ECosystem Approach for Sustainable Aquaculture ECASA

Assessment of production and water quality impacts of shellfish aquaculture using farm-scale models

ECASA Stakeholder Conference

http://www.ecasa.org.uk/

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ECASA.org

ShellSIM

Plymouth Marine Laboratory

UNIVERSITÀ CA' FOSCARI VENEZIA

ASSETS

ECASA Final Meeting, Crete, 17th-20th September 2007

Topics

- **System-scale models: overview, drivers**   5
- **System-scale models: carrying capacity**   9
- **Farm-scale models: drilling down**   3
- **FARM: People - Planet - Profit**   6
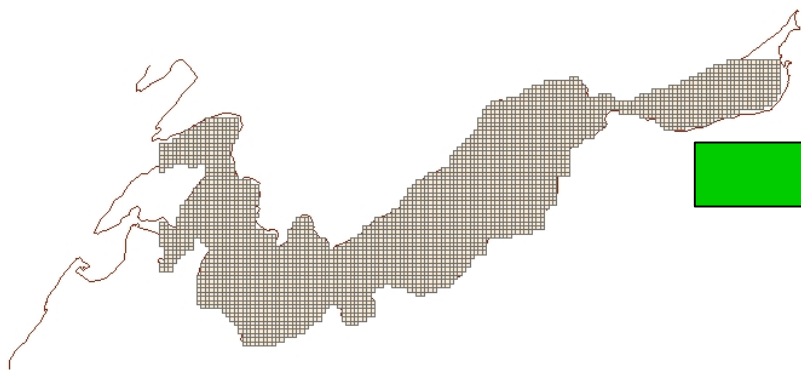- **Synthesis**   1

Slides

24+2

Guincho, Portugal

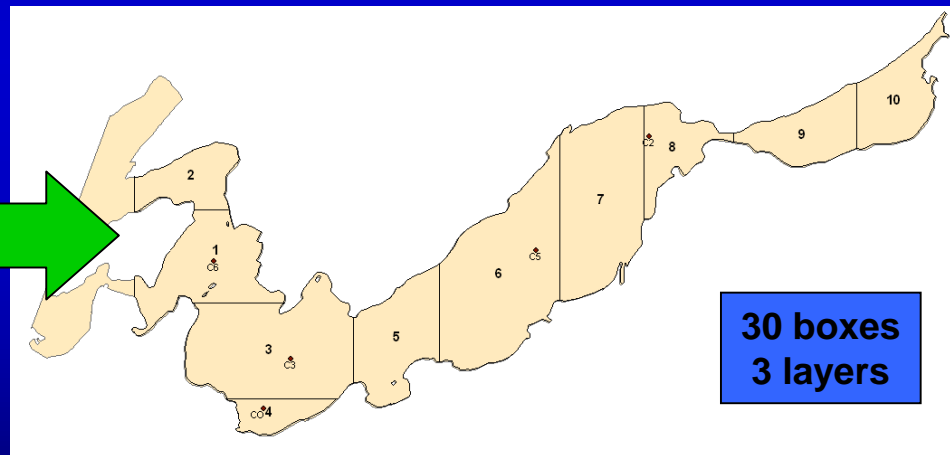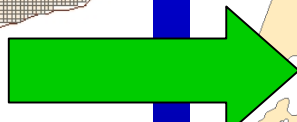# Loch Creran – EcoWin2000 model

Delft3D hydrodynamic model
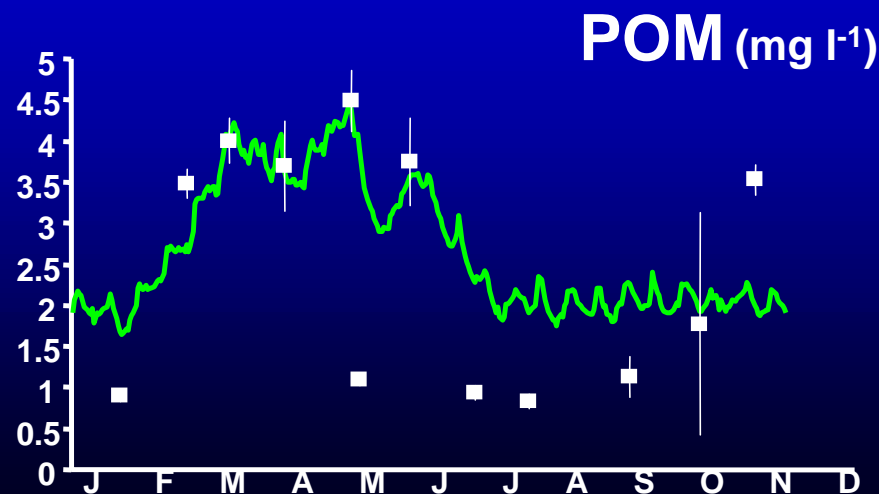
EcoWin2000 ecological model
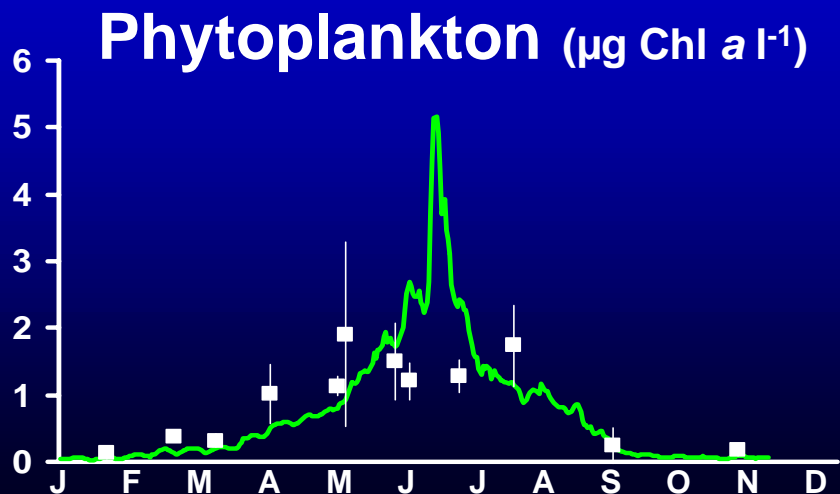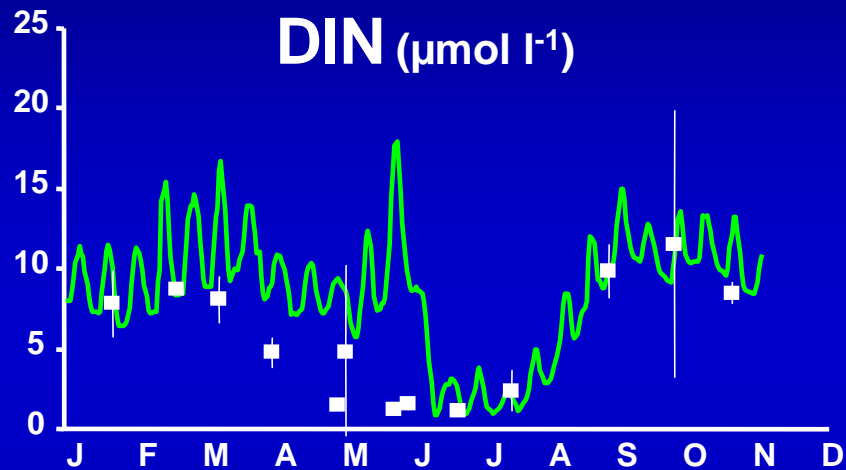

Many boxes 20 layers

30 boxes 3 layers

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

Validation of growth drivers
Loch Creran – Box 4 (Oyster Farm)

Ria Formosa – EcoWin2000 model

Model boxes

- 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

100 units of tracer in all boxes at start

Legend:
- Box 1
- Box 2
- Box 3
- Box 4
- Box 5
- Box 6
- Box 7
- Box 8
- Box 9
- e-time
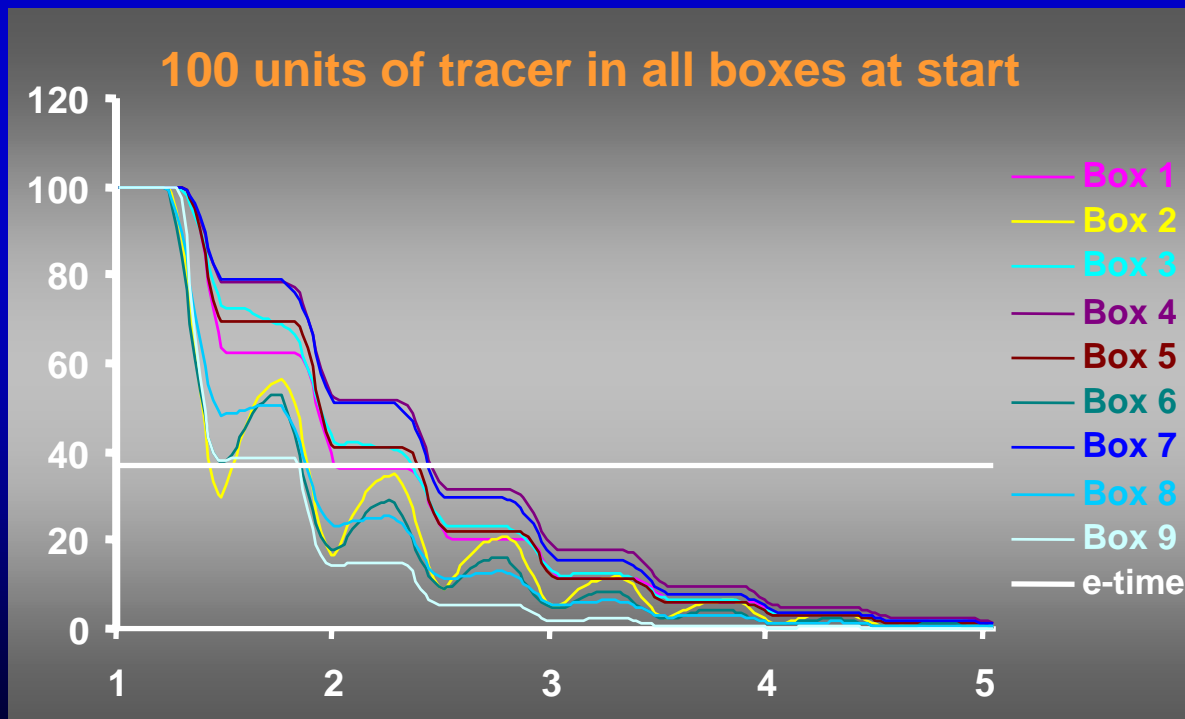
e-folding time: time for the concentration in a model box to be reduced by a factor of 1/e, i.e., from an initial concentration of 100% to about 37%

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

Validation of growth drivers
Ria Formosa – Box 2

BOX 2

DIN

SPM

Phytoplankton

POM
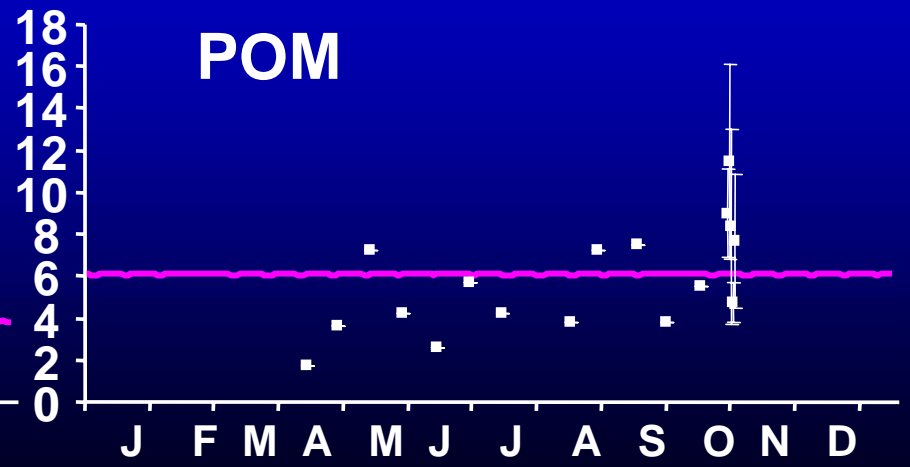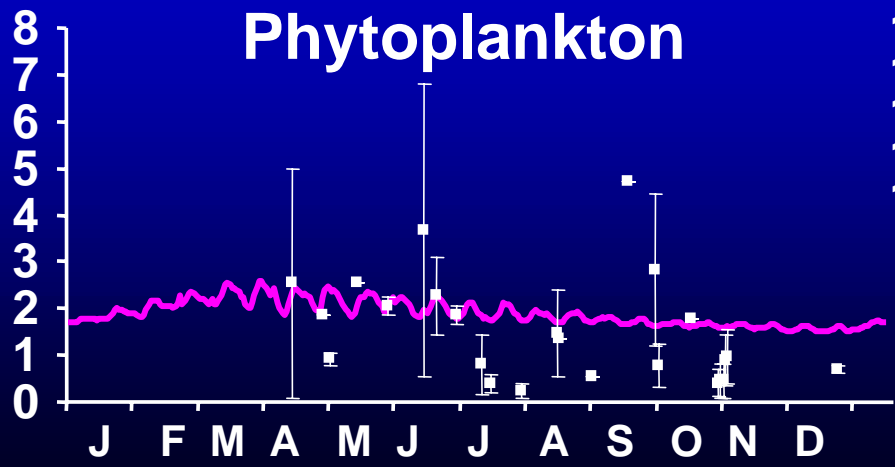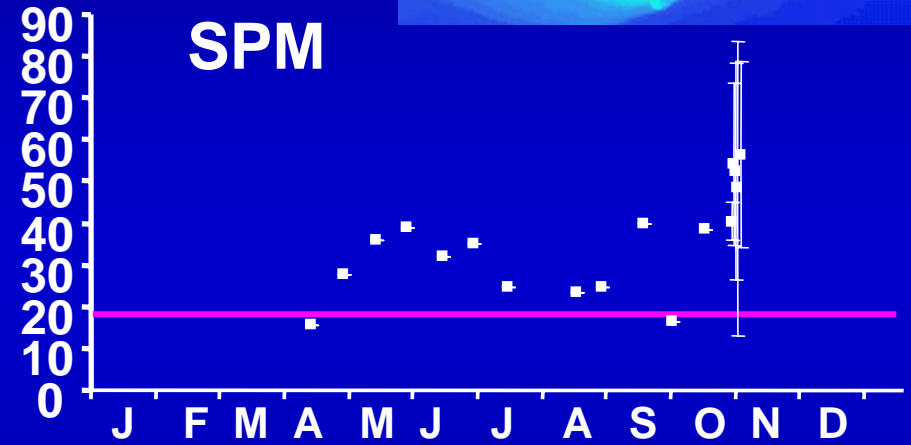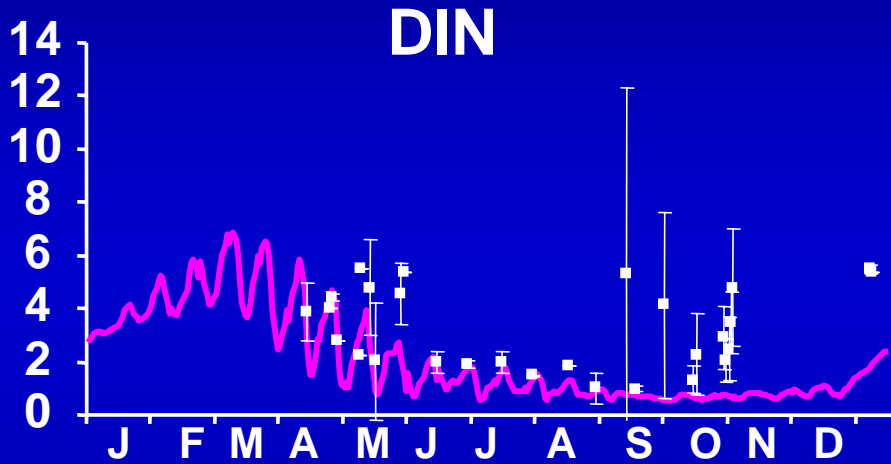
Aquaculture areas in Loch Creran

Mussels *(Mytilus edulis)*

Oysters *(Crassostrea gigas)*

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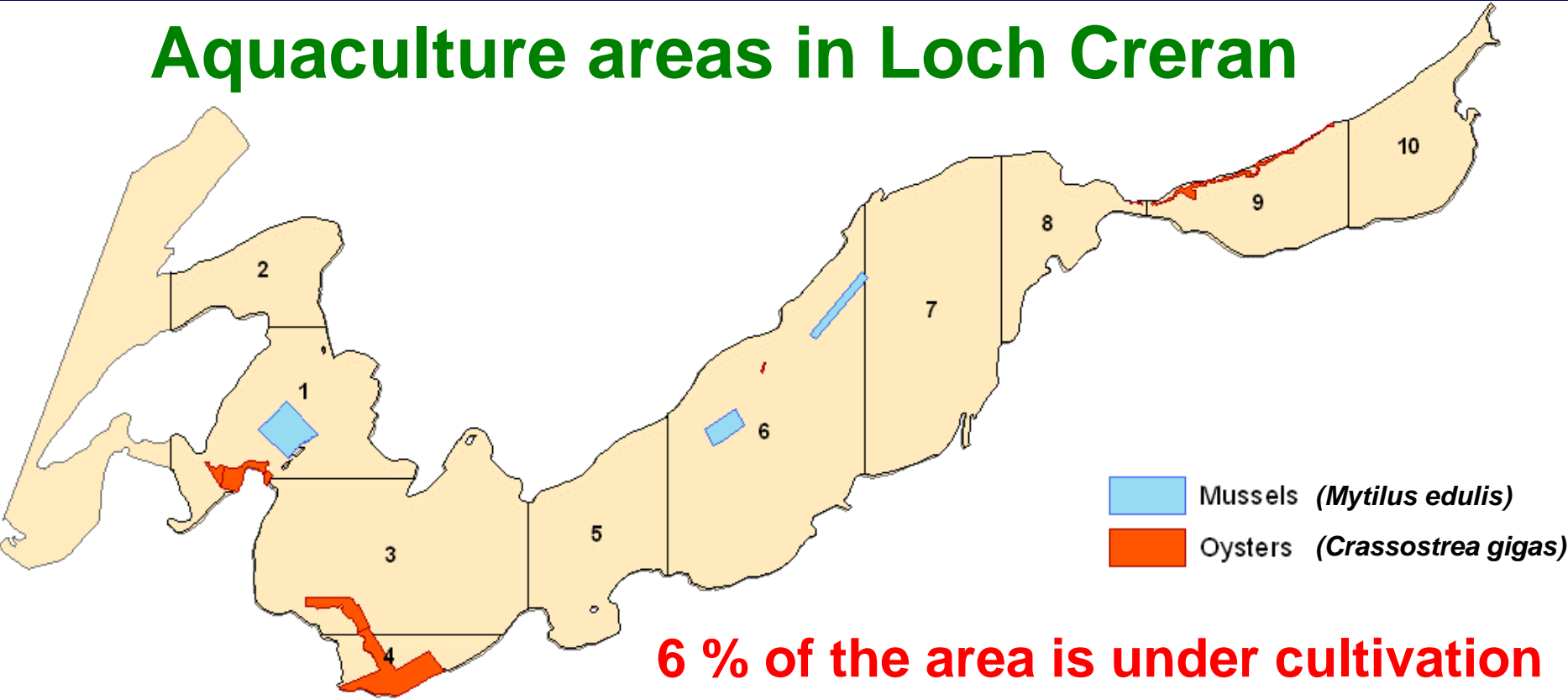
BOX	1 (M)	1 (O)	3 (O)	4(O)	6 (M)	6 (O)	8 (O)	9 (O)	Total
Area (ha)	150.2	150.2	263.4	51.5	295.1	295.1	78.3	105.0	1862
Aquaculture	10.4	5.9	5.4	16.5	8.4	0.1	0.06	3.5	115
% area	6.9	3.9	2.1	32	2.9	0.03	0.08	3.3	6.2

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

	Box	Aquaculture area	TPP (ton TFW)	APP
Pacific oyster	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)
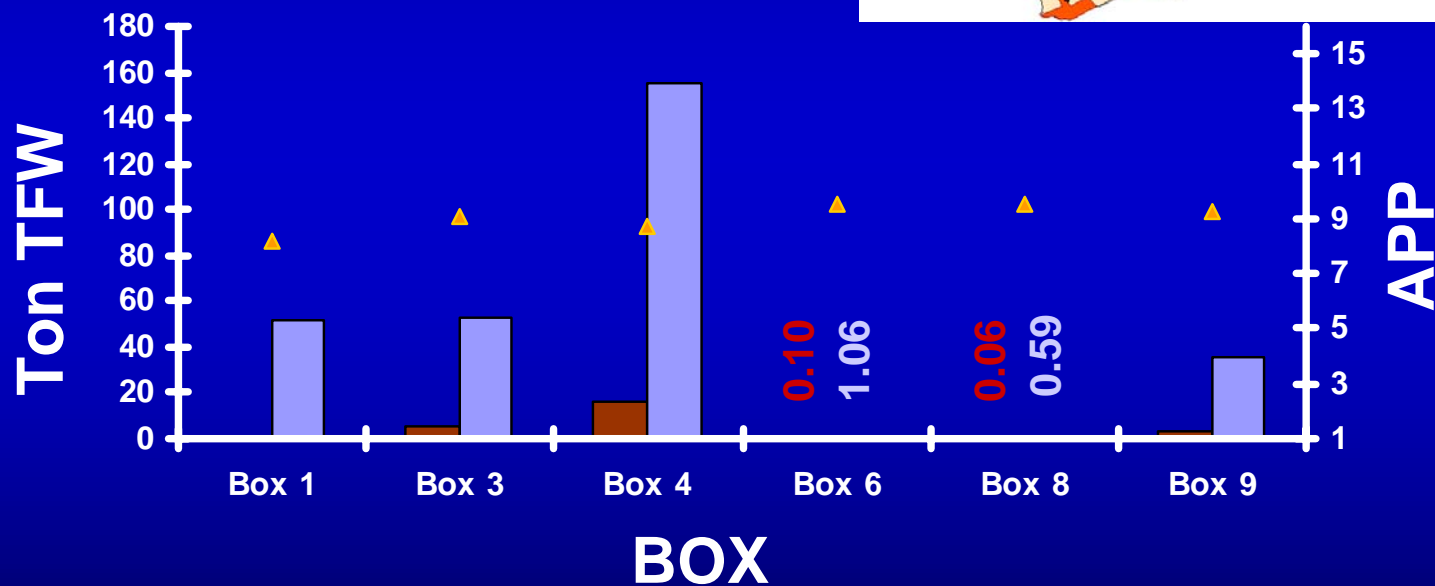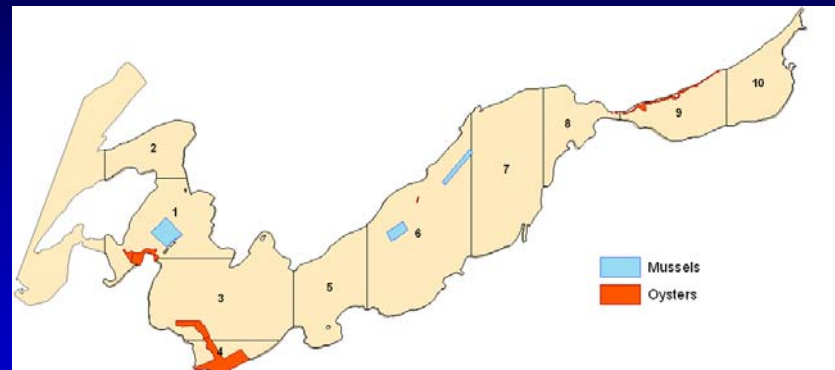
	Weight at harvest	> 50 g
	Total production	~ 300 ton
	APP	~ 9.05

Loch Creran – Biodiversity scenario
Oyster production with and without wild species

Production (tons)
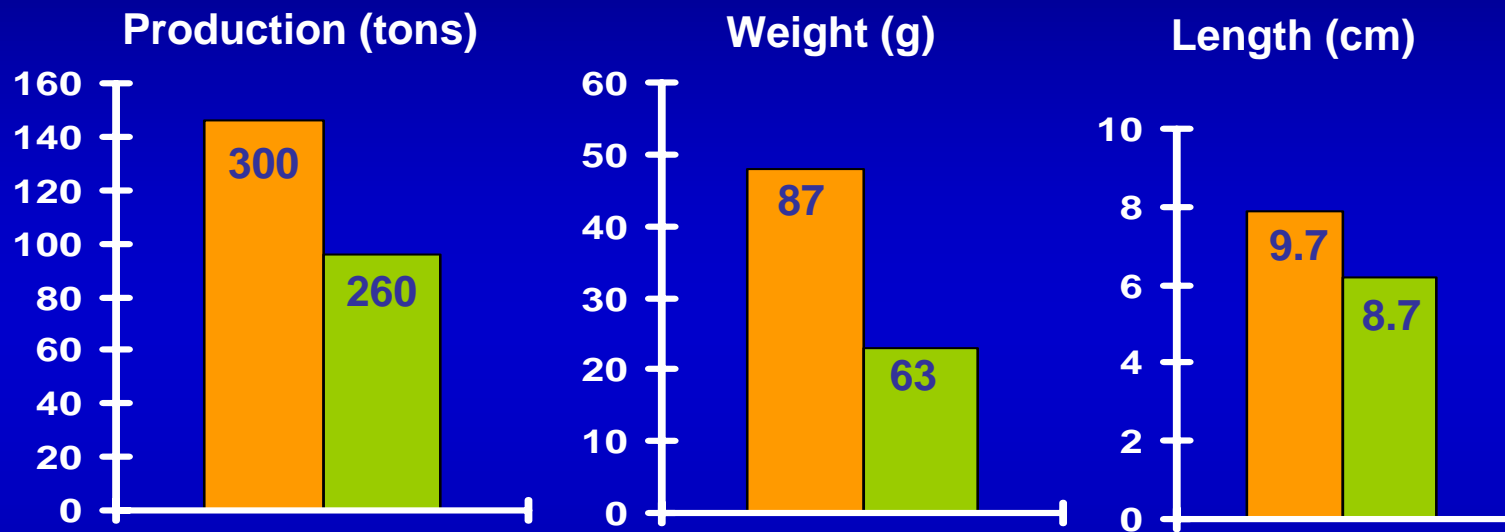
Weight (g)

Length (cm)

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

Aquaculture areas in Ria Formosa

7 % of the area is under cultivation

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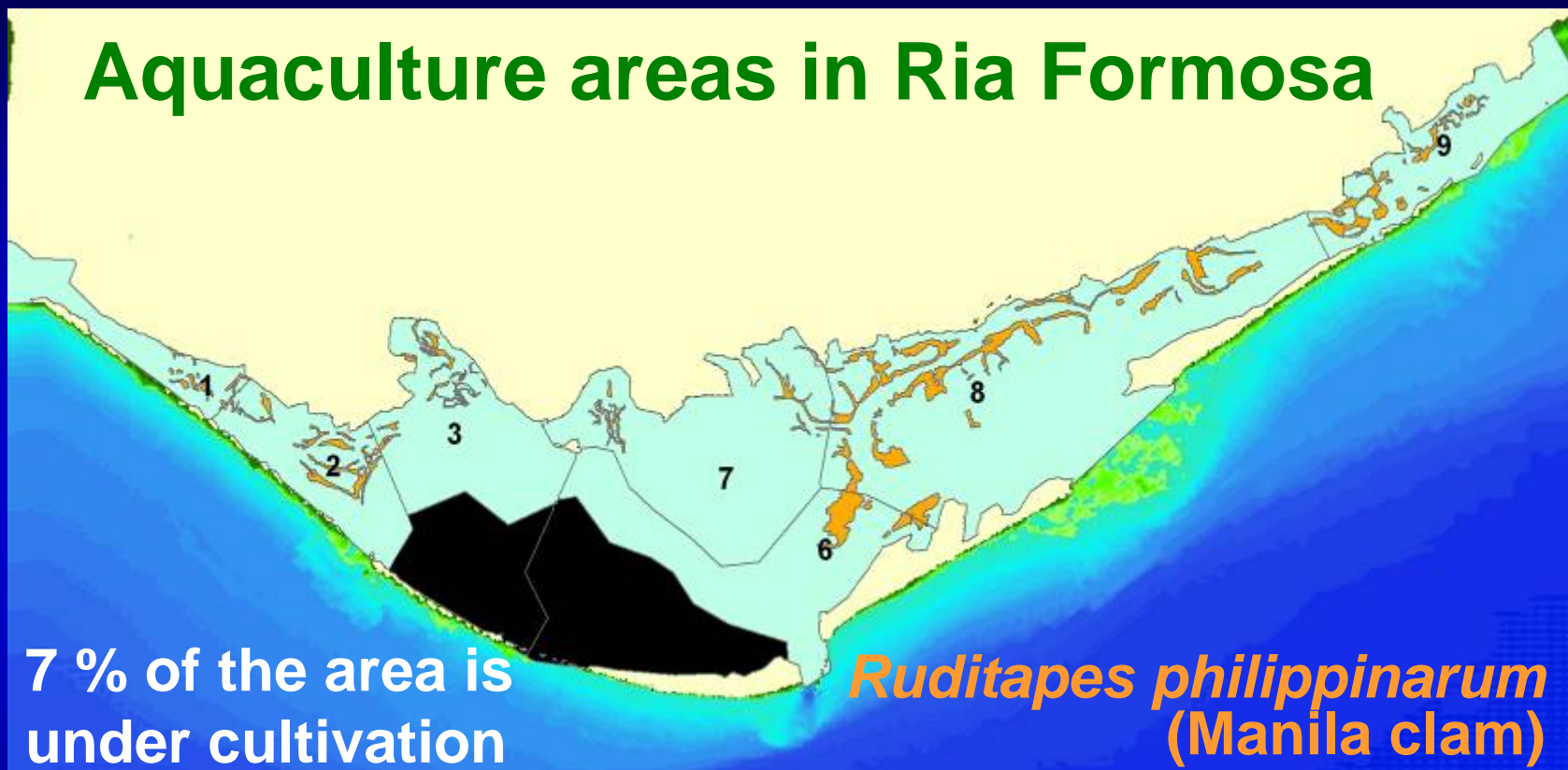
BOX	1	2	3	4	5	6	7	8	9
Area (ha)	225	514	709	493	763	963	1016	2164	473
Aquaculture	15	51	32	-	-	53	30	239	65
% of area	6.5	10	4.5	-	-	5.5	3	11	14

Ria Fomosa: Individual length and weight

Ruditapes philippinarum (Manila clam)
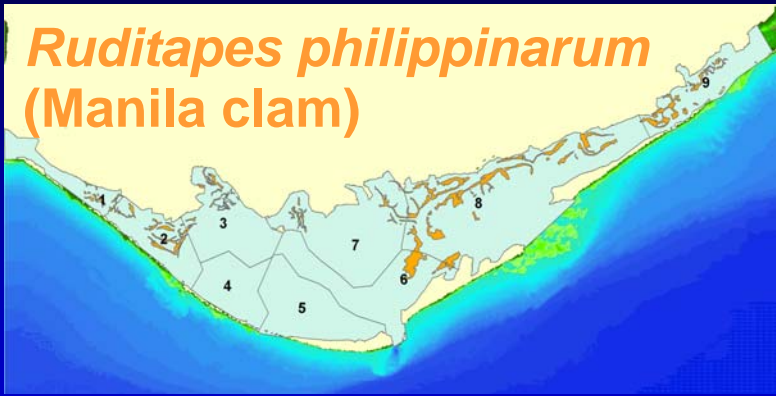
BOX
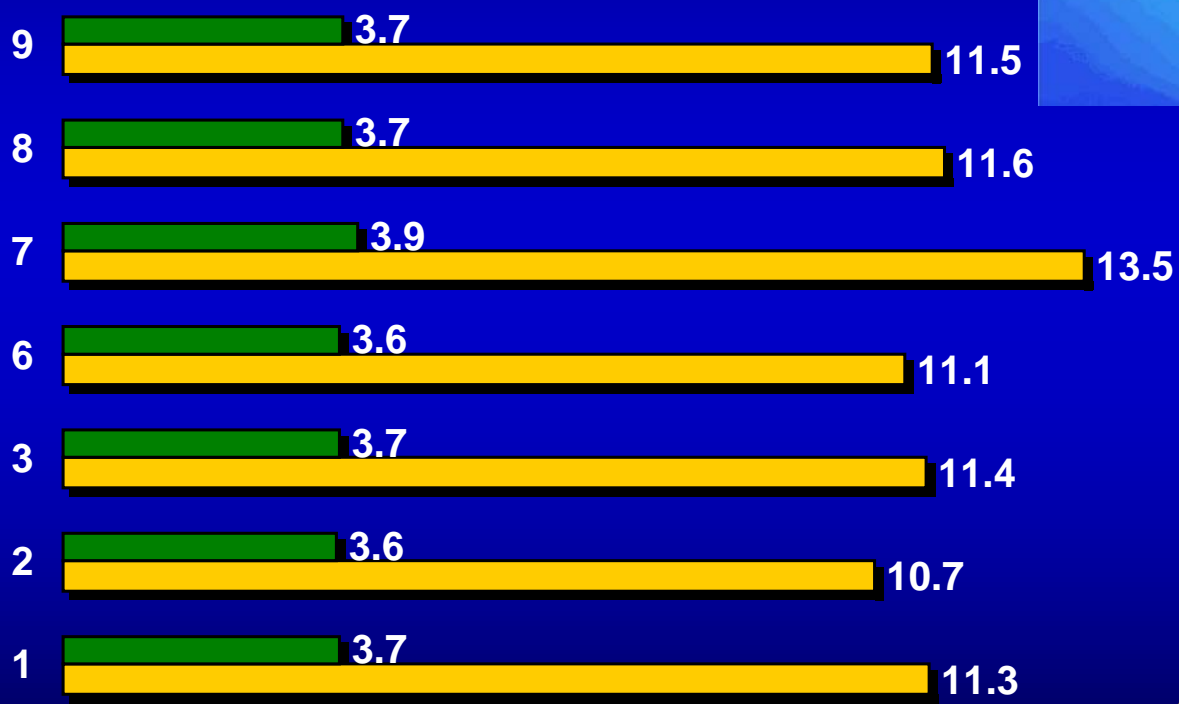
Clams

Clams
mean length ~ 3.7 cm
mean weight ~ 11.6 g

BOX	Length (cm)	Weight (g)
9	3.7	11.5
8	3.7	11.6
7	3.9	13.5
6	3.6	11.1
3	3.7	11.4
2	3.6	10.7
1	3.7	11.3

0   6   12   (cm) (g)

Culture period – April to September

■ Length (cm)
■ Weight (g)

Ria Formosa – EcoWin2000 model
Total production
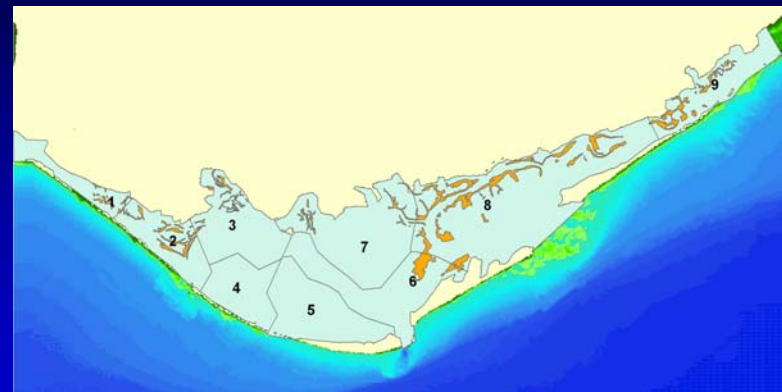
Model starts stabilising after year 3
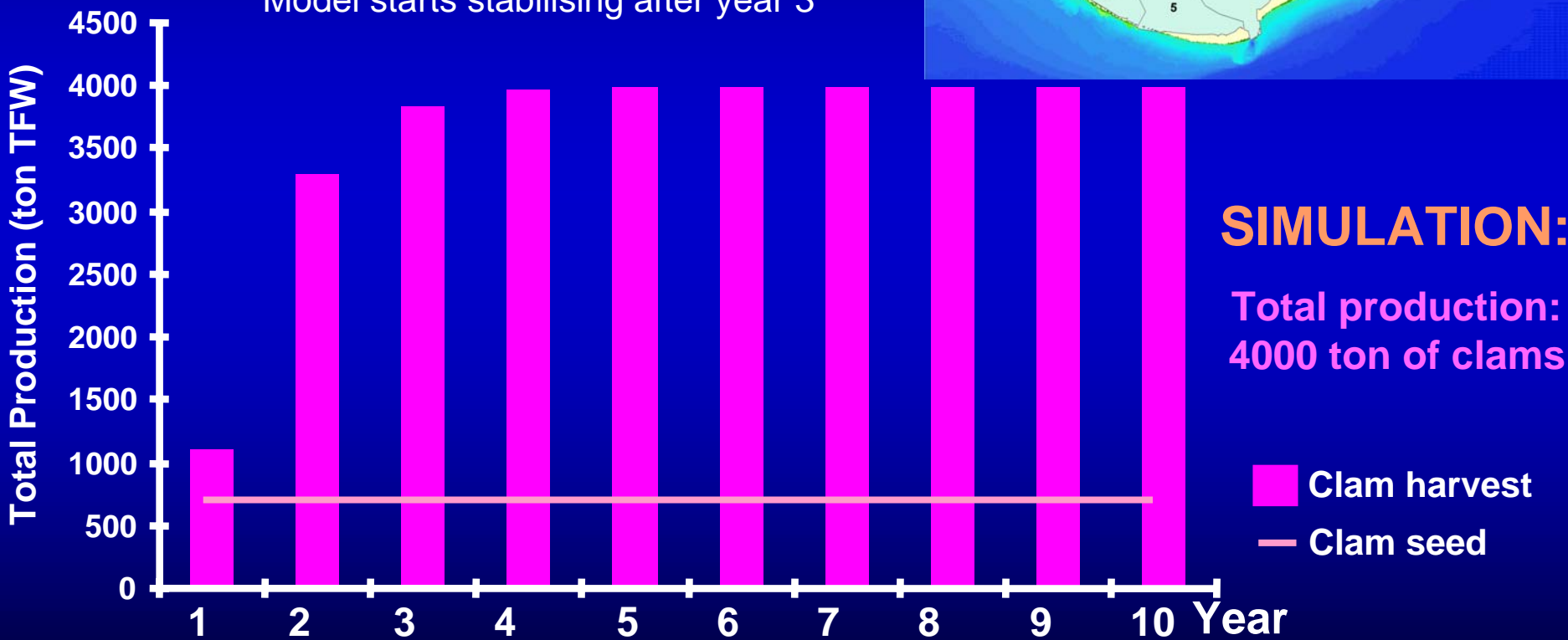
SIMULATION:

Total production:
4000 ton of clams

Total Production (ton TFW)

4500
4000
3500
3000
2500
2000
1500
1000
500
0

1   2   3   4   5   6   7   8   9   10   **Year**

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
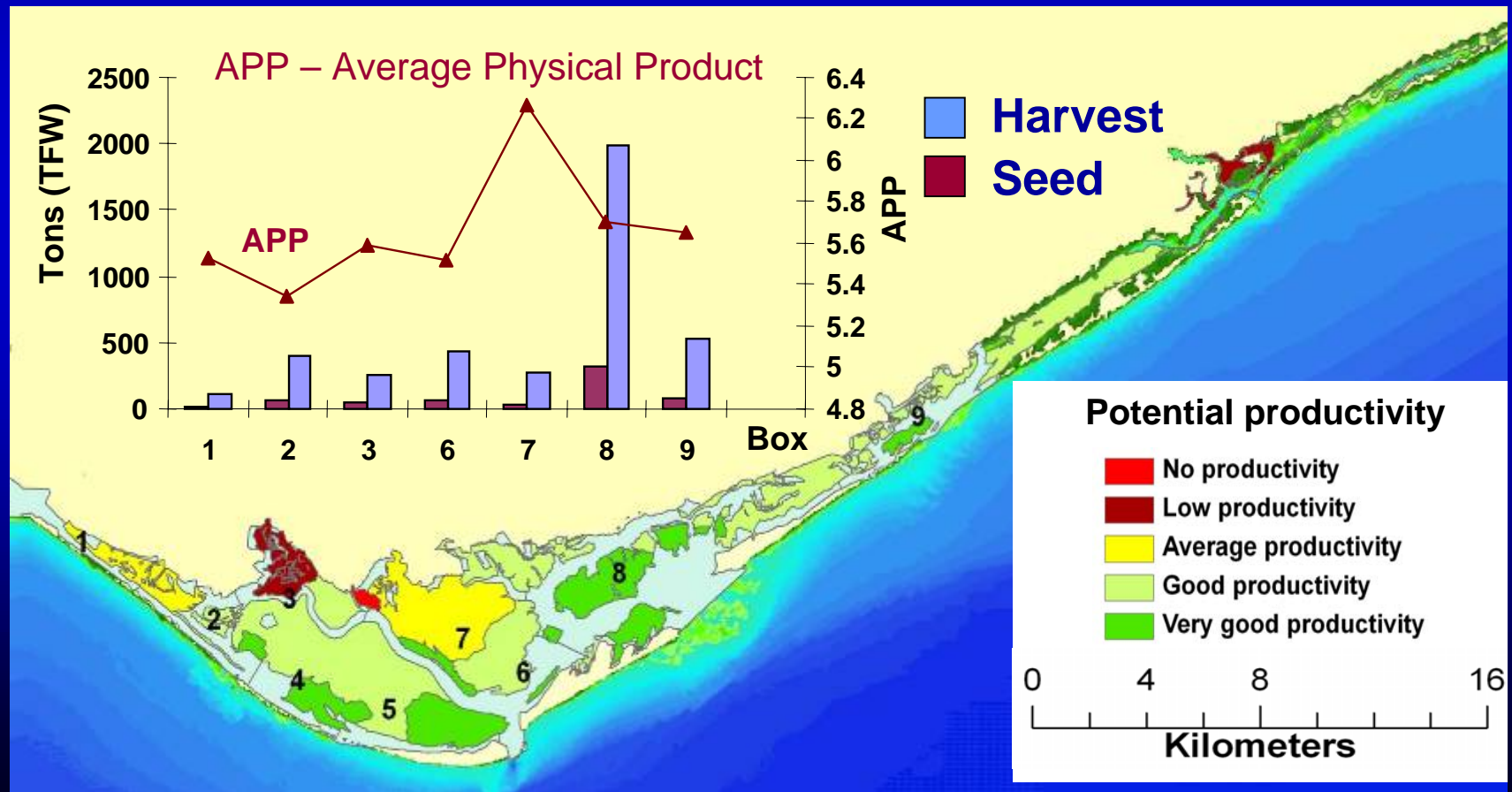
Ria Formosa - Average Physical Product

APP obtained in EcoWin2000 model for Manila clam culture

Potential productivity in Ria Formosa

N

5.65

5.7

6.27

5.59

5.34

5.51

Legend:
- APP
- Coastline
- 5.34
- 5.35 - 5.4
- 5.41 - 5.5
- 5.51 - 5.6
- 5.61 - 5.65
- 5.66 - 5.7
- 5.71 - 5.9
- 5.91 - 6
- 6.01 - 6.1
- 6.11 - 6.27

Productivity legend:
- No productivity
- Low productivity
- Average productivity
- Good productivity
- Very good productivity
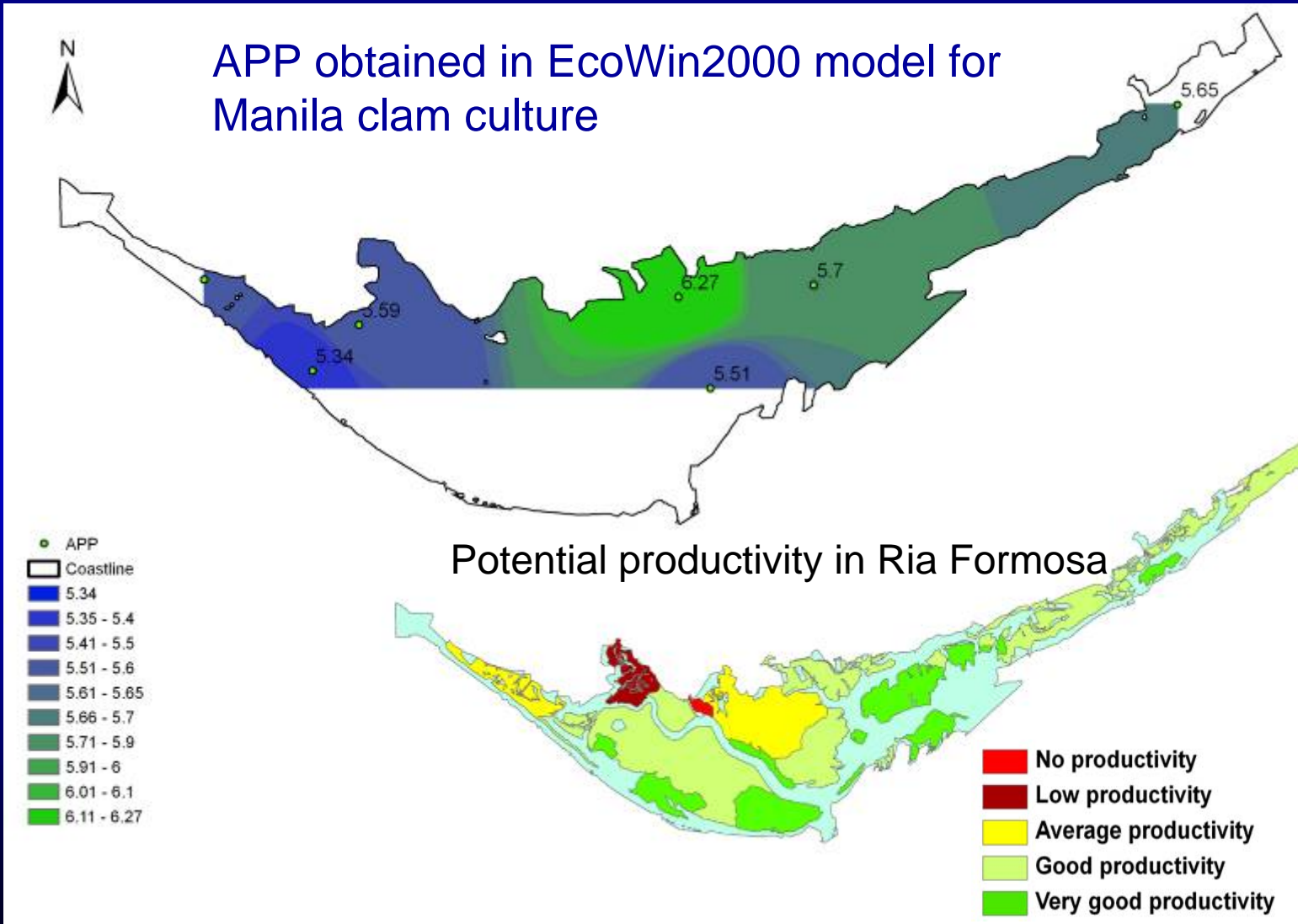
Farm-scale conceptual diagram
养殖区概念模型

Farm length

Width

Current

Shellfish

Current

Chl *a*

Chl *a*

POM

POM

Depth   1   2   3   n-1   n

Sections

FARM results

Loch Creran

Mussels
Oysters

Ria Formosa
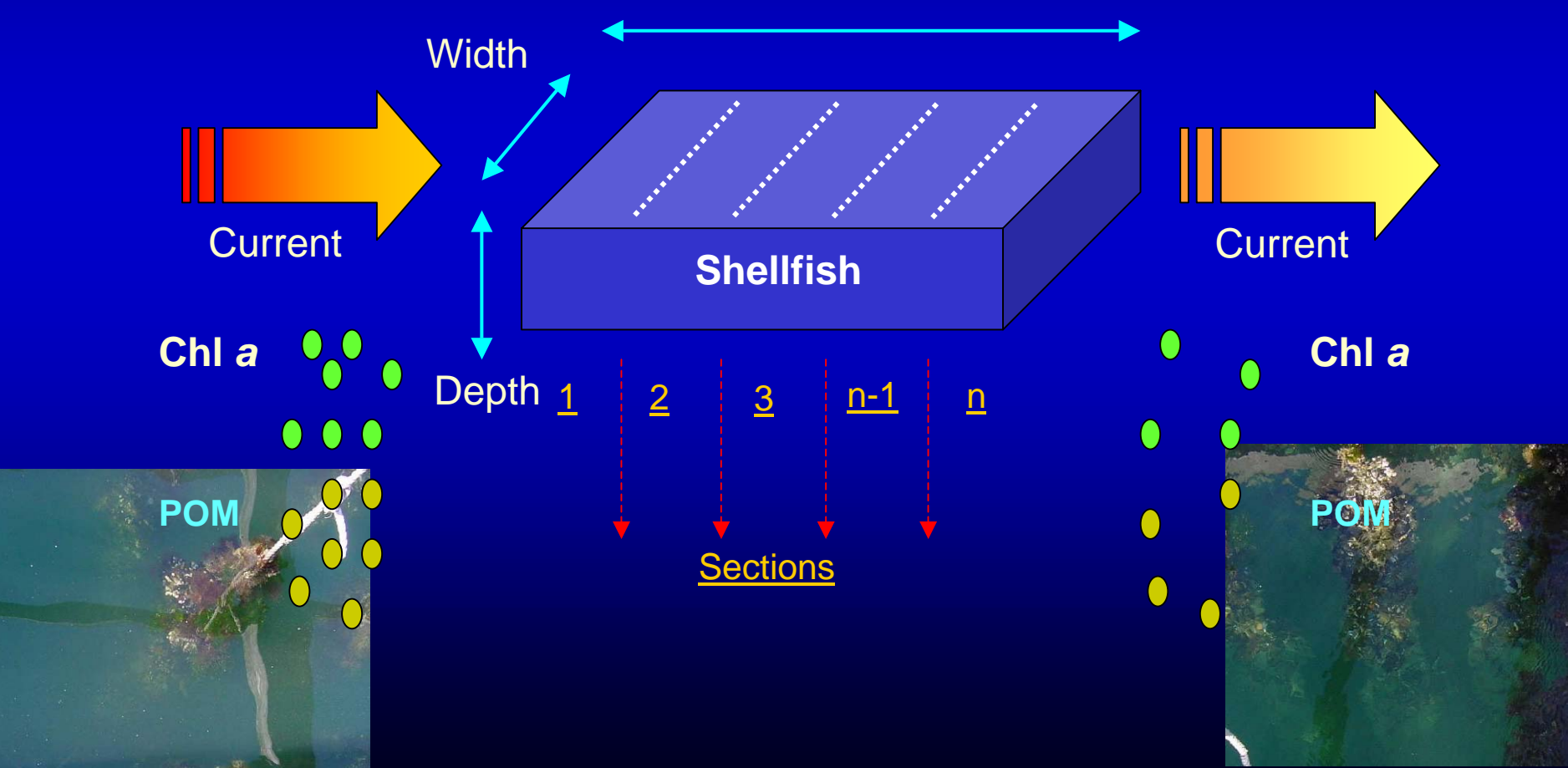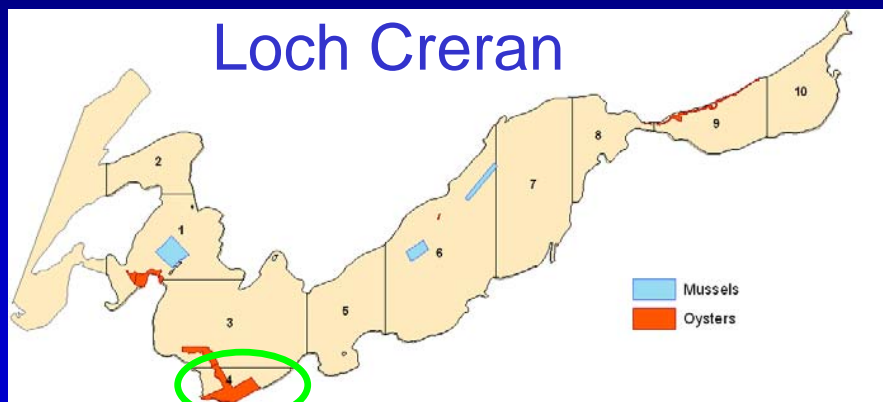
Box 4

(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

Loch Creran – Model outputs

FARM - Farm Aquaculture Resource Management

FARM drivers | FARM outputs | FARM mass balance

Results

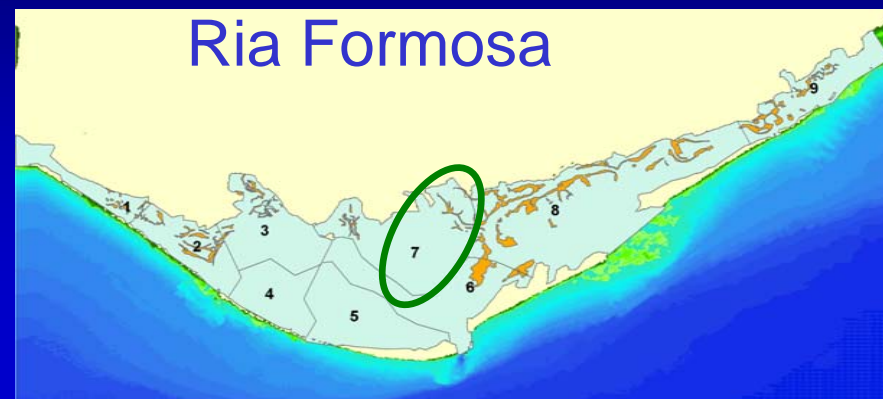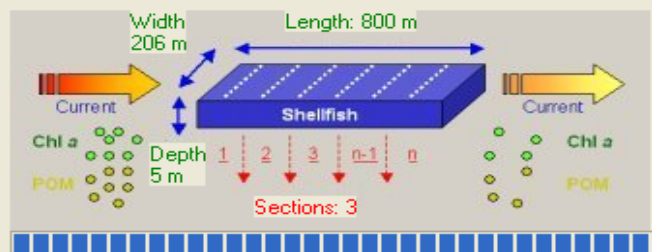|	A	B	C	D	E	F	G	H
1	Julian day	Chlorophyll	POM	TPM	Oxygen	Weight	Length	Harvest
2	-	(ug L-1)	(mg L-1)	(mg L-1)	(mg L-1)	(g TFW)	(cm)	(Tons TFW)
3	61	0.1676811235	3.06939747	12.0724977	7.999303275	1.58642373	2.572644208	1.663078913E-02
4	62	0.1713274798	3.109431249	12.26265367	7.999433508	1.599475077	2.57965315	1.134793654E-01
5	63	0.1744416477	3.146584463	12.449929	7.999406826	1.612734646	2.5867349	4.187592235E-01
6	64	0.1773991346	3.182934544	12.63640122	7.999336576	1.627328183	2.594484287	6.270173472E-01
7	65	0.1803795763	3.219434934	12.82302374	7.999274575	1.642612864	2.602551069	5.183906483E-01
8	66	0.1832885356	3.25559291	13.00930384	7.999194084	1.658137324	2.610693236	2.834364698E-01
9	67	0.1861171916	3.291374297	13.19520733	7.999093289	1.673900932	2.618908891	1.177957153E-01
10	68	0.188862558	3.326775318	13.38073009	7.998972057	1.689427408	2.62695059	3.89017191E-01
11	69	0.191533671	3.361852036	13.56592765	7.998833425	1.705182424	2.635060352	1.118350685E-01
12	70	0.1941523344	3.396720496	13.750914	7.998683704	1.72116555	2.643236547	2.883578566E-01

◄ | ► \ Drivers: interpolated data ∧ Results: Pacific oyster (Box 1) ∧ Results: Pacific oyster (Box 2) ∧ Results: Pacific oyster (Box 3) /

Model specs

Farm volume (m3)	824000
Box volume (m3)	274667
Timestep (days)	0.0077
Individual TFW (g)	26.34
Shell length (cm)	6.56
Nº timesteps	94608

Width 206 m · Length: 800 m · Current · Shellfish · Current · Chl a · Depth 5 m · 1 2 3 n-1 n · Chl a · POM · POM · Sections: 3

	A	B	C	D	E	F	G
1	Section	Seed	TPP	APP	TR	TC	Profit
2	-	(ton)	(ton)	-	(TVP k€)	(K€)	(K€)
3	1	4.1	32.4	7.86	161.8	4.1	157.7
4	2	4.1	30.4	7.39	152.2	4.1	148.1
5	3	4.1	28.7	6.96	143.4	4.1	139.3
6	Total	12.4	91.5	7.40	457.5	12.4	445.1
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 /

FARM Website · Run FARM · Exit

Loch Creran – Economic Analysis I

TPP

APP

103 ton

MPP

Optimisation
$VMP = MPP.P_o$
$VMP = P_i$
For $P_i = 20\%$ P_o, $MPP = 0.20$

Stage I 0

Stage II

Stage III

TPP (tons TFW)

APP and MPP (no units)

Seed (tons TFW)
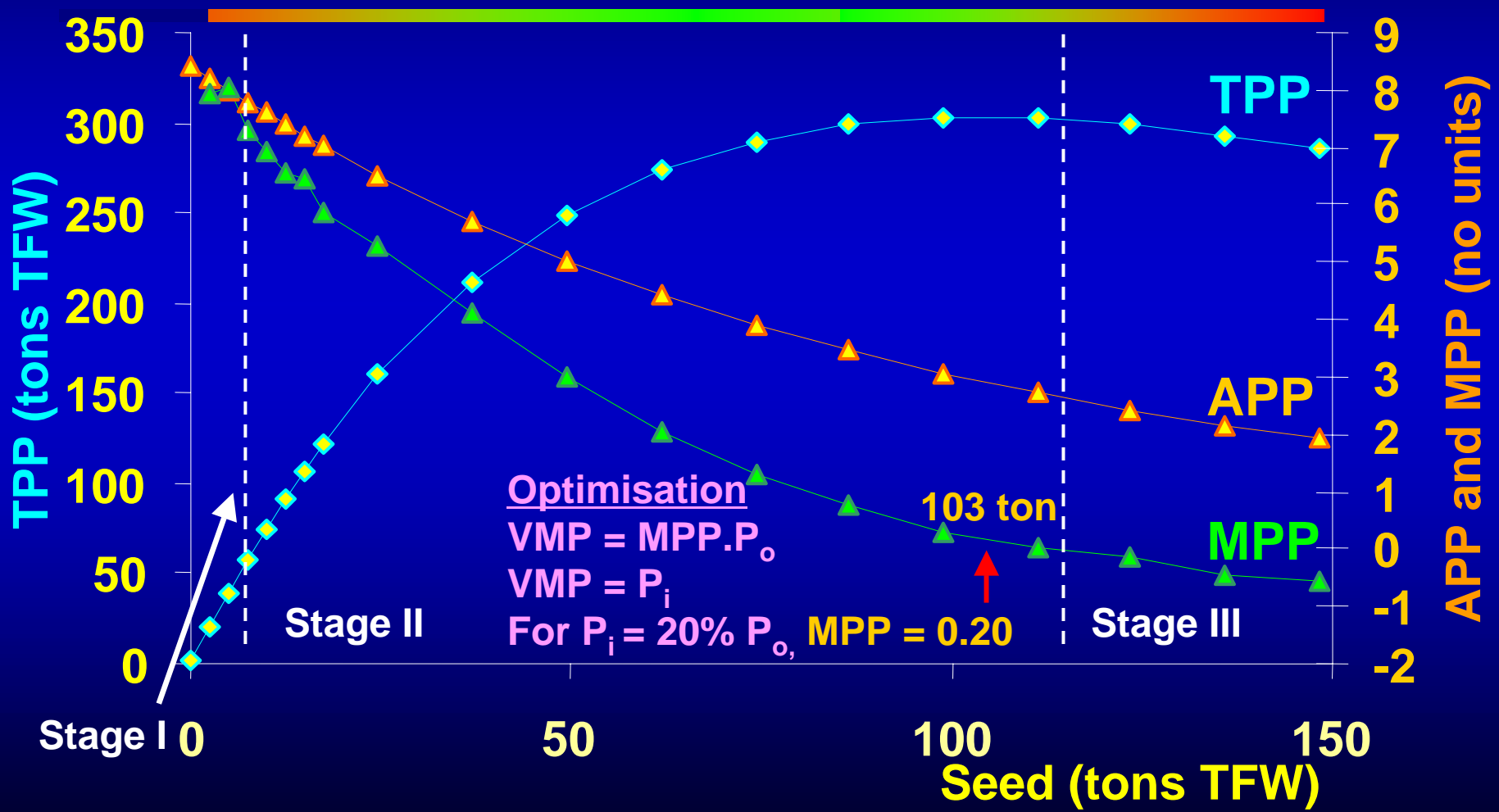
C. gigas, 730 day cultivation period, drivers from EcoWin2000
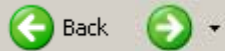
Loch Creran – Economic analysis II

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	8.21	7.91	39.6	101.5	2.5	99
5	39.6	8.00	8.04	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	302.7	3.06	0.30	1.49	1513.5	98.9	1415
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
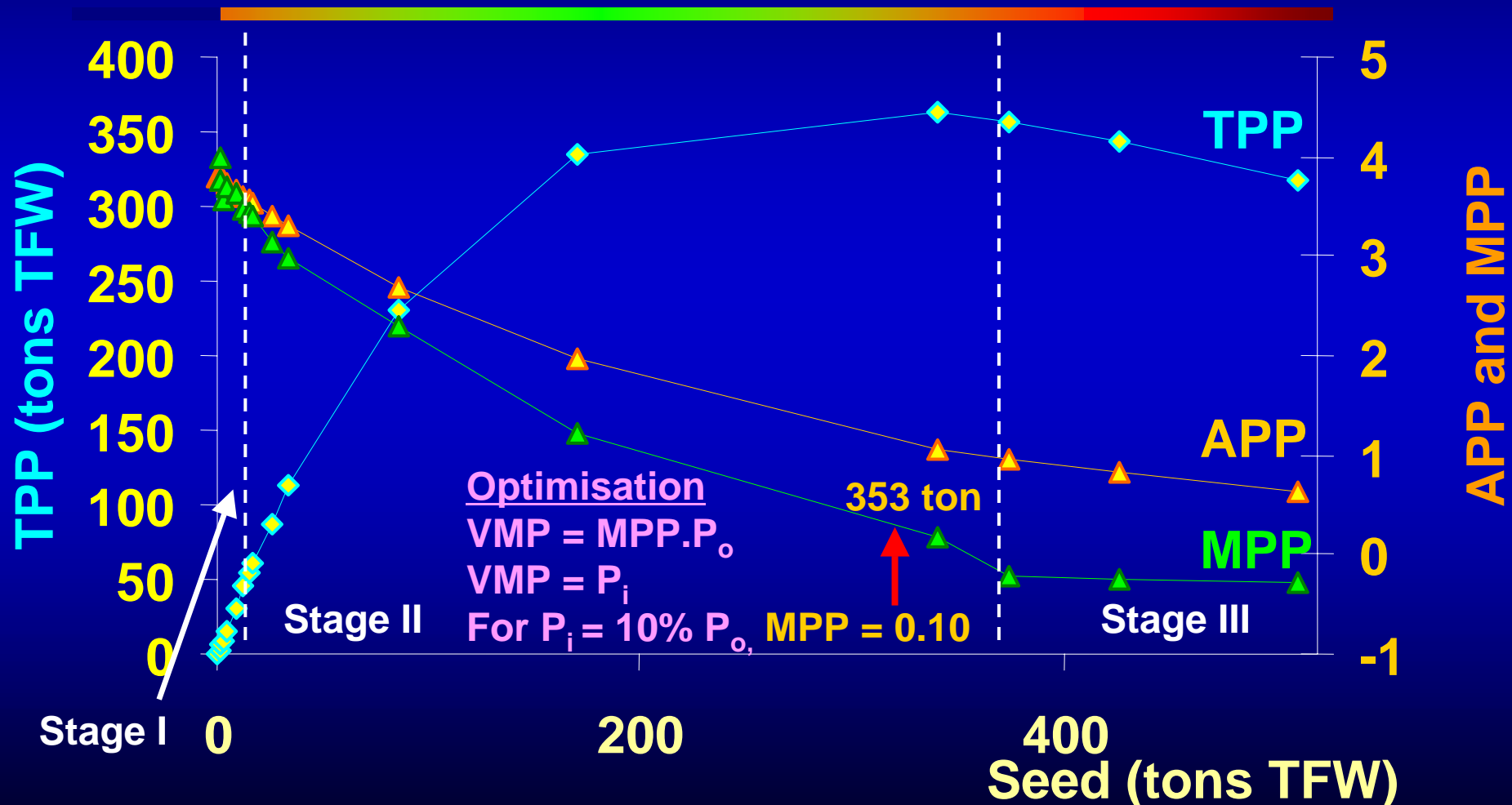
R. philippinarum, 180 day cultivation period, drivers from EcoWin2000

Ria Formosa – Model Scenarios

Seed = 15.3 tons   Cost = 15.3 k€

Nitrogen loading	TPP (ton)	APP	TR (TVP k€)	Profit (k€)	Chl a ($\mu g\ l^{-1}$)	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

Shellfish filtration

Phytoplankton removal
4451 kg C y-1

Detritus removal
41927 kg C y-1

Population equivalents
882 PEQ y-1

Loch Creran

N removal (kg y^{-1})

Algae	-692
Detritus	-6522
Excretion	142
Faeces	4161
Mass balance	-2911

ASSETS

Chl *a*

O$_2$

Score
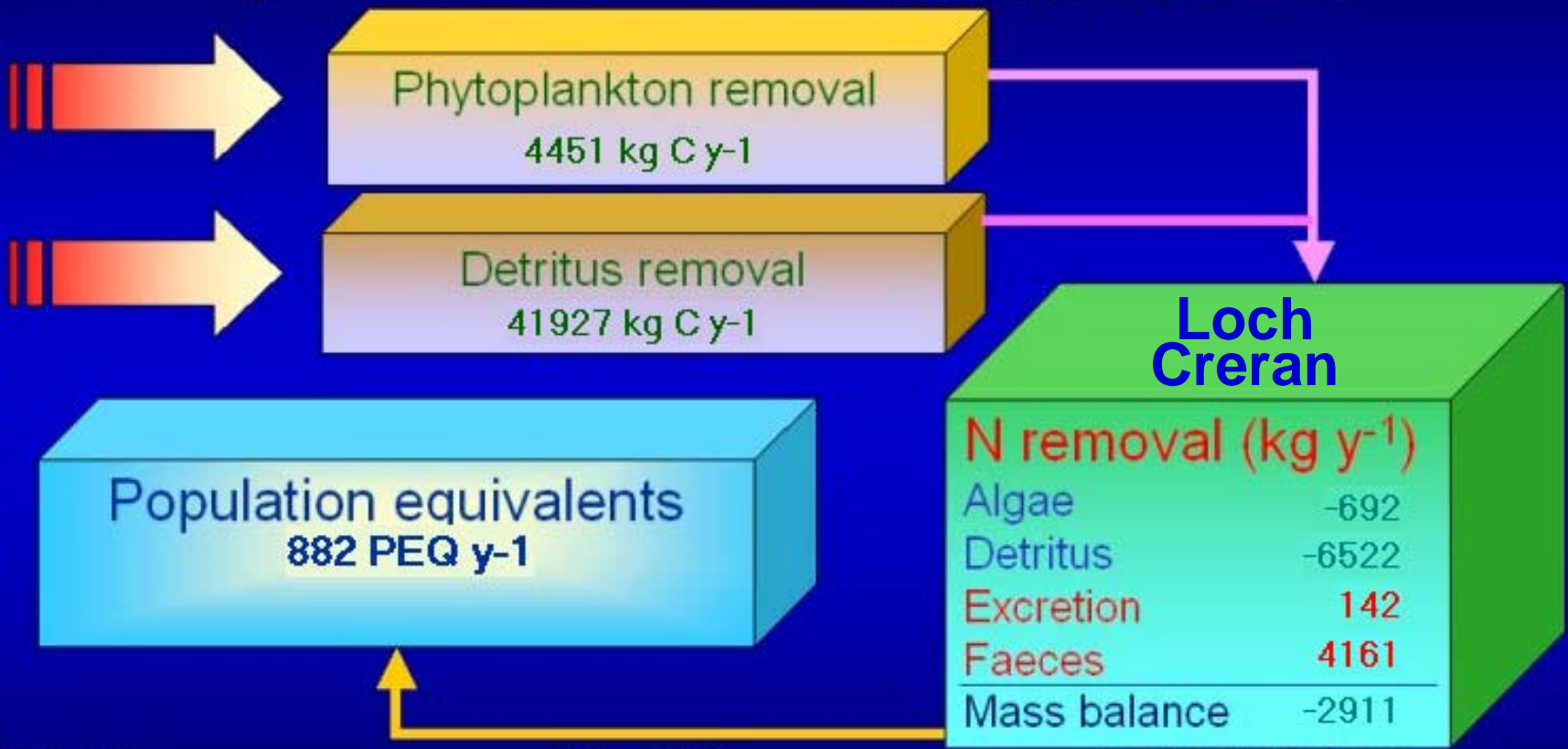
INCOME

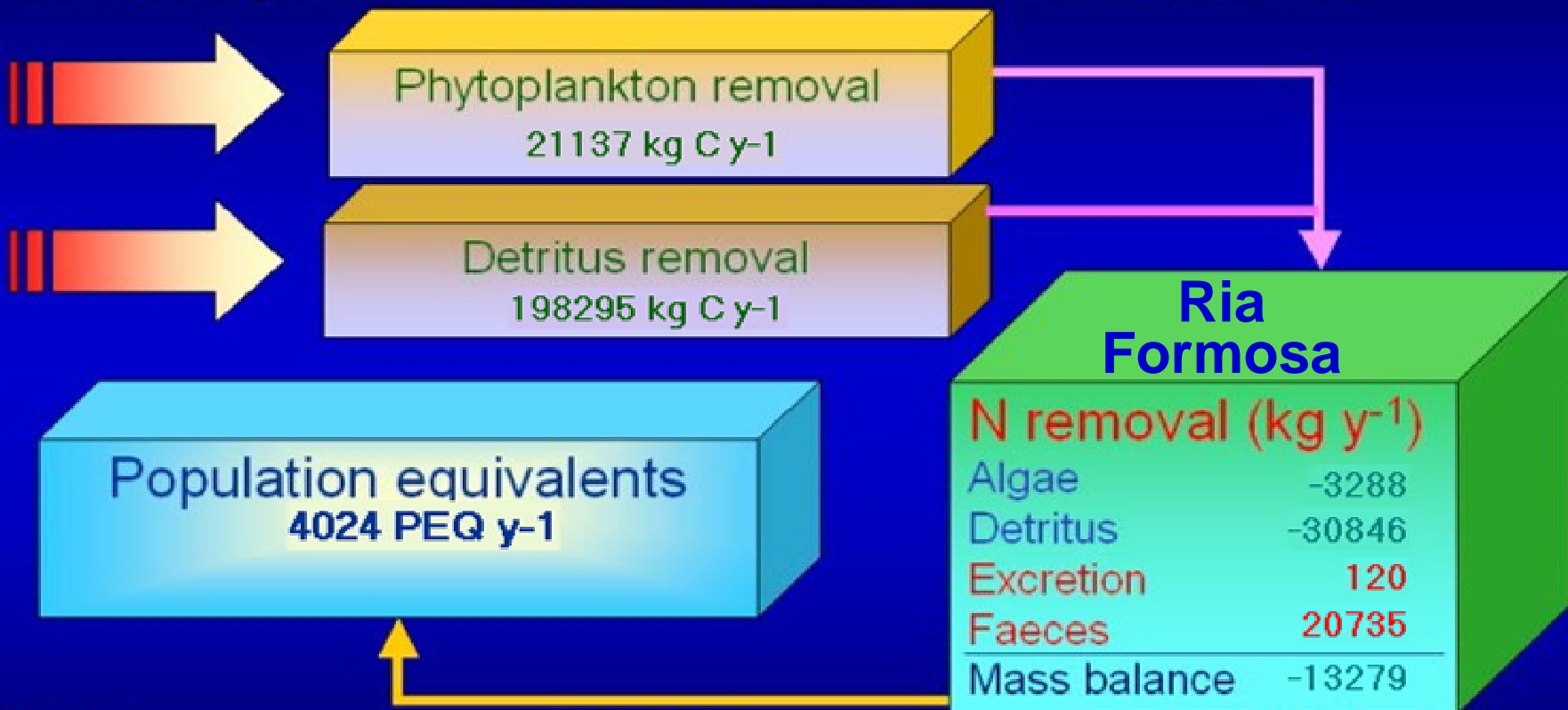|	
Shellfish farming:	228.7 k€ y-1
Nutrient treatment:	264.6 k€ y-1
Total income:	493.4 k€ y-1

PARAMETERS

Density: 50 oysters m-2
Cultivation period: 730 days
10% mortality
3.3 kg N y^{-1} PEQ

Eutrophication control 富营养化控制

Shellfish filtration

Phytoplankton removal
21137 kg C y–1

Detritus removal
198295 kg C y–1

Population equivalents
4024 PEQ y-1

Ria Formosa

N removal (kg y⁻¹)

Algae	-3288
Detritus	-30846
Excretion	120
Faeces	20735
Mass balance	-13279

ASSETS

Chl a

O₂

Score

INCOME

Shellfish farming:	1109.7 k€ y-1
Nutrient treatment:	1207.2 k€ y-1
Total income:	2316.9 k€ y-1

PARAMETERS

Density: 90 clams m-2
Cultivation period: 180 days
66% mortality
3.3 kg N y⁻¹ PEQ

Loch Creran

Ria Formosa

Final comments

- **The recipe: Field data + Experiments + Models = System-scale and farm-scale carrying capacity assessment (add databases, GIS and scaling);**

- **The toolbox: (i) System-scale models which include watershed drivers and pressures, biodiversity, etc. (ii) Farm-scale models driven by the former, and/or by measured data. These models use ShellSIM to simulate individual growth. Models are deployed on the web or are desktop-based for longer run times;**

- **The applications: (i) System-scale - Management level decision-support for licensing thresholds, agriculture inputs, WFD and Marine Strategy compliance, stakeholder consensus; (ii) Farm-scale: Screening models for determining optimal siting, culture densities, profit maximisation, eutrophication status and nutrient emissions trading and valuation.**

http://www.farmscale.org/   http://www.eutro.org/