River Outwelling Plumes: good or bad places to farm mussels?

Paul Gillespie,
Cawthron Coastal & Freshwater Group

Aquaculture management areas

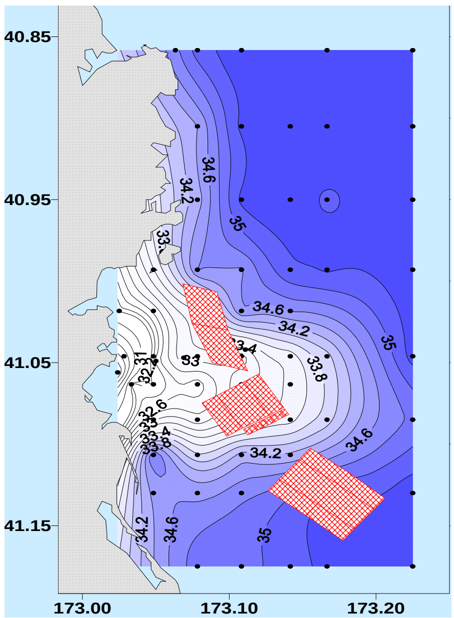
Aquaculture in New Zealand is entering a phase where the potential for development of large (*i.e*. 100s of hectares) farms positioned 3 to 10 or more kilometres offshore can be considered. The shellfish farming industry now actively pursues development of sites in areas provisionally designated by councils as Aquaculture Management Areas or AMAs. Applications are often based on the assumption that growth potential and water quality conditions will be appropriate. Whether or not this assumption is valid, depends on the location of the proposed development and the degree to which the farm would be affected by the highly mobile and often ill-defined river outwelling plumes. Without some preliminary investigation into these outwelling plumes, it can be somewhat of a gamble because some of the effects can be positive and others negative.

Re-defined catchment area

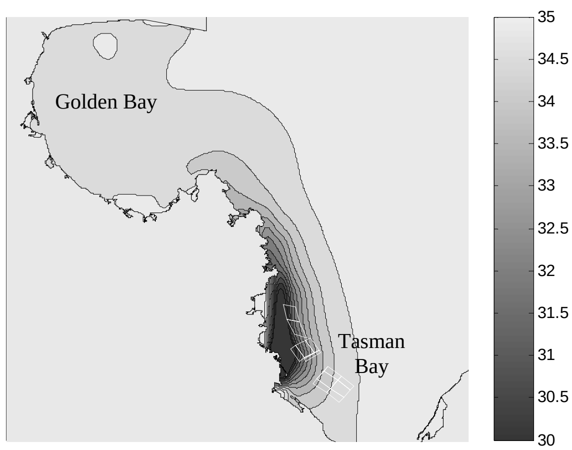
In order to address the potential coastal problems associated with land runoff, environmental managers and marine farm developers need to expand their definition of "catchment" to include the region that is significantly influenced by the river outflow. This emphasises the need for coastal activities like aquaculture and fishing to be considered alongside land catchment uses, like forestry and dairy farming, so that they can be managed in an integrated way.

River plume effects

Terrestrial contributions that can have an effect on shellfish resources and aquaculture growing conditions include plant nutrients, suspended sediments and a range of potential microbial and chemical contaminants. Tasman Bay and Golden Bay are good examples of regions that can be significantly affected by land use activities within contributing catchments. Research carried out through the Motueka Integrated Catchment Management (ICM) programme (http://icm.landcareresearch.co.nz/) has shown that, after a moderate rainfall event, the surface salinity plume from the Motueka River mouth can extend to more than 20 km into Tasman Bay encompassing a majority of the regions designated for mussel farming and/or shellfish spat harvesting. Cawthron's Nelson Bays hydrodynamic model indicates that, after a major flood event, the much expanded wind and tide driven plume can even push out around Separation Point and into Golden Bay.



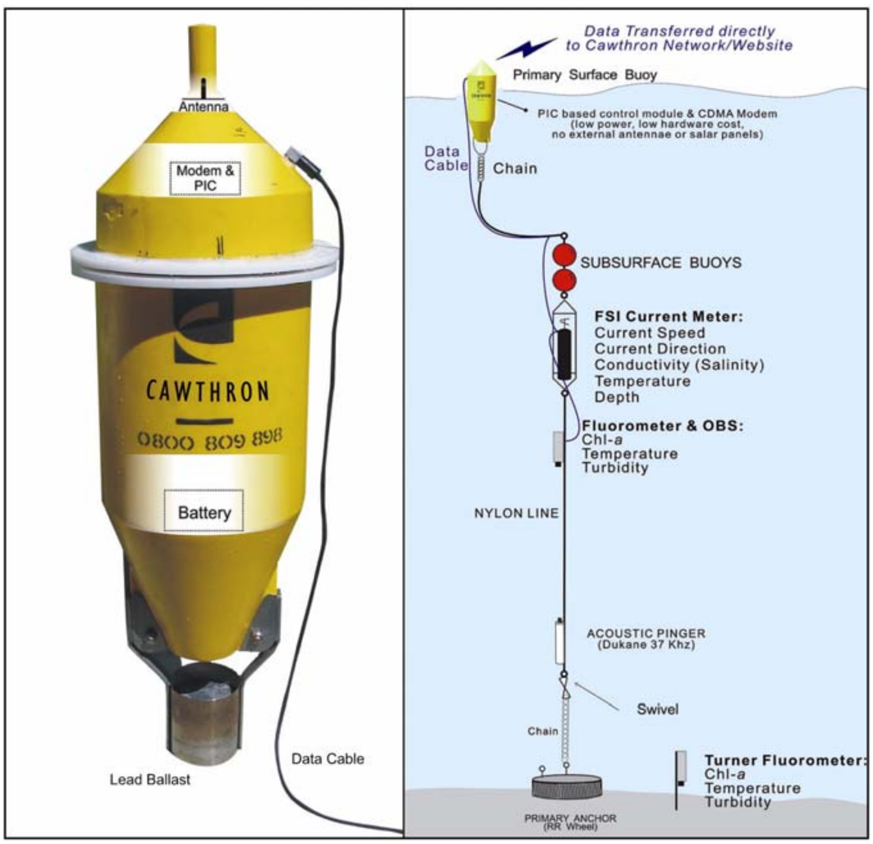
Surface salinity (psu) off the Motueka River mouth after a moderate rainfall event (flow 200 m^3/s).



Model prediction of surface salinity (psu) off the Motueka River mouth after a major rainfall event (flow 1000 m^3/s) and 20 knot southerly winds.

During rainfall events, the river outflow delivers sufficient nutrients (*i.e.* inorganic nitrogen and phosphorous) from the catchment to stimulate phytoplankton production within the western side of Tasman Bay. At the same time, the freshwater plume, which is less dense than seawater, floats out over the Bay setting up stratified conditions in the water column.

Cawthron maintains a buoy-mounted, real time data collection facility off the Motueka River mouth. Although a long term data set is ultimately required, a picture is emerging that shows some of the relationships between river flow, coastal water quality and fish and shellfish resources.



Cawthron's Motueka plume data collection buoy.

Growth potential for mussels

The stratified seawater conditions generally result in subsurface chlorophyll *a* (phytoplankton) maxima so the best growth potential for mussels is often five or more metres below the surface. Nitrogen is the most limiting nutrient for phytoplankton growth in Tasman Bay (and most temperate coastal regions). During 2005, the Motueka River contributed around 300 tonnes of nitrogen (TN) to the Bay. Other tributaries and the main wastewater outfalls along the coast contributed another 600 or so tonnes. The resulting annual loading estimate of about 900 tonnes seems like a lot but it appears to be well within the assimilative capacity of the Bay environment. If we put mussel farming into the equation, representing a net loss of nitrogen from the system, we can get a better idea of what the numbers mean. The harvest of farmed mussels, for instance, would remove nitrogen from the Bay environment at a rate of about 14 tonnes per 1000 tonnes of mussels (green weight) harvested.

So, in terms of nutrients, the existing land-use scenario in the Motueka catchment does not result in reduced water quality within the proposed aquaculture sites. On the contrary, the river plume provides a moderate boost to the growth potential for long line culture of mussels although the food supply is likely to be more variable over time and depth in the water column than in non-plume affected regions. For example, surface water phytoplankton biomass is often low in Tasman Bay during summer low rainfall periods, so mussel growth may be slow until a good storm mixes the water column to redistribute nutrient supplies from deeper layers.

But we still need to keep tabs on nutrient sources and sinks (ecosystem losses) to ensure that they remain in balance, because excessive nitrogen loading, particularly in semi-enclosed waters, can have the devastating coastal environmental effects seen in many other parts of the world (*e.g.* an over production of phytoplankton and associated bacteria leading to severe oxygen depletion and/or the proliferation of noxious or toxic species). This highlights the need to consider the entire (re-defined) catchment in order to manage appropriately.

Suspended sediments

Other aspects of water quality that are influenced by the river plume can also affect shellfish resources. Suspended sediment inflows during flood events can result in extensive plumes of highly turbid waters. This can be particularly devastating to benthic shellfish like scallops because sediments deposited on the seabed can be repeatedly resuspended by tidal currents creating a near-bottom high turbidity layer that interferes with suspension feeding activities. This condition can become chronic, particularly in regions where the sediment/water interface has repeatedly been disturbed due to dredging or trawling activities. Mussels suspended above the seabed, however, would only be affected for short periods after delivery of the sediment laden plume. Another word of caution about suspended sediments, however, is that they can contain a variety of contaminants depending on their source. Sediments eroded from the upper Motueka catchment, for example, contain substantially elevated nickel and chromium concentrations. Although the metals come from a natural source, the Red Hills mineral belt, they could have ecological consequences for seabed animal communities. Luckily, the metals-containing sediments do not appear to result in significantly elevated concentrations in shellfish flesh. More comprehensive sampling will be required to confirm this, however, because preliminary investigation (just a few samples analysed) revealed slightly elevated concentrations in scallop flesh. We also need to investigate the possibility that whole shellfish, like cultured mussels, might temporarily contain high metals in their intestinal tracts directly after a major rainstorm.

Faecal pathogens

In most cases, bacterial water quality will be the most important reason for mussel farmers to look closely at catchment land use characteristics and plume physical behaviour before deciding on the most suitable sites. Faecal indicator bacteria (and associated pathogens) from a variety of human, agricultural and wild animal sources can be delivered from catchments to aquaculture sites via river plumes. These sources can be very difficult to manage in complex, multi-use catchments like the Motueka, but the development of new molecular techniques, collectively called microbial source tracking (MST), may enable a more focussed management approach for improvement of bacterial water quality at the coastal end of the catchment.

What lessons have we learned?

It is clear that river plumes from even moderately-sized catchments can affect proposed aquaculture sites located considerable distances offshore. Some of the effects can be beneficial but there are also risks of adverse effects. The take home message for shellfish farmers is to consider how adjacent catchments may affect growing conditions and product quality at a potential farm location. Since terrestrial, freshwater and coastal catchment uses will undoubtedly change over time, it is essential that they be managed in an integrated way.