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Effects of exploitation of marine resources on epifaunal suspension-feeders

Introduction

The purpose of this project is to demonstrate and assess potential effects of suspended and settled material on selected benthic suspension-feeders due to exploitation or other digging activities in the seabed. The focus is on suspension-feeders from hard substrata habitats, as it is assumed that they rarely are exposed to high loads of suspended material and thus less tolerant compared to the soft bottom fauna.

In 1996 NERI, in collaboration with the Danish Forest and Nature Agency, DFNA (Skov- og Naturstyrelsen), and the Geological Survey of Denmark and Greenland (GEUS), measured concentrations of suspended material in wastewater and from several positions downstream from a vessel collecting pebble. The results from these measurements and the present study are integrated in the discussion.

Background

Exploitation of marine resources has taken place for many years. In Denmark approx. 6 million m^3 material is excavated per year (1987-1999). The material is used to make concrete, roads or sand for breakwaters and fillings. The yearly output has varied between 3.6 and 12.8 million m^3 with the largest amounts during the development of the Great Belt Bridge in 1989-1991, the Oresound Bridge 1996/97 and the expansion of the harbour of Århus in 1999. 99% of the material collected in 1999 was sand and gravel (Statistiske Efterretninger 2000).

When exploiting marine resources conservation and protection of important or sensitive areas need to be addressed. It is thus for DFNA to set the conditions and issue permits prior to excavation activities.

The knowledge of effects on epifauna and hard substrata species from excavation and digging activities is very limited (Hygum 1993, Kiørboe & Møhlenberg 1982). Previous studies of suspended material have focused on bivalves. Mainly adult mussels, and the results show that they are capable of coping with extreme high concentrations of suspended material (Kiørboe et al 1980, Petersen 1993). Even increased growth rate was found at moderate concentrations in one study with mussels (Kiørboe et al 1981). From these studies it has been deducted that in general there is limited effects on suspension-feeders from exploitation activities.

However, mussels and other bivalves are probably not suitable key species for benthic suspension-feeders. It has been shown that bivalves are capable of compensating for negative effects of suspended material by particle selection (Kiørboe & Møhlenberg 1981). Particle selection is not found for a lot of other suspension-feeders like e.g. ascidians, bryozoans, suspension-feeding polychaetes and sponges. Also, these organisms differ from bivalves by being completely immobile and do not have the same protective measures like the bivalve shells. Thus, these organisms are potentially more affected by suspended material than bivalves.

The experiments

Through different experiments in the laboratory and *in situ*, it is the purpose of this study to investigate effects on suspension-feeders of increased levels of suspended and settled material as experienced during exploitation activities. Three types of experiments were performed. In the 'catastrophe event' three 2 m^2 areas of the seabed were covered with material, as would

happen in near vicinity of the exploited field and changes in the fauna assemblages were monitored. Potential effects of suspended material were observed through different types of experiments. Two types of experiments were performed in order to reveal any immediate effects. Clearance rate (ml min^{-1} of water cleared for particles) was measured and behaviour (actively feeding or inactive) was monitored of suspension-feeders during 1-2 days of exposure to increased concentrations of suspended material. To demonstrate any long-term effects, growth rates were measured in experiments lasting 7 days.

Results

The highest concentrations and largest particles were used in the 'catastrophe event' experiment, where three plots (1x2 m^2) were covered with 5 cm of sand with a particle size of 0.1-0.3 mm. The layers covered small rocks and horse mussels and thus all epifauna covering those surfaces. The sand stayed for several months and even though horse mussels and sea anemones are mobile, several horse mussels and their associated fauna died. One year after the event, the sand had been resuspended but a difference in the fauna assemblage was still apparent compared to the surroundings (three 1x2 m^2 control plots). Experiments with smaller particles and lower concentrations were performed in the laboratory. Particles with a diameter of 63-125 µm were used in a study of behaviour/mortality of bryozoans and ascidians. No mortality was found within 48 hours with turbidity ranging between 8 and 15 NTU (Nephelometric Turbidity Units), but zooids of bryozoans reacted by retracting more frequently (15 times per hour compared to approx. 2 times per hour) and thus being inactive for longer periods (70% activity compared to 98%). In a similar study using particles of <63 µm in diameter, no effects were found for bryozoans.

The smallest particle fraction was also used in clearance rate studies with sponges, ascidians and horse mussels. Ascidians and horse mussels showed a decrease in clearance rate with turbidity ranging between 6 and 10 NTU. To study if the decreased clearance rate had long-term effects, growth rates of colonial ascidians and bryozoans were measured. After 7 days of exposure to approx. 10 NTU both groups were growing fine, and showed no sign of decreasing growth.

Discussion

The experiments in this project show some of the effects from exploitation activities. In order to assess the extent of effects on suspension-feeders the results have to be related to measurements of suspended particles from actual exploitation activities. Measurements of concentrations of suspended material in wastewater and from several positions downstream from a vessel collecting pebble were performed at Læsø Trindel in the northern part of Kattegat. A model was developed based on the results, showing concentration and size of settled particles as a function of distance from the source (Skov- og Naturstyrelsen 1996, Møhlenberg & Jensen 1997). The model showed that the majority of particles settled within 200 meters, and only particles smaller than 150 µm stayed in the water column and were transported further away.

In the clearance rate and behaviour experiments the maximum concentration was around 10 NTU, which in this study is equivalent to 30 mg l^{-1}. In the Læsø measurements these concentrations were found 100-300 meters from the vessel. In this range ascidians and horse mussels are affected and lower their clearance. The median diameter of particles in this area is 125 µm, thus bryozoans will also be affected and lower their activity.

The model show that particle concentration 600 meters downstream from the vessel is around 5 mm^3 l^{-1} and particles are in the size range of 1.5-50 µm. Assuming a size-spectra similarity between the particles from the laboratory experiments and the Læsø Trindel, 5 mm^3 l^{-1} equals 7-8 mg l^{-1}. At these concentrations effects are still seen as decreased clearance rates of ascidians and horse mussels. The particles are of the smallest fraction and would not lead to disturbance in the behaviour of bryozoans or to decreased growth in long-term exposure. However, the question is what the particle size is 600 meters from the vessel. Mikkelsen & Pejrup (2000) have showed that particles had flocculated 1,500 meters downstream from a digging vessel. With the observed current velocity it took approx. 50 minutes for the particles to travel this distance and

the 9 µm particles made flocculates of an average diameter of 109 µm. The density of the particles decreased from 2.390 kg m^{-3} to 1.501 kg m^{-3}. Thus the settling velocity had only decreased 1.5 times despite the huge difference in particle diameter, and the flocculates were still in the water column. In the Læsø measurements the current was weaker, and particles took approx. 75 minutes to travel 600 meters. It has been shown that measurements on a Coulter Counter particle counter destroy the aggregates larger than 7-25% of the orifice (see in Mikkelsen & Pejrup 2000). If the same happens when using an Elzone particle counter, then the particles from Læsø might have formed larger flocculates than indicated in the study as an Elzone particle counter mounted with a 76 µm or a 95 µm orifice tube was used. If the flocculation phenomenon took place then particle suspension 600 meters from the vessel would affect the behaviour of bryozoans.

600 meters from the vessel at Læsø Trindel, the highest particle concentrations of 1.5-50 µm particles was at 5 to 7 meters of depth. In the area it was 12 meters to the bottom, and the particles would therefore be able to travel another 600 meters before settling. However, it is practically impossible to give a general indication of how far the smallest particle fractions would be able to influence suspension-feeders. It highly depends on the current velocity and depth in the area.

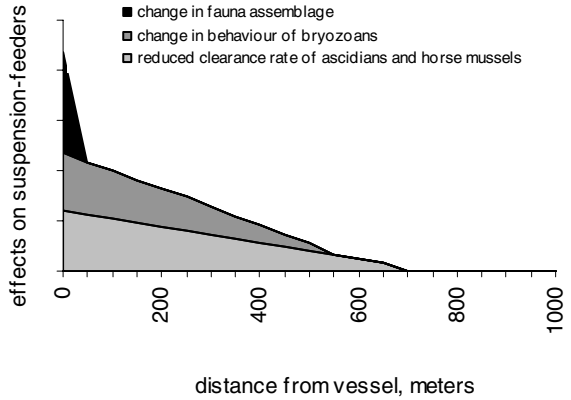

FIGURE: Effects on suspension-feeders found in this project related to a model for suspended material from Læsø Trindel.

The different experiments with epifaunal suspension-feeders show short-term effects (hours) up to 1.2 km from exploitation activities, and long-term effects (months/years) on fauna in near vicinity of the vessel (Figure). The extent of the long-term effects on epifauna depends on the duration of the activities. In the observations from Læsø Trindel, 80% of the suspended material settled within 50 meters from the vessel in a 30 meters wide tail (Møhlenberg & Jensen 1997). The dry weight of the suspended material was between 27 and 45 g l^{-1} (Skov- og Naturstyrelsen 1996). With a content of 36 g l^{-1} and a pumping rate of 2,500 m^3 $hour^{-1}$, 90 tons of material would be suspended in one hour. If 80% of this material is deposited in a (50m x 30m) 1,500 m^2 area, it would on average result in a 2 cm thick layer of settled particles (density set to 2,600 kg m^{-3}). This is in good agreement with diver observations immediately after one hour of suction activities at Læsø Trindel. In the 'catastrophe event' experiment a 5 cm layer of sand was deployed. I.e. after 2-3 hours, effects would be seen as found in the 'catastrophe event' experiment in a 1,500 m^2 area. At Læsø Trindel a total of 3 hours of suction resulted in 120 m^3 of useful material. I.e. for every 1 m^3 collected 10 m^2 of seabed would be covered with suspended material, which as shown in the 'catastrophe event' experiment still would be affected a year later. How long the settled particles in general stay before resuspension, and thus how severe they affect the epifauna depends on if/when the wind and current would be able to resuspend the material. The energy transfer from wind to waves and currents depends on the free stretch on which the wind can act on the water surface. In an enclosed sea as the Kattegat, the direction of the wind is of great importance for the wave amplitude and thus how deep the wave movement is capable of resuspending material. Floderus (1988) made a model and divided Kattegat into 5x5.5 mile squares, and calculated how often resuspension occur in each square, depending on wind direction and force, and the water depth. In the area around Schultz Grund where the 'catastrophe event' experiment took place it happens 0.1-2% (0.5-7 days $year^{-1}$), and in the area around Læsø Trindel it happens 40-100% (146-365 days $year^{-1}$). However, it is very difficult to make satisfactory models of frequency and particle size that is resuspended and moved (Floderus 1988, Møhlenberg & Jensen 1997, Skov- og Naturstyrelsen 1991). Furthermore, even large stones

are being moved if stuck to macro algae holdfast from e.g. *Laminaria*, whose leaves can serve as 'sails' in the current.

Conclusion

There are short and long-term effects on epifaunal suspension-feeders when exploiting marine sediments. Effects are most severe near the vessel (<100 meter) either from direct influence of the suction pump or other equipment, or due to heavy load of settled material. In this area it would take months/years for the fauna to recover, unless the habitat is irreversible altered. The 'catastrophe event' experiment in combination with a model from some exploitation activities at Læsø Trindel indicates that 10 m^2 of seabed is affected for every 1 m^3 of material collected. Re-suspension of the settled material and thus the recovery of the area depend on water depth and the exposure for wave action and current.

Suspension-feeders within 1-1.5 kilometres downstream of a vessel would be affected short-term. Effects include changed behaviour, reduced activity or reduced clearance rate. In this range no long-term effects were found in this study.

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