A JOURNEY INTO THE GREAT PACIFIC GARBAGE PATCH

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PREVIOUS WORK

A GLOBAL INVENTORY OF SMALL FLOATING PLASTIC DEBRIS

Quantification of floating microplastics at global scale using three different numerical models and historical concentration data from trawl collections.

Concentrations in the GPGP predicted highest in offshore oceanic waters with values > 1 kg/km² for microplastics.

INTRODUCING SIZE CLASSES

Combining field observation techniques with manta trawls and visual surveys to describe a larger size spectrum consideration

- Microplastics (0.333 – 1 mm & 1 – 4.75 mm)
- Mesoplastics (4.75 – 200 mm)
- Macroplastics (>200 mm)

In the North Pacific Ocean, one order of magnitude difference in mass concentration between microplastics (> 1 kg/km²) and macroplastics (> 10 kg/km²)

STUDY REQUIREMENTS

Quantification across a large debris size spectrum: use orders of magnitude!
- **Micro** (0.05 – 0.5 cm)
- **Meso** (0.5 – 5 cm)
- **Macro** (5 – 50 cm)
- **Mega** (> 50 cm)

Characterize ocean plastic by polymer and debris type:
- Type **H** (Hard/Sheet plastics)
- Type **N** (Nets/Ropes/Filaments)
- Type **F** (Foam)
- Type **P** (Preproduction pellets)

Resolve the temporal variability of buoyant ocean plastic concentration at the surface of the Great Pacific Garbage Patch.
THE MEGA EXPEDITION

18 VESSELS BETWEEN JULY - SEPTEMBER 2015

A fleet of sailing and research vessels collecting data (net tows and visual surveys) in the North Pacific subtropical waters. Vessels carried out net tows of 0.35 – 4 hours duration, while navigating at 0.7 - 6.8 knots.

COMBINING DIFFERENT MONITORING TECHNIQUES

2 Mega Nets (6 x 1.5 m mouth, 15 mm square mesh) were deployed on board the RV Ocean Starr with 2 concurrent Manta Nets (0.9 x 0.15 m mouth, 0.5 mm square mesh) to compare monitoring techniques.
THE MEGA EXPEDITION

MONITORING EFFORT

652 surface net tows were carried out by 18 participating vessels between 25°N – 41°N and 129 - 156°W.

3.9 km$^2$ surveyed by Manta nets
n = 350 stations for micro- and mesoplastics.

13.6 km$^2$ surveyed by Mega nets
n= 76 stations for macroplastics.
THE MEGA EXPEDITION

THE GHOSTNET PROBLEM

While the surfaces covered by Manta and Mega net tows were acceptable to respectively quantify micro/meso and macroplastics, the surveyed area was considered not sufficiently representative when estimating the contribution of larger debris (megaplastics, size > 50 cm).

Among the four ghostnets retrieved by the RV Ocean Starr, the one pictured on the right was the largest.

Dry weight - 140 kg.
LEAVING ON A JET PLANE
THE AERIAL EXPEDITION

TWO RECONNAISSANCE FLIGHTS IN OCTOBER 2016

Hercules C-130 aircraft flying at 400 m above sea level inside the GPGP collecting aerial imagery (RGB camera, SWIR imager and Lidar) over 311.0 km$^2$ of sea surface area.

COLLECTING 7,298 SINGLE-FRAME MOSAICS

Analysis and machine-learning algorithm implementation for the detection of debris on a RGB imagery set with pixel resolution of 10 cm at the sea surface.

Additional SWIR and LiDAR data currently under analysis.
SAMPLE COLLECTION ANALYSIS

Sample from one Manta net tow

Sample from one Mega net tow

Aerial mosaic with spotted debris

Sorting, counting and weighting plastic particles

Debris characterization
MEASURED CONCENTRATION DATA

RESULTS BY SIZE CLASS
Average (min – max)

MICROPLASTICS
• 2.5 (0.07 – 26.4) kg/km²
• 678,000 (20,108 - 11,054,595)#/km²

MESOPLASTICS
• 3.9 (0.0003 – 88.4) kg/km²
• 22,000 (261 - 321,712)#/km²

MACROPLASTICS
• 16.8 (0.4 - 70.4) kg/km²
• 690 (40 - 2,433)#/km²

MEGAPLASTICS
• 46.3 (0.4 - 428.1) kg/km²
• 3.5 (0.5 - 11.6)#/km²
MODELLING THE FORMATION OF THE GPGP

RESOLVING TEMPORAL VARIABILITY

Sea surface current reanalysis (global 1/12° resolution) and simulation of transport constituents from wind (Windage coefficient) and waves (Stokes drift).

Release of Lagrangian particles from five different source scenarios:

• Coastal population
• River inputs
• Fishing
• Aquaculture
• Shipping
MODELLING THE FORMATION OF THE GPGP

RESOLVING TEMPORAL VARIABILITY

MODELLED GPGP CENTRE LATITUDE

El Niño Southern Oscillation ENSO index

MODELLED GPGP CENTRE LONGITUDE

Pacific Decadal Oscillation PDO index
MODELLING THE FORMATION OF THE GPGP

CALIBRATION AND VALIDATION

a) The **GPGP boundary** (blue line) is estimated by comparing microplastic concentration measurements (circles) to model particle visit averages accounting for seasonal and interannual variations.

b) Model validation showing median measured mass concentration for microplastics of stations outside and inside predicted 1 kg/km² GPGP boundary.

c) Measured versus modelled mass concentrations for all sizes

d) Same as (c) but with numerical concentrations.
RESULTS

Our model predicted at least **79 (45-129) thousand tonnes** of ocean plastic are floating inside an area of **1.6 million km$^2$**.
RESULTS

CHARACTERIZATION BY SIZE AND TYPE

Over three-quarters of the GPGP mass was carried by debris larger than 5 cm and at least 46% was comprised of fishing nets.

MASS AND COUNT DISTRIBUTION

Microplastics accounted for 8% of the total mass but 94% of the estimated $1.8 \ (1.1-3.6)$ trillion pieces floating in the area.
RESULTS

LONG TERM ANALYSIS

A dynamic GPGP model boundary allowed us to determine whether surface net tows from previous studies were sampling inside or outside the GPGP.

Average microplastic mass concentration measured by net tows inside the GPGP boundary showed an exponential increase over the last decades, rising from an average 0.4 kg/km² (± 0.2 SE, n = 20) in the 1970s to 1.23 kg/km² (± 0.06 SE, n = 288) in 2015.
CONCLUSIONS

• ~80,000,000 kg of buoyant ocean plastic currently in the GPGP

A figure 4 to 16 times higher than previously estimated, supported by more robust monitoring method for larger debris.

• SIZE MATTERS!

Buoyant plastic pollution in subtropical accumulation zones is mostly comprised of microplastics if we consider numerical concentration BUT 92% of the plastic mass is carried by larger debris.

• Plastic concentration has been increasing exponentially in the GPGP over the last decade and, at a faster rate than surrounding waters i.e. influx of debris is greater the natural removal processes.

This can be proved by the use of time-coherent numerical models.

• Our results raise new question on the persistency of buoyant plastic in subtropical accumulation zones >> How long for the existing macro litter at sea to naturally disappear from the surface ???

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THANK YOU