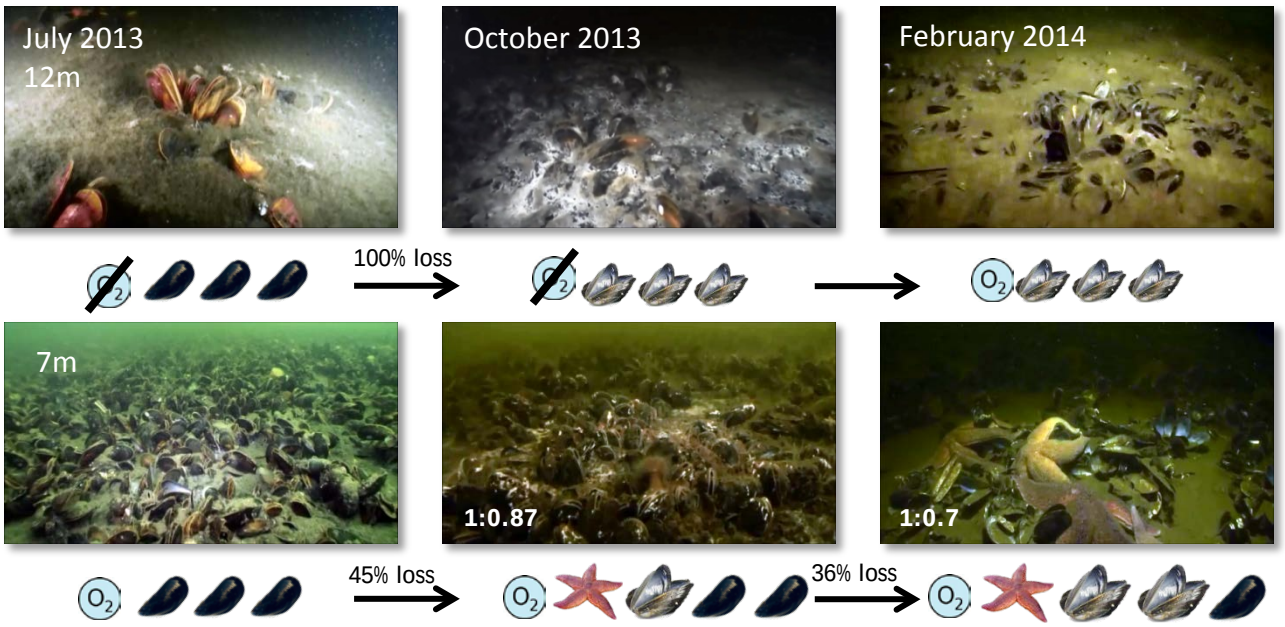
# NOTE: DLD: FROM ANOXIC EVENTS TO STARFISH PREDATION – THISTED BROAD

Written by: Camille Saurel, Mia Gommesen, Ditte Toerring DSC DTU Aqua – June 2014

## ABSTRACT.

In the summer 2013, some mussels from a mussel bed in deep water in Thisted broad (12m) were transplanted to shallower waters (4m). The growth of both the original bed and the replanted one were monitored for 7 months. Mussels left in their original location died from anoxic conditions, while mussels transplanted survived and grew. Nevertheless, 65% of the replanted mussels disappeared, most probably due to starfish predation.




## INTRODUCTION.

Every summer, periods of anoxic condition at the bottom of certain zones of the fjord are responsible for the death of all sessile leaving organisms. An experiment was conducted at Thisted Broad to displace mussels that would potentially die during such anoxic event. Mussels from a 12 m depth zone of the fishing area 28 were displaced to a 7 m zone in fishing area 30, reported free of oxygen depletion events. Mussels were collected and relayed in June-July 2013; video recordings and samplings were conducted at both sites for a period of 7 months.

The aim was to investigate if mussels collected from a deep area subjected to oxygen depletion would survive and grow if they were relayed in a shallower site with no oxygen depletion.

# MATERIAL AND METHODS.

## EXPERIMENTAL DESIGN

1000 t of Mussels from area 28 were dredged and relayed in area 30 in June 2013.

On the 23/07/2013, in area 28, 4 ring samples (0.25 $m^2$) were taken at each of the coordinates (in total 16 ring samples) and videos were taken at positions 2 and 3 (see Table 1 and Figure 1 ). In fishing area 30, 8 ring samples were taken at two positions (named "1+2" and "3+4", see Table 1 and Figure 1) such as at each position 4 ring samples were taken in one direction and 4 in the opposite direction; Videos were taken at each position. All samples were processed on board. If a ring sample was to big the total weight was noted and a subsample was taken (weight and processed). Live mussels from each position were pooled and frozen for size measurement and Condition Index.

On the 01/10/2013, the same sampling protocol was conducted for area 30 than previously, but for area 28 mussels were dead and less samples were taken (see Table 1). Live mussels from each position were pooled and frozen for size measurement and Condition Index. The same sampling procedure was repeated on the 26th of February 2014.

**Table 1:** list of the measurements realized at the different sampling events for the 2013 experiment at Thisted Broad: (video recording from diver cameras)

| Station \ Date | 06/2013 | 23/07/2013 | 01/10/2013 | 26/02/2014 |
|---|---|---|---|---|
| Thisted 28<br>Anoxic conditions | 1000 tons<br>dredged | 4 stations x 4ring samples<br>2 Videos st 2 & 3 | St3 x 4ring samples<br>2 videos st 1 & 3 | St3 x 4ring samples<br>2 videos st 1 & 3 |
| Thisted 30<br>Relay plot | 1000 tons<br>relayed | 2x2 stations x 4ring samples<br>4 Videos st 1 & 2 | 2x2 stations x 4ring samples<br>4 Videos st 1 & 2 | 2x2 stations x 4ring samples<br>4 Videos st 1 & 2 |

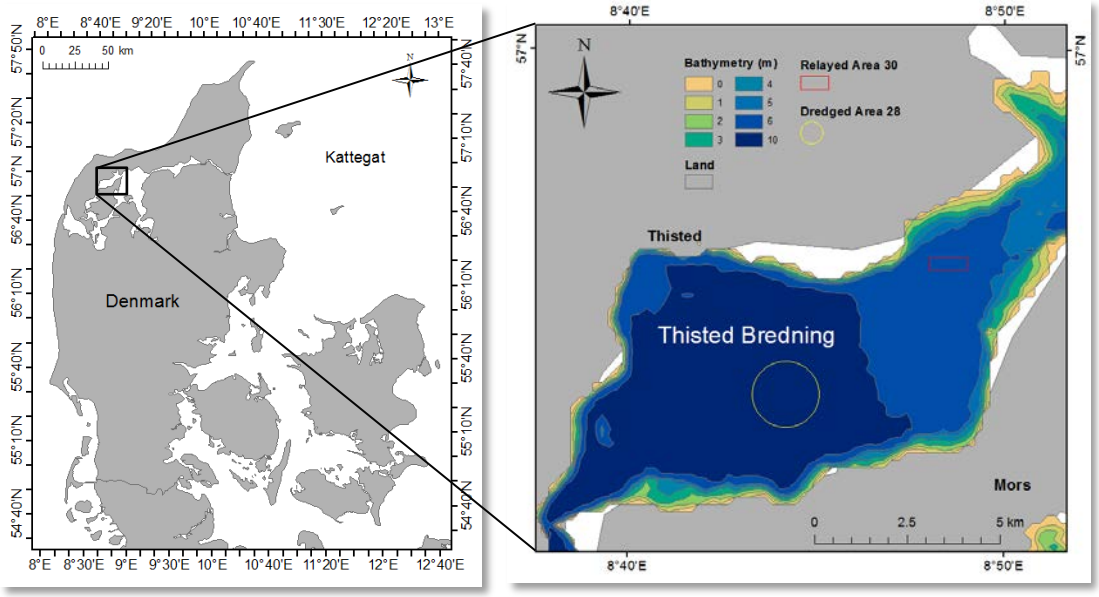



**Figure 1**: Map of the dredged Area 28 and relayed Area 30 in Thisted Bredning, Limfjorden - Denmark.

## LABORATORY PROCEDURES

All laboratory procedures occurred at the Danish Shellfish Centre after the sampling took place in the field.

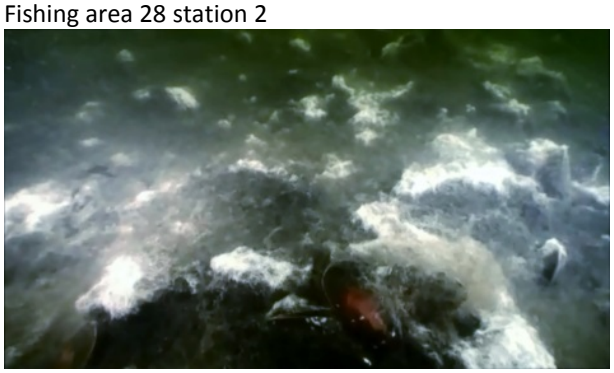
a. Morphometry (morph): A sample of ~100 mussels was collected and shell length (SL mm) and shell width (SW mm) and shell height (SH mm) were recorded for each individual. In the laboratory total fresh weight (TFW g), flesh wet weight (FWW g) and flesh dry weight (FDW g). FDW was obtained by drying the flesh of the mussels for 3 days at 80ºC.
b. Condition Index (CI): CI was measured as $(FDW)^3/(SL)^6$
c. Video: a video footage was realized in November 2011 above the mussel bed during the experiment and in November 2013 after the harvesting.

# RESULTS AND DISCUSSION:

## VIDEO RECORDING

The videos show that in July 2013 there were in area 28 heavy signs of oxygen depletion occur with black sediments, white spots and dying mussels (Figure 2), on the other hands the mussels that were dredged from area 28 and relayed in area 30 looked healthy and in dense beds with presence of other organisms such as starfish (Figure 2). In October 2013, there are only empty shells left in a black and white colored sediment at station 28 while mussels in relayed at the fishing area 30 are still alive and fouled with keel worms (*Pomatoceros triqueter* Trekantorm-DK) (Figure 3).

Fishing area 28 station 2



Fishing area 30 station 1+2

Fishing area 28 station 3

*White anoxic patches are visible*

Fishing area 30 station 3+4

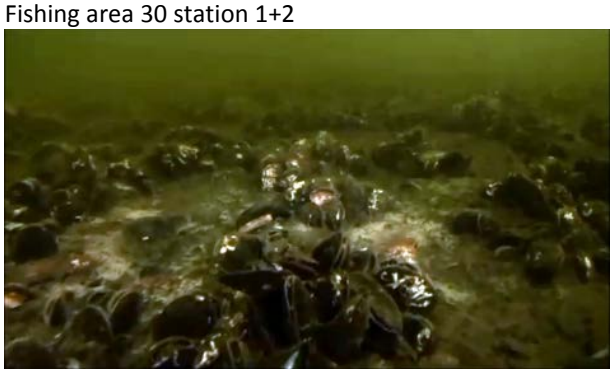
*Mussels are alive in dense beds, starfish are present*

**Figure 2.** Photo captures from the video of the 23/07/2013 above both the mussel bed from fishing area 28 and from the relayed mussels in fishing area 30.

In February 2014, 4 months after the last survey, the sediments from area 28 seem to be recovering and some live animal such as *Pomatoschistus minutus* (Sandkutling-DK Sand goby-EN) are present on the top of the sediment. The relayed mussel in fishing area 30 seem less dense than the previous sampling session and with more empty shells (Figure 3).

Fishing area 28 station 1

Fishing area 30 station 1+2



Fishing area 28 station 3

*Mussels seem all dead, and sediment is black with white spot showing anoxic conditions*

Fishing area 30 station 3+4

*Mussels are alive in dense patches*

**Figure 3.** Photo captures from the video of the 01/10/2013 above both the mussel bed from fishing area 28 and from the relayed mussels in fishing area 30.

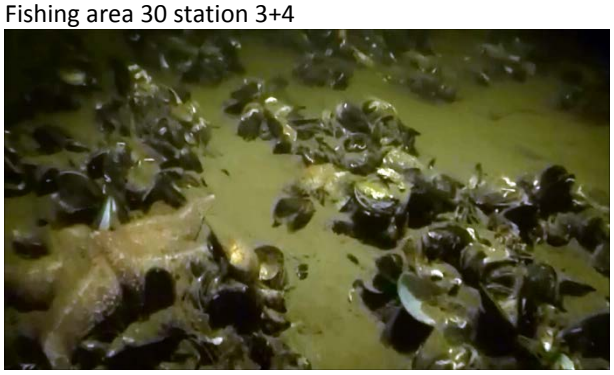
Fishing area 28 station 1

Fishing area 30 station 1+2

Fishing area 28 station 3

*Dead shells only, the sediment is recovering, there are alive fish crawling on top of the sediment*

Fishing area 30 station 3+4



*Live mussels but less dense than before, mix of empty shells, starfish are present. What is the role of predation?*

**Figure 4.** Photo captures from the video of the 26/02/2013 above both the mussel bed from fishing area 28 and from the relayed mussels in fishing area 30.

## DENSITY AND BIOMASS RESULTS

In July 2013, in the anoxic bed, many mussels were opened and empty, and other had already died. This site exhibited a strong smell. The open shells were identified as recently dead. The shells which still contained meat were counted as living. They were not used for calculating CI, as they were considered to have died a few days before sampling.

The condition index in July, just after the transplant was significantly higher in the relayed mussels than in the mussels left in the original deep bed (Figure 5). There is a loss of biomass at the end of the experiment. The mussels are big.

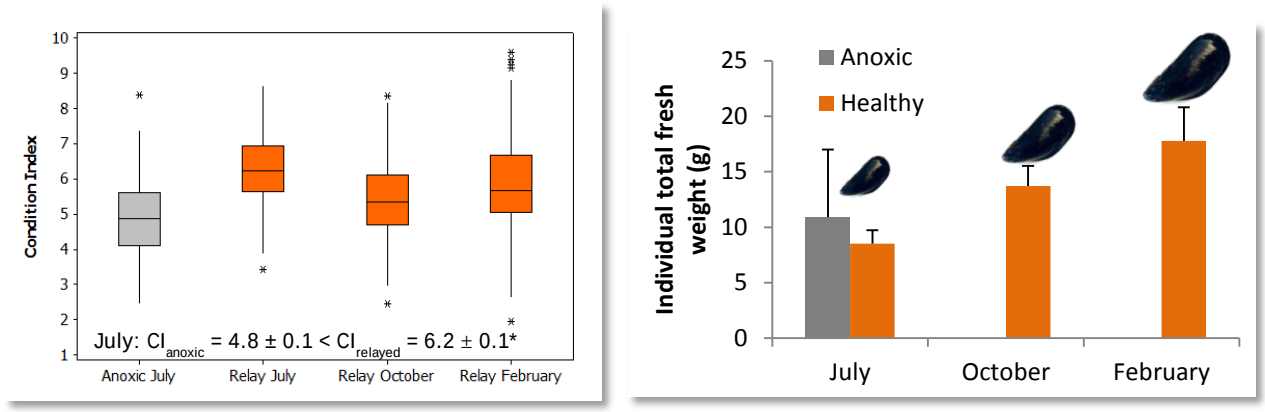



**Figure 5.** a) Condition Index (CI) and b) Individual total fresh weight (g) for the anoxic and relayed bed in July only and for the relayed bed in October and February 2013.

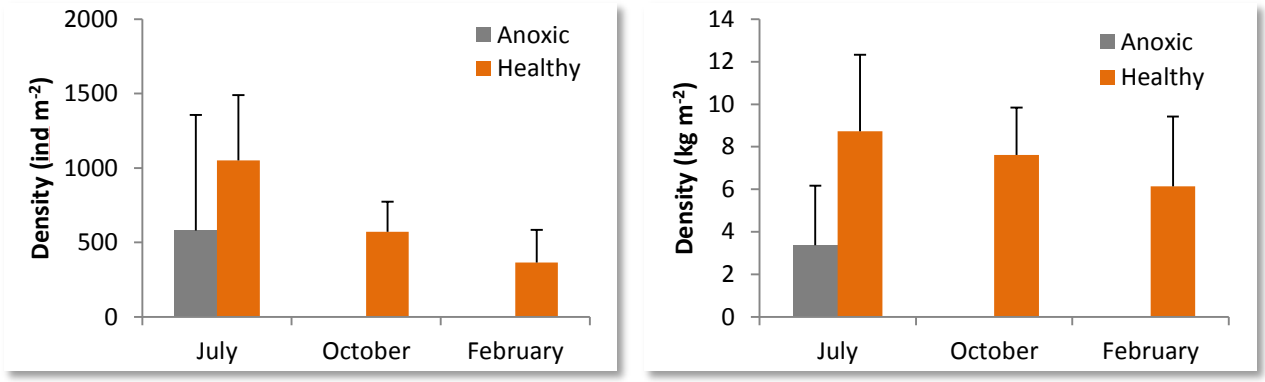



**Figure 6.** a) Density (ind. $m^{-2}$) and b) Density (kg $m^{-2}$) for the anoxic and relayed bed in July only and for the relayed bed in October and February 2013.

## SURVIVAL AND GROWTH OF RELAYED BED

The relayed mussels are fatter than the dying mussels that stayed in the anoxic area in July 2013. After July 2013, 100% of the anoxic bed was dead. In October 2013, 95% of the relayed mussels had reached a commercial size (> 45 mm). In February 2014, 99% had reached a commercial size, but 65 % died mainly from starfish predation.

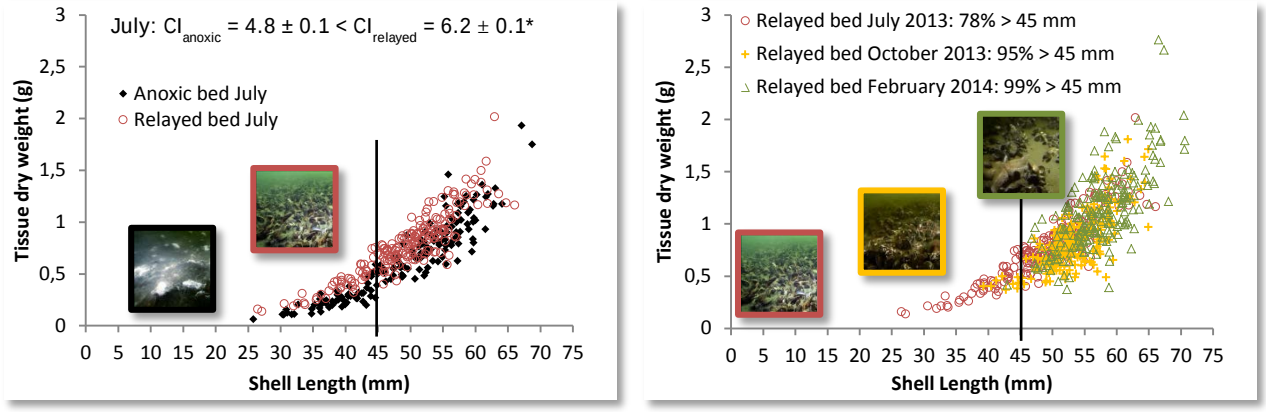



**Figure 7.** Tissue dry weight (g) vs shell length (mm) a) In July for both anoxic and relayed bed and b) in July 2013 to February 2014 for the relayed bed. (N = 50 individuals per samples).

The shell length for the different samples was very variable, and not statistical test was applied, as the assumption for equal variance were not met (Figure 8). The subsample of maximum 50 individuals in Figure 8a shows that samples 28_07_3, 28_07_4, 30_07_1 and 30_07_2 were slightly skewed to larger mussels in comparison to Figure 8b.

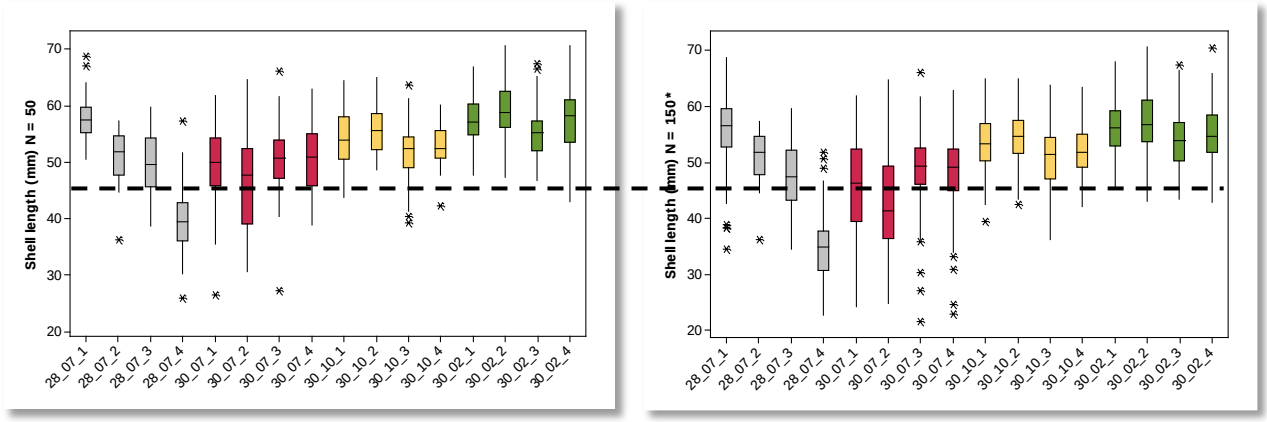



**Figure 8.** shell length (mm) of the 4 samples in July (07) for both anoxic (28) and relayed bed (30) , and in October 2013 (10) and February 2014 (02) for the relayed bed (N = 50 individuals). A) for N = 16-50 for each samples, and b) for N = 16-150 individuals

## CONCLUSIONS

The relaying of mussels from an anoxic deep bed to a shallower bed with no anoxic condition revealed to be beneficial and instead of 100% mortality after 4 months, only 45% of the mussels died. This result is promising for future management of saving bed that would otherwise disappear during anoxic condition in summer. Another important point is that mussel biomass increased but the density decreased due to heavy predation. At the end of the experiment, after 7 month, 65% of the mussels had disappeared, and mussels were heavily fouled with keel worm (*Pomatoceros triqueter*). We recommend that instead of waiting for 99% of the mussels to reach the commercial size of 45mm, mussel should have been harvested as soon as 95% of the mussels had reached this size, in October 2013 in this case. Mussels were less fouled, and in higher number. Moreover, the biomass as kg per $m^{-2}$ seems to decrease with time.

Another point, from a laboratory procedure perspective, is the variability in shell length, a sample of 150 animals vs 50 animals did not change the large variability in the results, and the fact that statistical tests for variance of the sample could not be applied to do the fact that the data did not meet the assumptions.