

# Physical Processes in Blue Hill Bay and Net-Pen Aquaculture

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Physical oceanographic processes play a key role in determining the environmental impact of discharges from fin-fish aquaculture. The nature and vigor of these physical processes vary widely throughout the bays and estuaries of the Gulf of Maine. Thus, there is wide range of potential aquaculture sites in Maine. There are robust regions with strong mixing and rapid flushing, and there are highly vulnerable regions where flushing rates are low and mixing relatively weak. One can not subject this wide spectrum of oceanographic provinces within the Gulf of Maine to the organic loadings associated with net-pen aquaculture and expect similar results at each of the sites.

One of the most important characteristics that determine the sensitivity of a potential site to damage from aquaculture-derived discharges is the flushing rate or exchange with the open Gulf. The flushing rate of a bay is a central element in determining the concentrations of carbon, nitrogen, and other contaminants that will build up in the water body over time. Regions characterized by high flushing rates can withstand a greater degree of discharge from pens than regions with low flushing rates. In order to predict with any confidence the impacts of aquaculture on a particular location, it is of fundamental importance to have a good estimate of residence time of the waters receiving these discharges.

Preliminary studies of the circulation and hydrography of Blue Hill Bay conducted in the summer of 1999, suggest that the overall flushing time of Blue Hill bay is on the order of months (Pettigrew, 1999). In contrast, the flushing time of Cobscook Bay, the site of the much of the salmon aquaculture in the state, is on the order of days. This difference is very significant, and suggests that it is imprudent to assume that the experience in Cobscook Bay can be readily applied to Blue Hill Bay or other regions of the Gulf of Maine with much less energetic flushing. It is very important to realize that the flushing estimate for Blue Hill Bay is a very crude estimate that is based on a study not specifically designed to address this issue. The flushing estimate could be significantly too high or too low. In addition, the flushing rates and other important physical processes in Blue Hill, and other bays and estuaries, can vary significantly from one location within the bay to another. Thus there are expected to be a range sites within a given bay that may result in high or low local impact, and high or low overall impact.

Another important factor determining the suitability of a particular site is the strength of the tidal currents that largely determine the degree of vertical mixing during the summer in the Gulf of Maine. In regions of strong tidal flows, such as Cobscook Bay, the tidal currents are strong enough to prevent the development of vertical density stratification in the summer. Thus, the vertical mixing associated with the tidal currents stirs the water column throughout the year and allows the dissolved oxygen in the deeper waters to be continually replenished.

In comparison to Cobscook and other aquaculture sites in the Gulf of Maine, Blue Hill Bay has weak tidal currents. As a result, stratification develops in the summer season that isolates the deep water from exchange with the atmosphere. This isolation means that dissolved oxygen levels in the deeper waters may be seasonally depleted by the processes of respiration and decay of organic matter. Both of these oxygen depleting processes will be enhanced by the farming of fin fish in the high densities common in net-pen aquaculture.

The studies conducted in the summer of 1999 showed that large regions of Blue Hill Bay are already characterized by oxygen depletion, and are in fact episodically observed to be below the 85% saturation level that is used in the state as a water quality standard. Once again, the local tendency toward oxygen depletion will depend upon details of the circulation and mixing and also upon other inputs including municipal sewage treatment plants.

The effluents from net-pen aquaculture would have little negative impact on the marine environment if the aquaculture sites were located in the open, well flushed, and vigorously mixing waters of the Gulf of Maine. However, the bays and estuaries of the Gulf of Maine are generally much more sensitive to aquaculture activities and caution needs to be exercised when instituting these activities in our sheltered waters. Thus it is prudent to require a level of scientific knowledge sufficient to be able to make accurate estimates of the flushing rates and the degree of vertical mixing prior to approving new lease sites in Blue Hill and other bays and estuaries in the Gulf of Maine. The studies to acquire this level of knowledge should include direct measurements of the summer stratification of the bays, circulation patterns in the bays including exchange with the open the gulf, and numerical simulations, which use the direct measurements for calibration, to calculate flushing and mixing at various regions within the bay.