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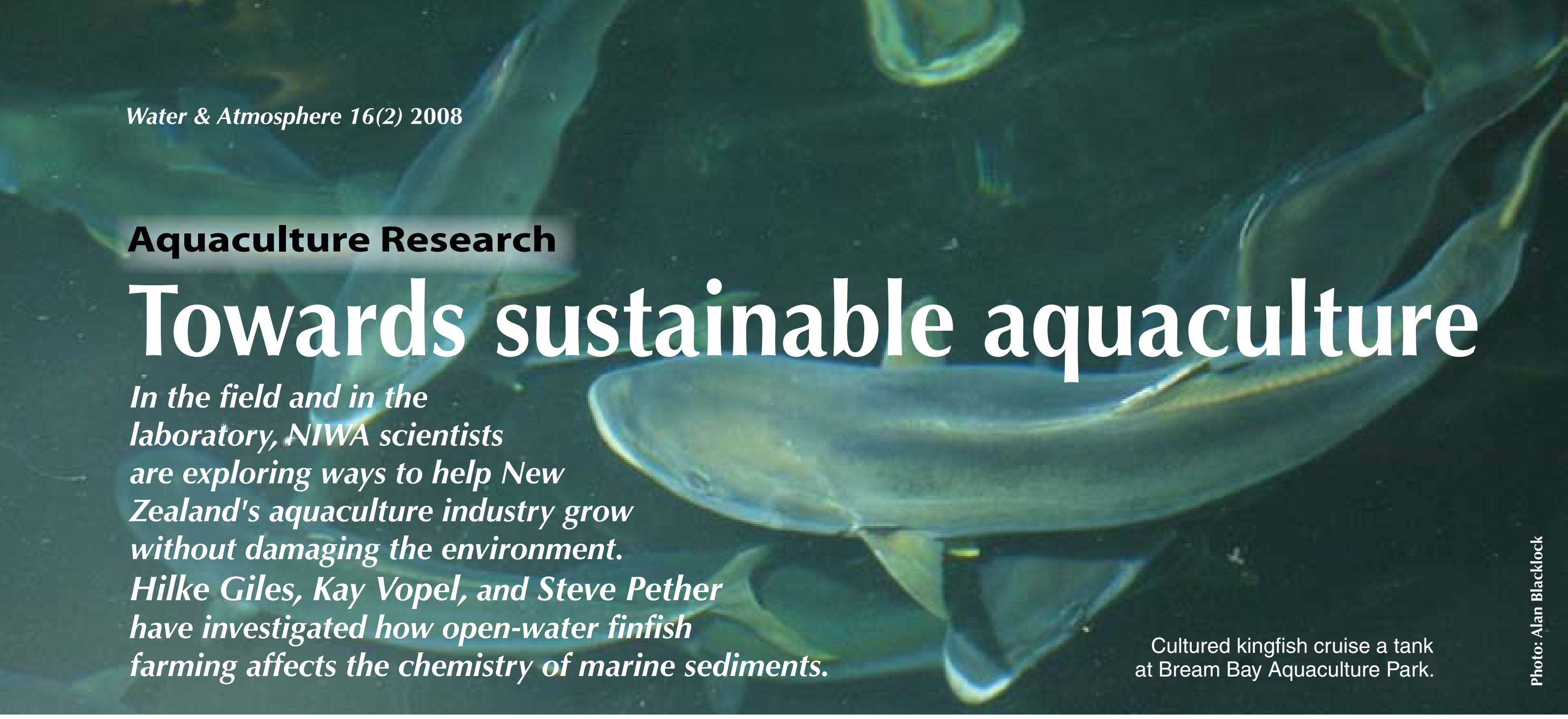


Aquaculture Research

Towards sustainable aquaculture

In the field and in the laboratory, NIWA scientists are exploring ways to help New Zealand's aquaculture industry grow without damaging the environment. Hilke Giles, Kay Vopel, and Steve Pether have investigated how open-water finfish farming affects the chemistry of marine sediments.

Cultured kingfish cruise a tank at Bream Bay Aquaculture Park.

Photo: Alan Blacklock

Aquaculture is a rapidly growing industry in New Zealand with plans to raise annual production from today's $300 million to $1 billion by 2025. New Zealand aquaculture is dominated by products with high quality but moderate value, such as Greenshell™ mussels, Chinook salmon, and Pacific oysters. Some of the industry's planned growth can be met through improvements of these species; however, the greater opportunity lies in new higher-value species, such as kingfish (*Seriola lalandi lalandi*).

NIWA has made great progress in breeding kingfish. A remaining obstacle to large-scale commercial cultivation is the potential effect on the marine environment. One way of learning about these impacts is by simulating them in the laboratory.

Environmental effects of fish farming

The main concern about developing a new marine fish farm is usually how it may affect water quality. The key to understanding these effects lies with the processes that take place in the sediment.

Fish are typically farmed in coastal areas in cages near the water surface. Fish faeces and uneaten feed sink to the seafloor, where they enrich the sediment with organic material. Fish farms also have other effects on the ecosystem, but this enrichment is the most significant effect.

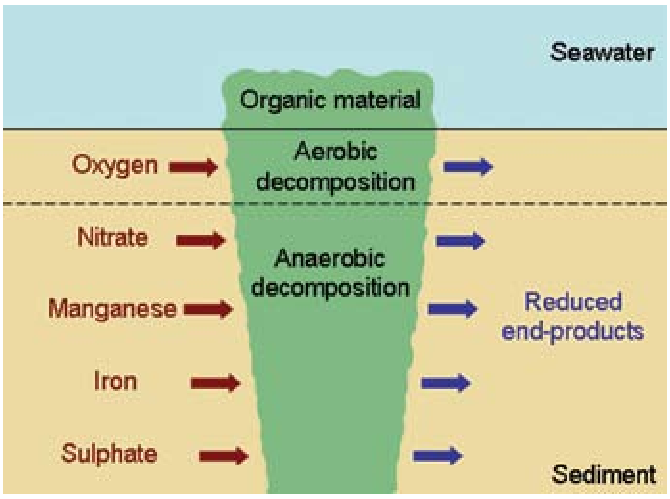
In the sediment, organic material is broken down by a complex network of microbial **reduction–oxidation** (or **redox**) reactions. This process provides food for microbes and therefore increases their activity. Microbes that live in the upper few millimetres of sediment use oxygen as a source of energy to break down organic material and thus create an **oxygen demand** in the sediment.

Below this upper sediment layer, organic matter is broken down by microbes that use other sources of energy, mainly nitrate, iron and manganese compounds or sulphate. This process is called **anaerobic** decomposition and produces reduced end-products. These end-products are mobile in the sediment. They diffuse within the water between the sediment grains (**porewater**) and are redistributed if the sediment is mixed, for example by burrowing animals or by **resuspension** of the sediment by strong currents. If these reduced end-products enter the upper sediment layer they are oxidised by oxygen and this also creates an oxygen demand in the sediment.

Commercial success one step at a time

- NIWA has successfully bred kingfish in tanks; now we need to understand the environmental impacts of raising them in open-water cages.
- With laboratory experiments we're measuring how the fish faeces that fall from cages affect the chemistry of the sediments below.
- Our results so far suggest that sediment oxygen levels are depleted under fish cages and also indicate that this is less of an issue where strong water currents help mix the sediments.

The large amount of organic matter deposited below fish cages changes the rates of almost all redox reactions. It also changes the **flux** of reaction products between the sediment and the overlying seawater. These fluxes can have important consequences for the seawater quality. For example, fish farming can result in the release of nutrients from the sediment that support the growth of algae in the water. It can also result in the release of toxic hydrogen sulphide. The effects of fish farming on ecosystem functioning thus depend on redox reactions in the sediment.



Graphic: Hilke Giles

The microbial processes at work in the sediment beneath a fish cage during decomposition of organic material, such as fish faeces. The energy source for microbes in the upper sediment layer is oxygen. Below this upper layer, nitrate, manganese, iron, and sulphate provide the energy. The reduced end-products are mobile in the sediment and can be oxidised by oxygen if they enter the upper sediment layer.

Photos: Kay Vopel

Clockwise from top left:
Four cores in the lab experiment:
S = sediment (no treatment)
SR = resuspended sediment
SF = sediment with faeces
SFR = resuspended sediment with faeces.

A close-up of the layer of fish faeces on one of the sediment cores.

Hilke Giles measures oxygen in the cores during the laboratory experiment. The black instrument is an automated microelectrode porewater analyser.

Simulating kingfish farming in the laboratory

To find out what happens when fish faeces are deposited on sediment, we set up an experiment in the laboratory. We submerged cores of coastal sediment in seawater tanks. To some cores we added faeces from kingfish living in tanks at NIWA's Bream Bay Aquaculture Park, while some sediment cores were left untreated.

In the coastal environments typically used for aquaculture, tidal currents resuspend the sediment surface, lifting the top sediment layer so it mixes with seawater before settling down again when the currents weaken. We also wanted to investigate if this process modifies the effect of fish farming on the sediment. To simulate resuspension, we vigorously stirred the surface sediment of some sediment cores before adding faeces.

Glossary

aerobic – in the presence of oxygen
anaerobic – in the absence of oxygen
biogeochemistry – field of study combining biology, geology, and chemistry
flux – exchange of reaction products between the sediment and the overlying water
oxygen demand – consumption of oxygen during microbial activity
porewater – water between the grains in sediment
redox – short for reduction–oxidation
reduction–oxidation – microbial processes that remove (**reduce**) and add oxygen molecules
resuspension – mixing of the top layer of sediment into the water above

Our results

As we expected, adding fish faeces to the sediment increased the sediment oxygen demand significantly. We found that:

- Oxygen in the sediment decreased more rapidly with depth in the cores where fish faeces were added, due to the high oxygen demand by microbes.
- Oxygen demand was less when sediment was resuspended before fish faeces were added.

Implications for fish farming in New Zealand

Our experiment suggests that fish farms in areas where sediments are periodically resuspended by tides and currents may have less effect on the sedimentary environment than fish farms in calm areas. We'll learn more about these effects with more detailed analyses of our results.

We're on the brink of understanding the connections between fish farming, environmental parameters, and processes in the sediment and seawater, and soon we'll be able to give better advice regarding the ecosystem effects of fish farming. W&A

Further reading

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Dr Hilke Giles is a sediment biogeochemist who works on measuring and modelling aquaculture effects on sediment processes; she is based at NIWA in Hamilton. Dr Kay Vopel, formerly at NIWA, is now a senior lecturer at Auckland University of Technology. Steve Pether is an aquaculture technician at NIWA's Bream Bay Aquaculture Park.