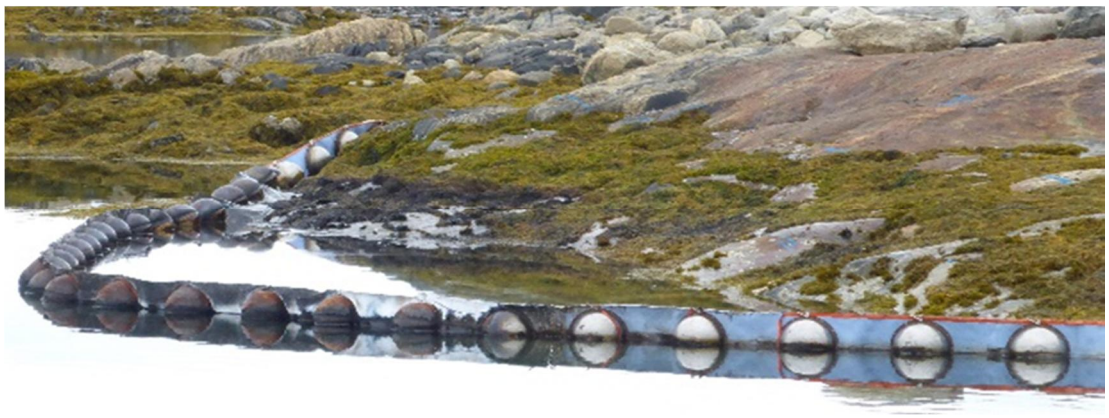
GRACE grant no 679266

# Report on results from field experiments in Greenland

D4.14

WP4:
WP4 Combat of oil spill in coastal arctic water



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# Contents

## Executive Summary

A test of coastal in situ burning (ISB) of an experimental oil spill was performed in 2017 in the vicinity of Færingehavn, south of Nuuk, Greenland, in a selected bay with suitable coastline.

For monitoring environmental effects of the coastal in situ burning, a baseline of the tidal community was performed in the area for the coastal in situ burning test and in a reference area.

The baseline was established by sampling of all tidal community organisms in 2017 (e.g., *Ascophyllum nodosum, Fucus distichus, F vesiculosus, Littorina* spp, and *Gammarus oceanicus*) exept *Semibalanus balanoides*, within a square of 25 × 25 cm. Coverage of fucoids and barnacles in the squares was estimated. The same sampling was performed in 2018, next to the squares sampled in 2017 with sufficient distance to avoid edge effects.

After the burning, samples were taken of the smothered *Fucus* spp. and *Ascophyllum nodosum*, along the impacted coastline and in three different tidal levels, to be analysed for the degree of smothering by oil and burn residue from the burning operation. Impact on *Fucus* spp. and *Ascophyllum nodosum* was estimated (heated, burned, smothered).

All together, a pattern appeared where the organisms in the highest tidal level and at the sampling points most directly impacted by the in situ burning operation were diminished by the coastal in situ burning operation.

Furthermore, as part of monitoring the environmental effects of the coastal ISB, silicone sheets and mussels were placed in different depth beneath the burning and collected the fourth day after the burning operation.

The data for total hydrocarbon (THC) concentration in the silicone sheets showed that the lighter fraction (C5-C9) were measureable in the silicone sheets beneath the in situ burning operation, but not in the silicone sheets placed in the reference bay.

For summing up, the coastal in situ burning has had a long-term effect on the vegetation in the high tidal level. Lighter fractions of the oil could be detected in the silicone sheets in the water column beneath the burn, indicating spreading of the these lighter fractions to the water column during the first 4 days after the burn.

# 1. Introduction

For operational and environmental research pilot scale oil spill experiments were conducted in vicinity of Færingehavn, south of Nuuk, Greenland, in two selected bays with suitable coastlines in 2017. One of the studies investigated the efficiency and environmental impacts of combating oil spill at a shoreline by in situ burning.

A thorough baseline study was performed to make the basis for the assessment of the impacts /effects on and short-term recovery of coastal ecosystems and key organisms when affected by burning oil. This was reported in deliverable D4.11 Baseline Monitoring report. Furthermore a video of the in situ burning experiment is viewable at https://www.youtube.com/watch?v=51ieM7h7ykM&feature=youtu.be

The in situ burning operation was planned to be initiated when tide was going down and reaching the level of the mid tidal zone to ensure direct effect on the tidal community organisms. Thereby optimal effect on the coastal tidal community organisms within the limited selected burning area was obtained for later assessment of the impact.

# 2. Locations

Two limited shoreline areas of 13 and 9 m, respectively, were selected in two adjacent bays which were considered to be comparable regarding substratum and wind exposure (Figs 1-3).

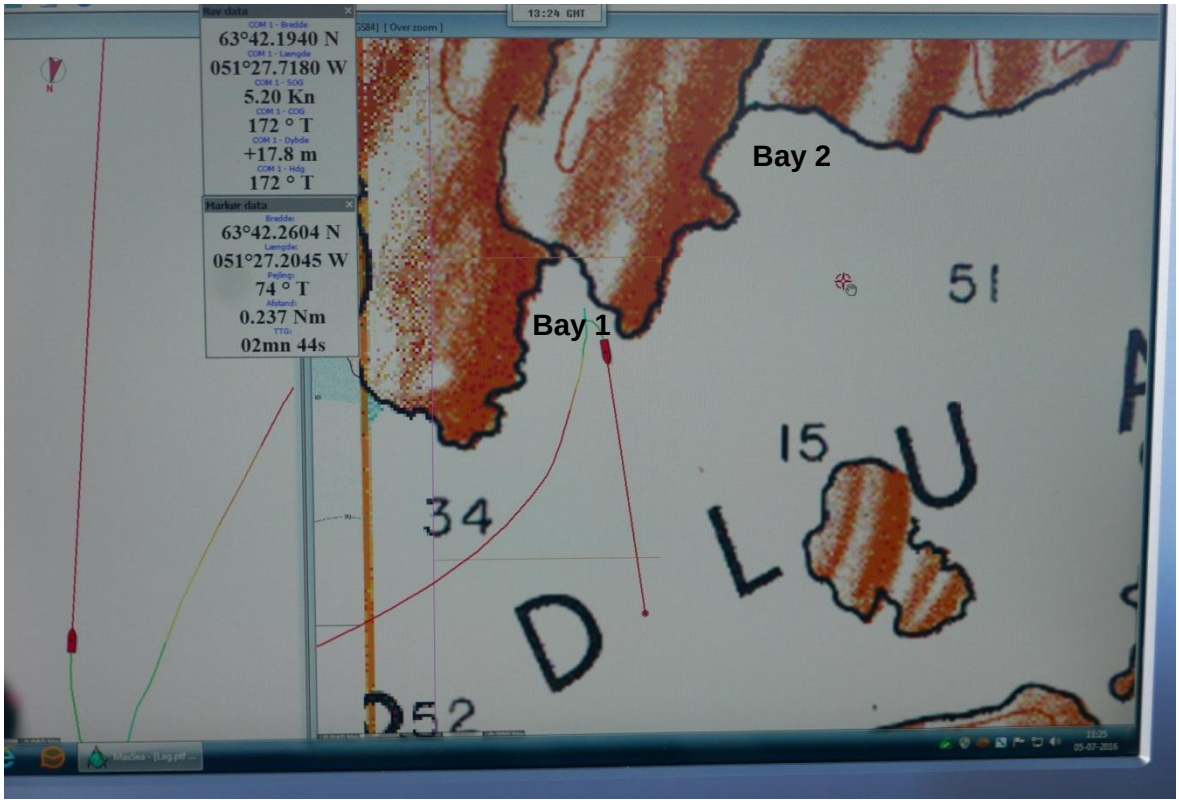



Fig.1. Location of Bay 1 and 2 (GPS position of Bay 1); test and reference bay, respectively.

## 2.1 Coastal in situ burning test location

Bay 1 (Fig. 1, 2):

Fig. 2. Bay 1, area of coastal in situ burning test marked with red ring.

## 2.2 Reference location

Bay 2 (Fig. 1, 3):

Fig. 3. Bay 2, reference area for coastal in situ burning test marked with yellow ring

## 3. Materials and methods

For monitoring environmental effects of the coastal in situ burning, a baseline of the tidal community was performed in the area for the coastal in situ burning test (Figure 4) and in a reference area.

Fig. 4. Area for coastal in situ burning test with preparation for the 2017 baseline sampling. The nails persisted for establishing the same sampling grid for the 2018 monitoring.

The baseline was established by sampling of all tidal community organisms (e.g., *Ascophyllum nodosum, Fucus distichus, F vesiculosus, Littorina* spp, and *Gammarus oceanicus*) exept *Semibalanus balanoides*, within a square of 25 × 25 cm. Coverage of fucoids and barnacles in the squares was estimated. For sampling methods, see Deliverable 4.11.

The same sampling was performed in 2018, next to the squares sampled in 2017 with sufficient distance to avoid edge effects.

The samples from 2017 have been processed, and biodiversity as well as biomass/abundance have been determined. The samples from 2018 have been weighed in the bag from where they were sampled, which may give an overestimate of the total sample biomass compared to the 2017 processed samples.

Right after the burning the impact on the tidal zone *Fucus* vegetation was assessed using the 2017 sampling grid with transects along the shoreline with up to 7 sampling points (areas) (sections) in each transect (Fig 4.)

Following criteria was used for categorising the impact:
- No impact, no sign of effect was to be observed
- Heated, the *Fucus* turned greenish
- Burned, actual black and crisp areas were observed on the vegetation
- Smothered, residues, oil or oil sheen were observed

Each category was graded by assigning + or -.

After the burning, samples also were taken of the smothered *Fucus* spp. and *Ascophyllum nodosum* along the impacted coastline and in three different tidal levels, to analyse for the degree of smothering from the burning operation.

In laboratory, the oil smothering of the *Fucus* and *Ascophyllum* was extracted by dichloromethane for UV fluorescence analysis. Furthermore, the dry weights of the *Fucus* and *Ascophyllum* samples were determined.

However, as this work is still in progress, the extracts colour intensity was determined from six categories of colour; 0, 20, 40 60, 80 and 100 % of the darkest colour (Figure 5 and Table 1). Impacts of the *Fucus* spp. and *Ascophyllum nodosum* were estimated (heated, burned, smothered), which were repeated on the day four after the in situ burning operation.

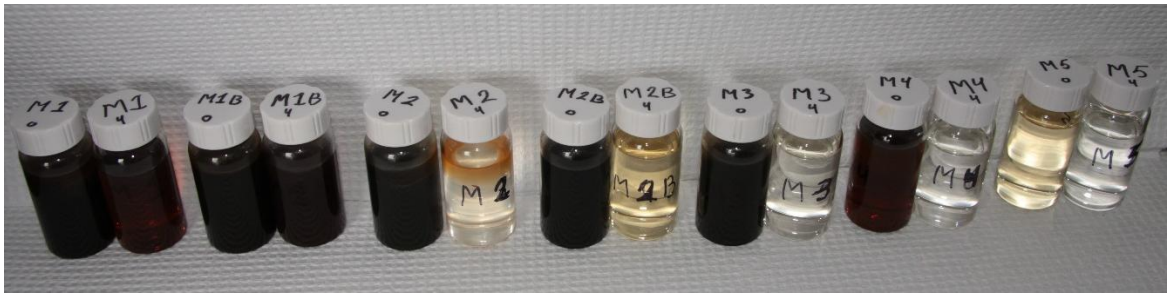



Figure 5. Example of extracts from oil and residue smothered *Fucus* and *Ascophyllum* in the coastal in situ burning area.

Table1. Six colour categories from *Fucus* and *Ascophyllum* smother extracts as percent of the darkest colour.

| % | colour |
|---|---|
| 0 | |
| 20 | |
| 40 | |
| 60 | |
| 80 | |
| 100 | |

Furthermore, as part of monitoring the environmental effects of the coastal ISB, silicone sheets (passive samplers) and mussels were placed in the water column at different depths (1 and 4 m) beneath the burning and collected the fourth day after the burning operation.

# 4 Results and discussion

Selected and preliminary results are shown below. Biomass data from 2018 are from un-processed samples and thus overestimated in comparison with the processed data from 2017. Therefore, all data are not yet statistically analysed and thus the reference data are not presented. All samples, data and results will be further processed and analysed for publishing in scientific journal.

## 4.1 Preliminary results for acute effects of coastal in situ burning operation on tidal organisms and degree of smothering from burn residues

From the impact categorisation, the pattern of impact on the coast can be illustrated (Figure 6a), and is supported by the photo underneath (Figure 6b)

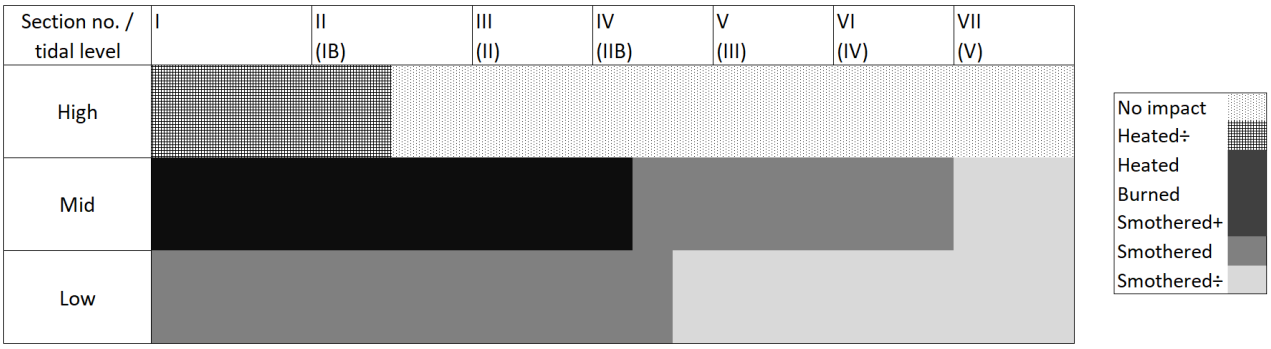
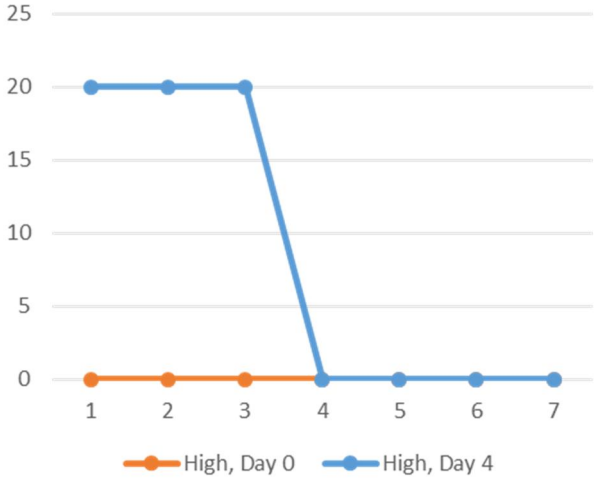
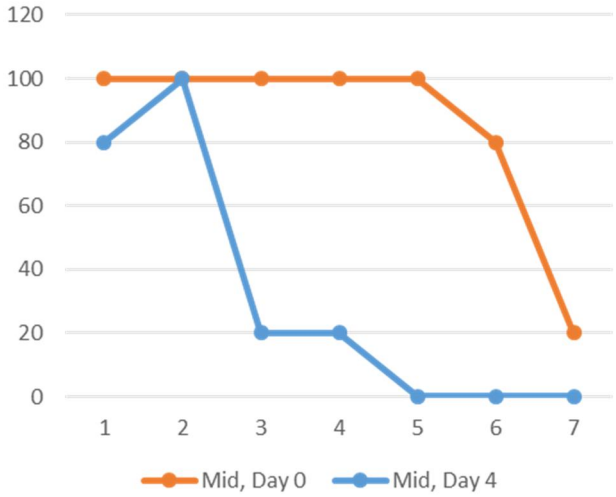



Figure 6. Impact from coastal in situ burning as assessed right after the burning by the following categories: no impact, heated, burned and smothered. Each category is graded by + or – if necessary. The sections I-VII represent areas of a transect from right to left and were marked with screws.

The pattern obtained from the assessment right after the in situ burning operation, was also supported by the extract colour of the samples taken for measurement of degree of smother (Figure 7). It can be seen from the charts in the left panel of Figure 7 that the impacted area from the in situ burning is in the left side of the area until sample section 5. Furthermore, at day 4, the smother is washed off, particularly in the mid-level of the area, whereas the oil smother is pushed up by the high tide to smother the upper part of the tidal zone, as well as oil on the sea surface smother the lower part of the tidal zone. The charts in figure 7 is followed by photos (right panel of the figure) to illustrate the burning, sampling of smothered *Fucus* and *Ascophyllum*, and the vegetation in the area as it looked at day 4, where the vegetation impacted by heat and had turned changed colour to light green and yellow.



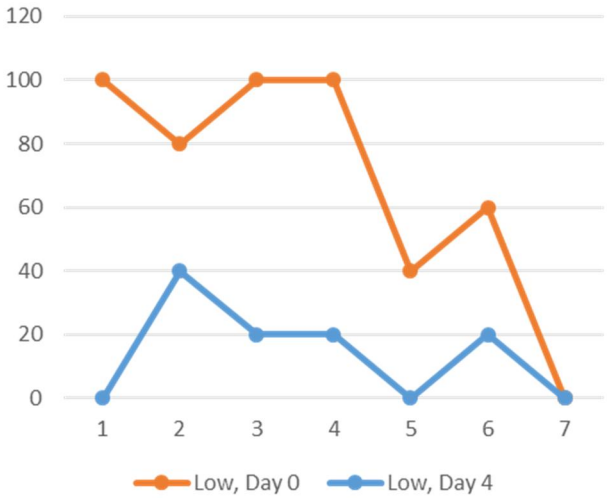




Figure 7. See legend on top of next page.

Figure 7. Extract colour from smothered *Fucus* in the sections 1-7 of the area prepared for the in situ burning operation of the three tidal levels. From top to bottom; high, mid, low levels. It can be seen that the impacted area from the in situ burning is in the left side of the area until sample section 5. Furthermore, at day 4, the smother is washed off particular in the mid level of the area, whereas the oil smother is pushed up by the high tide to smother the upper part of the tidal zone, as well as oil on the sea surface smother the lower part of the tidal zone. The right panel show photo illustrating, from top to bottom, the burning, sampling of smothered *Fucus* and how the vegetation looked in the area on day 4 after the burning.

## 4.2 Preliminary results for long-term effects of coastal in situ burning operation on tidal organisms

Comparison of the total biomass from the baseline studies in 2017 and monitoring studies in 2018 are presented in Figure 8.

It can be seen that only in the high tidal level and in the left side of the investigated area (sample sections 1-4), and where thein situ burning happened (Figure 6 and 7), there is a clear drop in total biomass. This may be due to higher protection to heat from the burning from more moisture attached to the *Fucus* and *Ascophyllum* tissue when lower in the tidal zone, which is covered by water in longer periods than in the high tidal level. From the same reason, the organisms in the high tidal level may be more stressed and hence more vulnerable to bottleneck events.

When pooling the data in samples from the impacted area (horizontal sampling sections 1-5) (Figure 9), as indicated by the initial impact assessment (Figure 6) and the smother analysis (Figure 7), the same pattern, now more pronounced, can be seen.

Also, when comparing total coverage and coverage of *Semibalanus balanoides*, there might be a drop in coverage percent, also in the high tidal level and in the area with the highest initial impact as illustrated in Figure 6. These data are under further processing.

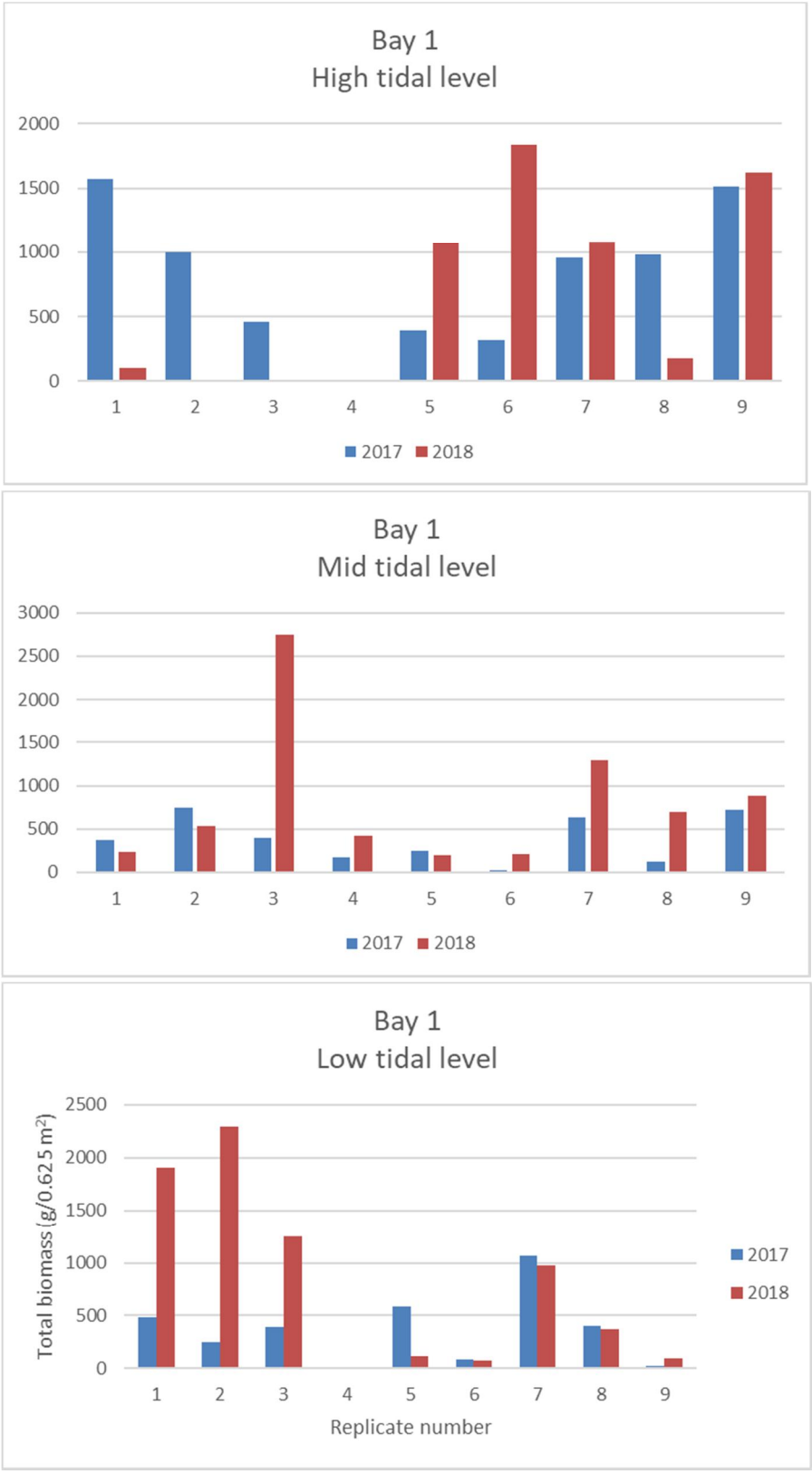
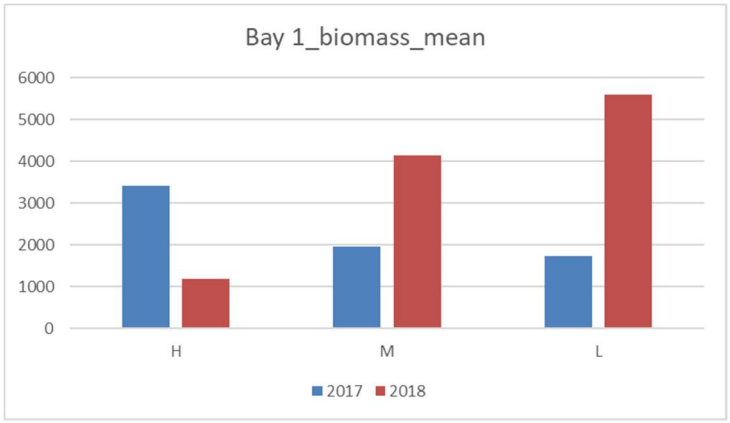



Figure 8. Total biomass at the three sampling levels along the horizontal transect sections. From top to bottom; high, mid and low tidal level. The total biomass at each horizontal sampling section is plotted for 2017 and 2018. The numbers 1-9 corresponds to the replicates in each tidal level.




Figur 9. Mean total biomass for the samples taken in the impacted area as indicated above (sampling sections 1-5). It is clear that there is a long term impact on the total biomass in the high tidal level compared to the mid and low tidal levels, which appear uneffected (total biomass from 2018 is not processed and hence it is assessed that the total biomass may be overestimated compared to the processed 2017 samples).

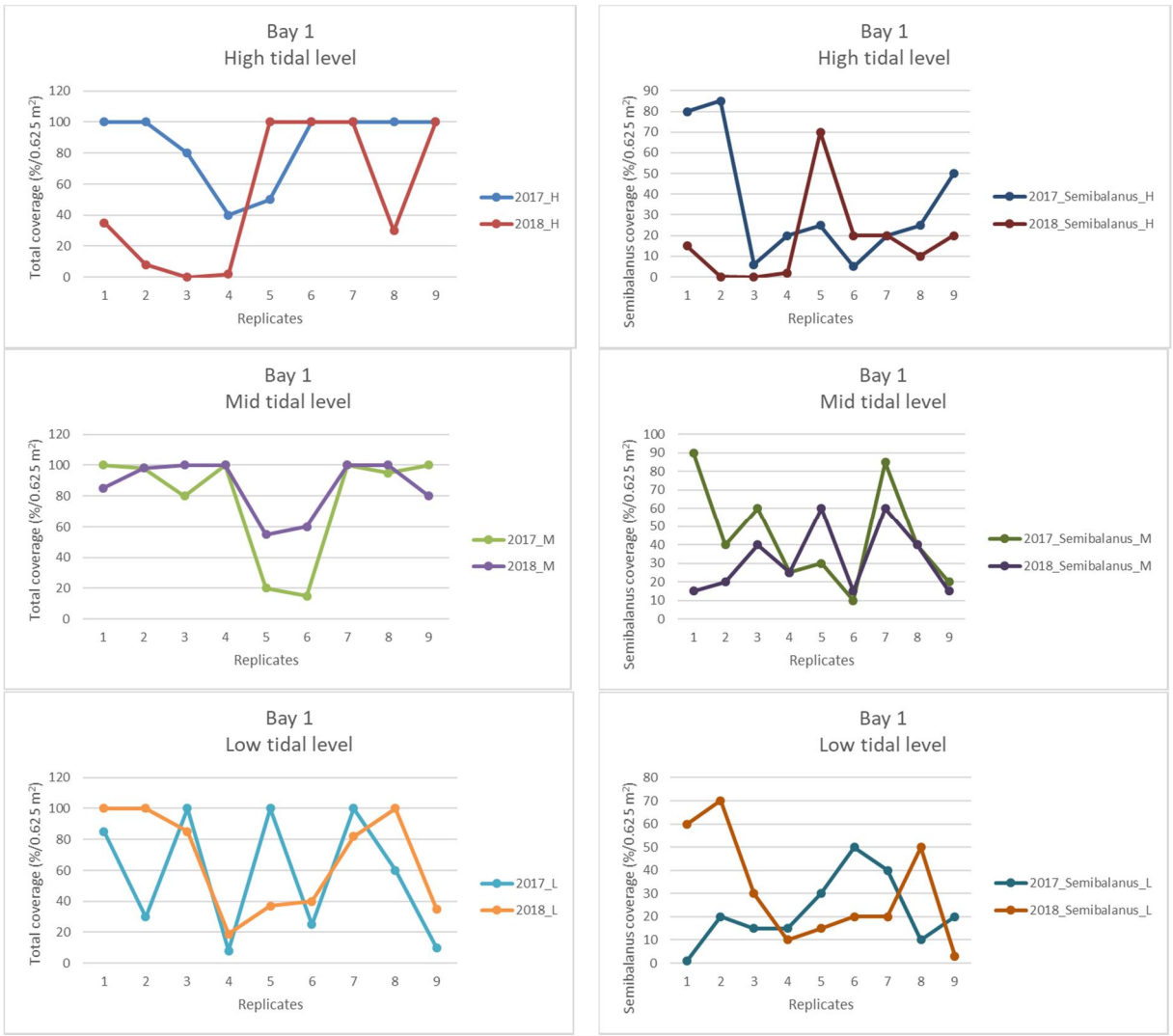



Figure 10. In the left panel of the figure, the coverage of vegetation by *Fucus* spp. and *Ascophyllum nodosum* in 2017 and 2018 is plotted. In the right panel of the figure, the coverage of Semibalanus balanoides in 2017 and 2018 is plotted. The numbers 1-9 corresponds to the replicates in each tidal level.

Data for THC concentrations in the silicone sheets are presented in Figure 11. Here it can be seen that at both 1 and 4 meter's depth beneath the in situ burnin goperation, the lighter oil frations (C5-C9) are presented by higher values than in those placed in the reference bay (Bay 2, Figure 2). The data are still being processed.

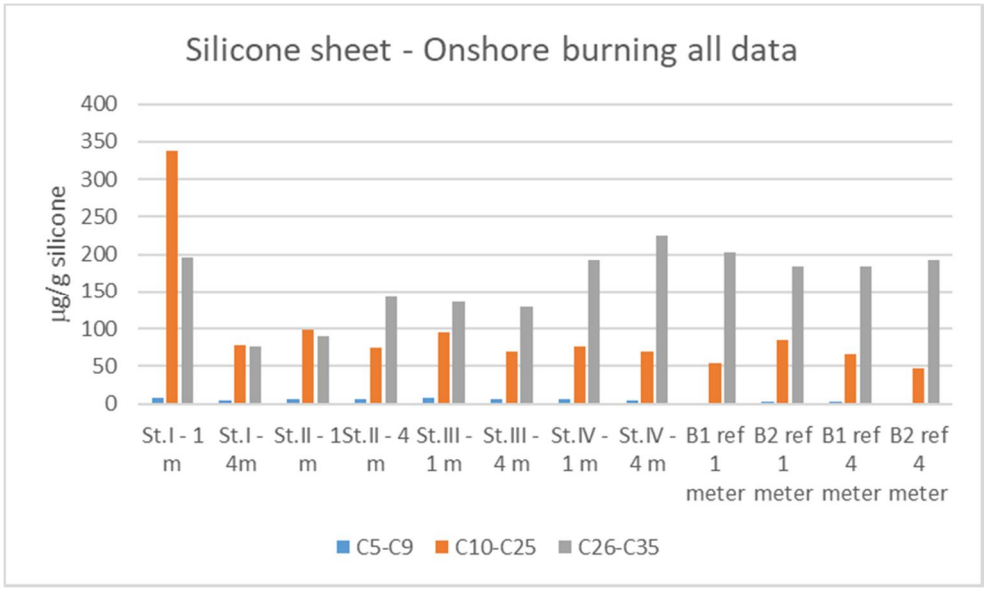



Figure 11. Fractions of the oil (C5-C9, C10-C25, C26-C35) as incorporated in silicone sheets beneath the in situ burning operation (St. I - St. IV, screw numbers in the horisontal transect at lowest tide level) and in the reference bay (ref). The lighter fraction is somewhat elevated in the in situ burning bay compared to those in the reference bay.

For summing up, the coastal in situ burning has had a long-term effect on the vegetation in the high tidal level. Lighter fractions of the oil could be detected in the silicone sheets in the water column beneath the burn, indicating spreading of the these lighter fractions to the water column during the first 4 days after the burn.