



2023 年(第 32回) ブループラネット賞
受賞者記念講演会

2023 Blue Planet Prize
Commemorative Lectures

リチャード・トンプソン教授
タマラ・ギャロウェイ教授
ペネロープ・リンデキュー教授
講演スライド集

マイクロプラスチックの発見—
環境への蓄積、影響、および対策

Professor Richard Thompson

Professor Tamara Galloway

Professor Penelope Lindeque

Slides for the Lecture

Discovering the Microplastic
Pollution on Marine Ecosystems



Discovering microplastics:
Their environmental accumulation, impacts and solutions
2023 Blue Planet Prize – Commemorative Lecture



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Discovering microplastics:
Their environmental accumulation, impacts and solutions




Richard Thompson - Discovery, environmental distribution, sources and pathways
Tamara Galloway - Environmental impacts and consequences for human health
Pennie Lindeque – Delivering evidence, raising awareness and evaluating solutions

2

 **PLYMOUTH**
Marine Institute



Prof Richard Thompson  @ProfRThompson

Discovery, environmental distribution, sources and pathways

International Marine litter Research Unit, University of Plymouth, UK

3

Marine Biologist to 'Godfather' of Micropalstics



1994 

4

A paper describing microscopic pieces of plastic 'Microplastics'

BREVIA

Lost at Sea: Where Is All the Plastic?

Richard C. Thompson,¹ Vive Olsson,² Richard P. Mitchell,³ Anthony Davis,¹ Steven J. Rowland,¹ Anthony M. G. Jahn,⁴ Daniel McGonigle,⁵ Andrea E. Russell⁶

Millions of metric tons of plastic are produced annually. Considerable large items of plastic debris are accumulating in marine habitats worldwide and may pose to organisms (1-3). Here we show that microscopic plastic fragments and fibers (Fig. 1A) are also widespread in the ocean and have accumulated in the pelagic zone and sedimentary habitats. The fragments appear to have resulted from degradation of larger items, but the environmental consequences are still unknown.

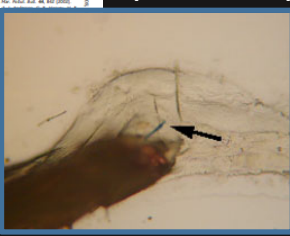
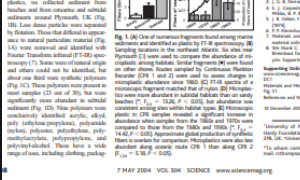
Over the past 40 years, large items of plastic debris have frequently been collected in habitats from the poles to the equator (4-6). Smaller fragments, particularly microplastics, have been reported (7) but have remained for low amounts. Microplastics are resistant to biodegradation, but will break down gradually through mechanical action (8). Many "biodegradable" plastics are composed with additives such as starch that biodegrade, but the residual fragments, nondegradable plastics (Fig. 1B). Some cleaning agents also contain abrasive plastic fragments (9). Hence, there is considerable potential for large-scale accumulation of microscopic plastic debris.

To quantify the abundance of microplastics, we utilized sediment traps, beachcombs and three container and artificial substrates around Plymouth, UK (Fig. 1C). Less than 100 particles were reported in the literature. These data differed in appearance to natural particulate material (Fig. 1A), were unsorted and identified with Fourier Transform infrared (FT-IR) spectroscopy (7). Some were identified as polypropylene (7), but were not identified as such and others could not be identified. We show that most synthetic polymers are not biodegradable in sediment (Fig. 1D). This polymer was present in sediment (Fig. 1E). This polymer was not only colorless, translucent, and polyethylene, polypropylene, polybutadiene, polystyrene, and polyvinyl chloride. There have been a wide range of uses including clothing packaging

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 observations were made in sedimentary habitats. To assess fragment trends in abundance, we examined plastic debris collected regularly since the 1950s along coastlines between Aberdeen and Oban (10 km) and from Lake Stary to Kazimierz (10 km) and from Lake Stary to Kazimierz (10 km) and from Lake Stary to Kazimierz (10 km).

Fig. 1. (A) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (B) Sediment traps in the pelagic zone, (C) beachcombs, (D) container and artificial substrates, (E) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (F) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (G) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (H) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (I) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (J) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (K) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (L) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (M) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (N) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (O) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (P) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (Q) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (R) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (S) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (T) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (U) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (V) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (W) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (X) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (Y) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8). (Z) FT-IR spectra of synthetic polymers from sediment and identified as plastic by FT-IR spectroscopy (8).

Mostly fibres, present in seawater and sediment around UK
Abundance had increased over decades
Eaten by a range of marine organisms
Indicated potential global accumulation and possible physical and chemical toxicity



Thompson et al. 2004

Microplastics - from discovery to a new field of research

BREVIA

Lost at Sea: Where Is All the Plastic?

Richard C. Thompson,¹ Vive Olsson,² Richard P. Mitchell,³ Anthony Davis,¹ Steven J. Rowland,¹ Anthony M. G. Jahn,⁴ Daniel McGonigle,⁵ Andrea E. Russell⁶

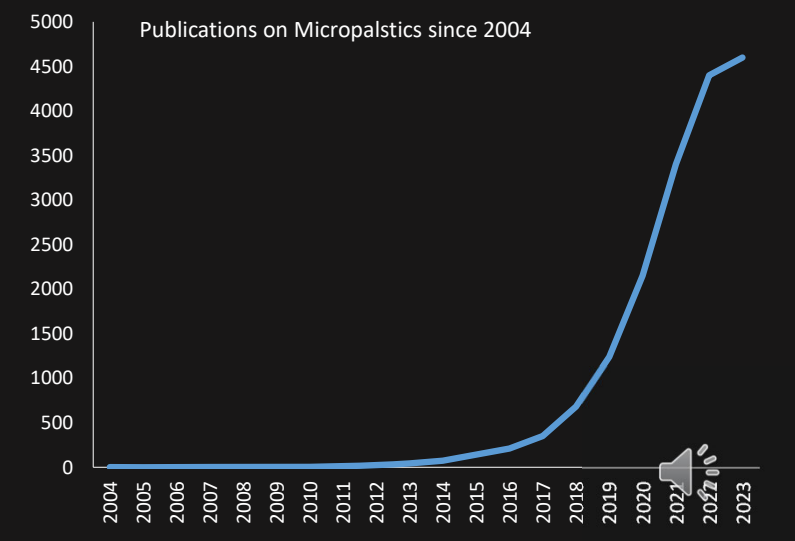
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Thompson et al. 2004

Global distribution on shorelines

ENVIRONMENTAL Science & Technology ARTICLE
pubs.acs.org/est

Accumulation of Microplastic on Shorelines Worldwide: Sources and Sinks

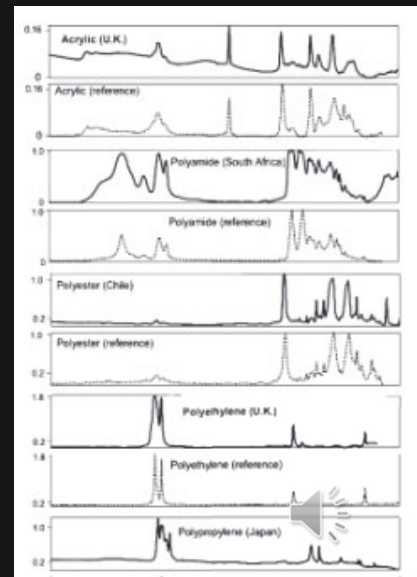
Mark Anthony Browne,^{*,1,4,5} Phillip Crump,¹ Stewart J. Niven,^{5,6} Emma Teuten,⁵ Andrew Tonkin,¹ Tamara Galloway,¹ and Richard Thompson⁵

A

No. of microplastic 250 mL⁻¹ sediment

- 1-10
- 11-20
- 21-30
- 31-40

Browne, Crump, Niven, Tonkin, Galloway and Thompson 2011



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Substantial accumulation in Arctic sea ice

AGU PUBLICATIONS

Earth's Future

RESEARCH ARTICLE Global warming releases microplastic legacy frozen in Arctic Sea ice

10.1002/2014EF000240

Key Points:

- Arctic Sea ice from remote locations contains tiny particles of microplastics
- Polymers in microplastics were identified using Fourier transform infrared spectroscopy

Rachel W. Obbard¹, Saeed Sadri², Ying Qi Wong¹, Alexandra A. Khitun¹, Ian Baker¹, and Richard C. Thompson²

¹Thayer School of Engineering at Dartmouth College, Hanover, New Hampshire, USA, ²Marine Biology and Ecology Research Centre, School of Marine Science and Engineering, University of Plymouth, Plymouth, UK

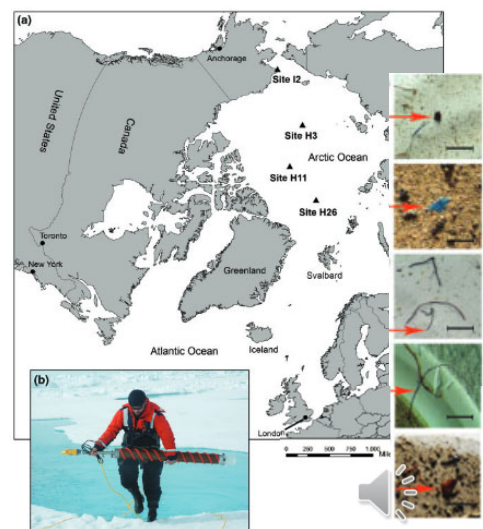


Figure 1. (a) Location of sea ice cores where microplastics, identified by Fourier transform infrared (FTIR) spectroscopy, were found (map by R. Lieb-Lappen, Thayer School of Engineering at Dartmouth College). (b) Sea ice core being collected during the NASA ICESCAPE expedition in July 2010 (photo courtesy of D. Perovich, CRREL).

Obbard, Sadri, Bakir, Thompson *et al.* 2014

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Substantial global accumulation far from human sources

3500m below sea level

8400m above sea level

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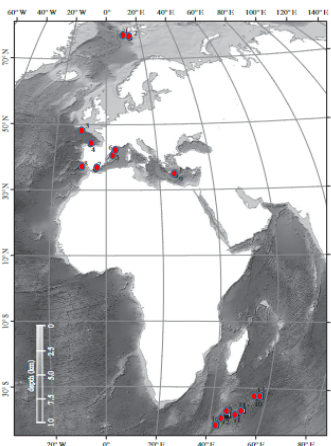
Cite this article: Woodall LC *et al.* 2014 The deep sea is a major sink for microplastic debris. *R. Soc. open sci.* 1: 140317. <http://dx.doi.org/10.1098/rsos.140317>

Received: 18 September 2014
Accepted: 18 November 2014

Subject category:
Earth science

Woodall, Sleight,
Coppock, Thompson *et al.* 2014

The deep sea is a major sink
for microplastic debris



One Earth

Article

Reaching New Heights in Plastic Pollution—
Preliminary Findings of Microplastics on Mount
Everest

NATIONAL
GEOGRAPHIC

Microplastics found near Everest's
peak, highest ever detected in the
world

From thinning glaciers to plastic pollution, a slew of new studies discover alarming signs of our environmental toll.



Napper, Thompson *et al.* 2020

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Accumulation in wild caught fish from UK waters

Marine Pollution Bulletin 67 (2013) 94–99

Contents lists available at SciVerse ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

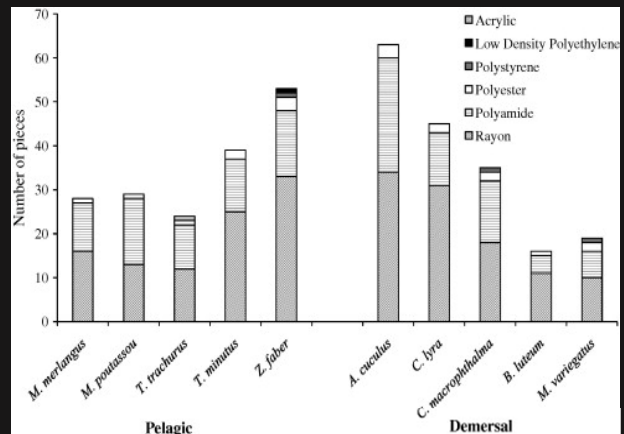
Occurrence of microplastics in the gastrointestinal tract of pelagic and demersal fish from the English Channel

A.L. Lusher^a, M. McHugh^b, R.C. Thompson^{a,*}

^aSchool of Marine Science and Engineering, Plymouth University, Drake Circus, Plymouth PL4 8AA, UK
^bMarine Biological Association of the United Kingdom, The Laboratory, Citadel Hill, Plymouth PL1 2PB, UK

ARTICLE INFO

Keywords:
Marine debris
Plastic
Feeding
Fishes
Polymer



504 individuals, 10 species
including those eaten by humans
Microplastics in gut of 36.5 %

Lusher, Mc Hugh, Thompson, 2013



10

Transfer from intestine to circulatory system and retained in tissues for several weeks

Environ. Sci. Technol. 2008, 42, 5026–5031

Ingested Microscopic Plastic Translocates to the Circulatory System of the Mussel, *Mytilus edulis* (L.)



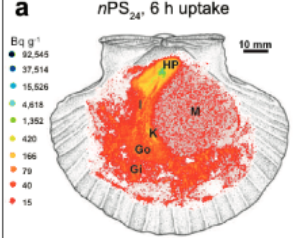
Browne, Dissanayake, Lowe, Galloway, Thompson *et al.* 2008

ENVIRONMENTAL Science & Technology

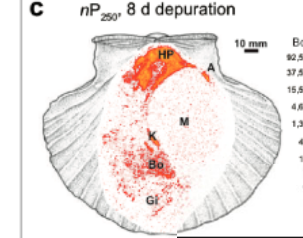
Cite This: Environ. Sci. Technol. 2018, 52, 14480–14486

Uptake, Whole-Body Distribution, and Depuration of Nanoplastics by the Scallop *Pecten maximus* at Environmentally Realistic Concentrations

a nPS₂₄ 6 h uptake



c nP₂₅₀ 8 d depuration



Nanoplastic had moved throughout the body in 6 hours

Al Sid Cheick, Rowland, Thompson *et al.* 2018

11

Nano plastics transfer from intestine throughout the body of a scallop in 6 hours and retained in tissues for several weeks

ENVIRONMENTAL Science & Technology

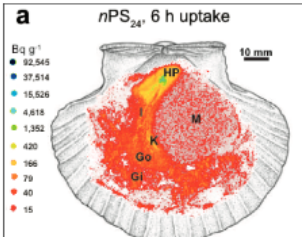
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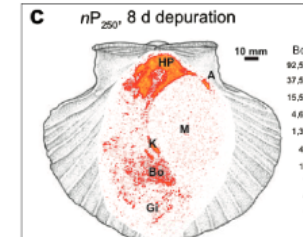
Maya Al-Sid-Cheikh,^{1,†} Steve J. Rowland,² Karen Stevenson,³ Claude Rouleau,¹ Theodore B. Henry,^{1,‡} and Richard C. Thompson^{*,1}

¹School of Biological and Marine Sciences, University of Plymouth, Drake Circus, Plymouth, PL4 8AA, UK
²School of Geography, Earth and Environmental Sciences, University of Plymouth, Drake Circus, Plymouth Kingdom
³Charles River, Elphinstone Research Centre, Elphinstone, Tranent EH33 2NE, United Kingdom
[†]Institut des Sciences de la Mer de Rimouski (ISMER), Université du Québec à Rimouski, 310 allée des Îles Québec Canada G5L 3A1
[‡]Institute of Life and Earth Sciences Heriot-Watt University, John Muir Building, Edinburgh, EH14 4AS, UK

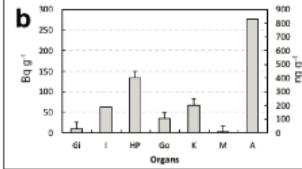
a nPS₂₄ 6 h uptake



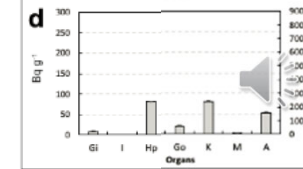
c nP₂₅₀ 8 d depuration



b



d



Al Sid Cheick, Rowland, Thompson *et al.* 2018

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Cosmetics as a source of microplastics



A paper that led to worldwide legislation

A triumph and a frustration in



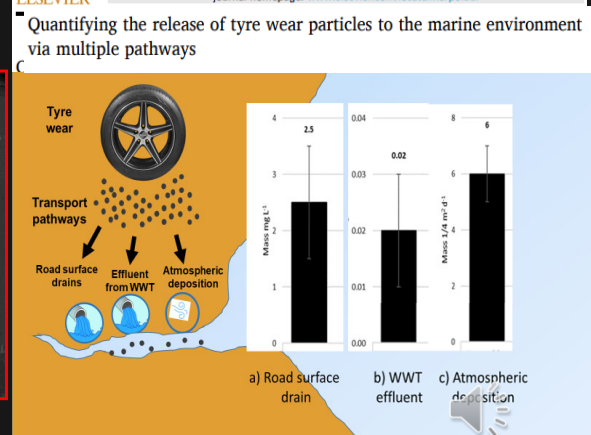
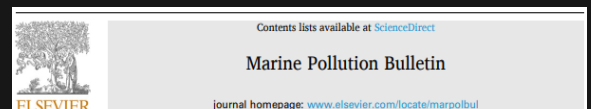
Napper, Bakir, Rowland and Thompson, 2015

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Tyre wear particles a major source - air and stormwater key pathways



Knight, Parker-Jurd, Al-Sid-Cheikh and Thompson, 2020



Parker-Jurd, Thompson, et al 2021

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Textiles as a major source and wastewater a major pathway for microplastics

Contents lists available at ScienceDirect
Marine Pollution Bulletin
 ELSEVIER journal homepage: www.elsevier.com/locate/marpolbul

Release of synthetic microplastic plastic fibres from domestic washing machines: Effects of fabric type and washing conditions
 Imogen E. Napper ^{*}, Richard C. Thompson

Polyester-Cotton Blend	Polyester	Acrylic
Average (Mean) Fibre Dimensions for Each Fabric Type		
Fibre diameter: 17.74 µm	Fibre diameter: 11.91 µm	Fibre diameter: 14.05 µm
Fibre length: 4.99 mm	Fibre length: 7.79 mm	Fibre length: 5.44 mm
Estimated Fibres Released Per Wash (60g)		
137,951	496,030	728,789

Napper and Thompson, 2016

ENVIRONMENTAL Science & Technology
 pubscs.org/est Article

Microfiber Release to Water, Via Laundering, and to Air, via Everyday Use: A Comparison between Polyester Clothing with Differing Textile Parameters

The diagram illustrates the pathways of microfiber release. On the left, a washing machine is shown with an arrow labeled 'WATER' pointing to a body of water containing red microfibers. On the right, a person is shown with an arrow labeled 'AIR' pointing to a cloud containing red microfibers. A central box shows a person walking, with arrows indicating the release of fibers into both the air and water environments.

De Falco, Thompson, et al. 2020

Rivers as a key pathway to the ocean

WATER RESEARCH 75 (2015) 63–82
 Available online at www.sciencedirect.com
 ScienceDirect
 ELSEVIER journal homepage: www.elsevier.com/locate/watres

Review

Microplastics in freshwater systems: A review of the emerging threats, identification of knowledge gaps and prioritisation of research needs

Dafne Erkes-Medrano ^{a,*}, Richard C. Thompson ^b, David C. Aldridge ^a

^a Aquatic Ecology Group, Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, United Kingdom
^b Marine Biology and Ecology Research Centre (MBERC), School of Marine Science and Engineering, Plymouth University, Drake Circus, Plymouth, Devon PL4 8AA, United Kingdom

Erkes-Medrano, Thompson, Aldridge, 2015

Contents lists available at ScienceDirect
Environmental Pollution
 ELSEVIER journal homepage: www.elsevier.com/locate/envpol

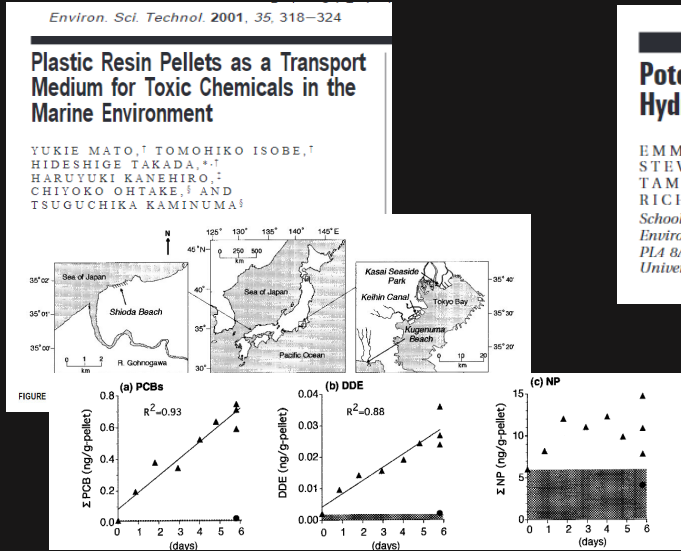
The abundance and characteristics of microplastics in surface water in the transboundary Ganges River[☆]

Imogen E. Napper ^{a,*}, Anju Baroth ^b, Aaron C. Barrett ^c, Sunanda Bhola ^b, Gawsia W. Chowdhury ^{d,e}, Bede F.R. Davies ^f, Emily M. Duncan ^g, Sumit Kumar ^b, Sarah E. Nelms ^h, Richard C. Thompson ^a

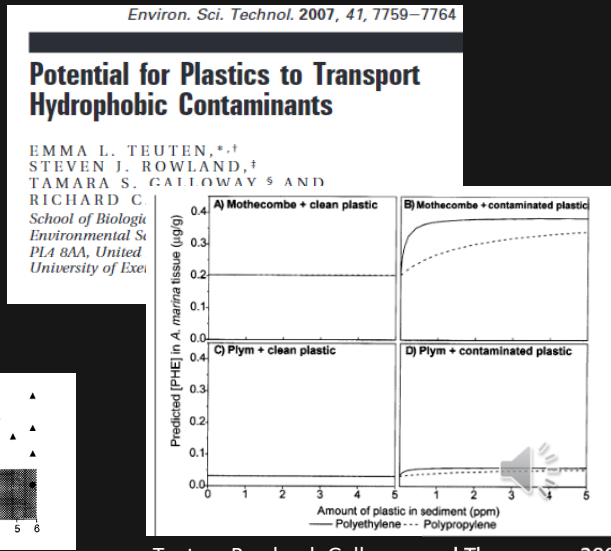


Napper, Thompson, Nelms, Duncan, Koldeway et al, 2021

Key work in Japan influenced our thinking on the transport of toxic chemicals by plastics



Mato, Isobe, Takada, Kanehiro, Ohtake and Kaminuma; 2001



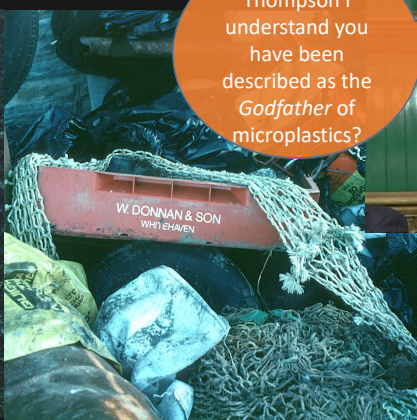
Teuten, Rowland, Galloway and Thompson; 2007

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Marine Biologist to 'Godfather' of Micropalastics



1994



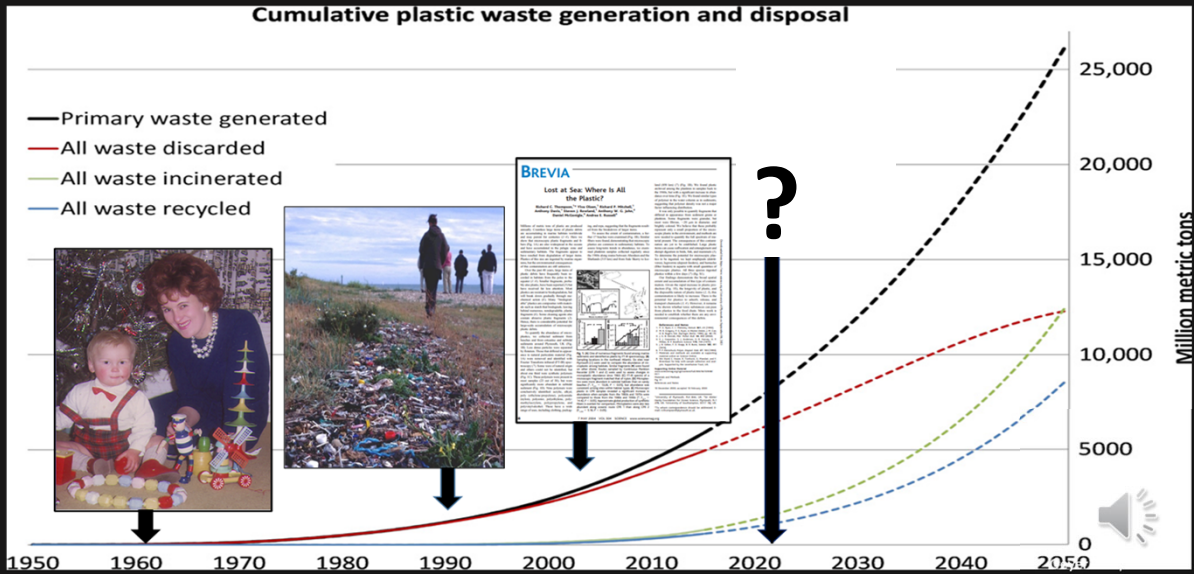
Professor Thompson I understand you have been described as the Godfather of micropalastics?



Mary Greagh, MP, 2016

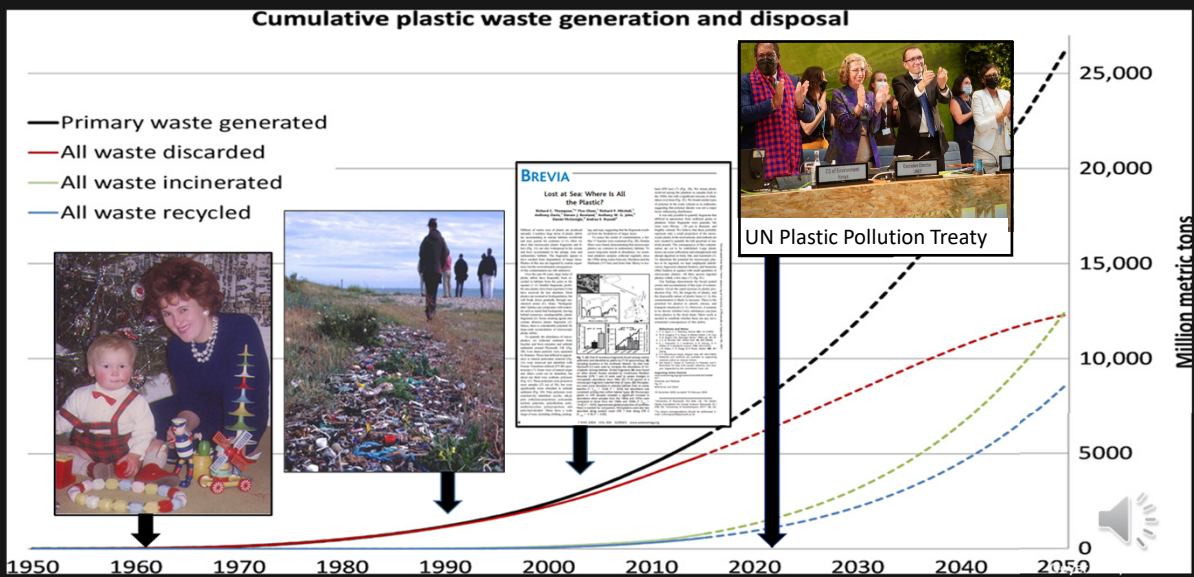
18

Right place – right time, hard work, 100 papers, what next ?



19

Right place – right time, hard work, 100 papers, what next ?



Our Blue Planet - its future and ours - is in our hands!

20



Prof Tamara Galloway OBE
Environmental impacts and consequences for human health



Environmental impacts and consequences for human health

Prof Tamara Galloway OBE
t.s.galloway@exeter.ac.uk





University of Exeter

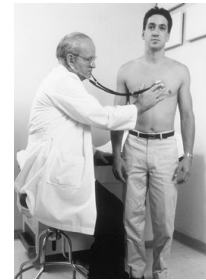


Ecotoxicology research group

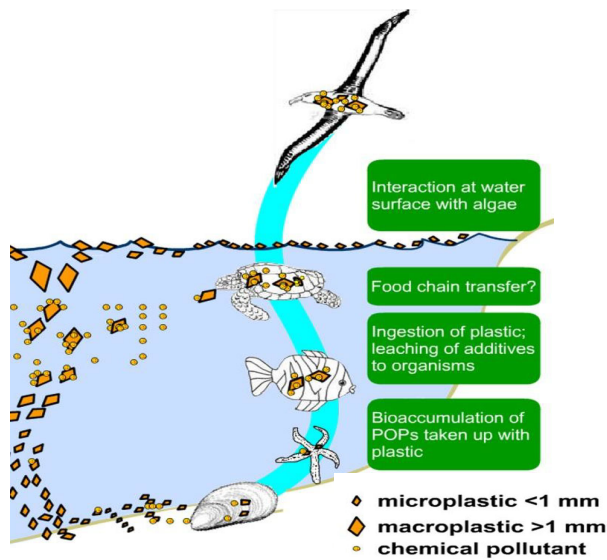
How does pollution damage living things?

What makes some species more vulnerable?

How can we use this knowledge to protect the environment and human health?



Which species to study?



Investigating microplastic trophic transfer in marine top predators*

Sarah E. Nelms^{1,2,3}, Tamara S. Galloway¹, Brendan J. Godley^{4,5}, Dan S. Jarvis¹, Penelope S. Lindgo^{6,7}

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²Centre for Ecology and Conservation, University of Exeter, Devon

³Environment and Change, University of Exeter, Devon

⁴Department of Zoology, University of Exeter, Devon

⁵Department of Biology, University of Exeter, Devon

⁶Department of Chemistry, University of Exeter, Devon

⁷Department of Physics, University of Exeter, Devon

Correspondence

Microplastic ingestion decreases energy reserves in marine worms

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¹Department of Biology, University of Exeter, Devon

²Department of Zoology, University of Exeter, Devon

³Department of Chemistry, University of Exeter, Devon

⁴Department of Physics, University of Exeter, Devon

⁵Department of Mathematics, University of Exeter, Devon

⁶Department of Engineering, University of Exeter, Devon

⁷Department of Mechanical Engineering, University of Exeter, Devon

seawater and sinks out of suspension to sediments; >25% of microplastics sampled from estuarine sediments ingested by *A. marina* were PVC [5]. Thus, we selected LUPVC, mimicking the size and shape of sediment (130 µm mean diameter; Figure 1E). We assessed chronic effects on feeding activity, immunity and energy reserves, and made short term observations on gut residence times.

Worms chronically exposed to 5% LUPVC by weight displayed significantly reduced feeding activity compared to control and 1% LUPVC-exposed worms (Figure 1A), supporting recent findings whereby 7.4% polystyrene by weight inhibited feeding activity in *A. marina* over 10 days [8]. Reduced feeding activity implies that either fewer particles are ingested overall or a lack of a protein coating on the

Ingested Microscopic Plastic Translocates to the Circulatory System of the Mussel, *Mytilus edulis* (L)

MARK A. BROWN^{1,2}, ANASTASIA DISSANAYAKE¹, TAMARA S. GALLOWAY¹, DAVID M. LITTLE^{1,3,4}, RICHARD C. THOMPSON¹

¹School of Biological Sciences, University of Plymouth, Drake Circus, Plymouth, PL4 8AA, U.K., and ²Plymouth Marine Laboratory, Prospect Place, Plymouth, PL1 2DB, U.K.

³Department of Zoology, University of Exeter, Devon

⁴Department of Chemistry, University of Exeter, Devon

Microplastic Ingestion by Zooplankton

Matthew Cole^{1,2}, Emma Lindgo¹, Eileen Homan¹, Claudia Habba¹, Rory Goodhead¹, Julian Morgan¹, and Tamara S. Galloway¹

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³School of Engineering, Mathematics and Physical Sciences, Physics Building, University of Exeter, Exeter, Devon, U.K.

⁴Department of Environmental Science, Bioscience, Geoffrey Pope Building, University of Exeter, Exeter, Devon, U.K.

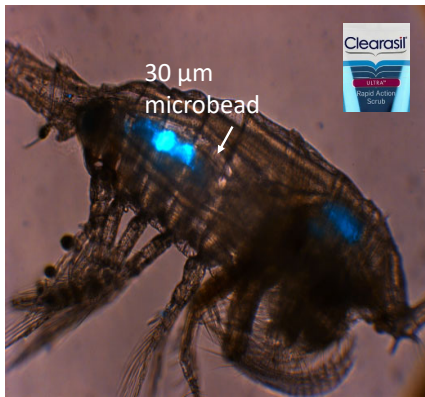
⁵Department of Chemistry, University of Exeter, Devon

⁶Department of Physics, University of Exeter, Devon

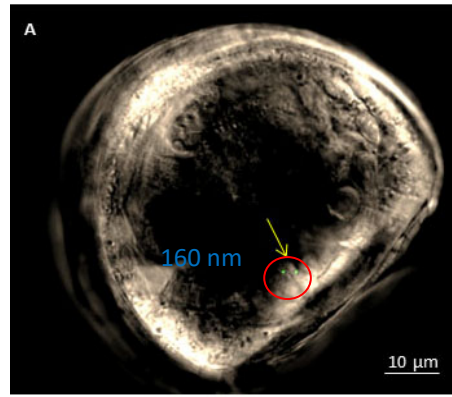
⁷Department of Mathematics, University of Exeter, Devon

⁸Department of Mechanical Engineering, University of Exeter, Devon

Microplastics enter the food web



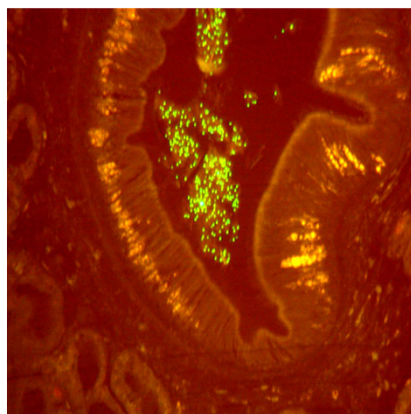
Centropages typicus marine copepod



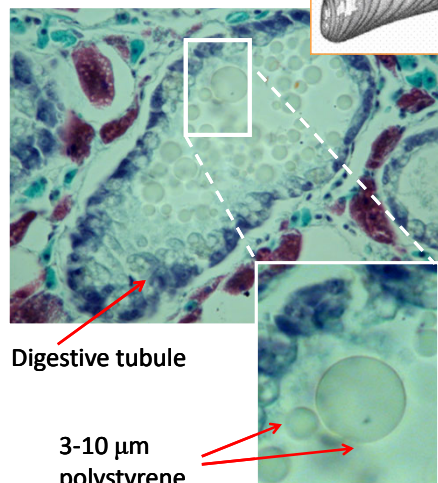
Crassostrea gigas: edible oyster

Cole and Galloway, ES&T 2015, Cole et al ES&T 2013

Particles are ingested and pass to the digestive tubules

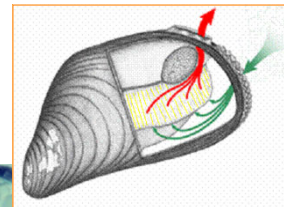


3 µm fluorescent polystyrene in gut cavity of *M. edulis*



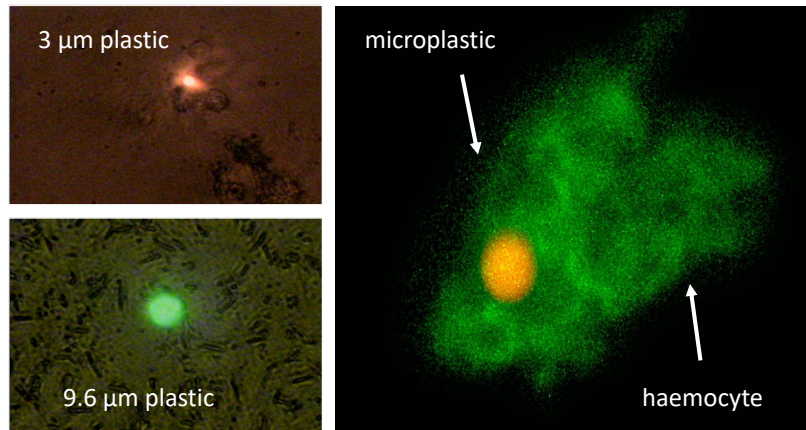
Digestive tubule

3-10 µm polystyrene



Browne et al., 2007 ES&T

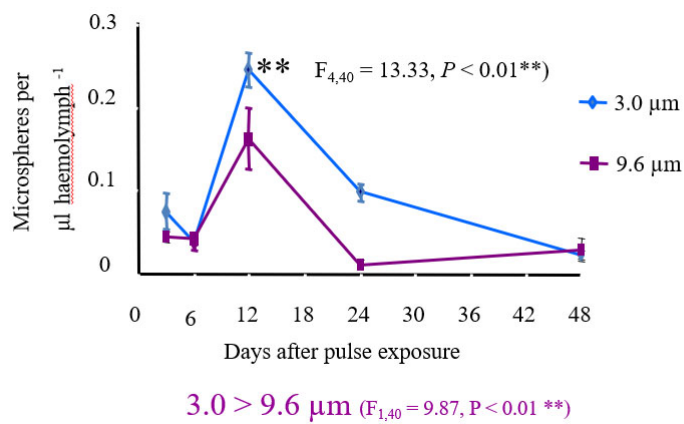
And accumulate in haemolymph



Browne et al 2007 ES&T

27

Particles are retained for up to 48 days



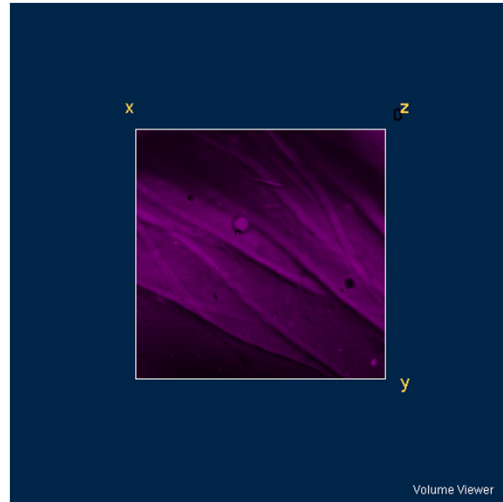
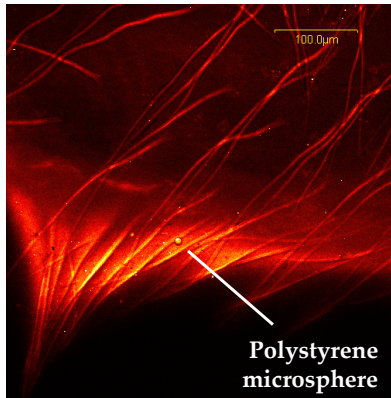
Browne et al 2007 ES&T

28

Microplastics retained by foregut setae

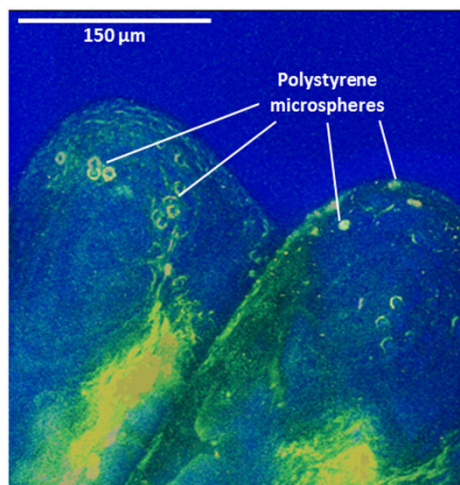


Raman scattering image at 2845 cm^{-1} (C-H bond resonance)

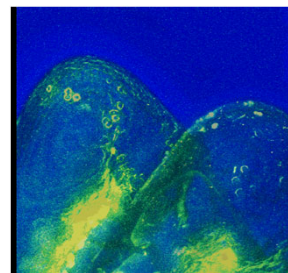


Watts et al., 2014 ES&T

.. and adhered to gill lamellae

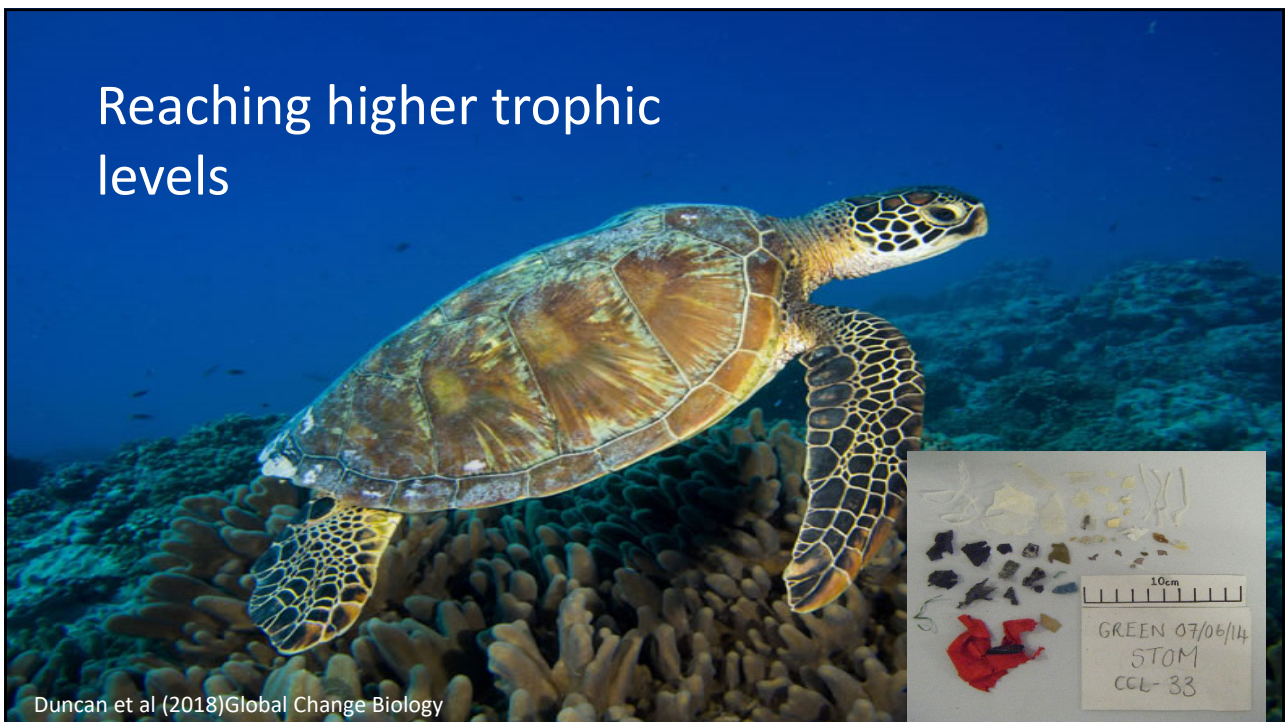


Resonance tuned to 803.2 nm (Aromatic C-H)



Watts et al., 2014 ES&T

Reaching higher trophic levels

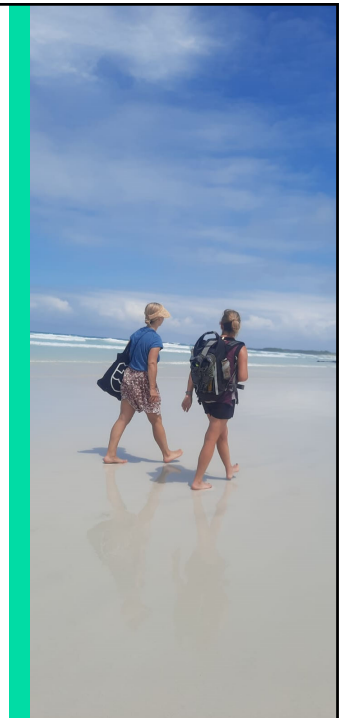


Duncan et al (2018) Global Change Biology

31

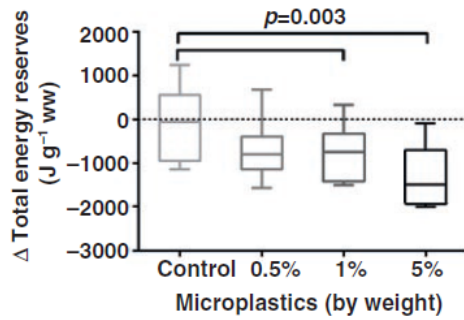


What harm do they cause?



32

Mounting microplastic pollution harms 'earthworms of the sea' – report

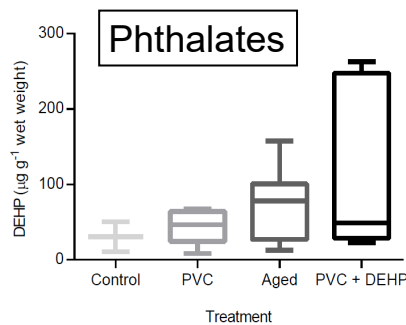
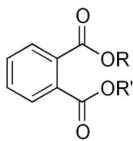


Worms cultured for 1 month in sediment with 1% pristine PVC

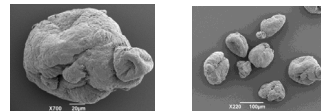


Wright et al Current Biology 2013

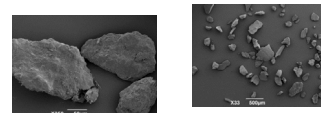
Transfer of intrinsic chemicals?



Worms cultured for 1 month in sediment with 1% plasticised PVC

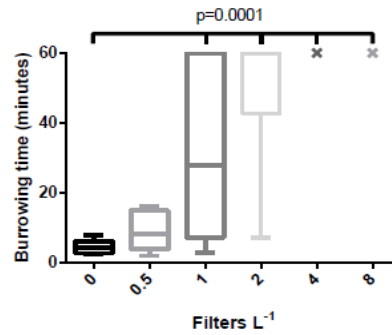
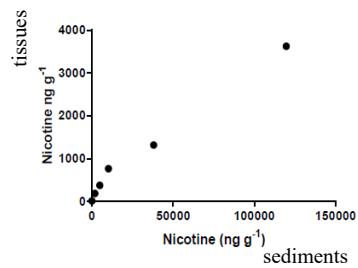
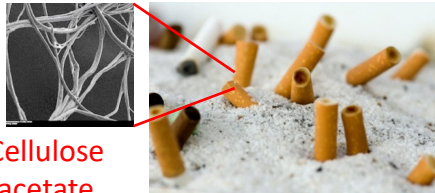


PVC particles 150- 250 µm



sediments < 250 µm

Transfer of adhered pollutants?



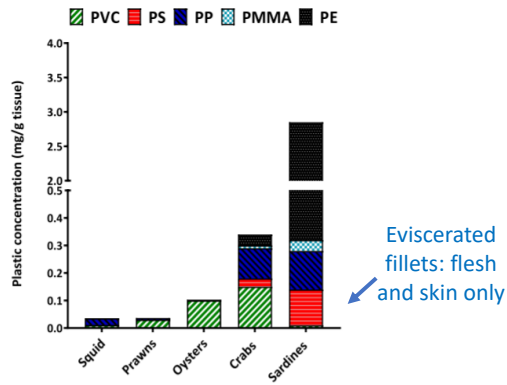
35

Are humans exposed to microplastics?



36

Microplastics in seafood



provided the author and source are cited.

ENVIRONMENTAL Science & Technology

pubs.acs.org/est

Article

Quantitative Analysis of Selected Plastics in High-Commercial-Value Australian Seafood by Pyrolysis Gas Chromatography Mass Spectrometry

Francisca Ribeiro,[#] Elvis D. Okoffo, Jake W. O'Brien, Sarah Fraissinet-Tachet, Stacey O'Brien, Michael Gallen, Saer Samanipour, Sarit Kasertoon, Jochen F. Mueller, Tamara Galloway, and Kevin V. Thomas

Check This Environ. Sci. Technol. 2020, 54, 9408–9417

Read Online

Human consumption:
Average meal of 3 sardines = 30mg plastic



Ribiero et al ES&T 2020

Modelled exposure estimates

- Average person consumes
- 11,000 particles per year from seafood (7µg)
 - 0.1-5g/week* from all food sources
 - 22 million microplastics/year through inhalation



Common activities generating microplastics

Mass change image chemical analysis item

0.4 – 250 particles / cm³



Sobhaniea et al 2020 Sci Rep

Open Access **Research**

BMJ Open An engaged research study to assess the effect of a 'real-world' dietary intervention on urinary bisphenol A (BPA) levels in teenagers

Tamara S Galloway,¹ Nigel Baglin,² Benjamin P Lee,³ Anna L Kocur,³ Maggie H Shepherd,^{4,5} Anna M Steele,^{4,5} BPA Schools Study Consortium,^{6,7,8,9,10,11} Lorna W Harries⁹

To cite: Galloway TS, Baglin N, Lee BP, et al. An engaged research study to assess the effect of a 'real-world' dietary intervention on urinary bisphenol A (BPA) levels in teenagers. *BMJ Open* 2018;0:e018742. doi:10.1136/bmjopen-2018-018742

ABSTRACT
Objective Bisphenol A (BPA) has been associated with adverse human health outcomes and exposure to this compound is near-ubiquitous in the Western world. We aimed to examine whether self-moderation of BPA exposure is possible by altering diet in a real-world setting.
Design An Engaged Research dietary intervention study

Strengths and limitations of this study

- This study represents the largest assessment to date of the potential for moderating one's own bisphenol A (BPA) exposure through diet.
- The study was carried out in a 'real-world' setting rather than a controlled environment.

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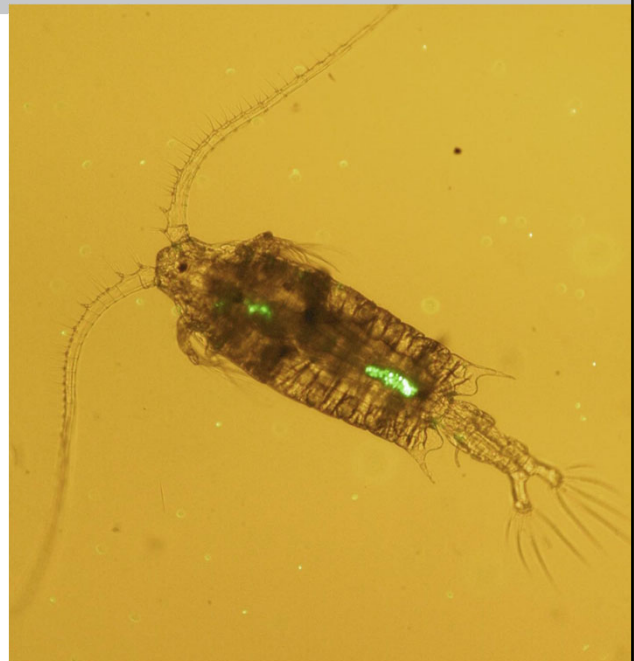
Prof Pennie Lindeque
 Delivering evidence, raising awareness and evaluating solutions

@LindequePk

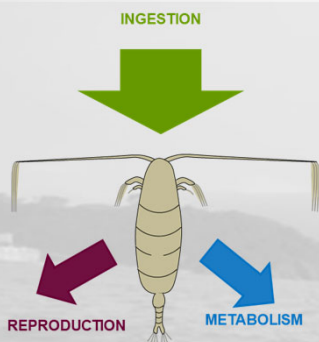
PML | Plymouth Marine Laboratory

40

- Zooplankton are common to marine ecosystems across the globe.
- Provide a key link in the marine food web and play vital roles in marine processes.
- Copepods play an important role in regulating Earth's climate



41

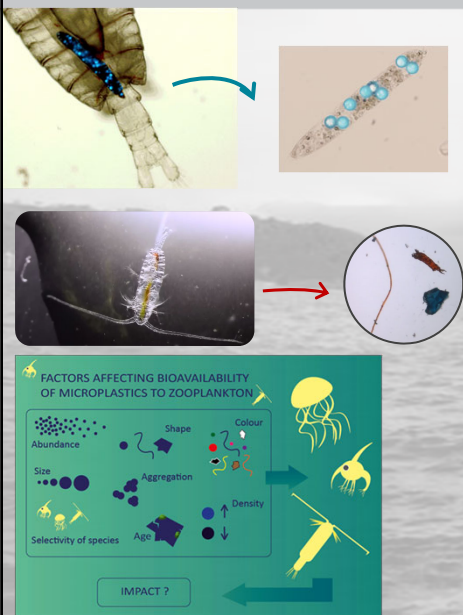


Copepods spend more energy than they consume: ENERGETIC SHORTFALL.



- Zooplankton have the capacity to ingest microplastics
- Reduced feeding capacity
- Decline in energy reserves
- Lower reproductive output
- Direct relevance to animal populations and communities
- Chemical profile of microplastic ingested may act as endocrine disruptors and impact moulting

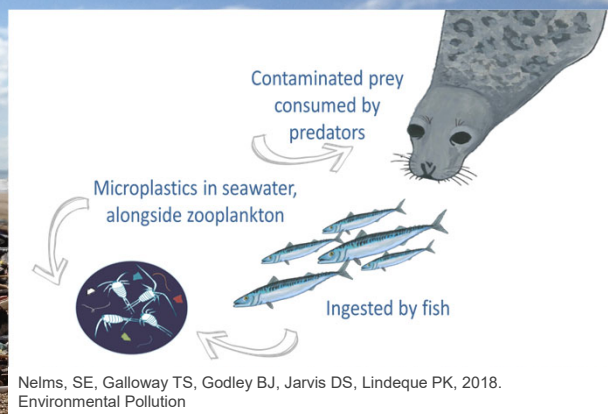
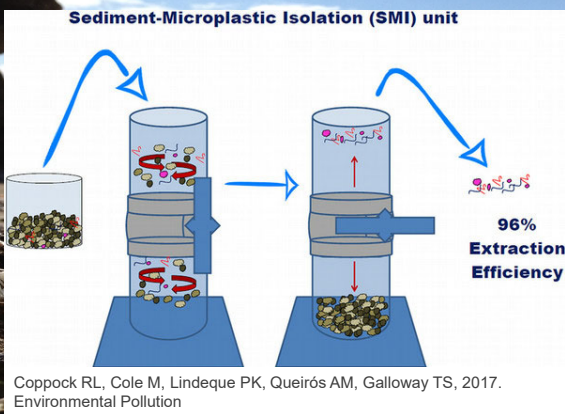
42



Botterell *et al.*, 2020. Environmental Science and Technology

- MP are egested in faecal pellets, alter the properties and sinking rates
- MP have been shown to be consumed by zooplankton in the natural environment
- May select what plastics they eat
- Lab based studies confirm shape of MPs influence their uptake
- Infochemical DMS increases ingestion of MP by zooplankton

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Our work is highly interdisciplinary

Chemistry

Remote sensing

Mathematical modelling

Socioeconomics

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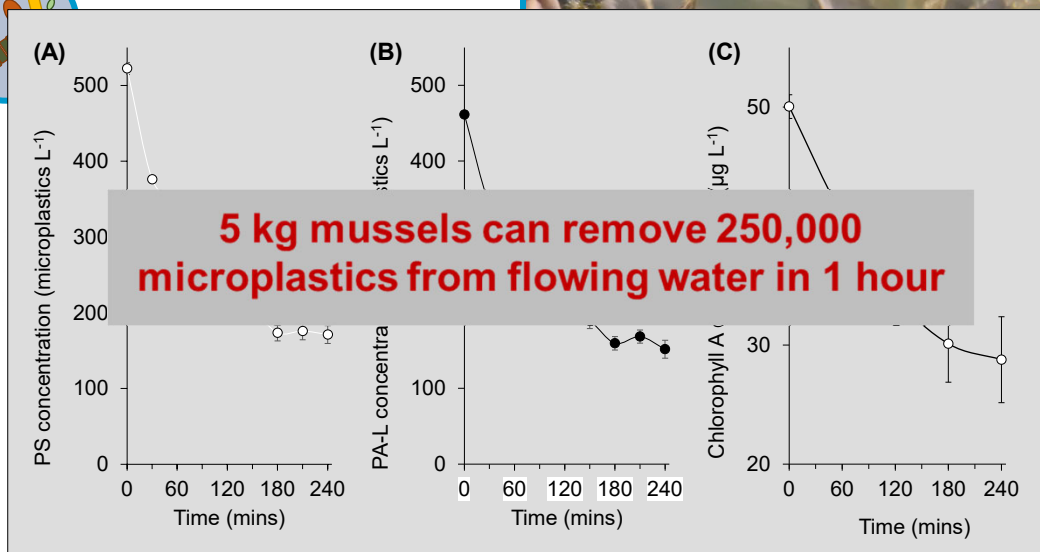
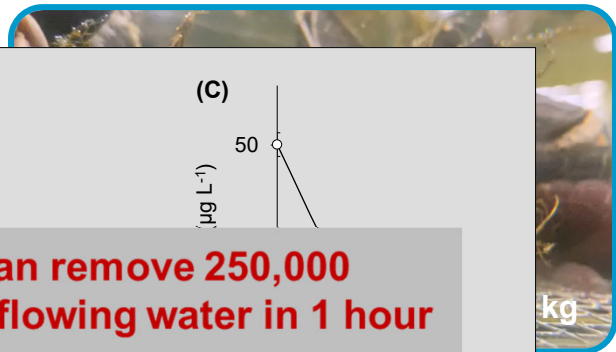
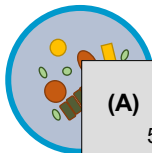
Research excellence supporting a sustainable ocean

- Mussels are pollution tolerant bivalve shellfish
- Voracious filter-feeders
- Natural biofilters that can improve water quality
- Widely evidenced to ingest microplastics



45

Research excellence supporting a sustainable ocean



46

Research excellence supporting a sustainable ocean

buoy

support ropes

cage

5 kg mussels

fine net

cod-end

5kg of mussels resulted in 4.5x more microplastics captured than in controls

Scope to expand testing to multiple sites with greater amount of mussels in stacked system

Cage system whereby mussels can't escape, are protected from predation, allows a flow of water over the mussels

- Clean up of marine litter is important
- Prevention should be the first priority
- Linear Economy
Take → Make → Waste
- Loss of valuable resources + environmental damage
- Consider the whole of a plastics life
- Circular economy

Design

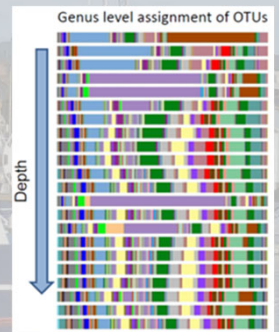
Manufacture

Circular Economy

Reduce, Re-use, Repair, Recycle, Repurpose

Consumption and Use

- Biodegradable bioplastics (BBPs) offer a possible solution
- Renewable carbon feedstock
- Enhanced biodegradation
- Applications with substantive pathways to the natural environment
- Need to improve our understanding of the fate and impact of BBPs
- Help guide development of innovative plastics
- Reduction in fossil fuels, environmentally safe.



Raising Awareness:

- We are passionate about disseminating our research to a wide audience
- Our pioneering work has reached a global audience:

Eating our way to extinction, Plastic Warriros, Inside Out Southwest, The One Show, Food Unwrapped, Springwatch, BBC and ITN news, El Jazeera – Earthrise program, 'Plastic Britain' documentary and Blue Planet II

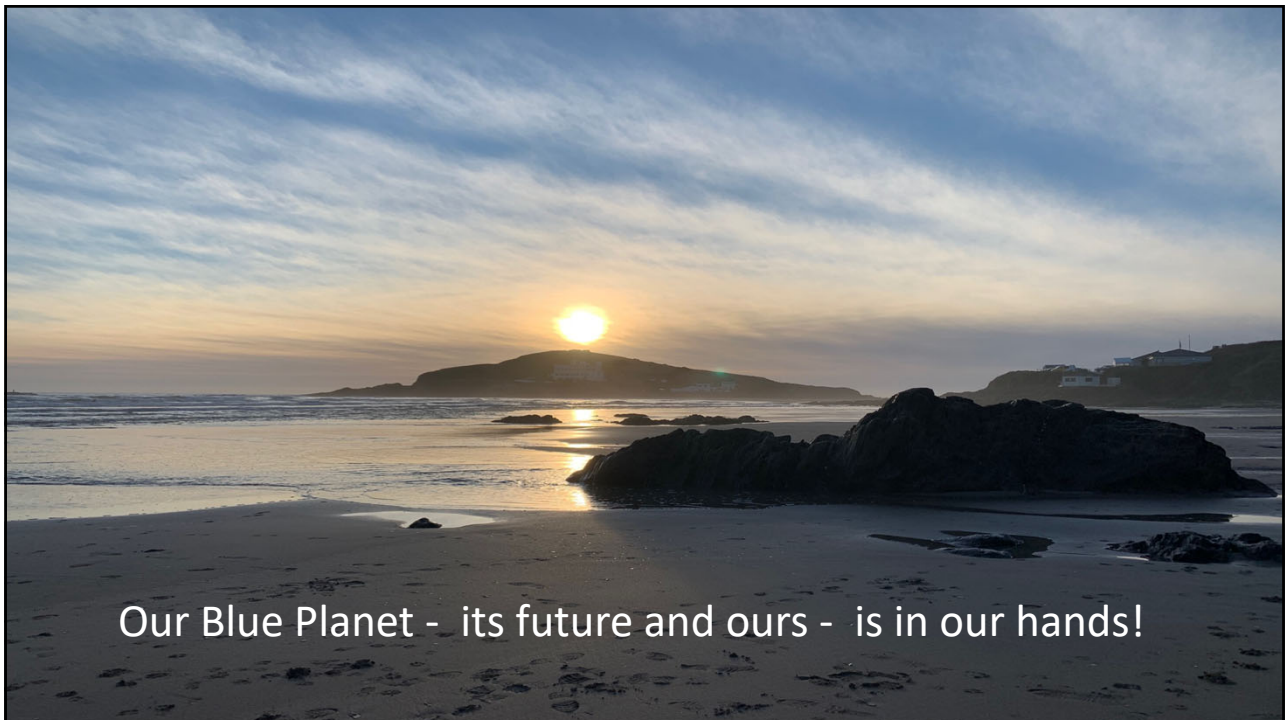


Giving Evidence

- Successful in highlighting the risks MP pose to marine life contributing to introduction of plastic bag levy and ban of cosmetic microbeads:

House of Lords, Parliamentary and Scientific Committee, National and International regulatory bodies, Environmental Audit Committee's collection of written and oral evidence on the Environmental Impact of MP, United Nations hearings on MP

- **Global Plastics Treaty**. Providing evidence to on-going International Negotiating Committee



Our Blue Planet - its future and ours - is in our hands!



Discovering microplastics:
Their environmental accumulation, impacts and solutions
Thank you - 2023 Blue Planet Prize – Commemorative Lecture

Environmental impacts and consequences for human health

Prof Tamara Galloway OBE
t.s.galloway@exeter.ac.uk

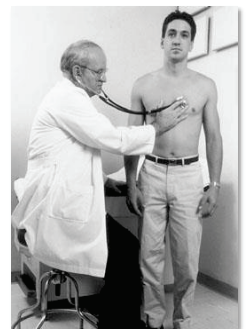


Ecotoxicology research group

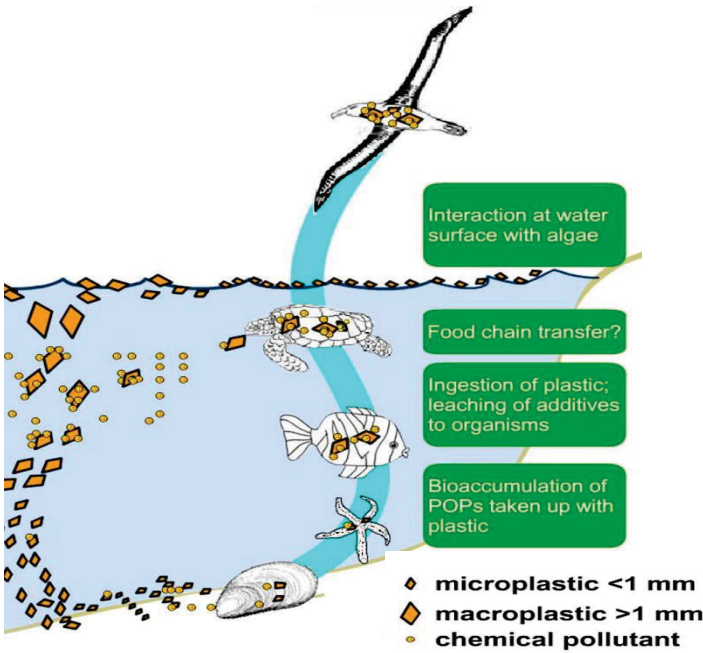
How does pollution damage living
things?

What makes some species more
vulnerable?

How can we use this knowledge to
protect the environment and human
health?



Which species to study?



Environmental Pollution

Investigating microplastic trophic transfer in marine top predators^{2*}

Sarah E. Nelms^{a,b,1}, Tamara S. Galloway^a, Brendan J. Godley^{b,c,d}, Dan S. Jarvis^e, Penelope K. Lindeque^{a,*}

Correspondence

Microplastic ingestion decreases energy reserves in marine worms

Stephanie L. Wright^{1,†}, Darren Rowe¹, Richard C. Thompson¹, and Tamara S. Galloway¹

Microplastic ingestion by marine organisms is increasing in the marine environment, but the effects of microplastic ingestion on the energy reserves of organisms are not clear. We investigated the effects of microplastic ingestion on the energy reserves of the marine polychaete worm *A. marina* over 10 days. Reduced feeding activity implies that either fewer particles are ingested overall or a lack of a protein coating on the

seawater and sinks out of suspension to sediments; >25% of microplastics sampled from estuarine sediments inhabited by *A. marina* were PVC (5). Thus, we selected UPVC, mimicking the size and shape of sediment (30 μm mean diameter; Figure 1E). We assessed chronic effects on feeding activity, immunity and energy reserves and made short term observations on gut residence times. Worms chronically exposed to 5% UPVC by weight displayed significantly reduced feeding activity compared to control and 1% UPVC-exposed worms (Figure 1A), supporting recent findings whereby 7.4% polystyrene by weight inhibited feeding activity in *A. marina* over 10 days (9). Reduced feeding activity implies that either fewer particles are ingested overall or a lack of a protein coating on the

Environ. Sci. Technol. 2008, 42, 5028-5031

Ingested Microscopic Plastic Translocates to the Circulatory System of the Mussel, *Mytilus edulis* (L.)

MARK A. BROWNE,^{1,†} AWANATHA DISSANAYAKE,¹ TANARA S. GALLOWAY,¹ DAVID M. LOWE,¹ AND RICHARD C. THOMPSON¹

School of Biological Sciences, University of Plymouth, Drake Circus, Plymouth, PL4 8AA, U.K., University of Exeter, Prince of Wales Road, Exeter, EX4 4PS, U.K., and Plymouth Marine Laboratory, Prospect Place, Plymouth, PL2 39PL, U.K.

Received February 02, 2008; Revised manuscript received May 01, 2008; Accepted May 07, 2008.

Plastics debris is accumulating in the environment and is fragmenting into smaller pieces as it does, the potential for

Microplastic Ingestion by Zooplankton

Melanie Cole,^{1,†} Anne Lindeque,¹ Elaine Fleming,¹ Claudia Habund,² Rhys Goodhead,³ Julian Moger,⁴ and Tamara S. Galloway¹

¹Plymouth Marine Laboratory, Prospect Place, The Hoe, Plymouth PL1 3DH, United Kingdom

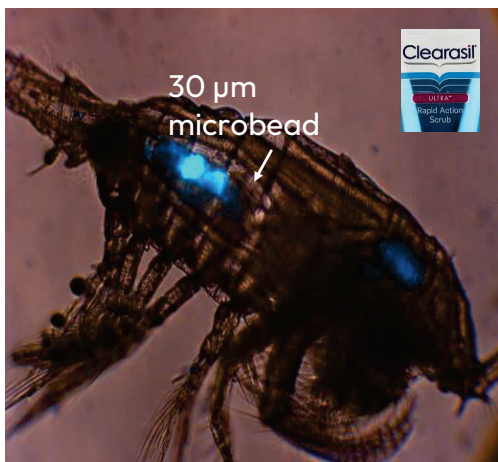
²Department of Biology, University of Exeter, Exeter, EX4 4JF, United Kingdom

³Department of Biology, University of Exeter, Exeter, EX4 4JF, United Kingdom

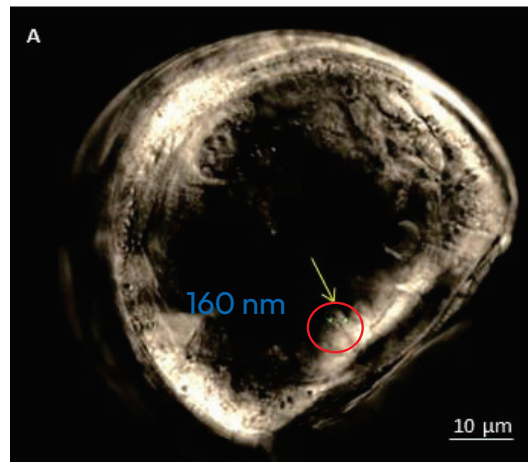
⁴College of Engineering, Mathematics and Physical Sciences, Physics, Physics Building, University of Exeter, Stocker Road, Exeter EX4 4QJ, United Kingdom

ABSTRACT: Small plastic debris, termed "microplastics," are a widespread and ubiquitous component of marine ecosystems. The ingestion of microplastics by marine biota, including diatoms, worms, fish, and seabirds, has been widely reported, but despite their role as critical links in marine food webs, the impact of microplastics on zooplankton remains under-researched. Here, we show that microplastics are ingested by, and may impair upon, zooplankton. We used histological techniques to document ingestion, digestion, and retention of microplastics by a range of zooplankton common to the north-eastern Atlantic Ocean.

Microplastics enter the food web

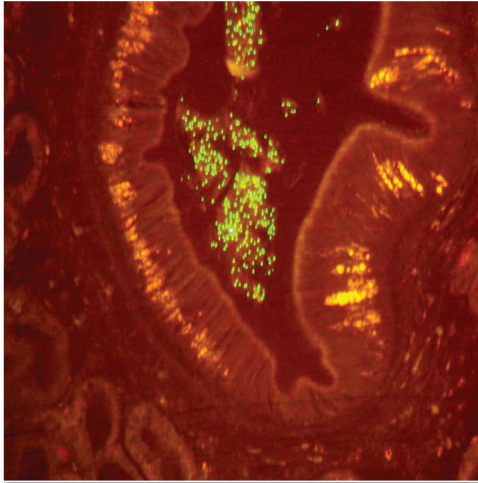
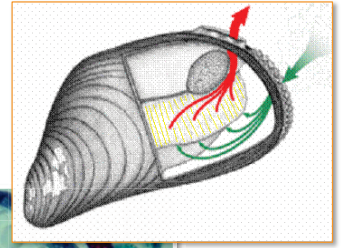


Centropages typicus
marine copepod

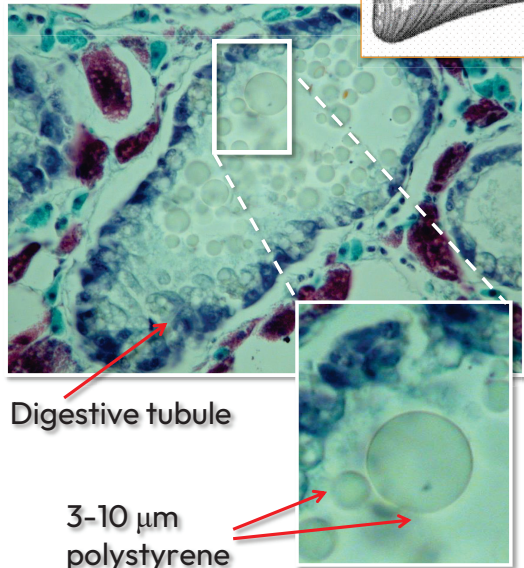


Crassostrea gigas
edible oyster

Particles are ingested and pass to the digestive tubules



3 µm fluorescent polystyrene in gut cavity of *M. edulis*

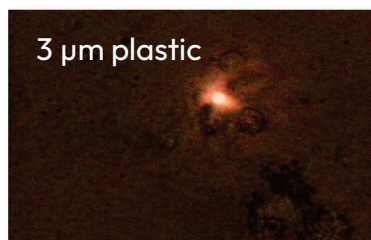


Digestive tubule

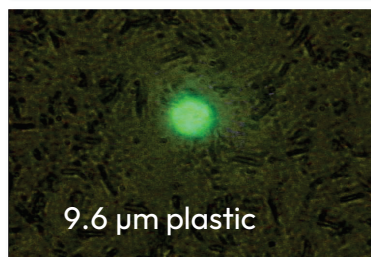
3-10 µm polystyrene

Browne et al., 2007 ES&T

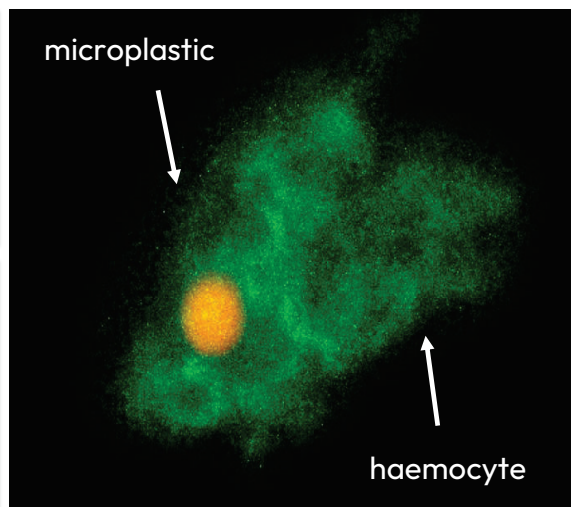
And accumulate in haemolymph



3 µm plastic



9.6 µm plastic

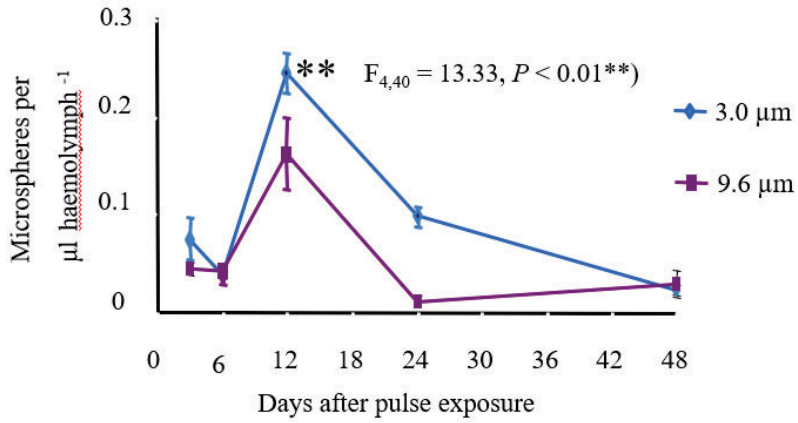


microplastic

haemocyte

Browne et al 2007 ES&T

Particles are retained for up to 48 days



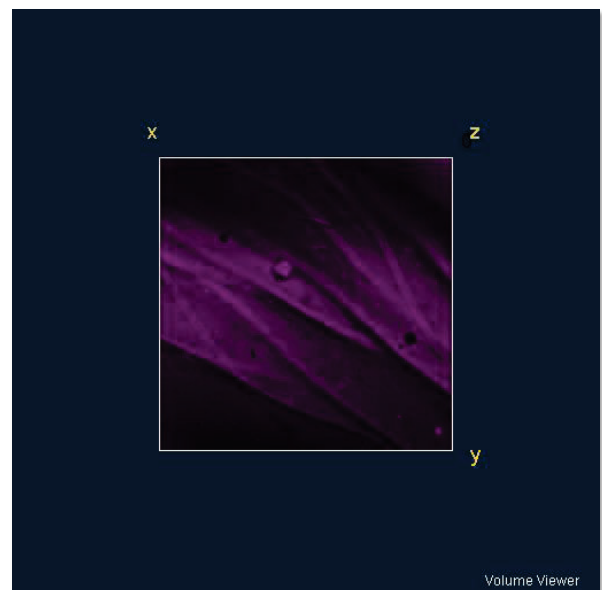
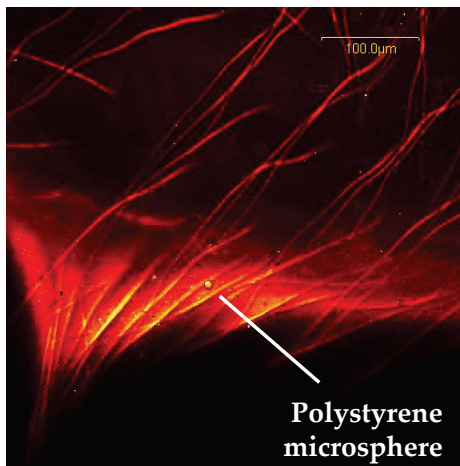
3.0 > 9.6 μm ($F_{1,40} = 9.87, P < 0.01^{**}$)

Browne et al 2007 ES&T

Microplastics retained by foregut setae

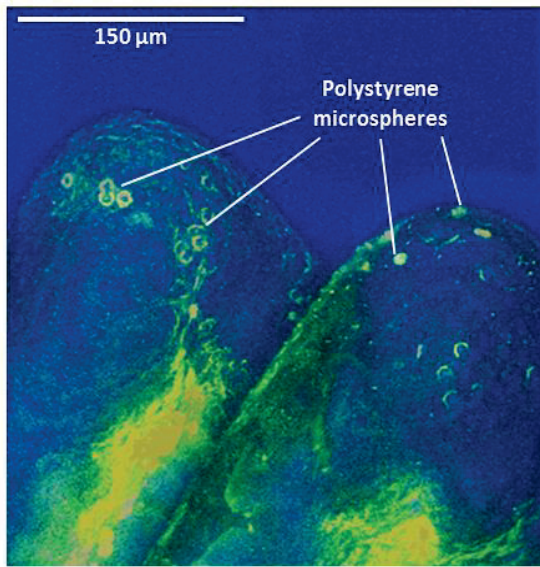


Raman scattering image at 2845 cm^{-1} (C-H bond resonance)

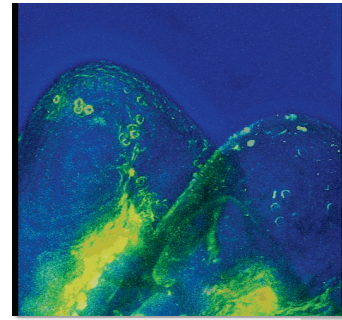


Watts et al., 2014 ES&T

.. and adhered to gill lamellae



Resonance tuned to 803.2 nm (Aromatic C-H)



Gill rakers (modified setae to clean the gills)

Watts et al., 2014 ES&T

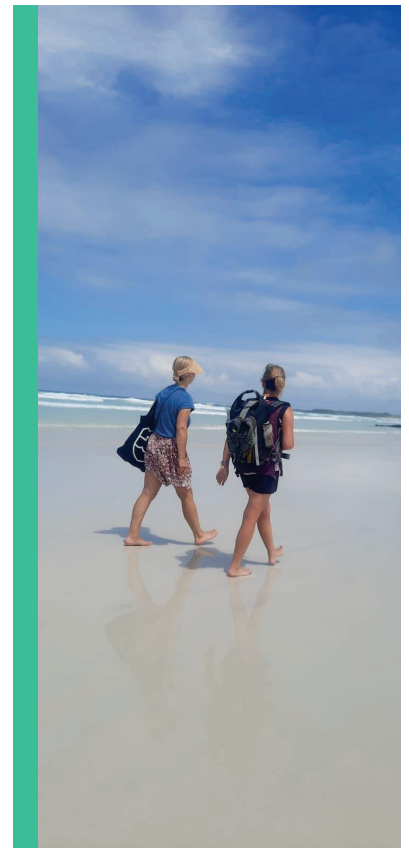
Reaching higher trophic levels



Duncan et al (2018) Global Change Biology

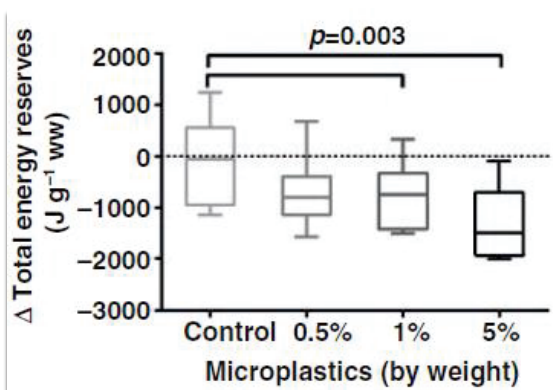


What harm do they cause?



theguardian

Mounting microplastic pollution harms 'earthworms of the sea' – report

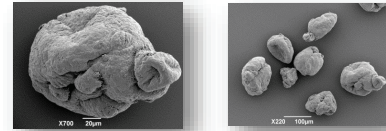
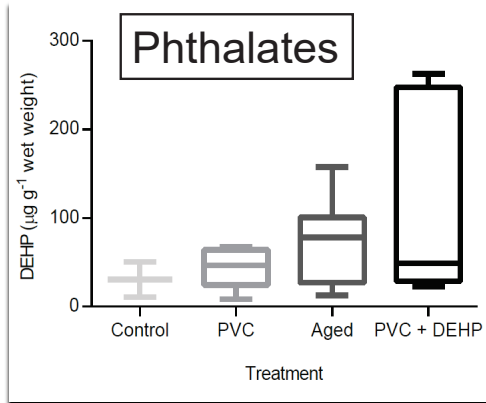
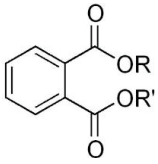


Worms cultured for 1 month in sediment with 1% pristine PVC

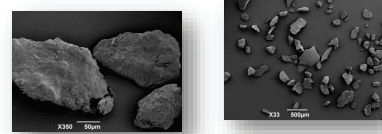


Wright et al Current Biology 2013

Transfer of intrinsic chemicals?



PVC particles 150- 250 µm



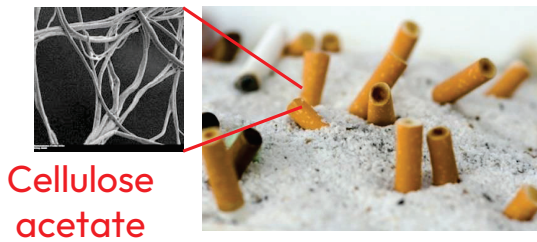
sediments < 250 µm



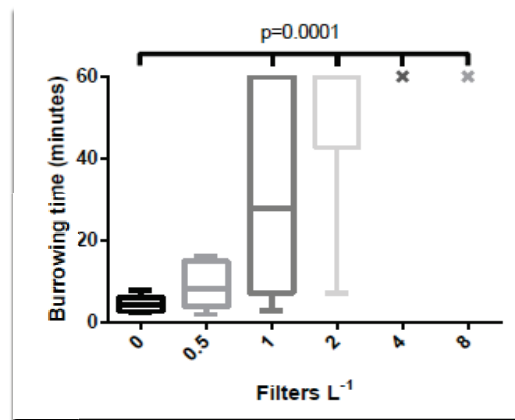
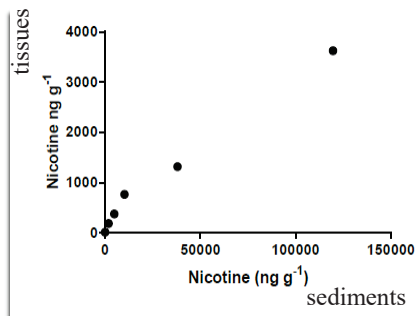
Worms cultured for 1 month in sediment with 1% plasticised PVC

Wright et al unpublished

Transfer of adhered pollutants?



Cellulose acetate

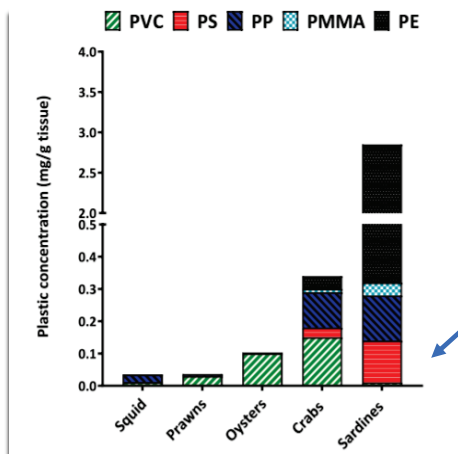


Wright et al., 2015. *Scientific Reports*

Are humans exposed to microplastics?



Microplastics in seafood



Eviscerated fillets: flesh and skin only

Environmental Science & Technology

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Article

Quantitative Analysis of Selected Plastics in High-Commercial-Value Australian Seafood by Pyrolysis Gas Chromatography Mass Spectrometry

Francisca Ribeiro,* Elvis D. Okoffo, Jake W. O'Brien, Sarah Fraissinet-Tachet, Stacey O'Brien, Michael Gallen, Saer Samanipour, Sarit Kaserzon, Jochen F. Mueller, Tamara Galloway, and Kevin V. Thomas

Cite This Environ. Sci. Technol. 2020, 54, 9408–9417

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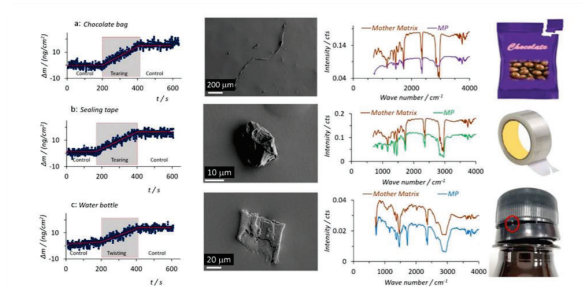
Human consumption:
Average meal of 3 sardines = 30mg plastic

Modelled exposure estimates

- Average person consumes
- 11,000 particles per year from seafood (7µg)
 - 0.1-5g/week* from all food sources
 - 22 million microplastics/year through inhalation



Common activities generating microplastics



Mass change image chemical analysis item

0.4 – 250 particles / cm²



Sobhaniea et al 2020 Sci Rep

Open Access
Research

BMJ Open An engaged research study to assess the effect of a 'real-world' dietary intervention on urinary bisphenol A (BPA) levels in teenagers

Tamara S Galloway,¹ Nigel Baglin,² Benjamin P Lee,³ Anna L Kocur,³ Maggie H Shepherd,^{4,5} Anna M Steele,^{4,5} BPA Schools Study Consortium,^{6,7,8,9,10,11} Lorna W Harries³

To cite: Galloway TS, Baglin N, Lee BP et al. An engaged research study to assess the effect of a 'real-world' dietary intervention on urinary bisphenol A (BPA) levels in teenagers. *BMJ Open* 2018;8:e018742. doi:10.1136/bmjopen-2018-018742

ABSTRACT
Objective Bisphenol A (BPA) has been associated with adverse human health outcomes and exposure to this compound is near-ubiquitous in the Western world. We aimed to examine whether self-moderation of BPA exposure is possible by altering diet in a real-world setting. **Design** An Engaged Research dietary intervention study

Strengths and limitations of this study

- ▶ This study represents the largest assessment to date of the potential for moderating one's own bisphenol A (BPA) exposure through diet.
- ▶ The study was carried out in a 'real-world' setting rather than a regulated, controlled environment.

Listen to the ocean



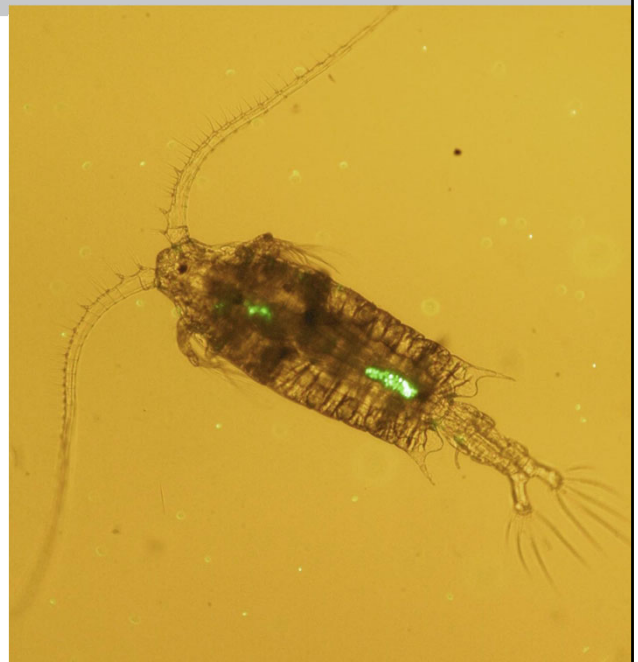
Working towards solutions.

Prof. Pennie Lindeque

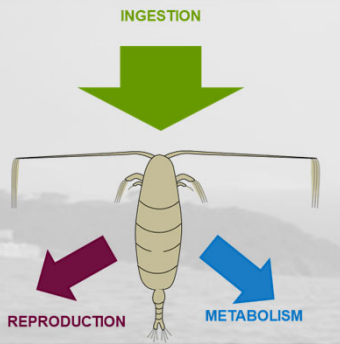


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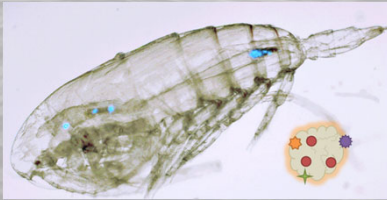
- Zooplankton are common to marine ecosystems across the globe.
- Provide a key link in the marine food web and play vital roles in marine processes.
- Copepods play an important role in regulating Earth's climate



2

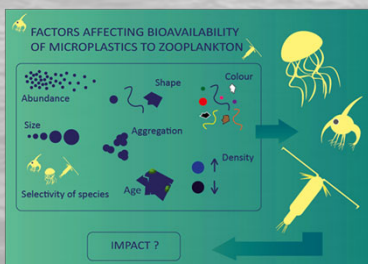


Copepods spend more energy than they consume: **ENERGETIC SHORTFALL.**



- Zooplankton have the capacity to ingest microplastics
- Reduced feeding capacity
- Decline in energy reserves
- Lower reproductive output
- Direct relevance to animal populations and communities
- Chemical profile of microplastic ingested may act as endocrine disruptors and impact moulting

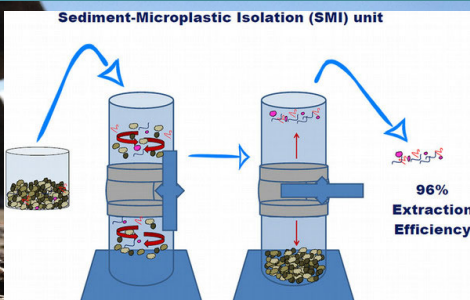
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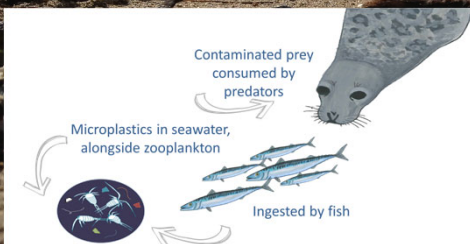
Botterell *et al.*, 2020. Environmental Science and Technology

- MP are egested in faecal pellets, alter the properties and sinking rates
- MP have been shown to be consumed by zooplankton in the natural environment
- May select what plastics they eat
- Lab based studies confirm shape of MPs influence their uptake
- Infochemical DMS increases ingestion of MP by zooplankton

4



Coppock RL, Cole M, Lindeque PK, Queirós AM, Galloway TS, 2017. Environmental Pollution



Nelms, SE, Galloway TS, Godley BJ, Jarvis DS, Lindeque PK, 2018. Environmental Pollution

- Our work is highly interdisciplinary
 - Chemistry
 - Mathematical modelling
 - Remote sensing
 - Socioeconomics
- Our ecological team has **expertise** in:
 - Environmental sampling
 - Method development (e.g. SMI unit)
 - Exposure studies
 - Ecotoxicology
 - Nature-based solutions

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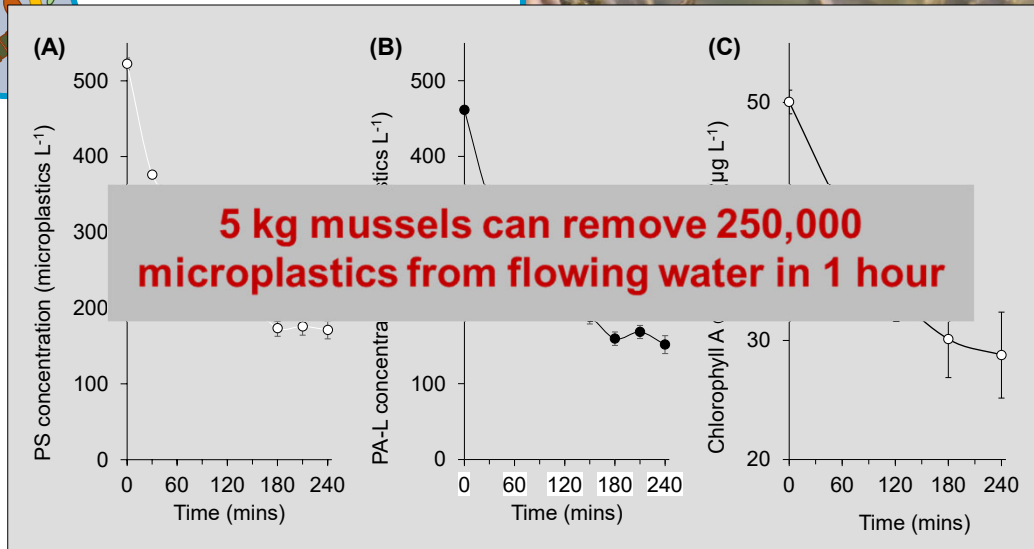
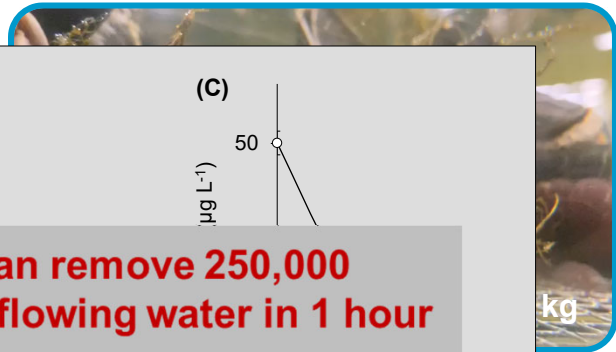
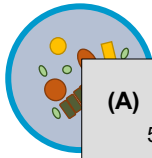
Research excellence supporting a sustainable ocean

- Mussels are pollution tolerant bivalve shellfish
- Voracious filter-feeders
- Natural biofilters that can improve water quality
- Widely evidenced to ingest microplastics



6

Research excellence supporting a sustainable ocean



7

Research excellence supporting a sustainable ocean

5 kg of mussels resulted in 4.5x more microplastics captured than in controls

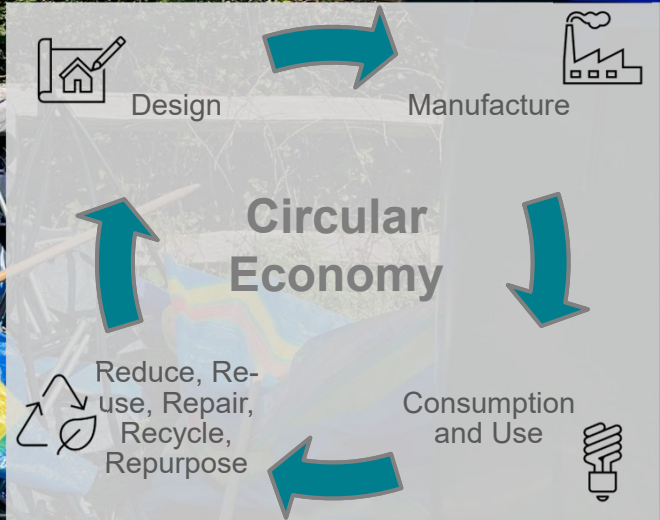
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Scope to expand testing to multiple sites with greater amount of mussels in stacked system

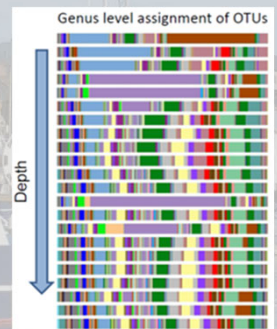
Cage system whereby mussels can't escape, are protected from predation, allows a flow of water over the mussels

8

- Clean up of marine litter is important
- Prevention should be the first priority
- Linear Economy
Take → Make → Waste
- Loss of valuable resources + environmental damage
- Consider the whole of a plastics life
- Circular economy



- Biodegradable bioplastics (BBPs) offer a possible solution
- Renewable carbon feedstock
- Enhanced biodegradation
- Applications with substantive pathways to the natural environment
- Need to improve our understanding of the fate and impact of BBPs
- Help guide development of innovative plastics
- Reduction in fossil fuels, environmentally safe.



Raising Awareness:

- We are passionate about disseminating our research to a wide audience
- Our pioneering work has reached a global audience:

Eating our way to extinction, Plastic Warriors, Inside Out Southwest, The One Show, Food Unwrapped, Springwatch, BBC and ITN news, El Jazeera – Earthrise program, 'Plastic Britain' documentary and Blue Planet II

Giving Evidence

- Successful in highlighting the risks MP pose to marine life contributing to introduction of plastic bag levy and ban of cosmetic microbeads:

House of Lords, Parliamentary and Scientific Committee, National and International regulatory bodies, Environmental Audit Committee's collection of written and oral evidence on the Environmental Impact of MP, United Nations hearings on MP

- Global Plastics Treaty. Providing evidence to on-going International Negotiating Committee



Thank you

