Finding Plastic Patches in Coastal Waters using Sentinel-2 Satellites

Lauren Biermann, Dan Clewley, Victor Martinez-Vicente, Konstantinos Topouzelis
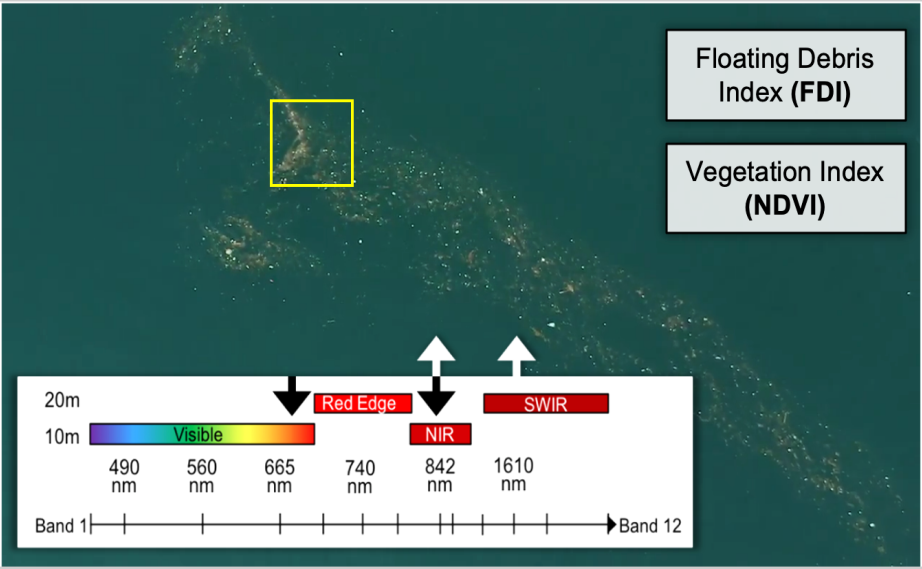
esa | PML | Plymouth Marine Laboratory

Background:

ESA Sentinel-2A and -2B launched in 2015 & 2017.

Coverage includes coastal waters every 2 to 5 days at **10 m** spatial resolution.

Limitations for detecting plastic includes cloudiness and bright wave caps.

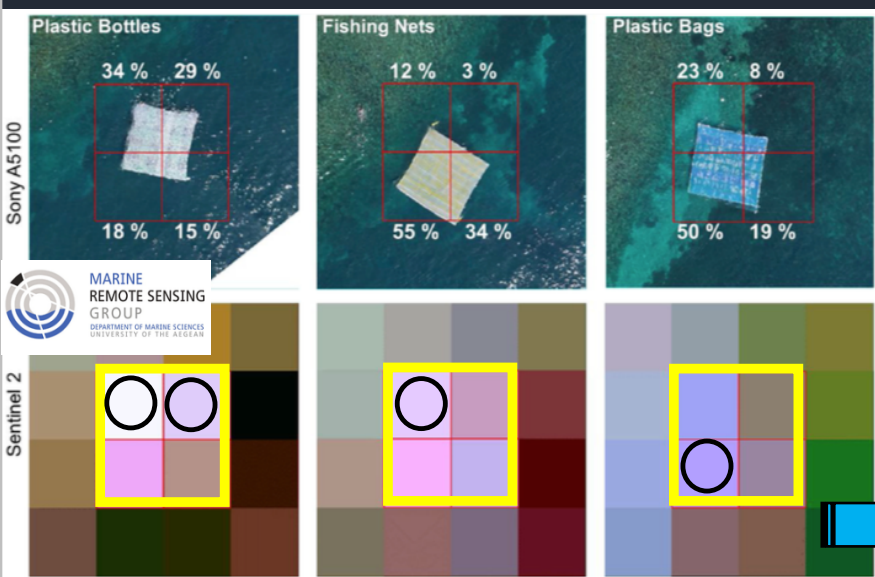Reliant on **submesoscale features** like fronts → → → to aggregate floating debris.

Floating Debris Index **(FDI)**

Vegetation Index **(NDVI)**

20m — Red Edge — SWIR
10m — Visible — NIR
490 nm — 560 nm — 665 nm — 740 nm — 842 nm — 1610 nm
Band 1 ———→ Band 12

Macroplastics : plastic pieces or fragments > 5 mm.

Coastal waters: plastic pollution is mostly from land.

If not recirculated onto beaches / sunk / removed through clean-up operations, these plastics will enter open ocean to become…

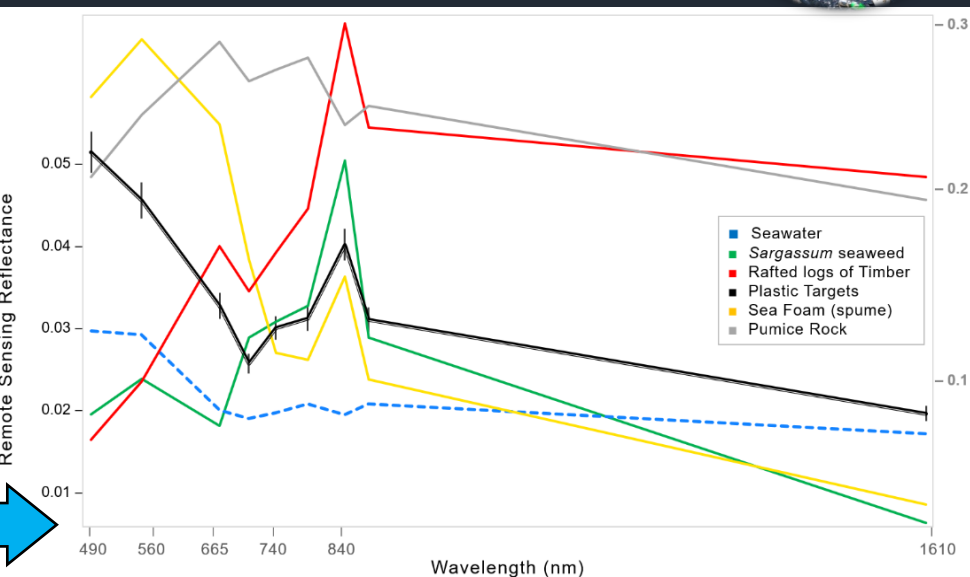Microplastics

Entangled

Ingested

FDI Subpixel Detection on 10m² Plastic Targets:

Plastic Bottles — 34 % — 29 % — 18 % — 15 %
Fishing Nets — 12 % — 3 % — 55 % — 34 %
Plastic Bags — 23 % — 8 % — 50 % — 19 %

Sony A5100

Sentinel 2

MARINE REMOTE SENSING GROUP
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(Figure from Topouzelis et al., 2019).

Spectral Signatures of Marine Debris:

Remote Sensing Reflectance

- Seawater
- *Sargassum* seaweed
- Rafted logs of Timber
- Plastic Targets
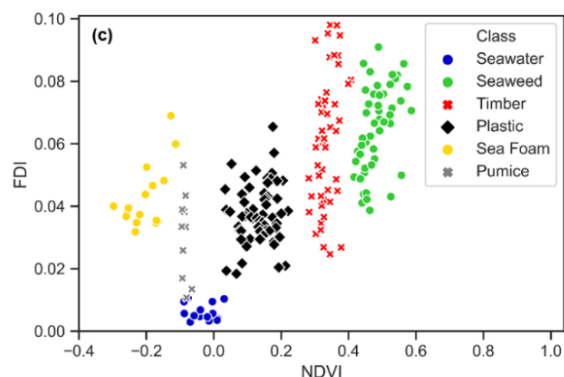- Sea Foam (spume)
- Pumice Rock

Wavelength (nm)

X-axis shows Sentinel-2 MSI bands from blue (490) to short-wave infrared (1610 nm)

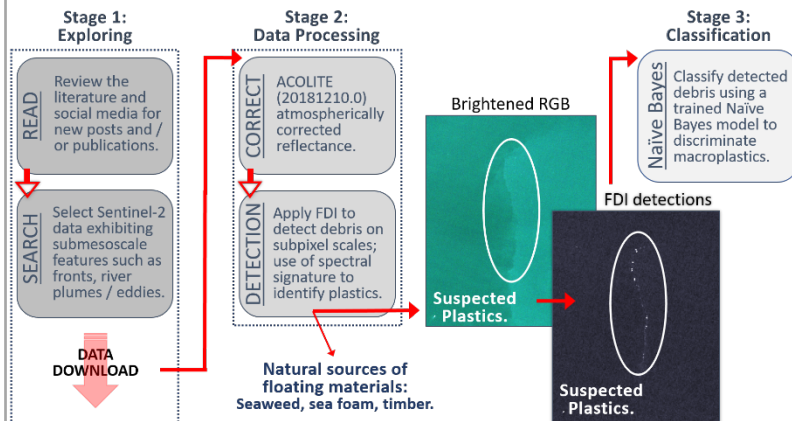# Building a Spectral Library of Floating Marine Materials:

- To discriminate plastic we used a **Naïve Bayes** (Bayesian) ML classification approach.
- Requires small number of samples to train. However, we only had 9 pixels from plastic targets; added validated plastic detections from Durban, South Africa:

In simple two-variable feature space of NDVI and FDI, we can see distinct clustering of validated plastics from Durban, seaweed from Barbados, timber from Canada, sea foam from the UK, Pumice from Toga, and seawater from all sites:

Searching for Patches of Floating Plastics 'in the wild':

Stage 1: Exploring

READ: Review the literature and social media for new posts and / or publications.

SEARCH: Select Sentinel-2 data exhibiting submesoscale features such as fronts, river plumes / eddies.

DATA DOWNLOAD

Stage 2: Data Processing

CORRECT: ACOLITE (20181210.0) atmospherically corrected reflectance.

DETECTION: Apply FDI to detect debris on subpixel scales; use of spectral signature to identify plastics.

Natural sources of floating materials: Seaweed, sea foam, timber.

Brightened RGB — Suspected Plastics.

FDI detections — Suspected Plastics.

Stage 3: Classification

Naïve Bayes: Classify detected debris using a trained Naïve Bayes model to discriminate macroplastics.

- Based on reports of marine plastics in the literature, popular press and social media, we detected aggregations of floating debris in the coastal waters off Accra (Ghana), Gulf Islands (Canada), Da Nang bay (Vietnam), and Scotland (UK).
- Aggregating features such as plumes, fronts and/or eddies tend to be visible in the RGB imagery, but the FDI has proven to be key for highlighting floating debris on subpixel scales.
- Example from off the Isle of May in Scotland below:

Isle of May, Scotland

Natural front

Sentinel-2 'true colour' image (RGB)

Floating Debris suspected to include plastics

Sentinel-2 Floating Debris Index (FDI)

<u>Sentinel-2 MSI satellite imagery generated using the ESA open-source Sentinel Applications Platform (SNAP) software.</u>

Machine Learning Classification Results:

- Across all sites, suspected plastics were classified as plastics by the Naïve Bayes model 86% of the time

Classification (predicted)

	1	2	3	4	5
1	1.0	0	0	0	0
2	0	1.0	0	0	0
3	0	0	1.0	0	0
4	0.03	0	0	0.86	0.11
5	0	0	0	0	1.0

Detected

1 = Seawater
2 = Seaweed
3 = Timber
4 = Suspected Plastics
5 = Sea Foam (spume)

- Detections off Ghana and Canada had highest agreement between suspected plastics and the model at 87% and 100%, respectively.
- Detections off Vietnam and Scotland showed agreements of 77% and 83%, respectively.
- Suspected plastics not classified as plastics were instead identified as seawater, suggesting that an insufficient amount of pixel was filled with floating debris, or spume.

Finding Plastic Patches in Coastal Waters using Optical Satellite Data

Lauren Biermann[1*], Daniel Clewley[1], Victor Martinez-Vicente[1] & Konstantinos Topouzelis[2]

Satellites collecting optical data offer a unique perspective from which to observe the problem of plastic litter in the marine environment, but few studies have successfully demonstrated their use for this purpose. For the first time, we show that patches of floating macroplastics are detectable in

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