Transport and fate of marine plastics





80% of marine plastics from land-based sources



Third International Marine Debris Conference Miami 1994



Dumping of plastic banned since 1989 (MARPOL Annex V)



Urban centres are key sources of macroplastics



Quantification of microfibre levels in South Africa's beach sediments, and evaluation of spatial and temporal variability from 2016 to 2017

S. de Villiers

Centre for Coastal Paleoscience, Nelson Mandela University, PO Box 77000, Port Elizabeth 6031, South Africa





Up to 800 fibres.dm⁻³

80% from land-based sources

but it depends where you are...

Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic SCIENTIFIC REPORTS

L. Lebreton^{1,2}, B. Slat¹, F. Ferrari¹, B. Sainte-Rose¹, J. Aitken³, R. Marthouse³, S. Hajbane¹, S. Cunsolo^{1,4}, A. Schwarz¹, A. Levivier¹, K. Noble^{1,5}, P. Debeljak^{1,6}, H. Maral^{1,7}, R. Schoeneich-Argent^{1,8}, R. Brambini^{1,9} & J. Reisser¹

Nearly half of all plastic mass in the North Pacific gyre is fishing gear

Fishery/marine equipment = 87% mass at Inaccessible Island



80% from land-based sources

but it depends where you are...

and 'general' litter hard to assign to source



PET drink bottles at Inaccessible



Increase at 15% per year, twice as fast as other litter types



Released from South America

Released from China

www.plasticadrift.org



Most bottles come from China, probably from merchant shipping



Bottle origins in relation to shipping routes



Up to 30% of SA beach litter comes from offshore sources Land-based sources dominate close to urban sources



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. Russell³

Science 2004



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Microplastics? (note no increase since 1980s...)

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, ¹Anthony Andrady, ⁵ Ramani Narayan, ⁶ Kara Lavender Law⁷ Science 2015



~5-12 million tonnes of plastic entered the sea in 2010

Plastic Pollution in the World's Oceans: More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea

Marcus Eriksen¹*, Laurent C. M. Lebreton², Henry S. Carson^{3,4}, Martin Thiel^{5,6,7}, Charles J. Moore⁸, Jose C. Borerro⁹, Francois Galgani¹⁰, Peter G. Ryan¹¹, Julia Reisser¹² 2014



If 5-12 million tonnes of plastic enter the sea each year, where is it going?

Environmental Research Letters 2017

All is not lost: deriving a top-down mass budget of plastic at sea

Albert A Koelmans^{1,2,6}, Merel Kooi¹, Kara Lavender Law³ and Erik van Sebille^{4,5}

A balanced budget requires rapid fragmentation and sinking = fast turnover of floating macroplastics (average 3 years)



Predict rapid decrease of floating plastic if inputs cease >99% of all macroplastics on seafloor

A global mass budget for positively buoyant macroplastic debris in the ocean

Laurent Lebreton^{1,2}, Matthias Egger ¹ & Boyan Slat¹

2019

SCIENTIFIC REPORTS

natureresearch



Macroplastic in North Pacific Gyre is >5 years old, consistent with long predicted drift times to reach gyres



96-98% of macroplastics predicted to strand within 1 year

1% of stranded plastics resuspended into coastal waters/year

33% of coastal plastics advected offshore/year

Degradation macro-micro = 3% per year (constant beaches/sea)

Modelling the accumulation and transport of floating marine micro-plastics around South Africa



C. Collins^{a,*}, J.C. Hermes^{a,b,c}

Marine Pollution Bulletin 2019

62% of floating microplastics strand on SA beaches >90% from east-couth coast cities



Predicted stranding locations for floating microplastics



Urban 'halos' not only indicate importance of local sources also imply limited dispersal

Implications for beach litter?

distanti di birini santisana

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Science 2015

South Africa ranked 11th worst polluter globally ~90,000 – 250,000 tonnes estimated to enter the sea in 2010

If ~60% of floating plastics strand = 35,000-100,000 tonnes/year 12-50 kg/m given a 3000 km coastline

But average standing stock <0.1 kg/m (max ~1 kg/m)

Buried litter

no



Mass: 94% surface macro 5% buried macro 1% micro

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1) Estimates of land-based inputs are overestimated





The Orange-Vaal River

Sampled twice: wet and dry season

But hard to measure episodic inputs...

Lisa Guastella

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- 2) Estimates of % stranding are overestimated



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- 1) Estimates of land-based inputs are overestimated
- 2) Estimates of % stranding are overestimated
- 3) Beach turnover rates are faster than we think

Cleaning beaches: sweeping the rubbish under the carpet

Peter G. Ryan and Debbie Swanepoel South African Journal of Science Vol. 92 June 1996



By 1995, 70% of beaches cleaned Total effort ~55,000 km cleaned per year

How much is removed by beach cleaning?



StrandPublic beach cleaned regularly: 0.06 kg/m (84% buried)beachClosed beach not cleaned: 1.36 kg/m (34% buried)

95% reduction in mass due to cleaning (but doesn't balance mass budget)

25x

What happens to plastic that doesn't strand?

Modelling the accumulation and transport of floating marine micro-plastics around South Africa

C. Collins^{a,*}, J.C. Hermes^{a,b,c}

Marine Pollution Bulletin 2019

Predicted drift tracks for low density microplastics and % advected offshore (export to black = Atlantic Ocean, blue = Indian Ocean)



Cape Town (81%)

Port Elizabeth (3%)

Durban (10%)





Days







Items carry up to 5x their own mass in goose barnacles

Does size and buoyancy affect the long-distance transport of floating debris? Peter G Ryan Environmental Research Letters (2015) 100 Duration afloat depends on density and size/shape Surface area:volume ratio 10 Small items: size paramount 1 Large items: shape paramount 0.1 Rectangles 1:10:100 1:5:10 0.01 Cubes Spheres 10 20 30 40 50 60 0 Spherical diameter (cm)



Ups and Downs in the Ocean: Effects of Biofouling on Vertical Transport of Microplastics

Merel Kooi,**^{†©} Egbert H. van Nes,[†] Marten Scheffer,[†] and Albert A. Koelmans^{†,‡©}

Yo-yo effect: Biofouling causes plastic to sink, but regain buoyancy



as epibionts die or are eaten once items sink below the photic zone

2017

Lepas anserifera found on 2 items:

Bread bag made 3 months before (185 m deep, 170 km off Agulhas)

Margarine tub (685 m deep) also colonised by benthic epibionts

Yo-yo effect might not be that important?



MARINE ECOLOGY

From the surface to the seafloor: How giant larvaceans transport microplastics into the deep sea

Kakani Katija,*[†] C. Anela Choy,*[†] Rob E. Sherlock, Alana D. Sherman, Bruce H. Robison

SCI. ADV. 2017





90% contain plastic

Great Shearwater

The seabed as the ultimate sink

Macrolitter in 235 benthic fish survey trawls (2019)



Average density for all litter: 3.4 items.km⁻² and 2.1 kg.km⁻²

plastics: 3.0 items.km⁻² and 0.3 kg.km⁻²

Lower than other trawl surveys (and insufficient to balance the budget) Low densities seemingly confirmed by ROV footage

What goes down, sometimes can come up...

Microplastics in sea coastal zone: Lessons learned from the Baltic amber

Irina Chubarenko, Natalia Stepanova

Environ. Pollut. 2017



- Amber has similar density (1.05-1.1 g/cm³) to polystyrene and nylon
- Strandings linked to stormy wind/wave conditions which lift amber (and dense plastics) off the seabed, and carry it ashore
- PET bottles and metal cans washing ashore after 3-5 years on the seabed with evidence of mechanical wear (rocky seabed)



Intertidal litter at Muizenberg corner:

1.65±1.30 litter items·m⁻¹ (12±10 g·m⁻¹, n=36 months) Excluding November 2017: 65 items·m⁻¹ (72 g·m⁻¹)

Current uncertainties and evidence gaps

- We don't have a balanced plastic mass budget regionally or globally
- Better understanding of plastic fluxes and sinks (seafloor/midwater)
- Main focus should be to get a better estimate of land-based inputs (which links to monitoring efficacy of mitigation measures)

Implications for tackling plastic pollution

The lack of a balanced plastic mass budget doesn't alter policy We know there's a problem; focus should be on tackling it...

The fact that most plastic derives from local sources has 2 advantages:

- Easy to monitor the efficacy of mitigation measures
- Reducing local sources of plastic will see rapid, local benefits

