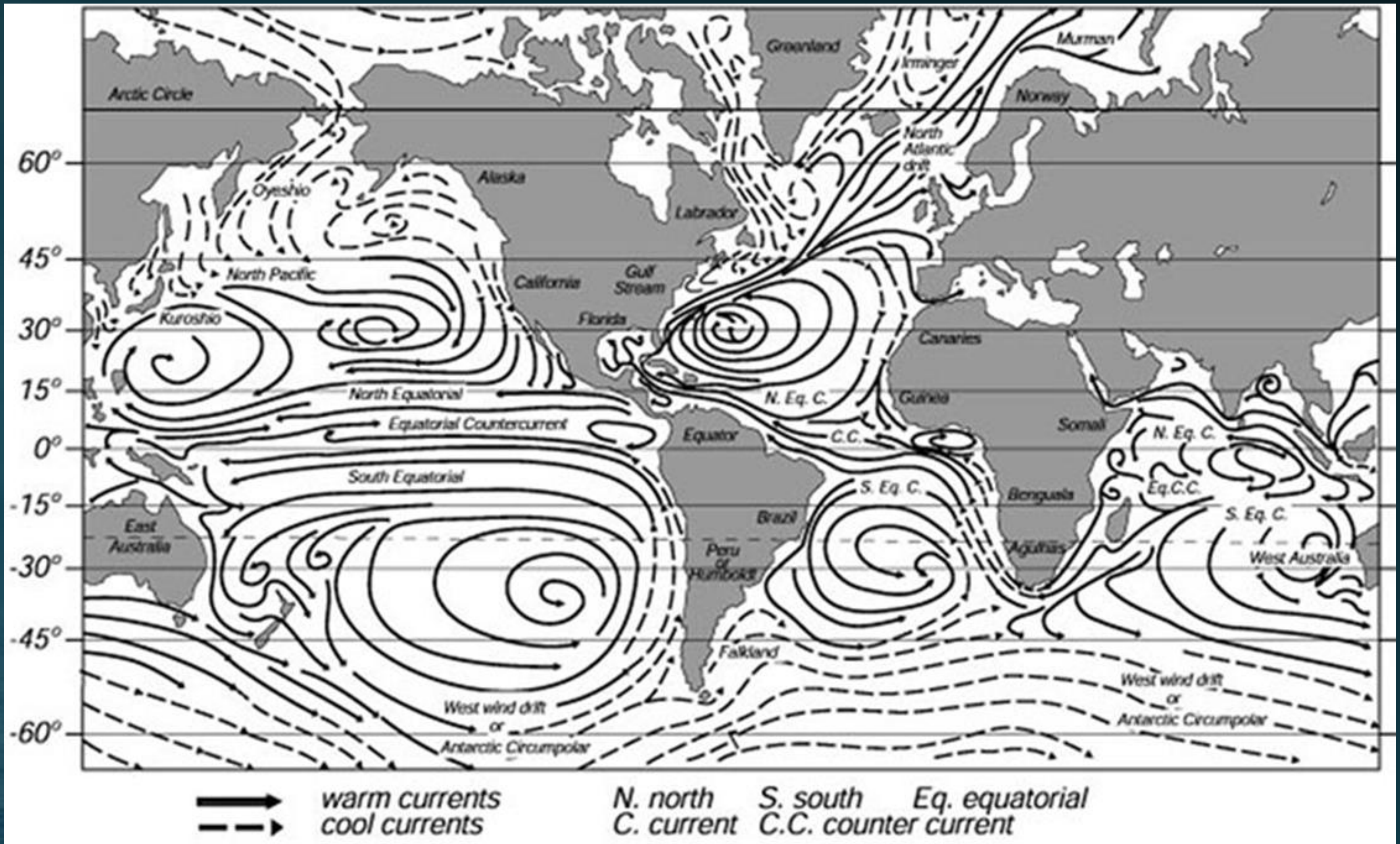
The Plastic Ocean

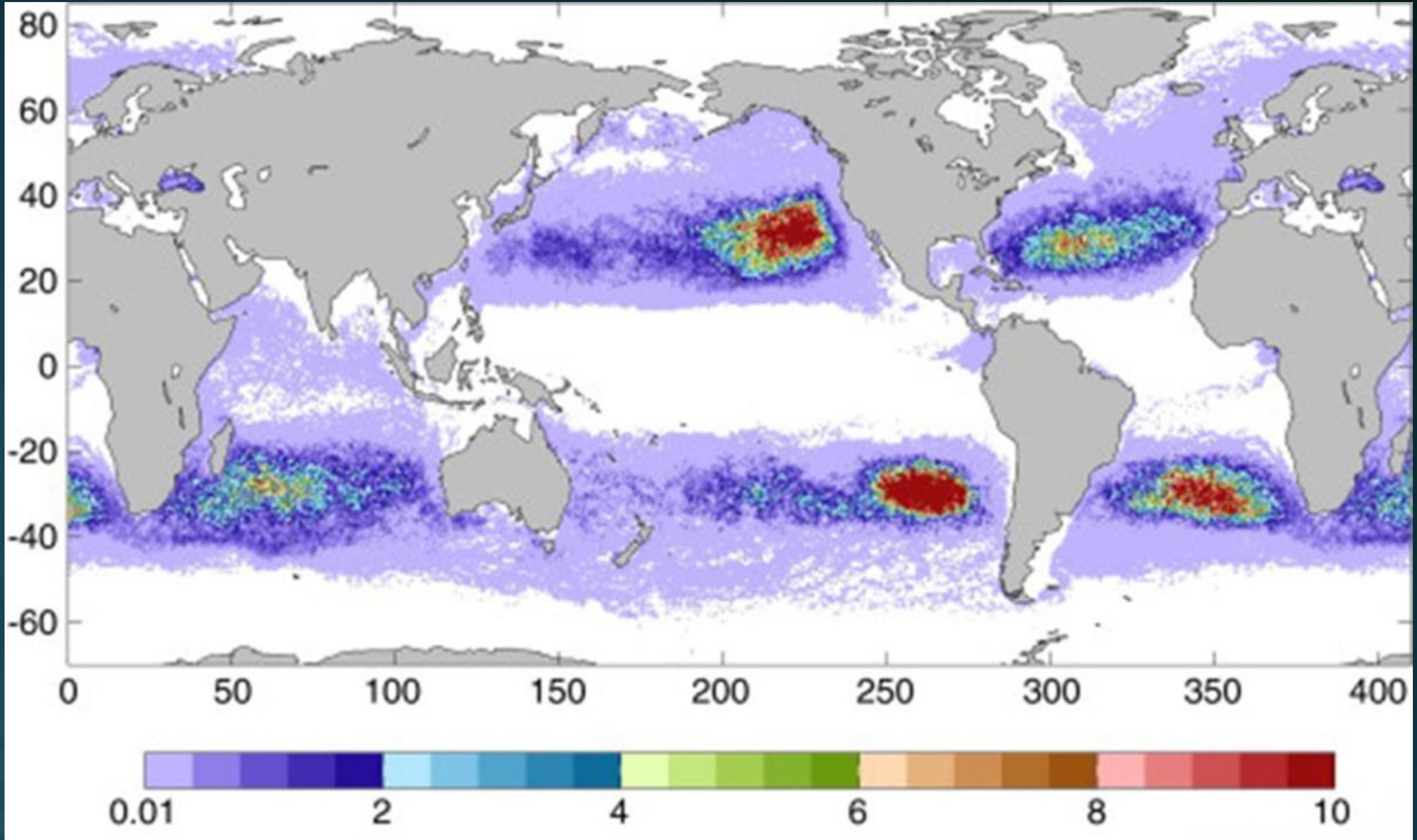
Michael Gonsior

Bonnie Monteleone, William Cooper, Jennifer O'Keefe, Pamela Seaton, and Maureen Conte

Ocean Surface Currents



Drifter Density



Dohan, K., and N. Maximenko. 2010. Monitoring ocean currents with satellite sensors. Oceanography23(4):94–103, doi:10.5670/oceanog.2010.08.

Plastic does not biodegrade it photo-degrades breaking down into small particles that wreck havoc with marine life

Unfortunately, marine creatures mistake plastics in the ocean for food

Can you tell which is the hydrozoan and which is the plastic cheese wrap?

Unfortunately, marine creatures mistake plastics in the ocean for food

- turtles

Marine Pollution Bulletin 74 (2013) 225–230

Contents lists available at SciVerse ScienceDirect

Marine Pollution Bulletin

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

Presence of plastic debris in loggerhead turtle stranded along the Tuscany coasts of the Pelagos Sanctuary for Mediterranean Marine Mammals (Italy)

Tommaso Campani [a], Matteo Baini [a,*], Matteo Giannetti [a,d], Fabrizio Cancelli [b], Cecilia Mancusi [c], Fabrizio Serena [c], Letizia Marsili [a], Silvia Casini [a], Maria Cristina Fossi [a]

[a] Department of Physical, Earth and Environmental Sciences, University of Siena, Siena, Italy
[b] Accademia dei Fisiocritici, University of Siena, Italy
[c] ARPAT, Environmental Protection Agency of Tuscany Region, Livorno, Italy
[d] Department of Life Science, University of Siena, Italy

ARTICLE INFO

Keywords:
Marine debris
Loggerhead turtle
Plastic
Tyrrhenian Sea

ABSTRACT

This work evaluated the presence and the frequency of occurrence of marine litter in the gastrointestinal tract of 31 *Caretta caretta* found stranded or accidentally bycaught in the North Tyrrhenian Sea. Marine debris were present in 71% of specimens and were subdivided in different categories according to Fulmar Protocol (OSPAR 2008). The main type of marine debris found was user plastic, with the main occurrence of sheetlike user plastic. The small juveniles showed a mean ± SD of marine debris items of 19.00 ± 23.84, while the adult specimens showed higher values of marine litter if compared with the juveniles (26.87 ± 35.85). The occurrence of marine debris observed in this work confirms the high impact of marine debris in the Mediterranean Sea in respect to other seas and oceans, and highlights the importance of *Caretta caretta* as good indicator for marine litter in the Marine Strategy Framework Directive (MSFD) of European Union.

1. Introduction

Plastic marine debris accumulation and dispersal is a growing problem on a global scale, affecting all marine environments (Moore, 2008; Gregory, 2009). Marine debris, defined as any manufactured or processed solid waste imported into the marine environment (Coe and Rogers, 1997), are proven to have a widespread negative impact on marine wildlife. Although there are various types of debris, plastics (synthetic organic polymers) make up most of the marine litter worldwide. The main sources of marine debris are litter from ships, fishing and recreational boats, and garbage carried into the sea from land-based sources in industrialized and highly populated areas (Derraik, 2002). The threat of marine debris to the marine environment has been ignored for a long time and only in the last decades it has been given serious attention.

Marine organisms may be impacted by litter in various ways. At least 43% of existing cetacean species, all species of marine turtles, approximately 36% of the world's seabird species, and many species of fish have been reported to ingest marine litter (Katsanevakis, 2008).

The entanglement of marine species, especially fish (Sazima et al., 2002), turtles (Carr, 1987), birds (Arnould and Croxall, 1995) and mammals (Shaughnessy, 1980; Beck and Barros, 1991; Arnould and Croxall, 1995) has been frequently described as a serious mortality factor. Ingestion of debris (mainly plastics) in seaturtles, seabirds and marine mammals has often harmful effects, such as a worsening physical condition (Spear et al., 1995), diminished food stimulus (Ryan et al., 1988), blockage of gastric enzyme secretion, lowered steroid hormone levels, delayed ovulation and reproductive failure (Azzarello and Van Vleet, 1987), internal injuries and death following blockage of the intestinal tract (Ryan et al., 1988; Beck and Barros, 1991).

Loggerhead turtles (*Caretta caretta*) are carnivorus, foraging primarily on benthic invertebrates throughout their distribution range. The high diversity in the type of their prey demonstrates versatility in foraging behavior, suggesting that the loggerhead is a generalist (Plotkin and Amos 1990).

On the basis of these considerations the loggerhead turtles can ingest large quantity of plastic debris that can be mistaken for food.

* Corresponding author. Address: Department of Physical, Earth and Environment Sciences, University of Siena, via P.A. Mattioli 4, 53100 Siena, Italy. Tel.: +39 0577232883.

E-mail addresses: campani@unisi.it (T. Campani), bainimatt@gmail.com (M. Baini), giannetti12@unisi.it (M. Giannetti), cancelli@unisi.it (F. Cancelli), c.mancusi@arpat.toscana.it (C. Mancusi), f.serena@arpat.toscana.it (F. Serena), letizia.marsili@unisi.it (L. Marsili), Silvia.casini@unisi.it (S. Casini), fossi@unisi.it (M.C. Fossi).

0025-326X/$ - see front matter
http://dx.doi.org/10.1016/j.marpolbul.2013.06.053

Unfortunately, marine creatures mistake plastics in the ocean for food

- fish

Marine Pollution Bulletin 62 (2011) 1098–1102

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Plastic debris ingestion by marine catfish: An unexpected fisheries impact

Fernanda E. Possatto, Mário Barletta *, Monica F. Costa, Juliana A. Ivar do Sul, David V. Dantas

Laboratorio de Ecologia e Gerenciamento de Ecossistemas Costeiros e Estuarinos, Departamento de Oceanografia, Universidade Federal de Pernambuco, Av. Arquitetura s/n, Cidade Universitária, 50740-550 Recife, Pernambuco, Brazil

ARTICLE INFO

Keywords:
South America
Goiana Estuary
Marine debris
Fishery
Nylon
Polyamide
Living resources conservation

ABSTRACT

Plastic marine debris is a pervasive type of pollution. River basins and estuaries are a source of plastics pollution for coastal waters and oceans. Estuarine fauna is therefore exposed to chronic plastic pollution. Three important catfish species [*Cathorops spixii* (*N* = 60), *Cathorops agassizii* (*N* = 60) and *Sciades herzbergii* (*N* = 62)] from South Western Atlantic estuaries were investigated in a tropical estuary of the Brazilian Northeast in relation to their accidental ingestion of plastic marine debris. Individuals from all three species had ingested plastics. In *C. spixii* and *C. agassizii*, 18% and 33% of individuals had plastic debris in their stomachs, respectively. *S. herzbergii* showed 18% of individuals were contaminated. All ontogenetic phases (juveniles, sub-adults and adults) were contaminated. Nylon fragments from cables used in fishery activities (subsistence, artisanal and commercial) played a major role in this contamination. These catfish spend their entire life cycles within the estuary and are an important feeding resource for larger, economically important, species. It is not yet possible to quantify the scale and depth of the consequences of this type of pollution. However, plastics are well known threat to living resources in this and other estuaries. Conservation actions will need to from now onto take plastics pollution into consideration.

1. Introduction

The accumulation of plastic and its debris in marine and coastal environments is the result of the intense and continuous release of this pollutant into the environment. Marine debris can significantly affect wildlife, for example, via entanglement and ingestion. Since the second half of the 20th century, the ingestion of plastic marine debris by seabirds, turtles and mammals has been widely reported and reviewed (Laist, 1997; Moore, 2008; Gregory, 2009; Colabuono et al., 2009; Tourinho et al., 2010; Guebert-Bartholo et al., 2011).

Fish are also affected by plastic marine debris (Boerger et al., 2010; Carpenter et al., 1972; Hoss and Settle, 1990; Kubota, 1990; Laist, 1997). Fish are one of the largest and most diverse animal groups on the planet, and of undisputable ecological and economic importance (Nelson, 2006), which increases the chance of contact with plastic marine debris and the development of further consequences. The ingestion of plastics by fish is a common fisher's anecdote, and has been scientifically long-known to occur (Boerger et al., 2010; Carpenter et al., 1972; Hoss and Settle, 1990; Kubota, 1990; Laist, 1997). The groups that are most frequently reported as being affected by marine debris ingestion are sharks and rays (Laist, 1997), but bony fish are also listed as being threatened (Boerger et al., 2010; Carpenter et al., 1972; Kubota, 1990; Laist, 1997). Laboratory experiments have demonstrated that this process is highly viable when plastics, especially those of smaller sizes, are available mixed with food items (Hoss and Settle, 1990; Browne et al., 2010), and should be considered in actions aimed at fish and aquatic environment conservation.

Reports on the ingestion of plastic marine debris by fish usually list sporadic, rare or infrequent events, showing no temporal or spatial trends. The identification of patterns is restricted to some entanglements reports, but, for ingestion, there is little indication of systematic or analytical data in the literature (Boerger et al., 2010; Carpenter et al., 1972; Hoss and Settle, 1990; Kubota, 1990; Laist, 1997) when compared to other vertebrate groups. There is no record of the quantitative assessments of this sort of pollution on well-known fish populations. Studies with a high level of detail (identification and explanation of spatial and temporal patterns and ecological and conservation consequences) remain to be done as a development of the early general diagnosis and basic reports of the existence of the problem of plastics ingestion by marine biota (Ivar do Sul and Costa, 2007). Coastal species living in reefs and estuaries (Carpenter et al., 1972; Kartar et al., 1976), as well as large pelagic fish (Boerger et al., 2010; Kubota, 1990), are cited in the literature as having ingested whole items and/or fragments of plastics. Catfish (Ariidae) specifically show no record in the literature for this sort of impact.

In South America (Western South Atlantic), the Ariidae family appears to be the most abundant in the estuaries (Araújo, 1988; Azevedo et al., 1999; Barletta et al., 2003, 2005, 2008, 2010). At

* Corresponding author. Tel.: +55 81 2126 7223.
E-mail address: mario.barletta@pq.cnpq.br (M. Barletta).

0025-326X/$ - see front matter
doi:10.1016/j.marpolbul.2011.01.036

Marine Pollution Bulletin 69 (2013) 97–104

Contents lists available at SciVerse ScienceDirect

Marine Pollution Bulletin

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

Ingestion of plastic marine debris by longnose lancetfish (*Alepisaurus ferox*) in the North Pacific Ocean

Lesley A. Jantz [a,*], Carey L. Morishige [b,c], Gregory L. Bruland [d], Christopher A. Lepczyk [e]

[a] *Pacific Islands Regional Observer Program, National Oceanic and Atmospheric Administration, 1601 Kapiolani Blvd., Suite 1110, Honolulu, HI 96817, USA*
[b] *National Oceanic and Atmospheric Administration, Marine Debris Program, 1305 East West Highway, SSMC4 10th Floor, Silver Spring, MD 20910, USA*
[c] *I.M. Systems Group, Inc., 3206 Tower Oaks Blvd., Suite 300, Rockville, MD 20852, USA*
[d] *Biology Department, Principia College, 1 Maybeck Pl., Elsah, IL 62028, USA*
[e] *Department of Natural Resources and Environmental Management, University of Hawai'i at Mānoa, 1910 East-West Road, Honolulu, HI 96822, USA*

ARTICLE INFO

Keywords:
Hawaii-based longline fishery
Ingestion
Longnose lancetfish
Marine debris
Piscivorous fish
Plastic

ABSTRACT

Plastic marine debris affects species on most trophic levels, including pelagic fish. While plastic debris ingestion has been investigated in planktivorous fish in the North Pacific Ocean, little knowledge exists on piscivorous fish. The objectives of this study were to determine the frequency of occurrence and the composition of ingested plastic marine debris in longnose lancetfish (*Alepisaurus ferox*), a piscivorous fish species captured in the Hawaii-based pelagic longline fishery. Nearly a quarter (47 of 192) of *A. ferox* sampled contained plastic marine debris, primarily in the form of plastic fragments (51.9%). No relationship existed between size (silhouette area) or amount of plastic marine debris ingested and morphometrics of *A. ferox*. Although *A. ferox* are not consumed by humans, they are common prey for fish commercially harvested for human consumption. Further research is needed to determine residence time of ingested plastic marine debris and behavior of toxins associated with plastic debris.

Published by Elsevier Ltd.

1. Introduction

Pollution by plastic marine debris constitutes a major threat to marine life (Derraik, 2002). Ingestion of plastic marine debris by seabirds, turtles, and marine mammals is well acknowledged and recognized as a serious hazard (Andrady, 2011; Azzarello and Van Vleet, 1987; Derraik, 2002; Laist, 1997; Mallory, 2008; Moore, 2008; Teuten et al., 2009; Tomas et al., 2002). However, less is known about the ingestion of plastic marine debris by piscivorous marine fishes (Carpenter et al., 1972; Hoss and Settle, 1990; Kartar et al., 1973; Possatto et al., 2011).

Observations made incidental to other studies indicate that marine fish do ingest plastic marine debris (Hoss and Settle, 1990). For example, in a food habit study of longnose lancetfish (*Alepisaurus ferox*) by Kubota and Uyeno (1970), 78 pieces of plastic and rubber were found in the stomach contents of 36 specimens. Jackson et al. (2000) studied the diet of the southern opah and discovered a high occurrence, 14% of the total stomachs analyzed, of plastic debris with a maximum size of 67.5 cm. In a comparative food study of yellowfin tuna (*Thunnus albacares*) and blackfin tuna (*Thunnus atlanticus*), Manooch and Mason (1983) found a 31.6% frequency of non-food items (plants, feathers, globs of tar and plastics) in the stomachs of yellowfin tuna compared to 15.7% in blackfin tuna. Hoss and Settle (1990) also found that during laboratory experiments fishes in early life stages feed on polystyrene microspheres sorted to appropriate food particle size (100–500 μm). The first to report fish feeding on plastic marine debris was Carpenter et al. (1972) who found eight out of 14 species of fish collected in a plankton tow in the coastal waters of New England to contain plastic debris ranging in size from 0.1 to 2 mm. Kartar et al. (1973) observed plastic debris ingested by juvenile flounder in the Severn Estuary in Great Britain, while Colton et al. (1974) found no plastic debris in the gut contents of over 500 larval and juvenile fishes in the northwestern Atlantic. Early documentation of the ingestion of plastic by piscivorous marine fishes focused primarily on the larval and juvenile stages (Hoss and Settle, 1990). A more recent study on the ingestion of plastic marine debris examined the juvenile, sub-adult, and adult phases of three marine catfish species in a tropical estuary in Northeast Brazil (Possatto et al., 2011).

In the North Pacific Ocean, the Subtropical Convergence Zone (STCZ) is a known area of marine debris concentration (Kubota, 1994; Pichel et al., 2007; Maximenko et al., 2012). The STCZ is a region of surface layer convergence caused by wind fields and associated Ekman transports that concentrate marine debris and floating plankton (Howell et al., 2012; Kubota, 1994; Pichel et al., 2007). Due to the increased biological productivity in the STCZ, it has become a significant forage and migration corridor for species such

* Corresponding author. Tel.: +1 808 944 2253; fax: +1 808 973 2934.
E-mail addresses: Lesley.Jantz@noaa.gov (L.A. Jantz), Carey.Morishige@noaa.gov (C.L. Morishige), Greg.Bruland@prin.edu (G.L. Bruland), lepczyk@hawaii.edu (C.A. Lepczyk).

0025-326X/$ - see front matter Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.marpolbul.2013.01.019

Unfortunately, marine creatures mistake plastics in the ocean for food

- Whales

Dwarf sperm whale

Marine Pollution Bulletin 80 (2014) 210–221

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Evaluating the impacts of marine debris on cetaceans

Sarah Baulch *, Clare Perry

Environmental Investigation Agency (EIA), 62-63 Upper Street, London N1 0NY, United Kingdom

ARTICLE INFO

Keywords:
Marine debris
Cetaceans
Entanglement
Ingestion
Plastic

ABSTRACT

Global in its distribution and pervading all levels of the water column, marine debris poses a serious threat to marine habitats and wildlife. For cetaceans, ingestion or entanglement in debris can cause chronic and acute injuries and increase pollutant loads, resulting in morbidity and mortality. However, knowledge of the severity of effects lags behind that for other species groups. This literature review examines the impacts of marine debris on cetaceans reported to date. It finds that ingestion of debris has been documented in 48 (56% of) cetacean species, with rates of ingestion as high as 31% in some populations. Debris-induced mortality rates of 0–22% of stranded animals were documented, suggesting that debris could be a significant conservation threat to some populations. We identify key data that need to be collected and published to improve understanding of the threat that marine debris poses to cetaceans.

1. Introduction

The continued accumulation of debris in the marine environment is a growing global concern and is now considered a major threat to marine biodiversity (Stefatos et al., 1999; Macfayden et al., 2009; Sutherland et al., 2010; CBD, 2012). An estimated 6.4 million tonnes of marine litter is dumped in oceans every year (UNEP, 2005) and in hotspots of accumulation more than 3.5 million pieces of litter can occur per square kilometre (Yamashita and Tanimura, 2007). As well as being a problem of shocking magnitude it is also one which will be long-lived. Plastic, which constitutes between 60% and 80% of marine debris, may fragment but does not biodegrade and can persist in the marine environment for hundreds to thousands of years (Derraik, 2002; Barnes et al., 2009). A wide spectrum of marine habitats and fauna are now under pressure from its effects and quantities of marine debris are increasing even in the most remote areas, far removed from source locations (Derraik, 2002; Barnes et al., 2009).

For marine fauna, the primary impacts of marine debris are from ingestion or entanglement (Gregory, 2009). Ingestion may cause blockage of the digestive tract leading to starvation, whilst entanglement can result in drowning, suffocation or strangulation (Laist, 1997). Sub-lethal effects may also occur; entanglement or ingestion of debris can compromise feeding capacity and digestion and thereby cause malnutrition, disease, and reduced reproductive output, growth rates and longevity (McCauley and Bjorndal, 1999; Katsanevakis, 2008). In addition to the risk of physical trauma, when ingesting plastics animals are exposed to an additional source of toxins (Teuten et al., 2009; Andrady, 2011). The chemical additives in plastics and persistent, bioaccumulative and toxic (PBTs) chemicals which adsorb and concentrate on plastic in the water column can leach into the body following ingestion (Engler, 2012; Fossi et al., 2012). This further amplifies pollutant burdens within individuals and through transfer from prey to predator, within food chains (Eriksson and Burton, 2003).

The last few years have seen the impacts of marine debris documented in a wide range of species, from plankton (Thompson et al., 2004; Cole et al., 2013) and fish (Lusher et al., 2013) to marine megafauna (Boren et al., 2006; Fossi et al., 2012; Simmonds, 2012). Marine debris interactions are now known to be both widespread within the marine food web (Ivar do Sul and Costa, 2013) and occurring at high rates in some species groups (CBD, 2012). However for cetaceans the rates of mortality, morbidity and the population-level consequences remain poorly understood (Williams et al., 2011a; Simmonds, 2012).

Detection of debris interactions in cetaceans largely depends on data collected from the small sample sizes provided by stranded animals, presenting only a snapshot of the impacts occurring unseen at sea. From the point at which an interaction occurs a series of events must take place in order for it to be detectable – an animal must strand, be found, and then reported to the appropriate authority. Relatively few cetacean deaths are therefore documented; studies in the northern Gulf of California found that as few as one in every 50–250 (range: 0–6.2%) carcasses are recovered from cetacean deaths at sea, with high inter-specific variability in recovery rates (Williams et al., 2011b). Even when an animal does strand, only a fraction are subject to a full necropsy and in even fewer cases can a cause of death be established and is the data subsequently published. The decomposition or condition of the

* Corresponding author. Tel.: 44 2073547960.
E-mail address: sarahbaulch@eia-international.org (S. Baulch).

http://dx.doi.org/10.1016/j.marpolbul.2013.12.050
0025-326X/

Unfortunately, marine creatures mistake plastics in the ocean for food

- Seabirds

ARTICLE IN PRESS

Marine Pollution Bulletin xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Baseline

Prevalence of marine debris in marine birds from the North Atlantic

Jennifer F. Provencher[a,*], Alexander L. Bond[b], April Hedd[c], William A. Montevecchi[c], Sabir Bin Muzaffar[d], Sarah J. Courchesne[e], H. Grant Gilchrist[f], Sarah E. Jamieson[g], Flemming R. Merkel[h,i], Knud Falk[i], Jan Durinck[j], Mark L. Mallory[k]

[a] Department of Biology, Carleton University, National Wildlife Research Centre, Raven Road, Ottawa, Ontario K1A 0H3, Canada
[b] Department of Biology, University of Saskatchewan and Environment Canada, Saskatoon, Saskatchewan, Canada
[c] Cognitive and Behavioural Ecology Program, Department of Psychology, Memorial University of Newfoundland, Newfoundland and Labrador, Canada
[d] Department of Biology, United Arab Emirates University, United Arab Emirates
[e] Seabird Ecological Assessment Network, Tufts Cummings School of Veterinary Medicine, North Grafton, MA, USA
[f] National Wildlife Research Centre, Environment Canada, Ottawa, Ontario, Canada
[g] Museum of New Zealand/Te Papa Tongarewa, Wellington, New Zealand
[h] Department of Biosciences, Aarhus University, Roskilde, Denmark
[i] Greenland Institute of Natural Resources, Nuuk, Greenland
[j] Marine Observers, Snedsted, Denmark
[k] Biology Department, Acadia University, Wolfville, Nova Scotia, Canada

ARTICLE INFO

Key words:
Ocean
Plastic
Pollution
North Atlantic
Shearwater
Fulmar

ABSTRACT

Marine birds have been found to ingest plastic debris in many of the world's oceans. Plastic accumulation data from necropsies findings and regurgitation studies are presented on 13 species of marine birds in the North Atlantic, from Georgia, USA to Nunavut, Canada and east to southwest Greenland and the Norwegian Sea. Of the species examined, the two surface plungers (great shearwaters *Puffinus gravis*; northern fulmars *Fulmarus glacialis*) had the highest prevalence of ingested plastic (71% and 51%, respectively). Great shearwaters also had the most pieces of plastics in their stomachs, with some individuals containing as many of 36 items. Seven species contained no evidence of plastic debris. Reporting of baseline data as done here is needed to ensure that data are available for marine birds over time and space scales in which we see changes in historical debris patterns in marine environments (i.e. decades) and among oceanographic regions.

Plastic pollution is a major emerging problem facing the environment (UNEP, 2011). Since mass production of consumer plastics began in the post-World War II era, plastic pollution has spread to almost every habitat on earth (Barnes et al., 2009). Subsequently, plastics and their persistence have become a global problem for many organisms that live in the world's oceans.

Plastic pollution has a wide range of effects on marine wildlife. Mammals, turtles, sea snakes and seabirds are susceptible to entanglement in plastics bags, canned beverage rings, and other marine pollution (Bond et al., 2012; Gregory, 2009; Laist, 1997; Udyawer et al., 2013; Votier et al., 2011). Smaller pieces of plastics are also problematic, as a wide range of marine organisms can ingest these during foraging, including fish, sea turtles, marine mammals and birds (Boerger et al., 2010; Cadee, 2002; Gomercic et al., 2006; van Franeker et al., 2011). Although most ingested pieces of plastic are small, larger pieces can puncture the gastrointestinal tract (Brandao et al., 2011; Carey, 2011). In addition to the direct effects of starvation and gastrointestinal tract damage caused by indigestible plastics, animals that ingest plastics are also susceptible to indirect effects of harmful chemicals found in and on the plastic material (Tanaka et al., 2013; Teuten et al., 2009; Yamashita et al., 2011).

In response to plastic pollution and its potential negative impacts on the economy and local wildlife, several international policy measures have been established to limit litter entering the ocean (e.g., OSPAR, 2008). Recognizing the need to quantify and monitor marine plastic pollution, a system of Ecological Quality Objectives (EcoQOs) was implemented in the North Sea, one of which measures plastic ingestion by the northern fulmar (*Fulmarus glacialis*; van Franeker et al., 2011).

Many marine birds are susceptible to plastic ingestion, particularly those that consume small prey on the surface of the water, as this is where plastics tend to float and accumulate (Moser and Lee,

* Corresponding author. Tel.: +1 613 998 8843; fax: +1 613 998 0458.
E-mail address: Jennifer.provencher@ec.gc.ca (J.F. Provencher).

http://dx.doi.org/10.1016/j.marpolbul.2014.04.044
0025-326X/© 2014 Elsevier Ltd. All rights reserved.

Please cite this article in press as: Provencher, J.F., et al. Prevalence of marine debris in marine birds from the North Atlantic. Mar. Pollut. Bull. (2014), http://dx.doi.org/10.1016/j.marpolbul.2014.04.044

Marine Pollution Bulletin 77 (2013) 320–324

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Prevalence and composition of marine debris in Brown Booby (*Sula leucogaster*) nests at Ashmore Reef

CrossMark

Jennifer L. Lavers *, Jarrod C. Hodgson, Rohan H. Clarke

School of Biological Sciences, Monash University, Building 17, Clayton, Victoria 3800, Australia

ARTICLE INFO

Keywords:
Brown Booby
Marine debris
Nesting ecology
Plastic pollution
Sula leucogaster
Timor Sea

ABSTRACT

Anthropogenic debris is ubiquitous in the marine environment and has been reported to negatively impact hundreds of species globally. Seabirds are particularly at risk from entanglement in debris due to their habit of collecting food and, in many cases, nesting material off the ocean's surface. We compared the prevalence and composition of debris in nests and along the beach at two Brown Booby (*Sula leucogaster*) colonies on Ashmore Reef, Timor Sea, a remote area known to contain high densities of debris transported by ocean currents. The proportion of nests with debris varied across islands (range 3–31%), likely in response to the availability of natural nesting materials. Boobies exhibited a preference for debris colour (white and black), but not type. The ephemeral nature of Brown Booby nests on Ashmore Reef may limit their utility as indicators of marine pollution, however monitoring is recommended in light of increasing demand for plastic products.

1. Introduction

Plastics and other anthropogenic debris (hereafter referred to as marine debris, or simply debris), much of it originating from fishing activities and run-off from rivers, are increasing rapidly in the world's oceans (Ribic et al., 1997; Gregory, 2009; Ryan et al., 2009). While ubiquitous in the marine environment, debris tends to concentrate at oceanographic sites where marine animals aggregate to feed (Laist, 1987; Pichel et al., 2007; Howell et al., 2012). Consequently, the ingestion of, or entanglement in, debris has been reported in more than 265 species of birds, fish, turtles, and whales (Laist, 1997; Derraik, 2002).

In the Sulidae (gannets and boobies), adult males collect debris, primarily at sea, during courtship and incorporate it rather conspicuously into their nests (Moore and Wodzicki, 1950; Nelson, 1978). This behaviour, along with the ingestion of debris by seabirds, can provide information on temporal changes in the type, quantity, and source of debris present in the marine environment (Ryan, 2008; van Franeker et al., 2011; Bond et al., 2012). However, it also increases the risk of entanglement of both juveniles and adults and therefore poses a conservation concern (Laist, 1997; Parker and Blomme, 2007; Votier et al., 2011).

Marine debris is prevalent in the nests of gannets (*Morus* sp.) and has been the focus of numerous studies (Schrey and Vauk, 1987; Montevecchi, 1991; Schneider, 1991; Norman et al., 1994; Cooper and Petersen, 2009; Bond et al., 2012). In contrast, only one study briefly mentions debris in booby (*Sula* sp.) nests (Ostrowski et al., 2005). In order to provide insight into the frequency of this behaviour in boobies, we assessed (1) the type, colour, and mass of marine debris incorporated into Brown Booby (*Sula leucogaster*) nests on breeding islands in the Timor Sea, and (2) the capacity of nest debris to act as an indicator of the amount and type of debris in marine environments where direct, quantitative data are not available. We also briefly discuss the extent to which nest debris poses an entanglement risk for this declining species.

2. Methods

2.1. Study sites

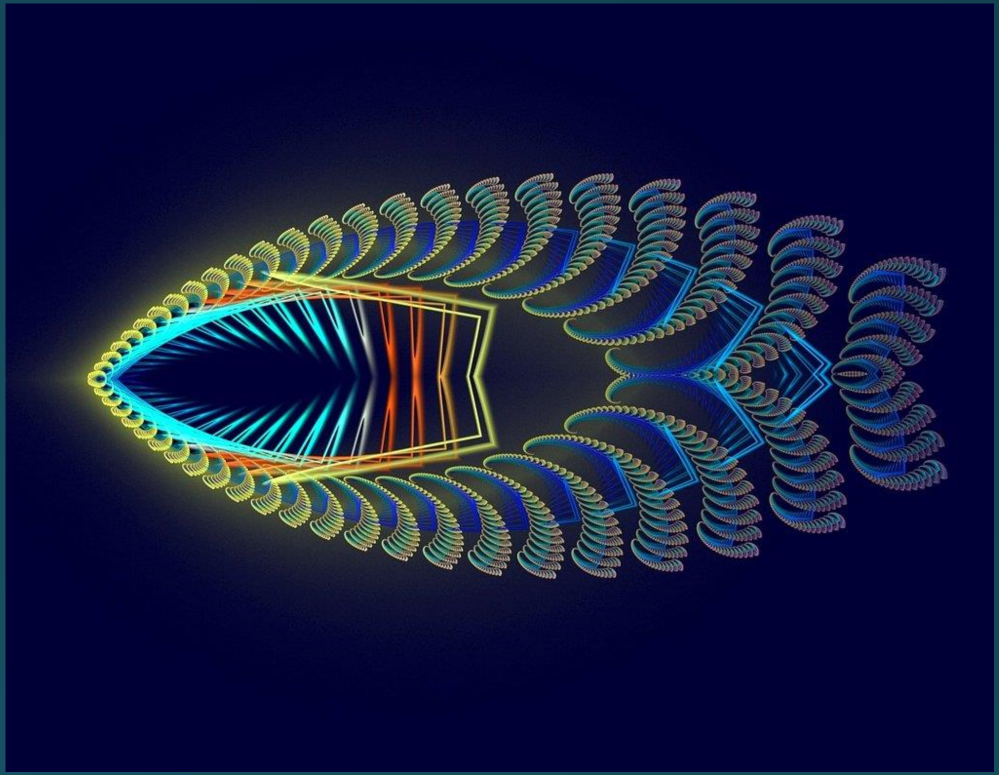
Ashmore Reef Commonwealth Marine Reserve (12°20′S, 123°0′E) lies within Australian Commonwealth waters, approximately 630 km north of Broome, Western Australia (Fig. 1). The reef contains four lightly vegetated islands (East, Middle, and West Islands and Splittgerber Cay; total land area ~54 ha) and is home to some of the most important seabird rookeries on the North West Shelf (Clarke et al., 2011). It is recognised as a Ramsar wetland of international importance (Ramsar Convention Bureau, 2013) and is designated as an Important Bird Area (BirdLife International, 2013). The Brown Booby is the most abundant of the three species of Sulidae breeding at Ashmore Reef with an estimated 2632 and 3453 pairs breeding on East and Middle Islands in April 2013, respectively (Clarke and Herrod, 2013).

* Corresponding author. Tel.: +61 (03)9905 0269.
E-mail address: Jennifer.Lavers@monash.edu (J.L. Lavers).

0025-326X/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.marpolbul.2013.09.026

Unfortunately, marine creatures mistake plastics in the ocean for food

- And the list goes on and on and on….



Marine Environmental Research 95 (2014) 89–95

Contents lists available at ScienceDirect

Marine Environmental Research

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

Evidence of microplastics in samples of zooplankton from Portuguese coastal waters

J.P.G.L. Frias [a,*], V. Otero [b,c], P. Sobral [a]

[a] IMAR – Instituto do Mar, Departamento de Ciências e Engenharia do Ambiente, Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa, 2829-516 Monte de Caparica, Portugal
[b] Departamento de Conservação e Restauro, Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa, 2829-516 Monte de Caparica, Portugal
[c] REQUIMTE-CQFB, Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa, 2829-516 Monte de Caparica, Portugal

A R T I C L E I N F O

Article history:
Received 29 October 2013
Received in revised form
27 December 2013
Accepted 4 January 2014

Keywords:
Microplastics
Plastic
Zooplankton
MSFD
FTIR
Portugal

A B S T R A C T

Records of high concentrations of plastic and microplastic marine debris floating in the ocean have led to investigate the presence of microplastics in samples of zooplankton from Portuguese coastal waters. Zooplankton samples collected at four offshore sites, in surveys conducted between 2002 and 2008, with three different sampling methods, were used in this preliminary study. A total of 152 samples were processed and microplastics were identified in 93 of them, corresponding to 61% of the total. Costa Vicentina, followed by Lisboa, were the regions with higher microplastic concentrations (0.036 and 0.033 no. m^{-3}) and abundances (0.07 and 0.06 cm^3 m^{-3}), respectively. Microplastic: zooplankton ratios were also higher in these two regions, which is probably related to the proximity of densely populated areas and inputs from the Tejo and Sado river estuaries. Microplastics polymers were identified using Micro Fourier Transformed Infrared Spectroscopy (μ-FTIR), as polyethylene (PE), polypropylene (PP) and polyacrylates (PA). The present work is the first report on the composition of microplastic particles collected with plankton nets in Portuguese coastal waters. Plankton surveys from regular monitoring campaigns conducted worldwide may be used to monitor plastic particles in the oceans and constitute an important and low cost tool to address marine litter within the scope of the Marine Strategy Framework Directive (2008/56/EC).

1. Introduction

In recent years, the presence and impacts of plastic marine debris (PMD) have been documented throughout the world in all oceans. Plastic debris, which may be unintentionally lost or deliberately discarded, tend to accumulate in coastal areas, posing a direct threat to marine fauna through ingestion and/or entanglement (Crimmins et al., 2002; Allen et al. 2012; Cole et al. 2013; Wright et al., 2013).

It is estimated that 80% of PMD derive from land sources (Allsopp et al., 2006), being transported by water courses (river streams, drainage systems, ocean currents) (Corcoran et al., 2009; Furness, 1983; Laist, 1987, 1997; Gregory and Andrady, 2003) and/or migratory animals (birds, turtles, dolphins, seals, among others) (Ryan et al., 2009; Teuten et al., 2009; Franeker et al., 2011), enabling PMD to travel great distances, being found in remote regions, far away from any known source (Ivar do Sul and Costa, 2007; Barnes et al. 2009; Martins and Sobral, 2011; Heskett et al., 2012).

PMD concentration increase in the oceans is linked to human consumption behaviour, industrial activities and poor waste management. Buoyancy contributes to the wide dispersion of PMD in the open ocean, as plastics float and are transported by surface currents. High concentrations of plastics and microplastics accumulate in convergence zones known as ocean gyres (Pichel et al., 2007).

Reports of the high incidence of PMD in the North Pacific Central Gyre (Moore et al., 2001, 2002; Moore, 2008; Goldstein et al., 2012), and in other places of the world, have raised concern and an unprecedented interest for research on the topic in the areas of marine sciences (Derraik, 2002; Arthur et al., 2008; Thompson et al., 2004) as well as in social sciences (Thiel et al. 2003; Bravo et al. 2009; Hinojosa and Thiel, 2009; Luís and Spínola, 2010).

Microplastics, defined as plastic materials or fragments with diameter below 5 mm (Arthur et al., 2008), have also the tendency to increase concentration over time as result of plastic degradation. Factors like solar radiation, abrasion, water and wind movements cause PMD to break into progressively smaller pieces without

* Corresponding author. Tel.: +351 212948300x10103.
E-mail addresses: jpfrias@fct.unl.pt, joaopgldefrias@gmail.com (J.P.G.L. Frias).

0141-1136/$ – see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.marenvres.2014.01.001

Marine Debris also creates navigational hazards

Radar bar deliberately cutoff from a large vessel

Collecting samples using a manta trawl

- 1 meter X .5 meter
- 330 micron net
- 2-3 knots
- Varied time from

15 minutes to 1 hr

The Plastic Ocean Project

http://www.plasticoceanproject.org/

Underwater look at the trawl

Samples from the North Atlantic Gyre (Bermuda Atlantic Time Series Station (BATS))

Results from first set of samples in the North Atlantic Sargasso Sea

Comparison between Carpenter and Smith (*Science*, **1972**, *175*, 1240-4), **11**-neuston net tows, 27 Sep – 18 Oct, 1971 and our **6**-manta (neuston) net trawls, 22-26 Jul 2009:		
Sample	Carpenter and Smith (1972)	Monteleone et al. (2009)
	Plastic Particles (g/km^2)	
Low	0.6	23.8
High	1,771	3,570
Mean	287	977

Separated samples by size, type, and color
(1-2.36 mm, most fragments are white)

Rough Estimate from study
Sargasso Sea is 3,520,000 km= 3,440 tonnes of plastic

Data comparison 2009 and 2010 surveys

Trawl	Sample Distance	Plastic Sample Weight	Plastic	Plastic	Plastic	North Atlantic Sub-Tropical Gyre*
	(m)	(g)	(g/m^2)	(g/km^2)	(kg/km^2)	Tonnes
July 2009						
1	3520	0.11	0.0000482	48.2	0.0482	170
2	1233	0.26	0.000326	326	0.326	1148
3	1295	0.02	0.0000238	23.8	0.0238	84
4	2579	1.43	0.000856	856	0.856	3013
5	1497	3.46	0.00357	3570	3.57	12566
7	4187	2.83	0.00104	1040	1.04	3661
					Mean by weight	**3440**
July 2010						
1	3401	1.9	0.000559	559	0.559	1966
3	1986	0.46	0.000232	232	0.232	815
4	1921	1.383	0.000720	720	0.720	2534
5	2658	0.488	0.000184	184	0.184	646
6	1475	1.846	0.001250	1250	1.250	4405
7	3004	1.234	0.000411	411	0.411	1446
8	2486	1.948	0.000784	784	0.784	2758
9	1711	1.457	0.000852	852	0.852	2997
10	2199	3.365	0.001530	1530	1.530	5386
11	747	1.717	0.002300	2300	2.300	8091
12	935	3.015	0.003230	3230	3.230	11851
					Mean by weight	**3854**
	Combined Estimate of the Plastic Pollution in the NASTG					**3708**

*3,520,000 square kilometers

- combined average NA subtropical gyre surface waters **~3200 tonnes of plastic**
- plastic distribution is highly variable- some of this can be associated with eddies
- association between plastic distribution and Sargassum mats is not strong

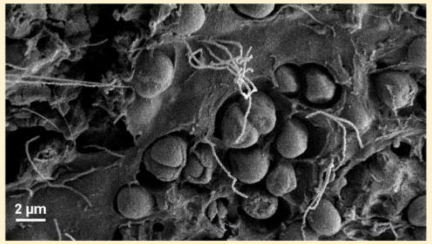
Findings

- Every Sargasso trawl contained plastic
- Plastics were extremely heterogeneous
- Preliminary data suggests there is an increase in accumulation
- Plastics washed out to sea appear to photo-degrade, fragment, and wash up on Bermuda ‘s beaches

PROCESSING THE SAMPLES

THE PLASTISPHERE

A NEW MARINE ECOSYSTEM



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 debris can impact the gyre interior that is more than 1000 km from land. Plastic debris in the North Atlantic Subtropical Gyre[4] and North Pacific Subtropical Gyre is well-documented[5−9] and models and limited sampling confirm that 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

Received: March 26, 2013
Revised: May 26, 2013
Accepted: June 7, 2013
Published: June 7, 2013

http://startsomegood.com/plasticoceans


THANK YOU!