



Address Go Links

People, Planet and Profit

Shellfish aquaculture and coastal zone management



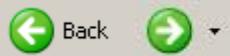
ASSG International Conference '07

<http://www.farmscale.org/>

J.G. Ferreira



ASSG2007 Meeting, Oban, 18th-19th October 2007



Address Go Links

Topics



- System-scale models: overview, drivers
- System-scale models: carrying capacity
- Farm-scale models: drilling down
- FARM: People - Planet - Profit
- Synthesis

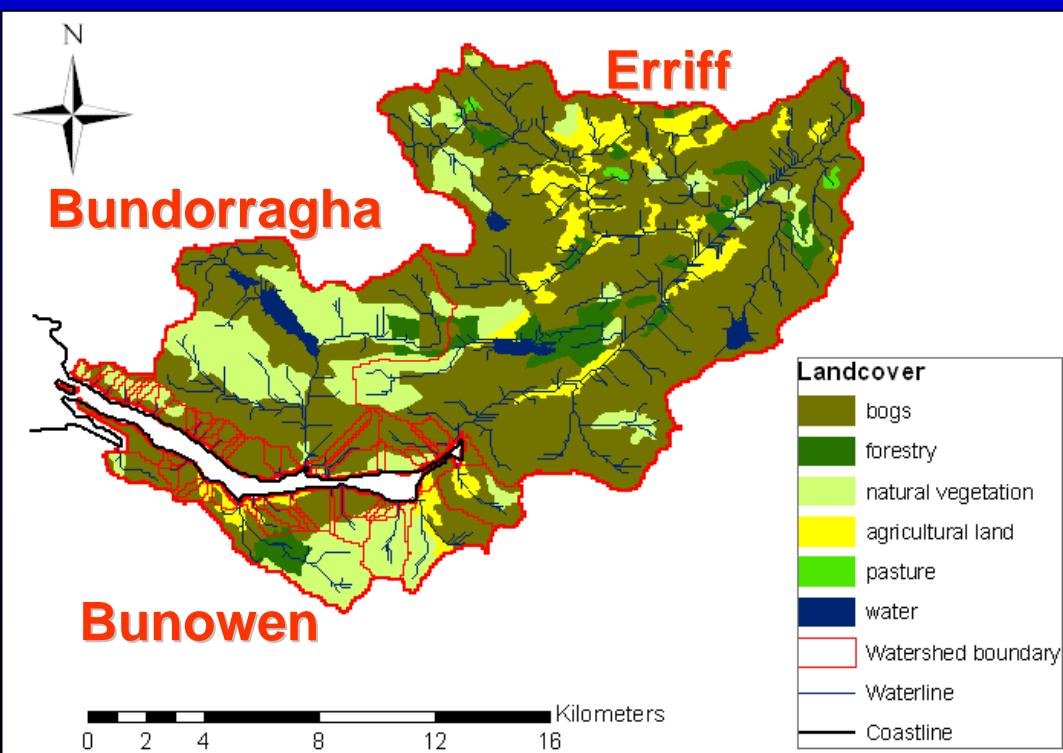
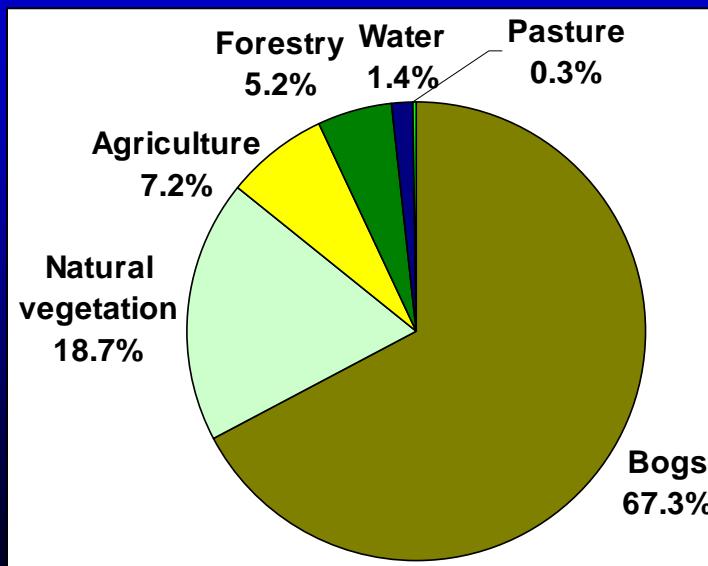
Slides
7
10
3
7
1

28+2

Catchment area and landcover

- Catchments and river network delineated from radar topography (SRTM).
 - Runoff assumed to flow down the steepest slope.
- Landcover taken from the CORINE 2000 map.

Total catchment area: 266 Km²



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

Go Links



Nutrient loads

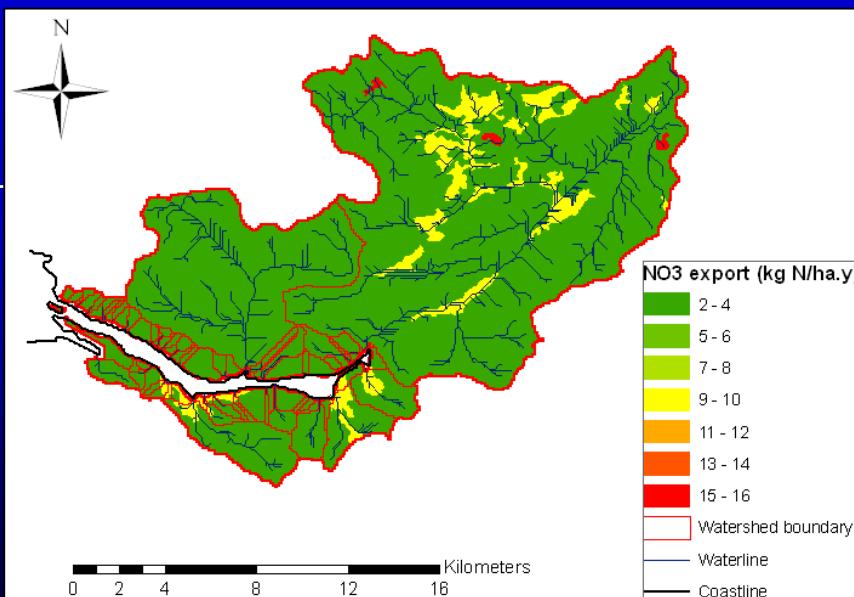
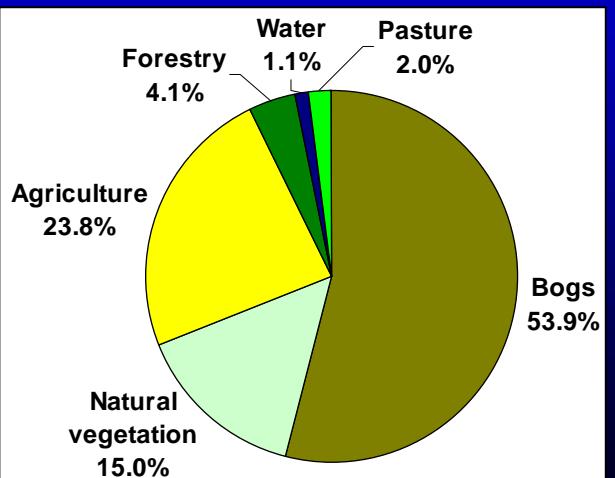
- Catchment nutrient loads for N (NO_3 and NH_4) and P (DRP) estimated from landcover using export coefficients.
 - Export coefficients per landcover taken from Foy and Girvan's (2004) work on northern Ireland.

Average concentrations (mg L^{-1})	
DIN	0.39
$\text{NO}_3\text{-N}$	0.35
$\text{NH}_4\text{-N}$	0.04
DRP	0.04

Annual load (estimated)

Nitrogen (NO_3)	Ton N	66.4
Nitrogen (NH_4)	Ton N	8.4
Phosphorus (DRP)	Ton P	7.4

Catchment
nitrate
sources, per
landcover type



Spatial distribution of nitrate sources

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

Go Links

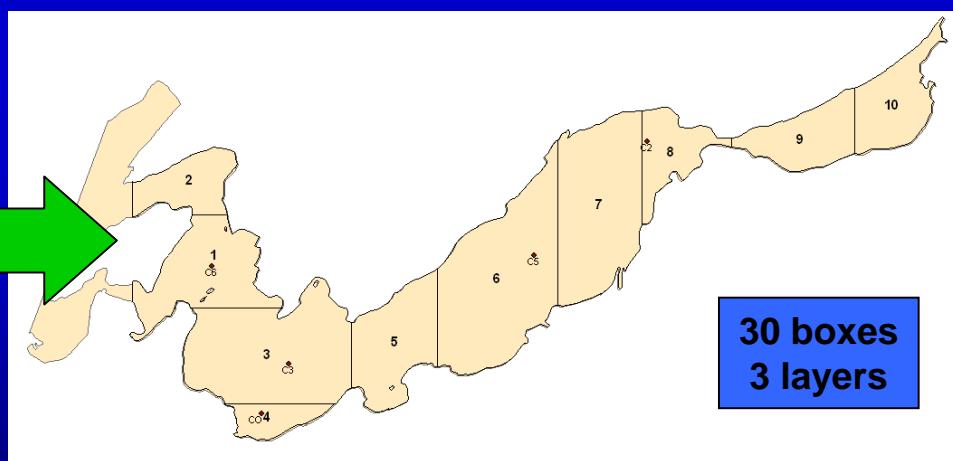
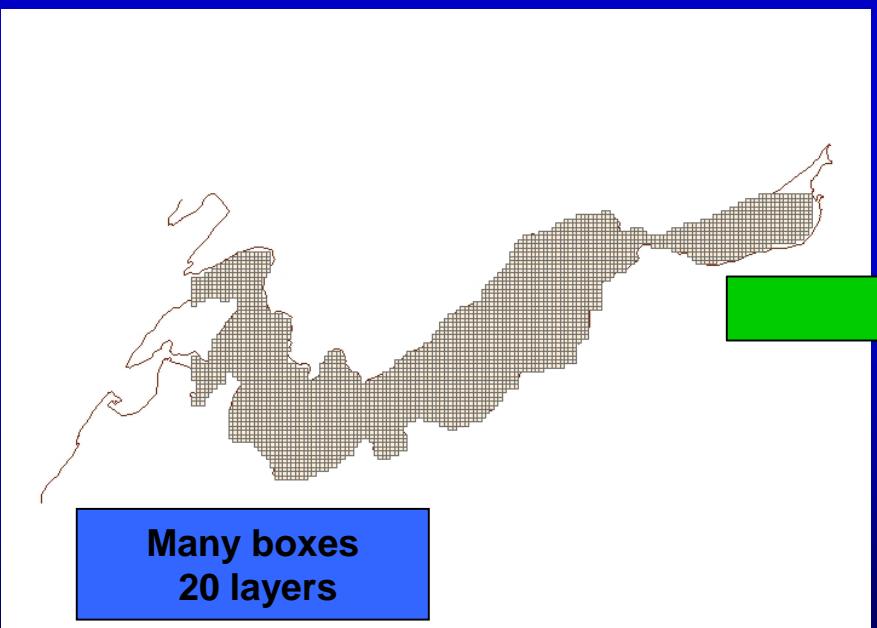


Loch Creran – EcoWin2000 model

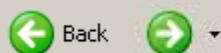
Delft3D
hydrodynamic model



EcoWin2000
ecological model

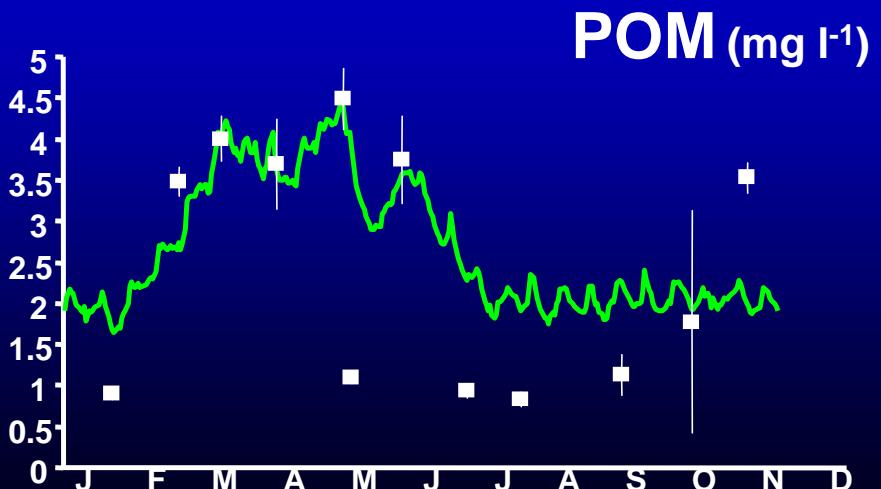
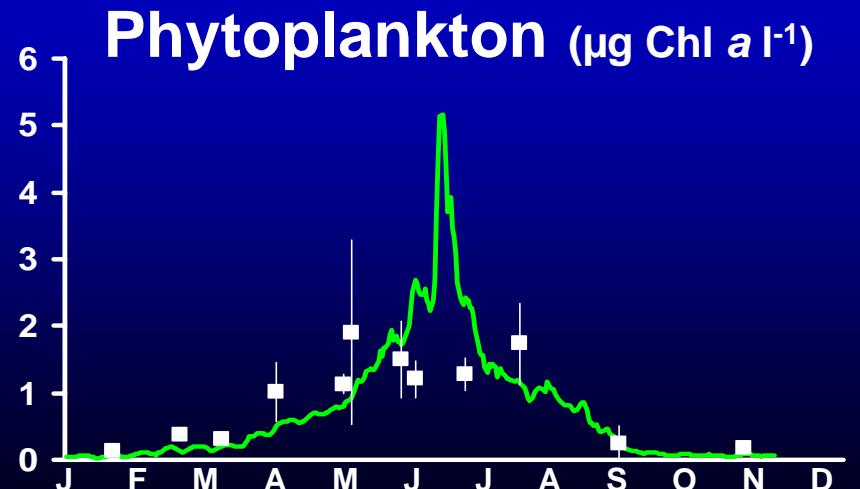
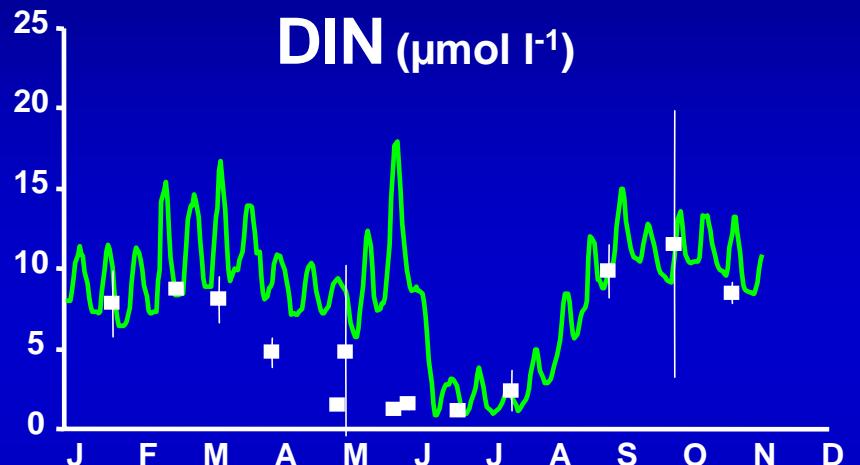


A much coarser grid is used in biogeochemical models than in hydrodynamic models.

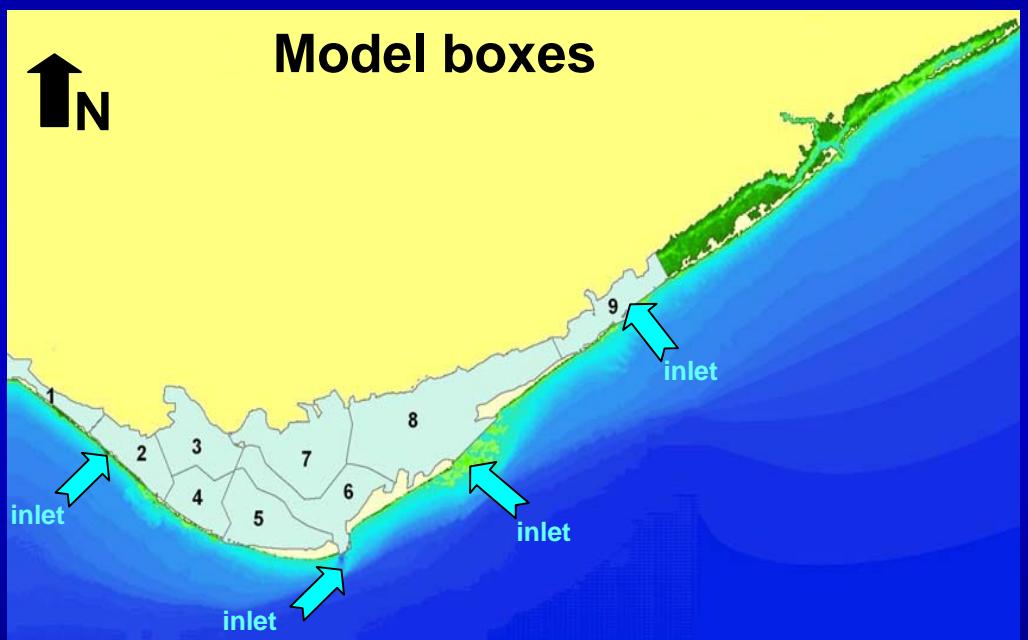
Address <http://www.ecowin.org/> Go Links

Validation of growth drivers

Loch Creran – Box 4 (Oyster Farm)



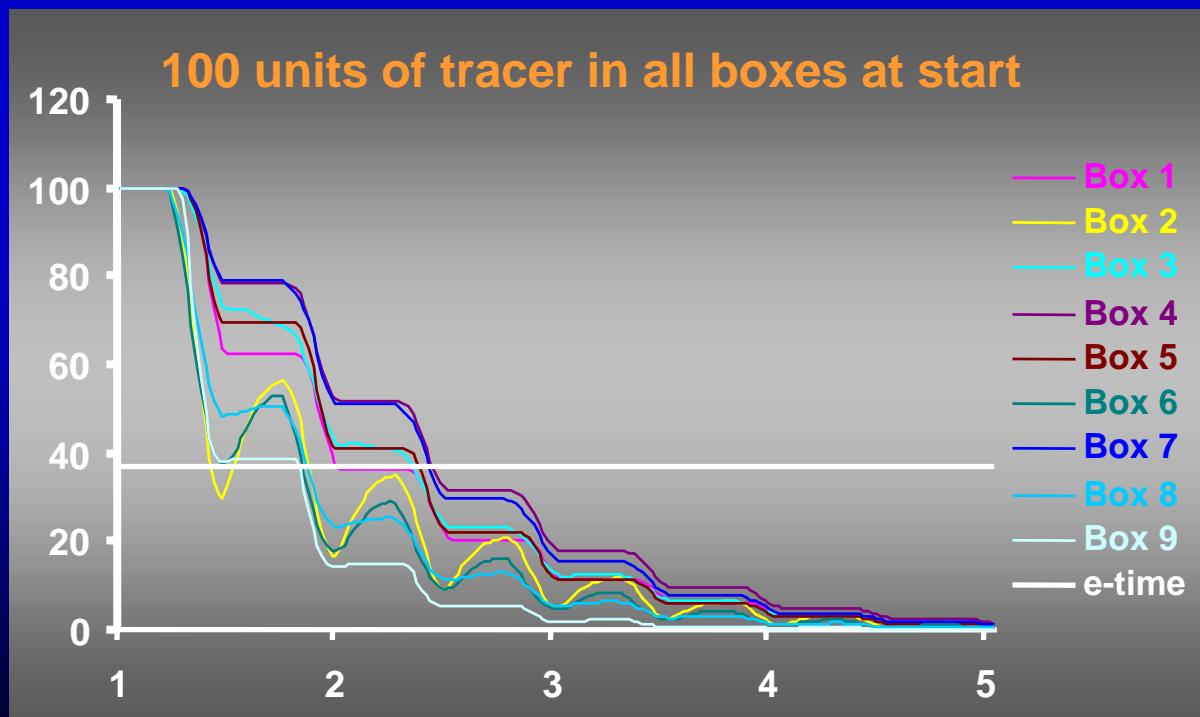
Ria Formosa – EcoWin2000 model



- 9 boxes
- 1 vertical layer
- 4 ocean inlets
- Water fluxes simulated with the MOHID hydrodynamic model

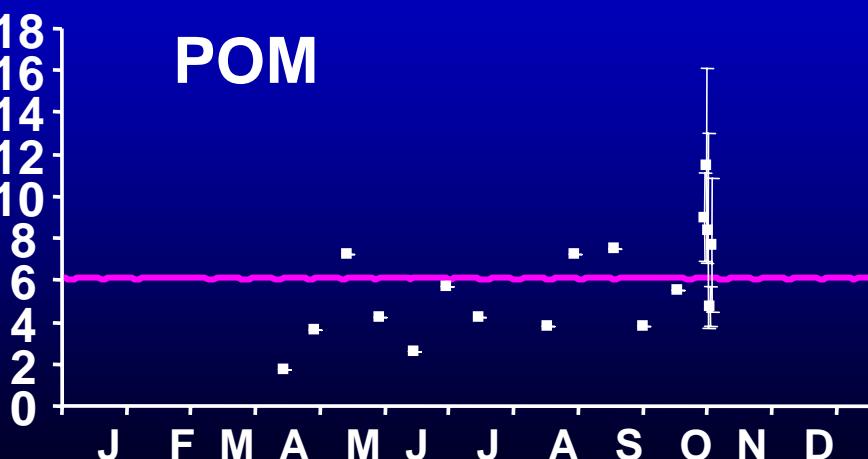
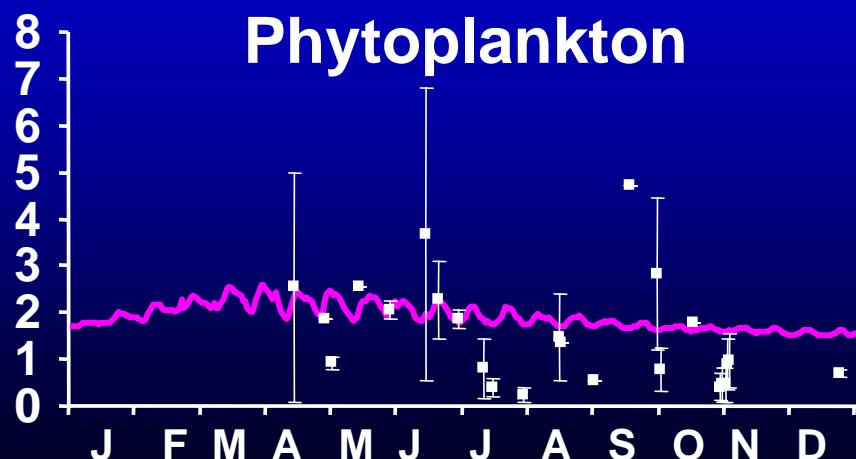
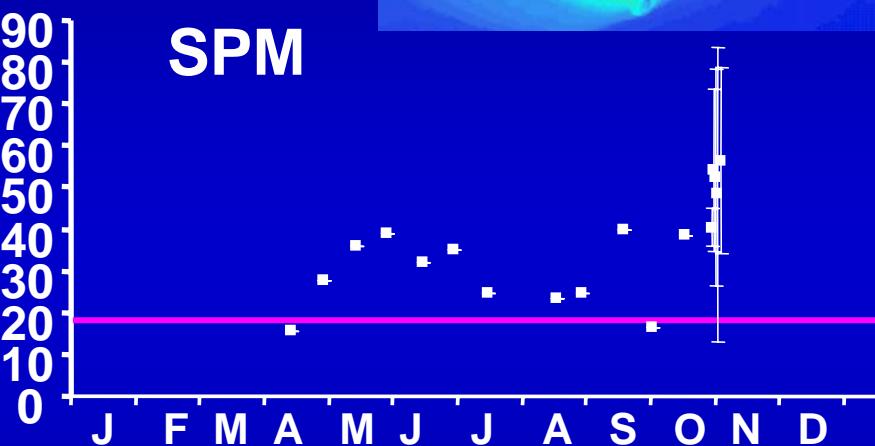
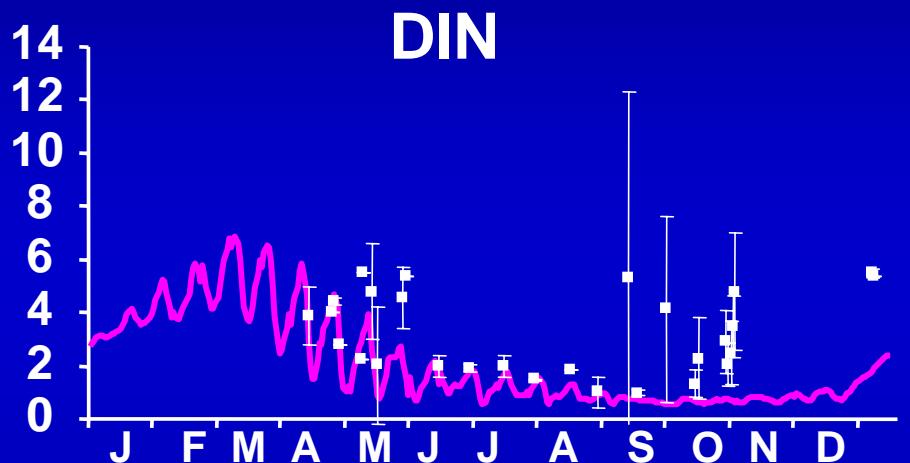
EcoWin2000 model – Ria Formosa Residence time

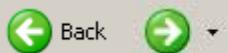
- Water residence time: 1 – 1.5 days



e-folding time: time for the concentration in a model box to be reduced by a factor of $1/e$, i.e., from an initial concentration of 100% to about 37%

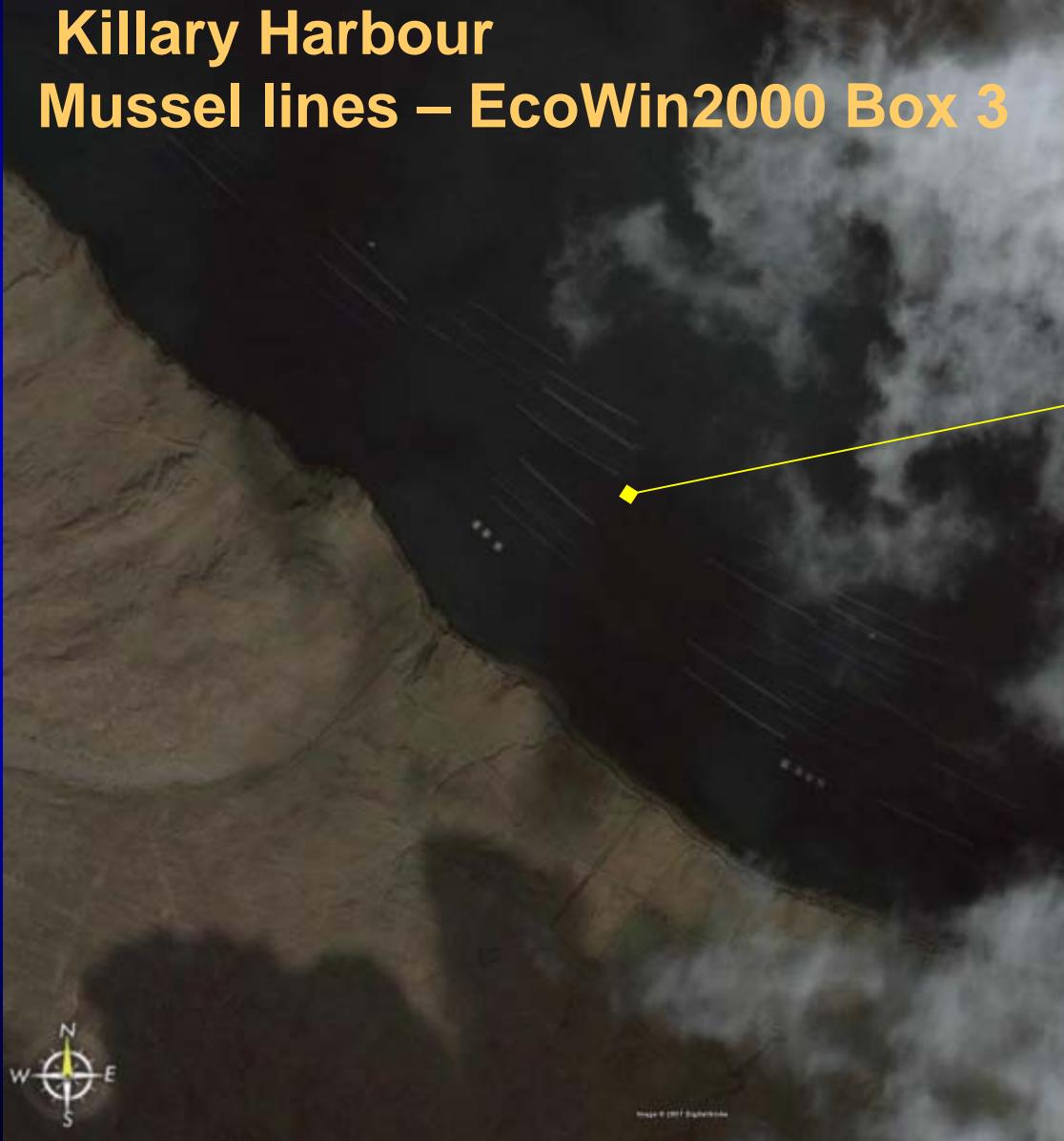
Validation of growth drivers Ria Formosa – Box 2



Address

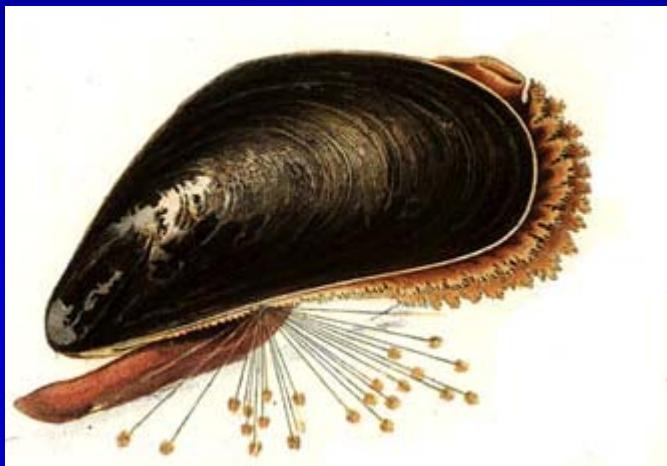
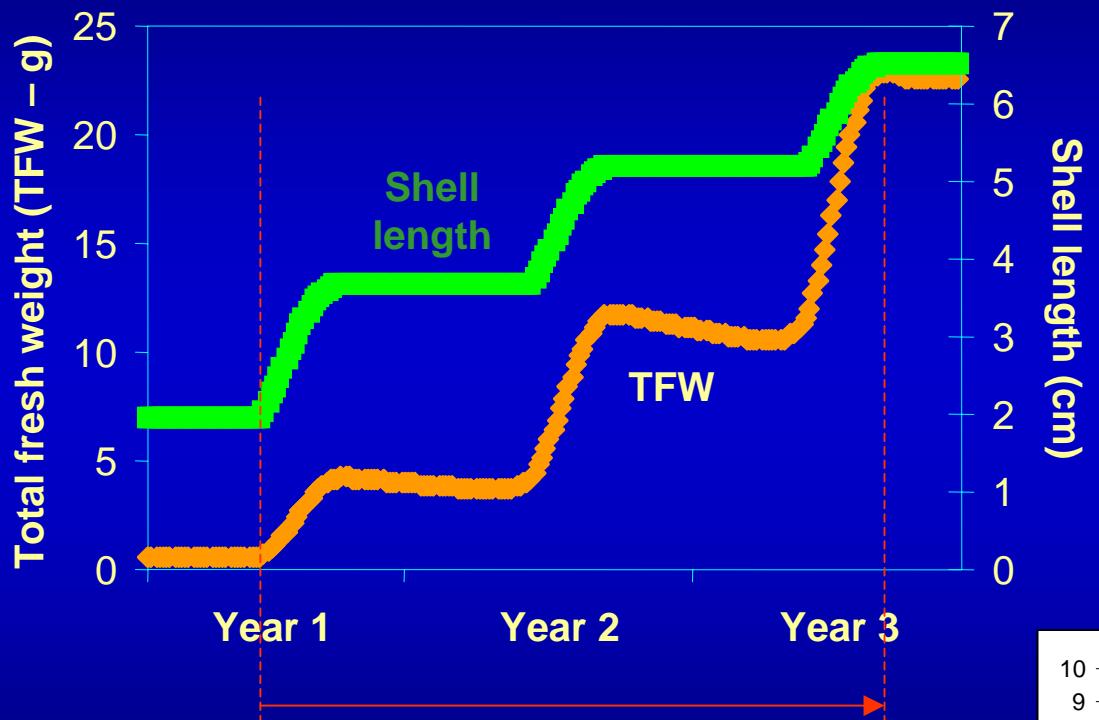
Links

Killary Harbour Mussel lines – EcoWin2000 Box 3



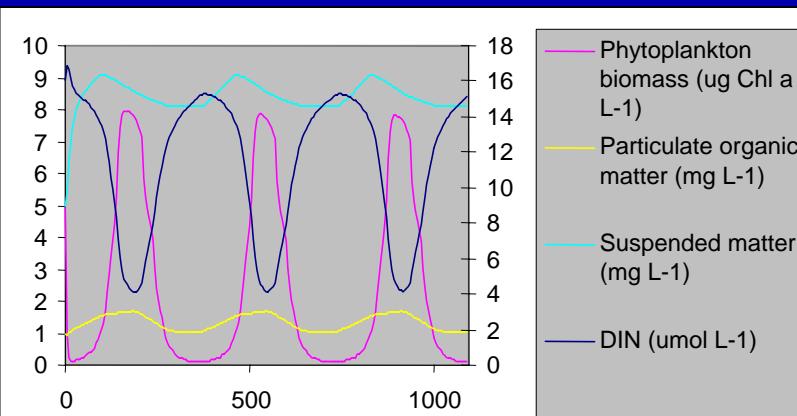
EcoWin2000 – Killary Harbour 2D model

Mussel individual growth in Box 3



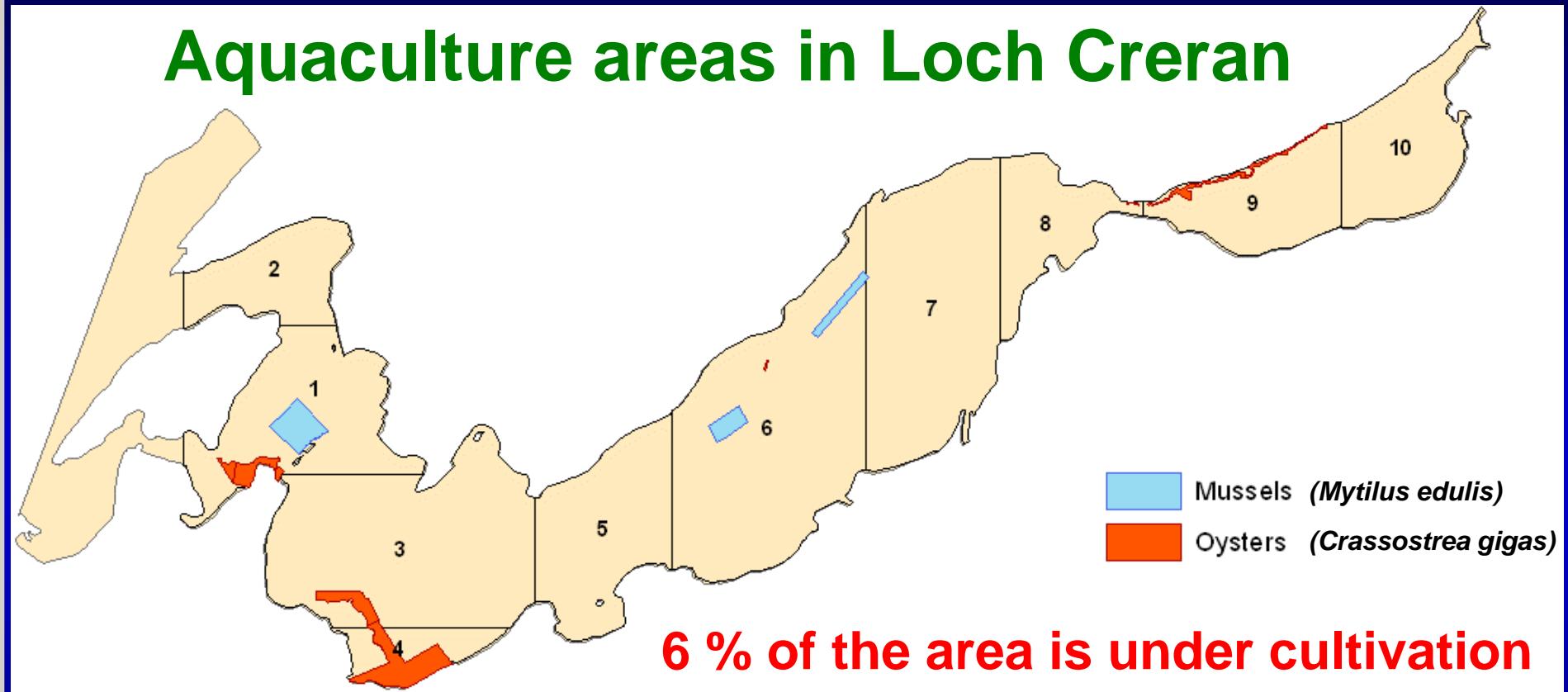
Application of ShellSIM within EcoWin2000

Growth drivers simulated by EcoWin2000





Aquaculture areas in Loch Creran



BOX	1 (M)	1 (O)	3 (O)	4(O)	6 (M)	6 (O)	8 (O)	9 (O)	Total
Area (ha)	150.2	150.2	263.4	51.5	295.1	295.1	78.3	105.0	1862
Aquaculture	10.4	5.9	5.4	16.5	8.4	0.1	0.06	3.5	115
% area	6.9	3.9	2.1	32	2.9	0.03	0.08	3.3	6.2



Loch Creran – EcoWin2000 model

Synthesis of outputs (stable model)



Box	Aquaculture area	TPP (ton TFW)	APP
1	5.9	52	8.2
3	5.4	53	9.1
4	16.5	155	8.7
6	0.1	1	9.5
8	0.06	0.6	9.5
9	3.5	35	9.3
Total/Average	31.5	~300	9.8

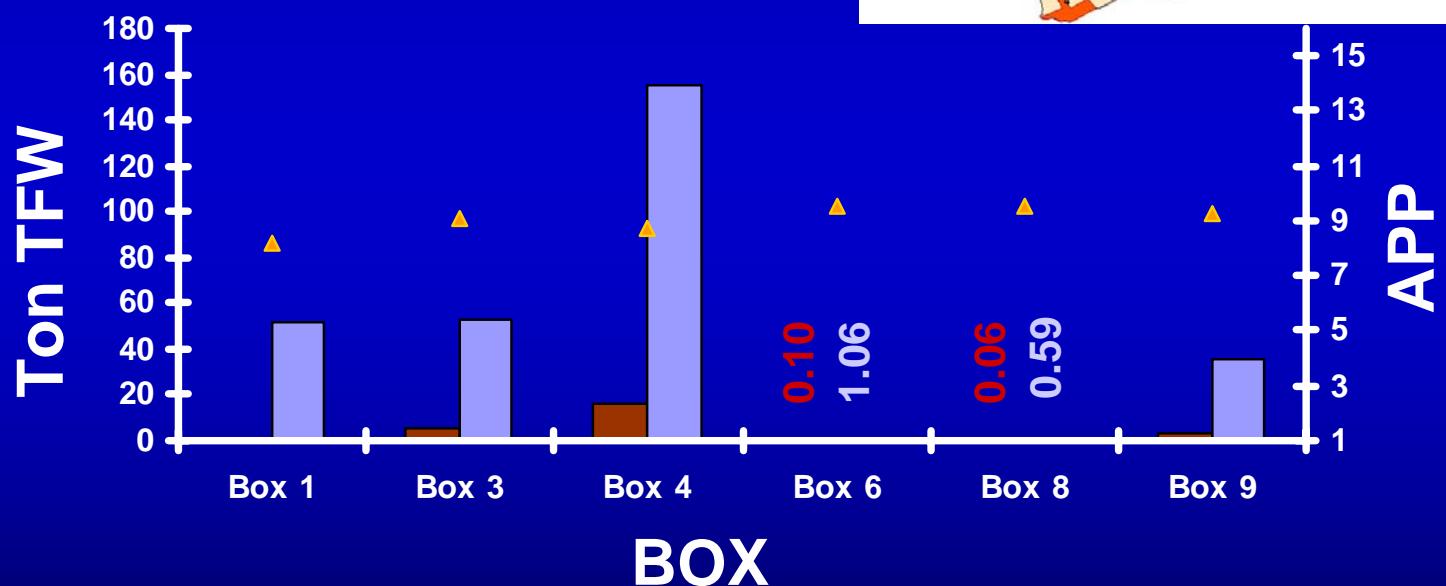
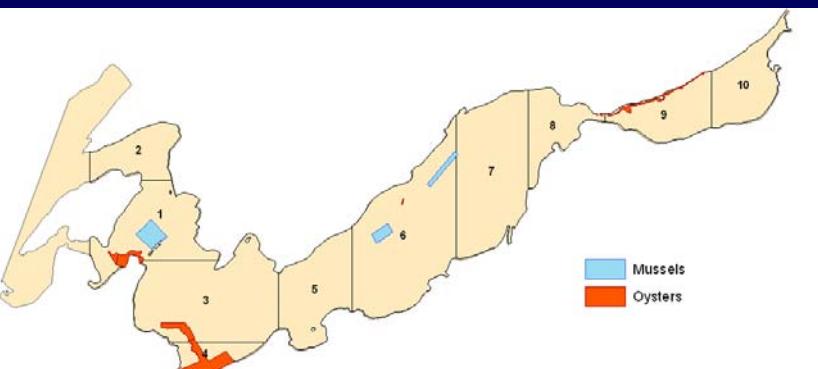
Higher APP values were obtained in the upper reaches of the Loch.
Values for validation of boxes closer to the river were not available.



Loch Creran – EcoWin2000 model

Oysters: Seed, harvest and Average Physical Product (APP)

(Stable model - year 10)



APP

Seeded

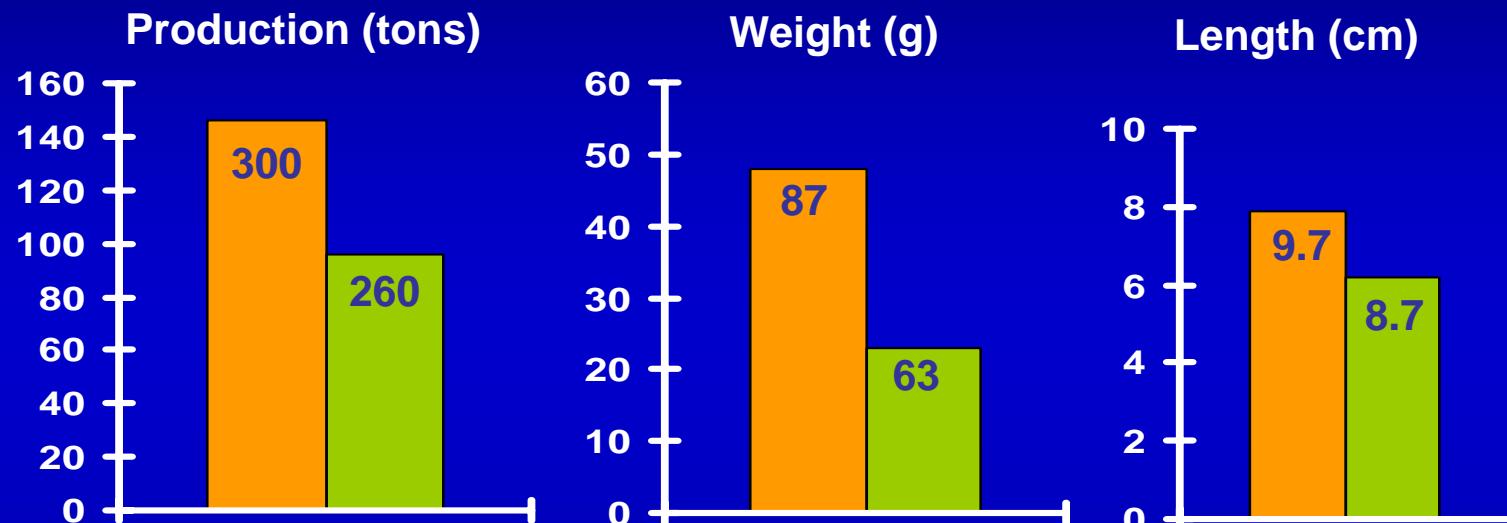
Harvested

Weight at harvest
Total production
APP

> 50 g
~ 300 ton
~ 9.05

Loch Creran – Biodiversity scenario

Oyster production with and without wild species



Indicator	% reduction
Production	13%
Individual weight	27.6%
Individual length	10.3%

- Without wild species
- With wild species

The model indicates that oyster production is higher when competition for food due to wild species is not considered.

10 year run



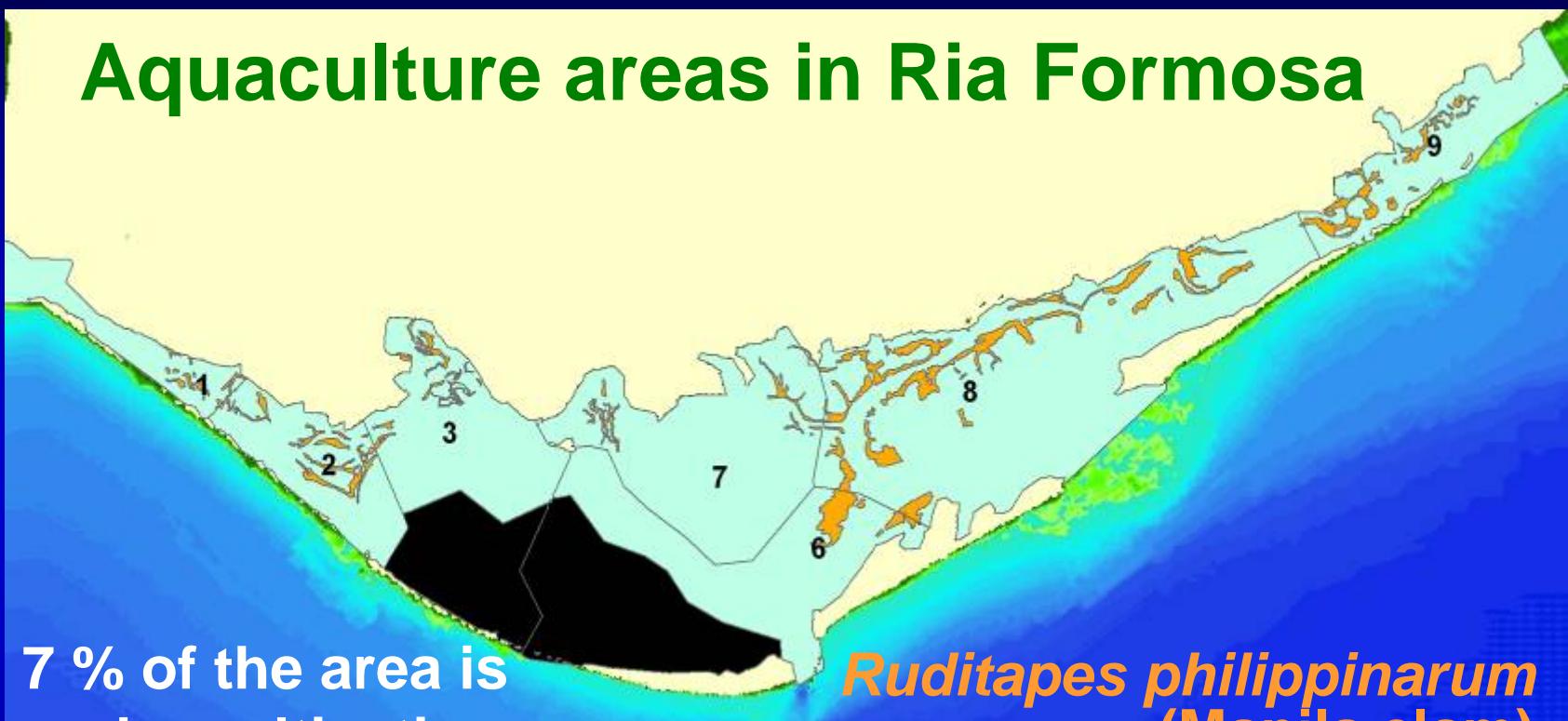
Address

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

Go

Links

Aquaculture areas in Ria Formosa



BOX	1	2	3	4	5	6	7	8	9
Area (ha)	225	514	709	493	763	963	1016	2164	473
Aquaculture	15	51	32	-	-	53	30	239	65
% of area	6.5	10	4.5	-	-	5.5	3	11	14



Address

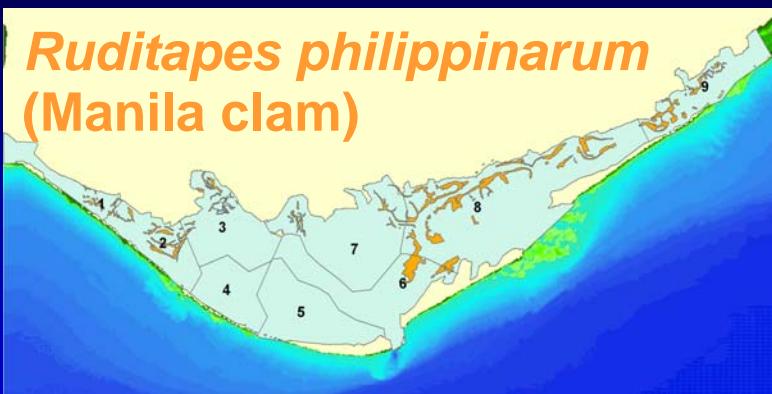
http://www.ecowin.org/



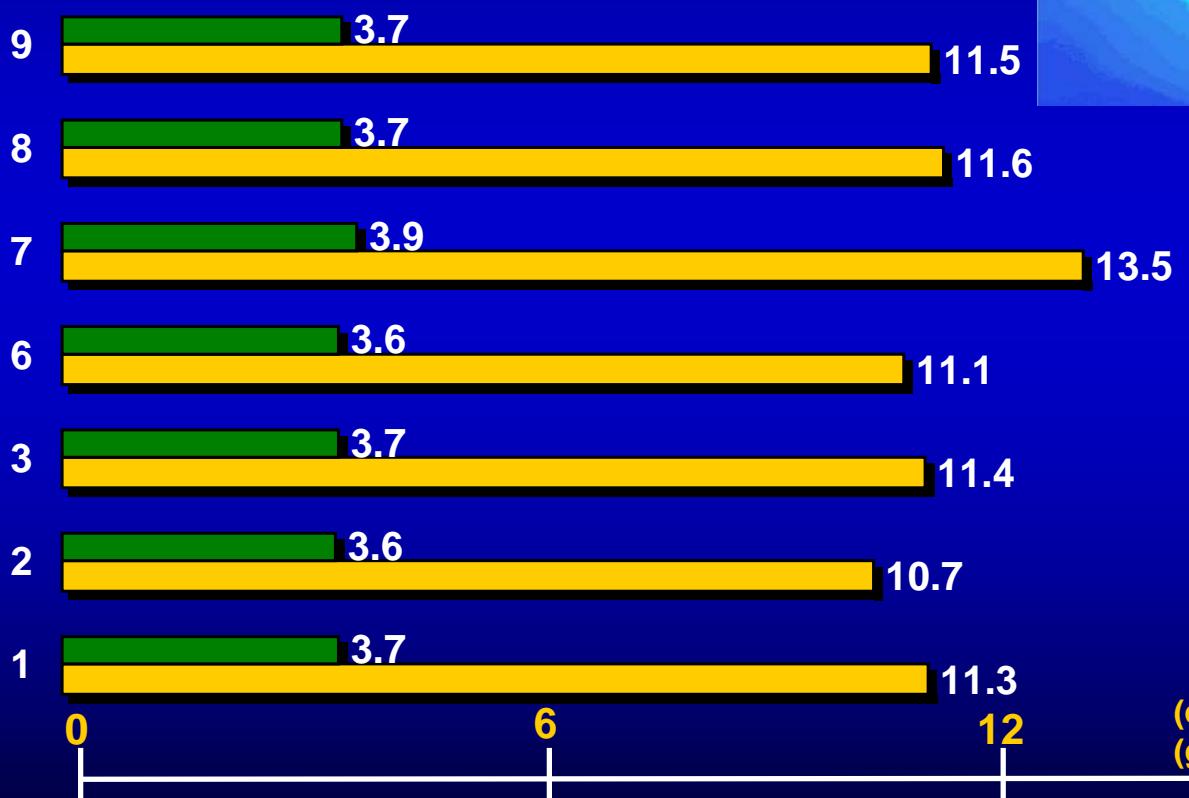
Links

Ria Fomosa: Individual length and weight

BOX



Clams



Clams
mean length ~ 3.7 cm
mean weight ~ 11.6 g

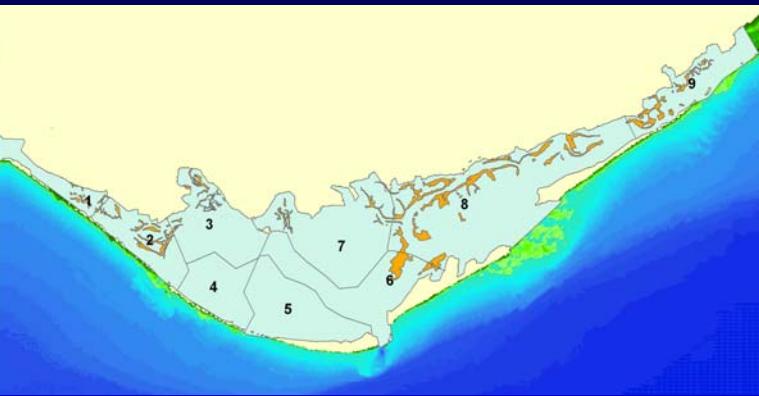
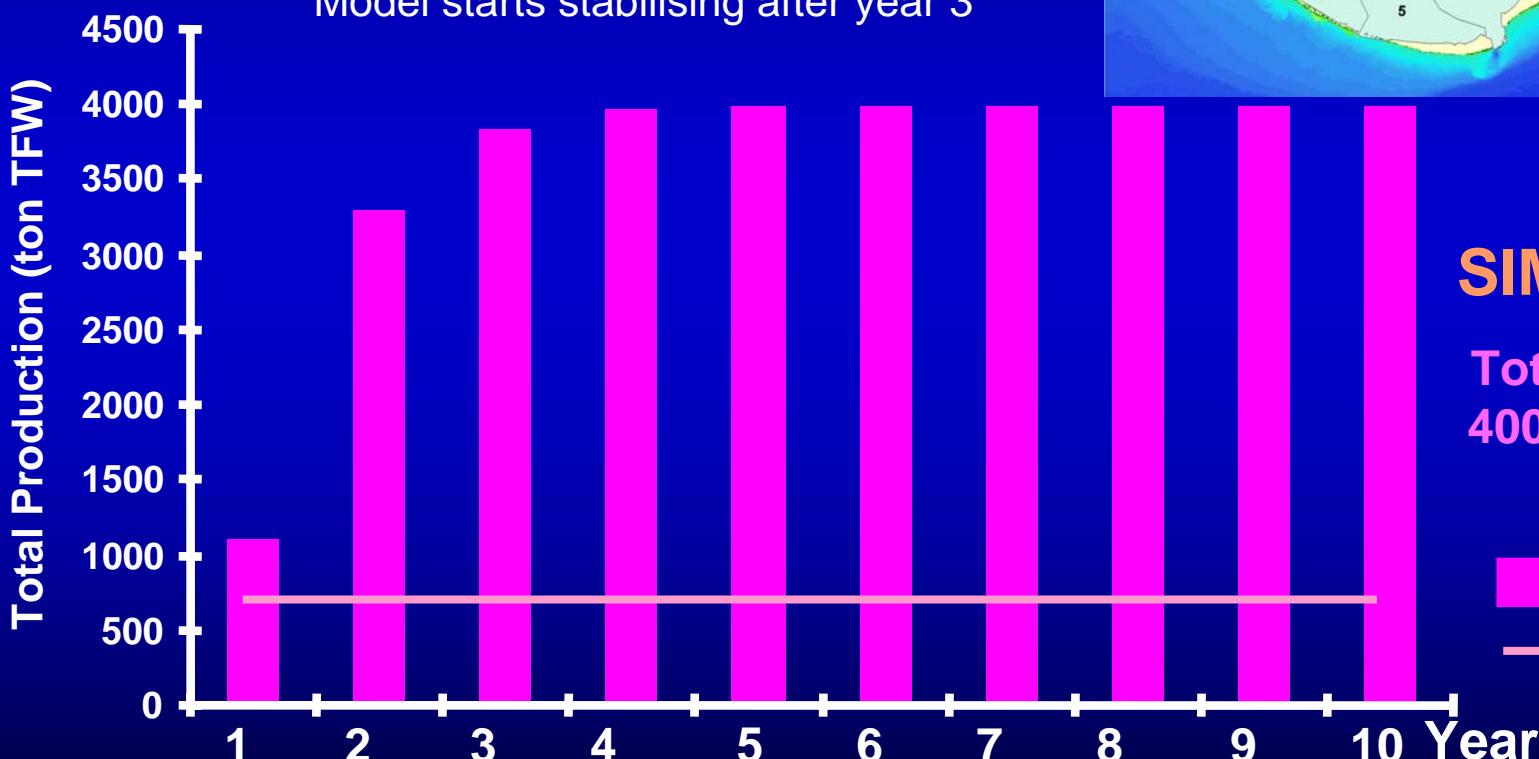
Culture period – April to September

(cm)
(g)

Length (cm)
Weight (g)

Ria Formosa – EcoWin2000 model Total production

Model starts stabilising after year 3



SIMULATION:

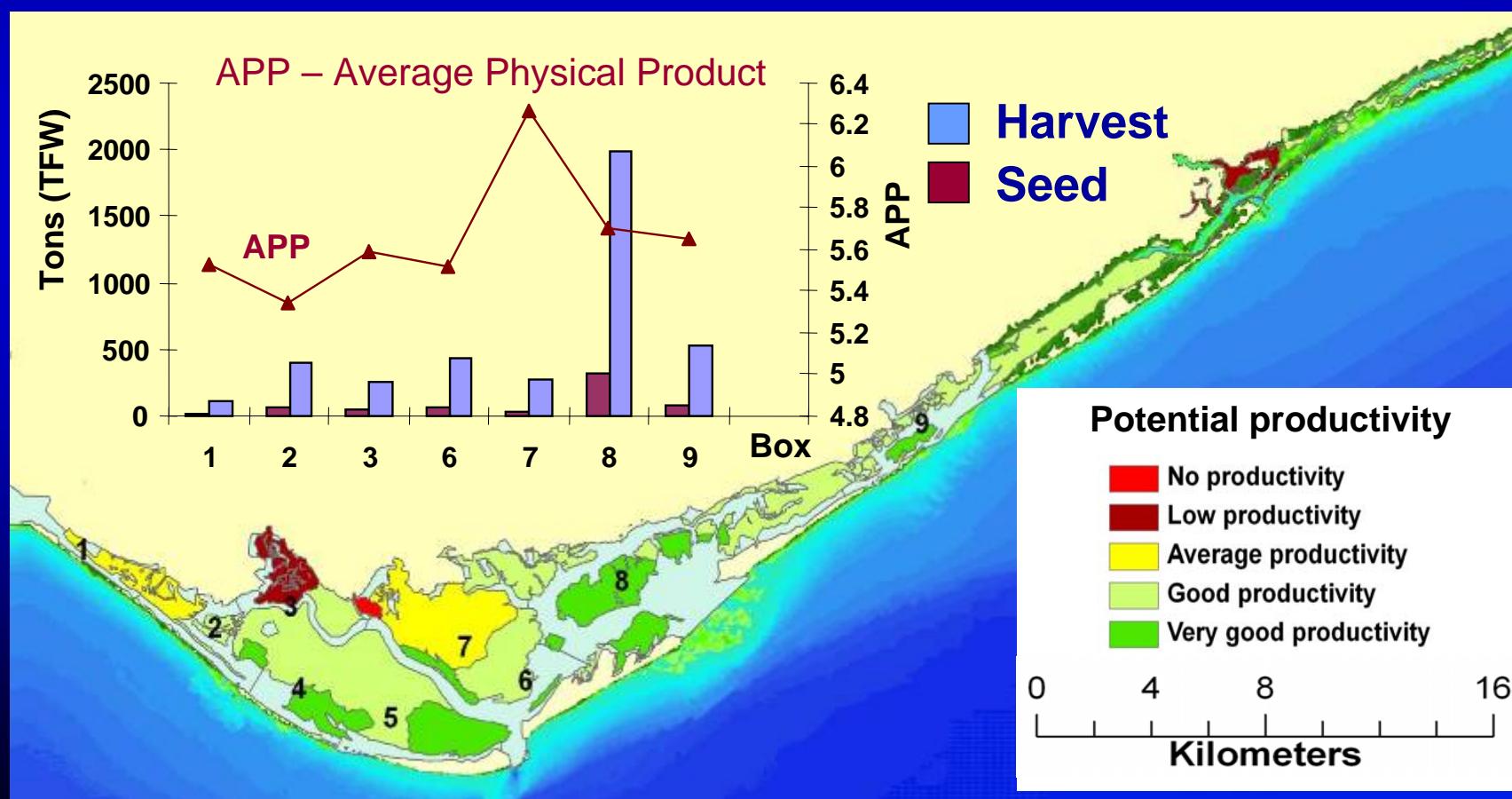
Total production:
4000 ton of clams

Clam harvest
— Clam seed

Production in Ria Formosa has been fluctuating in recent years between 3000 and 4000 ton y^{-1}
(Pers. com. President of the Algarve Aquaculture Association)

Productivity in Ria Formosa

Comparison between model results in clam cultivation areas and potential productivity in different areas of Ria Formosa

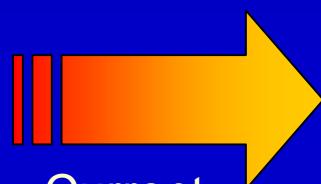


Farm-scale conceptual diagram

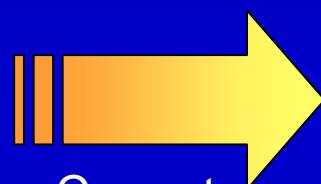
养殖区概念模型

Farm length

Width



Current



Current



POM

Depth 1

Shellfish

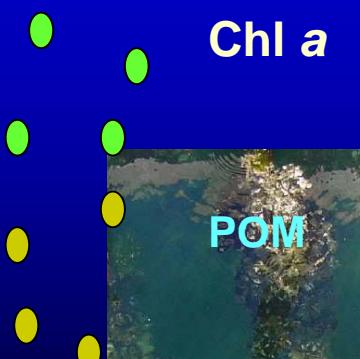
2

3

n-1

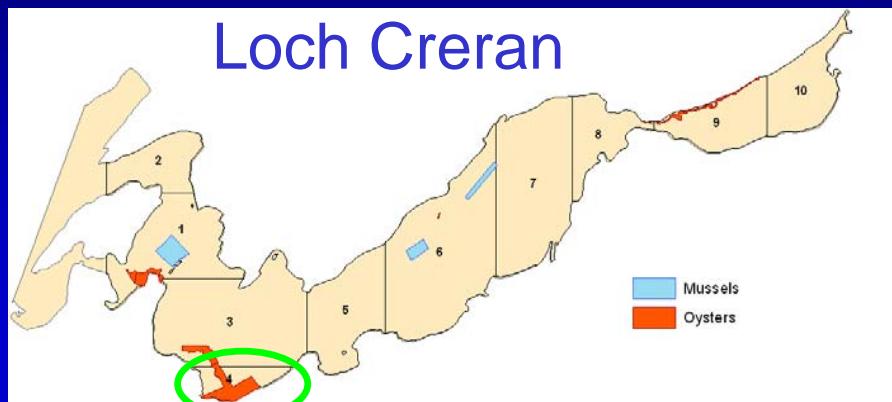
n

Sections



POM

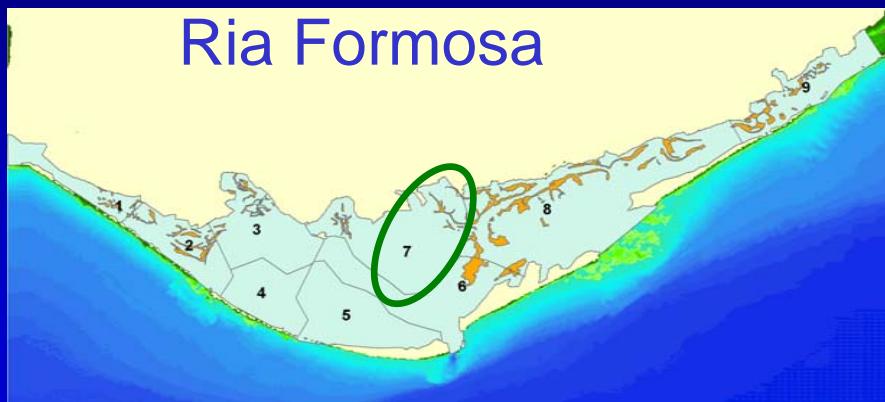
FARM results



Box 4

(aquaculture = 16.5 ha)

- Farm layout:
 - 206 m x 800 m
 - 5 m depth
- Culture practice:
 - Pacific Oyster
 - ~ 1 ton ha^{-1} (50 ind m^{-2})
 - 730 day cultivation



Box 7

(aquaculture = 11.4 ha)

- Farm layout:
 - 71 m x 1600 m
 - 3 m depth
- Culture practice:
 - Manila Clam
 - 1.35 ton ha^{-1} (90 ind m^{-2})
 - 180 day cultivation



Address http://www.ecowin.org/ Go Links

Loch Creran – Model outputs

FARM - Farm Aquaculture Resource Management

FARM drivers | FARM outputs | FARM mass balance |

Results

A	B	C	D	E	F	G	H
1	Julian day	Chlorophyll	POM	TPM	Oxygen	Weight	Length
2	-	(ug L-1)	(mg L-1)	(mg L-1)	(mg L-1)	(g TFW)	(cm)
3	61	0.1676811235	3.06939747	12.0724977	7.999303275	1.58642373	2.572644208
4	62	0.1713274798	3.109431249	12.26265367	7.999433508	1.599475077	2.57965315
5	63	0.1744416477	3.146584463	12.449929	7.999406826	1.612734646	2.5867349
6	64	0.1773991346	3.182934544	12.63640122	7.999336576	1.627328183	2.594484287
7	65	0.1803795763	3.219434934	12.82302374	7.999274575	1.642612864	2.602551069
8	66	0.1832885356	3.25559291	13.00930384	7.999194084	1.658137324	2.610693236
9	67	0.1861171916	3.291374297	13.19520733	7.999093289	1.673900932	2.6189008891
10	68	0.188862558	3.326775318	13.38073009	7.99892057	1.689427408	2.62695059
11	69	0.191533671	3.361852036	13.56592765	7.998833425	1.705182424	2.635060352
12	70	0.1941523344	3.396720496	13.750914	7.998683704	1.72116555	2.643236547

Drivers: interpolated data | Results: Pacific oyster (Box 1) | Results: Pacific oyster (Box 2) | Results: Pacific oyster (Box 3) |

Model specs

Farm volume (m ³)	824000
Box volume (m ³)	274667
Timestep (days)	0.0077
Individual TFW (g)	26.34
Shell length (cm)	6.56
Nº timesteps	94608

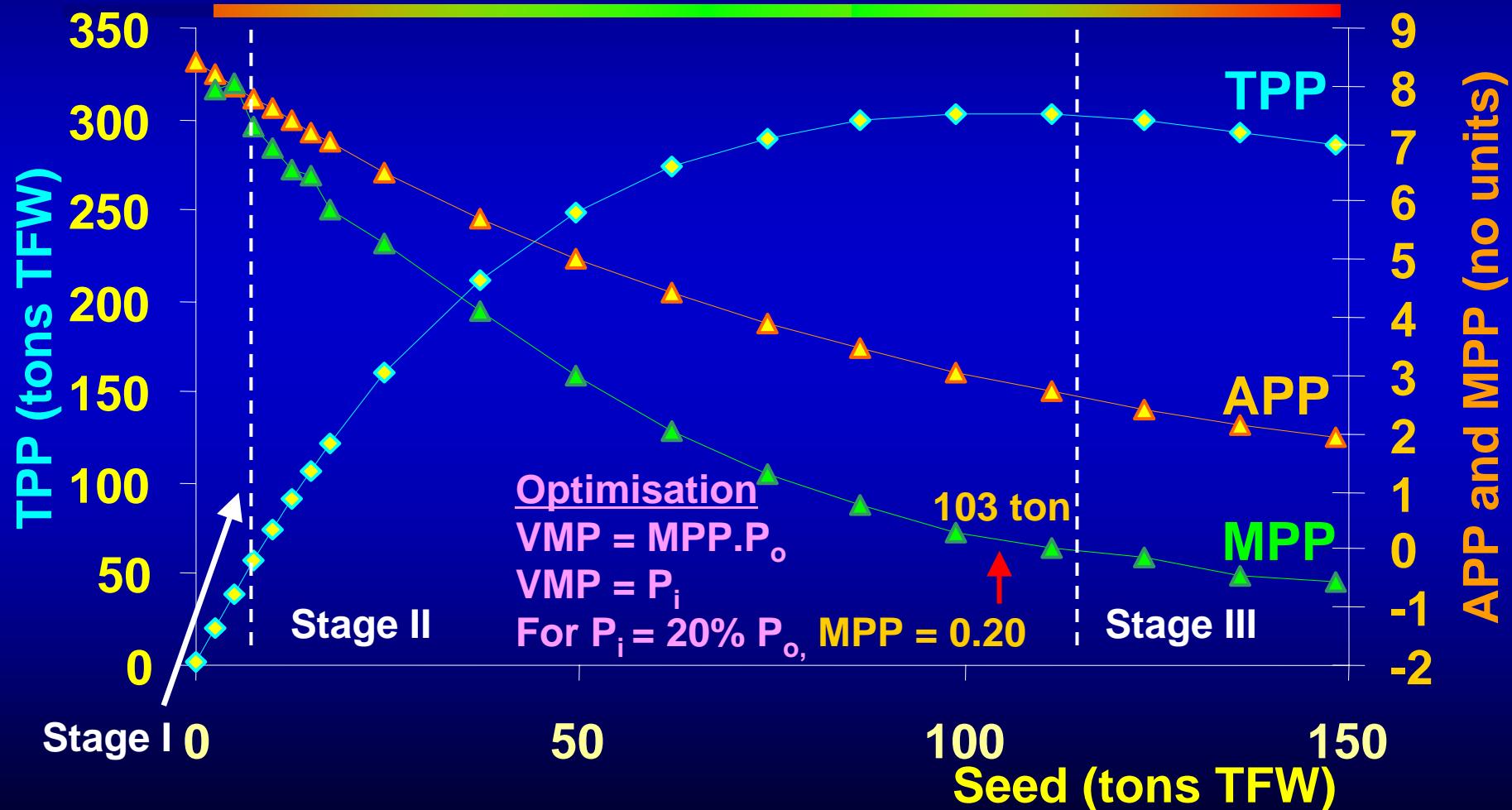
Diagram

Table A

A	B	C	D	E	F	G
1	Section	Seed	TPP	APP	TR	TC
2	-	(ton)	(ton)	-	(TVP k€)	(K€)
3	1	4.1	32.4	7.86	161.8	4.1
4	2	4.1	30.4	7.39	152.2	4.1
5	3	4.1	28.7	6.96	143.4	4.1
6	Total	12.4	91.5	7.40	457.5	12.4
7						
8		Inflow	Outflow			
9	Chlorophyll a (ug L-1)	2.0	1.9			
10	Diss. oxygen (mg L-1)	8.0	8.0			
11	ASSETS grade	5	5			

Summary outputs

Loch Creran – Economic Analysis I



C. gigas, 730 day cultivation period, drivers from EcoWin2000



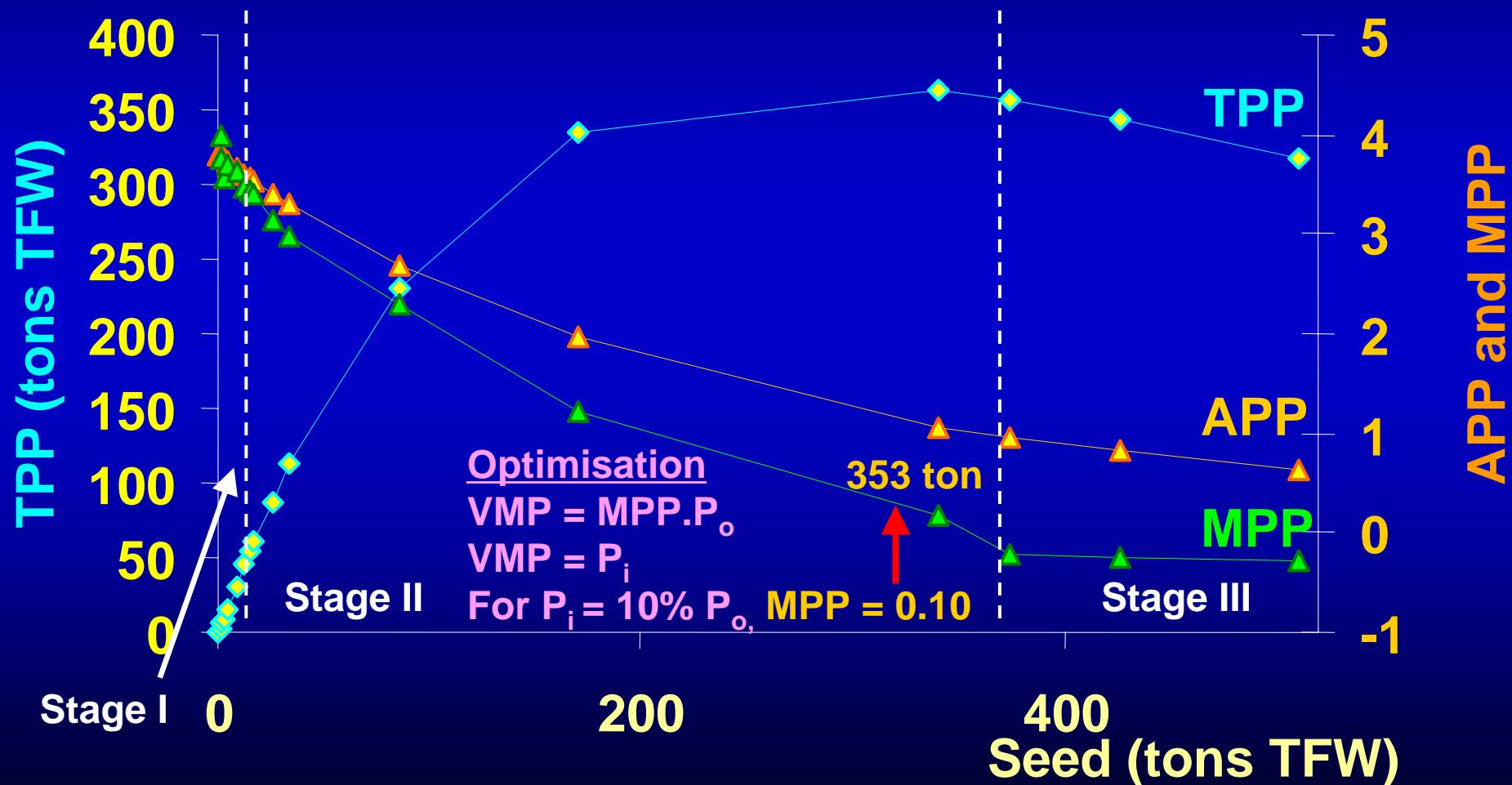
Address <http://www.ecowin.org/> Go Links

Loch Creran – Economic analysis II

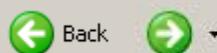
Seed (ton)	TPP (ton)	APP	MPP	VMP (k€)	TR (TVP k€)	TC (k€)	Profit (k€)
0	0	0	0	0	0	0	0
2.5	20.3	<u>8.21</u>	7.91	39.6	101.5	2.5	99
5	39.6	8.00	<u>8.04</u>	40.2	198	4.9	193
7.5	57.8	7.80	7.28	36.4	289	7.4	282
10	75.1	7.60	6.92	34.6	375.5	9.9	366
12.5	91.5	7.4	6.56	32.8	457.5	12.4	445
15	107	7.21	6.46	32.3	535	14.8	520
25	160.7	6.5	5.28	26.4	803.5	24.7	779
50	248.6	5.03	2.98	14.9	1243	49.4	1194
74	289.9	3.91	1.30	6.49	1449.5	74.2	1375
99	<u>302.7</u>	3.06	0.30	1.49	<u>1513.5</u>	98.9	<u>1415</u>
124	298.9	2.42	-0.15	-0.77	1494.5	123.6	1371
150	286.2	1.93	-0.58	-2.89	1431	148.3	1283

Price of input (P_i) = 1 €kg $^{-1}$; Price of output P_o = 5 €kg $^{-1}$

Ria Formosa – Economic Analysis



R. philippinarum, 180 day cultivation period, drivers from EcoWin2000

Address Go Links

Ria Formosa – Model Scenarios

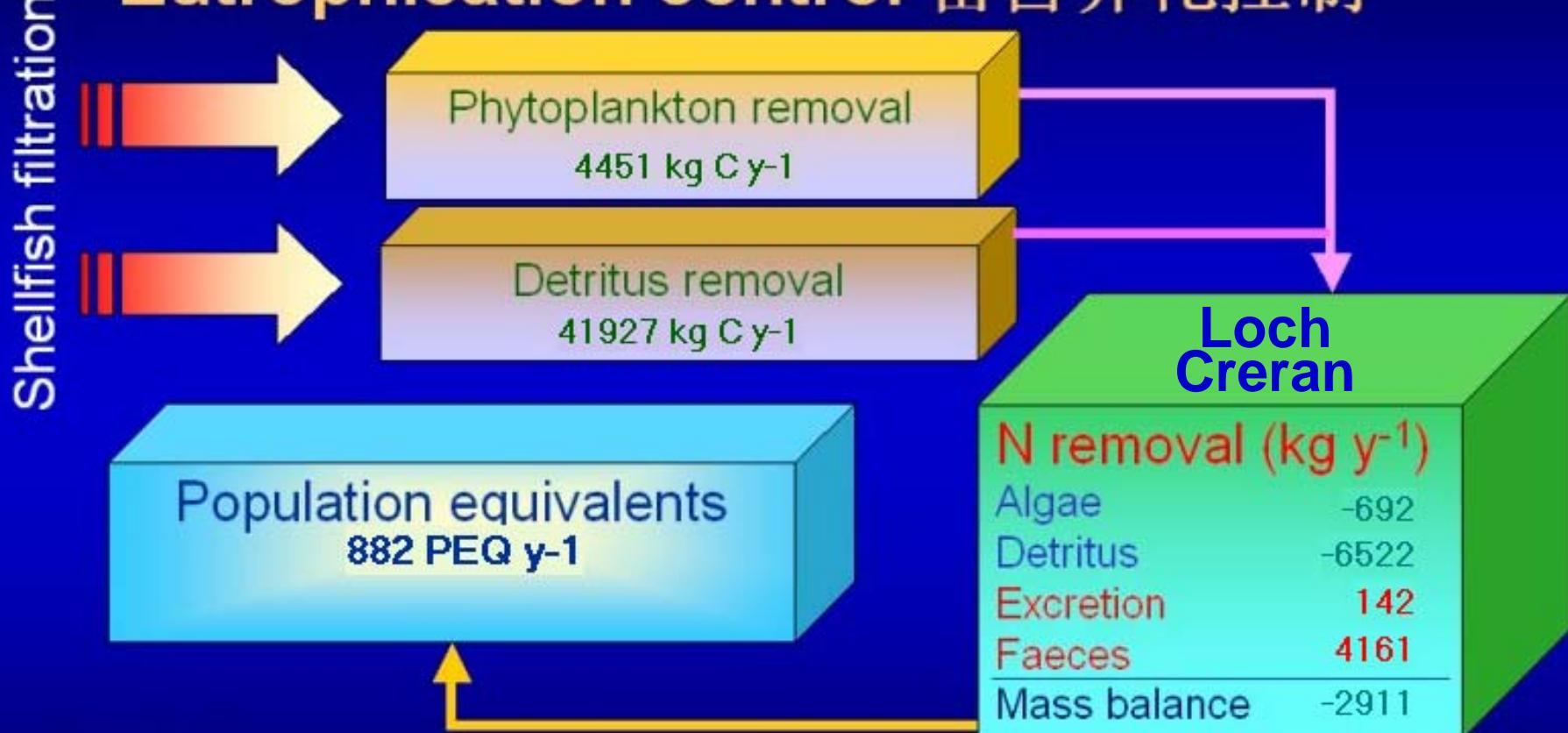
Seed = 15.3 tons

Cost = 15.3 k€

Nitrogen loading	TPP (ton)	APP	TR (TVP k€)	Profit (k€)	Chl a ($\mu\text{g l}^{-1}$)	DO (mg l^{-1})	ASSETS
Standard	54.7	3.57	547.3	532	2.5→2.3	3.1→2.5	
x 1.5	55.8	3.64	558.5	543	2.5→2.4	3.0→2.3	
x 2	56.9	3.71	569.4	554	2.5→2.3	3.0→2.2	
x 5	63.2	4.12	632.4	617	2.9→2.9	2.7→2.0	

Notes: Price of input (P_i) = 1 €kg⁻¹; Price of output P_o = 10 €kg⁻¹

Eutrophication control 富营养化控制

**ASSETS****INCOME****PARAMETERS**

Shellfish farming:	228.7 k€ y ⁻¹
Nutrient treatment:	264.6 k€ y ⁻¹
Total income:	493.4 k€ y ⁻¹

Density: 50 oysters m⁻²
 Cultivation period: 730 days
 10% mortality
3.3 kg N y⁻¹ PEQ



Address

http://www.ecowin.org/

Go

Links

FARM - Integrated multi-trophic aquaculture

	Section 1	Section 2	Section 3	Total	Culture
PEOPLE					
Production (ton TFW)	73.6	34.6	7.9	116.1	Shellfish
TPP	73.6	52.2 (+10)	42.4 (+20)	168.2 (+30)	IMTA
	0	10	20	30	Fish
PLANET					
Chlorophyll ($\mu\text{g L}^{-1}$)	6.6	5.2	4.2		Shellfish
Percentile 90	6.6	5.1	3.9		IMTA
	8.2	8.2	8.2		Fish
POM (mg L^{-1})	5.1	3.7	2.7		Shellfish
Percentile 90	5.1	4.8	6.2		IMTA
	5.4	5.5	7.0		Fish
TPM (mg L^{-1})	16.6	12.3	8.9		Shellfish
Percentile 90	16.6	14.5	15.6		IMTA
	16.8	15.0	16.4		Fish
PROFIT					
APP	28.3	13.3	3.0	14.9	Shellfish
	28.3	20.1	16.3	21.6	IMTA
	-	-	-	-	Fish

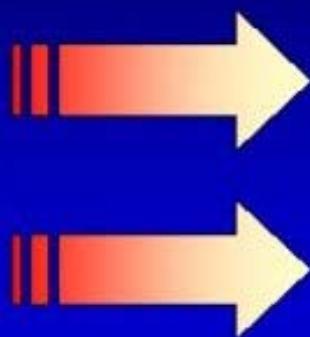
3000 X 20 X 10m blue mussel raft farm. Shellfish: 200 mussels per m^2 .
 Fish: 20 cages in section 2 and 40 in section 3. Each cage has 250 fish.
 Dissolved oxygen and ammonia are unchanged across all scenarios.



Address <http://www.ecowin.org/> Go Links

Shellfish filtration

Eutrophication control 富营养化控制



Phytoplankton removal
60040 kg C y⁻¹

Detritus removal
174517 kg C y⁻¹

Population equivalents
4040 PEQ y⁻¹

IMTA scenario with fish	
N removal (kg y ⁻¹)	
Algae	-9340
Detritus	-27147
Excretion	532
Faeces	22622
Mass balance	-13333

ASSETS



INCOME

Shellfish farming: 841.2 k€ y⁻¹
 Nutrient treatment: 1212.1 k€ y⁻¹
 Total income: 2053.3 k€ y⁻¹

PARAMETERS

Density: 200 mussels m⁻²
 Cultivation period: 365 days
 10% mortality
 3.3 kg N y⁻¹ PEQ

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

Go Links



Loch Creran



Dungarvan Bay



Ria Formosa

Final comments

- A combination of models running at different time and space scales is at the core of successful carrying capacity analysis;
- Simulation of the catchment, and its role in contributing water and nutrients to a loch or bay, is a fundamental part of the management toolset;
- The trade-off between multiple year simulation and spatial complexity, with acceptable accuracy, is required for building a bridge to microeconomic models, which use a decadal time scale;
- The triple bottom line, i.e. optimising people, planet and profit, is the key to sustainable mariculture. The West cannot compete on quantity;
- The challenge lies in bringing the three components of the 3XP equation together as a holistic indicator of sustainable carrying capacity.