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Accumulation and natural disintegration of solid wastes caught on a screen suspended below a fish farm cage

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Abstract

A new method consisting of a screen-like device to trap and manage solid waste from below a fish cage is proposed. To examine its effectiveness, a mathematical model was developed to predict the amount of waste and its degradation over time under low-current conditions. It was also used to examine the effects of fish stocking, feed conversion ratio, screen size, mesh size and harvest rate on the total amount accumulated and time required to degrade the waste after harvest. The characteristics of waste and fish feed used to develop the model were experimentally determined as they degraded in a tank of oxygenated 8 °C saline water. As the solid waste degraded, the carbon (%) and COD (mg/(L g dry weight)) remained constant as N (%) increased and C/N decreased. Bacteria degradation consisted of activities related to both mineralization and the physical breakdown of the waste into tiny particles. After 30–40 days in cold and saline water, approximately 50% of the waste matter disappeared from the 3 mm mesh screen ($p < 0.001$). The experimental waste degradation rate (kg m^{-2} day^{-1}) increased with increasing specific area of waste (kg m^{-2}) ($r^2 = 0.97$). Model simulations indicated that staggering fish harvests was the most effective method for reducing waste loads and the period for total waste removal after fish harvest. Future work will focus on the fate within the environment of the tiny particles released by the degradation process and the effect of current on waste erosion rates.

Keywords: C/N ratio; Chemical oxygen demand; Benthic impacts; Environmental effects; Salmon farming

1. Introduction

Waste produced by fish farms contains carbon, phosphorus and nitrogen in dissolved and suspended solids (Ackefors and Enell, 1990; Naylor et al., 2000) as well as metals, such as zinc and copper (Beveridge, 1996; Edwards, 1998; Kempf et al., 2002). In cage farming, suspended solids that are the result of uneaten food and faeces can accumulate beneath the cages especially under low-current conditions (McGhie et al., 2000; Naylor et al., 2000). High accumulation may affect benthic fauna, sediment chemistry, degradation rate and environmental quality (Clarke and Phillips, 1989). Through the process of decomposition, oxygen

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in and above the sediments can become depleted, and under anoxic conditions gases, such as nitrogen, carbon dioxide, methane and hydrogen sulphide can be generated. As well, waste degradation rates could decrease as anaerobic decomposition generally proceeds at a slower rate than aerobic decomposition does. High accumulation of waste solids beneath fish farming sites can affect the caged fish since oxygen depletion and formation of chemical species toxic to the fish can lead to self-pollution and a reduction in production (Folke and Kautsky, 1989).

Typically, the solution to solid waste accumulation is a period of production inactivity, so that the solid wastes on the sea floor have time to naturally degrade or erode. This process is called site fallowing. The Canadian Aquaculture Industry Alliance (CAIA) has promoted this practice to allow benthic recovery, and states that below most farming sites the benthic community recovers after 6–9 months post harvest (CAIA Salmon Facts, 2003). Recovery appears to depend on site characteristics and farming operation (e.g. Brooks et al., 2003, 2004). Peer-reviewed studies do not exist that could be used to suggest an appropriate fallowing time valid for all farming conditions. Disadvantages of fallowing include lost production potential, possible negative impacts on fauna and negative public perception. Due to these disadvantages, the development of an alternative waste management system is required for a more sustainable industry.

The research described herein involves the development of a new waste management method that relies on a screen-like device below fish farm cages. Conceptually, the screen would trap the solids for natural breakdown and/or on-site treatment. Land-based fish farming operations have used stationary screens as an effective pre-treatment step to remove particulates from effluent (e.g. Makinen et al., 1988; Bergheim and Forsberg, 1993; Bergheim et al., 1993). Clogging rapidly occurs if concentrations of suspended particles are too high or as with the case of fish waste, the material tends to be adhesive (Wheaton, 1985; Cripps and Bergheim, 2000). Below a sea cage, the clogging that is a problem for land-based treatment would be used to an advantage to enhance solids retention on the screen-like device.

It is anticipated that the new method would be compatible with current infrastructure and could cover the entire affected zone. The required screen area would be site specific and dependant upon depth below the cage, currents and bottom topography. In general, screen area increases with suspension depth below a cage. Locating the screens too close to the cage bottom, however, could result in production decline due to the outputs from waste degradation and competition for dissolved oxygen.

Degradation rates on the screen are expected to be higher than benthic rates, since the solid waste surface area exposed to dissolved oxygen is higher on the screen (both sides of the screen) and dissolved oxygen and water temperature just under the cage are generally greater than at benthic levels. The potential benefits of the proposed method include compatibility with in-place infrastructure, collection of dispersed waste and an increase in degradation rates and recovery times as compared to the conventional fallowing periods.

The aim of the research was to characterize the solid waste by measuring particle size, composition, chemical oxygen and degradation rate, and to use this information to develop a model that could be used to predict accumulation and removal on a screen below a typical fish farm. Promising results would help generate an interest in a field trial wherein the benthic recovery rates below screened and non-screened areas could be compared.

2. Solid waste characterization and degradation experiments

The purpose of these experiments was to track the degradation and chemical composition of solid waste and fish feed pellets on a screen suspended in water under conditions similar to those found at a fish farm with low-current conditions (i.e. a condition that would favor degradation by microorganisms over physical breakdown and dispersion by current). This would provide information relating to a "worst" case scenario.

2.1. Solid waste material

Solid waste was collected every 2–3 h on three Atlantic salmon fish farms using 1 m diameter funnels suspended 15 m below the surface in fall and early winter during three trips, each one lasting 4 days. Samples were collected from three cages (sized 33 m × 33 m in area) at once on each farm. The