Application of a Multi-Model Framework for Integrated Ecosystem Management in Lough Foyle

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http://fojo.org/

Application of a Multi-Model Framework EASE - Enhanced SMILE for Lough Foyle

- The EASE project and modelling framework
- Terrestrial loading and modelling
- Hydrodynamic modelling and upscaling
- Ecosystem modelling for carrying capacity
- Role of shellfish in eutrophication control
- Synthesis

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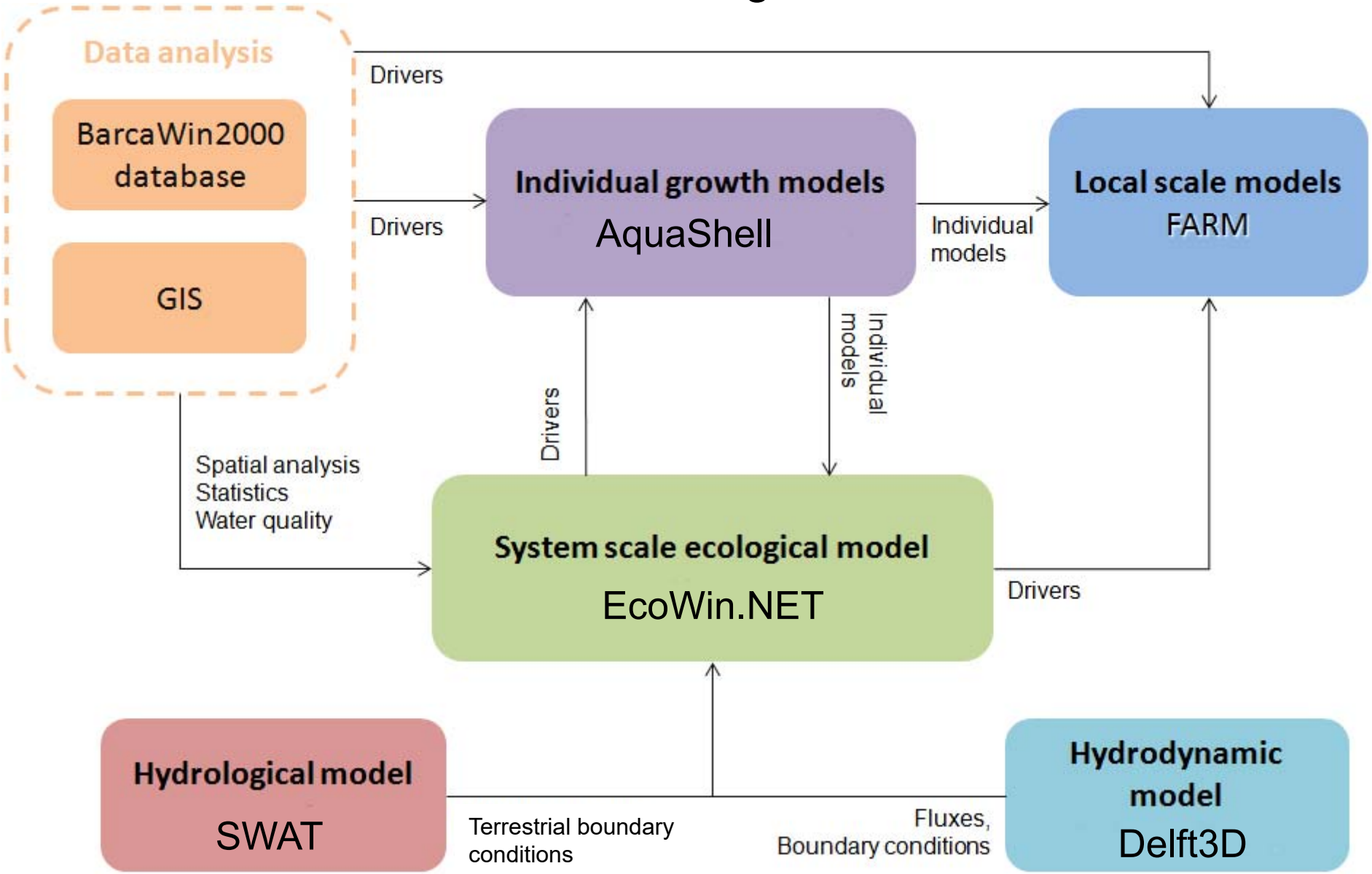
General modelling framework



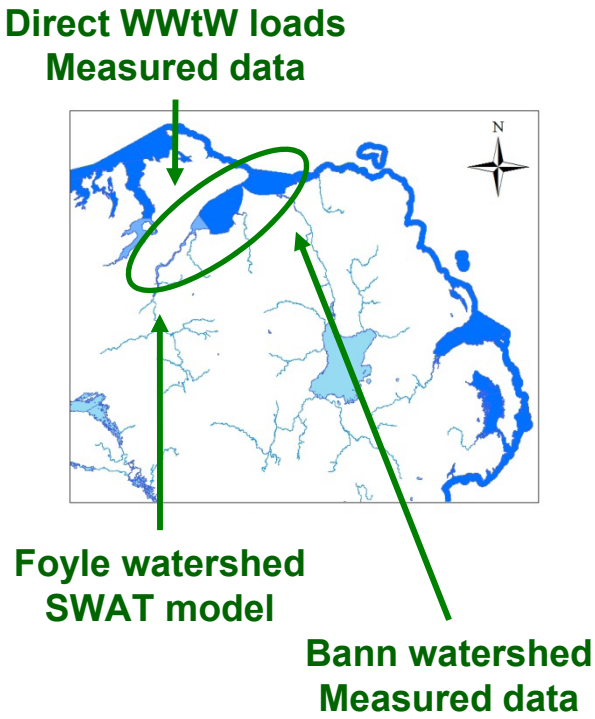
System-scale for budgets, farm-scale for direct recycling.

SWAT application for the Foyle catchment
General objectives

1. Estimate the **terrestrial loads** to Lough Foyle
   - Loads: water, sediment, dissolved N and P, particulate organic matter (POM)
   - Sources: WWtWs, agriculture
   - Reference year: 2014
   - Time-step: daily

2. Build a modelling tool capable of **apportioning sources** and **assessing scenarios**
   - The SWAT eco-hydrological model was applied and calibrated for the Foyle watershed

Methodology



Integration of catchment modelling is critical to deal with European directives such as the Water Framework Directive.

Direct input points (WWtW, Bann) and SWAT simulation area

29 watersheds

330 HRUs

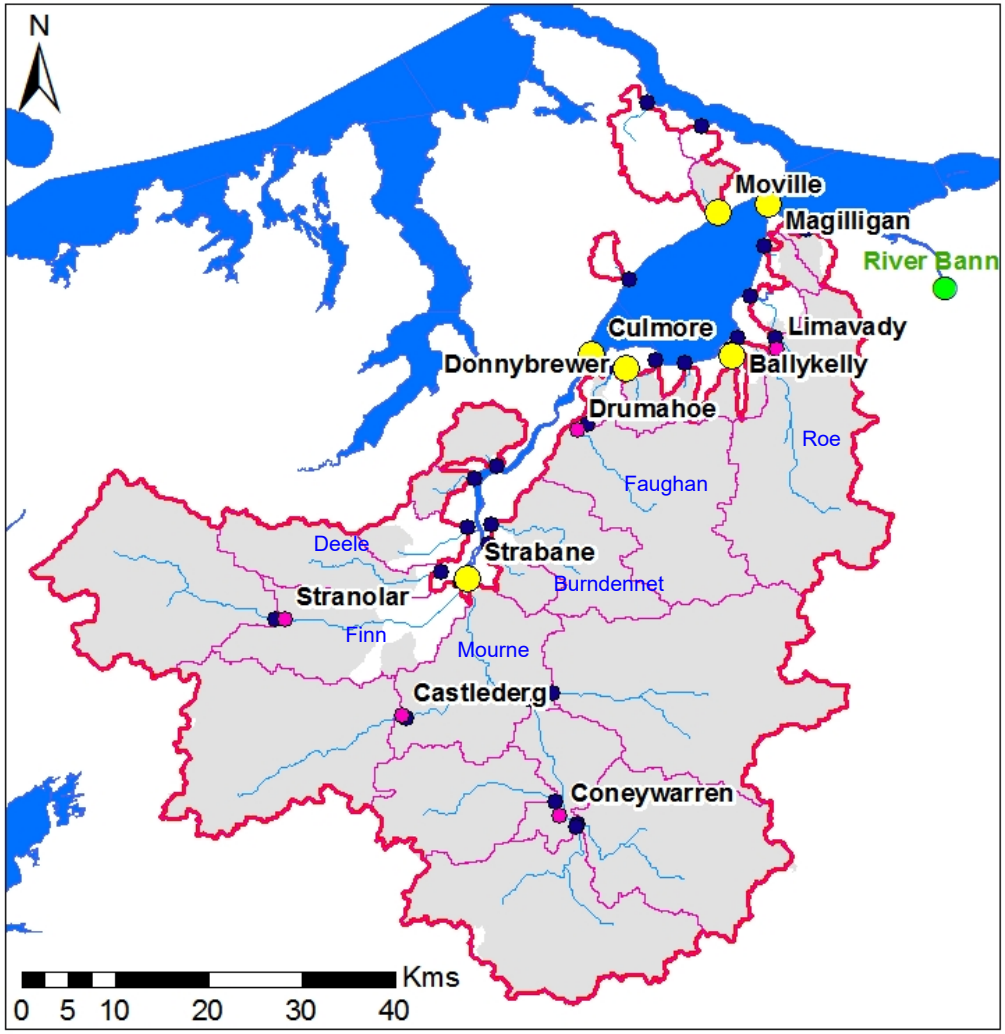
Hydrological Response Units

11 WWtW

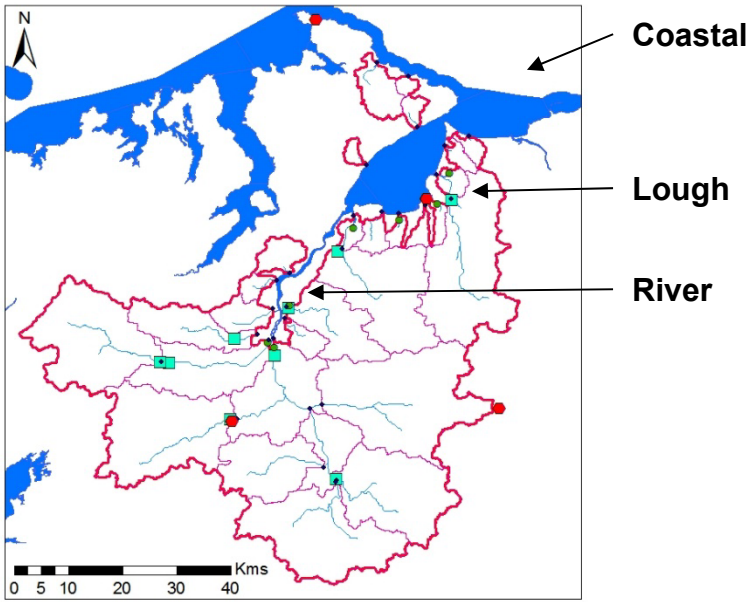
Waste Water treatment Works

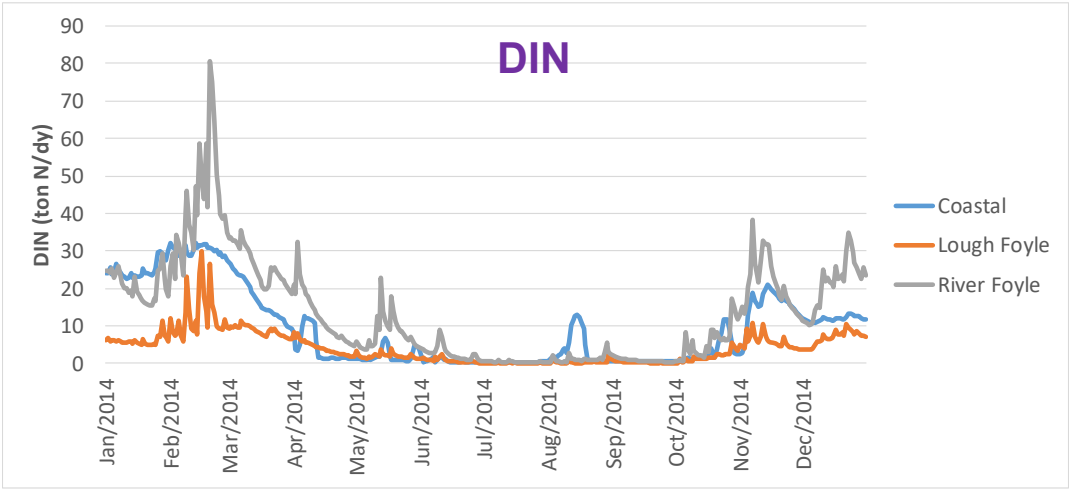
Measured loads

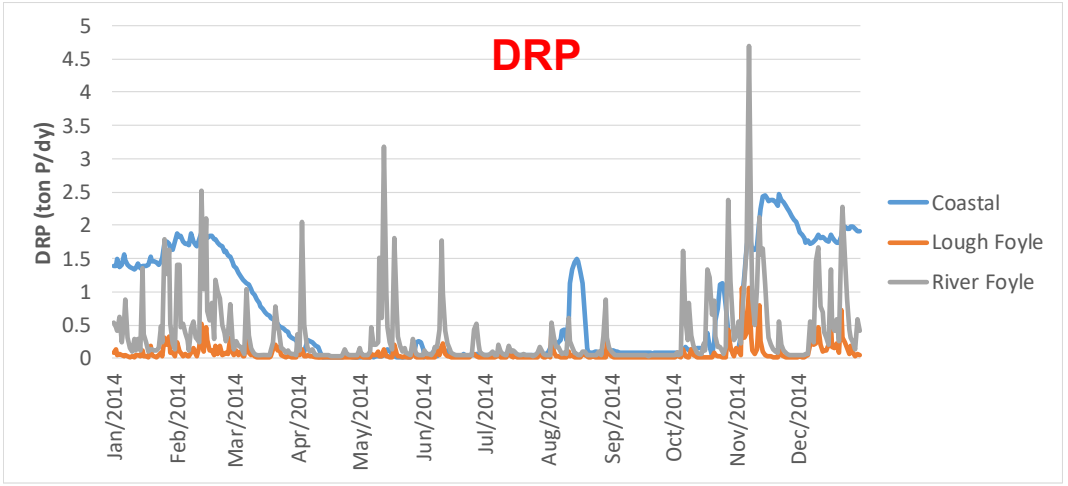
Moville: untreated



SWAT outputs
Nutrient loads in time: 2014



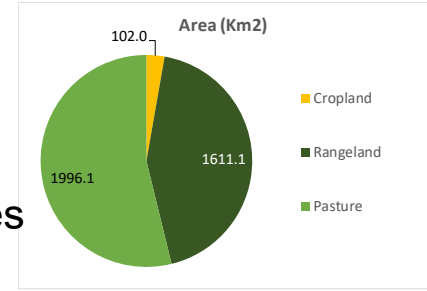


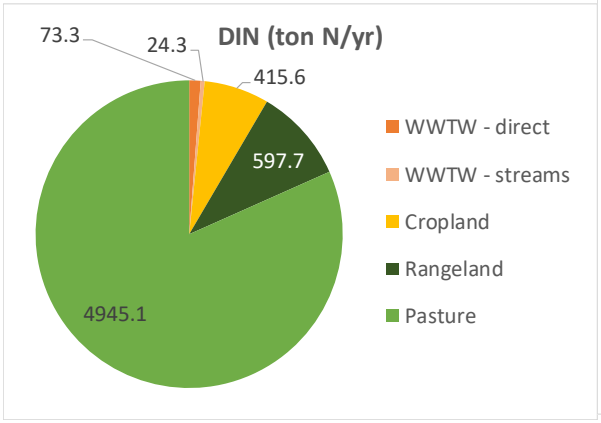


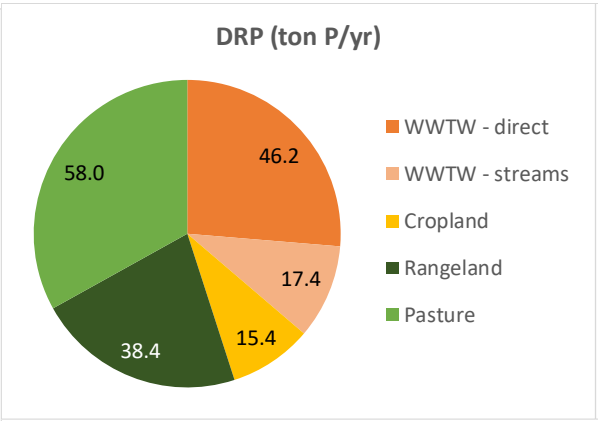
Daily loads are used to drive the nutrient input for the carrying capacity model, with simulated inputs to appropriate model boxes.

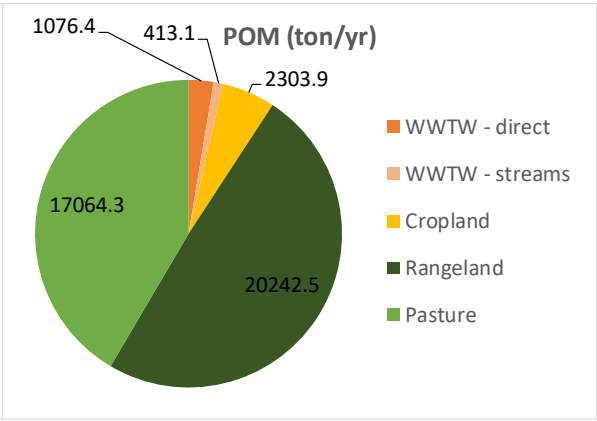
SWAT - source apportionment (Foyle only)

- Main DIN source: diffuse pasture – follows fertilizer application
- DRP sources: point-source & diffuse
  - Diffuse: low erosion rates leads to exports at “background” values
- DIN & DRP results broadly agree with Foy and Girvan, 2004
- POM sources: diffuse – follows landuse
  - Diffuse: low erosion rates leads to exports at “background” values
  - Point source: negligible exports due to WW treatment







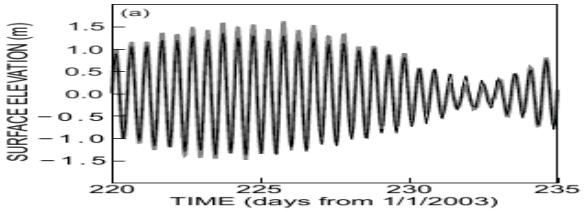


Without source apportionment, management is a black art. Source control in systems such as Lough Foyle is complex, costly, and socially challenging.

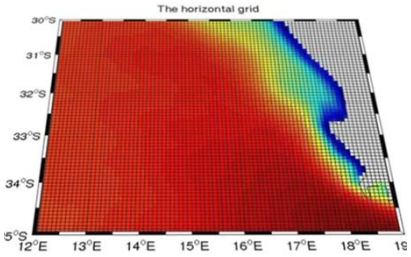
Hydrodynamic modelling for detailed circulation patterns

Delft3D - Flow

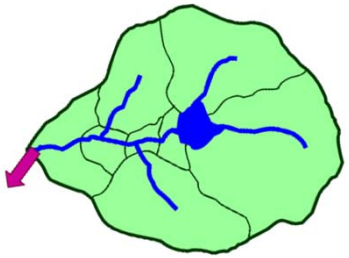
Atmospheric forcing



Tide



Flow

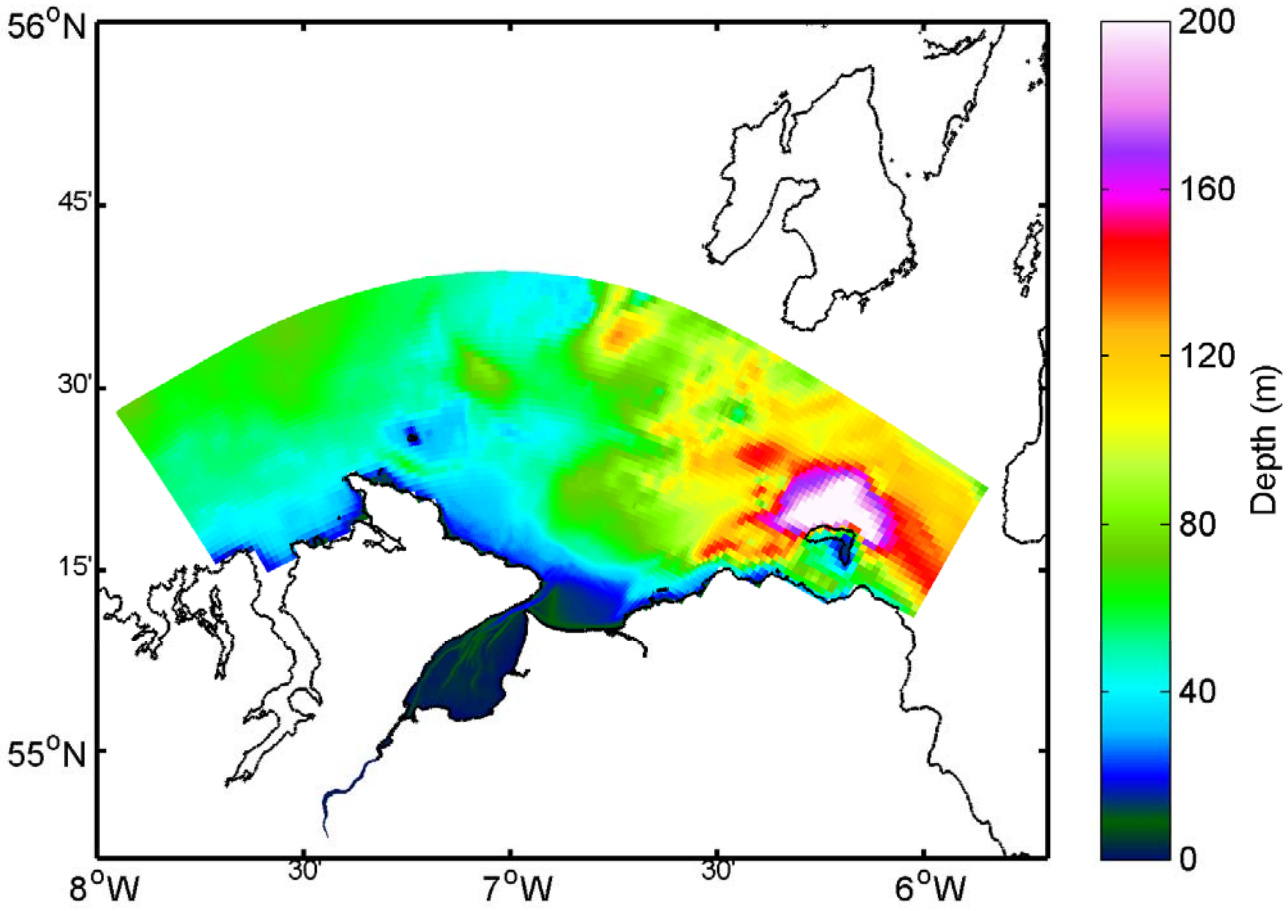


River flow

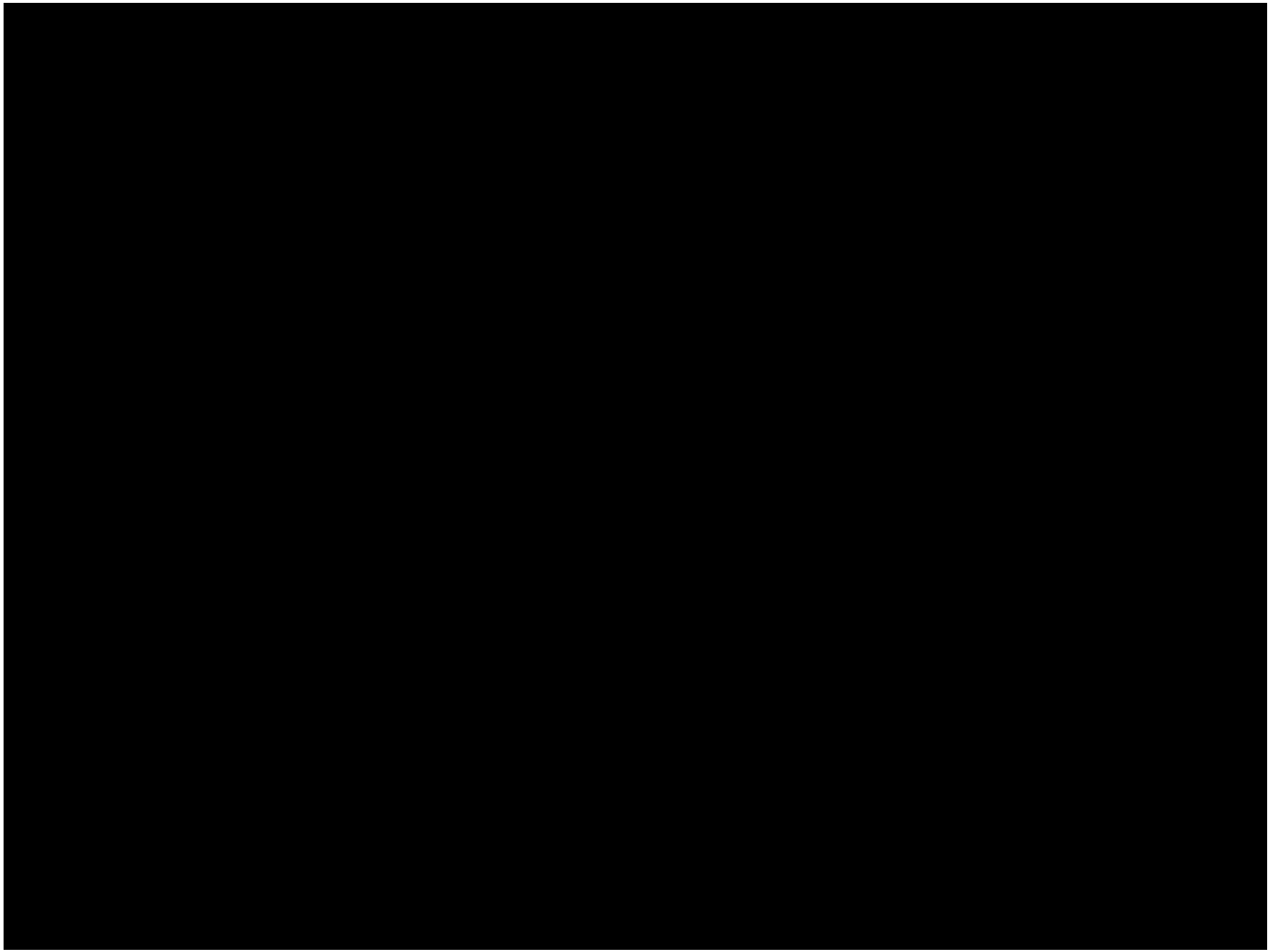
Water Quality / Ecological Modelling

Free and open source, tidal response, drying and flooding, evaporative processes, inner shelf circulation, shelf stratification.

Components of the model: Bathymetry

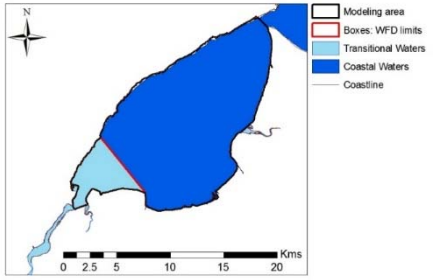


Some Like It Hot!

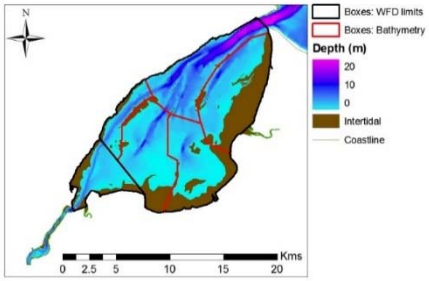


EcoWin model boxes

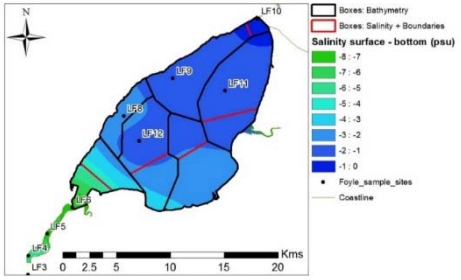
Division of Lough Foyle into simulation areas



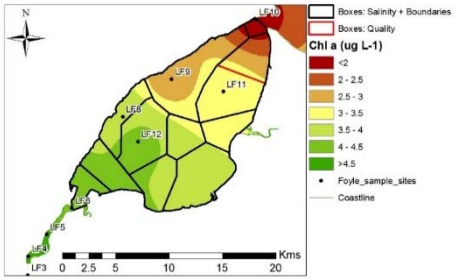
1. WFD water bodies



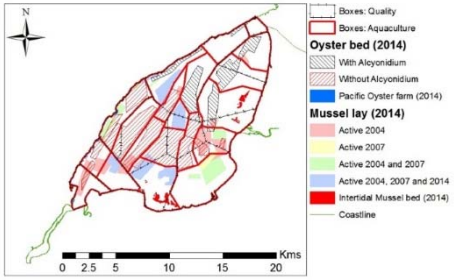
2. physical: bathymetry



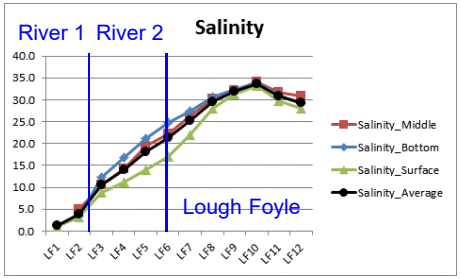
3. physical: salinity



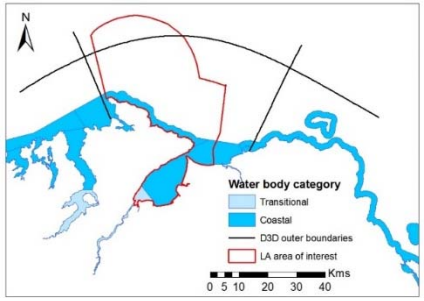
4. water quality



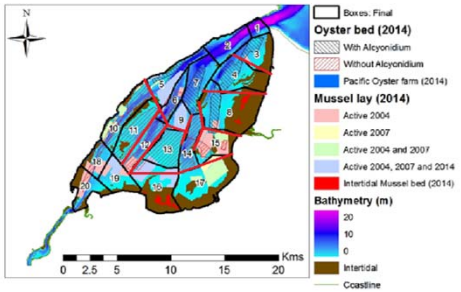
5. aquaculture



6. Foyle river: salinity gradient



7. Coastal areas: WFD water bodies + LA area

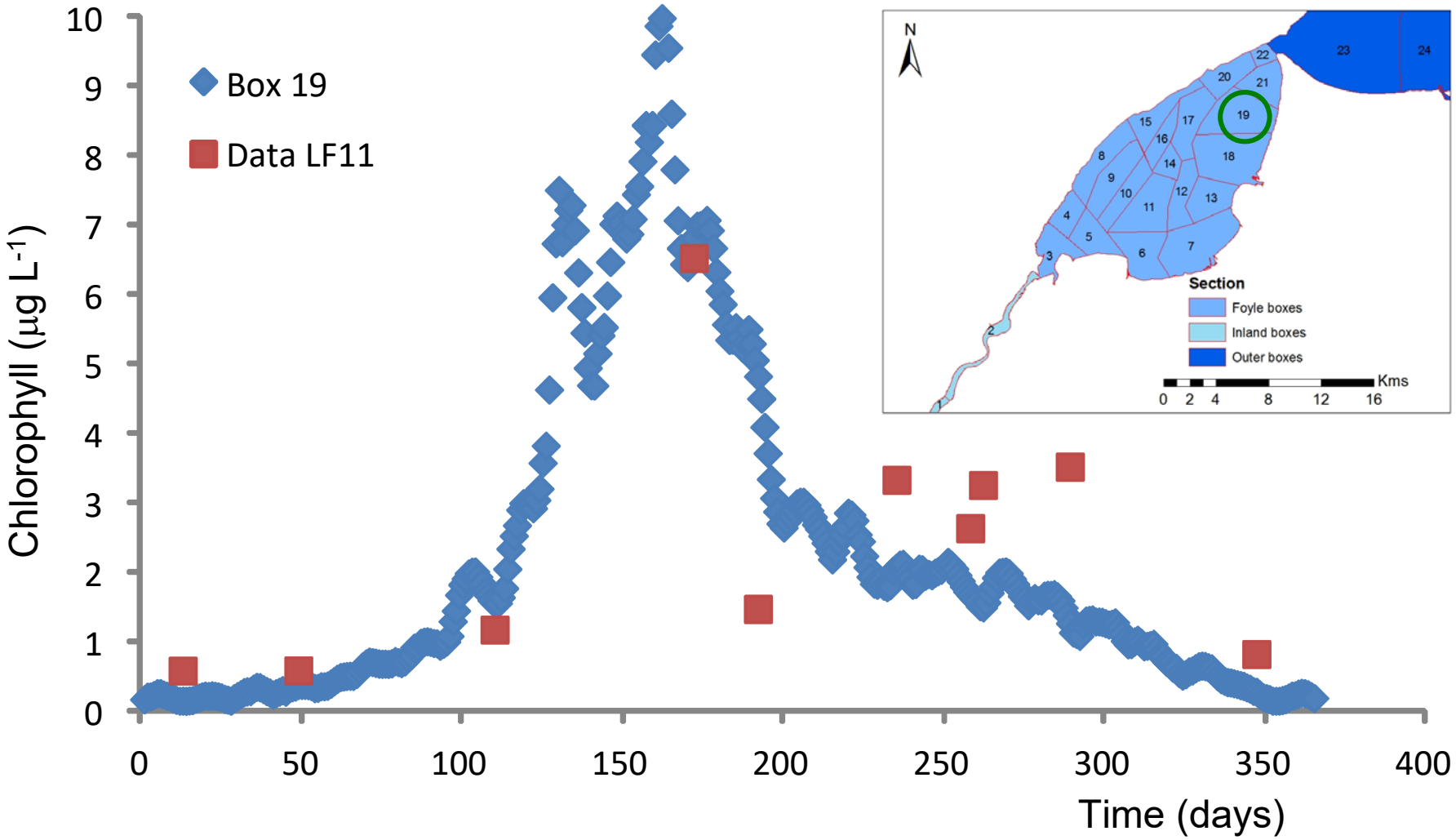


8. expert review (Loughs Agency)

Before a model is deployed in EcoWin, multicriteria analysis and stakeholder consultation is used to define simulation areas.

EcoWin.NET model - EASE

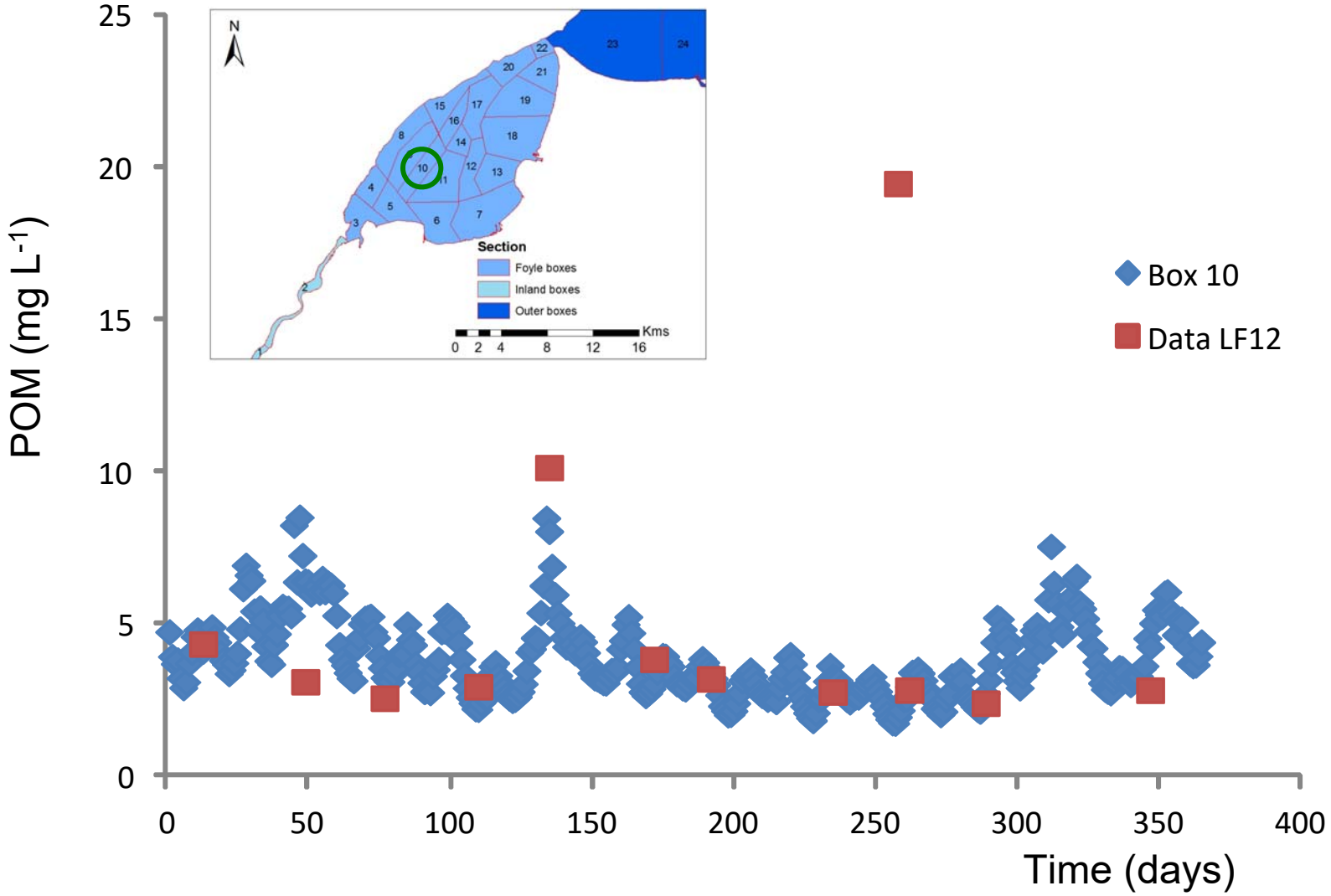
Water quality validation – chlorophyll (Model Year 2)



EcoWin appears to reproduce the range and general pattern of chlorophyll variation.

EcoWin.NET model - EASE

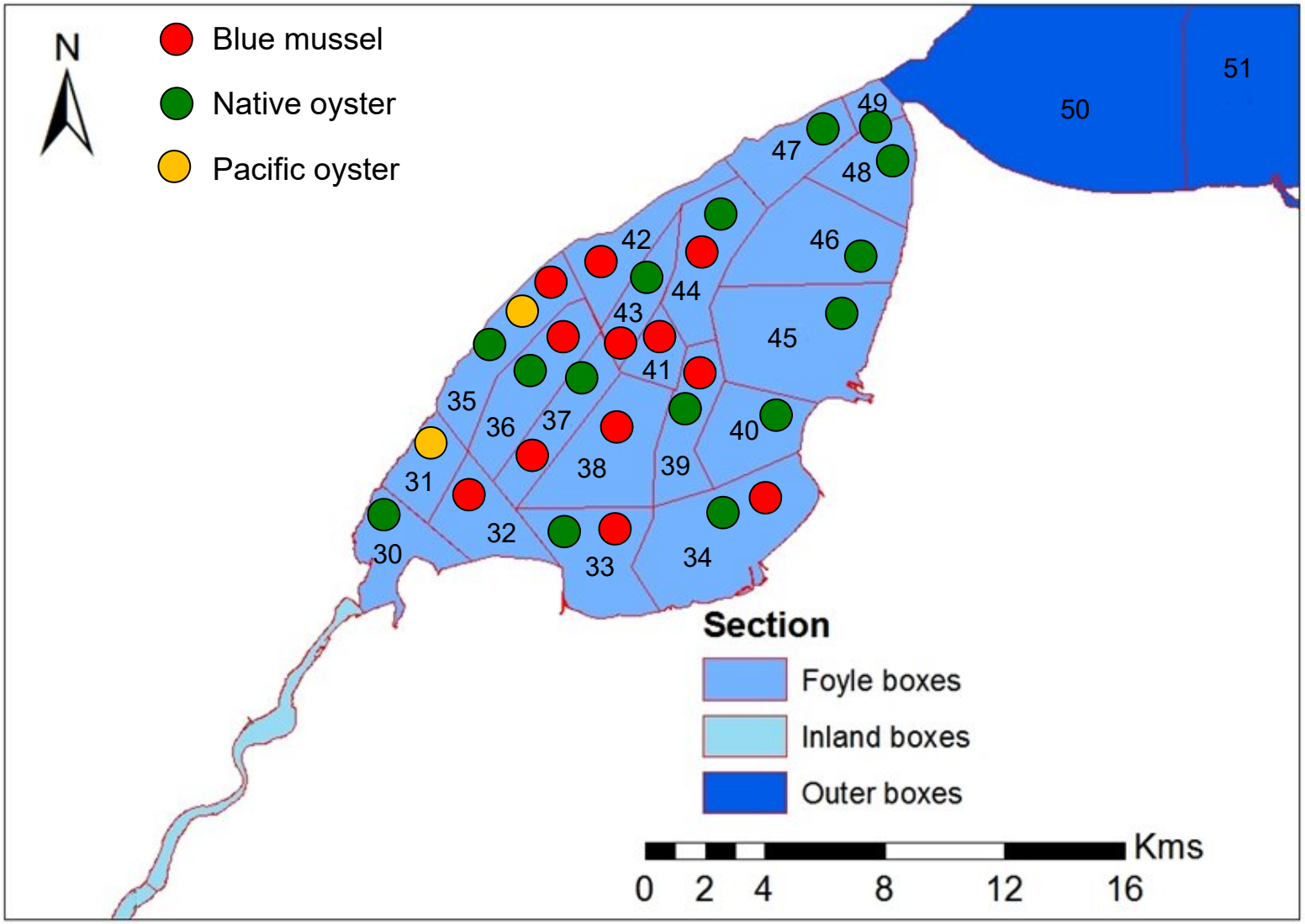
Water quality validation – POM (Model Year 2)



Model calibration focused on optimising shellfish growth drivers, with an emphasis on salinity, temperature, chlorophyll, and POM.

EcoWin.NET

Lower boxes are assigned for shellfish culture



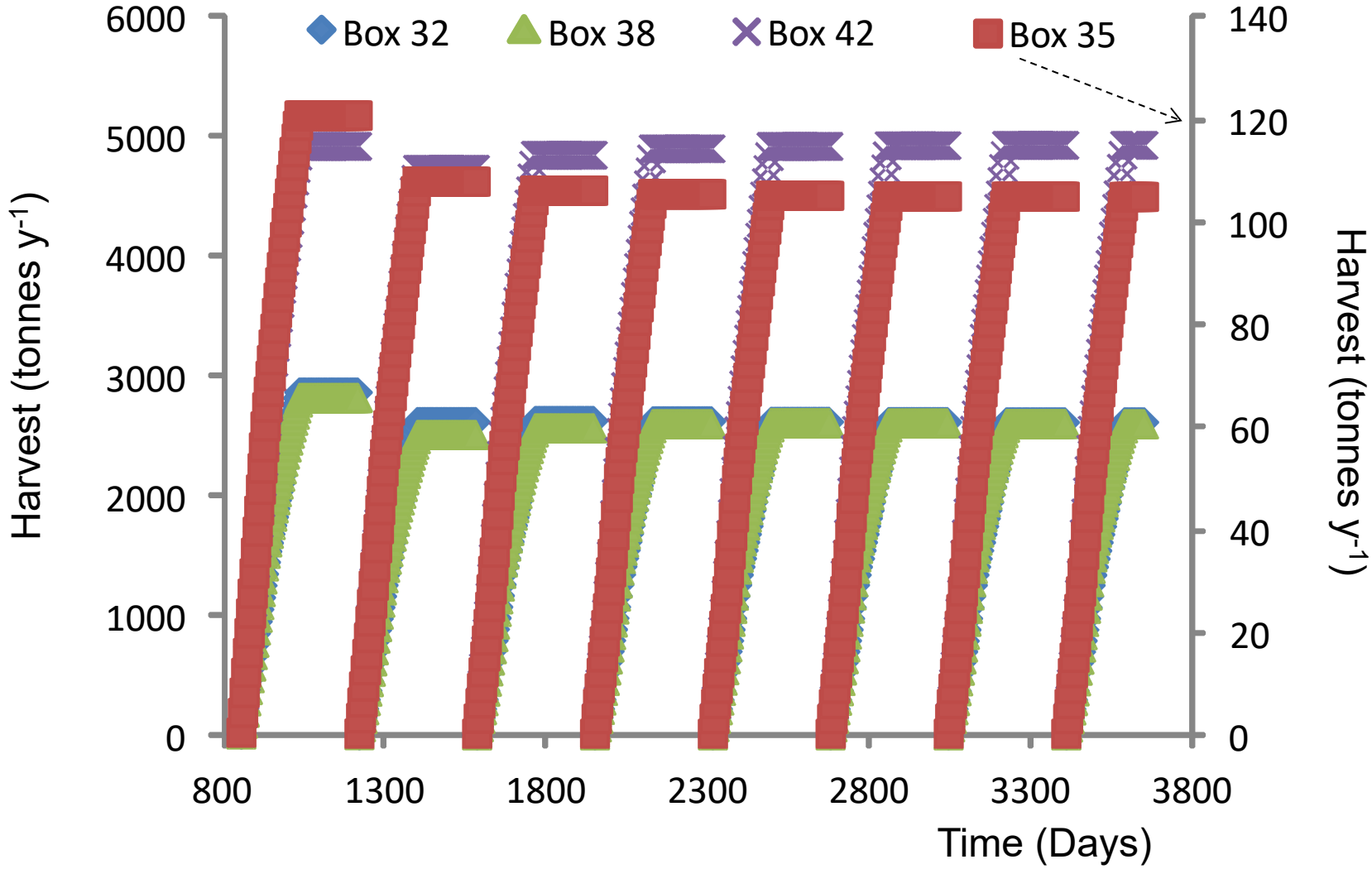
Yields vary substantially among boxes. The following slides show outputs for each species, with all objects active.

EcoWin.NET shellfish model
Harvest yields for Year 9 (tonnes)

Box	Blue mussel	Native oyster	Pacific oyster
30	-	1.87	-
31	-	3.96	1009.53
32	2742.90	2.50	-
33	101.29	-	-
34	99.72	1.52	-
35	108.93	13.31	936.42
36	291.73	14.28	-
37	58.83	4.97	-
38	2777.59	-	-
39	97.06	6.78	-
40	-	4.24	-
41	3003.21	-	-
42	5053.06	0.22	-
43	1364.02	0.62	-
44	160.54	0.10	-
45	-	0.36	-
46	-	0.95	-
48	-	0.03	-
49	-	-	-
Total	15859	56	1946

Production of native oysters in some boxes (e.g. 32, 42, 43) is strongly limited by blue mussel culture. Wild species are also important.

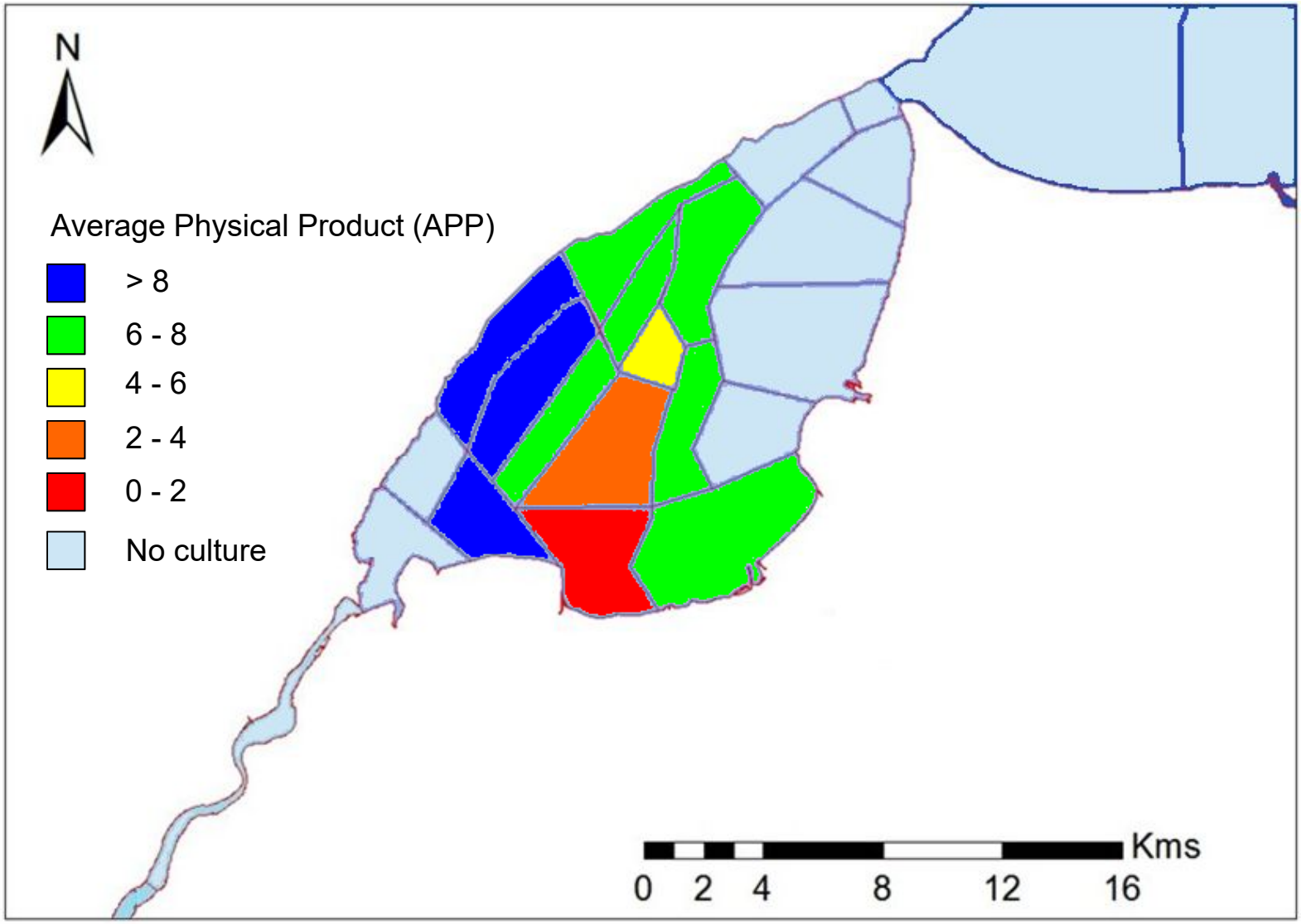
EcoWin.NET Lough Foyle Model
Blue mussel harvest over time – standard model



Blue mussel spin-up is very fast and harvest stabilizes.

EcoWin.NET

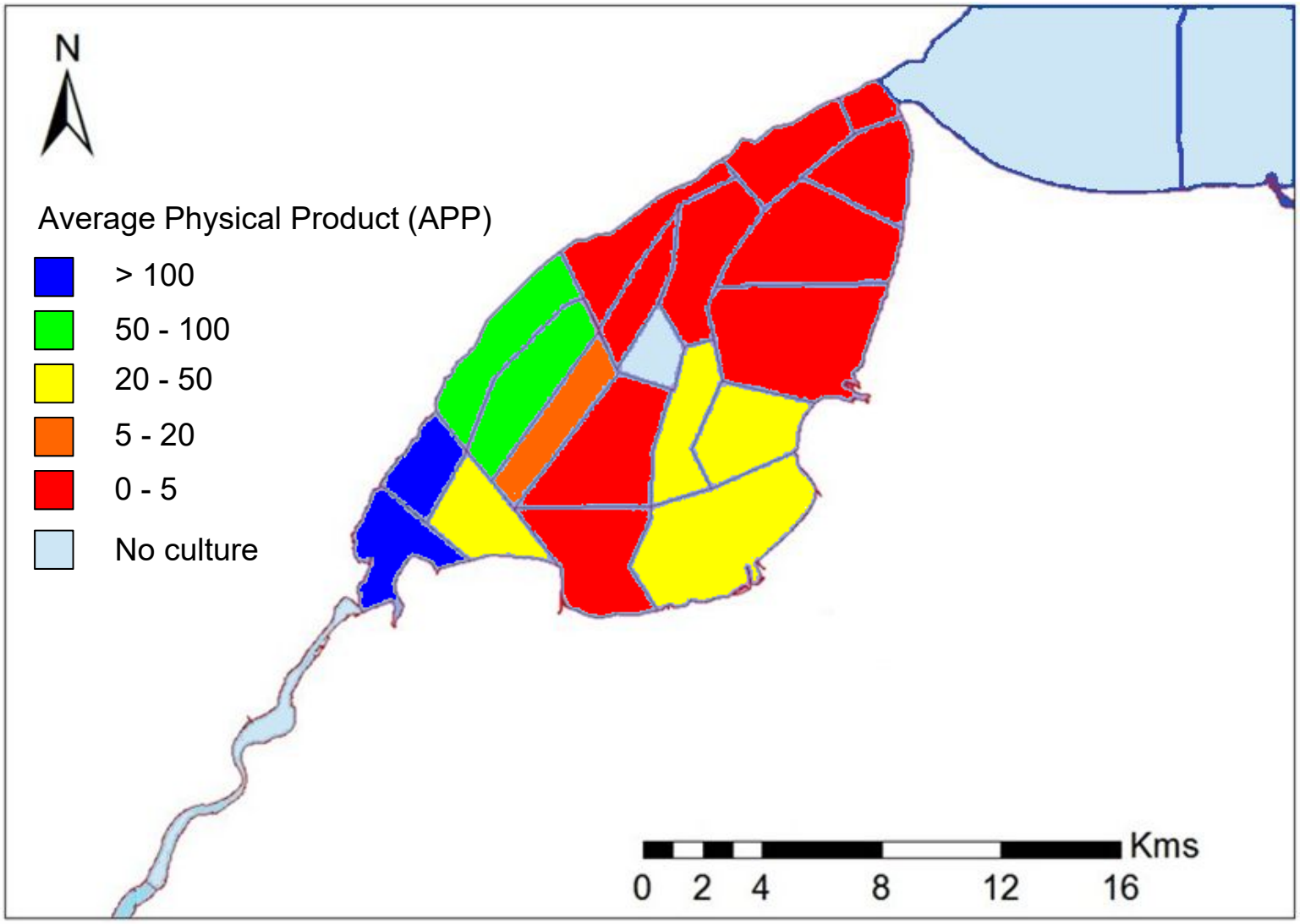
Blue mussel Average Physical Product (APP)



Yields vary substantially among boxes, with best performance in the northern and middle upstream sections of Lough Foyle.

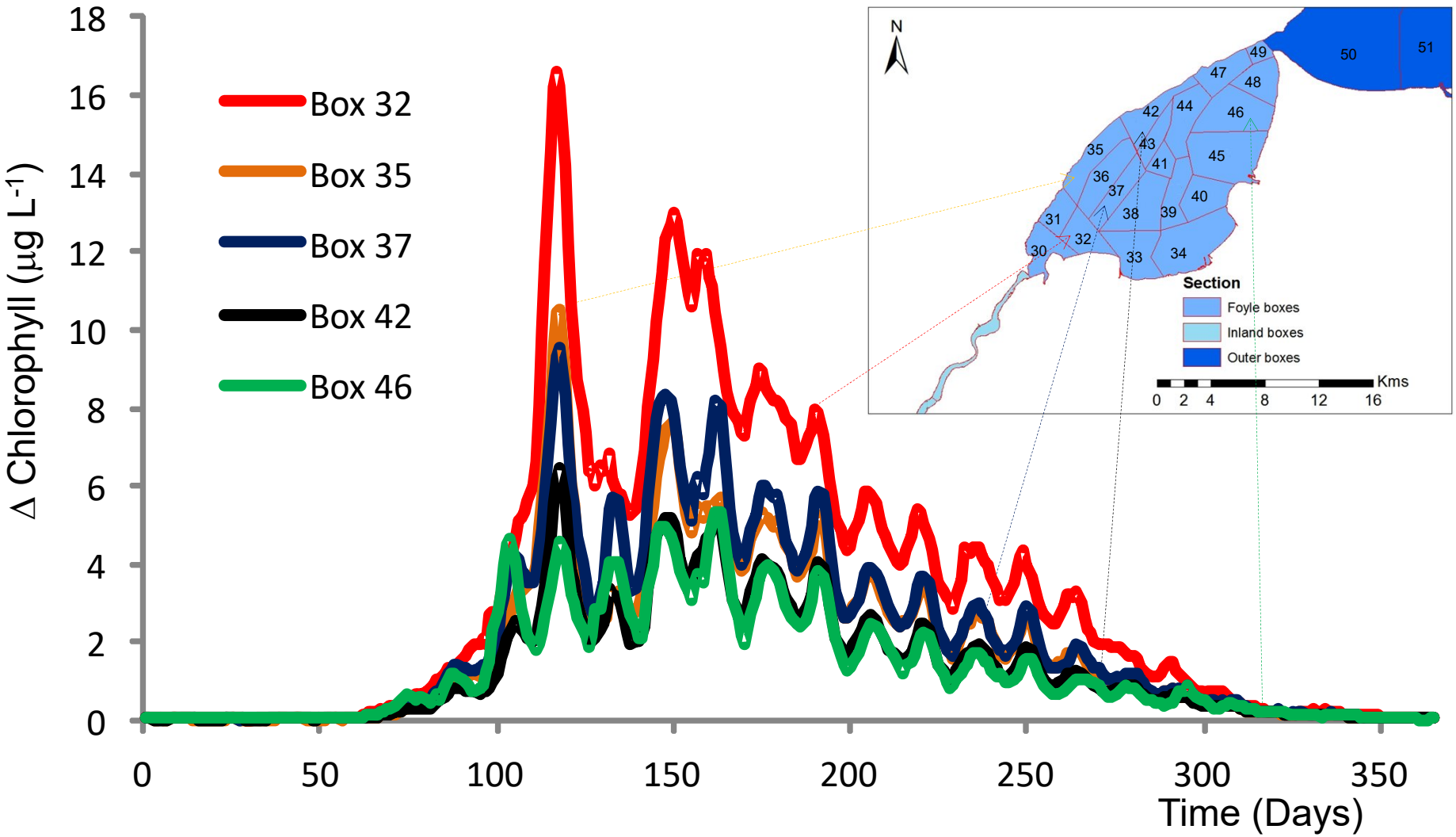
EcoWin.NET

Native oyster Average Physical Product (APP)



Yields vary substantially among boxes, with best performance in the upstream area of Lough Foyle.

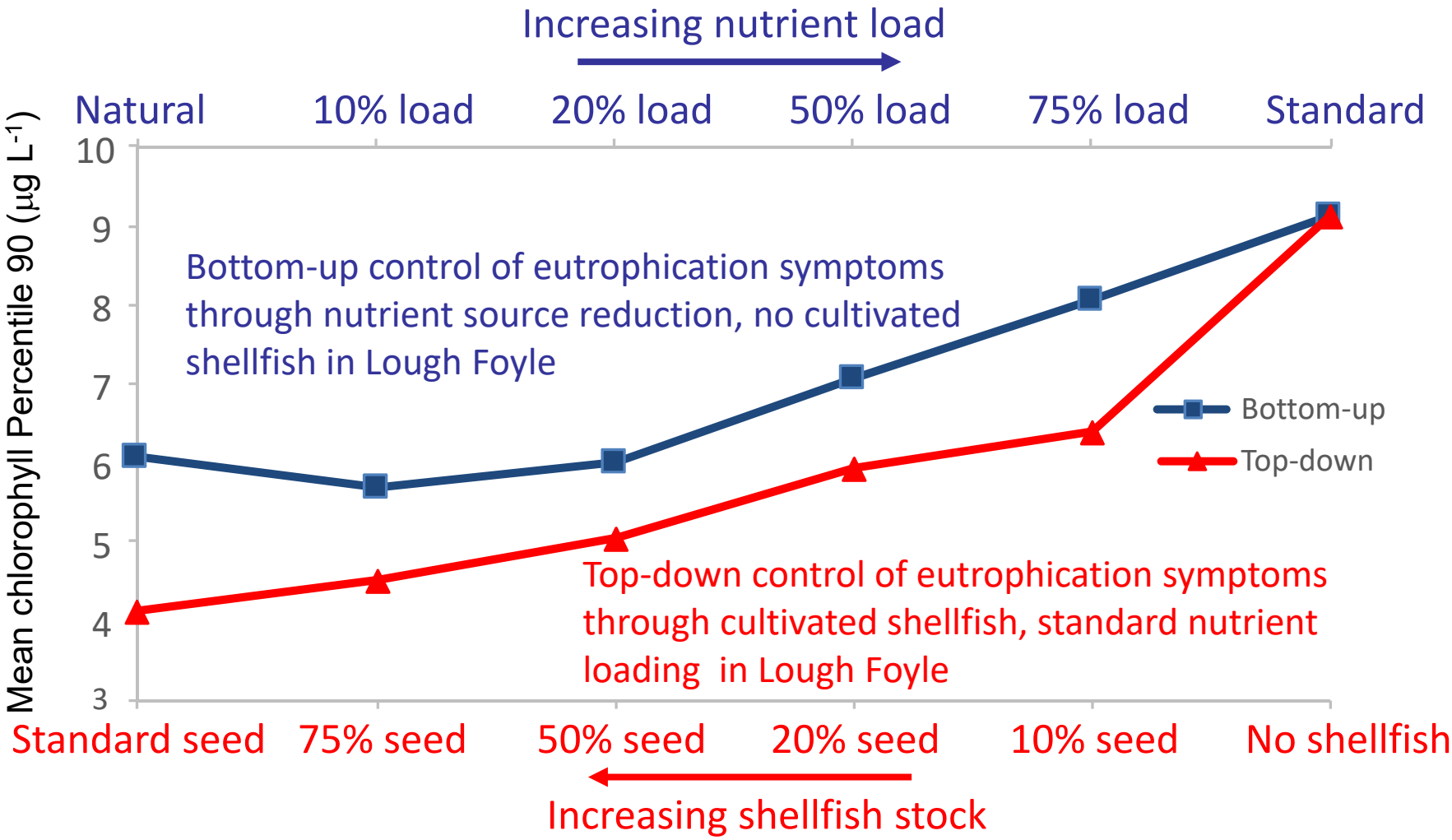
EcoWin.NET Lough Foyle Model
Phytoplankton drawdown – standard model, Year 9



The strongest drawdown is in the central and upper parts of the lough, where both native oyster (*O. edulis*) and blue mussel (*M. edulis*) are grown.

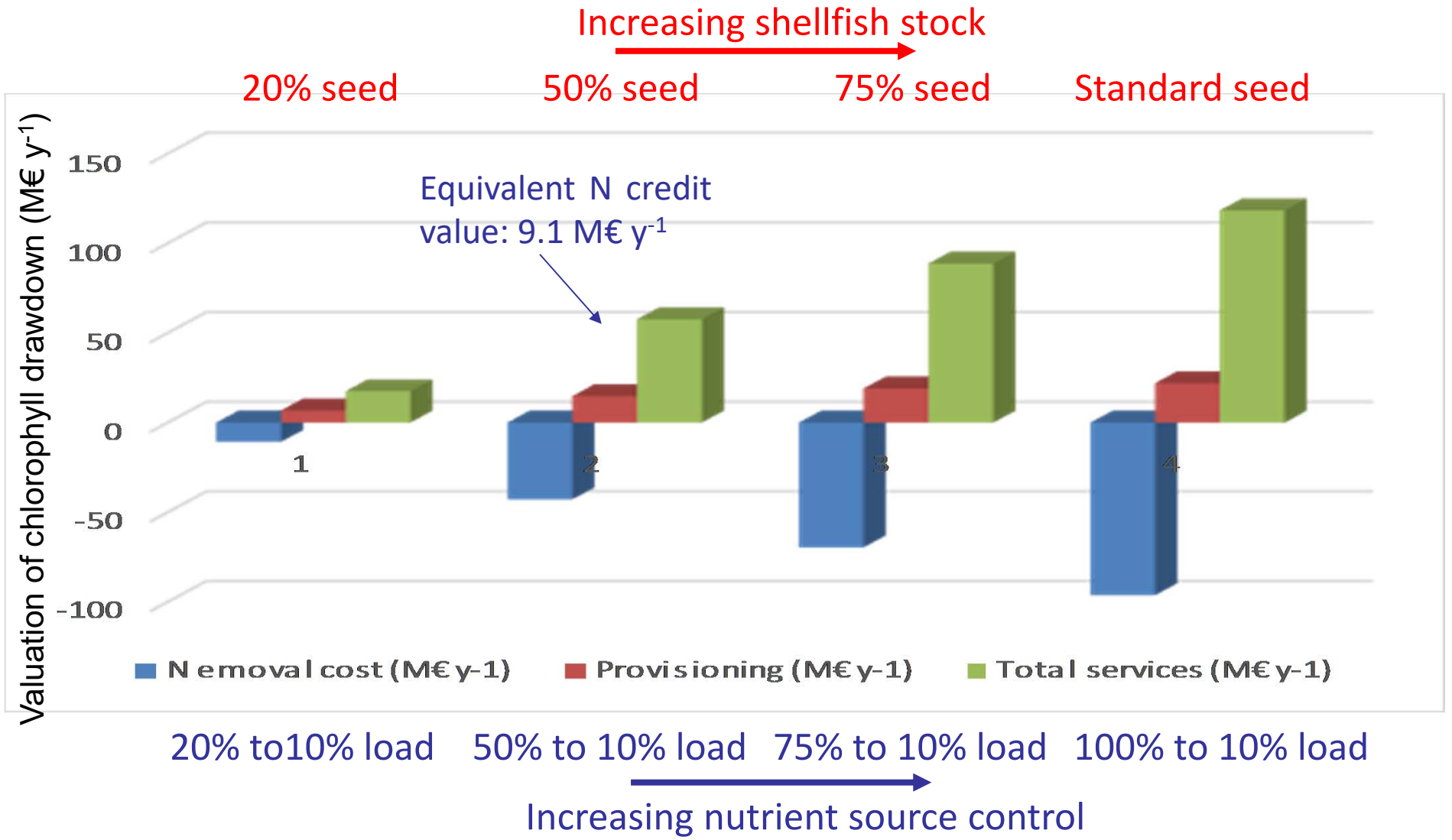
EcoWin.NET Lough Foyle Model

Chlorophyll drawdown with bottom-up and top-down control



Shellfish culture outperforms source-control in controlling eutrophication symptoms, and provides an additional provisioning service.

EcoWin.NET Lough Foyle Model
Valuation of shellfish ecosystem services



The value of the regulatory service of chlorophyll removal by shellfish is far higher than the value estimated through direct nutrient removal.

Synthesis

- A full ecological model was set up for the Foyle, integrated both at the catchment and shelf sea scales;
- There is no silver bullet: different models work within a framework but have standalone capabilities;
- Some areas of the Foyle have elevated chlorophyll peaks, production is driven by diffuse sources of nutrients;
- Cost of lowering chlorophyll P_{90} by 1 ug L^{-1} is about 27 M€ y^{-1};
- Shellfish culture is key for eutrophication management – more effective than nutrient control, but does not exempt agricultural BMP (moral hazard), or resolve microbiological issues;
- EASE supports the EU Water Framework Directive (WFD), Marine Strategy (MSFD), and Habitats. Applications include licensing, restoration, risk assessment, climate change analysis.

http://longline.co.uk/eaap/