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Reconciling Aquaculture's Influence on the Water Column and Benthos of an Estuarine Fjord – a Case Study from Bay d'Espoir, Newfoundland

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Abstract One unifying principle proposed for the environmental influence of aquaculture is that when flushing is poor (> 2 d.), the maximal biomass produced in an area will be constrained by accumulation of waste products in the water column. In the Bay d'Espoir estuarine fjord on the south coast of Newfoundland, under-ice salmonid culture in cages in protected bays with low flushing rates (5 to 20 d.) is a challenging component of the annual production cycle. However, in two years of environmental monitoring of such protected bays, no significant change to water quality was observed. A measurable influence on the benthos was more frequently detected, but localized. Thus the inconsistency of Bay d'Espoir; it has a low flushing rate, yet there was no observable change to the water column. Possible reasons for this are discussed, and include: the sheer amount of water (i.e., potential for within-basin mixing/dilution and biodegradation) in this estuarine fjord; increased surface transport of nutrients; the benefit of fallowing; and, diminished relative loadings to the water column and benthos in winter conditions for an industry in its early stages of development. Further refinement of assimilative capacity estimates for this and other similar suboptimal areas will have to resolve this apparent contradiction prior to espousing "unifying principles".

Keywords Assimilative capacity · Benthos · Environmental impact · Modeling · Water column

Abbreviations

H holding or assimilative capacity
ΔC allowable change in nutrient level (μmol N l^{-1})

R rate of nutrient release by fish (mol N d^{-1} kg^{-1})
T flushing rate (m^3 d^{-1})
V volume (m^3)
mt metric tons (1 mt = 1000 kg)

1 Introduction

Monitoring and simulation efforts have been put to use in several countries to understand and control the impacts of net-pen aquaculture on the environment [1]. These efforts have been directed at investigating both water column [2–6] and benthic impacts [7–13]. However, few studies have compared simultaneous effects on the water column and benthos [10, 12–16]. This growing body of work suggests that aquaculture operations will cause greater change to the water column surrounding the net pens than to the benthos beneath the net pens. An estimated 47.6% to 63.8% of the total carbon [9, 17], 65.0 to 65.1% of the total nitrogen [9, 18], and 31.4% of the total phosphorus [19] input as feed ultimately enter the water column as soluble waste. Furthermore, approximately 50% of the particulate nitrogen and phosphorus reaching the sediment layer translocates back to the water column [20]. This would increase the aforementioned losses to 82.5% to 83.5% of nitrogen, and 68.3% of phosphorus input as feed that ultimately enters the water column as soluble waste. Thus using a mass balance approach to investigate nutrients lost to the environment, relatively more enter the water column than the benthic food chain.

While the mass balance approach suggests a theoretical proclivity towards increased water column impacts, degradation of benthic habitats, particularly for salmonid mariculture, is more frequently observed [1, 8, 10]. It is this benthic degradation rather than that of the water column that is likely to cause negative impacts and subsequent fish disease issues for the farmer [21]. Comparing those studies that have demonstrated a direct impact of aquaculture on water column variables, it was often observed that changes are most pronounced in eutrophic, shallow, or very confined areas that have long flushing times [11, 15, 22, 23], and included the Baltic [24], Hong Kong [15], and areas of Norway [14]. As an example, prolonged flushing times are associated with a greater incidence of change to the water column [25].

For any given body of water, the production capacity can be calculated using either a benthic model developed from carbon burial rates (B) [12], or from water quality variables (W) [6, 12]. A B/W production ratio can be calculated as the benthic production estimate divided by the water column production estimate, and can be used to determine which milieu is limiting. Values less than 1.0 indicate that the water column estimate is larger,