Modelling Aquaculture Impact

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Presentation summary

- Ecosystem assimilation capacity
- Types of modelling
- Mass balance modelling
  - Case study – Bolinao, Philippines
- Depositional modelling
  - Case study – Panabo, Philippines
- Use of modelling for optimisation of aquaculture production
Modelling aquaculture impacts

• As part of the EIA before aquaculture is established in a certain area, the potential impact on the environment should be assessed.

• One of the only ways of doing this is to use models together with other data collected from the area.

• Once aquaculture has been established, monitoring may show whether or not the actual impact are
  • within the acceptable limits or not
  • Stable
  • increasing with time (accumulating)
Aquaculture impacts

Impacts from
- Dissolved nutrients
- Particulate nutrients

- Ecosystem capacity to assimilate the excess nutrients
Ecosystem assimilative capacity

• The Ecosystem assimilative capacity its ability of the ecosystem to deal with inputs of waste wherever they arise.

• **Aquaculture** - cage fish farming waste components are nutrients, particulates and associated potential biochemical oxygen demand (BOD) resulting from the metabolism of fish food

• **Other sectors** - it is important to take into account waste such as sewage discharges and agriculture run off, livestock production and forestry.
Ecosystem assimilative capacity

- Nutrient output by aquaculture depends on
  - Aquaculture system (pond, cage, raft, pen)
  - Level of intensification
- The Environmental capacity of a particular area depends on
  - Water currents or water exchange
  - Assimilative capacity of the water body or ecosystem (upland, estuary, near-shore)
Types of model

- **Mass balance** – models the impact of dissolved nutrients on water quality

- **Depositional** - models the impact of particulate nutrients on sediment quality

- **Dynamic** – model change in the environment over time
**Types of model – Mass balance**

**Mass balance equation models** - can be used for many different parameters but is most widely used in a water quality to model nitrogen and phosphorus concentrations in and from aquaculture systems.

Fish pond

Fish cage
Aquaculture nutrient balance

Simplified fish farm

Feed (C, N & P) → Fish (C, N & P)

Dissolved C
Dissolved N
Dissolved P

Particulate C
Particulate N
Particulate P

Water flow
Inputs, uptake and outputs

Less than 30% of the nutrient inputs are retained by the fish.

The remainder go into the environment where they are assimilated or concentrated.
Nutrient budget and fate - Phosphorous

Fish food 94-97 %

Harvest 17-19 %

Juveniles 3-6 %

Loss of fish 1 - 4 %

External food

Sedimentation 50-57 %

Solute release 25-30 %

benthic flux 2-4 %

Sediment accumulation 47-54 %
Impact on the sediments

Nutrient levels in the sediment

- **Sustainable levels**
  - slight build up of organic layer on the seabed
  - Organic layer not increasing over time
- **Unsustainable level**
  - Build up of thick organic layer
  - Change in benthic diversity
  - Smothering of seagrass
  - Smothering of corals
Phosphorus plume from fish cages
Nutrient impact on water column

Nutrient concentration in the water

- **Sustainable levels**
  - Stable dissolved nutrient levels that do not breach water quality standards
  - Slightly increased algae production and zooplankton production
  - Increased wild fishery production

- **Unsustainable levels**
  - leads to high algae production
  - Eutrophication
  - algal bloom – algae die off – low/no oxygen – fish kill
Norad funded EMMA project 3 case study areas
Bolinao and Anda
Bolinao Bay 2006

Fish cages   460
Fish pens    266
Oyster farms 254
23,000 tonne/yr
8.1 t/ha fish
0.6 t/ha mollusc
220 tonnes feed/day
Reoccurring fish Kills in Bolinao

Fish kill
Fish kill
Fish kill
Fish kill
Fish kill
Fish kill

Boom  Bust  Boom  Bust  Bust  Bust  Fish kill  Boom?


a Verceles et al., 2000, b FRMP,2001; c Sagip, 2005; d LGCAMC, e PDI,2002; f OPAG
Estimating maximum aquaculture carrying capacity for Bolinao Bay

The process of determining carrying capacity for fish aquaculture based on determining the critical phytoplankton concentration

- Natural nutrient input
- Aquaculture nutrient input
- Water body characteristics, water volume, and water exchange
- Natural equilibrium
- Phytoplankton growth
- Phytoplankton concentration
- Carrying capacity
Estimation of all nutrient sources
(cages + pens + river + domestic + agricultural) – (mollusc + flushing)
Types of model - Depositional

- **Depositional models (particle tracking)** predict the particulate outputs from fish cage aquaculture (quantity and location) and can be used in predicting the organic footprint and impact on the sediment and sensitive demersal flora and flora.
- They use particle tracking models that use hydrodynamic data (current speed, direction and dispersion) to predict organic flux from cage culture to the seabed.
- They can be used to predict sustainable aquaculture yields, local impacts of fish farming, and water quality.
This family of models is used by regulators for licensing of aquaculture ventures

- **Depomod** – North Atlantic (mainly salmon farms in Scotland)
- **Meramod** – Mediterranean (mainly seabass and seabream in Greece and Turkey)
- **Tropomod** – Tropical
  - Milkfish and grouper in marine waters
  - Tilapia in freshwater
TROPOMOD

- Tropomod a conversion of Depomod and Meramod from cold and temperate areas to tropical conditions

There are three main modules:
  - particle tracking,
  - resuspension
  - benthic response.
- Predictions of solids accumulation (grams/m²/yr)
- It also takes into account the different species and behaviour of faecal pellets in the water column.
- It is validated for marine and freshwater cage farms in the Philippines
Current profiles in stratified waters are complex. Particles settling at different rates are subject to current shear and turbulence.
Output - advice to regulators and producers on cage spacing, feeding strategy, etc.

Contour map of waste flux grams solids m\(^{-2}\) bed day\(^{-1}\)

- **Benthic community**
  - 75 Heavily impacted (no animals)
  - 14 Intermediate (some effect)
  - 1 Limit of benthic impact

Example: Is the effected area contained within the “allowable zone of effect”
Typical impact footprints

**Dispersive sites**
- Strong currents
- Impact over a larger area (up to 100 m) but less intense
- Typical of fish farms in Scotland

**Depositional sites**
- Weaker currents
- Impact over a limited area (up to 30 m)
- But more intense
- Typical of farms in Greece
Use to minimise impact

Closely spaced cages  Largely spaced

a. tightly clustered (square)  

b. largely spaced out (circular) 

Solids flux (g m\(^{-2}\) yr\(^{-1}\))
Optimising production – Panabo MP
Panabo AquaPark – Existing and reorganised

b) 3 zones of 6 ha each inshore
2 zones offshore larger cages (polar circles)
9 Inshore Grouper zones

Spacing between zones results in less impact and also more space for IMTA units
Panabo AquaPark – Existing and offshore zones added

Good feeding scenario improves inshore areas

Offshore Milkfish zones in deeper areas results in good dispersion