Interaction between natural benthic communities and cultivated blue mussels in Belfast Lough: Role in top-down control of eutrophication

Heather Moore, Adele Boyd, M. Service, Richard Corner, J.G. Ferreira
What is shellfish aquaculture?
Where is shellfish aquaculture?
Carrying capacity - a multidimensional problem

Four pillars for sustainable aquaculture.
Background Information

- Sustainable Mariculture in northern Irish Lough ecosystems (SMILE) model: integrated framework for the determination of sustainable carrying capacity in shellfish production areas.

- Model combines field data, experimental results and various types of models, ranging from individual shellfish growth models to broad-scale ecosystem models.

- The model captures the essential information at each simulation scale, allowing decadal runs that provide results on cultivation of commercial species, nutrient and chlorophyll cycling.

- The modelling framework facilitates integrated analyses of animal-environment interrelations affecting overall production at system-scales, according to different temporal and spatial scenarios and accounting for conservation aspects such as the presence of wild species.
Study Objectives

- Apply an ecosystem-based approach to the management of shellfish culture (TEASMILE) in Belfast Lough through the extension of the ecological model built for the SMILE project

- This was achieved by developing the wild species (natural benthic filter-feeder) component of the model

  1. Interaction between natural benthic communities and cultivated shellfish (blue mussel, *Mytilus edulis*)

  2. Effects of the above components on primary production and phytoplankton biomass, particularly with respect to top-down control of eutrophication
Legislative context

• Water Framework Directive (2000/60/EC) mandates that the biological quality element (BQE) phytoplankton abundance, biomass, and composition (ABC) must be at Good or High Status. Shellfish aquaculture can assist in organic extraction for top-down control of eutrophication.


• The management decisions needed for both the WFD and MSFD are very complex. Results from models applied in TEASMILE support decision-makers for both directives.
Case study: Belfast Lough

- Shallow semi-enclosed marine bay on the eastern coast of Northern Ireland
- 130 km$^2$ bay, catchment of 900 km$^2$
- Inner Lough: mudflats and lagoons. Outer Lough: mainly rocky shores with some small sandy bays
- 19$^{th}$ century: lough changed from a productive shellfishery to an industrialized port
- 70% of population of Northern Ireland lives in the catchment (nutrient input)
- Natura 2000 designated sites, Ramsar Site and ASSI
- Over 20 years of bottom culture mussel industry ($M.\ edulis$)
Case study: Aquaculture

- There are currently 21 licensed subtidal aquaculture sites for the culture of blue mussels (*Mytilus edulis*) within Belfast Lough.

- The total area of Belfast Lough occupied by aquaculture is approximately 1,270 hectares.

- Cultivation began in 1989. Belfast Lough is the largest production area for bottom grown mussels in NI. 50-75% of total NI mussel production.

- In Northern Ireland aquaculture is now worth over £6 million annually.
Model framework

Data analysis
- BarcaWin2000 database
- GIS

Individual growth models
- Drivers

System scale ecological model
- Drivers

Local scale models FARM
- Individual models

Hydrological model
- Nutrient transport

Hydrodynamic model
- Fluxes, Boundary conditions

System-scale for budgets, farm-scale for direct recycling
Belfast Lough - hydrodynamics

Delft3D Hydrodynamic model

EcoWin2000 ecological model

- 480 boxes, 8 s layers
- 42 boxes, 2 σ layers

How did we use this? - study objectives
Why?

• SMILE evolved to adopt a more detailed ecosystem based approach by extending the ecological model as demonstrated here with TEASMILE - greater emphasis on ecosystem health

• Ensure model representative of natural ecosystem - populate model with real data for habitat and species - hence developing the wild species (natural benthic filter-feeder) component of the model
Interaction between natural benthic communities and cultivated shellfish

- EcoWin was expanded to include a detailed simulation of the benthic wild species:
  - 1. non-commercial benthic filter-feeders, species clustered as per associated habitat types
  - 2. commercially valuable natural (wild) species (intertidal mussels and cockles)

- Impacts of filter-feeders on primary production and phytoplankton biomass, with respect to top-down control of eutrophication.

- Support decision-making in context of WFD
EcoWin.Net model - TEASMILE approach for wild species

- Collate benthic grab data by species and abundance, analyse by means of clustering software;
- Select most representative species with respect to mean abundance. Around ten species will be chosen for each sediment category;
- Determine typical filtration rates for selected species, using literature data;
- Identify areas for the selected sediment types in each EcoWin box using GIS;
- Correct for unclassified areas per EcoWin box;
- Recode EcoWin to accept detailed data for wild species and simulate filtration and food removal;
- Add wild species data to EcoWin;
- Recalibrate and validate model;
- Explore development scenarios.
Effects on primary production and phytoplankton biomass

- **Run 1:** There was no aquaculture within the Lough (only natural wild species present). Used as Baseline.

- **Run 2:** All currently licensed aquaculture sites were activated at a rate of seeding (in terms of tonnage/ha) determined using the three year mean from observed data (2010-2012, DARD) plus baseline.

- Chlorophyll a (Chl a) was used as a proxy for phytoplankton biomass.

- Model boxes based on areas which have similar topography, biogeochemistry and using the Water framework Directive boxes as guidelines.
Effects on primary production and phytoplankton biomass

- Measured Chl a data in the lough shows an annual variation of up to a 41% recorded between sampling years.
- As a precaution a minimum of 50%, of baseline values of Chl a should remain for wild species.
- Hence aquaculture activities should not reduce Chl a concentrations by greater than 50% of baseline values.
- Table shows the % reduction in Chl a between the two model runs.
Effects on primary production and phytoplankton biomass

- Water Framework Directive (WFD), Coastal water body classification - percentile 90 Chl a in µg L⁻¹ states; < 5µg L⁻¹ = high status 5 - 10µg L⁻¹ = good status.

Mussel feeding provides a valuable ecosystem service, reducing Chl a levels and suppressing eutrophication during summer months.
Conclusions

• Natural Benthic Communities exert top-down control
  - Variability due to habitat type and the abundance and diversity of wild species

• Aquaculture species exert top-down control in each of the lower model boxes
  - Variability is due to different intensity of aquaculture in each box

• An example is shown in Box 39 where aquaculture reduces the Chl-a concentrations to below the 5µg L⁻¹ Chl-a WFD “high” threshold

• Shellfish aquaculture within Belfast Lough provides an ecosystem service while simultaneously contributing to local employment and food security.
Thank you