GESAMP *Science for Sustainable Oceans*

The Joint Group of Experts on Scientific Aspects of Marine Protection

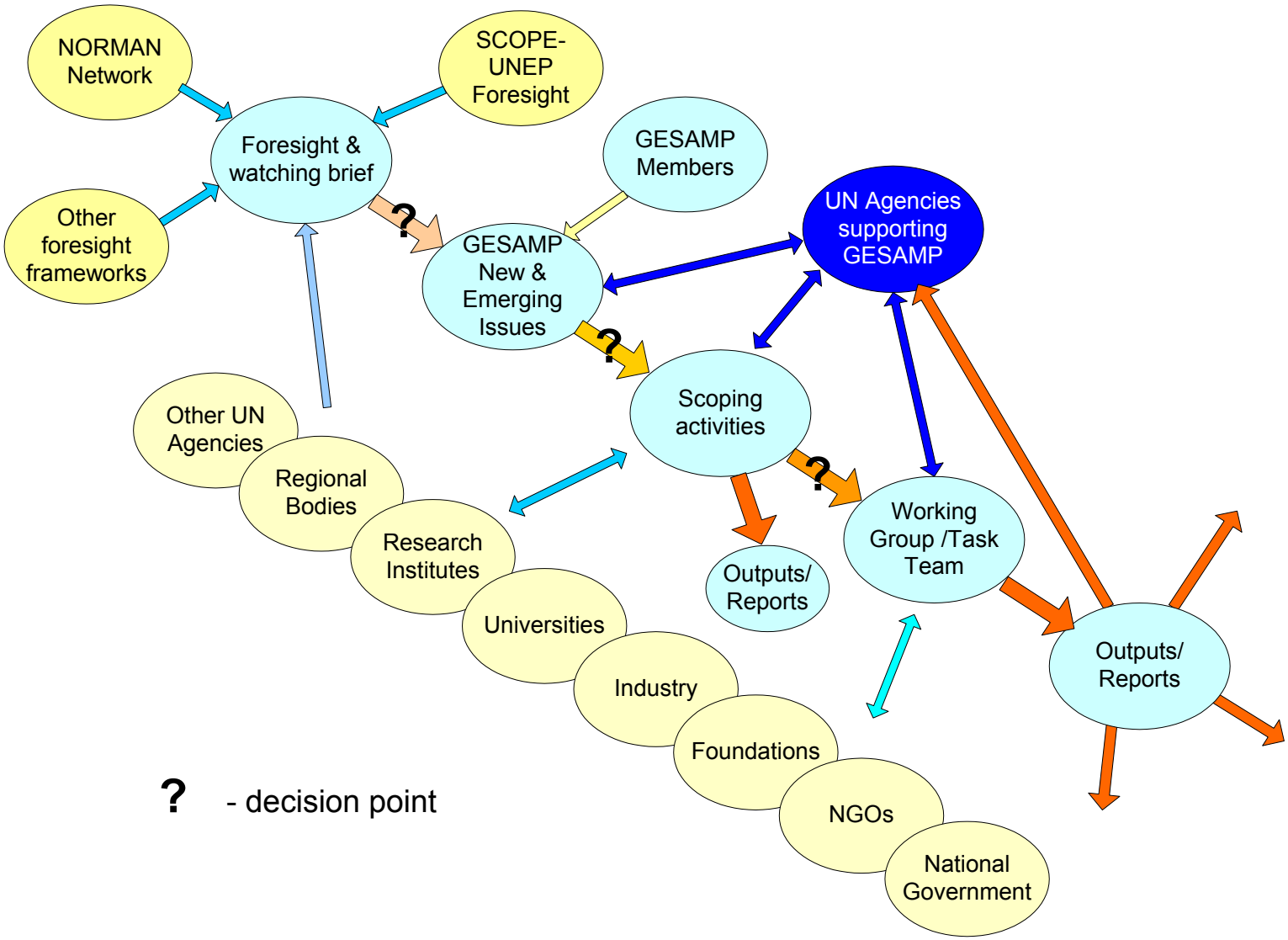
Working Group 40

Sources, fate & effects of micro-plastics in the marine environment – a global assessment

Inception meeting

13th – 15th March, UNESCO-IOC, Paris

GESAMP New & Emerging Issues framework



GESAMP New & Emerging Issues framework

NORMA Network

Other foresight frameworks

Industry

Foundations

NGOs

Go

? - decision point

BBC Radio 4 series
'*Costing the Earth*'
December 2006

GESAMP New & Emerging Issues framework

2006

SCOPE-UNEP Foresight

2007-08

GESAM Membe

UN Agencies supporting GESAMP

GESAMP New & Emerging Issues

?

Scoping activities

?

Other UN Agencies

Regional Bodies

Research Institutes

Universities

Industry

Foundations

NGOs

National Government

Outputs/ Reports

Working Group /Task Team

Outputs/ Reports

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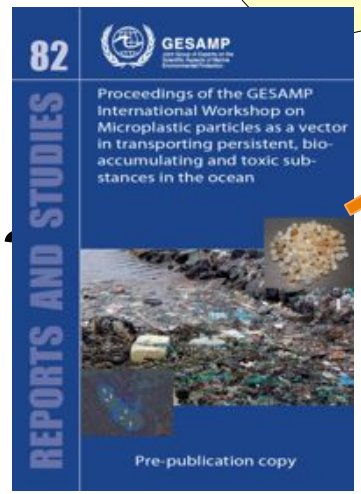


Conclusion of the Paris 2010 Workshop?
there is a need for a GESAMP assessment

Present status

- The potential impacts of micro-plastics, and contaminants absorbed to micro-plastics, are poorly understood
- This is a global issue that requires a multi-sector response
- Further research & monitoring are required to reduce the uncertainties
- There is a need to synthesise scattered information from a broad range of disciplines

GESAMP

- Has a long history of conducting assessments
- Can bring together the relevant broad expertise: materials science, physical oceanography/modelling, marine biology, chemistry, ecotoxicology, policy
- Has a global perspective

GESAMP Working Group 40: Sources, fate & effects of micro-plastics in the marine environment – a global assessment (2012 – 2015)

Lead Agencies: UNESCO-IOC & IMO
additional sponsors: UNEP, UNIDO, NOAA, PlasticsEurope, ACC

Overall objective:

To conduct a ***global assessment*** of the sources, fate and effects of micro-plastics in the ocean, based on existing information. This is to include the potential physical effects of ingested micro-plastic particles as well as potential effects of chemicals present within the plastic (e.g. additives) or as absorbed contaminants (e.g. PCBs).

WG40 – global distribution of Members

GESAMP Working Group 40

Terms of Reference (agreed in May 2011)

1st Phase

1. Estimate rates of inputs of micro-plastics (resin pellets, abrasives, personal care products) and plastics (including main polymer types); involves developing methodology, using monitoring data, identifying proxies(e.g. population centres, shipping routes, tourism revenues)
2. Modelling [*review of*] transport, distribution & areas of accumulation

2nd Phase

3. Processes (physical, chemical & biological) controlling the rate of fragmentation and degradation, including estimating long-term behaviour
4 Modelling [*review*] continues using results of ToR 3

3rd Phase

5. Uptake by biota and biological impacts

WG40 outputs

Freely available on-line & print

Reports:

- Inception meeting
- Annual progress briefings – to GESAMP/sponsors
- Assessments reports on each Term of Reference
- Final Assessment

GESAMP review

Peer-reviewed publications

Summaries for public/policy/media

External peer-review

Audience:

- UN Agencies
- Other sponsoring organisations
- Regional Seas commissions
- Other regional bodies (e.g. European Union)
- Maritime sectors (e.g. shipping, tourism, fisheries)
- Terrestrial sectors (e.g. municipalities, waste recycling, packaging, plastics industry)
- General public
- Scientific community

Inception meeting objectives:

- Meet the other WG members
- Be reminded about the topics & disciplines involved – sources, distribution, fate, material properties, physical & chemical effects, measures/policies
- Be reminded about other related initiatives
- Capture the expectations of the WG sponsors and other interested parties
- Endorse the terms of reference or suggest changes
- Agree the outputs
- Agree the division of responsibilities and practical running of the WG
- Discuss location & timing of future meetings
- Write an Inception Meeting Report

Inception meeting revised agenda:

- Day 1 morning – review objectives, review state of knowledge, knowledge gaps, priorities plus feedback
- Day 1 afternoon – continue review plus feedback
- Day 2 morning – break-out groups on goals, 'burning questions', outputs;
- Day 2 afternoon – discussion based on the morning session
- Day 3 morning – agree work programme, goals, filling gaps, practical running of WG, responsibilites, next meeting

Each session had a rapporteur to capture the discussion

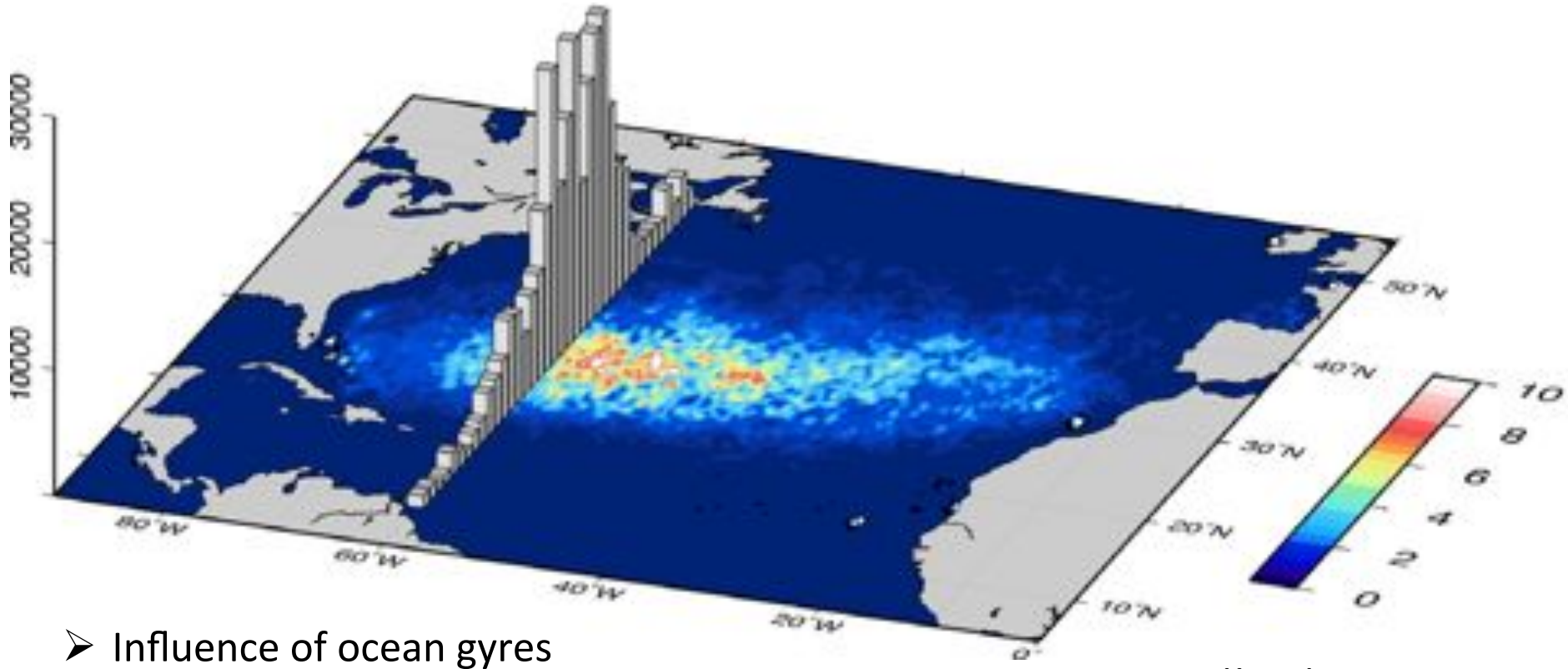
Distribution & types of micro-plastics

- ‘primary’ – e.g. resin pellets, industrial scrubbers, skin/ tooth cleaners
- ‘secondary’ – breakdown of larger items

Polymers in toothpaste

Observed distribution of micro-plastics in the ocean

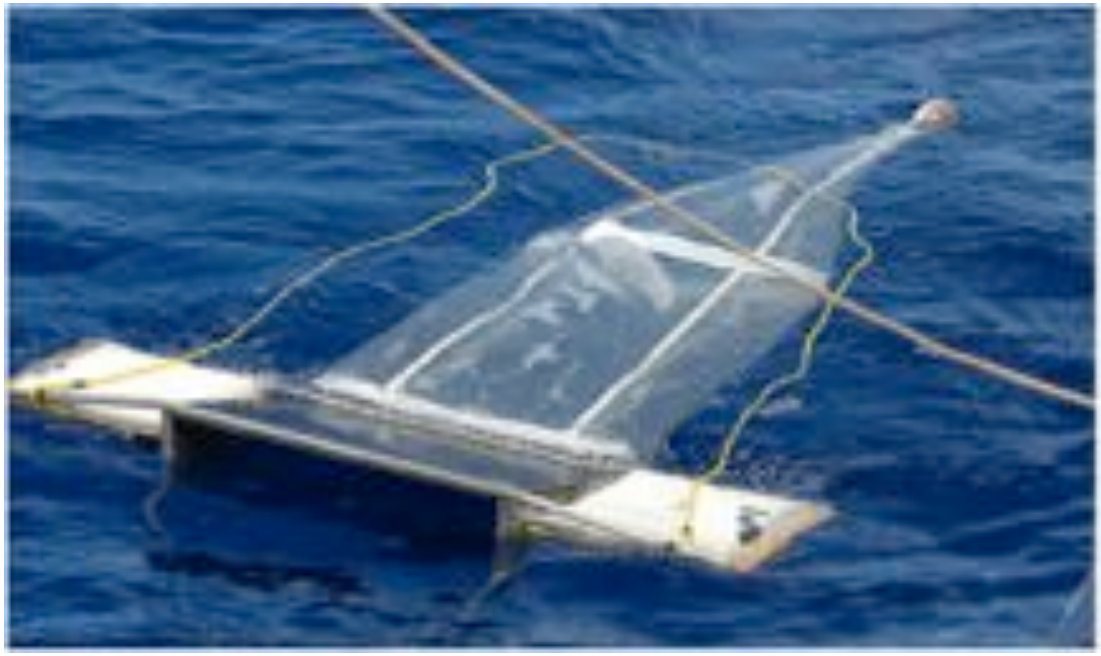
- Published reports of micro-plastics since early 1970s
- Re-analysis of archived samples has provided most comprehensive data



- Influence of ocean gyres
- No temporal trend over 18 years

Kara Law

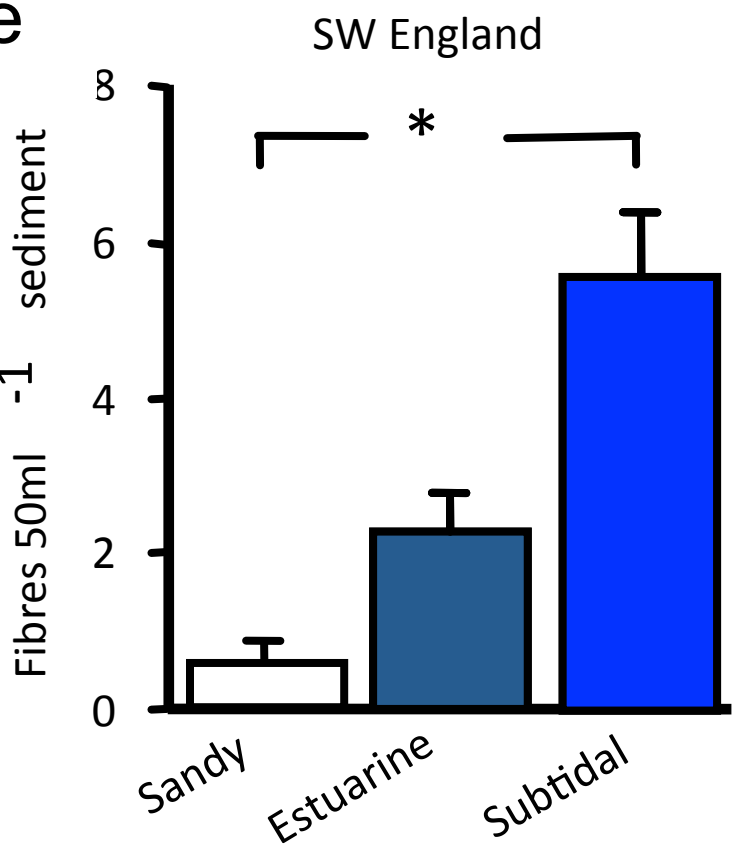
Sampling for micro-plastics in the water column



Effects being made to harmonize sampling and analysis methods (e.g. NOAA, EU)

Distribution in sediments highly variable & un-predictable

Blue plastic fibre, diameter ~20µm



KIMO Sweden

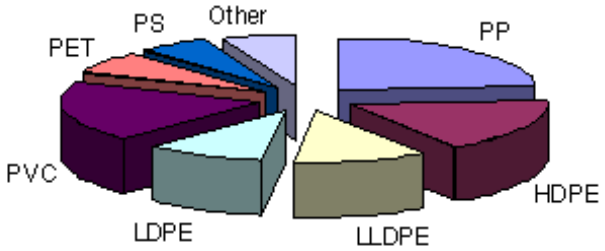
	Red fibres	Blue fibres	Black / transp.	Milky-white spheres	Σ particles per m³	+/- sd
Lysekil, Southern harbour	50	1 900	450	0	2 400	
Lysekil, Southern harbour, inner harbour	100	550	500	0	1 150	
Lysekil, Southern harbour, nrthern Släggö	50	350	200	0	600	
Lysekil, outer Släggö	50	100	50	0	200	
Björkö harbour, mean of 2 samples	0	400	250	0	450	283
Björkö ferry,mean of 3 samples	0	200	100	0	167	126
Tjuvkils huvud, harbour	50	200	0	0	250	
Stenungsund, location 3	25	0	25	1 575	1 625	
Stenungssunds leisure-boat harbour	50	150	50	850	1 100	
Stenungsund, location 4	50	300	50	750	1 150	
Stenungsund, industrial harbour	0	150	0	102 400	102 550	
Lysekil, Gäven-Byxeskär	80	120	320	40	560	
Lysekil, Gäven	70	160	80	0	310	

102,550 particles m^{-2}

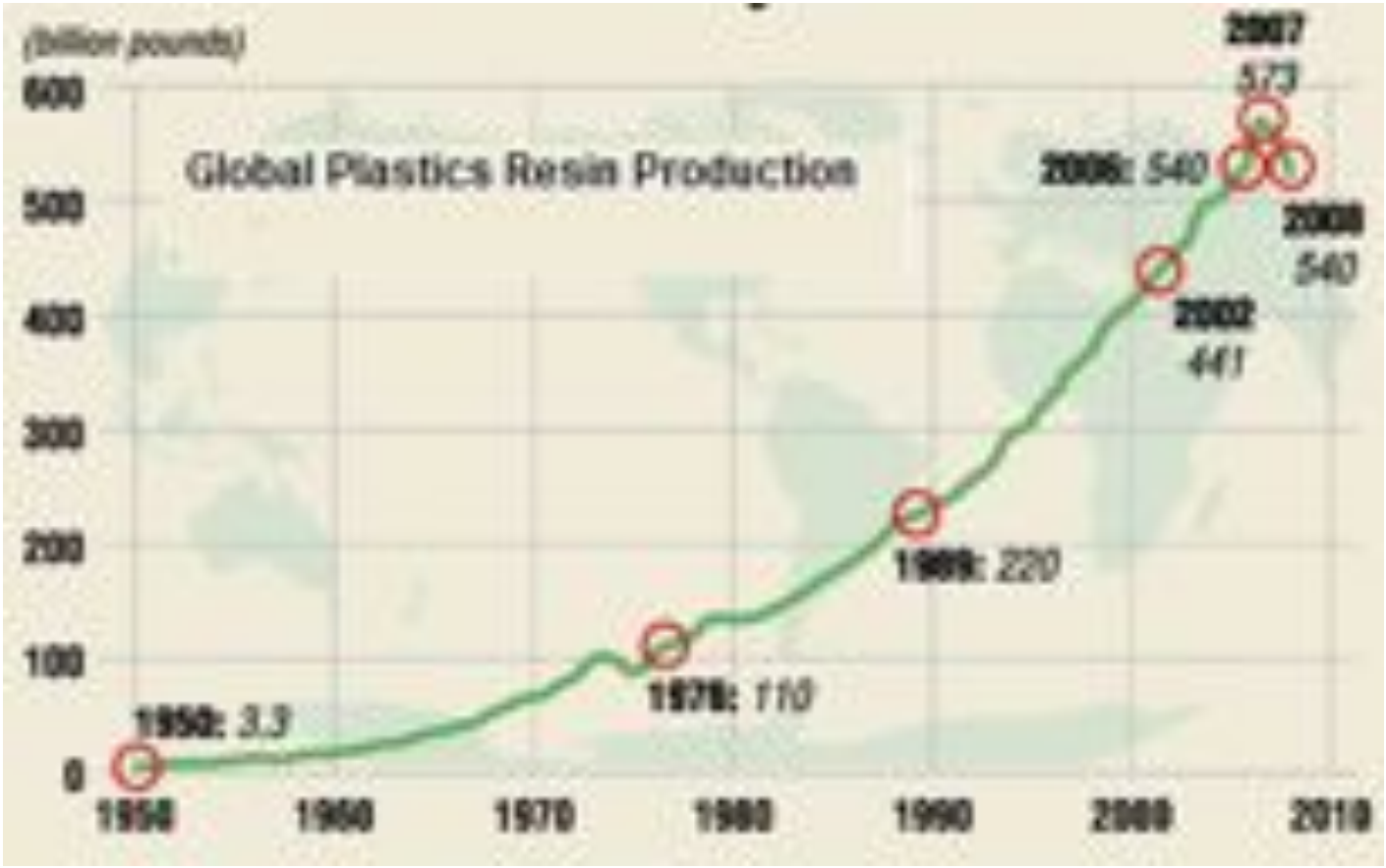
Distribution in biota - gut contents of birds & fish

van Franeker *et al.* 2005

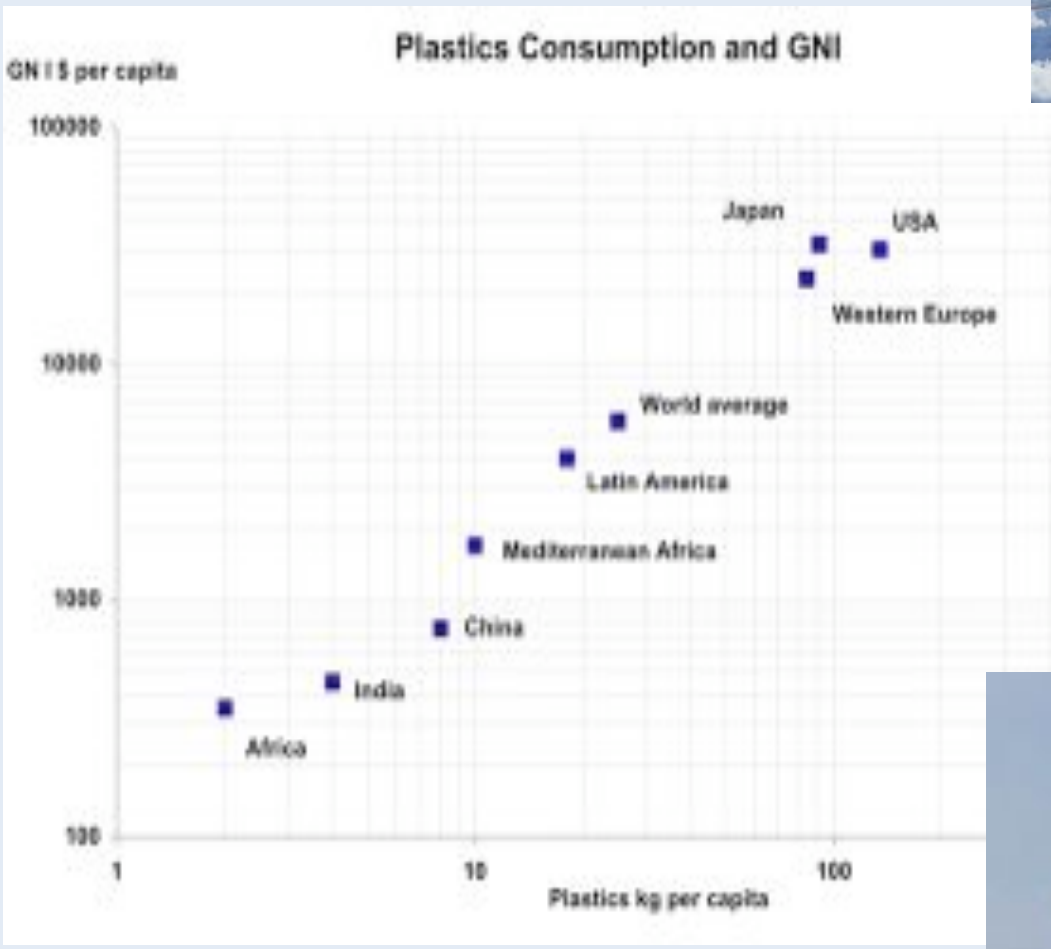
Demand for plastics



- 1000s different types produced
- Most production is of a few common types



Potential future growth in demand



	B 777	B787
Plastic	11%	50%
Aluminum	70%	20%
Steel	11%	10%
Titanium	7%	15%

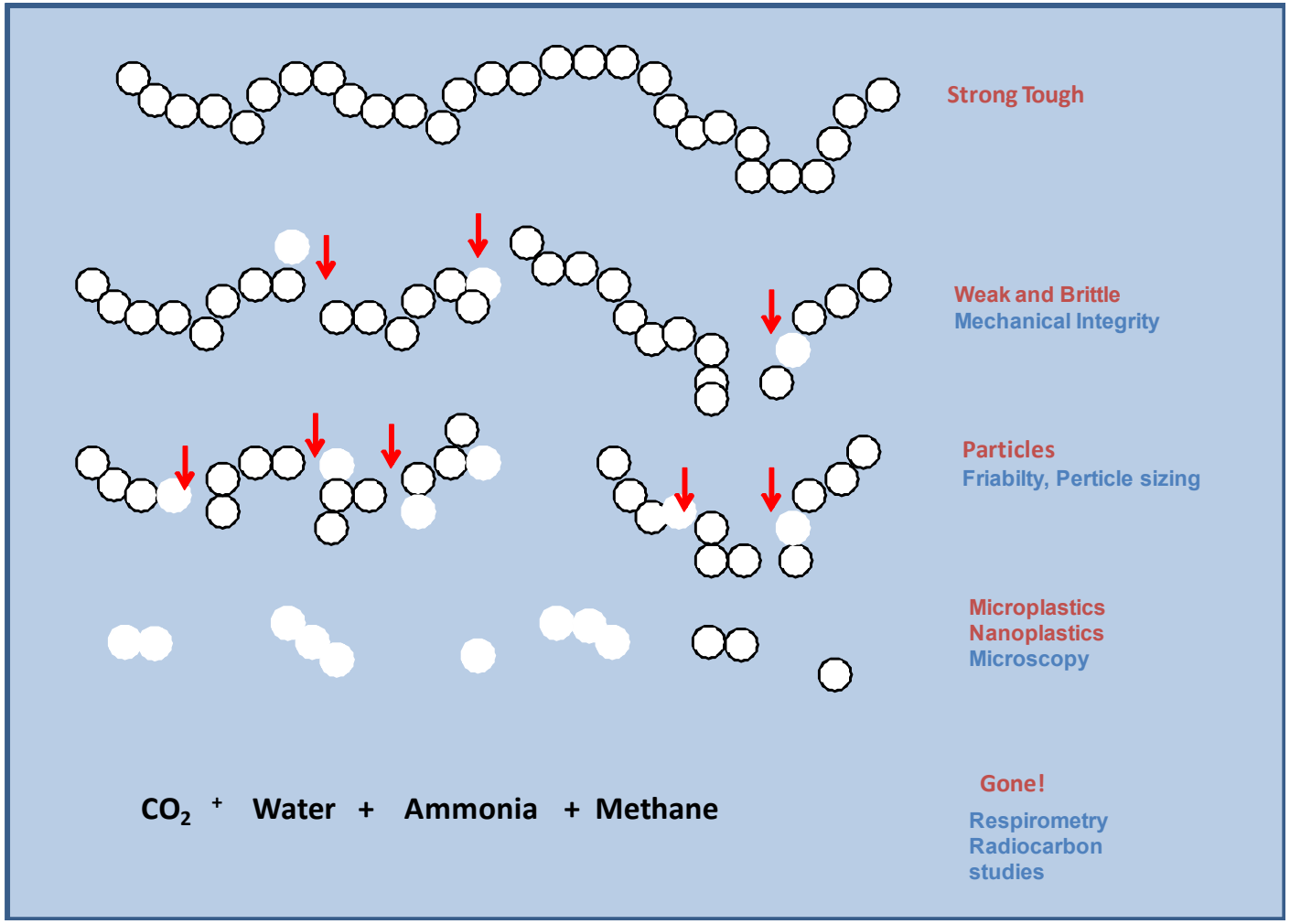
Specific gravity of common plastics - Seawater SG ~ 1.02

Type	Applications	Specific gravity
Polyethylene	Plastic bags, six-pack rings, fishing gear	0.91-0.95
Polypropylene	Rope, caps, gear, strapping	0.90-0.92
Polystyrene (expanded)	Bait boxes, caps, floats	0.10-1.05
Polystyrene	Utensils, containers	1.04-1.09
Polyvinyl chloride	Film, pipes, containers	1.16-1.30
Polyamide/nylon	Gear, rope	1.13-1.15
Polyethylene terephthalate (PET)	Bottles, strapping, gear	1.34-1.39
Polyester resin & glass fibres		>1.35
Celluslose acetate	Cigarette filters	1.22-1.24

Microbial colonisation will increase apparent SG - most plastics will eventually sink!

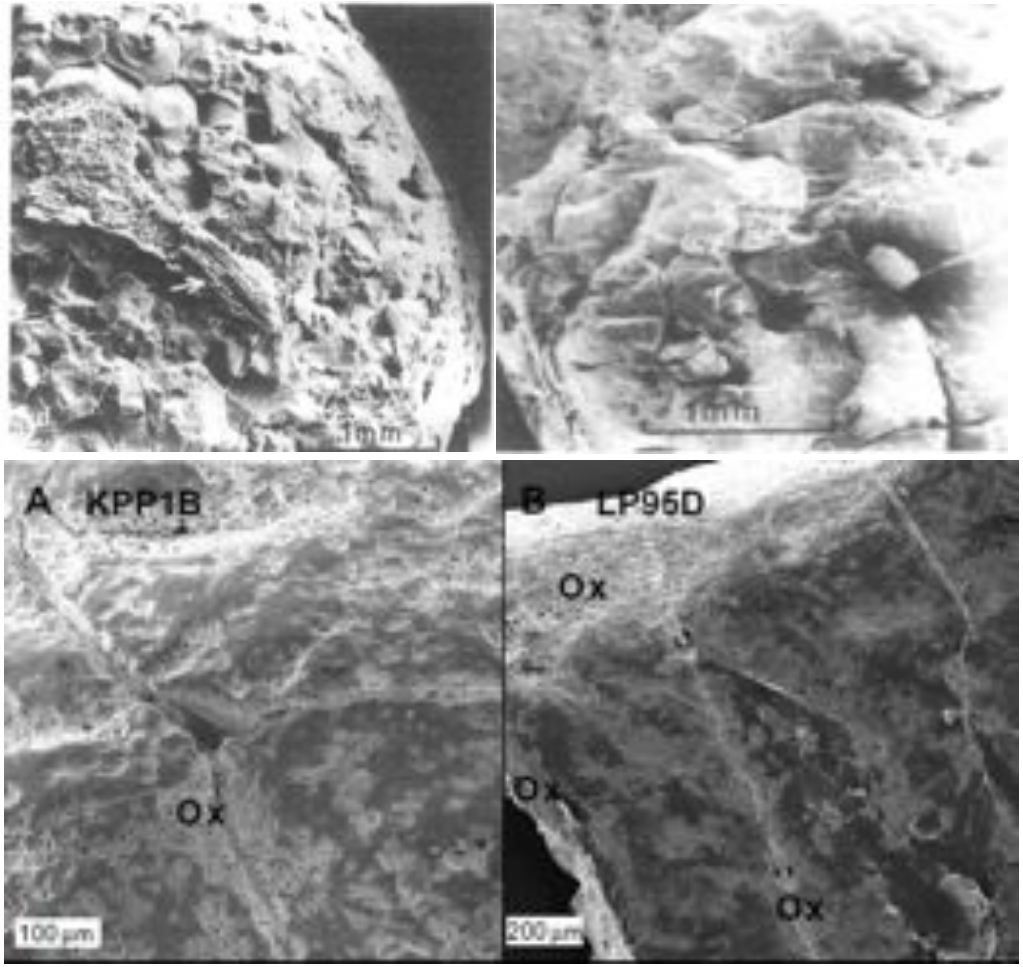
Andrady, 2011, MPB

Simple model of polymer degradation



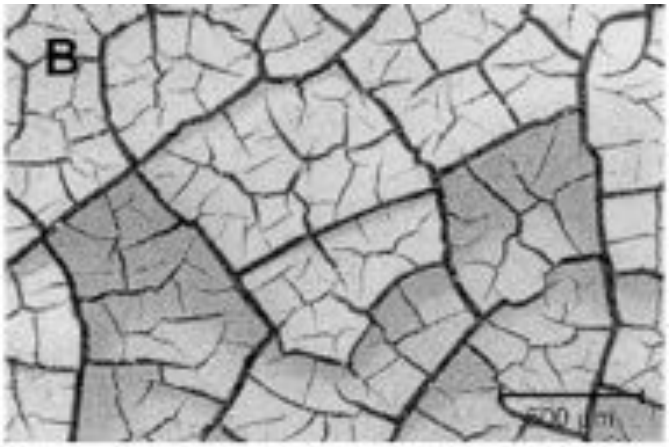
Tony Andrady

Surface Cracking in UV Degradation.



Gregory (1983) Marine Environmental Research 10:73-92
Corocoran et al., (2009) Marine Pollution Bulletin 58 :80–84

Especially with PE and PP yellowing discoloration and surface cracking are characteristic consequence of UV degradation.

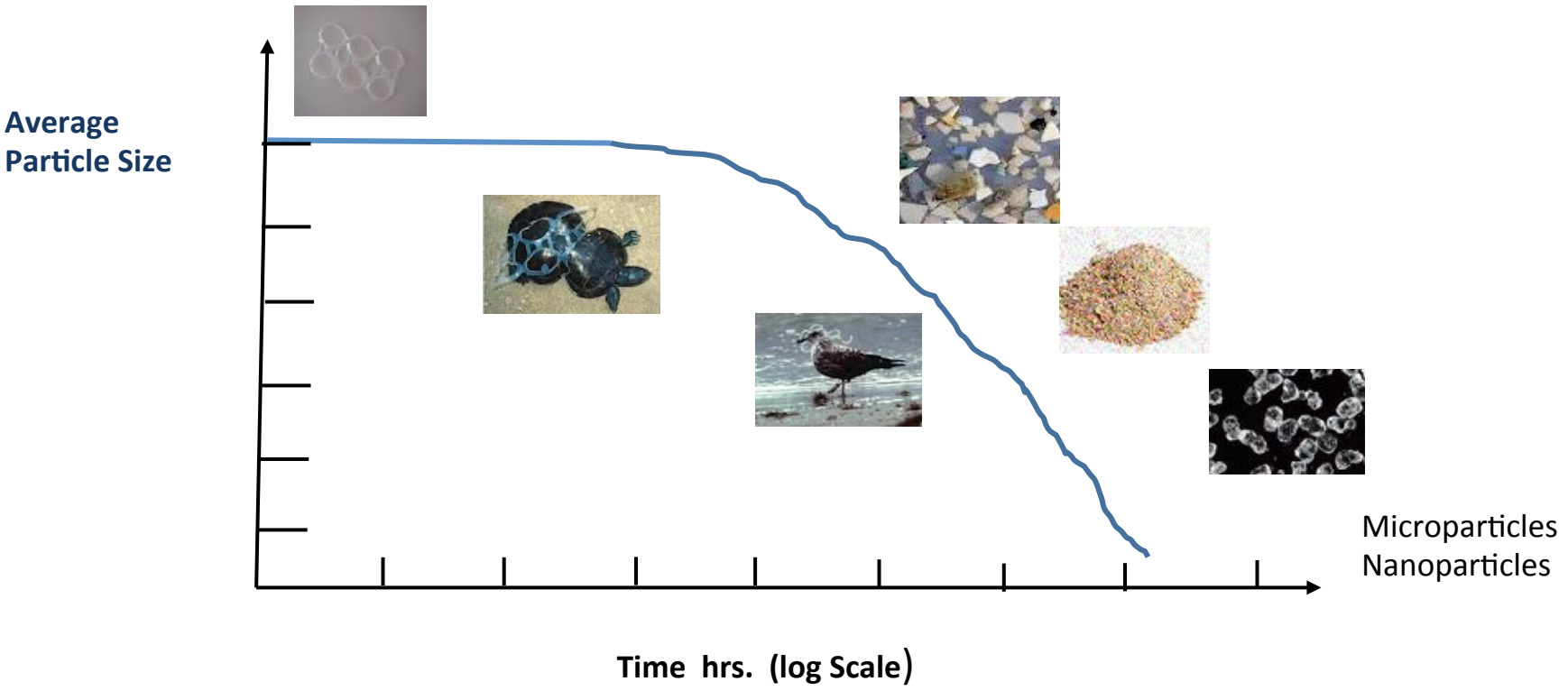


sample surface aged under QUV for 800 h (Küpper, et al., 2004)

Degradation of Plastics in the Oceans.

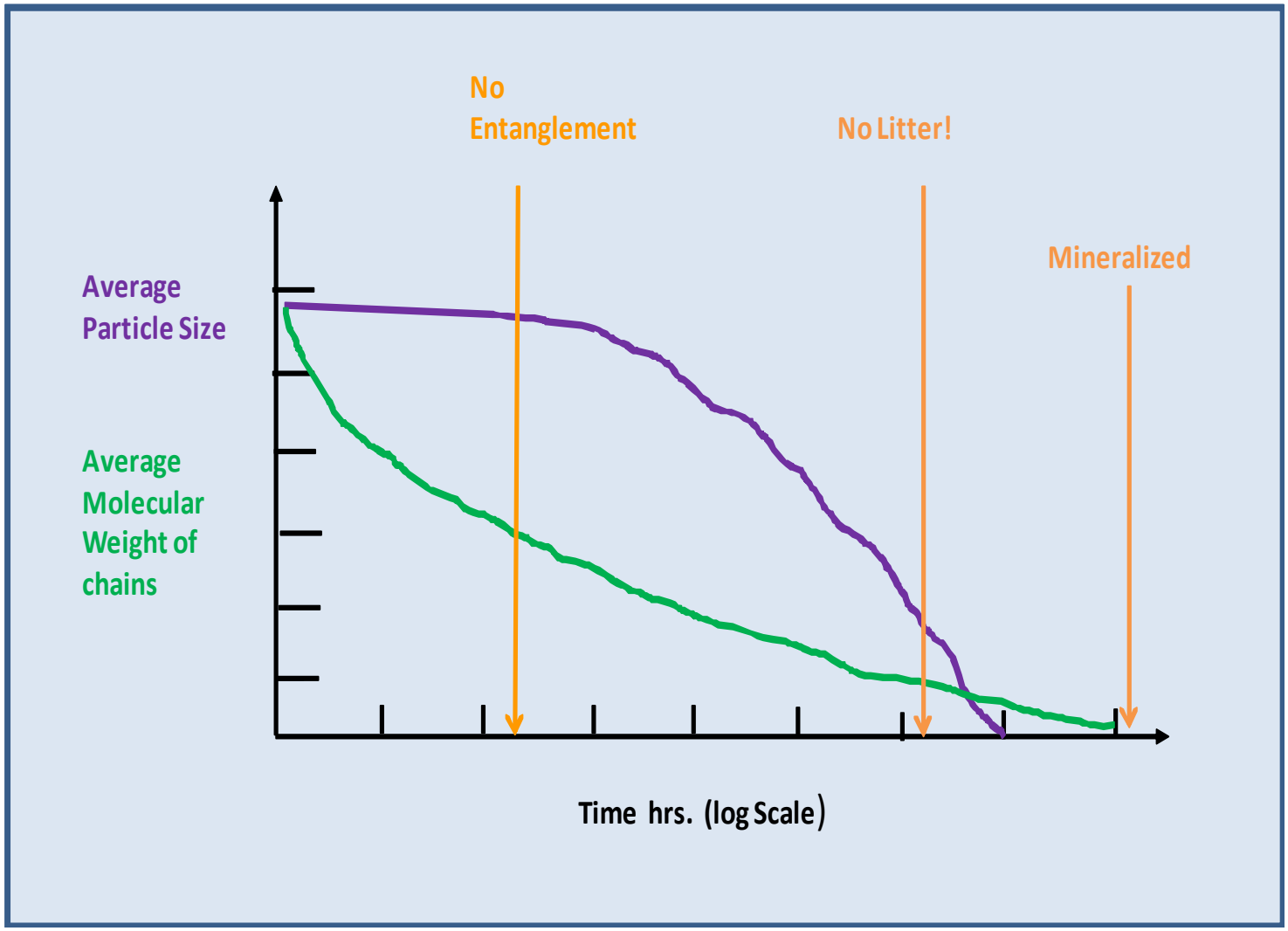
Beach Environment	Solar UV available Oxygen available Temperatures high	High to moderate rates of degradation. Similar rates to degradation of plastics on land environments
Surface Water Layer	Solar UV available Oxygen available Temperatures low Limitations due to fouling.	Degradation rates retarded by several orders of magnitude.
Mid-Water and Ocean Bottom	Solar UV not available Oxygen levels low Temperatures very Low Pressure effects?	Degradation rates are extremely slow.

Weakening and Fragmentation



Fishing gear debris in waters off Amchitka Islands

Schematic of size vs. effect over time



Biological interactions with microplastics

- **Biofilms** form on microplastics, as the particles are quickly colonized by microorganisms including bacteria and diatoms.

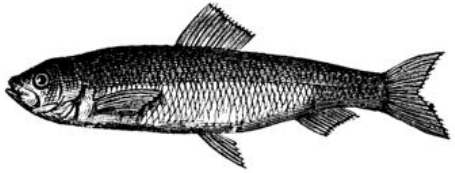
- Field and laboratory research has shown that microplastics are **ingested and retained** by marine organisms, after which size-dependent absorption into certain tissues may take place; food chain transfer of microplastics from prey to predator has already been demonstrated in a field study.

- many possible effects of exposure to microplastics have been postulated but **these hypotheses must be tested** with scientific rigour.

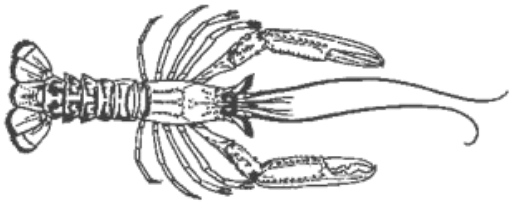
Microplastic exposure in North Sea biota: field

Northern Fulmars (NL) 95% of stomachs contain litter ≥1 mm (incl. 'microplastic' 1-5 mm) *Van Franeker et al. 2011*

Cod, whiting, gray gurnard
'Plastics' listed as prey item in UK marine fish stomach content analysis n=22 cases since 1990 *Pinnegar & Platts 2011*

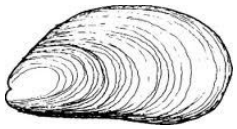


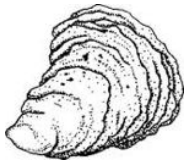
Herring 'small plastic fragments have been found in 1% of 500 individual Herrings from the Northern North Sea', pilot study van *IMARES, 2010-2011*



Crustacea (Norway lobster) *Nephrops norvegicus*
83% of animals (n=120) had microplastic in stomach (mainly filaments), Clyde Sea, Scotland (W). *Murray & Cowie 2011*

Microplastic uptake by marine organisms

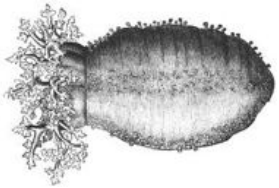




Mussel Browne e.a. 2008 Ward & Kach 2009

Oyster Ward & Kach 2009

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



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

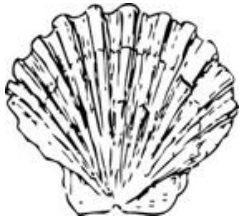
Norwegian lobster *N. norvegicus* Muray & Cowie 2011

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

Interactions between contaminants, additives & micro-plastics in the marine environment

Effects in ecotoxicology

- **…cells, individuals, populations, ecosystems…**
- Stresses can be **abiotic** (e.g. synthetic chemicals, particle toxicity), or **biotic** (e.g. pathogens, predation, etc.)
- Direct and indirect effects
- Chronic and acute effects
- Classic: **exposure x hazard = risk**
- Hazard = toxic properties
- Single chemicals and **mixture** tox
- **Multiple modes** of toxic action and **multiple symptoms**: inflammation, physiological stress, neurotox, endocrine disruption, carcinogenicity, behavioural changes

Challenges of proving physical & chemical effects

- Relatively few dedicated studies;
- particle toxicity is size- and shape-dependent;
- toxicity is dependent on the specific chemical make-up of the micro-plastic particle (poly-, di- monomer, additives, sorbed contaminants);
- diversity of possible types of micro-plastics in any given environmental matrix (combination of size/shape & composition);
- diversity of uptake routes and accumulation patterns in vastly different marine life forms and habitats;
- diversity of potential ecological effects (e.g. vectors for viruses/invasive species; food chain transfer; biogeochemical cycles, biodiversity etc).

Additives in plastics

- 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

- Monomers, dimers..

ca. 4 up to 80% of the polymer end product

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

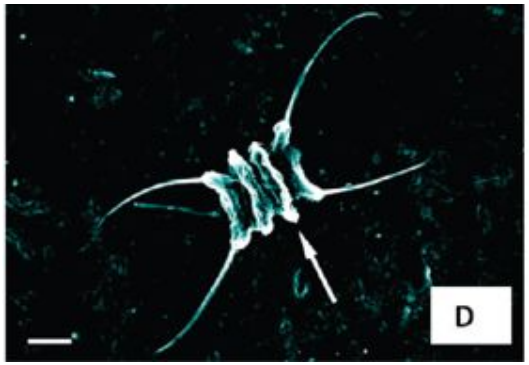
Lessons from mammalian toxicology

- several studies of the **fate and pathology of ultrafine plastic particles** in animal models and human cells, and human placental perfusion studies (to investigate transfer from mother to foetus) have provided particle toxicity data

- **Toxicity data for many polymer additives and environmental contaminants** associated with microplastics are also available for use in hazard assessment.

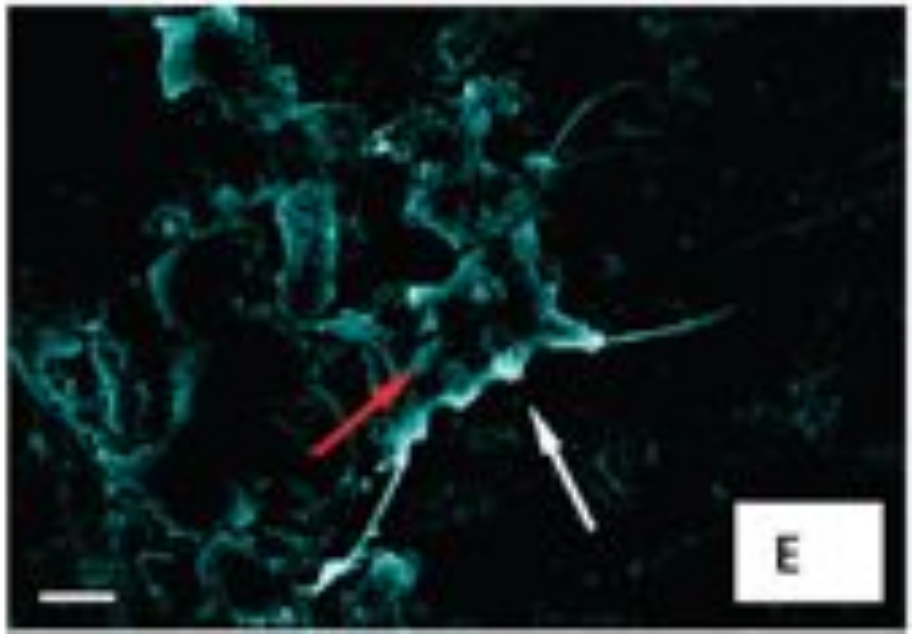
- emerging field of (**aquatic**) **nanotoxicological research** has many links to the study of microplastics toxicity.

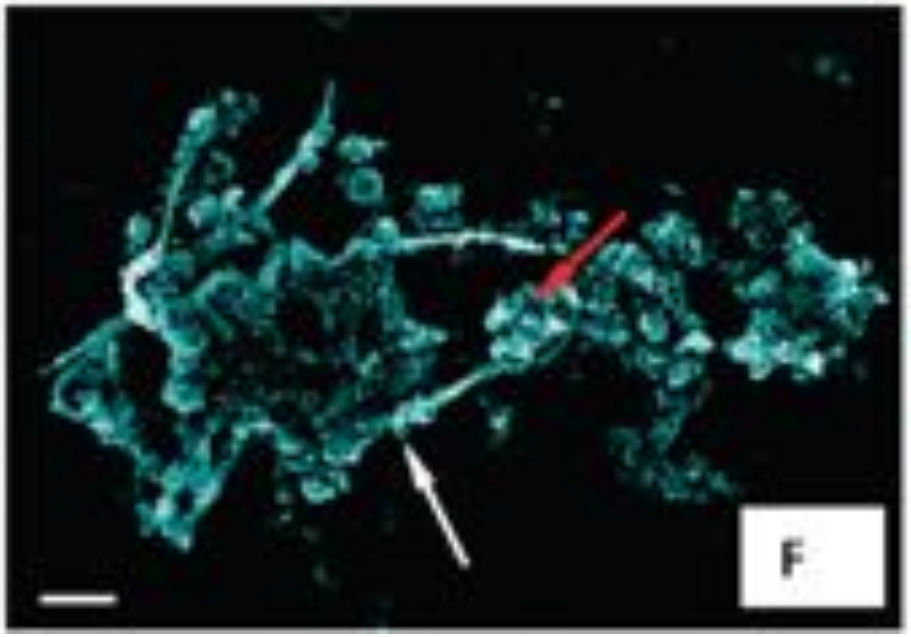
Scenedesmus and polystyrene



- Reduced photosynthetic capacity observed in primary producer

Bhattacharya *et al. 2010*





Conclusions on potential effects

- Marine organisms are **exposed** to microplastics but biological **effects have not been adequately studied** (detected in the tissues of a variety of key species in the marine food chain worldwide (plankton, crustaceans, mussels, fish and seabirds)

- substrate surface area for microorganism growth increases: **new habitat** created - biodiversity changes?

- It is expected that the ecological effects of microplastics will be comprehensively characterized and quantified in the coming **decades**.

- **Size, shape and composition** give clues about potential toxicity (and possible sources/mitigation measures)

NOAA Marine Debris Programme

Perspective :Microplastics are an issue of emerging concern.

Program activities as they relate to microplastics:

(1) assist in coordinating researchers and

(2) determine the effects of microplastics to

(3) better manage the impacts.

Workshops and working groups

Research

Management

NOAA Initiatives - Workshops

First International Research Workshop on
The Occurrence, Effects, and Fate of Microplastic Marine Debris 2007

Sessions focused on occurrences, impacts to organisms, impacts of exposures, and effects on biogeochemical cycling.

Working Definition: Any solid material <5mm that is primarily composed of synthetic polymers.

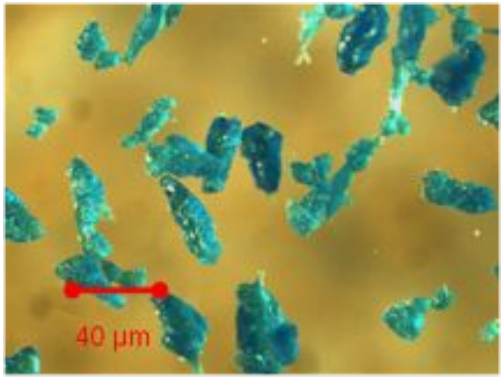
Second Research Workshop on Microplastic Debris October 2010

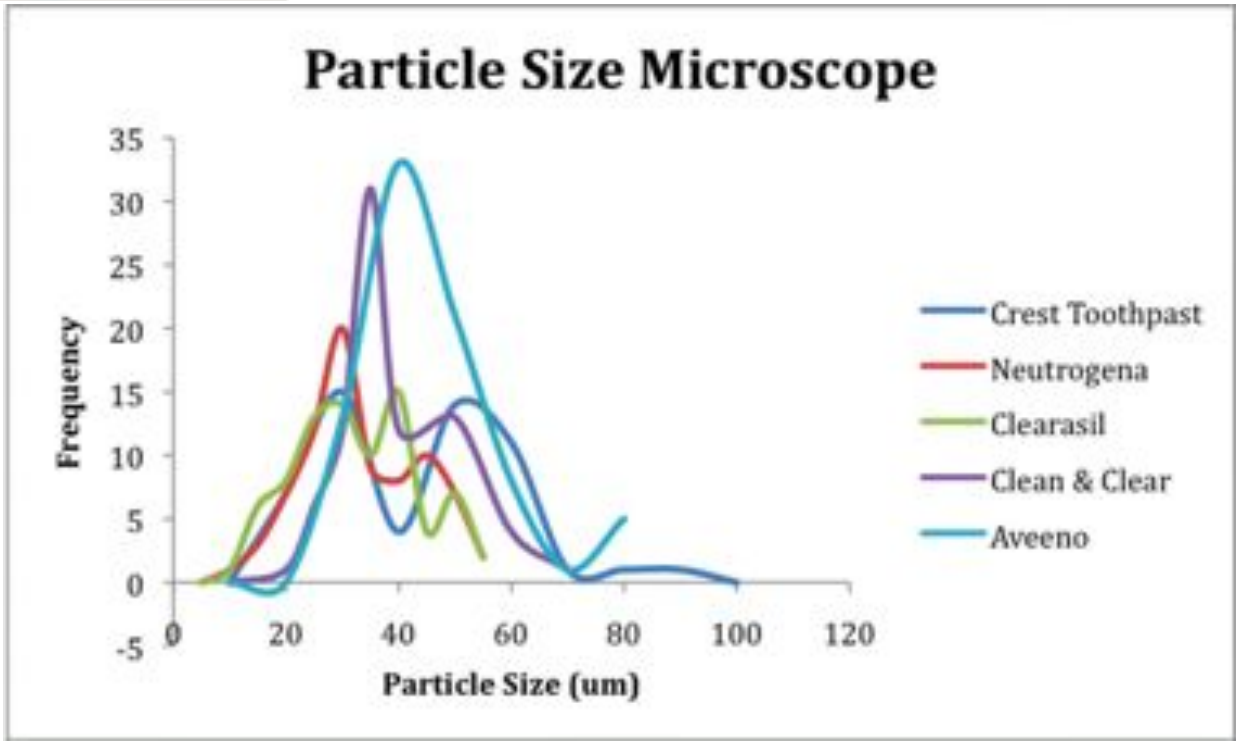
The workshop applied risk assessment principles to the microplastics issue.

Many unknowns were determined. Next steps include obtaining more information about
- Effluents as a source of MP
- Potential for bioaccumulation
- Chemical (de)sorption

NOAA Research initiatives:

- Standardized monitoring protocols for all size classes
  - shorelines and surface waters
- Microplastics Analytical Methods (grant)
  - University of Washington, Dr. Joel Baker
- Chemical Impacts (grants)
  - University of Alaska, Dr. John Kennish. Desorption of chemicals from plastics in simulated gut contents
  - University of Maryland, Dr. Upal Ghosh. Sorption and leaching potential of PCBs to plastics, changes in sorption based on degradation / weathering


40 µm


Particle Size Microscope
Frequency
35
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
Particle Size (um)
Crest Toothpast
Neutrogena
Clearasil
Clean & Clear
Aveeno

Microplastic concentrations in perspective

	North Atlantic (Law *et al.*, 2010)	Puget Sound (this study)
chlorophyll-a (ug/L)	0.5	2.1
phytoplankton (mg/m^3)	30	130
microzooplankton (mg/m^3)	0.3	---
mesozooplankton (mg/m^3)	1.7	---
DOM (mg/m^3)	850	2000
Microplastics (mg/m^3)	0.008 - 1.1	0.0002 – 0.29

Also Horner *et al.* (2005), Calbet *et al.*, (2008), PSAMP (2010), Goldbert *et al.*, (2010)

CENTER FOR URBAN WATERS

www.urbanwaters.org

Europe/Gulf/Africa	45 %
America	31 %
East Asia/India/Australia	24 %

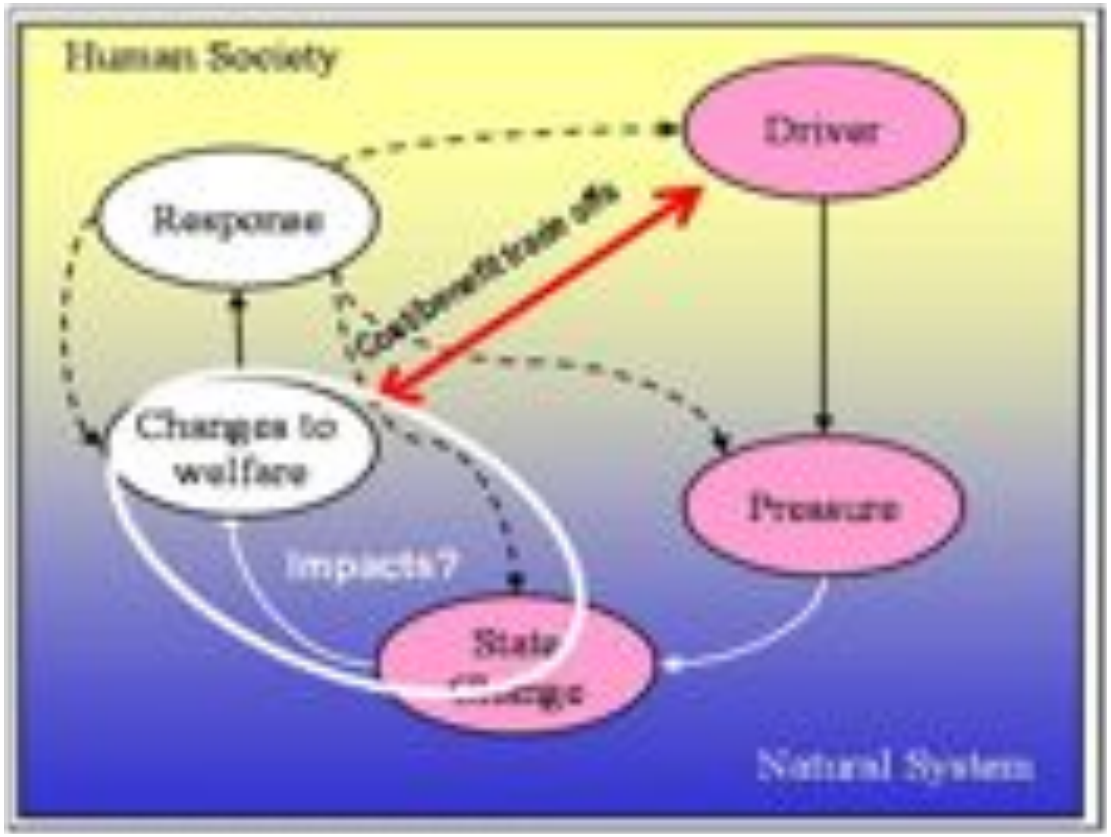
Sharing best practices

Global Action Plan

Being clear about the assessment
….. not just another review

	Review	**Assessment**
Audience	Scientists/specialists	Decision-makers
Conducted by	One or a few	Large and varied group
Topic	Simple& narrow	Broad & complex
Identifies gaps in:	Research: curiosity-driven	Knowledge for implementation; problem-driven
(Un)certainty statements	Not required	Essential
Judgement	Hidden	Required but clearly flagged
Coverage	Exhaustive, historical	Sufficient to deal with main range of uncertainty
Synthesis	Not required	Essential to reduce complexity

Placing assessment within an accepted framework



DPSIR – Driver-Pressure-State-Impact-Response

Overall conclusions of the inception meeting

1. The proposed ToRs and Work Programme are appropriate and justified, and the WG is timely. We will plan to work closely with other initiatives and make use of earlier studies to make cost-effective use of the limited resources.

2. We know enough to undertake an assessment, and to work on exposure pathways. There are *missing blocks* in the conceptual structure of our understanding, but we need to find out what these are.

3. Recent publications have started to suggest ecological effects of micro-plastics are occurring and it is important that WG40 looks at the evidence impartially***. Whether micro-plastics are having a significant ecological impact is perhaps the most important question WG40 should address.*** As well as individual effects, we should consider ecosystem/population effects.

4. Monitoring programmes for micro-plastics are under development. We need to be able to link monitoring data with effects data to advise whether we are looking at the most appropriate targets/indicators and in the most appropriate places.

5. An assessment of present monitoring techniques can be included under ToR 1, and link to related initiatives such as under the MSFD Technical Sub Group.

6. Available time-series do not show convincing trends in micro-plastic concentrations, implying we are missing important pathways (e.g. sinking particles) or failing to sample representatively. Greater rigour is needed when assessing particle properties.

7. Rates of degradation are critical, and it is important to link expertise on materials science with expertise on physical, chemical and biological oceanography.

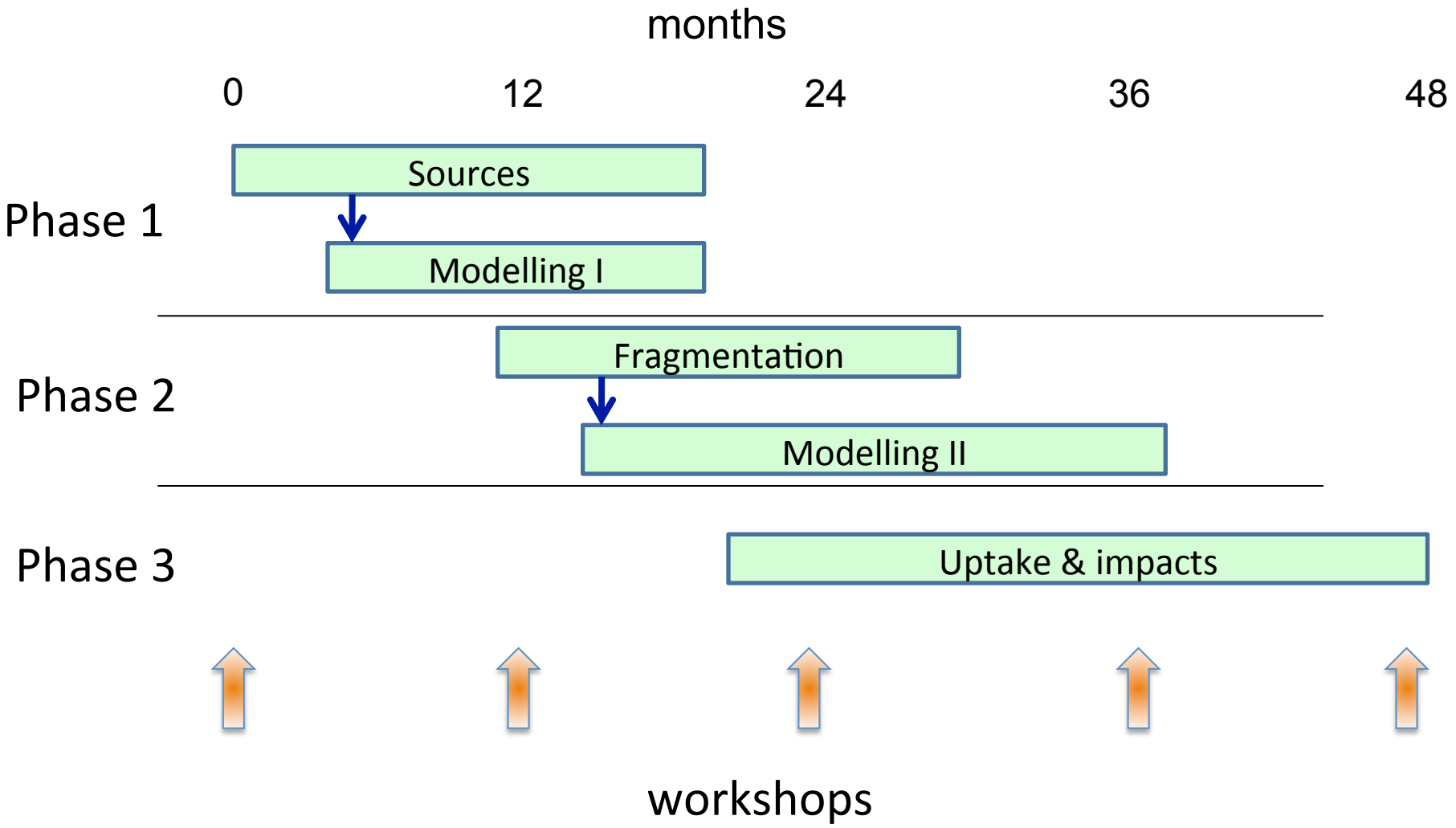
8. Unusually we are in the position to get on top of a problem before it becomes a big issue (in contrast to PCBs)

9. There is a need to place micro-plastics in context with other particulate matter (e.g. nano-particles, black carbon).

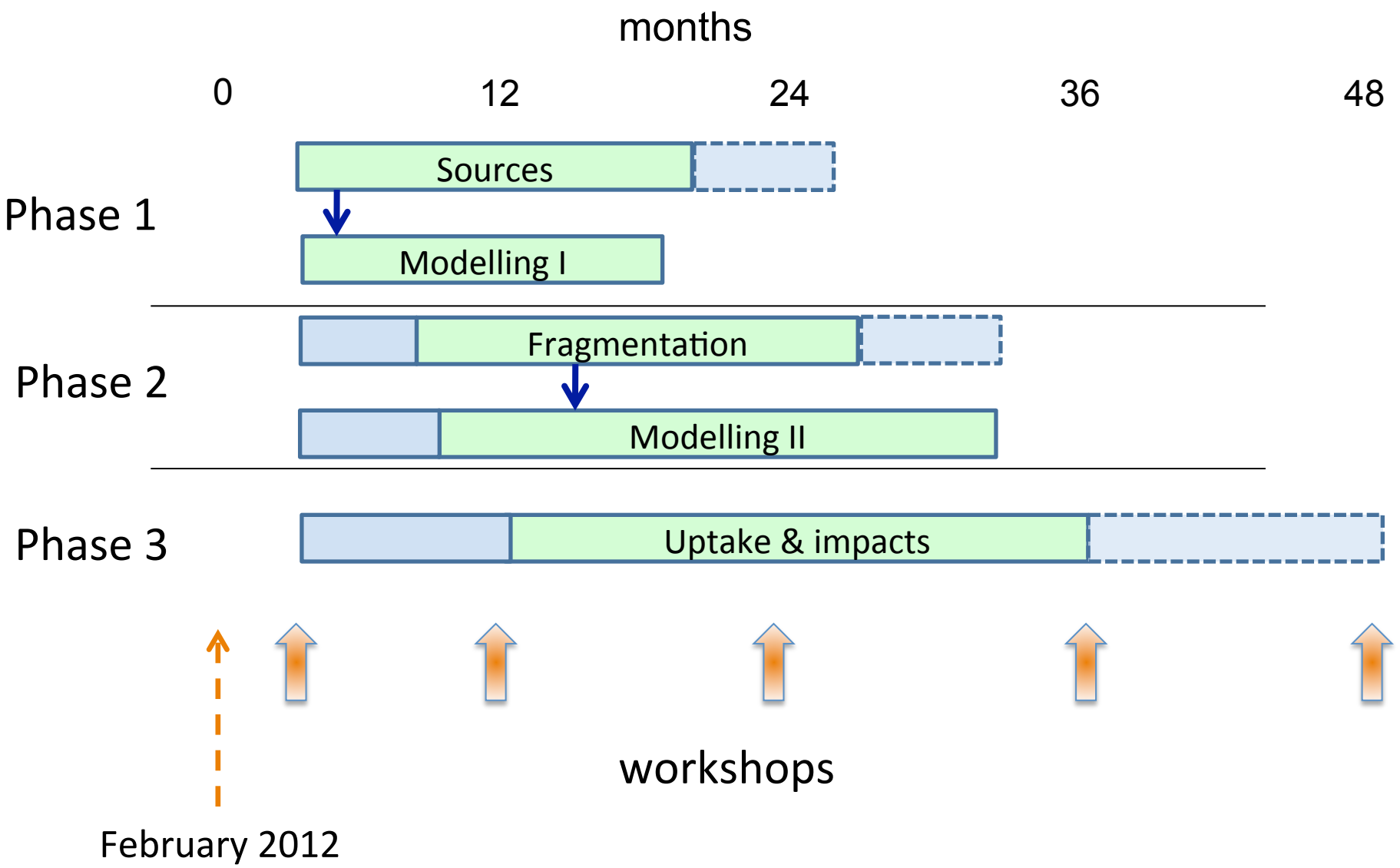
10. We need to consider the bio-concentration of micro-plastics, as well as their role in the bio-magnification of POPs.

11. We need to be able to advise Agencies and decision makers on whether monitoring is needed.

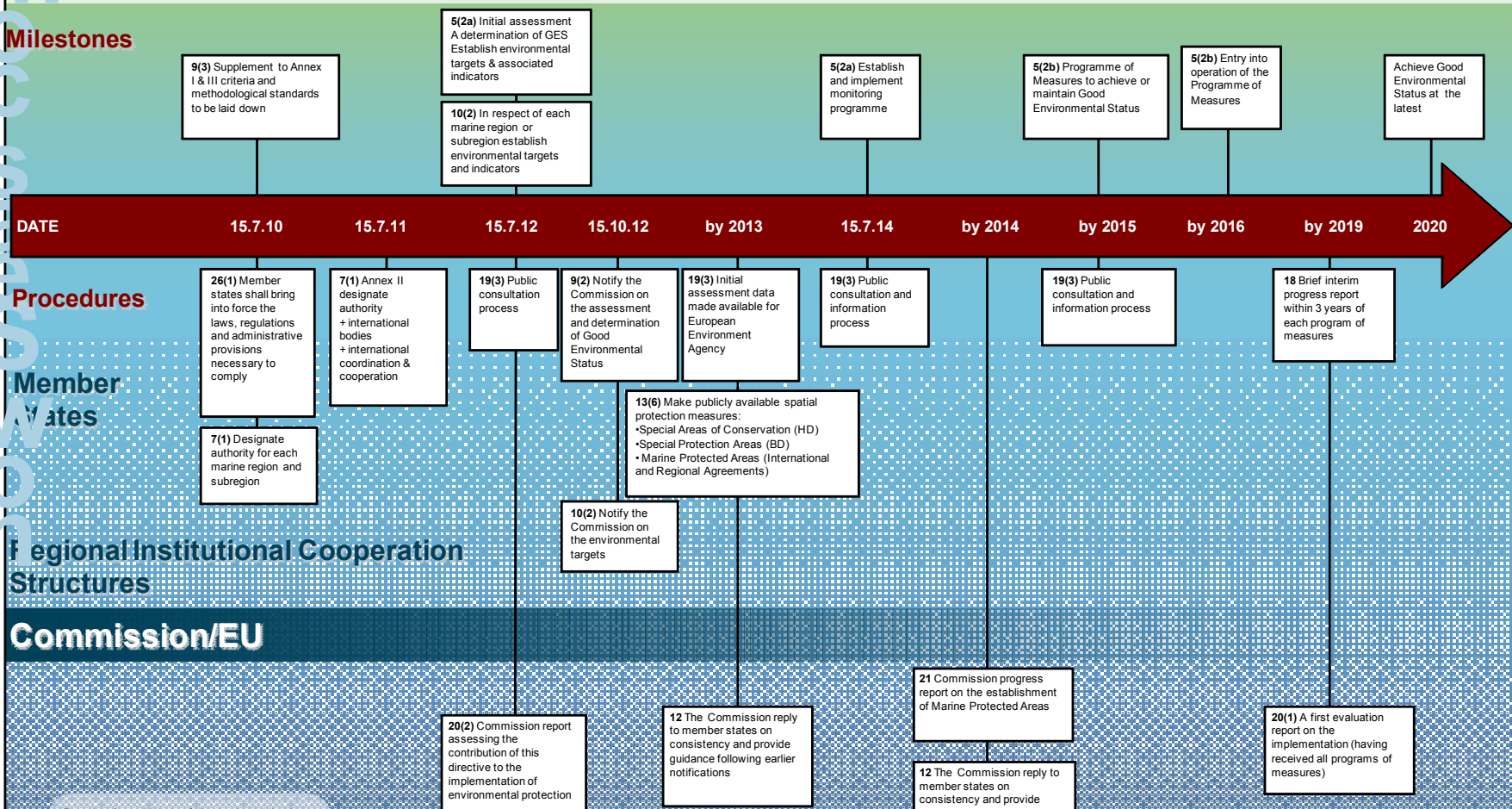
WG40 – original time-frame



WG40 – potential time-frame



A TIMELINE FOR THE IMPLEMENTATION OF THE MARINE STRATEGY FRAMEWORK DIRECTIVE



Entry into force 20th day following its publication in the Official Journal of the European Union

General Provision: The Commission must respond within 6 months

17(2) Every six years the marine strategy shall be updated

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SETAC Berlin Program

Microplastics: an emerging risk to the marine environment.

Two platform presentation slots: Tuesday, 22 May
10:45-12:50 (6 presentations)
Synthesis of the issues, monitoring studies, estimates of microplastic loads, chemical concentrations (e.g., POPs, additive chemicals)

13:55-16:00 (6 presentations)
Flame retardant leaching, uptake of microplastics by organisms, bioavailability of sorbed chemicals, techniques to estimate ingestion effects

Poster exhibition: Tuesday, 22 May
08:00-18:30 (11 presentations)
Wide range of issues – policy, uptake of microplastics by organisms, chemical partitioning, etc.

http://berlin.setac.eu/

Proposed revisions to Terms of Reference:

These revisions were suggested following a discussion at the Inception Meeting of the need to distinguish *Assessments* from *Reviews,* and will be presented for approval at G39:

~~1. Estimate~~ ***Assess*** rates of inputs of micro-plastic particles (e.g. resin pellets, abrasives, personal care products) and macro-plastics (including main polymer types) into the ocean; to include developing methodology, using monitoring data, identifying proxies (e.g. population centres, shipping routes, tourism revenues);
2. Review ***and assess*** modelling of surface transport, distribution & areas of accumulation of plastics and micro-plastics, over a range of space- and time-scales;
3. Review ***and assess*** processes (physical, chemical & biological) controlling the rate of fragmentation and degradation, including estimating long-term behaviour and estimate rate of production of 'secondary' micro-plastic fragments;
4. Review ***and assess*** long-term modelling including fragmentation, seabed and water column distribution, informed by the results of ToR 3;
5. Review ***and assess*** uptake by biota, physical biological impacts at a population level.

Additional ToR:

6. Assess the need to incorporate social/welfare aspects, including public perceptions