Plastics and the environment

Richard Quilliam

UNIVERSITY of STIRLING


BLUE PLANET II
Take a deep breath
BBC/Blue Planet II

Thomas Ling, Radio Times 20 Nov, 2017

BBC | Your account | News | Sport | Weather | iPlayer | TV | Radio | More | Search

drowning in plastic

Filter | All | News | Programmes | Music | Newsround

Available on iPlayer

Drowning in Plastic

Wildlife biologist Liz Bonnin discovers the true dangers of plastic in our oceans.

BBC One 90 MINS

Available for 21 days First shown: 1 Oct 2018

Entanglement

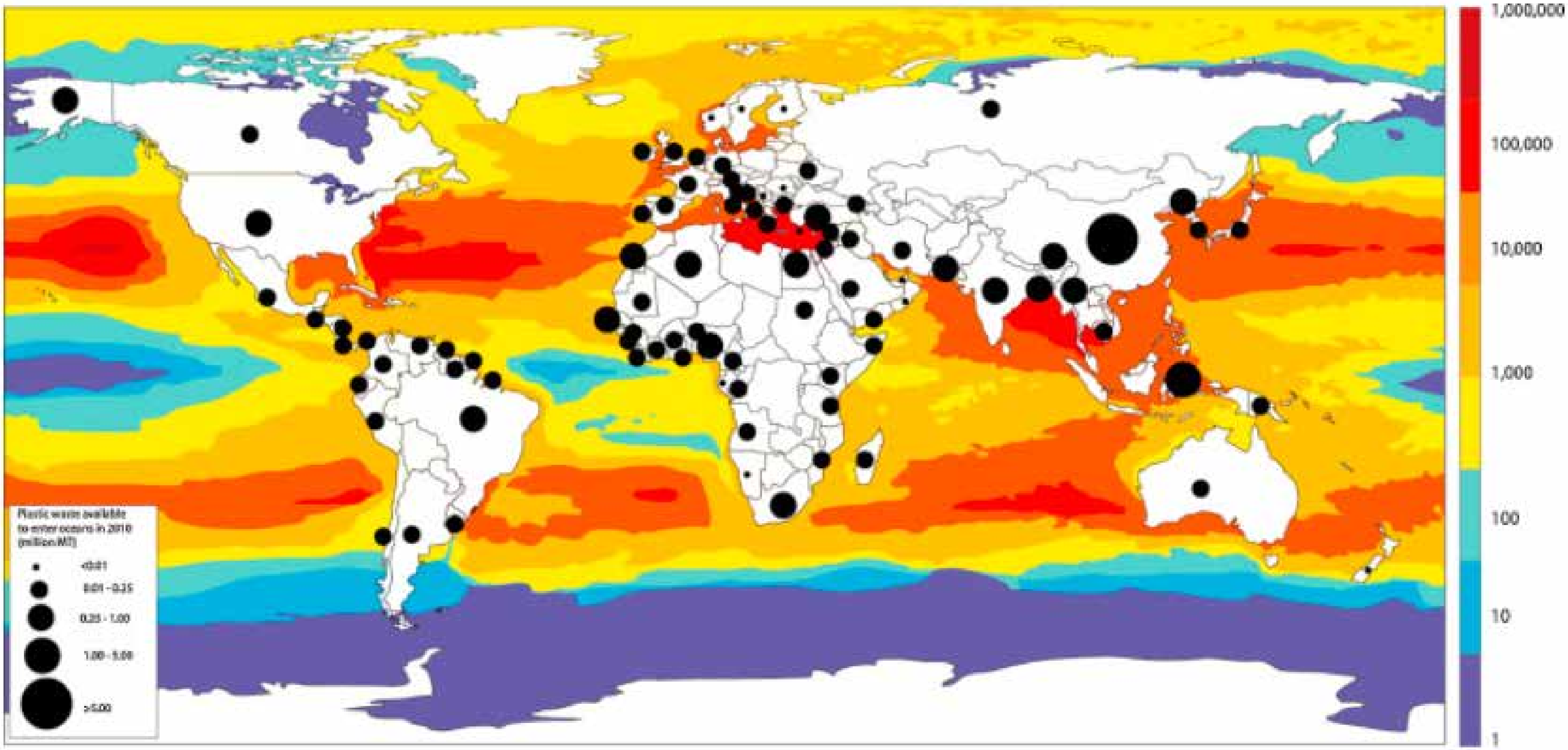


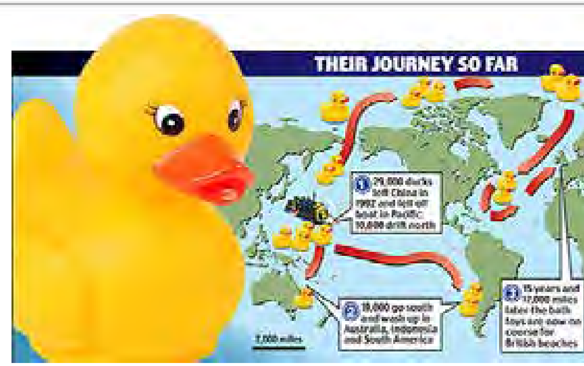

Ingestion

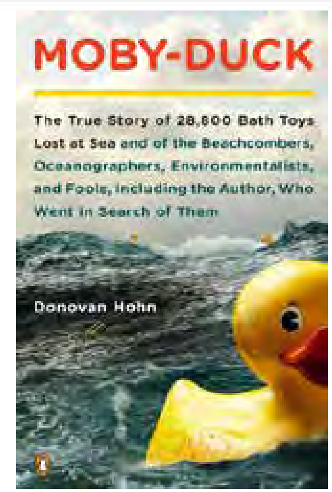




Fishing and livelihoods







Eriksen et al., 2014 Plastic pollution in the world's oceans: more than 5 trillion pieces weighing over 250,000 tons afloat at sea. PLoS One, e111913

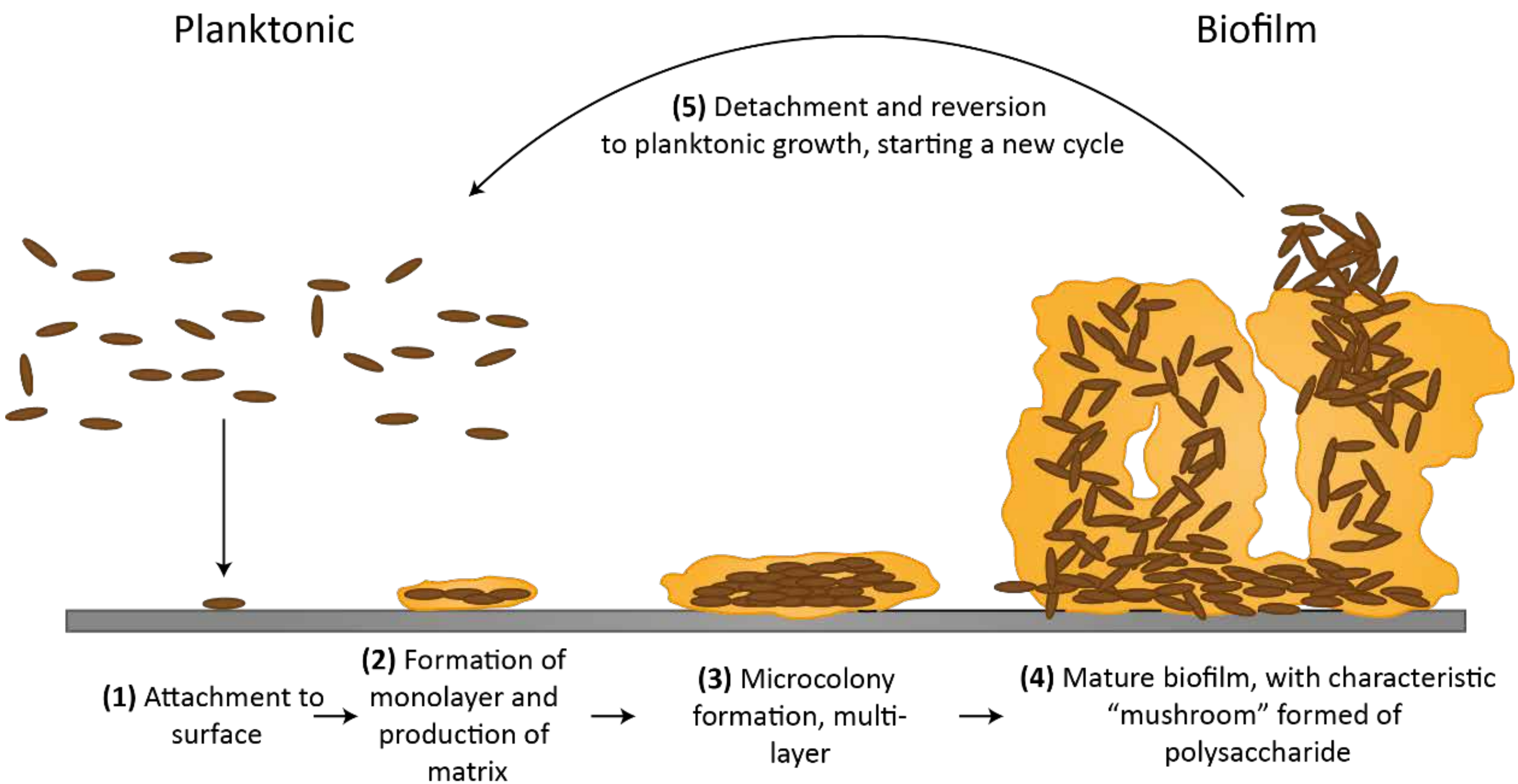
Jambeck et al., 2015 Plastic waste inputs from land into the ocean. Science, 347, 768-771

Zalasiewicz et al., 2016 The geological cycle of plastics and their use as a stratigraphic indicator of the Anthropocene. Anthropocene, 13, 4-17.

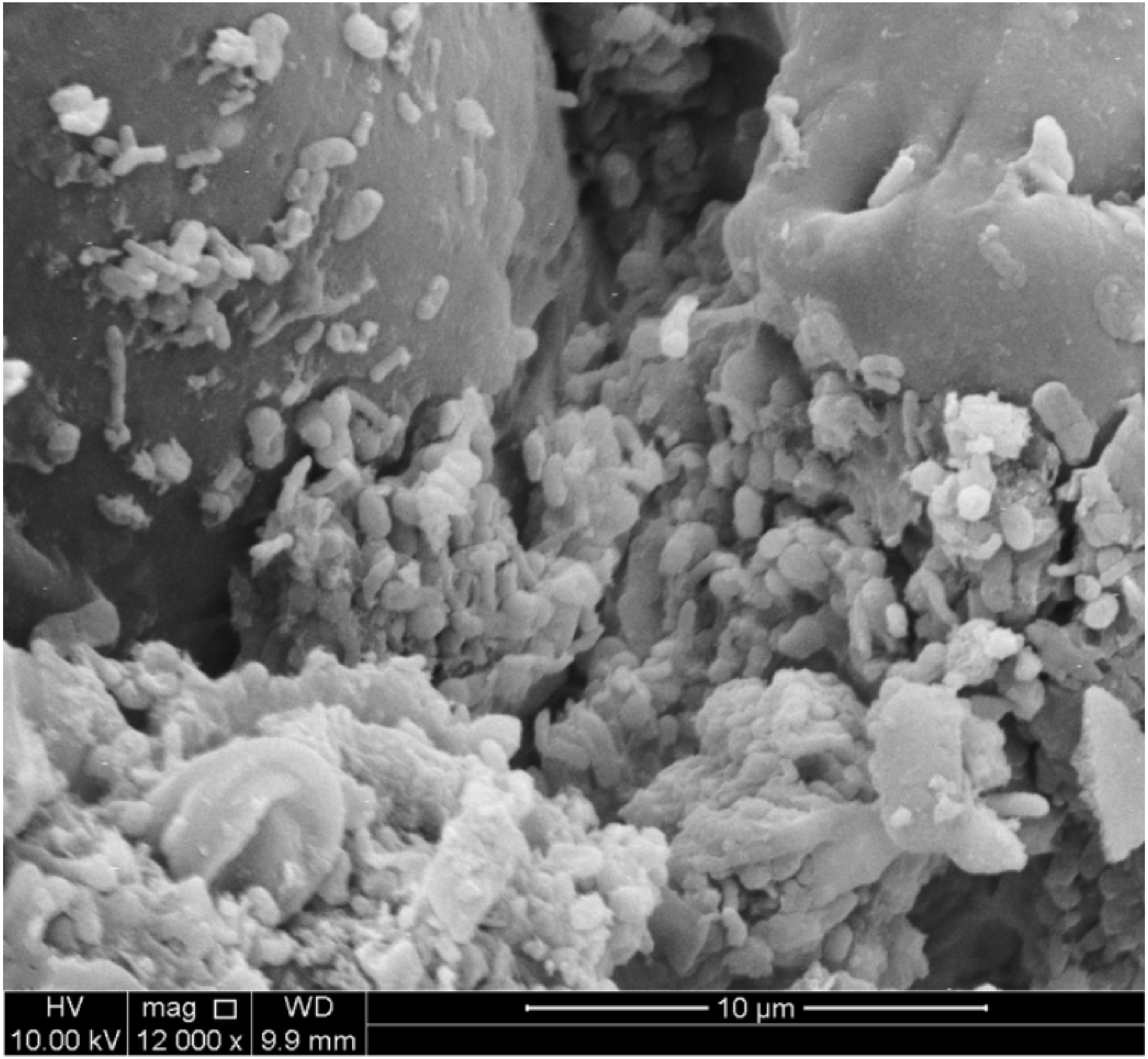
Rafting and dispersal

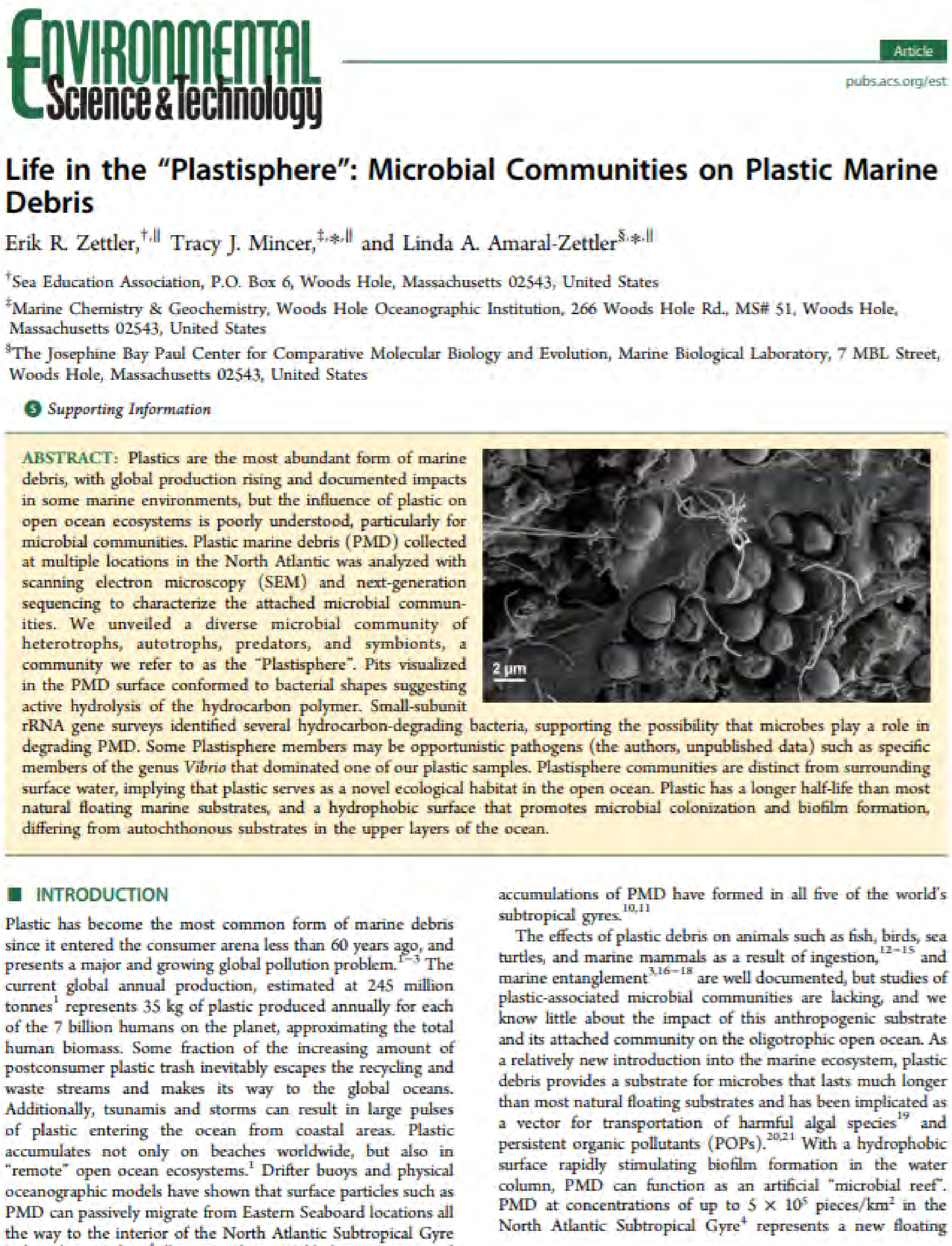
...and the introduction of alien species

Biofilm formation



Birte Hollmann, Mark Perkins, (University of Nottingham); British Society for Immunology


HV
10.00 kV
mag
12 000 x
WD
9.9 mm
10 µm



Environmental Science & Technology

Article

pubs.acs.org/est

Life in the "Plastisphere": Microbial Communities on Plastic Marine Debris

Erik R. Zettler,[†,∥] Tracy J. Mincer,[‡,*,∥] and Linda A. Amaral-Zettler[§,*,∥]

[†]Sea Education Association, P.O. Box 6, Woods Hole, Massachusetts 02543, United States

[‡]Marine Chemistry & Geochemistry, Woods Hole Oceanographic Institution, 266 Woods Hole Rd., MS# 51, Woods Hole, Massachusetts 02543, United States

[§]The Josephine Bay Paul Center for Comparative Molecular Biology and Evolution, Marine Biological Laboratory, 7 MBL Street, Woods Hole, Massachusetts 02543, United States

Supporting Information

ABSTRACT: Plastics are the most abundant form of marine debris, with global production rising and documented impacts in some marine environments, but the influence of plastic on open ocean ecosystems is poorly understood, particularly for microbial communities. Plastic marine debris (PMD) collected at multiple locations in the North Atlantic was analyzed with scanning electron microscopy (SEM) and next-generation sequencing to characterize the attached microbial communities. We unveiled a diverse microbial community of heterotrophs, autotrophs, predators, and symbionts, a community we refer to as the "Plastisphere". Pits visualized in the PMD surface conformed to bacterial shapes suggesting active hydrolysis of the hydrocarbon polymer. Small-subunit rRNA gene surveys identified several hydrocarbon-degrading bacteria, supporting the possibility that microbes play a role in degrading PMD. Some Plastisphere members may be opportunistic pathogens (the authors, unpublished data) such as specific members of the genus *Vibrio* that dominated one of our plastic samples. Plastisphere communities are distinct from surrounding surface water, implying that plastic serves as a novel ecological habitat in the open ocean. Plastic has a longer half-life than most natural floating marine substrates, and a hydrophobic surface that promotes microbial colonization and biofilm formation, differing from autochthonous substrates in the upper layers of the ocean.

2 μm

INTRODUCTION

Plastic has become the most common form of marine debris since it entered the consumer arena less than 60 years ago, and presents a major and growing global pollution problem.[1−3] The current global annual production, estimated at 245 million tonnes[1] represents 35 kg of plastic produced annually for each of the 7 billion humans on the planet, approximating the total human biomass. Some fraction of the increasing amount of postconsumer plastic trash inevitably escapes the recycling and waste streams and makes its way to the global oceans. Additionally, tsunamis and storms can result in large pulses of plastic entering the ocean from coastal areas. Plastic accumulates not only on beaches worldwide, but also in "remote" open ocean ecosystems.[1] Drifter buoys and physical oceanographic models have shown that surface particles such as PMD can passively migrate from Eastern Seaboard locations all the way to the interior of the North Atlantic Subtropical Gyre in less than 60 days,[4] illustrating how quickly human-generated accumulations of PMD have formed in all five of the world's subtropical gyres.[10,11]

The effects of plastic debris on animals such as fish, birds, sea turtles, and marine mammals as a result of ingestion,[12−15] and marine entanglement[3,16−18] are well documented, but studies of plastic-associated microbial communities are lacking, and we know little about the impact of this anthropogenic substrate and its attached community on the oligotrophic open ocean. As a relatively new introduction into the marine ecosystem, plastic debris provides a substrate for microbes that lasts much longer than most natural floating substrates and has been implicated as a vector for transportation of harmful algal species[19] and persistent organic pollutants (POPs).[20,21] With a hydrophobic surface rapidly stimulating biofilm formation in the water column, PMD can function as an artificial "microbial reef". PMD at concentrations of up to 5×10^5 pieces/km^2 in the North Atlantic Subtropical Gyre[4] represents a new floating

- Plastic marine debris collected at multiple locations in the North Atlantic
- Scanning electron microscopy to visualise microbial community
- Next generation DNA sequencing to characterise the community compared to the surrounding seawater

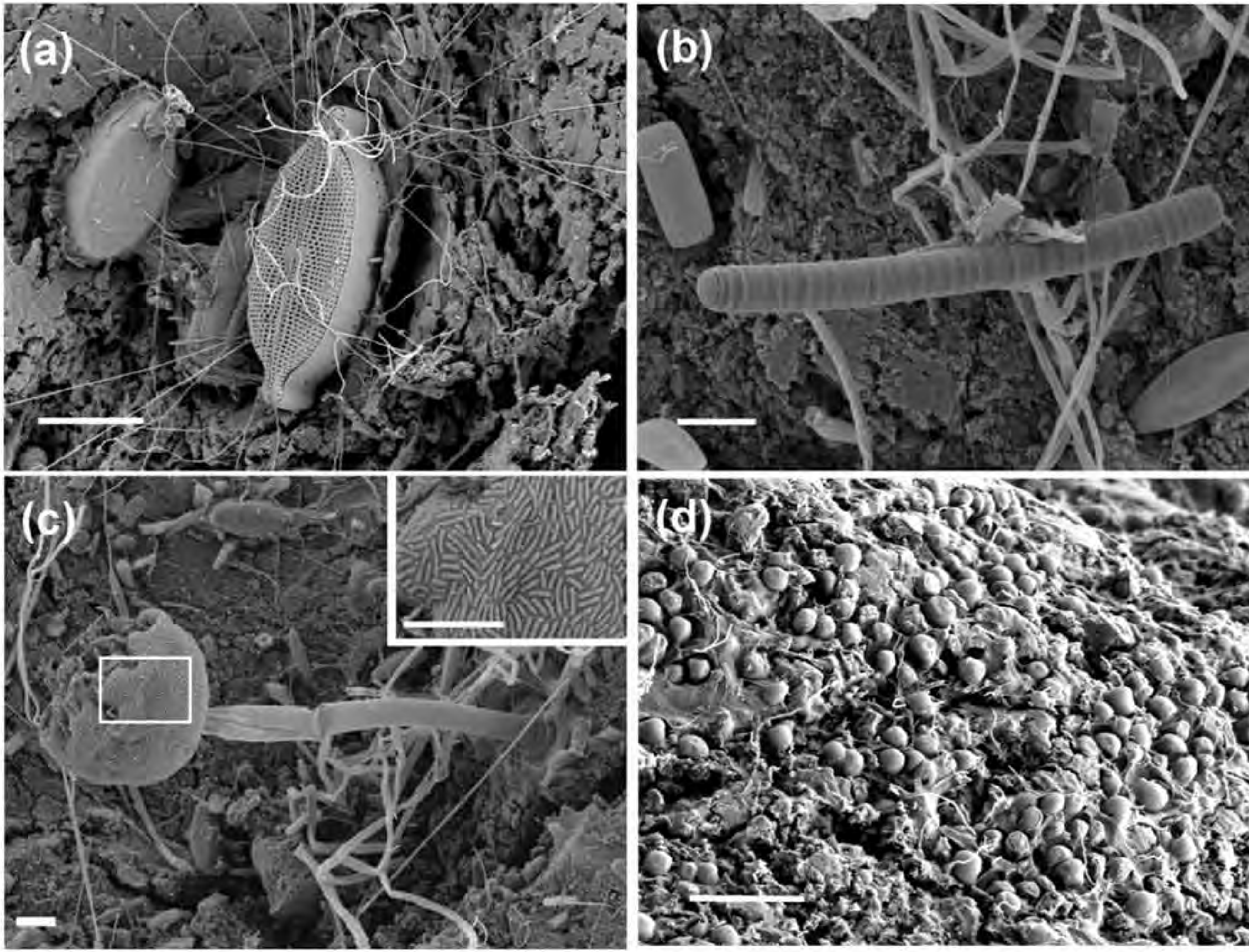


Figure 2. SEM images showing examples of the rich microbial community on PMD: (a) pennate diatom on sample C241_07 with possible prosthecate filaments produced by *Hyphomonas*-like bacteria; (b) filamentous cyanobacteria on sample C230_01; (c) stalked predatory suctorian ciliate in foreground covered with ectosymbiotic bacteria (inset) along with diatoms, bacteria, and filamentous cells on sample C230_01; (d) microbial cells pitting the surface of sample C241_12. All scale bars are 10 μm.

Contents lists available at ScienceDirect

Marine Environmental Research

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

Microbial hitchhikers on marine plastic debris: Human exposure risks at bathing waters and beach environments

Anisha Keswani [a,*], David M. Oliver [a], Tony Gutierrez [b], Richard S. Quilliam [a]

[a] Biological and Environmental Sciences, School of Natural Sciences, University of Stirling, Stirling, FK9 4LA, UK
[b] School of Life Sciences, Herriot Watt University, Edinburgh, EH14 4AS, UK

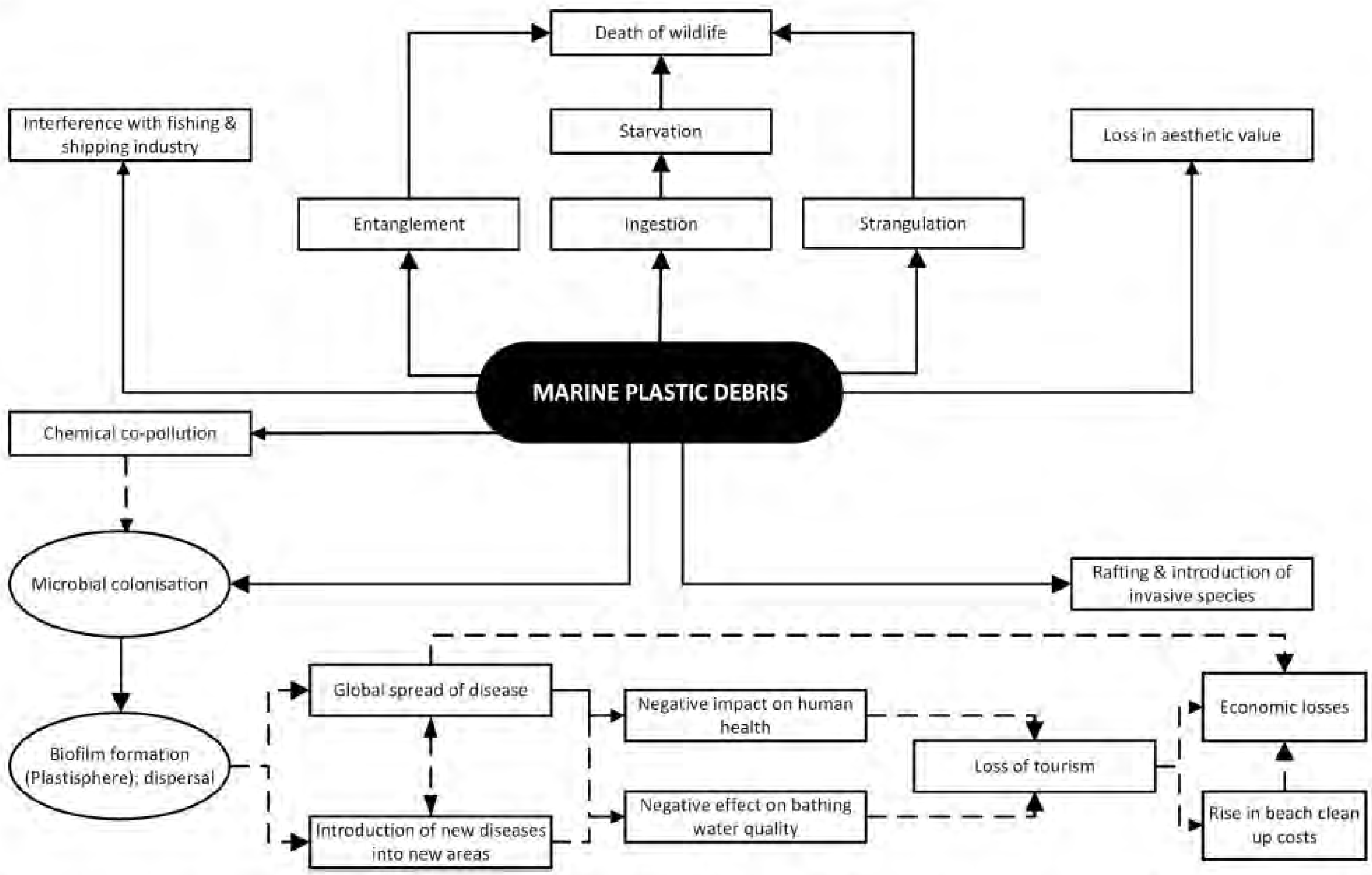
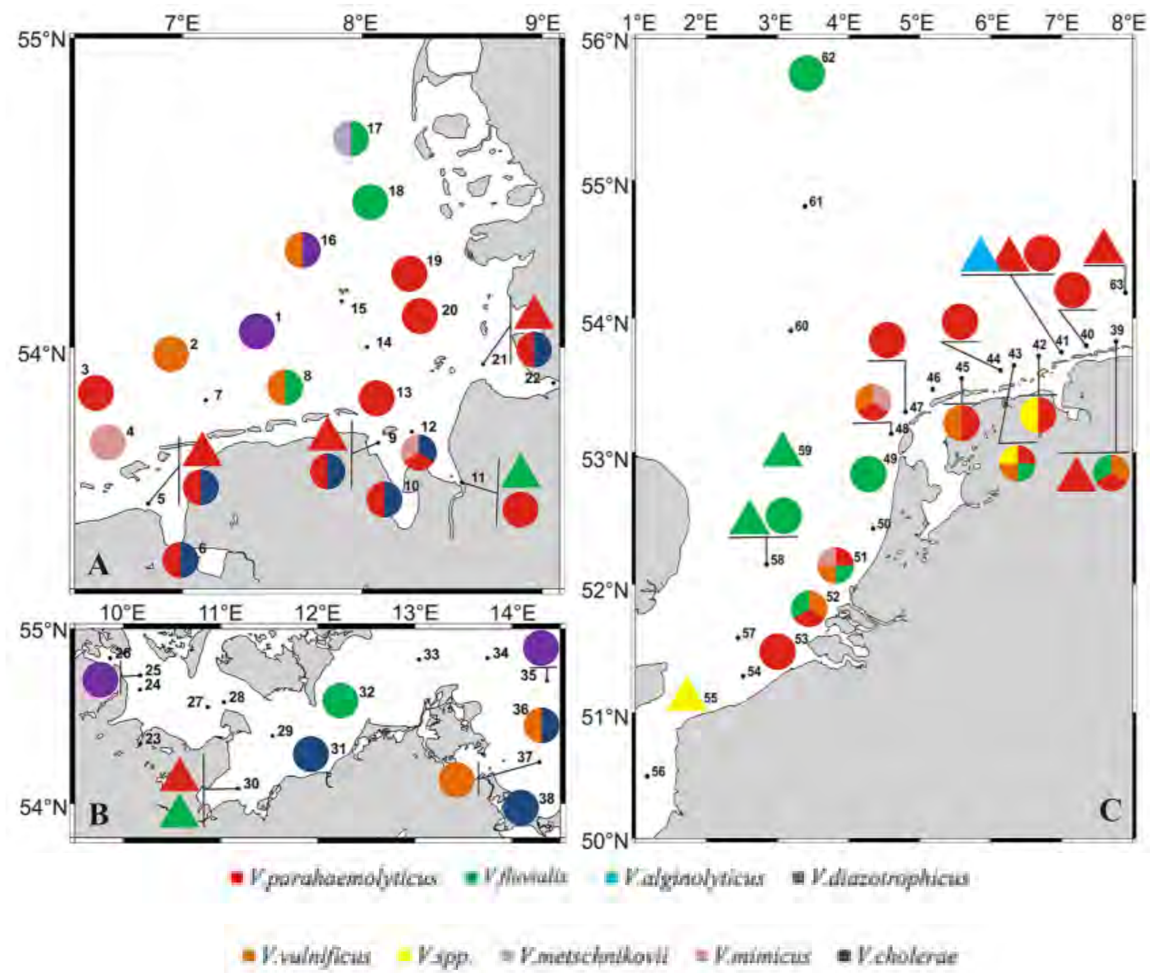


Fig. 1. Impacts and interactions of marine plastic debris. Solid black arrows indicate known effects; dotted black arrows indicate the yet unexplored effects/interactions as mediated by marine plastic debris.

Do pathogens bind to marine plastics...? Evidence from DNA sequencing

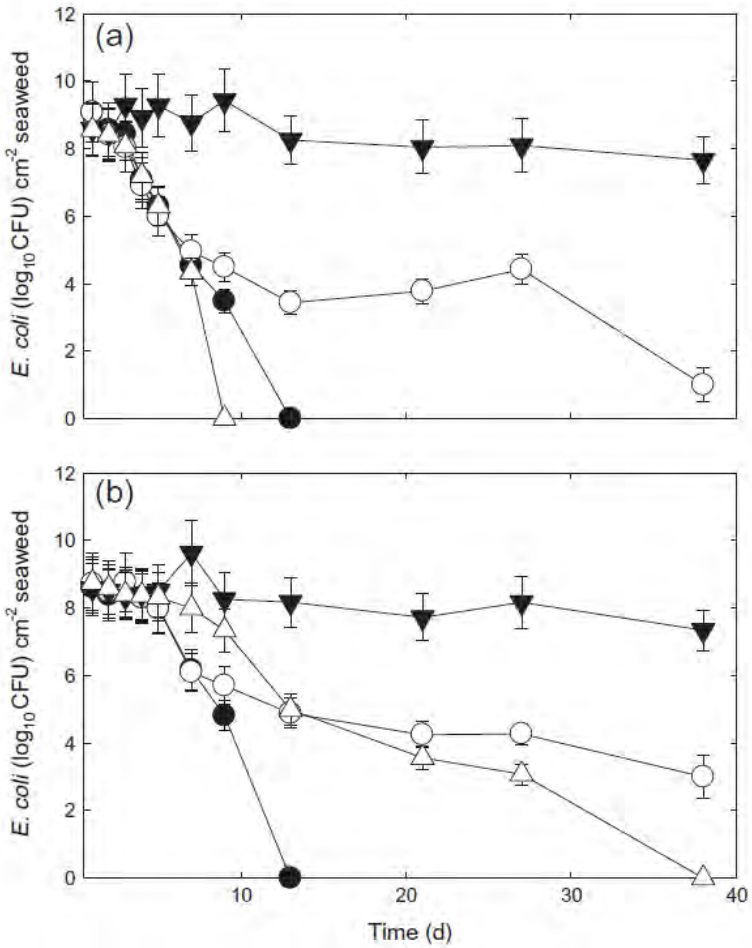


Kirstein et al., (2016). Dangerous hitchhikers? Evidence for potentially pathogenic *Vibrio* spp. on microplastic particles. Marine Environmental Research, 120, 1-8.

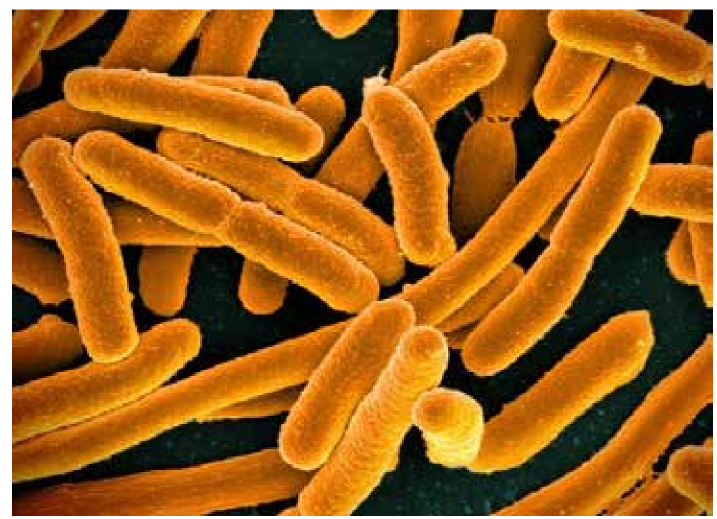
Human exposure routes




Does marine plastic debris influence the persistence of pathogens at bathing beaches?



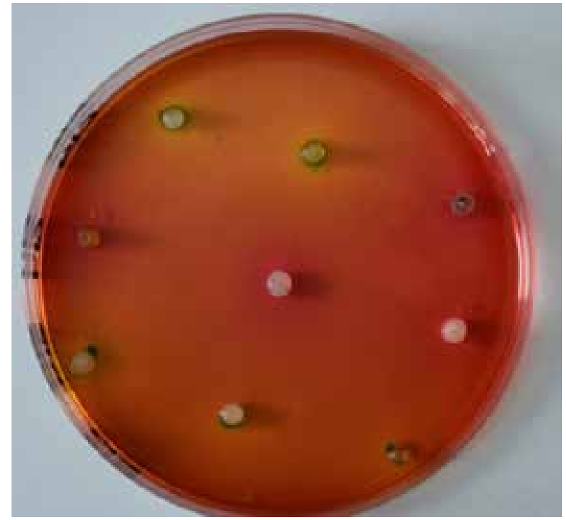
E. coli is a faecal indicator organism (FIO) used as a compliance parameter in the EU Bathing water Directive



Quilliam et al., (2014). Seaweeds and plastic debris can influence the survival of faecal indicator organisms in beach environments. Marine Pollution Bulletin. 84, 201-207.

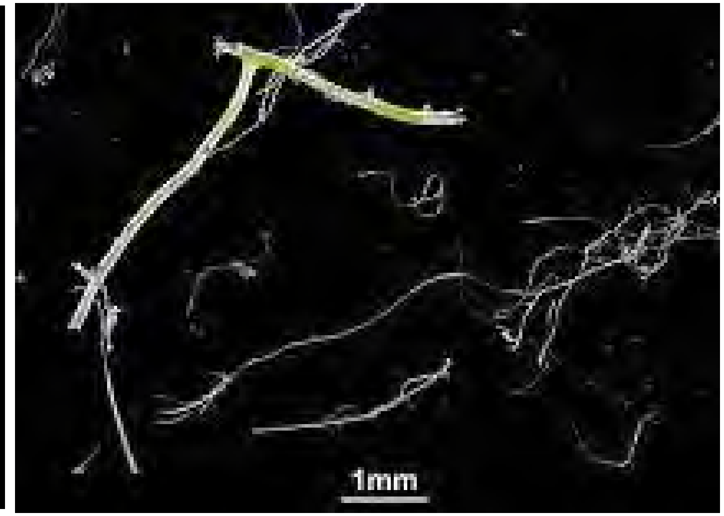
Nurdles on bathing beaches...

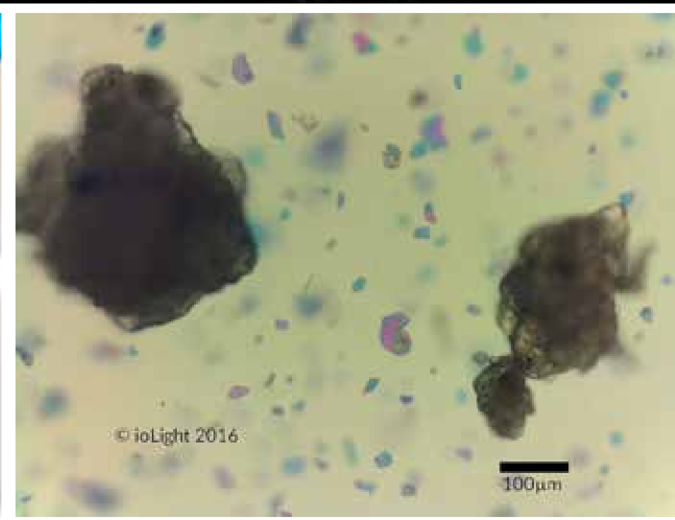
...16% colonised by *E. coli*



Quilliam et al., (in review). Colonisation of plastic pellets (nurdles) by *E. coli* at bathing beaches. *Marine Environmental Research*

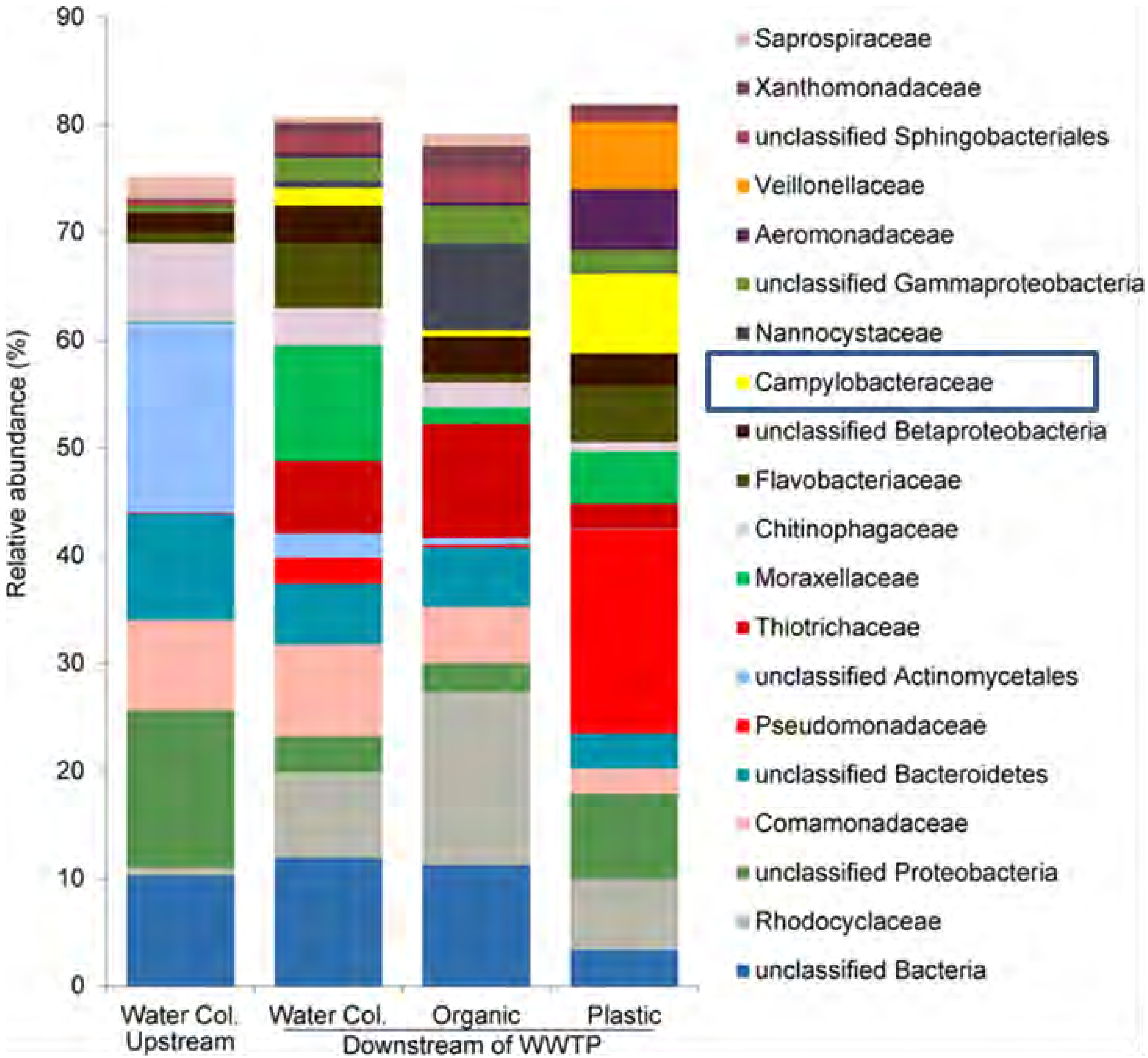
Microplastics (< 5 mm)





Waste water treatment works

An opportunity for pathogen colonisation...?



McCormick et al., (2014). Microplastic is an abundant and distinct microbial habitat in an urban river. Environmental Science & Technology, 48, 11863-11871.

Biofilms and gene exchange

Environmental Pollution 237 (2018) 253–261

Contents lists available at ScienceDirect

Environmental Pollution

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

ELSEVIER

Microplastic pollution increases gene exchange in aquatic ecosystems☆

Maria Arias-Andres [a,b,c], Uli Klümper [d,e], Keilor Rojas-Jimenez [a,f], Hans-Peter Grossart [a,b,g,*]

[a] *Department of Experimental Limnology, Leibniz Institute of Freshwater Ecology and Inland Fisheries, Alte Fischerhuette 2, 16775 Stechlin, Germany*
[b] *Institute of Biochemistry and Biology, Potsdam University, Maulbeerallee 2, D-14469 Potsdam, Germany*
[c] *Central American Institute for Studies on Toxic Substances, Universidad Nacional, Campus Omar Dengo, P.O. Box 86-3000, Heredia, Costa Rica*
[d] *European Centre for Environment and Human Health, University of Exeter, Medical School, Royal Cornwall Hospital, Truro, United Kingdom*
[e] *ESI & CEC, Biosciences, University of Exeter, Penryn Campus, Cornwall, United Kingdom*
[f] *Universidad Latina de Costa Rica, Campus San Pedro, Apdo. 10138-1000, San José, Costa Rica*
[g] *Berlin-Brandenburg Institute of Advanced Biodiversity Research – BBIB, Freie Universität Berlin, Altensteinstr. 34, 14195 Berlin, Germany*

ARTICLE INFO

Article history:
Received 1 December 2017
Received in revised form 26 January 2018
Accepted 19 February 2018
Available online 26 February 2018

ABSTRACT

Pollution by microplastics in aquatic ecosystems is accumulating at an unprecedented scale, emerging as a new surface for biofilm formation and gene exchange. In this study, we determined the permissiveness of aquatic bacteria towards a model antibiotic resistance plasmid, comparing communities that form biofilms on microplastics vs. those that are free-living. We used an exogenous and red-fluorescent *E. coli* donor strain to introduce the green-fluorescent broad-host-range plasmid pKJK5 which encodes for trimethoprim resistance. We demonstrate an increased frequency of plasmid transfer in bacteria asso

Biofilms and AMR gene transfer

Contents lists available at ScienceDirect

International Journal of Hygiene and Environmental Health

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

Do plastics serve as a possible vector for the spread of antibiotic resistance? First insights from bacteria associated to a polystyrene piece from King George Island (Antarctica)

Pasqualina Laganà[a,1], Gabriella Caruso[b,*,1], Ilaria Corsi[c], Elisa Bergami[c], Valentina Venuti[d], Domenico Majolino[d], Rosabruna La Ferla[b], Maurizio Azzaro[b], Simone Cappello[b]

[a] Dept. of Biochemical and Dental Sciences and of the Morphological and Functional Images, University of Messina, Messina, Italy
[b] Institute for Coastal Marine Environment (IAMC), National Research Council (CNR), Messina, Italy
[c] Dept. of Physical, Earth and Environmental Sciences, University of Siena, Siena, Italy
[d] Dept. of Mathematical and Computer Sciences, Physical Sciences and Earth Sciences, University of Messina, Messina, Italy

ARTICLE INFO

Keywords:
Plastic
Polystyrene
Plastisphere
Antibiotic resistance
Vector
Antarctica

ABSTRACT

The retrieval of a polystyrene macro-plastic piece stranded on the shores in King George Island (South Shetlands, Antarctica) gave the opportunity to explore the associated bacterial flora. A total of 27 bacterial isolates were identified by molecular 16s rRNA gene sequencing and 7 strains were selected and screened for their ability to produce biofilm and antibiotic susceptibility profiles. All the bacterial isolates were able to produce biofilm. The Kirby-Bauer disk diffusion susceptibility test to 34 antibiotics showed multiple antibiotic resistances against the molecules cefuroxime and cefazolin (belonging to cephalosporins), cinoxacin (belonging to quinolones) and ampicillin, amoxicillin + clavulanic acid, carbenicillin and mezlocillin (belonging to beta-lactams). The obtained results suggest that plastics can serve as vectors for the spread of multiple resistances to antibiotics across Antarctic marine environments and underline the relevance of future studies on this topic.

1. Introduction

To date, a plethora of studies are documenting the ubiquitous occurrence in diverse environmental matrices of different and relatively

transport of land litter by wind, represent important routes through which plastic pollution reaches marine environments ((Ryan et al., 2009; Jambek et al., 2015)). Sludge amendment or plastic mulching are relevant sources for plastic contamination in continental systems

Discharge and transport to human receptors

Microplastics can accumulate in mussel flesh

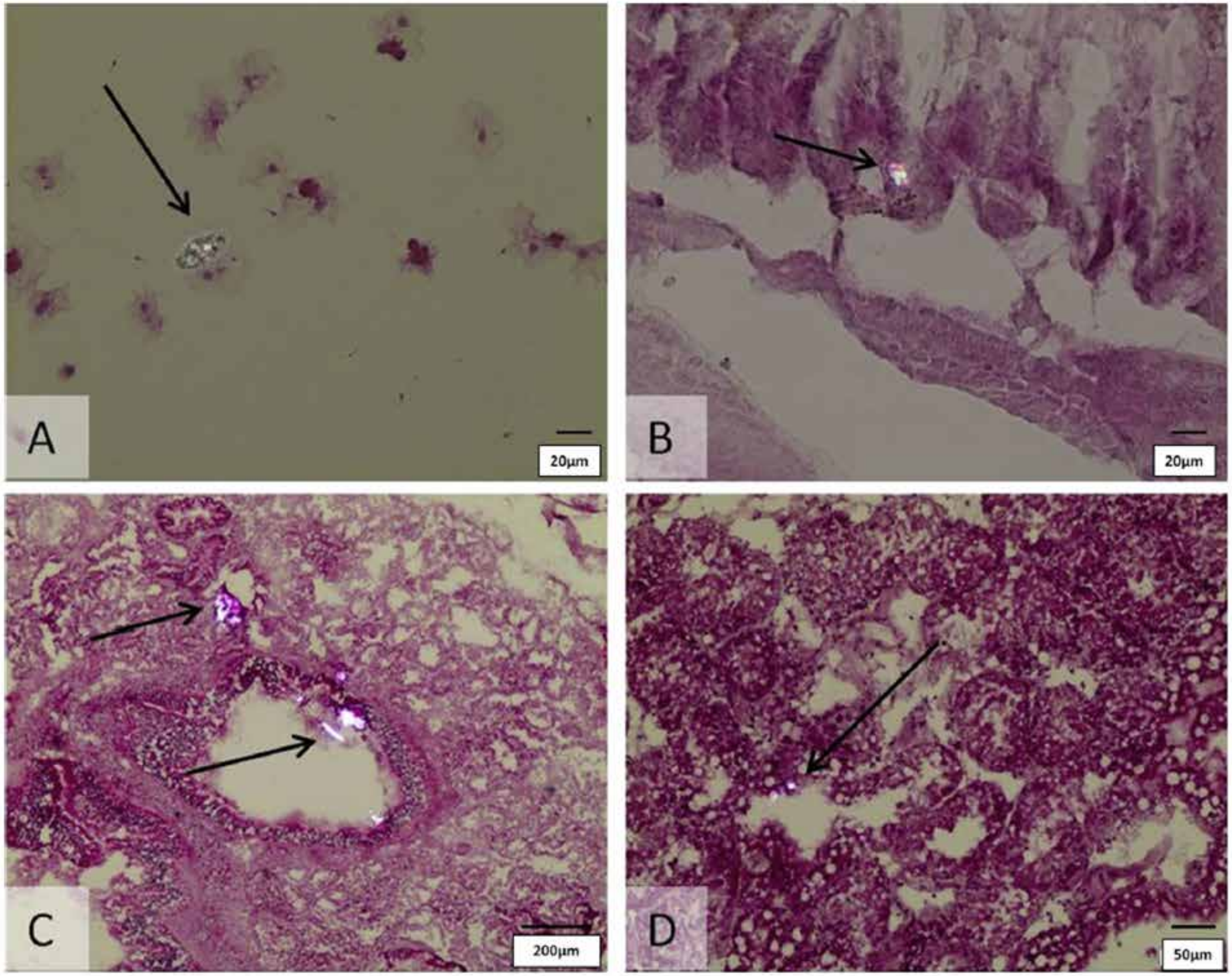


Fig. 3. Polarized-light microscopy images showing the presence of plastic particles in haemolymph (A), gills (B), gut lumen and epithelium (C), digestive tubules (D).

Avio et al., (2015). Pollutants bioavailability and toxicological risk from microplastics to marine mussels. Environmental Pollution, 198, 211-222.

Toxicology of plastics

- Plasticisers (mainly phthalates) are sometimes added to plastics to increase the plasticity, but can leach out over time
- Persistent organic pollutants (POPs) can bind to plastics
  - e.g. PAHs and PCBs

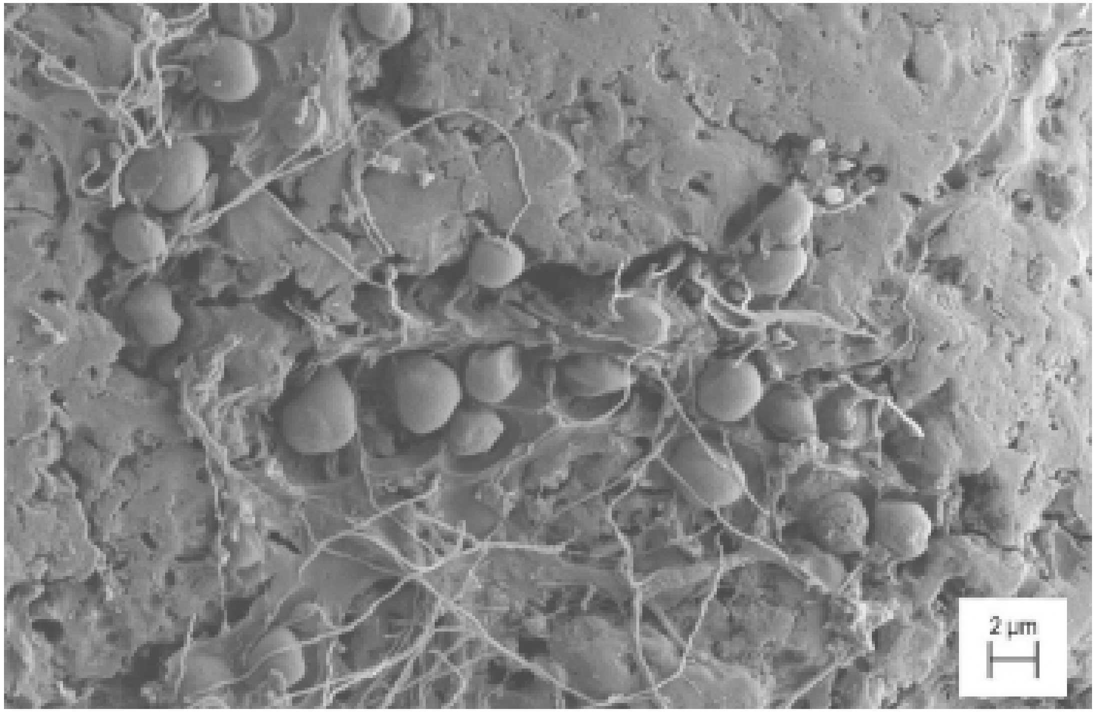
Bioaccumulation of toxins in the food chain

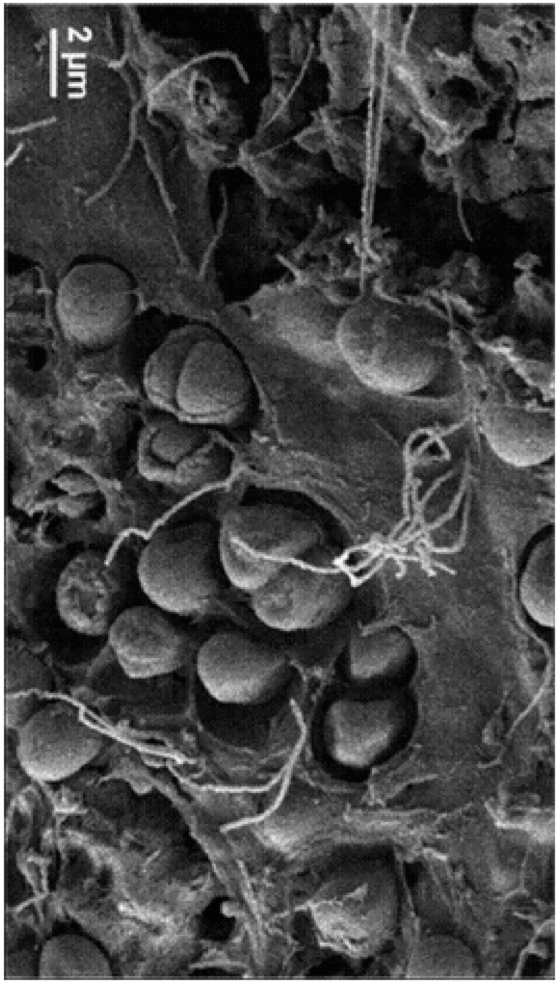
- Most laboratory-based absorption-desorption studies use non-colonised plastic...
- ...however, microbes in the plastisphere may either mitigate toxicity through biodegradation, or enhance it by increased biofilm binding

What are the multi-pollutant and multi-scale effects of microplastics in the environment...?

Plastics are not just a marine issue

Microbial Biodegradation...?





Zettler et al., (2013). Life in the "plastisphere": microbial communities on plastic marine debris. Environmental Science & Technology, 47(13), 7137-7146.

Are microbes the solution...?

INDEPENDENT IDY/LIFE INDYBEST LONG READS INDY100

Plastic-eating bacteria discovered by student could help solve global pollution crisis

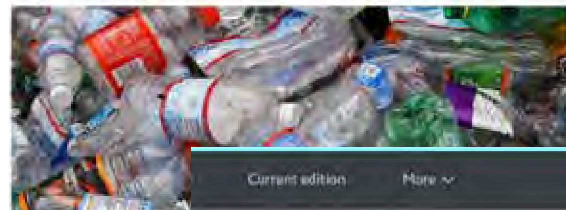
Exclusive: Microbes found near plastic refinery degrade material, turning it into food

Tom Embury-Dennis | @tomemburyd | Saturday 30 June 2018 20:02 | 28 comments

A student may have found a solution to one of the world's most urgent environmental crises – breeding bacteria capable of "eating" plastic and

CNN

New plastic-eating bacteria could help save planet



BBC NEWS

Science & Environment

Recycling hope for plastic-hungry enzyme

By Mary Halton

Scientists have improved a naturally occurring enzyme which can digest some of our most commonly polluting plastics.

NewScientist

News Technology Space Physics Health Environment Mind Video

Bacteria found to eat PET plastics could help do the recycling

Current edition More

The Economist

Greenery

An enzyme that digests plastic could boost recycling

Auf Wiedersehen, PET

Print edition | Science and technology

A MILLION plastic bottles are sold every minute. Many are not recycled and

Dr Richard Quilliam
Biological & Environmental Sciences
Faculty of Natural Sciences
University of Stirling
http://rsquilliam.wordpress.com/
@RS_Quilliam

UNIVERSITY of STIRLING