Scenario testing of fisheries management strategies using a high resolution ERSEM-POM ecosystem model

G. Petihakis, C.J. Smith, G. Triantafyllou, G. Sourlantzis, K.-N. Papadopoulou, A. Pollani, and G. Korres

H.C.M.R.

The Problem

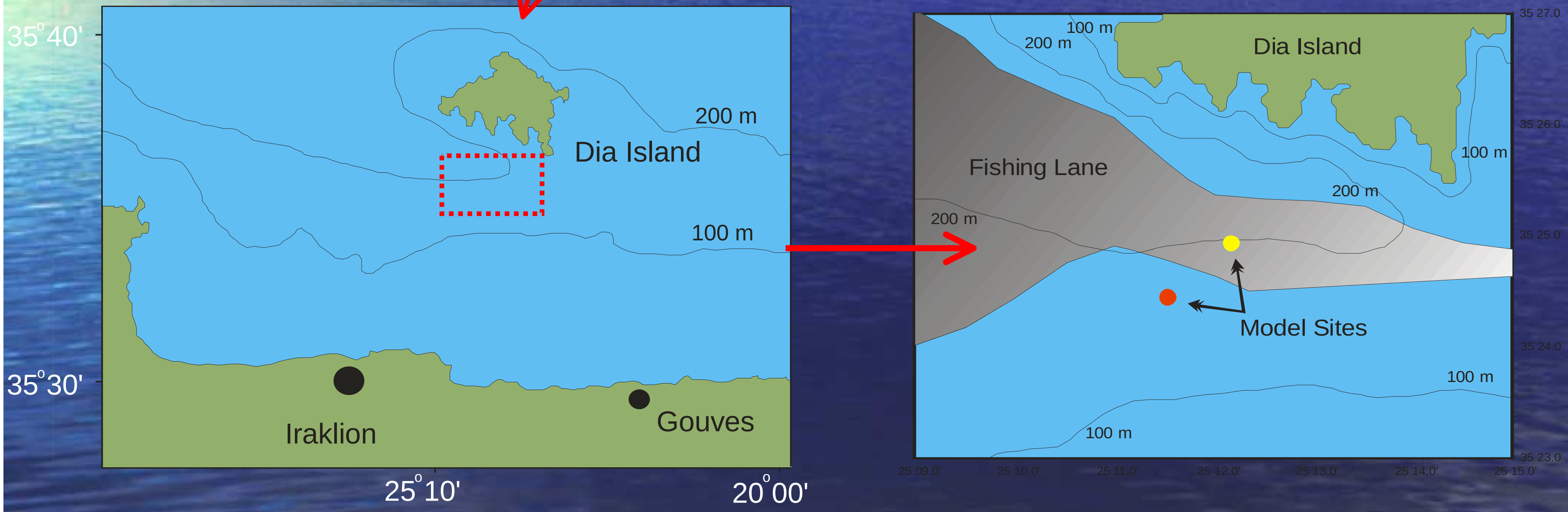
- Fishing impacts for long periods were studied on a single species level, adding more species as our knowledge grew with time. During the last years the need for a holistic approach becomes more and more evident.

- The direct impacts of trawling (fish mortality, destruction of benthic organisms) have been studied to a significant extent in contrast with the indirect effects such as the prey – predator relations, the nutrient fluxes, the sediment resuspension, sedimentation etc.

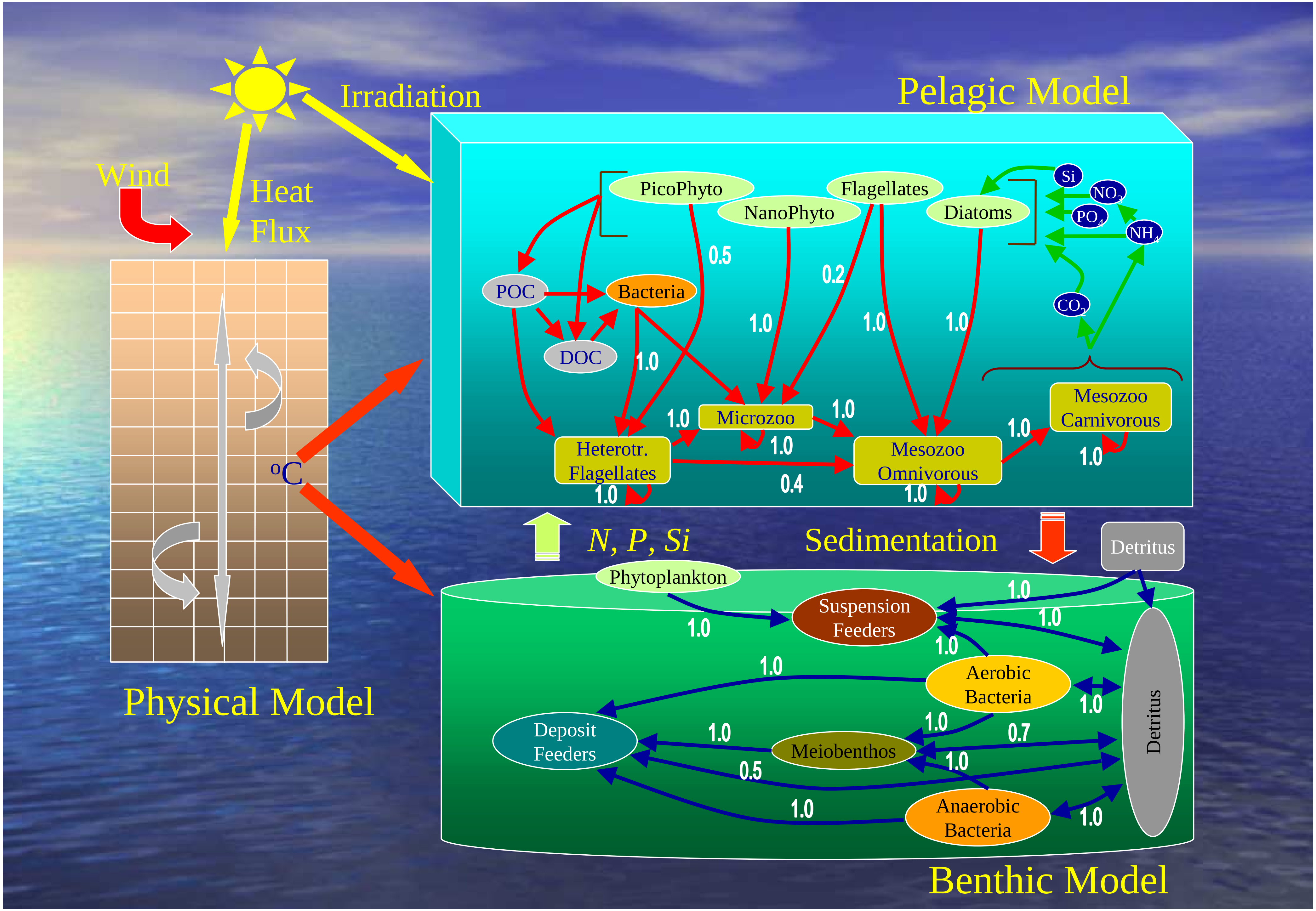
- During the last years more and more effort has been directed towards ways to predict such changes with the use of models. In the beginning statistical models relying on long data sets were the ones which could offer some sort of prediction on the expected direct impacts. As more and more knowledge was acquired dynamical models were developed including however very crude approximations on a number of unresolved processes.

- In this work during the Cost-Impact project a dynamic complex model was used in an attempt to simulate the indirect effect of trawling in the lower part of the food chain with particular emphasis in the carbon flux.

Application Site



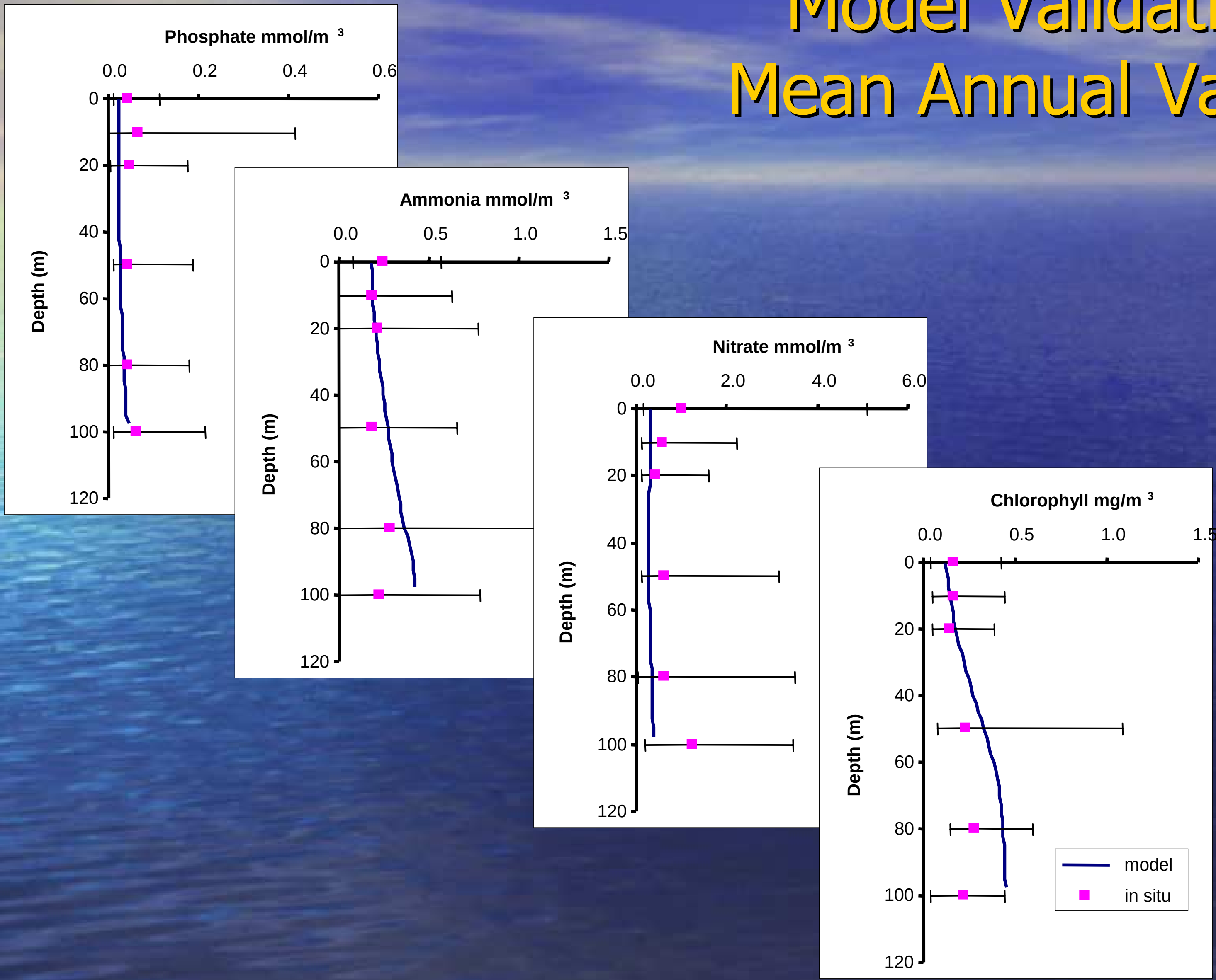
H.C.M.R.


Pelagic Model
Irradiation
Wind
Heat Flux
°C
Physical Model
PicoPhyto
NanoPhyto
Flagellates
Diatoms
Si
NO3
PO4
NH4
CO2
POC
Bacteria
DOC
Microzoo
Heterotr. Flagellates
Mesozoo Omnivorous
Mesozoo Carnivorous
0.5
0.2
1.0
0.4
N, P, Si
Sedimentation
Detritus
Phytoplankton
Suspension Feeders
Aerobic Bacteria
Deposit Feeders
Meiobenthos
Anaerobic Bacteria
0.7
0.5
Benthic Model

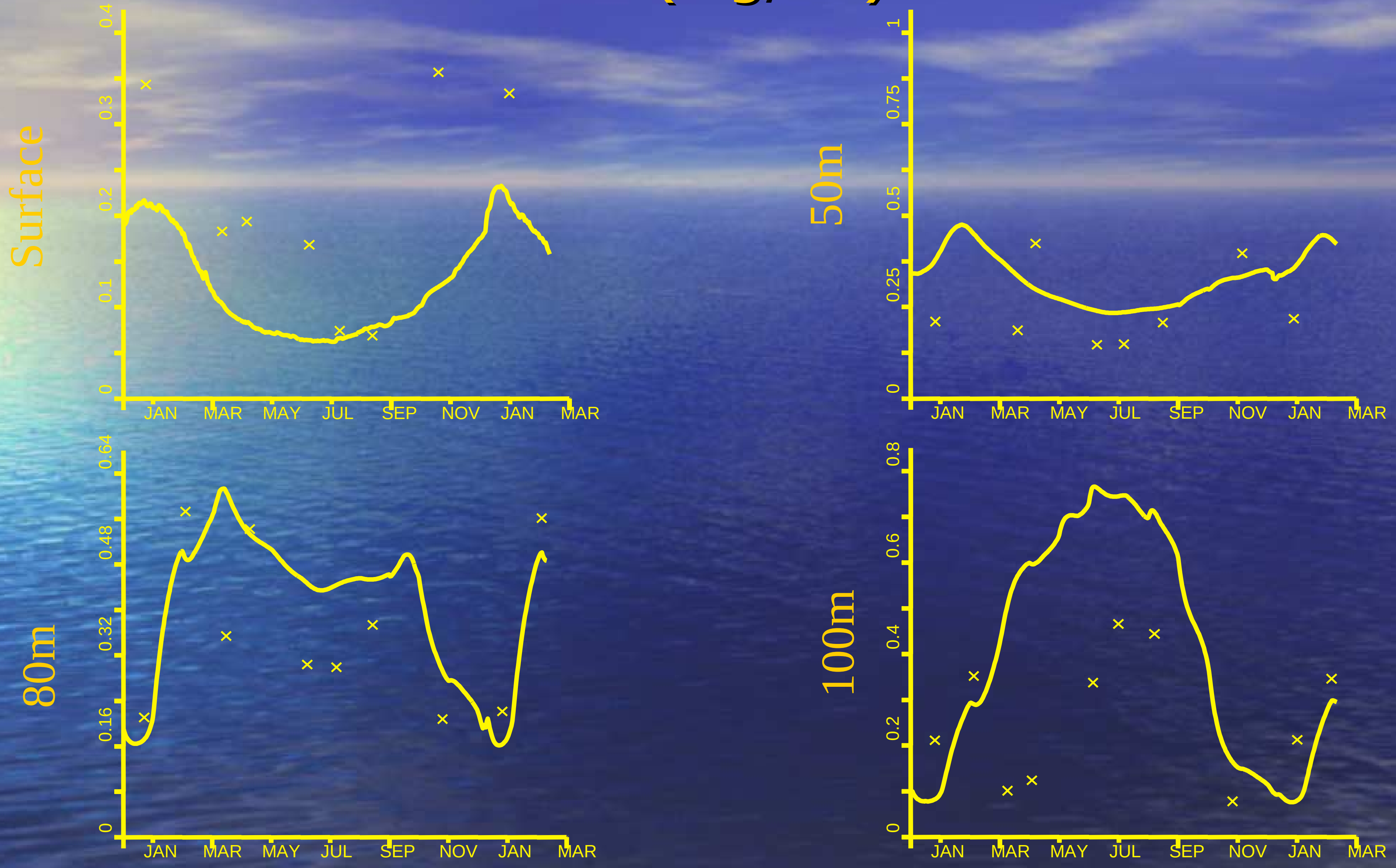
1D Model

- 40 boxes in the vertical
- 3-hour wind data from POSEIDON System
- Surface relaxation to mean monthly water temperature and salinity
- Biogeochemical initial fields from January
- Incorporation of important processes
  - Variable C/Chl
  - Bacterial nutrient limitation

Model Validation
Mean Annual Values

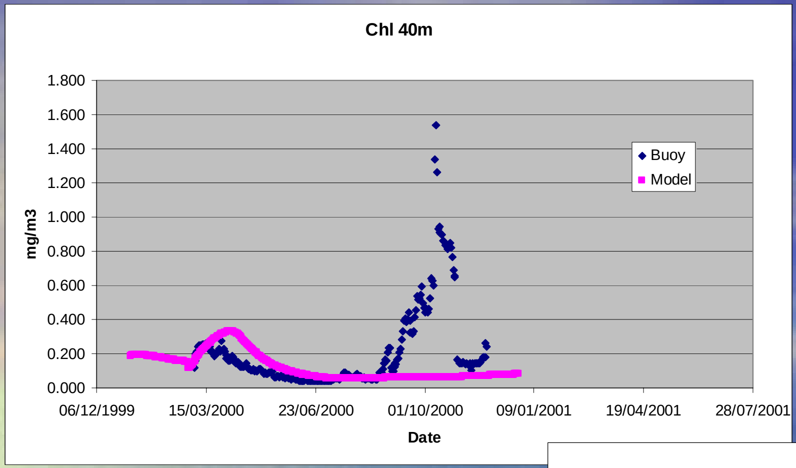


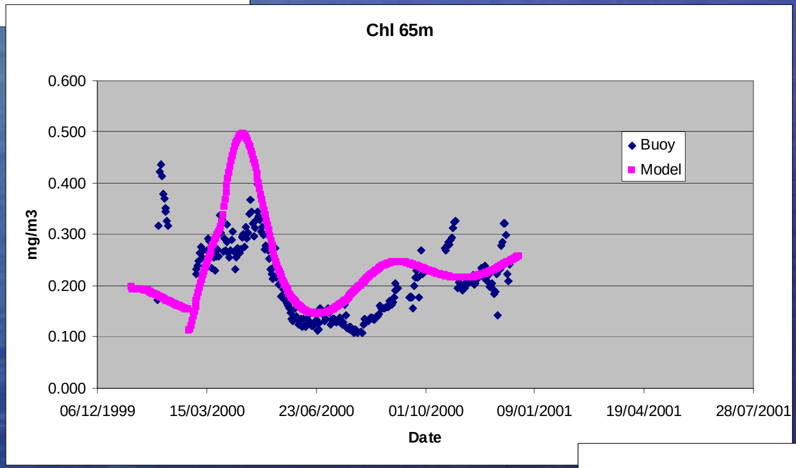
Chl (mg/m^3)

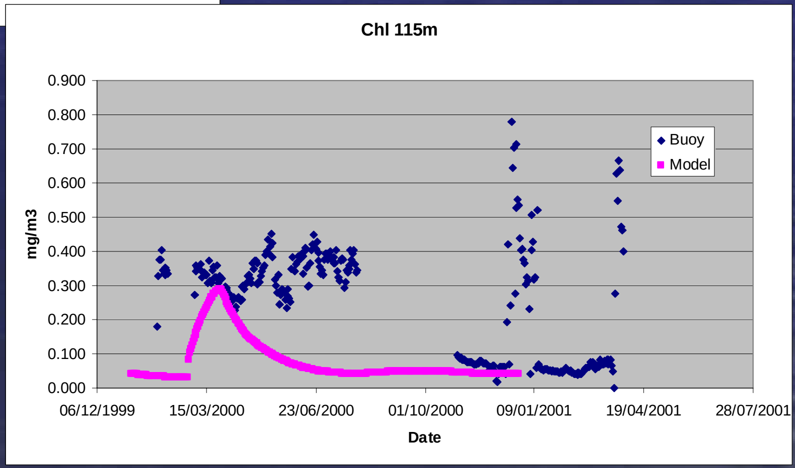


Surface
0
0.1
0.2
0.3
0.4
JAN MAR MAY JUL SEP NOV JAN MAR
50m
0
0.25
0.5
0.75
1
JAN MAR MAY JUL SEP NOV JAN MAR
80m
0
0.16
0.32
0.48
0.64
JAN MAR MAY JUL SEP NOV JAN MAR
100m
0
0.2
0.4
0.6
0.8
JAN MAR MAY JUL SEP NOV JAN MAR

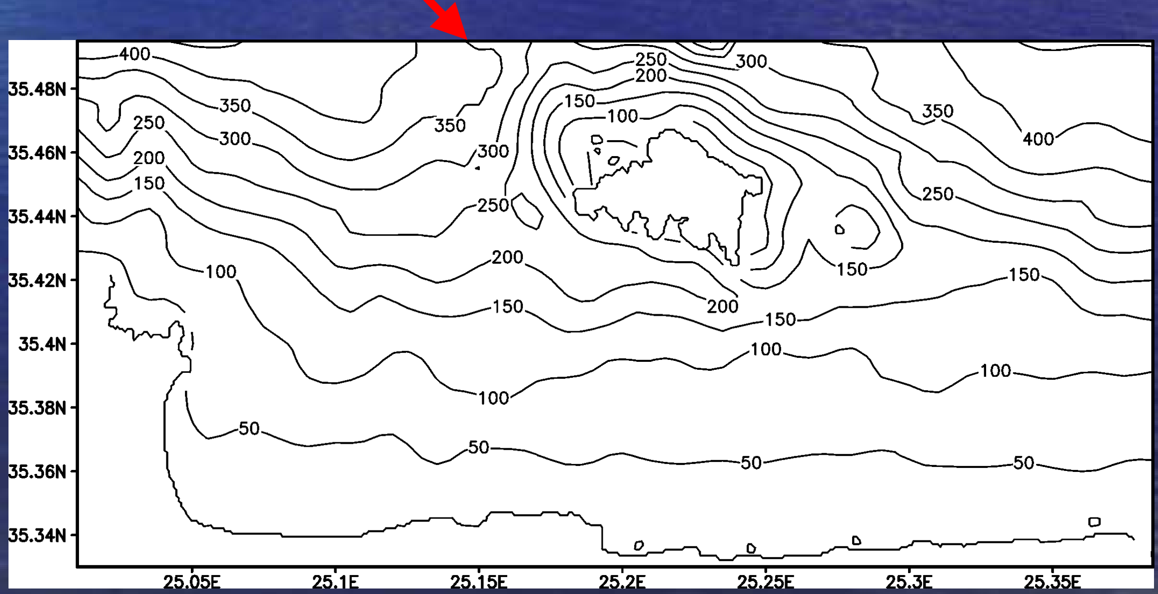
M3A buoy data





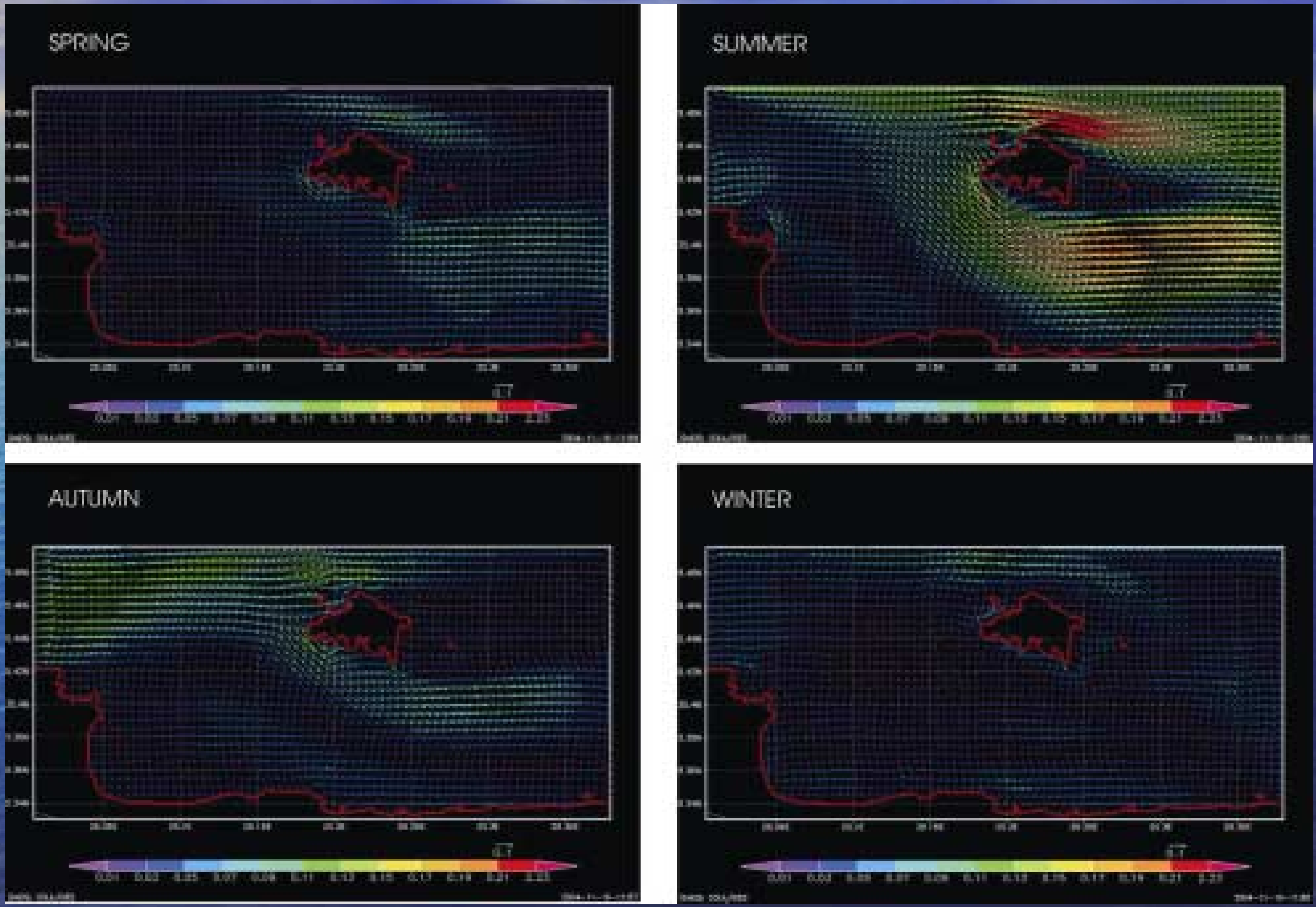


3D Model

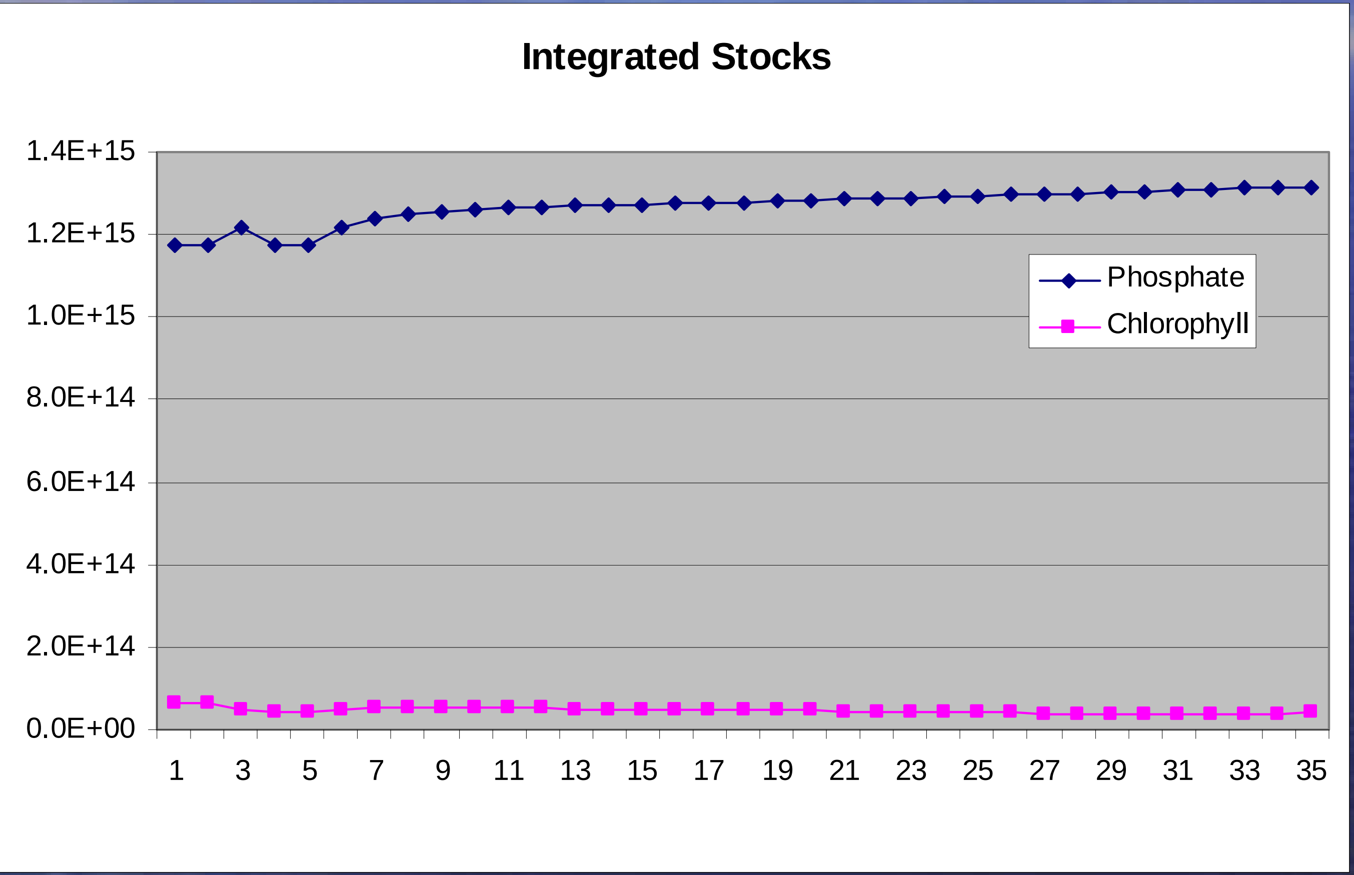

35.48N
35.46N
35.44N
35.42N
35.4N
35.38N
35.36N
35.34N
25.05E
25.1E
25.15E
25.2E
25.25E
25.3E
25.35E
400
350
300
250
200
150
100
50

- 25°01΄E – 25°385΄E and 35°33΄N – 35°495΄N
- High resolution model – horizontal resolution 0.3 min (~ 500 x 500 m)
- Grid 76 x 34 boxes
- One-way nested with the Cretan-Sea ecosystem model
- Initial fields and parameterization from the 1D model
- 1D ecosystem models in the boundaries
- Simulation period: 10-years → steady state
  1-year → results

Mean Seasonal Velocity Fields



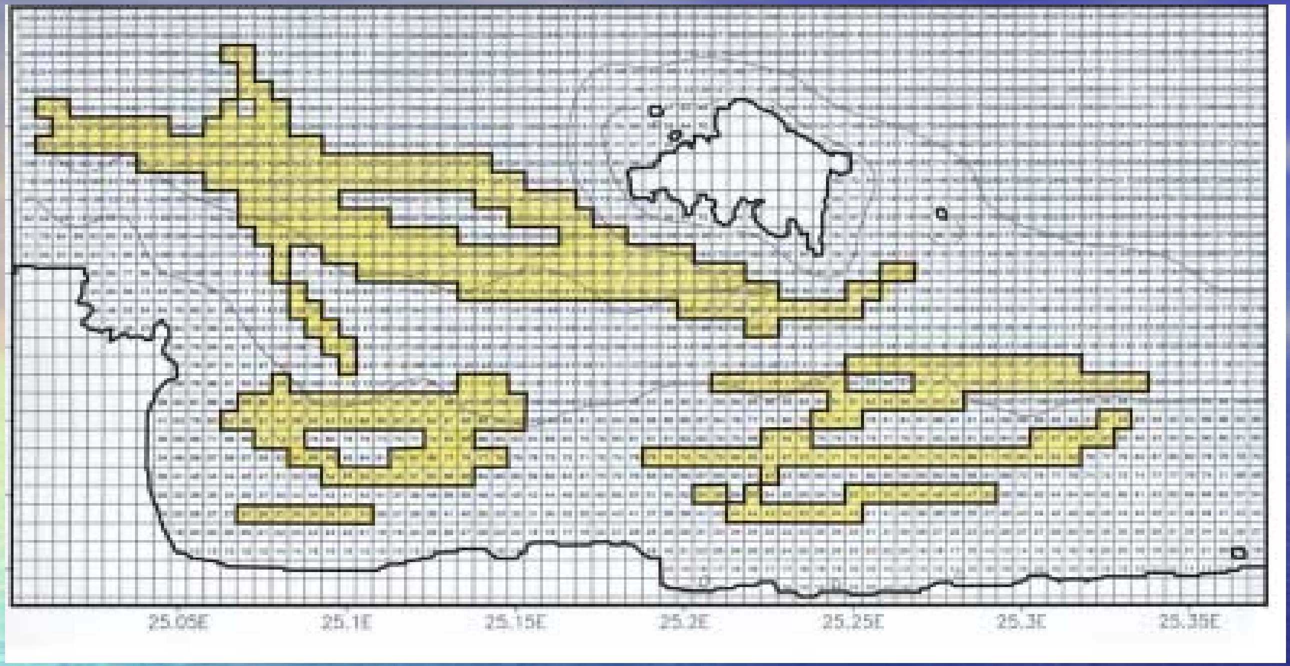
Conservativeness



	Primary Production (mgC/m²/d)	Bacterial Production (mgC/m²/d)
(Turley *et al.*, 2000) Jul 94 – Oct 95	243 *(100m)*	130 *(100m)*
(Psarra *et al.*, 2000) Jul 94 – Oct 95	220 *(100m)*	
(Van Wambeke *et al.*, 2000) Mar & Sept 95		131 *(100m)*

(Siokou *et al.*, 2002)	**Primary Biomass** (mgC/m²)	**Bacterial Biomass** (mgC/m²)
March	1488 ± 364	1423 ± 43
September	645 ± 81	1505 ± 432

	MODEL
Primary Production mgC/m²/d	187 (112 – 237)
Bacterial Production mgC/m²/d	120 (92 – 142)
Phytoplankton Biomass mgC/m²	1709 (1459 – 2205)
Bacterial Biomass mgC/m²	1109 (1008 – 1157)



Experiment

- Trawling – 1 October – 31 May
- Standard run – no trawling
- Random sampling 1 box every 2 days + 2 adjacent
- 55% mortality for deposit feeders
- 97.8% mortality for suspension feeders
- 50% benthic bacteria
- Dead organic matter → POC, PON και POP

Scenarios

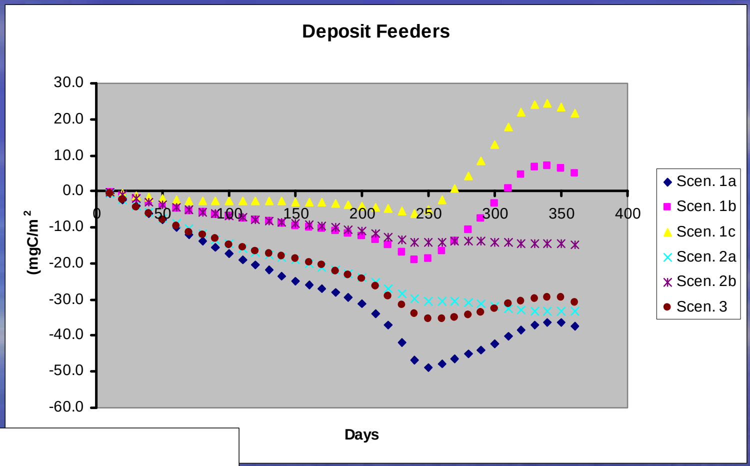
Gear Selectivity

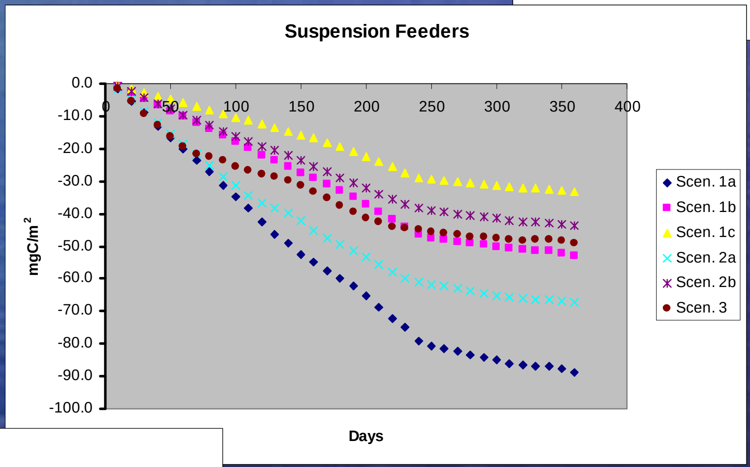
Access Control

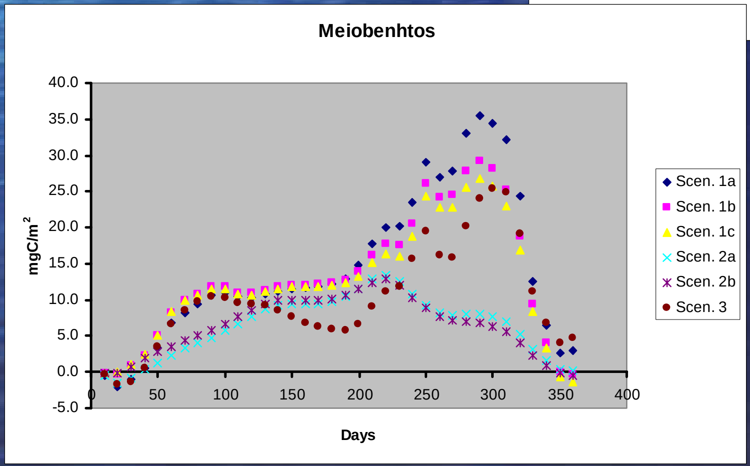
Fishing Effort

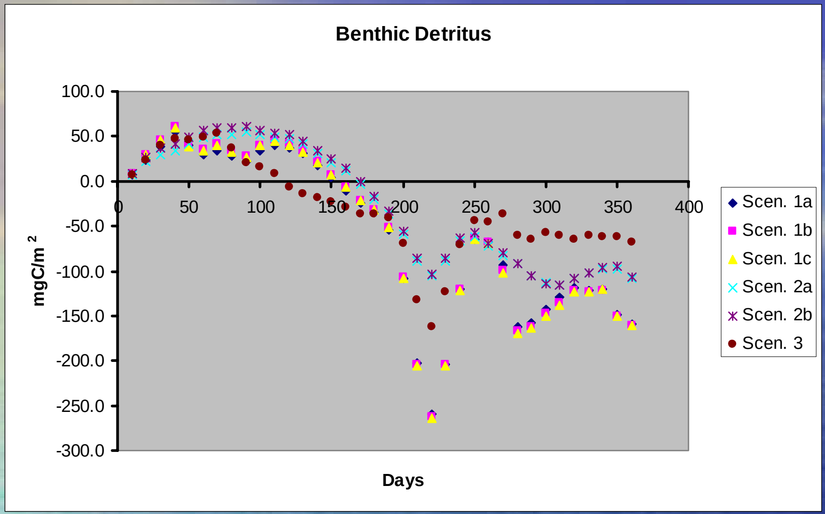
RUN	Scenario	Fishing Effort	Fishing Period	Mortality	Trawled Area
Std	No Fishing	-	-	-	-
1a	No change (existing fishing effort and area)	100%	October - May	100%	100%
1b	No change Reduced mortality	100%	October - May	50%	100%
1c	No change Reduced mortality	100%	October - May	30%	100%
2a	Reduced fishing area	100%	October - May	100%	>100m isobath
2b	Reduced fishing area Reduced mortality	100%	October - May	50%	>100m isobath
3	Reduced Effort	50%	October - May	100%	100%

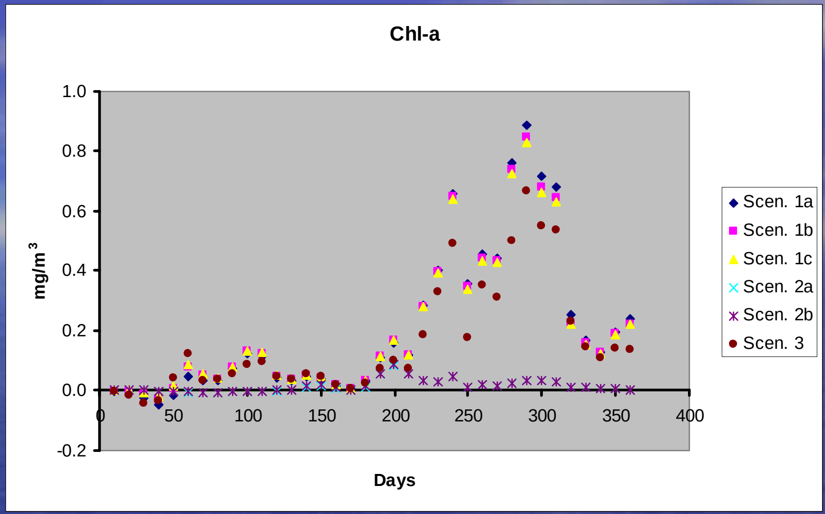
Results

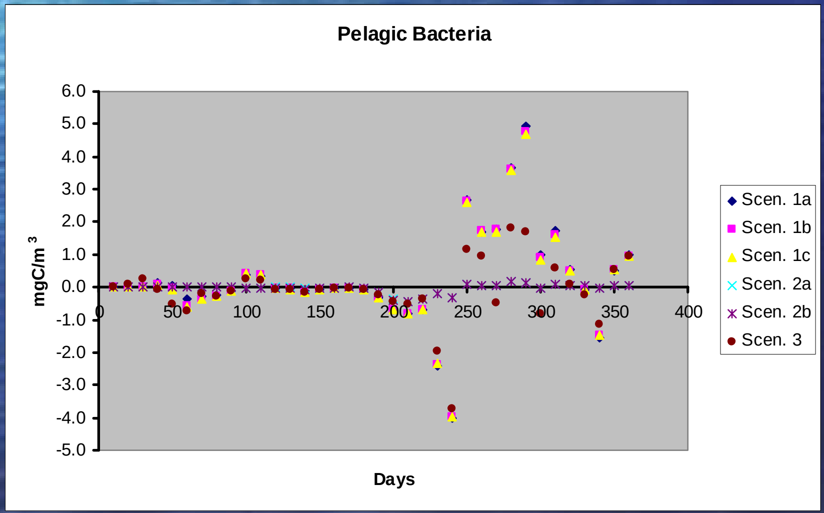

Deposit Feeders
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
0
50
100
150
200
250
300
350
400
(mgC/m 2
Days
Scen. 1a
Scen. 1b
Scen. 1c
Scen. 2a
Scen. 2b
Scen. 3

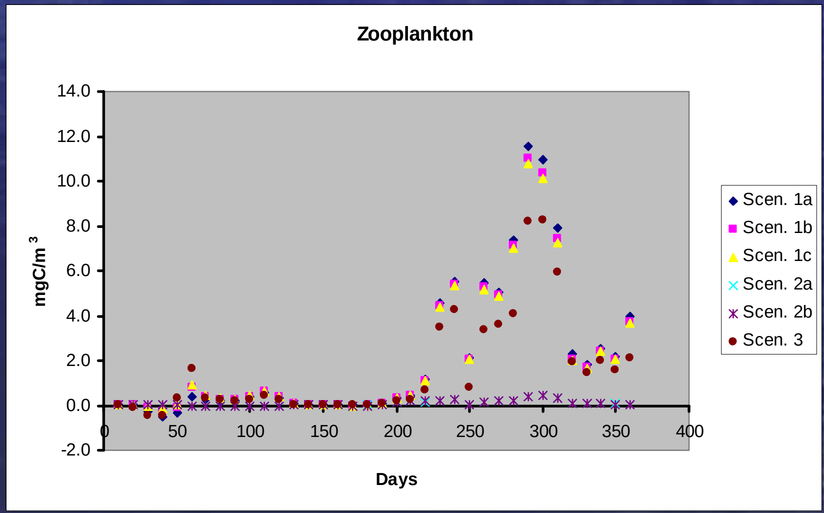

Suspension Feeders
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100.0
0
50
100
150
200
250
300
350
400
mgC/m 2
Days
Scen. 1a
Scen. 1b
Scen. 1c
Scen. 2a
Scen. 2b
Scen. 3

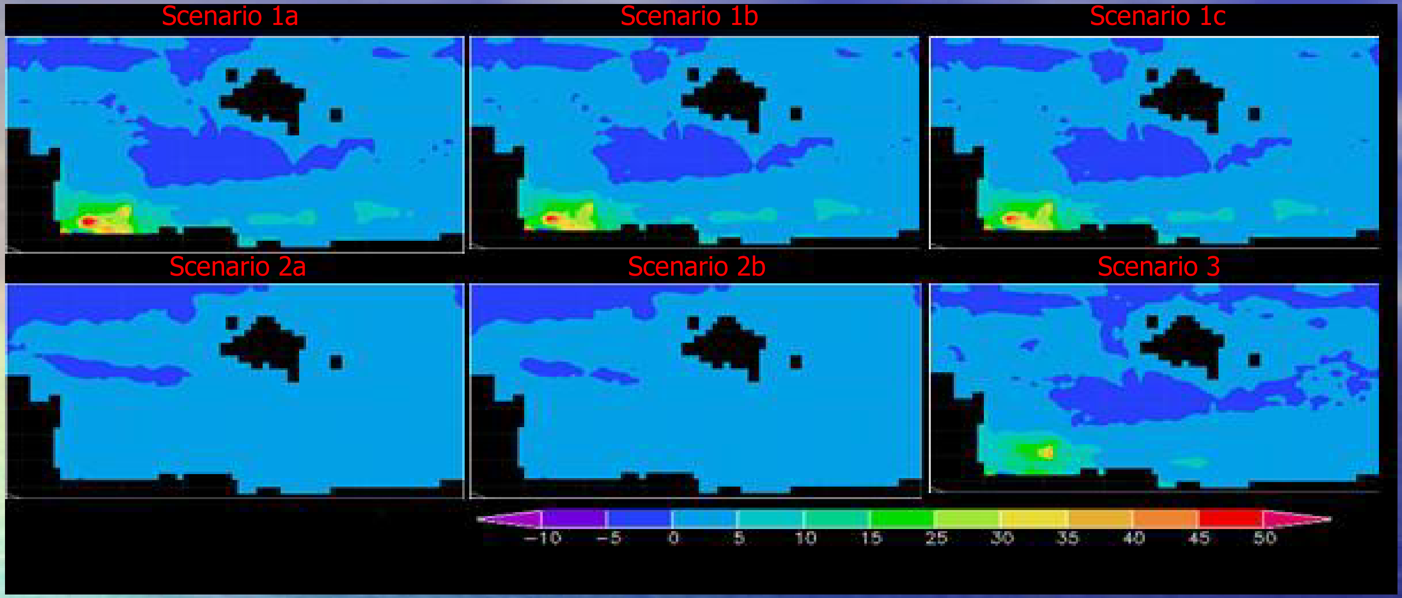

Meiobenhtos
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
0
50
100
150
200
250
300
350
400
mgC/m 2
Days
Scen. 1a
Scen. 1b
Scen. 1c
Scen. 2a
Scen. 2b
Scen. 3


Benthic Detritus
100.0
50.0
0.0
-50.0
-100.0
-150.0
-200.0
-250.0
-300.0
0
50
100
150
200
250
300
350
400
mgC/m 2
Days
Scen. 1a
Scen. 1b
Scen. 1c
Scen. 2a
Scen. 2b
Scen. 3


Chl-a
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
0
50
100
150
200
250
300
350
400
mg/m 3
Days
Scen. 1a
Scen. 1b
Scen. 1c
Scen. 2a
Scen. 2b
Scen. 3

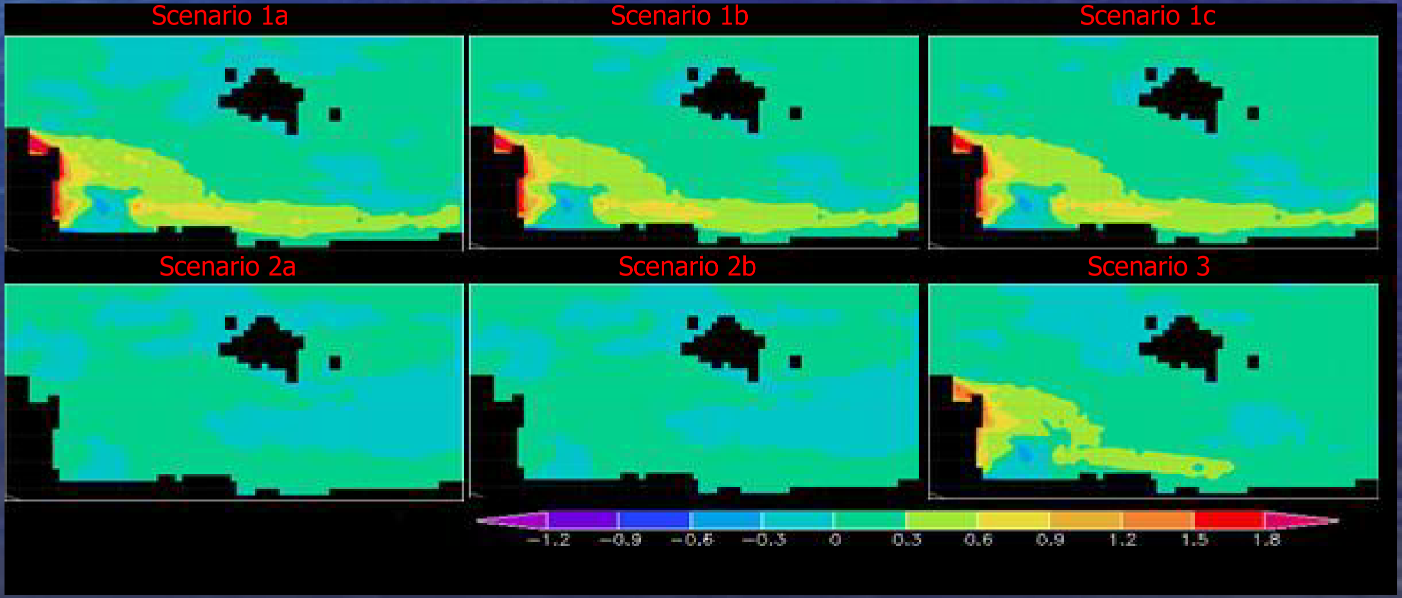

Pelagic Bacteria
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
0
50
100
150
200
250
300
350
400
mgC/m 3
Days
Scen. 1a
Scen. 1b
Scen. 1c
Scen. 2a
Scen. 2b
Scen. 3


Zooplankton
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
0
50
100
150
200
250
300
350
400
mgC/m 3
Days
Scen. 1a
Scen. 1b
Scen. 1c
Scen. 2a
Scen. 2b
Scen. 3



Primary Productivity $mgC/m^2/d$

Bacterial Productivity $mgC/m^2/d$



Conclusions

- There is a strong coupling between trawling impacts and the hydrodynamic fields of the area.
- The absence of suspension feeders, deposit feeders and benthic bacteria results in the significant increase of meiobenthos and benthic detritus.
- Production in the water column increases due to trawling (phytoplankton, zooplankton)
- There were no significant differences in the integrated productivity of the system with the reduction of mortality (scenario 1 a, b and c)
- Trawling affects the pelagic variables not only in the immediate area but also in outer areas of the simulation field

- Shallow areas are more strongly affected by trawling in contrast to deeper areas where effects remain local and rather insignificant
- The scenario with the least variability in the primary production is the one with the reduction in trawling area (2)
- The only scenarios that allowed the return of the deposit feeders were the ones with reduction in mortality (1b & 1c)
- Scenarios 2 (area limitation) resulted in one order of magnitude lower biomass in the pelagic variables compared to scenarios 1 (mortality reduction) and 3 (fishing effort reduction)
- The model can be used in the analysis of the system offering valuable help towards decision making issues

- However before we proceed to the exploitation of the results we must pay attention to the assumptions done, to the limitations of the model as well as to the various other dimensions associated with the problems such as socioeconomics etc.

- This particular model will be further developed incorporating important missing processes and in particular extending the food web with the higher trophic levels