Carrying capacity assessment and impact of aquaculture in Chinese bays [*1,*2]

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[*1] – European Union INCO-DC contract Nº ERBIC4CT 98-0291

[*2] - J.P. Nunes, J.G. Ferreira, F. Gazeau, J. Lencart-Silva, Zhang, X.L, Zhu M.Y., & Fang J.G., 2003. A model for sustainable management of shellfish polyculture in coastal bays. Aquaculture, 219/1-4, 257-277

Topics

- Objectives
- Locations
- Methodologies
- Modelling approaches and results
- Final comments

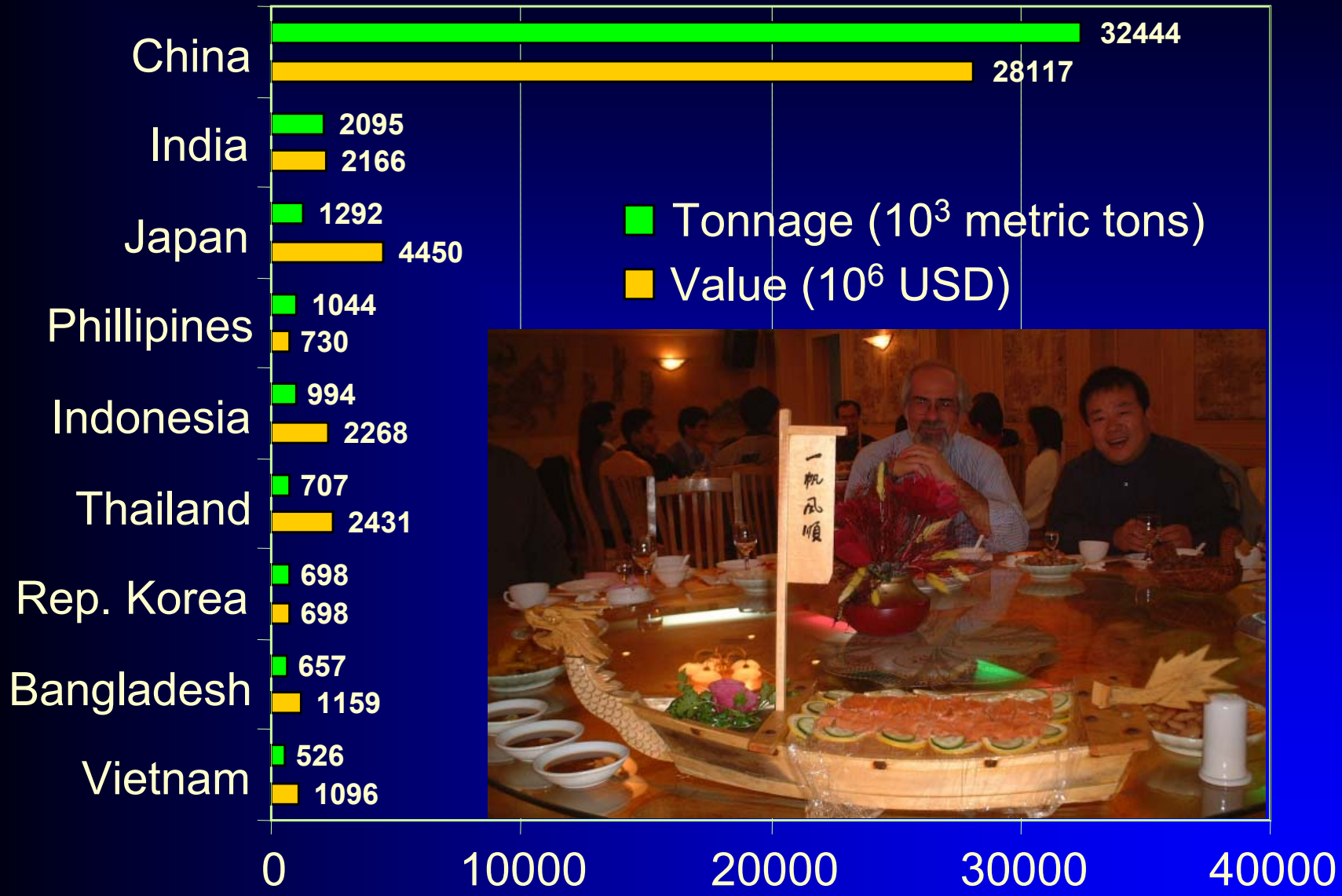
Carrying capacity assessment and impact of aquaculture on Chinese bays

Objectives

- Study interactions between aquaculture and environment in coastal areas, including those between different types of aquaculture or exploitation of natural resources, with an emphasis on polyculture
- Establish models that predict the carrying capacity for aquaculture and its resulting impacts according to different types of aquaculture in different environments
- Provide scientific information and recommendations that facilitate sustainable aquaculture management

Project funded by EU INCO-DC contract Nº ERBIC4CT 98-0291

Aquaculture in China



Notes:

(a) Only countries with production greater than 500,000 ton y^{-1} are shown

(b) Over half the production is from marine and brackish waters

Two bays in Shandong Province

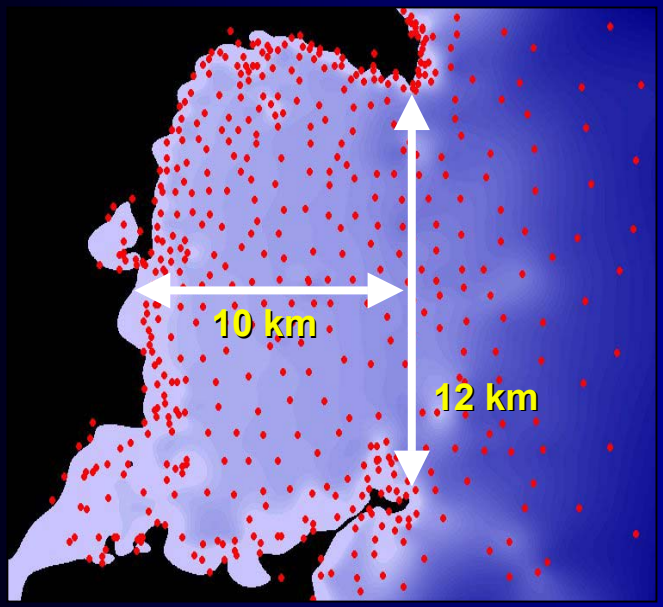
Key features of the two bays

System	Area (km^2)	Volume (10^6 m^3)	Cultivated species	Other uses	Pressures and issues
Sanggou Bay	140	100	Chinese scallop Pacific oyster Kelp	-	~150,000 people Heavy bivalve mortality
Jiaozhou Bay	400	2800	Bay scallop Chinese scallop Pacific oyster Manila clam	Sewage Industrial waste Shipping/port Recreation	6 million people Redfield ratio (N/P) has changed from 10 to 24 in 40 years

Methodologies

Fieldwork

- Key species, cultivation and system description

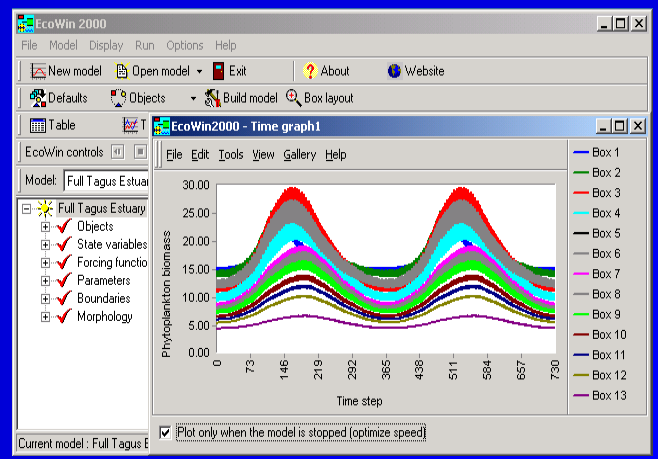


Data processing

- Databases, GIS, conversion of data into information

Modelling

- Models with different objectives, at different scales



Methodologies

Fieldwork

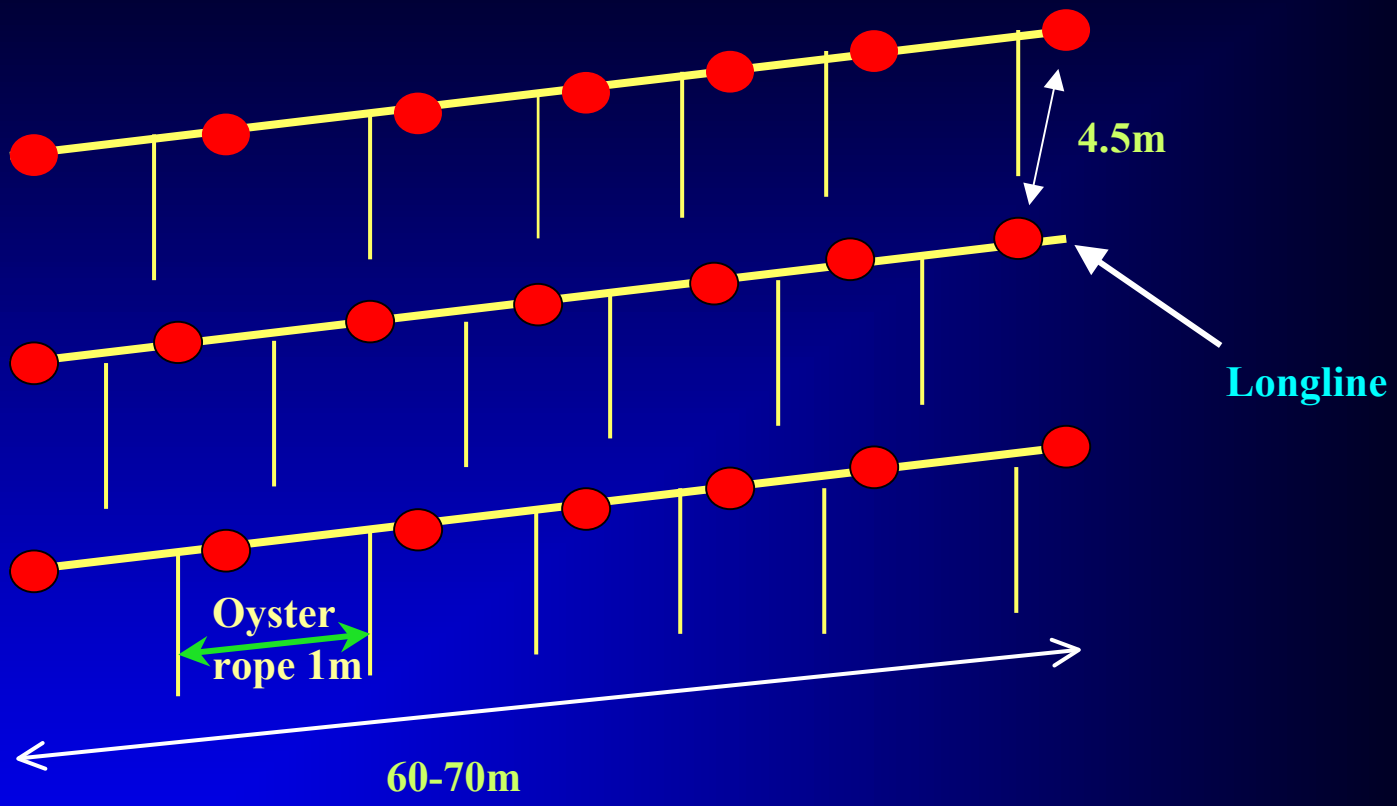
- Define culture practice (methods, timing and quantities)
- Experimentally determine growth parameters for key species
- Carry out growth trials for target species
- Measure water quality data in field campaigns for the two bays

Once upon a time…
The (his)story of the Mu

Unit name	Area (m2)	Equivalent area	ha area (m2)
Mu	666.66	1/15 ha	10000
Sanggou Bay	Culture Mu	1600-1800	1/15 Sanggou culture ha 25500
Jiaozhou Bay	Culture Mu	3000-5000	1/15 Jiaozhou culture ha 45000-75000
Laizhou Bay	Culture Mu	5000-8000	1/15 Laizhou culture ha 75000-120000

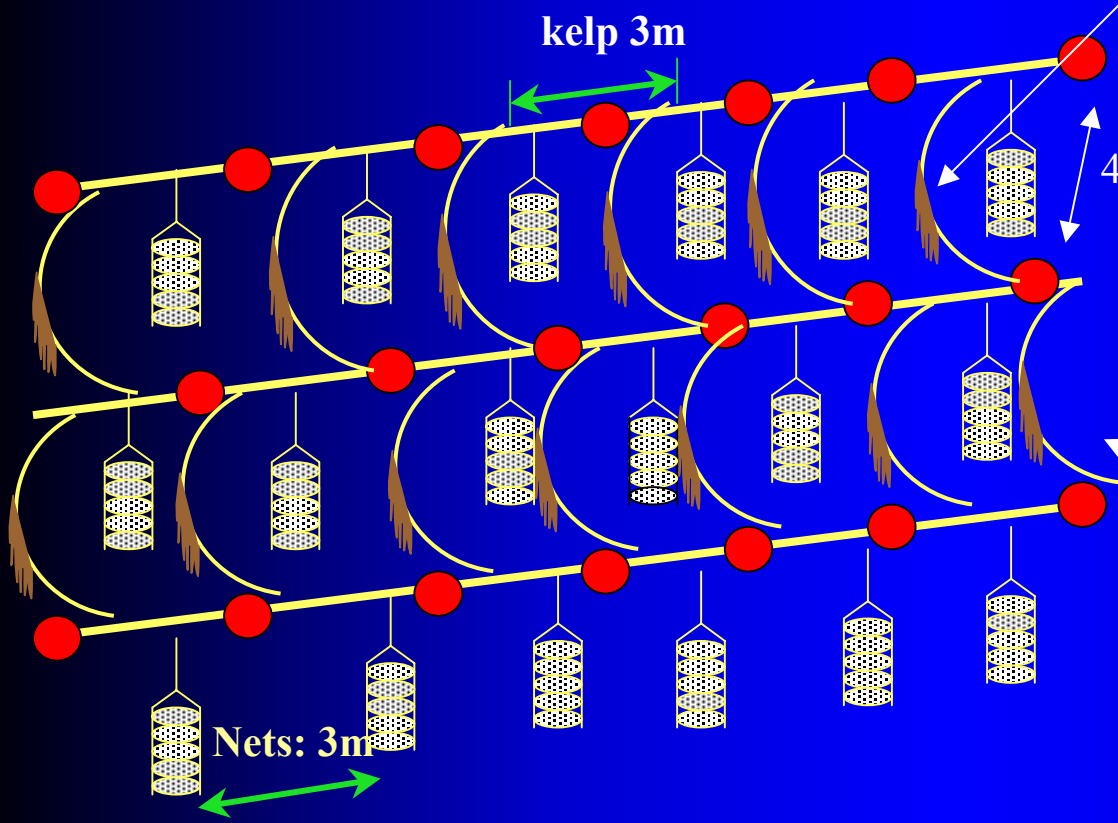
Note: The Culture Mu (like the medieval bushel) is also used in agriculture, and has a similar variability, being indexed to yield – The area of the Culture Mu is therefore linked to the exploitation carrying capacity.

Sanggou Bay monoculture – Pacific oyster



- 30 Scallop shells as base, about 10cm apart, with 6-10 oysters each. 400 ropes/Culture Mu, i.e. 400 culture ropes/1600-1800 m^2, 250 oysters/ rope:40-75 oysters/m^2.
- Ropes are 2-3m long.
- 6 longlines per culture Mu, 30 longlines per block, then 8m channel for navigation.

Sanggou Bay polyculture - Kelp and scallop



Kelp yield - 5kg dw per "double" rope inside the bay, 10kg outside the bay. 333-375 g dw/ m^2. All harvested. Data calculated for inside the bay.

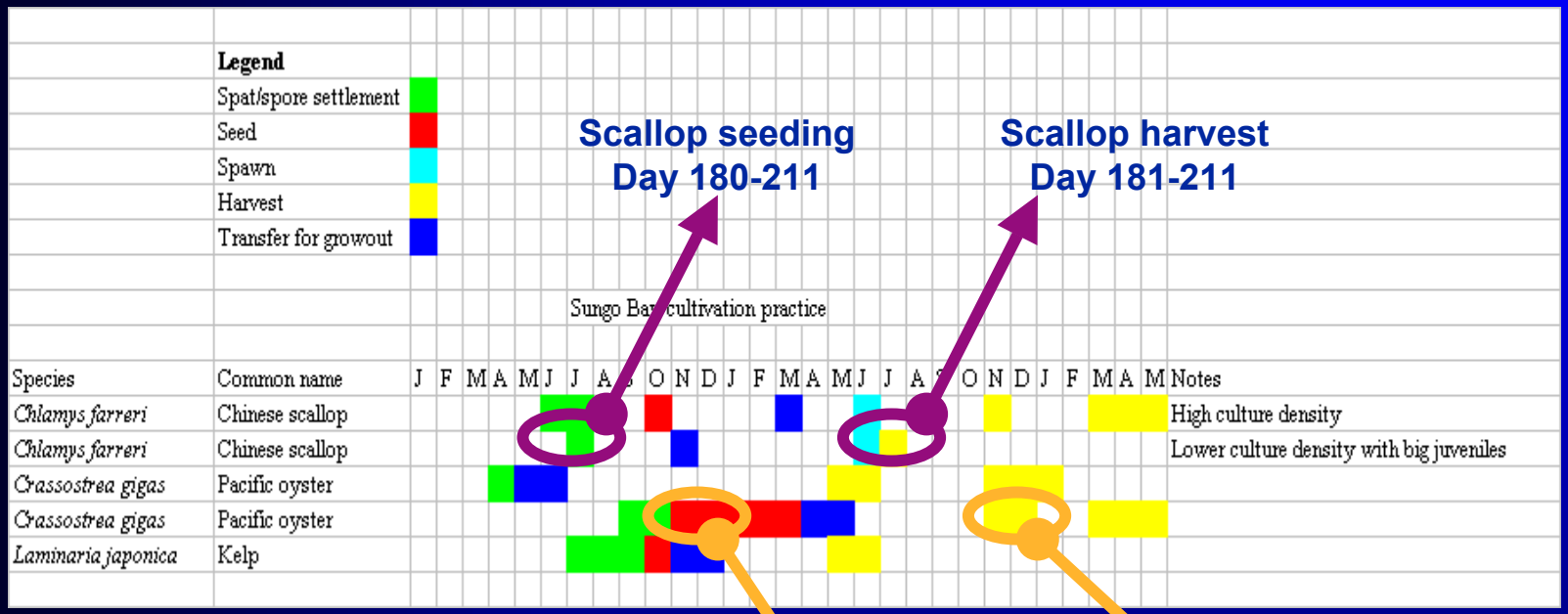
Longline. In some cases the ratio of kelp ropes:scallops is 1:1, others 1:2, others 2:1

Kelp rope- 2.5m, 30-35 plants X 2 for "double" rope

- **8-10 layers per Chinese lantern, 30 scallops per layer, 120 nets per culture Mu, i.e. 120 culture nets/1600-1800 m^2, 240-300/ net:16-22.5 scallops/ m^2.**
- **Scallop nets are 2-3m long. 6 longlines per culture Mu, 30 longlines per block, then 8m channel for navigation.**

EcoWin 2000 – Sanggou Bay model

Culture practice – first approach (May 2001)

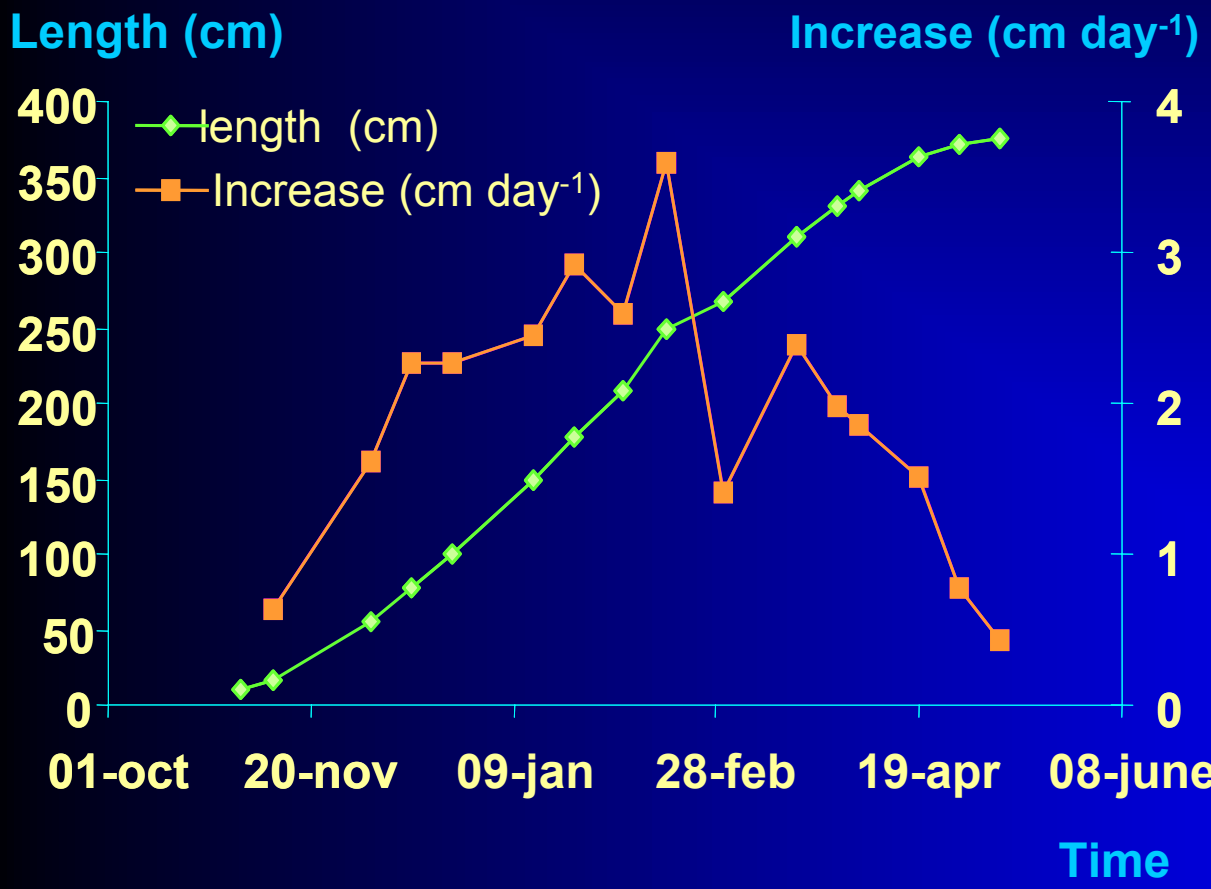


Source: Culture practice data from FIO, YSFRI and SMCI (pers. com., May 2000)

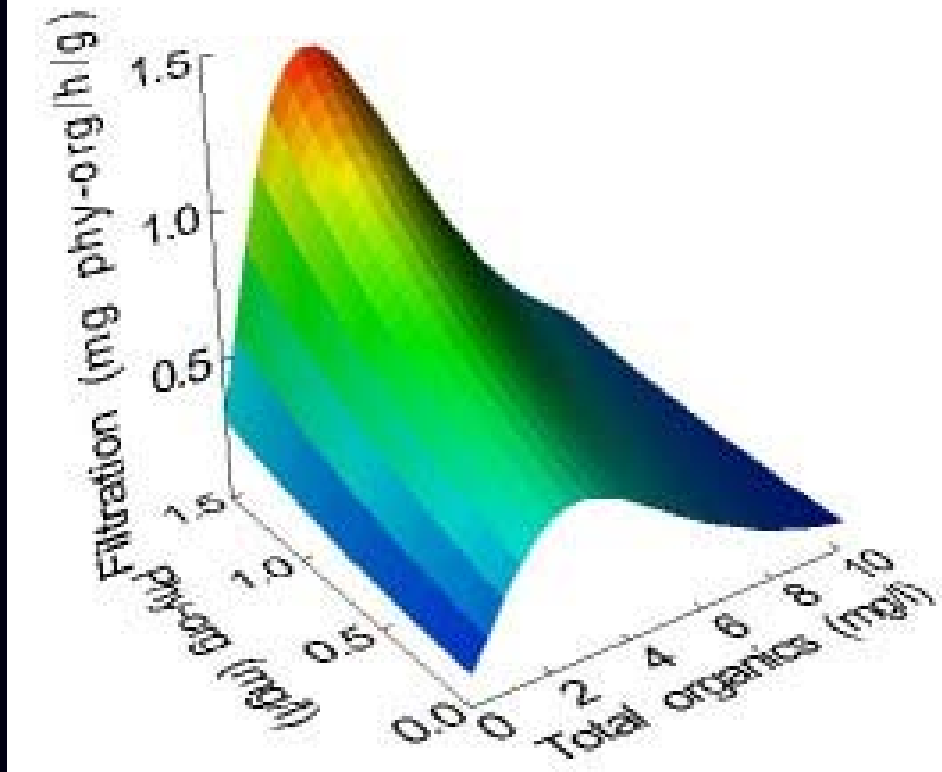
- ✓ Seed weight: 0.05 DW (1.7g TFW, Gazeau, 2000)
- ✓ Harvestable weight: ≥ 65 g TFW (Tentative value)

Kelp harvest in Sanggou Bay, China

Growth of kelp (*Laminaria japonica*)



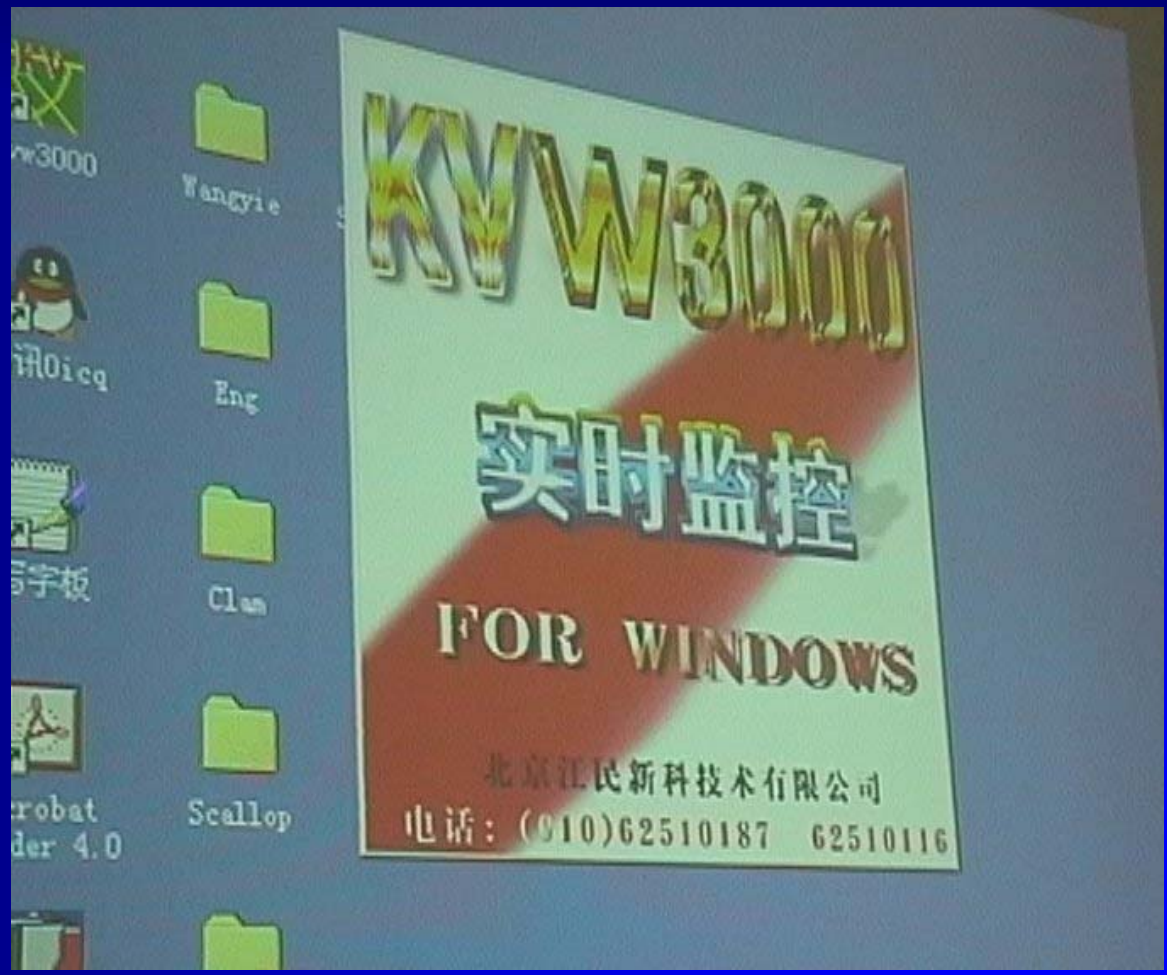
Growth of Chinese Scallop (*Chlamys farreri)*



Methodologies

Information management

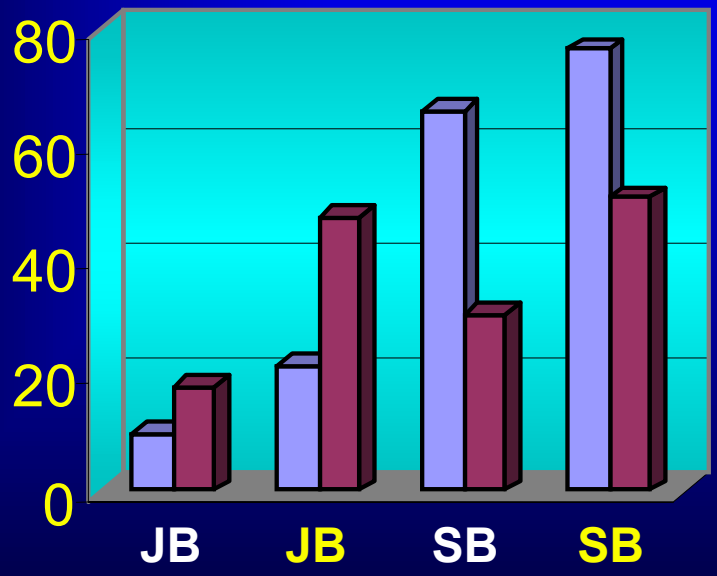
- Development of relational databases
- Geographical Information Systems

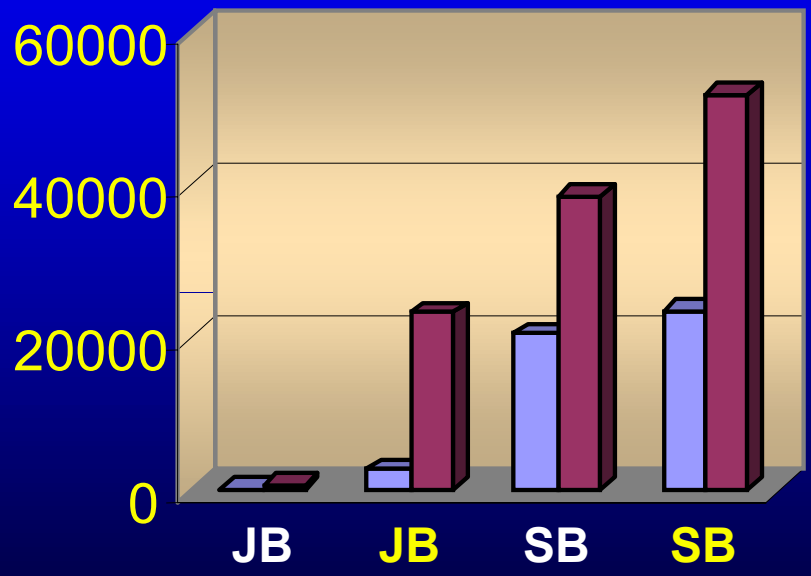


BarcaWin 2000
Data assimilation

Historical data

Full dataset

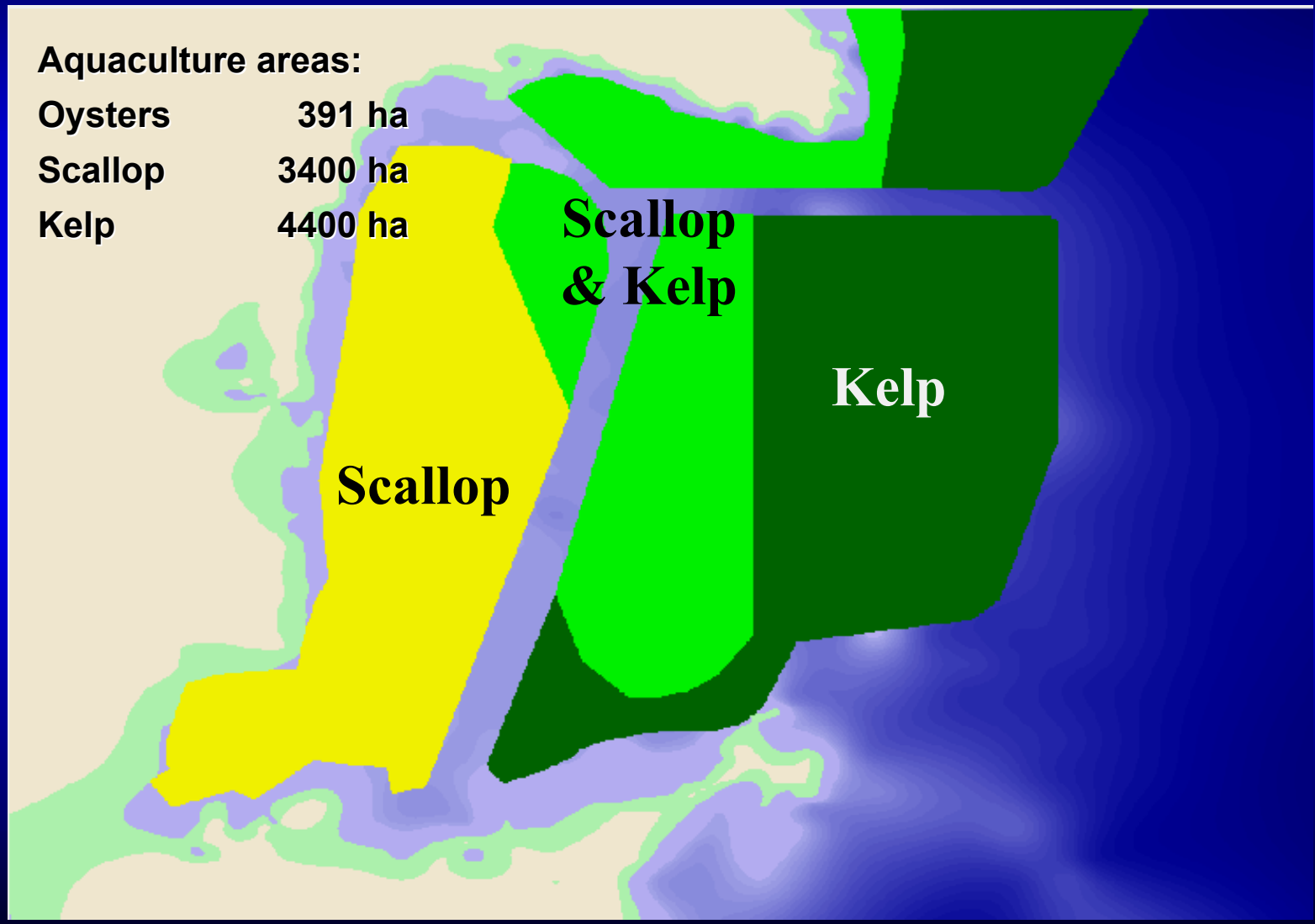




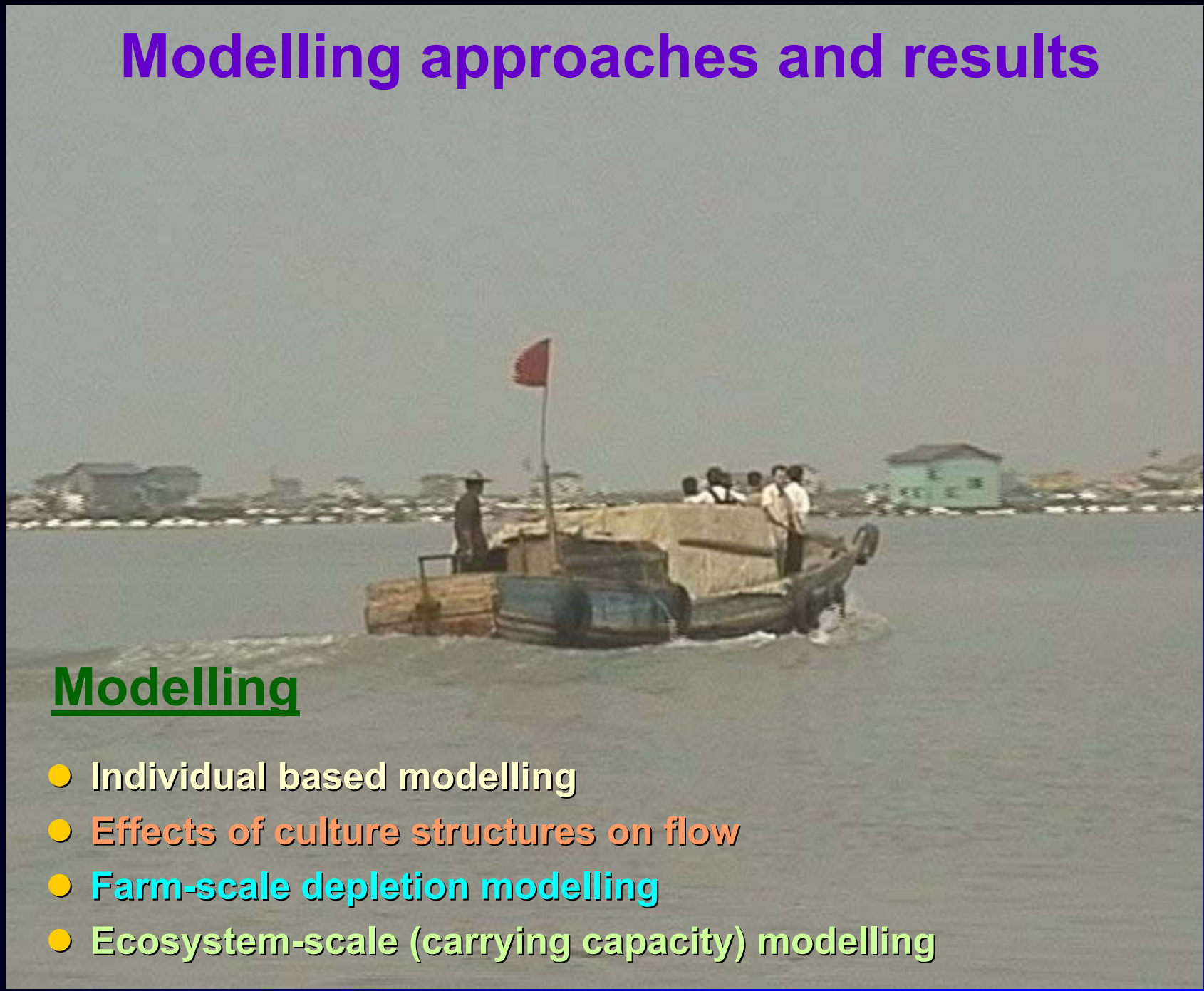
	JB	JB	SB	SB
Stations	10	22	66	77
Parameters	18	48	31	51

	JB	JB	SB	SB
Samples	80	2728	20536	23621
Results	677	23327	38717	51793

Sanggou Bay cultivation areas 1993/94 GIS determination



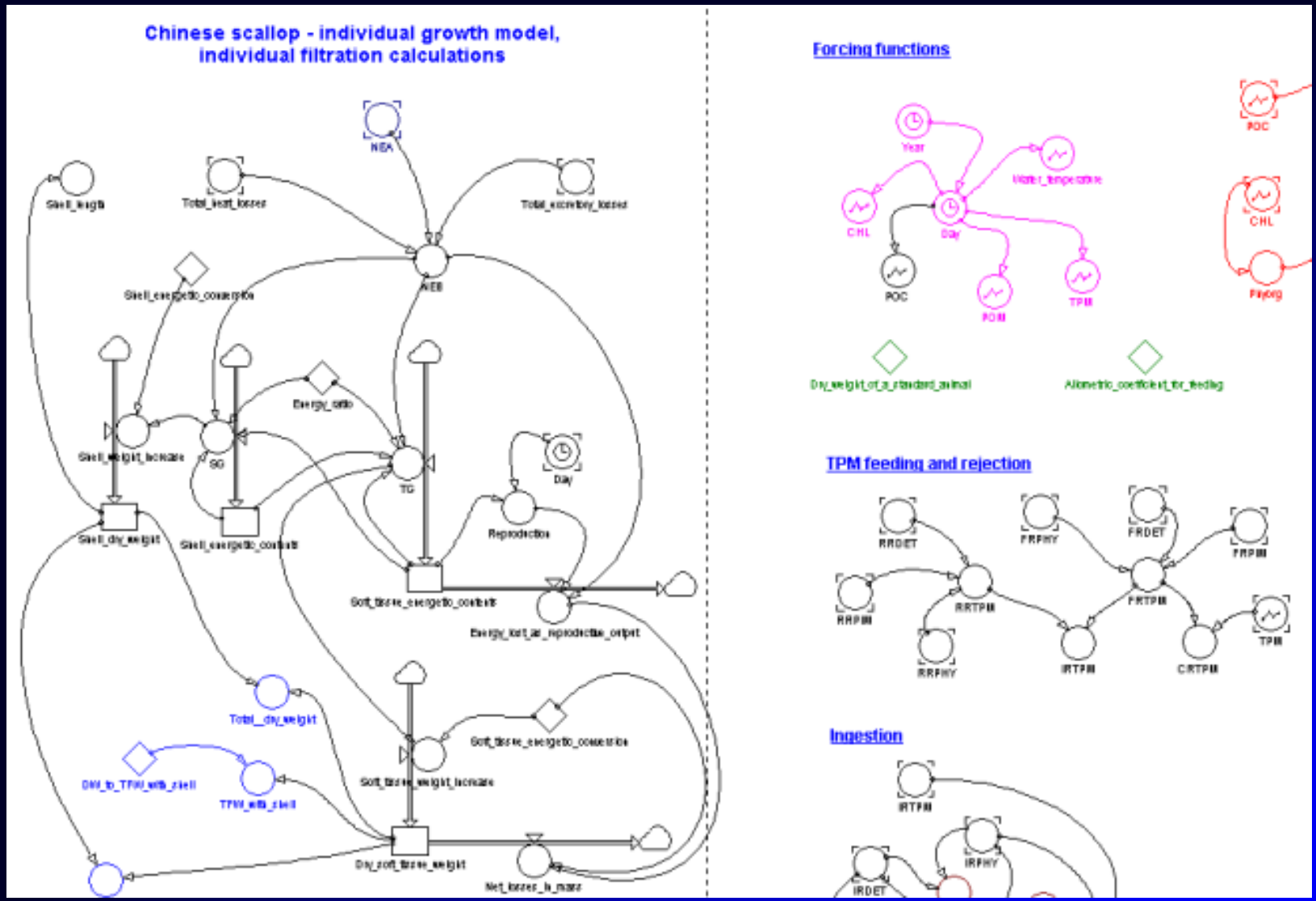
Modelling approaches and results



Modelling

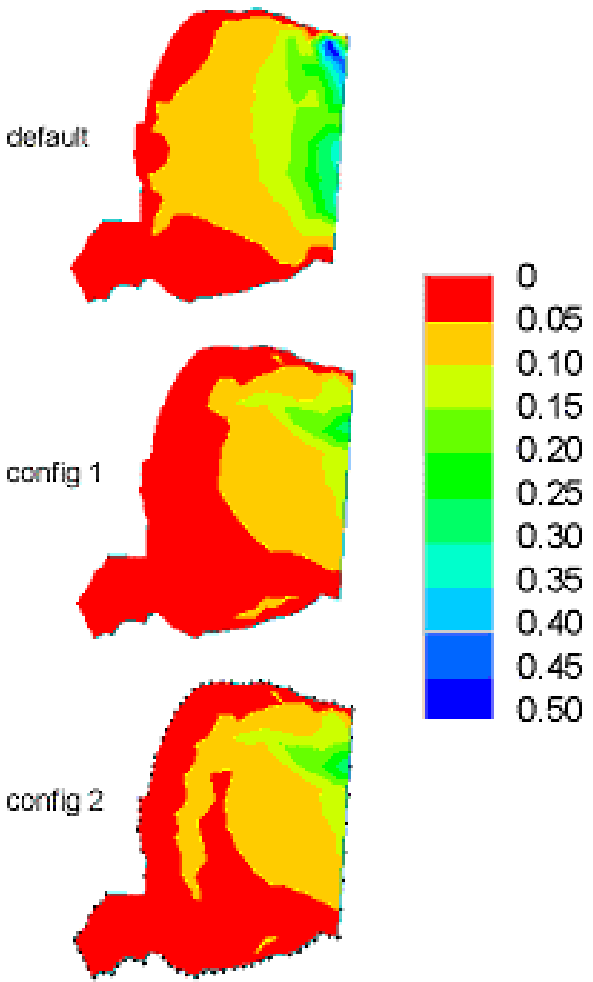
- Individual based modelling
- Effects of culture structures on flow
- Farm-scale depletion modelling
- Ecosystem-scale (carrying capacity) modelling

Individual growth modelling



Visual modelling platform, simulation of individual processes for the Chinese scallop.
Hawkins et al, 2002. A functional model of responsive suspension-feeding and growth in bivalve shellfish, configured and validated for the scallop *Chlamys farreri* during culture in China. J.Exp.Mar.Biol.Ecol., 281: 13-40.

Modelling effects of culture structures

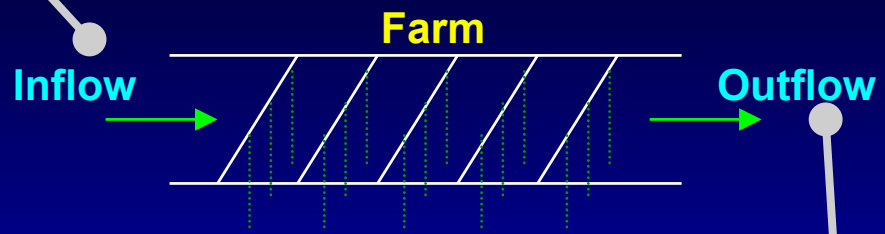


Finite element hydrodynamic model implemented in Aquadyn™

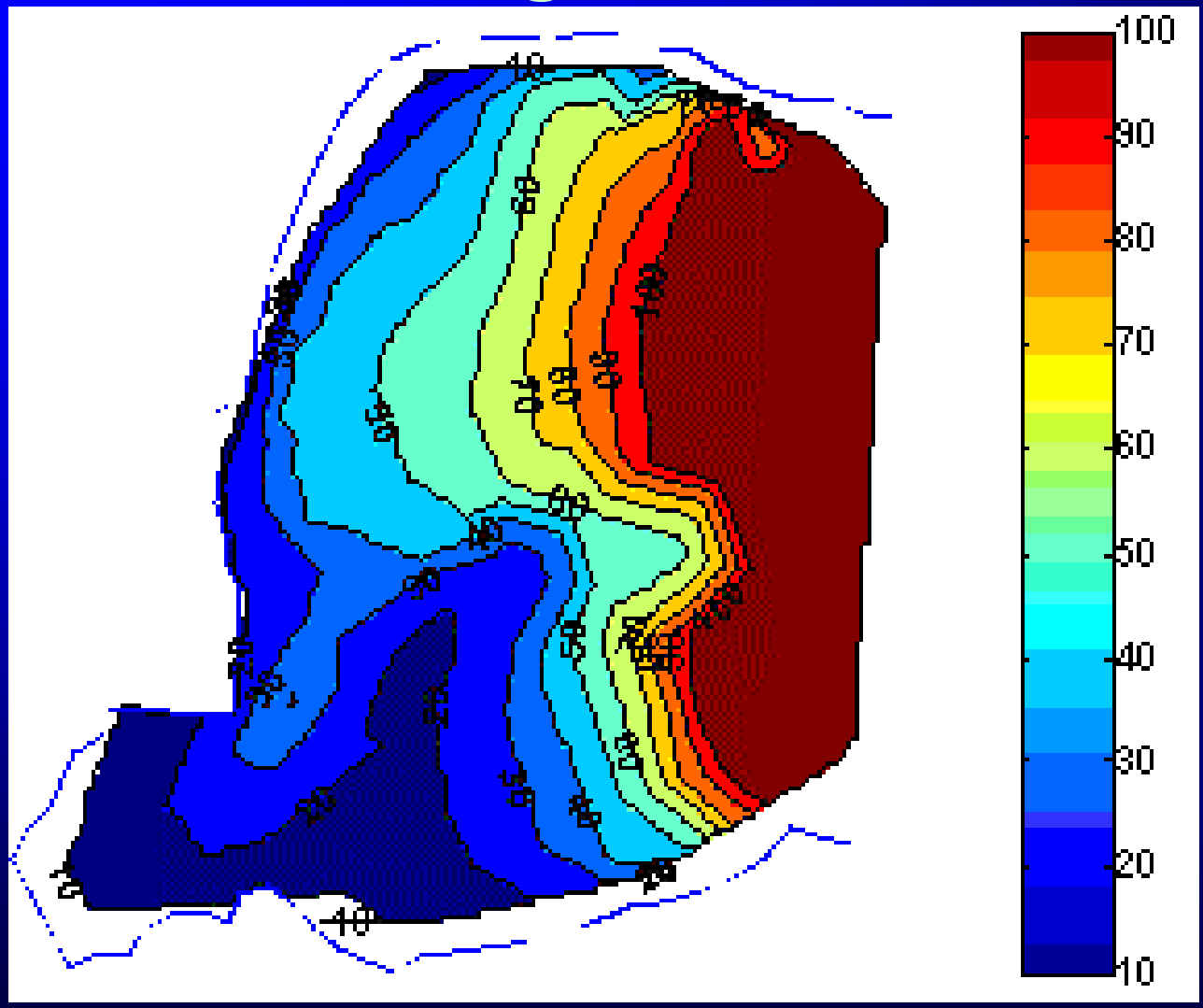
Default: No aquaculture
Culture configuration 1
Culture configuration 2

Grant & Bacher, 2001. A numerical model of flow modification induced by suspended aquaculture in a Chinese Bay. Can.J.Fish.Aquat.Sci., 58: 1003-1011.

Modelling farm-scale food depletion



Modelling farm-scale food depletion



Approach

1. A length scale of 1000m was used (local depletion)
2. The depletion model couples food transport, food consumption and scallop growth at scale of a cultivated area
3. Food transport is determined from local current fields using a 1D model
4. Food supply is based on spatially discrete field measurements
5. Food consumption (and scallop growth) is based on individual growth models

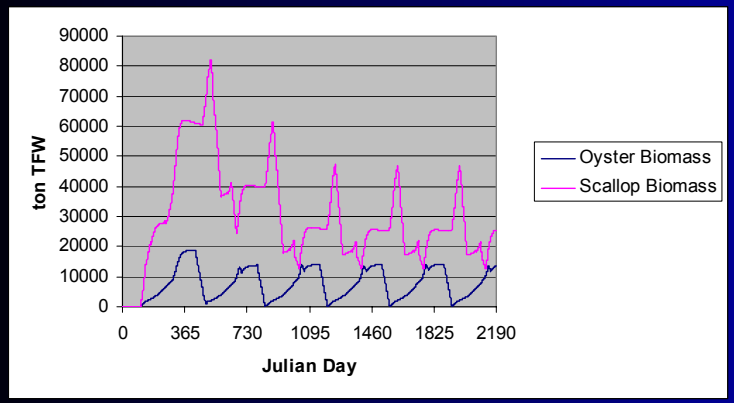
Density ($n^o\ m^{-3}$) of cultivated scallops predicted by the depletion model when only local density effects are considered

Bacher et al, 2003. Modelling the effect of food depletion on scallop growth in Sungo Bay (China). Aquat. Living Resources, 16, 1, 10-240

Modelling ecosystem carrying capacity

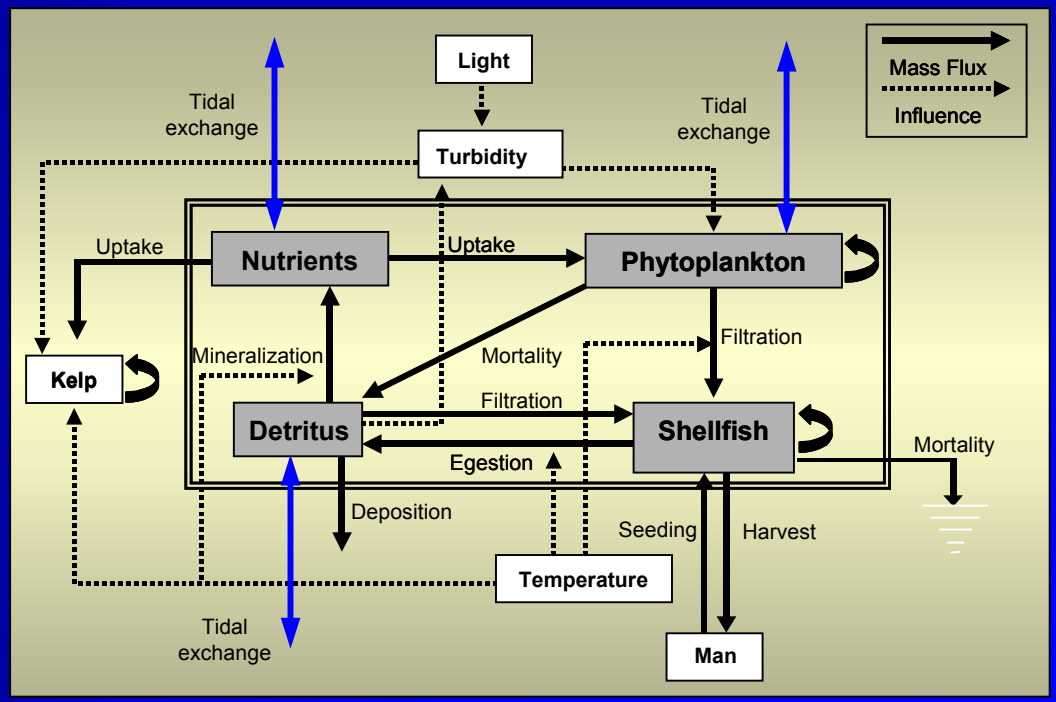
EcoWin2000 model specifications

- ✓ 10 objects, including kelp, oysters and scallops and man
- ✓ Individual growth and demographic distribution for oysters and scallops, using multiple inheritance
- ✓ About 40 state variables, not including derived variables
- ✓ Mass fluxes only are considered at ocean interface
- ✓ 6 year runtime (2190 days), with one hour timestep (takes about 2 minutes to run on a Pentium IV)

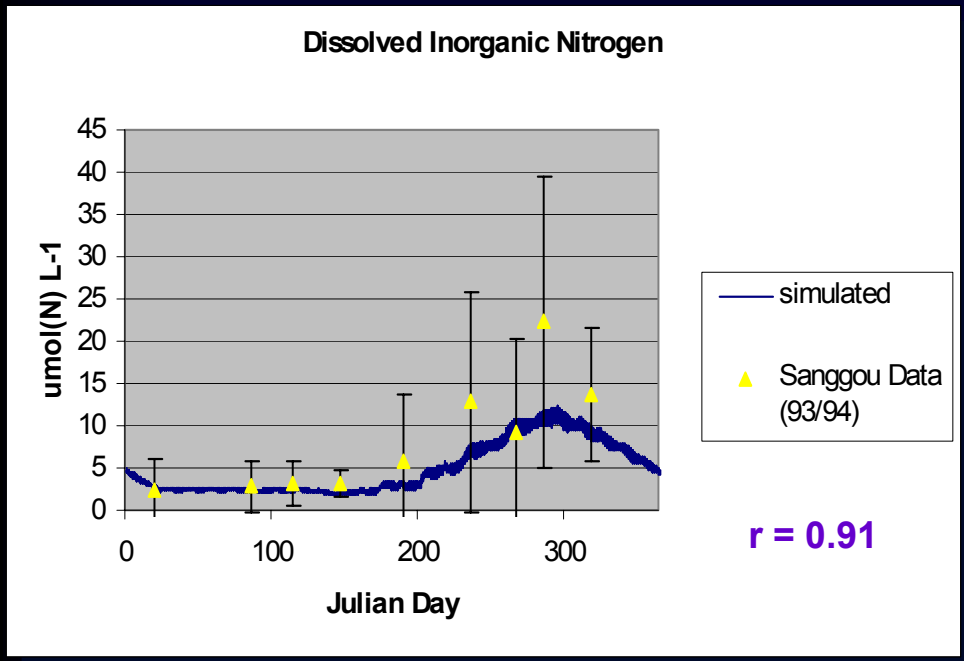


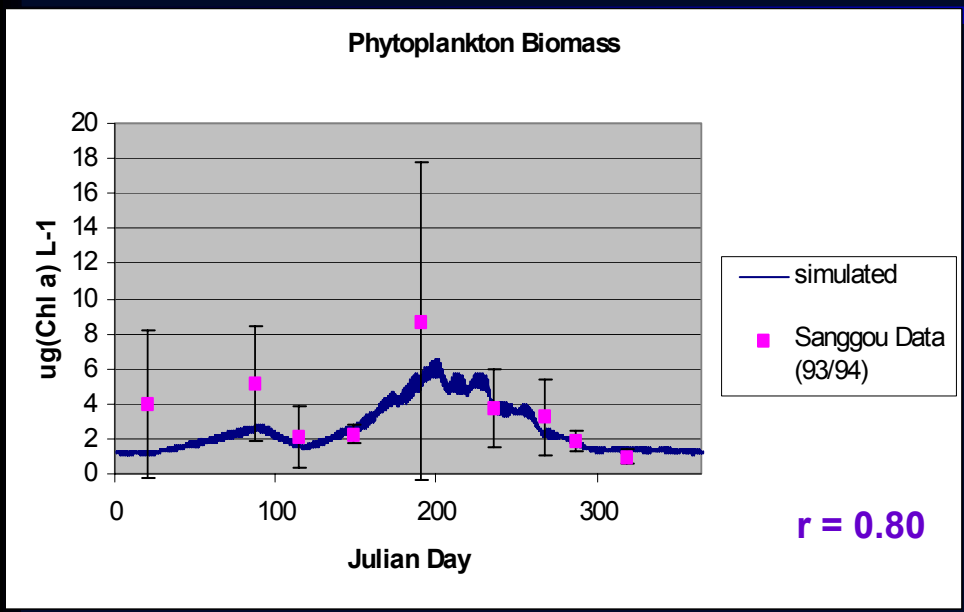
EcoWin2000 modelling platform, full coupled model.

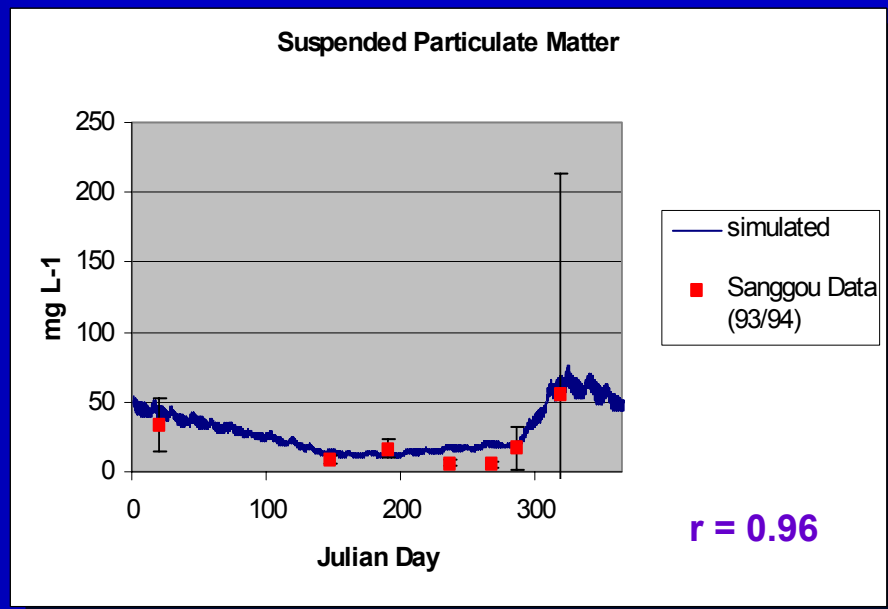
Nunes et al, 2003. A model for sustainable management of shellfish polyculture in coastal bays. Aquaculture, 219/1-4, 257-277



Tuning the model

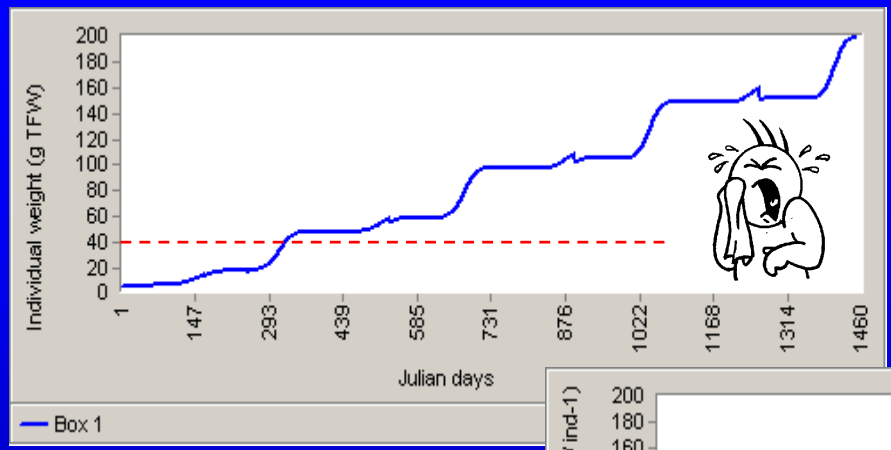






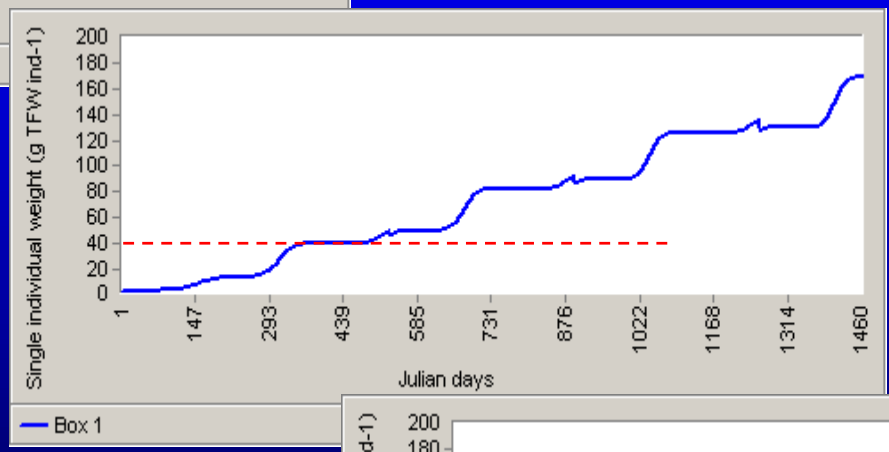
EcoWin 2000 – Sanggou Bay model

Chinese scallop individual growth under different conditions

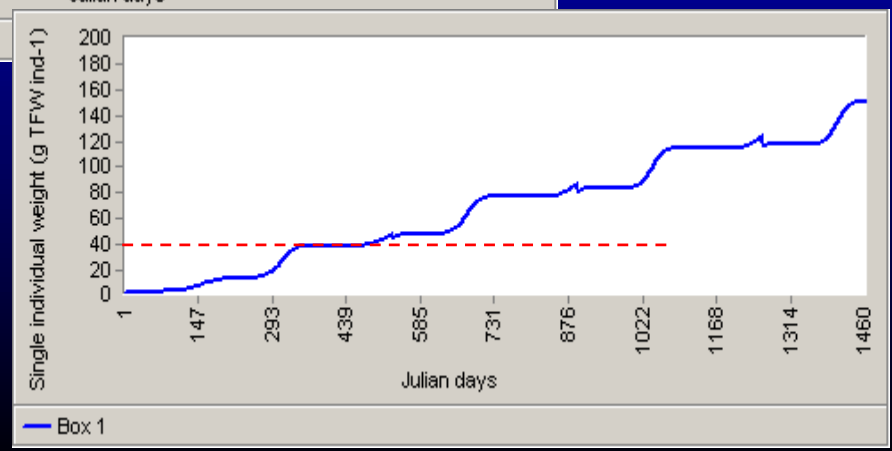


Single individual, all alone in the bay...

Single individual, standard model 93-94

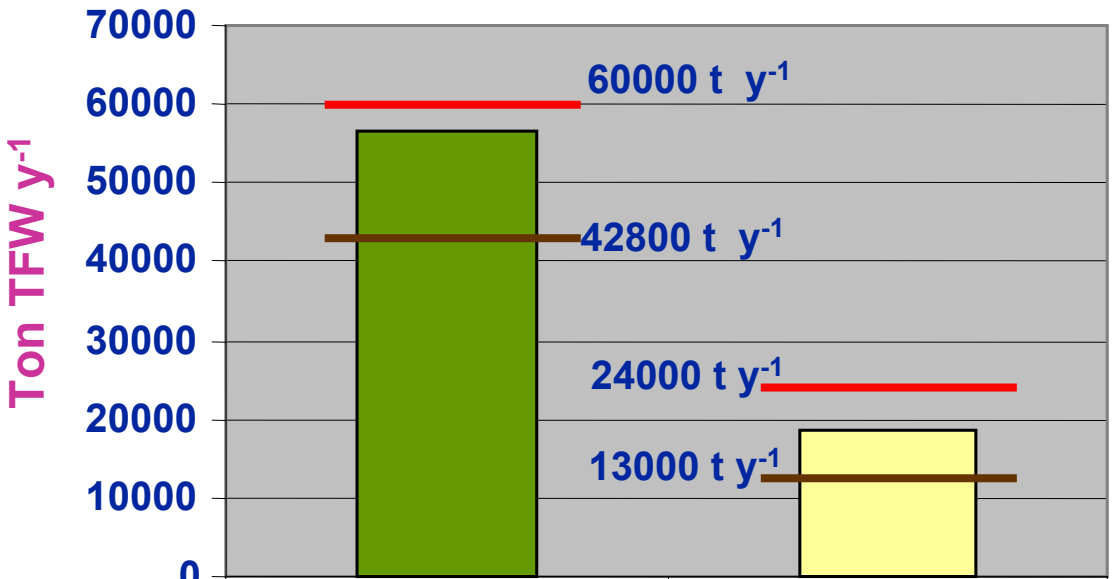


Single individual, 10X seeding rate, Model 93-94



Application of the EcoWin2000 model to Sanggou Bay

Annual scallop and oyster harvest



	Scallops	Oysters
Simulated harvest	56500	18400

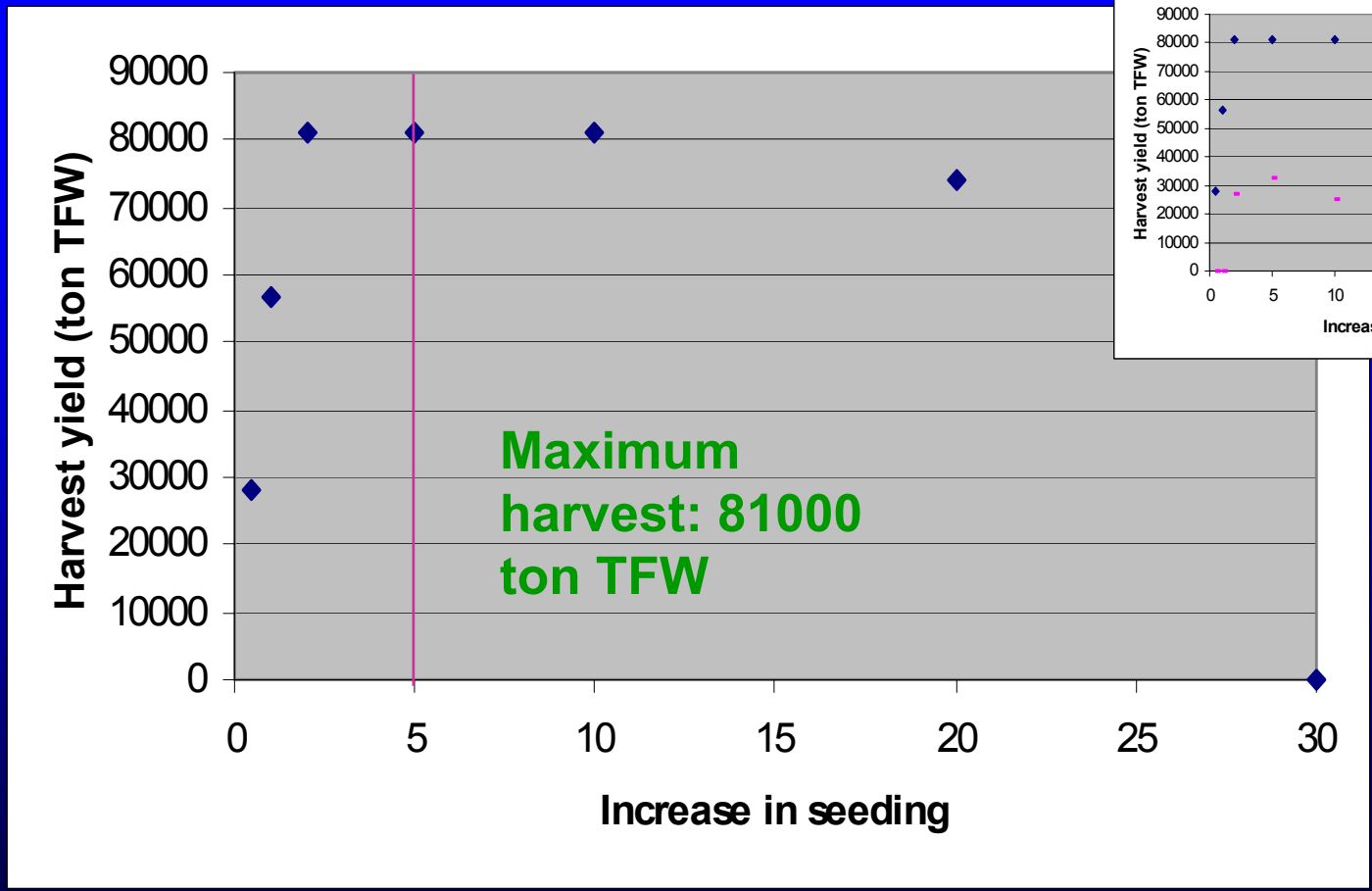
Run conditions: 6 year run with 1h timestep, values for year 6, ten objects active

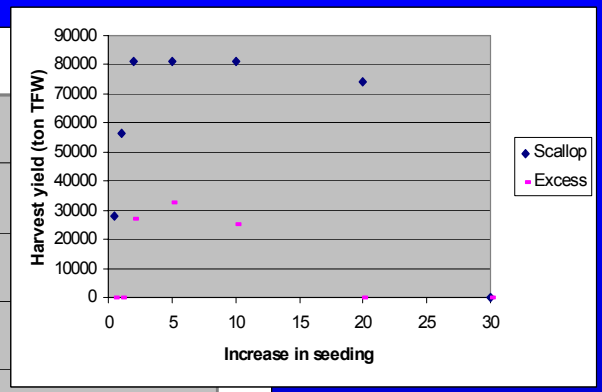
EcoWin 2000 – Sanggou Bay model
Mass balance for phytoplankton
(internal processes : standard model)

Sources ($gC\ m^{-2}\ y^{-1}$)	
Net primary production	63.97
Sub-total	*63.97*
Sinks ($gC\ m^{-2}\ y^{-1}$)	
Natural mortality	-18.9
Oyster phytoplankton uptake	-1.89
Scallop phytoplankton uptake	-3.48
Sub-total	-24.27
Total sources and sinks ($gC\ m^{-2}\ y^{-1}$)	*39.70*

Results for year 6 of the standard model

EcoWin 2000 – Sanggou Bay model
Scallop overseeding

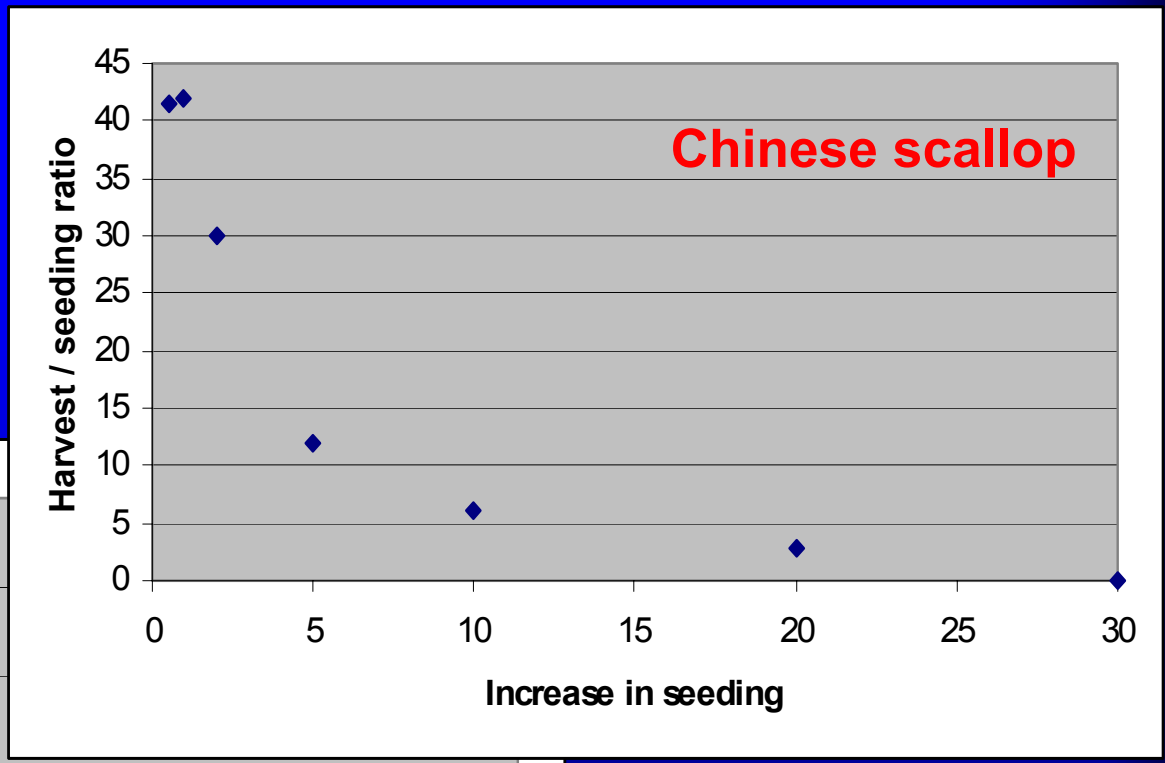


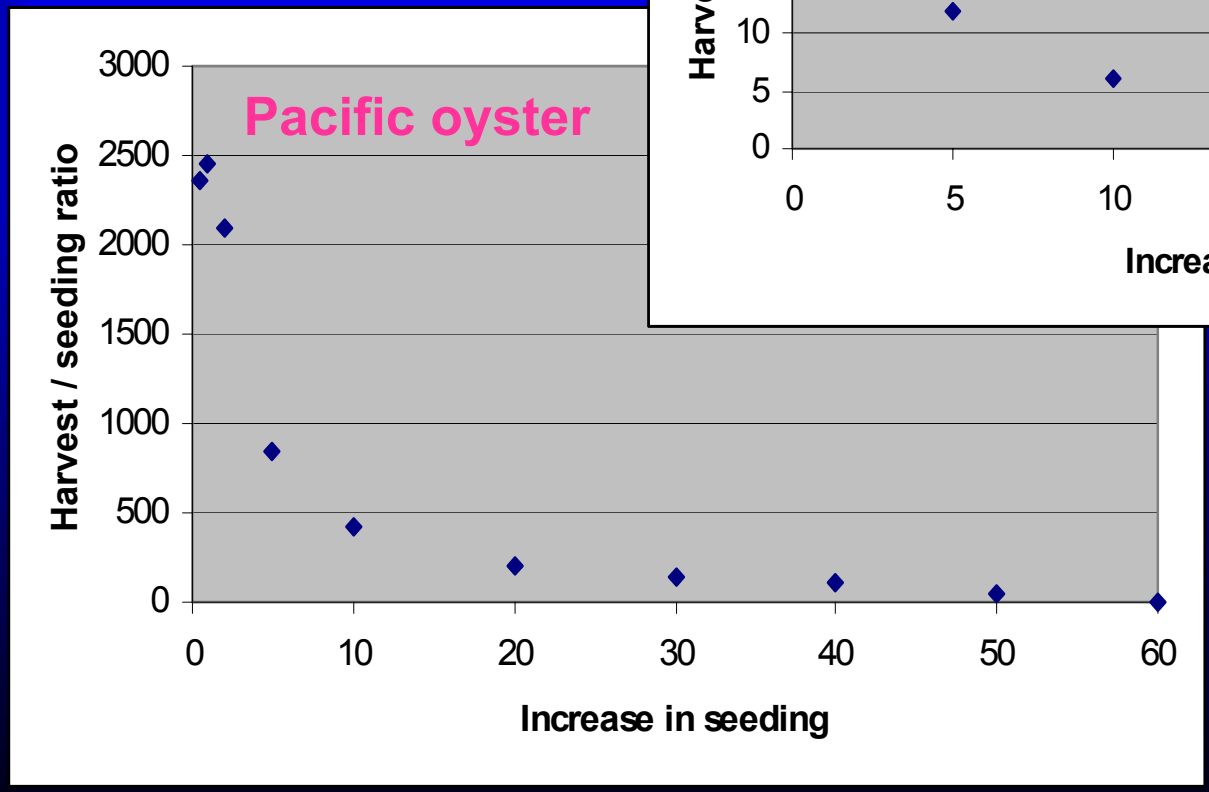


Run conditions: 6 year run with 1h timestep, values for year 6, ten objects active

EcoWin 2000 – Sanggou Bay model

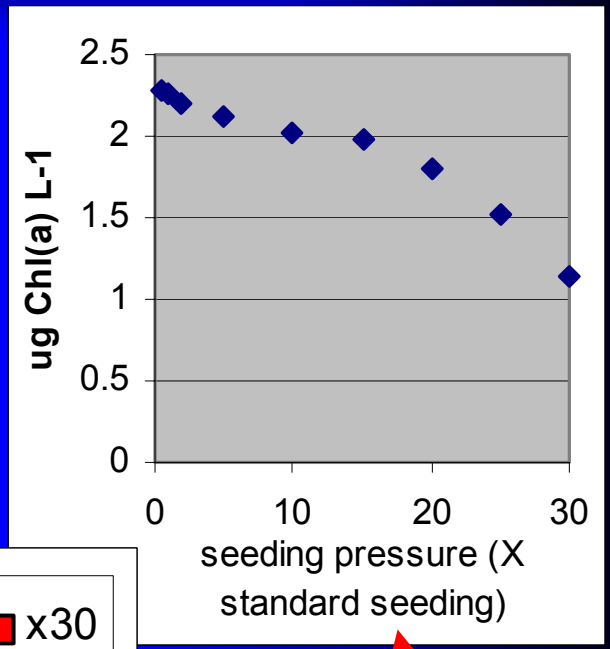
Harvesting and seeding: Scallop and oysters

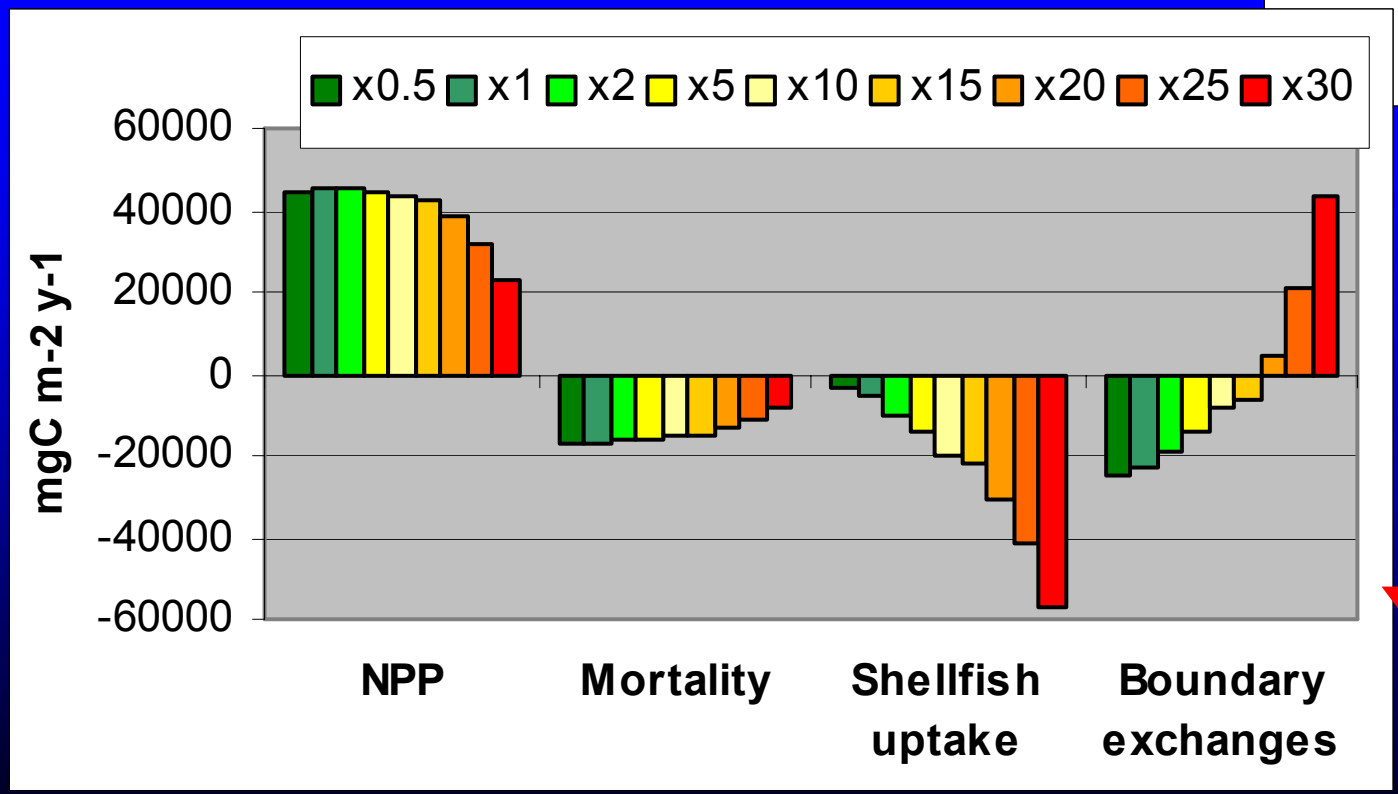




Run conditions: 6 year run with 1h timestep, values for year 6, ten objects active

Comparison between standard model and scenario Phytoplankton

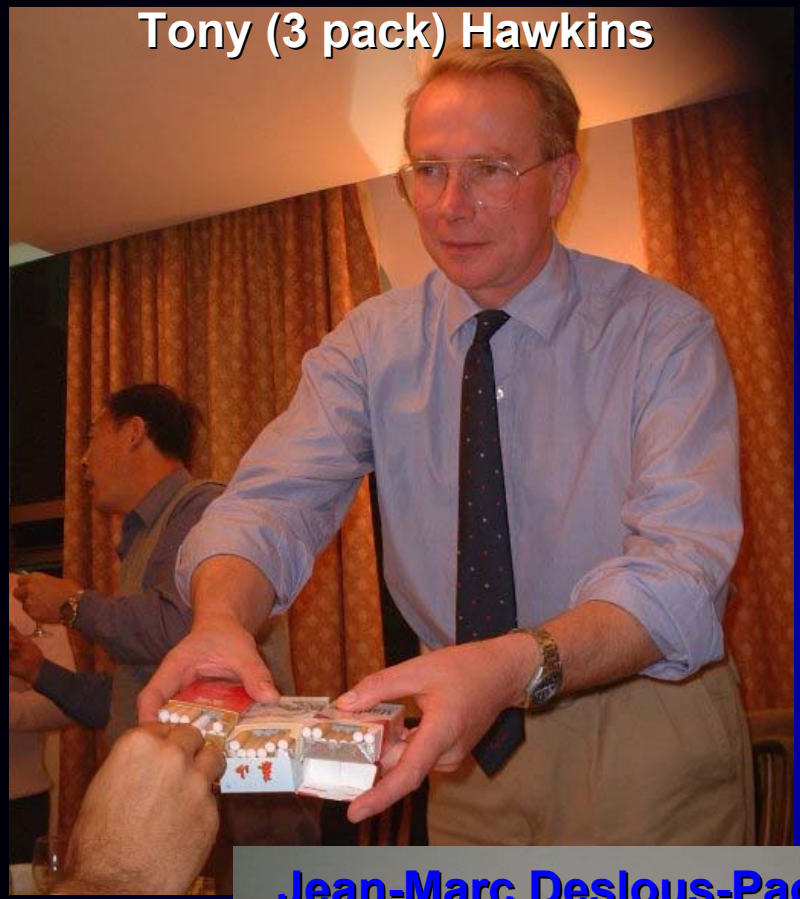




Phytoplankton concentration in the bay

Phytoplankton mass balance

Movie credits

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