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Organic Enrichment from Marine Finfish Aquaculture and Effects on Sediment Biogeochemical Processes

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Abstract Organic enrichment of sediments underlying fish farms in temperate and tropical coastal zones is reviewed to identify similarities and important biogeochemical differences. Improvements in technology have allowed farms to move from depositional sites to more erosional offshore locations. However, low cost farms are still being located in sheltered areas, in particular in the tropics. Important differences in the response of sediment geochemical variables to organic enrichment are associated with finfish aquaculture located under highly diverse hydrographic and sedimentological conditions in different coastal areas. In temperate latitudes where farms are often located over soft bottom, organic enrichment increases sediment microbial activity and may alter benthic community structure. Enhanced anaerobic activity may lead to accumulation of sulfides with adverse effects on aerobic bacteria, plants and fauna due to progressive oxygen depletion. In warm temperate waters, such as the Mediterranean and tropical latitudes,

many farms are located in more advective areas with coarse-grained carbonate-rich sediments. Effects of organic enrichment in these areas are less well described, but studies have also shown sulfide accumulation in sediments indicative of deteriorated benthic habitats.

Keywords Aquaculture · Organic enrichment · Sediment biogeochemistry · Sea grass communities

1 Introduction

Many industrial uses of the coastal zone result in increasing release of nutrients. In an area of restricted exchange with offshore water, this often leads to nutrient and organic matter enrichment (eutrophication) [1, 2]. Meyer-Reil and Köster [3] described critical changes associated with eutrophication in coastal waters. Progressive stages of enrichment include increased inorganic and organic nutrients, microbial biomass and enzymatic decomposition of substrates, nitrification, denitrification and benthic oxygen and nutrient fluxes. Evidence is also accumulating to show that with increasing eutrophication the ratio of autotrophic to heterotrophic microbial processes is reduced as increasing amounts of organic matter are respired in sediments than in the water column [4]. As organic enrichment of aquatic ecosystems increases, the balance between pelagic and benthic metabolism appears to shift to become dominated by benthic processes.

In oligotrophic and mesotrophic coastal marine systems, where high turbidity does not limit light and phytoplankton production, material flow and cycling predominantly occur in the water column. This is illustrated in Chesapeake Bay where almost two-thirds of total annual oxygen consumption occurred in the water column [5]. In eutrophic, nutrient-rich areas however, heterotrophy predominates based largely on stored organic matter in sediments. In coastal areas, this fundamental shift in ecosystem structure may be reflected seasonally. For example, during spring and late summer following input of organic matter sedimented from algal blooms benthic respiration increases [6]. This natural seasonal cycle may be enhanced when organic matter released from aquaculture sites results in peaks in benthic mineralization, aerobic and anaerobic respiration in late summer [7–10]. A shift in the balance between pelagic and benthic respiration could occur on an inlet-wide scale in coastal areas as a result of finfish aquaculture activity if increases in sedimentation of fine-grained particles and associated organic matter are sufficient to cause sulfide accumulation in sediments [9, 10]. When finfish and shellfish aquaculture facilities are located in coastal areas that receive other sources of organic waste, soluble and particle matter products released as a result of aquaculture operations are added to what may be an already high