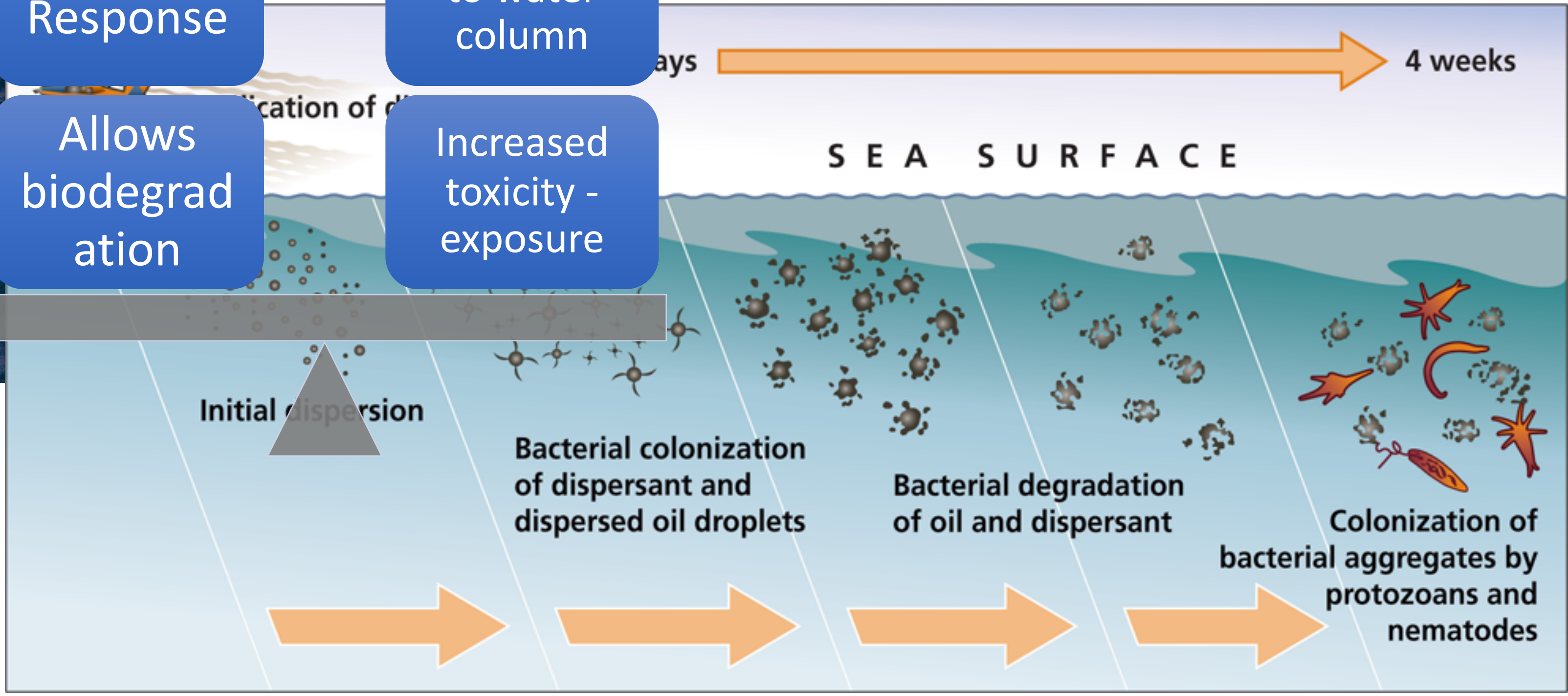
How to mitigate an Oil Spill?

Mechanical Recovery

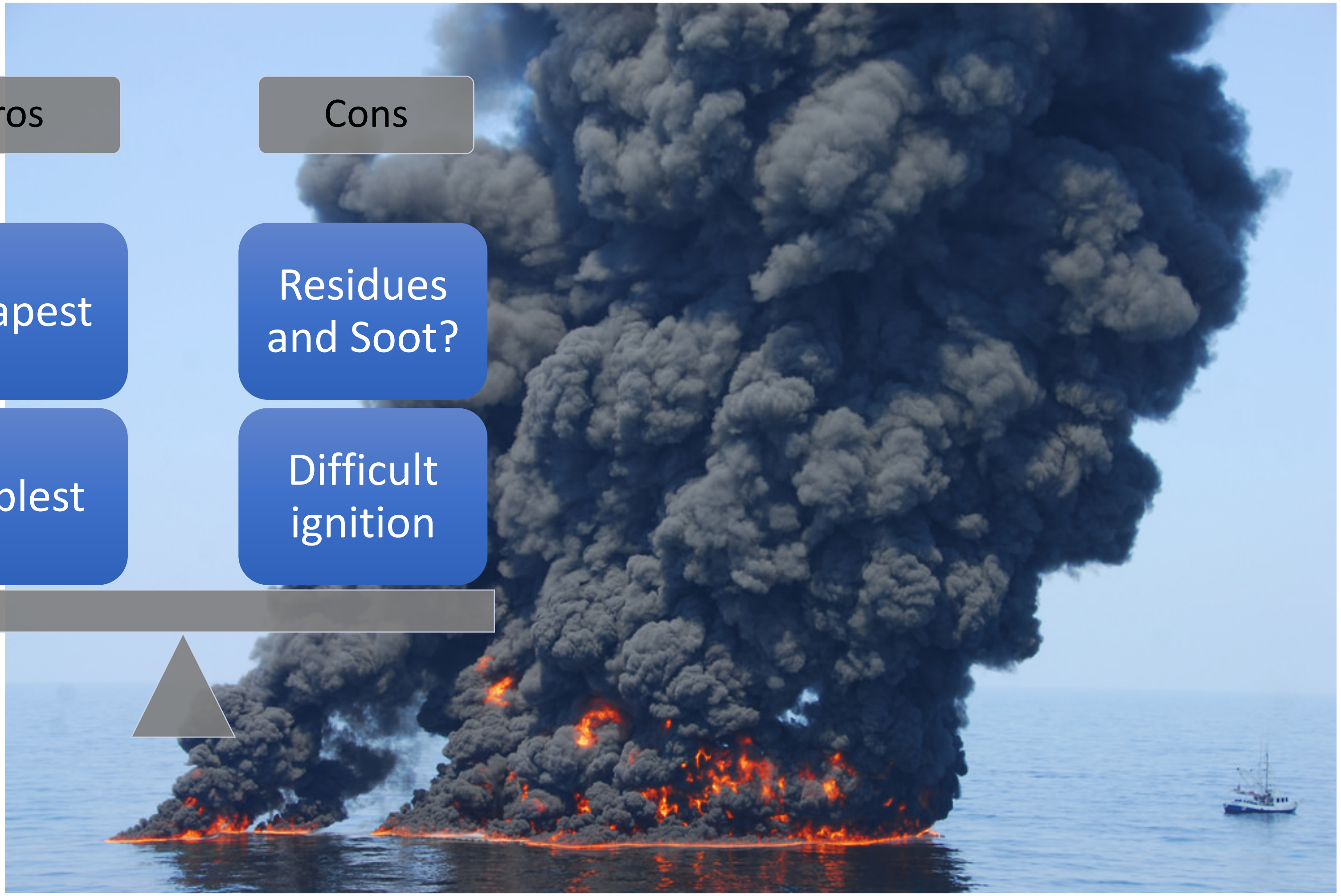
Pros	Cons
Relatively simple	Time consuming
Complete removal	Expensive
	Requires equipment
	Generates waste

Chemical Dispersants

Pros	Cons
Fast Response	Transfers oil to water column
Allows biodegradation	Increased toxicity - exposure



In-Situ Oil Burning



Pros

- Cheapest
- Simplest

Cons

- Residues and Soot?
- Difficult ignition

There is not such thing as perfection

- Mechanical removal is the standard method but applies mainly in small scale events

- Chemical dispersants in combination with bio-remediation and in-situ burning are more efficient and faster response measures for large scale events (but require immediate action)

- In order to use either dispersants or *in-situ* burning as alternative response method to a marine oil spill, a Net Environmental Benefit Analysis (NEBA) is required to minimize the negative impact on the environment by choosing the best (combination of) response methods for the given situation

- **Knowledge gap:** Both the effects of dispersants and residues/soot of in-situ burning on plankton communities and food web have not been studied extensively

To burn or not to burn?
Impact of in-situ oil burning by-products on marine plankton: A mesocosm experimental approach

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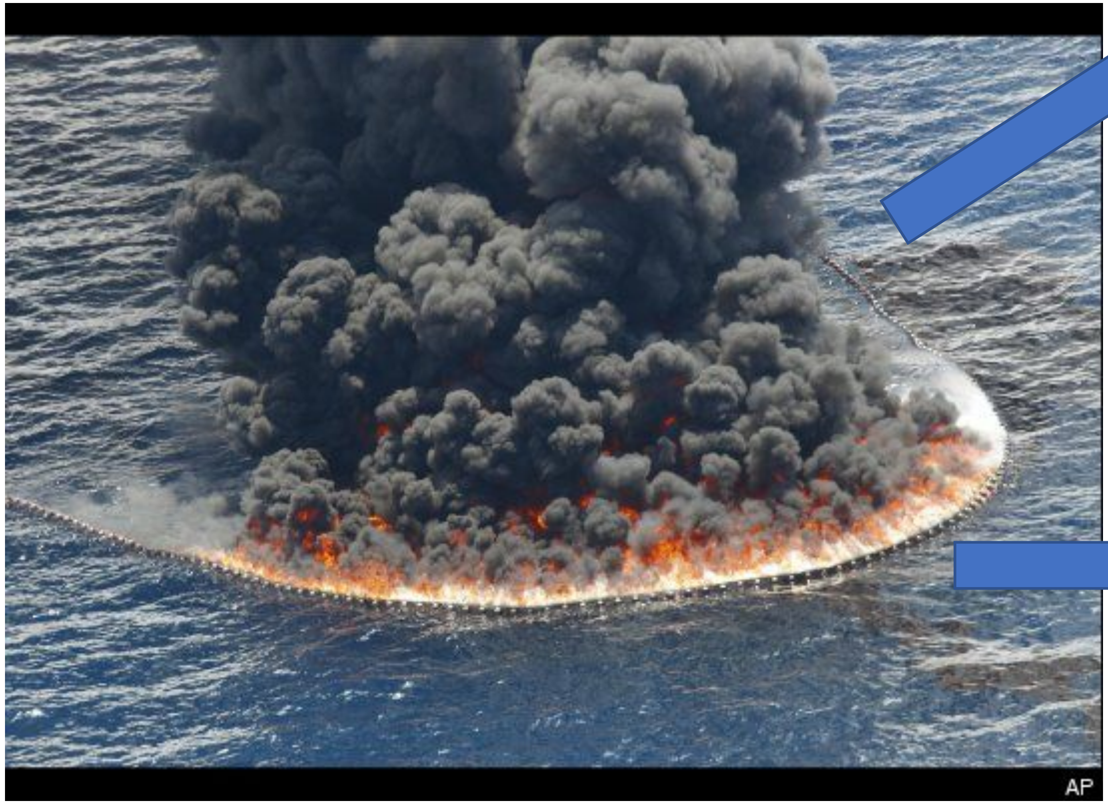
What we were looking for?

In-situ Burning by-products:
Fate?
Toxicity?
Biodegradation potential?



Atmospheric emissions (CO_2, particulate matter, CO, NOx, Volatile Organic Compounds, PAHs) :
Impact assessment on a broad range of organisms at various trophic levels (bacteria → mussels)

Oil burning residues:
Chemical characterization
Behavior at sea (floating/sinking etc)
Fate and biodegradation
Impact assessment on plankton communities

How can you perform experiments with contaminants on the entire plankton community?

Mesocosms:

Controlled and replicated experimental water enclosures, large enough (3.5 m³ in our experiment), that allow experiments in close to natural conditions.
Mesocosms are considered the most reliable reliable way to to predict effects of future environmental and anthropogenic pressures on the complex aquatic ecosystems.

H2020 AQUACOSM (2017-2020)
and
H2020 AQUACOSMplus (2020-2024)

The EU network of mesocosm facilities for research on marine and freshwater ecosystems

For more information:
www.aquacosm.eu

CretaCosmos :
The mesocosm facility of HCMR in the East Mediterranean

How we did it – 1

Coastal water was collected from the ultra-oligotrophic Eastern Mediterranean Sea (200m from the coast – North of Heraklion, Crete, Greece) and transferred to the mesocosms

How we did it – 2

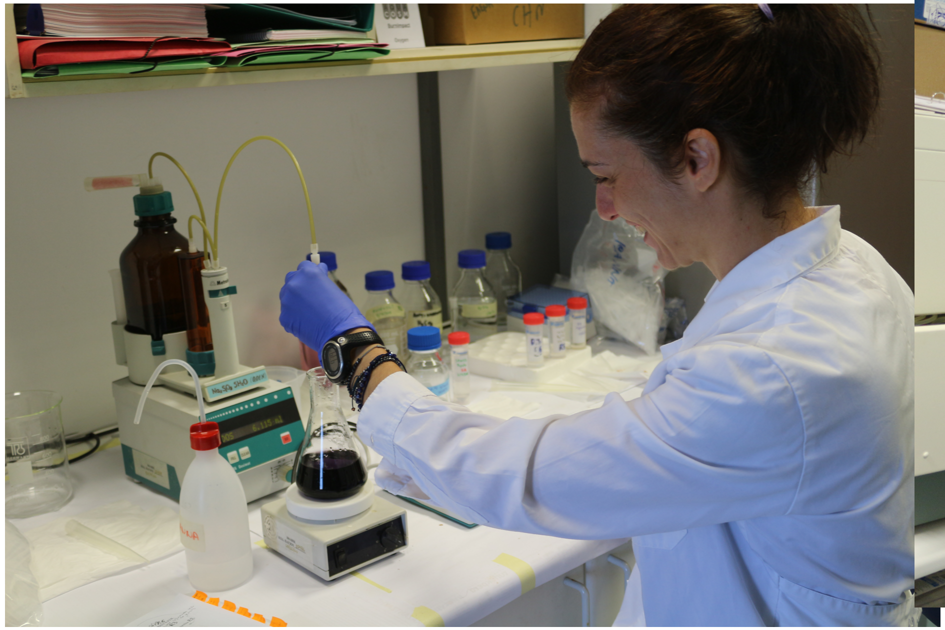
- A custom-designed "soot collection devise" was developed that allowed the collection of soot from one and its transportation to another in the form of artificial rain
- Iranian Crude Oil was added to 3 mesocosms where it was burned (**B**: Burn treatment),
- Soot was transferred to other 3 mesocosms (**S**: Soot treatment).
- Another 3 mesocosms served as the Control treatment (**C**)

How we did it – 3

The experiment run for 26 days:
Main sampling Days: 0, 1, 3, 6, 10, 14, 19, 22, 26

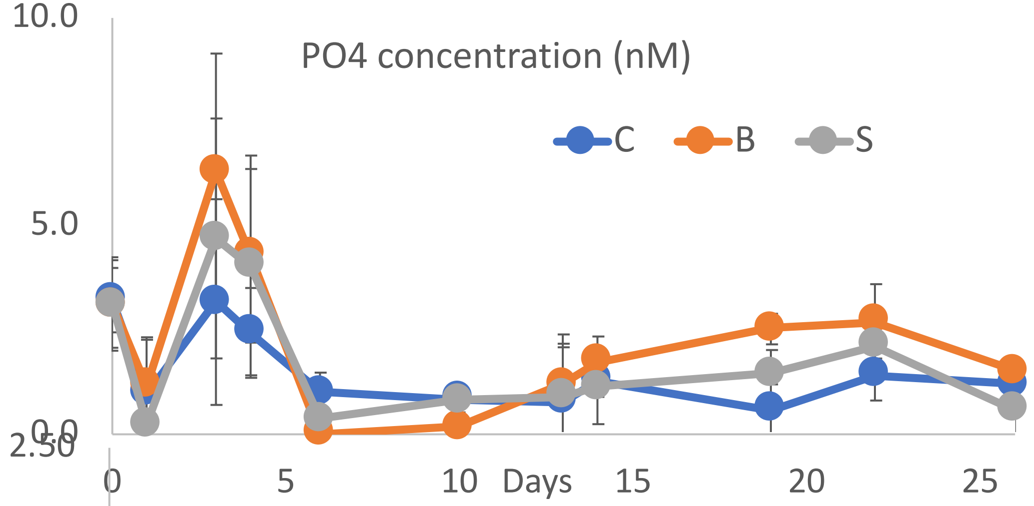
Samples were analysed for:

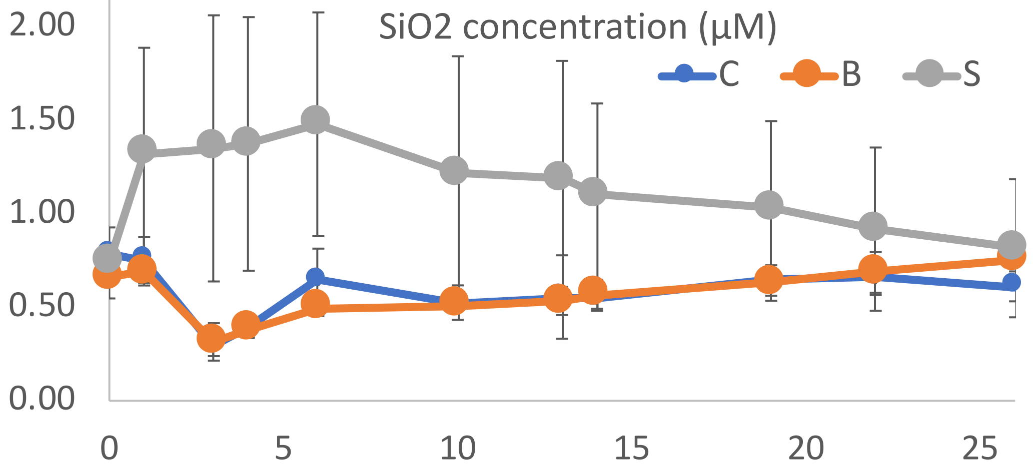
- Chemical characterisation of burned residues and soot
- POC, DOC/DOM, O_2, nutrients concentration
- Abundance/Biomass of plankton web (from viruses to copepods)
- Bacterial Diversity (16S rRNA) and quantification of oil degrading genes
- Toxicity on bacteria, zooplankton and mussels
- Zooplankton productivity

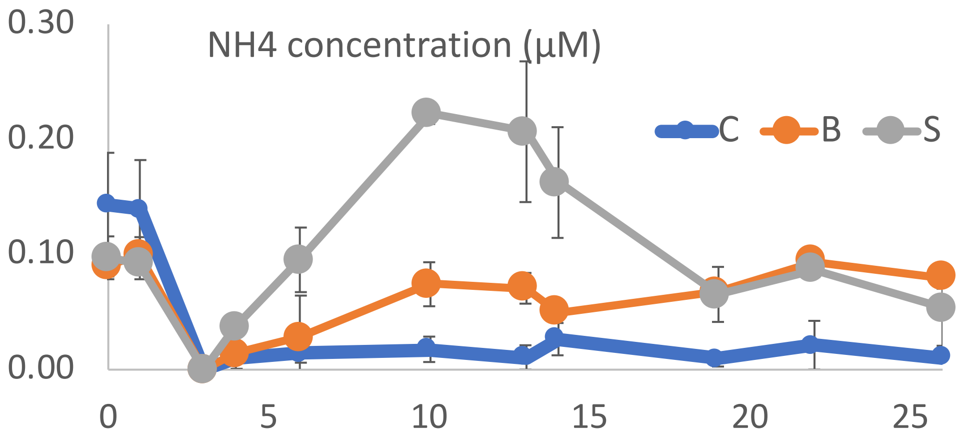


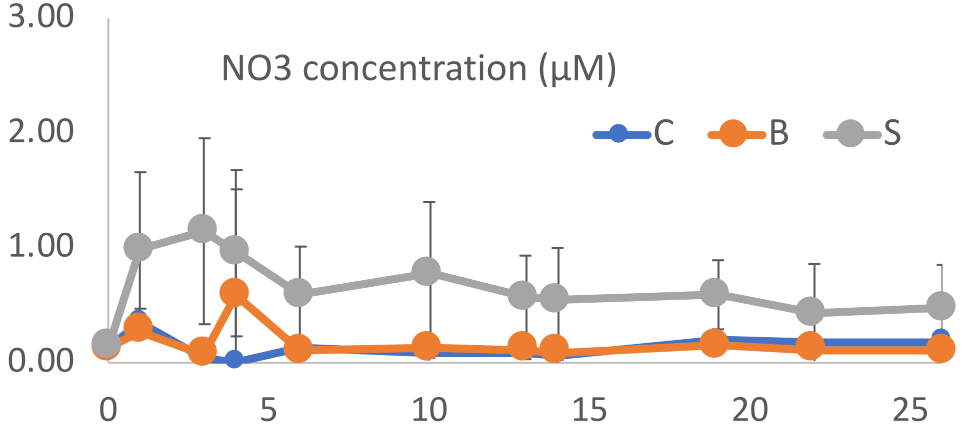
Nutrient Concentration:

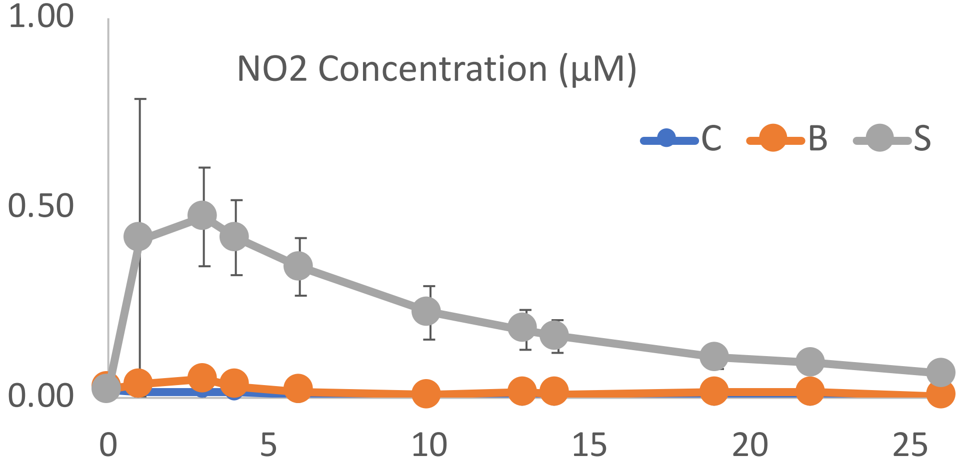
Increased ammonium, nitrate, nitrogen dioxide and silicon dioxide on Soot treatment.

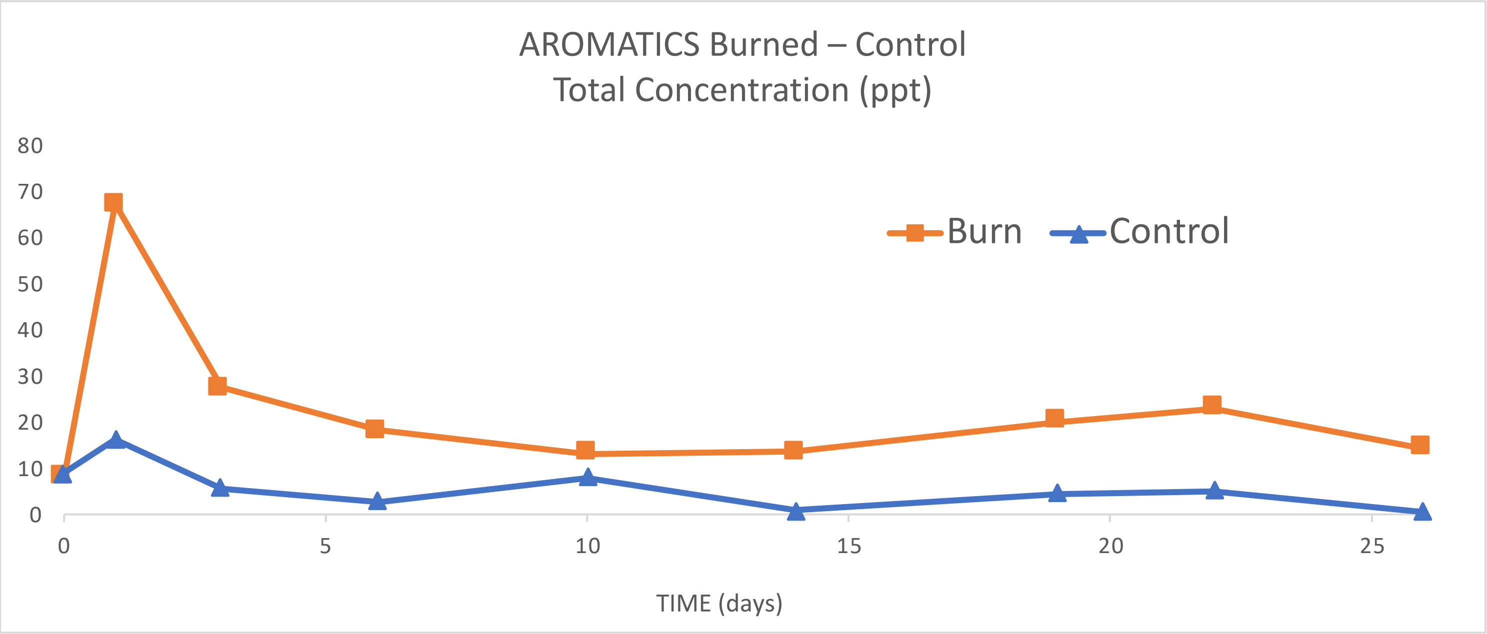


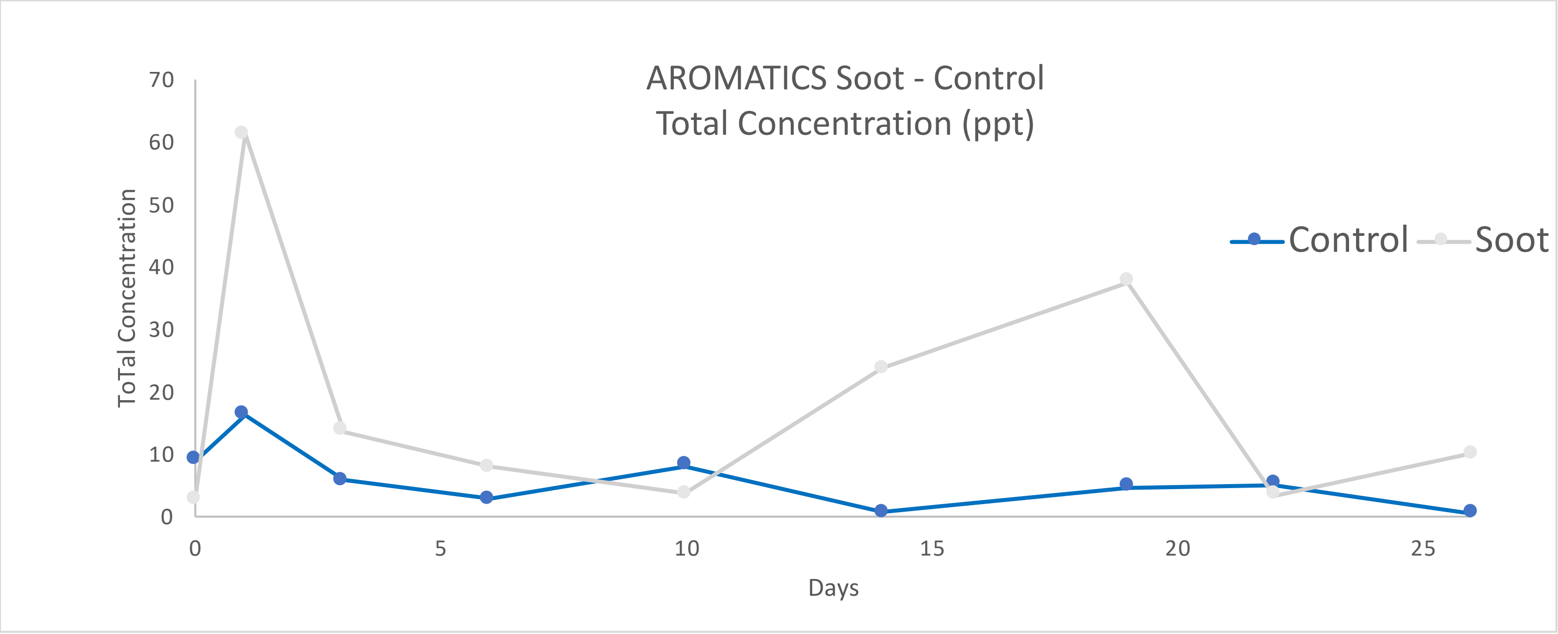








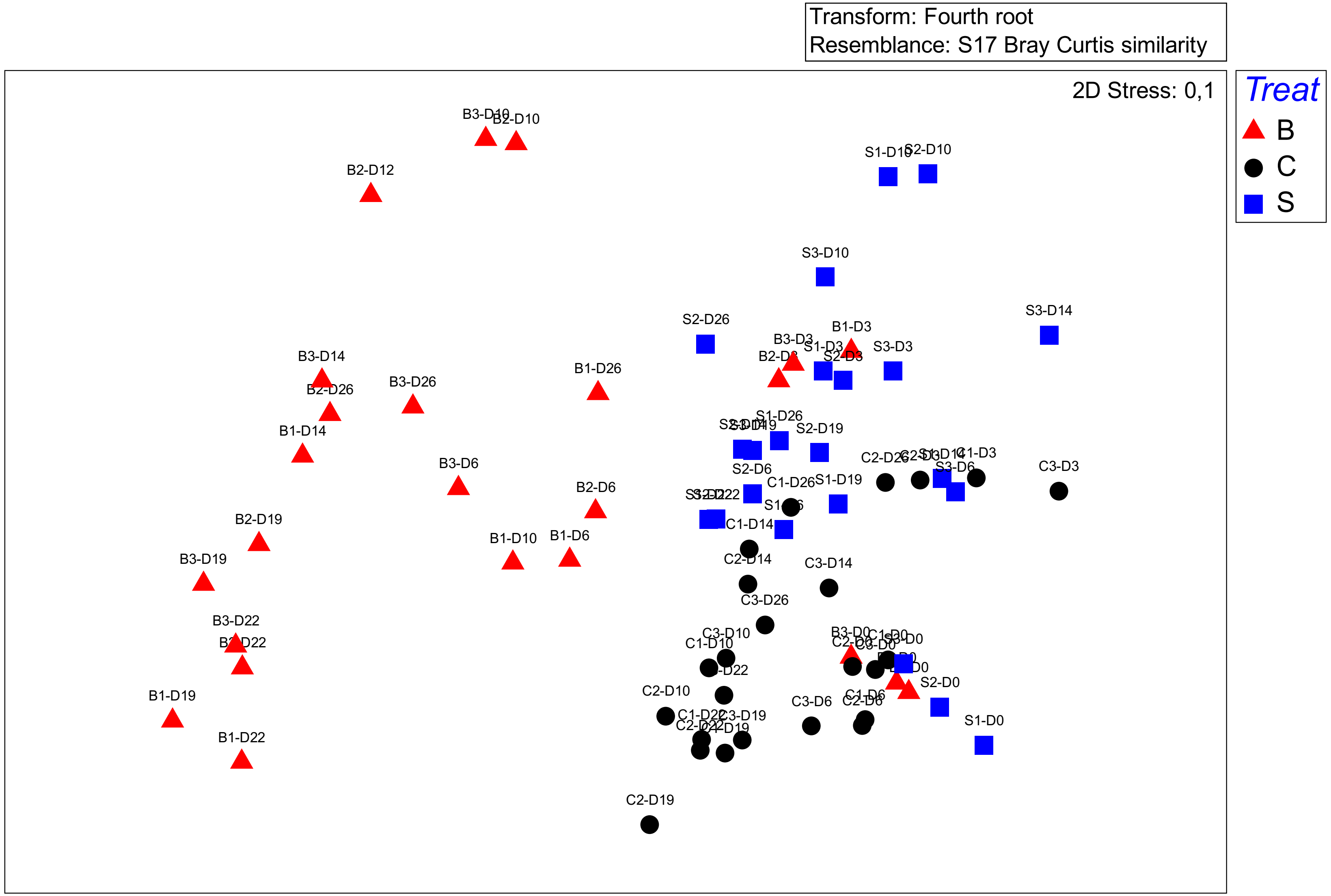




So, is there any oil in the water?

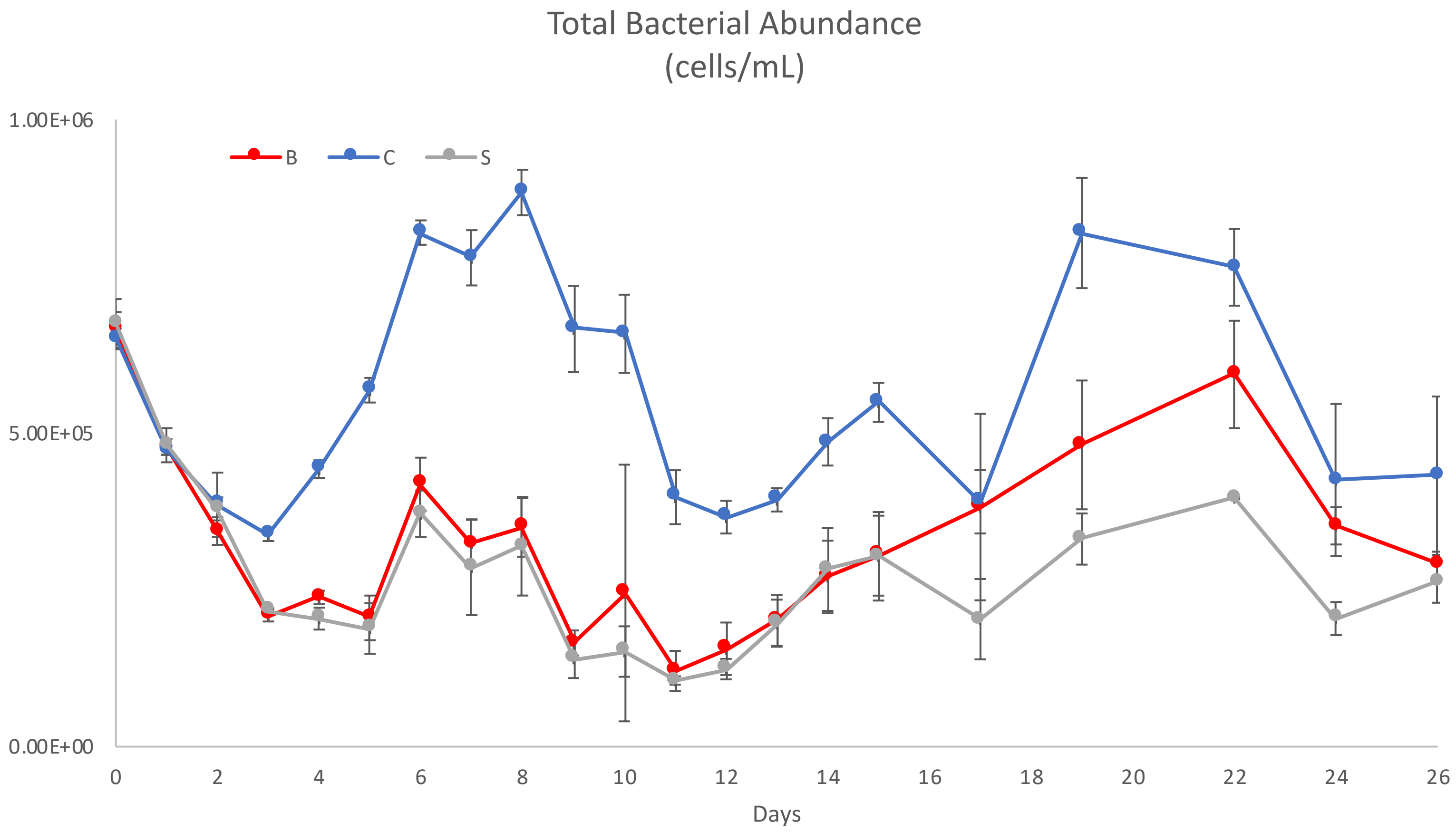
Total Aromatic Compounds Concentration on Burn and Soot treatments compared to Control

MDS Analysis
on the abundance of Total Viruses, Prokaryotic and Pico-Eukaryotic Cells



ANOSIM:
All treatments are statistically different (0.1%) both in global and in pairwise tests

SIMPER Analysis reveals that the differences between the Burned treatment and the Soot and Control are mainly due to viral abundance (approx. 60%) while the differences among Soot and Control are due to bacteria (54.04%)



Bacteria play a very significant role in degrading PAHs in the sea (specific hydrocarbon degrading species)

It was expected to show increased abundance on Burned and Soot treatments after the first days of the experiment, even in an ultra oligortrophic sea.

East Med microbes are P-limited

On Day 2, a small amount of PO_4 was added to the mesocosms leading to increased concentrations detected on Day 3 and 4.

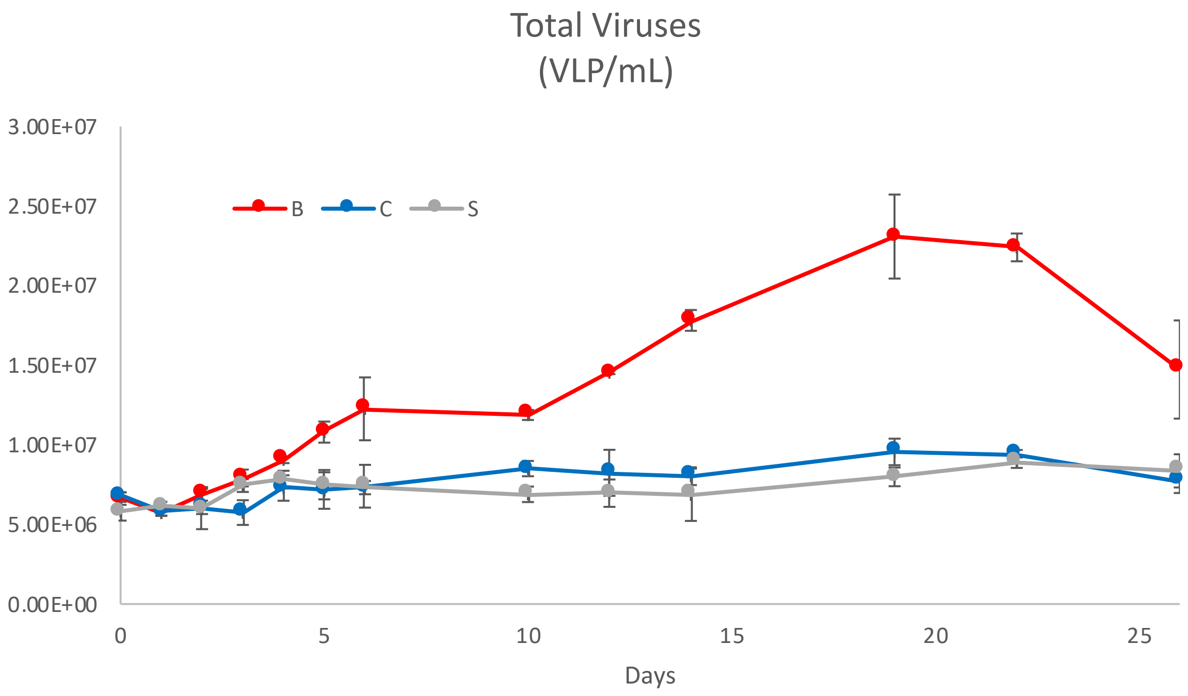
Despite the “consumption” of the Phosphorus, bacteria on ”Carbon-rich” mesocosms remain lower than Control.

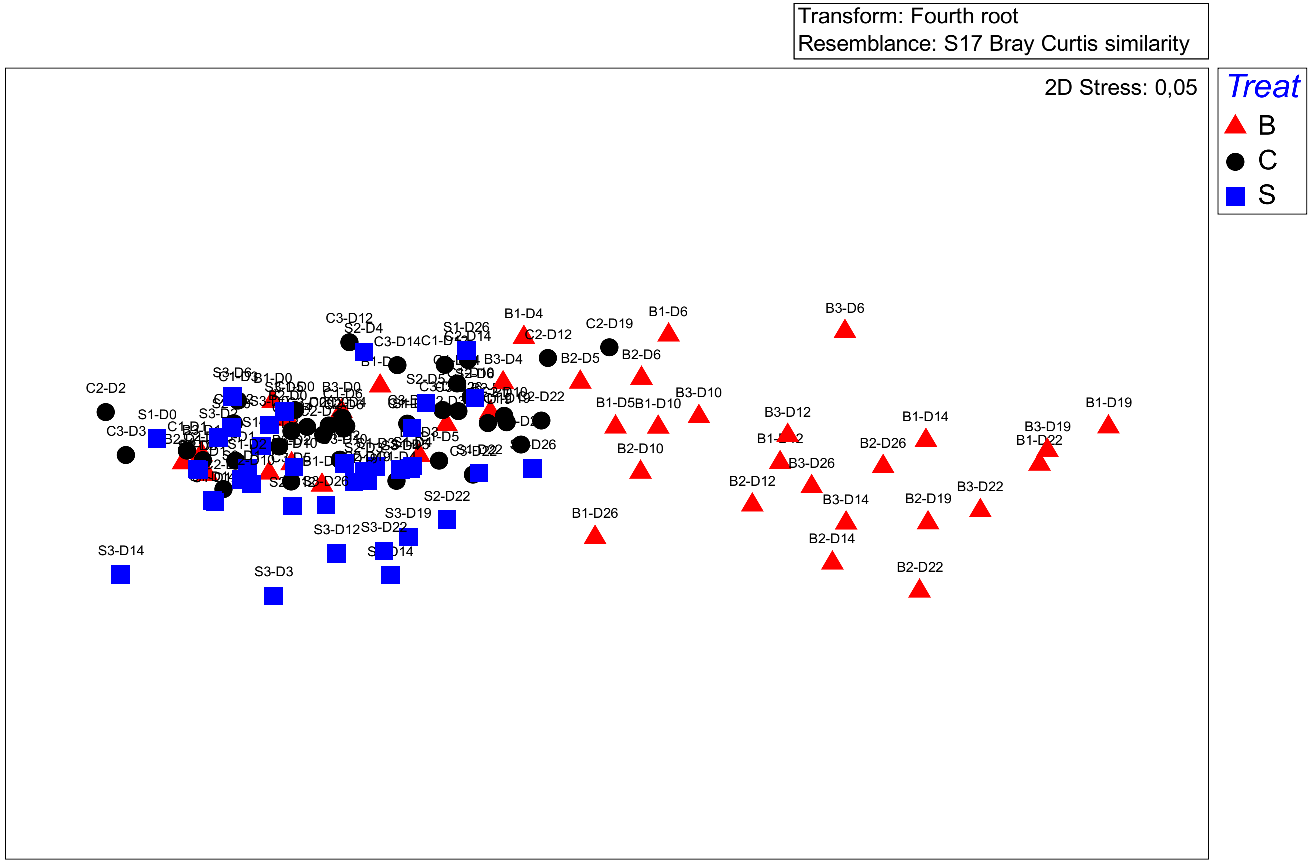
Why?

Marine Viruses: The vast majority of viruses in the sea are bacteriophages

Viruses on Burned residue treatment are significantly more abundant than the other two treatments, especially after the Day 4 of the experiment

The difference is mainly due to the Low Fluorescence (LFV) and Medium Fluorescence (MFV) viruses (approx. 55% and 25% respectively).

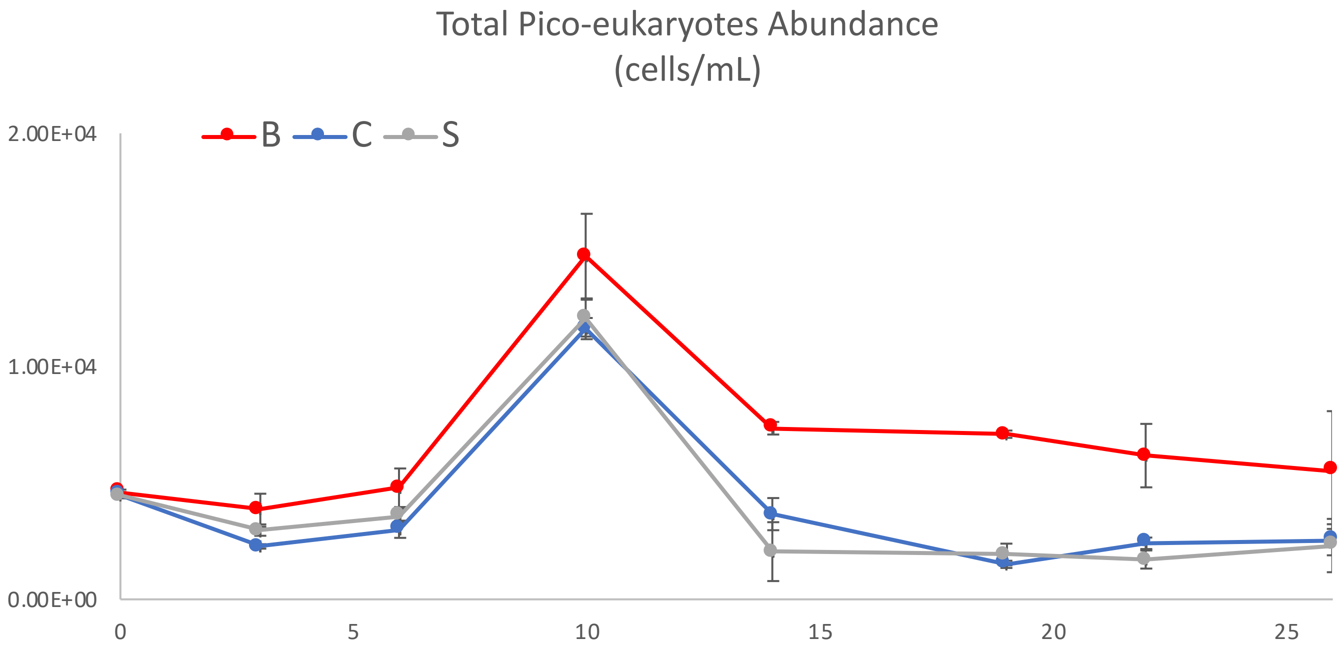


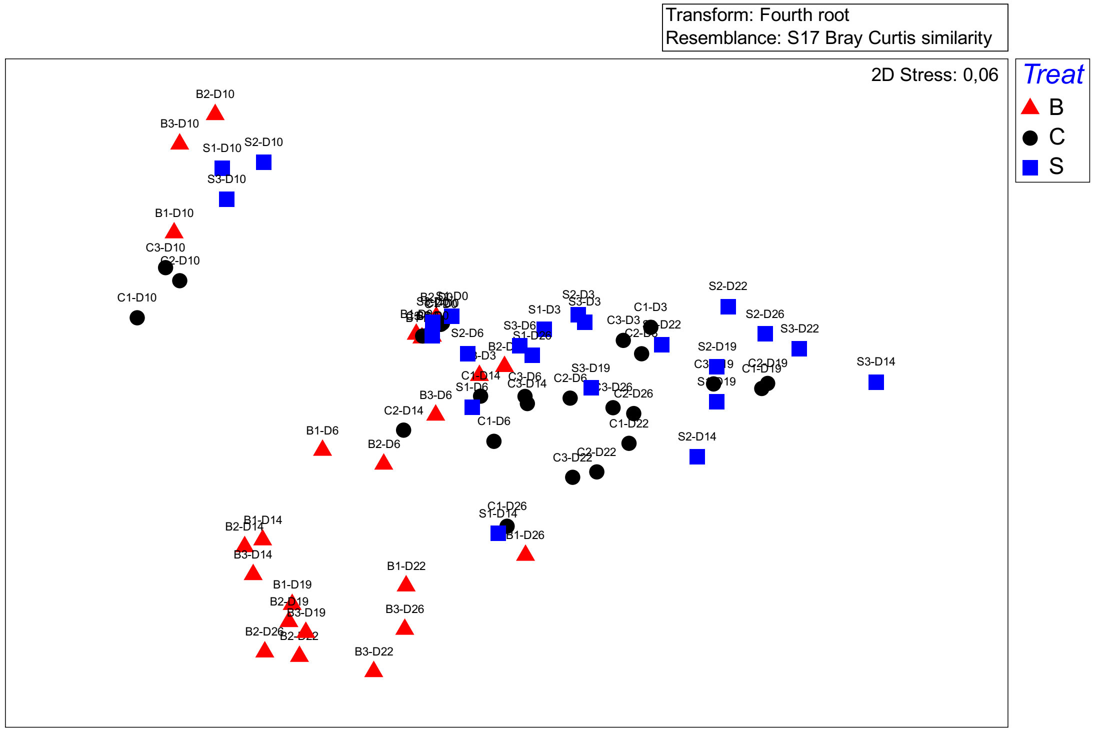


The Smallest Eukaryotic Cells

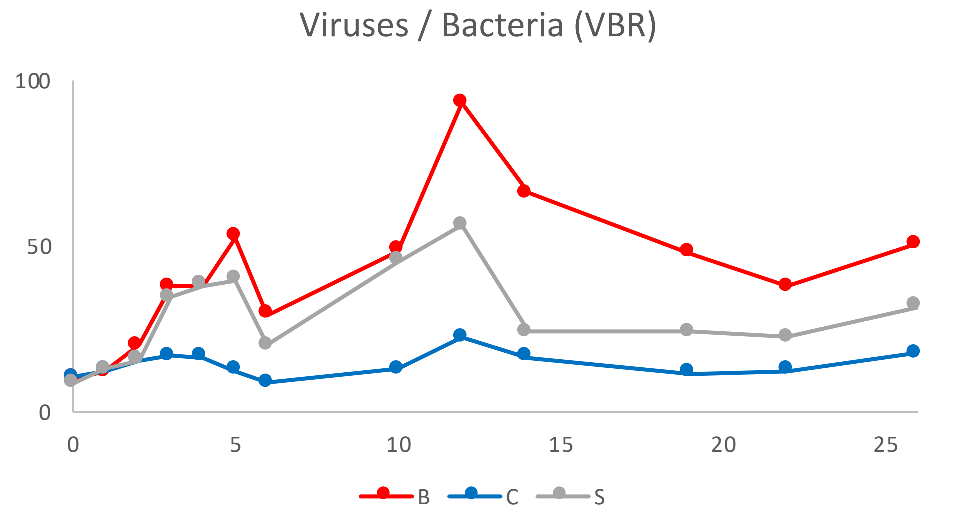
Similarly to the viruses, Burned treatment has more pico-eukaryotic microbes compared to Control and Soot (0.1%) especially after Day 10, until the end of the experiment.

No statistical significant differences between Soot and Control were detected.

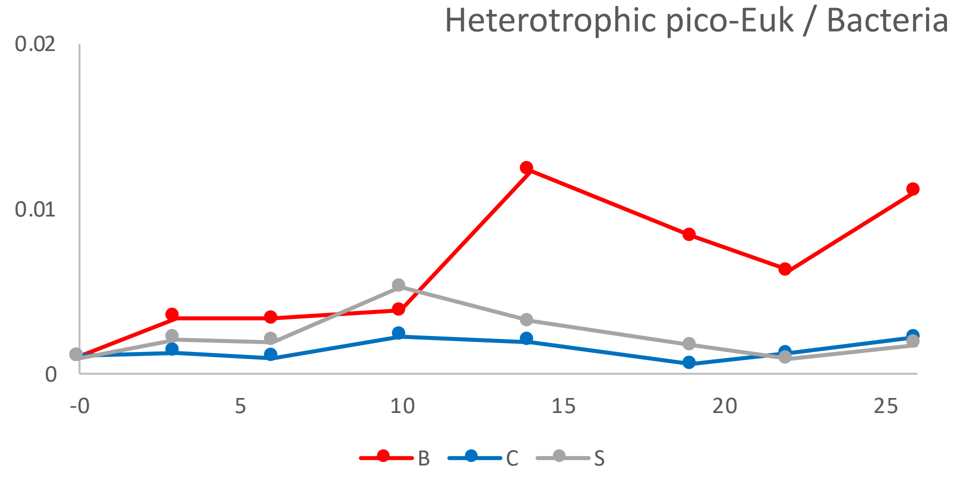




Based on the Virus to Bacteria Ratio (VBR) and the Heterotrophic pico-Eukaryotes to Bacteria Ratio it can be hypothesized that from the 3rd day day after the oil burning, viruses are controlling the bacterial population on both PAHs containing treatments



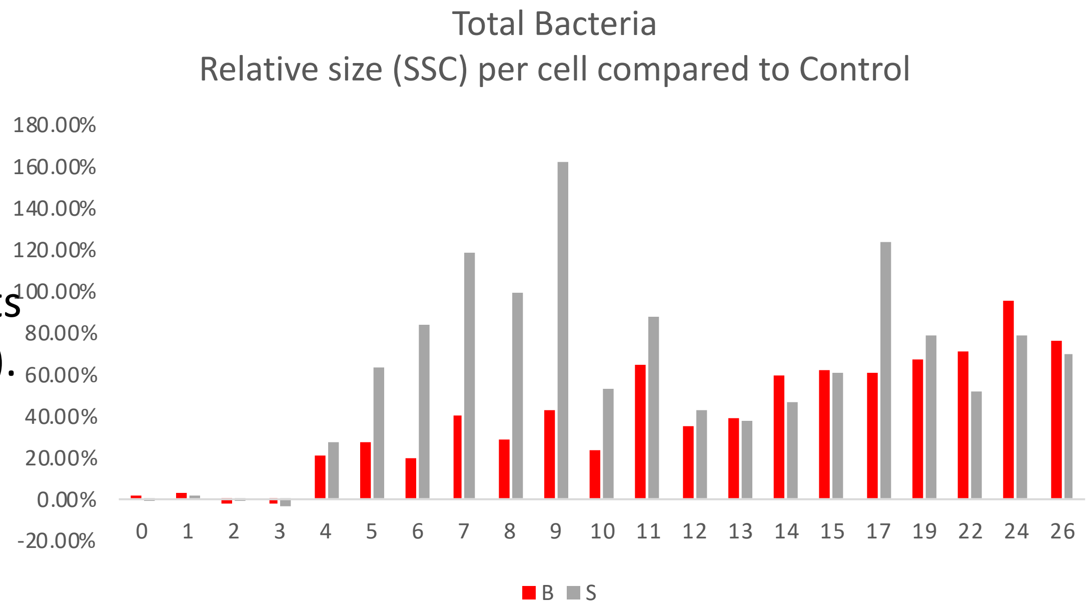
Two weeks after the burning of the oil, flagellates seem to play also a significant role on the bacterial abundance, especially on the Burned treatment

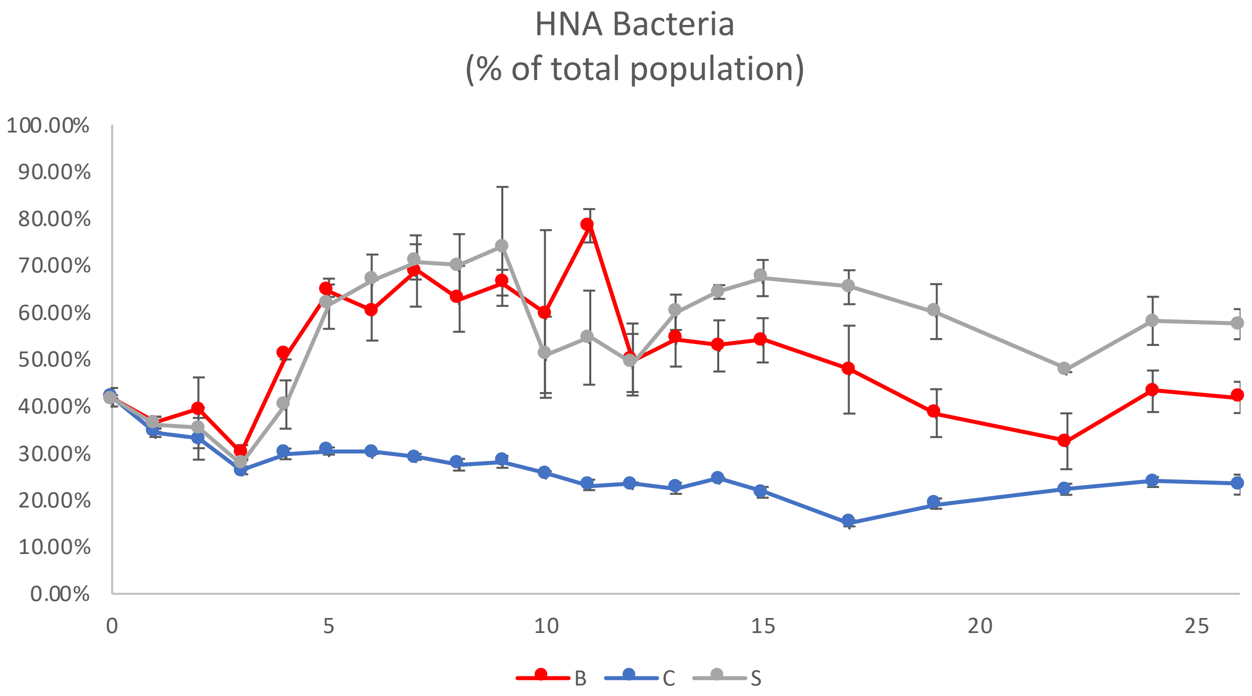


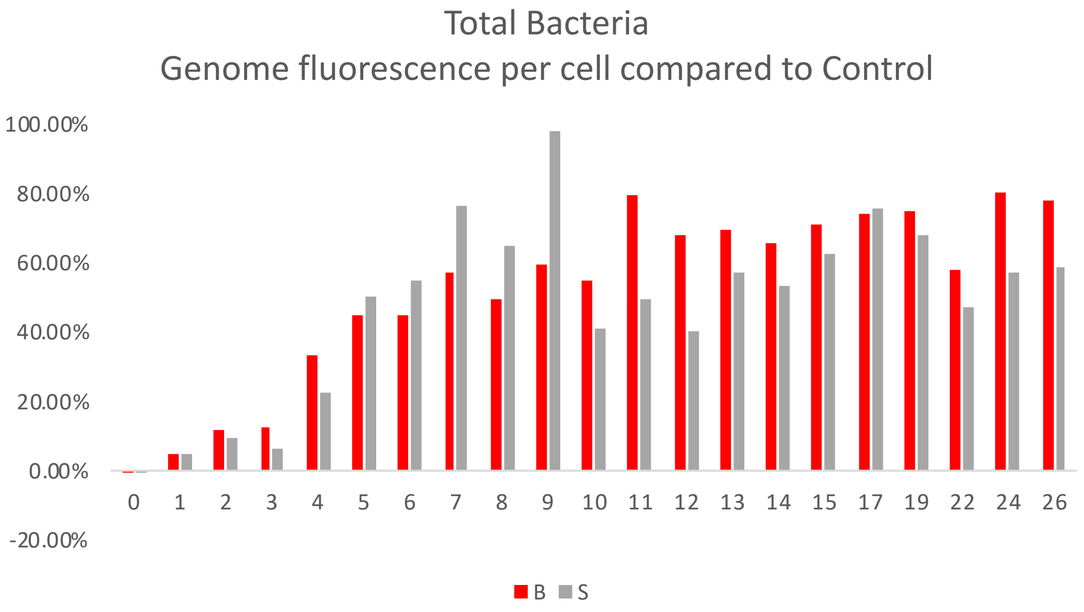
It is also clear that 4 days after the oil burning, there is a noticeable "change" on the "quality" of the bacterial community.

Bacteria seem to be more active on Burned and Soot treatments (High Nucleic Acid, HNA), to have bigger genome size (or vast amounts of RNA?) and to be relatively bigger (as it is expressed by Side Scatter).

This "quality step" could stimulate viral lysis (especially due to the potential high percentage numbers of lysogenic cells in oligotrophic areas) explaining the increased VBR after Day 3.

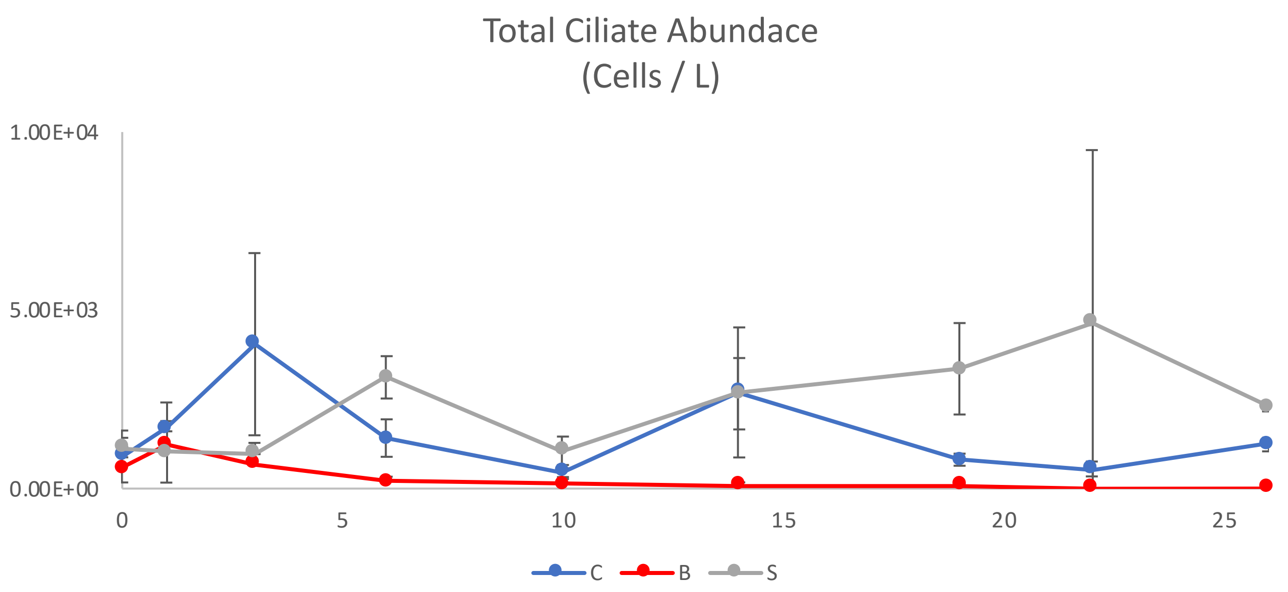


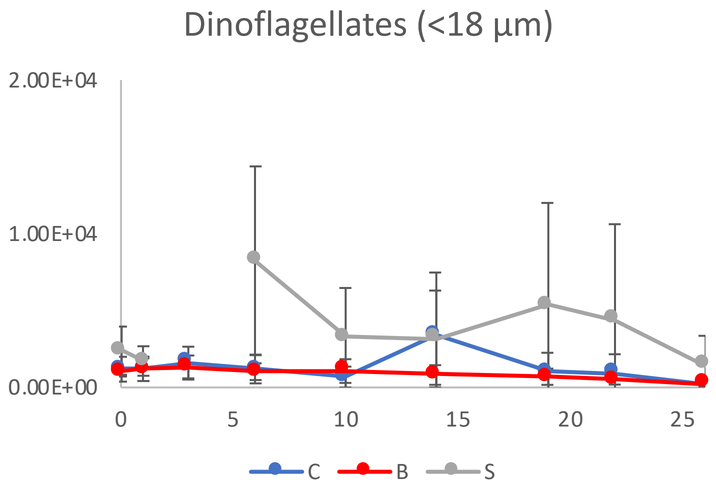


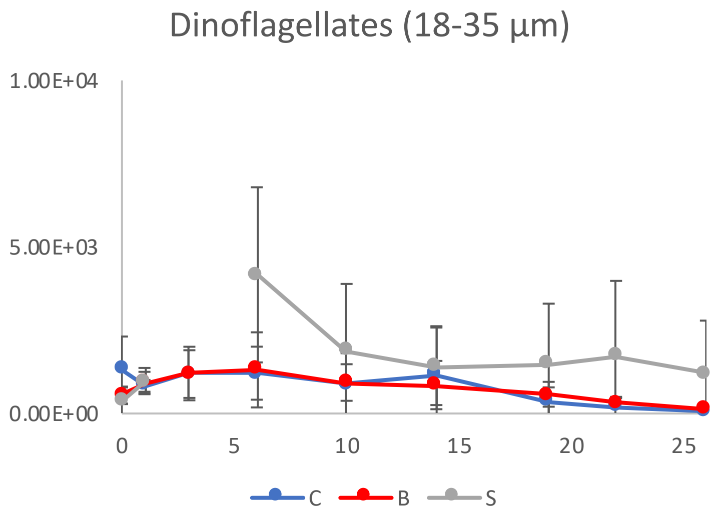


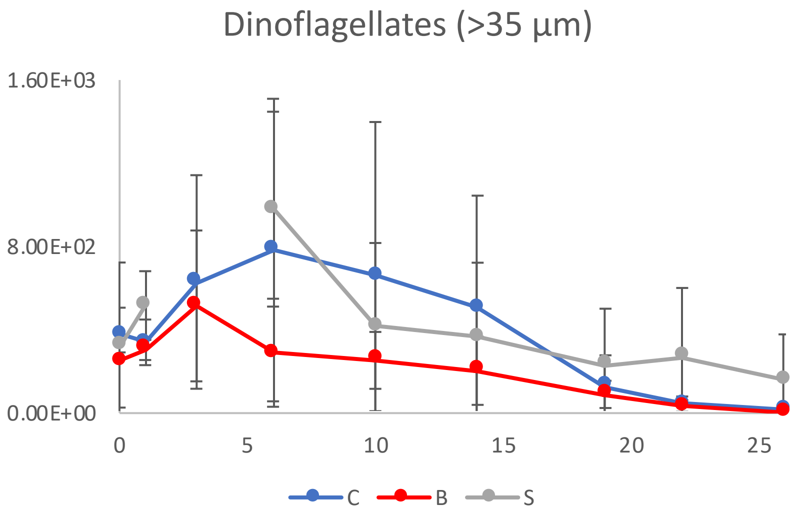
Pico-Eukaryotic abundance in Soot treatment may be affected by the microplankton.

The presence of PAHs in the water seem affect severely the ciliate abundace









To be continued …

- This experiment was funded by the H2020 AQUACOSM project.

- If you want to participate in a mesocosm experiment or propose your own:

www.aquacosm.eu

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