IVM Institute for Environmental Studies

VU UNIVERSITY AMSTERDAM

Macroplastics, microplastics and environment impact

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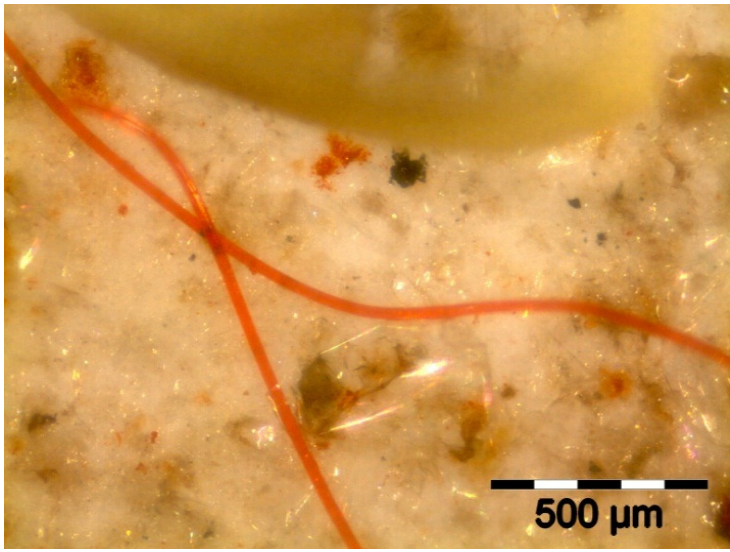
What is marine litter?

'Any persistent, manufactured or processed solid material disposed of or abandoned in the marine and coastal environment' (UNEP 2005)

- **Plastics and rubber**
- Metal
- Glass
- Other manufactured materials

Macro litter → Micro litter <5 mm



Microplastics in the North Sea (IVM)

and <1 micron…

Northern Fulmar stomach contents

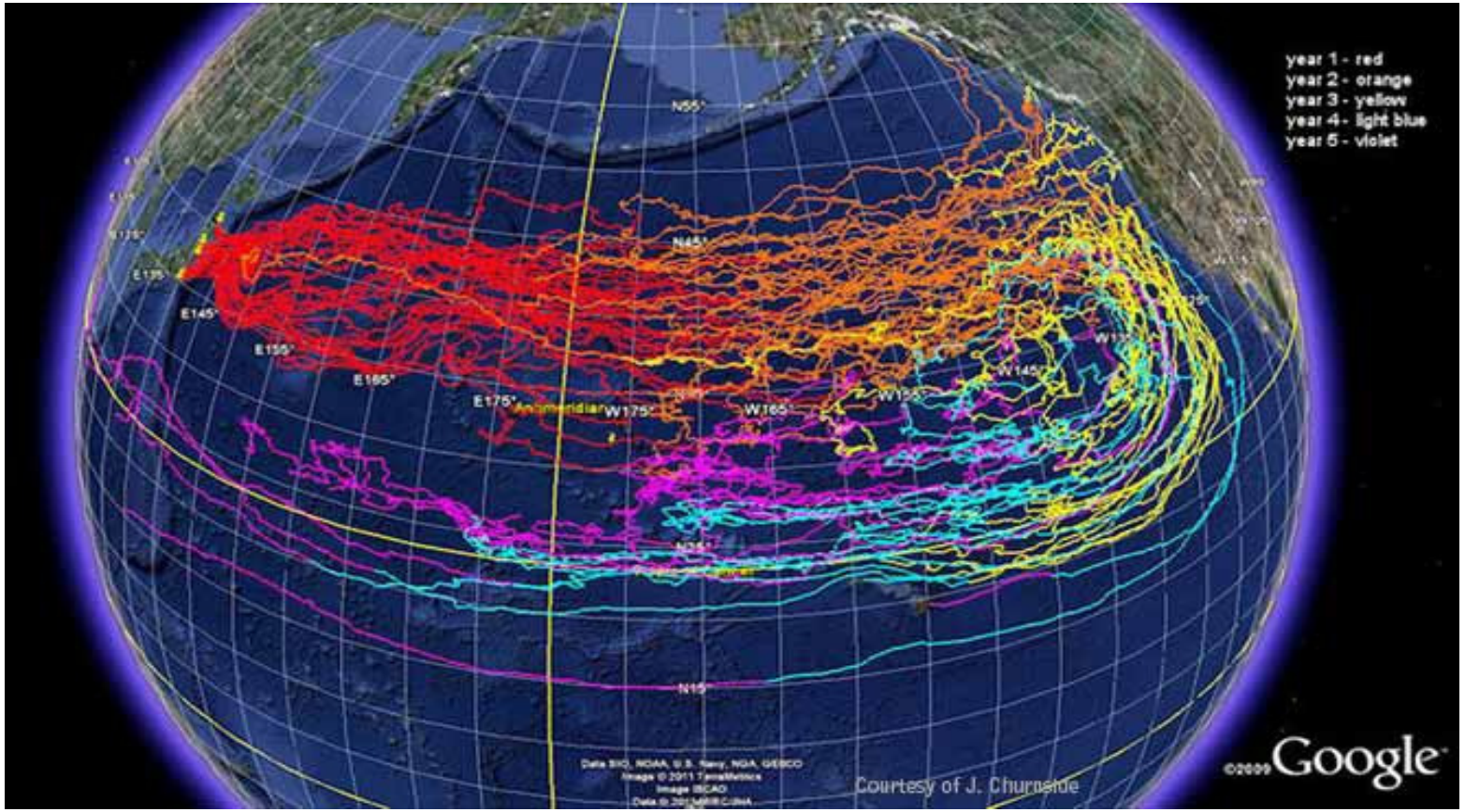
Van Franeker et al. Environ Poll. 2011

Litter comes from populated areas…

Without modern waste management…


With modern waste management…

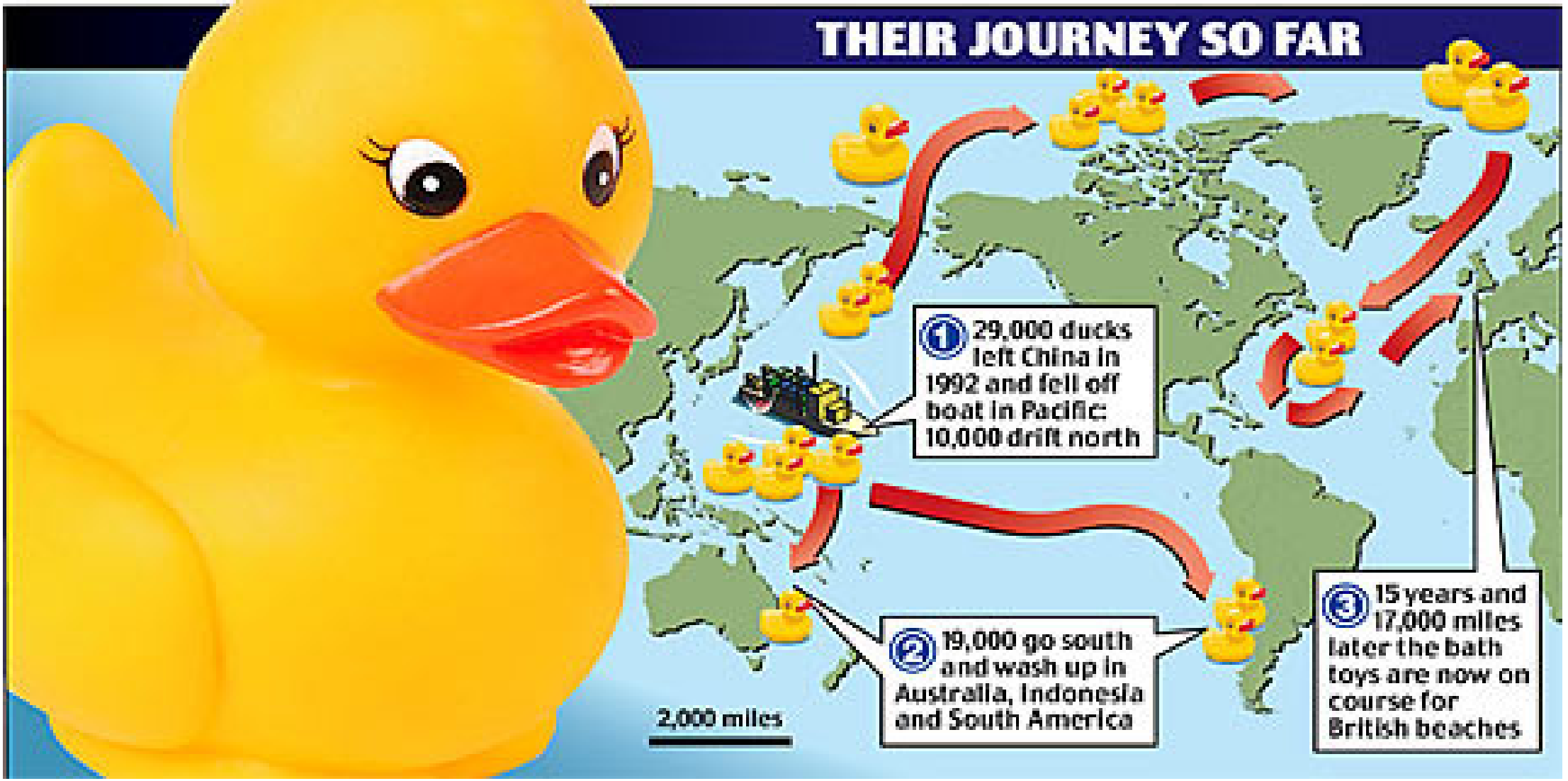
Natural disasters, e.g. tsunami



NOAA has run a model using OSCURS (Ocean Surface Current Simulator).
Year 1 = red; Year 2 = orange; Year 3 = yellow; Year 4 = light blue; Year 5 = violet

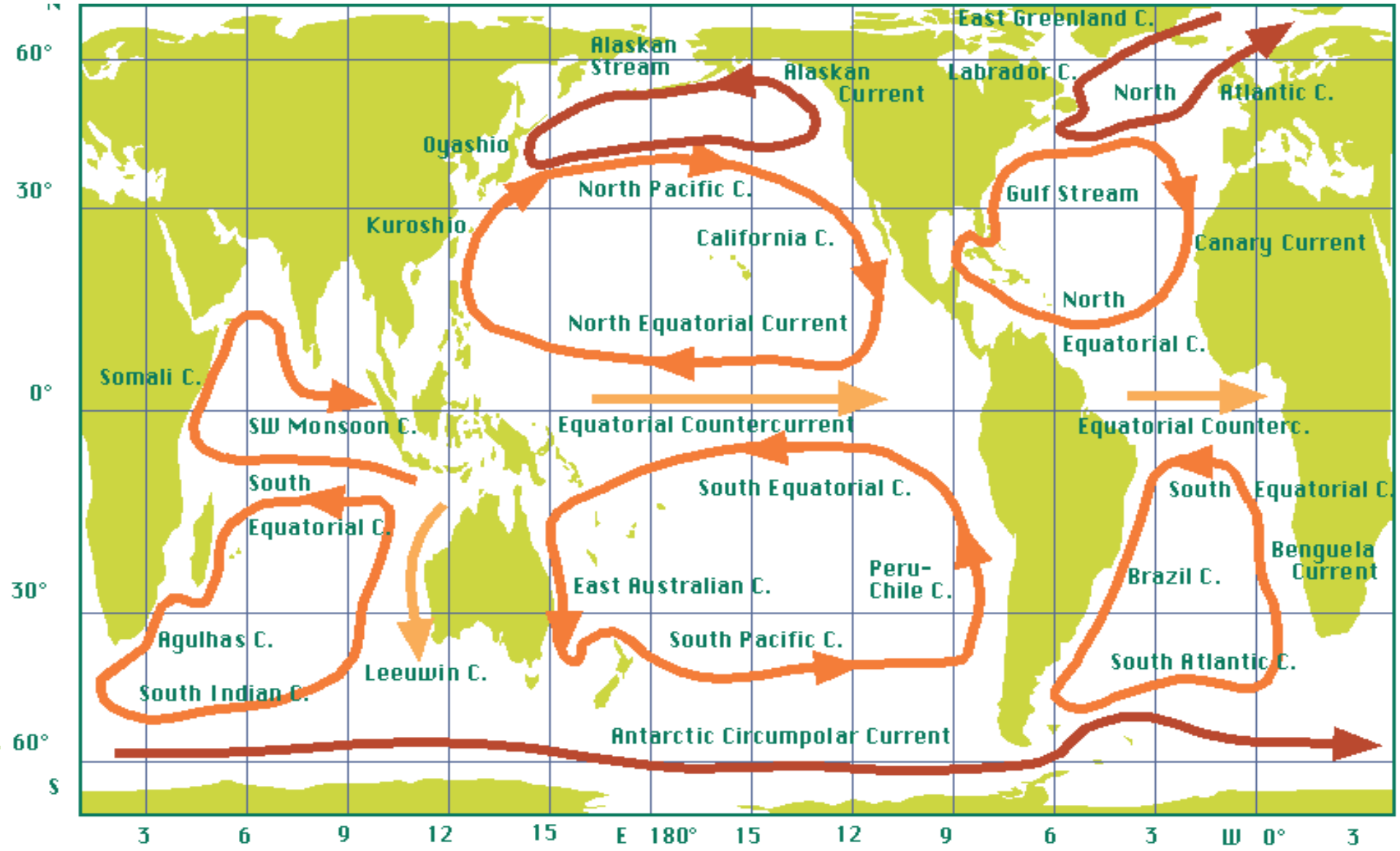
By 2016 the debris will have circled back towards Hawaii

29,000 bath toys spill, 1992, Pacific

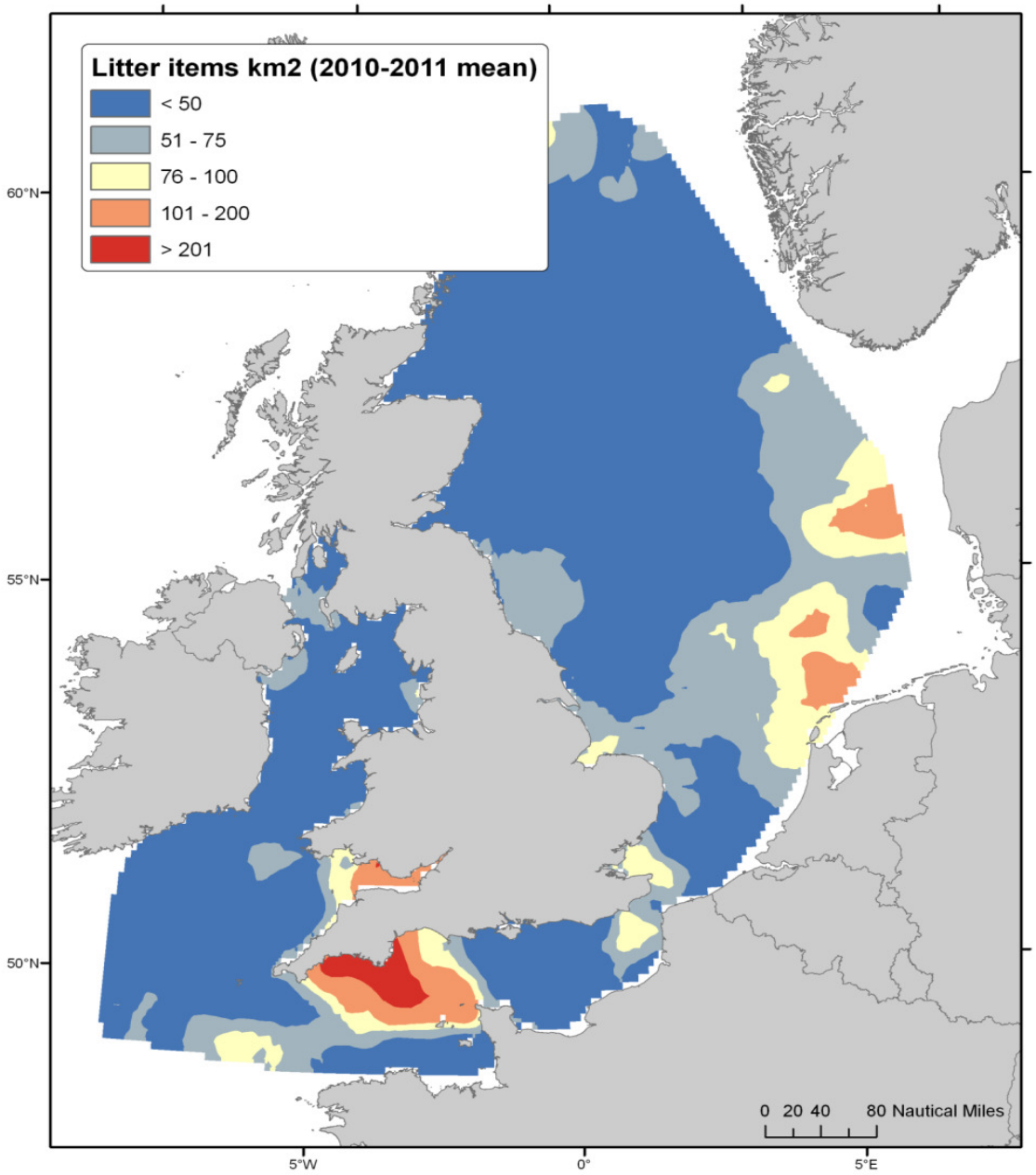


Plastic litter on the move

www.algalita.org

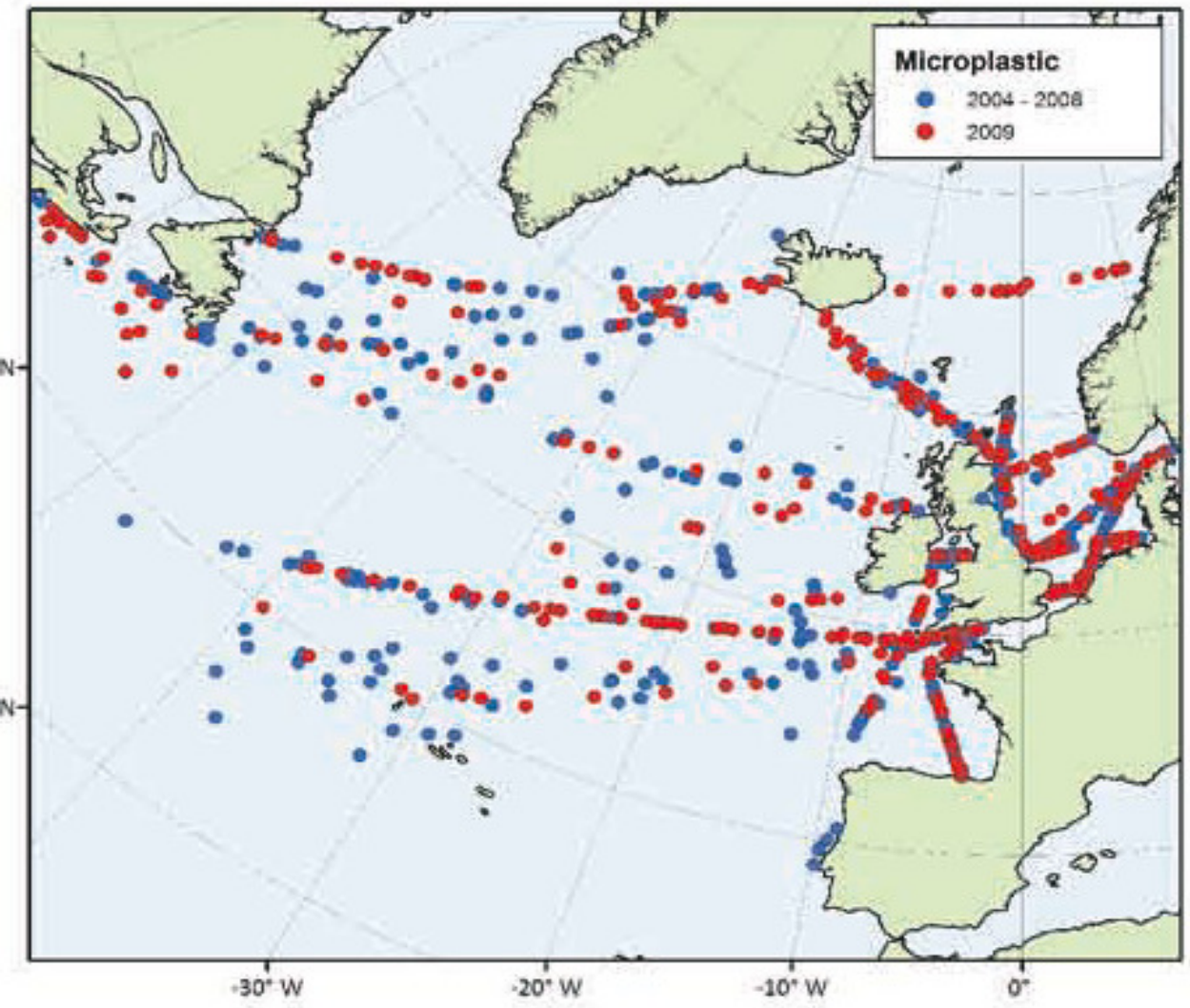


Distribution of litter on the sea bed



Thomas Maes
Cefas (UK)

UK Marine Ecological Status Report (2010)



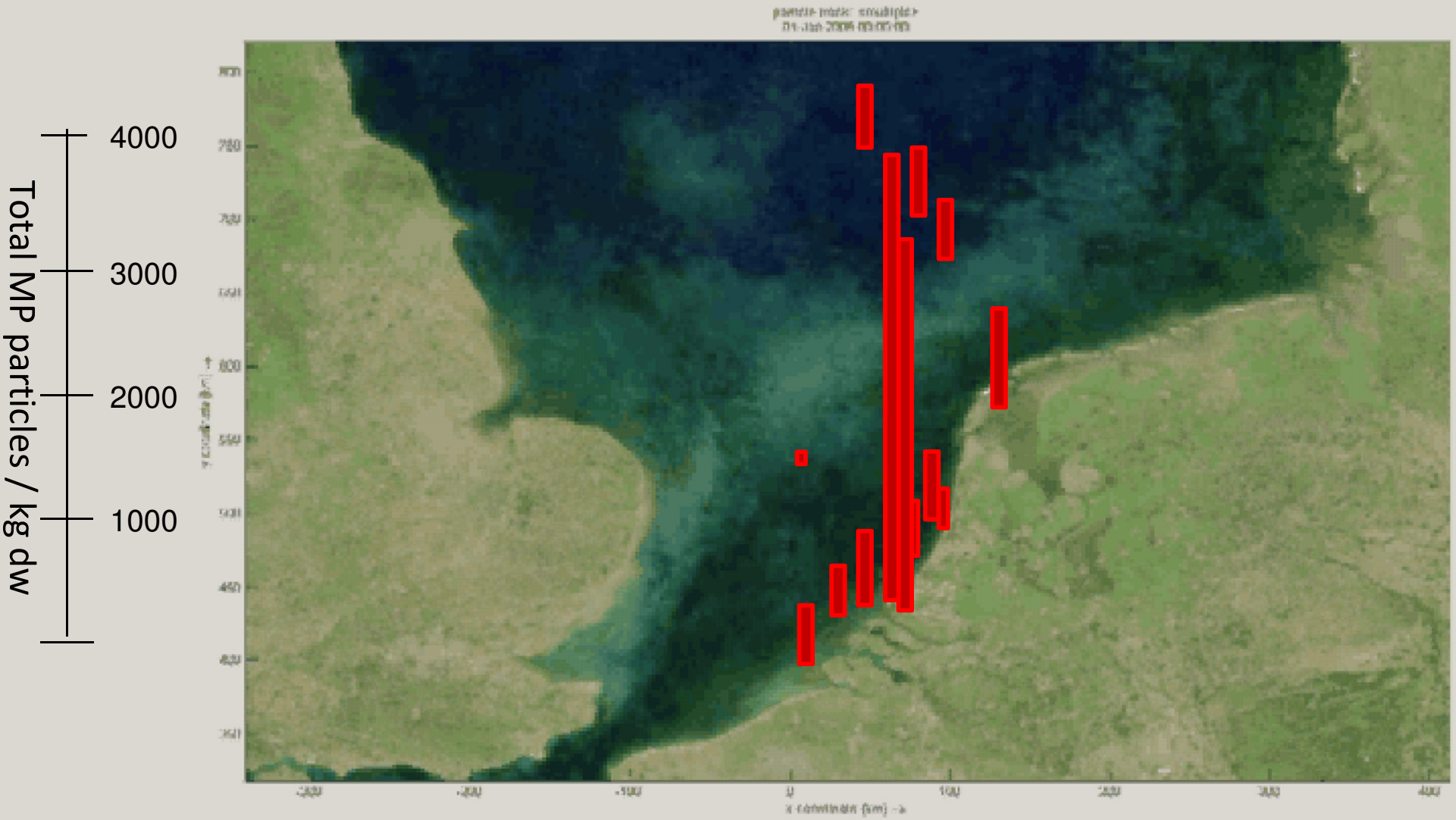
The geographical distribution of microplastics recorded on CPR samples in 2009 and between 2004-2008. While the distribution largely reflects CPR sampling frequency it does show that microplastics are widely distributed in the North Atlantic including the offshore oceanic environment.

Edwards et al. 2011

Microplastics in seawater

Net mesh	Microplastics / m^3	Location	Ref
280 µm	0.04 - 0.05	shipping routes UK, 10 m depth	Thompson et al. 2004
80 µm	150-2400	Swedish coast, sea surface	Norén 2008
0.5-2 mm	102,000	Swedish harbour near PE plant, sea surface	Norén 2008
10-500 µm	200-1000	Skaggerak, Norwegian S coast, sea surface	Norén & Naustoll 2011
333 µm	0.2-1.6	Doggerbank, sea surface	Leslie, 2012

Microplastic in every sample of North Sea sediments



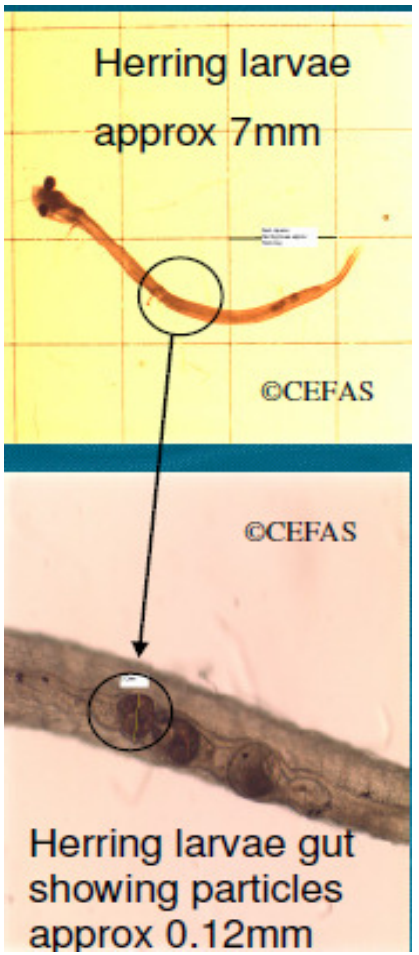
Microplastics in subtidal, offshore, harbour sediments

Microplastics per L or kg sediment	Location	Reference
50 particles / L wet sediment (estuarine) 110 particles (subtidal)	UK coast, estuarine areas	Thompson et al. 2004
20 -160 particles / L wet sediment	UK, Tamar estuary	Browne et al. 2010
124, 186, 390 particles / kg dry sediment (harbours) 71 – 269 particles /kg dry sediment (offshore)	Belgian coast	Claessens et al. 2011
20 -3320 particles / L wet sediment (‘hotspot’)	Swedish coast and (industrial) harbours	Norén 2008

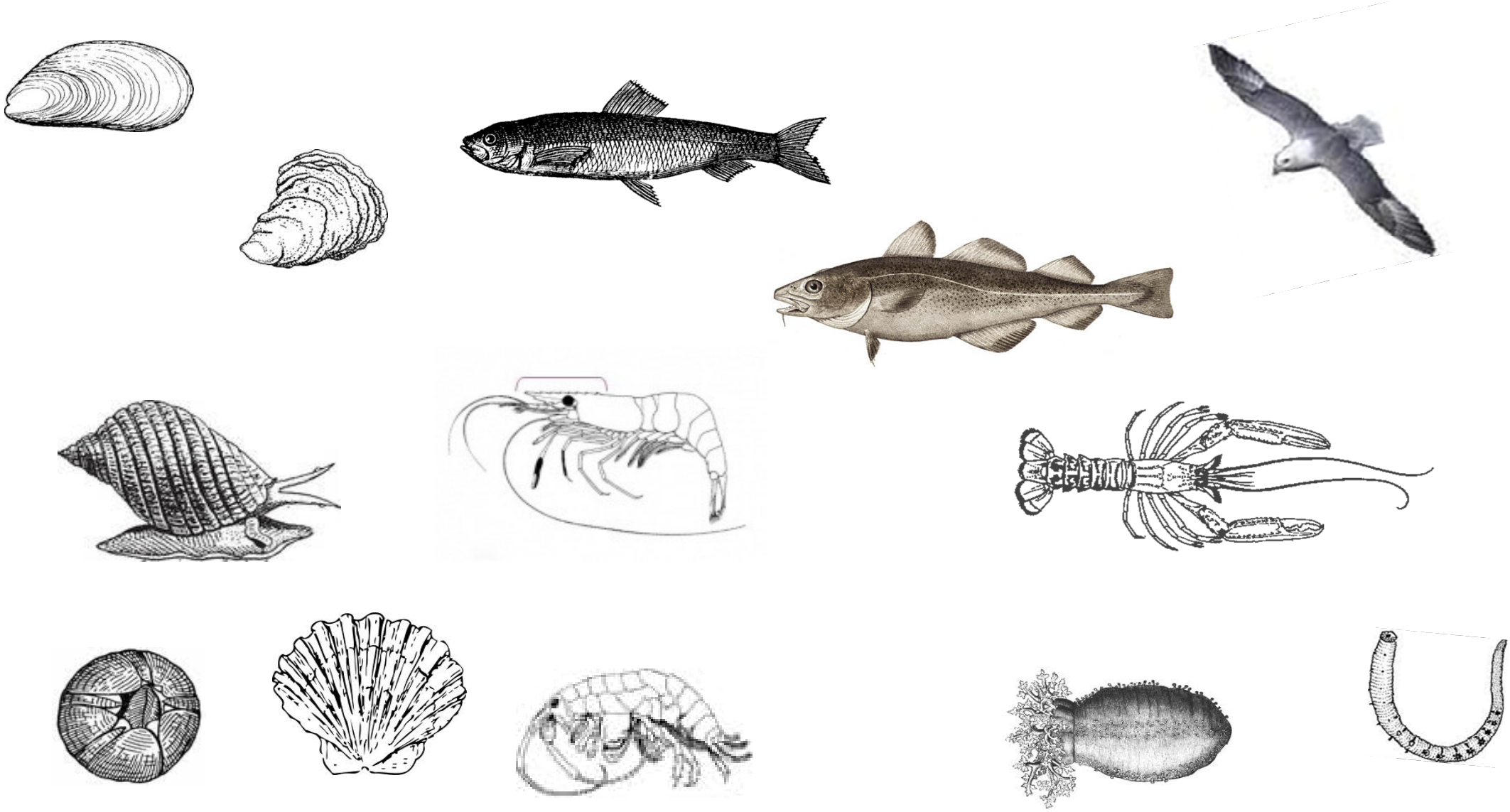
Impact: Entanglement/ingestion

Ingestion of small fragments

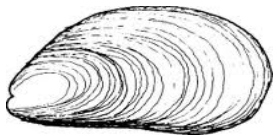
Fish larvae

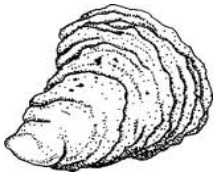


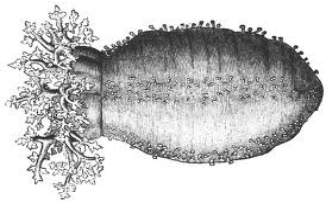
Microplastic uptake by North Sea marine organisms

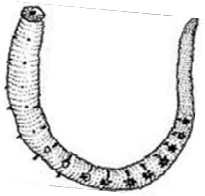


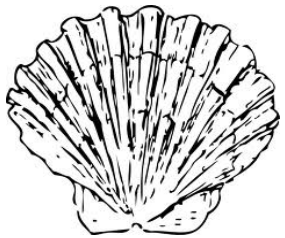
Microplastic uptake by marine organisms - lab











Mussel Browne e.a. 2008 Ward & Kach 2009

Oyster Ward & Kach 2009

Sea cucumber (4 species Echinodermata, Holothuroidea) Graham & Thompson 2009

Lugworm *A. marina* Teuten e.a.2007, Thompson e.a. 2004

Norwegian lobster *N. norvegicus* Muray & Cowie 2011

Shrimp *Orchestia gammarellus* Thompson e.a. 2004

Barnacles *Semibalanus balanoides* Thompson e.a. 2004

Sea scallop *Placopecten magellanicus* Brillant & MacDonald 2000

***Biofilms** Lobelle & Cunliffe 2011, Harrison et al. 2010

***Scenedesmus** Bhattacharya et al. 2010

Microplastics: adverse effects observed

Marine species	Microplastic exposure and effect	Reference
Blue mussel *Mytilus edulis*	Absorbtion of 1-80 µm MPs **Granulocytoma formation** (inflammation) Increase in SB haemocytes, **Decrease in lysosome stability**	Koehler & von Moos, 2010
Blue mussel *Mytilus edulis*	Exposure to 10, 30 90 µm MPs Indications for selective uptake of 10 µm MPs **Reduced clearance rate**	Van Cauwenberghe, 2012
Blue mussel *Mytilus edulis*	Exposure to/absorption of 30 nm PS causes **reduced valve opening and filtering activity**	Wegner et al. 2012
Phytoplankton *Scenedesmus*	Adsorption of 20 nm PS **Hindered algal photosynthesis** and promotion of algal ROS indicative of oxidative stress	Bhattacharya et al. 2010
Carp species *Carassius carassius*	Absorption of 24 nm NPs Food chain transport of NPs **affects behaviour and fat metabolism**	Cedervall et al. 2012

Microplastics effects on mammals

Species	MP exposure and effect	Reference
Human lymph and circulatory system	Absorption of PE particles **taken up in lymph and circulatory system** from gastro-intestinal tract	Hussain et al. 2001
[illegible]	[illegible]	
Rat	Lung **inflammation and enzyme activities** were affected, with increasing severity as particle size decreased	Brown et al. 2001
Human airway smooth muscle cell	Fluorescent 40 nm PS particles **decreased cell contractility**	Berntsen et al. 2010
Human endothelial cells (blood vessels)	Carboxyl PS latex beads in sizes of 20-500 nm were tested. 20 nm PS particles induced **cellular damage** through apoptosis and necrosis	Fröhlich et al. 2010

‘Particle toxicity’

Additives – plastics compounding

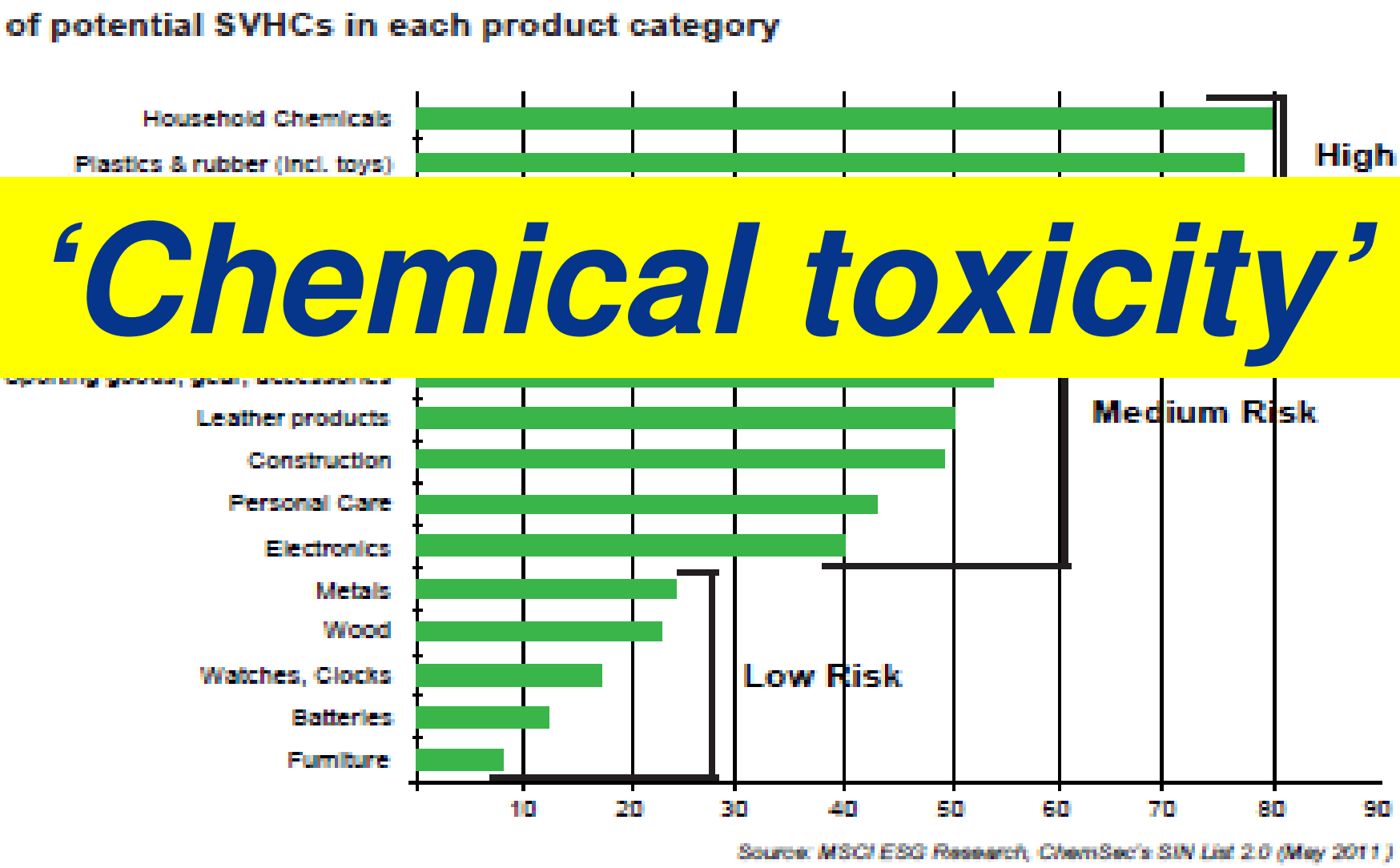
plasticizers (e.g. dibutyl phthalate, diethylhexyl phthalate, dimethyl phthalate, butyl benzyl phthalate and bisphenol A (BPA))
flame retardants (e.g. PBDE and nonhalogenated FRs)
antioxidants (e.g. amines)
biocides
heat stabilizers
impact modifiers
pigments, colourants
lubricants
UV stabilizers
antistatic agents
surface modifiers
recyclate (re)stabilizers
Fragrances
Antistatic chemicals
monomers

Leaching affected by:

1) ratio of pore diameter of polymer to size of additive molecule
2) Co-migration
3) Temperature, pH
4) Phys-chem characteristics of receiving phase

Chemicals contribute to litter's ecological risks

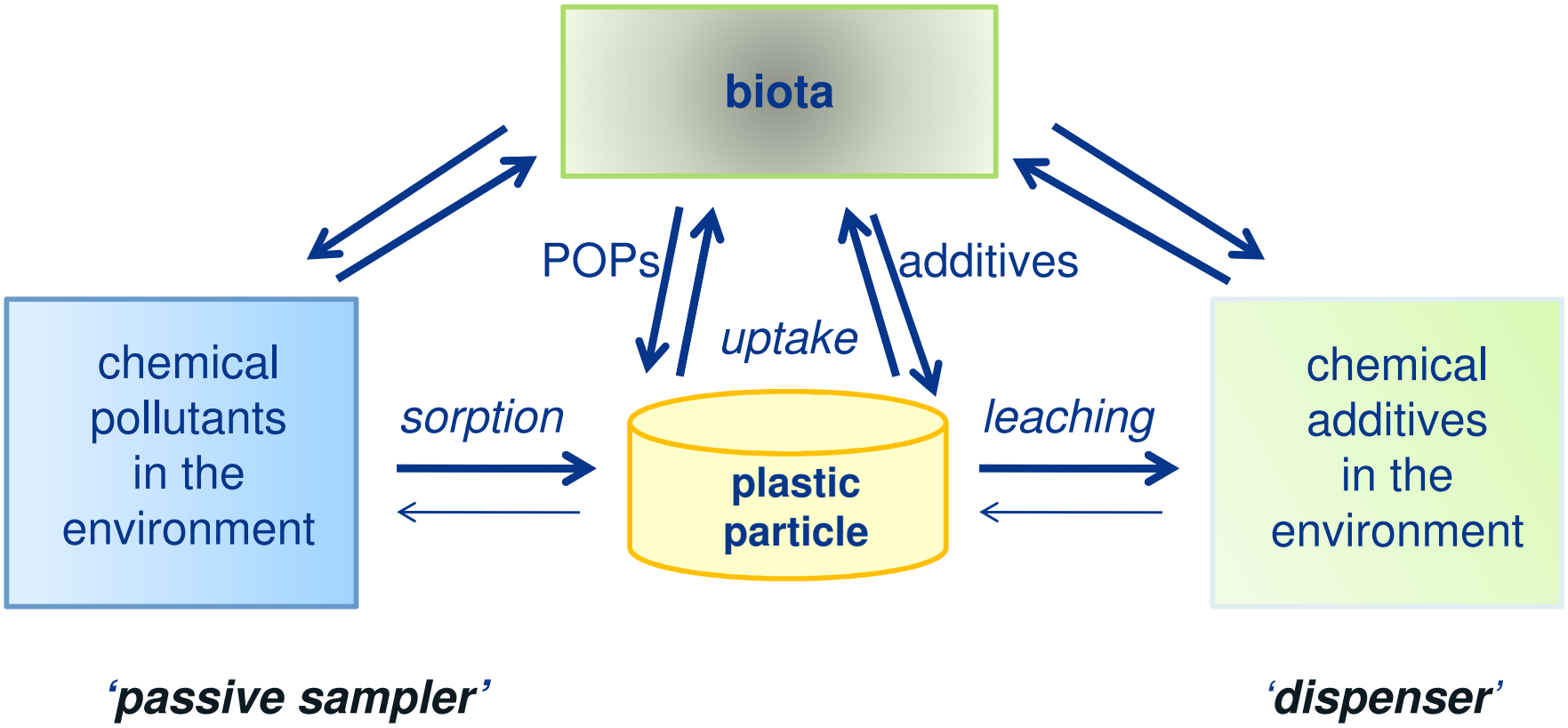
Figure 4. Substances of Very High Concern (SVHC) risk profiles for quoted companies



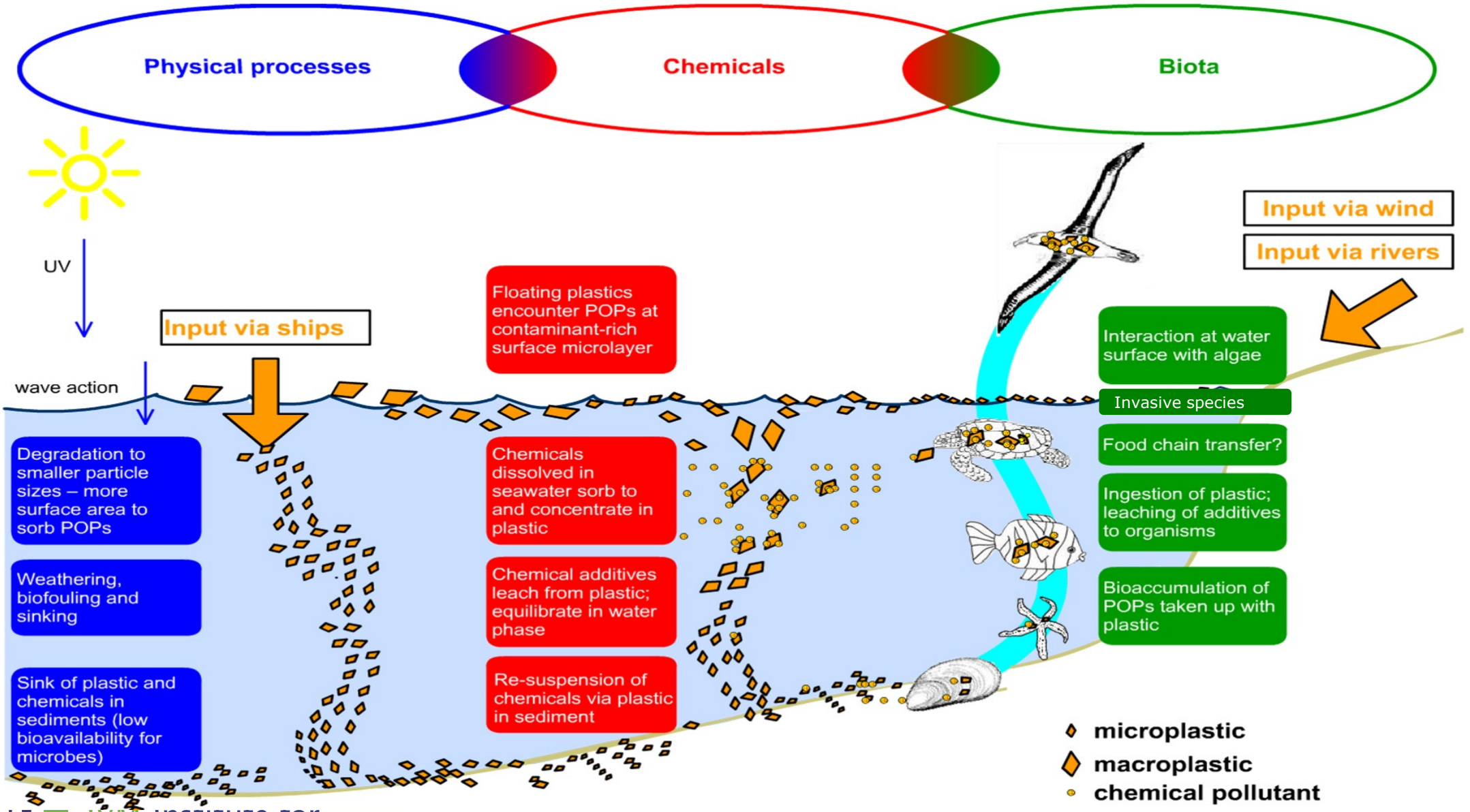
'Chemical toxicity'

Source: MSCI ESG Research, ChemSec's SIN List 2.0 (May 2011)

Sorption and additive (and monomer) leaching



Marine plastic litter and the Sea



Marine plastic is P, LRT, a bit B, and T

Persistent - esp. plastics

LRTransport - see it in five oceanic gyres, arctic/antarctic and deep sea

Bioaccumulation of 'large' MPs is mild: maybe 0-1 MP/kg seawater

Toxic - range of effects due to particles << 1 mm and/or chemicals leaching, entanglement/starvation effects.

Sublethal (micro); sometimes lethal (macro)

Substrate and transport vector for alien species, pathogens, chemicals

Emissions are expected to grow with growing plastic production and consumption

Socio economic IMPACT of plastic

Economic costs and risks

- Costs of beach cleanups
- Degraded areas negatively affect tourism
- Damage to motors/fishing gear

Social

- Residents of coastal communities, tourists, recreationists
- Well-being
- Consumer trust (food safety)

CleanSea

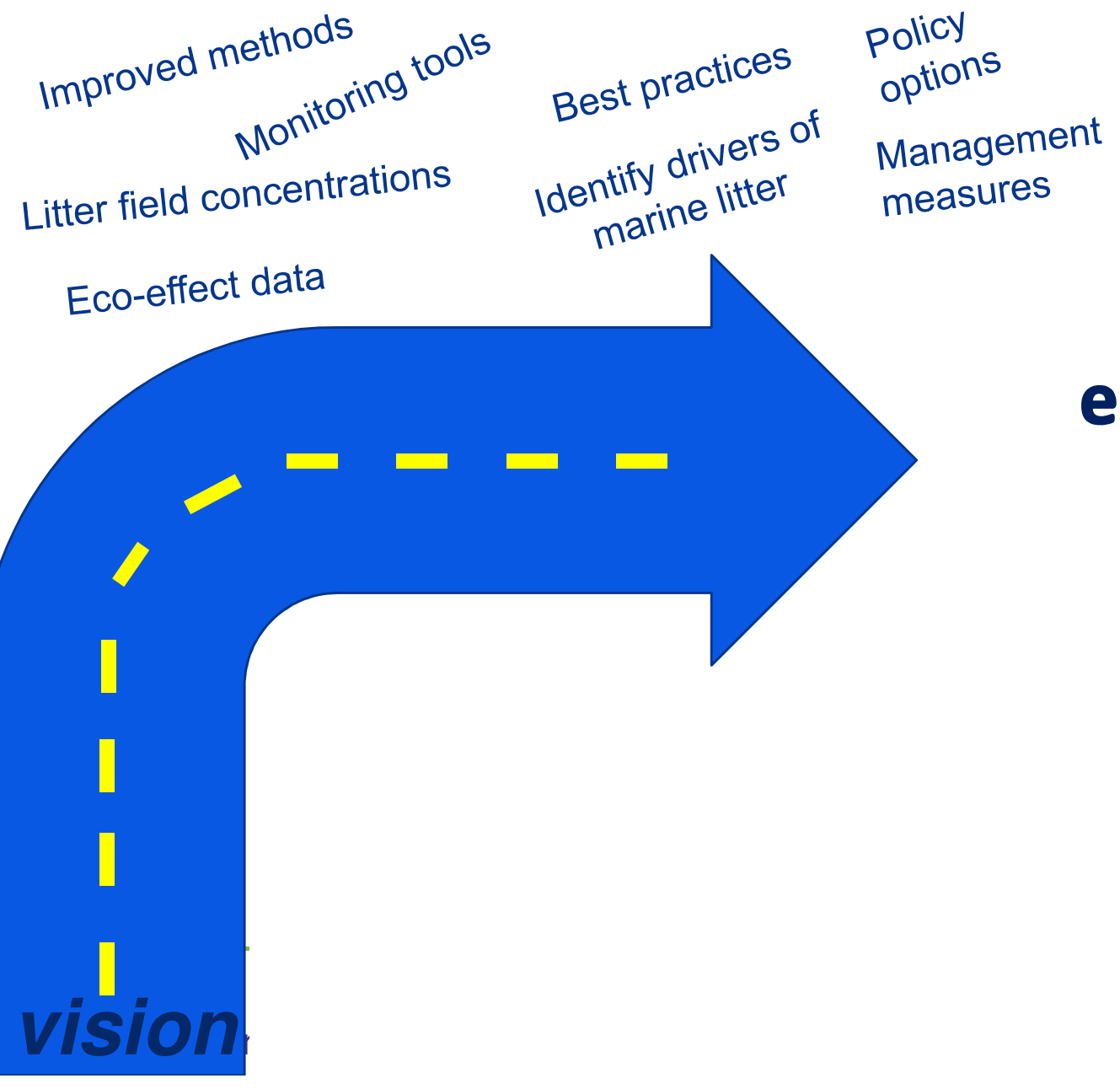
Towards a Clean Litter-Free European Marine Environment through Scientific Evidence Innovative Tools and Good Governance

FP7 Ocean for Tomorrow Program

Marine Strategy Framework Directive MSFD Descriptor 10:

"Properties and quantities of marine litter do not cause harm to the coastal and marine environment"

Overarching Goal of CleanSea Project

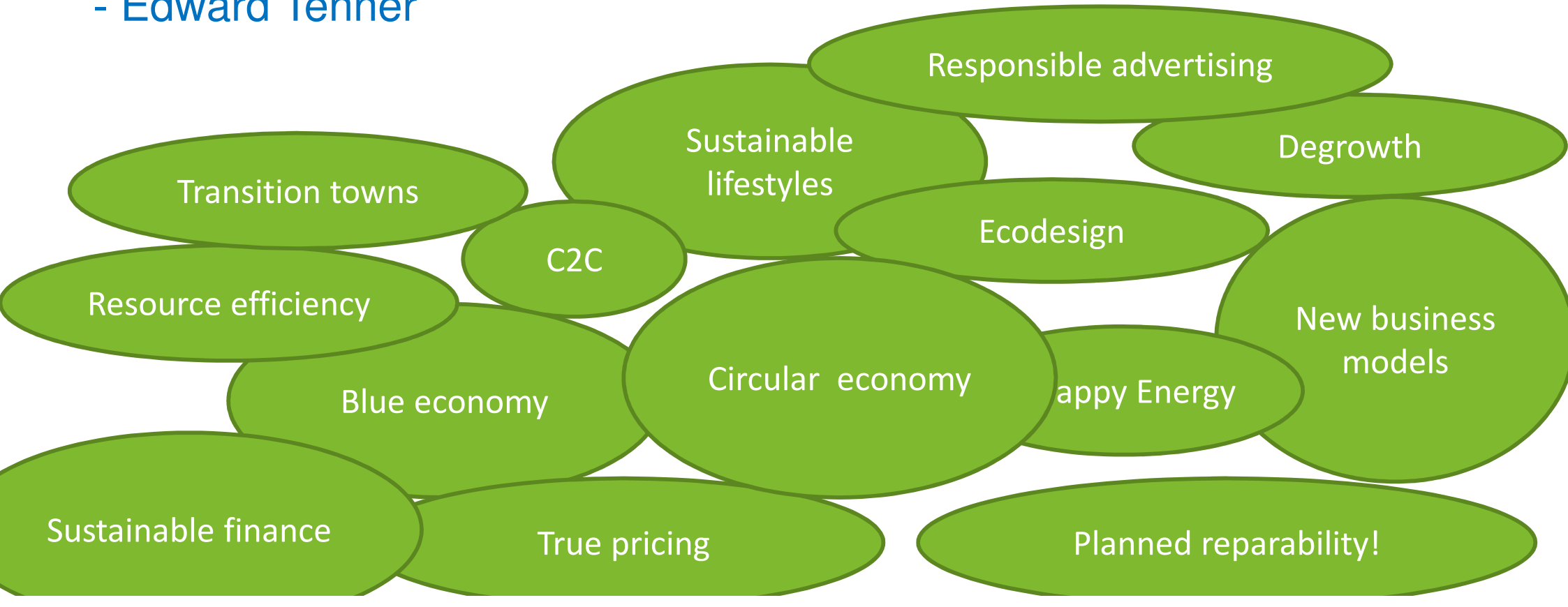


Roadmap to 'good environmental status' for marine litter in 2020

Plastic Soup 1 Nature 0

"*hardship and disasters are mere challenges to a boundless human ingenuity*"

- Edward Tenner



What would you do for a plastic-free sea ?

www.cleansea-project.eu

heather.leslie@vu.nl

CleanSea

SEVENTH FRAMEWORK PROGRAMME