Issue of plastics in the coastal and marine environment and possible solutions –

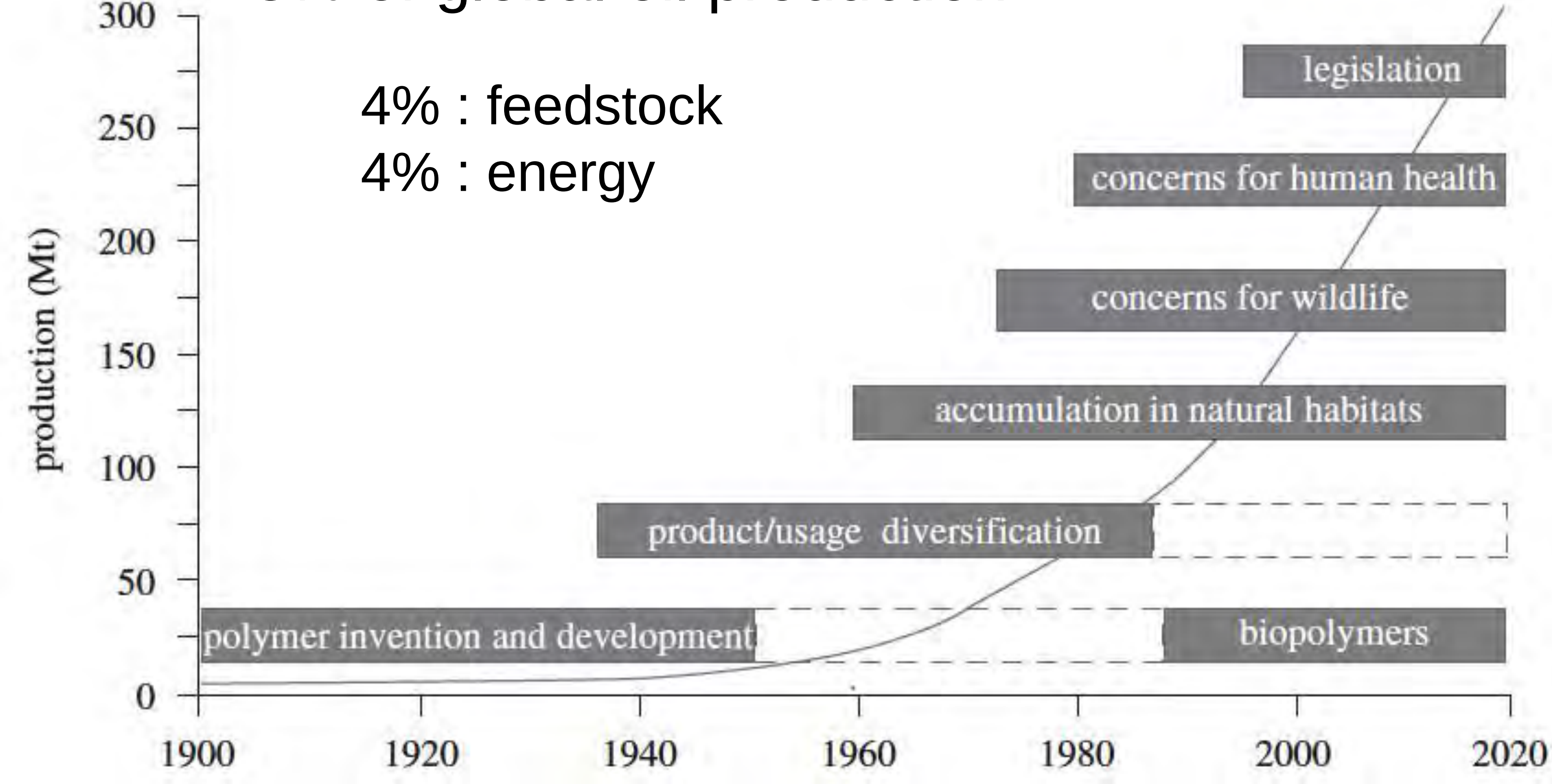
Hideshige TAKADA

Laboratory of Organic Geochemistry (LOG)
Tokyo University of Agriculture and Technology

Continuous increase in plastic production

8% of global oil production

4% : feedstock
4% : energy



1933:Production of Polyethylene started.

Thompson et al., 2009

CITARUM RIVER, INDONESIA

Photo from Dr. Charles Moore

Photo from Dr. Charles Moore

Photo from Dr. Charles Moore


Ishigaki Island, Japan
Photo from Dr. Atsuhiko Isobe

Plastic fragments from remote island

Plastic fragments are dominant over resin pellets

Microplstics (< 5 mm) in Tokyo Bay

Plastics accumulated at 5 gyres in the ocean.

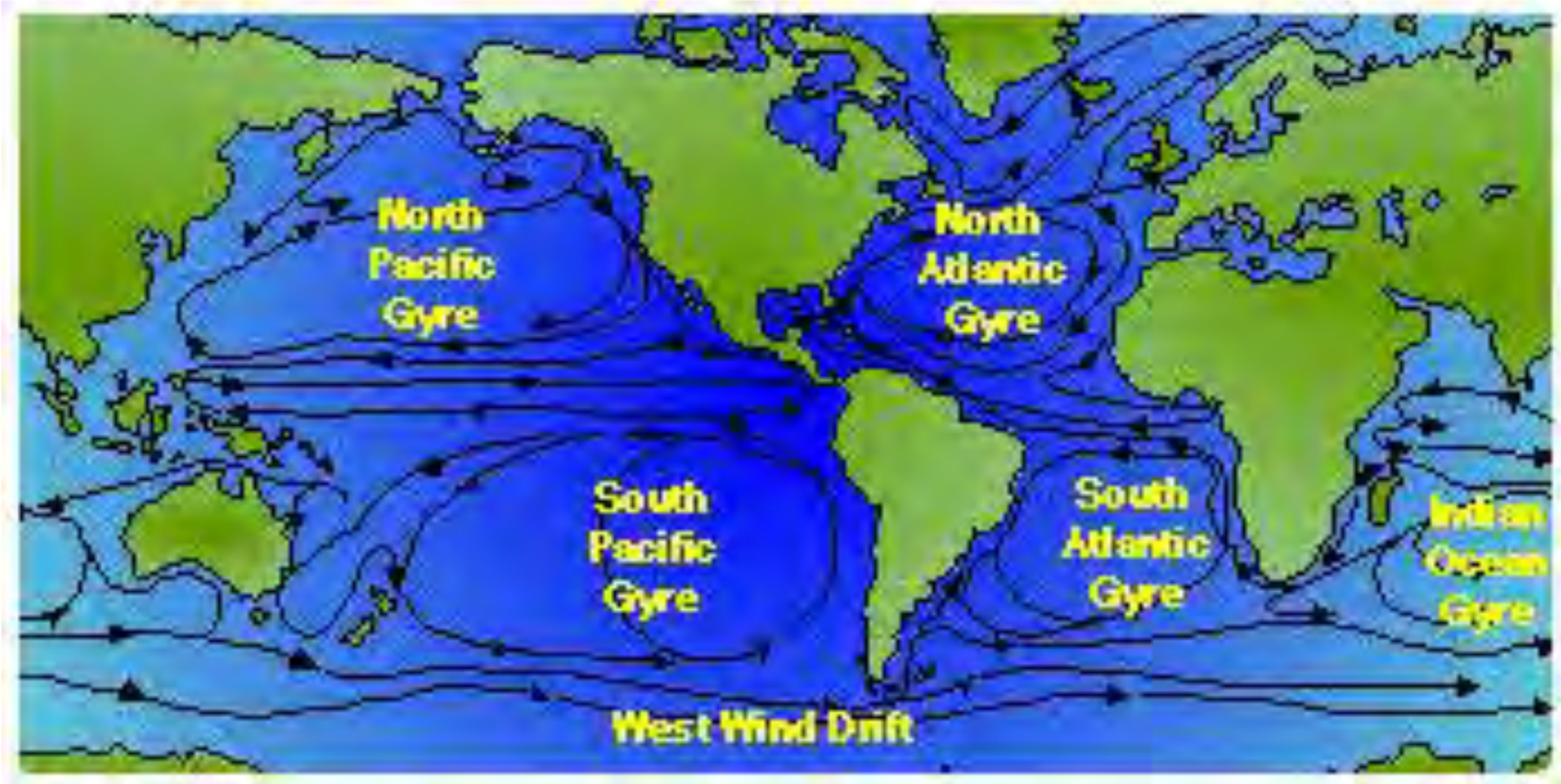


Photo from Dr. Charles Moore

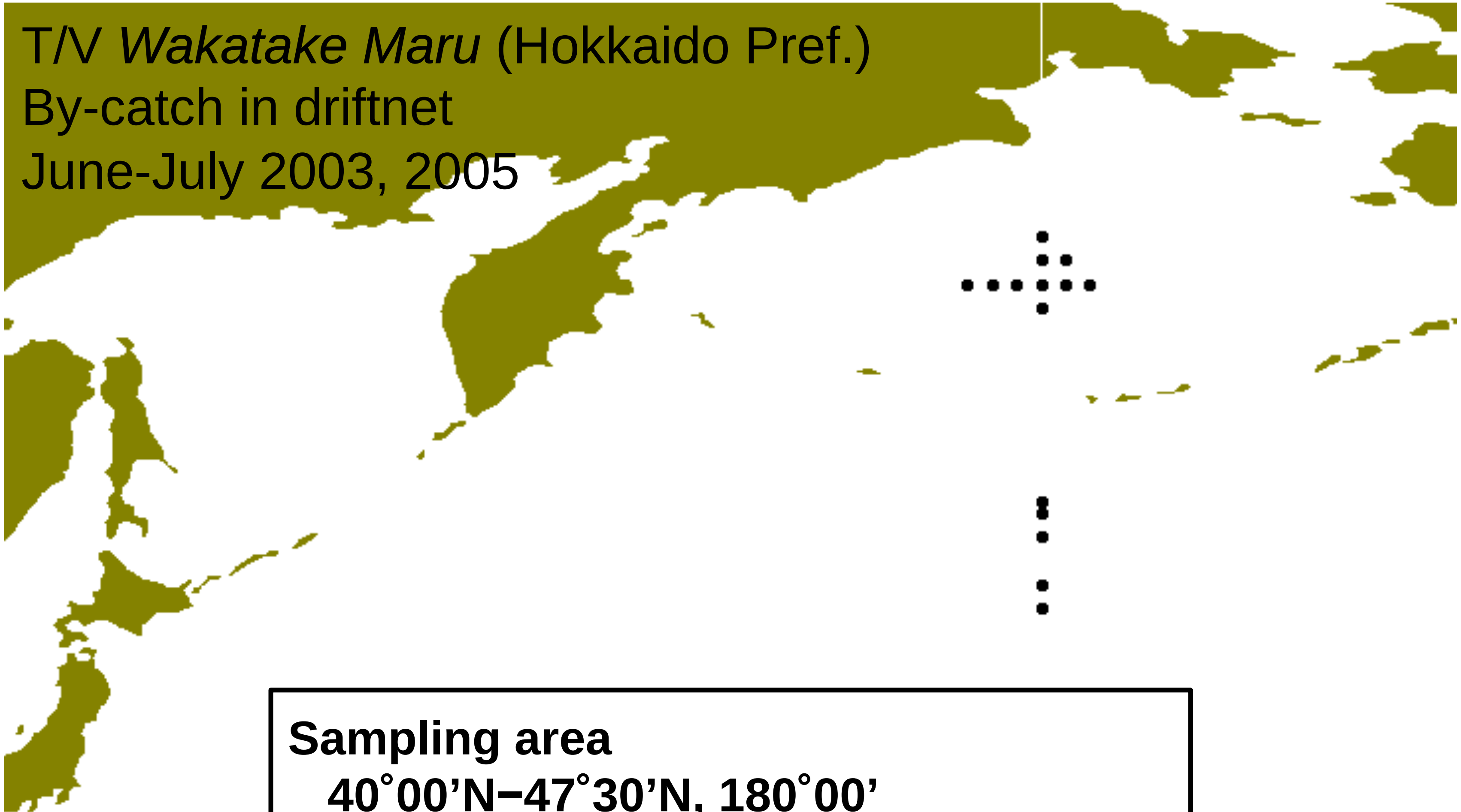
Microplstics accumulated in central gyre of the Pacific :
Plastics 6 times more than plankton

Photo from Dr. Charles Moore

Marine organisms ingest plastics

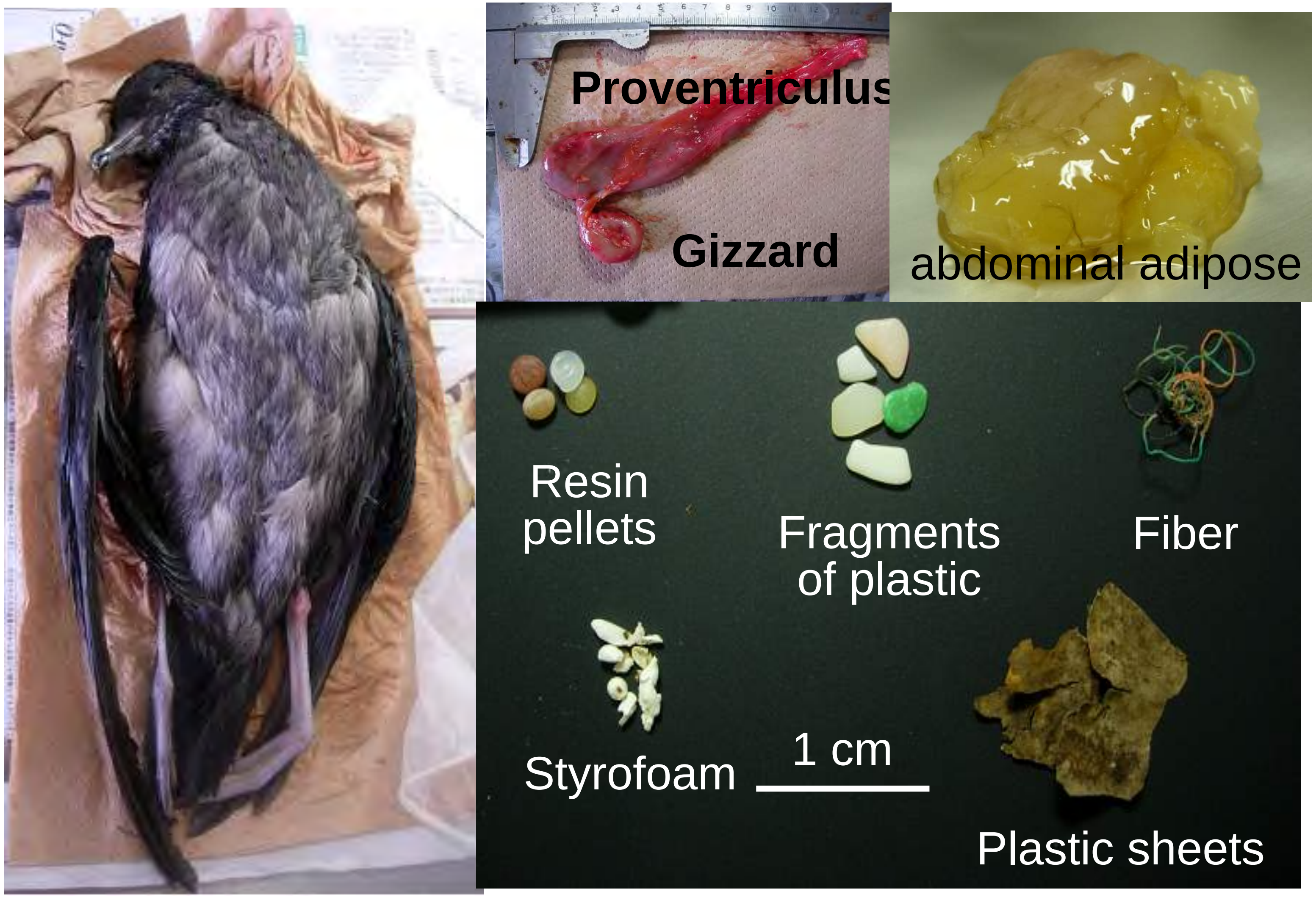
Albatross

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 in stomach of the short-tailed shearwater



- Amount of plastics found in stomach
- PBDEs concentrations in abdominal adipose

Plastics detected in digestive tract of short-tailed shearwater

0.1 g – 0.6 g per an individual

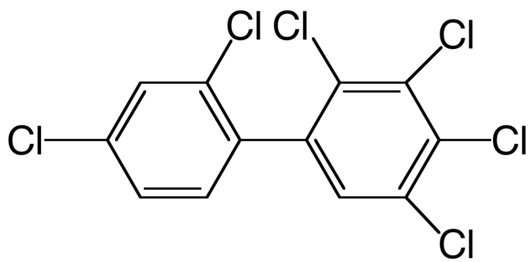
Marine organisms ingest plastics

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

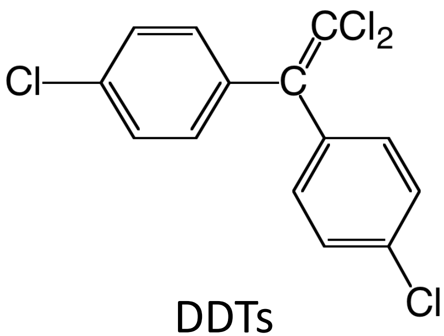
Physical impacts of the ingested plastics have been reported for many species of organisms (Wright et al., 2013).

Plastics carry two types of chemicals in marine environment

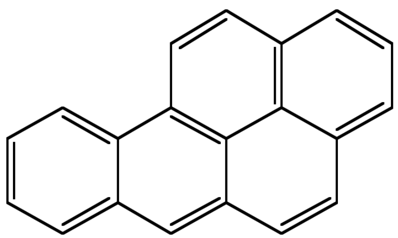
Sorption from ambient seawater



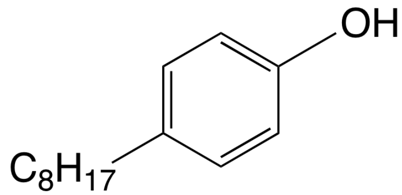
Polychlorinated biphenyl (PCBs)



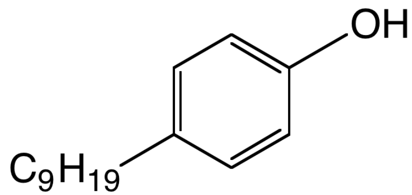
DDTs



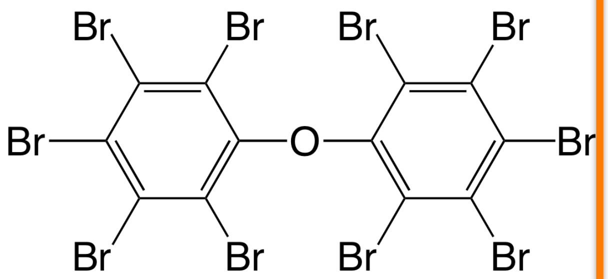
Polycyclic aromatic hydrocarbons (PAHs)



Octylphenol

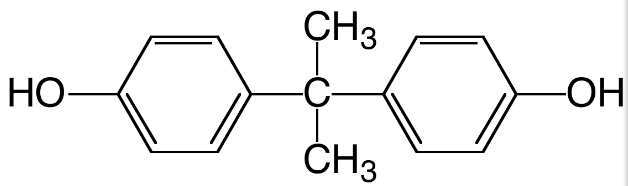


Nonylphenol



Polybrominated diphenyl ethers (PBDEs)

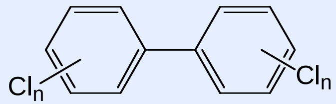
Additive-derived chemicals



Bisphenol A

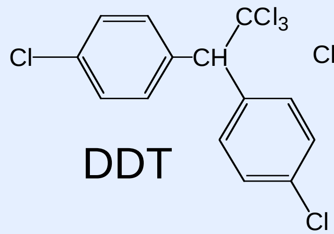
Persistent organic pollutants (POPs)

PCBs

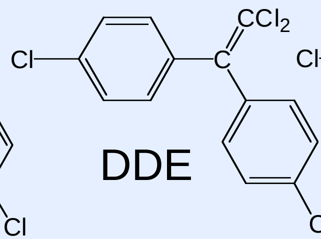


- Industrial products for a variety of uses including dielectric fluid, heat medium, and lubricants.
- Endocrine disrupting chemicals

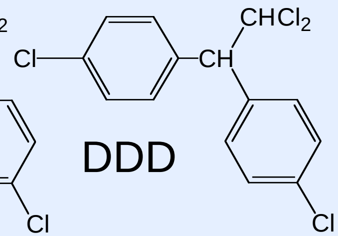
DDTs



DDT



DDE



DDD

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

✓Man-made chemicals

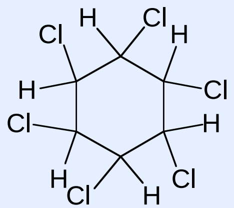
✓Persistent (stable, resistant to degradation)

✓Toxic to human and marine organisms

✓Hydrophobic (lipophilic)

✓Bioaccumulative

HCH

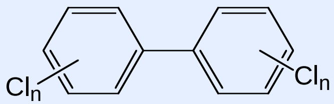


- Insecticide

Regulated by Stockholm convention

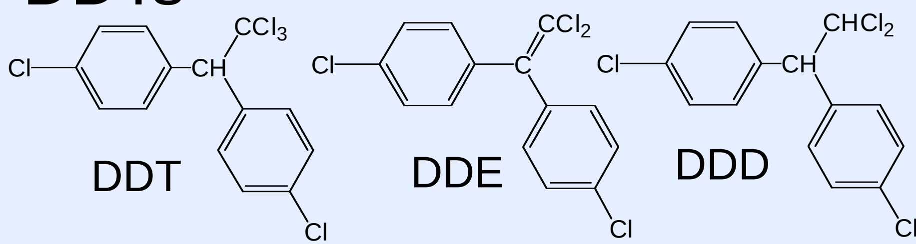
Pellets accumulate POPs from seawater

PCBs



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

DDTs



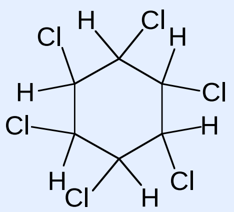
DDT DDE DDD

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

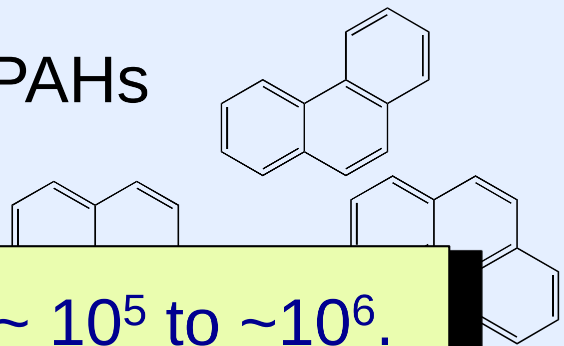
adsorption from ambient seawater

Plastics

HCH

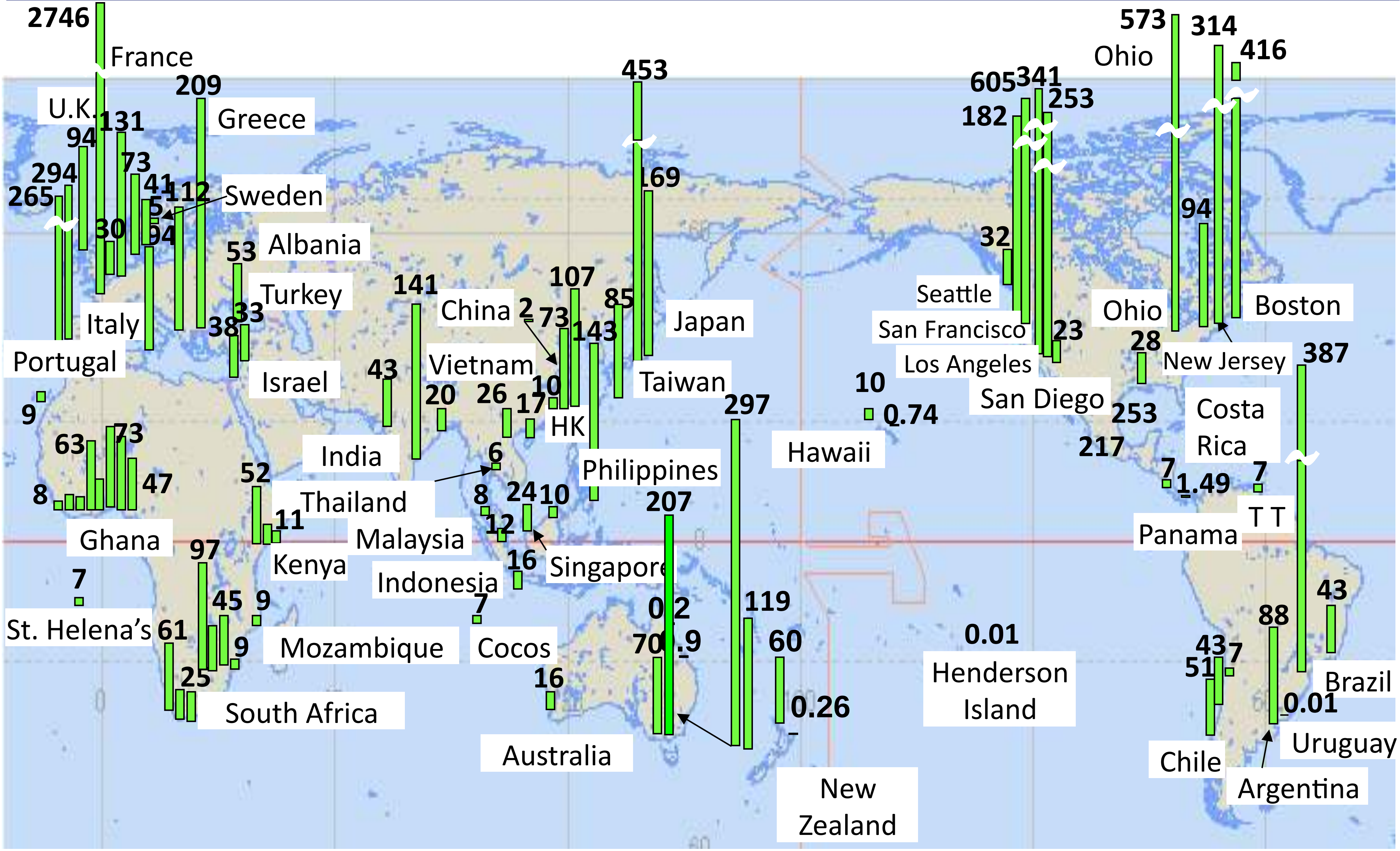


PAHs



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

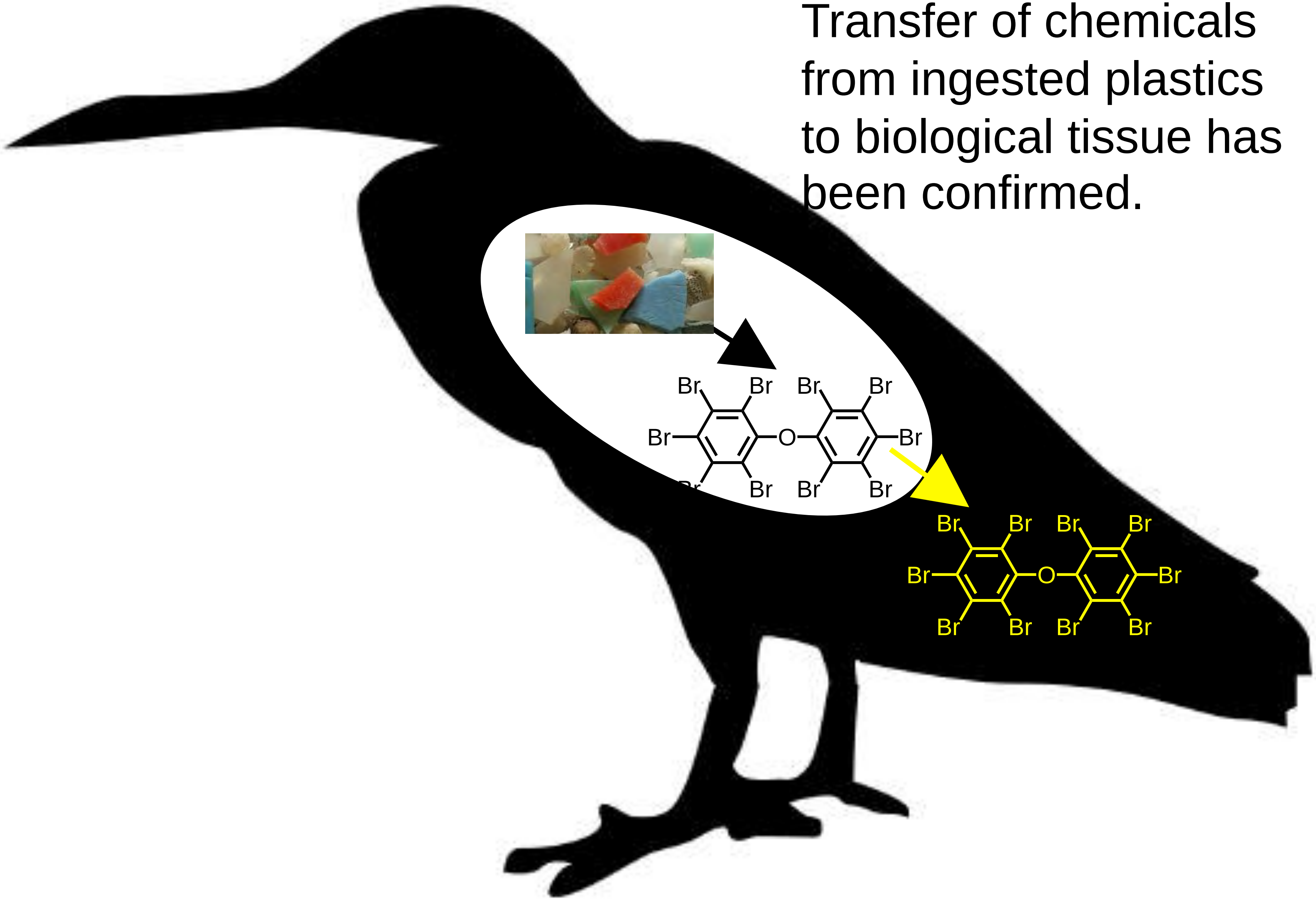
International Pellet Watch : monitoring & increase of public awareness
Plastics carry hazardous chemicals in marine environments



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

Transfer of chemicals from ingested plastics to biological tissue

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



Increased pollutants concentrations with increasing plastic ingestion

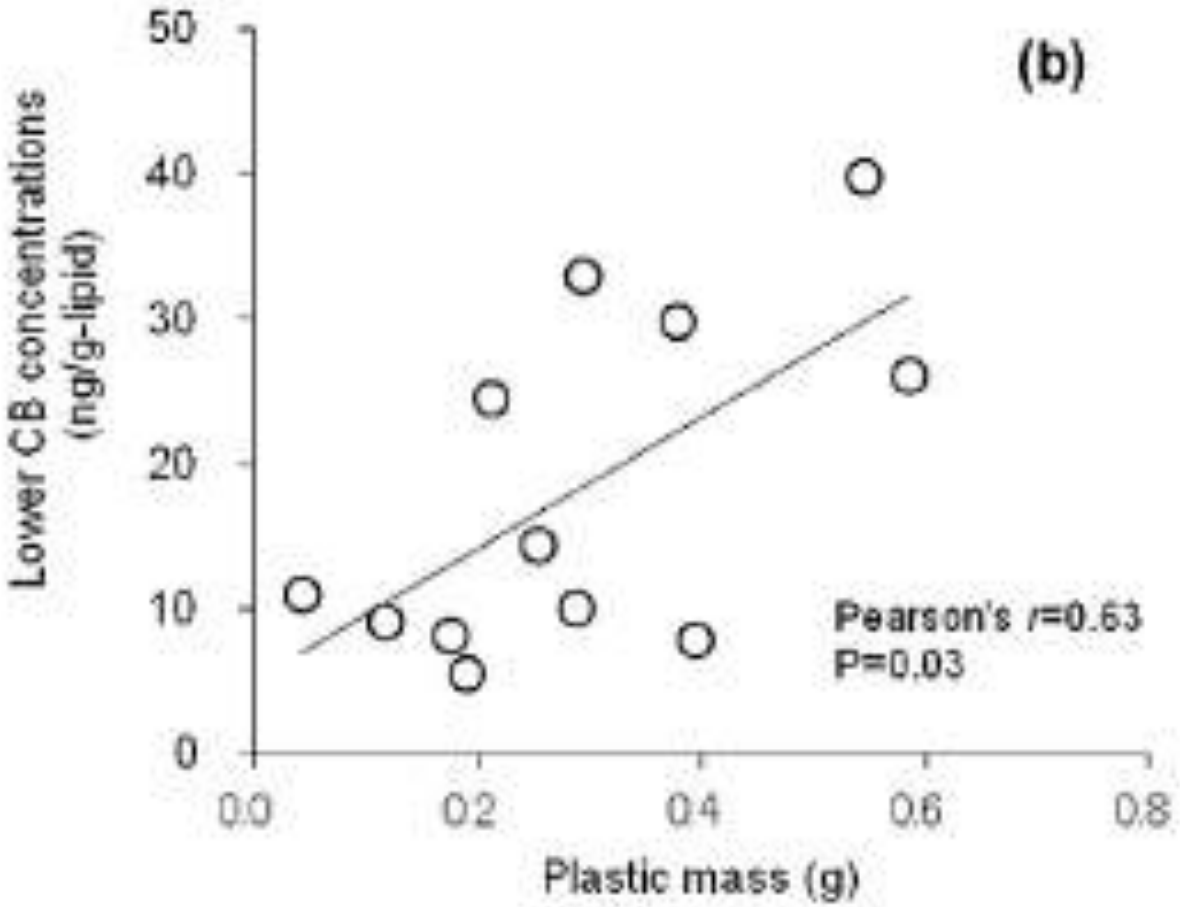
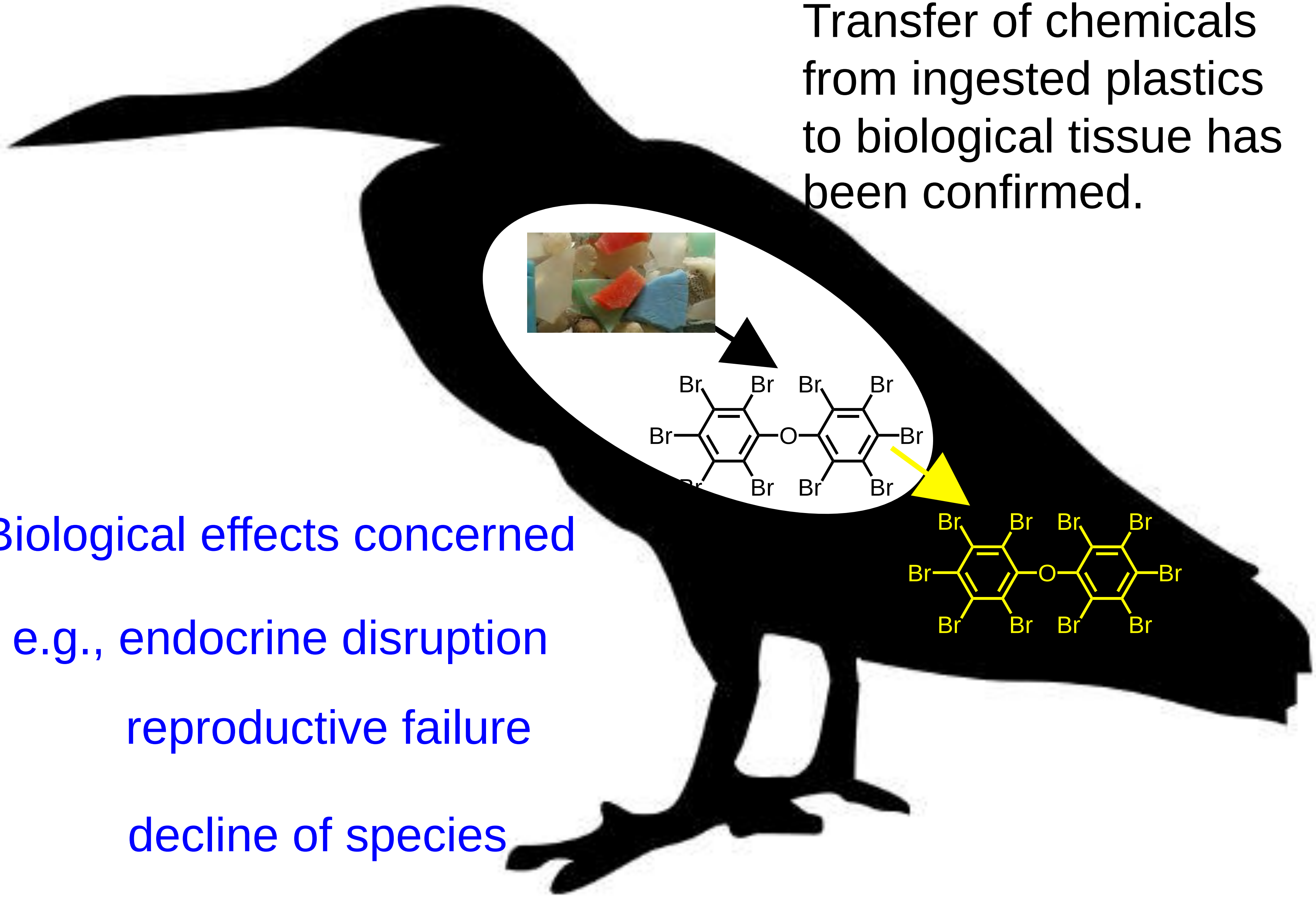


Fig. 4. Relationships between ingested plastic mass and concentrations of (a) total PCBs, (b) lower-chlorinated congeners (Cl number 2–4, see Fig. 3), and (c) higher-chlorinated congeners (Cl number 5–9, see Fig. 3) in abdominal adipose tissues of shearwaters that ingested plastics.

Transfer of chemicals from ingested plastics to biological tissue



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

Biological effects concerned

e.g., endocrine disruption

reproductive failure

decline of species

***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

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.

3R is the key to solve the problems of plastics in marine environments

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

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

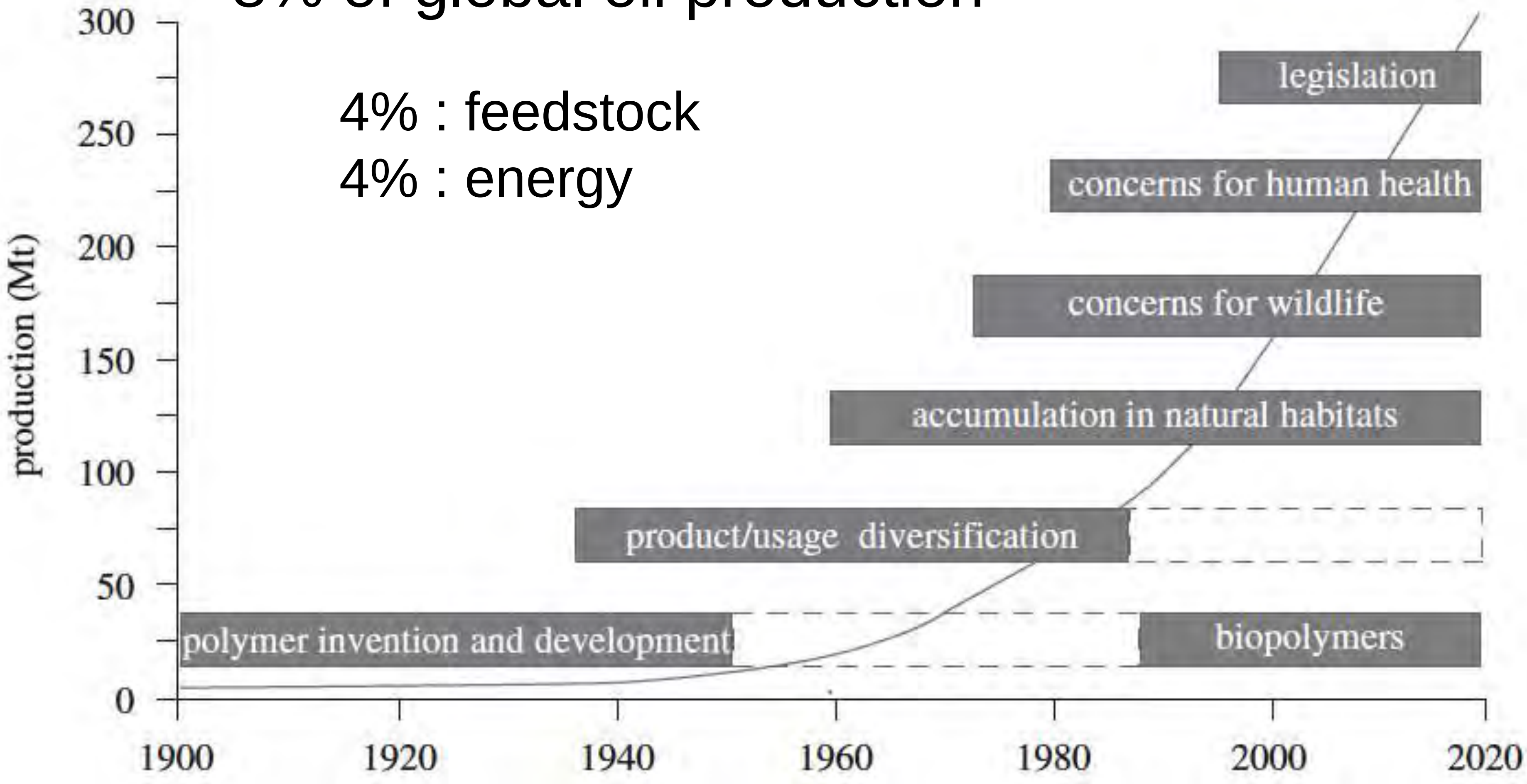
3R

- Reduce
- Reuse
- Recycle

Continuous increase in plastic production

8% of global oil production

4% : feedstock
4% : energy



40 % of plastic production : non-durable

Thompson et al., 2009

No single-use plastics

Majority of plastics in marine environment is land-derived.
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 produces CO_2

No single-use plastic!

Key : increase in public awareness
International Pellet Watch :

Bring our messages to society and policy-makers.
Work with people

International Pellet Watch

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

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

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

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

Sorting

PE, yellowing pellets

Analysis for POPs (PCBs, organochlorines, PAHs)

By GC-MS/MS, GC-MS, GC-ECD
more than 5 pools of 5 pellets
to exclude sporadic high concentration

Mapping POPs pollution

http://www.pelletwatch.org/

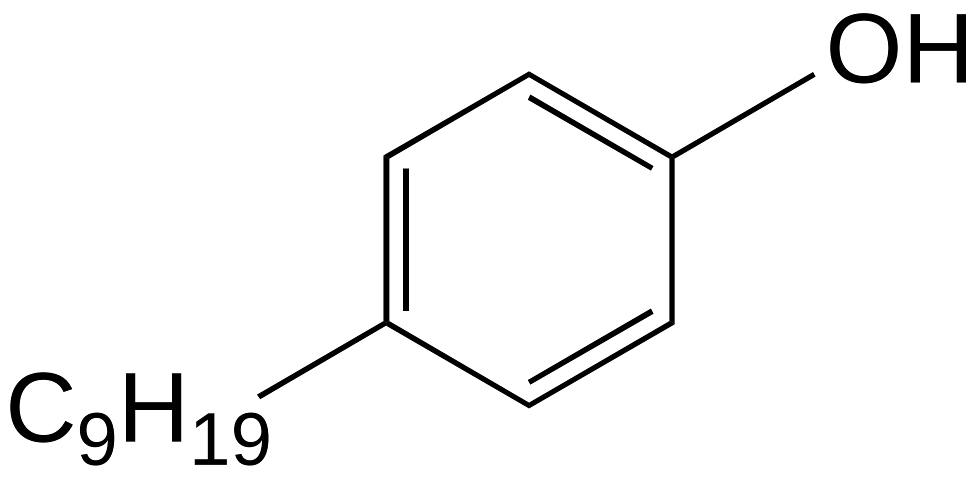
- **Feed the data** back to the collaborators via e-mail
- **Releasing** the results on **web**

Hope for Future

Hope for future

Flying Endocrine Disrupters?

Nonylphenol : Endocrine disrupting chemicals

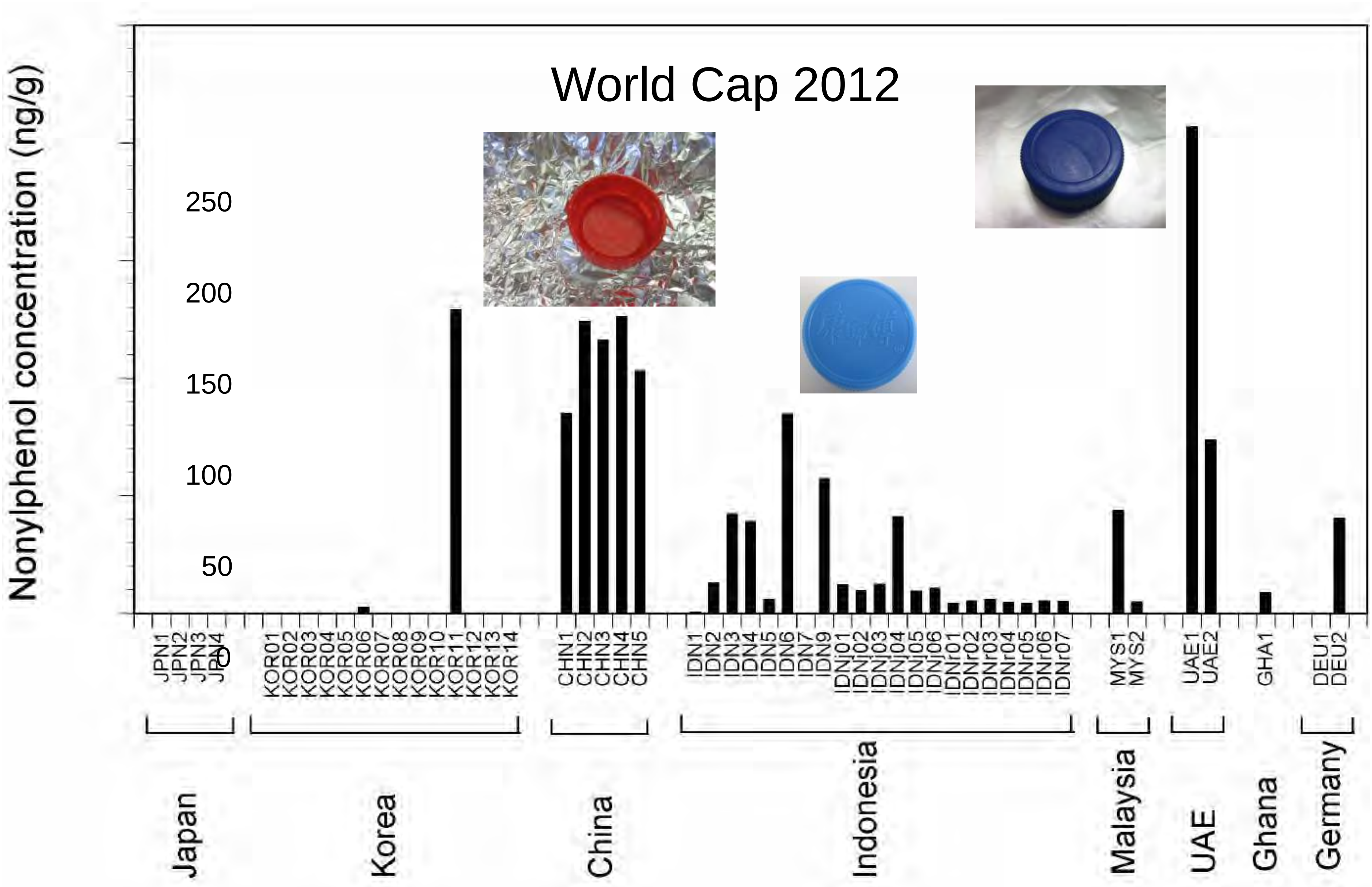


Additives to plastic

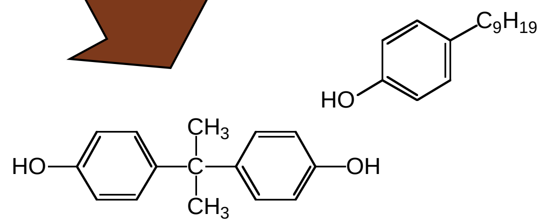
Antioxidants
Antistatic agents

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

Endocrine disrupting chemicals released from plastic caps of mineral water bottles



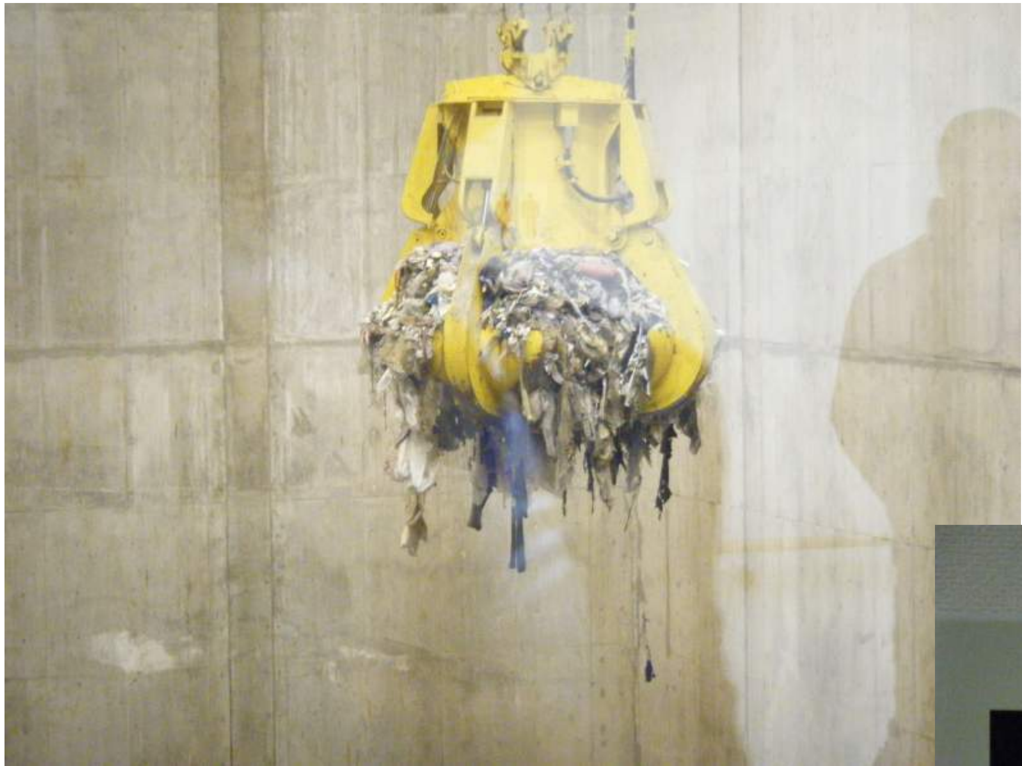
After disposal of plastics in landfill, hazardous chemicals contaminate surface and groundwater

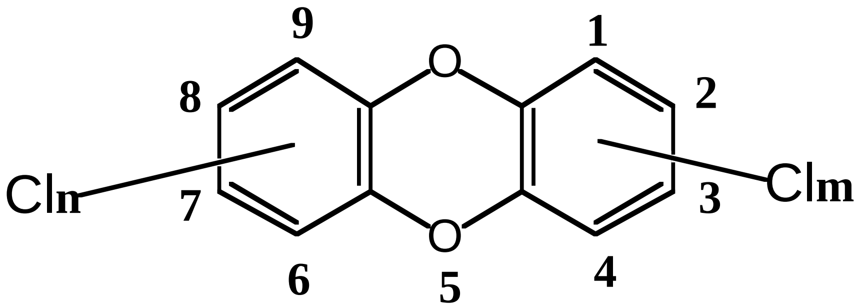


Plastic-derived chemicals

After disposal of plastics in landfill, hazardous chemicals contaminate surface and groundwater

Incineration of plastics with halogen generates toxins such as dioxins





n+m = 1 - 8

Polychlorinated dibenzo-*p*-dioxins (PCDDs; Dioxins)

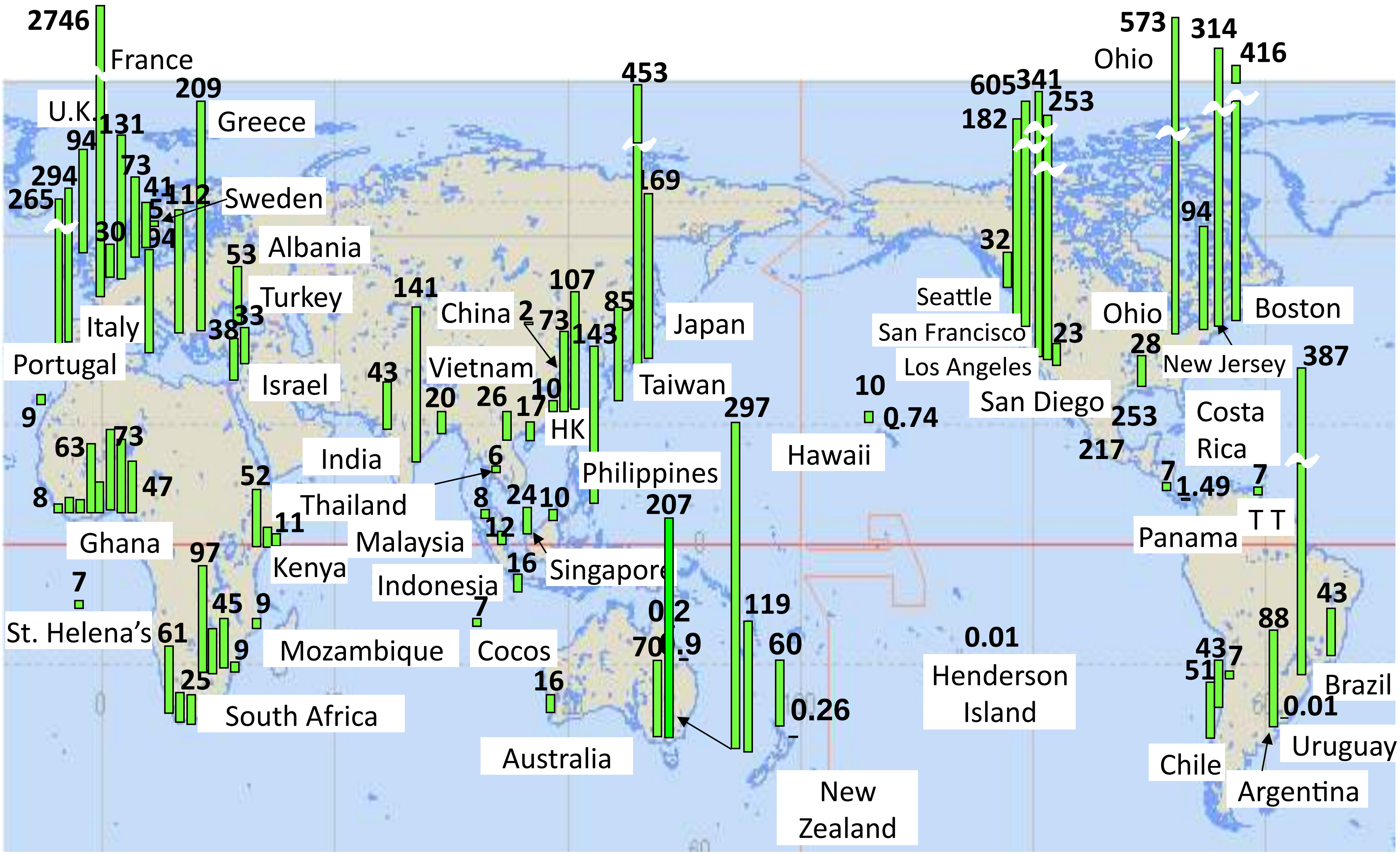
75 congeners

Construction, operation, maintenance, and final disposal of incinerators take huge cost

If we would pay 100 million USD, we can avoid dioxine pollution. However, can we pay if forever? Accident may discharge toxins to surroundings.

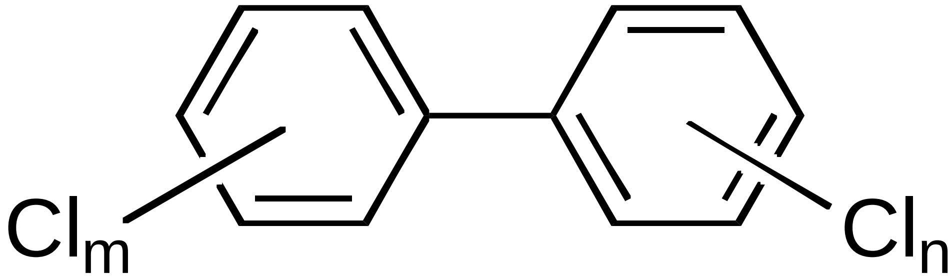
Do you prefer this cost and risk rather than recycling-oriented society?

Plastics carry hazardous chemicals in marine environments



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

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

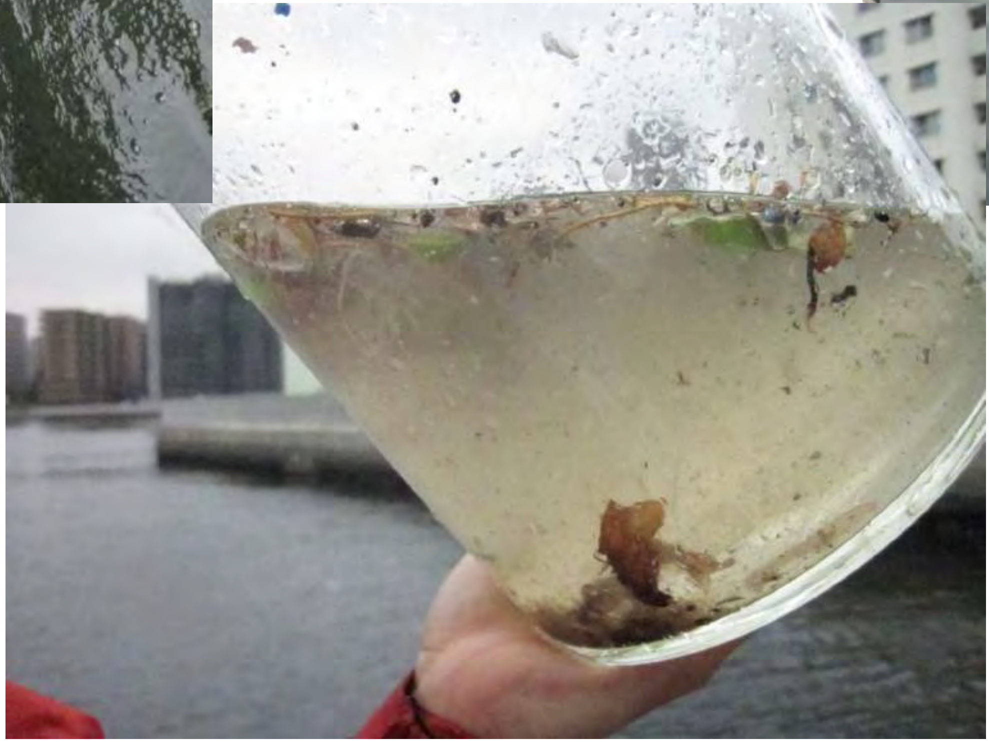
PCBs were used from 1950s to early 1970s in industrialized countries.

Their usage was banned in 1970s

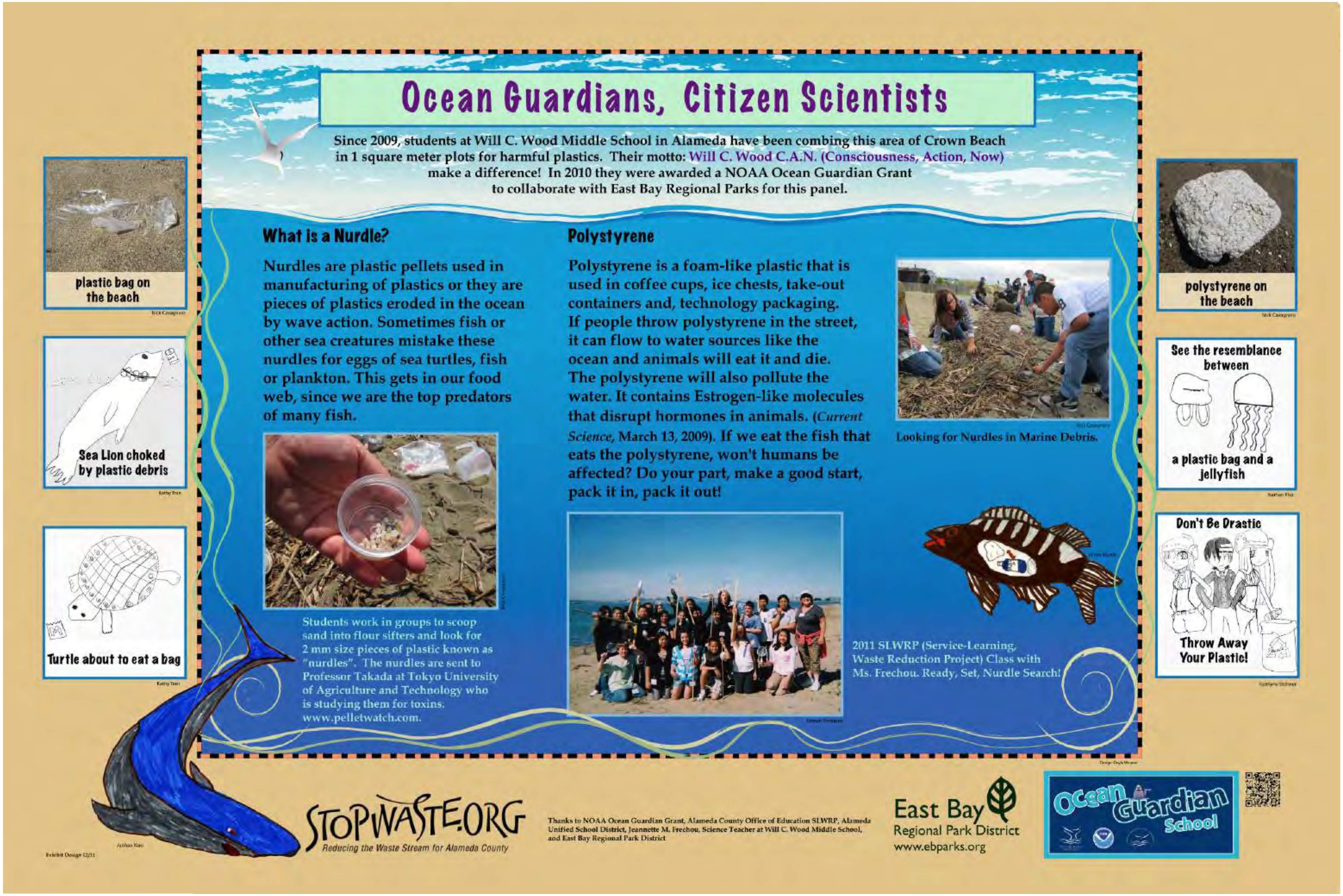
PCBs are deleterious to marine life, especially upper-trophic-level organisms that tend to accumulate the compounds in their tissues. While the precise toxicological effects of PCBs are often unclear, they have been implicated in reproductive abnormalities in marine mammals (e.g., porpoises, seals, sea 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.

After disposal of plastics in landfill, hazardous chemicals contaminate surface and groundwater

Microplastics collected by plankton-net



Hope for future



Crossbill in cormorant in Great Lakes

Increase in Academic and public attention on marine plastics in USA and Europe

2010 Feb. American Geological Union (AGU) meeting

2010 May Society of Ecotoxicology and Chemistry (SETAC) Europe

2010 June GESAMP Workshop, Paris

2010 Sep. International Symposium in Matsuyama

2010 Nov. SETAC North America

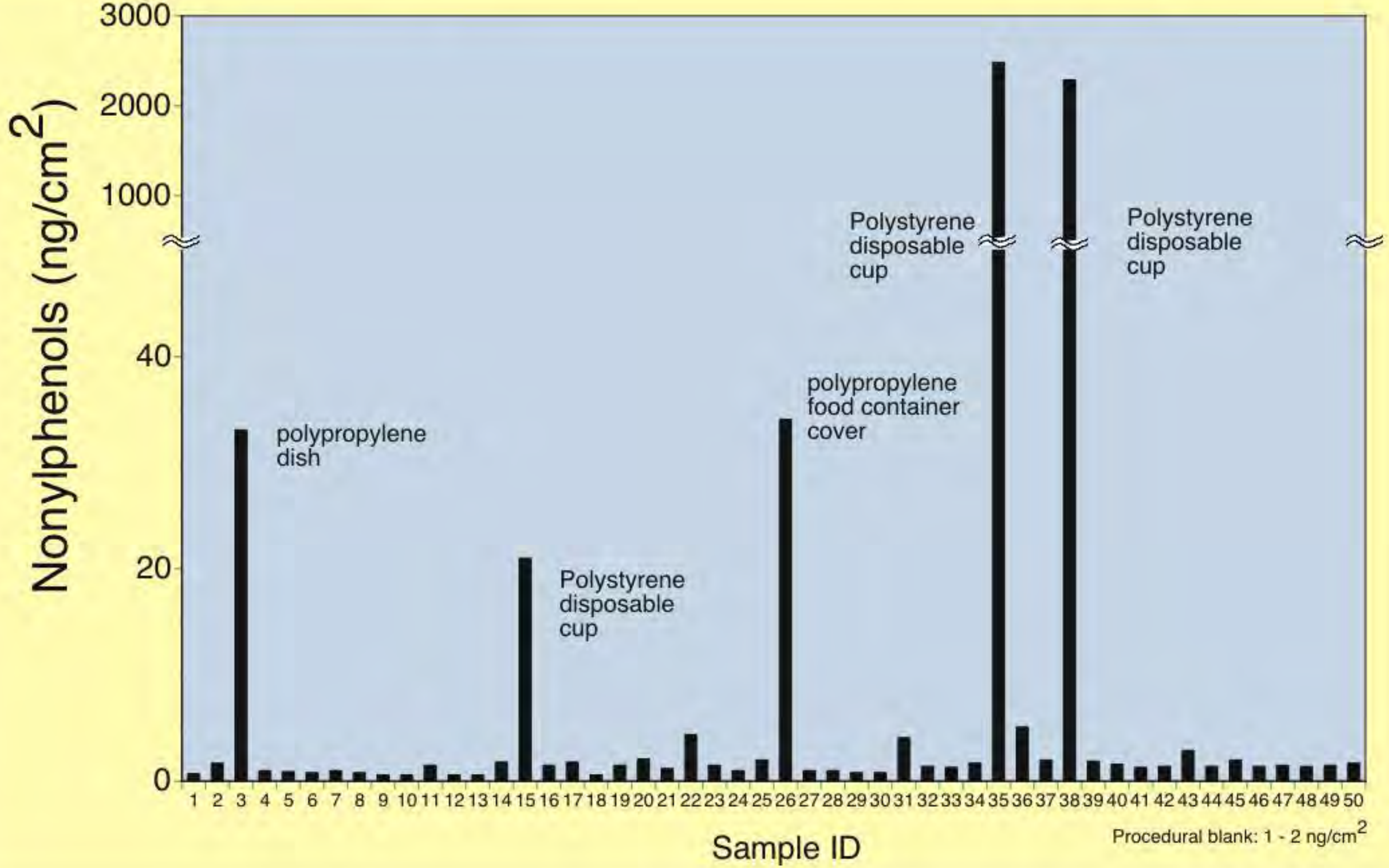
2010 Nov. NOAA Tacoma workshop

2011 Mar. International Marine Debris Conference, Hawaii

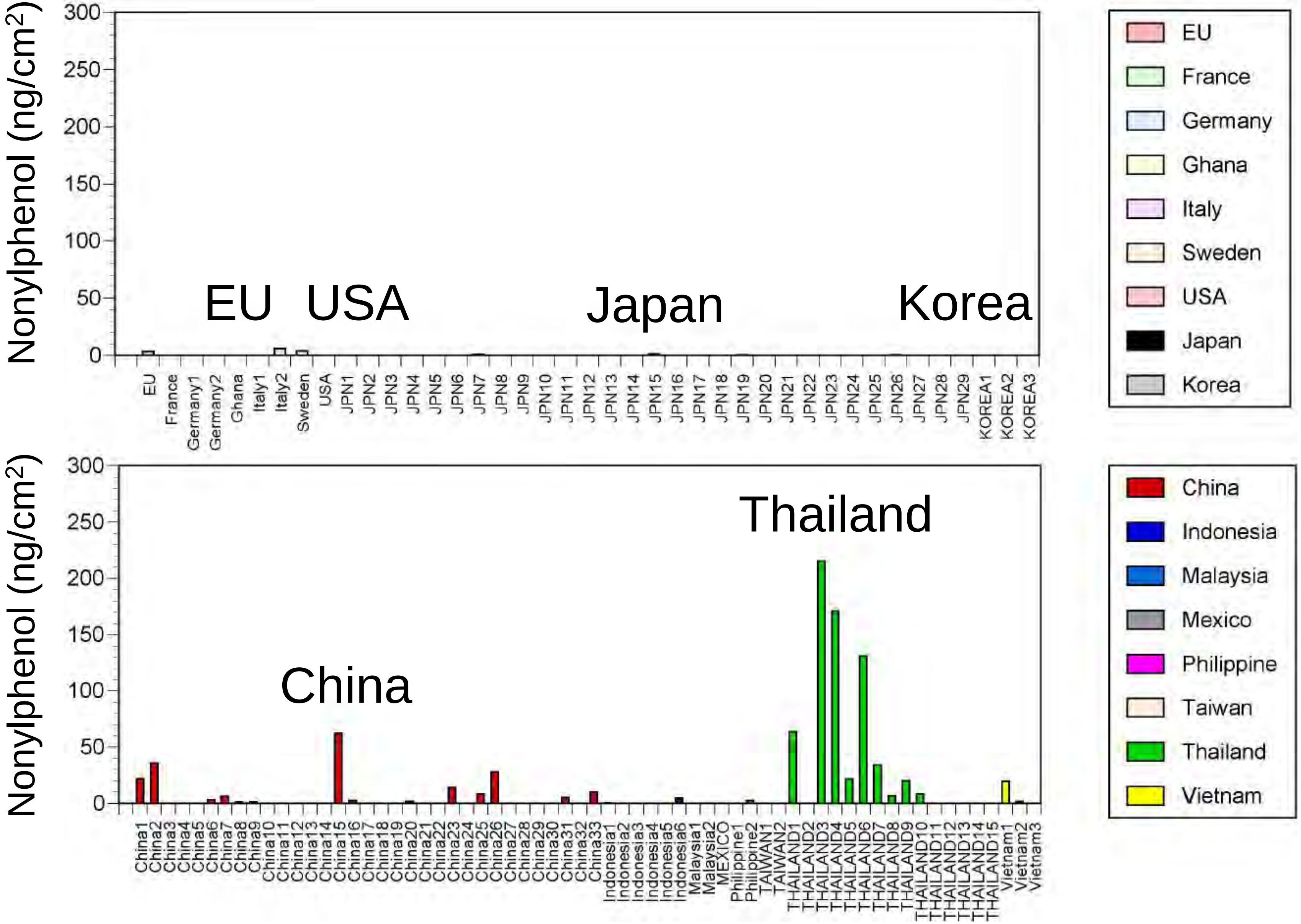
2011 May SETAC Europe

2012 May SETAC Europe

Nonylphenols released from plastic cups, dishes and food containers



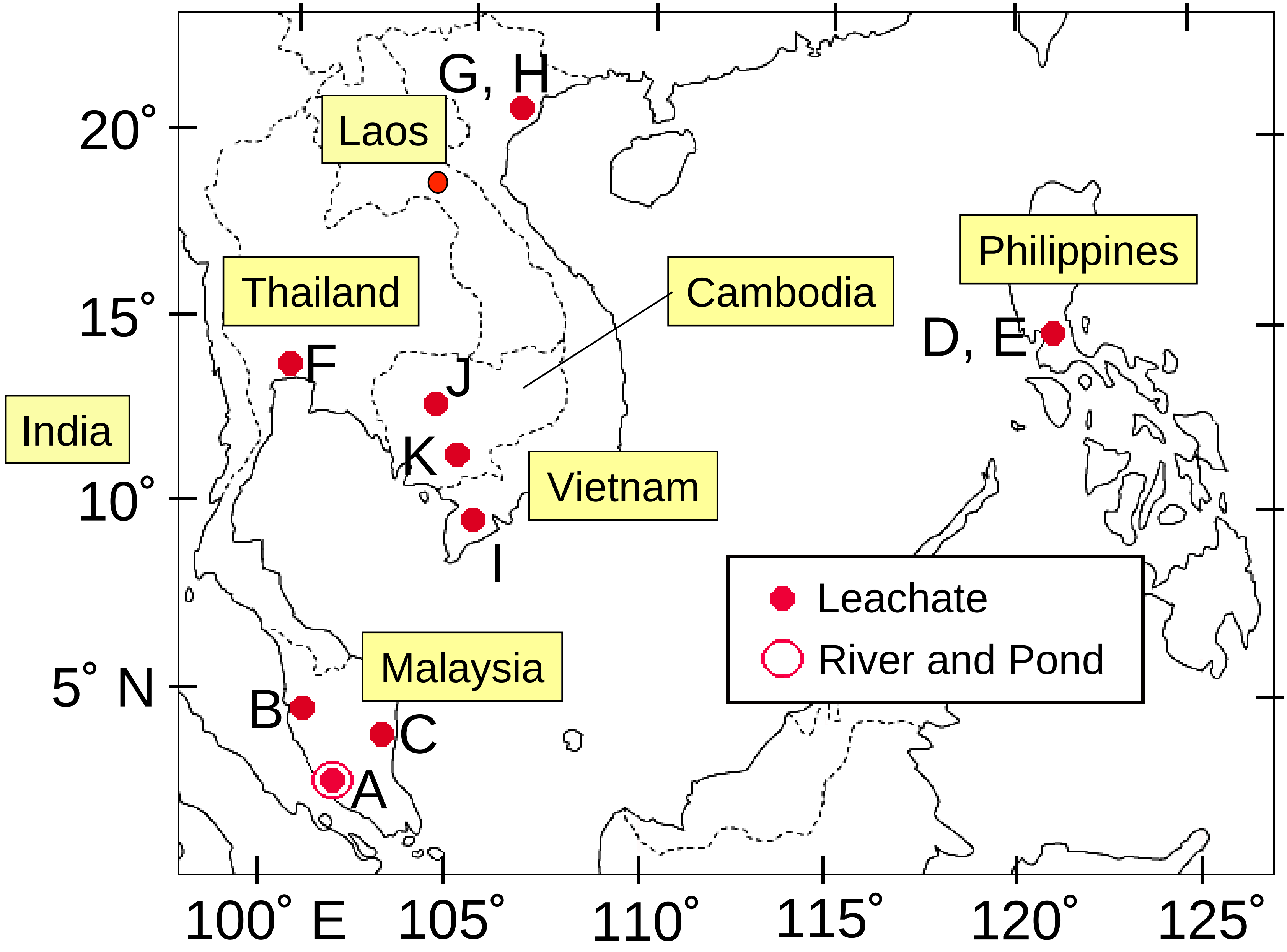
Nonylphenols leached from plastic products



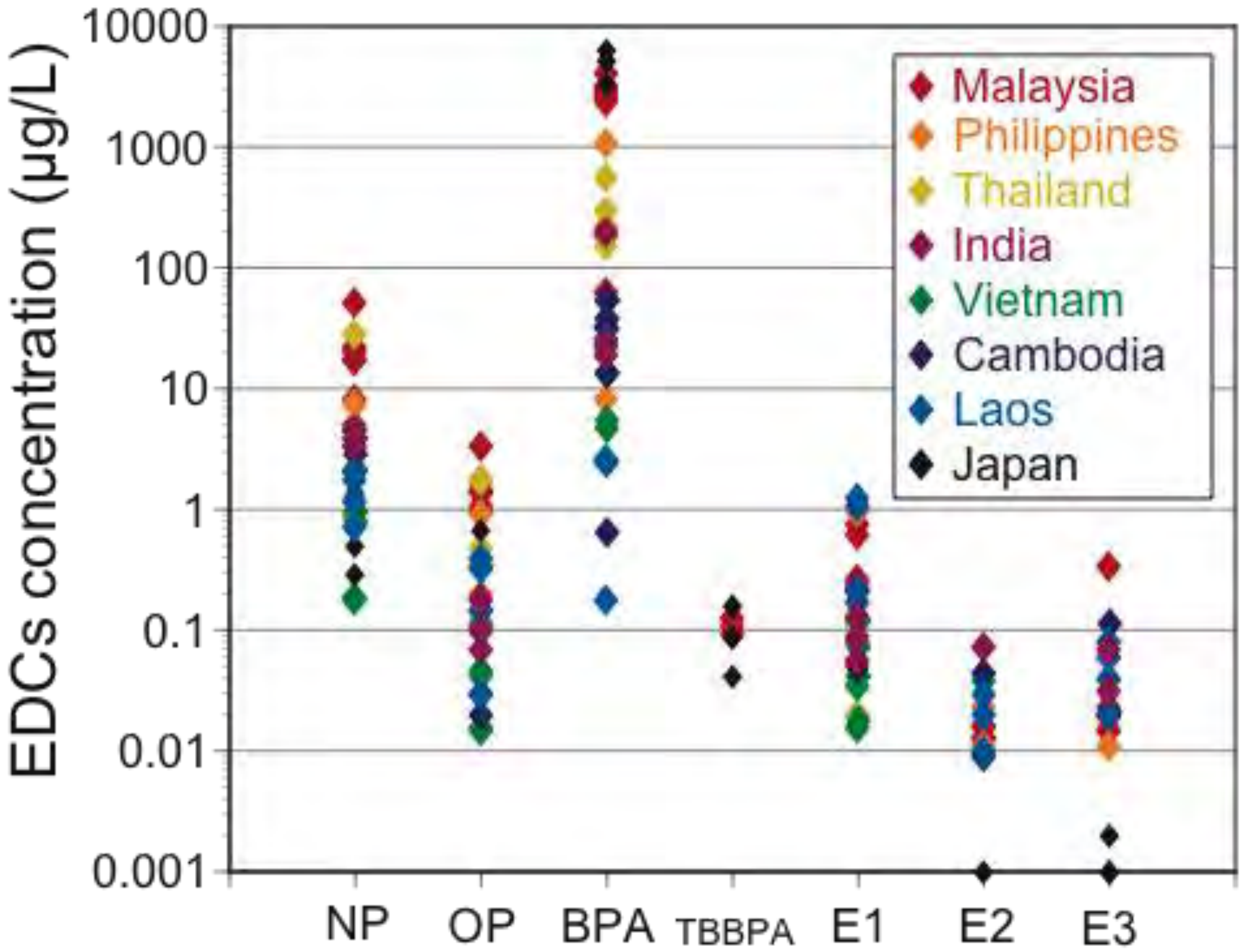
Nonylphenols are still leached from imported plastic products

On the usage of plastic food containers, you will be exposed to hazardous chemicals

Sampling locations of Leachate samples from Land-fill sites



Endocrine disrupting chemicals (EDCs) concentrations in leachate samples from Tropical Asian countries



GESAMP

Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection

Proceedings of the GESAMP International Workshop on Microplastic particles as a vector in transporting persistent, bio-accumulating and toxic substances in the ocean

UNEP YEAR BOOK

EMERGING ISSUES IN OUR GLOBAL ENVIRONMENT

2011

UNEP

United Nations Environment Programme

Plastic Debris in the Ocean

Every year large amounts of plastic debris enter the ocean, where it slowly fragments and accumulates in convergence zones. Scientists are concerned about the possible impacts of small plastic fragments—microplastics—in the environment. The role of plastics as a vector for transporting chemicals and species in the ocean is as yet poorly understood, but it is a potential threat to ecosystems and human health. Improved waste management is the key to preventing plastic and other types of litter from entering the ocean.

The ocean has become a global repository for much of the waste we generate. Marine debris includes timber, glass, metal and plastic from many different sources. Recently, the accumulation and possible impacts of microplastic particles in the ocean have been recognized as an emerging environmental issue. Some scientists are increasingly concerned about the potential impact of releases of persistent bio-accumulating and toxic compounds (PBTs) from plastic debris. At the same time, the fishing and tourism industries in many parts of the world are affected economically by plastic entering nets, fouling propellers and other equipment, and washing up on beaches. Despite international efforts to stem the flow of plastic debris, it continues to accumulate and impact the marine environment. To reduce the quantity of plastic entering the ocean, existing management instruments need to be made more effective and all aspects of waste treatment and disposal need to be improved.

Several common types of plastic are buoyant and have been transported by ocean currents to the remotest regions of the planet, including the Arctic and Antarctic (Barnes et al. 2010). Media attention has focused on reports of the relatively high incidence of plastic debris in areas of the ocean referred to as 'convergence zones' or 'ocean gyres'. This has given rise to the widespread use of terms like 'plastic soup', 'garbage patch' and 'ocean landfill'. Such terms are rather misleading in that much of the plastic debris in the ocean consists of fragments that are very small in size while the areas where they are floating are not, for example, distinguishable on satellite images. Nevertheless, publicity resulting from media reports and from the activities of several NGOs has helped to raise public and political awareness of the global scale of the plastic debris problem, together with the larger issue of marine litter.

Microplastics are generally considered to be plastic particles smaller than 5 millimetres in diameter (Arthur et al. 2009).

Persistent, bio-accumulating and toxic substances (PBTs) have a range of chronic health effects, including endocrine disruption, mutagenicity and carcinogenicity. A subset is regulated under the Stockholm Convention on Persistent Organic Pollutants (POPs).

Assessing the extent of the problem

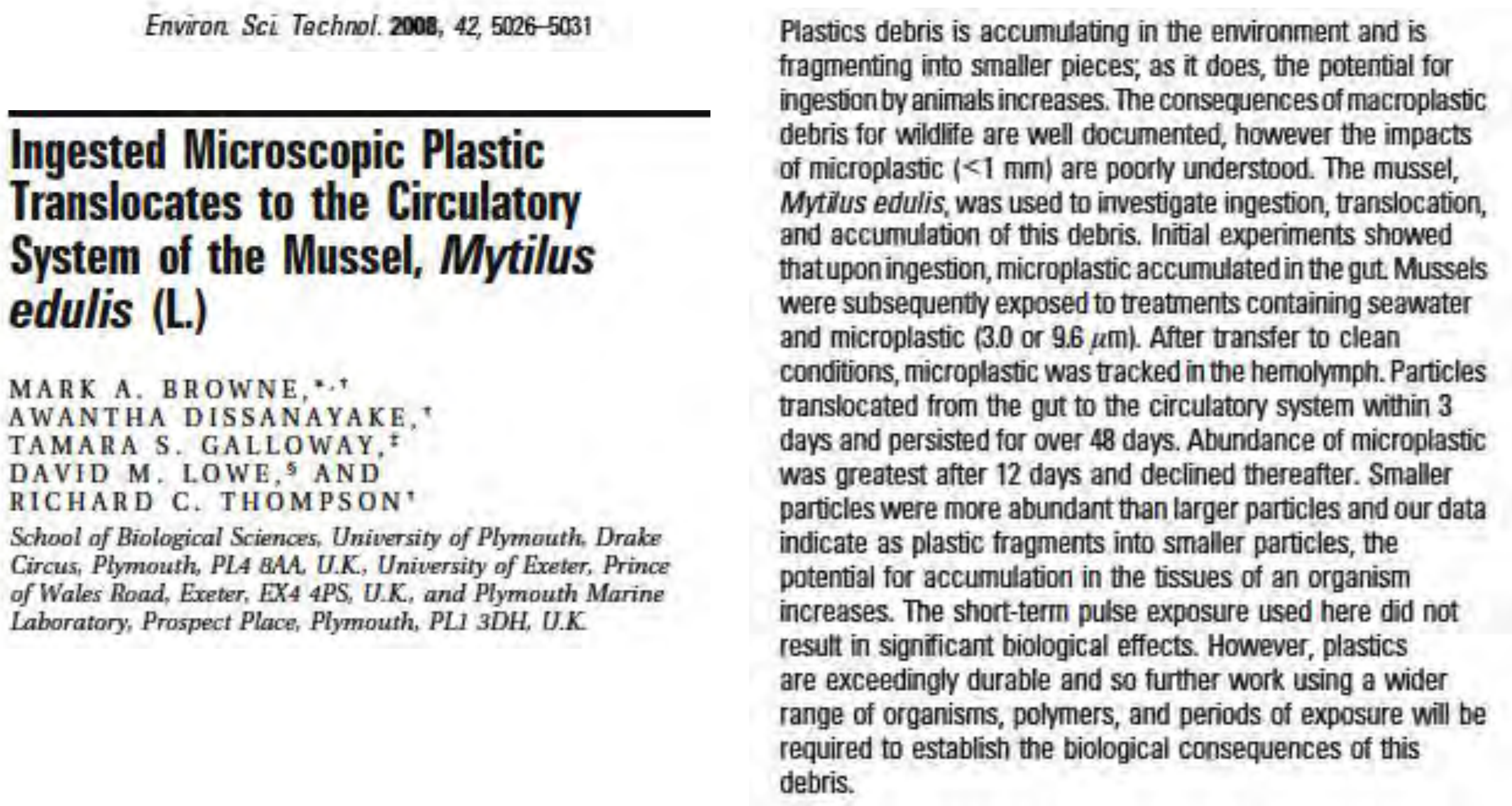
It is difficult to quantify the amounts and sources of plastic and other types of debris entering the ocean. Land-based sources include poorly managed landfills, riverine transport, untreated sewage and storm water discharges, industrial and manufacturing facilities with inadequate controls, wind-blown debris, recreational use of coastal areas, and tourist activities (Barnes et al. 2009). These sources are thought to dominate the overall supply of marine debris, but there are important regional variations. For example, shipping and fisheries are significant contributors in the East Asian Seas region and the southern North Sea (UNEP/COBSEA 2009, Galgani et al. 2010). In general, more litter is found closer to population centres, including a greater proportion of consumer plastic items such as bottles, shopping bags and personal hygiene products (Ocean Conservancy 2010).

The greatest technological development of modern plastics occurred during the first half of the 20th century. Their production and use have continued to expand rapidly up to the present day (**Figure 1**). In many sectors, they have become a popular material for packaging (**Box 1**). A major benefit of their use in the food industry is that it can extend shelf life, thus decreasing the risk of infection and reducing food waste.

Ship- and platform-based sources of plastic litter in the ocean include fishing and recreational vessels, cruise liners, merchant shipping, oil and gas platforms, and aquaculture facilities (**Figure 2**).

Authors: Peter Kershaw (chair), Saido Katsuhiko, Sangjin Lee, Jon Samseth and Doug Woodring
Science writer: John Smith

Translocation of microscopic plastics to circulatory system of bivalves


Environ. Sci. Technol. 2008, 42, 5026–5031

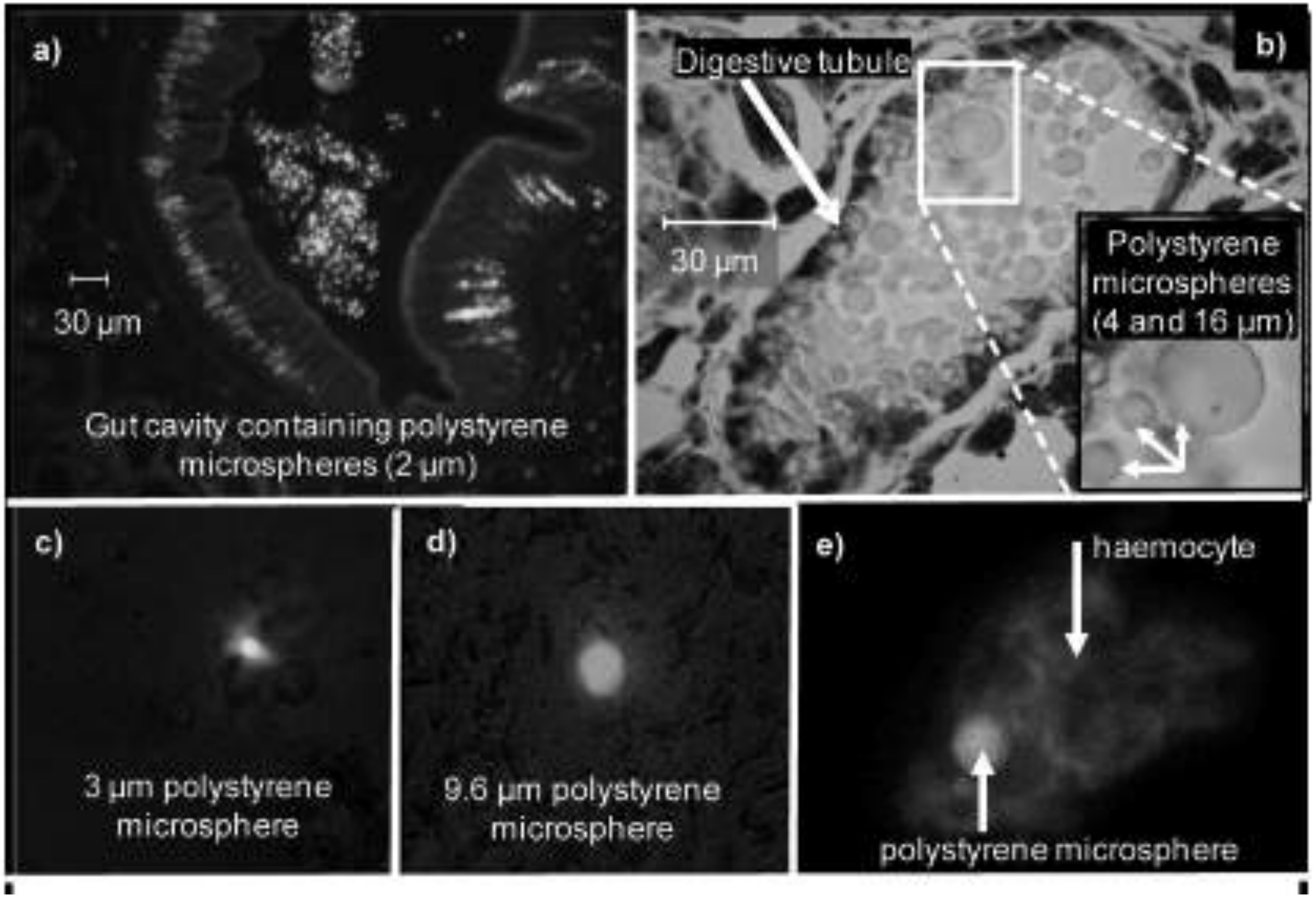
Ingested Microscopic Plastic Translocates to the Circulatory System of the Mussel, *Mytilus edulis* (L.)

MARK A. BROWNE,[*,†]
AWANTHA DISSANAYAKE,[†]
TAMARA S. GALLOWAY,[‡]
DAVID M. LOWE,[§] AND
RICHARD C. THOMPSON[†]

School of Biological Sciences, University of Plymouth, Drake Circus, Plymouth, PL4 8AA, U.K., University of Exeter, Prince of Wales Road, Exeter, EX4 4PS, U.K., and Plymouth Marine Laboratory, Prospect Place, Plymouth, PL1 3DH, U.K.

Plastics debris is accumulating in the environment and is fragmenting into smaller pieces; as it does, the potential for ingestion by animals increases. The consequences of macroplastic debris for wildlife are well documented, however the impacts of microplastic (<1 mm) are poorly understood. The mussel, *Mytilus edulis*, was used to investigate ingestion, translocation, and accumulation of this debris. Initial experiments showed that upon ingestion, microplastic accumulated in the gut. Mussels were subsequently exposed to treatments containing seawater and microplastic (3.0 or 9.6 μm). After transfer to clean conditions, microplastic was tracked in the hemolymph. Particles translocated from the gut to the circulatory system within 3 days and persisted for over 48 days. Abundance of microplastic was greatest after 12 days and declined thereafter. Smaller particles were more abundant than larger particles and our data indicate as plastic fragments into smaller particles, the potential for accumulation in the tissues of an organism increases. The short-term pulse exposure used here did not result in significant biological effects. However, plastics are exceedingly durable and so further work using a wider range of organisms, polymers, and periods of exposure will be required to establish the biological consequences of this debris.

Translocation of microscopic plastics to circulatory system of bivalves

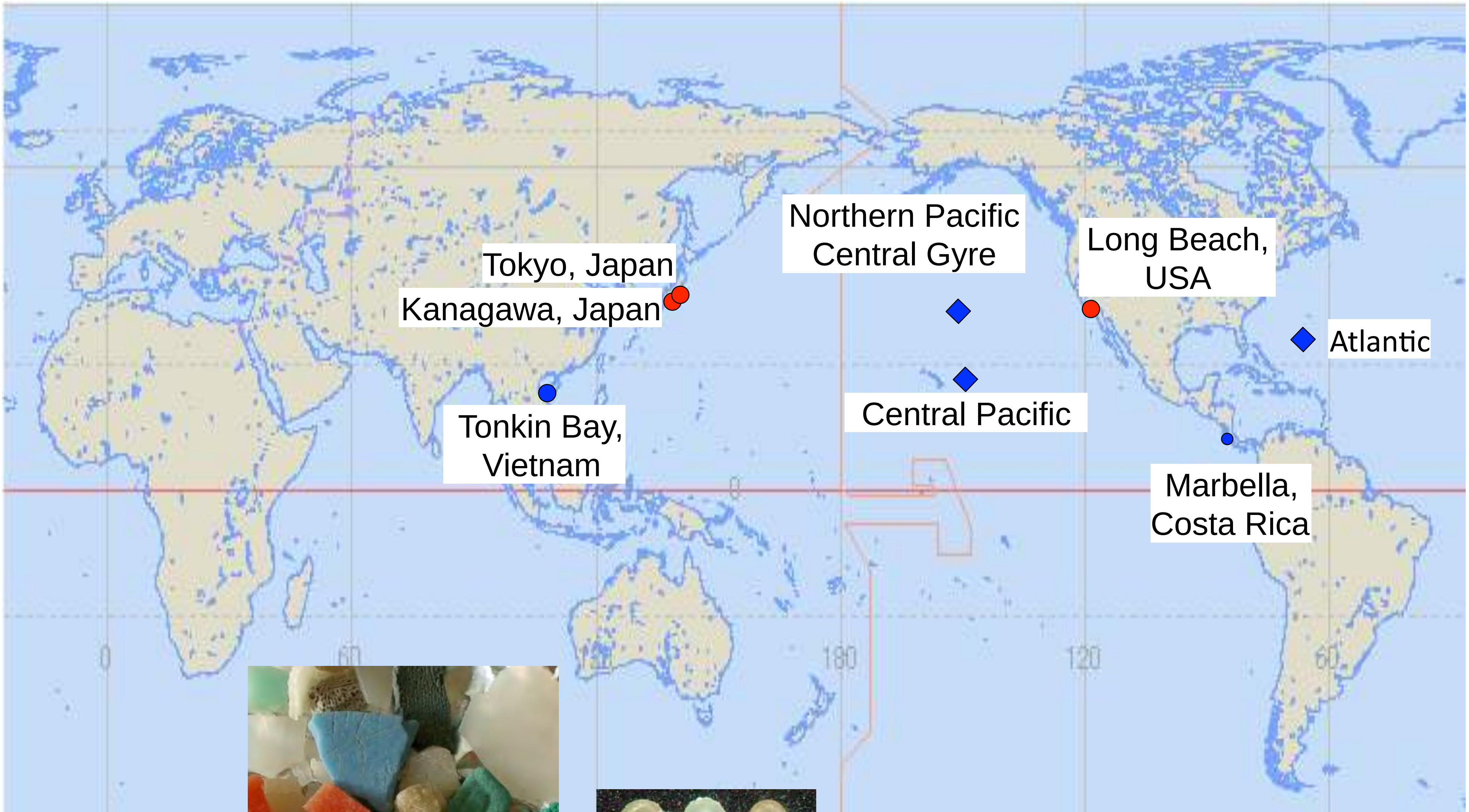


Browne, M.A., Dissanayake, A., Galloway, T.S., Lowe, D.M., Thompson, R.C., 2008. Ingested microscopic plastic translocates to the circulatory system of the mussel, *Mytilus edulis* (L.). Environ. Sci. Technol. 42, 5026–5031.

Plastic debris on beaches

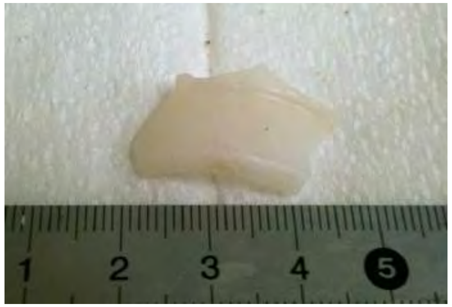
Manila Bay

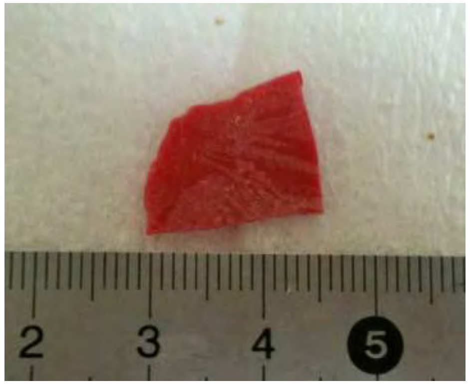
Sampling locations of user plastic fragments and pellets

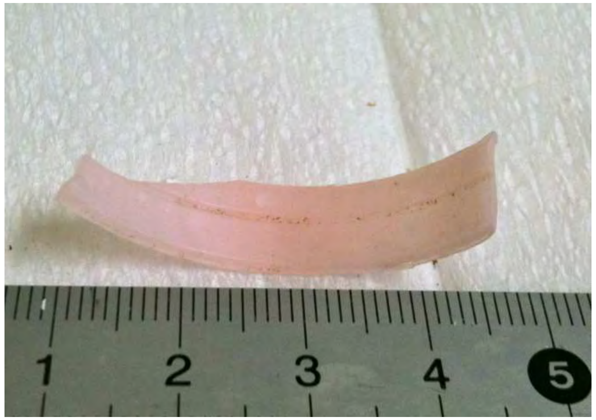


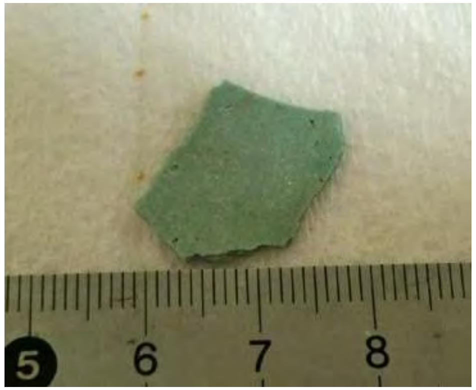
● Urban beach
● Rural beach
◆ Open ocean

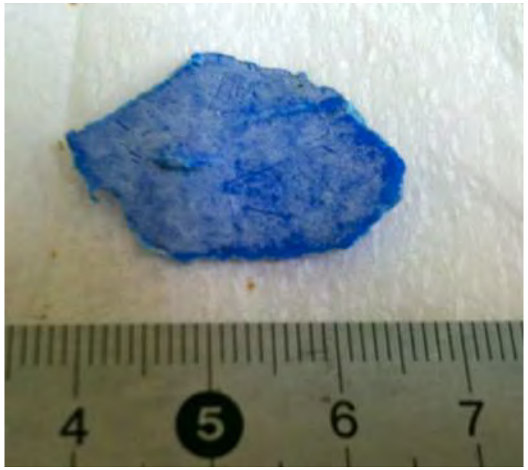
Examples of analyzed plastic fragments





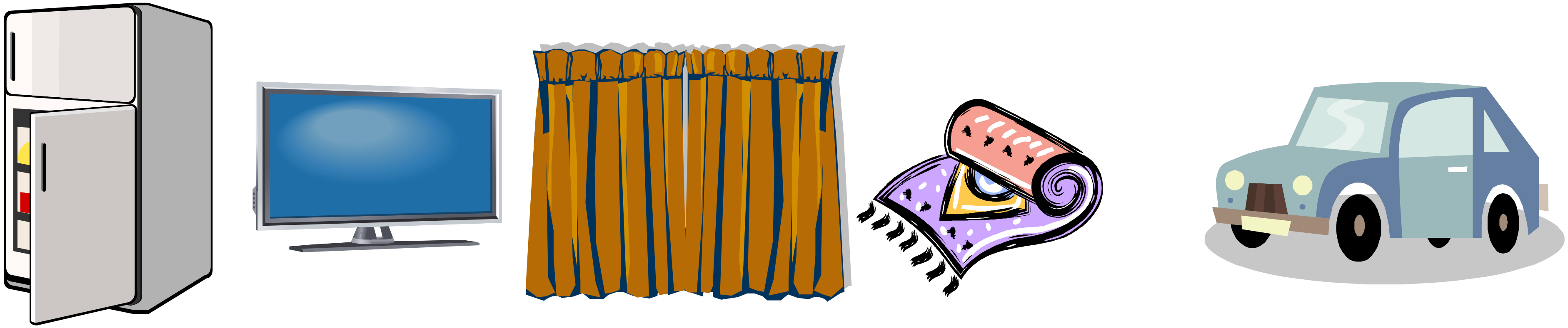






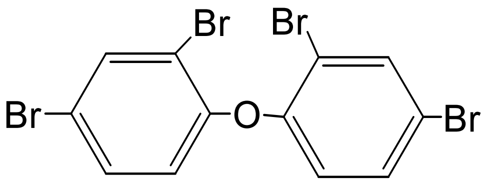
PBDEs : Flame retardants

applied in various electric products and fabrics.



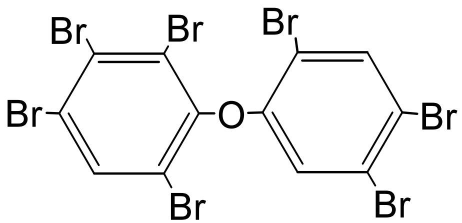
3 technical products (mixtures of congeners)

Penta BDE
(Br4, Br5)



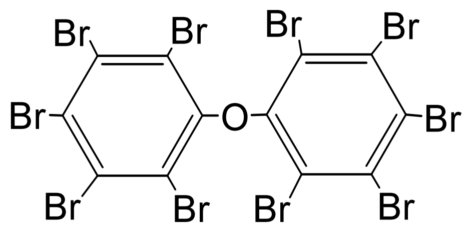
e.g., BDE47

Octa BDE
(Br7,8)



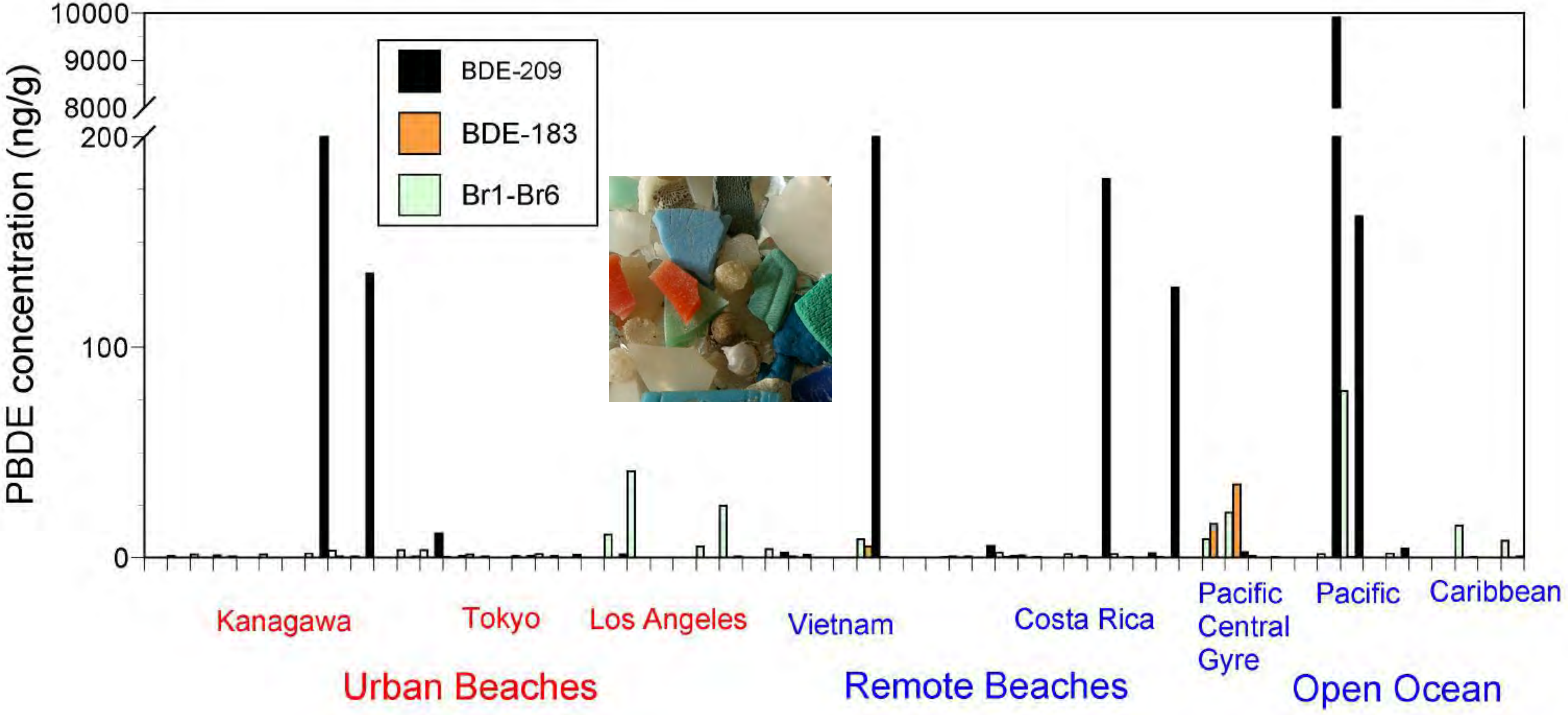
e.g., BDE183

DecaBDE
(Br10)



e.g., BDE209

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

International Pellet Watch

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

Since 2005

Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Marine Pollution Bulletin 52 (2006) 1547–1548
MARINE POLLUTION BULLETIN
www.elsevier.com/locate/marpolbul

Editorial

Call for pellets! International Pellet Watch Global Monitoring of POPs using beached plastic resin pellets

On our beaches, we see various quantities of many materials (e.g., seaweed, driftwood, trash, plastic fragments, cigarette ends) along the high-tide line. Among them, we can commonly find plastic resin pellets. Recently we have started a global monitoring programme of persistent organic pollutants (POPs) using these stranded plastic resin pellets (International Pellet Watch: http://www.tuat.ac.jp/~gaia/ipw/index.html).

Plastic resin pellets are small granules, generally with shape of a cylinder or a disk with a diameter of a few mm (Fig. 1). These plastic particles are the industrial raw material of plastics which are transported to manufacturing sites where "user plastics" are made by re-melting the pellets and molding them into the final products. Resin pellets can be unintentionally released to the environment, both during manufacturing and transport. The released resin pellets are carried by surface run-off, streams and river waters, eventually leading to the ocean. Because of their environmental persistence, they are distributed widely in the ocean and are now found on beaches all over the world. In 2001, we revealed the existence of various organic micro-pollutants (i.e., polychlorinated biphenyls: PCBs, DDE, and nonylphenol) in these stranded plastic resin pellets collected on beaches (Mato et al., 2001).

Fig. 1. Plastic resin pellets.

Because of the hydrophobic nature of the plastic surfaces, hydrophobic pollutants such as PCBs and DDTs are adsorbed to the pellets from the surrounding seawater with concentration factors of up to 10^6. We observed a weak correlation between PCBs concentrations in plastic resin pellets collected on beaches with levels in traditional monitoring media (i.e., mussels), although large piece-to-piece variability of PCB concentrations was also observed (Endo et al., 2005). Because the resin pellets are distributed on beaches the world over, and because collection and shipping of the pellets are easy, we propose global monitoring of persistent organic pollutants (POPs) using these beached plastic resin pellets.

In the International Pellet Watch project, we ask people from all countries to collect plastic resin pellets on their nearby beaches and send them to our laboratory via air-mail. No cooling nor freezing is necessary during shipment. People just need to put the pellets into a paper envelope and post it to us. To get representative data, we need 100–200 pieces of pellets (preferably yellowed pellets) from each location. Organic micro-pollutants in the pellets will be analyzed in our laboratory. Based on the analytical results, global distributions of these organic micro-pollutants will be mapped. Results will be sent to the participants through e-mail and will be released on the web as well.

The purpose of International Pellet Watch is to understand the current status of global POPs pollution, and the advantage of Pellet Watch is its extremely low cost of sampling and shipping as compared with conventional monitoring using water, sediment and biological samples. Further, we can draw global POPs pollution maps for a very low cost. Already several NGOs who conduct beach clean-up projects are helping with sample collection.

So far, our spatial coverage is very limited and of course the strength of the programme will be related to the coverage

0025-326X/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.marpolbul.2006.10.010

GHANA
Christmas 1988
HELLAS
ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ
Πάρος
Takada
MAIL
Customs Douane CN22
May be opened officially
LC615871570AU
Detailed description of contents
Plastic bottle caps
To
Professor Hideshige TA
Laboratory of Organic
Faculty of Agricultur
Tokyo University of
Fuchu, Tokyo 183-
Laboratory of Organic Geochemistry
Dr. Hideshige T
Tokyo Univer
Fuchu, To
銀鑛灣酒店
Silvermine Beac
Managed by Miramar Internati
29.09.09
Royal Mail
POSTAGE PAID UK
Small Packet
signedfor
international
R
Royal Mail
D.D. 2 Lot 648 Silvermine Bay, Mui Wo, Lantau Island

Plastic Resin Pellets

International Pellet Watch

To globally monitor persistent organic pollutants (POPs) by using beached plastic resin pellets

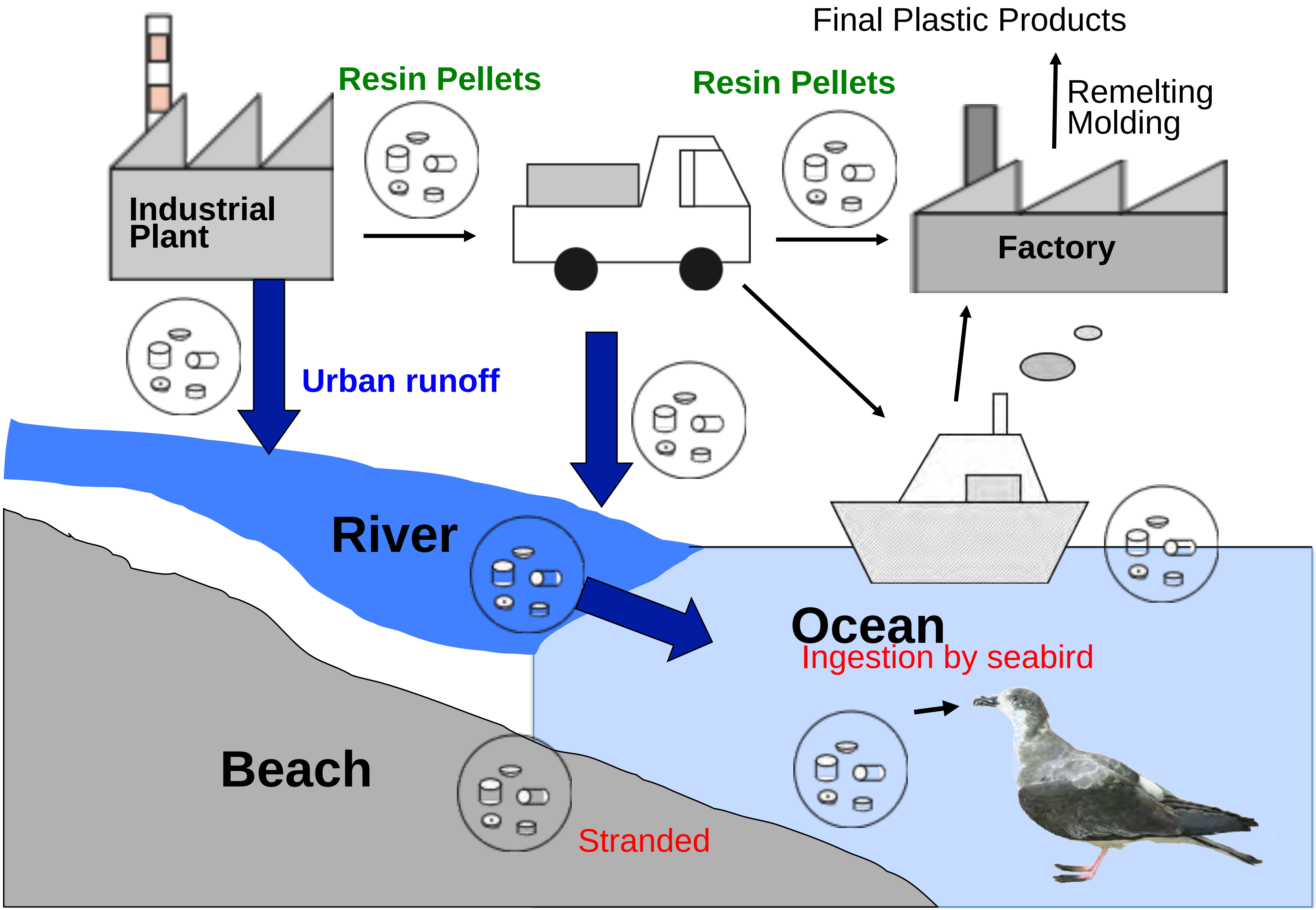
To understand magnitude and spatial distribution of chemical risk associated with marine plastics.

Under cooperation with world NGO

established in 2005

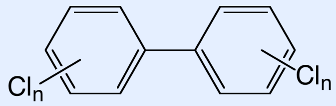
Plastic Resin Pellets

Resin pellets, industrial feedstock of user plastics, are spilled during transport and manufacturing and they are widely distributed in the ocean



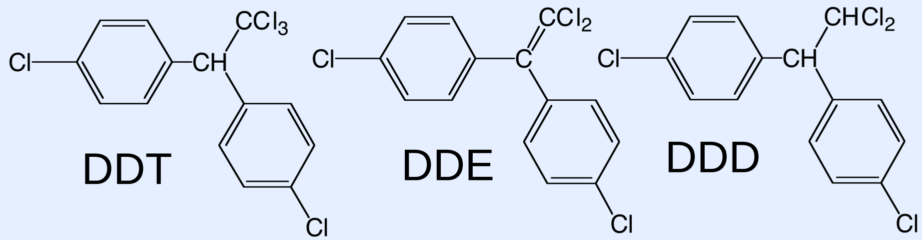
Plastics accumulate organic pollutants from seawater

PCBs



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

DDTs

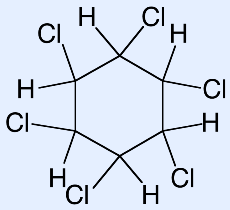


- DDT and its metabolites such as DDE and DDD.
- DDT was used as insecticides
- Endocrine disrupting chemicals

adsorption from ambient seawater

Plastics

HCH



- Insecticide

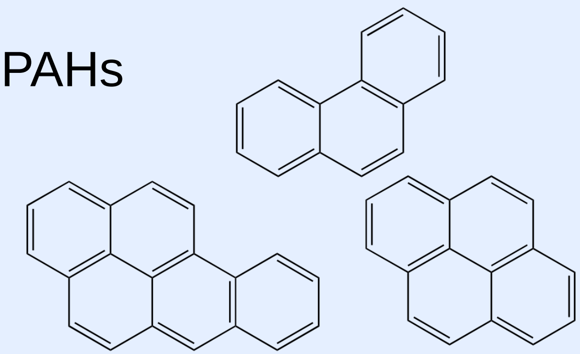
$-(CH_2-CH_2)_n-$

Polyethylene (PE)

$-(CH_2-CH(CH_3))_n-$

Polyprorylene (PP)

PAHs



Mato *et al*. (2001), *ES&T*

Hope for future

Topics

1. Introduction of International Pellet Watch

2. Hazardous chemicals associated with plastic fragments.

3. Ingestion of plastics by marine organisms.

4. Transfer of hazardous chemicals from ingested plastics to internal system of marine organisms.

5. No single-use plastic.

Microscopic plastics (< 1 mm) bring POPs to lower-trophic-level organisms and induce biological stress

Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress

Chelsea M. Rochman[1], Eunha Hoh[2], Tomofumi Kurobe[1] & Swee J. Teh[1]

Microplastic ingestion decreases energy reserves in marine worms

Stephanie L. Wright[1], Darren Rowe[1], Richard C. Thompson[2], and Tamara S. Galloway[1,*]

Microplastic Moves Pollutants and Additives to Worms, Reducing Functions Linked to Health and Biodiversity

Mark Anthony Browne,[1,2,*] Stewart J. Niven,[1,3,4] Tamara S. Galloway,[5] Steve J. Rowland,[4] and Richard C. Thompson[1]
[1]School of Marine Science & Engineering, Plymouth University, Drake Circus, Plymouth PL4 8AA, UK
[2]National Center for Ecological Analysis & Synthesis, University of California, Santa Barbara, 735 State Street, Suite 300, Santa Barbara, CA 93101-3351, USA
[3]Waters Canada, Guelph, ON N1H 6H9, Canada
[4]School of Geography, Earth and Environmental Sciences, Plymouth University, Plymouth PL4 8AA, UK
[5]College of Life & Environmental Sciences, University of Exeter, Exeter EX4 4PS, UK

Animals from sedimentary ha
plastic can accumulate concer
times greater than those in se
more microplastic in habitats
downwind [4].

Surprisingly, the relative imp
tic versus sediments as vecto
of animals is poorly understo
lating the gut of lugworms ind
mulate from seawater to mi
greater transfer from micropla
ral organic carbon is scarce [9]
for fish predict that eating m
burdens of pollutants becaus

Microscopic plastics (< 1 mm) bring POPs to lower-trophic-level organisms and induce biological stress

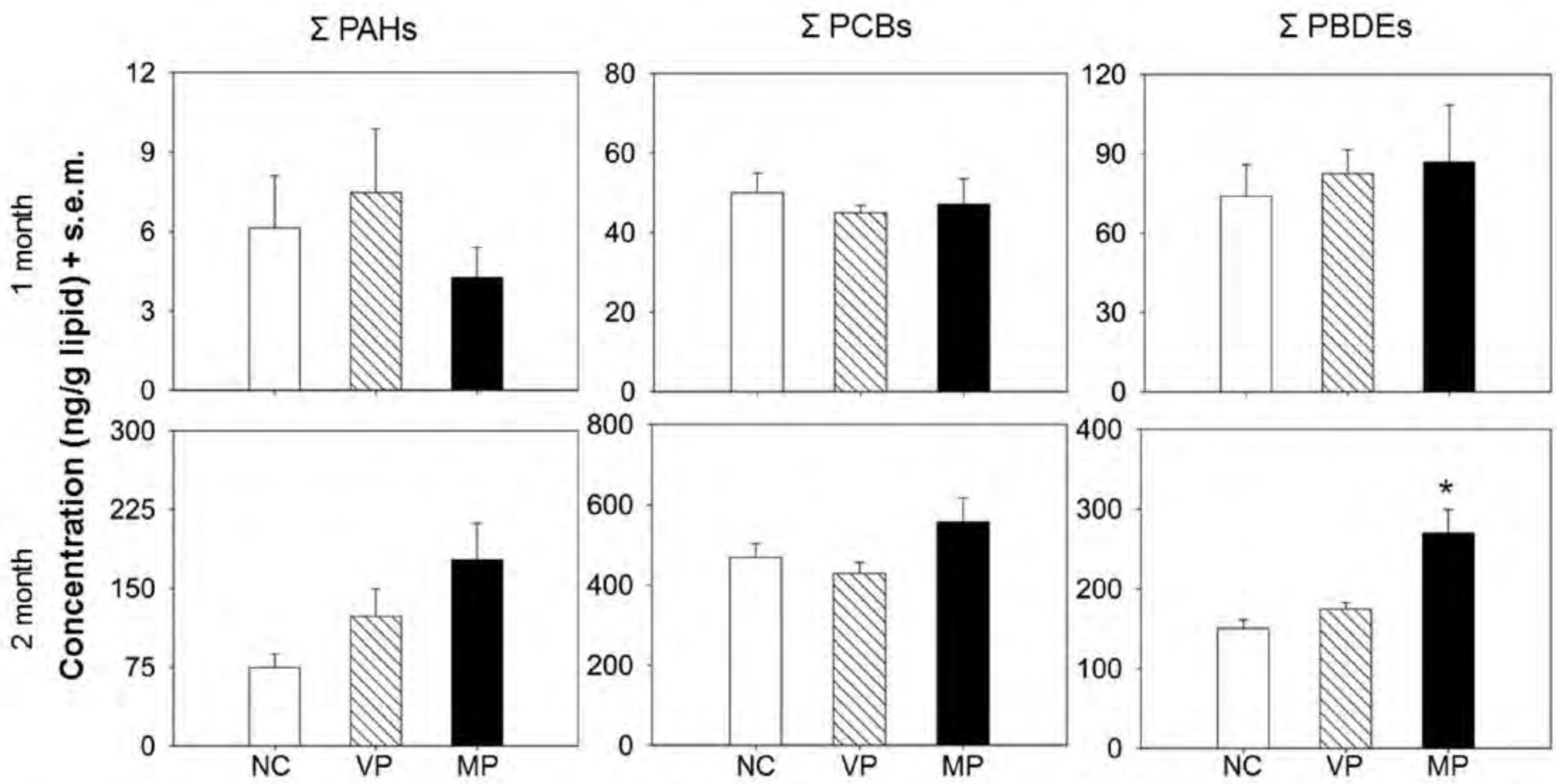


Figure 2 | Body burden of *Oryzias latipes* after the 1- and 2-month exposure. Bar graphs show mean concentrations (ng/g lipid + s.e.m) of total PAHs (left), PCBs (middle) and PBDEs (right) in fish tissue ($n = 3$) after one (top) and two (bottom) months of exposure. White bars represent the negative control (NC), bars with diagonal lines represent the virgin-plastic (VP) and black bars represent the marine-plastic (MP) treatment. A 2-factor ANOVA showed no significant differences between treatments for total PAHs, PCBs or PBDEs after 1 month and for total PAHs and PCBs after 2 months, but showed a significant difference ($P = 0.0003$) between treatments for total PBDEs after 2 months. A post-hoc SNK distinguished the marine-plastic having greater concentrations than the virgin-plastic and control treatment.

Environmental Pollution 187 (2014) 124–129

Contents lists available at ScienceDirect

Environmental Pollution

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

Plastic ingestion by Flesh-footed Shearwaters (*Puffinus carneipes*): Implications for fledgling body condition and the accumulation of plastic-derived chemicals

Jennifer L. Lavers[a,*,1], Alexander L. Bond[b], Ian Hutton[c]

[a] *Institute for Marine and Antarctic Studies, University of Tasmania, Private Bag 129, Hobart, Tasmania 7005, Australia*
[b] *Environment Canada, 11 Innovation Boulevard, Saskatoon, Saskatchewan S7N 3H5 Canada*
[c] *Lord Howe Island Museum, PO Box 157, Lord Howe Island, New South Wales 2898 Australia*

ARTICLE INFO

Article history:
Received 15 September 2013
Received in revised form
17 December 2013
Accepted 20 December 2013

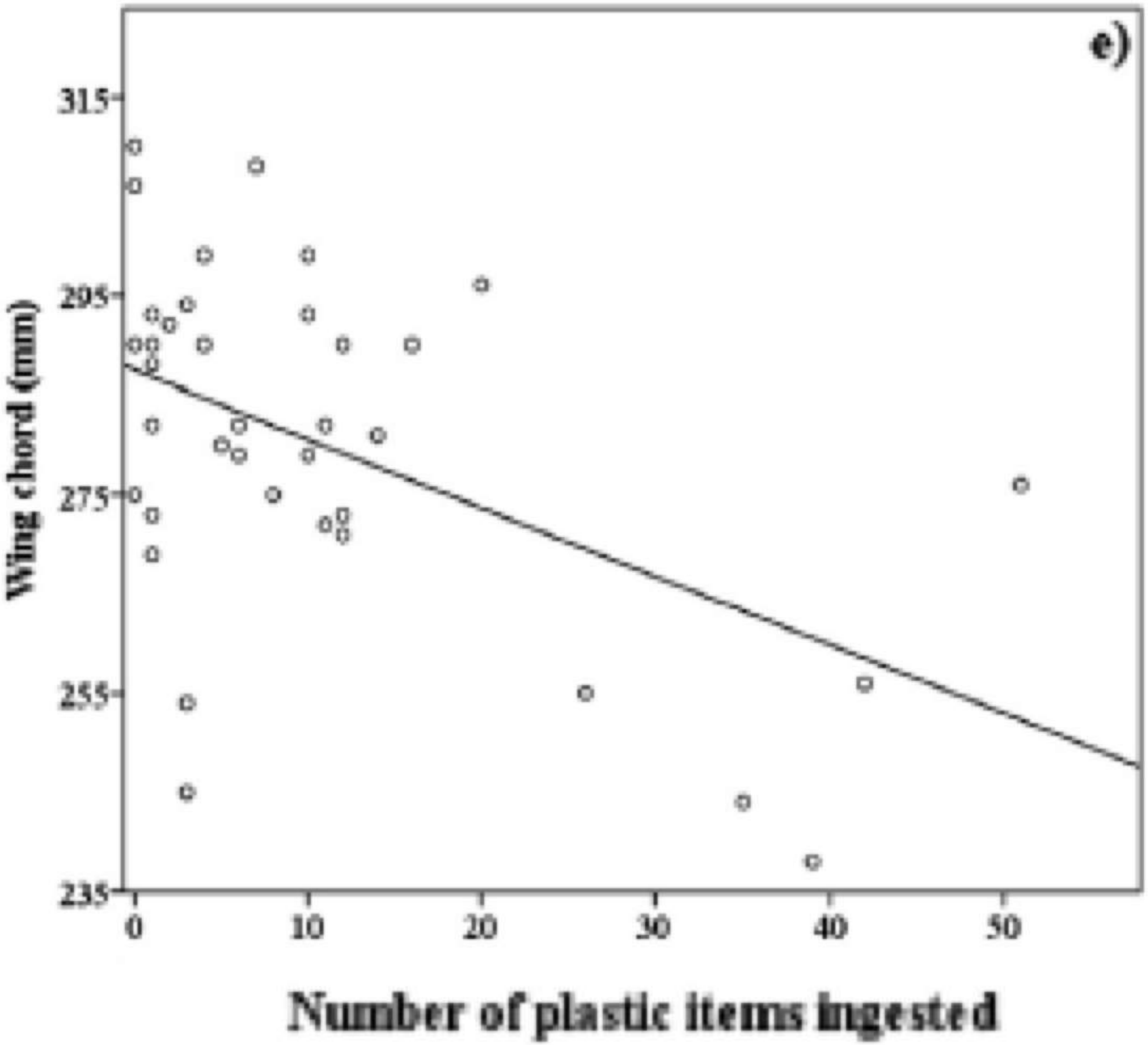
Keywords:
Body condition
Flesh-footed Shearwater
Marine debris
Plastic ingestion
Trace metals

ABSTRACT

To provide much needed quantitative data on the lethal and sublethal effects of plastic pollution on marine wildlife, we sampled breast feathers and stomach contents from Flesh-footed Shearwater (*Puffinus carneipes*) fledglings in eastern Australia. Birds with high levels of ingested plastic exhibited reduced body condition and increased contaminant load ($p < 0.05$). More than 60% of fledglings exceed international targets for plastic ingestion by seabirds, with 16% of fledglings failing these targets after a single feeding (range: 0.13–3.21 g of plastic/feeding). As top predators, seabirds are considered sentinels of the marine environment. The amount of plastic ingested and corresponding damage to Flesh-footed Shearwater fledglings is the highest reported for any marine vertebrate, suggesting the condition of the Australian marine environment is poor. These findings help explain the ongoing decline of this species and are worrying in light of increasing levels of plastic pollution in our oceans.

Flesh-footed shearwater from Southern pacific

Reduced body condition with increasing plastic ingestion



Plastic ingestion may lead to decline of the species of seabirds

ABSTRACT

To provide much needed quantitative data on the lethal and sublethal effects of plastic pollution on marine wildlife, we sampled breast feathers and stomach contents from Flesh-footed Shearwater (*Puffinus carneipes*) fledglings in eastern Australia. Birds with high levels of ingested plastic exhibited reduced body condition and increased contaminant load ($p < 0.05$). More than 60% of fledglings exceed international targets for plastic ingestion by seabirds, with 16% of fledglings failing these targets after a single feeding (range: 0.13–3.21 g of plastic/feeding). As top predators, seabirds are considered sentinels of the marine environment. The amount of plastic ingested and corresponding damage to Flesh-footed Shearwater fledglings is the highest reported for any marine vertebrate, suggesting the condition of the Australian marine environment is poor. These findings help explain the ongoing decline of this species and are worrying in light of increasing levels of plastic pollution in our oceans.

Trashes on high-tide line on our beaches

Trashes on high-tide line on our beaches

Trashes on high-tide line on our beaches

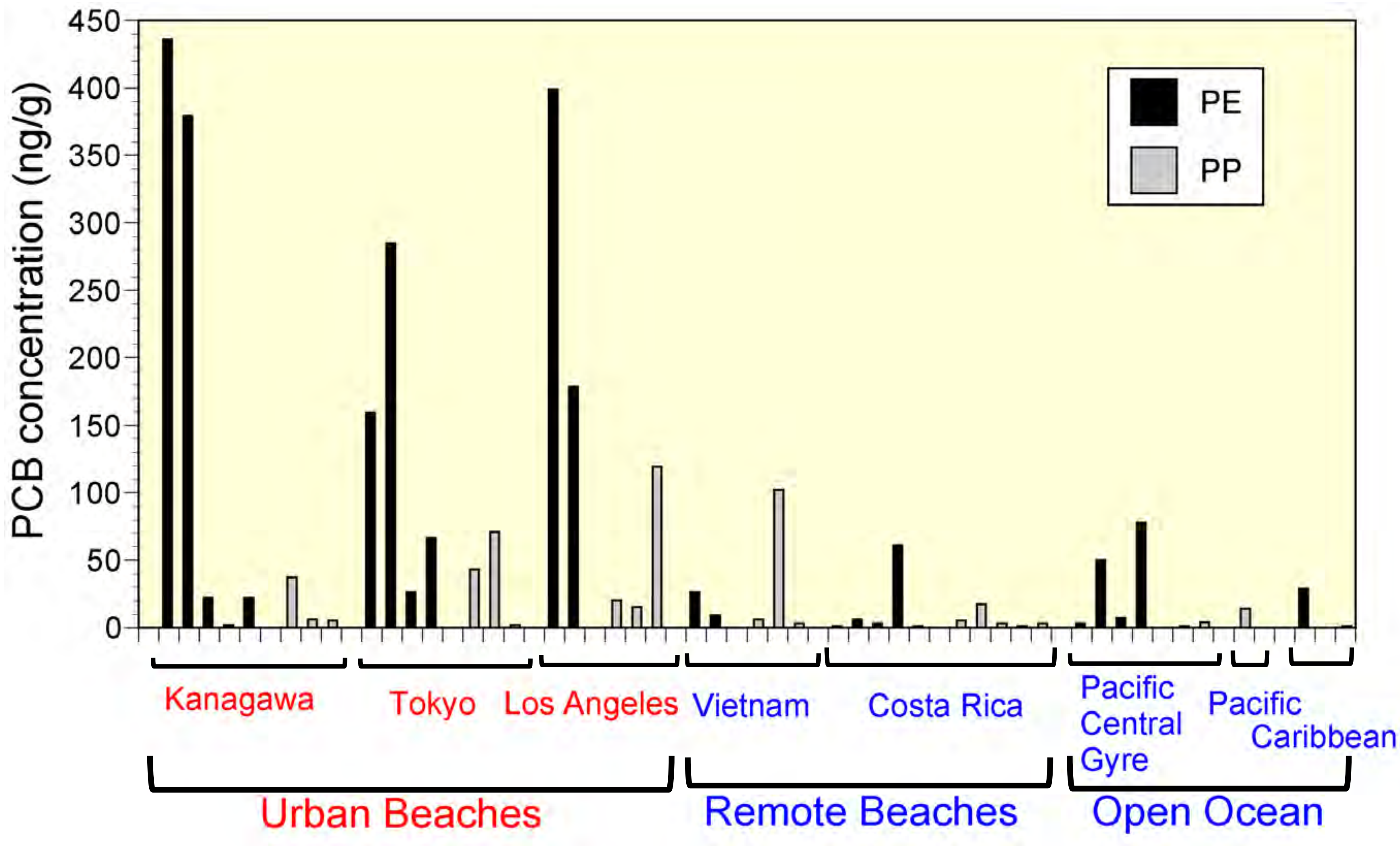
Plastic Resin Pellets as a Transport Medium for Toxic Chemicals in the Marine Environment

Environmental Science & Technology
2001, vol.35, 318-324

~250 locations from 50 countries

Plastic fragments are dominant over resin pellets

Distribution of PCBs in plastic fragments

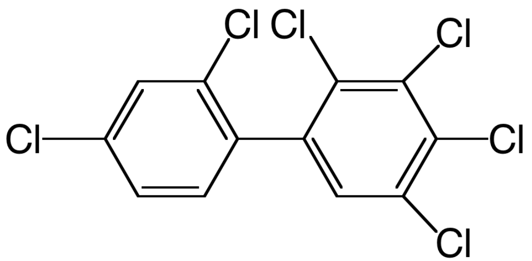


➡ Sporadic high concentrations of PCBs were detected even in remote beaches and open ocean

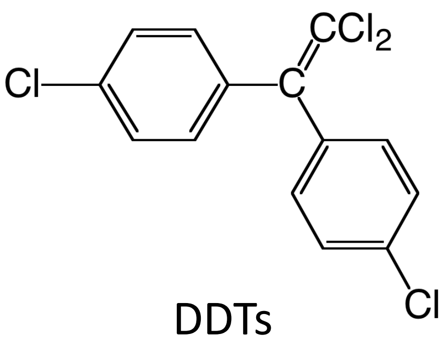
Plastics carry two types of chemicals in marine environment

Sorption from ambient seawater

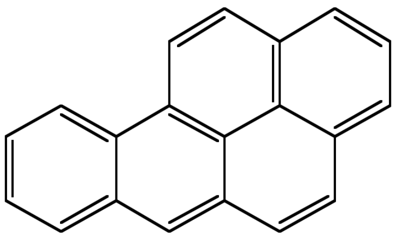
Additive-derived chemicals



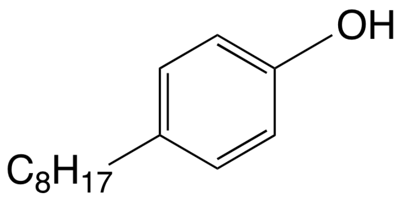
Polychlorinated biphenyl (PCBs)



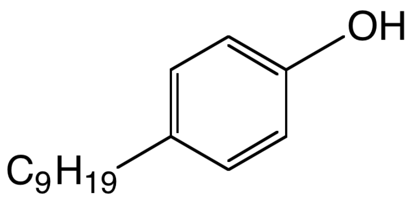
DDTs



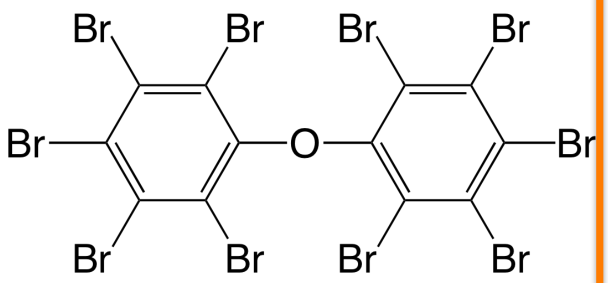
Polycyclic aromatic hydrocarbons (PAHs)



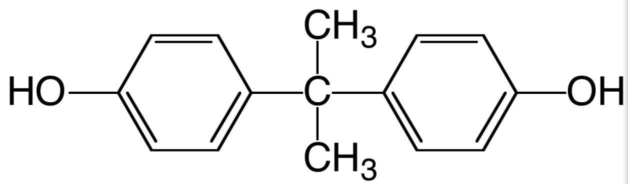
Octylphenol



Nonylphenol



Polybrominated diphenyl ethers (PBDEs)



Bisphenol A

First Alert of marine plastic pollution in 1972

Plastics on the Sargasso Sea Surface

Carpenter and Smith (1972) ***Science***, March 17 p.1240-1241.

Fig. 1. Typical plastic particles from tow 2. White pellets are on the left.

Plastic particle pollution of the surface of the Atlantic Ocean : Evidence from a seabird

Rothstein (1973),
The Condor, vol.75, p.344-345

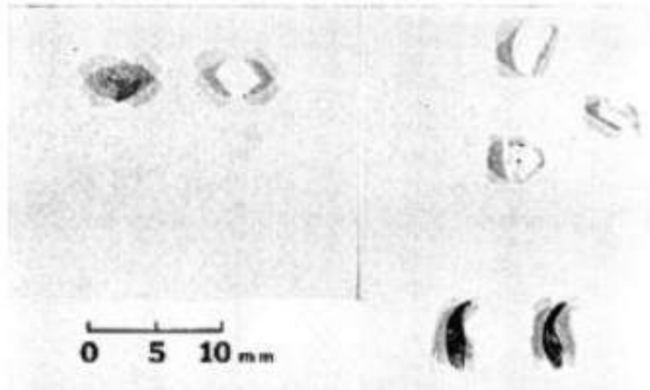
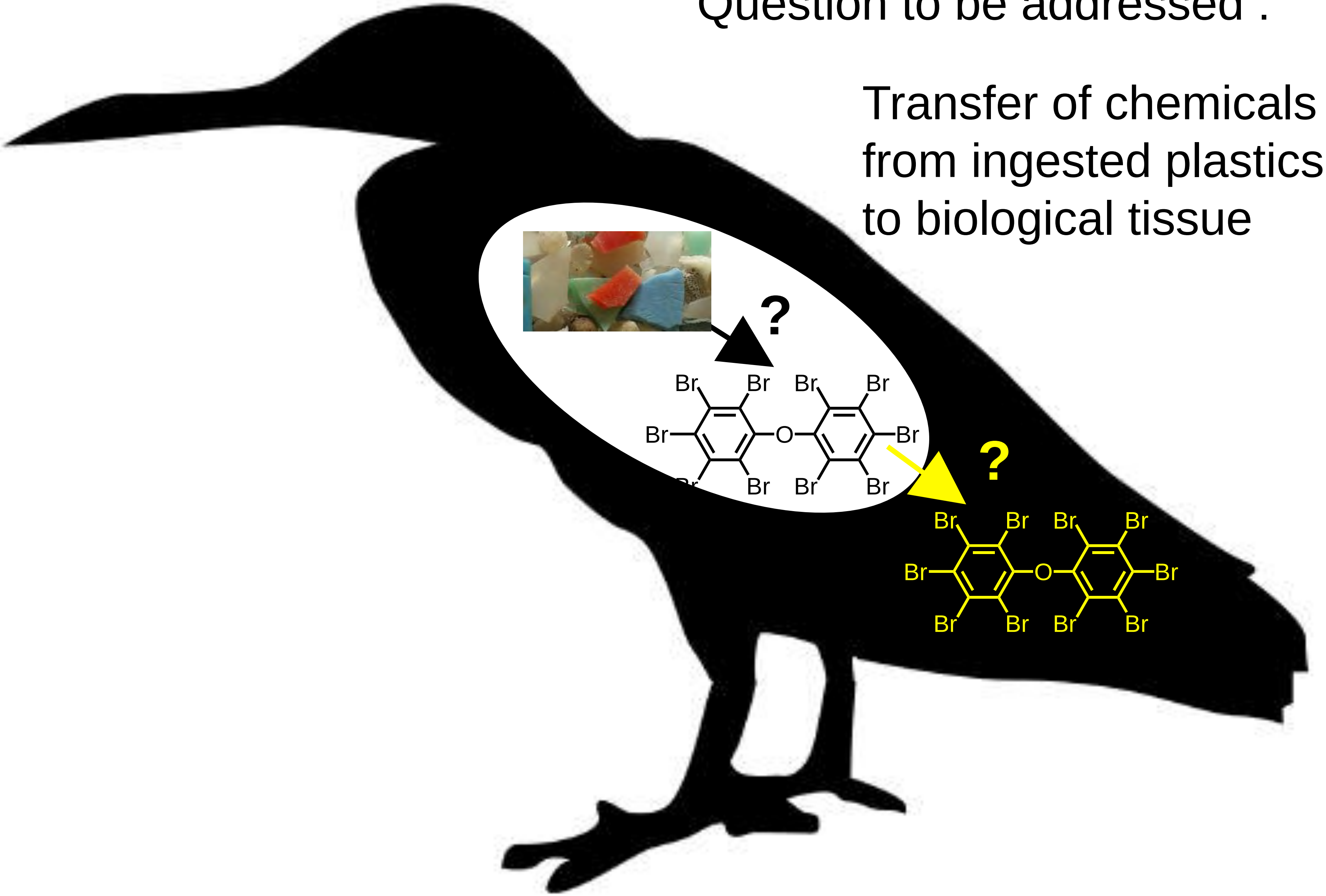


FIGURE 1. Objects found in the stomachs of two Leach's Petrels. The two pieces of plastic in the upper left corner were found in the gizzard of a petrel collected on Gull Island, Newfoundland. The three pieces of plastic as well as the two claw-like structures in the right half of the figure were all found in the gizzard of a petrel collected on Kent Island, New Brunswick. The claw-like structures have been tentatively identified as the pharyngeal teeth of a large polychaete.

Transfer of chemicals from ingested plastics to biological tissue

Question to be addressed :

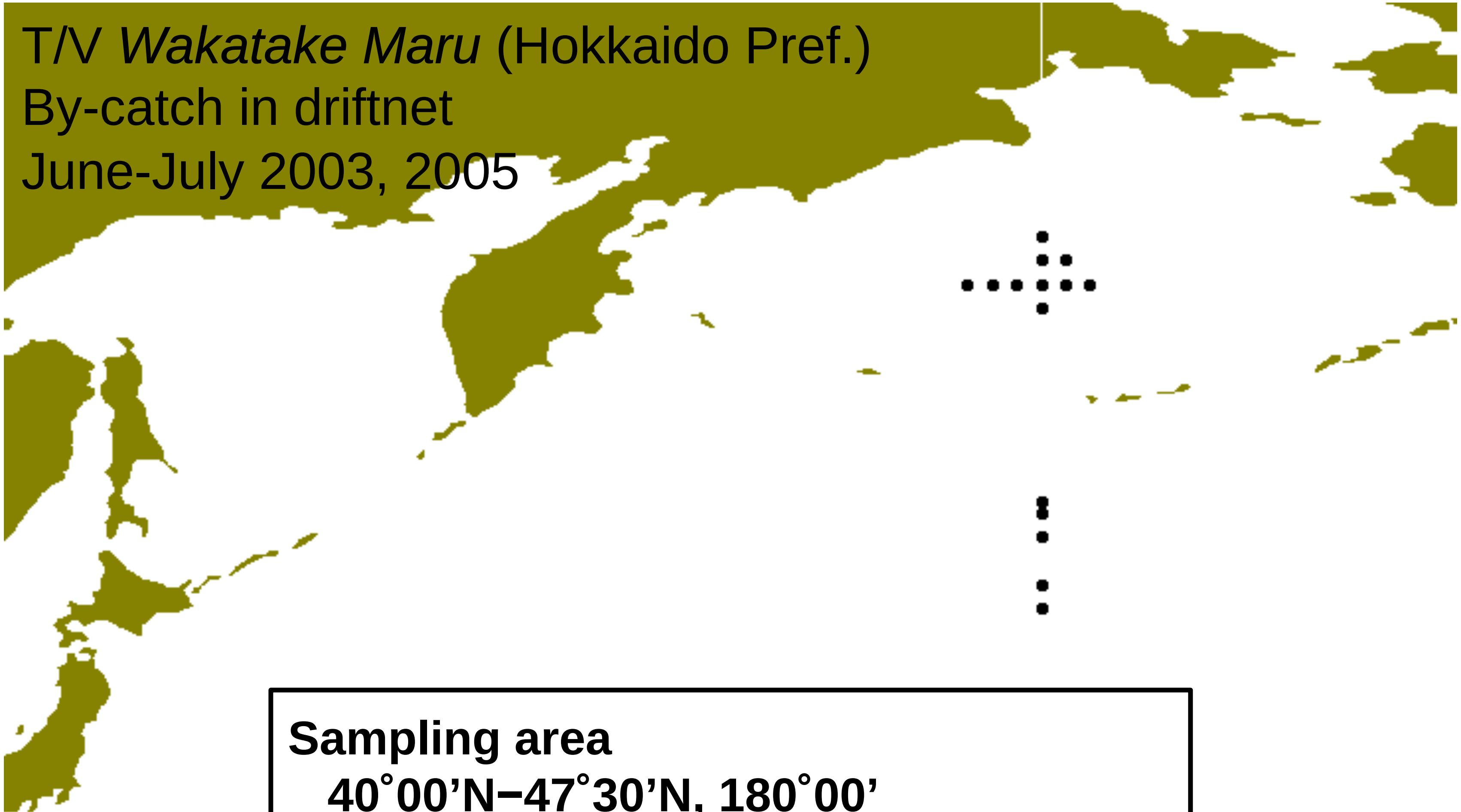
Transfer of chemicals
from ingested plastics
to biological tissue



Materials and methods

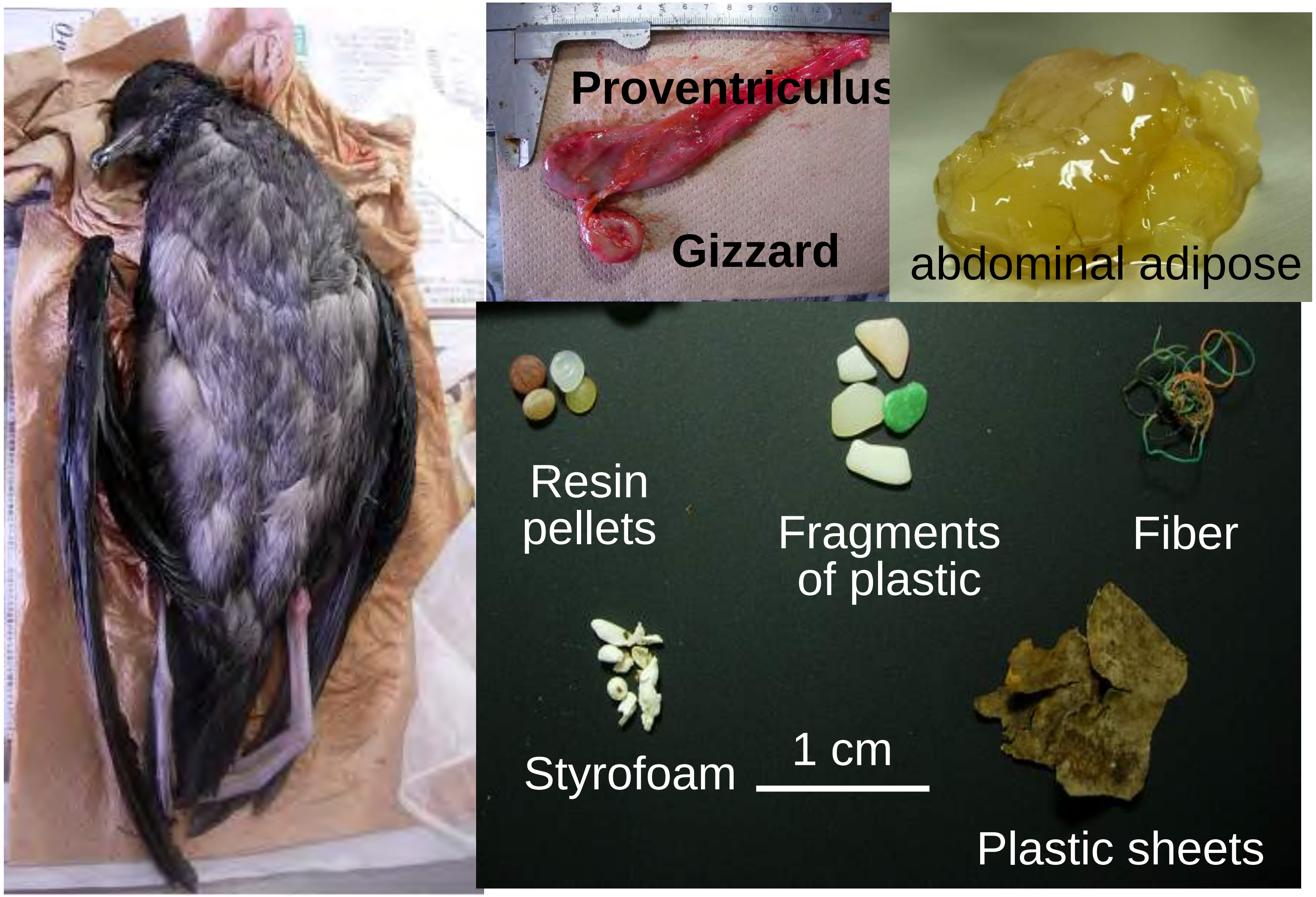
Collection of seabirds and their prey (lantern fish, squid)

T/V *Wakatake Maru* (Hokkaido Pref.)
By-catch in driftnet
June-July 2003, 2005



Sampling area
40°00’N−47°30’N, 180°00’
55°30’N−58°30’N, 178°00’ E−178°00’ W

Abdominal adipose of circus of short-tailed shearwater by-catch



- Amount of plastics found in stomach
- PBDEs concentrations in abdominal adipose

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*

Faculty of 1000

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

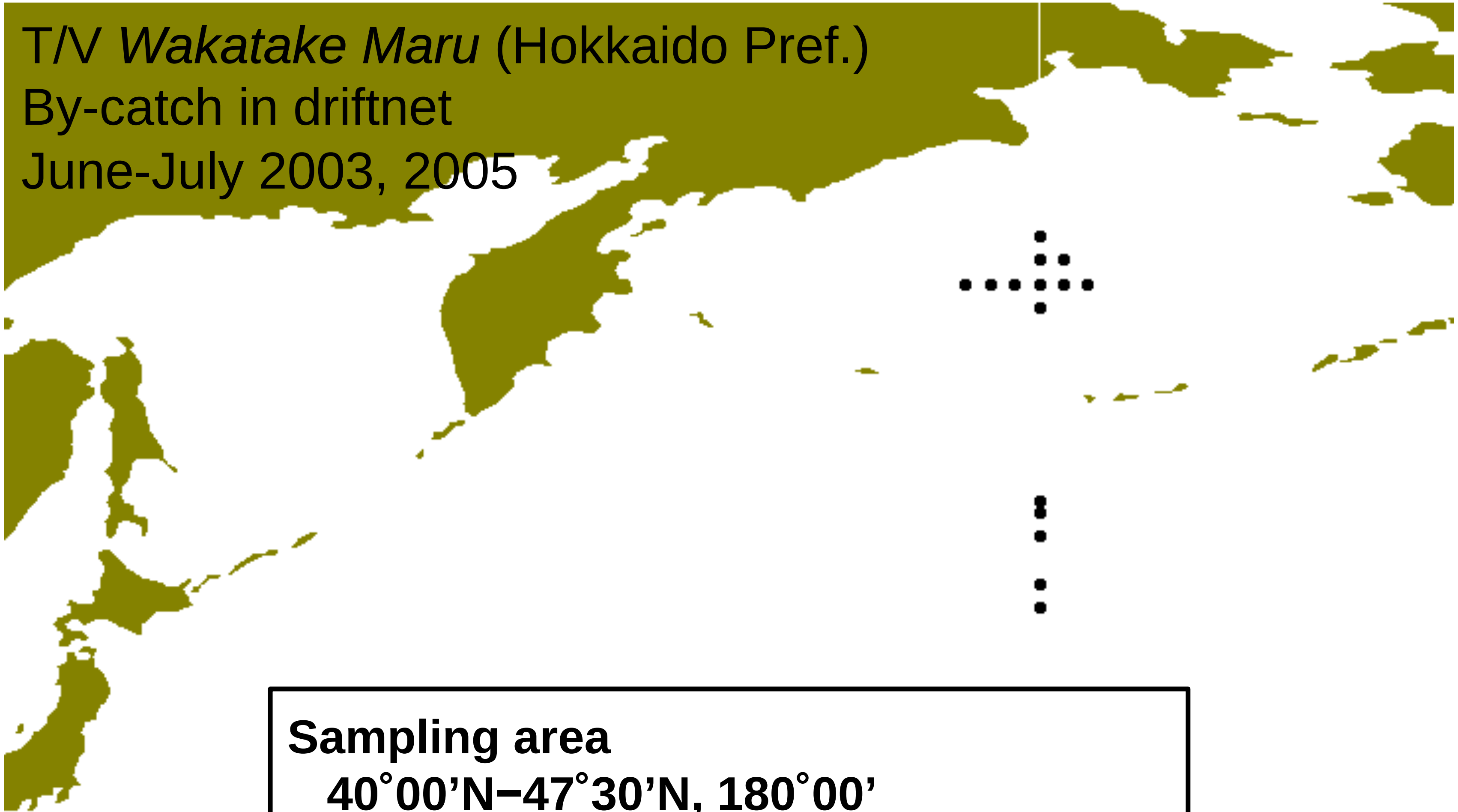
Keywords:
Polybrominated diphenyl ethers (PBDEs)
Plastic debris
Additives
North Pacific Ocean
Short-tailed shearwater
Bioaccumulation

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.

Materials and methods

Collection of seabirds and their prey (lantern fish, squid)

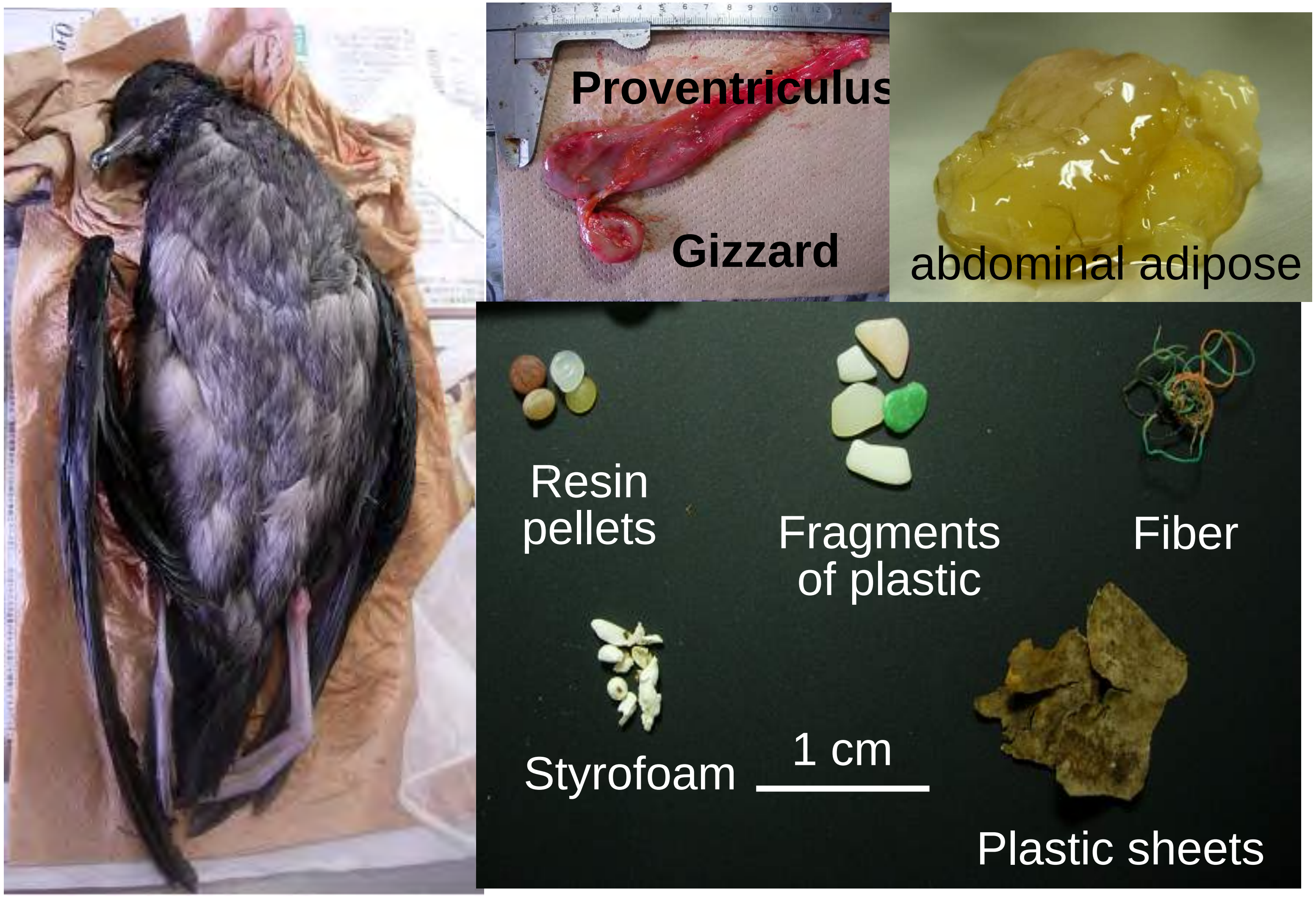


Sampling area

40°00'N−47°30'N, 180°00'

55°30'N−58°30'N, 178°00' E−178°00' W

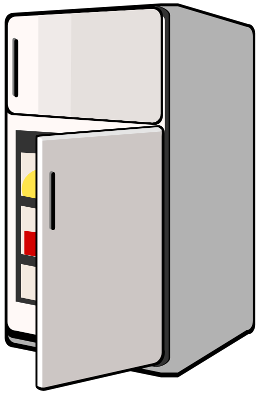
Abdominal adipose of circus of short-tailed shearwater by-catch

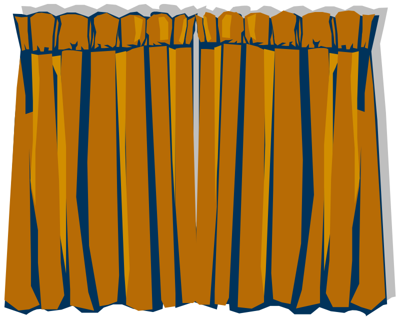
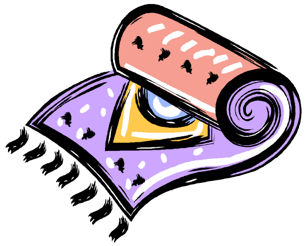


- Amount of plastics found in stomach
- PBDEs concentrations in abdominal adipose

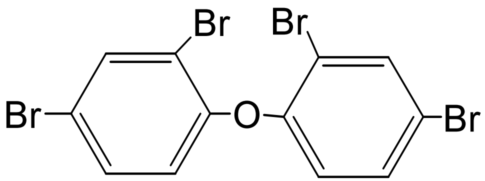
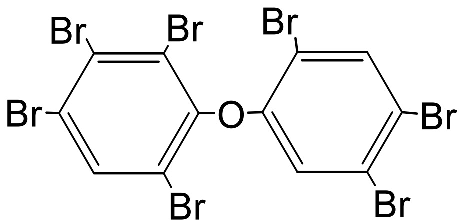
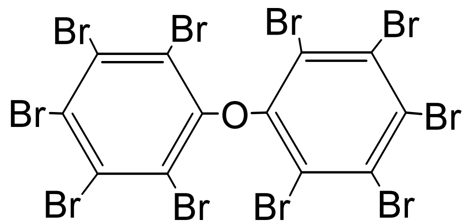
PBDEs : Flame retardants

applied in various electric products and fabrics.

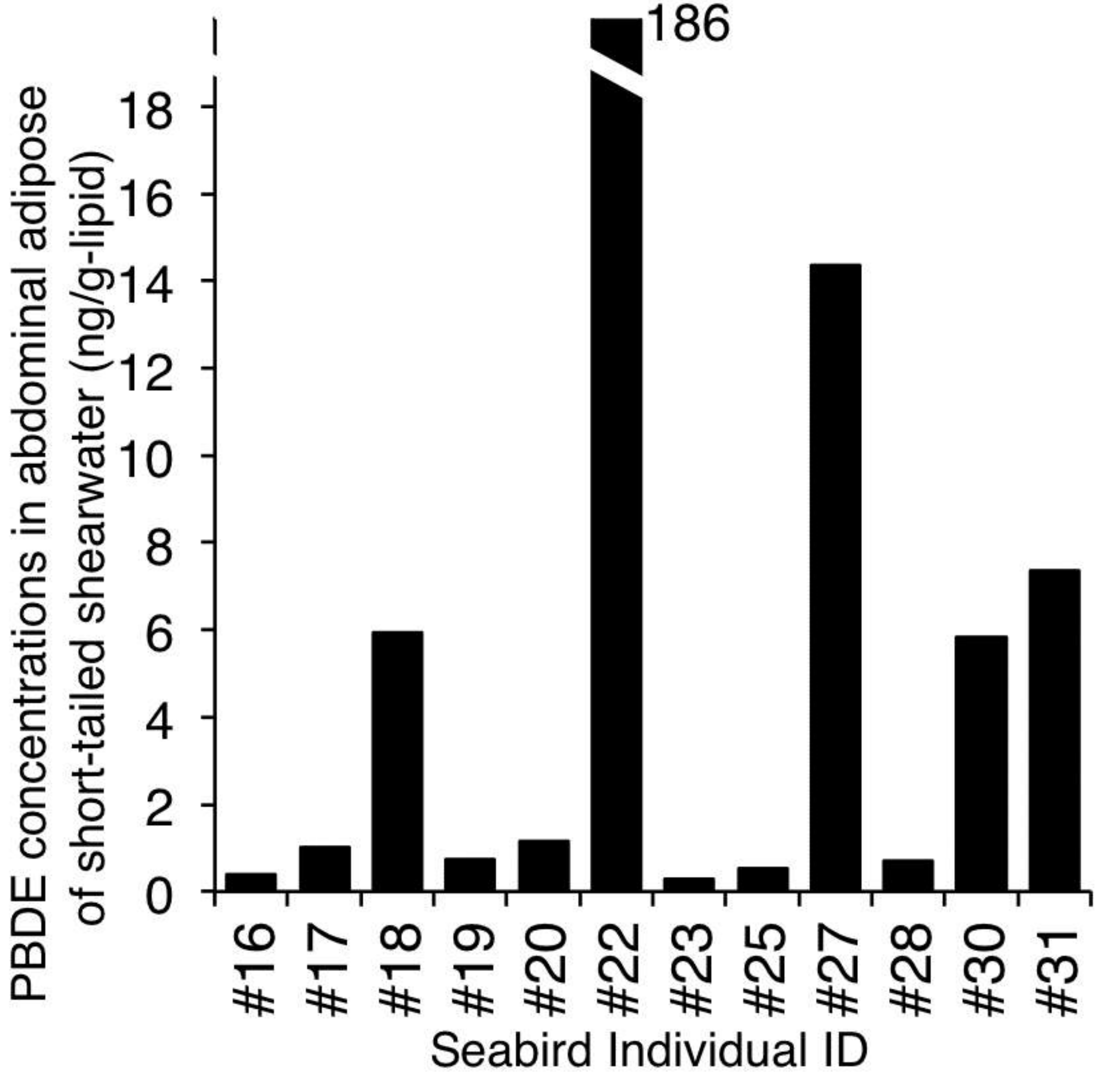



3 technical products (mixtures of congeners)

Penta BDE	Octa BDE	DecaBDE
(Br4, Br5)	(Br7,8)	(Br10)
		
e.g., BDE47	e.g., BDE183	e.g., BDE209

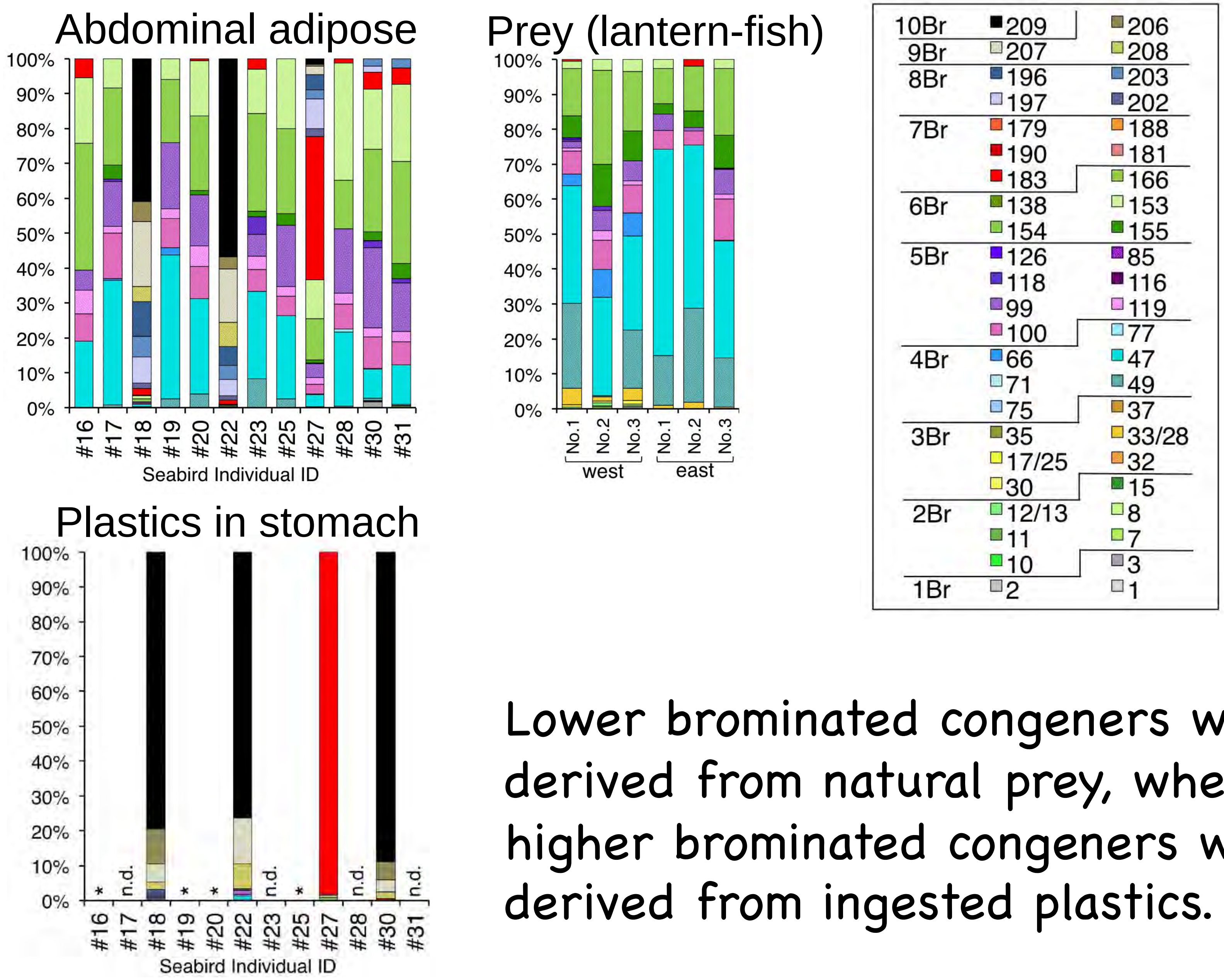
PBDEs detected in the abdominal adipose of the short-tailed shearwater



PBDEs were detected in abdominal adipose of all the individuals.

Blank
BDE#47 : 0.0006 ng/g-lipid
BDE#209 :0.03 ng/g-lipid

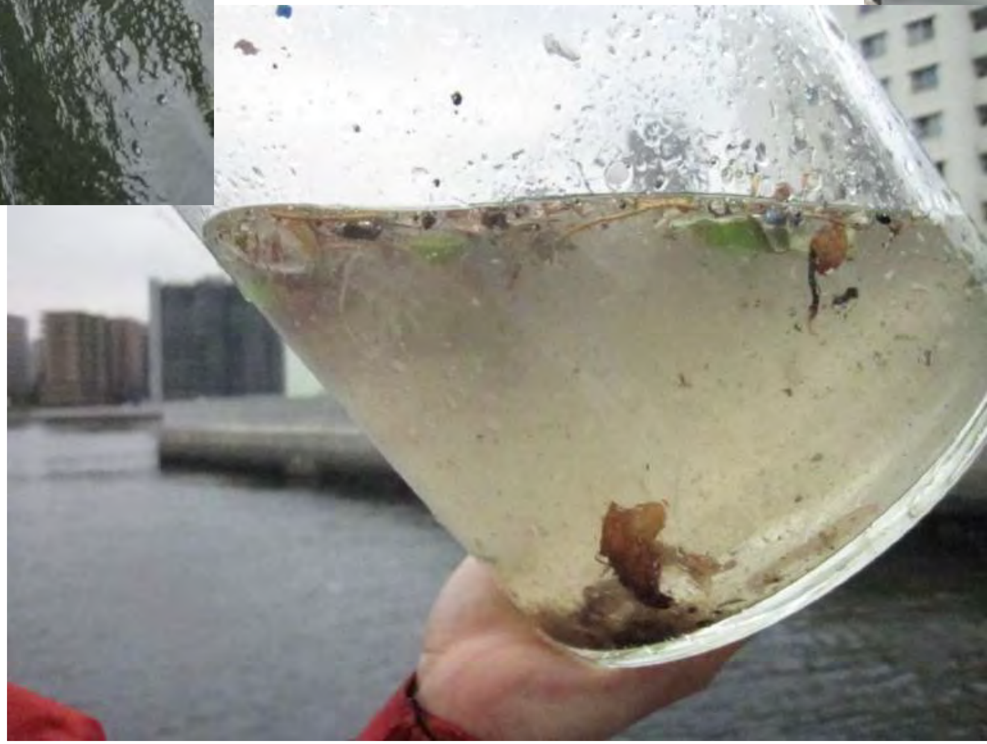
Composition of BDE congeners in seabird adipose, plastics in the stomachs, and their prey.



Lower brominated congeners were derived from natural prey, whereas higher brominated congeners were derived from ingested plastics.

Microplstics (< 5 mm) in Tokyo Bay

Microplastics collected by plankton-net



Plastics accumulated in a gyre in open ocean

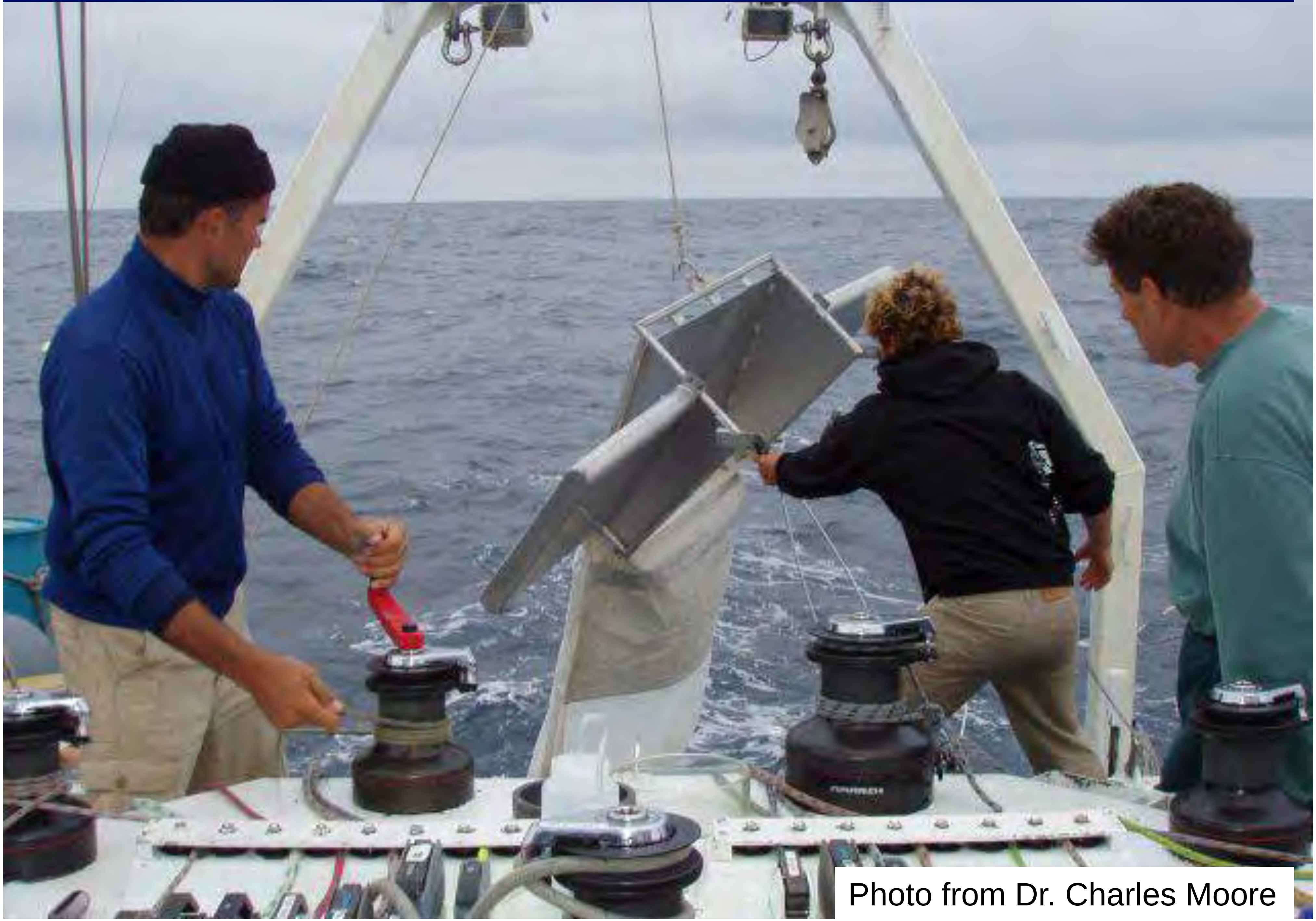
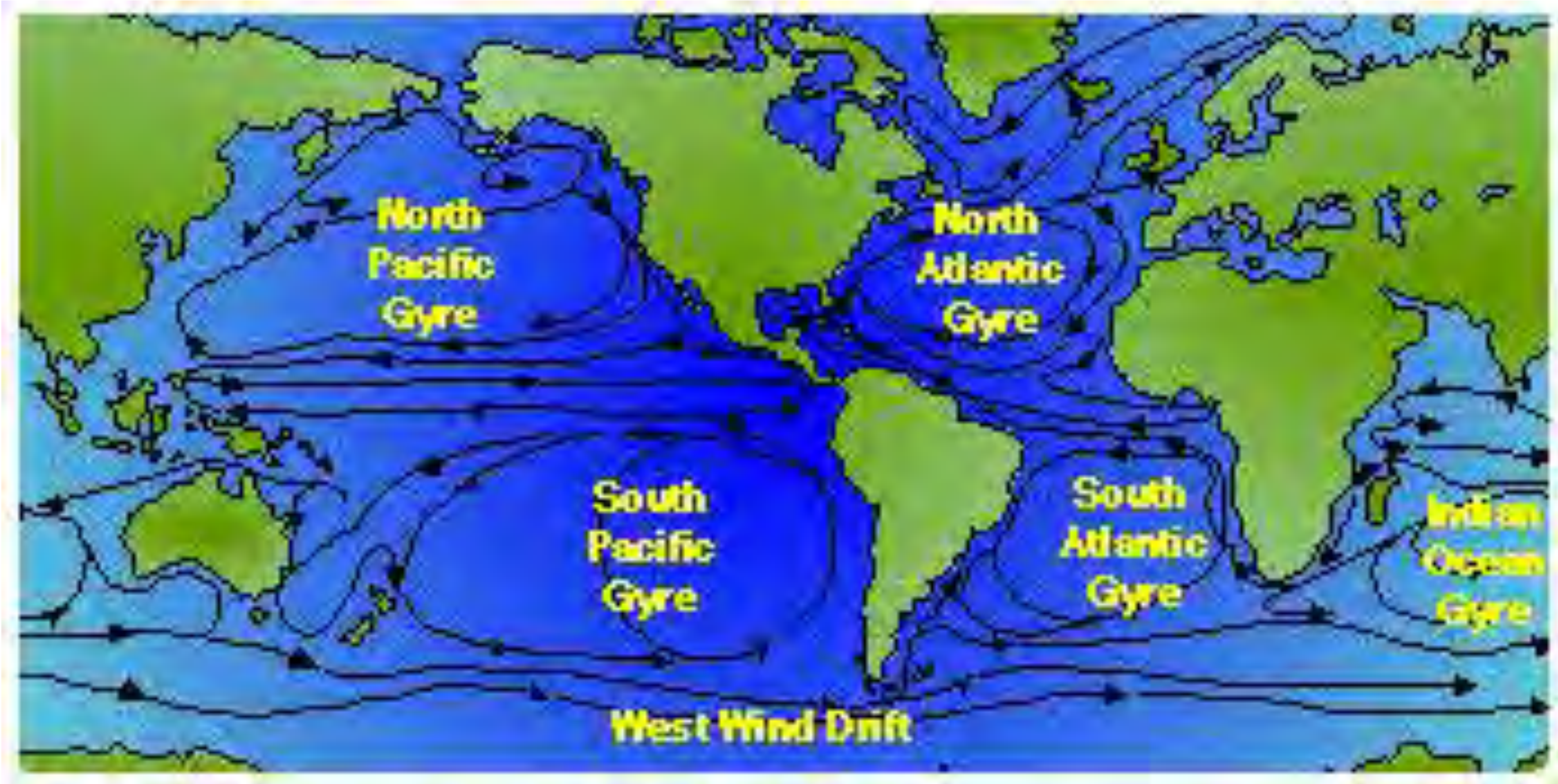


Photo from Dr. Charles Moore

Microplstics (< 5 mm) in Tokyo Bay

Microplstics accumulated in central gyre of the Pacific : Plastics 6 times more than plankton

Plastics accumulated at 5 gyres in the ocean.



SOUTH PACIFIC GYRE April 2011

Photo from Dr. Charles Moore

Indian Ocean Gyre April 2010

Photo from Dr. Charles Moore

SOUTH ATLANTIC GYRE, AUGUST 2010

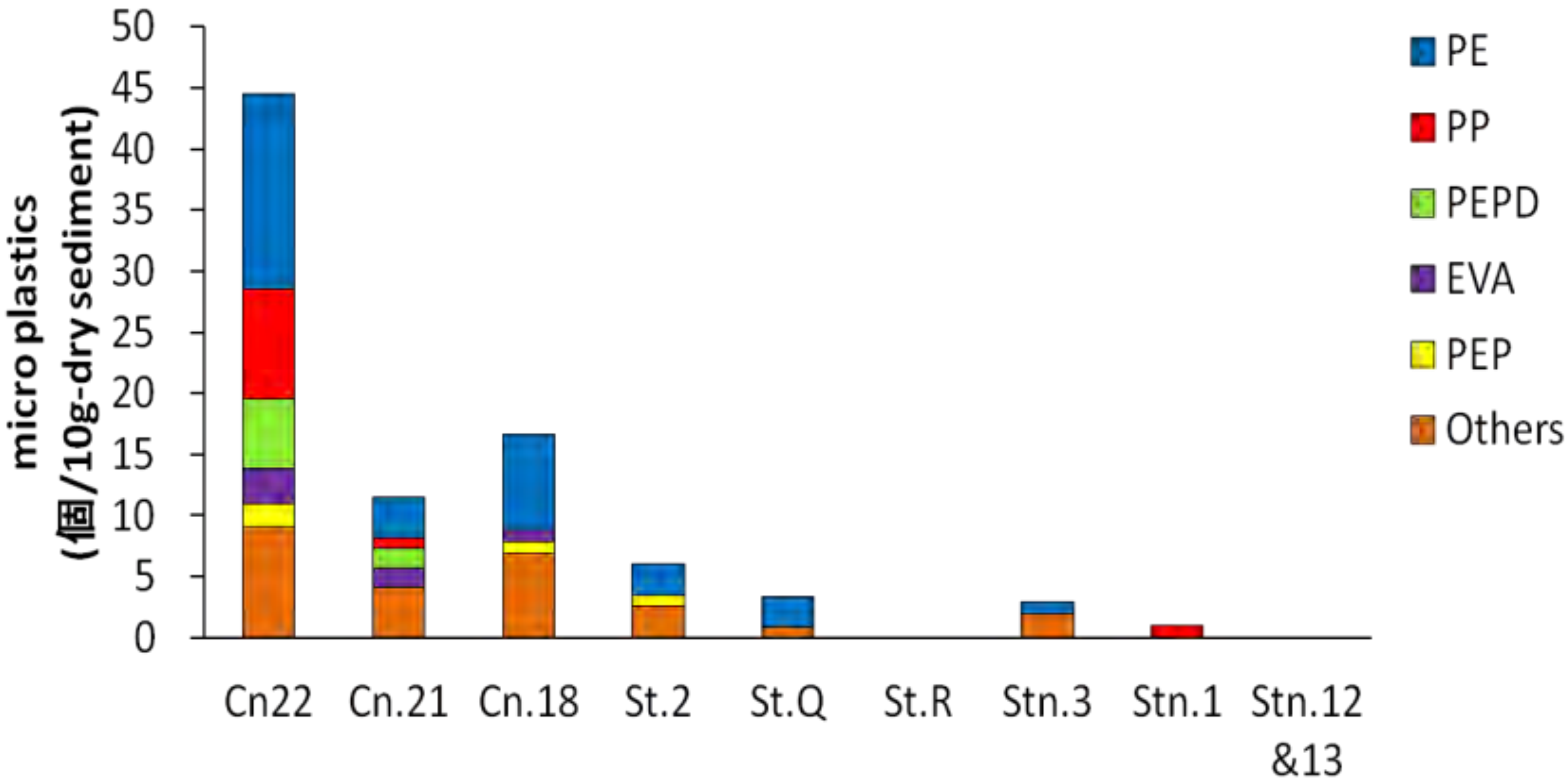
Photo from Dr. Charles Moore

Microplstics (< 5 mm) in Tokyo Bay

Origins of microplasitics

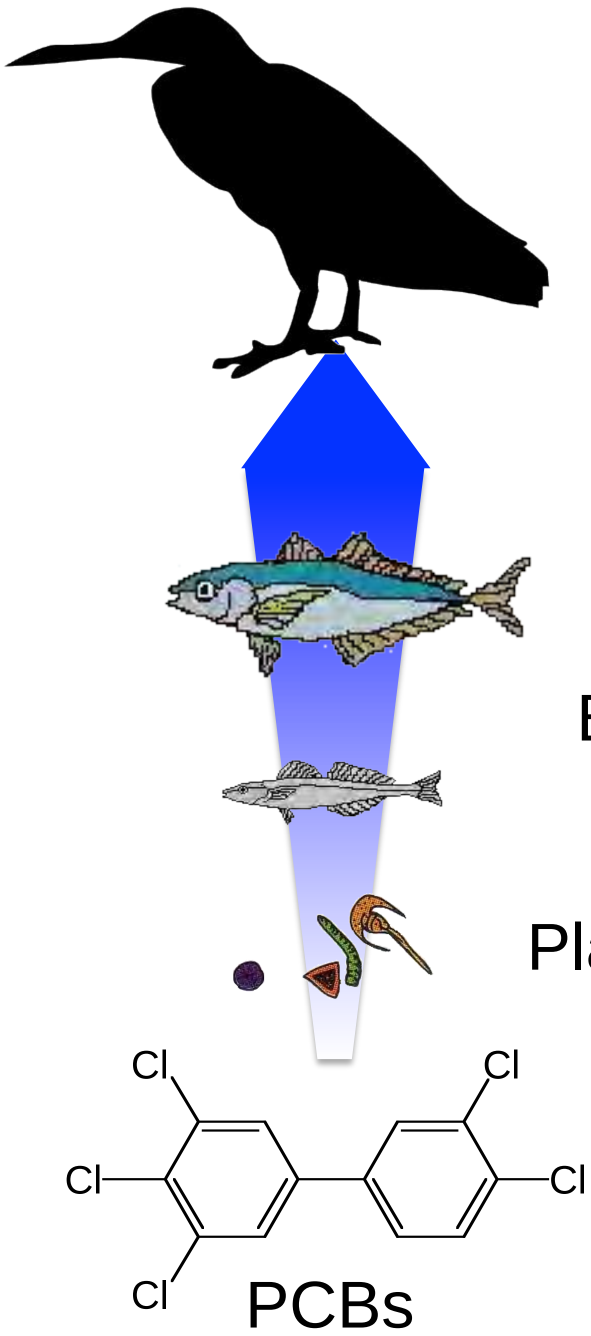
- Fragmentation of waste plastics
- Plastic resin pellets
- Chemical fabric
- Scrub in cosmetics
- Sponge designed for crumble for cleaning

Microplastics accumulated in bottom sediments



Biomagnification of POPs through maine food web

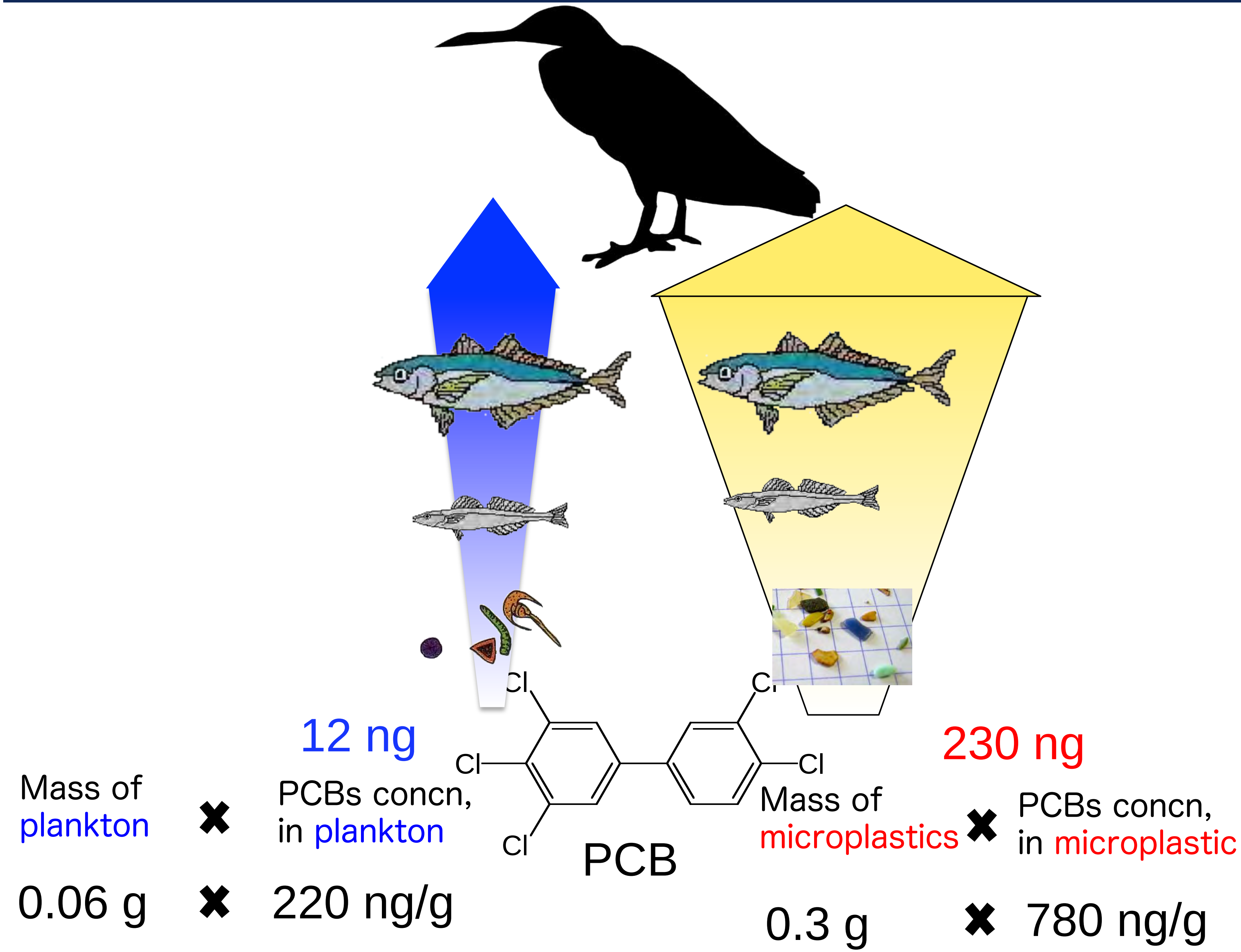
Top-predators are exposed
to biomagnified POPs



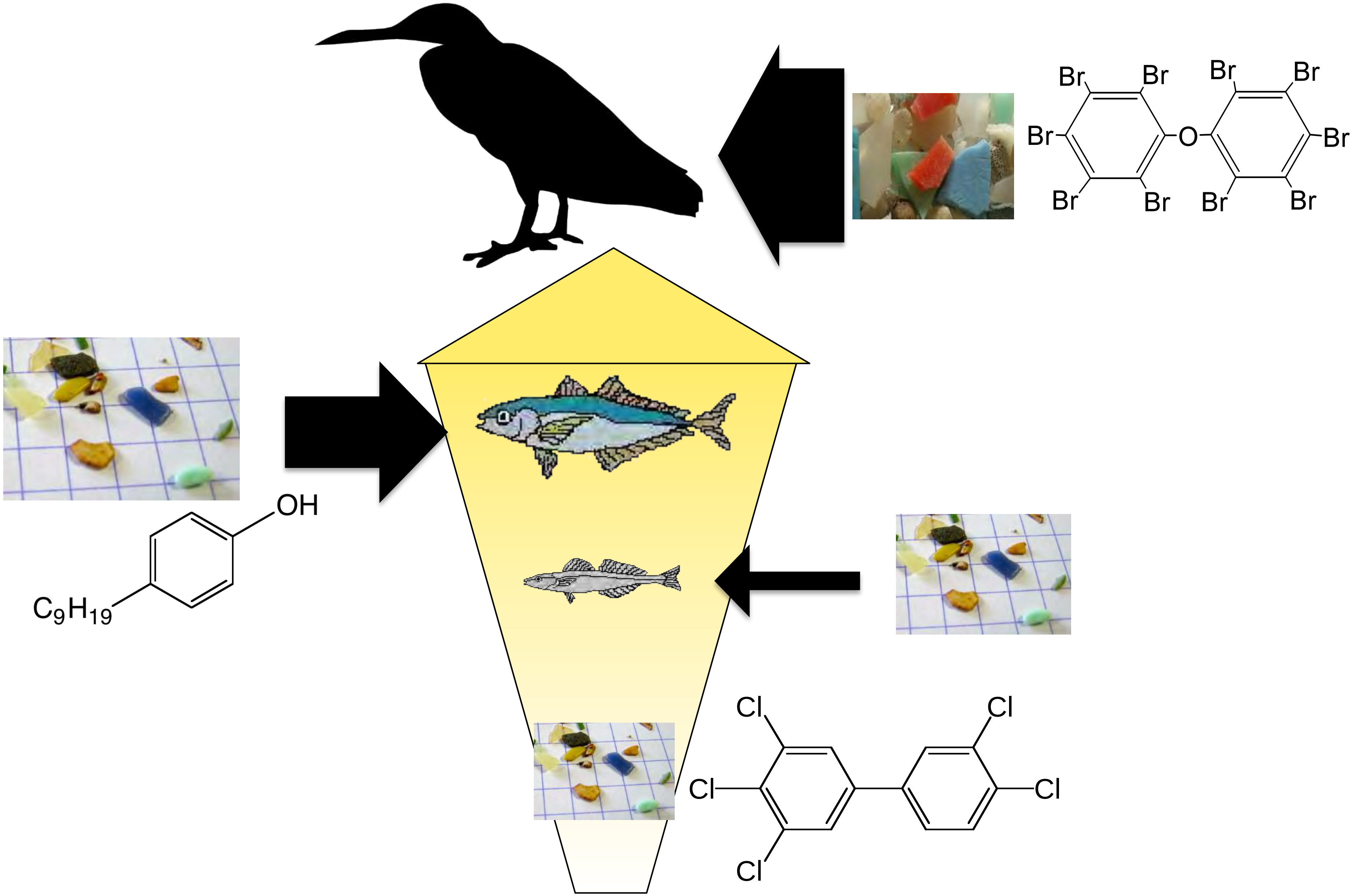
Biomagnification

Plankton

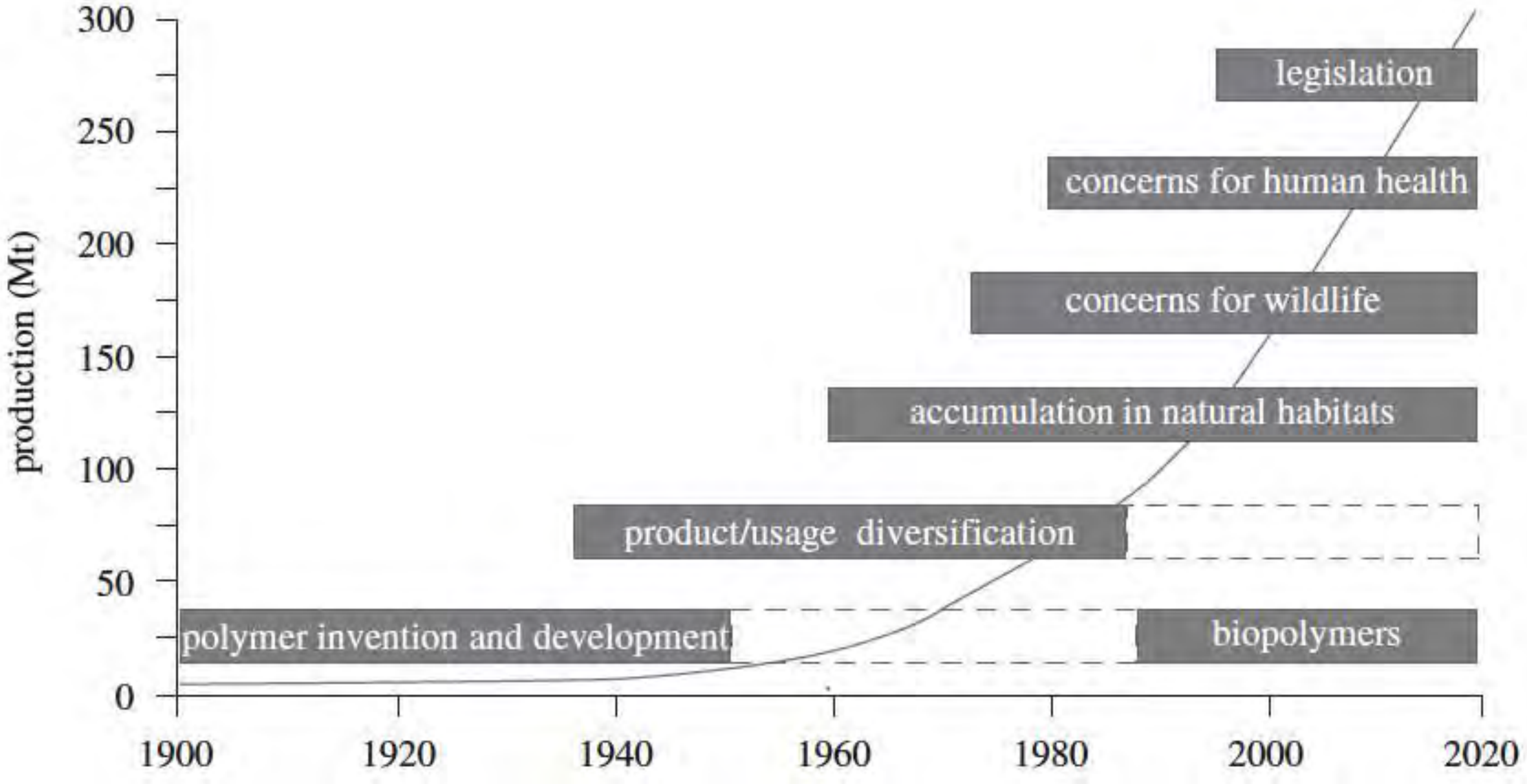
Plankton-derived exposure < Microplastic-derived exposure



Multi-level invasion of plastics and associate pollutants to ecosystem



Continuous increase in plastic production



1933:Polyethylene discovered.

Thompson et al., 2009

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

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.

3R

Reduce

Reuse : non-reusable plastics

Recycle : consumes energy and produces CO_2

Precautionary Principle

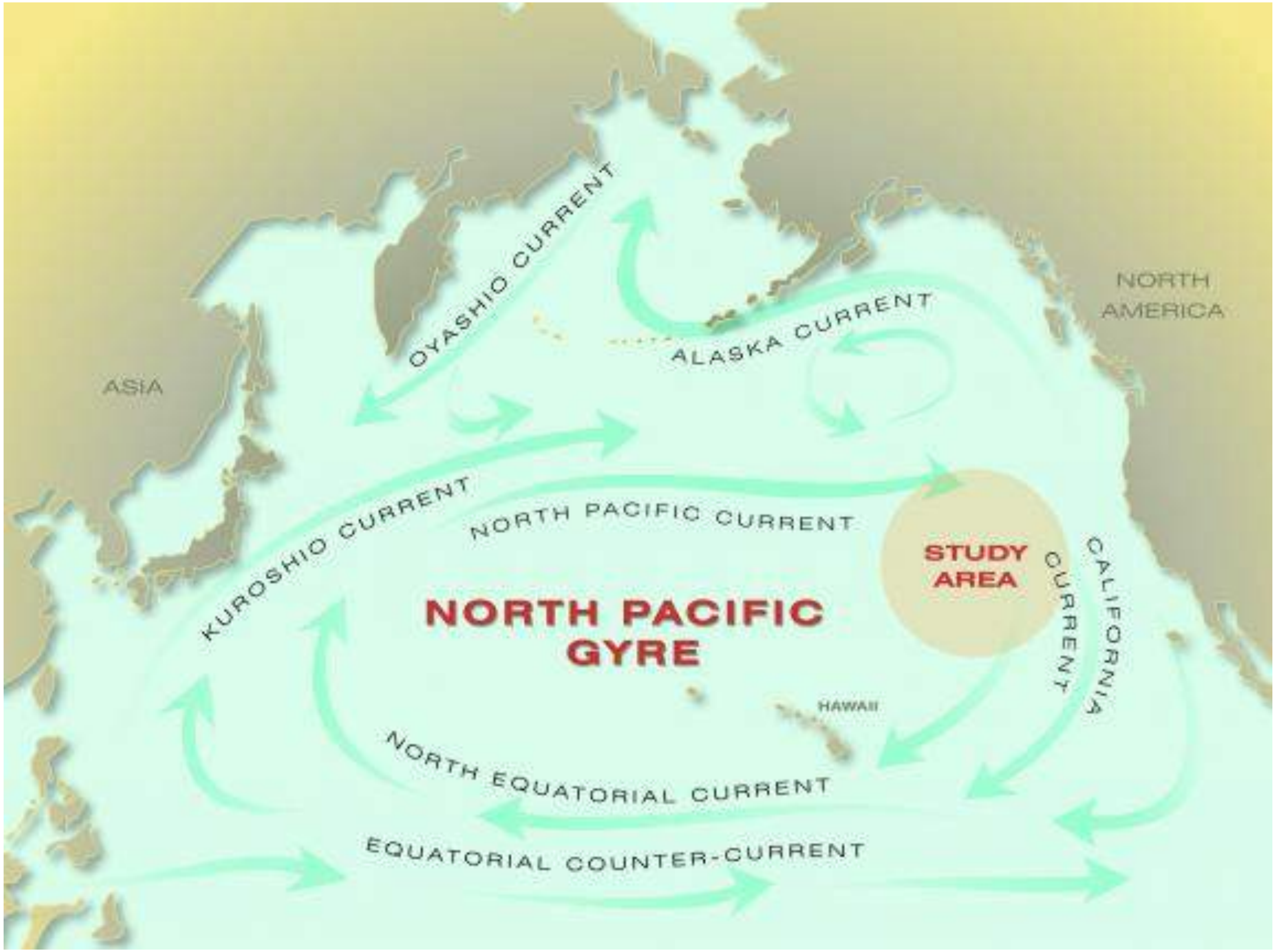
No single-use plastic!

For panel discussion

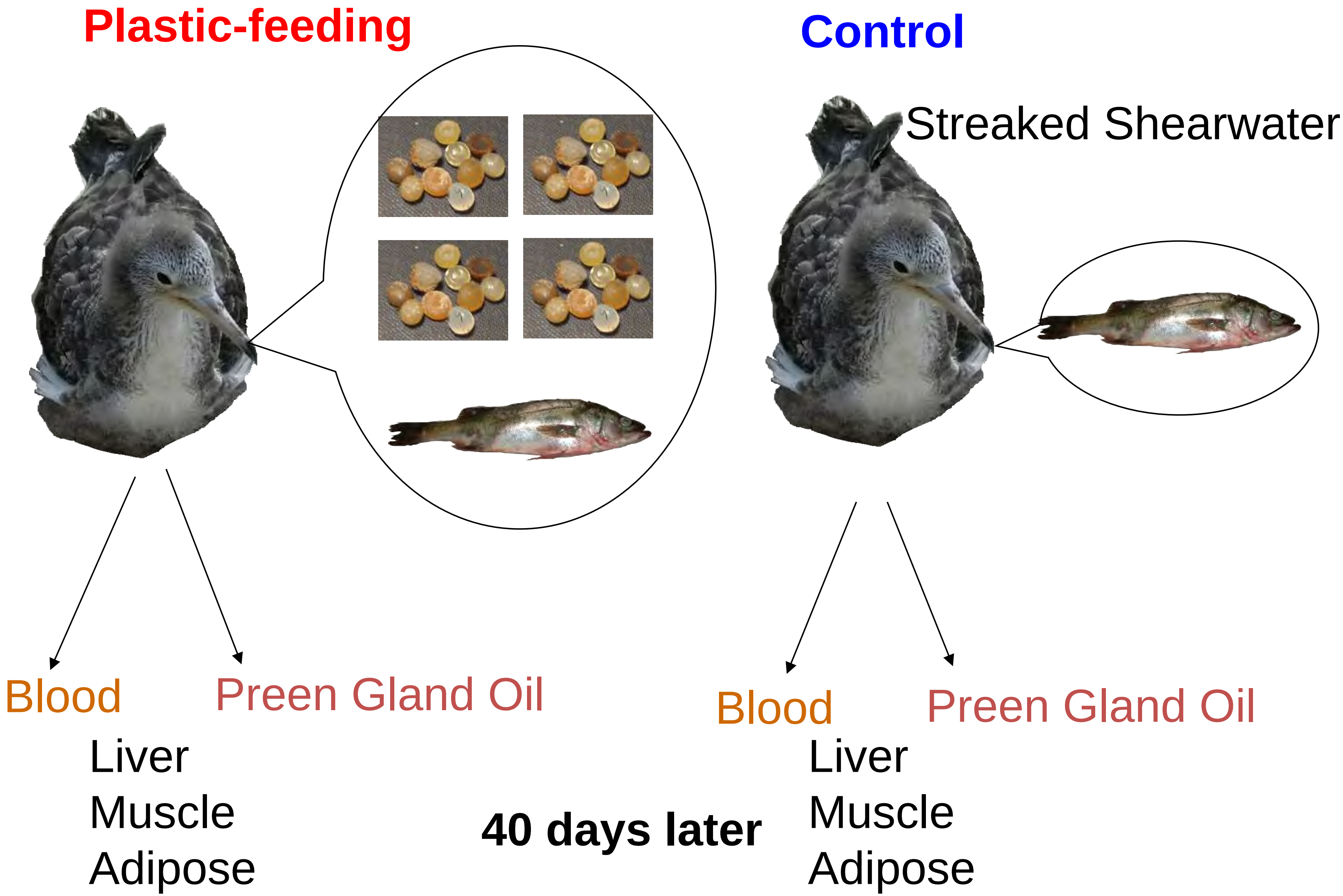
Plastics detected in digestive tract of short-tailed shearwater

Plastics detected in digestive tract of short-tailed shearwater

外洋にもプラスチックゴミが溜まる場所がある



Feeding Experiment using chick of seabird



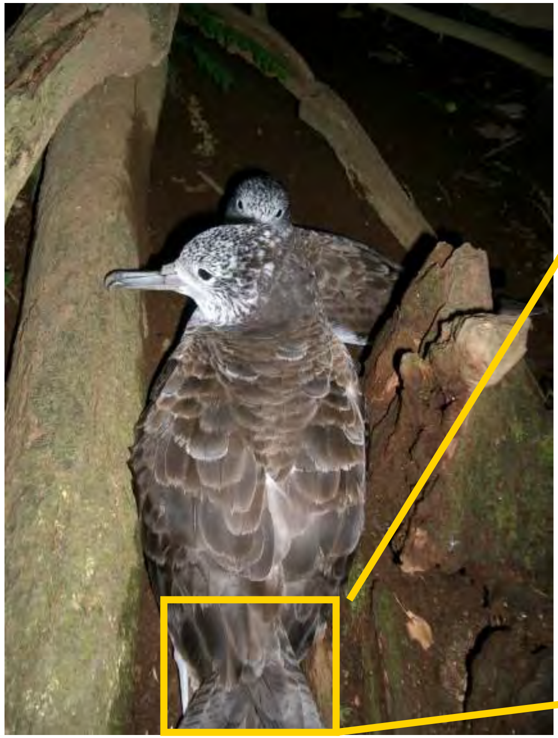
POPs monitoring by using **Preen Gland Oil**

: non-invasive approach

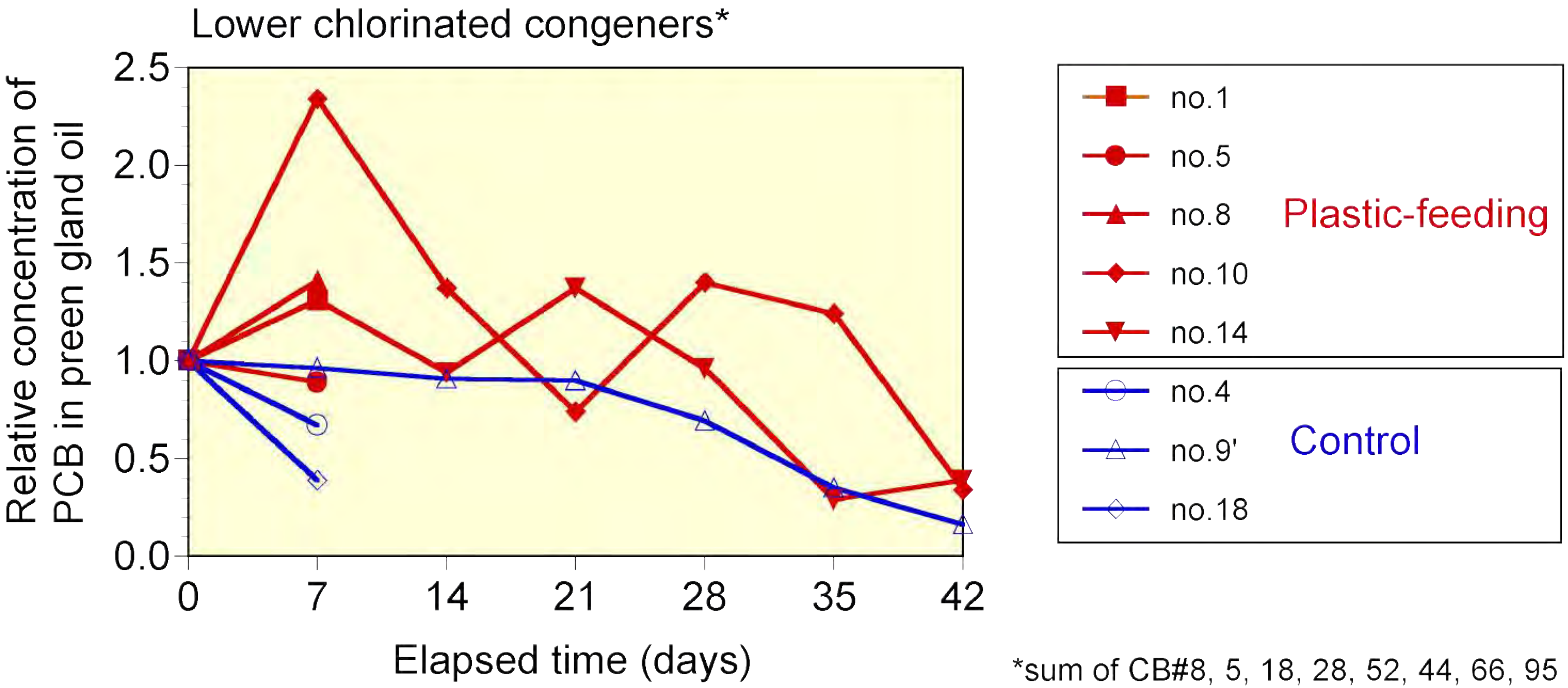
Environ. Sci. Technol. **2007**, *41*, 4901–4906

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†

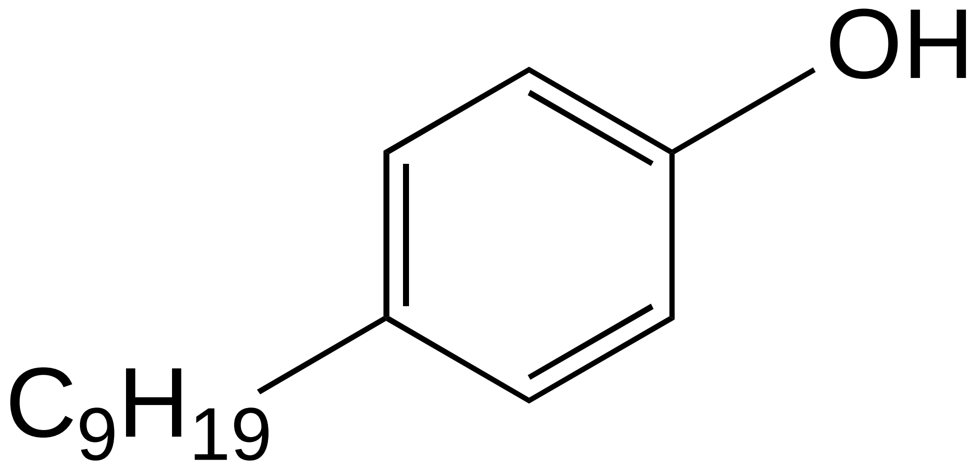


Increase in PCBs in preen gland oil was observed after ingestion of plastics contaminated with PCBs.



*sum of CB#8, 5, 18, 28, 52, 44, 66, 95

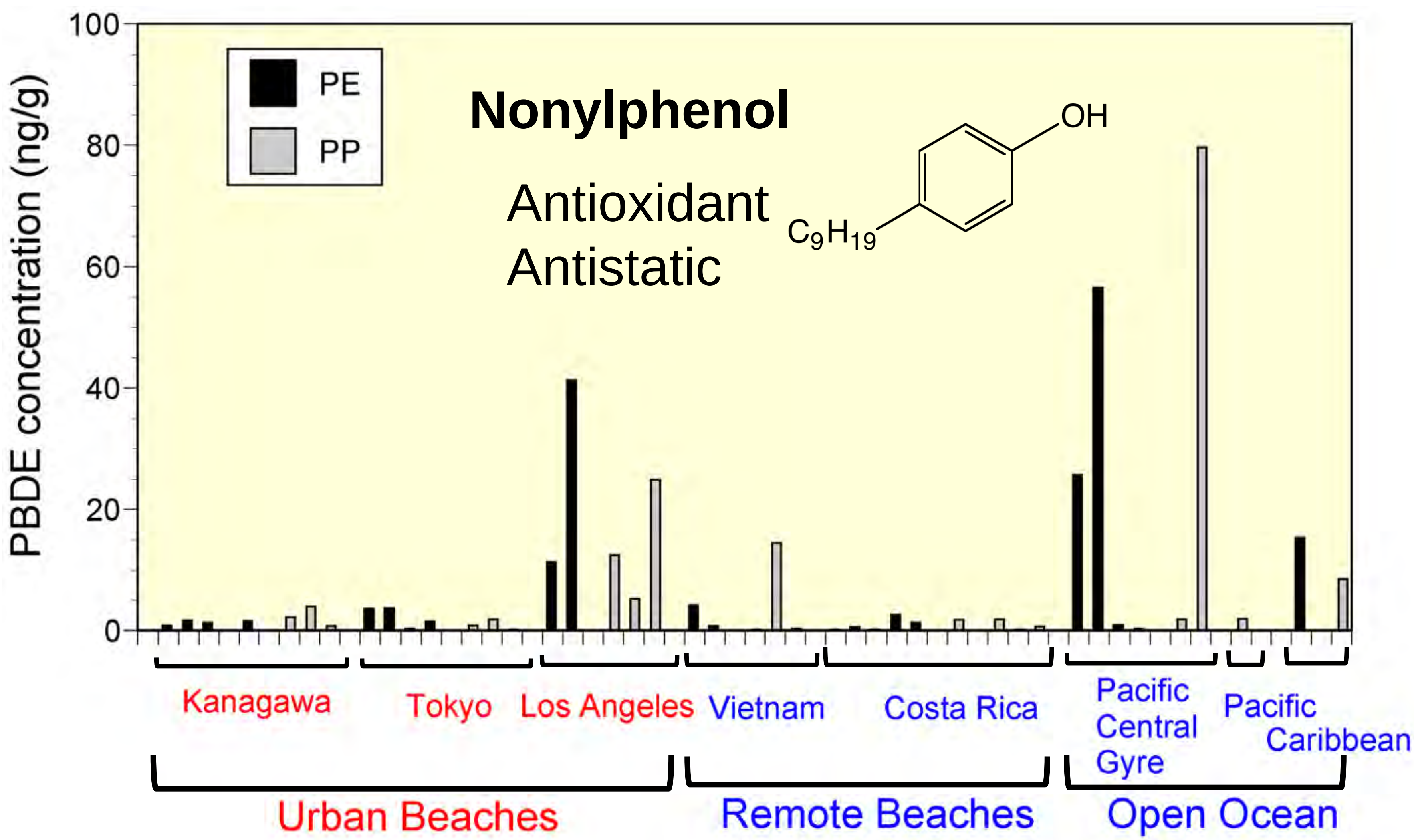
Nonylphenol : Endocrine disrupting chemicals



Additives to plastic

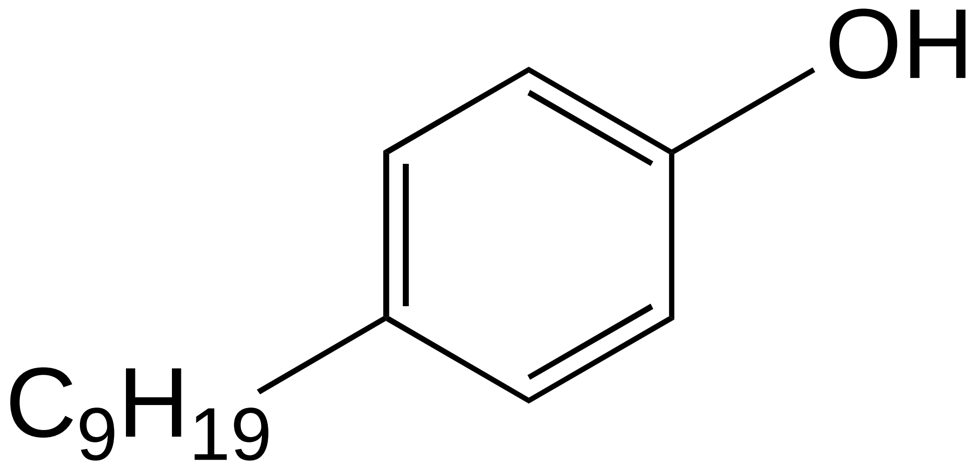
Antioxidants
Antistatic agents

Distributions of additive-derived chemicals in marine plastic fragments



➡ High concentrations of additive-derived chemicals were detected both in remote and urban areas

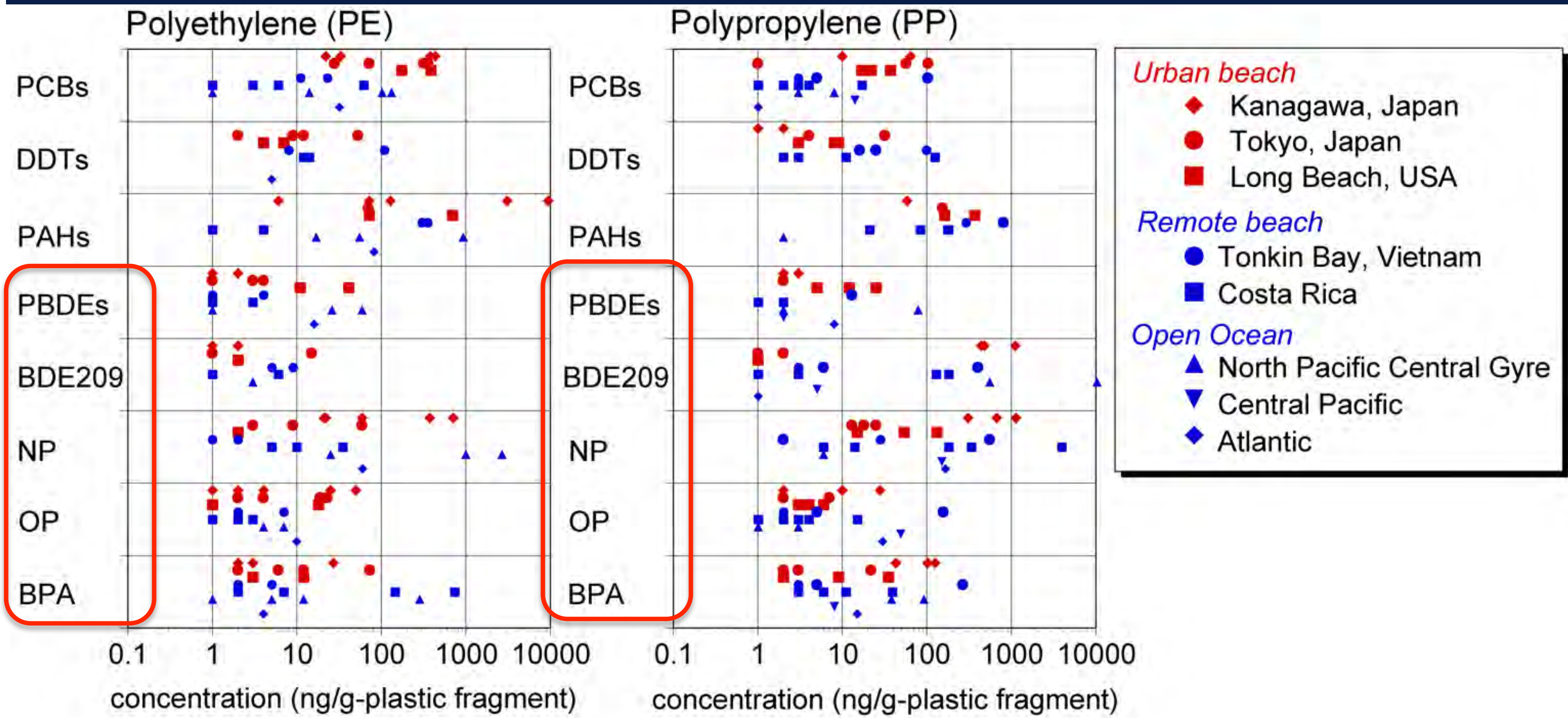
Nonylphenol : Endocrine disrupting chemicals



Additives to plastic

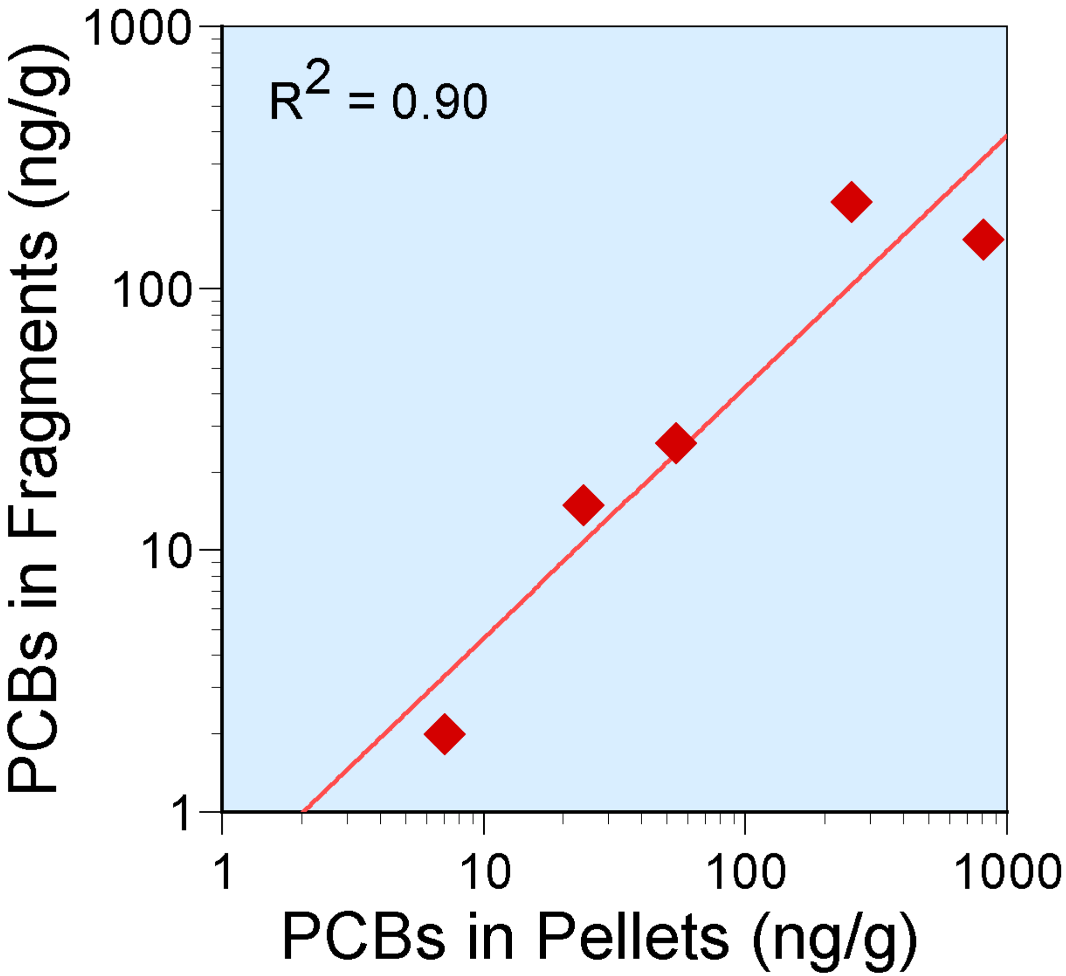
Antioxidants
Antistatic agents

Detection of additive-derived chemicals in marine plastic fragments



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

Correlation of PCB concentrations between plastic fragments and plastic resin pellets



DDT and its degradation products

DDT (**D**ichloro-**d**iphenyl-**t**richloroethane)

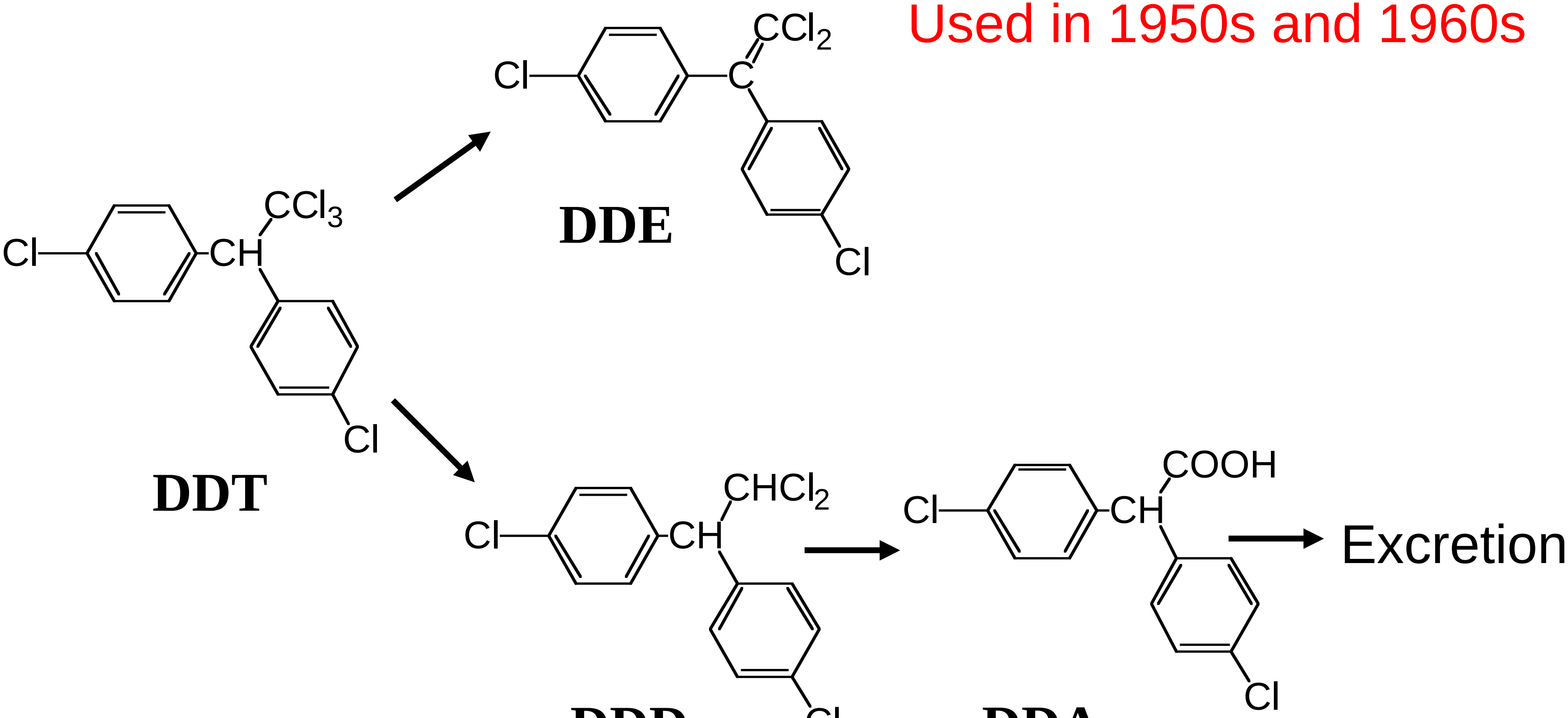
DDE (**D**ichloro-**d**iphenyl-dichloro**e**thylene)

DDD (**D**ichloro-**d**iphenyl-**d**ichloroethane)

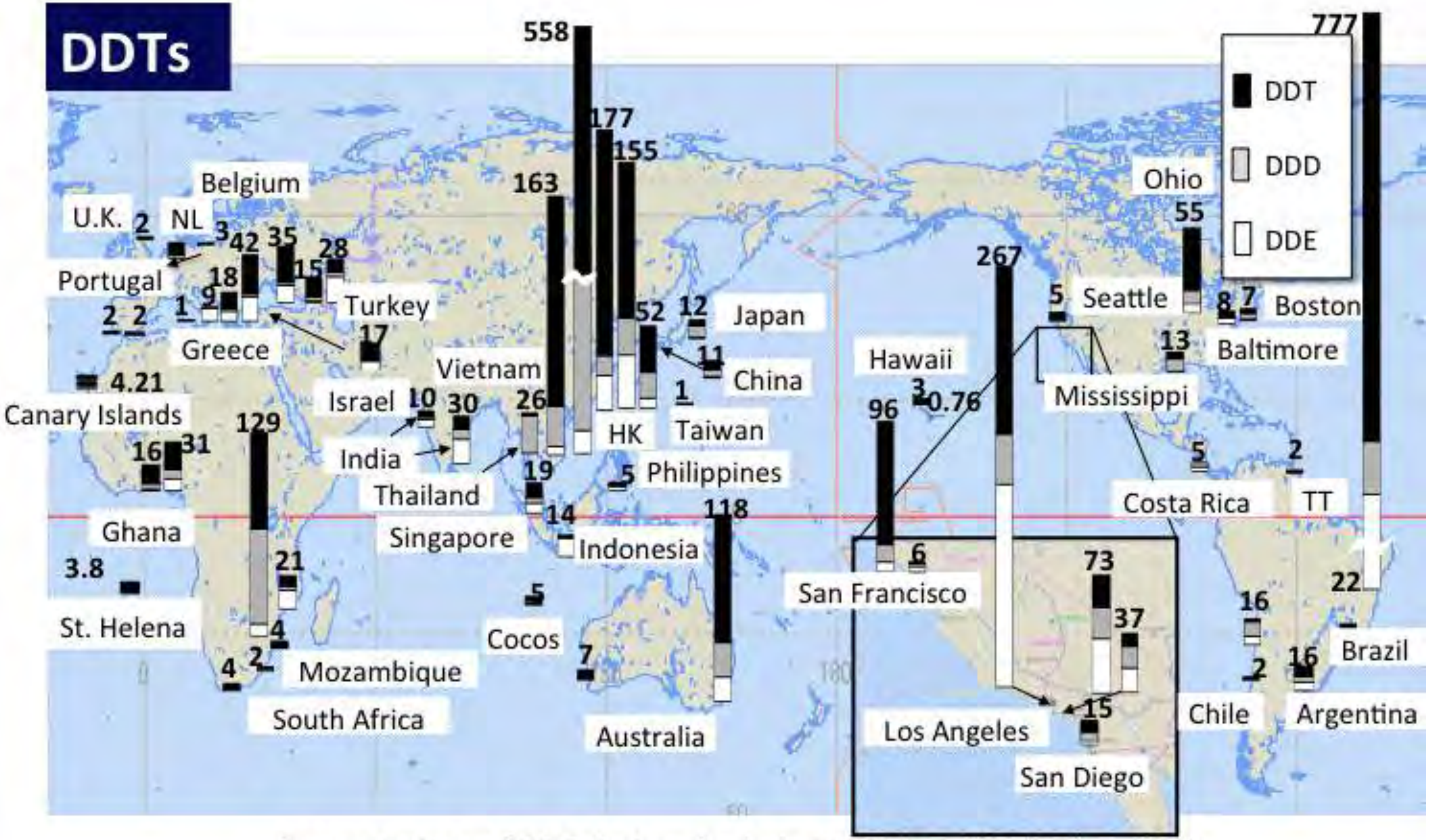
DDA (**D**icloro-**d**iphenyl-**a**cetic acid)

Insecticide

Used in 1950s and 1960s

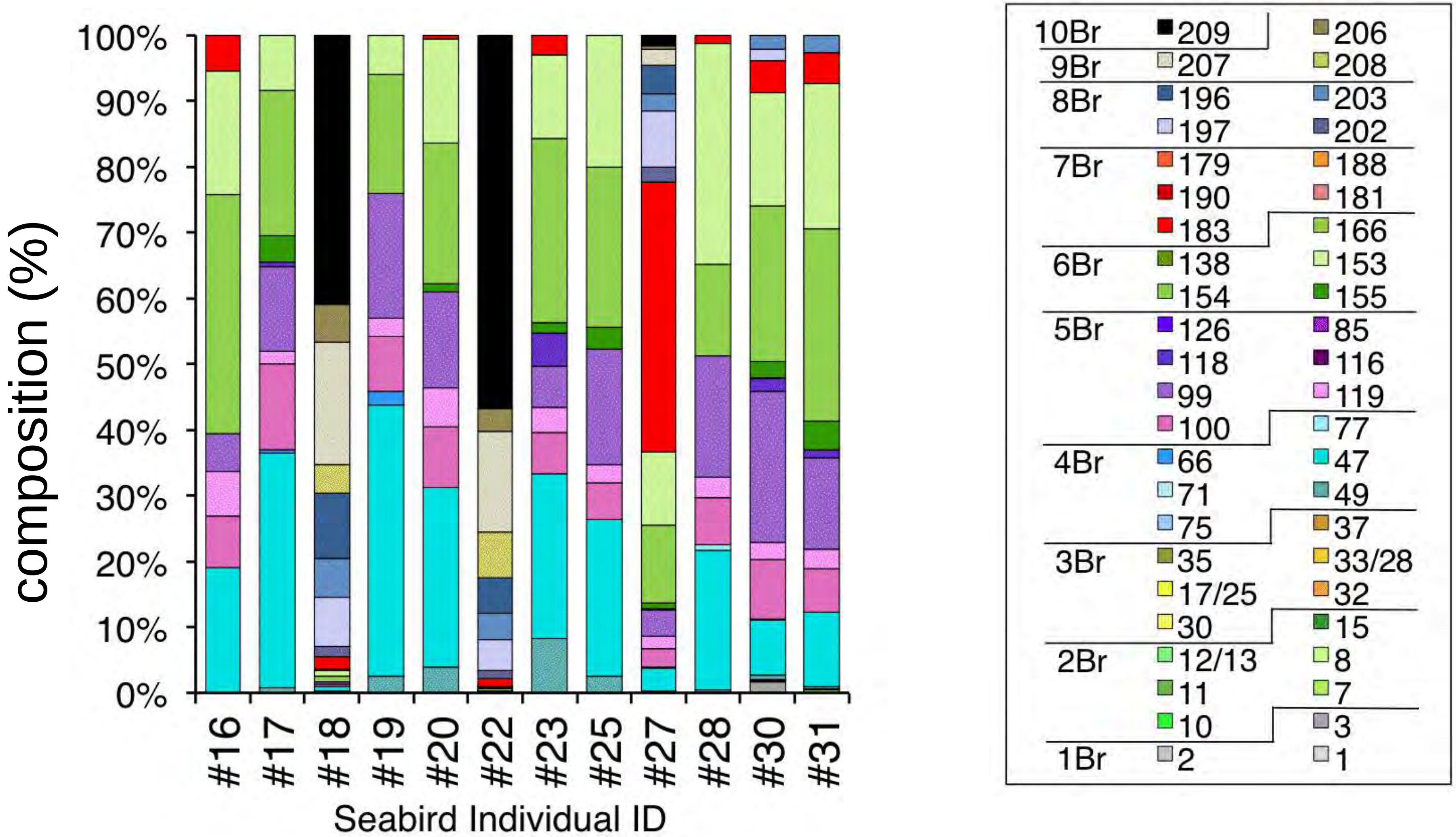


DDT **DDE** **DDD** **DDA**



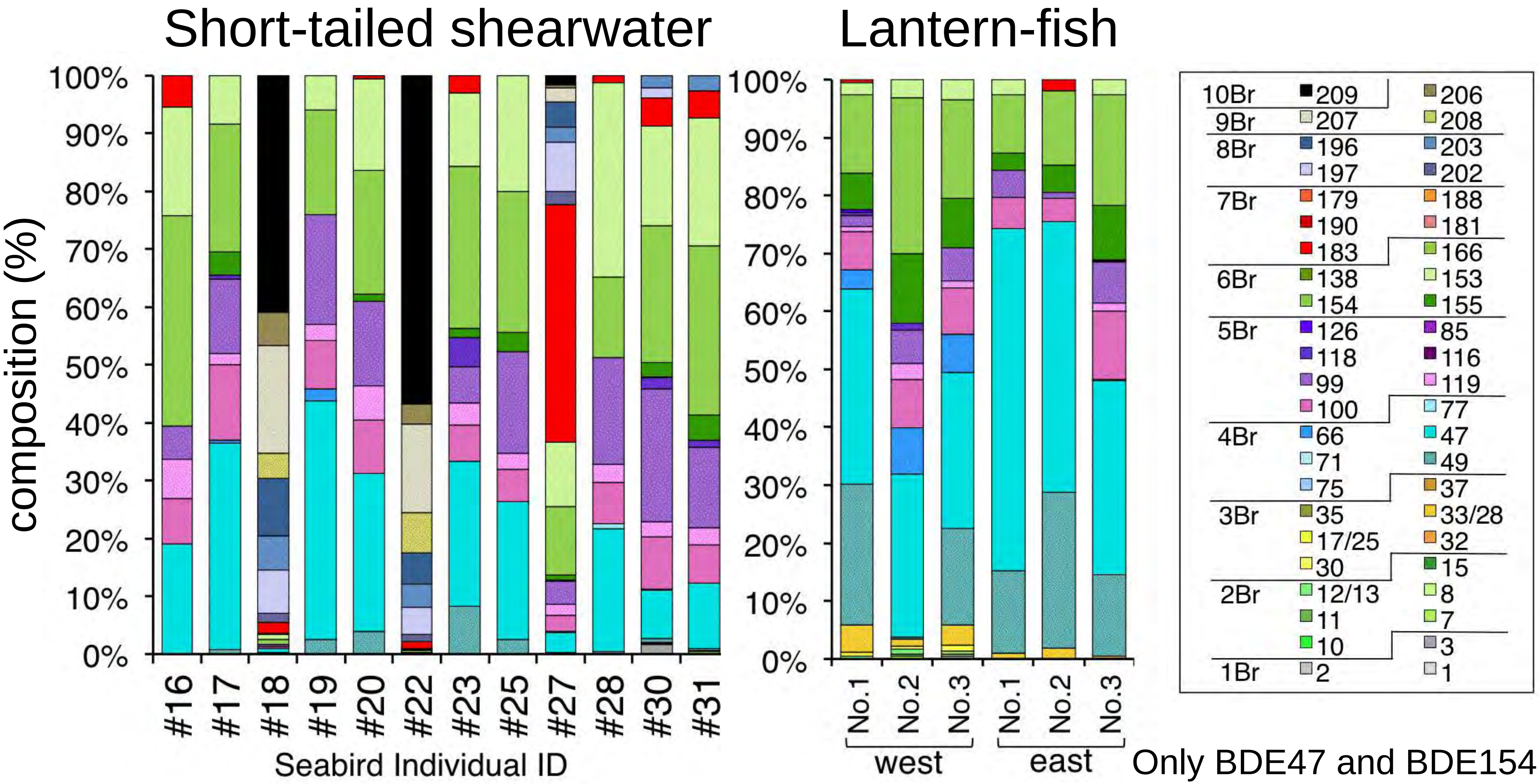
Concentration of DDTs in beached plastic resin pellet (ng/g-pellet)

Composition of BDE congeners in the abdominal adipose of the short-tailed shearwater



Tetra, penta, hexa-BDEs were dominant in most of the seabirds.
Higher brominated congeners (BDE209, 183) were dominant in 3 seabird.

Composition of BDE congeners in the abdominal adipose of the seabirds and their prey

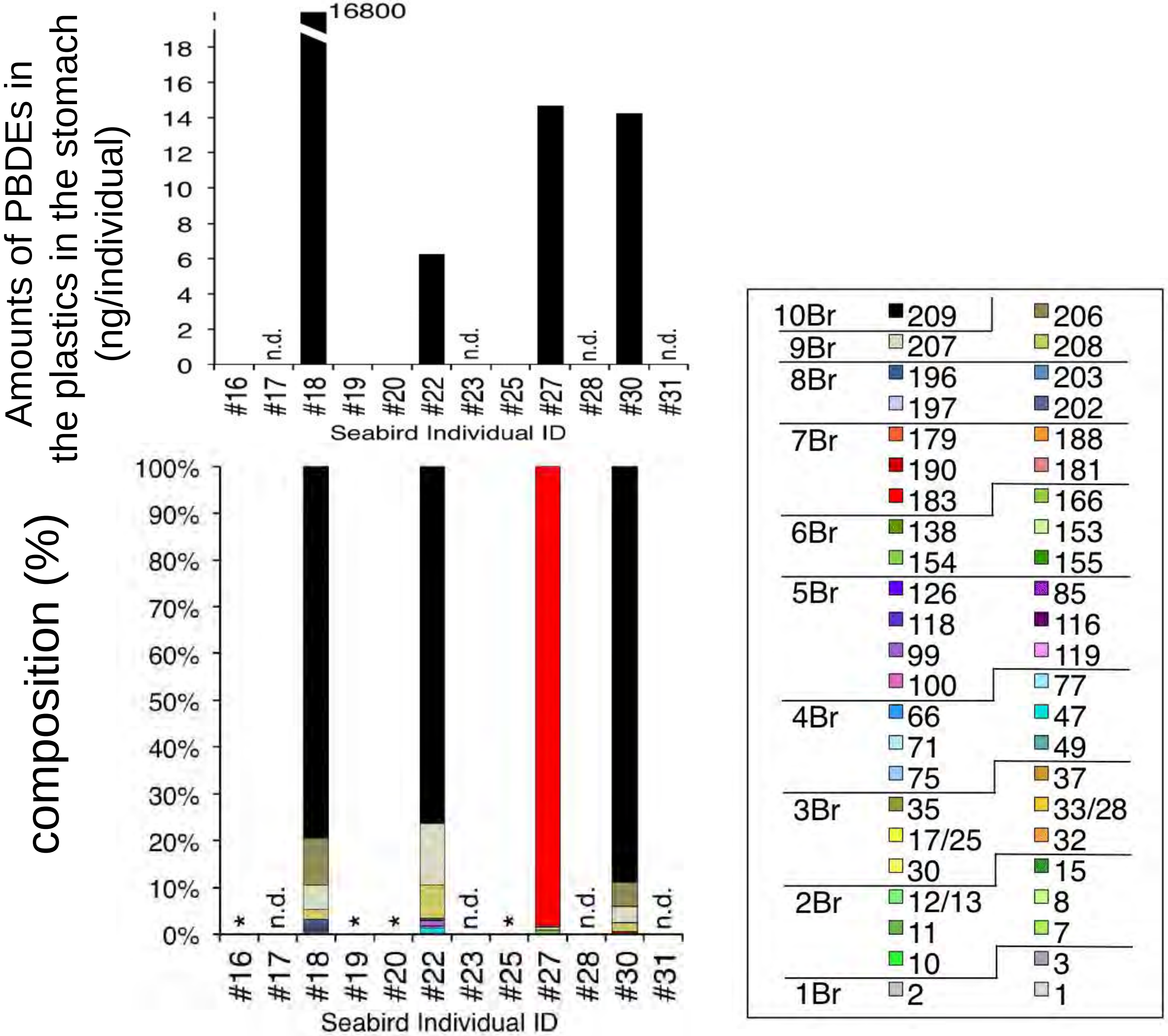


Only BDE47 and BDE154 were detected in squid.

Congener profiles of most of the seabirds were similar to their natural prey.

The three seabirds contained higher brominated congeners which were not contained in their natural prey.

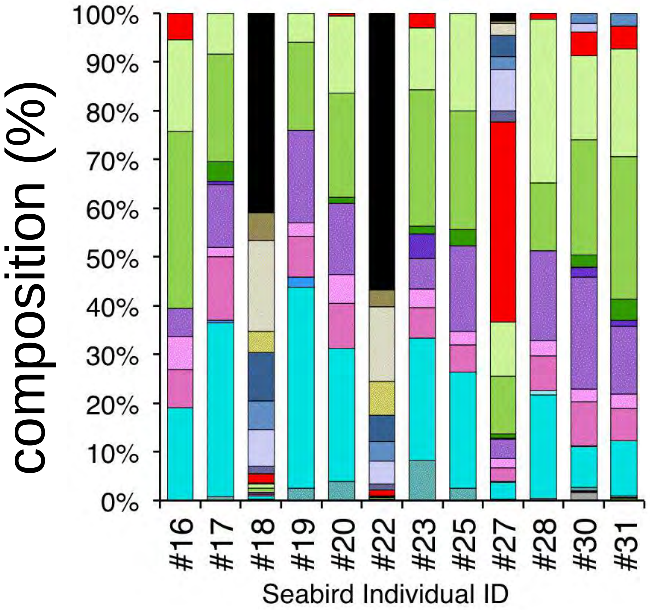
PBDEs in the plastics in the stomach of the short-tailed shearwater.

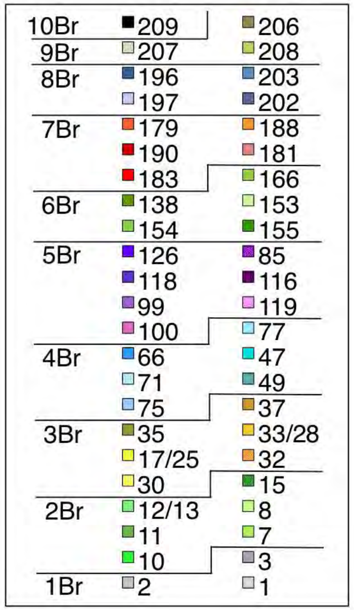


Higher brominated congeners (BDE209, 183) were dominant in the plastics in the seabirds.

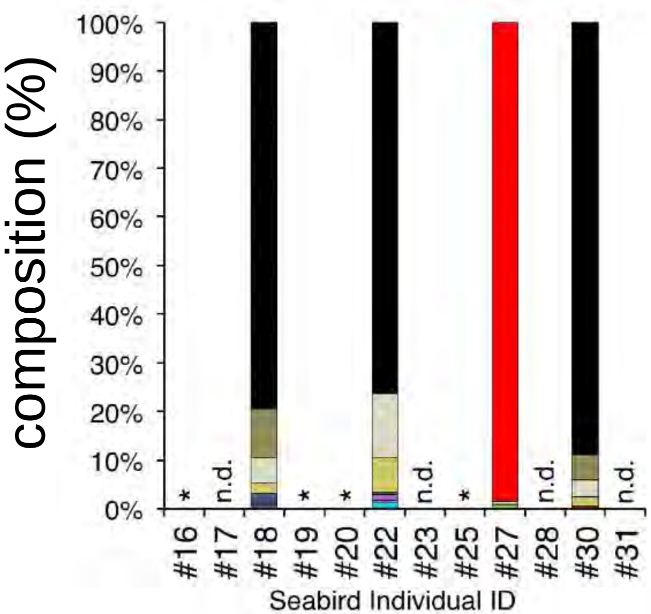
Composition of BDE congeners in the abdominal adipose of the seabirds and the plastics in their stomachs.

Abdominal adipose





Plastics in stomach



Detection pattern of higher boriminated congeners were consistent between adipose and plastic.

Conclusions

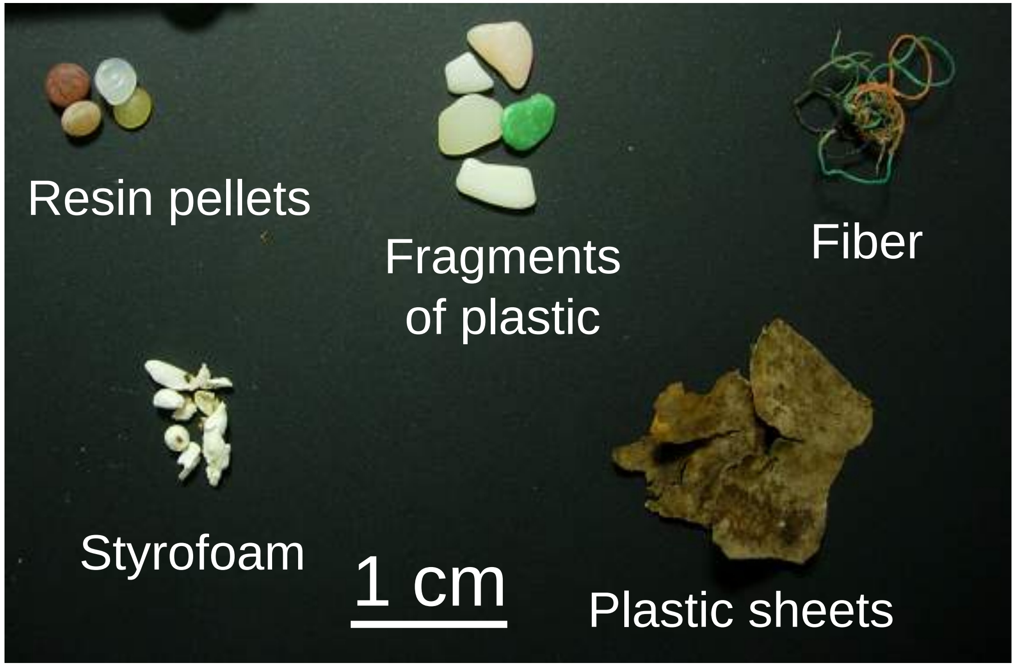
Significant concentrations of additive-derived chemicals (i.e., BDE209 and BDE183) were detected in tissue of seabird which ingest plastics.

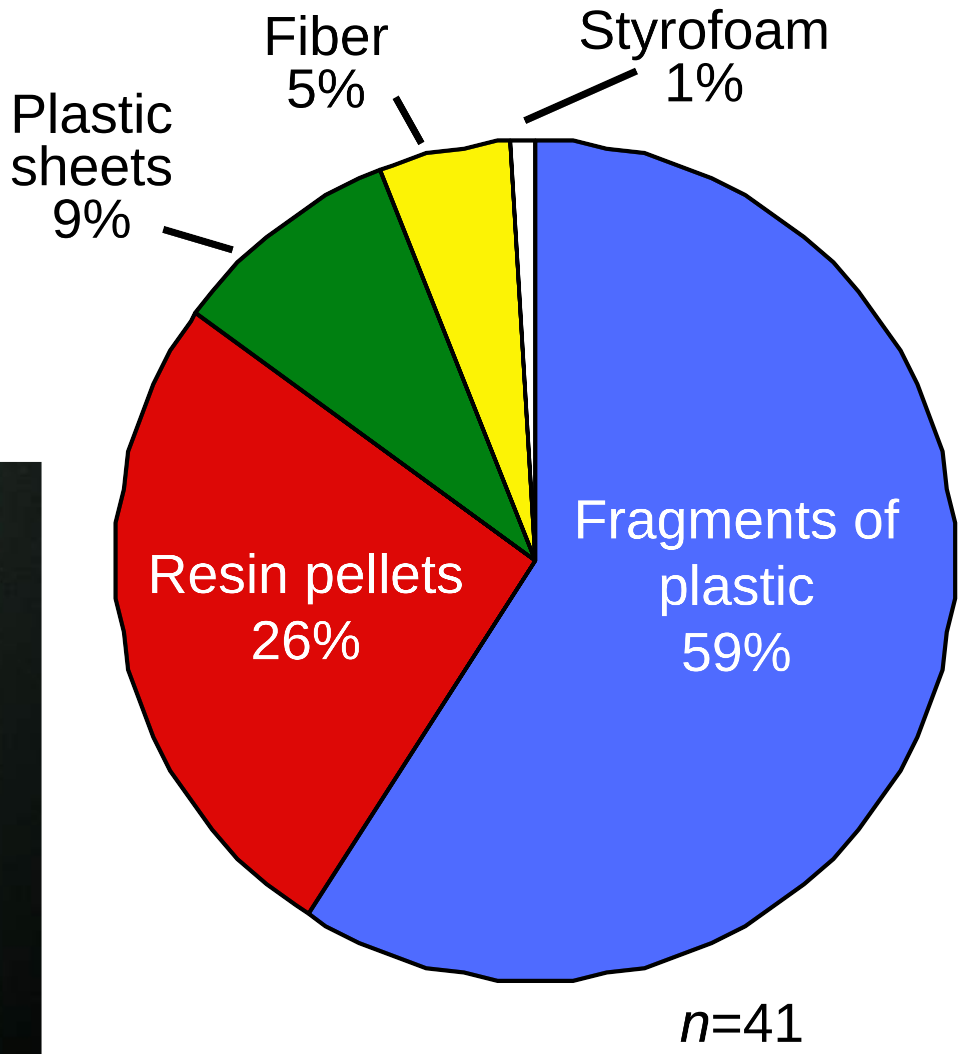
Detection pattern of BDE209 and BDE183 was consistent between ingested plastics and adipose among the individuals

These data strongly suggest the transfer of the chemicals from plastics to internal tissue of seabirds which ingest marine plastics.

Fragments of user plastics are dominant over pellets in marine environments

Short-tailed shearwater
Puffinus tenuirostris

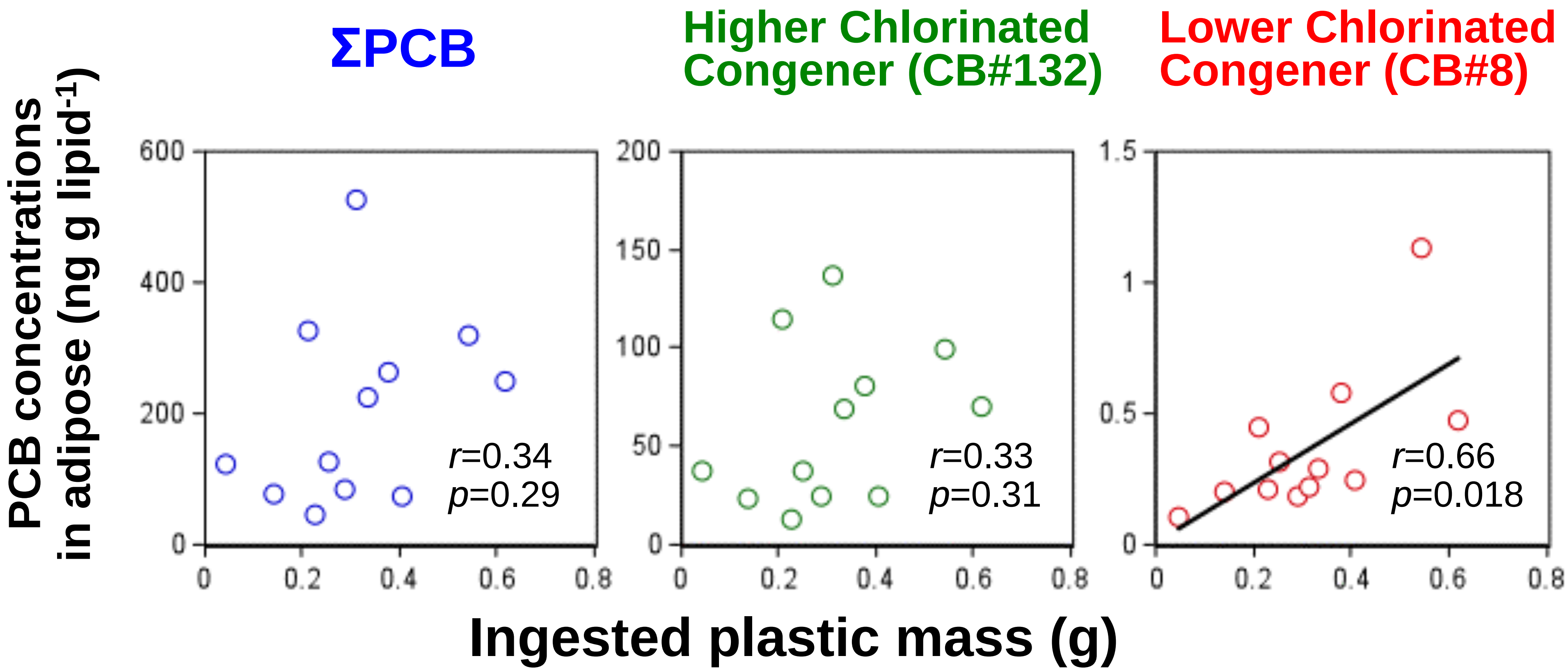




Type and composition of plastics found in the stomachs of short-tailed shearwater.

Yamashita et al. 2011

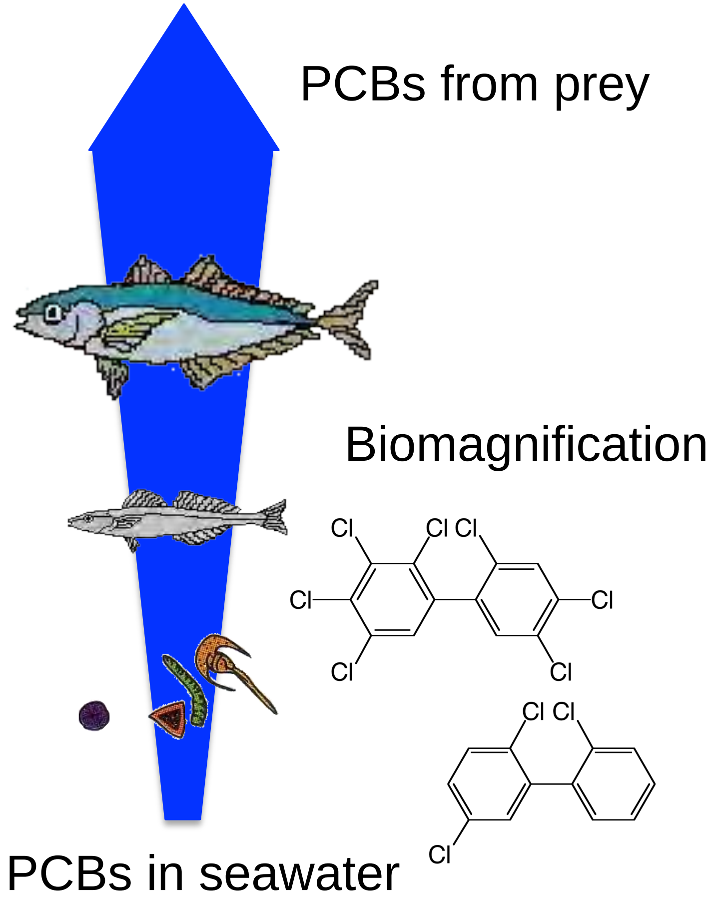
Relationships between ingested plastic mass and PCB in abdominal adipose of short-tailed shearwater.



Significant but weak correlation between ingested plastic mass and concentrations of lower chlorinated congeners (CB#8). No correlation for total PCBs.

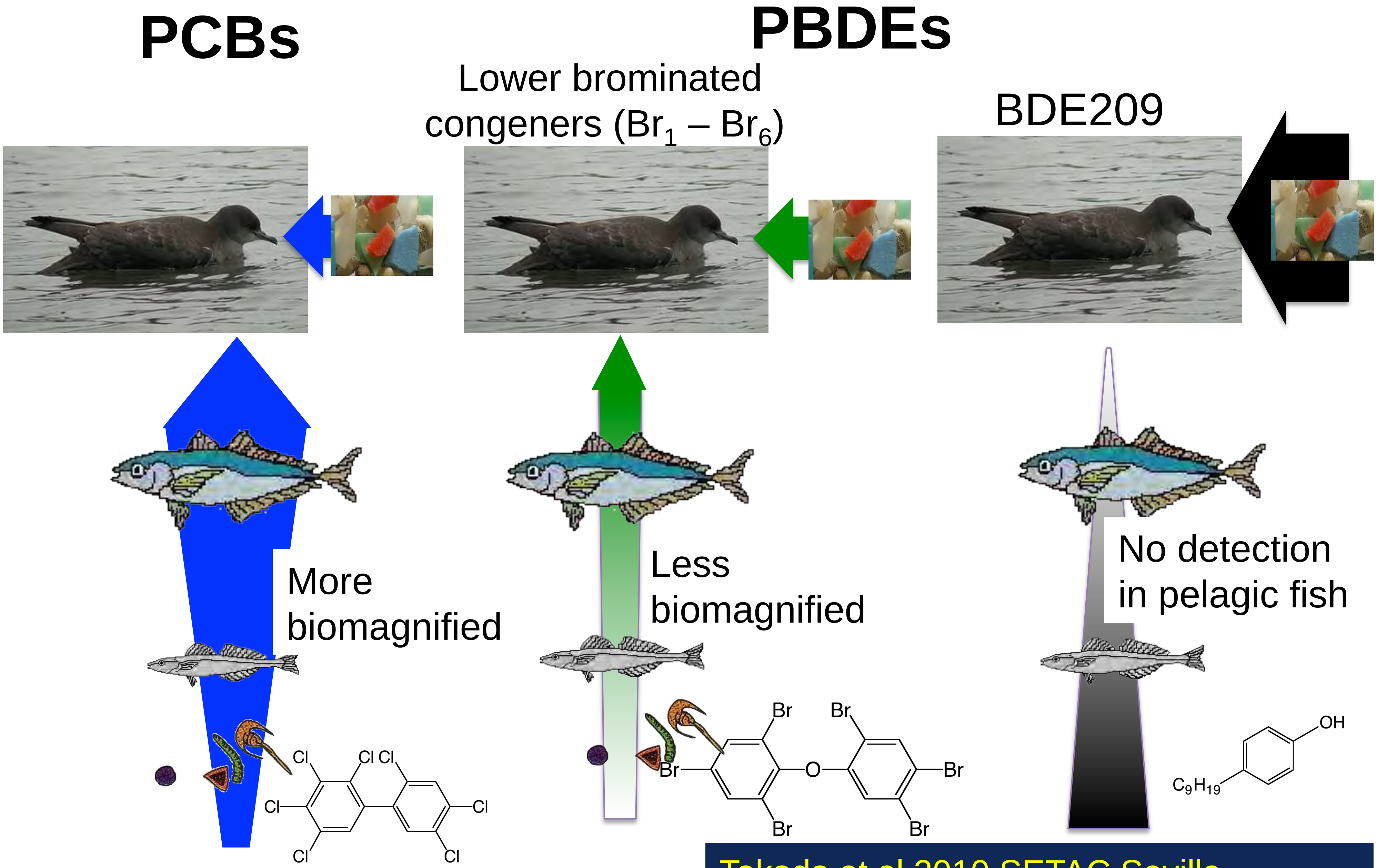
Yamashita et al. 2011

Exposure of contaminants both from plastics and prey

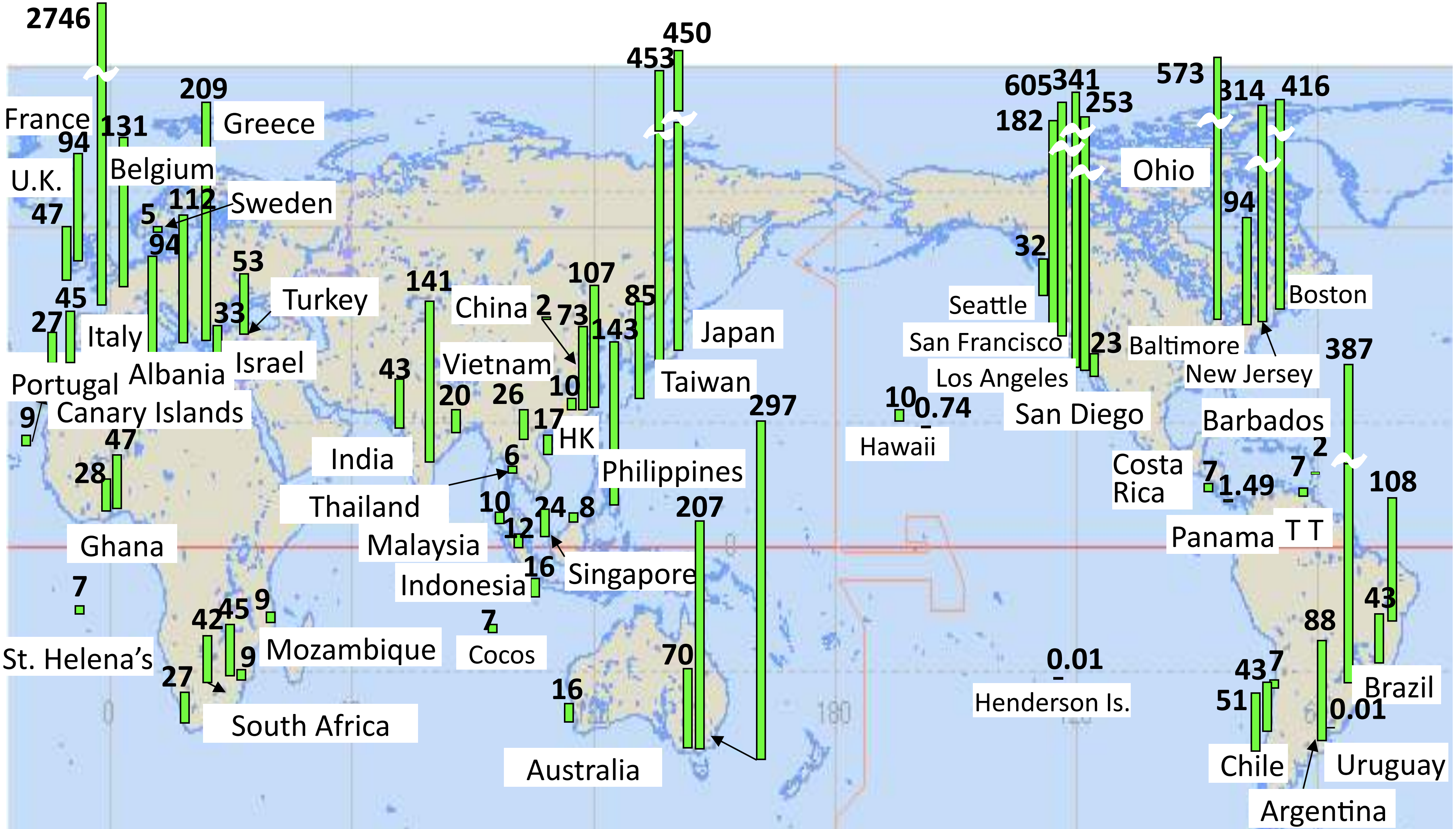


Takada et al.2010 SETAC Seville

Plastic-derived PBDEs could have more impact on exposure of the contaminants to oceanic seabird

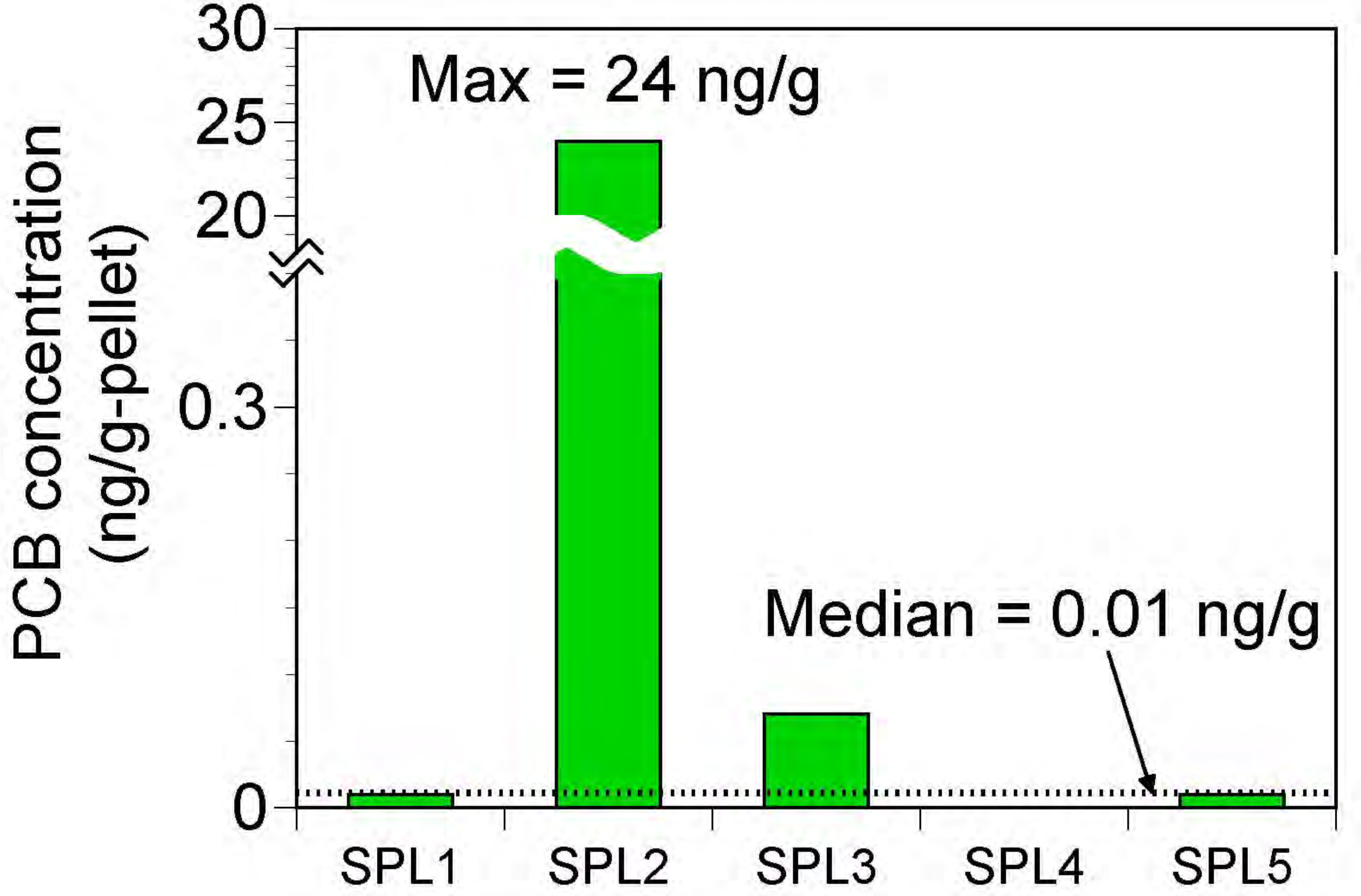


Takada et al.2010 SETAC Seville



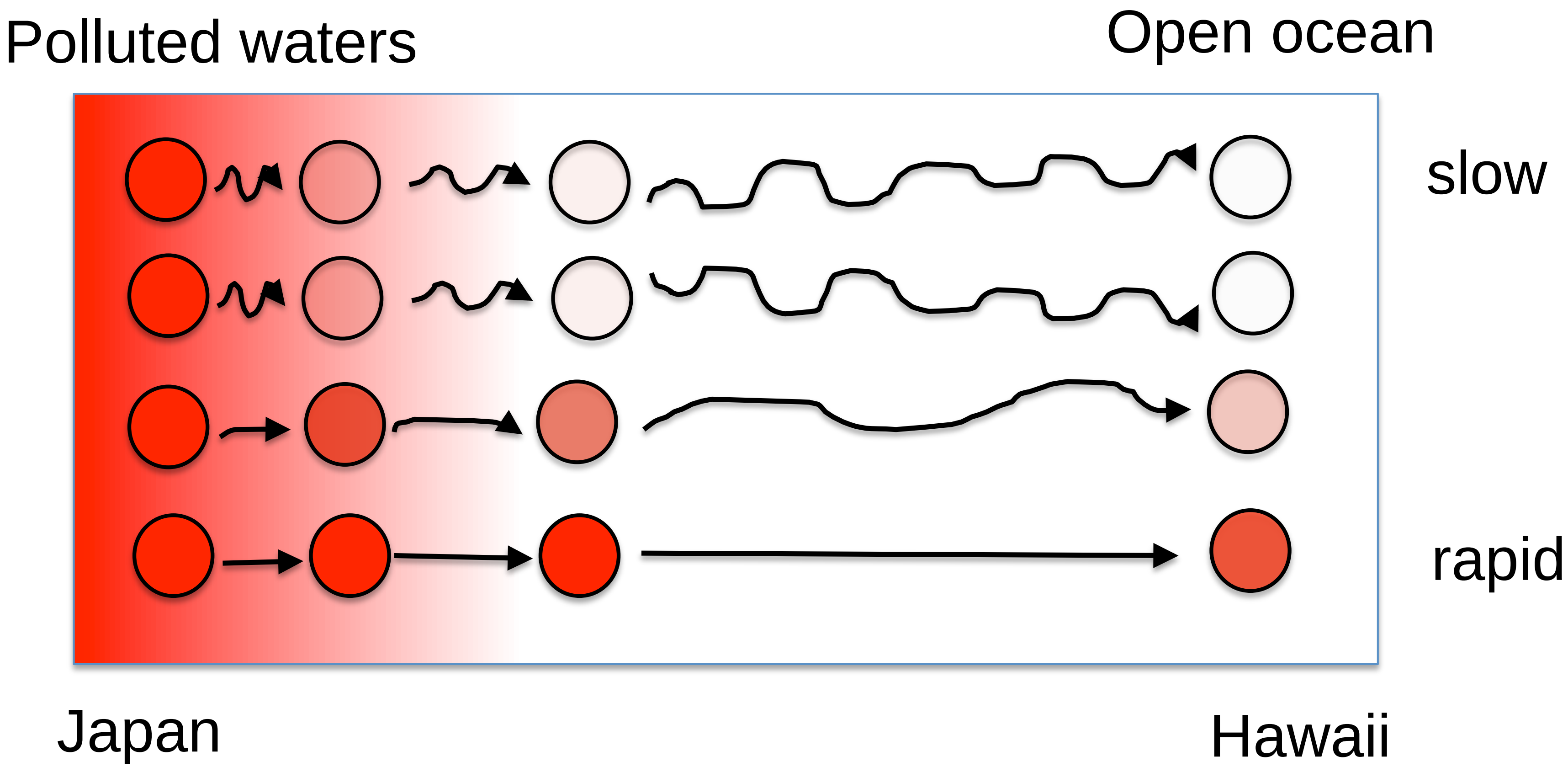
Concentration of PCBs* in beached plastic resin pellet (ng/g-pellet)

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



Max = 24 ng/g
Median = 0.01 ng/g
PCB concentration (ng/g-pellet)
30
25
20
0.3
0
SPL1
SPL2
SPL3
SPL4
SPL5

Slow desorption and fast transport may cause sporadic high concentration of PCBs in plastic from open ocean

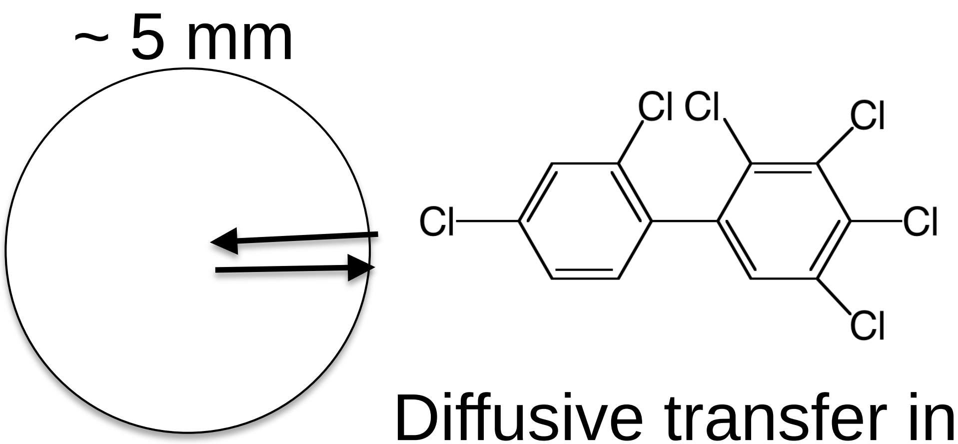


Different speed/route of transport

Non-equilibrium : slow sorption/desorption

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

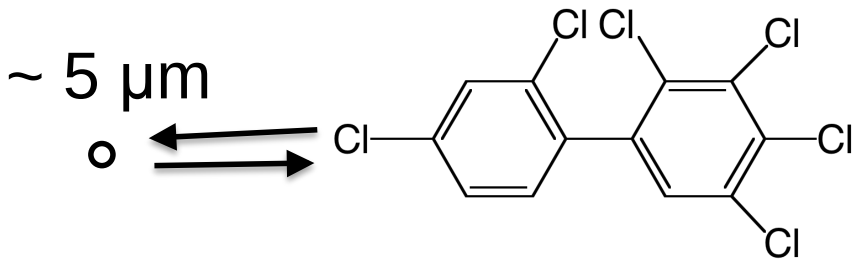
Larger diameters and slow diffusive transport cause non-equilibrium



Diffusive transfer in plastic matrix

Plastic fragment/pellet with 3 mm diameter

Long time (~ 1 year) to reach equilibrium



surface process

Conventional vector : sediment particle with a few μm

Fast (~ hours) to reach equilibrium