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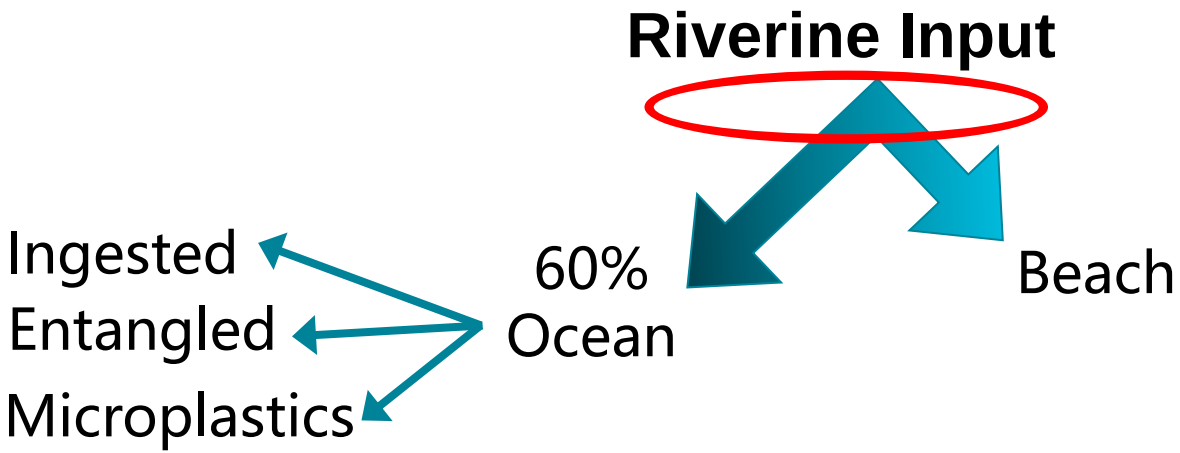
# Detecting Floating Debris

Towards a method for detecting macroplastics in coastal waters using data collected by earth observation satellites.

Lauren Biermann, Victor Martinez-Vicente

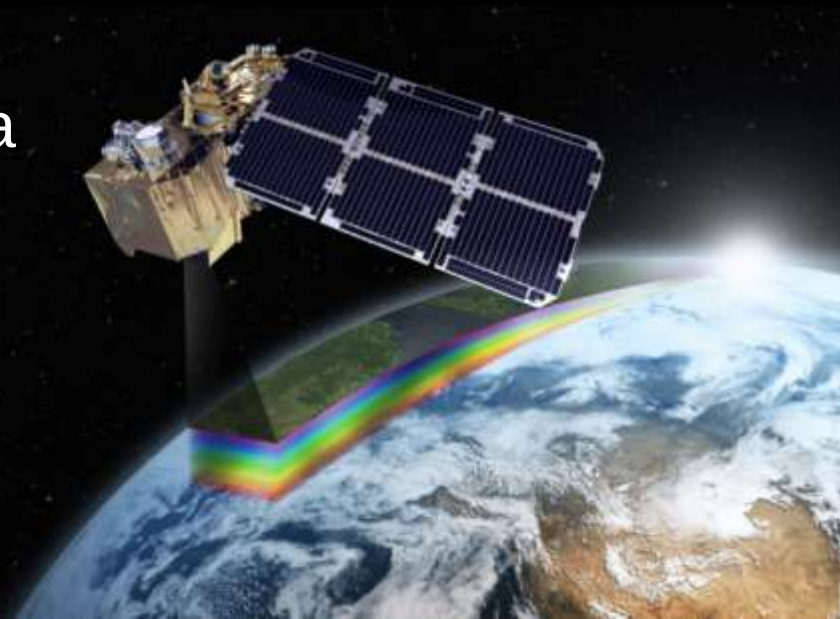
# Marine Litter and Floating Macroplastics

- **Macro**plastics = any plastics or plastic fragments larger than 5mm.
- Majority of micro- to macroplastics enter our coastal waters from land-based sources.



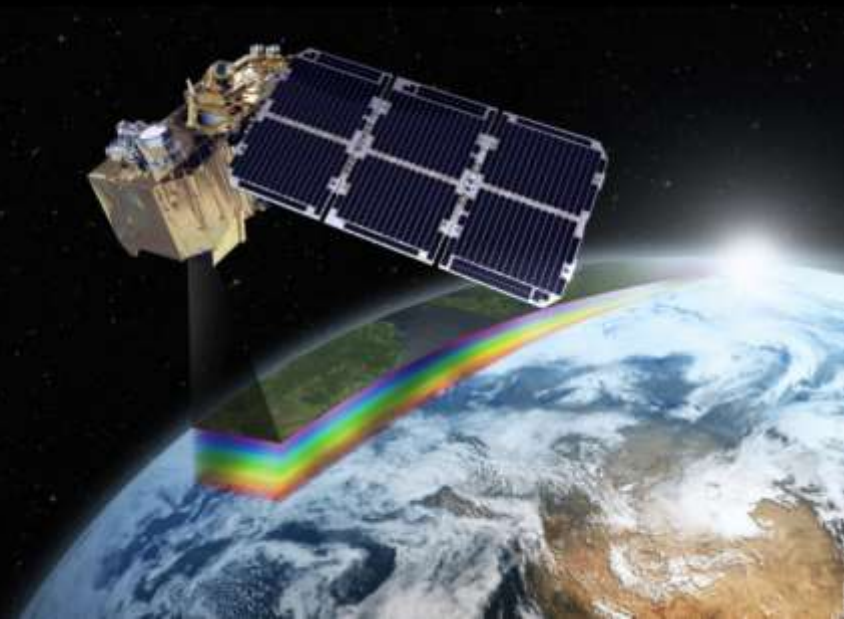
# Satellites to detect floating macroplastics

- Satellite data are not yet widely used for the detection of macroplastics in the marine environment.
- Limiting factors include:
  - Lack of *in situ* validation data
  - Environmental factors
  - Satellite sensor limitations



# Using Sentinel-2 to detect floating debris

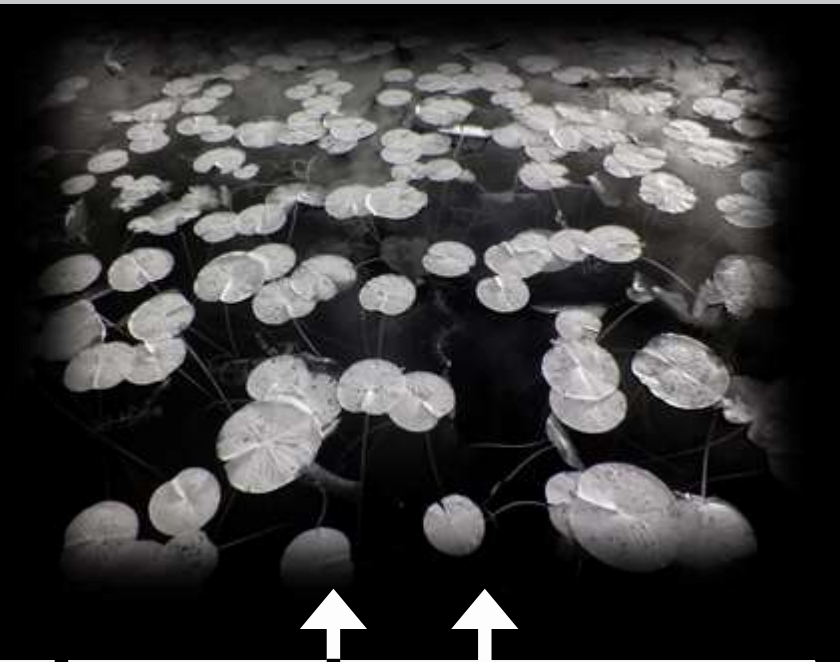
- Sentinel-2A & B satellites were launched in 2015 & 2017.
- Developed for terrestrial services, but coverage includes coastal waters.
- Image every 2 to 5 days at 10m spatial resolution.
- Submesoscale features are known to aggregate floating materials.

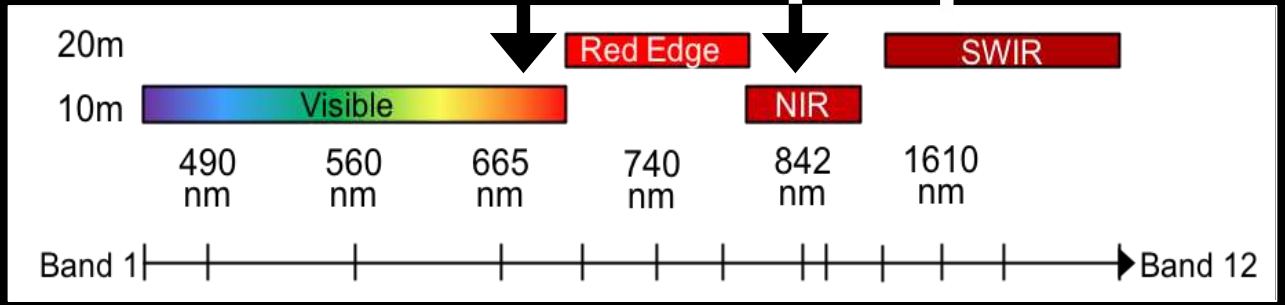



Video from
@HFiskJohnson


2019-08-25, Sentinel-2B L1C, Custom script
BEESTON
RYLANDS
CHILWELL
Beeston Pond
River Trent
River Trent
Clifton Lane
SILVERDALE
Clifton Blvd.
COMPTON
ACRES
Works Pond
Nottingham Road
Holme Pit
CLIFTON
River Trent
Tween Pond
River Trent
Barton Lane
Conneries Pond
River Trent
River Trent
River Trent
Remembrance Way
Ruddington
Barton-in-Fabis
River Trent
Remembrance Way
500 m
Credit: European Union, contains modified Copernicus Sentinel data 2019, processed with EO Browser
Copernicus
SENTINEL Hub

| MSI band | Descriptor | Wavelength | Resolution |
|---|---|---|---|
| Band 1 | Coastal Aerosol | 443 nm | 60 m |
| Band 2 | Blue | 490 nm | 10 m |
| Band 3 | Green | 560 nm | 10 m |
| Band 4 | Red | 665 nm | 10 m |
| Band 5 | Red Edge 1 | 704 nm | 20 m |
| Band 6 | Red Edge 2 | 740 nm | 20 m |
| Band 7 | Red Edge 3 | 780 nm | 20 m |
| Band 8 | Near Infrared | 842 nm | 10 m |
| Band 8a | Narrow NIR | 865 nm | 20 m |
| Band 9 | Water Vapour | 940 nm | 60 m |
| Band 10 | SWIR Cirrus | 1375 nm | 60 m |
| Band 11 | SWIR 1 | 1610 nm | 20 m |
| Band 12 | SWIR 2 | 2190 nm | 20 m |





# Processing and sub-pixel detection

Atmospheric Correction:

- ACOLITE processor (RBINS) for Sentinel-2 conserves NIR to SWIR wavelengths – Dark Spectrum Fitting.

Sub-pixel Debris Detection:

- Based on a floating algae index developed by Hu (2009), red edge (RE) bands were incorporated to develop the **Floating Debris Index**:

$$FDI = Rrs_{,NIR} - R_{rs,RE} - (R_{rs,SWIR} - R_{rs,RE})\frac{(\lambda_{NIR} - \lambda_{RE})}{(\lambda_{SWIR} - \lambda_{RE})}$$

# 10 m x 10 m Plastic Targets

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REMOTE SENSING
GROUP
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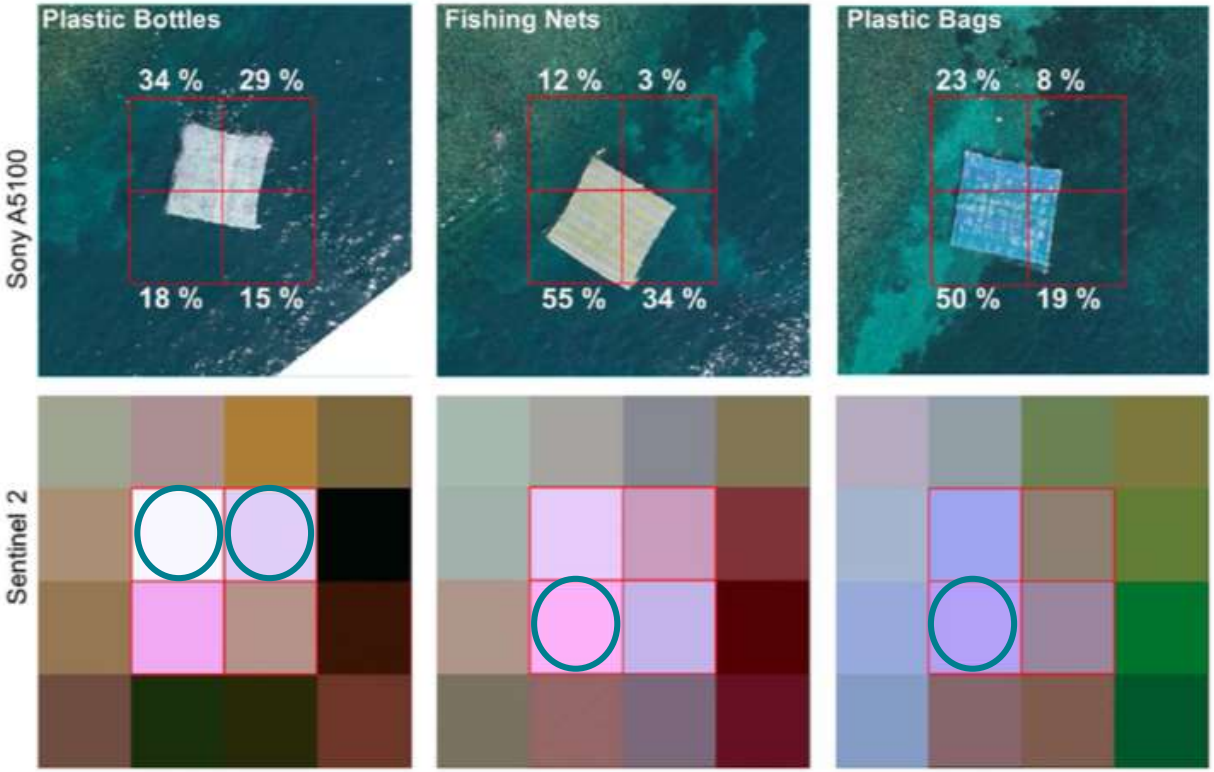
UNIVERSITY OF THE AEGEAN



# 10 m x 10 m Plastic Targets

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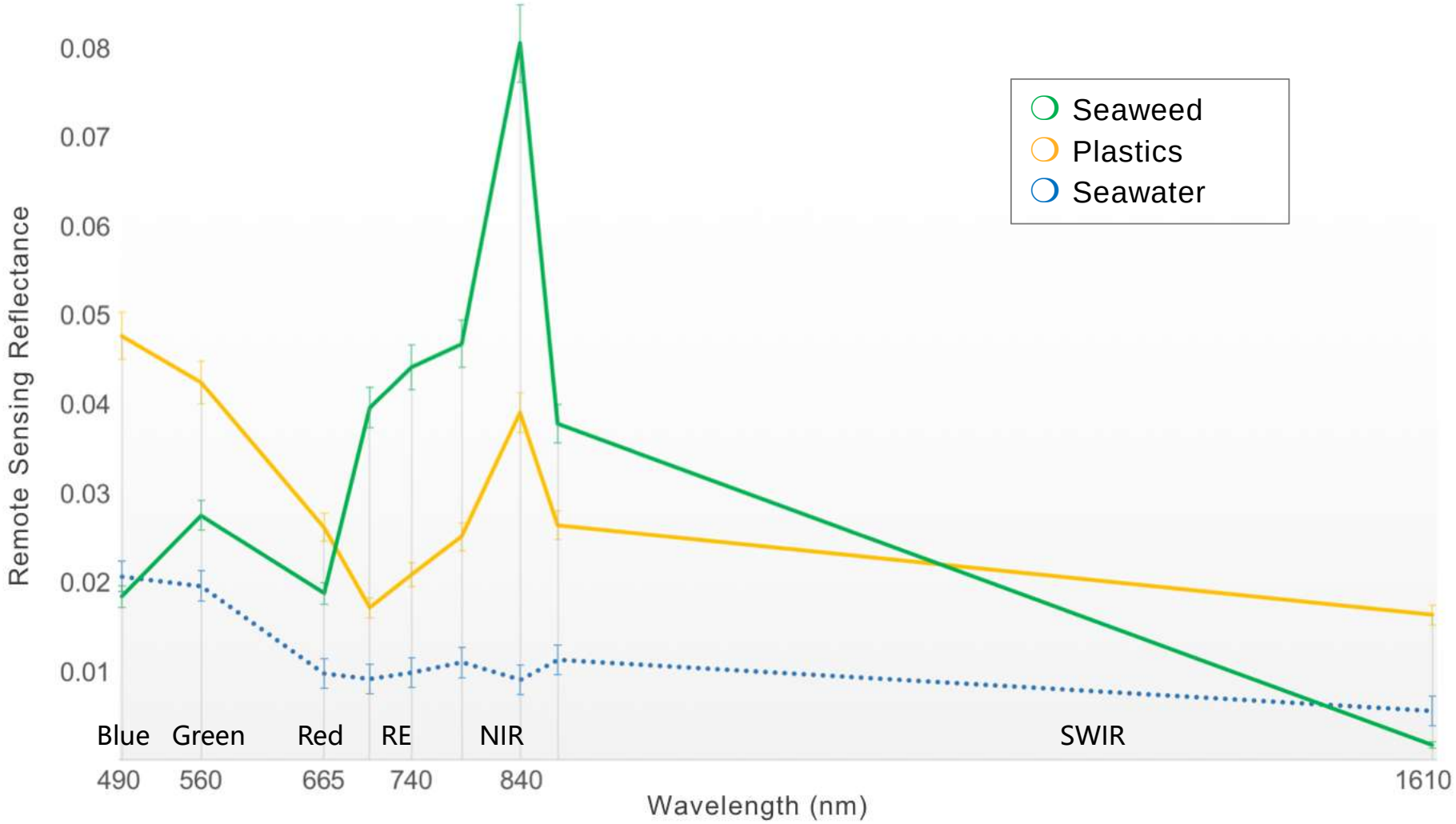
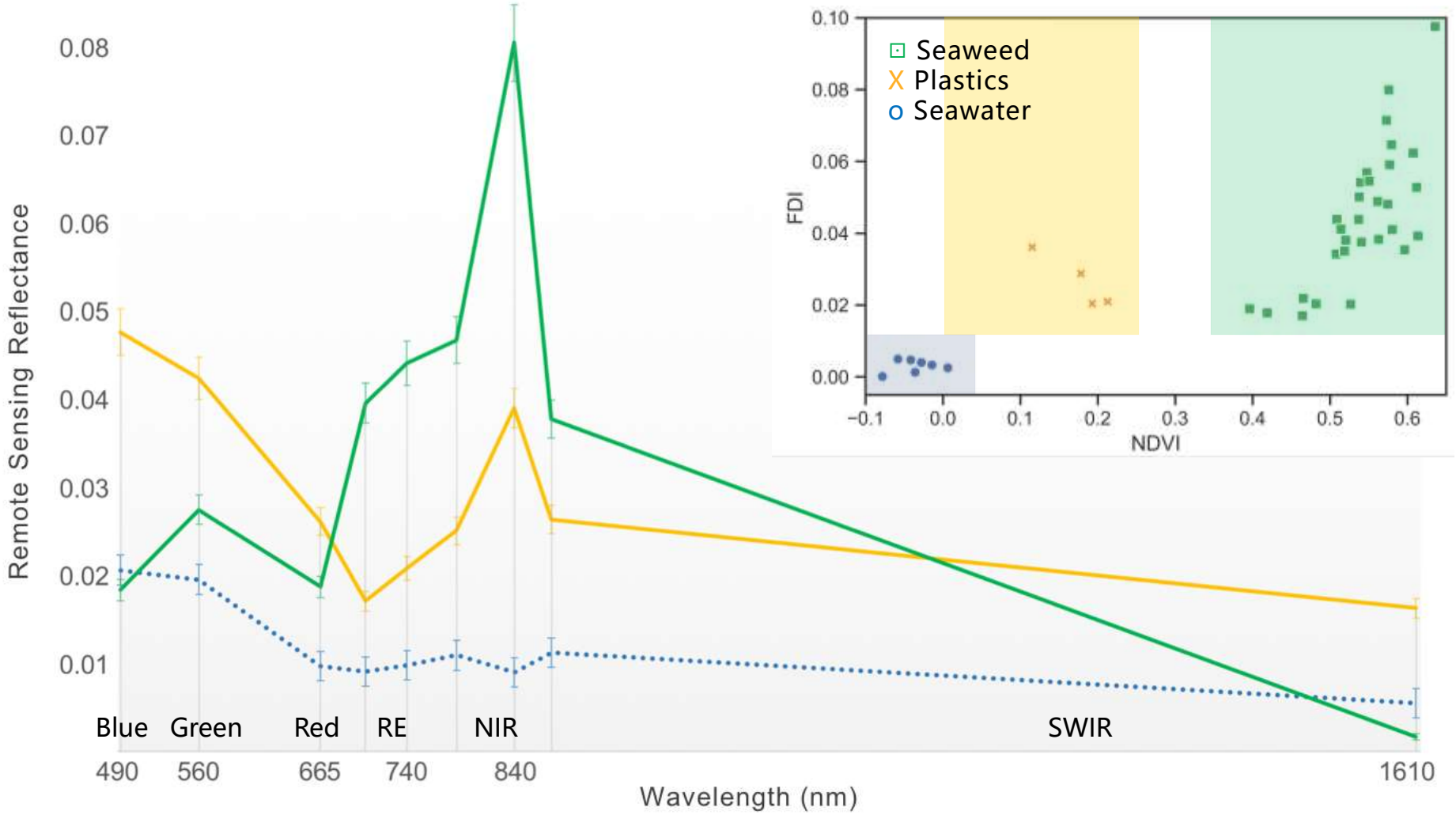
Topouzelis K, Papakonstantinou A, Garaba, S.P. (2019).
**Detection of floating plastics from satellite and unmanned aerial systems (PlasticLitterProject 2018).**
*International Journal of Applied Earth Observation and Geoinformation*


Seaweed
Plastics
Seawater
Remote Sensing Reflectance
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
Blue
Green
Red
RE
NIR
SWIR
490
560
665
740
840
1610
Wavelength (nm)

# Macroalgae

- Sargassum seaweed is increasingly widespread.
- Floating ‘rafts’ can be up to seven meters deep.



Remote Sensing Reflectance
0.08
0.07
0.06
0.05
0.04
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0.02
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Blue
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Wavelength (nm)
Seaweed
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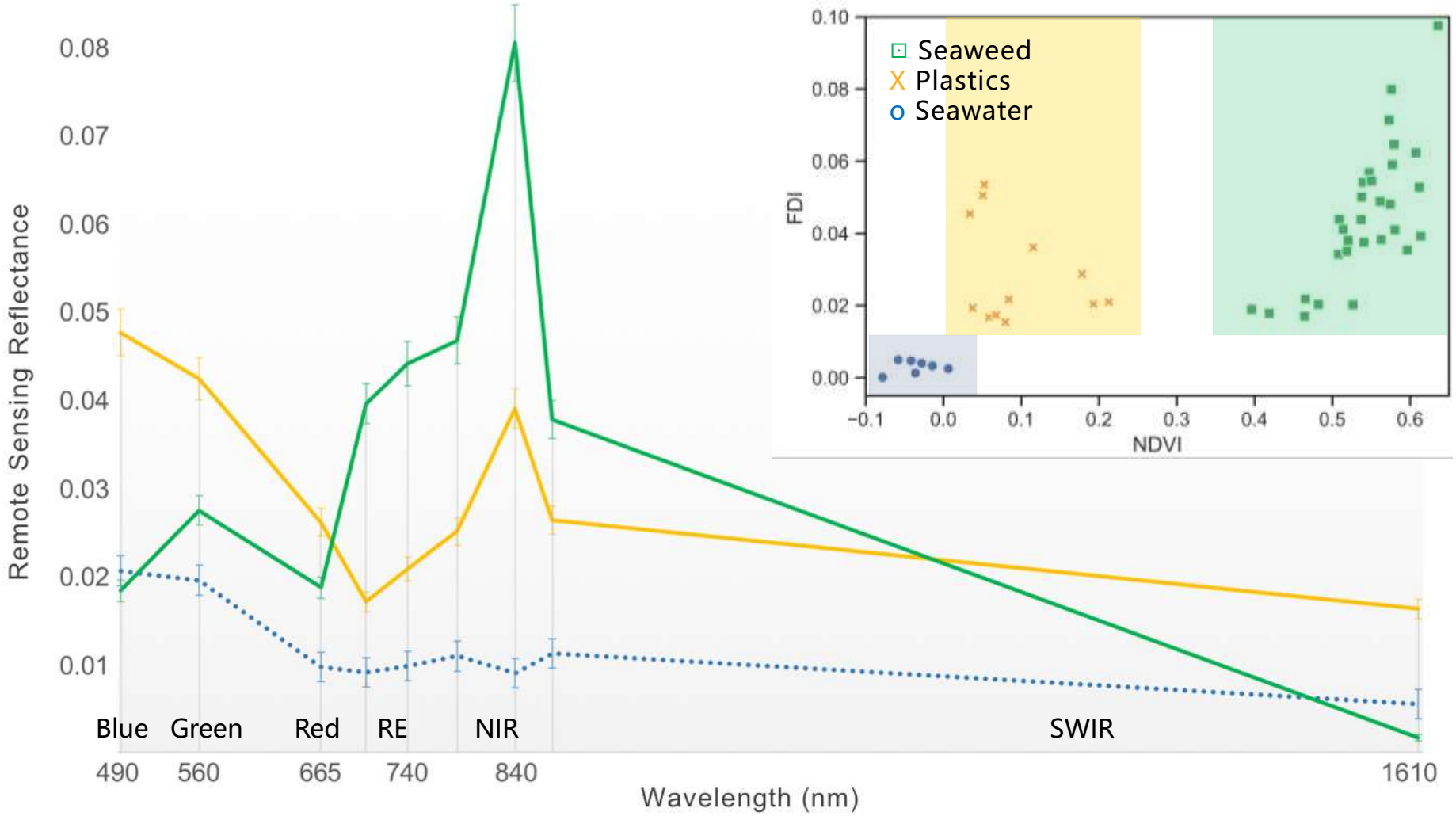
FDI
0.10
0.08
0.06
0.04
0.02
0.00
−0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
NDVI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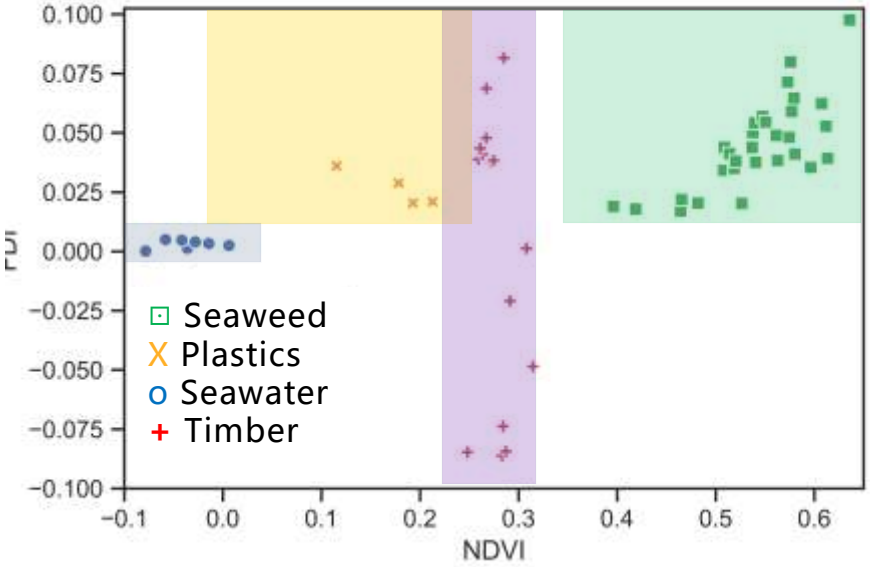
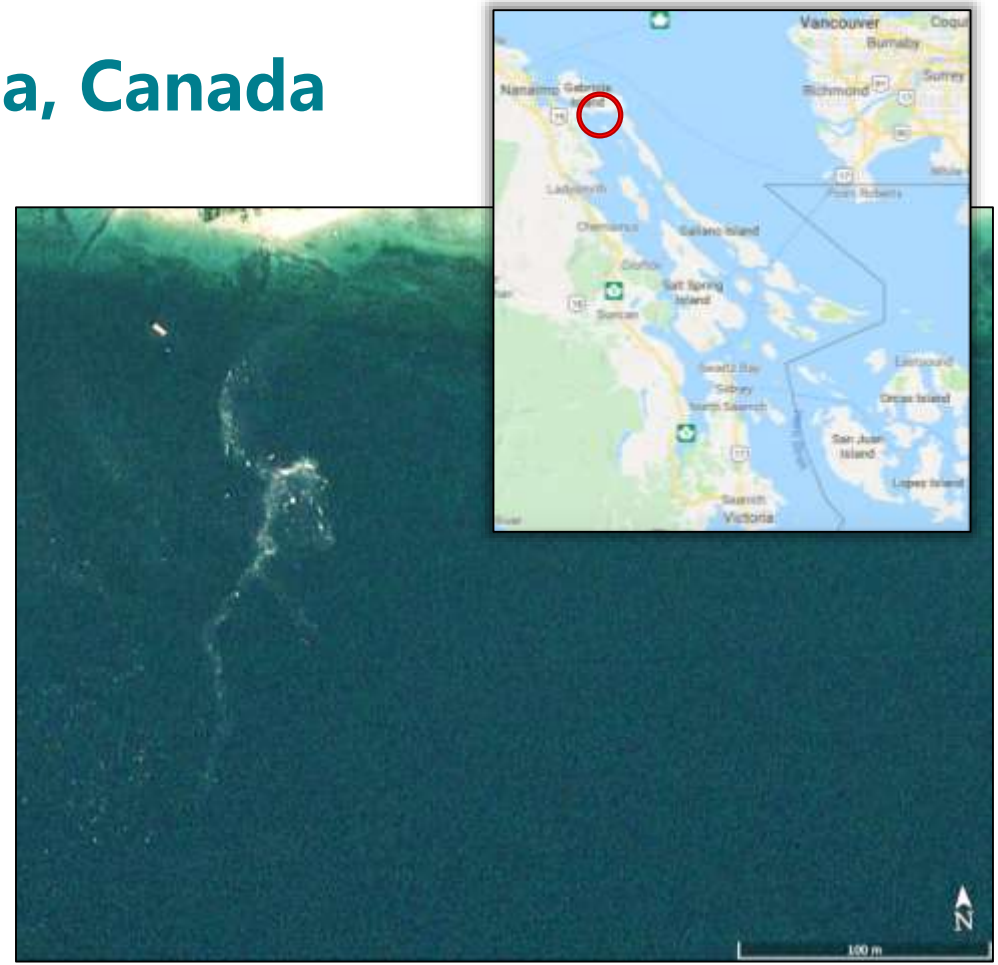
0.1
0.2
0.3
0.4
0.5
0.6
NDVI

# Study Site: South Gabriola, Canada

- Timber rafting site with woody debris evident in high res. data.
- Also documented plastic pollution.



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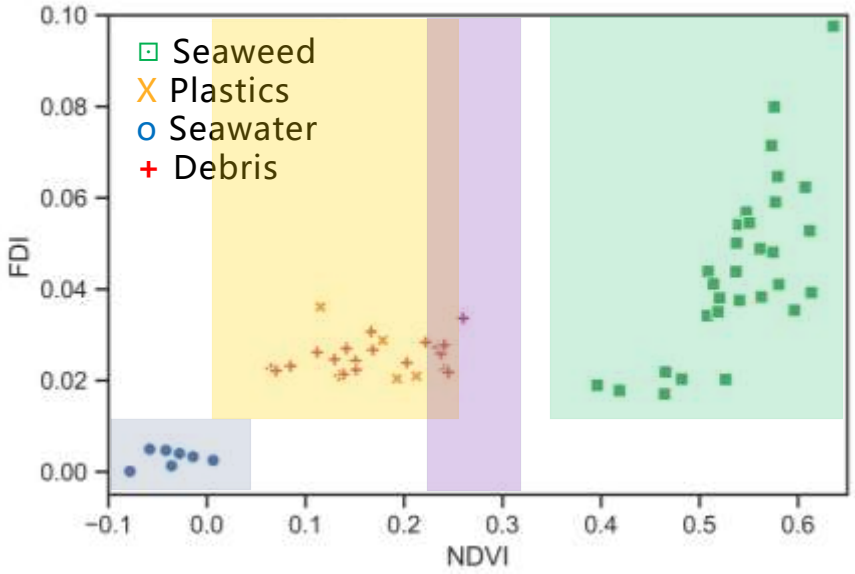
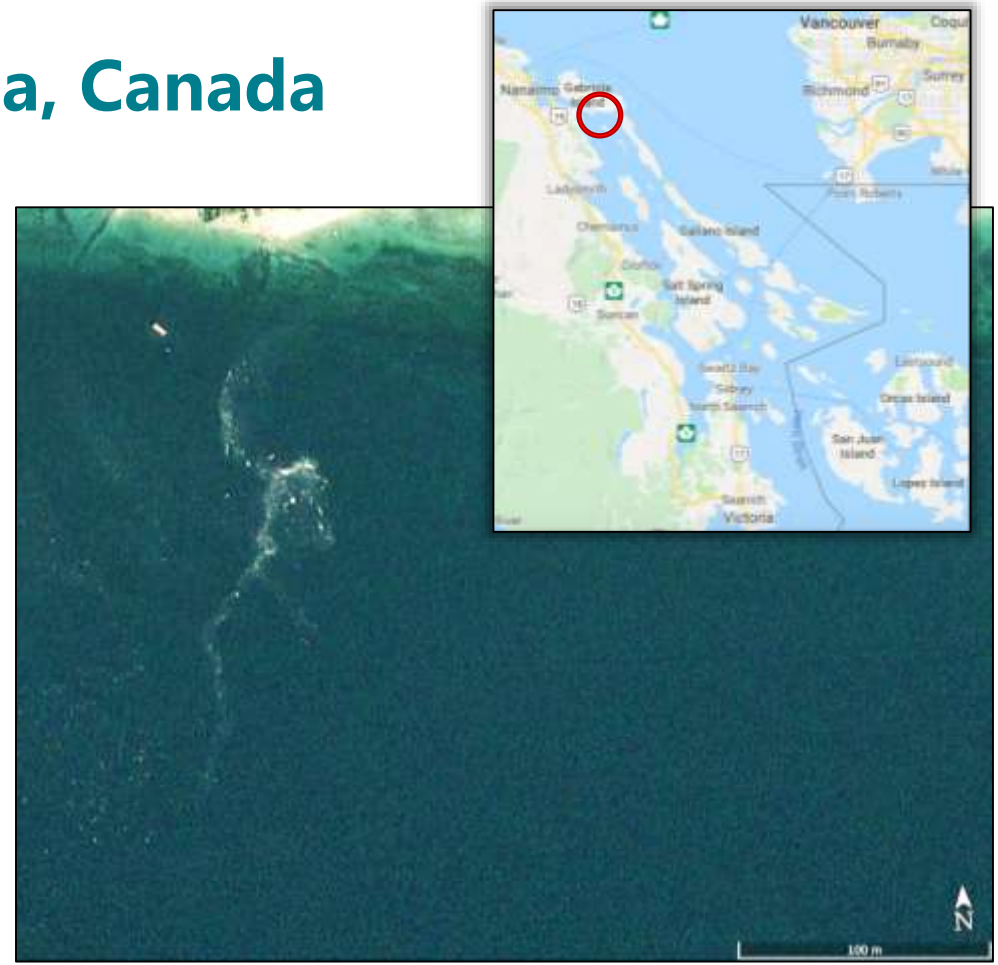
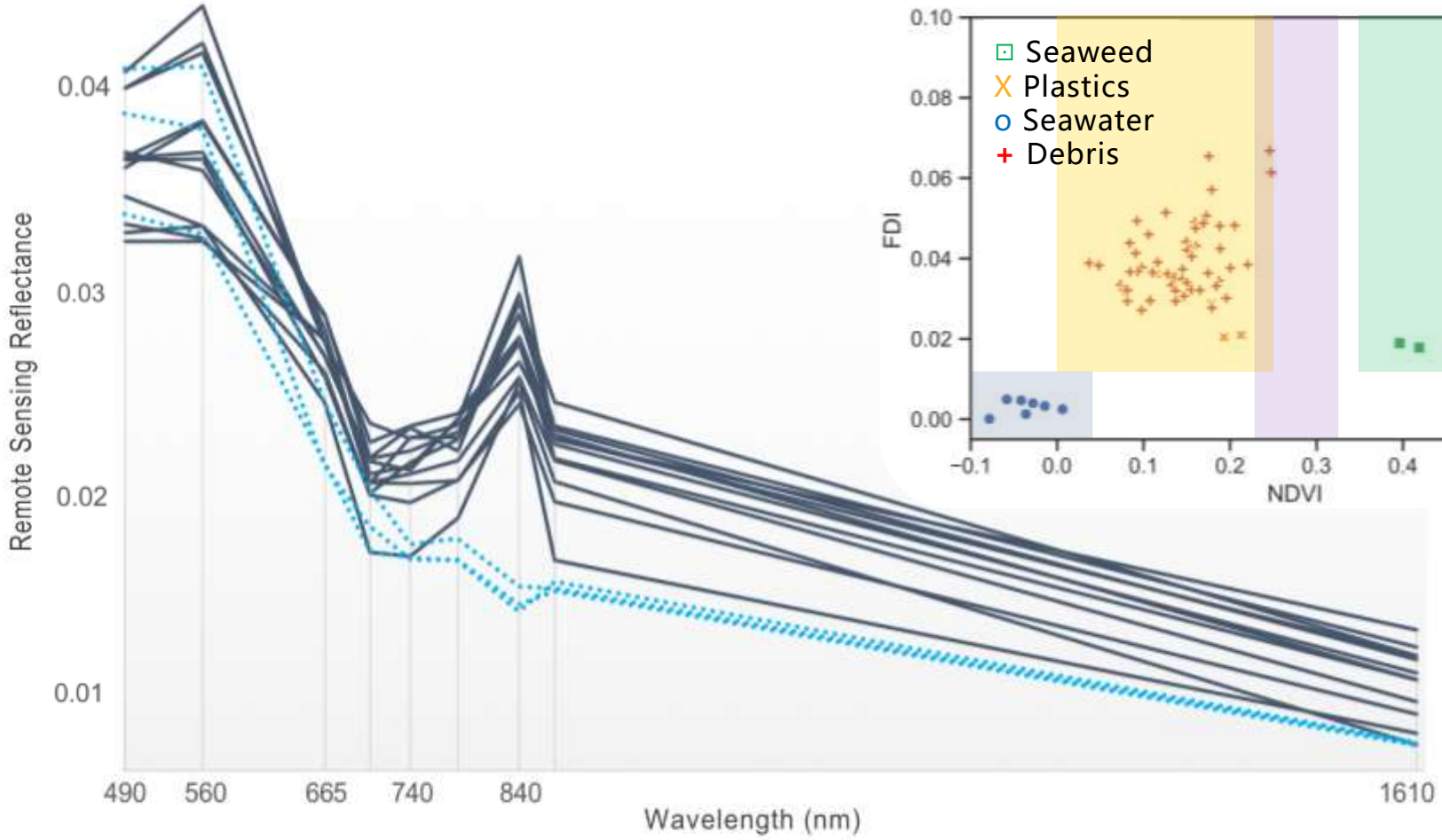


# Study Site : Durban, South Africa

- Over several days in April 2019, the coastal city of Durban, South Africa, experienced severe flooding.
- 60 people died, houses and roads were washed away, and enormous amounts of debris including plastics chocked the harbour and beaches.
- Photos kindly shared by Grant Blakeway, with permission to share.


Remote Sensing Reflectance
0.04
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0.02
0.01
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1610
Wavelength (nm)
Seaweed
Plastics
Seawater
Debris
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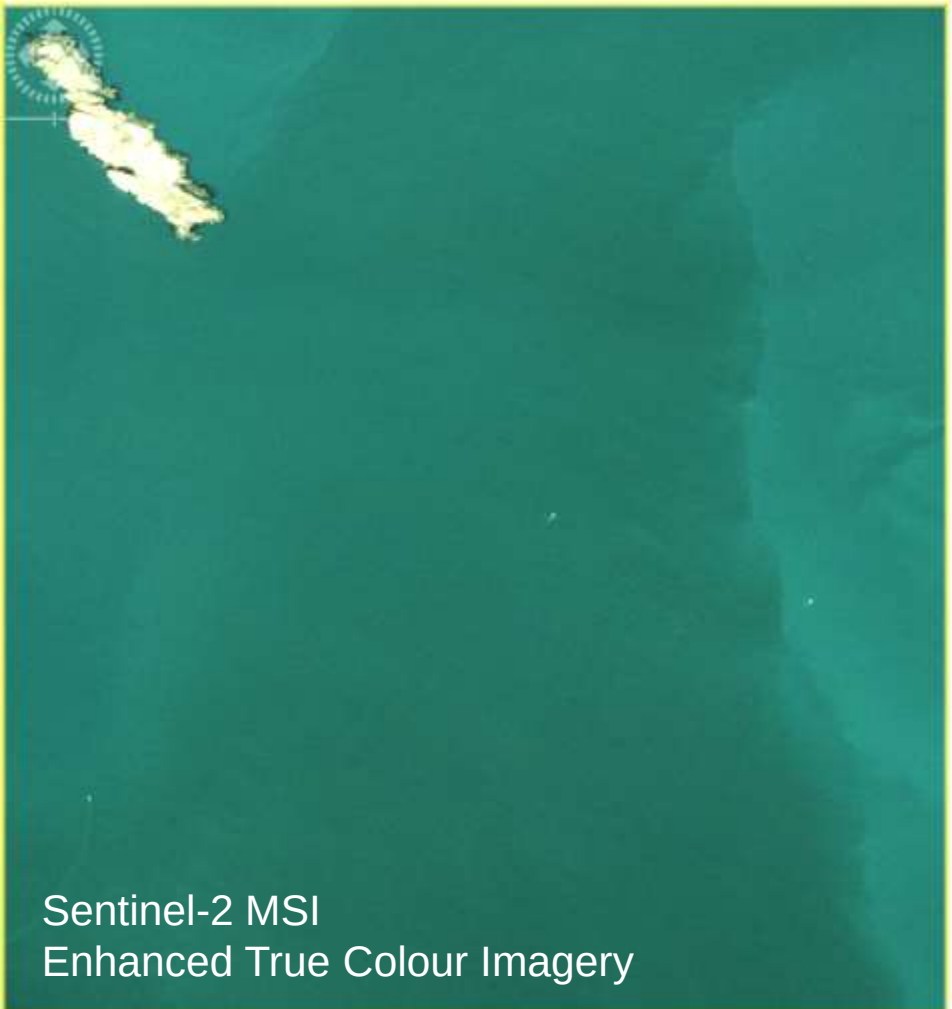
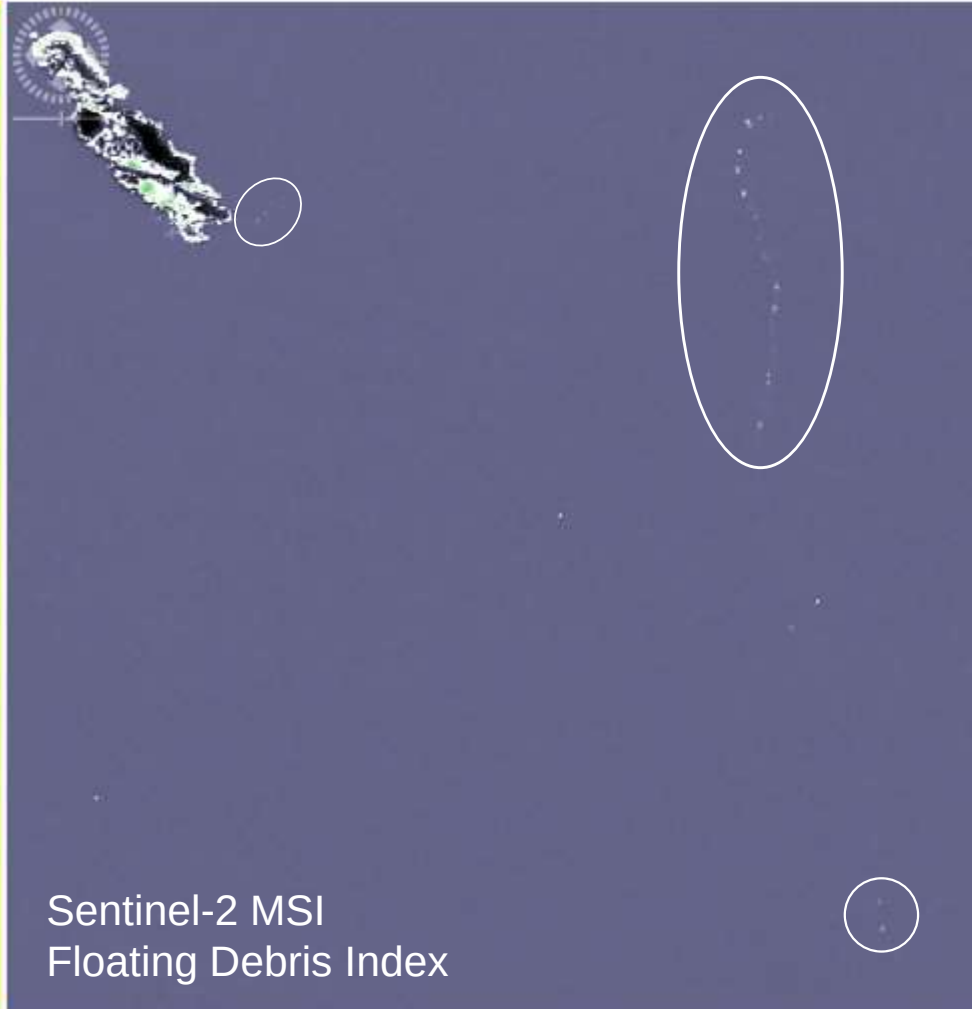
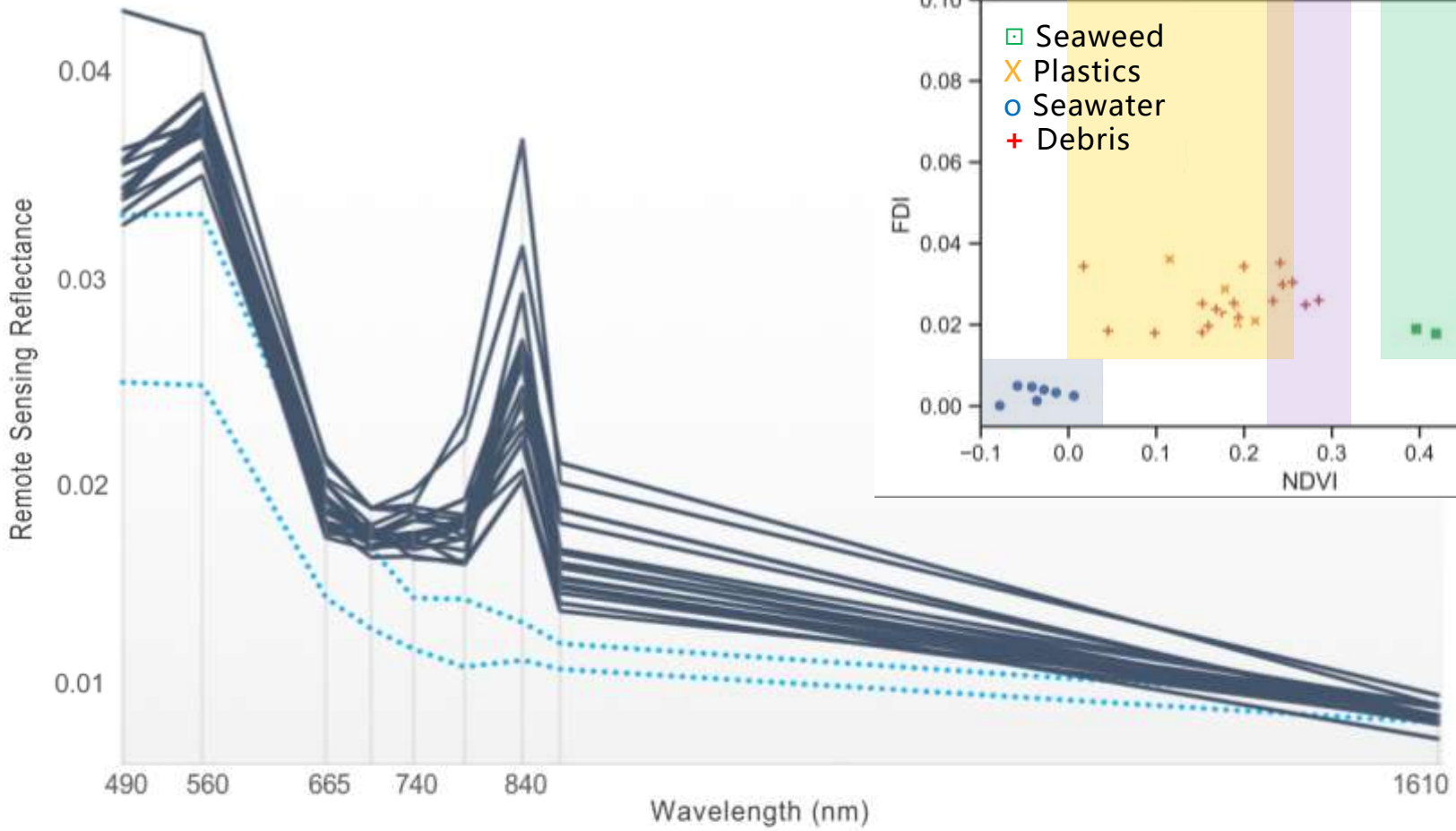
0.06
0.04
0.02
0.00
−0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
NDVI

# Study Site : East Coast of Scotland, UK

- Marine Conservation Society: across 135 Scottish beaches, litter (mainly plastics and polystyrene) increased by 14% since 2017.
- No *in situ* data or high resolution imagery from PLANET.
- Sea Mammal Research Unit student @MattIDCarter shared pictures showing pervasiveness of litter along the Firth of Forth.


Sentinel-2 MSI
Enhanced True Colour Imagery


Sentinel-2 MSI
Floating Debris Index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0.02
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560
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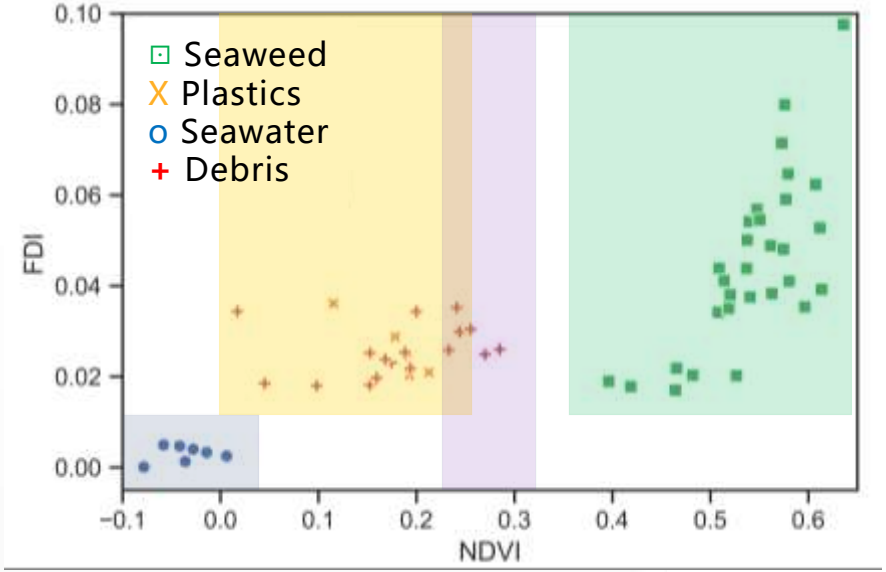
840
1610
Wavelength (nm)


Seaweed
Plastics
Seawater
Debris
FDI
0.10
0.08
0.06
0.04
0.02
0.00
−0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
NDVI


GREENLAND
CANADA
UNITED STATES
MEXICO
Pacific Ocean
Atlantic Ocean
BRAZIL
ALGERIA
LIBYA
EGYPT
RUSSIA
CHINA
INDIA
Indian Ocean
AUSTRALIA

## Stage 1: Exploring

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

**SEARCH**
'By Eye': select cloud-free and wavecap-free Sentinel-2 imagery with fronts / eddies.

**DATA DOWNLOAD**

## Stage 2: Data Processing

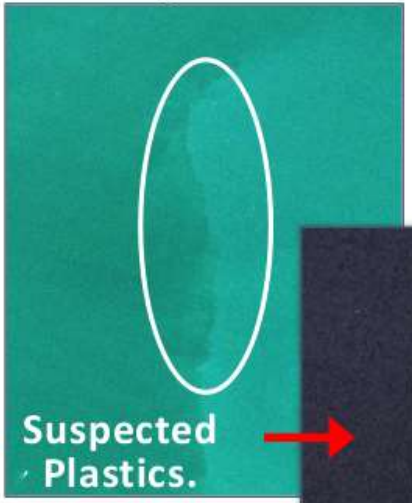
**CORRECT**
ACOLITE (20181210.0) atmospherically corrected reflectance.

**DETECT**
Open RGB image in SNAP; apply the FDI and NDVI algorithms.
'By Eye':

**Library:** Boats, foam, buoys, glint.

**Vegetation:** Floating plant materials, macroalgae.

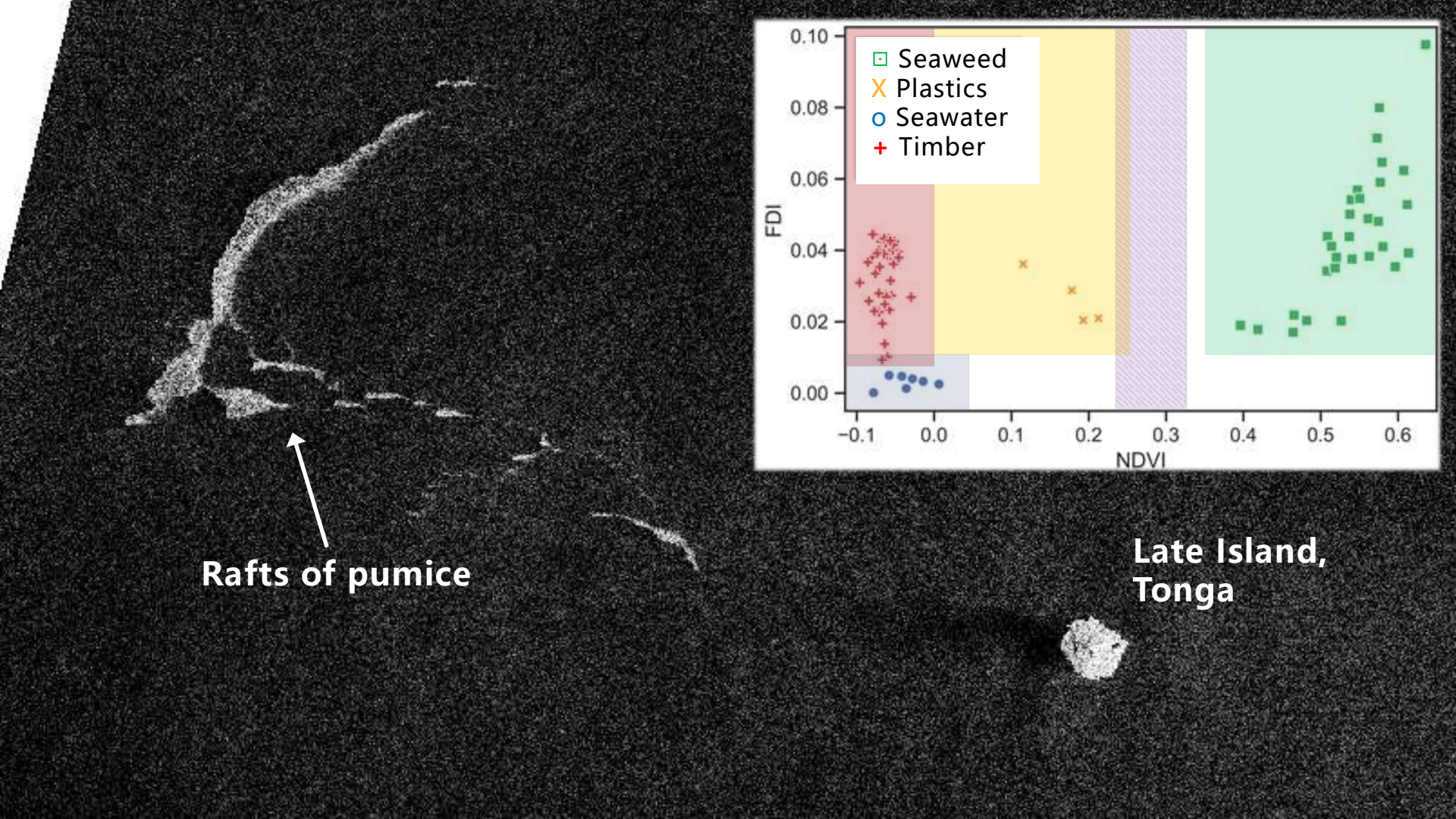
Brightened RGB




FDI detections


## Stage 3: Identification

**MAP_ref**
Extract FDI and NDVI values; examine against MAP_ref scatter plot to identify potential macroplastics.


Seaweed
Plastics
Seawater
Timber
FDI
NDVI
0.10
0.08
0.06
0.04
0.02
0.00
−0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Rafts of pumice
Late Island, Tonga

# In conclusion:

- Plastic has a distinct spectral signature.
- The FDI has proven to be successful at detecting floating objects on subpixel scales.
- In a 2-variable feature space, plastics can already be distinguishable from other floating objects, especially pumice and plants.
- Inherent uncertainty resulting from target ambiguity – ruling out other forms of debris helps, but *in situ* validation is needed.
- More work to be done on the atmospheric correction, and for unmixing of pixels to determine composition.
- The future is automated!

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NERC SCIENCE OF THE ENVIRONMENT

# With special thanks to:

Sevrine Sailley (NERC JaSS project), Stephen Goult and the NEODAAS team.

Copernicus Europe's eyes on Earth

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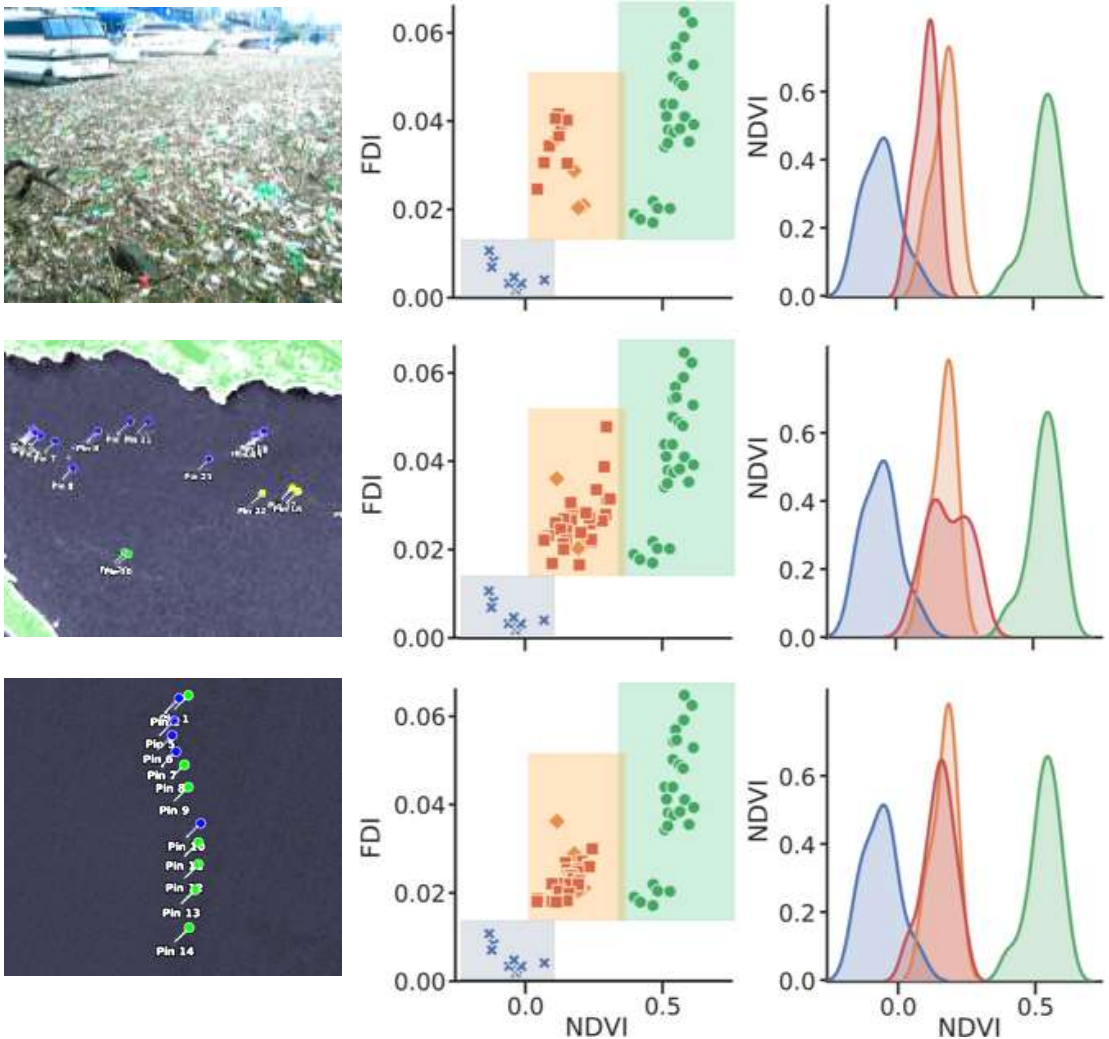
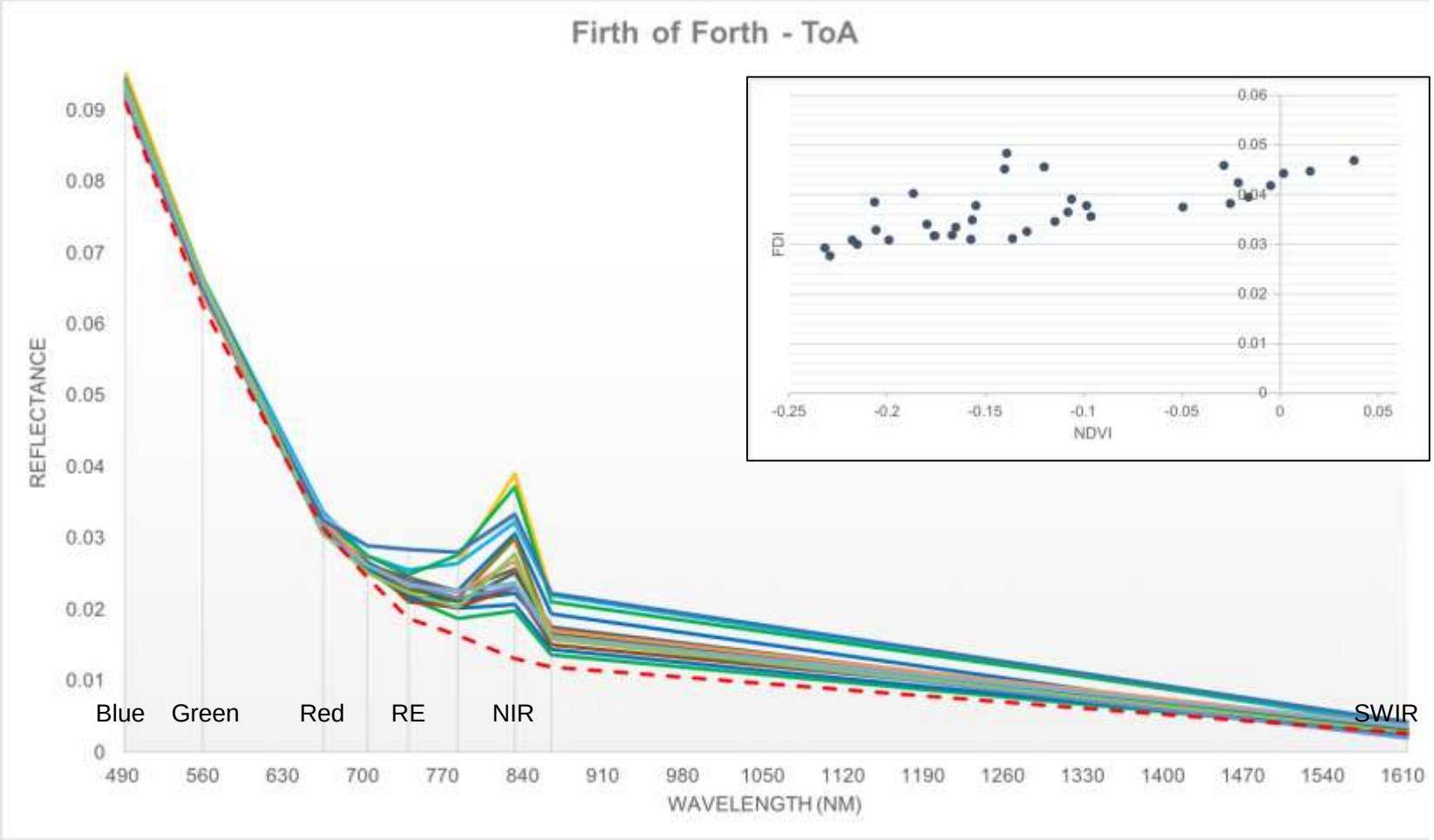
esa

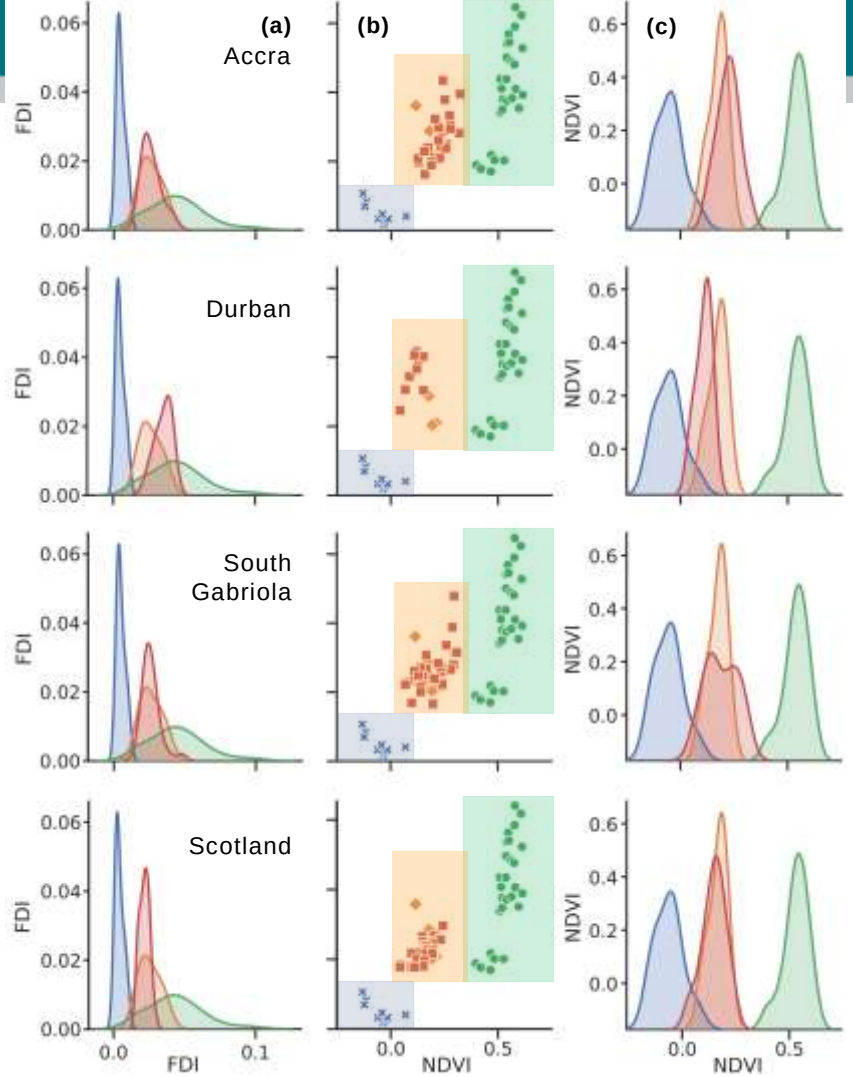

FDI
0.06
0.04
0.02
0.00
NDVI
0.6
0.4
0.2
0.0
0.0
0.5
Pin 1
Pin 7
Pin 8
Pin 9
Pin 13
Pin 14

# Marine Atmospheric Correction (AC):

- Removes atmospheric components from ‘true’ ocean surface reflectance values.
- Marine ACs often rely on the black pixel assumption of near-zero water-leaving radiances in the NIR.
- This will also remove any spectral signals from floating debris…
- Trialling with Sen2Cor and POLYMER.
- ACOLITE processor (RBINS) for Sentinel-2 conserves NIR to SWIR wavelengths – Dark Spectrum Fitting AC approach.

Vanhellemont, Q., *in prep*. **The dark spectrum fitting atmospheric correction for Landsat and Sentinel-2.**


Firth of Forth - ToA
REFLECTANCE
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Blue
Green
Red
RE
NIR
SWIR
490
560
630
700
770
840
910
980
1050
1120
1190
1260
1330
1400
1470
1540
1610
WAVELENGTH (NM)
FDI
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.25
-0.2
-0.15
-0.1
-0.05
0
0.05
NDVI


(a)
(b)
(c)
Accra
Durban
South Gabriola
Scotland
FDI
NDVI
0.00
0.02
0.04
0.06
0.0
0.2
0.4
0.6
0.1
0.5