Hdb Env Chem Vol. 5, Part M (2005): 239–251
DOI 10.1007/b136013

Published online: 15 July 2005

The Effect of Marine Aquaculture on Fine Sediment Dynamics in Coastal Inlets

T. G. Milligan (✉) · B. A. Law

Department of Fisheries and Oceans, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, N.S. B2Y 4A2, Canada
milligant@mar.dfo-mpo.gc.ca, lawb@mar.dfo-mpo.gc.ca

Abstract The formation and deposition of large, fast-sinking aggregates by flocculation governs the distribution of fine particulate material within the coastal zone. Three major factors control the development of a flocculated suspension: (1) particle number or concentration, (2) particle adhesion efficiency or stickiness, and (3) particle break-up, most often due to an applied shear. The steady state equilibrium size distribution of a flocculated suspension reflects a dynamic balance between particle aggregation and disaggregation; changes to concentration, composition, or turbulence can hence affect the distribution of fine particulate material, both inorganic and organic. Owing to the close association of many surface-active contaminants with flocs, the aggregation dynamics of the particulate material will strongly influence their fate. The introduction of waste feed, faecal material, and their resulting degradation products from open cage aquaculture operations in the coastal zone will potentially increase both particle concentration and particle stickiness. As a result, the natural flocculation and depositional equilibrium of an inlet can shift towards increased deposition of fine-grained particulate material within flocs and the sequestering of contaminants within the sediment. Evidence for such a shift in fine-sediment dynamics and contaminant transport has been found in the Western Isles region of New Brunswick.

Keywords Aquaculture · Contaminants · Far-field effects · Flocculation · Sediment

1 Introduction

The seabed beneath salmon aquaculture pens is altered by the increased flux of material from above. Using various parameters such as organic carbon,

redox potential (Eh), and sulphide, the area influenced by increased sediment accumulation has been identified and found to be dependent on the sedimentary conditions at the site [1]. Areas with high bottom stress naturally have much lower accumulation rates due to both initial dispersal of falling material and subsequent reworking of the accumulated waste [2, 3]. The rate of accumulation of wastes beneath salmon cages forms the basis of the environmental effects monitoring carried out in Canada. Accumulation rates sufficient to induce anoxia in the sediments require alterations to husbandry practices so that degradation of the region below the cages is reduced. Low accumulation rates are equated with low impact. What is not considered, however, is the fate of the material that is removed from the cage site and presumably added to the normal population of particulate material in a bay or inlet. This material would be subject to the same processes controlling the fate of other sediment in the region. Determining its fate requires a mechanistic understanding of how this additional material interacts with the naturally occurring sediment, and how it would impact the fine sediment dynamics of the receiving basin.

Bottom sediments preserve within their disaggregated inorganic grain size (DIGS) distributions a record of the physical transport processes responsible for their formation. In simple terms, the accumulation of sediment at any point in an inlet can be considered a balance between deposition from suspension and removal by currents and waves. Land and shore erosion produces inorganic sediment grain size distributions in which the amount of material in each logarithmically increasing size class follows a power-law relationship, from sub-micron-sized clays to coarse sands and gravels [4–6]. The exponent in these relationships depends on the composition of the source rock and expresses the relative abundance of fine versus coarse grains [6]. During transport, repeated settling and suspension modifies these size distributions. In particular the coarsest material is lost to deposition, so that the maximum grain size of a sediment defines the maximum turbulent energy to which the sediment is exposed [7, 8]. The degree of sorting indicates how frequently the material is resuspended, the extreme case of which is beach sands which have very well sorted, narrow size distributions, the modal diameters of which reflect wave energy [8].

The third process that controls the size distribution of bottom sediment is the mode of deposition. Fine-grained sediment is deposited as either single grains or in agglomerations of many particles, called flocs, and the relative proportions of these depositional modes are representative of the environmental conditions. Conceptually, a simple box model consisting of two boxes representing single grains and flocs illustrates this effect (Fig. 1). Removal of single grains from suspension is dependent on their individual settling velocity (Stokes settling) whereas removal of aggregated grains is controlled by the settling velocity of the flocs, on the order of $1\ \mathrm{mm\ s^{-1}}$. The most important controls on the extent of aggregation of sediment include: (1) particle