GEM – Geochemical and Ecological Modelling

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To investigate sustainable biological carrying capacities of key European coastal zones

KeyZones

Clew Bay
FARM™ screening model results

http://www.keyzones.org

A. Sequeira, J.G. Ferreira
A. J. S. Hawkins

KeyZones Stakeholders Meeting
Dublin 11th July 2007

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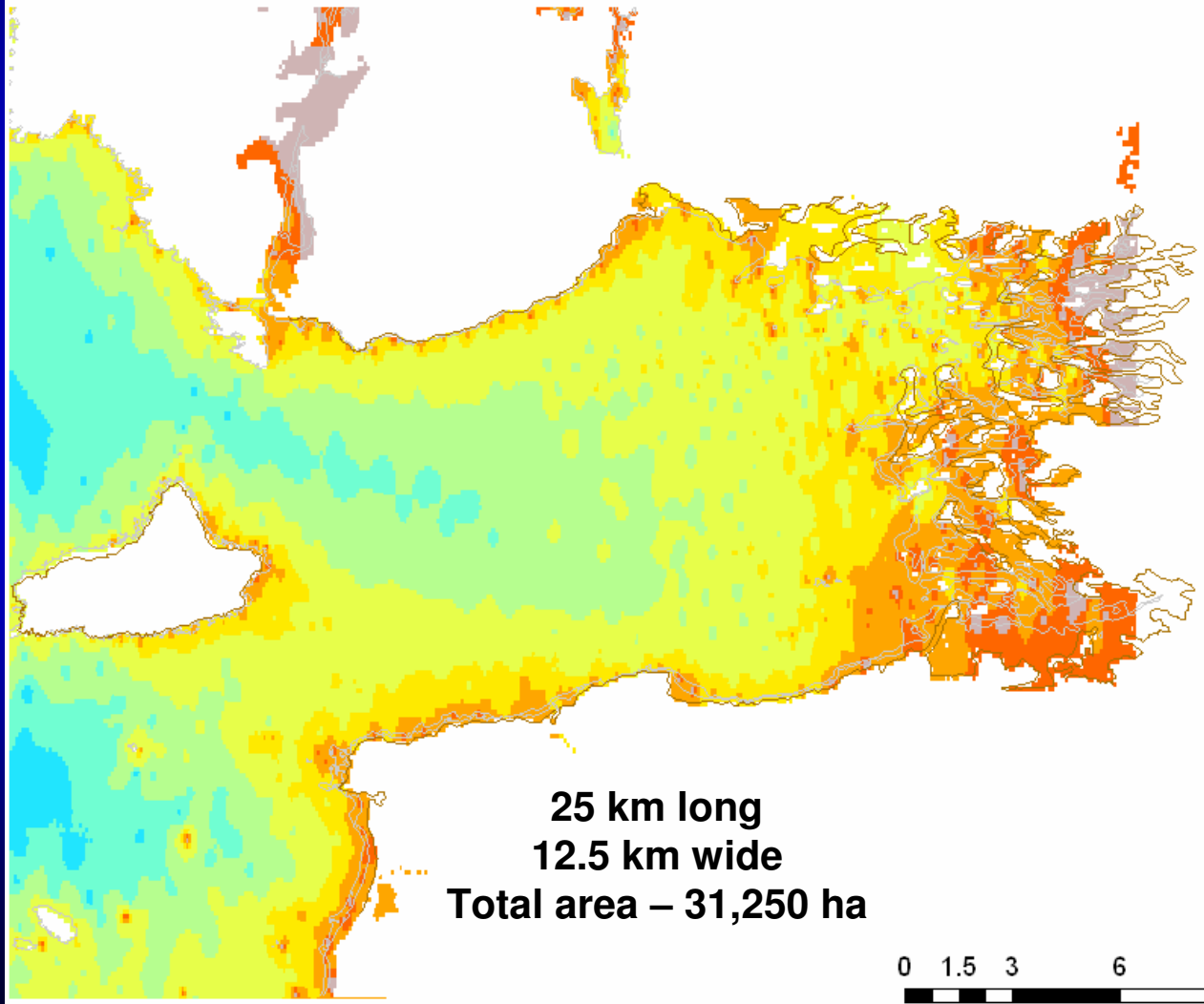
Clew Bay - Bathymetry



N

Coast line
0 m

Depth (m)

0 - 1
1 - 2
2 - 5
5 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50- 60
60 - 70
70 - 93

25 km long
12.5 km wide
Total area – 31,250 ha

0 1.5 3 6 9 12

Kilometers

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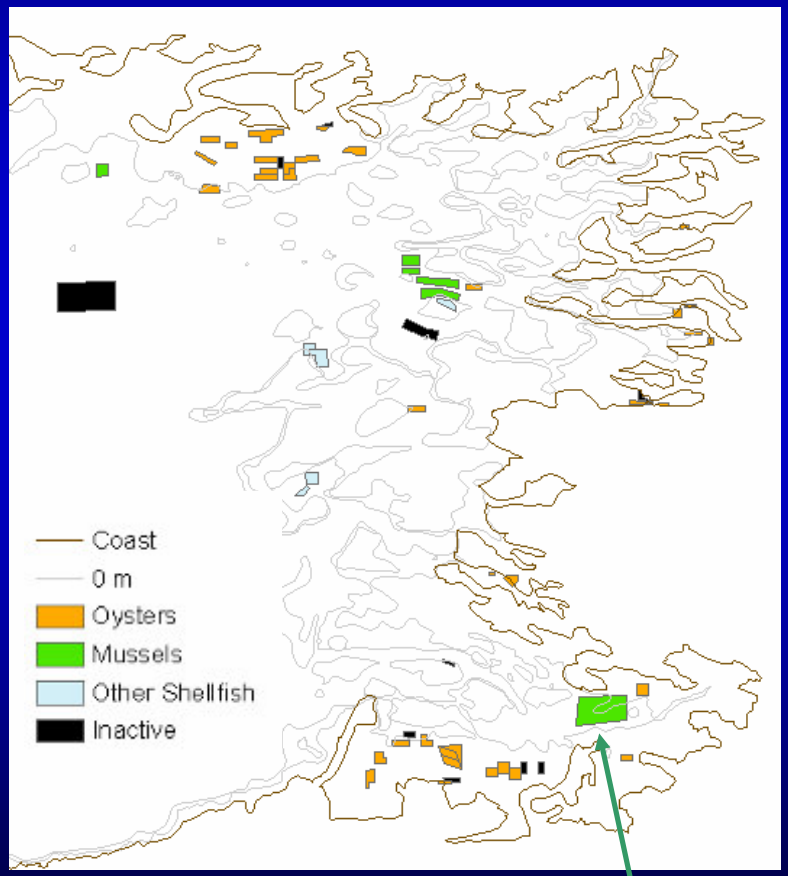
Clew Bay – Shellfish aquaculture areas



Bottom mussels

- Shellfish aquaculture areas:
  - Mussels: ~75 ha (0.24 % of bay)
    - Rope: 37.3 ha
    - Bottom: 37.5 ha
  - Oysters (trestles): 103.4 ha (0.33% of bay)
  - Other shellfish: ~20 ha (0.06% of bay)

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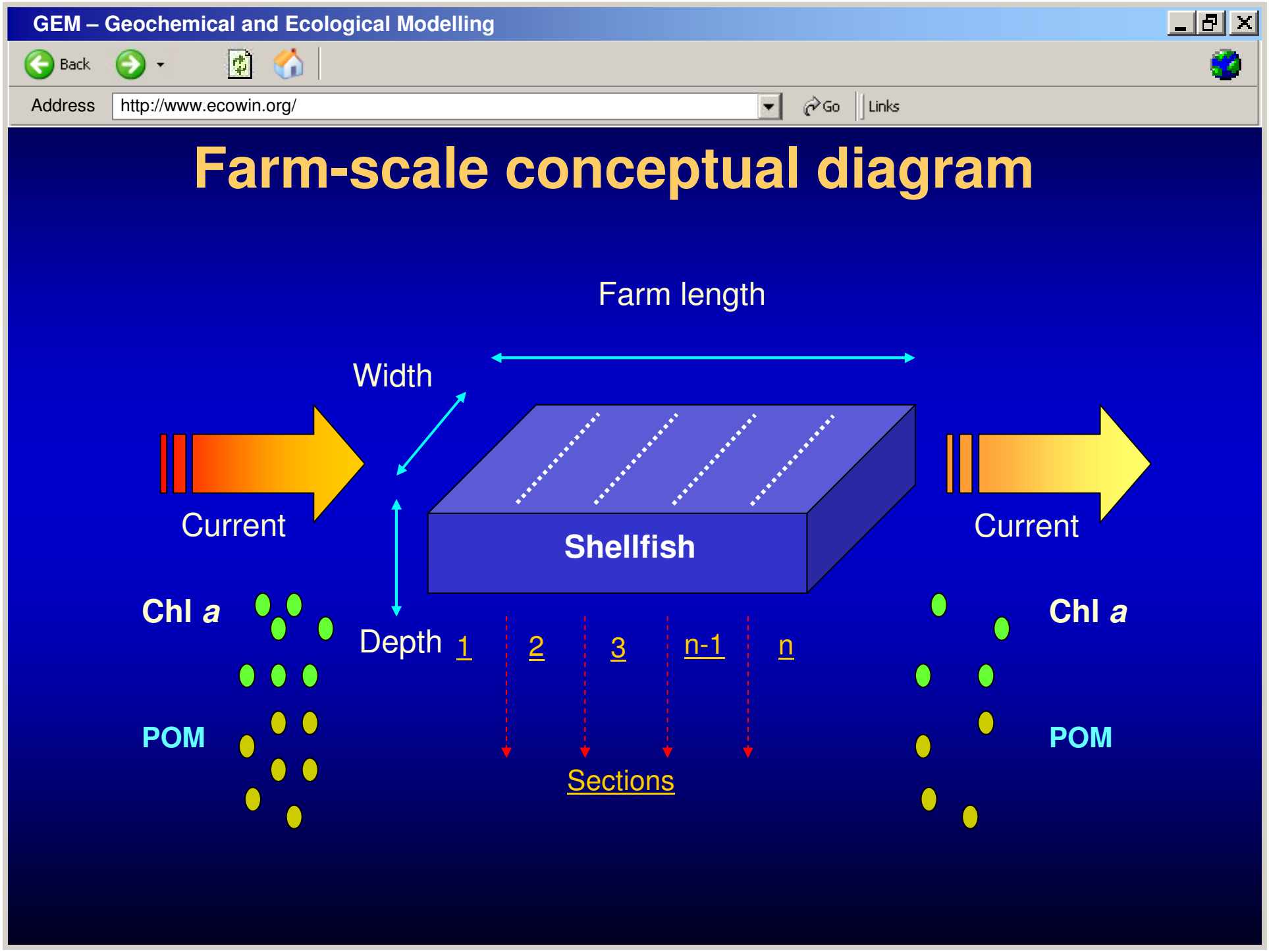
Modelling farm-scale food depletion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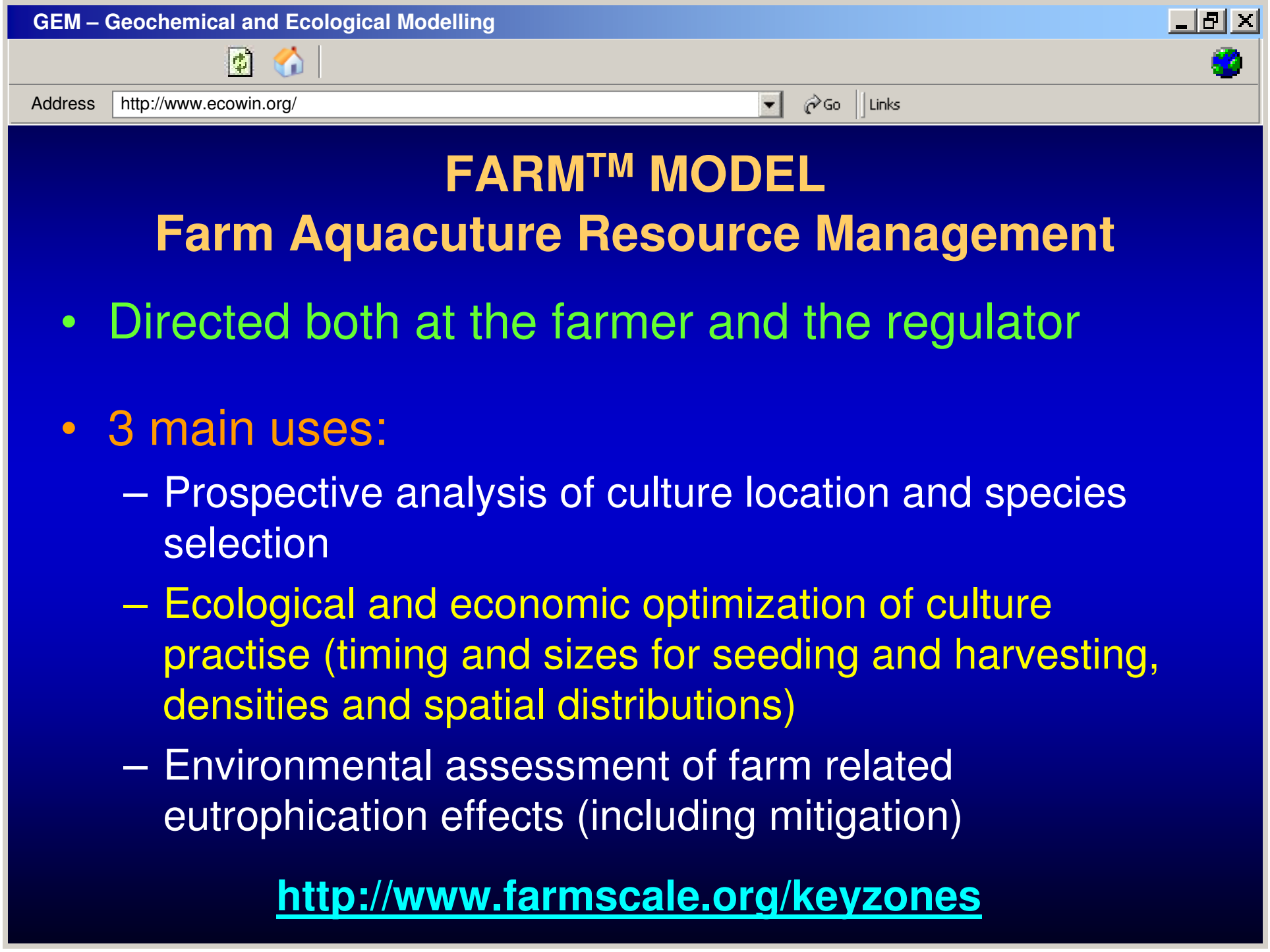
Farm-scale conceptual diagram
Farm length
Width
Current
Shellfish
Current
Chl a
Depth
1
2
3
n-1
n
Chl a
POM
POM
Sections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FARM™ MODEL
Farm Aquaculture Resource Management
• Directed both at the farmer and the regulator
• 3 main uses:
– Prospective analysis of culture location and species selection
– Ecological and economic optimization of culture practise (timing and sizes for seeding and harvesting, densities and spatial distributions)
– Environmental assessment of farm related eutrophication effects (including mitigation)
http://www.farmscale.org/keyzones

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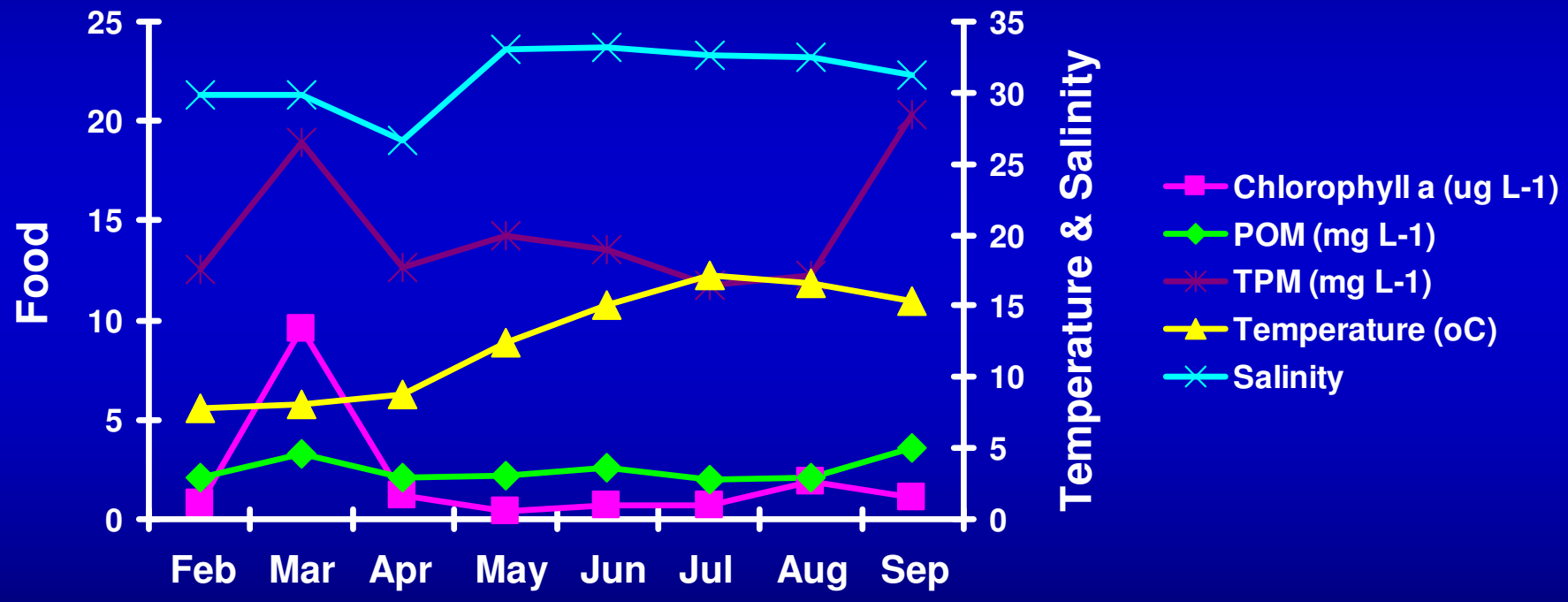
FARM model – Growth drivers



- Drivers
  - field data from the KEYZONES project measured at Inishcarrick (Clew Bay North) – mean values per day

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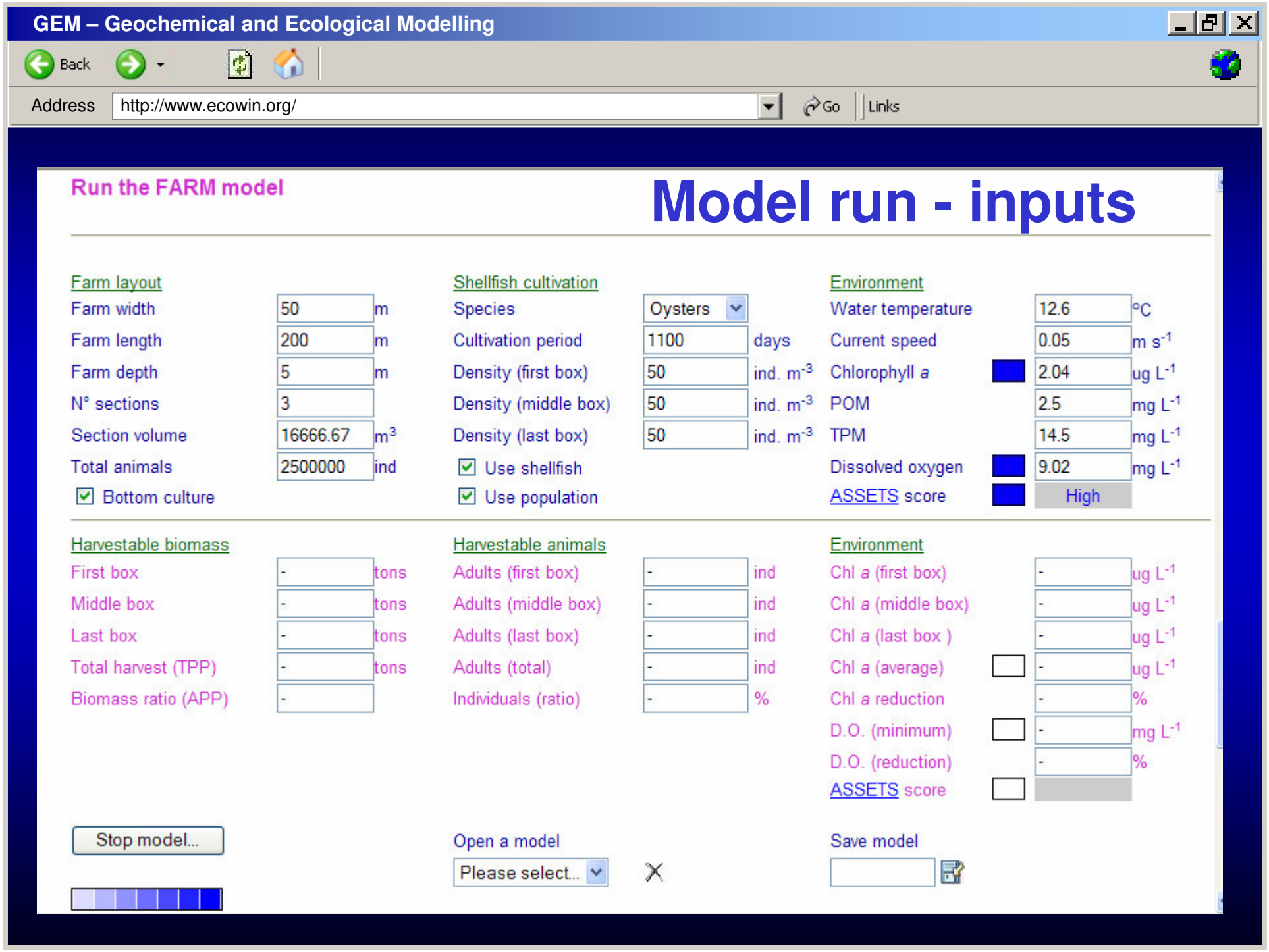
FARM model - Drivers

Farm **Clew Bay North**	**Dimensions (m)** **50X200 (X5) (x10)**		**Cultivation** **1100 days**
Food	**Chl *a* (μg L^{-1})** **Time series**	**POM (mg L^{-1})** **Time series**	**TPM (mg L^{-1})** **Time series**
Environment	**Current (m s^{-1})** **0.05**	**T (° C)** **Time series**	**O_2 (mg L^{-1})** **9.02**

	Species	**Species**
	Oyster *C. gigas*	**Mussel *M. edulis***
Cultivation	**Standard (1 ha)**	**Standard (1 ha)**
Density (ind m^{-3}) **Sections 1,2,3**	**50 (all)**	**50 (all)**
Total seed (X10^3 ind)	**2500**	**5000**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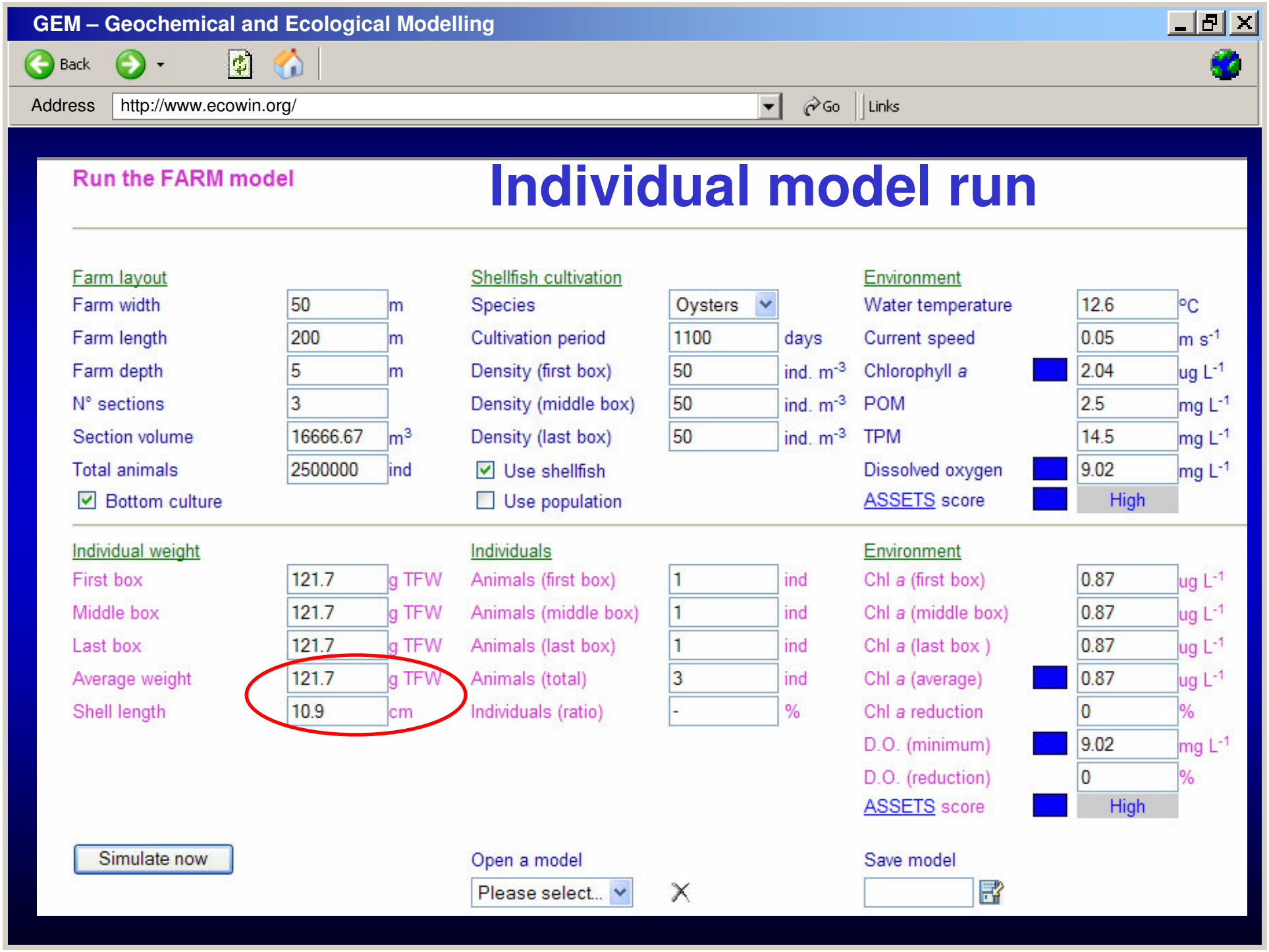
Links
Run the FARM model
Model run - inputs
Farm layout
Farm width 50 m
Farm length 200 m
Farm depth 5 m
N° sections 3
Section volume 16666.67 m3
Total animals 2500000 ind
Bottom culture
Shellfish cultivation
Species Oysters
Cultivation period 1100 days
Density (first box) 50 ind. m-3
Density (middle box) 50 ind. m-3
Density (last box) 50 ind. m-3
Use shellfish
Use population
Environment
Water temperature 12.6 °C
Current speed 0.05 m s-1
Chlorophyll a 2.04 ug L-1
POM 2.5 mg L-1
TPM 14.5 mg L-1
Dissolved oxygen 9.02 mg L-1
ASSETS score High
Harvestable biomass
First box - tons
Middle box - tons
Last box - tons
Total harvest (TPP) - tons
Biomass ratio (APP) -
Harvestable animals
Adults (first box) - ind
Adults (middle box) - ind
Adults (last box) - ind
Adults (total) - ind
Individuals (ratio) - %
Environment
Chl a (first box) - ug L-1
Chl a (middle box) - ug L-1
Chl a (last box) - ug L-1
Chl a (average) - ug L-1
Chl a reduction - %
D.O. (minimum) - mg L-1
D.O. (reduction) - %
ASSETS score
Stop model...
Open a model
Please select..
Save model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Run the FARM model
Individual model run
Farm layout
Farm width 50 m
Farm length 200 m
Farm depth 5 m
N° sections 3
Section volume 16666.67 m3
Total animals 2500000 ind
Bottom culture
Shellfish cultivation
Species Oysters
Cultivation period 1100 days
Density (first box) 50 ind. m-3
Density (middle box) 50 ind. m-3
Density (last box) 50 ind. m-3
Use shellfish
Use population
Environment
Water temperature 12.6 °C
Current speed 0.05 m s-1
Chlorophyll a 2.04 ug L-1
POM 2.5 mg L-1
TPM 14.5 mg L-1
Dissolved oxygen 9.02 mg L-1
ASSETS score High
Individual weight
First box 121.7 g TFW
Middle box 121.7 g TFW
Last box 121.7 g TFW
Average weight 121.7 g TFW
Shell length 10.9 cm
Individuals
Animals (first box) 1 ind
Animals (middle box) 1 ind
Animals (last box) 1 ind
Animals (total) 3 ind
Individuals (ratio) - %
Environment
Chl a (first box) 0.87 ug L-1
Chl a (middle box) 0.87 ug L-1
Chl a (last box) 0.87 ug L-1
Chl a (average) 0.87 ug L-1
Chl a reduction 0 %
D.O. (minimum) 9.02 mg L-1
D.O. (reduction) 0 %
ASSETS score High
Simulate now
Open a model
Please select...
Save model

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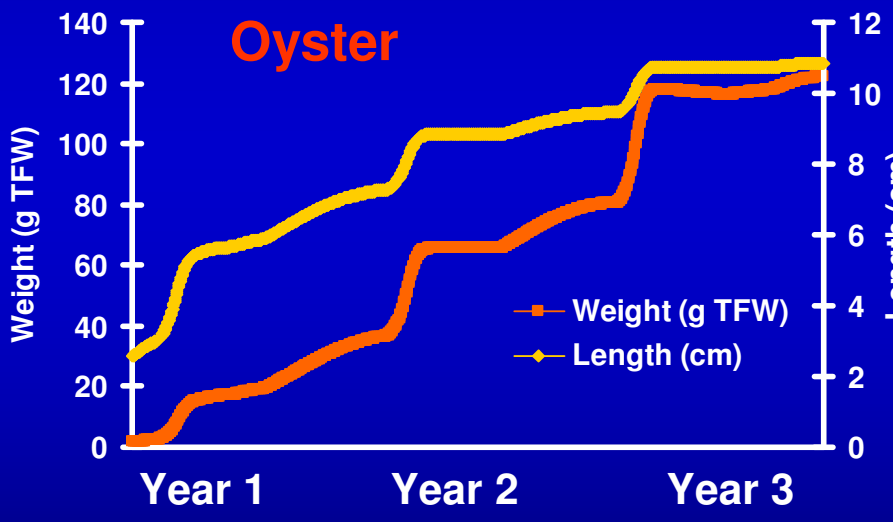
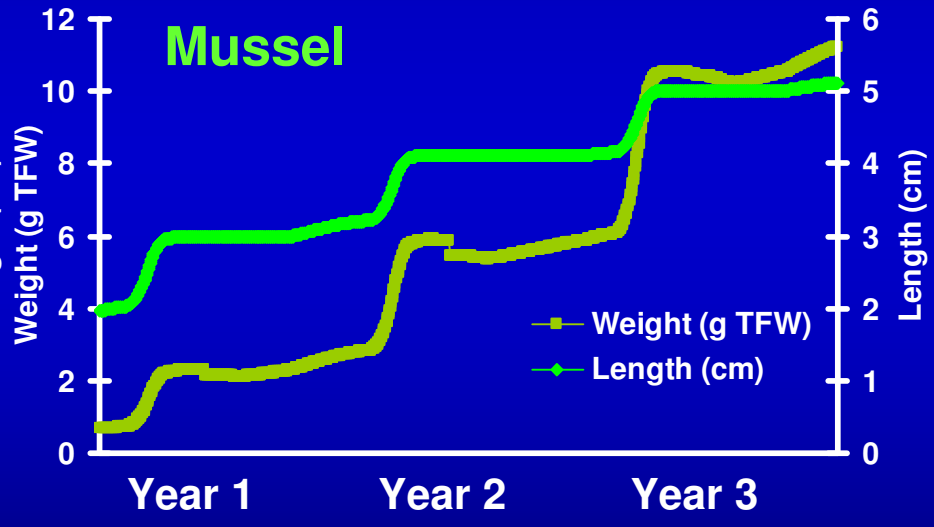
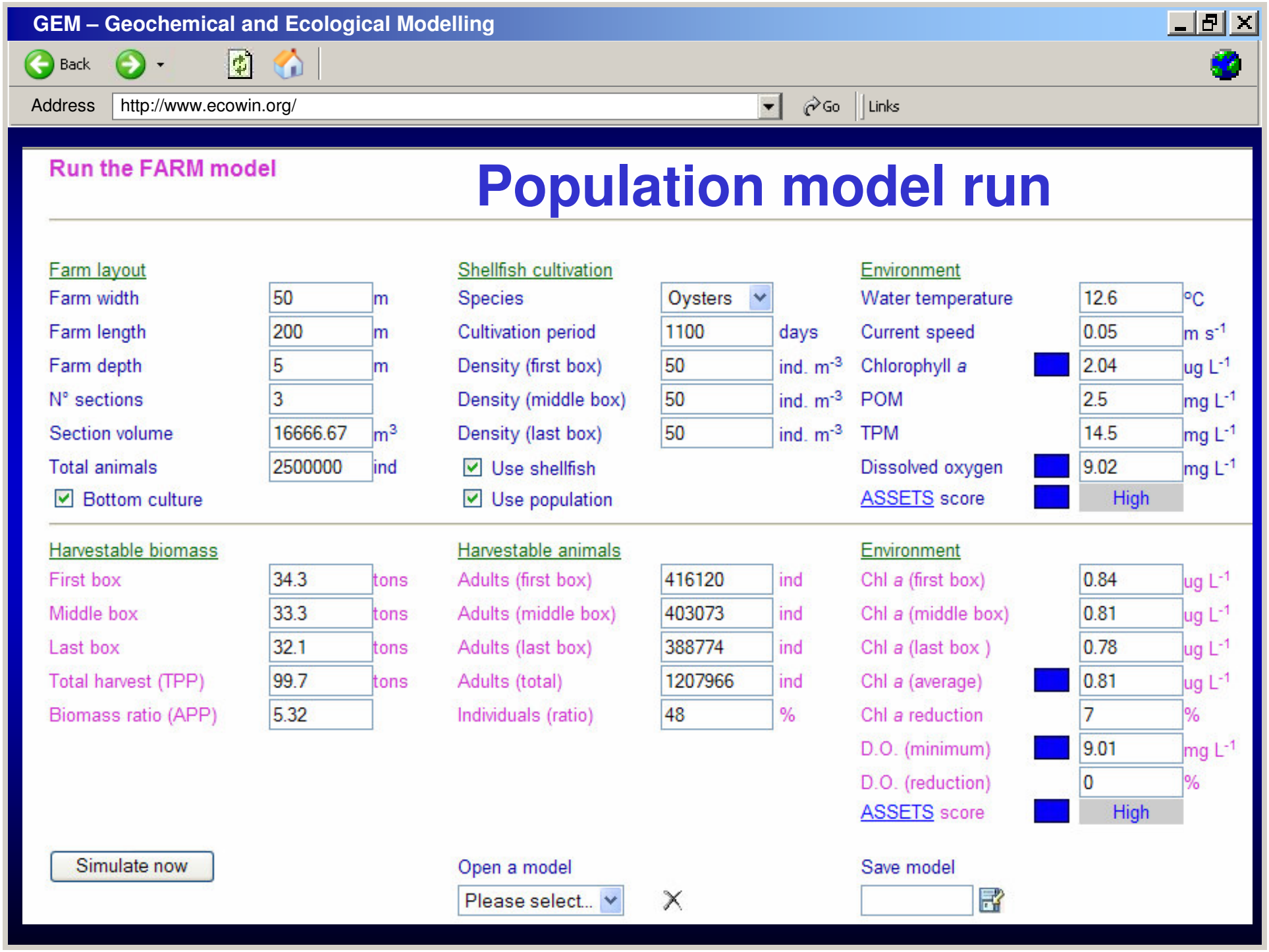
Integration of FARM and ShellSIM models

- Individual growth was simulated by ShellSIM using the same set of drivers
- In the ShellSIM model only 1 animal was considered, growing in 1m^3 of water





Model	Weight (g)	Length (cm)	Weight (g)	Length (cm)
FARM	121.7	10.9	11.3	5.1
ShellSIM	122.1	10.86	11.21	5.12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Address
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Links
Run the FARM model
Population model run
Farm layout
Farm width 50 m
Farm length 200 m
Farm depth 5 m
N° sections 3
Section volume 16666.67 m3
Total animals 2500000 ind
Bottom culture
Shellfish cultivation
Species Oysters
Cultivation period 1100 days
Density (first box) 50 ind. m-3
Density (middle box) 50 ind. m-3
Density (last box) 50 ind. m-3
Use shellfish
Use population
Environment
Water temperature 12.6 °C
Current speed 0.05 m s-1
Chlorophyll a 2.04 ug L-1
POM 2.5 mg L-1
TPM 14.5 mg L-1
Dissolved oxygen 9.02 mg L-1
ASSETS score High
Harvestable biomass
First box 34.3 tons
Middle box 33.3 tons
Last box 32.1 tons
Total harvest (TPP) 99.7 tons
Biomass ratio (APP) 5.32
Harvestable animals
Adults (first box) 416120 ind
Adults (middle box) 403073 ind
Adults (last box) 388774 ind
Adults (total) 1207966 ind
Individuals (ratio) 48 %
Environment
Chl a (first box) 0.84 ug L-1
Chl a (middle box) 0.81 ug L-1
Chl a (last box) 0.78 ug L-1
Chl a (average) 0.81 ug L-1
Chl a reduction 7 %
D.O. (minimum) 9.01 mg L-1
D.O. (reduction) 0 %
ASSETS score High
Simulate now
Open a model
Please select..
Save model

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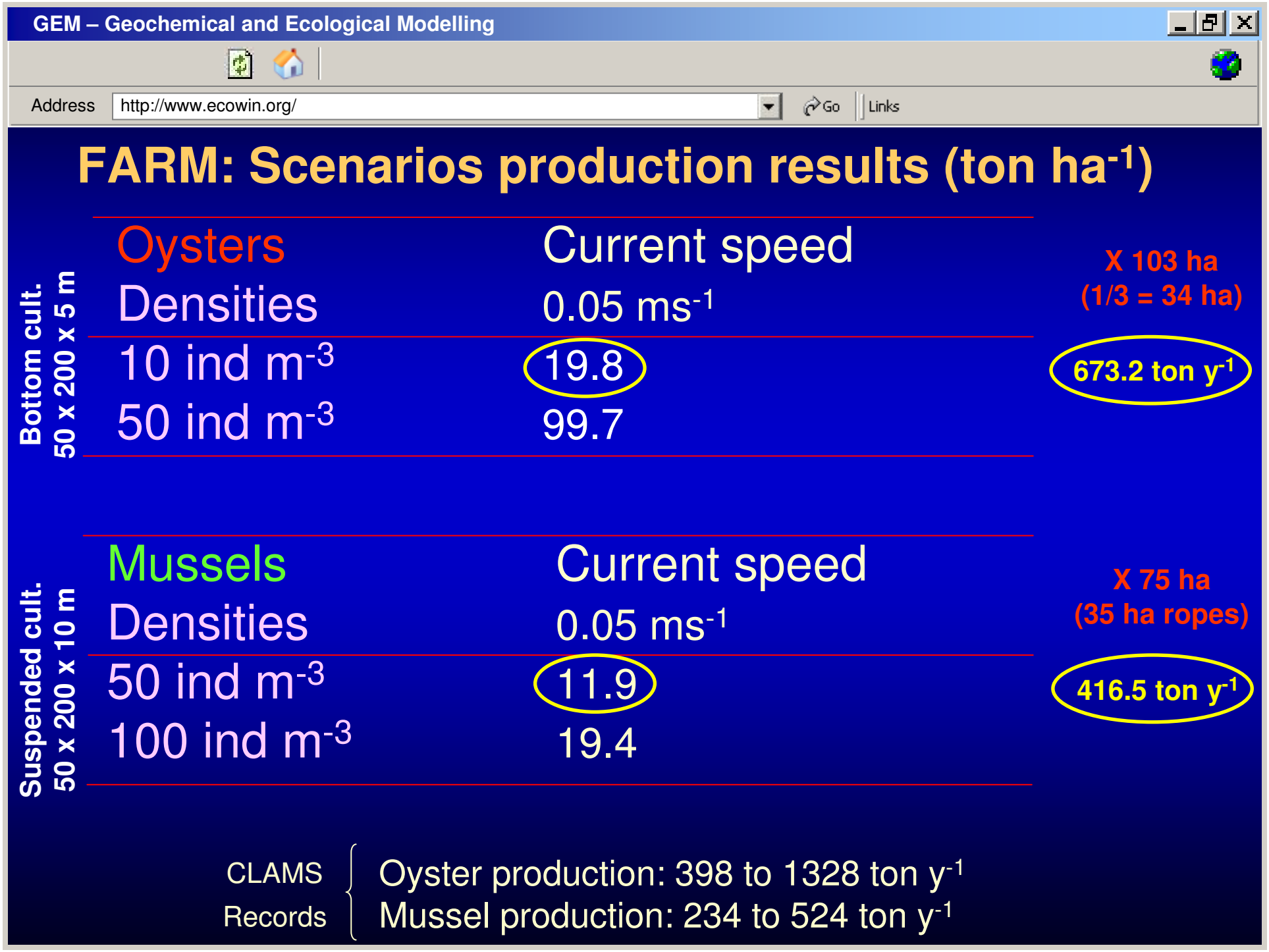
FARM model - Outputs

	OYSTERS Bottom culture	MUSSELS Suspended culture
Cultivation scenario	Standard	Standard
Density (ind m^{-3}) Sections 1,2,3	50 (all)	50 (all)
Area seeded	1 ha (5 m depth)	1 ha (10 m depth)
Total harvest (ton TFW)	99.7	11.9
APP	5.32	2.38
Final mean Chl *a* (µg L^{-1})	0.81	0.83
Final mean O2 (mg L-1)	9.01	9.01
ASSETS score	High	High
Income (k€ year 2000)	131.7	7.1

No changes in the ASSETS score because color was already blue (WFD - High).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FARM: Scenarios production results (ton ha-1)
Bottom cult.
50 x 200 x 5 m
Oysters
Densities
Current speed
0.05 ms-1
10 ind m-3
19.8
50 ind m-3
99.7
X 103 ha
(1/3 = 34 ha)
673.2 ton y-1
Suspended cult.
50 x 200 x 10 m
Mussels
Densities
Current speed
0.05 ms-1
50 ind m-3
11.9
100 ind m-3
19.4
X 75 ha
(35 ha ropes)
416.5 ton y-1
CLAMS
Records
Oyster production: 398 to 1328 ton y-1
Mussel production: 234 to 524 ton y-1

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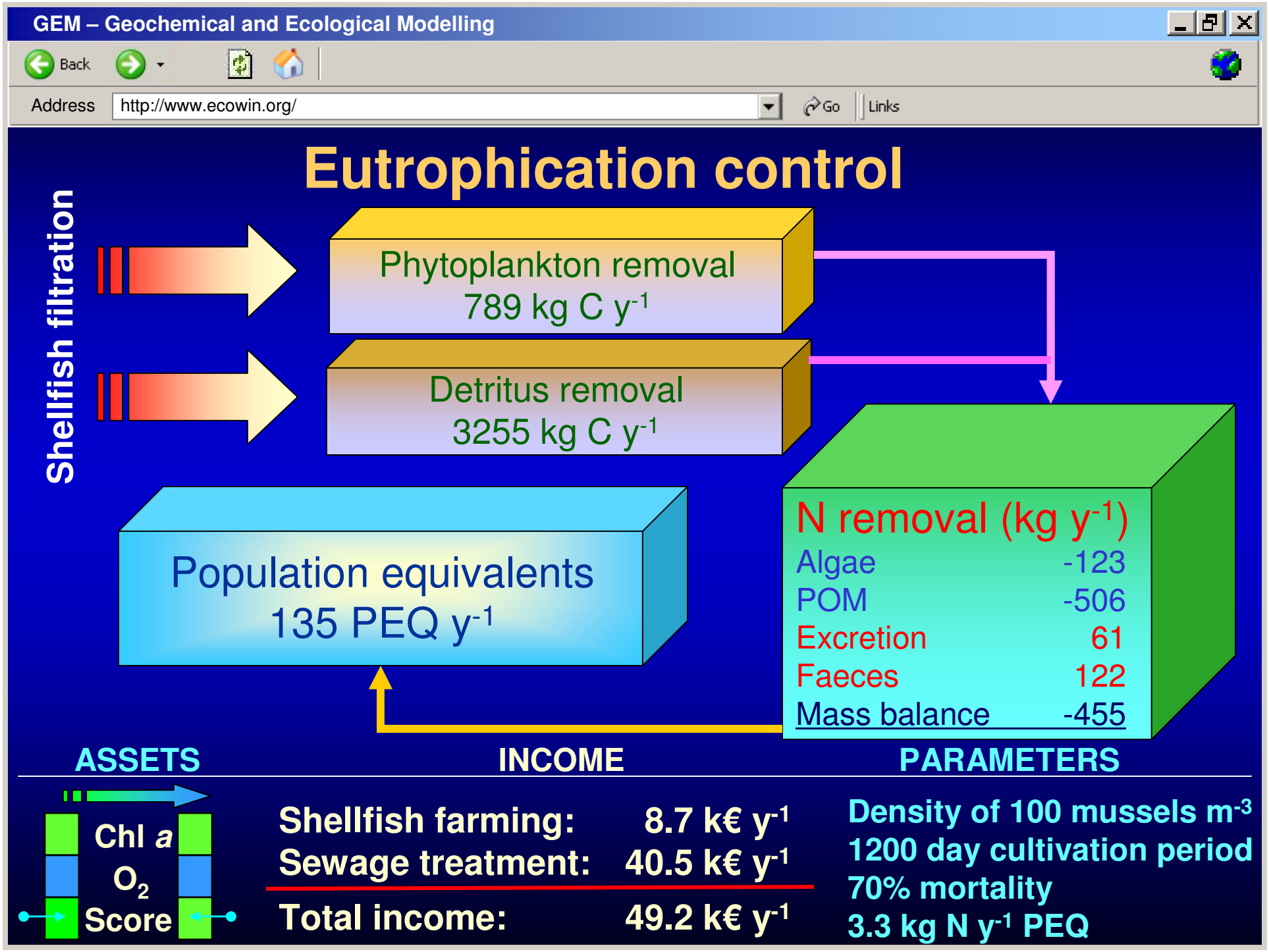
Results – ASSETS model

WFD

Farm	Dimensions (m)	Species	Cultivation (d)
	300X20X5	*M. edulis*	1200
Food	Chl *a* (μg L^{-1})	POM (mg L^{-1})	TPM (mg L^{-1})
	Time series	Time series	Time series
Environment	Current (m s^{-1})	T (° C)	O_2 (mg L^{-1})
	0.1	Time series	8.6
Cultivation scenario	**Low**	**Medium**	**High**
Density (ind m^{-3})	**25 (all)**	**100 (all)**	**300 (all)**
Total seed (X10^3 ind)	750	3000	9000
Total harvest (TFW)	1.2	3.8	7.6
Final mean Chl *a* (μg L^{-1})	8.9	8.7	8.4
Final min. O_2(mg L^{-1})	8.6	8.6	8.6
ASSETS grade	Good	Good	Good
Income (k€)	9	28.5	57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Eutrophication control
Shellfish filtration
Phytoplankton removal
789 kg C y-1
Detritus removal
3255 kg C y-1
Population equivalents
135 PEQ y-1
N removal (kg y-1)
Algae -123
POM -506
Excretion 61
Faeces 122
Mass balance -455
ASSETS
INCOME
PARAMETERS
Chl a
O2
Score
Shellfish farming: 8.7 k€ y-1
Sewage treatment: 40.5 k€ y-1
Total income: 49.2 k€ y-1
Density of 100 mussels m-3
1200 day cultivation period
70% mortality
3.3 kg N y-1 PEQ

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Synthesis

- FARM is directed both at the farmer and the regulator, and its application in KEYZONES fits in well with the project objectives;
- The seamless integration of ASSETS, allowing eutrophication assessment using a subset of primary and secondary symptoms, means that FARM is effectively a sreening model both for shellfish productivity and water quality;
- The model's deceptively simple interface hides complex internal processing, including transport equations, shellfish individual growth, population dynamics and dissolved oxygen balance;
- The Clew Bay FARM model has been implemented as a web-based client-server application and is available at:

http://www.farmscale.org/keyzones

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To investigate sustainable biological carrying capacities of key European coastal zones

KeyZones

Loch Creran
EcoWin2000 model results

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KeyZones Stakeholders Meeting
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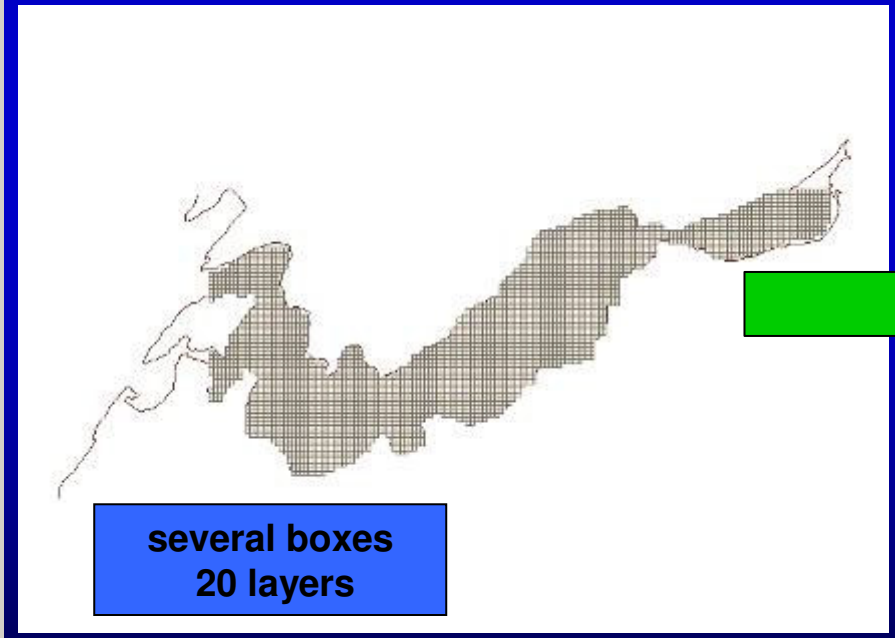
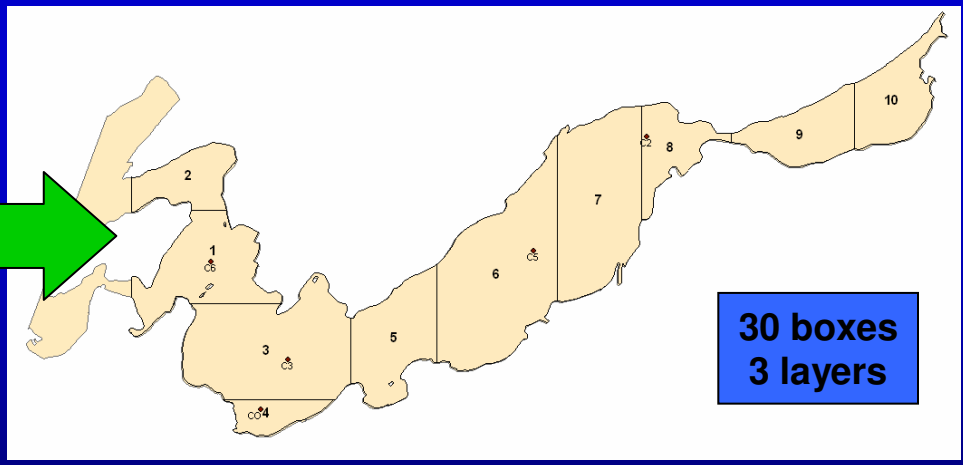
Loch Creran – Model upscalling

Delft3D
Hydrodynamic model

EcoWin2000
Ecological model



several boxes
20 layers



30 boxes
3 layers

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

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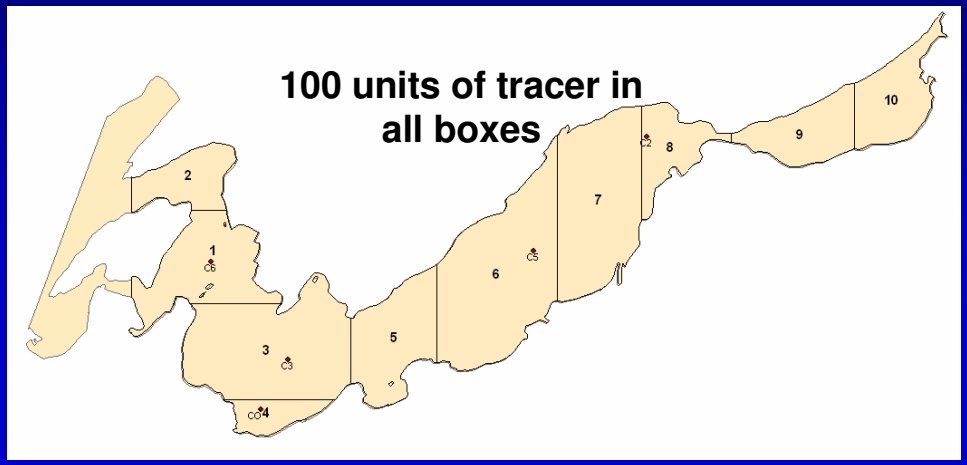
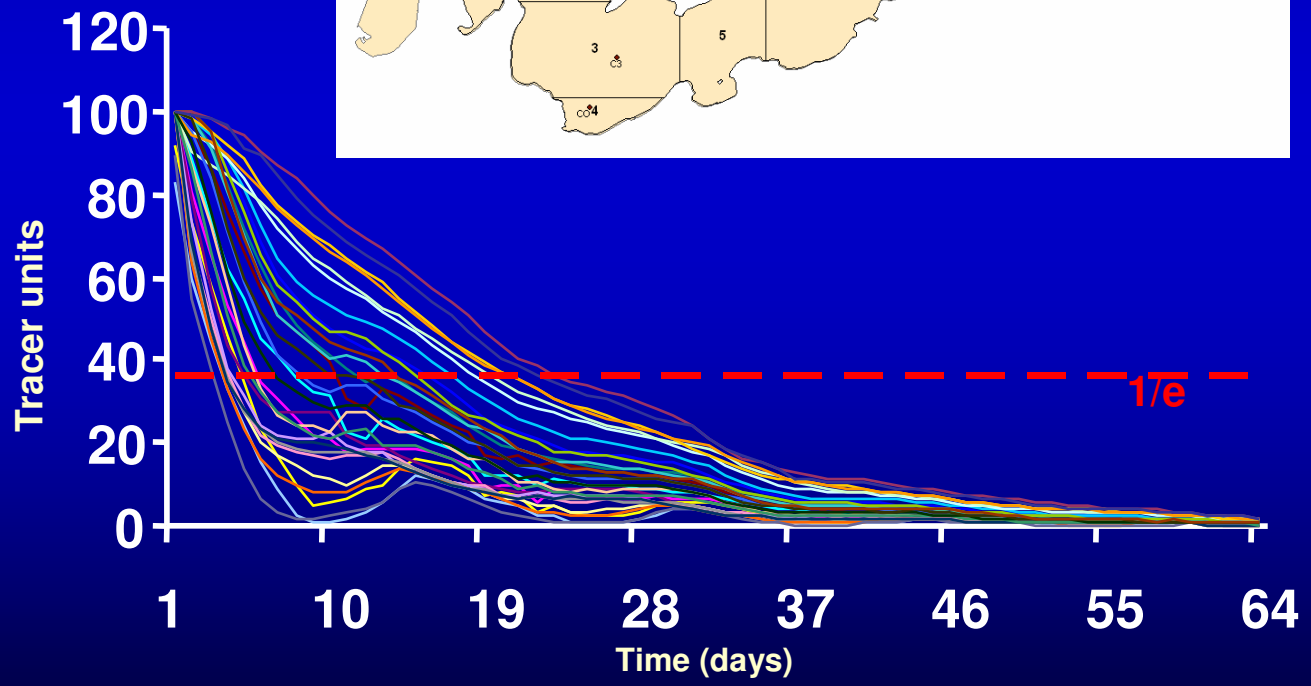
Loch Creran residence time

EcoWin2000 model



Water residence time

e.g. 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%



e-folding time: 3 to 23 days

Total residence time – 9.5 days

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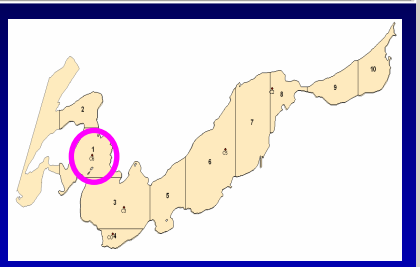
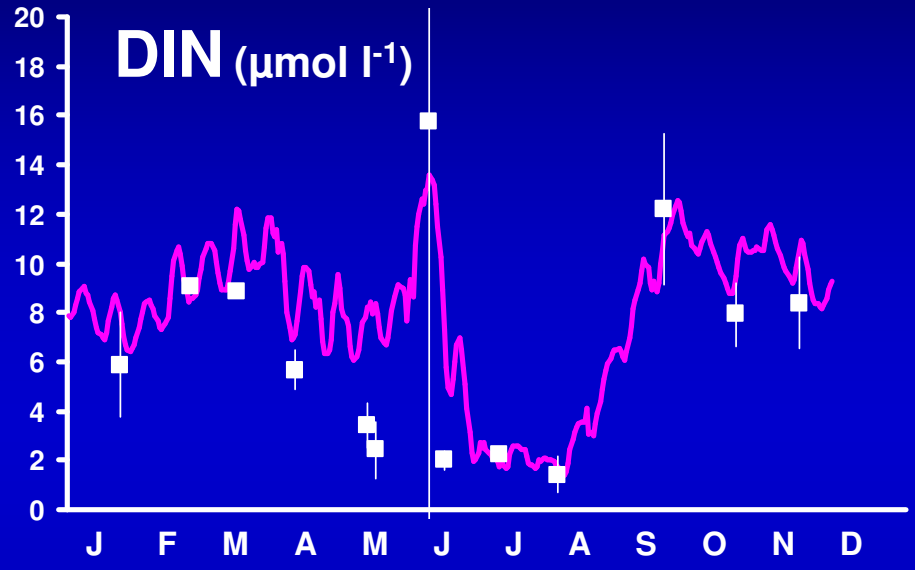
Box 1 – Loch entrance

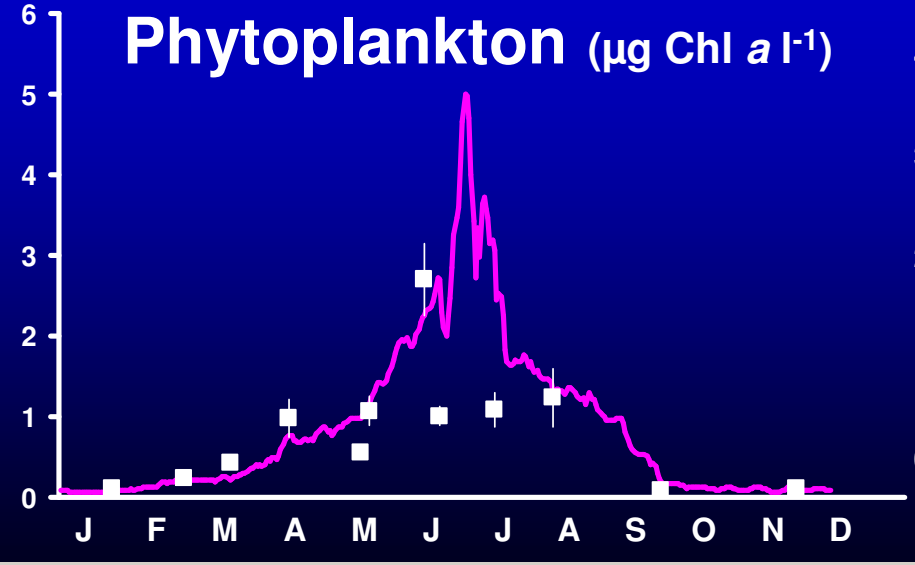


DIN (µmol l^{-1})

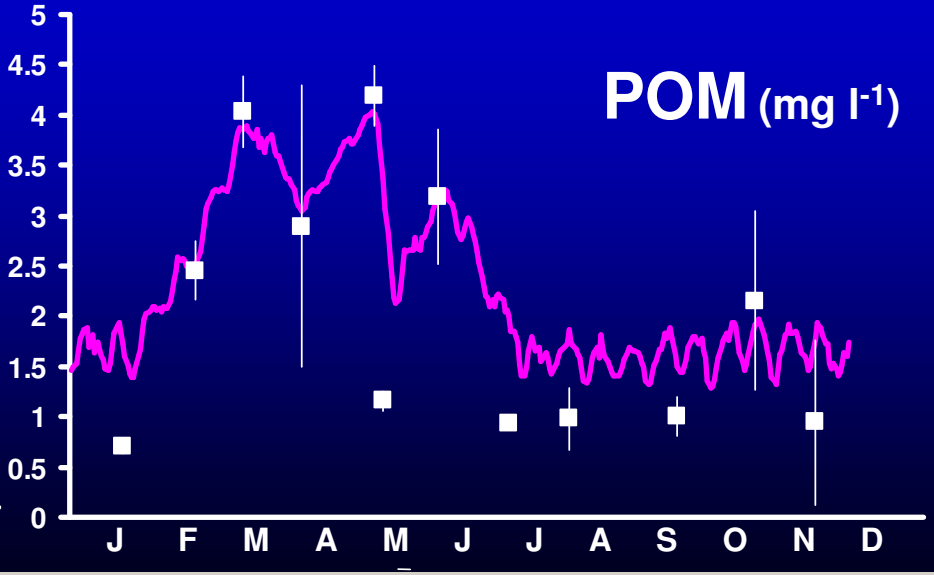


SPM (mg l^{-1})

Phytoplankton (µg Chl *a* l^{-1})



POM (mg l^{-1})



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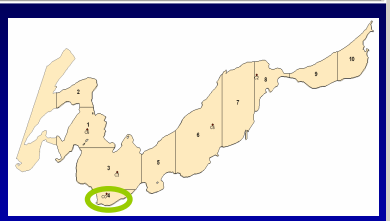
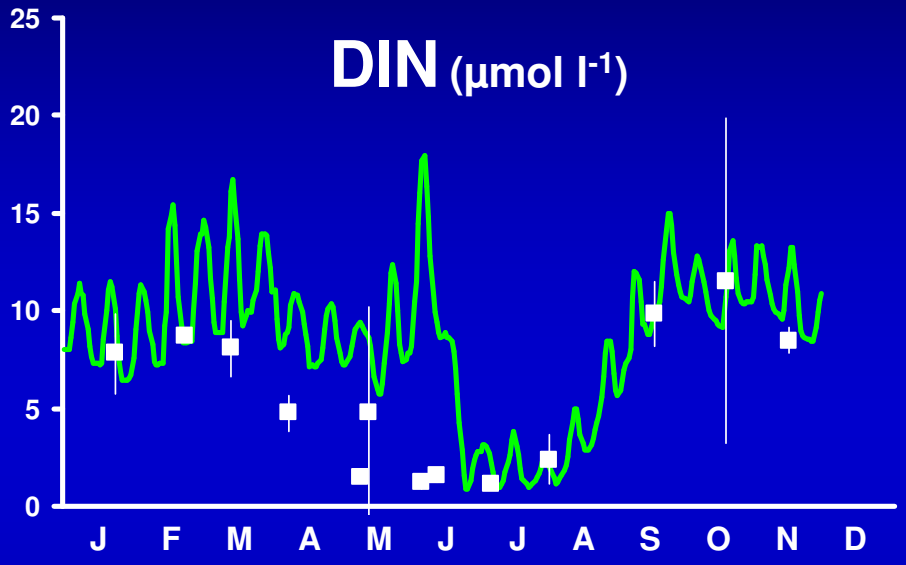
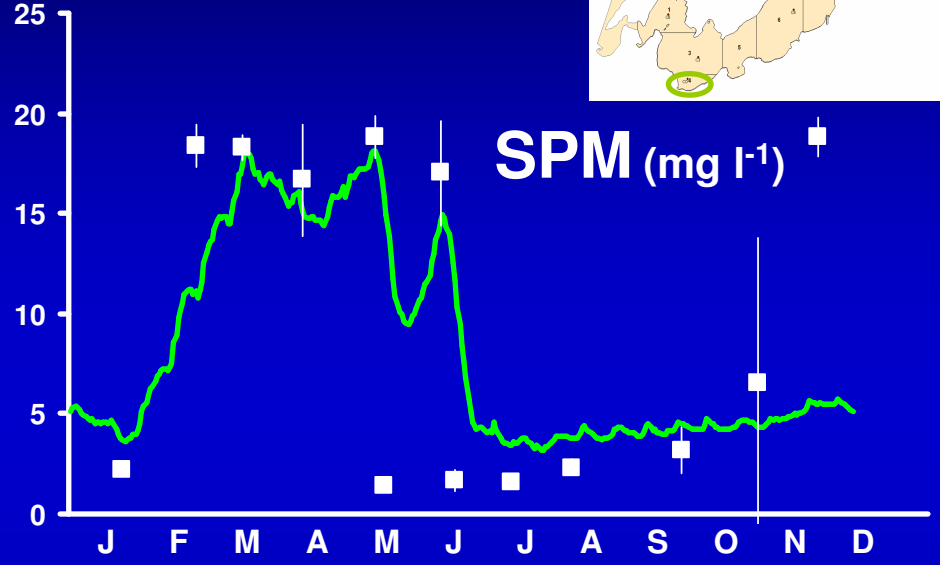
Box 4 – Oyster Farm



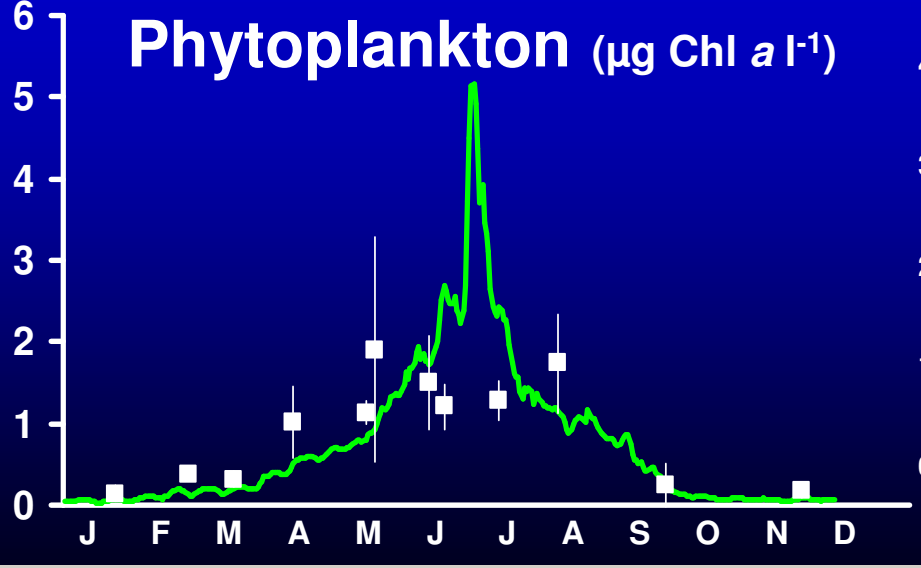
DIN (µmol l^{-1})



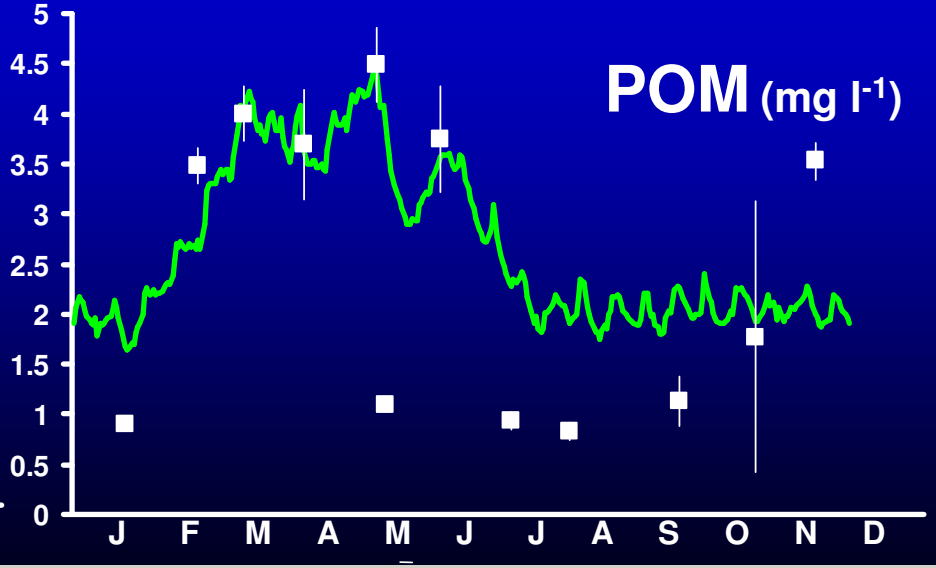
SPM (mg l^{-1})



Phytoplankton (µg Chl *a* l^{-1})



POM (mg l^{-1})



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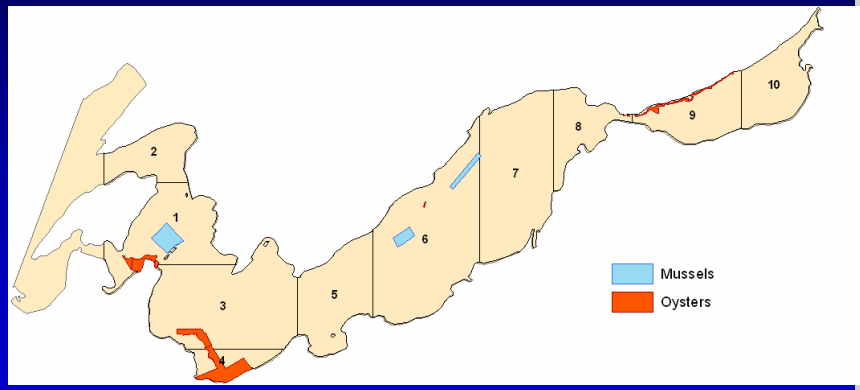
Loch Creran – Aquacultures

Cultivated species:

M → Blue mussel (*Mytilus edulis*)

O → Pacific oyster (*Crassostrea gigas*)



Box	Area (ha)	Aquaculture (ha)	% of box
1 (M)	150.2	10.4	6.9
1 (O)	150.2	5.9	3.9
3 (O)	263.4	5.4	2.05
4 (O)	51.5	16.5	32
6 (M)	295.1	4.54 + 3.88	28.9
6 (O)	295.1	0.1	0.03
8 (O)	78.3	0.06	0.08
9 (O)	105.0	3.5	3.3

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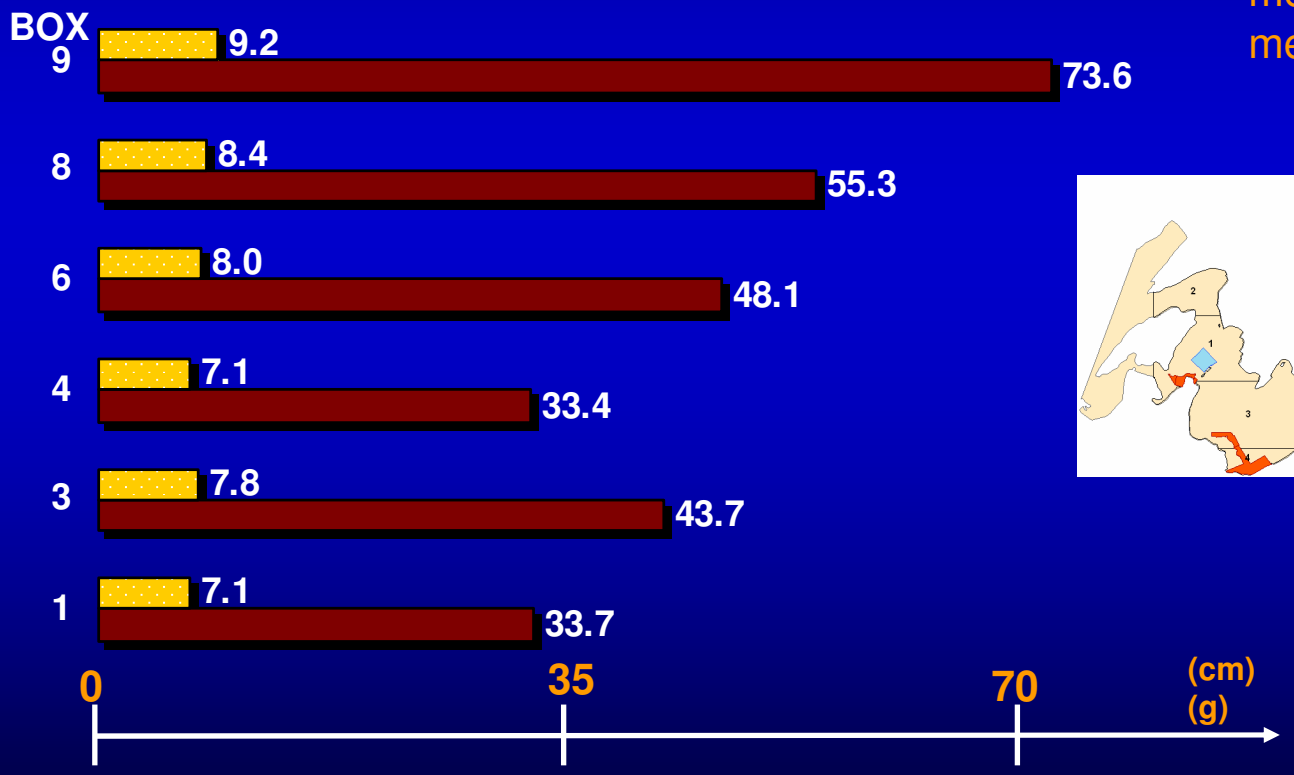
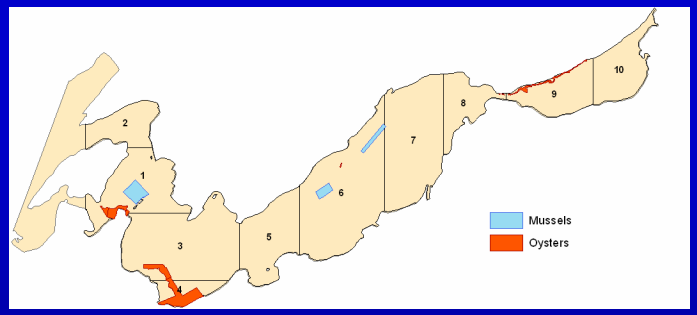
Loch Creran - Oyster
Individual length and weight

Oysters
mean length ~ 8 cm
mean weight ~ 50 g





Length (cm)

Weight (g)

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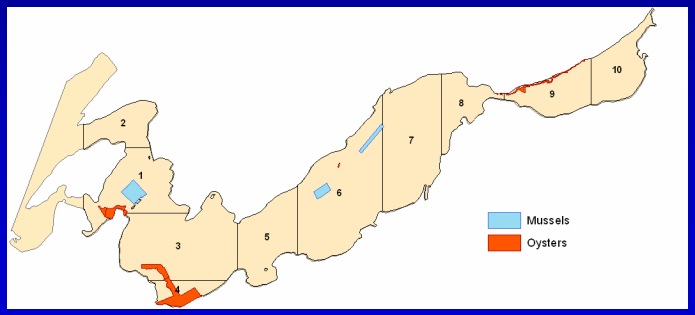
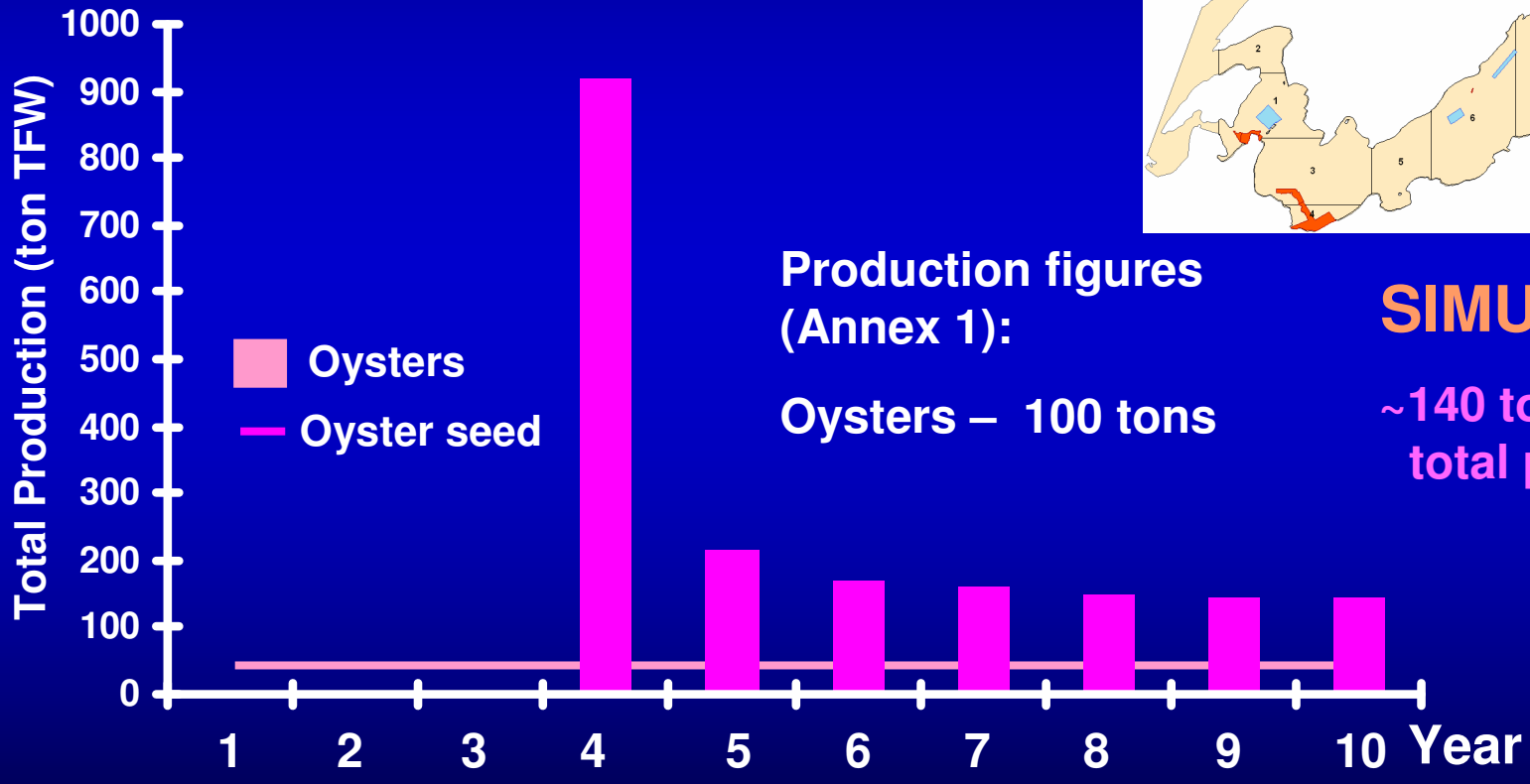
Loch Creran – EcoWin2000 model
Total oyster production - 10 year simulation





Production figures (Annex 1):

Oysters – 100 tons

SIMULATION:

~140 ton for Oyster total production

Model starts stabilising arround year 6, due to simulation of crop rotation.
Results shown for production values correspond to in year 10.

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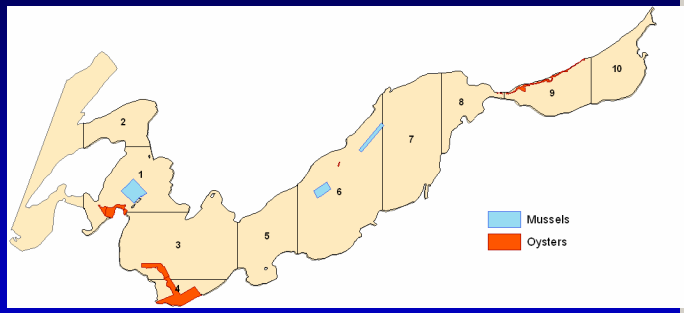
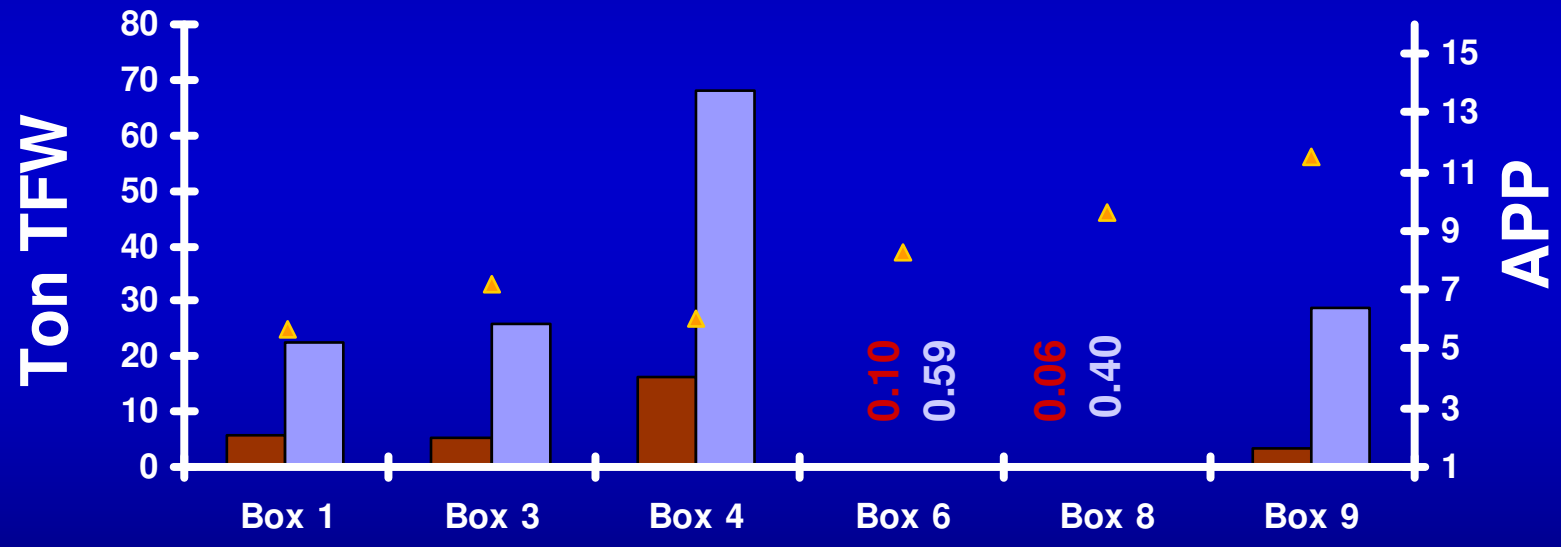
Loch Creran – EcoWin2000 model
Oysters : total seed and total harvest
(Stable model - year 10)





APP

Seeded

Harvested

Weight at harvest	> 50 g
Total production	~ 140 ton
APP	~ 8

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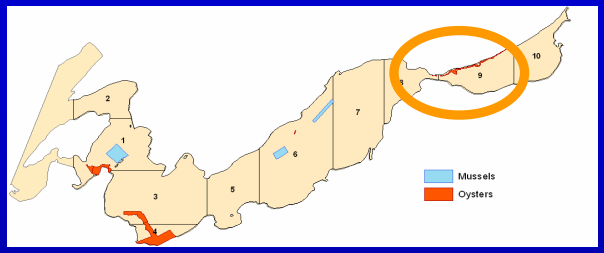
Loch Creran – EcoWin2000 model
Synthesis of outputs (stable model)

	Box	Aquaculture area	TPP (ton TFW)	APP	TPP per ha
Oyster	1	5.9	22.4	5.6	3.8
	3	5.4	25.9	7.2	4.8
	4	16.5	67.8	6.0	4.1
	6	0.1	0.59	8.3	5.8
	8	0.06	0.40	9.6	7.0
	9	3.5	28.9	11.5	8.2
	Total	31.46	~ 146	-	-
	Average	-	-	8	5.6



Production >= 7 ton ha^{-1}

Higher production values per area are predicted for the upper reaches of the Loch.

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Loch Creran – Scenario 1
Doubling the oyster culture

Box	Seeded (ton)		Harvested (ton)		APP		SIW (g)	
	Standard	Scenario	Standard	Scenario	Standard	Scenario	Standard	Scenario
1	5.9	11.8	22.4	44.3	5.6	4.6	33.7	33.1
3	5.4	10.8	25.9	51.4	7.2	5.8	43.7	43.1
4	16.5	33	67.8	133.7	6.0	4.9	33.4	32.5
6	0.1	0.2	0.59	1.2	8.3	6.8	48.1	47.8
8	0.06	0.12	0.40	0.8	9.6	7.9	55.3	55.2
9	3.5	7	28.9	57.7	11.5	9.4	73.6	73.3
	31.5	63	146	289.2	~8	6.6	~ 48	47.5

Seeding twice the tonnage, a 100 % increase can be seen in total production, though APP values are lower as well as individual weights.

10 year run

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Loch Creran – Scenario 2
Increase in water temperature

WATCH Humans blamed for climate change

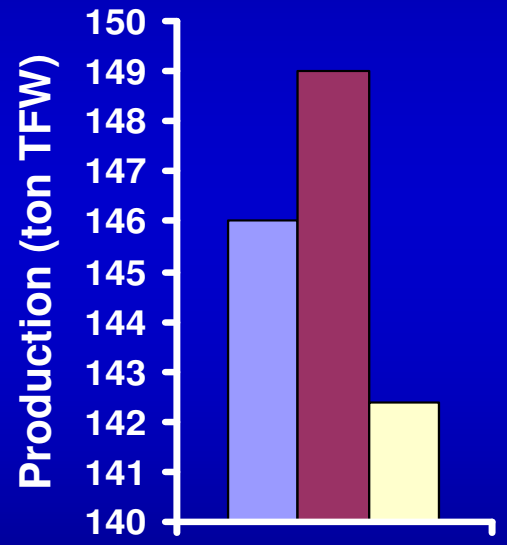
Human activity is likely to increase global temperatures by 1.8-4C over the next century, scientists warn.

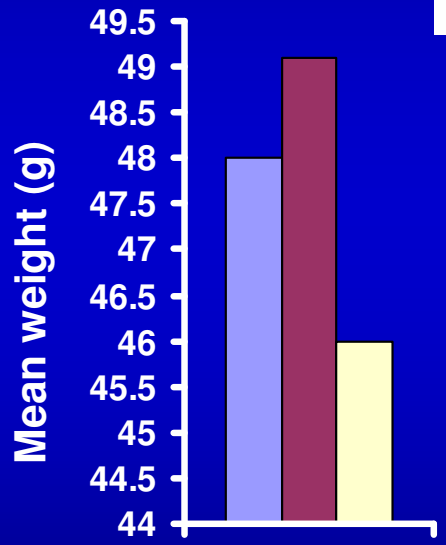
How computers model the climate

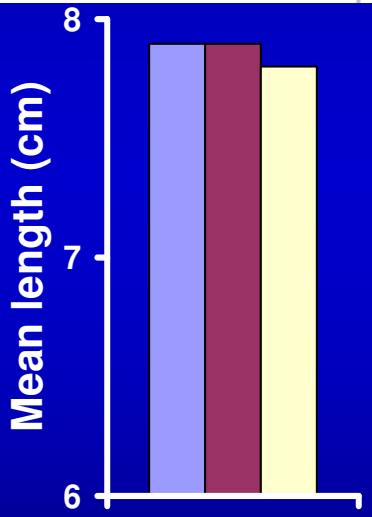
Climate Change: To act or not?

Climate report

Oysters







Standard

+ 1ºC

+ 4ºC

	Oysters
+ 1ºC	>2%
+ 4ºC	<3%

With a small temperature increase, a sligth increase in production and individuals weight is observed.

10 year run

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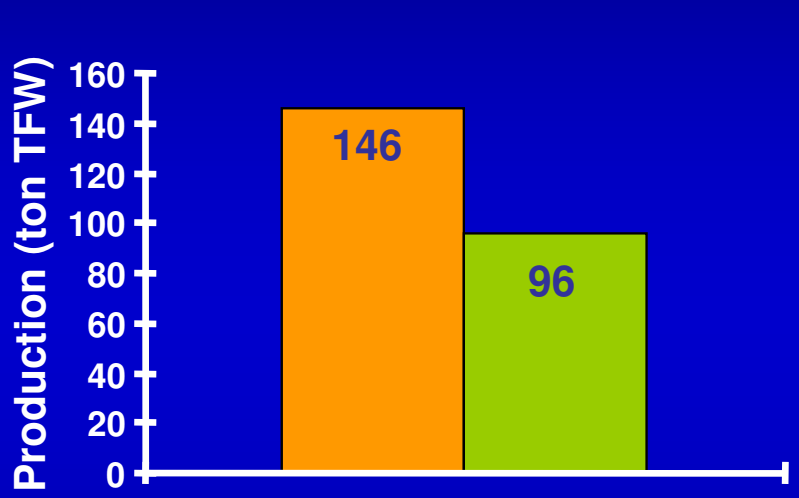
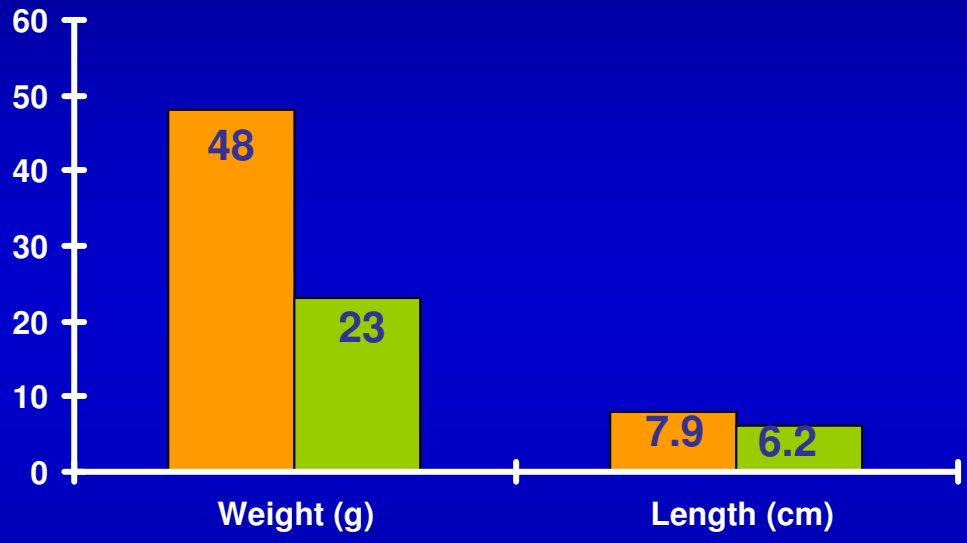
Loch Creran – Scenario 3
Oyster production with and without wild species





% of reduction	Oyster
Production	34%
Individual weight	52%
Individual length	21.5%

Without wild species
With wild species

The model show that oyster production are higher when competition for food (due to wild species) is not considered.

10 year run

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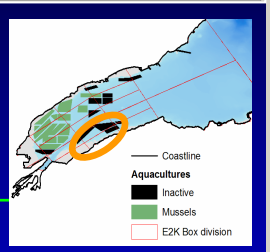
Belfast Lough - Scenario
Active aquacultures in box 29



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.

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Final comments

- A brief methodological overview, together with some results, were presented for system scale assessment in Loch Creran
- Examples of scenario applications which can be tested include changes in culture practice, nutrient loading, climate change and conservation aspects
- Ideas for the future include improved catchment modelling (carried out for Foyle in SMILE) and socio-economic interrelations
- The KeyZones team are especially indebted to to the producers
- We hope these products will become of practical value to industry and management

http://www.keyzones.com