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The mobilisation of sediment and benthic infauna by scallop dredges

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ABSTRACT

We present the results of experiments to assess the immediate impact of scallop dredging on the seabed sediment and on the inhabiting infauna. The passage of the scallop dredge is shown to homogenise the seabed, flattening sand ripples. The turbulent wake entrains up to the equivalent of a 1 mm layer of sediment per unit of swept width, although an analysis of the finer particles material implies that the suspended silt material must originate from depths of at least 10 mm.

The species most abundant in the sediment plume either swim actively in the water column or are found in, or on, the upper layers of the substrate, whereas those most abundant in core samples taken from the sediment, but not present in the net samples, are almost all tube-building or deep burrowing.

The vertical stratification of sediment concentration and of animal numbers in the water column suggests that even if some of these species respond actively to the presence of the dredge, once entrained, they are transported more or less passively in the same way as the larger sediment particles.

There was no difference between the core samples taken before or after towing suggesting that animals mobilised by the dredge resettle in the tow path. Our analysis does not provide any information regarding the fate of these animals.

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1. Introduction

The environmental and ecological impacts of towed demersal fishing gears have been the subject of many studies and a number of reviews have been published collating and assessing the impact these gears can have on benthic habitats and communities (Kaiser et al., 2006, 2002; Løkkeborg, 2005; Collie et al., 2000; Auster and Langton, 1999; Jennings and Kaiser, 1998; Hall, 1999). While most studies have focussed on biological impacts, physical ones have also been considered and the disturbance to the seabed due to trawling and dredging has been measured using a range of optical and acoustic techniques (Lucchetti and Sala, 2012; Ivanović et al., 2011; Lambert et al., 2012; Boulcott and Howell, 2011). The mobilisation of sediment is an important factor in this regard as it is related to the release of nutrients, benthic infaunal mortality and the resuspension of phytoplankton cysts and copepod eggs (Brown et al., 2013).

In the Firth of Lorne, Scotland, particular concerns have been raised about the sediment mobilised during scallop dredging for *Pecten maximus*, which it is thought may resettle and smother the feeding and respiratory organs of some of the benthic species on nearby cobble and rocky reefs (Dale et al., 2011). The scallop dredges used in Scotland have nine teeth on a spring loaded bar behind which a mat of linked steel rings is fixed. A heavy netting cover is attached to the ring mat to form a bag in which the scallops are retained (Galbraith et al., 2004). Typically two towing beams, with around eight dredges shackled to each, are towed from either side of the fishing vessel, although, the exact number will depend on the size of the vessel (Figs. 1 and 2). The spring loaded teeth and the steel ring mat will loosen and penetrate the sediment, which may make it easier to mobilise and make deeper sediment more available.

A number of authors have examined the sediment put into the water column behind gears such as scallop dredges fished in southeastern Australia, a clam harvesting gear in the Venice Lagoon and commercial and survey trawls in a range of fisheries (Black and Parry, 1999; Pranovi et al., 2004; Dounas, 2006, 2007; Dellapenna et al., 2006; Durrieu de Madron et al., 2005). Although these studies are very informative, they are concerned with specific gears on specific sediment types using different methodologies and it is difficult to generalise their results. To address this O'Neill and Summerbell (2011) look at the sediment remobilised in the wake of some of the elements of a demersal trawl that are in contact with the seabed on sediments classified as being sand, muddy sand and sandy mud. They demonstrate that the mass of sediment entrained behind towed fishing gear elements is directly related to the

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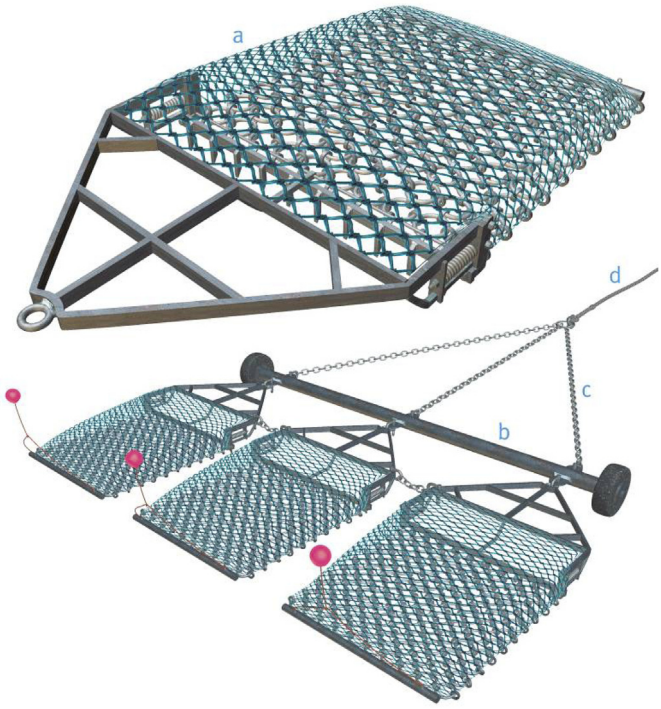

Fig. 1. The scallop dredge used in Scotland to fish for *Pecten maximus*. A typical vessel will fish about eight dredges from each side.

hydrodynamic drag of the element and the type of sediment over which it is towed. The hydrodynamic drag is related to the momentum transferred from the gear component to the fluid and manifests itself as turbulence and accelerated regions in the wake, which depending on the bed shear stress and sediment size and density may result in sediment being mobilised. While these processes are primarily hydrodynamic there may also be other gear-specific mechanisms involved that will have a bearing on the amount and composition of sediment put into the water column.

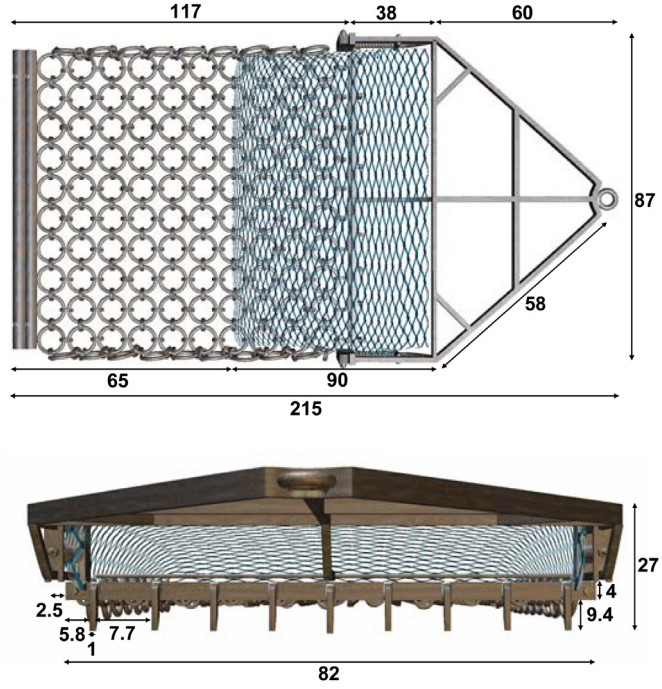

Fig. 2. The dimensions (in mm) of the scallop dredges used in these trials.

The situation with the benthic infauna is more complex. Some animals may react to the oncoming gear and enter the water column whereas those that remain in the sediment will be subject to the same physical forces as the sediment they inhabit. A proportion, depending on their size and density, the bed shear stress, and additional factors such as whether they are attached to anything, will be mobilised passively in a similar way as the sediment. The fate of all of these animals will depend on whether they are at an increased risk of predation, where they resettle if they have been put into the water column and/or the damage and stress they sustain. All but one of the studies of the impacts of scallop dredging on infaunal communities reviewed by Løkkeborg (2005) demonstrated a decrease in the abundance of some species and changes to community structure. The study of Eleftheriou and Robertson (1992), while not showing any significant changes in abundance or biomass of the infaunal community, reported that large numbers of the epifaunal and large infaunal organisms were destroyed. A more recent study (Hinz et al., 2012) of three different queen scallop (*Aequipecten opercularis*) gears find no evidence of a decrease of infaunal abundance but did find a decrease of biomass for one of the gears.

Here, we investigate the immediate impact of scallop dredging on the seabed sediment and on the inhabiting infauna. We focus on gaining a better understanding of the physical processes involved and in particular on quantifying the sediment and infauna entrained in the wake of a scallop dredge, measuring the large scale dimensions of the plume, characterising the physical alteration to the seabed and assessing the short term impact to infaunal species.

2. Materials and methods

Experimental trials took place on board the RV Clupea on sandy sediment grounds (with broken shell and pebbles) northeast of Colonsay, Scotland at depths of approximately 22 m during September 2007 (Fig. 3). Scallops were present on the grounds, but not in commercial quantities. Three different types of experiments were carried out and are labelled, (i) the towed underwater divers' vehicle (TUV) experiments, (ii) the benthic sledge experiments and (iii) the before-after control-impact (BACI) core sampling (with the laser stripe metrology). A Day grab was also used to obtain samples of the undisturbed sediment to compare the particle size composition of the plume with that of the seabed.

2.1. TUV experiments

The TUV is a working platform for divers using SCUBA that allows them to be towed alongside and work in close proximity to towed fishing gears (Fig. 4). One of the divers pilots the TUV and can direct it horizontally and vertically by adjusting the hydrofoils and move it forwards and backwards by communicating with the towing vessel to pay in or out the towing cable.

In these experiments a LISST 100X was attached to a 'wing' on the port side of the TUV. The LISST 100X is an in situ particle sizer and measures the particle size distribution and concentration of the sediment suspended in the wake of a scallop dredge. It uses the laser diffraction principle to estimate particle size and the resulting concentration of particles (measured in μl/l) is presented in 32 logarithmically increasing size ranges between 2.5 and 500 μm (microns) (Pottsmith, 2007).

Four tows took place where scallop dredges were towed from a beam. The pilot 'flew' the LISST 100X into the sediment plume at distances of approximately 2, 5, 10, 20, 30 and 50 m from the scallop dredge to measure the particle size and concentration of the

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