↑ ?

完新世

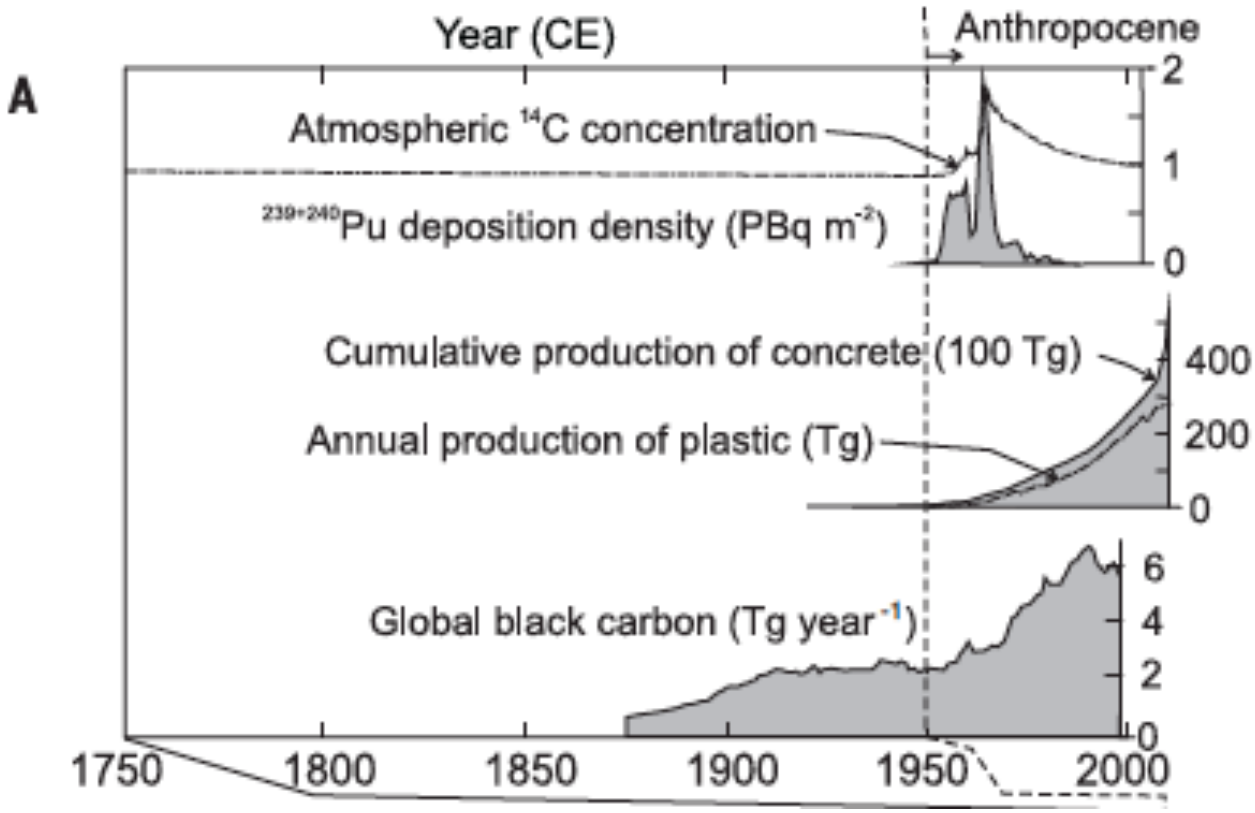
EARTH HISTORY

The Anthropocene is functionally and stratigraphically distinct from the Holocene

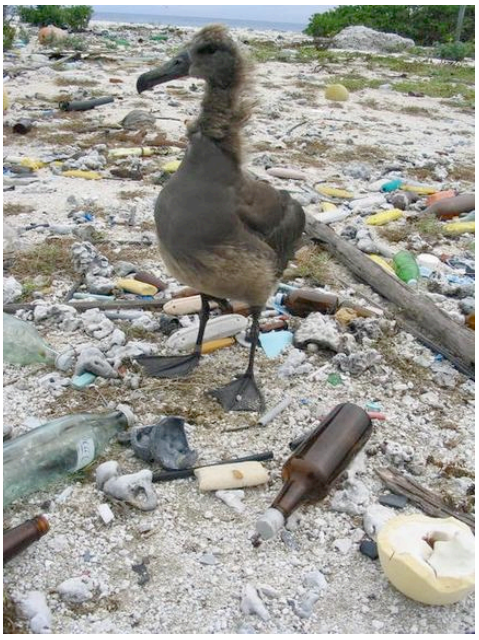
Colin N. Waters,[1*] Jan Zalasiewicz,[2] Colin Summerhayes,[3] Anthony D. Barnosky,[4] Clément Poirier,[5] Agnieszka Gałuszka,[6] Alejandro Cearreta,[7] Matt Edgeworth,[8] Erle C. Ellis,[9] Michael Ellis,[1] Catherine Jeandel,[10] Reinhold Leinfelder,[11] J. R. McNeill,[12] Daniel deB. Richter,[13] Will 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]

Science , Jan. 8, 2016

Plastics can be stored for geological time scale : Anthropocene

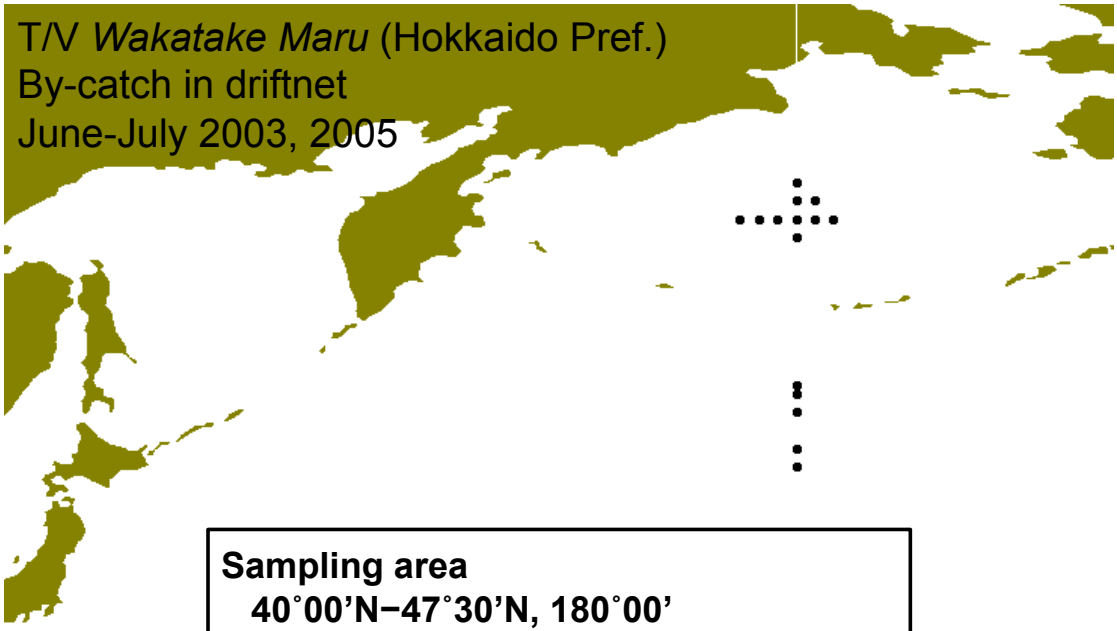


Plastics invade ecosystem



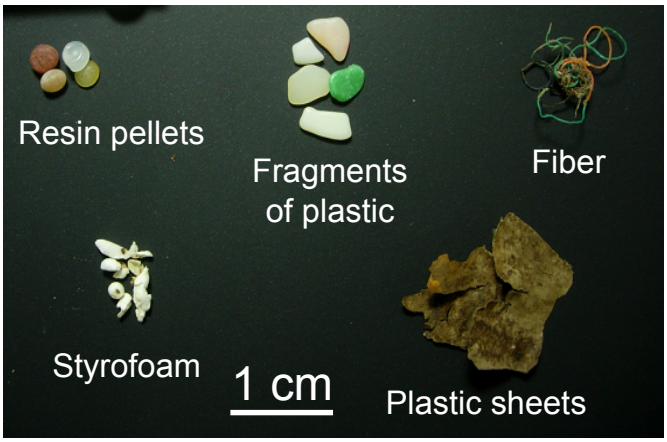
Albatross from Midway atoll

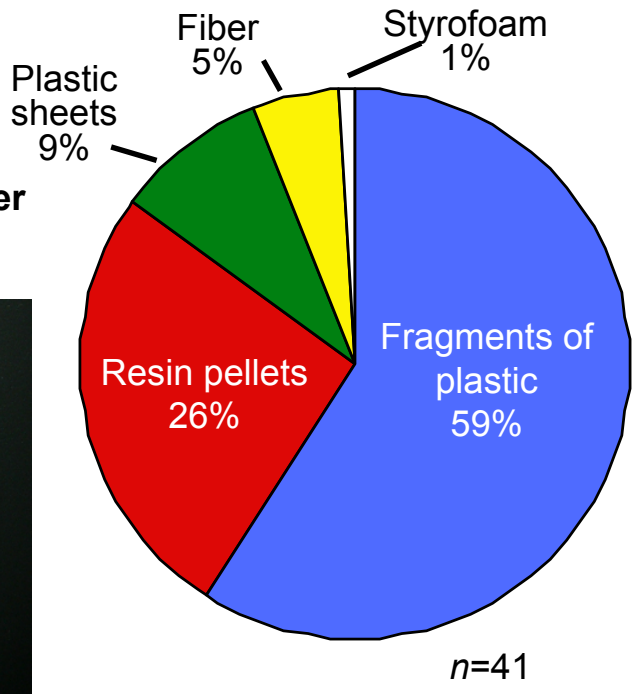
Short-tailed shearwater from Northern pacific



Plastics found in digestive tracts of the seabirds

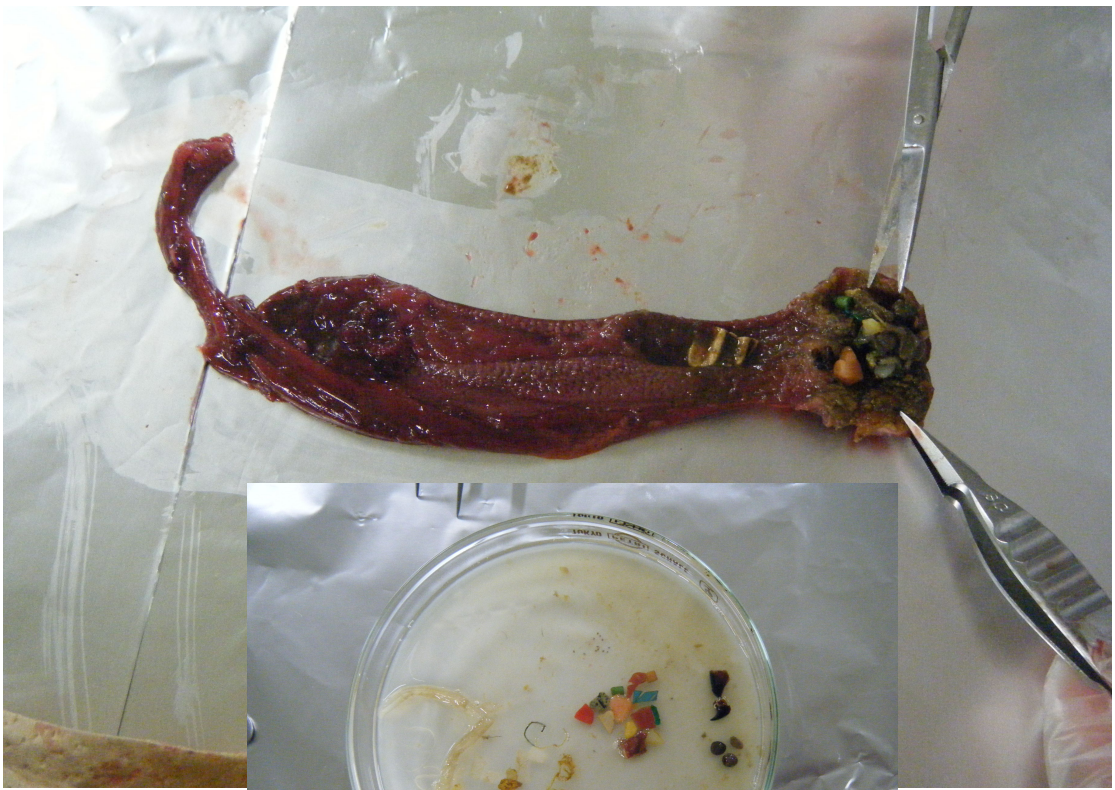
Short-tailed shearwater
Puffinus tenuirostris





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

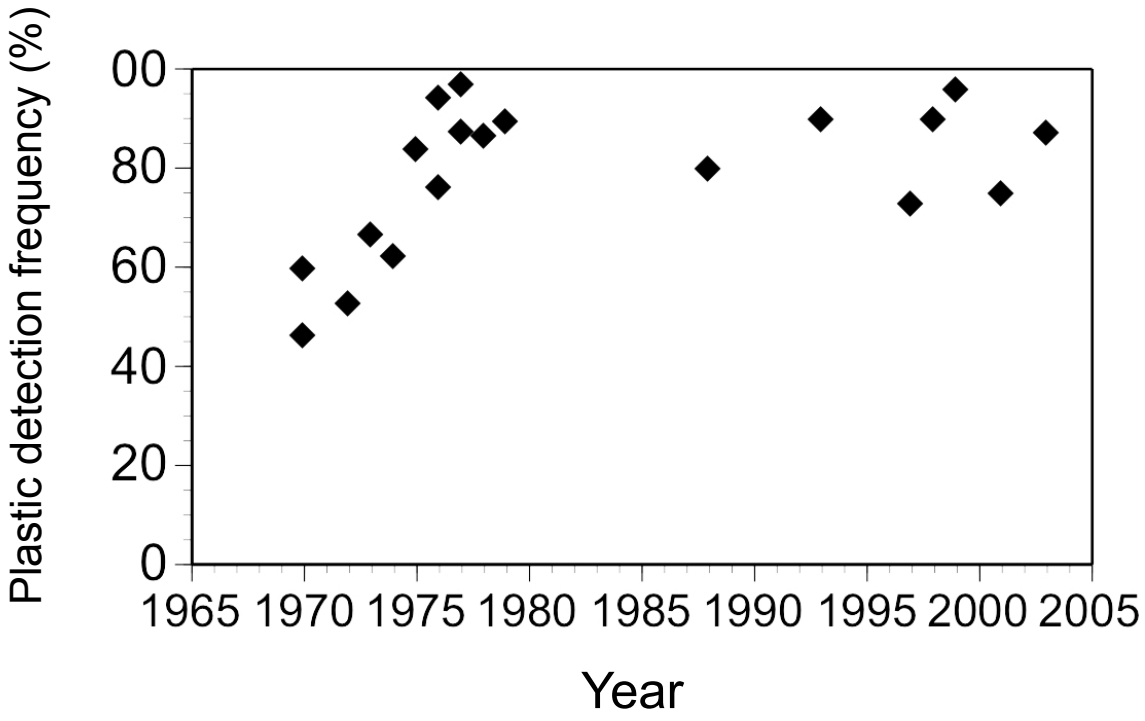
Yamashita et al. 2011



Plastics detected in digestive tract of short-tailed shearwater

0.1 g – 0.6 g per an individual

Temporal increasing trend in plastic ingestion



After Yamashita (2006)

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]

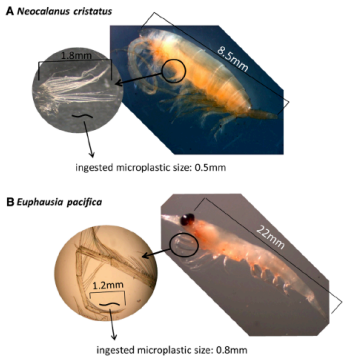


Fig. 2 The feeding appendage anatomy of **a** *N. cristatus* and **b** *E. pacifica* suggest that the sizes of ingested microplastic particles were within the physical limits of mouth gape and handling capacity of setae. The average microplastic particle size detected in this study is shown in relation to the size of setae for both zooplankton species

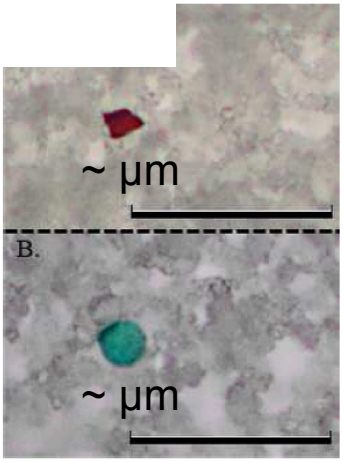


Fig. 1. Microplastics detected in the acid digested *Mytilus edulis* and *Crassostrea gigas*. A. Red particle recovered from *Mytilus edulis*; B. Green sphere detected in the soft tissue of *Crassostrea gigas*. (Scale bar: 50 µm). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

OPEN

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

Received: 01 April 2015
Accepted: 25 August 2015
Published: 24 September 2015

Chelsea M. Rochman[1], Akbar Tahir[2], Susan L. Willia
Jeffrey T. Miller[4], Foo-Ching Teh[1], Shinta Werorilan

SCIENTIFIC REPORTS

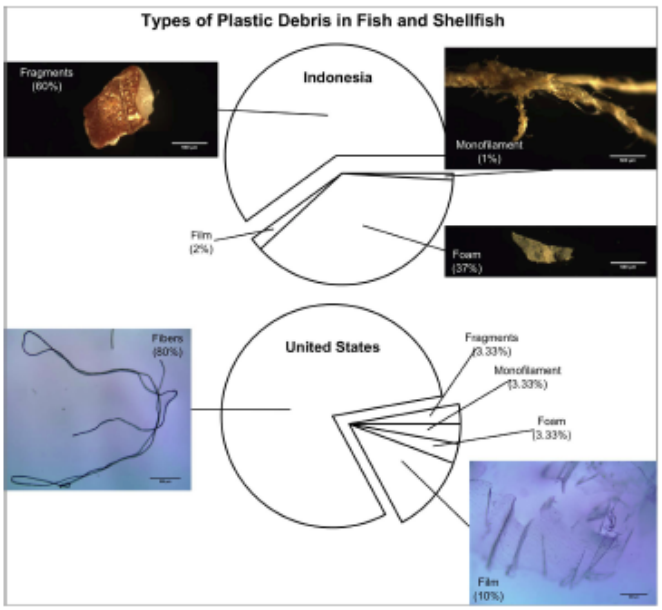


Figure 3. Types of anthropogenic debris in market fish products sampled from Indonesia and the United States. The pie charts above show the percentage of each type (i.e. plastic fragments, fibers, plastic film, plastic foam and plastic monofilament) of anthropogenic debris found across all fish sampled from Indonesia (top) and the United States (bottom). Images show examples of each type of debris found. Scale bars on all pictures are set at 500μm.

Microplastics were detected in 49 of 64 anchovies

Topics

Anthropocene : Plastic age

Plastic pollution in organisms, Water, Sediment core

Hazardous chemicals in marine plastics

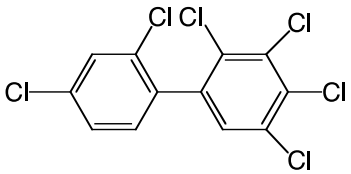
International Pellet Watch

Hazardous chemicals in microplastics

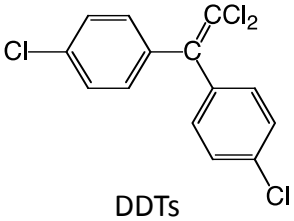
Transfer and accumulation of hazardous chemicals from ingested plastics to biological tissue

Plastics carry two types of chemicals in marine environment

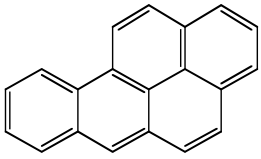
Sorption from ambient seawater



Polychlorinated biphenyl (PCBs)

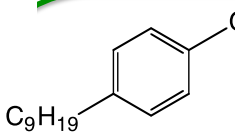


DDTs

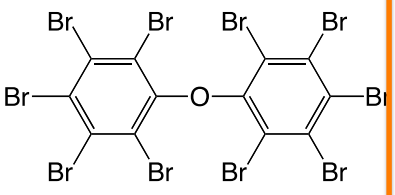


Polycyclic aromatic hydrocarbons (PAHs)

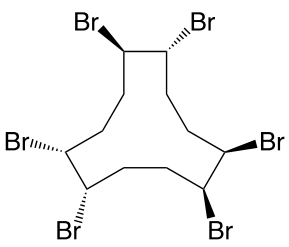
Additive-derived chemicals



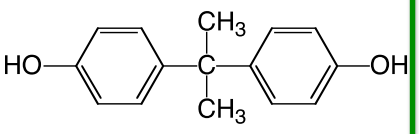
Nonylphenol



Polybrominated diphenyl ethers (PBDEs)



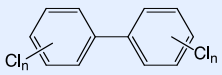
Hexabromocyclododecanes (HBCDs)



Bisphenol A

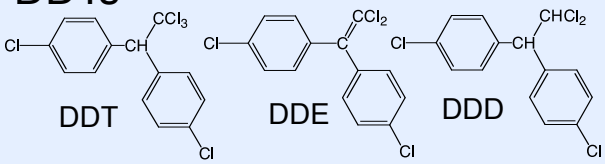
Pellets accumulate POPs from seawater

PCBs



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

DDTs

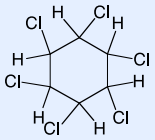


- DDT and its metabolites such as DDE and DDD.
- DDT was used as insecticides
- Endocrine disrupting chemicals

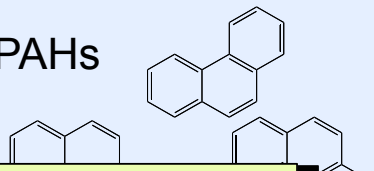
adsorption from ambient seawater

Plastics

HCH



PAHs



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

International Pellet Watch

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

Since 2005

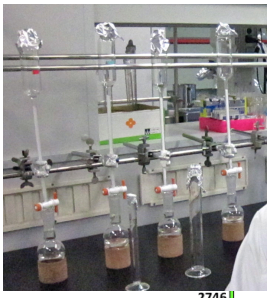
More than 50 pieces (~ 100 pieces) per one location

Air Mail

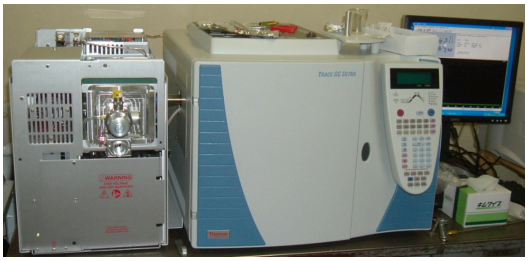
Laboratory of Organic Geochemistry, Dr. Hideshige Takada, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183-8509, Japan

Plastic resin pellet from various areas in the world

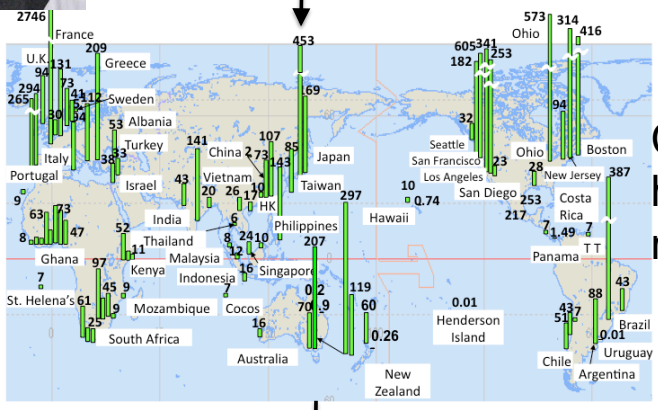
Analysis for persistent organic pollutants (POPs)



Chemical Analysis



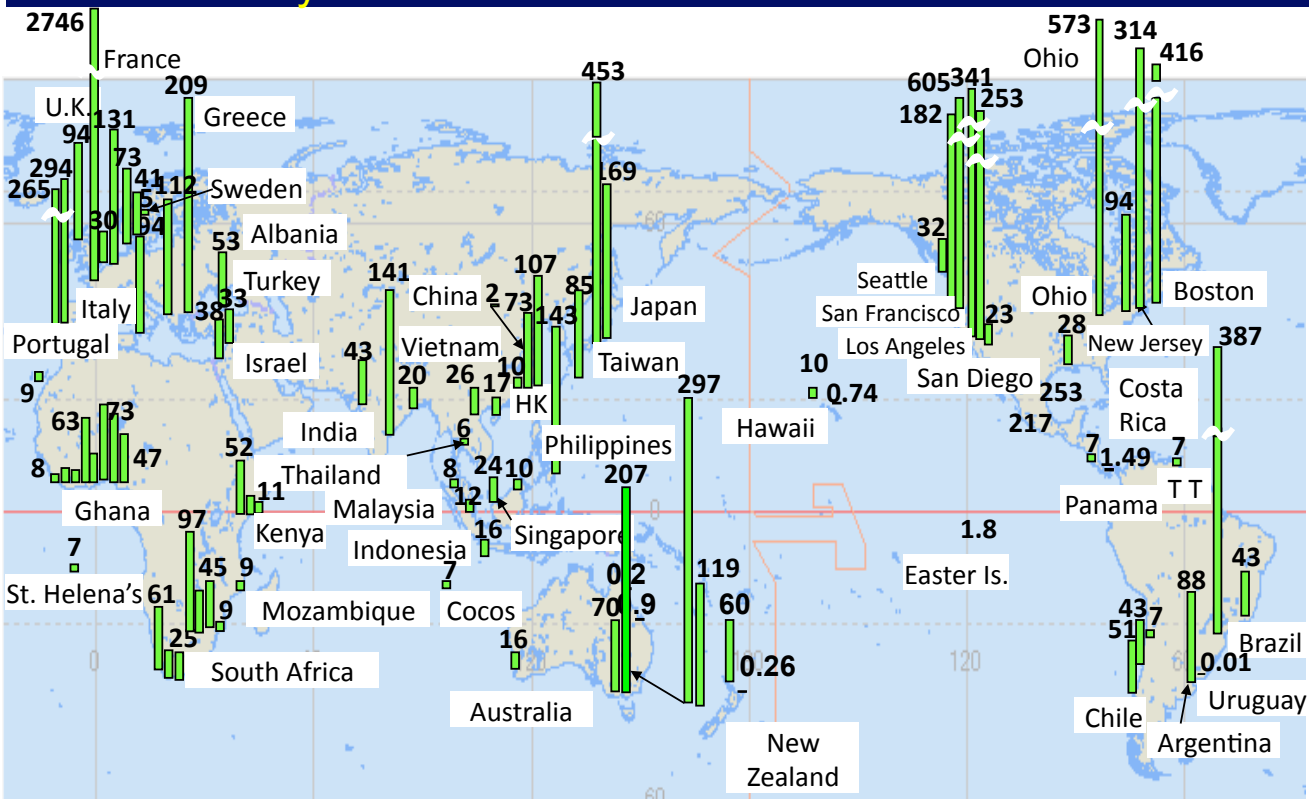
Status of Global pollution



Chemical hazardousness of marine plastics

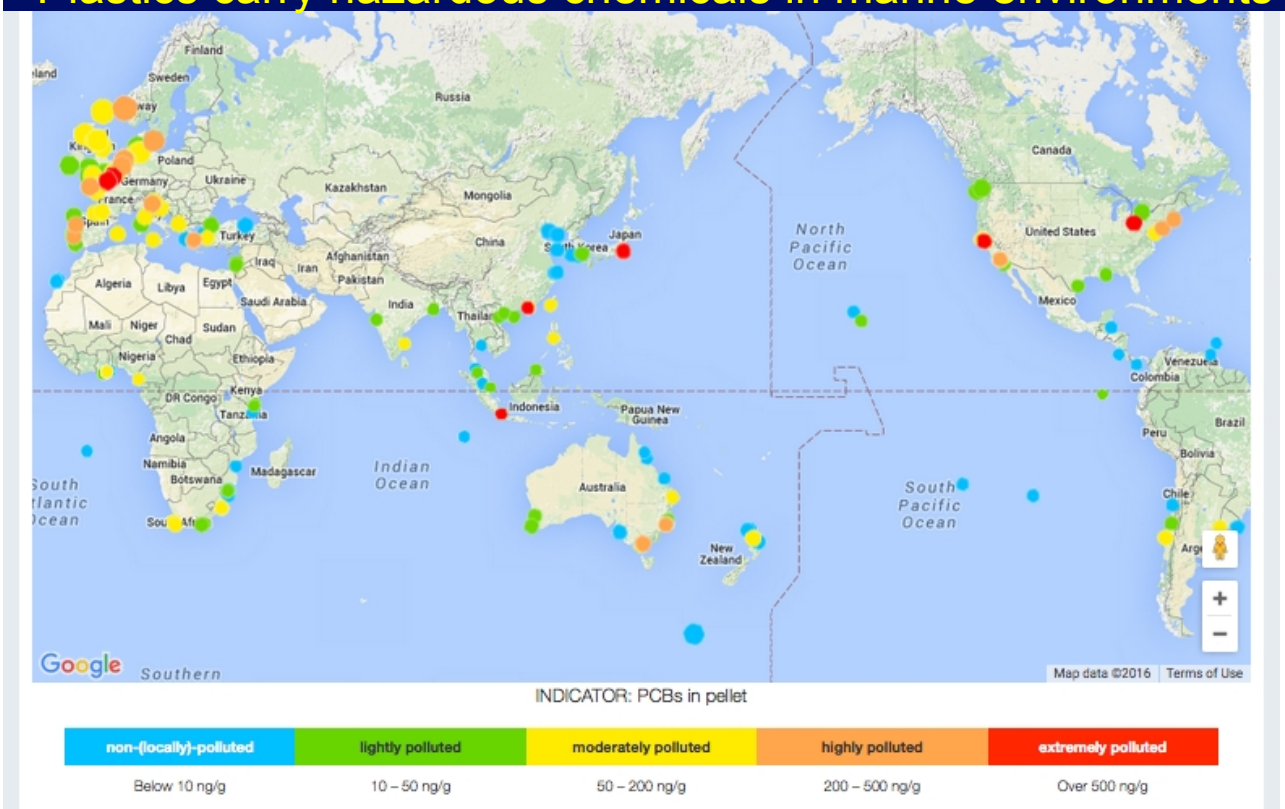
- **Feed the data** back to the collaborators via e-mail
- **Releasing** the results on **web** http://**www.pelletwatch.org/**

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



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

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



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

Topics

Anthropocene : Plastic age

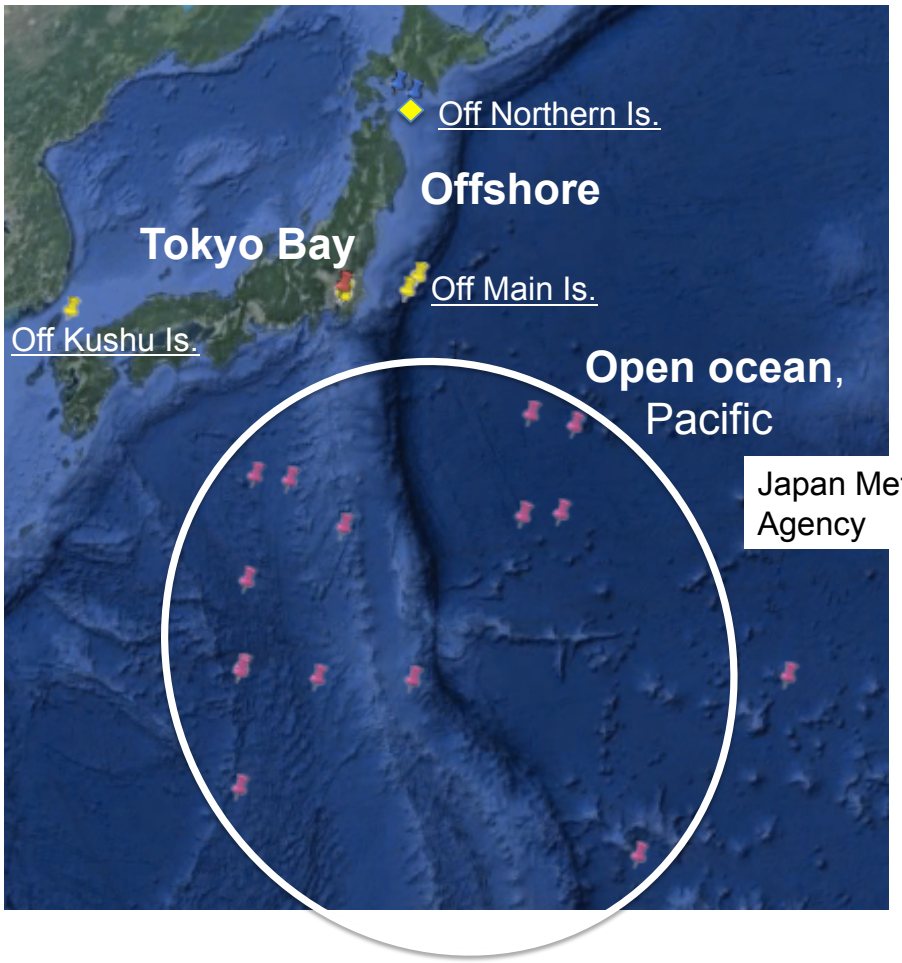
Plastic pollution in organisms, Water, Sediment core

Hazardous chemicals in marine plastics

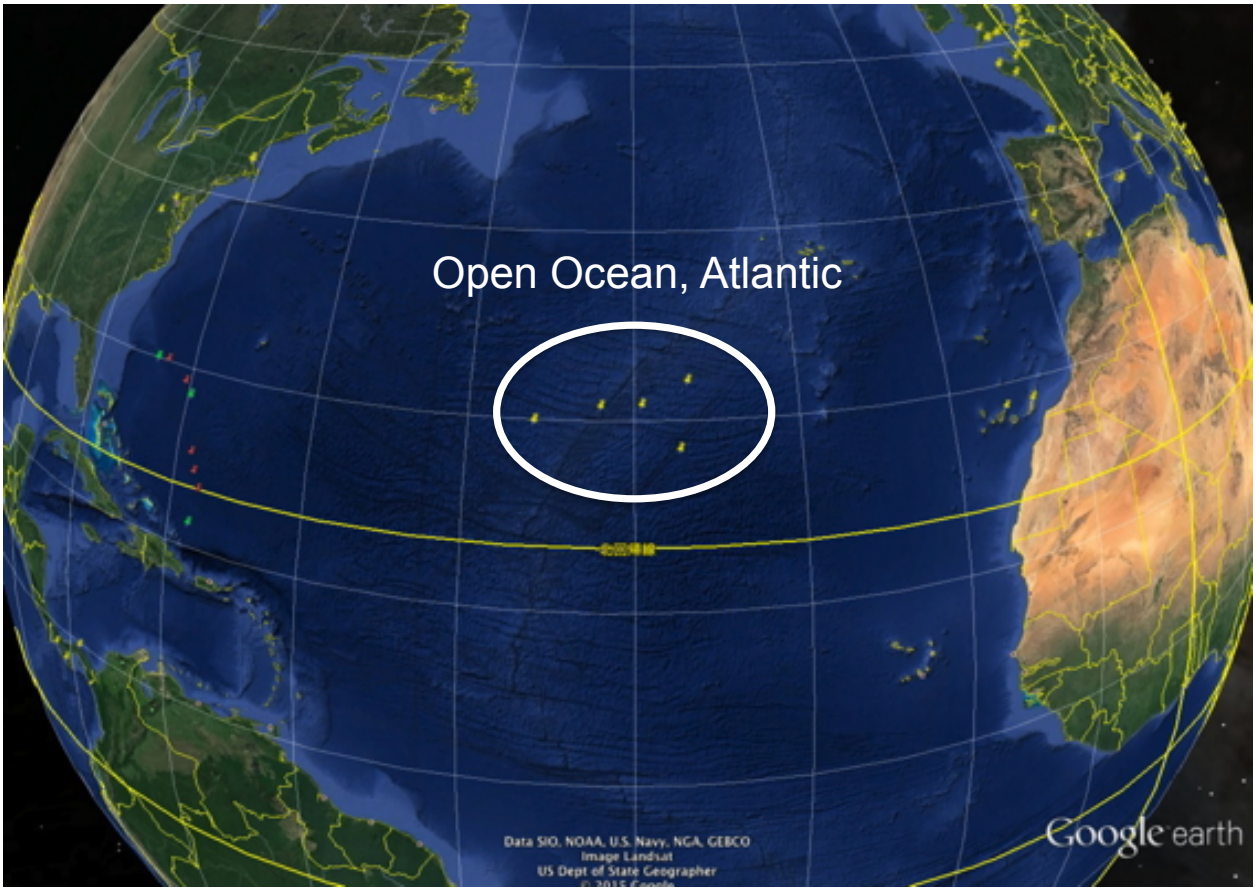
International Pellet Watch

Hazardous chemicals in microplastics

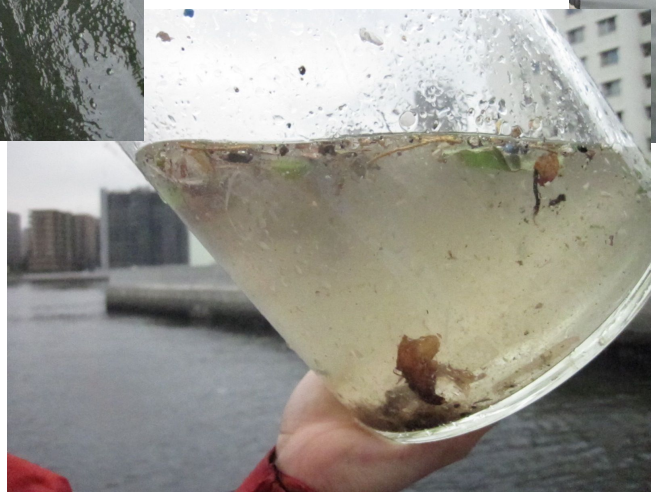
Transfer and accumulation of hazardous chemicals from ingested plastics to biological tissue



Microplastic samples from Ms. Nicole Trenholm: Ocean Research Project



Collecting microplastics in seawater



Microplastics for POPs analysis

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

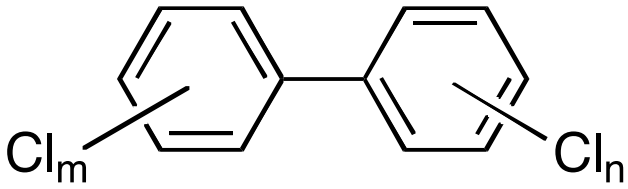
Alkanes

25% DCM in Hexane

PCBs, PBDEs

GC-ITMS

Polychlorinated biphenyls (PCBs)



m + n = 1 - 10

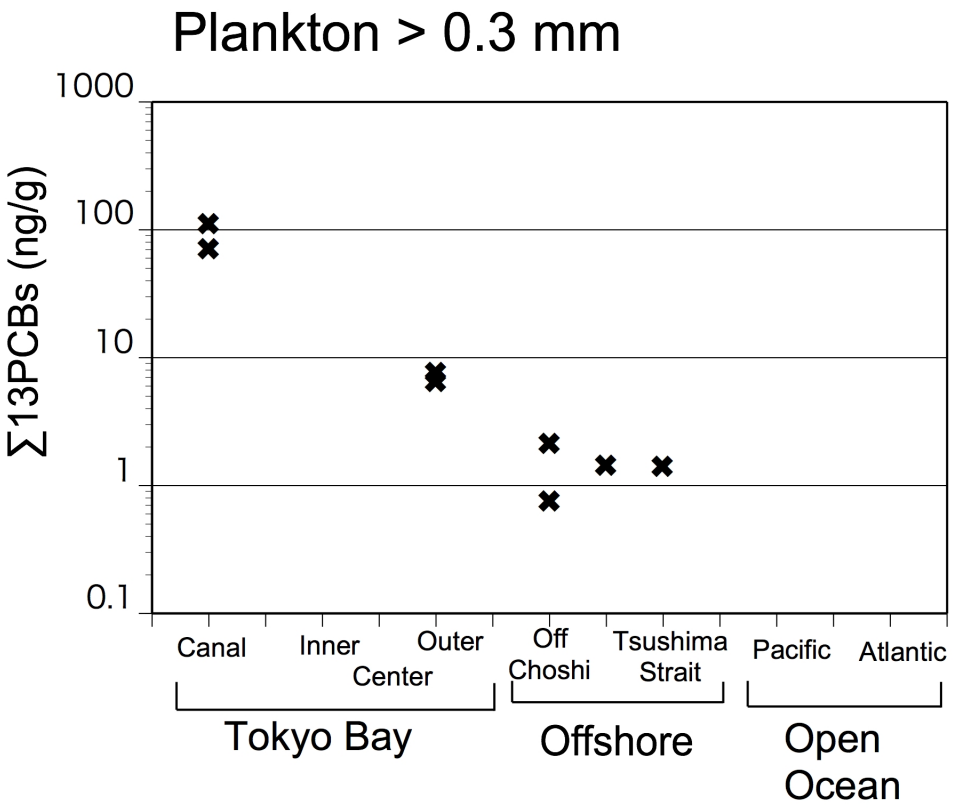
Commercial PCBs mixtures were used in a wide variety of applications, including

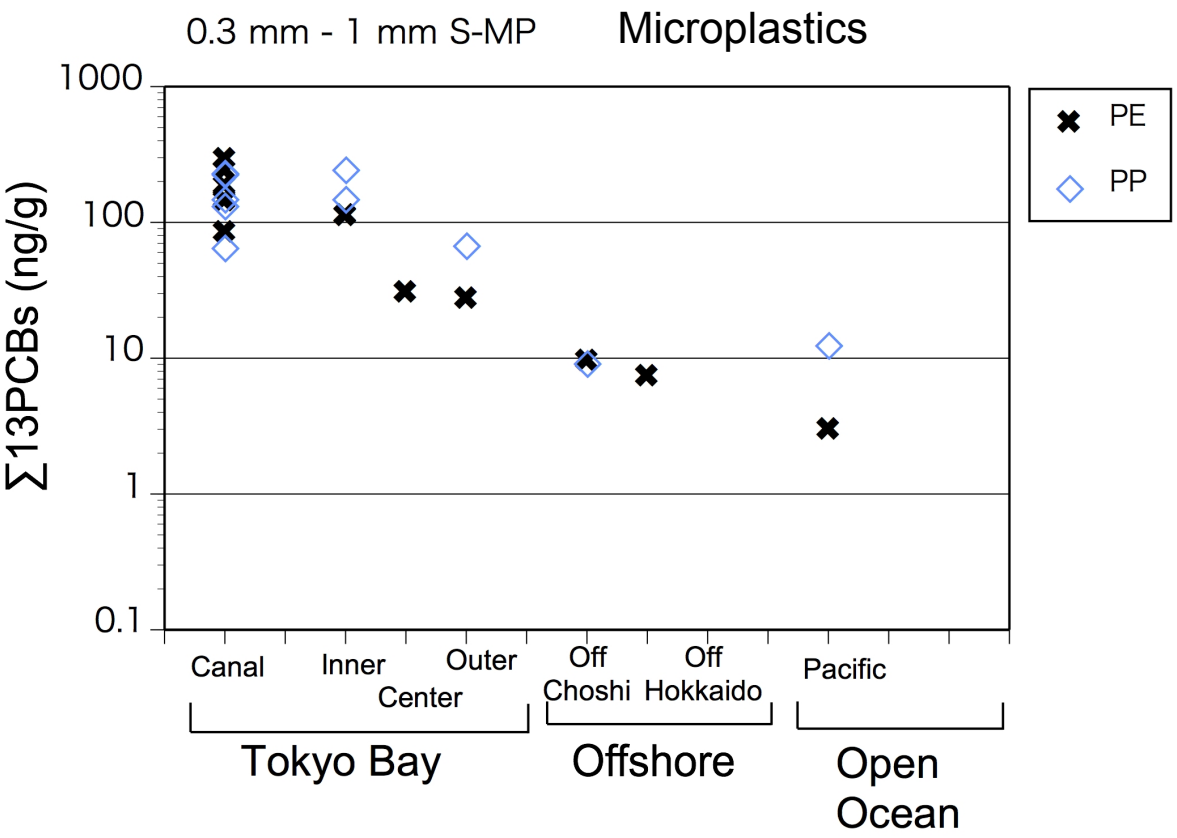
Dielectric fluids in capacitors and transformers
Heat transfer fluid

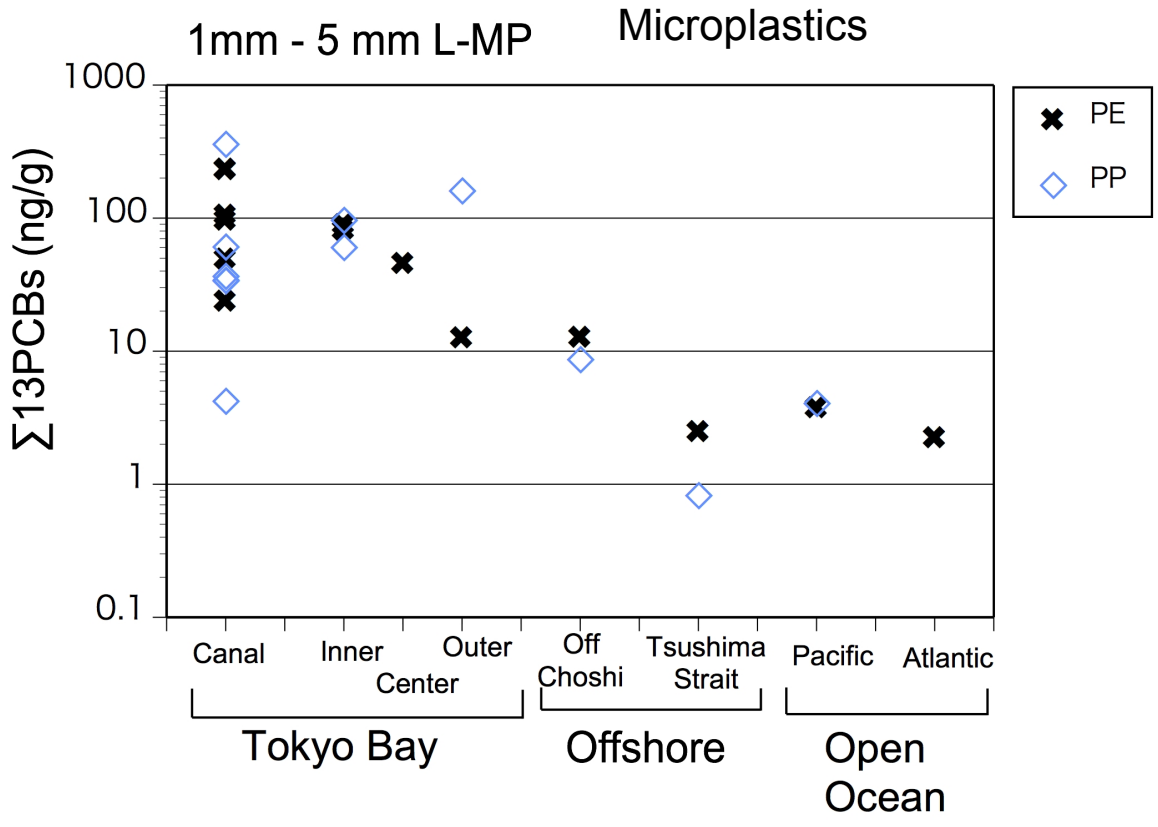
PCBs were used from 1950s to early 1970s in industrialized countries.

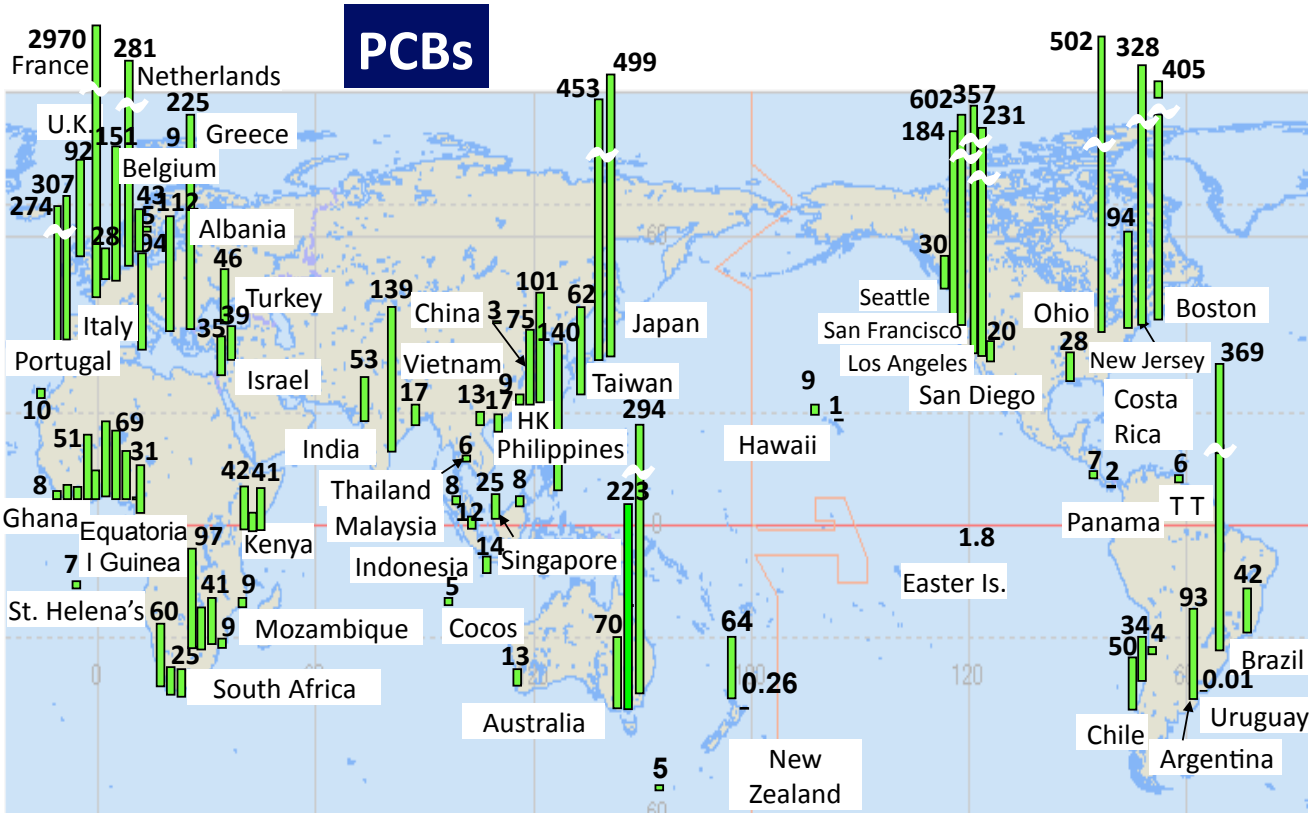
Their usage was banned in 1970s

PCBs are deleterious to marine life, especially upper-trophic-level organisms that tend to accumulate the compounds in their tissues. While the precise toxicological effects of PCBs are often unclear, they have been implicated in reproductive abnormalities in marine mammals (e.g., porpoises, seals, sea lions, whales).[1,46,47] In addition to being linked to a variety of chronic diseases in humans (e.g., skin lesions, reproductive disorders, liver damage), PCBs are suspected of being carcinogenic.




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

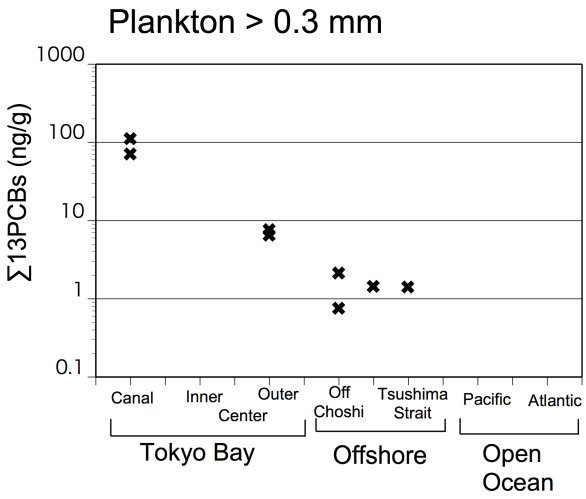

1mm - 5 mm L-MP
Microplastics
1000
100
10
1
0.1
∑13PCBs (ng/g)
PE
PP
Canal
Inner
Center
Outer
Off
Choshi
Tsushima
Strait
Pacific
Atlantic
Tokyo Bay
Offshore
Open
Ocean

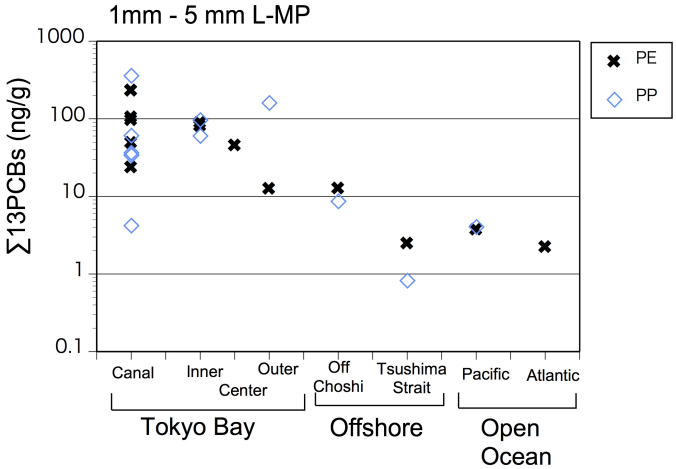


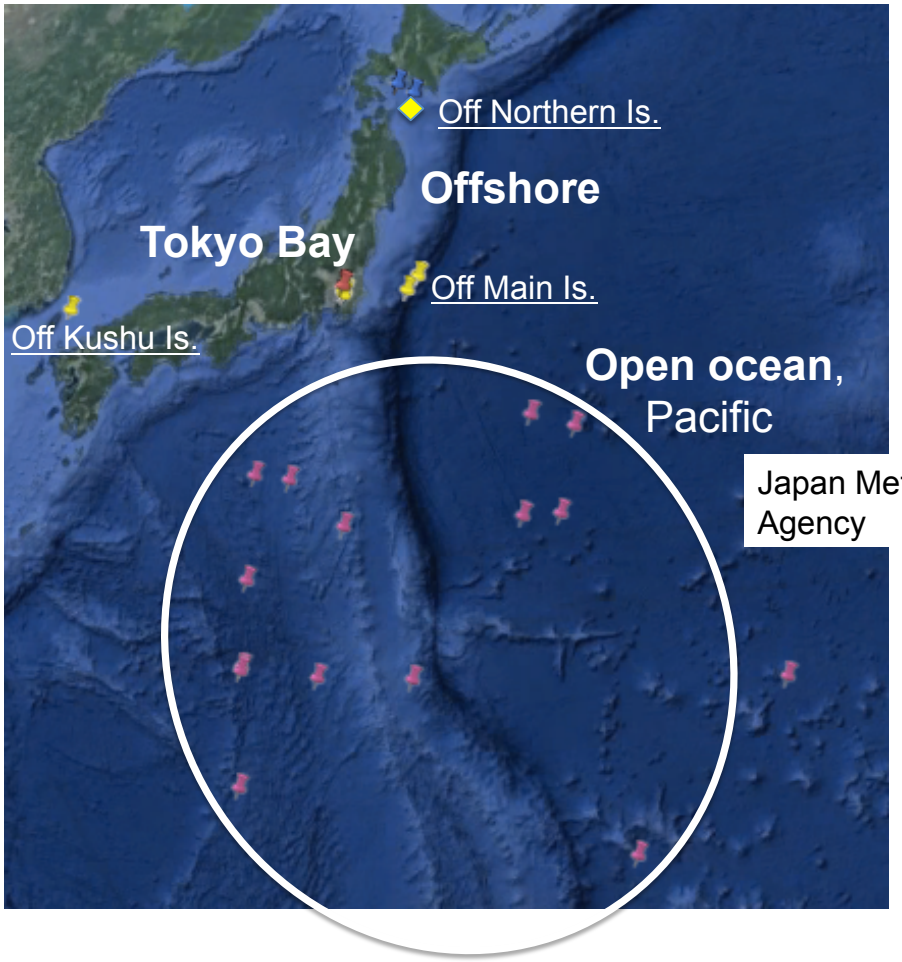
Concentration of PCBs* in beached plastic resin pellet (ng/g-pellet)

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

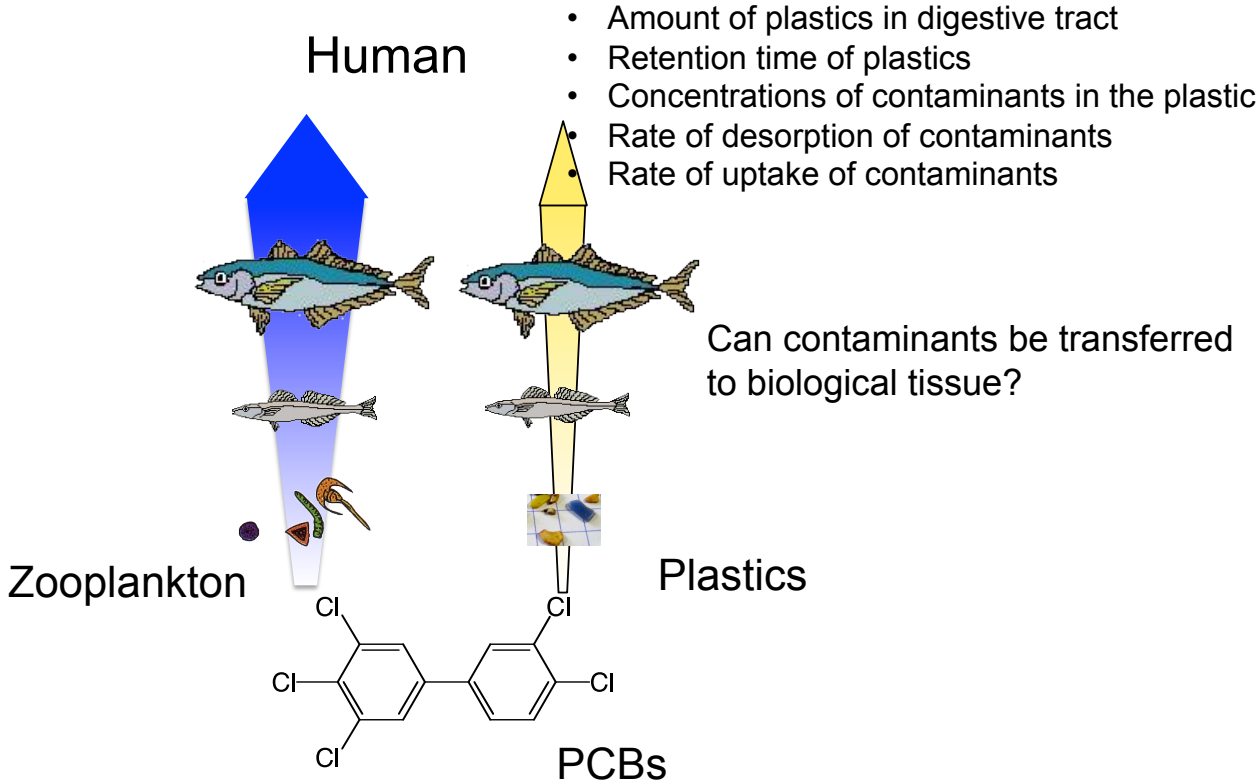
Measured by Polaris Q (Thermo Fisher Scientific)







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



- Amount of plastics in digestive tract
- Retention time of plastics
- Concentrations of contaminants in the plastic
- Rate of desorption of contaminants
- Rate of uptake of contaminants

Can contaminants be transferred to biological tissue?

Topics

Anthropocene : Plastic age

Plastic pollution in organisms, Water, Sediment core

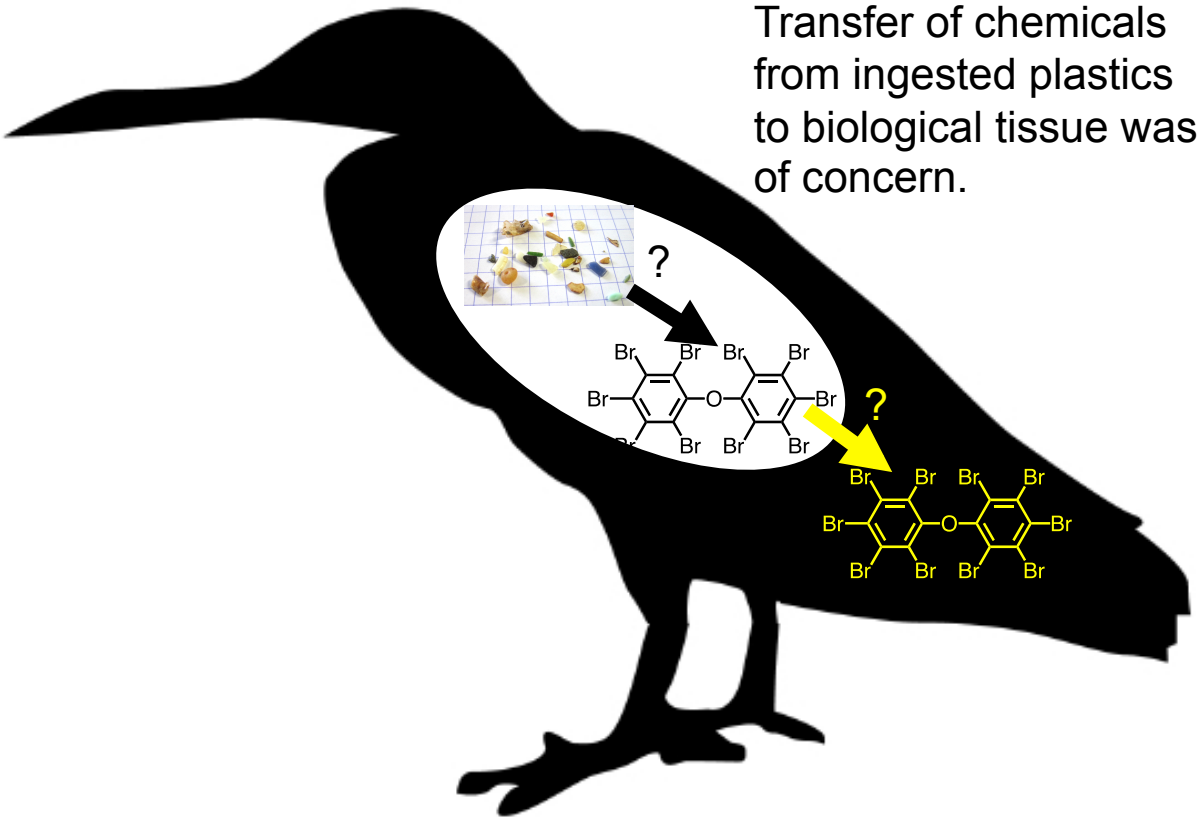
Hazardous chemicals in marine plastics

International Pellet Watch

Hazardous chemicals in microplastics

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

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]

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

Marine Pollution Bulletin 69 (2013) 219–222

Contents lists available at SciVerse ScienceDirect

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*
[c] *Faculty of Fisheries, Hokkaido University, Hakodate, Hokkaido, Japan*

ARTICLE INFO

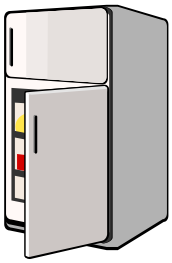
Keywords:
Polybrominated diphenyl ethers (PBDEs)
Plastic debris
Additives
North Pacific Ocean
Short-tailed shearwater
Bioaccumulation

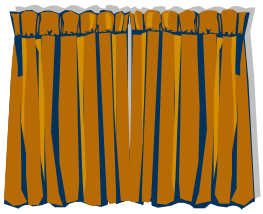
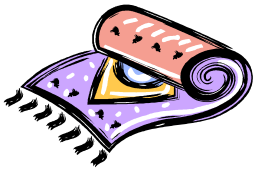
ABSTRACT

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.

PBDEs : Flame retardants

applied in various electric products and fabrics.



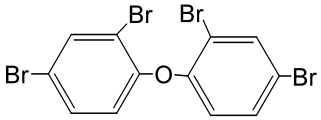



Lower brominated

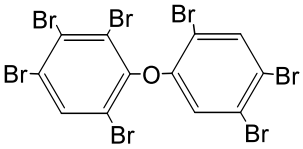
(Br4, Br5)

Higher brominated

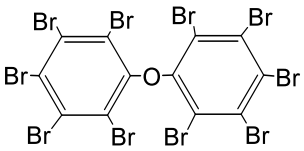
(Br7 - 10)



BDE47

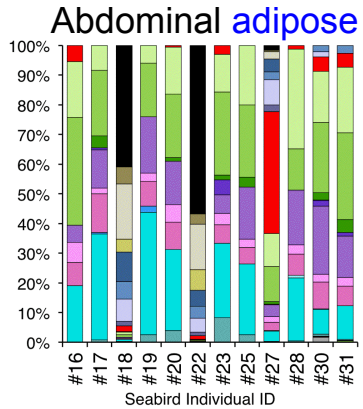


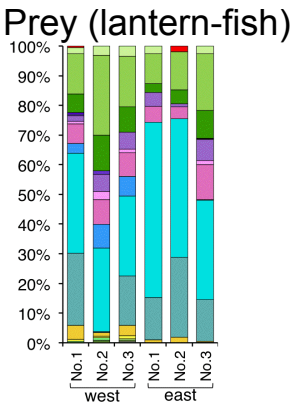
BDE183

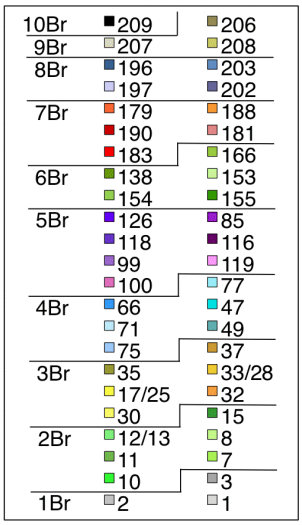


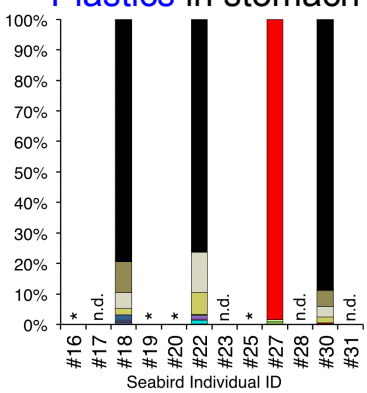
BDE209

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









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

ENVIRONMENTAL Science & Technology

Article

pubs.acs.org/est

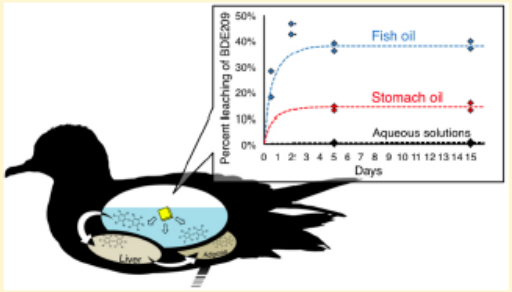
Facilitated Leaching of Additive-Derived PBDEs from Plastic by Seabirds' Stomach Oil and Accumulation in Tissues

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

[†]Laboratory of Organic Geochemistry, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183-8509, Japan
[‡]Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Kushiro, Hokkaido 085-0802, Japan
[§]Faculty of Fisheries, Hokkaido University, Hakodate, Hokkaido 041-8611, Japan

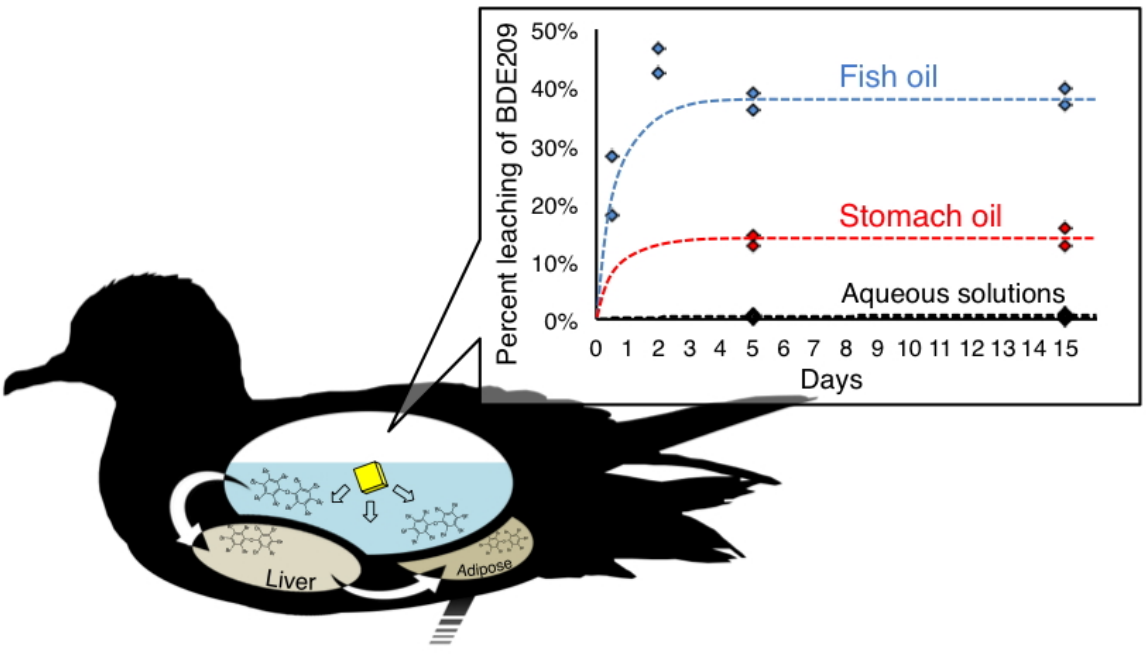
Supporting Information

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 hexa-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.

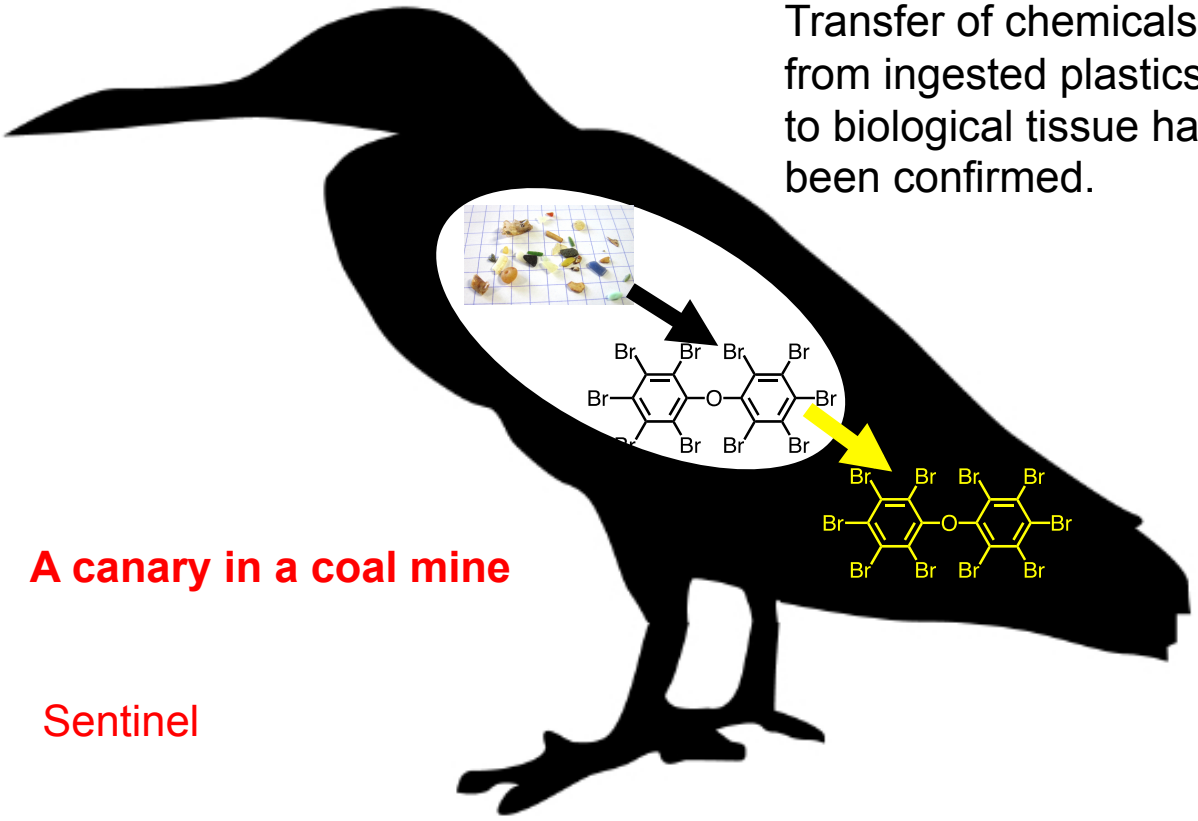


Stomach oil facilitates release of additive-chemicals to digestive fluid

Trojan Horse



Transfer of chemicals from ingested plastics to biological tissue



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

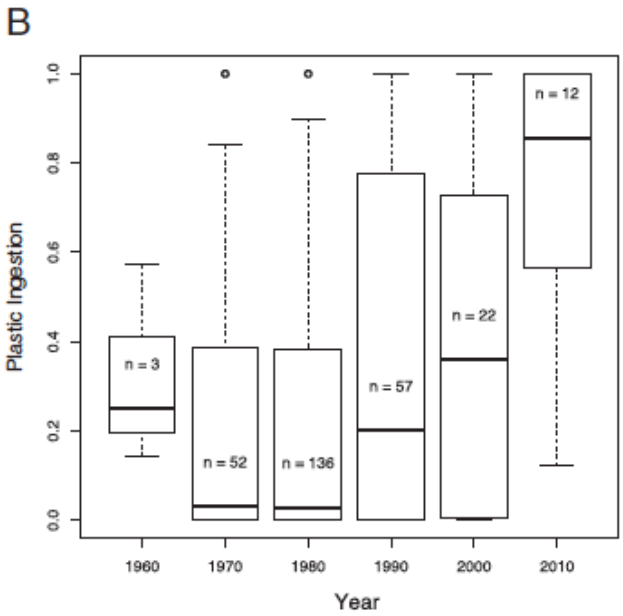
A canary in a coal mine

Sentinel

~90 % of seabirds ingest plastics

Threat of plastic pollution to seabirds is global, pervasive, and increasing

Chris Wilcox[a,1], Erik Van Sebille[b,c], and Britta Denise Hardesty[a]



Plastic ingestion : Chemical exposure?

Plastic Ingestion

- Amount of plastics in digestive tract
- Retention time of plastics
- Biological characteristics
- Concentrations of contaminants in the plastic
- Rate of desorption of contaminants
- Rate of uptake of contaminants

Accumulation of plastic-derived chemicals in organisms

Methods in Ecology and Evolution

Methods in Ecology and Evolution 2015, 6, 92–98 doi: 10.1111/2041-210X.12277

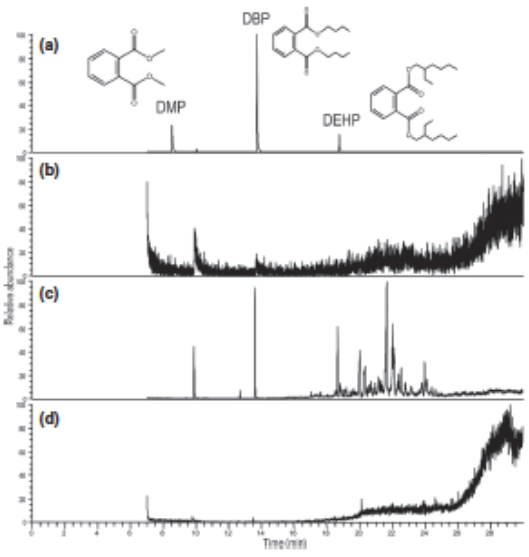
APPLICATION

A biochemical approach for identifying plastics exposure in live wildlife

Britta D. Hardesty*, Daniel Holdsworth, Andrew T. Revill and Chris Wilcox

CSIRO Oceans and Atmosphere Flagship, GPO Box 1538, Hobart, Tas., 7000, Australia

Fig. 1. Sampling the uropygial gland: with bird in the hand, gently massage the gland and express the oil.



Environ. Sci. Technol. **2007**, *41*, 4901−4906

Evaluation of Noninvasive Approach for Monitoring PCB Pollution of Seabirds Using Preen Gland Oil

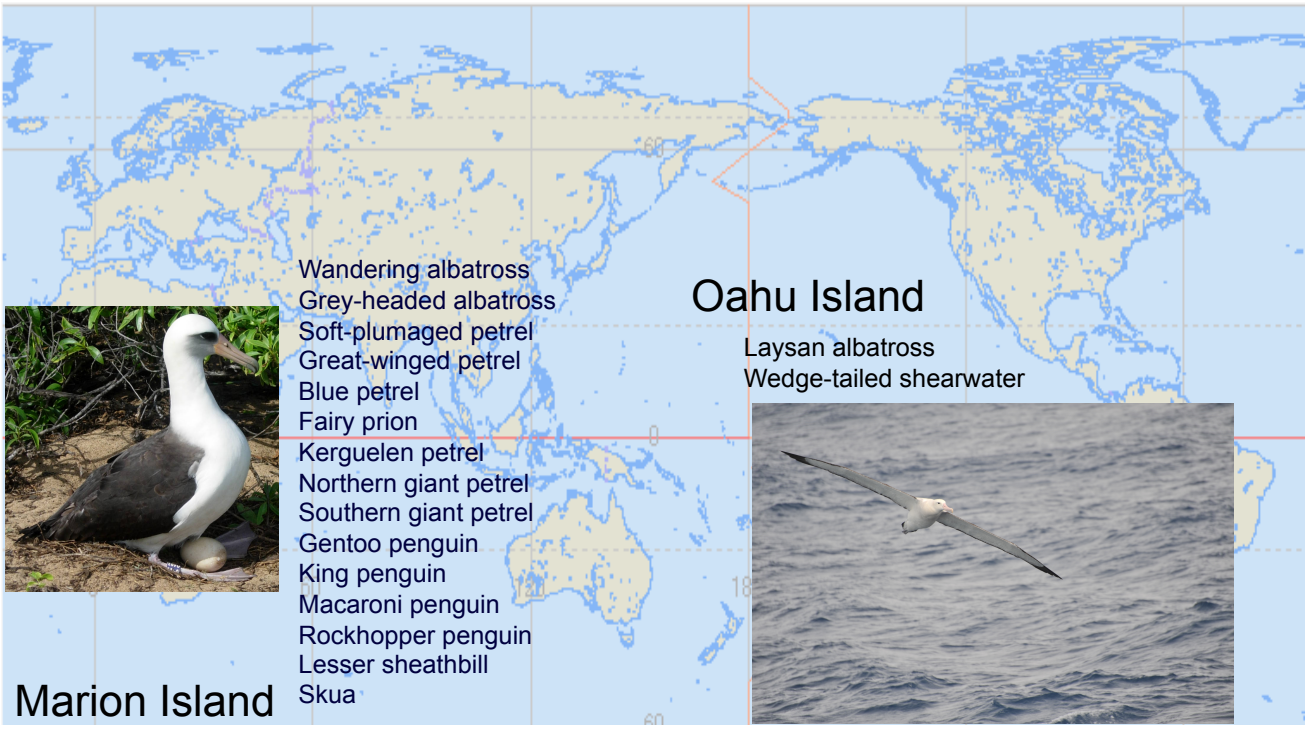
REI YAMASHITA,† HIDESHIGE TAKADA,*,‡ MICHIO MURAKAMI,‡ MASA-AKI FUKUWAKA,§ AND YUTAKA WATANUKI†

Faculty of Fisheries, Hokkaido University, Minato-cho 3-1-1, Hakodate, Hokkaido, 041-8611, Japan, Laboratory of Organic Geochemistry (LOG), Tokyo University of Agriculture and Technology, Saiwai-cho 3 Japan, Hokkaido Nationa Fisheries Research Agency

Although there i distributed widely a species from a limit their accumulation centrated in freshw Europe and North A data have been de oceanic islands (6– practical, and techr particularly from oc most of previous st However, this is a pa is difficult to plan.

Several methods from living birds, fc

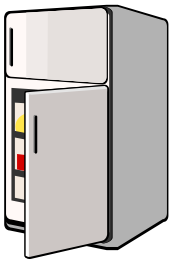
Preen gland oil from various species in various areas

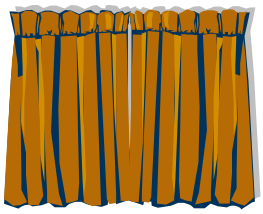
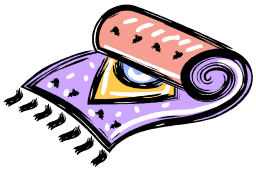


Some are impacted, while the others are not.
However, in future?

PBDEs : Flame retardants

applied in various electric products and fabrics.



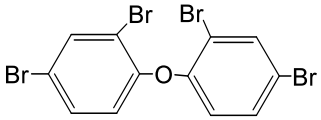



Lower brominated

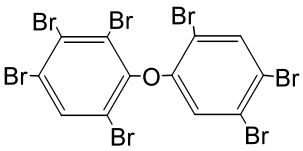
(Br4, Br5)

Higher brominated

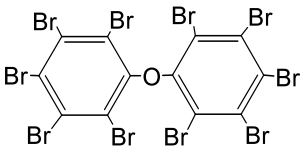
(Br7 - 10)



BDE47



BDE183



BDE209

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,[1] Anthony Andrady,[5] Ramani Narayan,[6] Kara Lavender Law[7]

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.

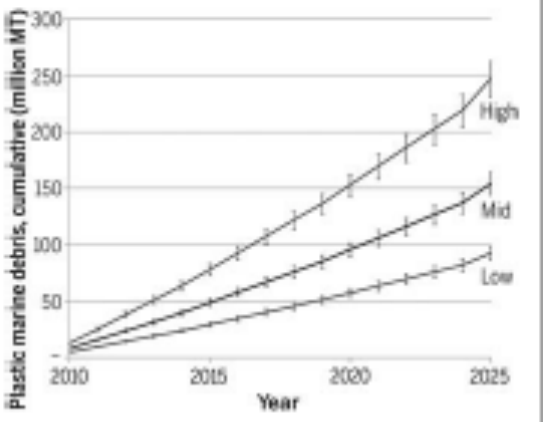


Fig. 2. Estimated mass of mismanaged plastic waste (millions of metric tons) input to the ocean by populations living within 50 km of a coast in 192 countries, plotted as a cumulative sum from 2010 to 2025. Estimates reflect assumed conversion rates of mismanaged plastic waste to marine debris (high, 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

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


COMMENT

ECODESIGN Olympic velodrome engineer builds with nature p.172

ECODESIGN Materials makers on how to do more with less p.174

THEATRE New York play explores why Isaac Newton stuck a needle in his eye p.175

METRICS Some altmetrics are too easy to game so lack credibility p.176

DIMITAR DILKOFF/AFP/GETTY

Reduction of inputs of plastic waste to the sea is necessary


Volunteer cleaners negotiate a Bulgarian reservoir jammed with plastics.

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.

No space for landfill
Limited resources to construct high-tech incinerator

3R

Precautionary principle

Reduce
Reuse : non-reusable plastics
Recycle : consumes energy and emits CO_2

No single-use plastic!

Plastic bag ban

Governmental regulation of **plastic bag** is required .