Plastics & microplastics in freshwater ecosystems: from sources & impacts to monitoring & management

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WHAT IS MARINE LITTER?

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- ✓ Marine litter can be *defined* as any persistent manufactured or processed solid material that is discarded, disposed of or abandoned in the marine and coastal environment.
- ✓ It is generated due to intentional or accidental discharges, and can also enter the sea by rivers, draining or sewage systems or winds.
- ✓ It may be visible (macrolitter), hardly visible or even invisible (microlitter)...

WHERE DOES IT COME FROM?

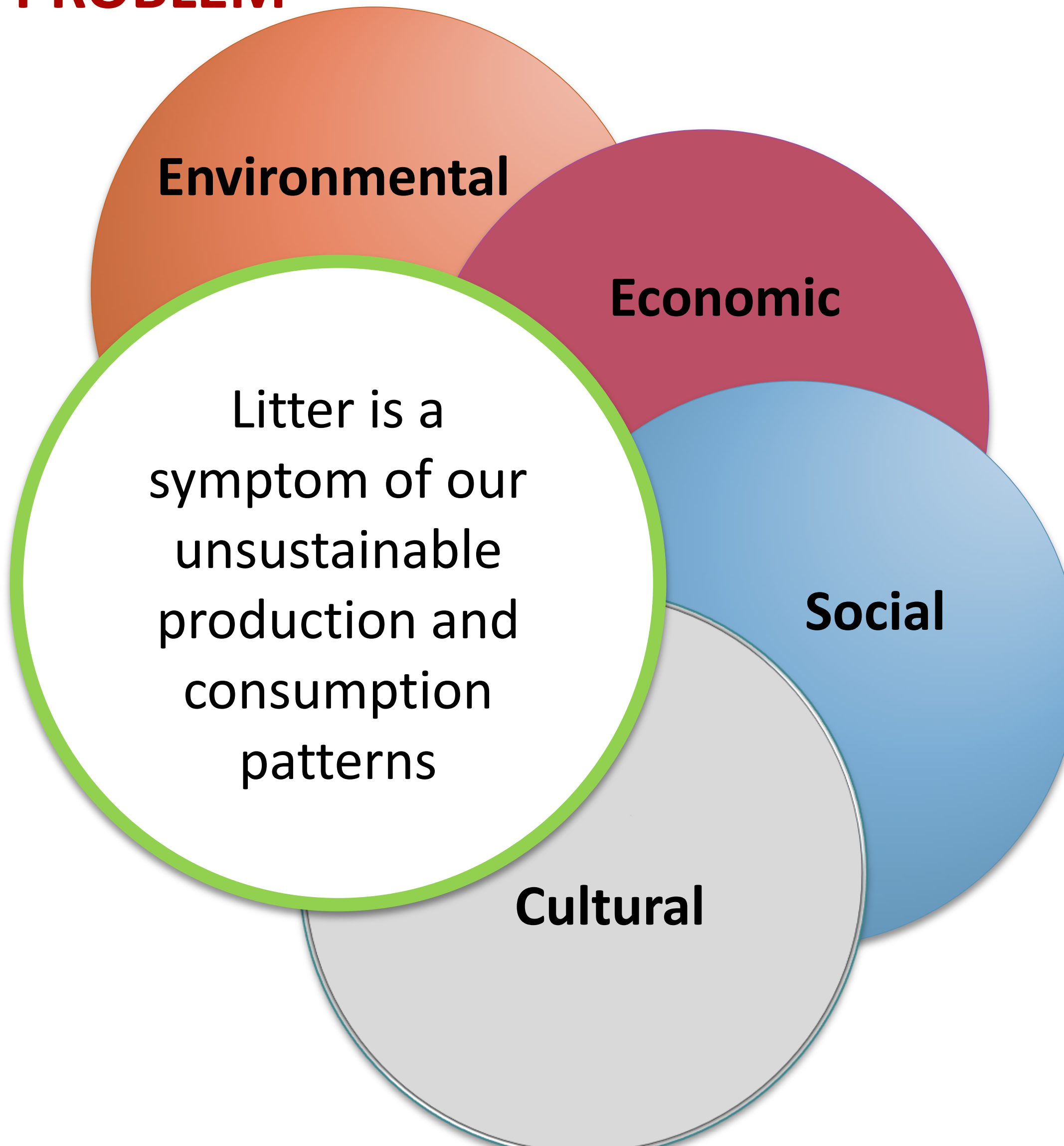
Land-based sources

- ✓ inappropriate waste disposal at households;
- ✓ inadequate urban solid waste management at all stages: collection, transportation, treatment and final disposal;
- ✓ discharge of untreated municipal sewage;
- ✓ discharge of untreated runoff and storm waters;
- ✓ discharge of inappropriately treated/untreated industrial waste.
- ✓ tourism and recreational activities. Beach goers leave behind significant amounts of litter.

Sea-based sources

- ✓ commercial fishing;
- ✓ fisheries and aquaculture;
- ✓ merchant and leisure shipping;
- ✓ recreational shipping;
- ✓ off-shore oil and gas platforms.

LITTER IN FRESHWATER & MARINE ENVIRONMENT: A GROWING PROBLEM OF GLOBAL CONCERN



FRAMING THE PROBLEM OF LITTER IN MARINE ENVIRONMENTS – WHAT DO WE KNOW?

- ✓ Marine litter is ubiquitous in the coastal and marine environment and their abundance is increasing;
- ✓ Plastics consistently rank as being the most abundant type of marine debris on a global scale;
- ✓ Marine litter poses a threat to wildlife and ecosystems with impacts varying from entanglement and ingestion, to bio-accumulation and bio-magnification of toxics either released from plastic items or adsorbed and accumulated on plastic particles; facilitation of introduction of invasive alien species; damages to benthic habitats and communities (e.g. through abrasion of coral reefs from fishing gear, disruption of colonies, reduced oxygenation or ‘smothering’ of communities)
- ✓ Marine litter impacts ecosystem services, human livelihoods and wellbeing;

THE EMERGING THREAT OF MICROPLASTICS

- Their abundance is increasing;
- They cannot be removed from the environment in significant quantities;
- They are ingested by large variety of organisms, with potential adverse effects that vary from physical damage of their digestive tract to toxic effects from inherent contaminants leaching from microplastics, or extraneous pollutants, adhered to microplastics, facilitation of invasive alien species.

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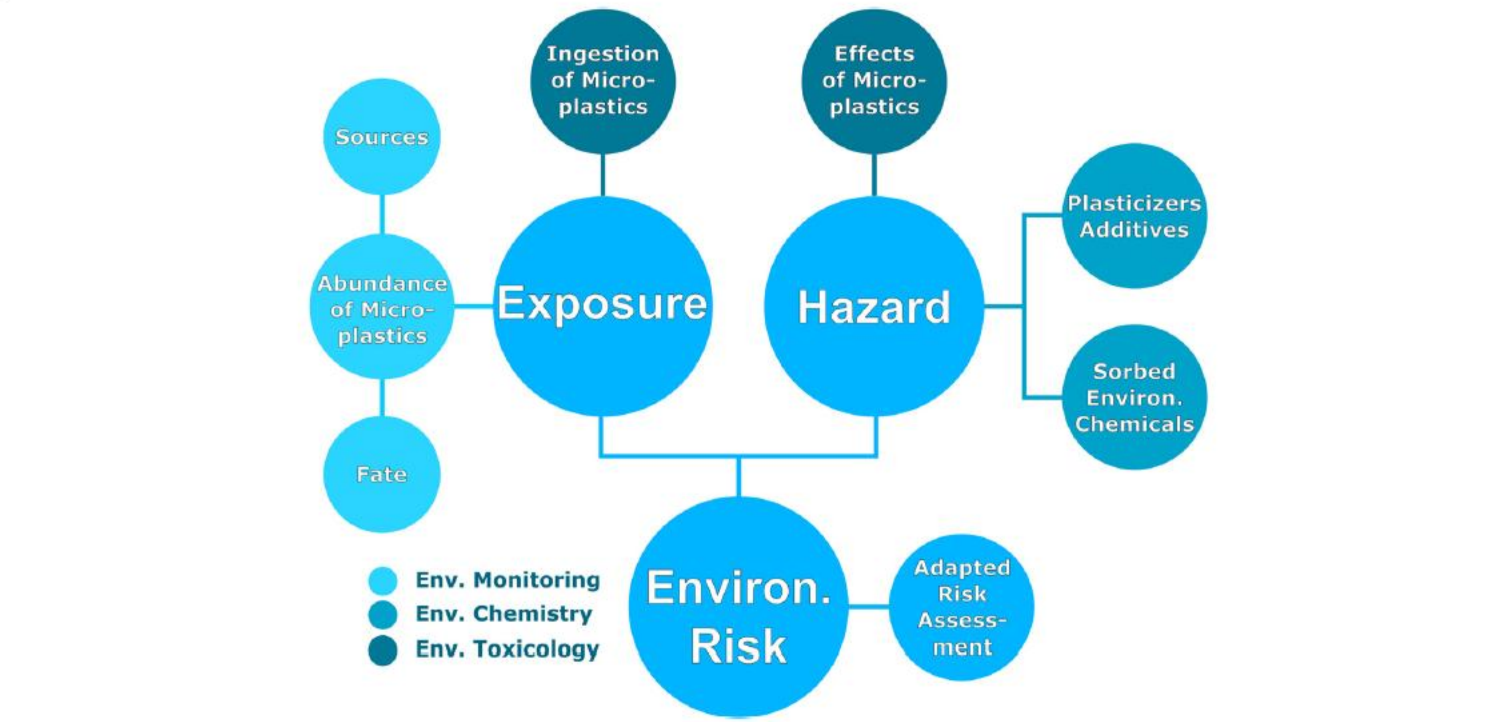

Figure 2 Research aspects with regard to freshwater microplastics. All areas need to be investigated more thoroughly to assess the environmental risk associated with microplastics in freshwater ecosystems.

Table 2 – Freshwater field and laboratory investigations of microplastic and organism interactions.

Study authors, field/lab study	Particle size, composition	Study aim	Taxa	Microplastic uptake? Yes/No/NA	Additional results
Dantas et al., 2012, field study	Size not indicated, nylon fragments	To determine plastic ingestion in two drum species in relation to varying season, habitat, and size-class.	Drum, juvenile, sub-adult, and adult, *Stellifer brasiliensis* and *Stellifer stellifer* (found in estuaries)	Yes	Between 6.9 and 9.2 % of individuals across all species ingested plastic. All size classes ingested plastic. Plastic ingestion differed by season, habitat and size class: Adults in the late rainy season in the middle estuary had the highest number of ingested fragments in their guts.
Hoellein et al., 2014 (conference abstract), field study	Not indicated	To detect microplastic sources, abundance, and effects in rivers.	Bacterial community (sequencing ongoing)	NA	Dense bacterial biofilms on microplastic.
Imhof et al., 2013, lab study	29.5 ± 26 μm (mean ± SD), polymethyl methacrylat	To measure microplastic uptake by freshwater fauna.	Cladoceran freshwater water flea, *Daphnia magna*	Yes	100% of individuals ingested microplastics
			Amphipod crustacean, *Gammarus pulex*	Yes	96 ± 0.03% (mean ± SE) of the faeces contained microplastic
			Clitellate worm, *Lumbriculus variegatus*	Yes	93 ± 0.07% (mean ± SE) of individuals ingested microplastics
			Ostracod, *Notodromas monacha*	Yes,	32.4 ± 3.8% (mean ± SE) of exposed individuals ingested microplastics
			Gastropod freshwater snail, *Potamopyrgus antipodarum*	Yes	87.8 ± 1.9% (mean ± SE) of the faeces contained microplastic
Oliveira et al., 2013, lab study	1 and 5 μm, polyethylene	To determine if microplastics modulate short-term toxicity of contaminants (pyrene).	Common goby, *Pomatoschistus microps* (found in estuaries)	Not indicated	Fish exposed to pyrene had delayed mortality when microplastics were present. Microplastics presence also led to increased pyrene metabolites.
Possatto et al., 2011, field study	Millimetre scale, nylon fragments and hard plastic	To determine ingestion of plastic debris by three catfish species at three size classes.	Catfish, juvenile, sub-adult, and adult, *Cathorops spixii*, *Cathorops agassizii*, *Sciades herzbergii* (found in estuaries)	Yes	Between 17 and 33 % of individuals across all species ingested plastic. All size classes ingested plastic. Size classes differed in number of ingested fragments.
Ramos et al., 2012, field study	1–5 mm, blue nylon fragments	To determine ingestion of plastic debris by 3 gerreid species at three size classes in the Goiana estuary.	Gerreidae fish, juvenile, sub-adult, and adult, *Eugerres brasilianus*, *Eucinostomus melanopterus* and *Diapterus rhombeus* (found in estuaries and mangroves)	Yes	Between 4.9 and 33.4 % of individuals across all species ingested plastic. All size classes (except *D. rhombeus* juveniles) ingested plastic. Species differed in the number and weight of ingested fragments. Size classes differed in number of ingested fragments. Adults of *E. brasilianus* that ingested fragments had lower mean total weight of gut contents.
Rochman et al., 2013b, lab study	3 mm LDPE pellets (virgin or marine treated)	To determine risk from chemicals sorbed on microplastics.	Japanese medaka, *Oryzias latipes* (amphidromous, found in fresh, brackish and marine waters)	Yes	Fish bioaccumulate pollutants sorbed on microplastics and experience liver toxicity.

Table 3 – Example microplastic encounters with biota in marine and freshwater organisms.

Impact	Examples from the marine literature: organism, lab/field study, reference	Examples from the freshwater literature: organism, lab/field study, reference
Ingestion	Fish, field, Lusher et al., 2013; fur seals, field, Eriksson and Burton, 2003; Lobster, field and lab, Murray and Cowie, 2011; mussel and oysters, field, Van Cauwenberghe and Janssen, 2014; planktonic invertebrates, lab, Setälä et al., 2014; zooplankton, lab, Cole et al., 2013;	Benthic and planktonic invertebrates (see Table 2), lab, Imhof et al., 2013; Fish, field, Sanchez et al., 2014
Differential ingestion of microplastic relative to natural particles	Sea cucumber, lab, Graham and Thompson, 2009	No evidence
Differential ingestion relative to organism life stage	Brachyuran larvae, lab, Cole et al., 2013	No evidence
Microplastics crossing into/out of cells or epithelia	Mussel, lab, Browne et al., 2008; Mussel and crab, lab, Farrell and Nelson, 2013; mussel, lab, von Moos et al., 2012	Daphia, lab, Rosenkranz et al., 2009
Retention/accumulation of microplastics in the organism, particle size-based feeding selectivity; differential rates of depuration based on particle size	Mussel, lab, Browne et al., 2008; Lobster, field and lab, Murray and Cowie, 2011; scallop, lab, Brillant and MacDonald, 2000; zooplankton, lab, Cole et al., 2013	Daphia, lab, Rosenkranz et al., 2009
Injury, disrupted feeding/swimming	Lugworm, lab, Besseling et al., 2012; Lugworm, lab, Browne et al., 2013; Lugworm, lab, Wright et al., 2013a; zooplankton, lab, Cole et al., 2013	No evidence
Stress, immune response, altered metabolic function, toxicity	Lugworm, lab, Browne et al., 2013; lugworm, lab, Wright et al., 2013a; Medaka fish,[b] lab, Rochman et al., 2013b; mussel, lab, von Moos et al., 2012	Medaka fish, lab, Rochman et al., 2013b
Contaminant bioaccumulation[a] (chemicals inherent in plastic)	No evidence Note: there is evidence that a plastic treatment diet has increased contaminant levels relative to the negative control diet, but no significant evidence of transfer to the organism (Rochman et al., 2013b)	No evidence Note: there is evidence that a plastic treatment diet has increased contaminant levels relative to the negative control diet, but no significant evidence of transfer to the organism (Rochman et al., 2013b)
Tumour formation	Medaka fish, lab, Rochman et al., 2013b	Medaka fish, lab, Rochman et al., 2013b
Altered mortality	Lugworm, lab, Besseling et al., 2012 (suggested based on microplastic presence in dead organisms, but not a significant evidence)	No evidence
Adsorption of chemicals, transfer of chemicals to organism	Lugworm, lab, Browne et al., 2013; Medaka fish, lab, Rochman et al., 2013b Seabird, field, Tanaka et al., 2013 (suggested by correlation)	Medaka fish, lab, Rochman et al., 2013b
Contaminant bioaccumulation[a] (chemicals sorbed on plastic)	Lugworm, lab, Besseling et al., 2012; Lugworm, lab, Browne et al., 2013; Medaka fish, lab, Rochman et al., 2013b	Medaka fish, lab, Rochman et al., 2013b
Disrupted feeding/swimming	Lugworm, lab, Browne et al., 2013;	No evidence
Modulation of contaminant toxicity -> Stress, immune response, altered metabolic function, toxicity	Lugworm, lab, Browne et al., 2013; Medaka fish, lab, Rochman et al., 2013b	Goby fish, lab, Oliveira et al., 2013 Medaka fish, lab, Rochman et al., 2013b
Modulation of contaminant toxicity -> Altered mortality	Lugworm, lab, Browne et al., 2013;	Goby fish, lab, Oliveira et al., 2013;
Dietary energy gain/nutritional condition	Lugworm, lab, Besseling et al., 2012; Lugworm, lab, Wright et al., 2013a (suggested impact)	No evidence

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KEY STEPS OF A SUCCESFUL PROBLEM SOLVING PROCESS OF PLASTICS & MICROPLASTICS | WHERE ARE WE

- Identification of the problem
- Understanding the problem
- Identification of possible solutions
- Selection of the appropriate solutions
- Putting solutions into action

KEY CHALLENGES & HINDRANCES THAT HAMPER DOWN THE EFFECTIVE CLOSURE OF THE PLASTIC LIFE CYCLE RELATED LOOPHOLES

- ✓ The limited and fragmented understanding of the problem due to the lack of accurate, coherent, reliable and comparable scientific data;
- ✓ The misconceptions and misunderstandings related to possible solutions, i.e. the case of bio-degradable or bio-based plastics, or end-of-pipe solutions like cleanups or the not viable option of microplastics removal from habitats ;
- ✓ The reluctance of countries to commit themselves to reaching ambitious targets via comprehensive programmes of measures coupled with the weak enforcement of existing laws in most countries and inadequate implementation of measures due to poor administration, unfavourable budget allocation, weak technical capacity, etc;
- ✓ The fact that litter is often considered as someone else's problem, inhibiting coordinated, diversified and multi-level actions;
- ✓ The poor exploitation of the full potential that litter initiatives and projects render for capitalization, replication and collective learning.

Monitoring definition

- ✓ Monitoring – Long term, standardized measurement, observation, evaluation and reporting of the environment in order to define status and trends.

FROM OBSERVATIONS AND KNOWLEDGE TO CONCRETE ACTIONS TOWARDS SOLUTIONS

- ✓ Monitoring is an intermittent (regular or irregular) series of observations in time, carried out to show the extent of compliance with a formulated standard or degree of deviation from an expected norm.

- ✓ For any monitoring programme, the objectives must be clearly stated, the methodology clearly defined and quality control implemented to ensure quality data.

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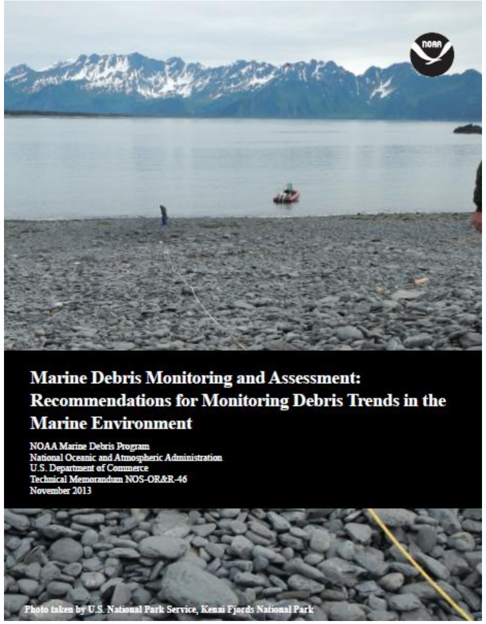
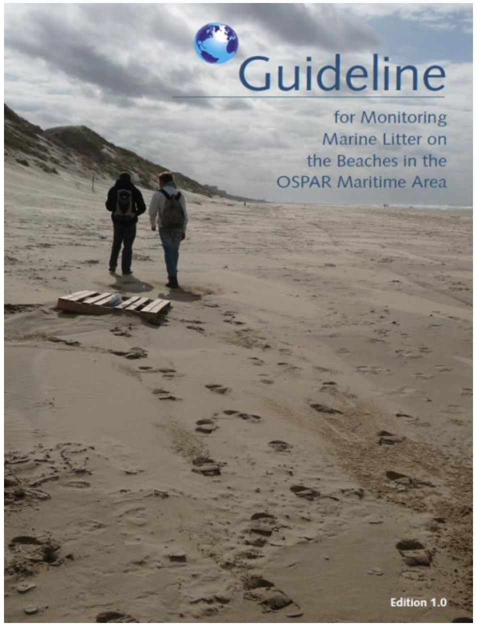
STANDARDIZED ML MONITORING | NOT YET THERE!





In recent years, research efforts have significantly increased the knowledge on the issue of marine litter however the field as a whole **has not adopted standardized monitoring procedures**.

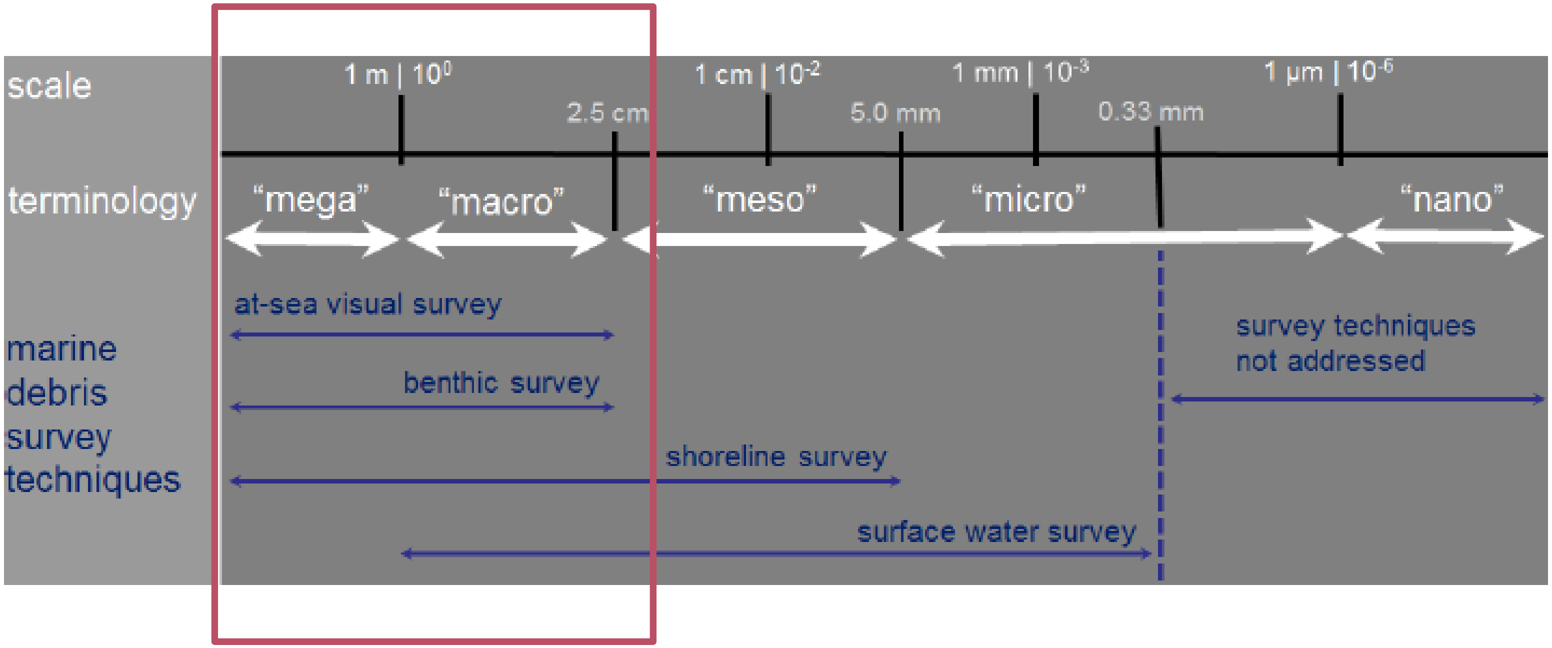
Within the frameworks of the MSFD and the Regional Seas Conventions considerable work is being carried out towards defining and/or establishing monitoring programmes which are coordinated, compatible, coherent, consistent and comparable.

OVERVIEW OF SELECTED MONITORING

Environ. matrice	Method/ protocol	Level of maturity	Technical requir.	Expertise needed
Beach	Visual/ collection	HIGH	LOW	LOW/ MEDIUM
Floating	Visual	HIGH	LOW	LOW/MEDIUM
Sea-floor	Diving	MEDIUM	MEDIUM	MEDIUM
Sea-floor	Bottom-trawling	MEDIUM/ HIGH	LOW/ MEDIUM	LOW/ MEDIUM
Biota	Fish (ingestion)	LOW	MEDIUM/ HIGH	MEDIUM/ HIGH

Method/ protocol	Level of maturity	Technical requir.	Expertise needed
Beach sediment	LOW	HIGH	HIGH
Sea surface & Riverine outflow *Manta trawl*	MEDIUM	MEDIUM/ HIGH	MEDIUM
Fish (ingestion)	LOW	MEDIUM/ HIGH	MEDIUM/ HIGH

ML SIZE CLASSES



Source: S. Lippiatt, S. Opfer, C Arthur. Marine Debris Monitoring and Assessment. NOAA Technical Memorandum NOS-OR&R-46, (2013).

BEACH LITTER MONITORING

Selection of survey sites

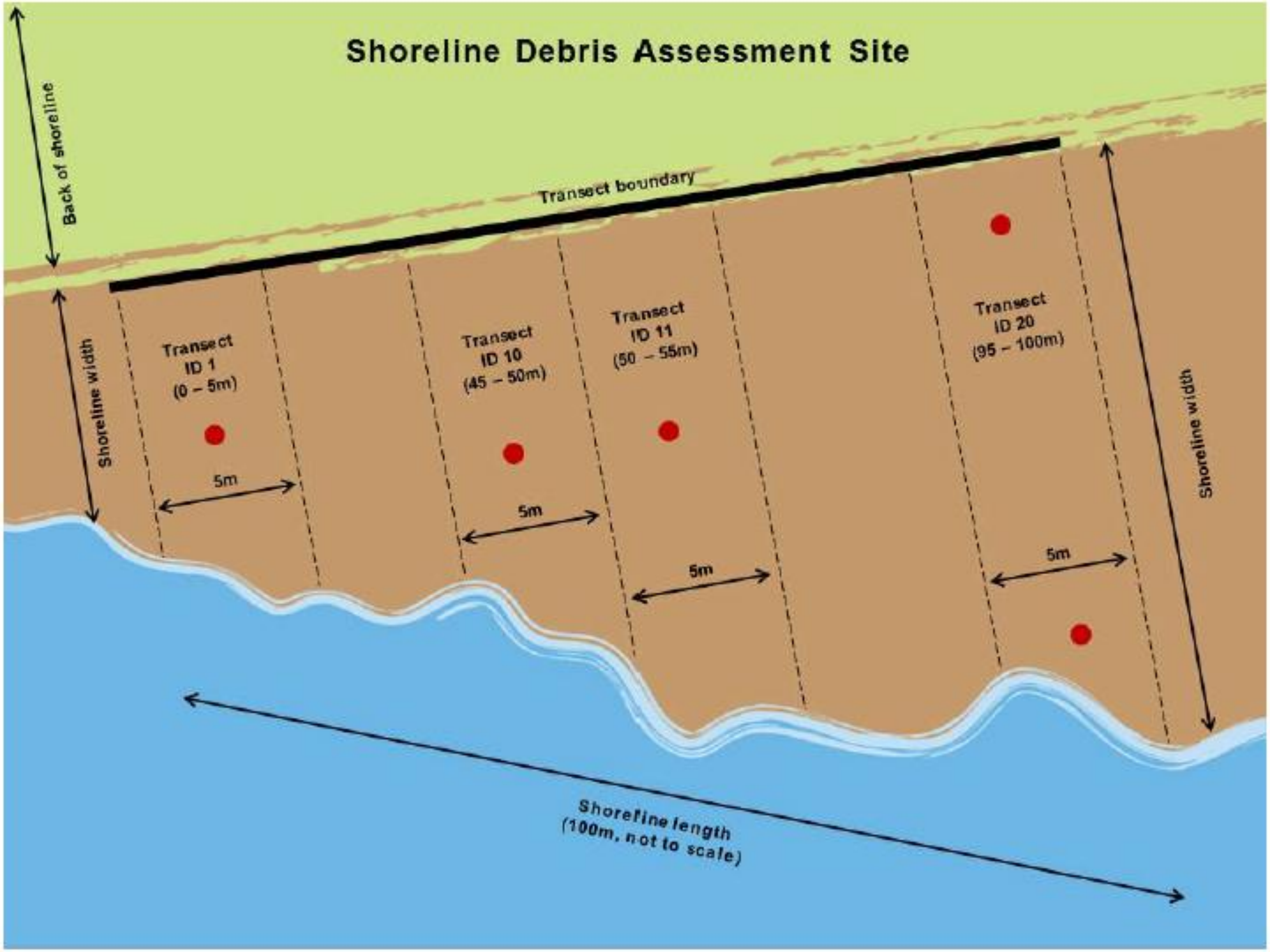
- ✓ Having a minimum length of 100 m;
- ✓ Low to moderate slope;
- ✓ Clear access to sea;
- ✓ Accessible to survey teams throughout the year;
- ✓ Ideally the site should not be subject to cleaning activities;
- ✓ Survey activities posing no threat to endangered or protected species.

Frequency & timing of surveys

Frequency: 4 surveys/year (minimum)

Surveys timing:

- ✓ Autumn: mid Sep-mid Oct
- ✓ Winter: mid Dec-mid Jan
- ✓ Spring: Apr
- ✓ Summer: mid Jun-mid Jul


Shoreline Debris Assessment Site
Back of shoreline
Transect boundary
Shoreline width
Transect ID 1 (0 – 5m)
Transect ID 10 (45 – 50m)
Transect ID 11 (50 – 55m)
Transect ID 20 (95 – 100m)
5m
5m
5m
5m
Shoreline width
Shoreline length (100m, not to scale)

COLLECTION & IDENTIFICATION OF LITTER ITEMS

According to the 'Master List', which consists of a set of over 200 items

The 'Master List' was developed based on the categories of items used in a series of other programmes:
Beach litter: UNEP, OSPAR, ICC, Slovenia
Floating litter: HELMEPA, NOAA, ECOOCEAN
For seabed: OSPAR/ICES & HELMEPA
For micro-litter: CEFAS

Size limits & classes of items to be surveyed

- ✓ The are no upper size limits
- ✓ A lower limit of 2.5 cm in the longest dimension
- ✓ Plastic pellets (~0.5cm) will be collected separately

ML MASTERLIST

ARTIFICIAL POLYMER MATERIALS			
Code	Items name	Item counts	Total
G1	4/6-pack yokes, six-pack rings		
G3	Shopping Bags, incl. pieces		
G4	Small plastic bags, e.g. freezer bags, including pieces		
G5	Plastic bag collective role; what remains from rip-off plastic bags		
G7	Drink bottles <=0.5l		
G8	Drink bottles >0.5l		
G9	Cleaner bottles & containers		
G10	Food containers incl. fast food containers		
G11	Beach use related cosmetic bottles and containers, eg. Sunblocks		
G12	Other cosmetics bottles & containers		
G13	Other bottles & containers (drums)		
G14	Engine oil bottles & containers <50 cm		
G15	Engine oil bottles & containers > 50 cm		
G16	Jerry cans (square plastic containers with handle)		
G17	Injection gun containers		
G18	Crates and containers / baskets		
G19	Car parts		
G21	Plastic caps/lids drinks		
G22	Plastic caps/lids chemicals, detergents (non-food)		
G23	Plastic caps/lids unidentified		
G24	Plastic rings from bottle caps/lids		
G25	Tobacco pouches / plastic cigarette box packaging		
G26	Cigarette lighters		
G27	Cigarette butts and filters		
G28	Pens and pen lids		
G29	Combs/hair brushes/sunglasses		
G30	Crisps packets/sweets wrappers		
G31	Lolly sticks		
G32	Toys and party poppers		
G33	Cups and cup lids		
G34	Cutlery and trays		
G35	Straws and stirrers		
G36	Fertiliser/animal feed bags		
G37	Mesh vegetable bags		
G40	Gloves (washing up)		
G41	Gloves (industrial/professional rubber gloves)		
G42	Crab/lobster pots and tops		
G43	Tags (fishing and industry)		
G44	Octopus pots		
G45	Mussels nets, Oyster nets		
G46	Oyster trays (round from oyster cultures)		
G47	Plastic sheeting from mussel culture (Tahitians)		
G49	Rope (diameter more than 1cm)		
G50	String and cord (diameter less than 1cm)		
G53	Nets and pieces of net < 50 cm		
G54	Nets and pieces of net > 50 cm		

RUBBER			
Code	Items name	Item counts	Total
G125	Balloons and balloon sticks		
G126	Balls		
G127	Rubber boots		
G128	Tyres and belts		
G129	Inner-tubes and rubber sheet		
G130	Wheels		
G131	Rubber bands (small, for kitchen/household/post use)		
G132	Bobbins (fishing)		
G133	Condoms (incl. packaging)		
G134	Other rubber pieces		
		Total weight (kg)	

CLOTH/TEXTILE			
Code	Items name	Item counts	Total
G137	Clothing / rags (clothing, hats, towels)		
G138	Shoes and sandals (e.g. Leather, cloth)		
G139	Backpacks & bags		
G140	Sacking (hessian)		
G141	Carpet & Furnishing		
G142	Rope, string and nets		
G143	Sails, canvas		
G144	Tampons and tampon applicators		
G145	Other textiles (incl. rags)		
		Total weight (kg)	

PAPER/CARDBOARD			
Code	Items name	Item counts	Total
G147	Paper bags		
G148	Cardboard (boxes & fragments)		
G150	Cartons/Tetrapack Milk		
G151	Cartons/Tetrapack (others)		
G152	Cigarette packets		
G153	Cups, food trays, food wrappers, drink containers		
G154	Newspapers & magazines		
G155	Tubes for fireworks		
G156	Paper fragments		
G158	Other paper items		
		Total weight (kg)	

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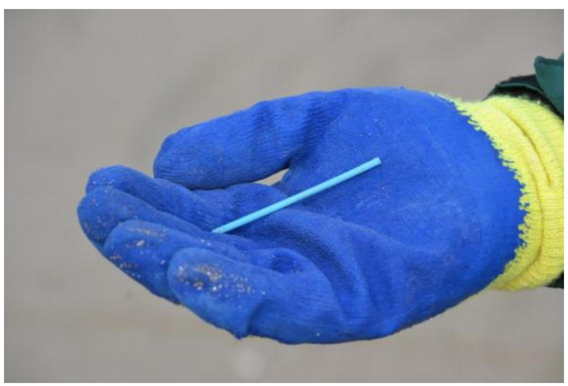


MONITORING OF LITTER IN BIOTA| PROTOCOL FOR LITTER INGESTION BY FISH

Related marine compartments

Pelagic & benthic feeding fish species → addressing litter in the water column and the seafloor

Sample size

At least 50 specimens per species and age group is recommended

MONITORING OF LITTER IN BIOTA| PROTOCOL FOR LITTER INGESTION BY FISH

Chemical treatment of stomachs

10% KOH or H_2O_2 at ambient temperature

Macro- vs micro litter

An 1mm sieve is used to separate micro-litter with dimensions smaller than 1mm and the fraction passing the sieve may then be used for micro-litter analysis.

Data reported

Incidence (% investigated stomachs containing litter)

Abundance by number (average number of items per individual)

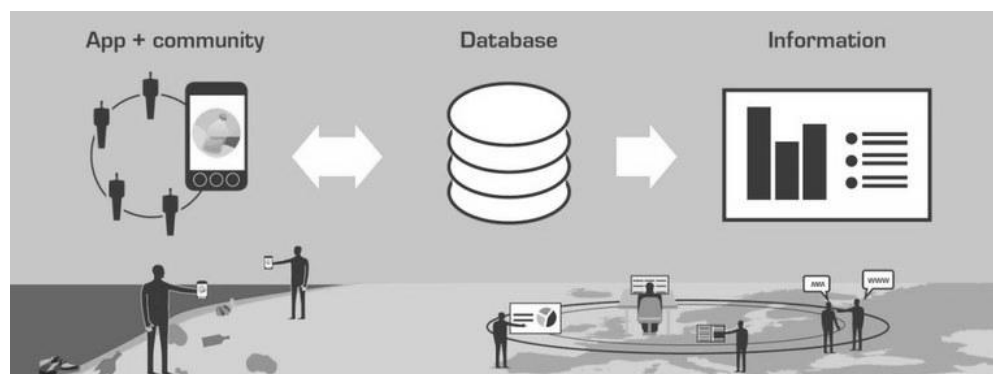
Abundance by mass (weight in grams)

PARTICIPATORY SCIENCE & ML

NGOs/volunteers provide crucial inputs to filling in the ML data gaps

socientize

White Paper
on Citizen Science for Europe



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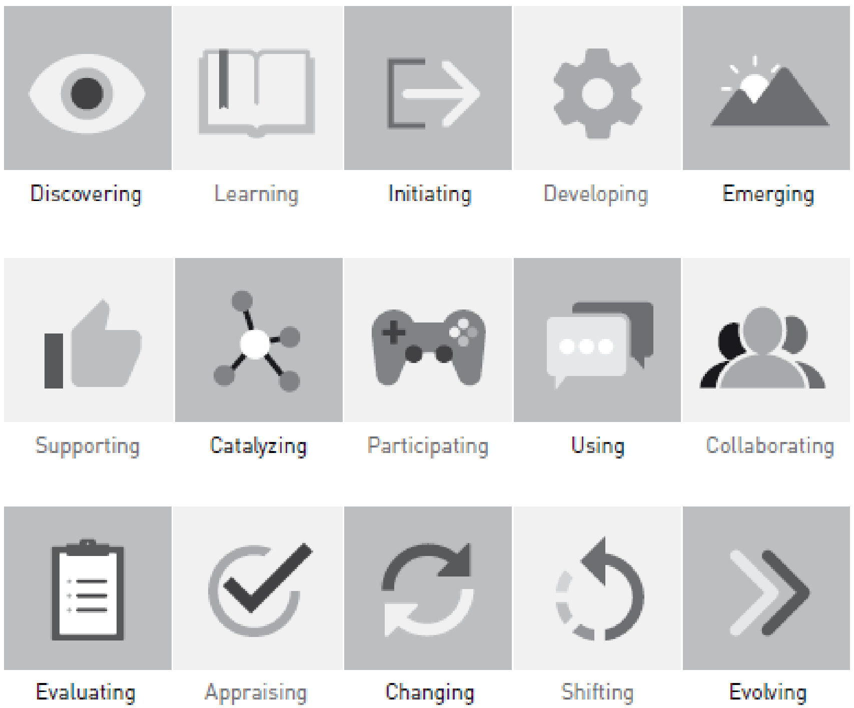
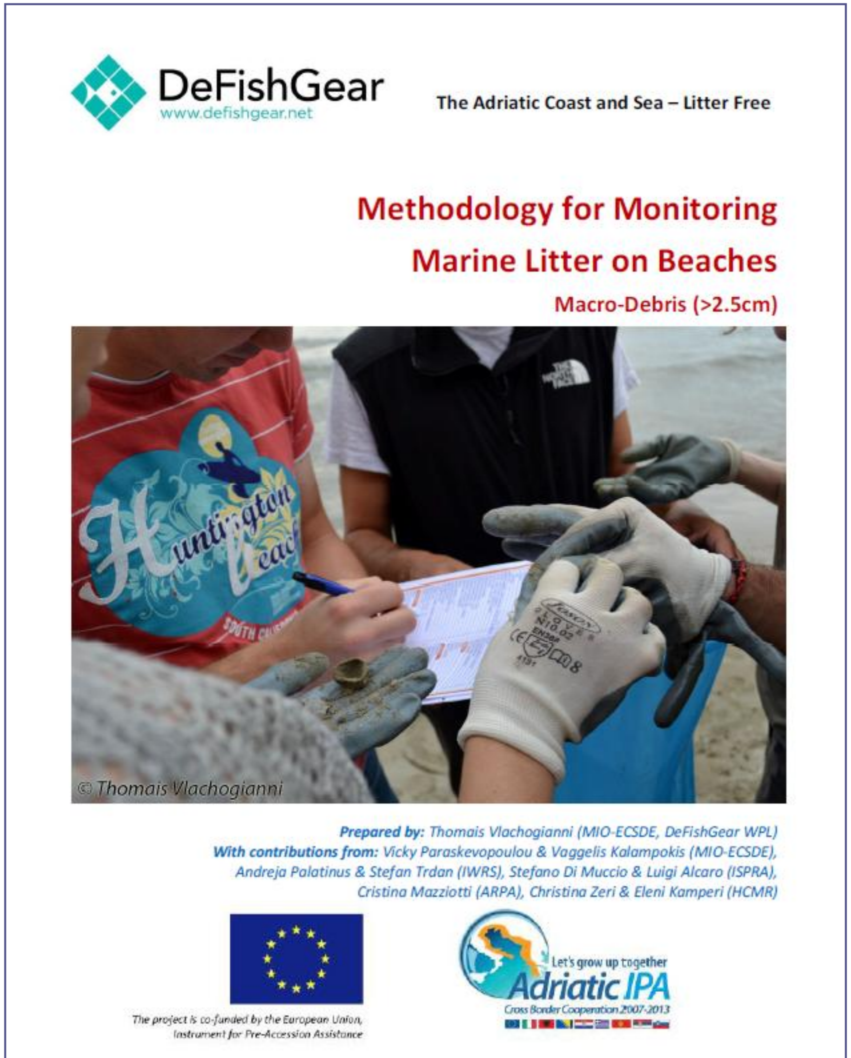
WHITE PAPER
ON CITIZEN SCIENCE FOR EUROPE

CITIZENS ARE...



RESEARCH



DeFishGear
www.defishgear.net

The Adriatic Coast and Sea – Litter Free

Methodology for Monitoring Marine Litter on Beaches

Macro-Debris (>2.5cm)

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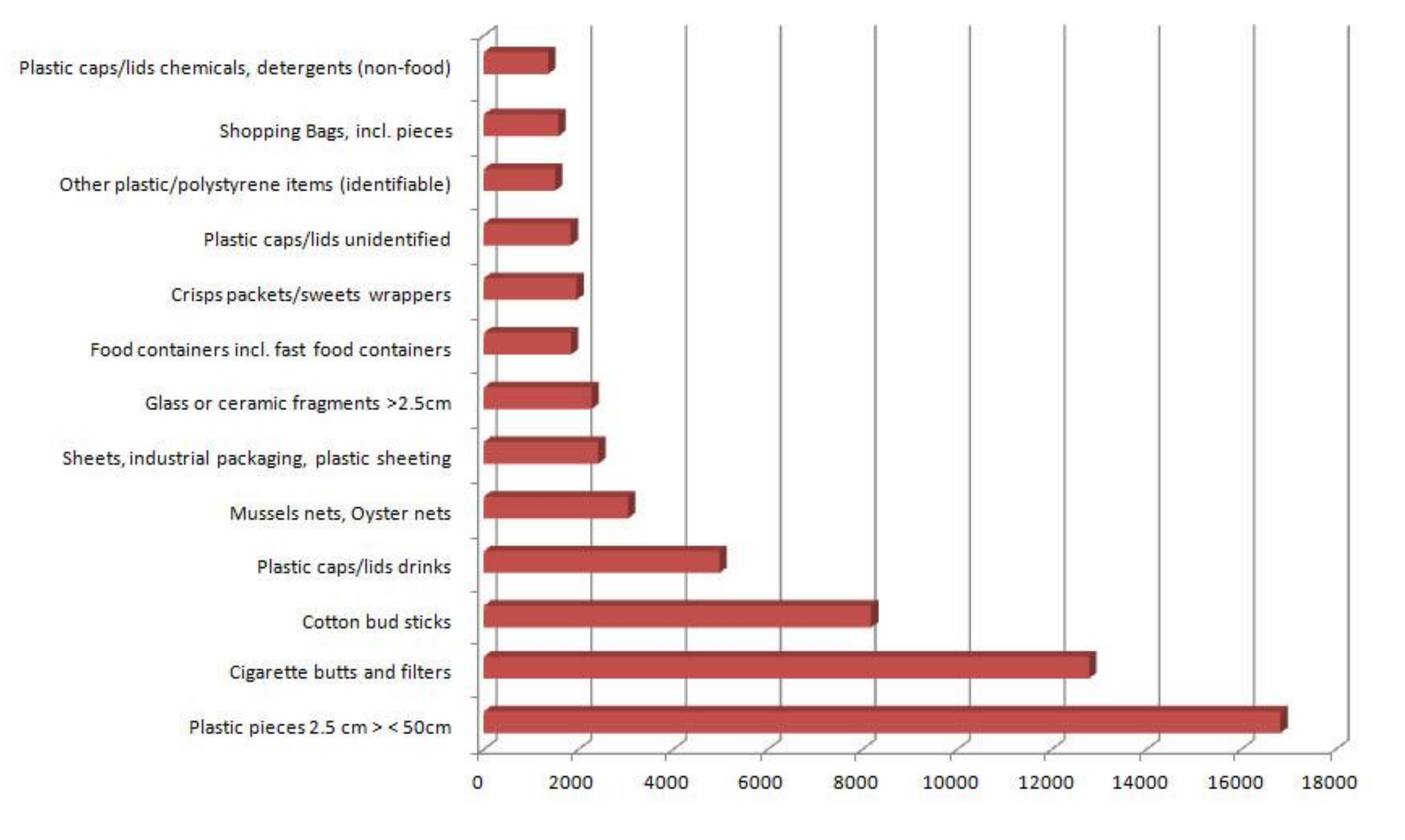
Let's grow up together
Adriatic IPA
Cross Border Cooperation 2007-2013

http://www.defishgear.net/news-events/defishgear-news/item/344-defishgear-launches-coordinated-marine-litter-monitoring-surveys-in-the-adriatic-sea

AGGREGATED RESULTS FOR BEACH LITTER



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THE WAY FORWARD:
CONCRETE ACTIONS NEEDED TO TACKLE THE ISSUE OF SOLID WASTE BASED ON PRINCIPLES

- The Precautionary Principle
- The Polluter-Pays Principle
- The Prevention at Source Principle
- The Ecosystem based Approach
- The Principle of Public Participation
- The Principle of Integration

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‘Beat the Microbead’ campaign

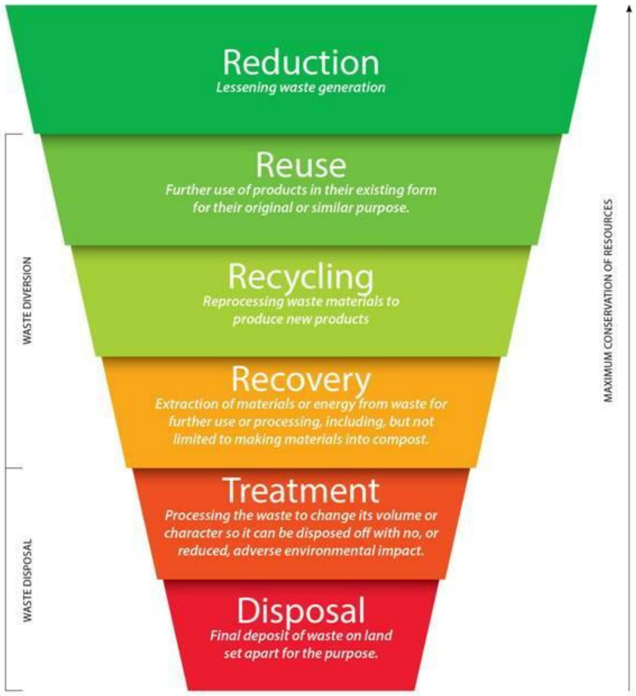
In 2012, a campaign to ‘Beat the Micro Bead’ was started by the Plastic Soup Foundation and the North Sea Foundation. It has been highly successful, starting with a number of retail chains in the Netherlands committing to stop adding micro beads to their products by mid-2013. De Tuinen went even further by refusing to trade with any supplier that has plastic in any of its products from 1 June 2013. These were followed by Unilever, one of the world’s largest consumer product companies, which decided in December 2012 to phase out the use of plastic micro beads as a scrub material in all its personal care products by 2015. In May 2013 L’Oréal, Beiersdorf, Colgate-Palmolive followed suit. Colgate-Palmolive has indicated its products will go plastic free in Europe by the end of 2013 and worldwide in 2014.

The 5Is…

- Information
- Integration
- Innovation
- Implementation
- International collaboration

KEEPING THE BENEFITS OF MATERIALS WITHOUT THE DEBRIS...

- ✓ Over the past decade, increased scientific interest has produced an expanding knowledge base for plastics and microplastics pollution and with knowledge comes greater responsibility.
- ✓ We all need to take our share of responsibility and embrace a full systemic change towards a circular economy. After decades of 'training' ourselves and our societies on consuming more and throwing things away, we need to find innovative ways to do more with less; ways to move away from single-use and superfluous products; ways that will allow us to move up the waste hierarchy...



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ZERO WASTE SOCIETIES | A UTOPIA?

Thank you!

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For more than twenty years joining forces & building bridges in the Euro-Mediterranean area