



# EcoWin2000 model application

## Final results



<http://www.ecowin.org/smile/>

**J.G. Ferreira, A. Sequeira,  
A.J.S. Hawkins, P. Monteiro,  
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SMILE Final Meeting  
AFBI/QUB Belfast  
6<sup>th</sup>-8<sup>th</sup> February 2007



# SMILE - Objectives

- 1. To establish functional models at the lough scale, describing key environmental variables and processes, aquaculture activities and their interactions;**
- 2. To evaluate the sustainable carrying capacity for aquaculture in the loughs, considering interactions between cultivated species, targeting marketable cohorts, and fully integrating cultivation practices;**
- 3. To examine the effects of overexploitation on key ecological variables;**
- 4. To examine bay-scale environmental effects of different culture strategies.**

# Carrying capacity – system scale

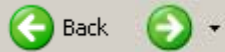


# Carrying capacity – farm scale



## Carrying capacity – raft scale





# Carrying capacity definitions and SMILE

## SMILE solution

- Physical** Bathymetry, morphology: GIS models  
Current speed and direction: Delft3D Model
- Production** Individual shellfish growth: ShellSIM, WinShell models  
Population growth: D3D-ShellSIM-EcoWin2000 framework
- Ecological** Ecosystem response - plankton, nutrients: E2K Model  
Wild species, reefs: E2K-GIS resource partitioning model  
Watershed management strategies: SWAT-E2K
- Social** The SMILE team has addressed this in China at the system scale, and in ECASA at the local scale using the FARM model. Not explicitly considered in SMILE

# Modelling framework

## Delft3D

Run Delft 3D for large domain (Western Irish Sea and four loughs) using a fine grid (each lough has hundreds of cells)

Define larger boxes (<50) within the loughs with GIS for E2K using (i) current and bathymetry data (ii) WFD (iii) aquaculture distribution

Use D3D to calculate water fluxes across these larger boxes at 30m intervals, and at the seaward boundary of the lough domain – supply these offline as spreadsheets

Hydrodynamic transport simulated in E2K by reading these spreadsheet files during an E2K model run

## EcoWin2000

Enter larger box areas, volumes etc from GIS into E2K

Implement individual growth model in E2K, test, and then add population dynamics

Run full E2K model, calibrate and validate

**Management scenarios**

Extract E2K initial conditions for state variables in each box, boundary conditions and calibration data

Measure individual shellfish growth rates in the field

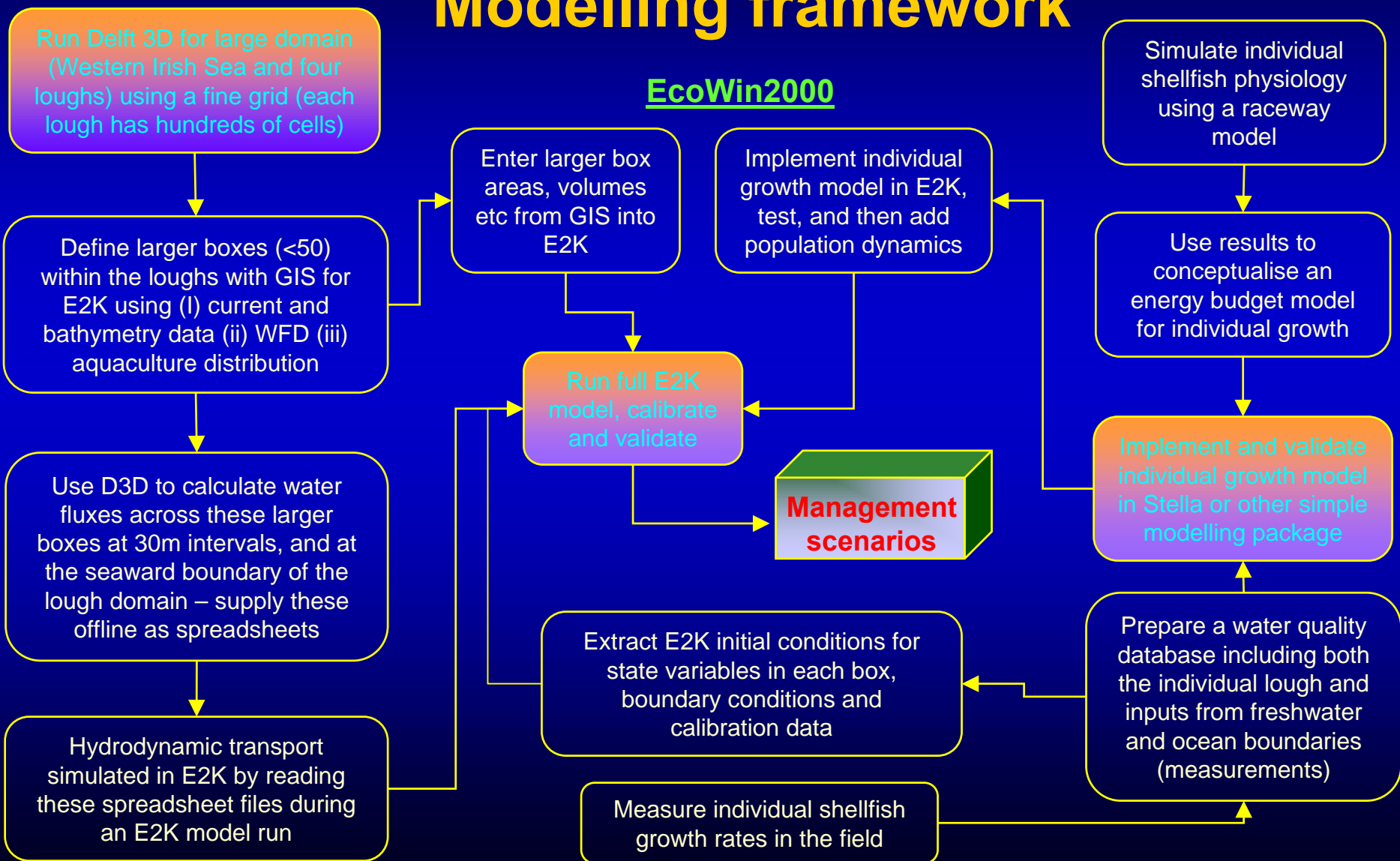
## ShellSim2006

Simulate individual shellfish physiology using a raceway model

Use results to conceptualise an energy budget model for individual growth

Implement and validate individual growth model in Stella or other simple modelling package

Prepare a water quality database including both the individual lough and inputs from freshwater and ocean boundaries (measurements)





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# Sustainable *Mariculture* in northern *Irish Lough Ecosystems* SMILE

## Foyle, Larne, Belfast, Strangford and Carlingford Lough EcoWin2000 model results

<http://www.ecowin.org/smile/>



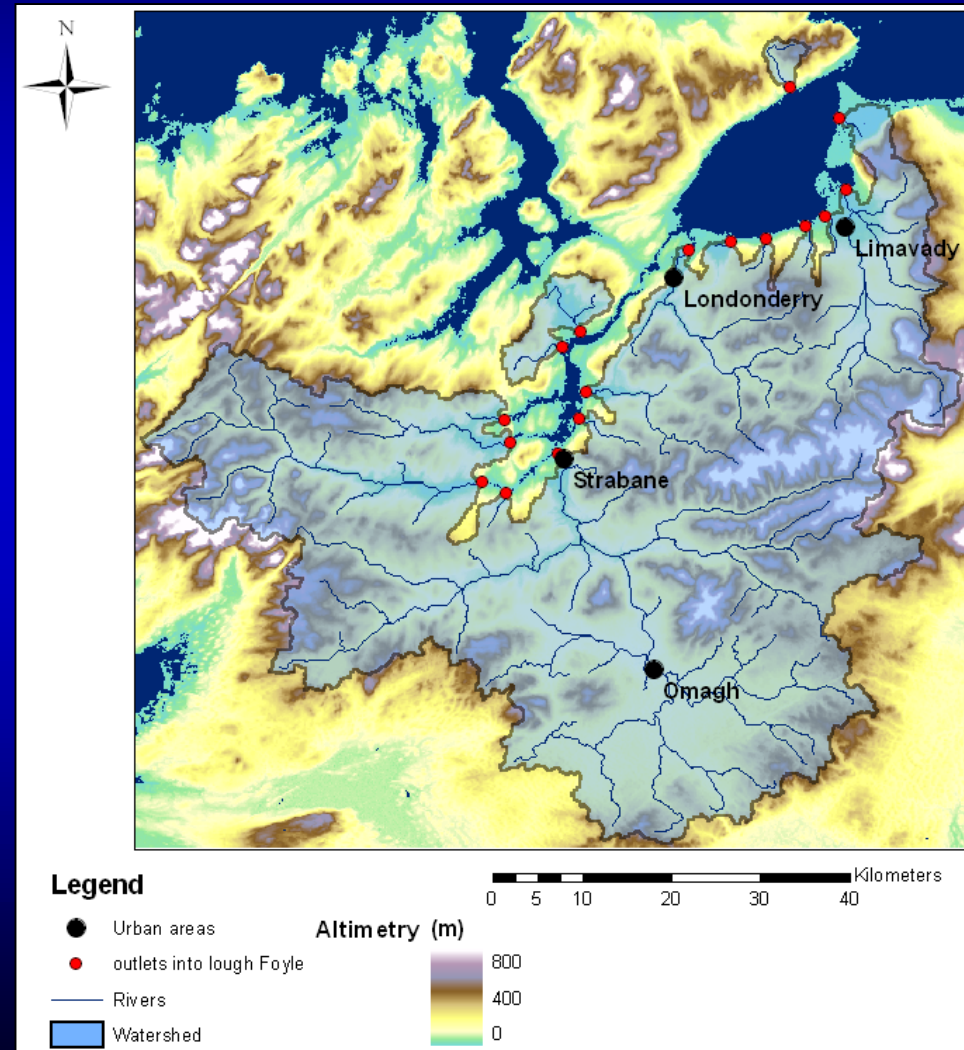
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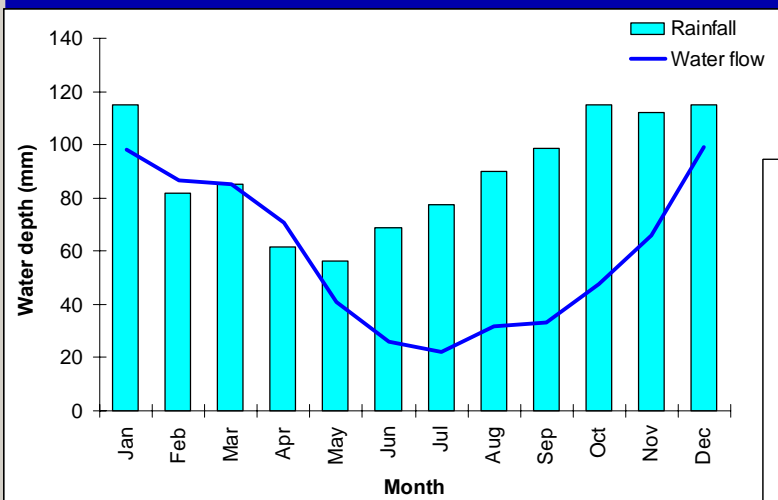


# Lough Foyle Catchment Modelling

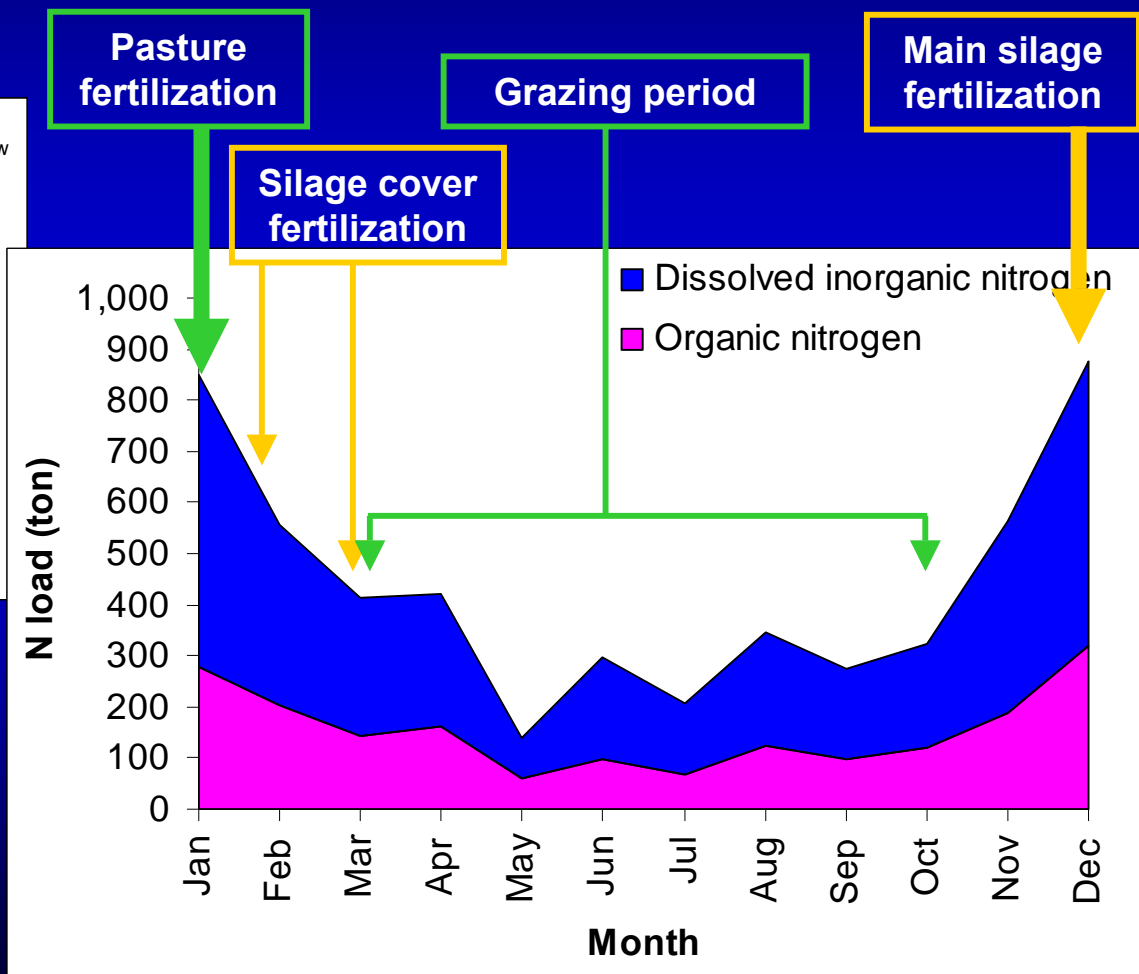
- **Tool: SWAT catchment model**
  - Simulates nutrient inputs from the catchment draining into Lough Foyle
- **Area: c. 3500 Km<sup>2</sup>**
  - Rivers Foyle, Faughan and Roe
  - Smaller catchments
- **Cities:**
  - Limavady, Londonderry, Omagh and Strabane
- **Processes:**
  - Agricultural and pasture fertilization
  - Livestock grazing
  - Urban wastewater



# Nitrogen Loads



**Seasonal rainfall and river runoff in the Lough Foyle catchment**

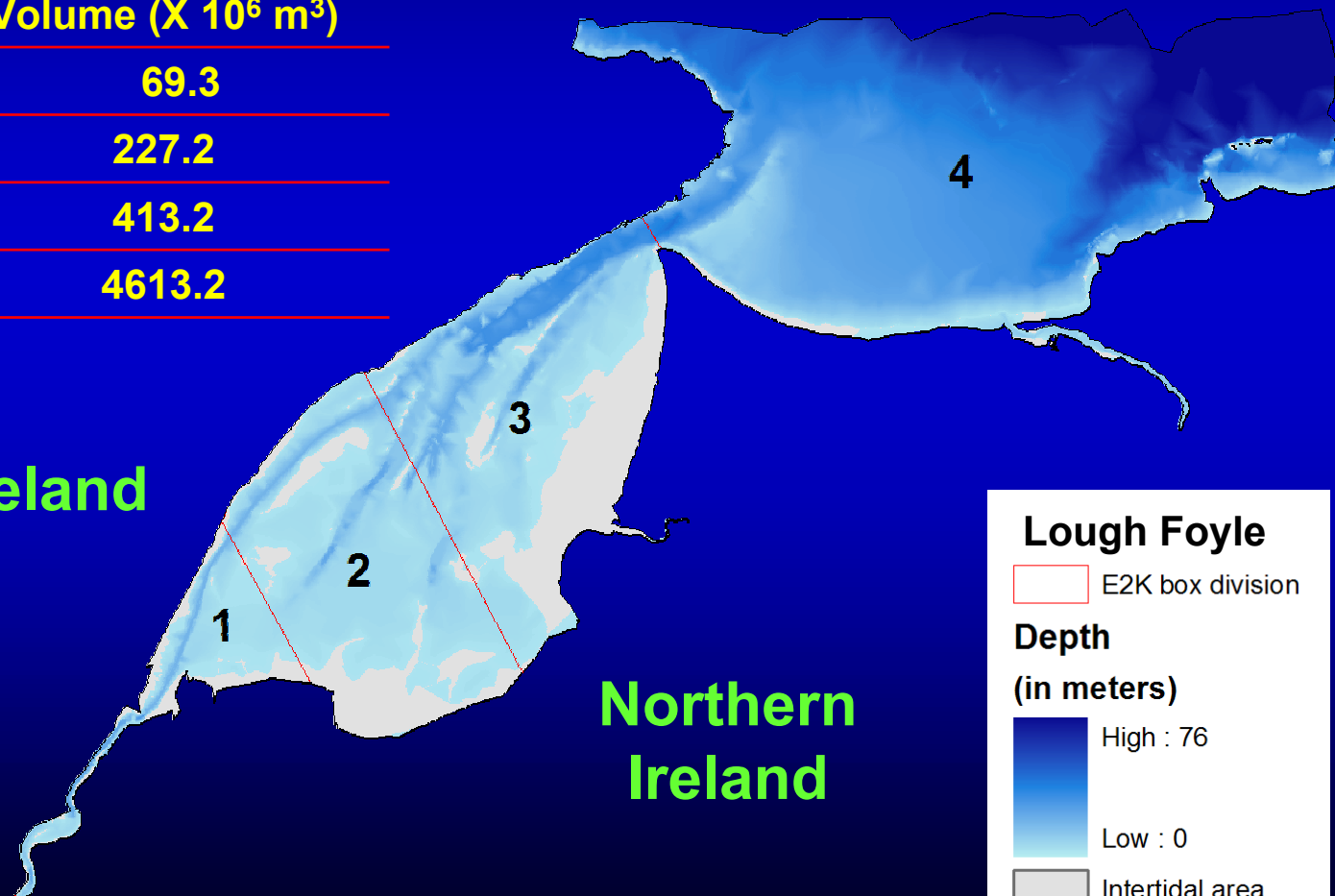


**Seasonal nitrogen load into Lough Foyle**

# Lough Foyle Model boxes

Box	Area (ha)	Volume (X 10 <sup>6</sup> m <sup>3</sup> )
1	2185	69.3
2	7595	227.2
3	9087	413.2
4	21292	4613.2

Ireland

Northern  
Ireland

## Lough Foyle

E2K box division

### Depth

(in meters)

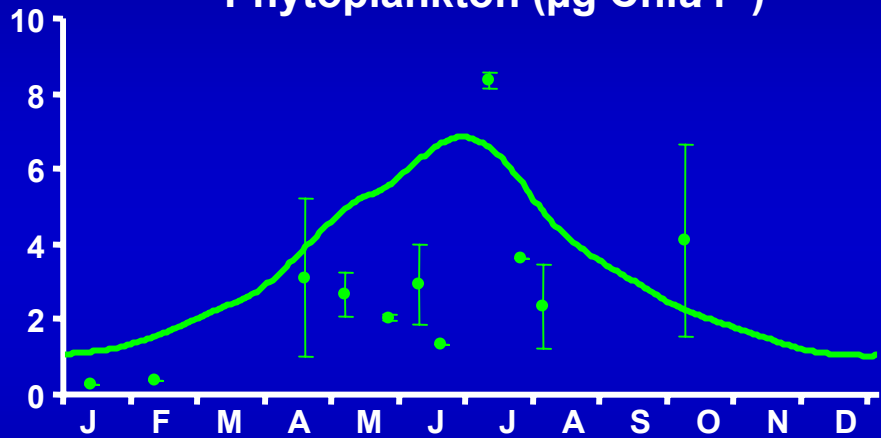
High : 76

Low : 0

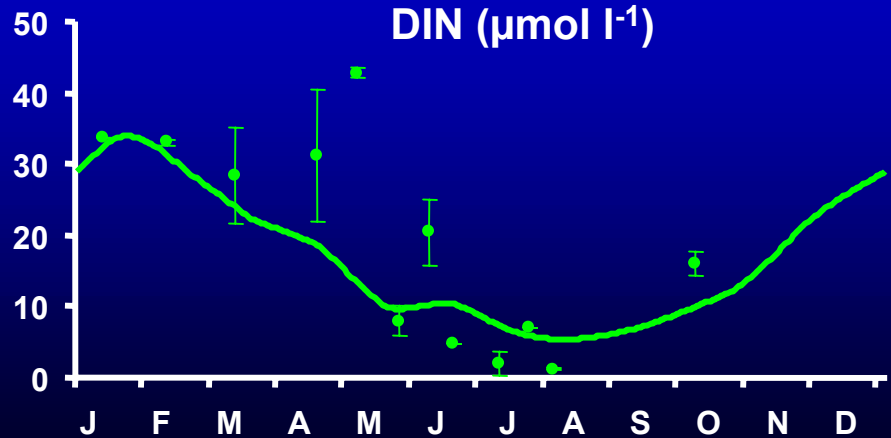
Intertidal area

# Lough Foyle - Model validation

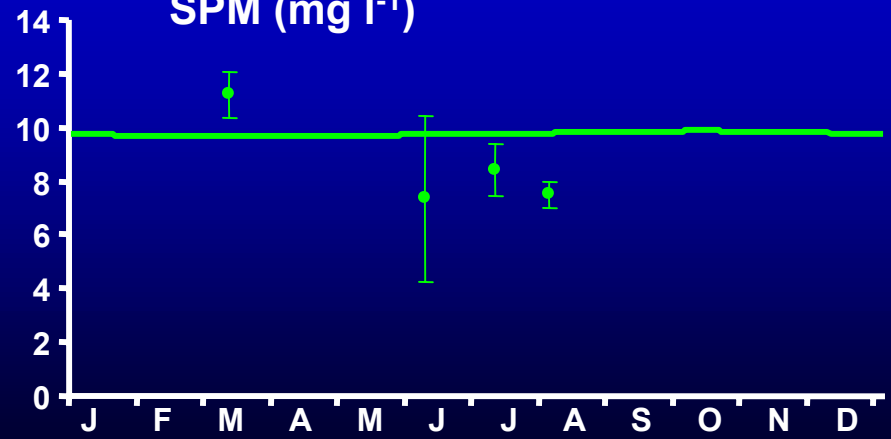
Phytoplankton ( $\mu\text{g Chla l}^{-1}$ )



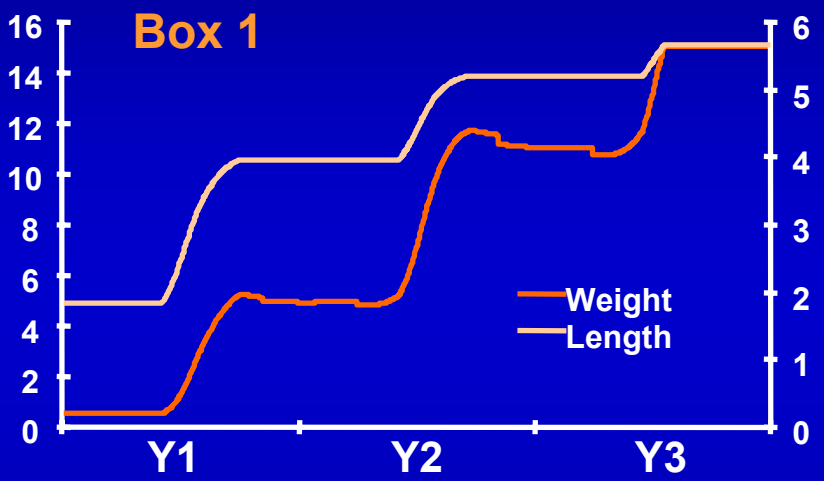
DIN ( $\mu\text{mol l}^{-1}$ )



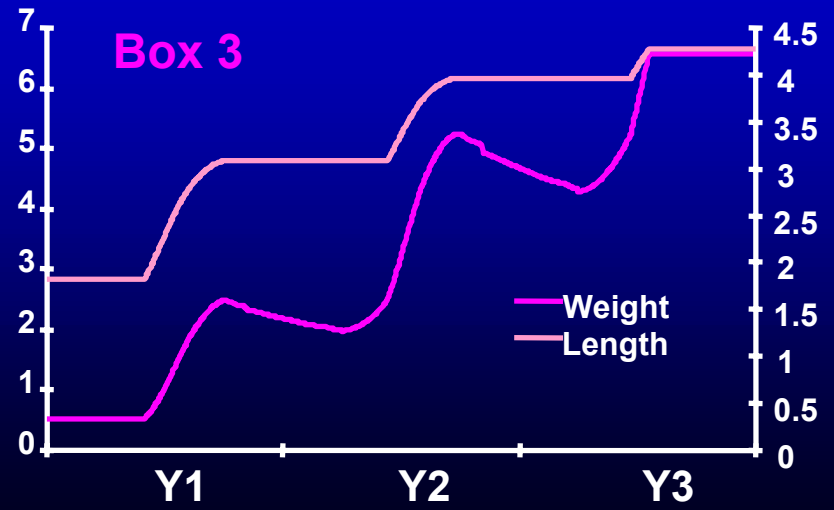
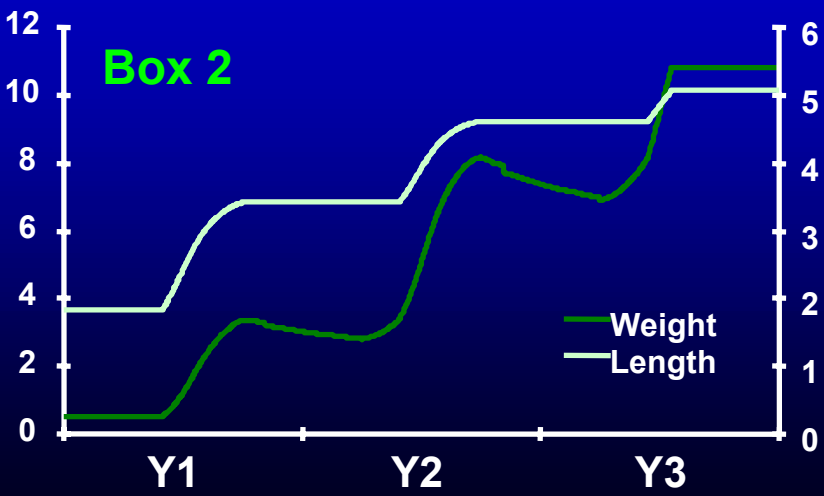
SPM ( $\text{mg l}^{-1}$ )



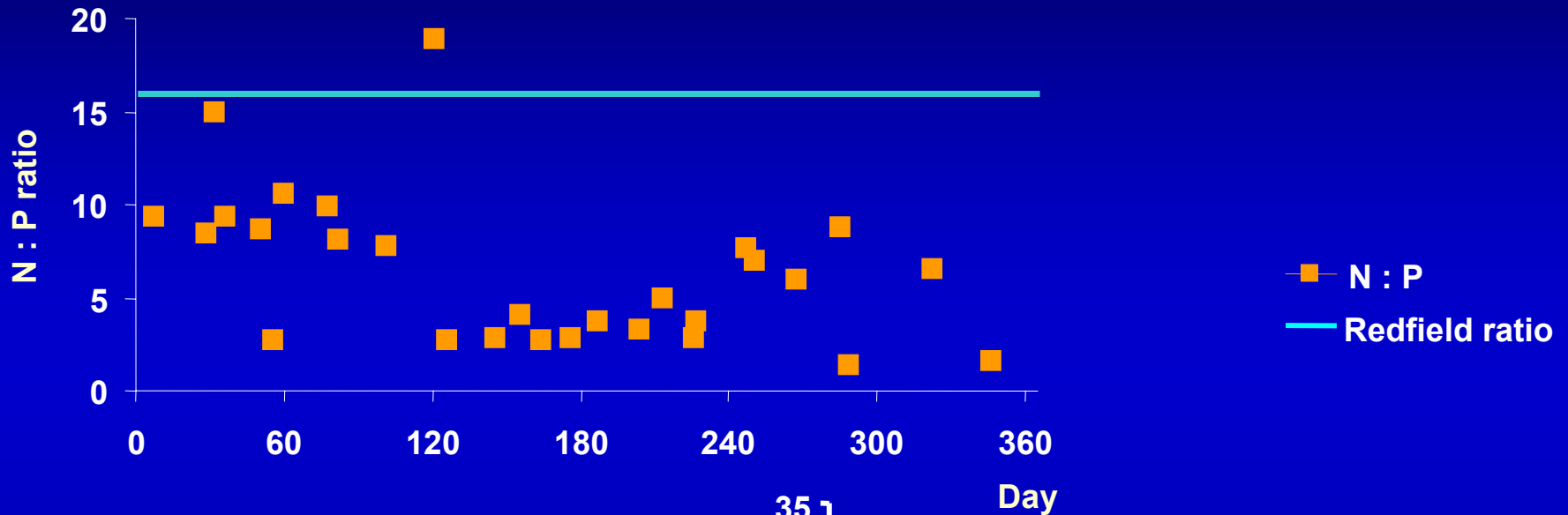
# Lough Foyle - Mussels: individual weight and length



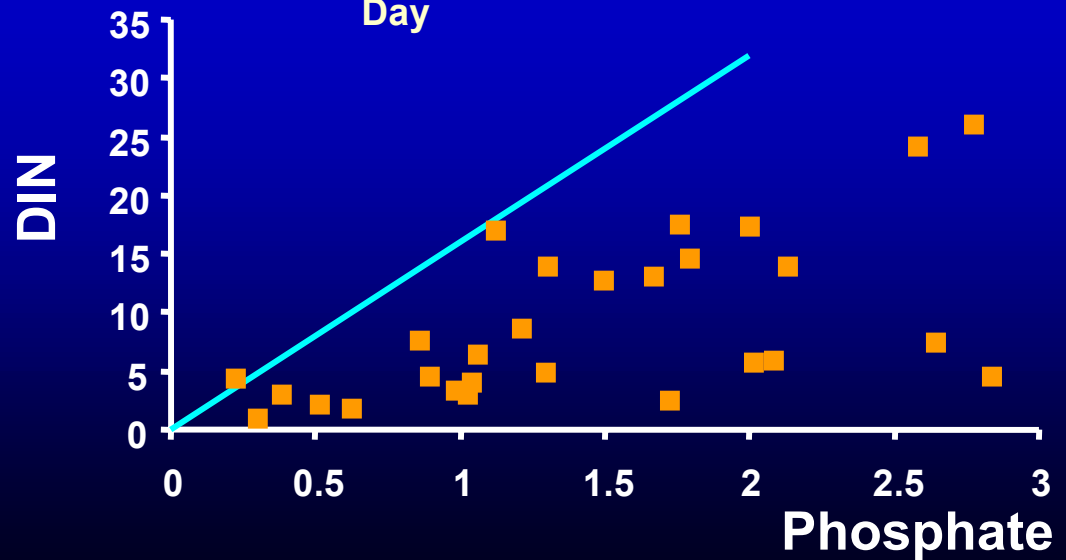
- EcoWin2000 shows good mussel individual weights in boxes 1 and 2.
- In box 3 the model is showing lower growth.



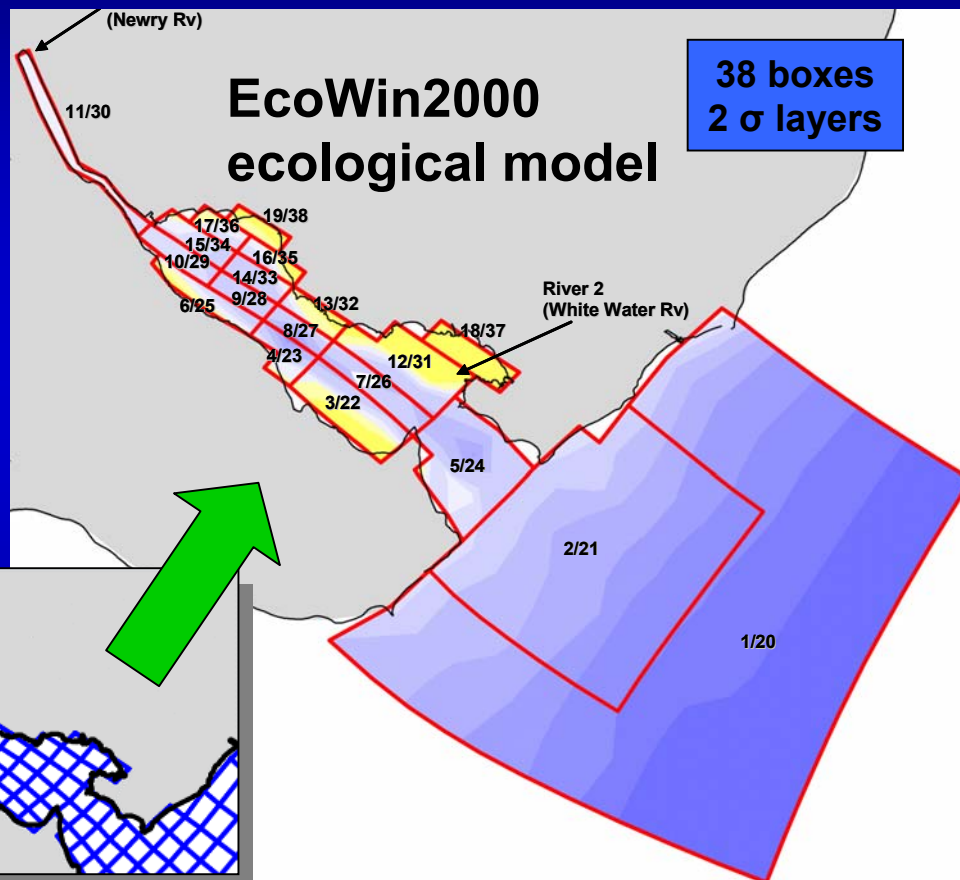
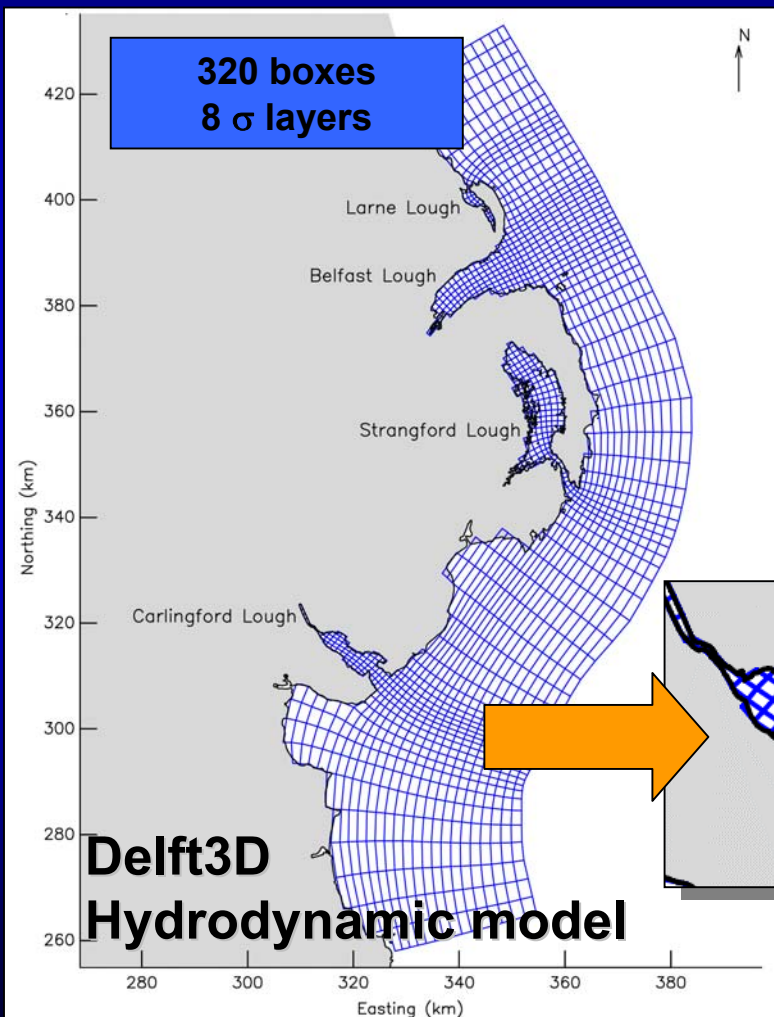
# Belfast Lough – Redfield ratio



Mean values per day for all data available in the historical database



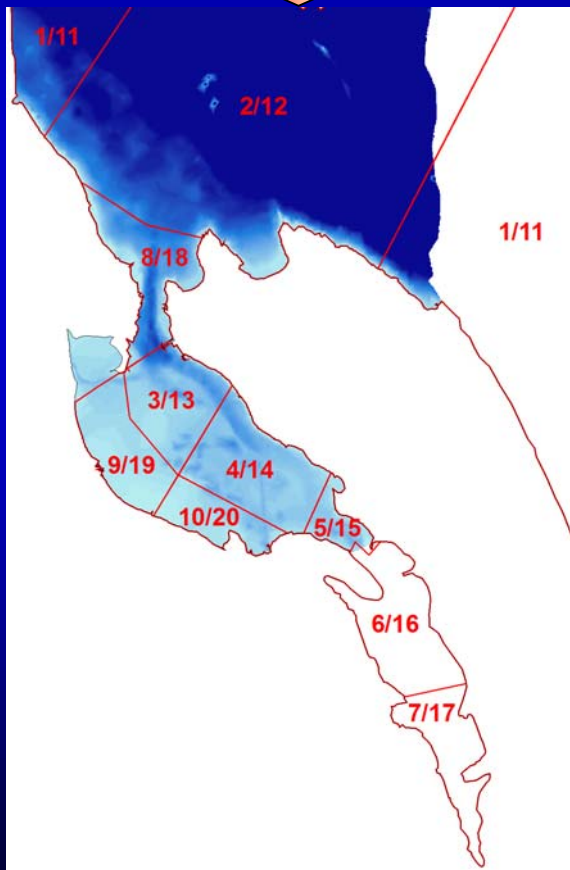
# Carlingford Lough



A much coarser grid is used in biogeochemical models than in hydrodynamic models.

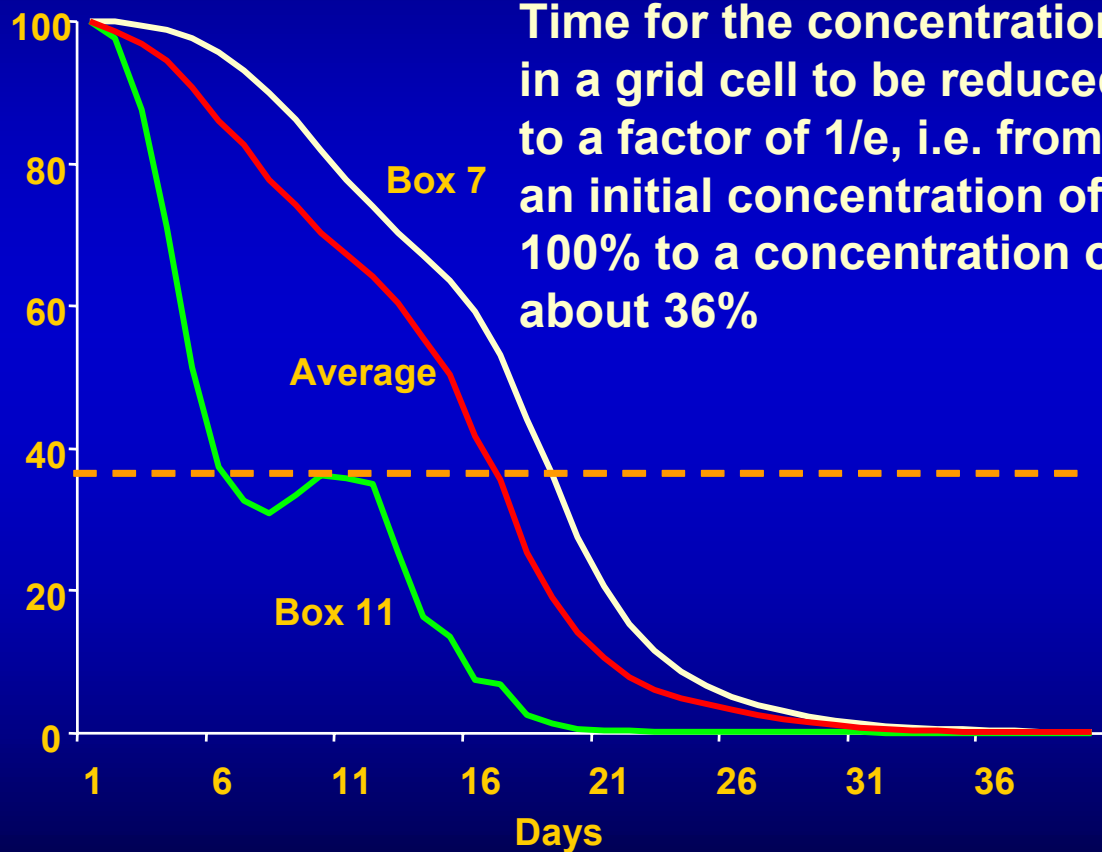
# Larne Lough residence time

100 Tracer Units in all Boxes



## Water residence time

Time for the concentration in a grid cell to be reduced to a factor of  $1/e$ , i.e. from an initial concentration of 100% to a concentration of about 36%

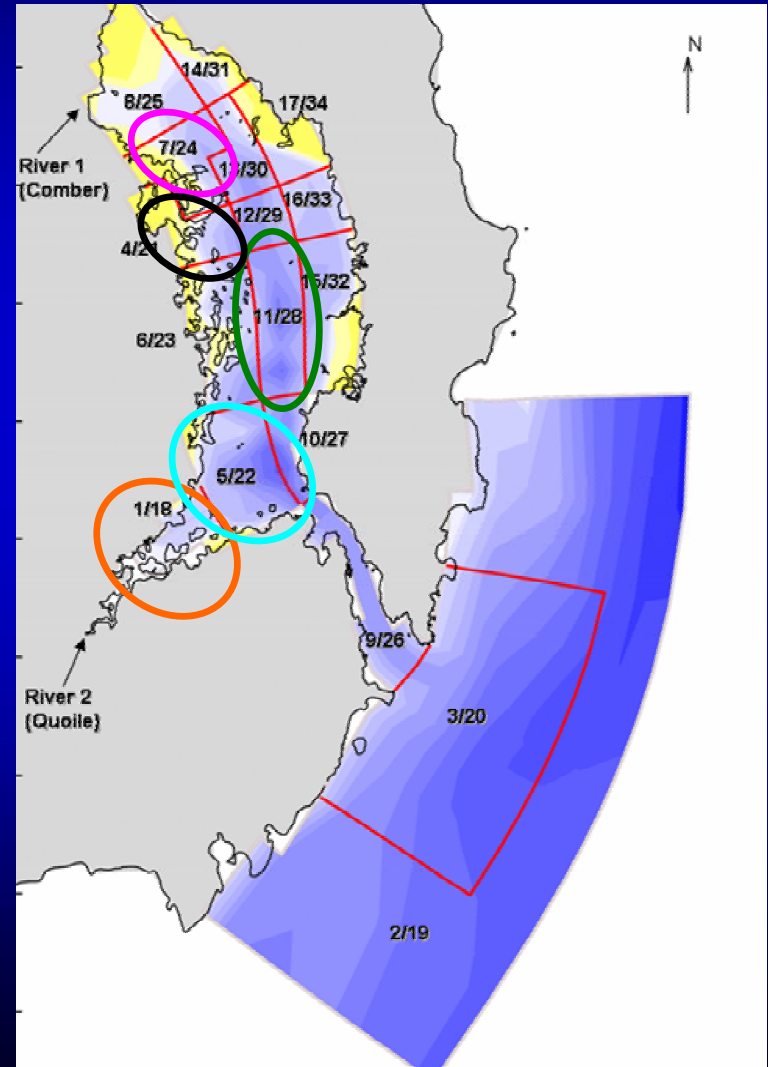


Residence time: 7-19 days  
Average residence time: 17 days

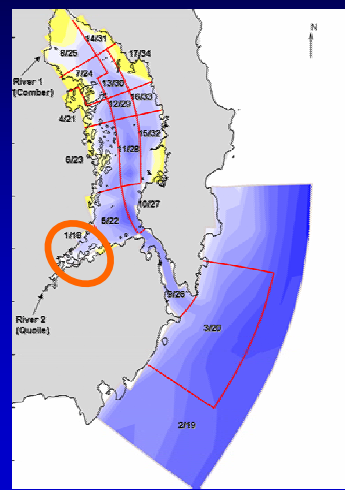


## Growth drivers - Model validation

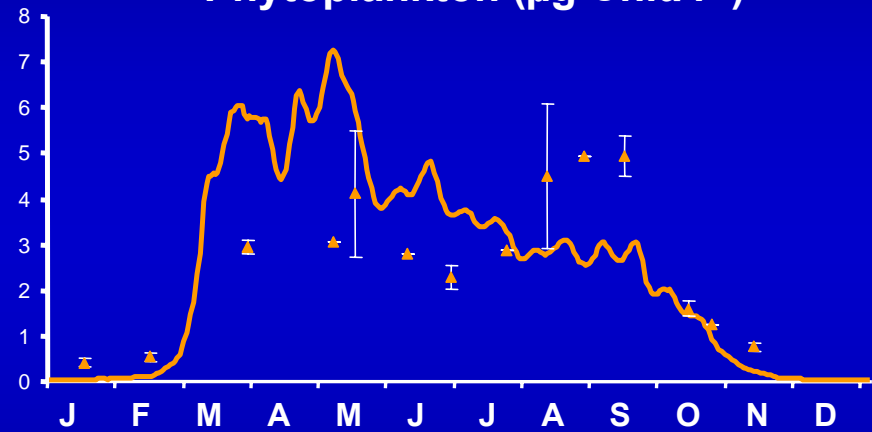
- Strangford model inputs:
  - Quoile river input: Q3 station data
  - Enler river + Ballyrickard STW inputs: adapted from “The trophic status of Strangford Lough” report
  - Ocean boundary: SL stations at the lough entrance and a mean value for SPM & POM



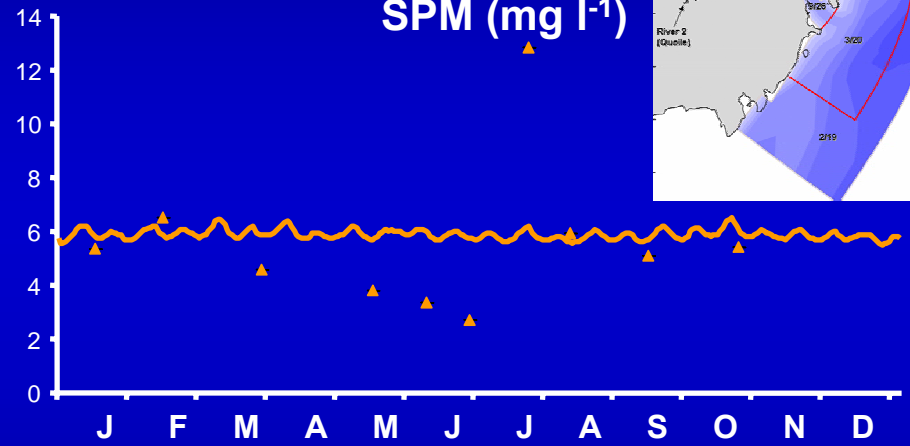
# Strangford Lough Box 18 - Near Quoile Pondage



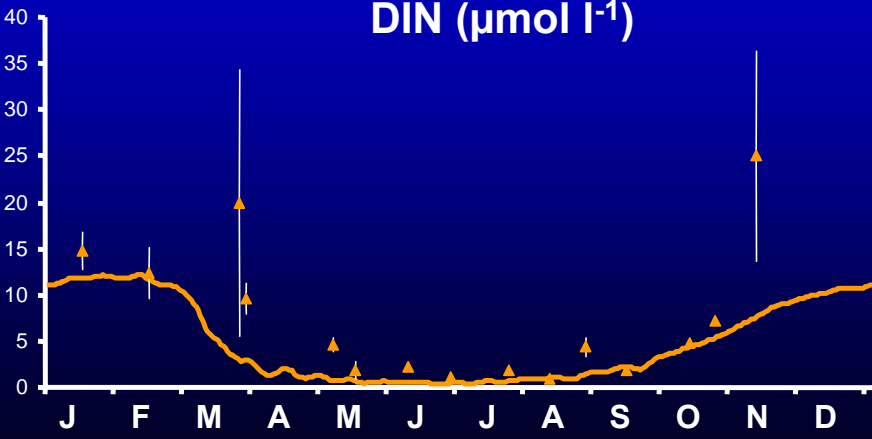
Phytoplankton ( $\mu\text{g Chla l}^{-1}$ )



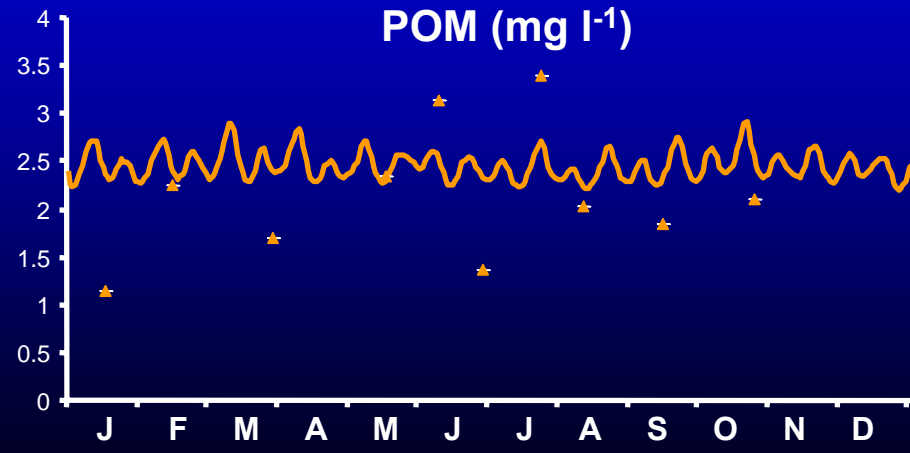
SPM ( $\text{mg l}^{-1}$ )



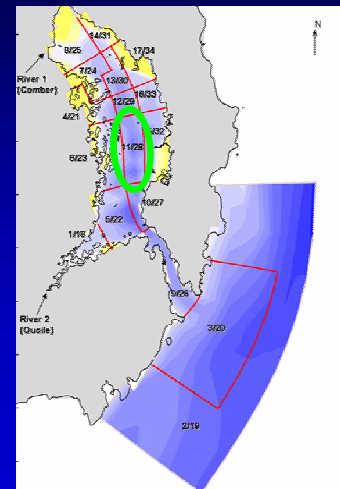
DIN ( $\mu\text{mol l}^{-1}$ )



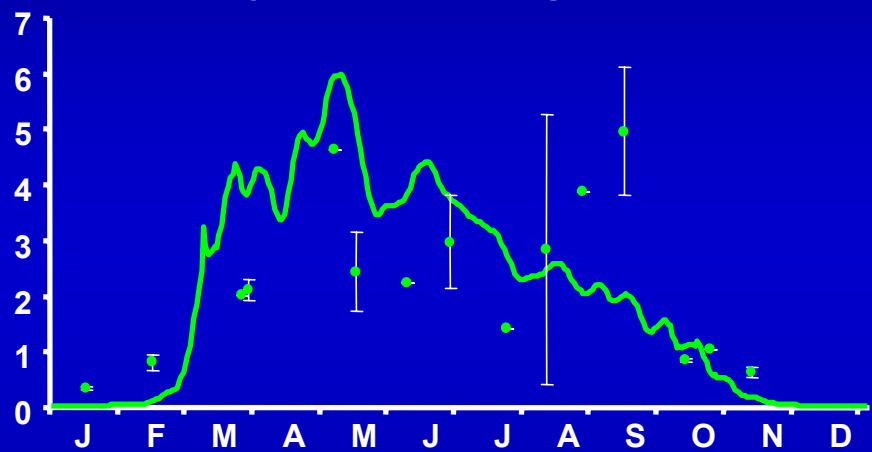
POM ( $\text{mg l}^{-1}$ )



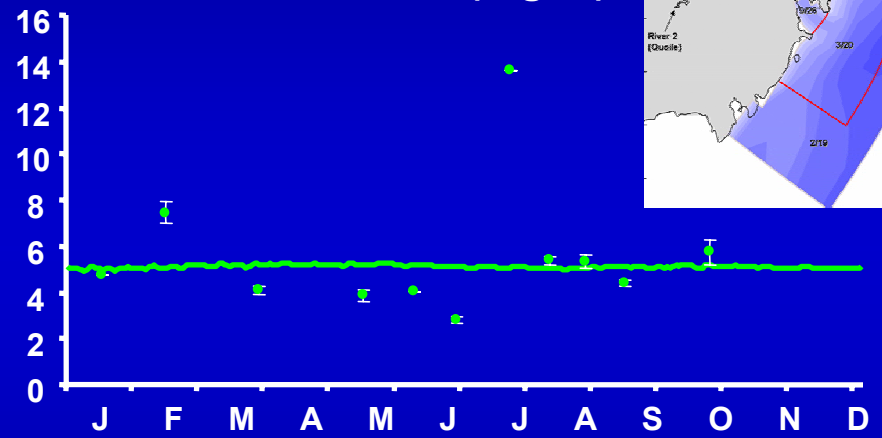
# Strangford Lough Box 28 – Central box



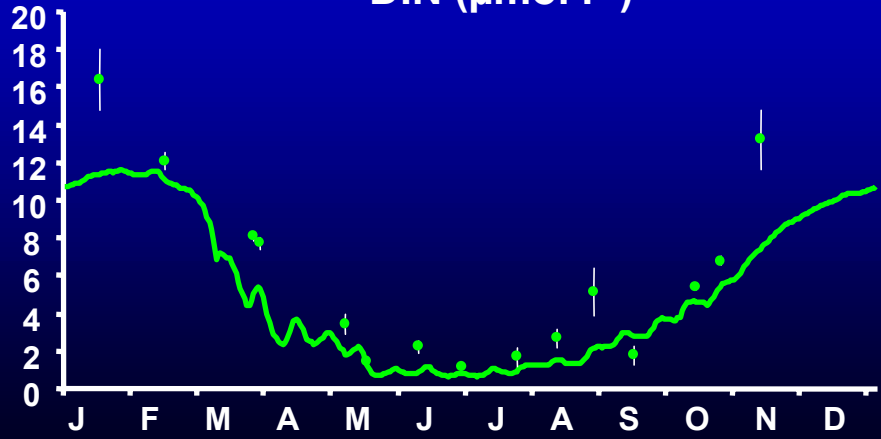
Phytoplankton ( $\mu\text{g Chla l}^{-1}$ )



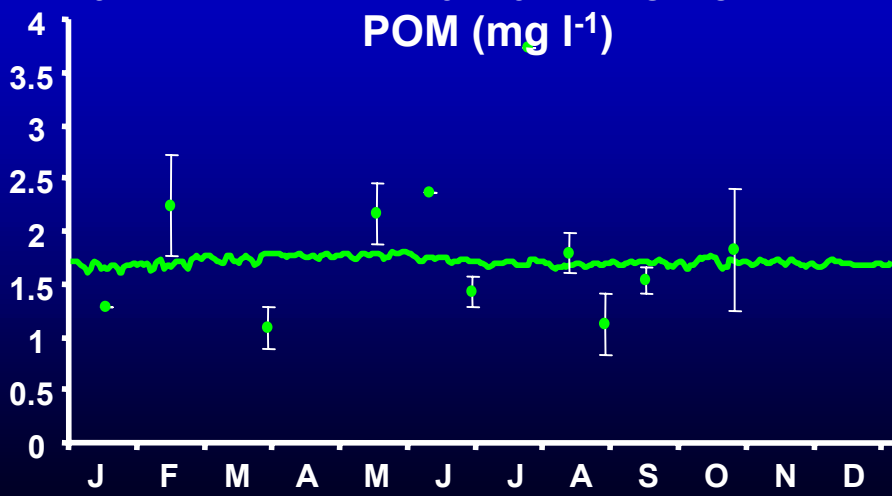
SPM ( $\text{mg l}^{-1}$ )



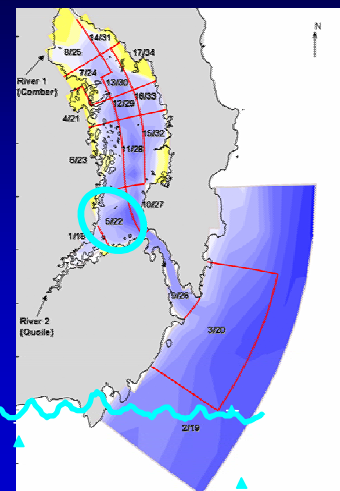
DIN ( $\mu\text{mol l}^{-1}$ )



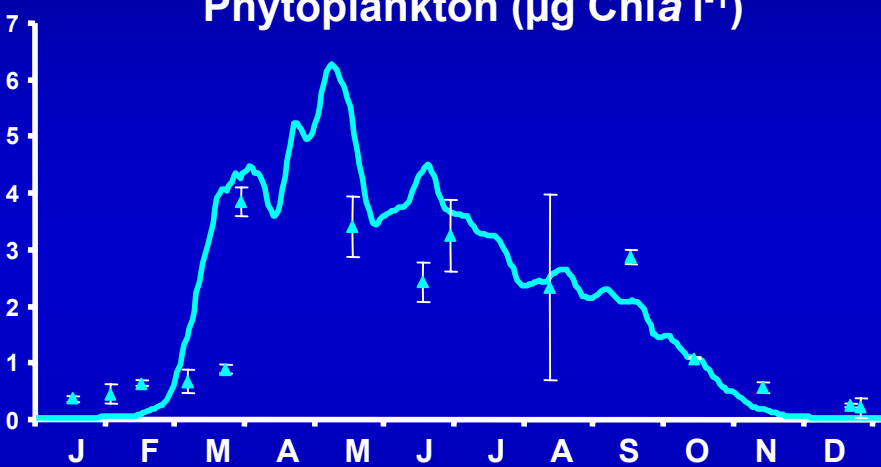
POM ( $\text{mg l}^{-1}$ )



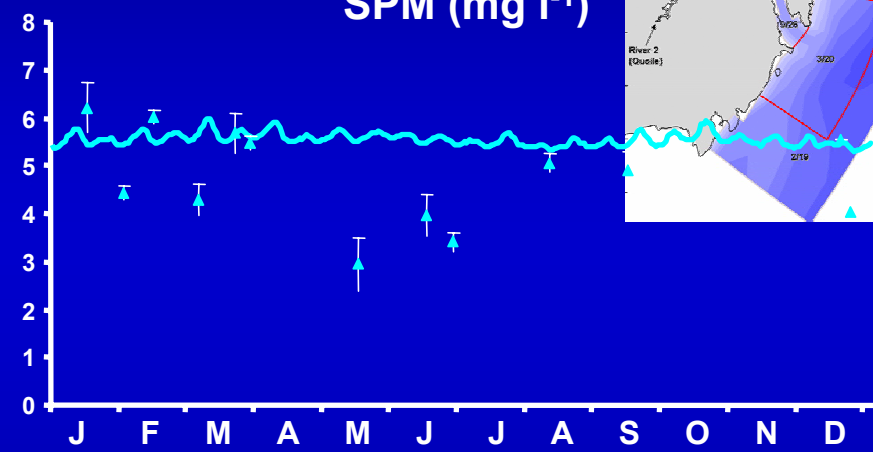
# Strangford Lough Box 22 - Lough entrance



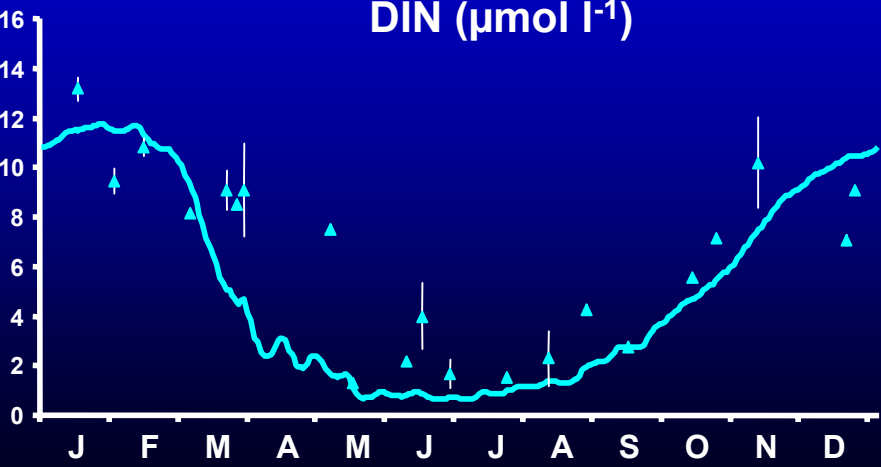
Phytoplankton ( $\mu\text{g Chla l}^{-1}$ )



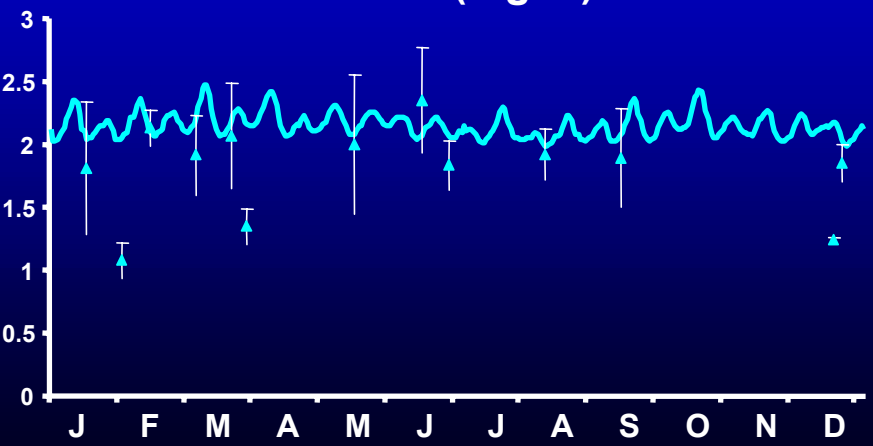
SPM ( $\text{mg l}^{-1}$ )



DIN ( $\mu\text{mol l}^{-1}$ )



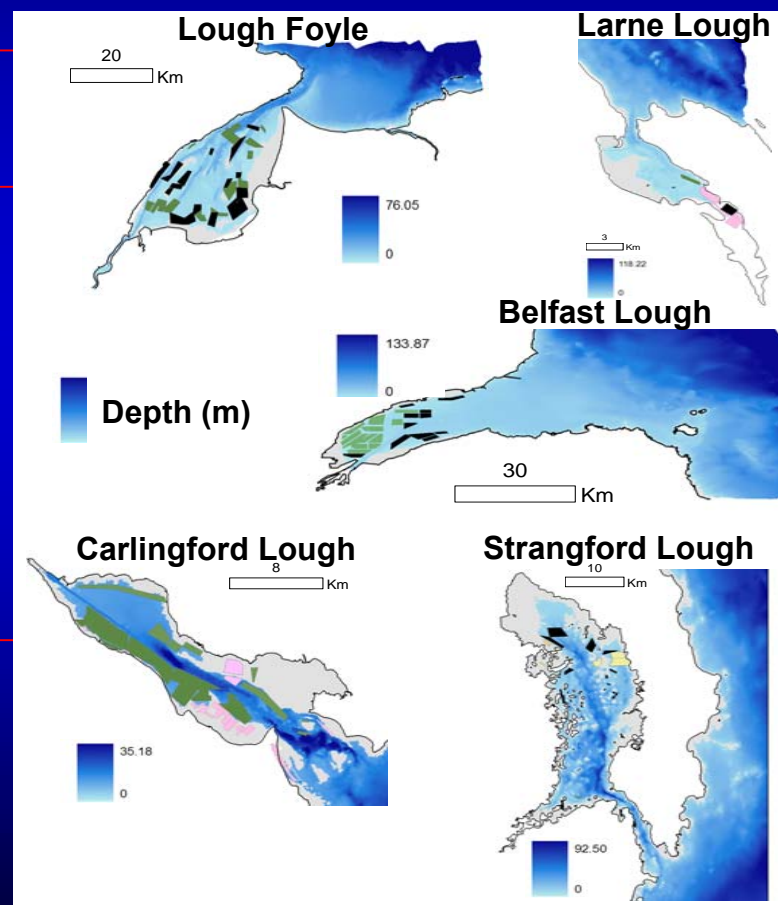
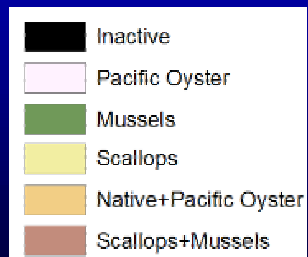
POM ( $\text{mg l}^{-1}$ )



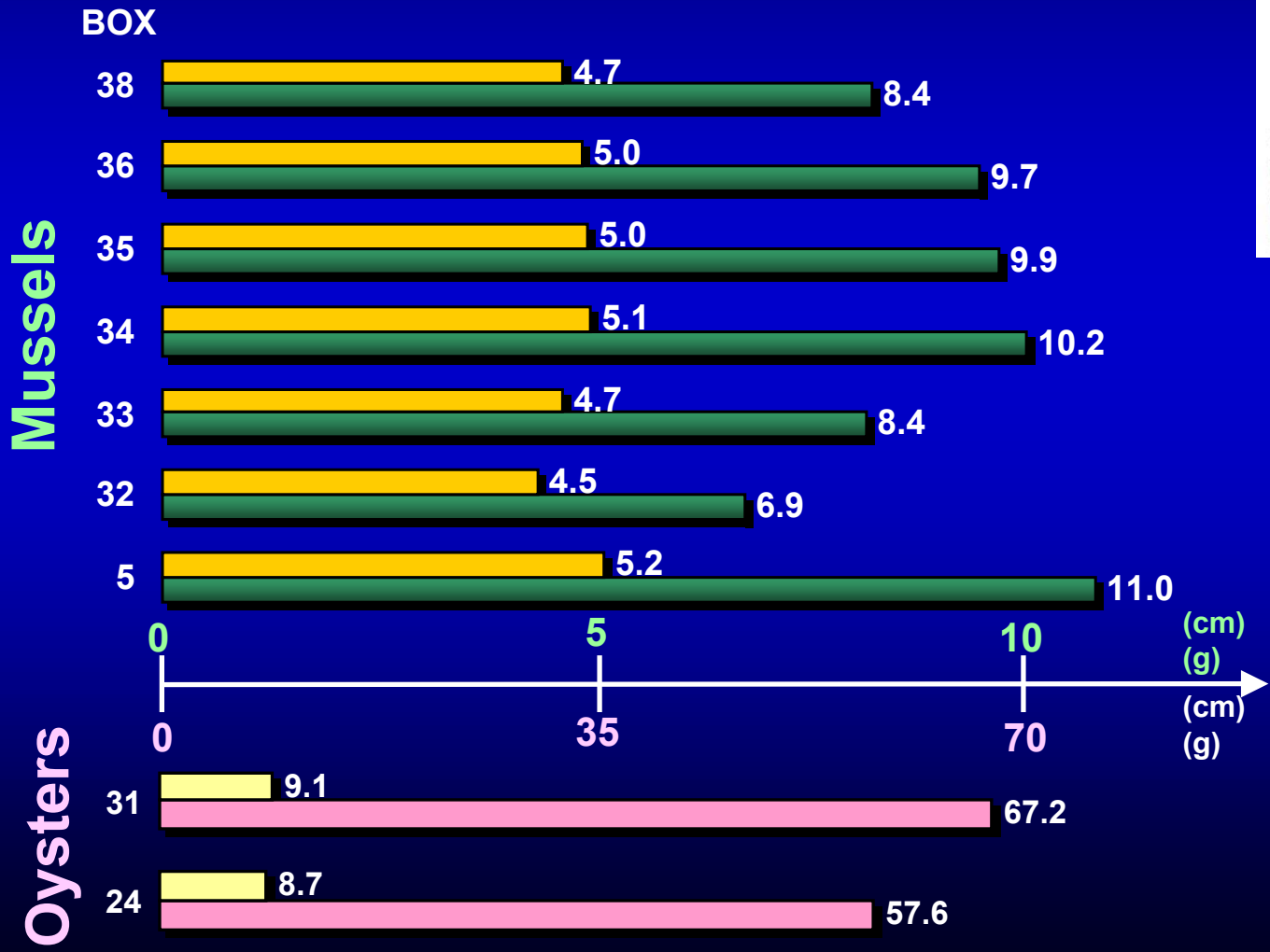
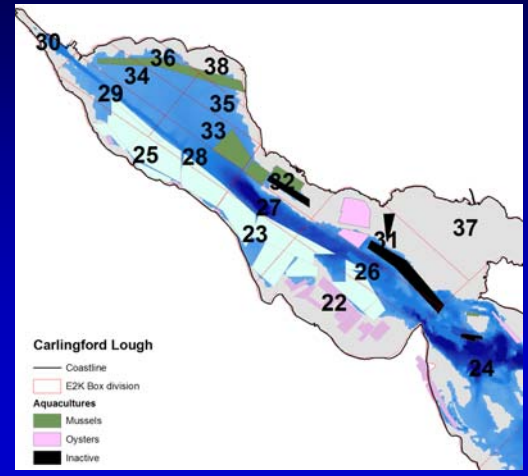
# SMILE Loughs - Aquaculture areas (ha)

Lough	Lough area	Mussel area	Oyster area	% of Lough
Foyle	18600	1602.9	0.07	8.6?
Larne	800	10.4	59.9	8.8
Belfast	13000	952.6	---	7.3
Strangford	14900	5.9	23.5	0.2
Carlingford	4900	867.5	197.8	21.7
Only NI		167.9	83.2	5.1

Though Lough Foyle has a greater aquaculture area, in Carlingford Lough a higher percentage of the system is occupied by aquaculture.



# Carlingford Lough Individual length and weight



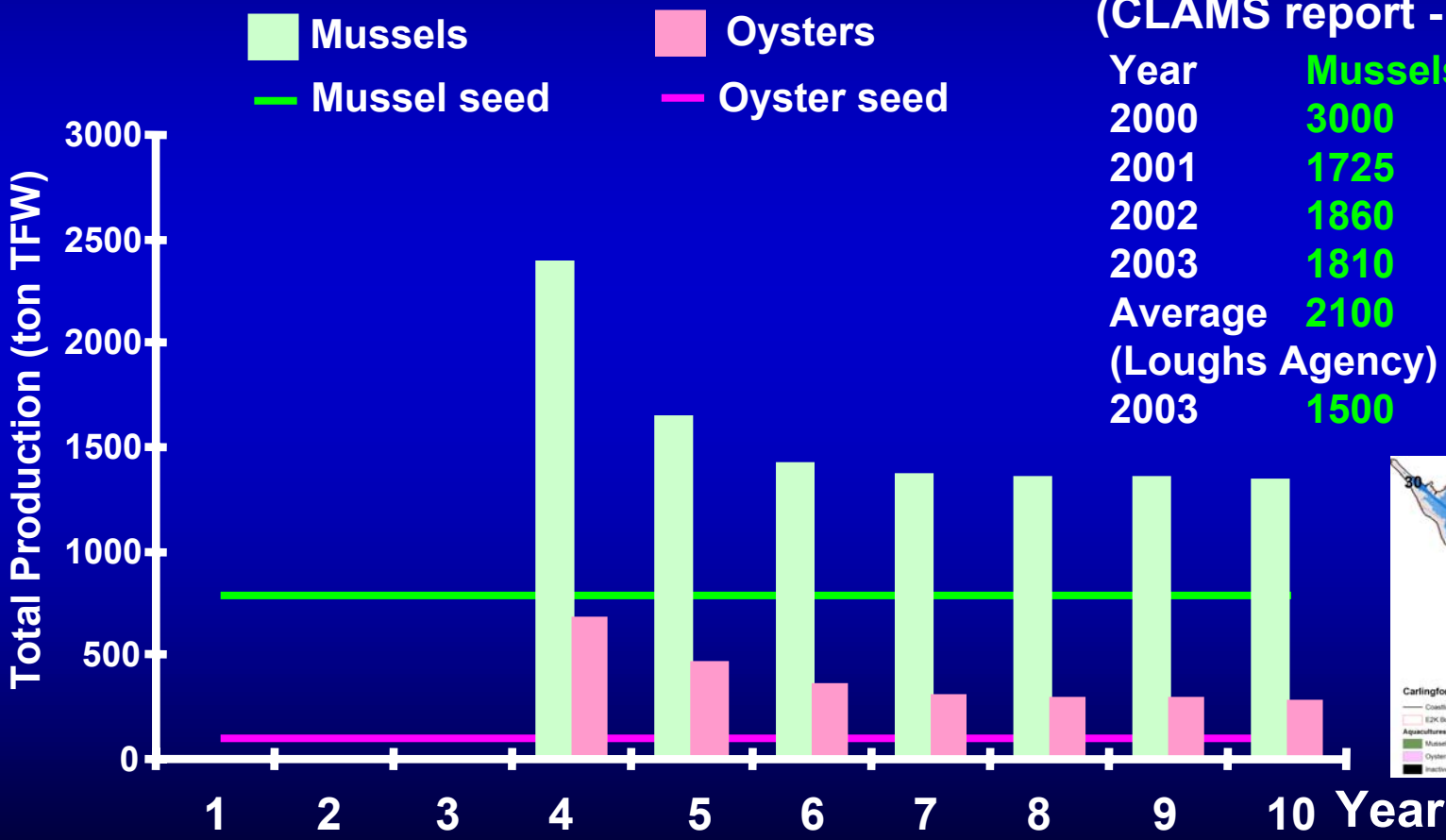
Mussels  
mean length = 5 cm  
mean weight = 9.2 g

Length (cm)  
Weight (g)

Oysters  
mean length = 9 cm  
mean weight = 62.4 g

# Carlingford Lough – EcoWin2000 model

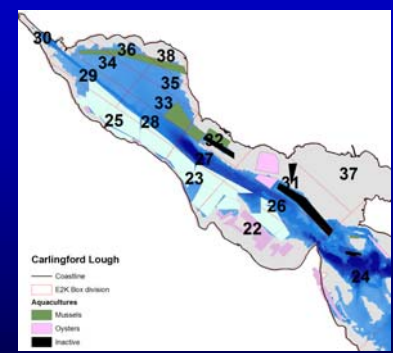
## Total production (NI + ROI) - 10 year simulation



Production figures  
(CLAMS report - BIM):

Year	Mussels	Oysters
2000	3000	411
2001	1725	365
2002	1860	878
2003	1810	495
Average (Loughs Agency)	2100	537
2003	1500	450

**SIMULATION:** 1300 ton Mussel total production  
280 ton Oyster total production

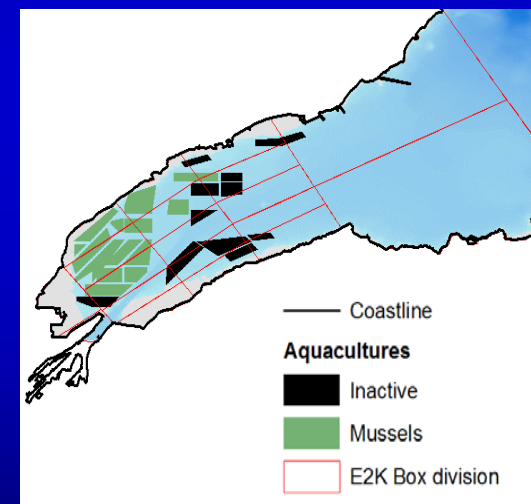




# Belfast Lough - EcoWin2000 model

## Synthesis of outputs (stable model)

Box	Aquaculture (ha)	TPP (ton TFW) Mussels	APP Mussels	TPP (per ha)
35	215	1258	2.7	5.82
36	3.2	28	4.2	8.75
37	19	57	1.4	3
38	98	517	2.4	5.28
39	301	1162	2.7	3.86
40	9.5	56	2.8	5.89
41	148	1072	3.4	7.24
42	158	1114	3	7.05
<b>Total</b>	<b>952</b>	<b>5964</b>	<b>---</b>	<b>---</b>
<b>Average</b>	<b>119</b>	<b>746</b>	<b>2.8</b>	<b>5.86</b>

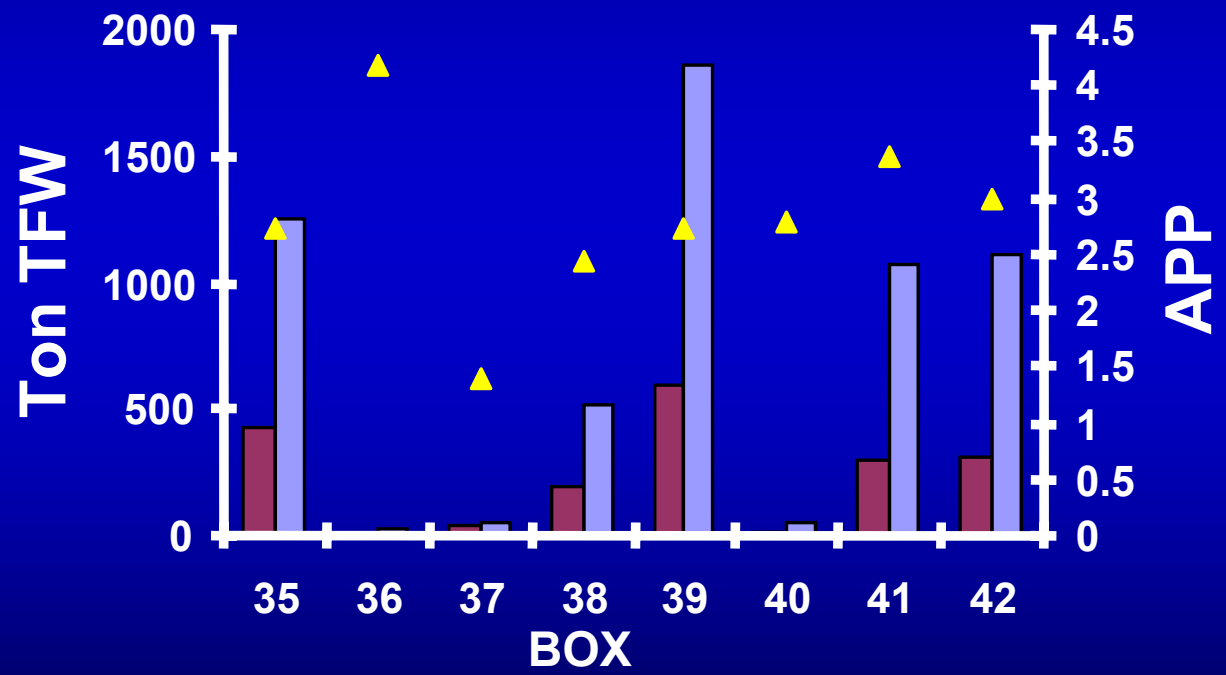




# Belfast Lough - EcoWin2000 model

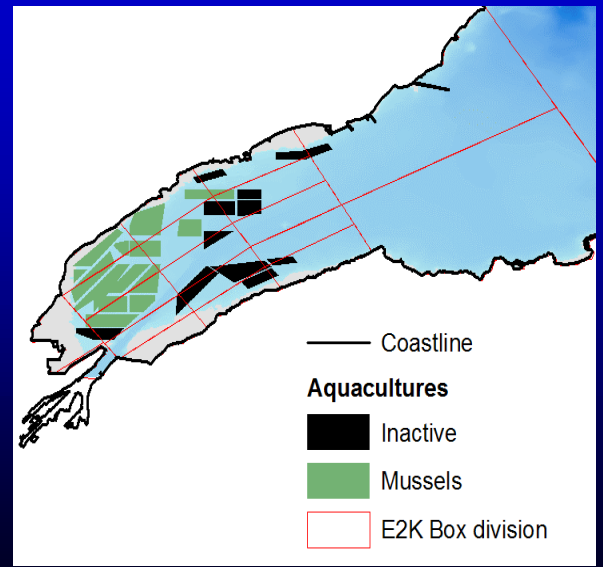
## Mussels: total seed and total harvest

### (Stable model - year 10)



- SEEDED
- HARVESTED
- ▲ Average Physical Product

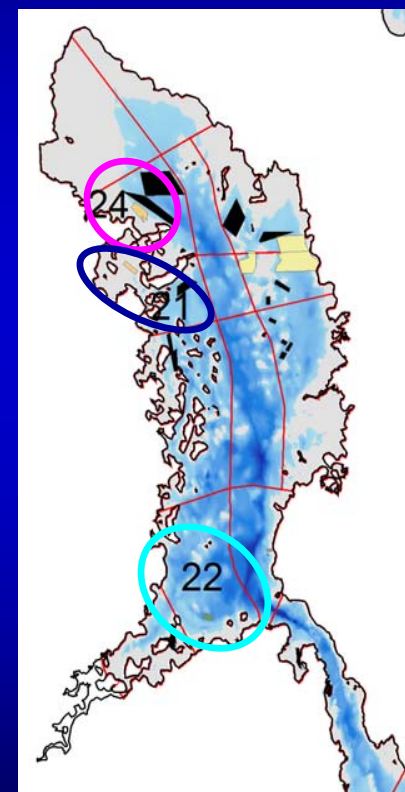
**Weight at harvest > 10.5 g**  
**Total production 6000 ton**  
**APP 3**



# Strangford Lough - EcoWin2000 model

## Synthesis of outputs (stable model)

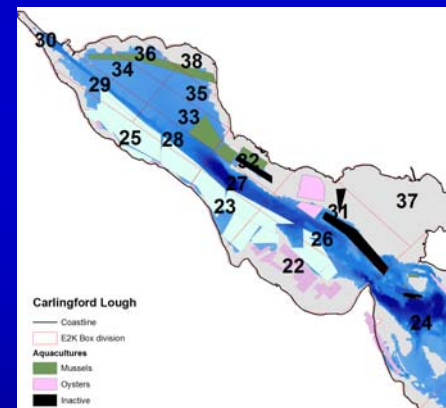
	Box	Aquaculture area	TPP (ton TFW)	APP	TPP per ha
Mussel	5	5.9	3.9	5.4	0.66
	22	5.9	4.8	1.4	0.81
	Total	5.9	9	-	-
	Average	-	-	3.4	0.74
Oyster	21	6	57	8.5	9.5
	24	17.5	166	8.4	9.5
	Total	23.5	223	-	-
	Average	-	-	8.4	9.5



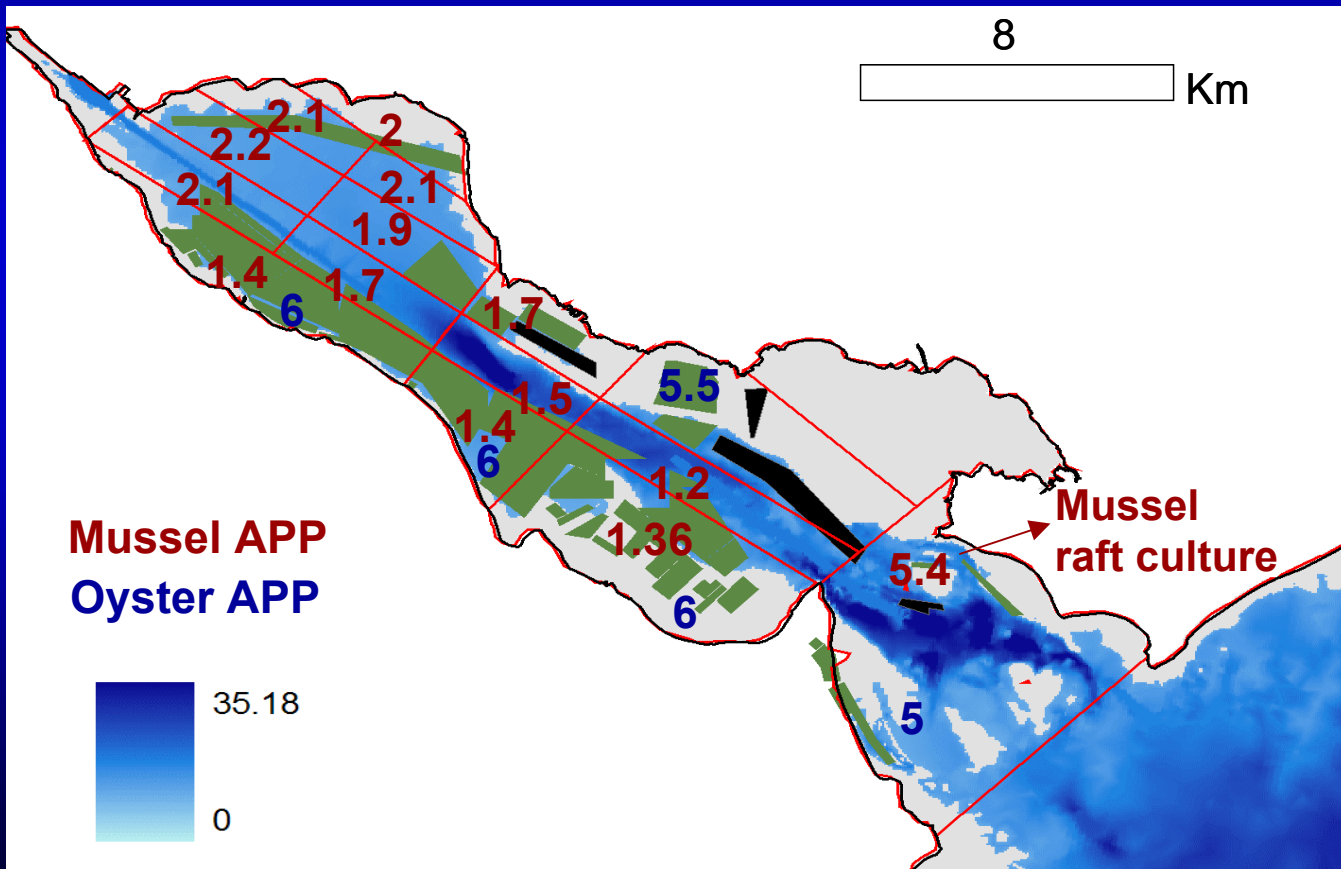
# Carlingford Lough - EcoWin2000 model

## Synthesis of outputs for NI (stable model)

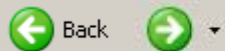
	Box	Aquaculture area	TPP (ton TFW)	APP	TPP per ha
Mussel	5	2.3	0.8	5.4	0.35
	32	42.1	71.8	1.7	1.7
	33	47.7	89.7	1.9	1.9
	34	15.2	31.8	2.2	2.1
	35	3.3	6.8	2.1	2.1
	36	32.1	67.4	2.1	2.1
	38	25.2	50.5	2	1.4
	Total	167.9	318.8	-	-
Average	-	-	2.49	1.62	
Oyster	24	26	31.9	5	1.22
	31	57.2	77.2	5.5	1.35
	Total	83.2	109.1	-	-
	Average	-	-	5.25	1.29



# Carlingford Lough - EcoWin2000 model Average Physical Product (APP) per box



APP for mussel bottom culture is relatively low, reflecting high mortality. The upper reaches of the lough have higher APP than the lower (seaward) half. Mussel raft culture and oyster trestles do significantly better.

Address 

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Links

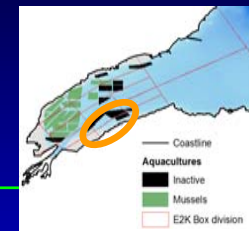
# EcoWin2000 model - Final results

## Lough comparisons and synthesis

	Carlingford (NI)	Strangford	Belfast	Total
<b>TPP (ton TFW)</b>				
Mussels	1300 (320)	9	5964	7273 (6293)
Oysters	280 (109)	223	-	503 (332)
<b>Total</b>	<b>1580 (429)</b>	<b>232</b>	<b>5964</b>	<b>7776 (6625)</b>
<b>Cultivation area (ha)</b>				
Mussels	865 (166)	6	954	1825 (1125)
Oysters	198 (83)	24	-	221 (107)
<b>Total cultivation area</b>	<b>1063 (249)</b>	<b>30</b>	<b>954</b>	<b>2046 (1232)</b>
<b>TPP per unit area (ton TFW ha<sup>-1</sup>)</b>				
Mussels	1.5 (1.9)	1.5	6.3	-
Oysters	1.4 (1.3)	9.5	-	-
<b>Total area (ha)</b>	<b>4900</b>	<b>14900</b>	<b>13000</b>	<b>32800</b>
<b>APP</b>				
Mussels	2.5	7	2.8	-
Oysters	5.3	8.4	-	-

# Belfast Lough - Scenario

## Active aquacultures in box 29



Box	Seeded		Harvested		APP		SIW	
	Standard	Scenario	Standard	Scenario	Standard	Scenario	Standard	Scenario
29	None	264	None	562	None	1.9	None	4.8
35	426	No change	1258	1222	2.7	2.6	9.3	8.8
36	6	No change	28	27	4.2	4.1	19.2	18.6
37	37	No change	57	56	1.4	1.4	3	2.9
38	193	No change	517	507	2.5	2.4	8.3	8
39	599	No change	1862	1841	2.7	2.7	9.7	9.5
40	19	No change	56	55	2.8	2.8	10.8	10.6
41	293	No change	1072	1062	3.4	3.3	14.3	14
42	313	No change	1114	1107	3	3.0	10.9	10.8
		1886 ↑ 2150	5964 ↑ 6441		~3 ↔ ~3		~11 ↓ ~10.8	

Increasing seed by about 14% results in a 10 % increase in total production, though slightly lower individual weights are observed.



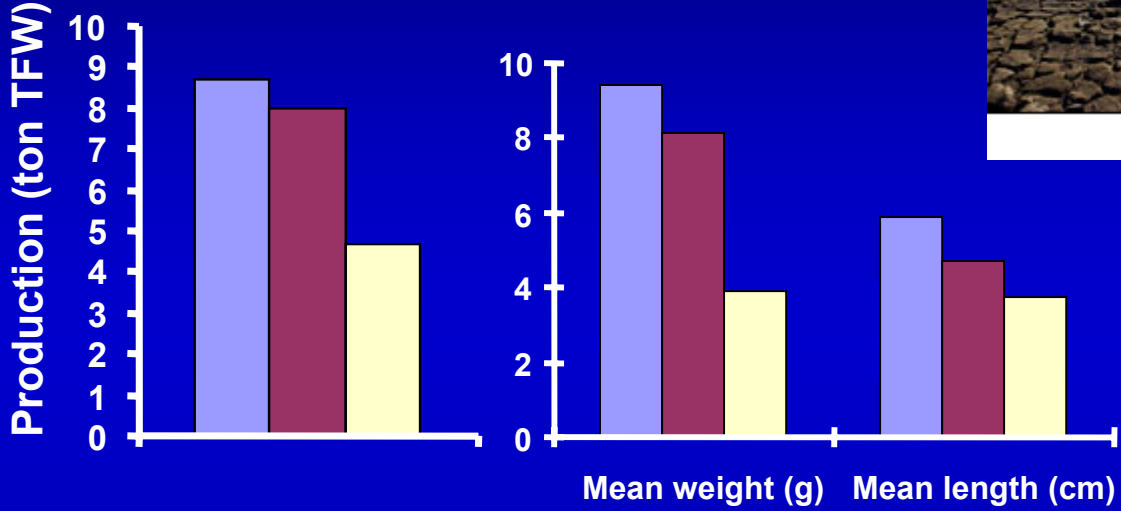
**WATCH** Humans blamed for climate change

Human activity is likely to increase global temperatures by 1.8-4C over the next century, scientists warn.

How computers model the climate  
 Climate Change: To act or not?  
 Climate report

# Strangford Lough - Scenario Increase in water temperature

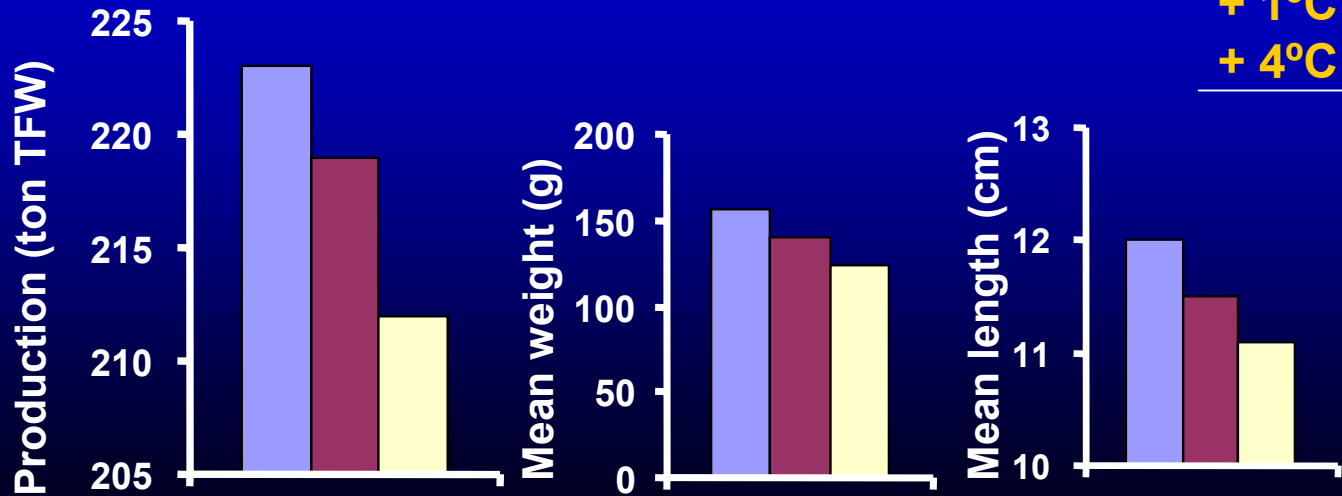
## Mussels



Standard  
 + 1°C  
 + 4°C

	Mussels	Oysters
+ 1°C	-10%	-2%
+ 4°C	-50%	-5%

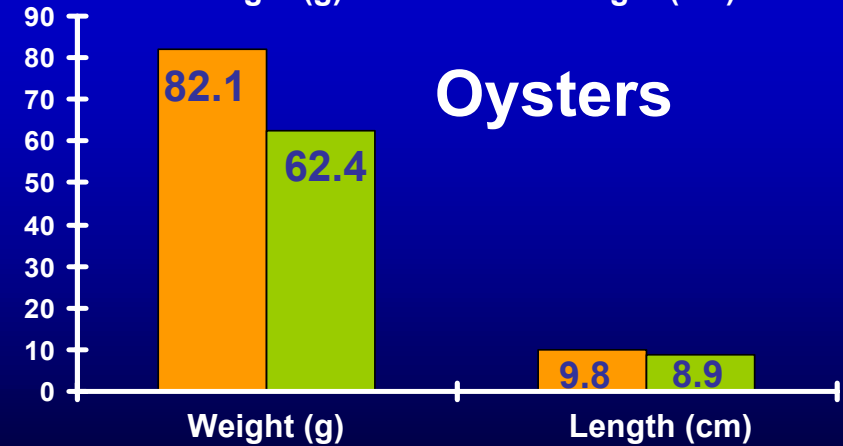
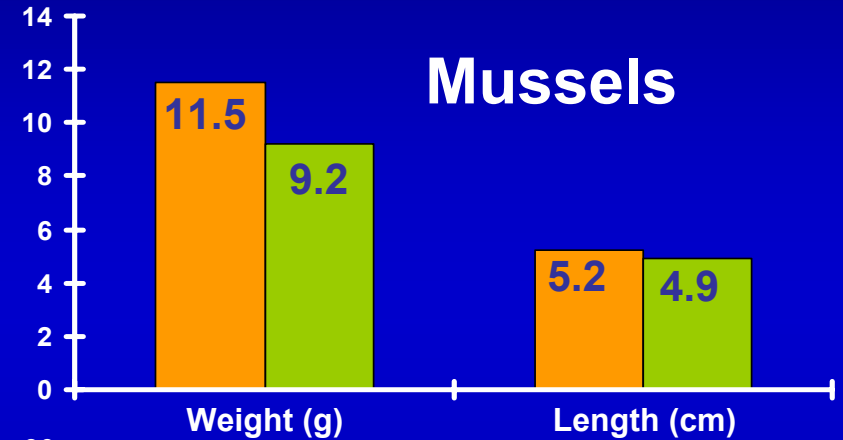
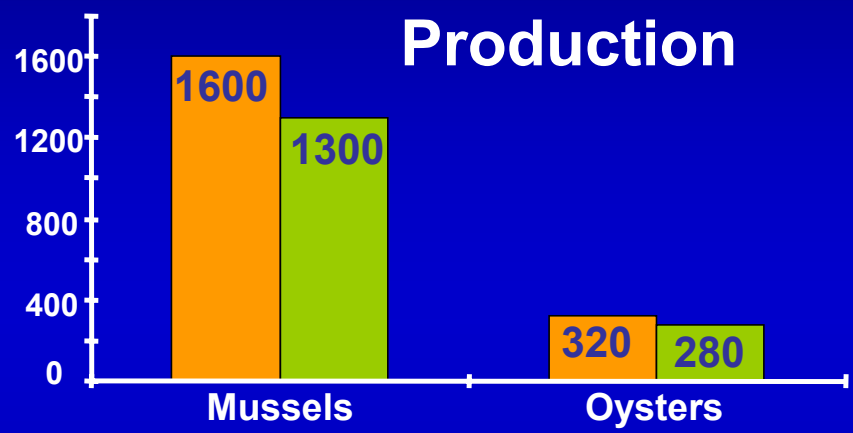
## Oysters



Due to differences in physiology, oysters are less sensitive to temperature increase than mussels.

# Carlingford Lough - Scenario with and without wild species

Without wild species  
With wild species



% reduction	Mussel	Oyster
Production	19%	12.5%
Individual weight	20%	24%
Individual length	5.8%	9.2%

**Both mussel and oyster production are higher when resource partitioning with wild species is not considered.**



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Go Links

# SMILE Products

- ✓ EcoWin2000 model installer
- ✓ Model files for the five loughs
- ✓ Winshell individual growth model
- ✓ All GIS projects
- ✓ BarcaWin2000 database installer
- ✓ All 10 databases (historical and project)
- ✓ SMILE book

File Edit View Favorites Tools Help

★ SMILE Products



SMILE  
SMILE PRODUCTS

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## SMILE PRODUCTS - RESTRICTED ACCESS

This page contains links to the various SMILE products. All these materials are downloadable, and can only be used under license from DARDNI.

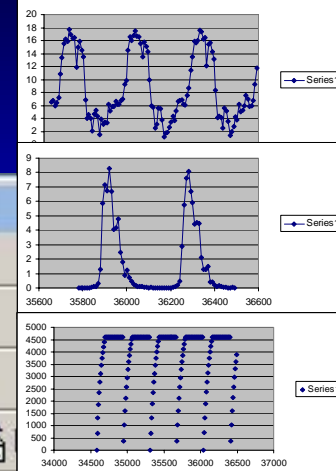
### DATABASES

To use the databases below, you need to download and install the BarcaWin2000 software, which is available [here](#). All the databases currently have the same username and password: **smile**

System	Records	File name and download link
Lough Foyle (historical)	27104	<a href="#">Historical DB Foyle.mdb</a>
Larne Lough (historical)	955	<a href="#">Historical DB Larne.mdb</a>
Belfast Lough (historical)	53170	<a href="#">Historical DB Belfast.mdb</a>
Strangford Lough (historical)	21658	<a href="#">Historical DB Strangford.mdb</a>
Carlingford Lough (historical)	39469	<a href="#">Historical DB Carlingford.mdb</a>
Lough Foyle (SMILE)	1519	<a href="#">Project DB Foyle.mdb</a>
Larne Lough (SMILE)	1405	<a href="#">Project DB Larne.mdb</a>
Belfast Lough (SMILE)	18144	<a href="#">Project DB Belfast.mdb</a>
Strangford Lough (SMILE)	16878	<a href="#">Project DB Strangford.mdb</a>
Carlingford Lough (SMILE)	5135	<a href="#">Project DB Carlingford.mdb</a>
Total	185437	

GEOGRAPHIC INFORMATION SYSTEMS

# Belfast Lough - EcoWin2000 Model 100 Year run – Performance data



EcoWin 2000

File Model Display Run Options Help

New model Open model Exit About Website

Defaults Objects Build model Sensitivity

Output wizard Table Time graph XY graph Surface plot Disk file

EcoWin controls

Model: Belfast Lough standard system

Belfast Lough standard system

- Objects
- State variables
- Forcing functions
- Parameters
- Boundaries
- Morphology

**Model status Finished**

Model run

Timestep (Minutes) 1752001  
 % executed 100  
 Simulation time 02:48:52

General information

Runtime (Days) 36500  
 Time (Days) 36500  
 Active objects 8  
 Forcing functions 20  
 State variables 53

100 year table

**Runs 100 years in under 3h, fully loaded, with a 30m timestep (over 1.5 million steps)**



# Technical developments



## 1GB Micro SD card

### Contains:

- ✓ EcoWin2000 model installer
- ✓ Model files for the five loughs
- ✓ Winshell individual growth model
- ✓ All GIS projects
- ✓ BarcaWin2000 database installer
- ✓ All 10 databases (historical and project)
- ✓ SMILE book

**EcoWin2000 – 64 bit processing on VISTA. Coming soon.**

**Upgrade from 32-bit architecture will significantly affect processing speed, models are expected to run at least twice as fast.**





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Links



## Final comments

- A brief methodology overview, together with detailed results, were presented for the application of ecological models to the five northern Irish Loughs, for the determination of sustainable carrying capacity for shellfish culture;
- More detailed models and results were shown for Carlingford, Strangford and Belfast loughs - exemplifications were shown for Larne and Foyle;
- **These models provide system-scale results - examples of scenario applications which can be tested included changes in culture practice, nutrient loading, water temperature rise and conservation aspects;**
- Ideas for the future include local-scale carrying capacity work, improved catchment modelling (carried out for Foyle in SMILE) and socio-economic work;
- The SMILE team are indebted to all of you, and very specially to the producers. We hope these products will be of practical value to industry and management. For a brief timeline, I suggest a 5 minute movie.

<http://www.ecowin.org/smile/>