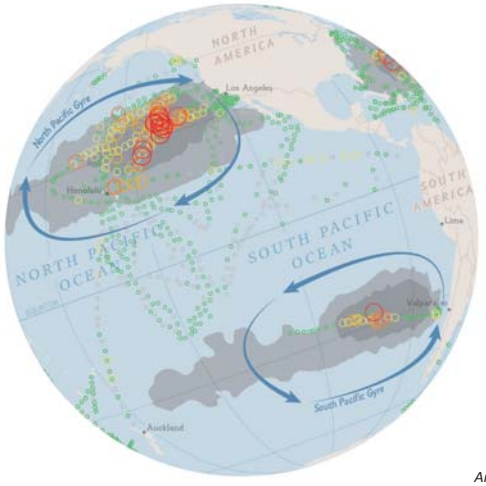
History and advances in the understanding of the marine microplastic pollution

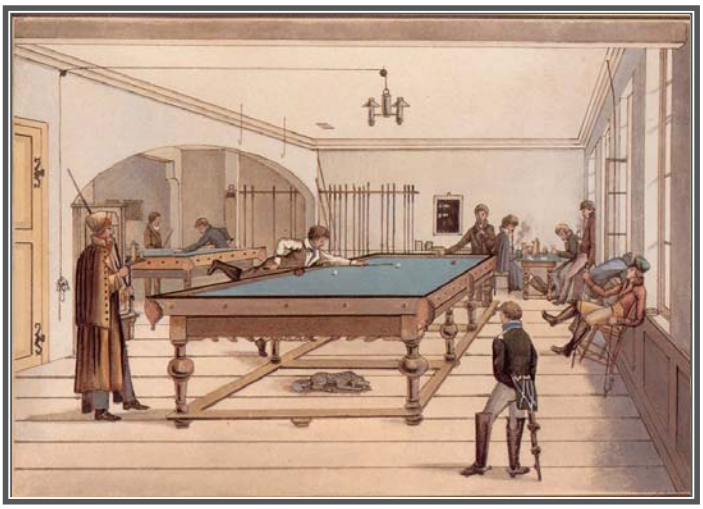


Andrés Cózar, Universidad de Cádiz

1865

The origin of the plastic

The popularization of the billiard game



Ivory billiard ball

The origin of the plastic

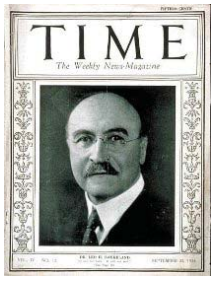
Phelan & Collander **bid 10.000 $ for the invention of an alternative material**

John Wesley Hyatt (1830-1920)
Inventor of the celluloid in 1870

1907

The origin of the plastic

Leo Baekeland created the bakelite, the first entirely artificial plastic.



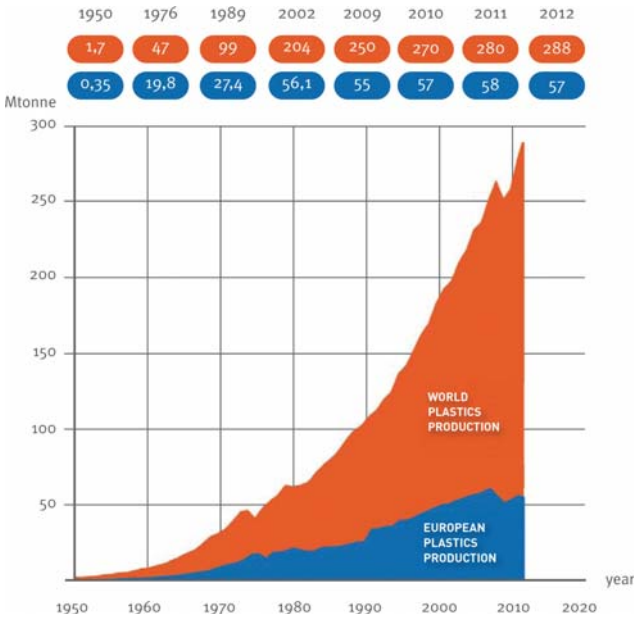
bakelite products

1950

The boom in the production and consumption of plastic

Throw away living, Life Magazine (1955)

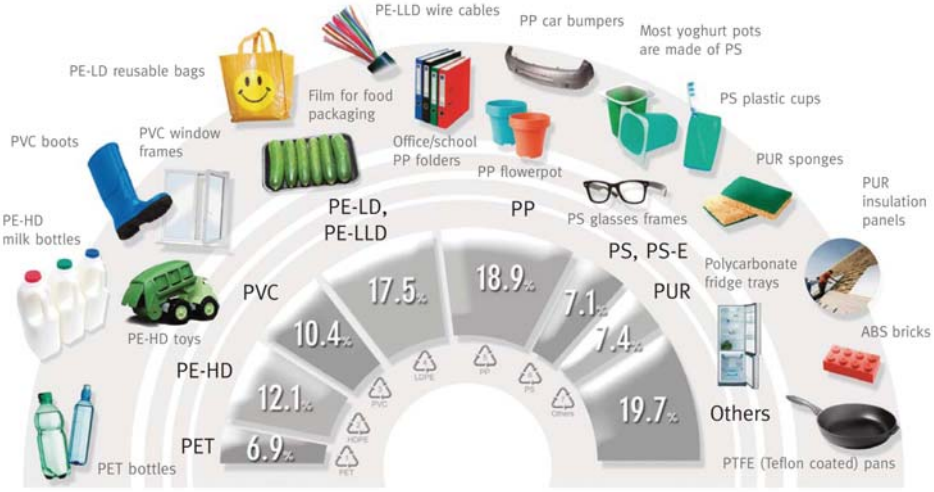
The boom in the production and consumption of plastic



Source: Plastic Europe

Plastic: A ideal material to create

Cost-effective, long-lasting, lightweight, pliable, impermeable, …

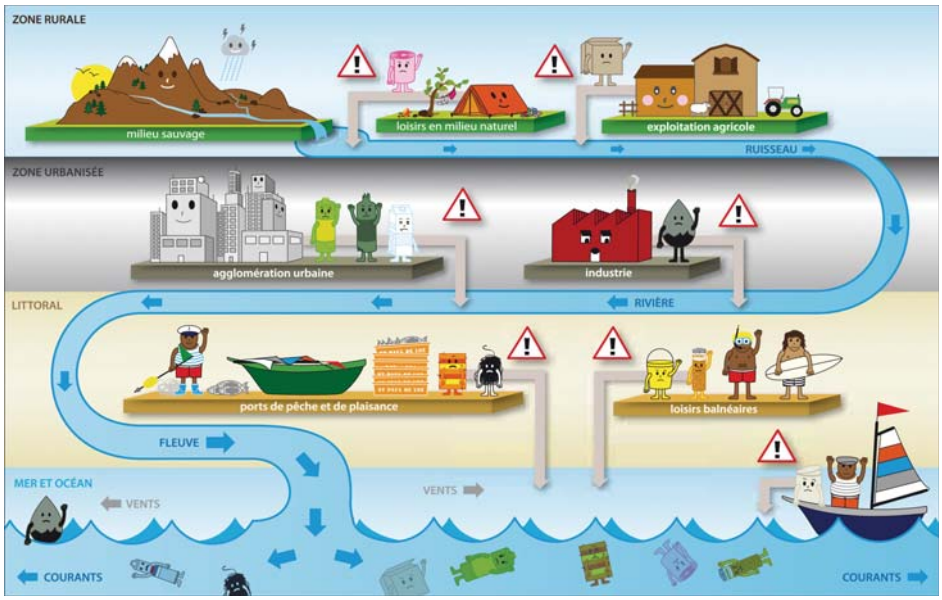


Source: Plastic Europe

The "Plastic Age"

Time line of the Ages of Man and its key material

Accumulation of plastic debris in runoff waters, reservoirs, lakes, rivers, urban drainage networks, and… SEAS and OCEANS



Source: Le Livre Bleu de TARA per la Méditerranée

1972

First report on abundant plastic debris on the ocean surface

SCIENCE, VOL. 175

Plastics on the Sargasso Sea Surface

EDWARD J. CARPENTER
K. L. SMITH, JR.
Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543

Abstract. *Plastic particles, in concentrations averaging 3500 pieces and 290 grams per square kilometer, are widespread in the western Sargasso Sea. Pieces are brittle, apparently due to the weathering of the plasticizers, and many are in a pellet shape about 0.25 to 0.5 centimeters in diameter. The particles are surfaces for the attachment of diatoms and hydroids. Increasing production of plastics, combined with present waste-disposal practices, will undoubtedly lead to increases in the concentration of these particles. Plastics could be a source of some of the polychlorinated biphenyls recently observed in oceanic organisms.*

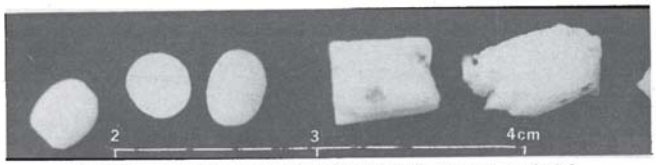


Fig. 1. Typical plastic particles from tow 2. White pellets are on the left.

1973

First evidence on plastic ingestion by seabirds

The Condor 75:344–366, 1973

SHORT COMMUNICATIONS

PLASTIC PARTICLE POLLUTION OF THE SURFACE OF THE ATLANTIC OCEAN: EVIDENCE FROM A SEABIRD

STEPHEN I. ROTHSTEIN
Department of Biological Sciences
University of California
Santa Barbara, California 93106

By sampling with neuston nets, Carpenter and Smith (1972) demonstrated the presence, in 1971, of small particles of plastic on the surface of the Sargasso Sea. The particles had an average concentration of 3500 pieces/km² and occurred over a distance of 1300 km. The occurrence, reported here, of similar particles in the stomachs of Leach's Petrels (*Oceanodroma leucorhoa*) indicates that this form of pollution and its consequences are probably more widespread, both temporally and geographically, than is suggested by the data of Carpenter and Smith.

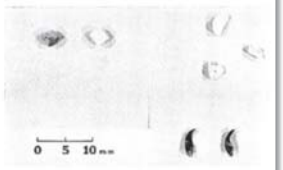
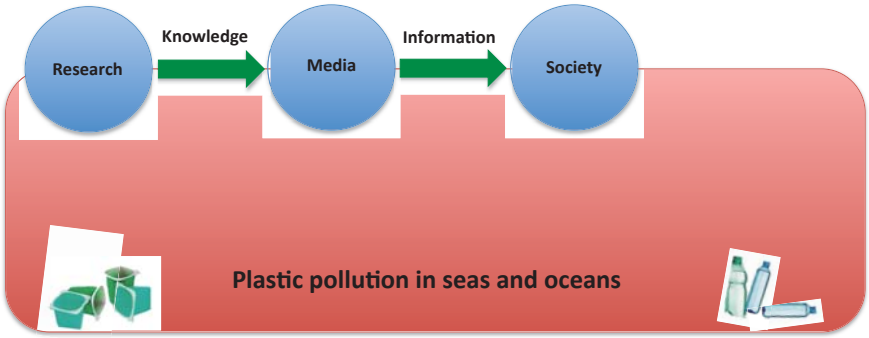


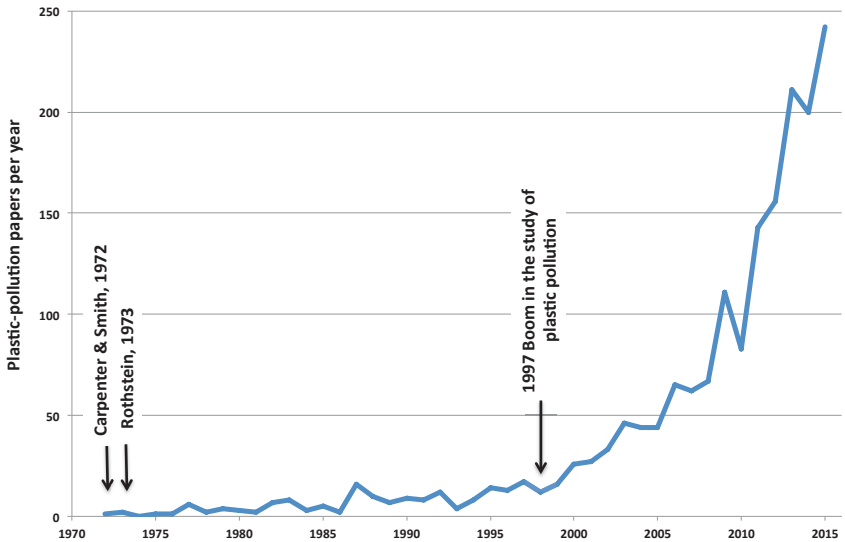
FIGURE 1. Objects found in the stomachs of two Leach's Petrels. The two pieces of plastic in the upper left corner were found in the gizzard of a petrel collected on Gull Island, Newfoundland. The three pieces of plastic as well as the two claw-like structures in the right half of the figure were all 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.

Photo: Peter LaTourrette

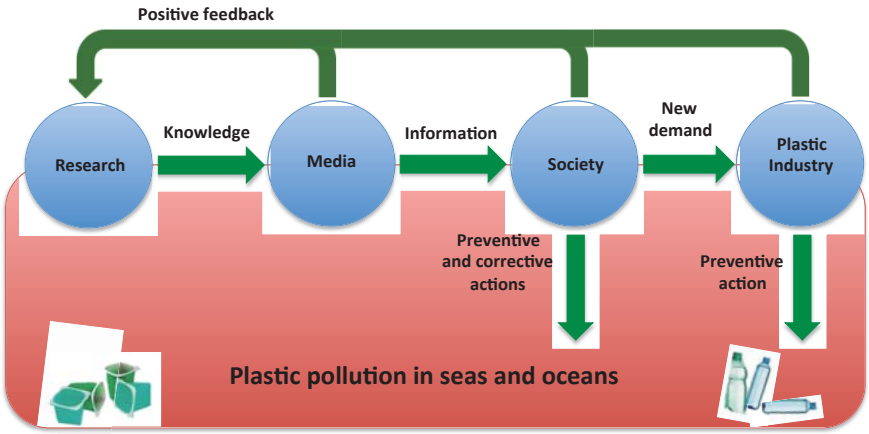
These signs had no effect on the society



These signs had no effect on the society



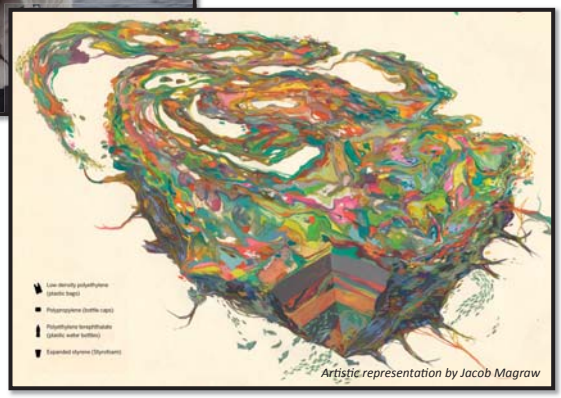
These signs had a significant effect on the society



1997

The great plastic accumulation of the North Pacific Ocean

Charles Moore discovers the great "patch" of plastic waste in the North Pacific.



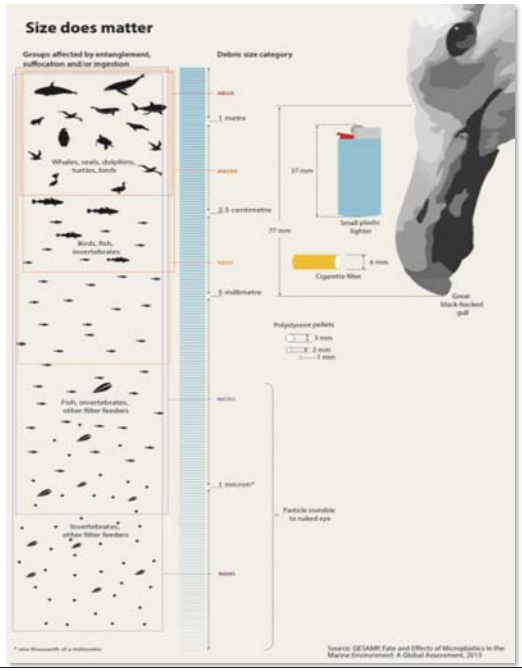
Artistic representation by Jacob Magraw

The list of species affected by marine plastic debris increases…

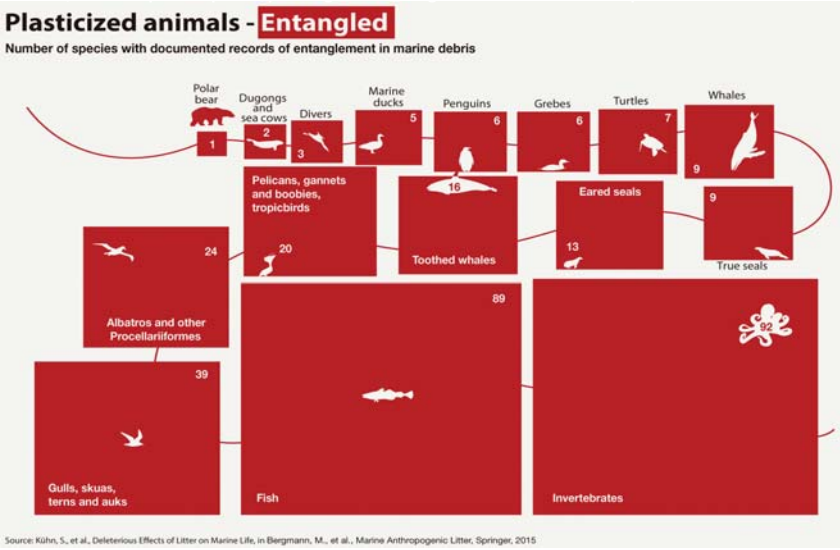
In 1997, Laist compiled impacts by entanglement or ingestion for a total of 136 species

SPECIES GROUP	TOTAL NUMBER OF SPECIES WORLDWIDE	NUMBER & PERCENTAGE OF SPECIES WITH ENTANGLEMENT RECORDS	NUMBER & PERCENTAGE OF SPECIES WITH INGESTION RECORDS
SEA TURTLES	7	6 (86%)	6 (86%)
SEABIRDS	312	51 (16%)	111 (36%)
PENGUINS (SPHENISCIFORMSES)	16	6 (38%)	1 (6%)
GREBES (PODICIPEDIFORMES)	19	2 (10%)	0
ALBATROSSES, PETRELS, SHEARWATERS (PROCCLLARIIFORMES)	99	10 (10%)	62 (63%)
PELICANS, BOOBIES, GANNETS, CORMORANTS, FRIGATEBIRDS, TROPICBIRDS (PELICANIFORMS)	51	11 (22%)	8 (16%)
SHOREBIRDS, SKUAS, GULLS, TERNS, AUKS (CHARADRIIFORMES)	122	22 (18%)	40 (33%)
OTHER BIRDS	-	5	0
MARINE MAMMALS	115	32 (28%)	26 (23%)
BALEEN WHALES (MYSTICETI)	10	6 (60%)	2 (20%)
TOOTHED WHALE (ODONTOCETI)	65	5 (8%)	21 (32%)
FUR SEALS & SEA LIONS (OTARIIDAE)	14	11 (79%)	1 (7%)
TRUE SEALS (PHOCIDAE)	19	8 (42%)	1 (5%)
MANATEES & DUGONGS (SIRENIA)	4	1 (25%)	1 (25%)
SEA OTTER (MUSTELLIDAE)	1	1 (100%)	0
FISH	-	34	33
CRUSTACEANS	-	8	0
SQUID	-	0	1
SPECIES TOTAL		**136**	**177**

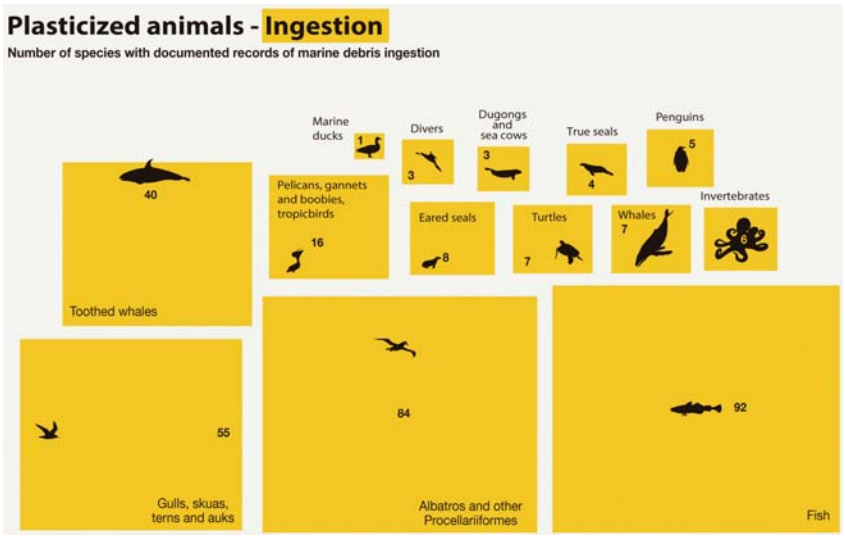
The list of species affected by marine plastic debris increases…



The list of species affected by marine plastic debris increases…



The list of species affected by marine plastic debris increases…



2004

First historical trend in marine plastic pollution

BREVIA

Lost at Sea: Where Is All the Plastic?

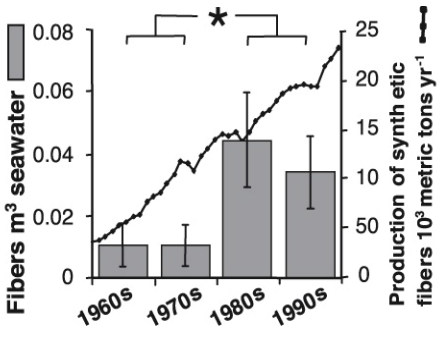
Richard C. Thompson,[1,*] Ylva Olsen,[1] Richard P. Mitchell,[1] Anthony Davis,[1] Steven J. Rowland,[1] Anthony W. G. John,[2] Daniel McGonigle,[3] Andrea E. Russell[3]

Millions of metric tons of plastic are produced annually. Countless large items of plastic debris are accumulating in marine habitats worldwide and may persist for centuries (*1–4*). Here we show that microscopic plastic fragments and fibers (Fig. 1A) are also widespread in the oceans and have accumulated in the pelagic zone and sedimentary habitats. The fragments appear to have resulted from degradation of larger items. Plastics of this size are ingested by marine organisms, but the environmental consequences of this contamination are still unknown.

Over the past 40 years, large items of plastic debris have frequently been recorded in habitats from the poles to the equator (*1–4*). Smaller fragments, probably also plastic, have been reported (*5*) but have received far less attention. Most plastics are resistant to biodegradation, but will break down gradually through mechanical action (*6*). Many "biodegradable" plastics are composites with materials such as starch that biodegrade, leaving behind numerous, nondegradable, plastic fragments (*6*). Some cleaning agents also contain abrasive plastic fragments (*2*). Hence, there is considerable potential for large-scale accumulation of microscopic plastic debris.

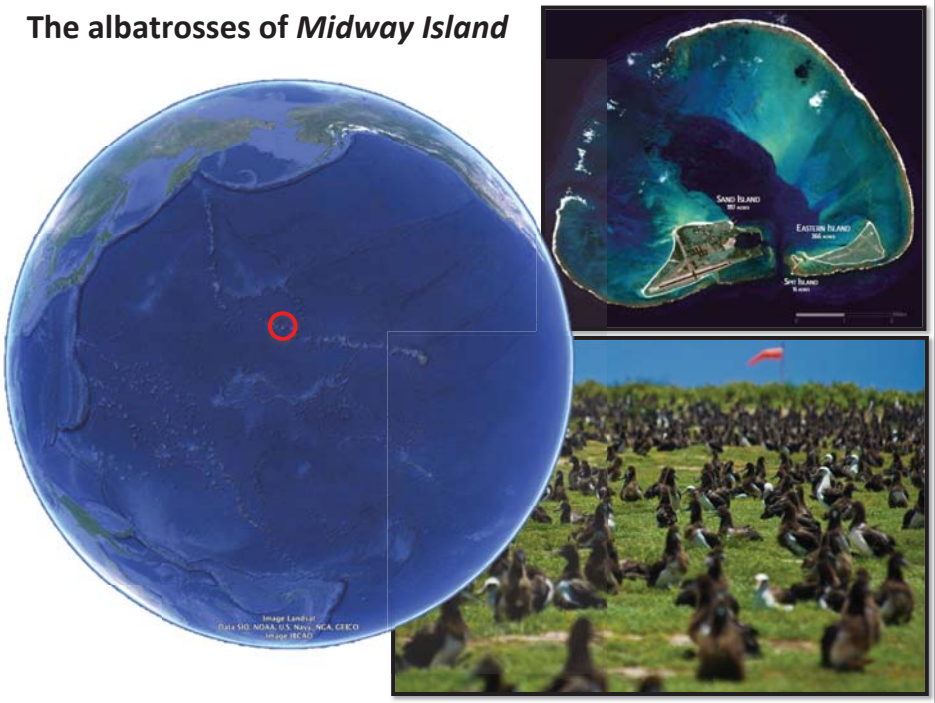
To quantify the abundance of microplastics, we collected sediment from beaches and from estuarine and subtidal sediments around Plymouth, UK (Fig. 1B). Less dense particles were separated it α, and rope, suggesting that the fragments resulted from the breakdown of larger items.

To assess the extent of contamination, a further 17 beaches were examined (Fig. 1B). Similar fibers were found, demonstrating that microscopic plastics are common in sedimentary habitats. To assess long-term trends in abundance, we examined plankton samples collected regularly since the 1960s along routes between Aberdeen and the Shetlands (315 km) and from Sule Skerry to Ice-



2009

The albatrosses of *Midway Island*



The albatrosses of *Midway Island*

Dead body of a albatross chick in Midway Island. Photo from Chris Jordan.

Photo: Chris Jordan

The albatrosses of *Midway Island*

Photo: Chris Jordan

2010

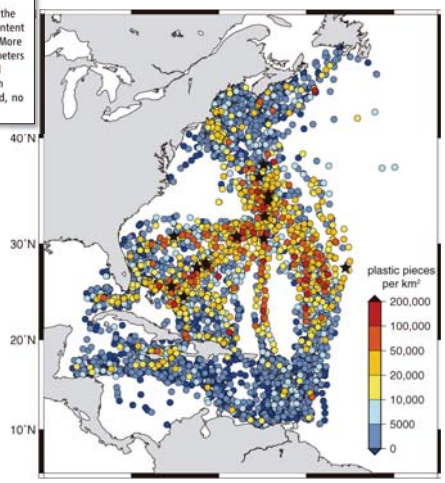
Mapping the western side of the North Atlantic plastic accumulation

www.sciencemag.org SCIENCE VOL 329 3 SEPTEMBER 2010

Plastic Accumulation in the North Atlantic Subtropical Gyre

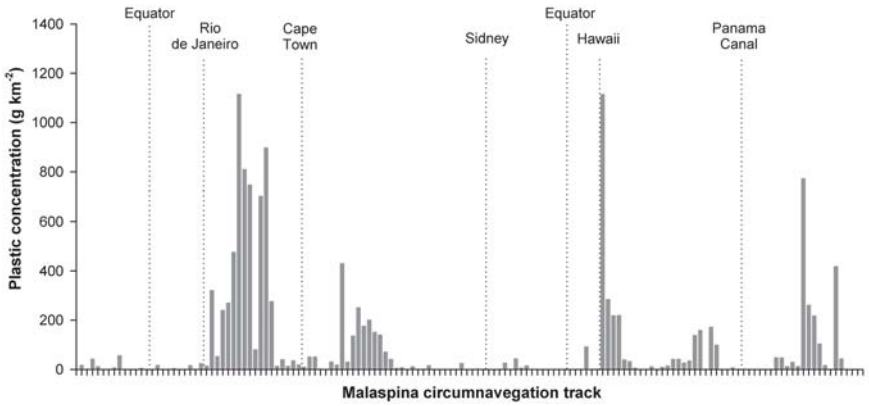
Kara Lavender Law,[1]* Skye Morét-Ferguson,[1,2] Nikolai A. Maximenko,[3] Giora Proskurowski,[1,2] Emily E. Peacock,[2] Jan Hafner,[3] Christopher M. Reddy[2]

Plastic marine pollution is a major environmental concern, yet a quantitative description of the scope of this problem in the open ocean is lacking. Here, we present a time series of plastic content at the surface of the western North Atlantic Ocean and Caribbean Sea from 1986 to 2008. More than 60% of 6136 surface plankton net tows collected buoyant plastic pieces, typically millimeters in size. The highest concentration of plastic debris was observed in subtropical latitudes and associated with the observed large-scale convergence in surface currents predicted by Ekman dynamics. Despite a rapid increase in plastic production and disposal during this time period, no trend in plastic concentration was observed in the region of highest accumulation.



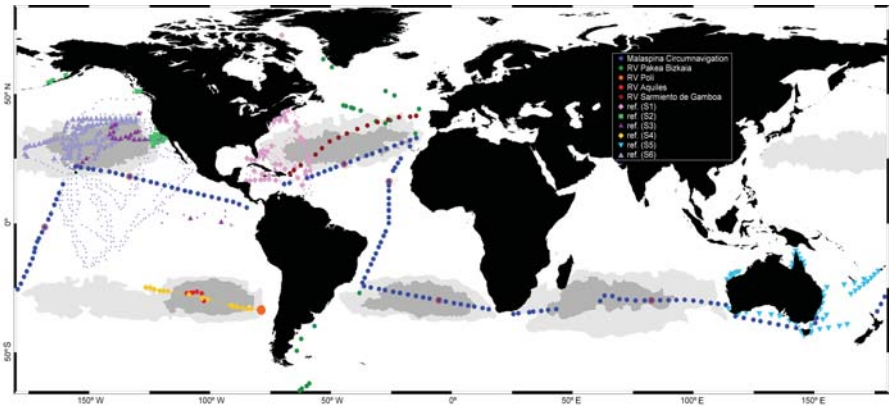
2014

The Malaspina 2010 Circumnavigation



Source: Cozar et al. 2014

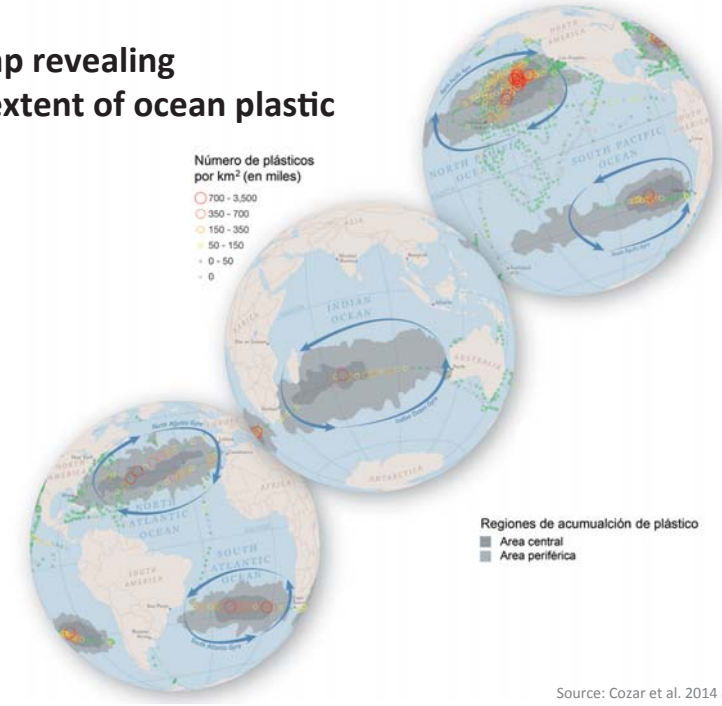
The Malaspina 2010 Circumnavigation



Data compiled for the analisis

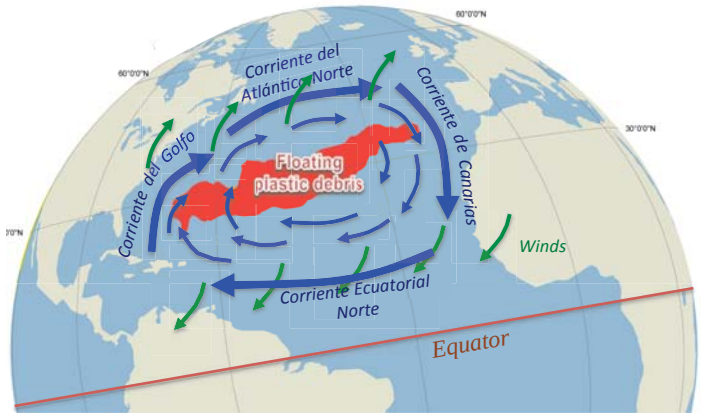
Source: Cozar et al. 2014

A map revealing the extent of ocean plastic

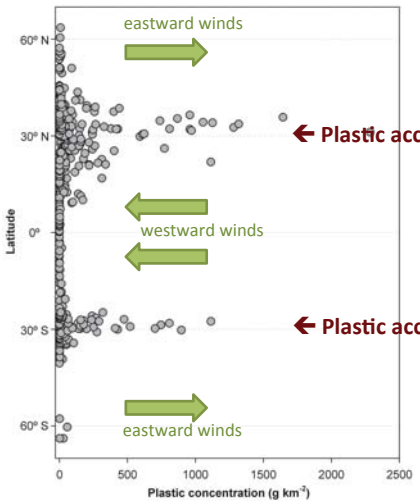


Source: Cozar et al. 2014 & Nat. Geo.

Why the plastic accumulates in the centre of the ocean basins



A latitudinal pattern of plastic pollution

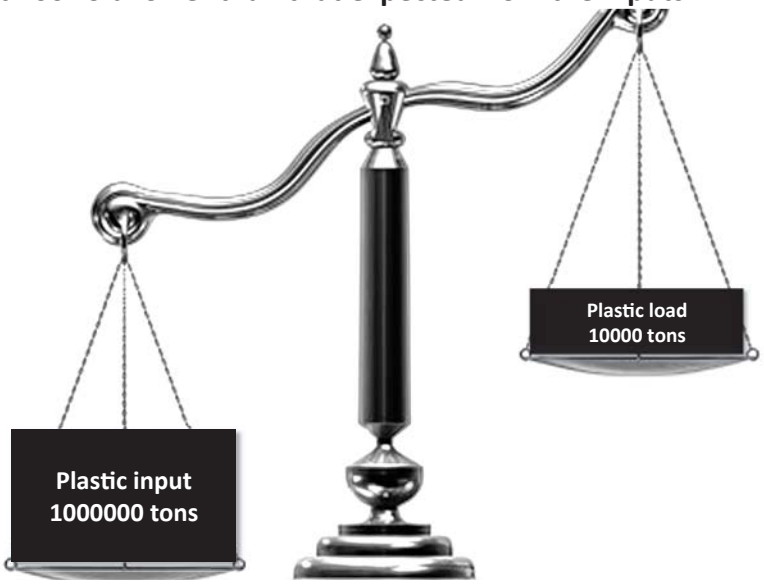


Plastic accumulation, 30º N

Plastic accumulation, 30º S

Source: Cozar et al. 2014

A first estimate of the global plastic load on the ocean surface… but 100-fold lower than that expected from the inputs



Main mechanisms removing plastic debris from the surface

1. Ballasting and sinking due to the growth of small organisms on the debris

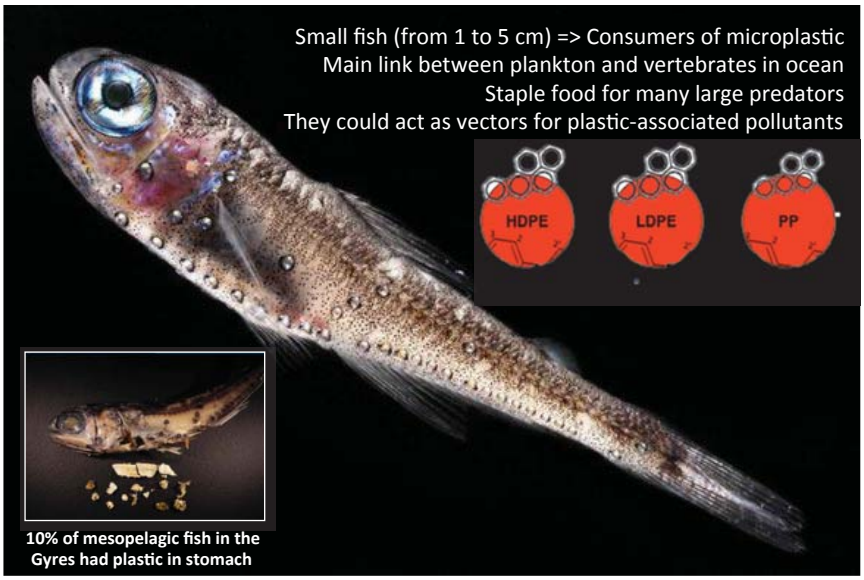
Source: B. Ubeda (UCA) y ML Pedrotti (LOV)

Main mechanisms removing plastic debris from the surface

2. The plastic ingestion by marine organisms

Source: Steve Woods (Bali, Indonesia, 2013)

Mesopelagic fish: An abundant and ubiquitious plastic consumer



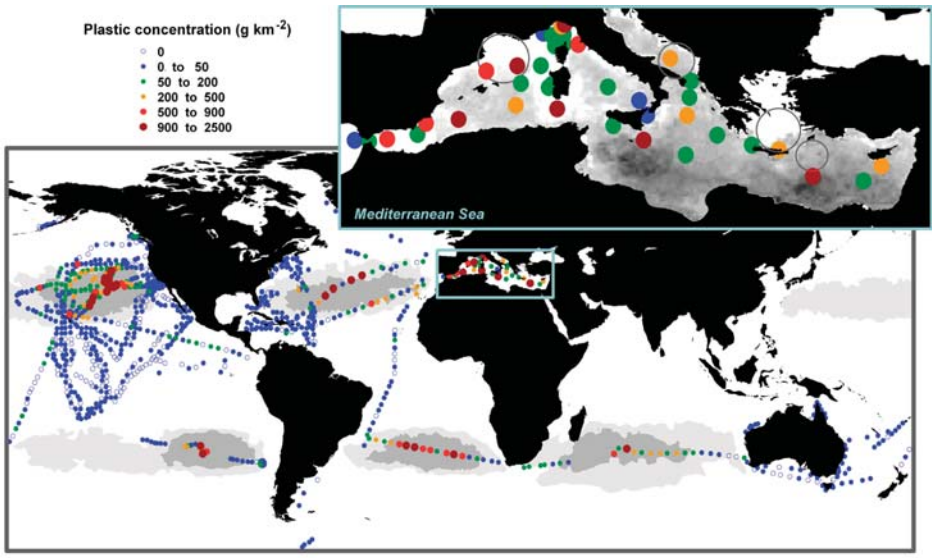
Mesopelagic fish: An abundant and ubiquitious plastic consumer

2015

Mediterranean Expedition

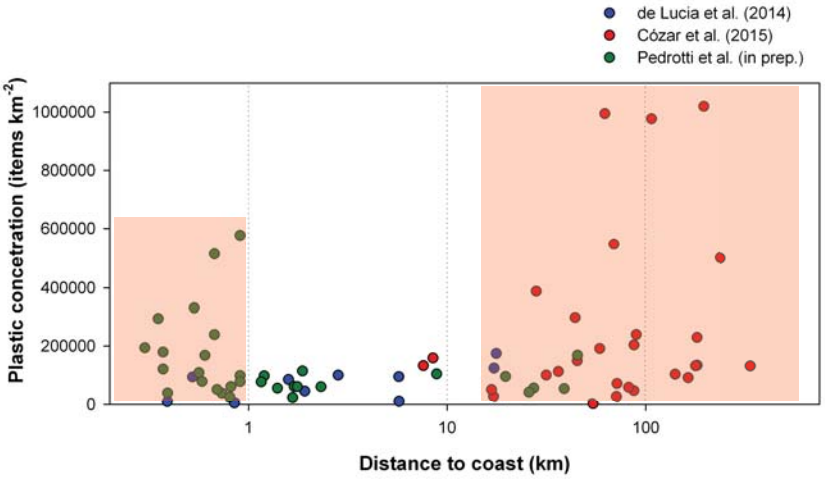
Mediterranean Expedition

As much plastic as in the Subtropical Gyres



Mediterranean Expedition

High plastic concentrations also in the coastal waters



Source: Pedrotti et al. 2016

Mediterranean Expedition

High plastic concentrations also in the coastal waters

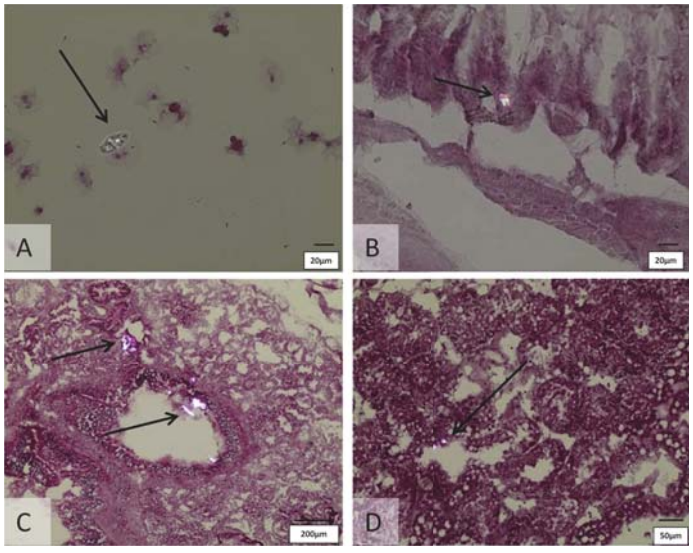
SCIENTIFIC REPORTS | 5:14340 | DOI: 10.1038/srep14340

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

Chelsea M. Rochman[1], Akbar Tahir[2], Susan L. Williams[3], Dolores V. Baxa[1], Rosalyn Lam[1], Jeffrey T. Miller[4], Foo-Ching Teh[1], Shinta Werorilangi[2] & Swee J. Teh[1]

The ubiquity of anthropogenic debris in hundreds of species of wildlife and the toxicity of chemicals associated with it has begun to raise concerns regarding the presence of anthropogenic debris in seafood. We assessed the presence of anthropogenic debris in fishes and shellfish on sale for human consumption. We sampled from markets in Makassar, Indonesia, and from California, USA. All fish and shellfish were identified to species where possible. Anthropogenic debris was extracted from the digestive tracts of fish and whole shellfish using a 10% KOH solution and quantified under a dissecting microscope. In Indonesia, anthropogenic debris was found in 28% of individual fish and in 55% of all species. Similarly, in the USA, anthropogenic debris was found in 25% of individual fish and in 67% of all species. Anthropogenic debris was also found in 33% of individual shellfish sampled. All of the anthropogenic debris recovered from fish in Indonesia was plastic, whereas anthropogenic debris recovered from fish in the USA was primarily fibers. Variations in debris types likely reflect different sources and waste management strategies between countries. We report some of the first findings of plastic debris in fishes directly sold for human consumption raising concerns regarding human health.

Nanoplastic: Debris even smaller than microplastic



← ***Nano-plastics incorporated in the tissue of mussels.*** Polarized-light microscopy images showing the presence of plastic particles in haemolymph (A), gills (B), gut lumen and epithelium (C), digestive tubules (D).

Source: Avio et al. 2015

First estimate of the plastic waste input from land

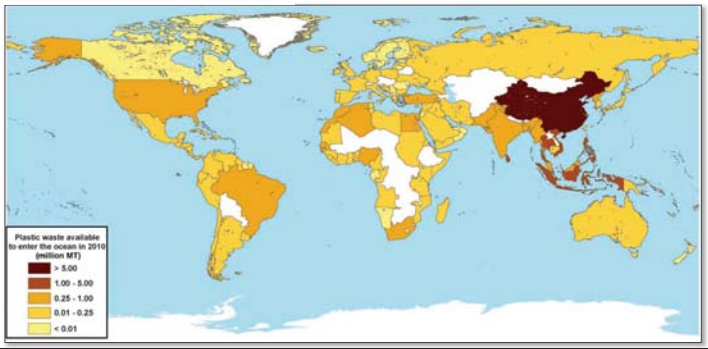
MARINE POLLUTION

Plastic waste inputs from land into the ocean

Jenna R. Jambeck,[1]* Roland Geyer,[2] Chris Wilcox,[3] Theodore R. Siegler,[4] Miriam Perryman,[1] Anthony Andrady,[5] Ramani Narayan,[6] Kara Lavender Law[7]

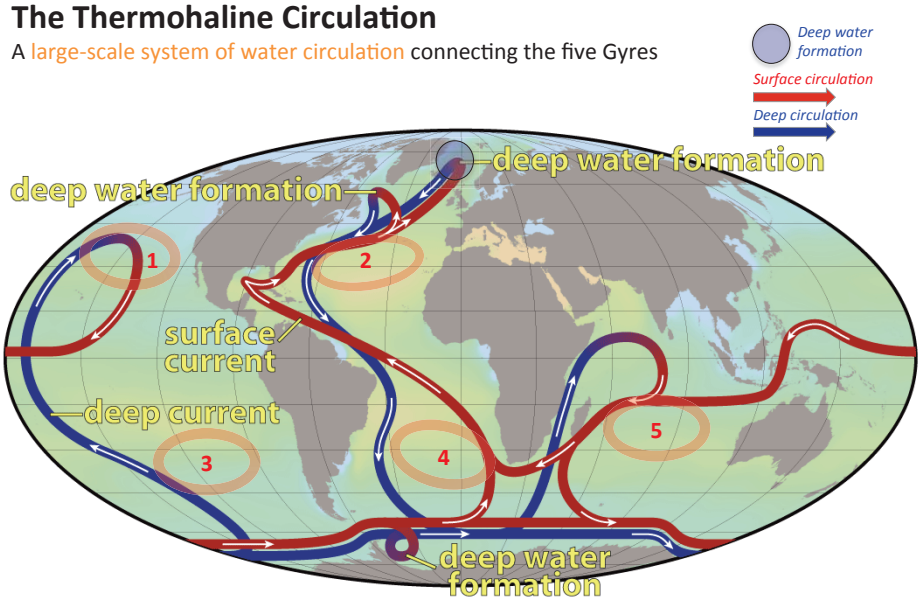
Plastic debris in the marine environment is widely documented, but the quantity of plastic entering the ocean from waste generated on land is unknown. By linking worldwide data on solid waste, population density, and economic status, we estimated the mass of land-based plastic waste entering the ocean. We calculate that 275 million metric tons (MT) of plastic waste was generated in 192 coastal countries in 2010, with 4.8 to 12.7 million MT entering the ocean. Population size and the quality of waste management systems largely determine which countries contribute the greatest mass of uncaptured waste available to become plastic marine debris. Without waste management infrastructure improvements, the cumulative quantity of plastic waste available to enter the ocean from land is predicted to increase by an order of magnitude by 2025.

Rank	Country	Econ. classif.	Coastal pop. [millions]	% mismanaged waste	Plastic marine debris [MMT/year]
1	China	UMI	262.9	76	1.32–3.53
2	Indonesia	LMI	187.2	83	0.48–1.29
3	Philippines	LMI	83.4	83	0.28–0.75
4	Vietnam	LMI	55.9	88	0.28–0.73
5	Sri Lanka	LMI	14.6	84	0.24–0.64
6	Thailand	UMI	26.0	75	0.15–0.41
7	Egypt	LMI	21.8	69	0.15–0.39
8	Malaysia	UMI	22.9	57	0.14–0.37
9	Nigeria	LMI	27.5	83	0.13–0.34
10	Bangladesh	LI	70.9	89	0.12–0.31
11	South Africa	UMI	12.9	56	0.09–0.25
12	India	LMI	187.5	87	0.09–0.24
13	Algeria	UMI	16.6	60	0.08–0.21
14	Turkey	UMI	34.0	18	0.07–0.19
15	Pakistan	LMI	14.6	88	0.07–0.19
16	Brazil	UMI	74.7	11	0.07–0.19
17	Burma	LI	19.0	89	0.07–0.18
18*	Morocco	LMI	17.3	68	0.05–0.12
19	North Korea	LI	17.3	90	0.05–0.12
20	United States	HIC	112.9	2	0.04–0.11

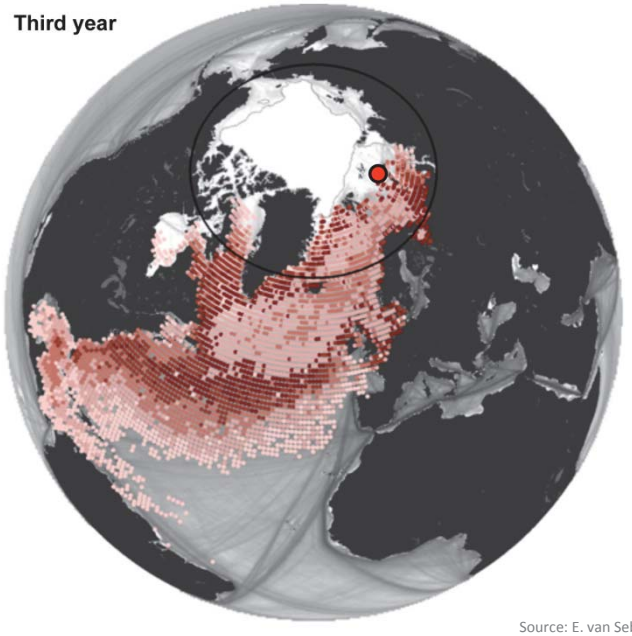


The Thermohaline Circulation

A large-scale system of water circulation connecting the five Gyres

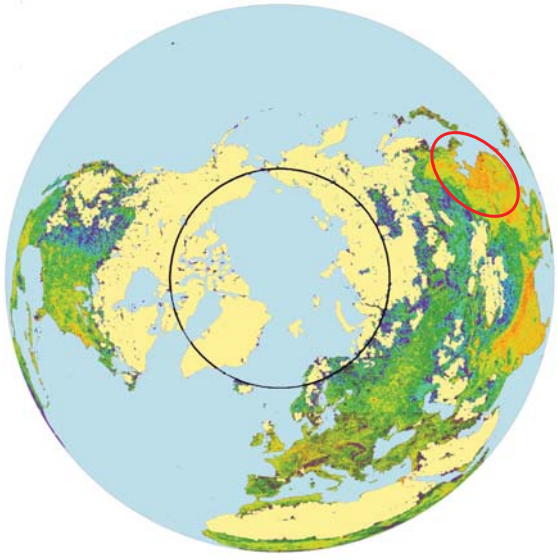


Transport simulation

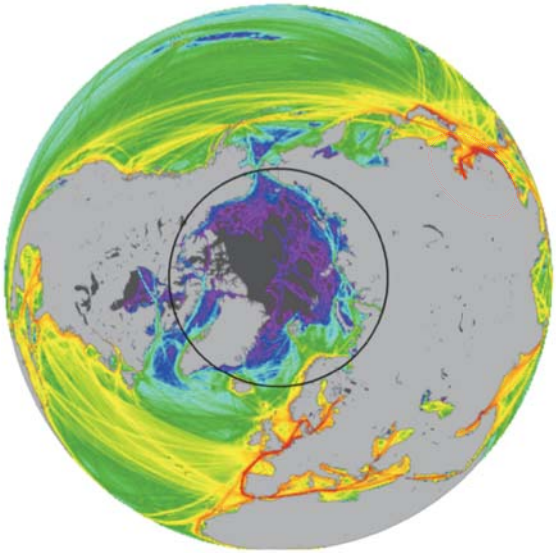


Source: E. van Sebille; in Cozar et al., in rev.

And what about the most populated world coastal regions?

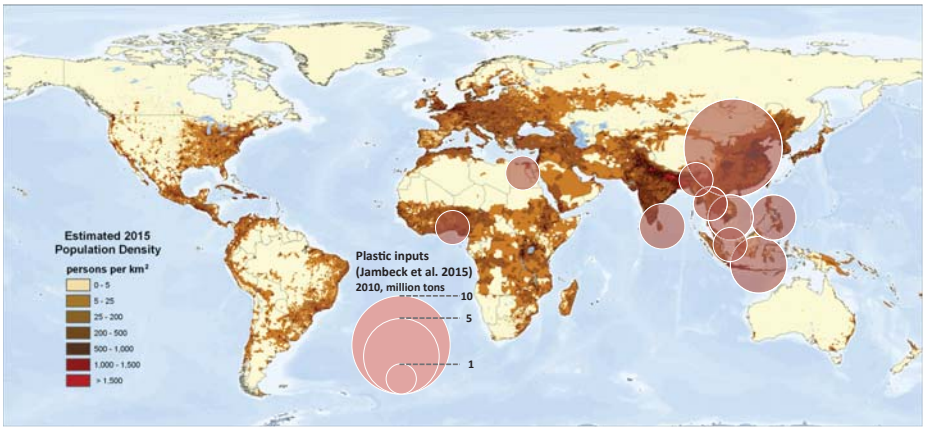


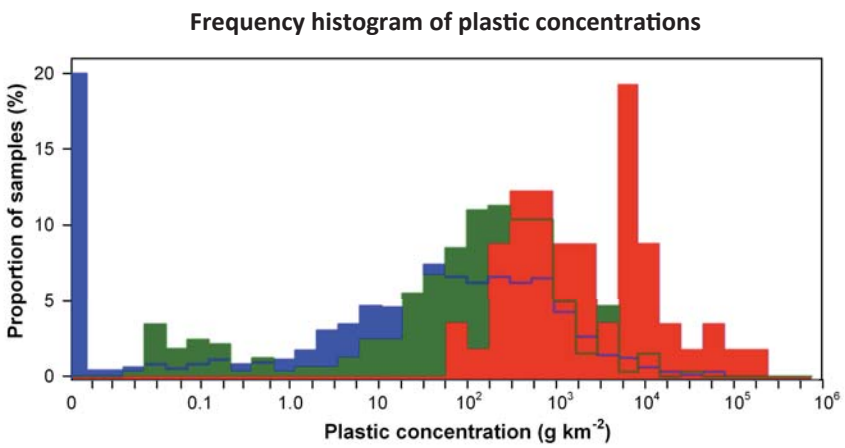
And what about the most populated world coastal regions?



Source: Cozar et al., in rev.

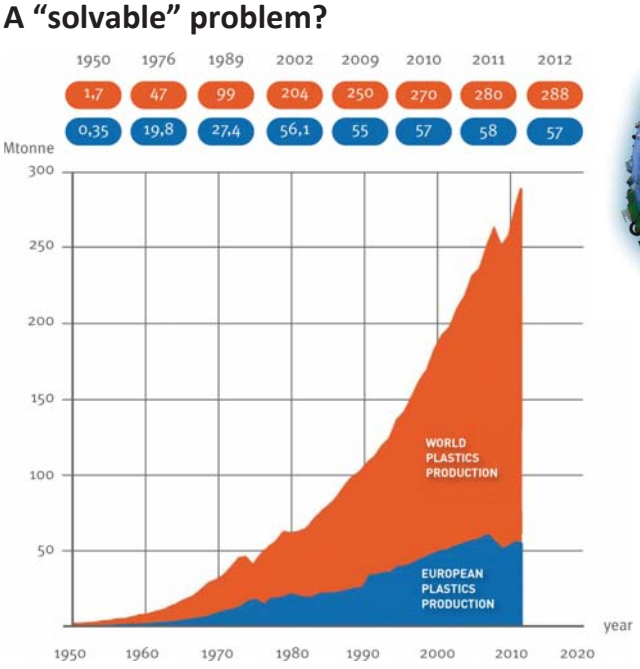
Top ten





Data of Japan: Isobe et al. 2014, 2015

A "solvable" problem?



A "solvable" problem?

BREVIA

Lost at Sea: Where Is All the Plastic?

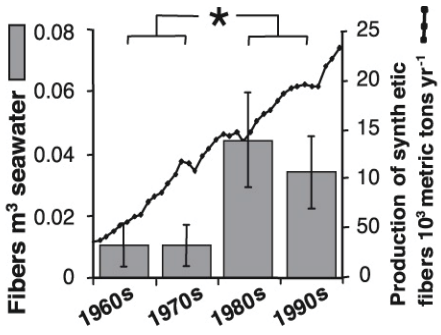
Richard C. Thompson,[1,2] Ylva Olsen,[1] Richard P. Mitchell,[1] Anthony Davis,[1] Steven J. Rowland,[1] Anthony W. G. John,[2] Daniel McGonigle,[3] Andrea E. Russell[3]

Millions of metric tons of plastic are produced annually. Countless large items of plastic debris are accumulating in marine habitats worldwide and may persist for centuries (*1–4*). Here we show that microscopic plastic fragments and fibers (Fig. 1A) are also widespread in the oceans and have accumulated in the pelagic zone and sedimentary habitats. The fragments appear to have resulted from degradation of larger items. Plastics of this size are ingested by marine organisms, but the environmental consequences of this contamination are still unknown.

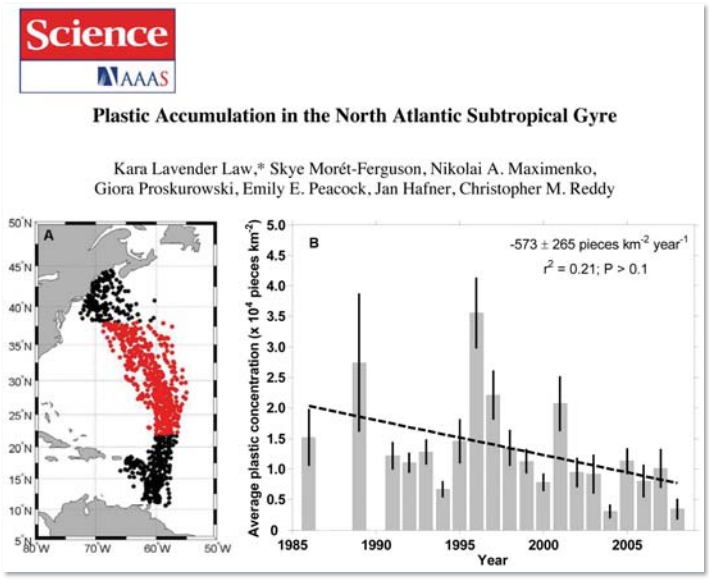
Over the past 40 years, large items of plastic debris have frequently been recorded in habitats from the poles to the equator (*1–4*). Smaller fragments, probably also plastic, have been reported (*5*) but have received far less attention. Most plastics are resistant to biodegradation, but will break down gradually through mechanical action (*6*). Many "biodegradable" plastics are composites with materials such as starch that biodegrade, leaving behind numerous, nondegradable, plastic fragments (*6*). Some cleaning agents also contain abrasive plastic fragments (*2*). Hence, there is considerable potential for large-scale accumulation of microscopic plastic debris.

To quantify the abundance of microplastics, we collected sediment from beaches and from estuarine and subtidal sediments around Plymouth, UK (Fig. 1B). Less dense particles were separated it α, and rope, suggesting that the fragments resulted from the breakdown of larger items.

To assess the extent of contamination, a further 17 beaches were examined (Fig. 1B). Similar fibers were found, demonstrating that microscopic plastics are common in sedimentary habitats. To assess long-term trends in abundance, we examined plankton samples collected regularly since the 1960s along routes between Aberdeen and the Shetlands (315 km) and from Isle Skerry to Lee-



A "solvable" problem?



Science
AAAS

Plastic Accumulation in the North Atlantic Subtropical Gyre

Kara Lavender Law,* Skye Morét-Ferguson, Nikolai A. Maximenko, Giora Proskurowski, Emily E. Peacock, Jan Hafner, Christopher M. Reddy

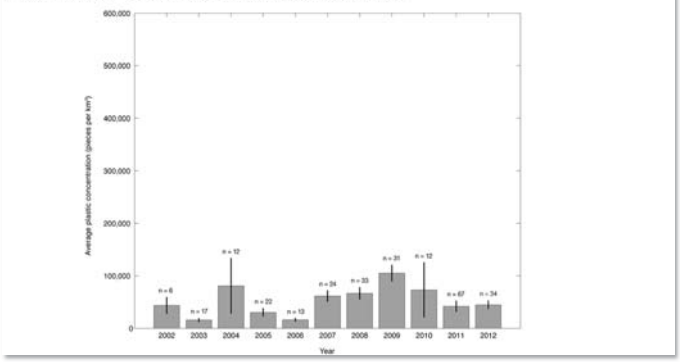
A "solvable" problem?

ENVIRONMENTAL Science & Technology

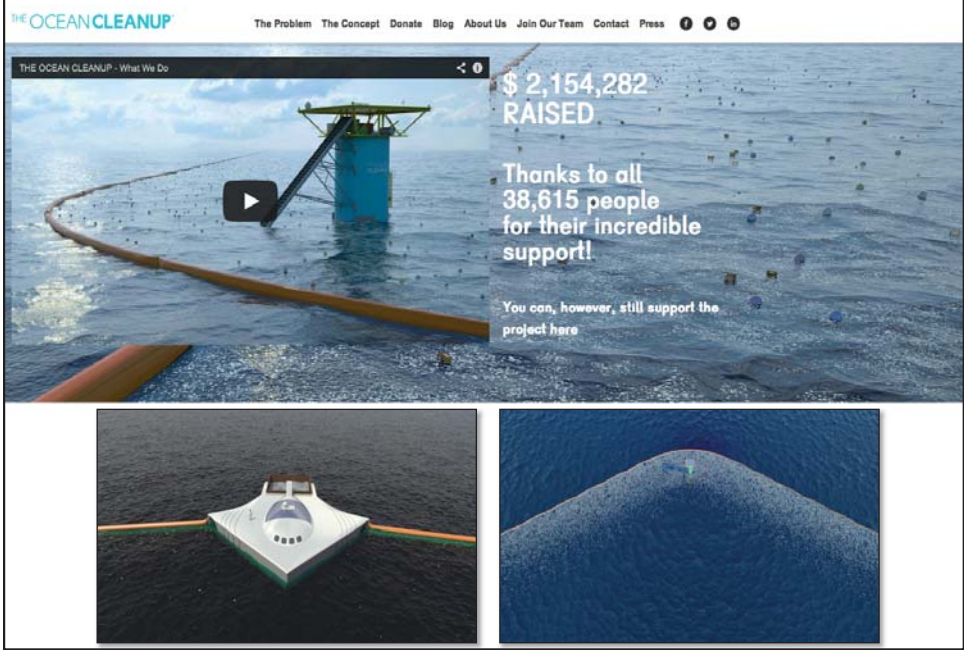
Article

Distribution of Surface Plastic Debris in the Eastern Pacific Ocean from an 11-Year Data Set

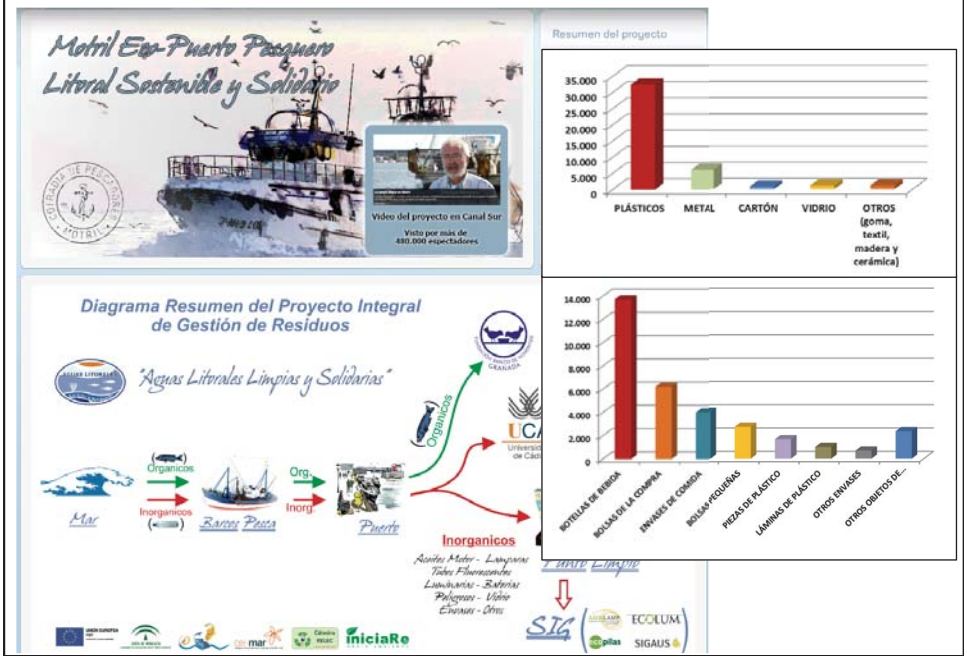
Kara Lavender Law,[†] Skye E. Morét-Ferguson,[†] Deborah S. Goodwin,[*,†] Erik R. Zettler,[*,†] Emelia DeForce,[†,§] Tobias Kukulka,[∥] and Giora Proskurowski[†,‡]



1. Clean-up of the plastic in the Gyres (mitigating)

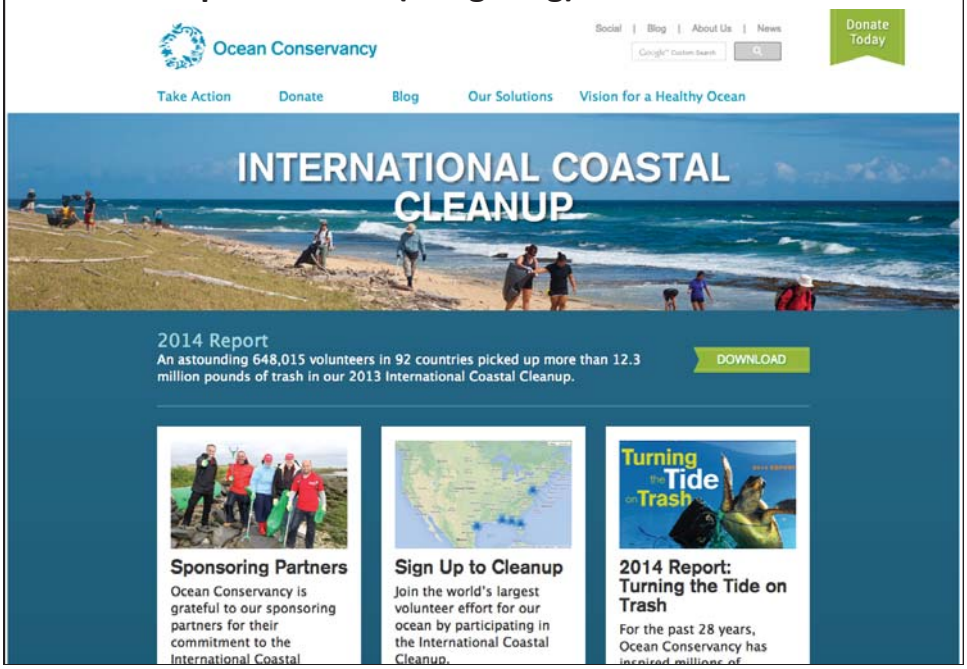


2. Clean-up of the coastal seafloor (mitigating)

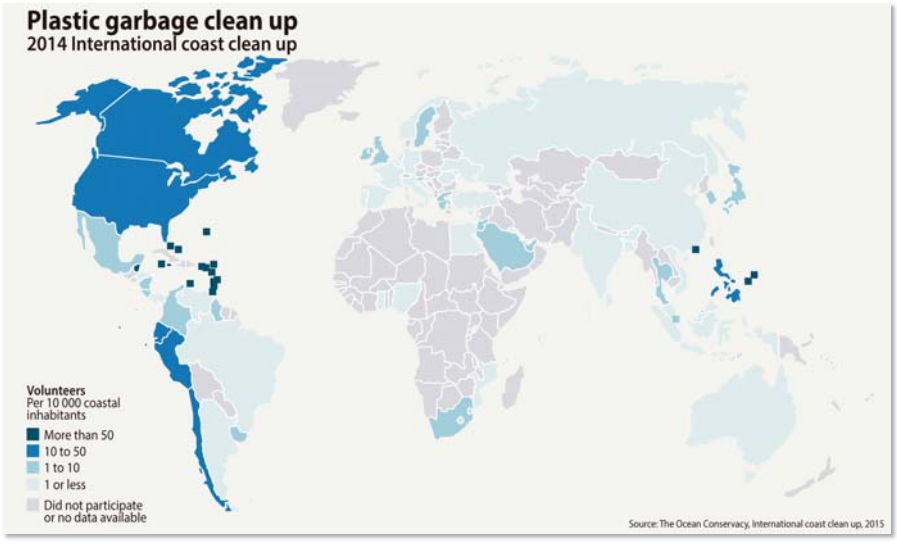


2. Clean-up of the coastal seafloor (mitigating)

3. Clean up of beaches(mitigating)



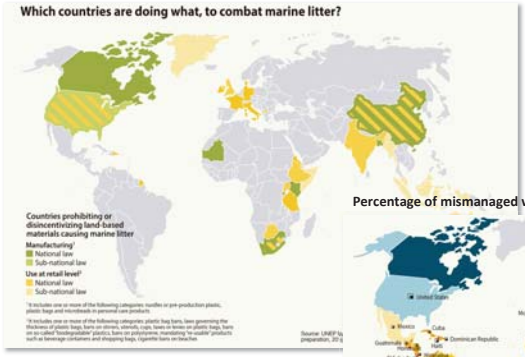
3. Clean up of beaches(mitigating)



4. Floating barriers in urban rivers (preventive)

5. Information and social awareness (preventive)

7. Economic incentives and Bans (preventive)
8. Investment in waste management (preventive)



Percentage of mismanaged waste

9. Design and industrial innovation (preventive)

New alternatives to the plastic, specially for the plastic consumed outdoor.
The chitosan is a biodegradable, impermeable, elastic, pliable, can double the rigidity of the plastic, and it is very abundant.

Javier Fernández (right), spanish researcher working on the chitosan

Just bin it!