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A model for sustainable management of penaeid shrimp fishery - application to Maputo Bay, Mozambique

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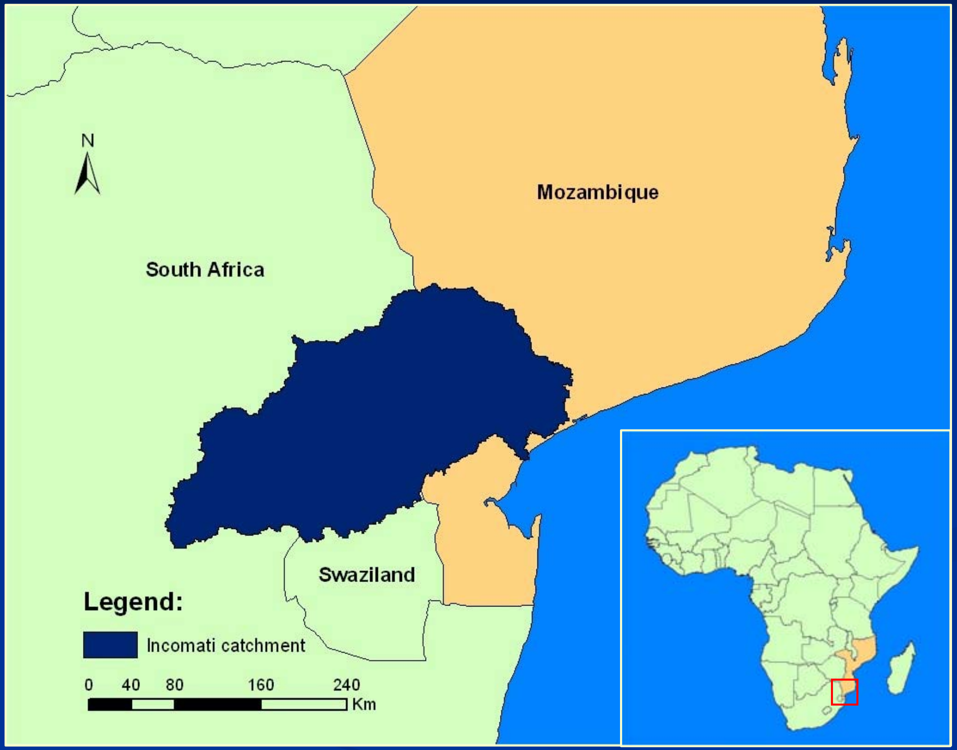
Study scope

Catchment2Coast project (ICA4-2001-10136)

Goal: study the impacts of human activities in the river catchment on downstream coastal resources

Approach: integration of several mathematical models

Study area: Incomati river catchment and more specifically the shrimp stock off Maputo Bay



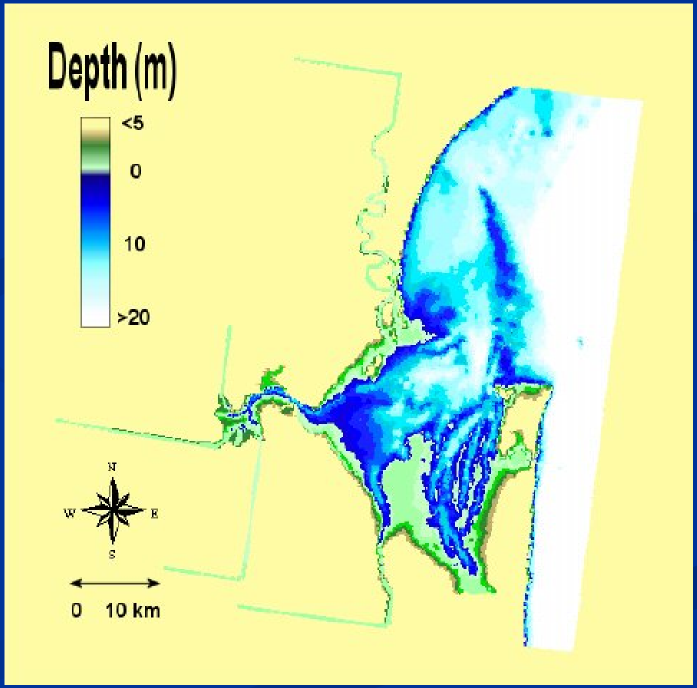
Work Package 6

"Ecology of commercially exploited shrimp resources in Maputo Bay"

Study site description

Total area	Total volume	Fishing area	Depth range	Bottom type	Tidal regime and amplitude	Mangrove area
1200 km^2	7200 x 10^6 m^3	343 km^2	1-20 m	Sandy/ muddy	Semi-diurnal 2 m	111.5 km^2

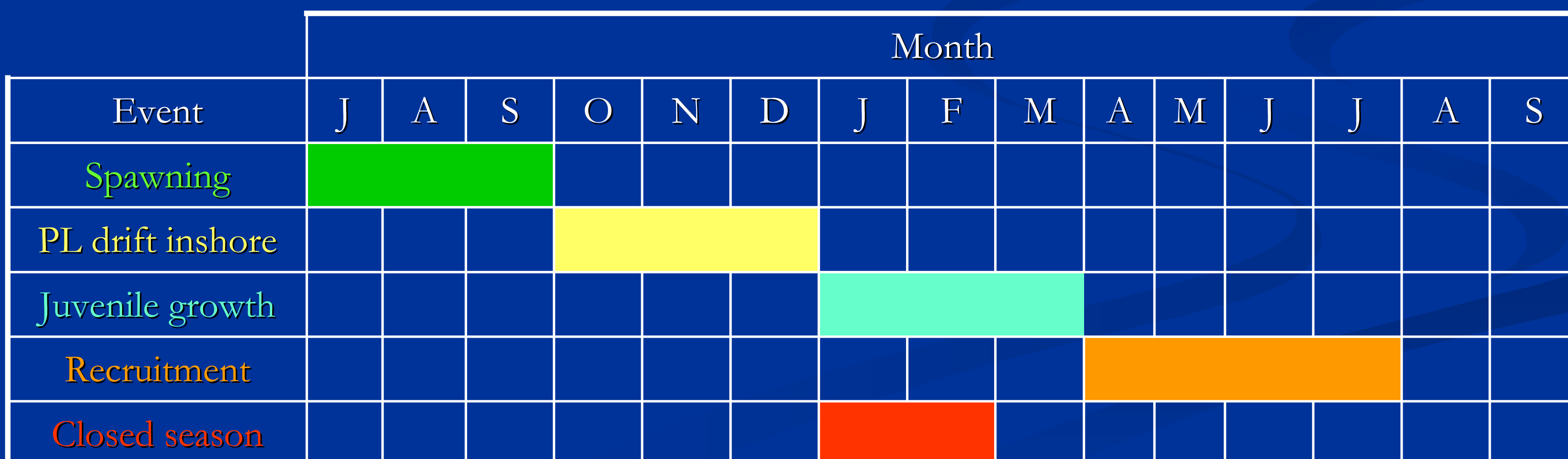
- Maputo Bay is one of the most important shrimp trawling areas of the Mozambican shelf
- Shallow water shrimp are caught both by a semi-industrial and a artisanal fleet at depths between 5-20 m
- *Penaeus indicus* constitutes about 60% of shrimp total catch in Maputo Bay and together with *Metapenaeus monoceros* represent 80% of the annual cacth



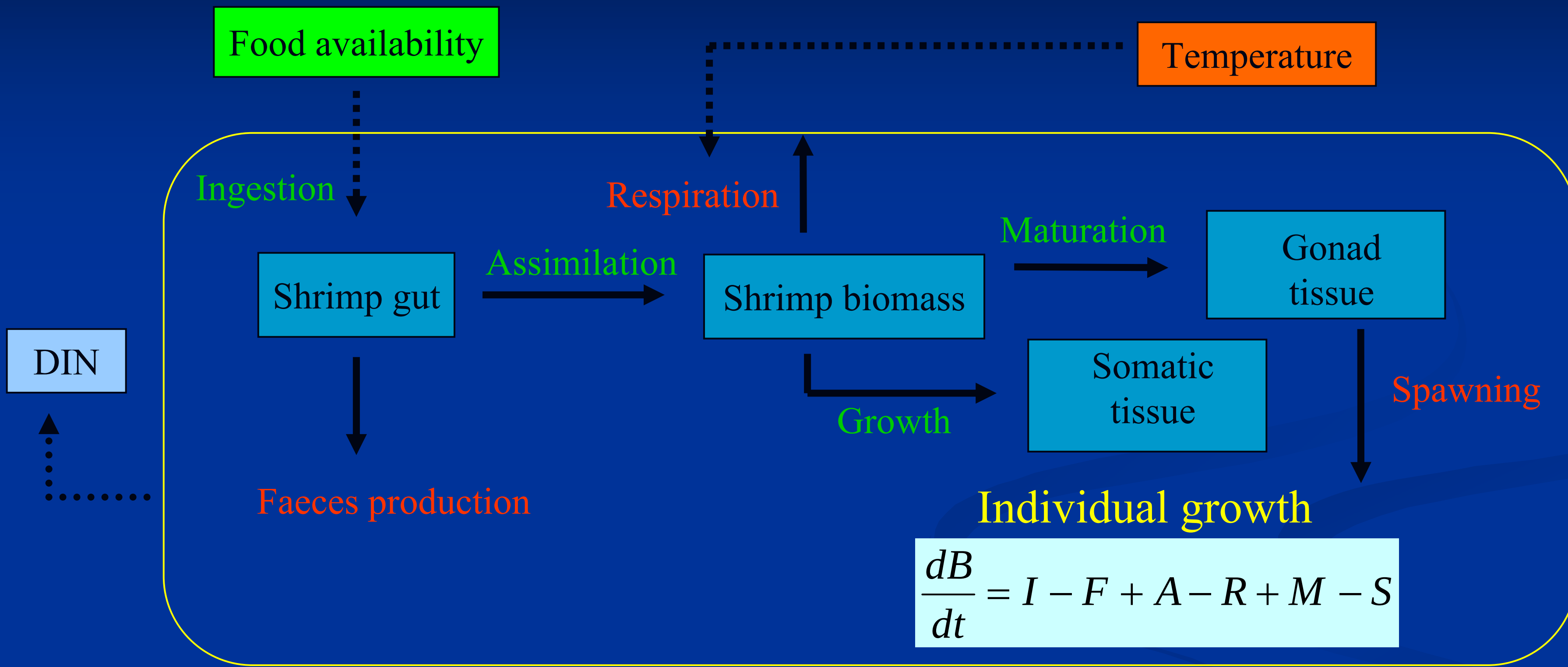
- Fishery regulation measures: mesh size and closed season

P. indicus – Background information

- The life cycle comprises several growth stages (larvae, postlarvae, juveniles, subadults and adults) and includes migrations between the estuary and the sea
- The estuarine stages (postlarvae and juveniles) live in shallow waters (< 5 m) and show a great preference for vegetated mangrove habitats over adjacent sand flats
- The marine stages (eggs, larve and adults) live in deeper waters (10-20 m) and are associated with sand or muddy substrates



Shrimp model – Concept



$$\frac{dB}{dt} = I - F + A - R + M - S$$

Individual SFG

Demographic model

$$\frac{\partial n(s,t)}{\partial t} = -\frac{\partial [n(s,t)\eta(s,t)]}{\partial s} - \mu[(s)n(s,t)]$$

Transition of individuals between size classes depends on individual SFG (η)

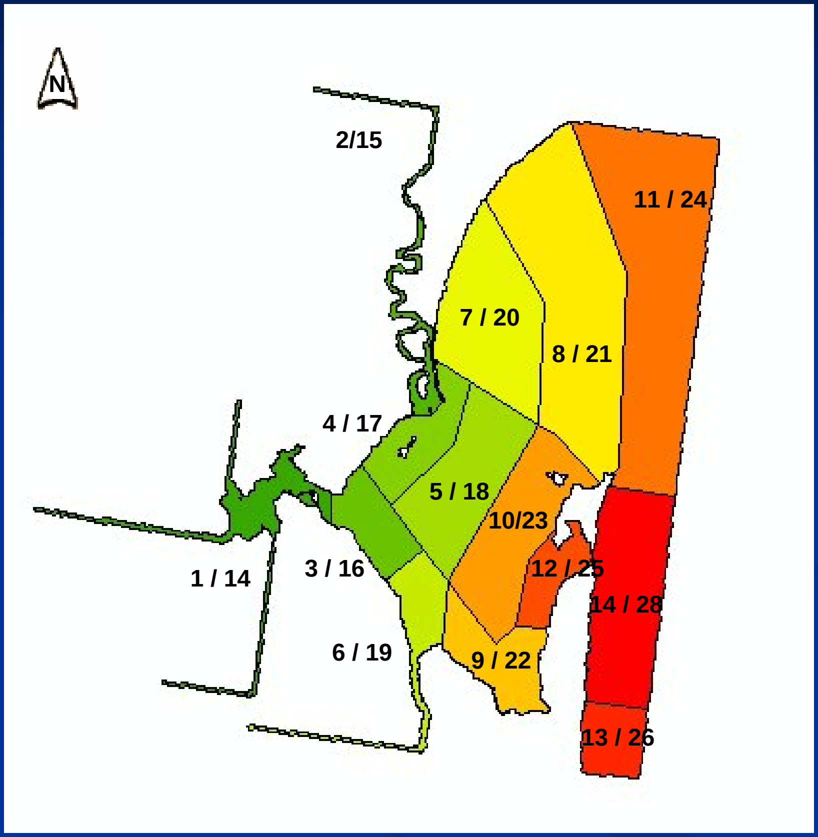
Ecosystem model

1. Division of the Bay in 28 boxes

- criteria
  - Hydrodynamics;
  - Mangrove distribution;
  - Nutrient input from rivers;

2. Forcing functions

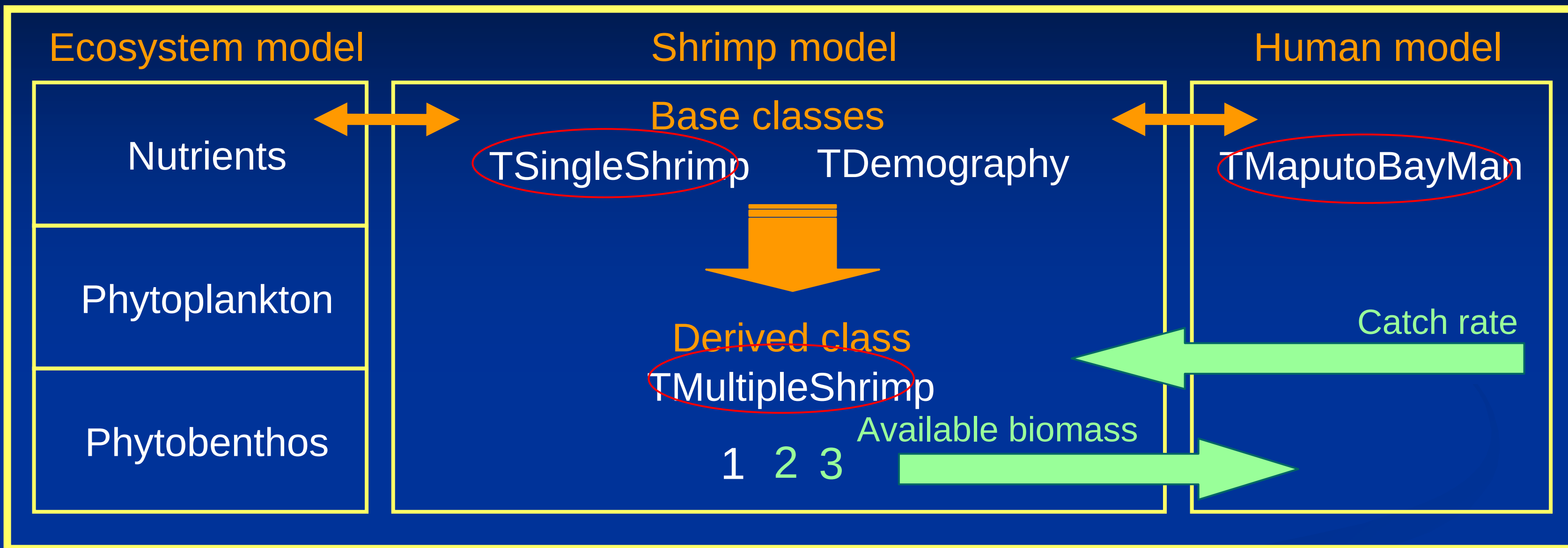
- implemented as C++ objects
  - ✓ Light
  - ✓ Water temperature
  - ✓ River/ocean, ocean/ocean boundaries (Nutrients, phytoplankton and salinity)



3. Simulation of the key state variables

- also implemented as C++ objects
  - ✓ Hydrodynamics (Delft3D)
  - ✓ Dissolved substances
  - ✓ Suspended particulate matter
  - ✓ Phytoplankton
  - ✓ Mangrove
  - ✓ Shrimp
  - ✓ Man

Shrimp model – Integration

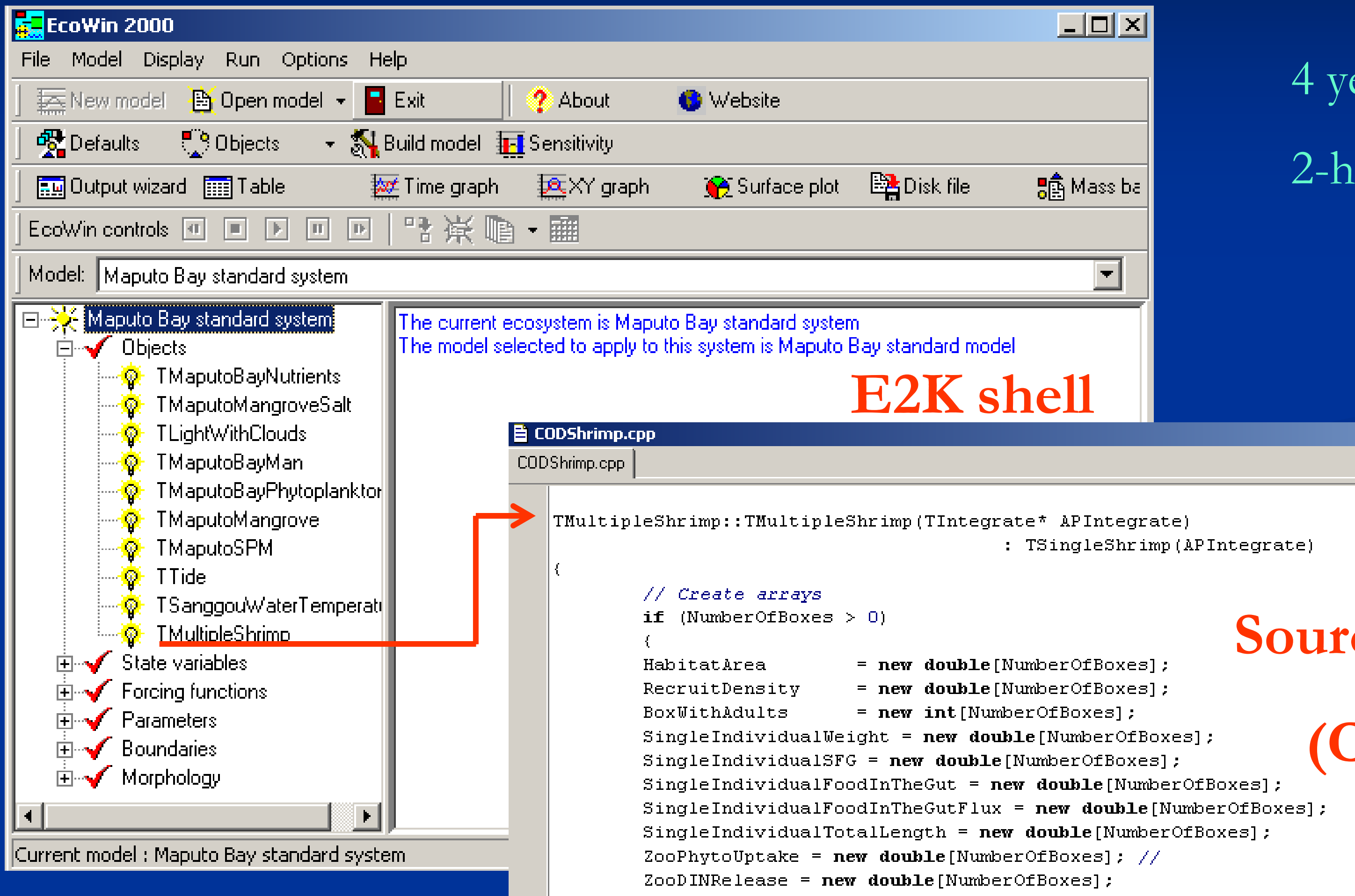


Nunes *et al.*, 2003; Nobre *et al.*, 2005

	Juvenile	Subadult	Adult
Average weight (g DW)	0.1 gDW	3.1 gDW	6.1 gDW
Habitat	Mangrove creeks	Bay	Bay
Model boxes	2, 4, 6 and 9	3, 5, 7, 10 and 12	3, 5, 7, 10 and 12

Shrimp model - Interface

EcoWin2000* platform (E2K)



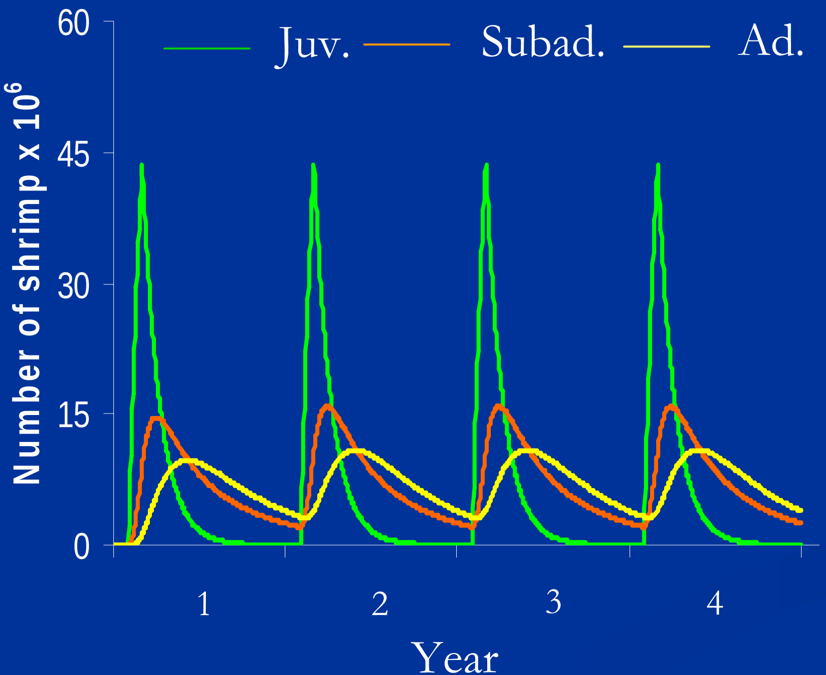
4 years

2-hour timestep

*Ferreira, JG. 1995. Ecowin – An object-oriented ecological model for aquatic ecosystems. Ecological Modeling, 79: 21-24.

Shrimp model - Results I

Annual average biomass (ton DW)						
	Area with mangrove			Area of subadults		
Year	Juvenile	Subadult	Adult	Juvenile	Subadult	Adult
1	16	0	0	3	115	187
2	16	0	0	3	128	229
3	16	0	0	3	128	229
4	16	0	0	3	128	230

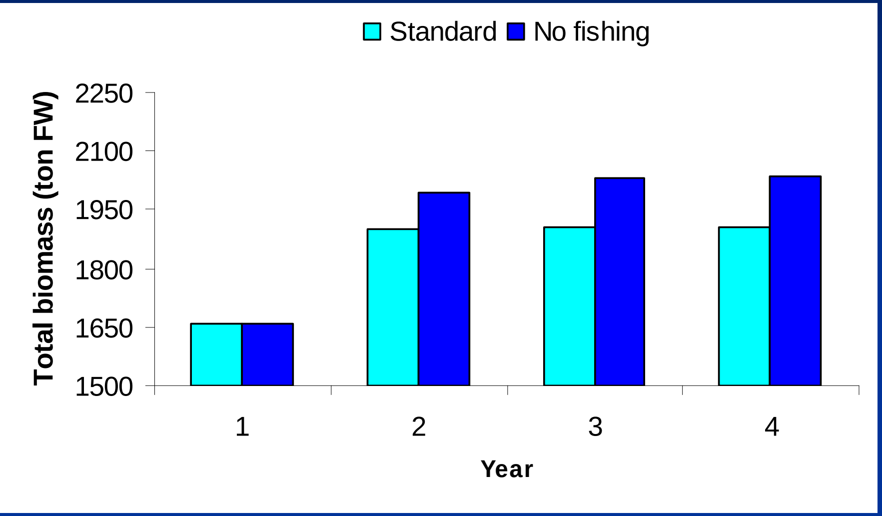


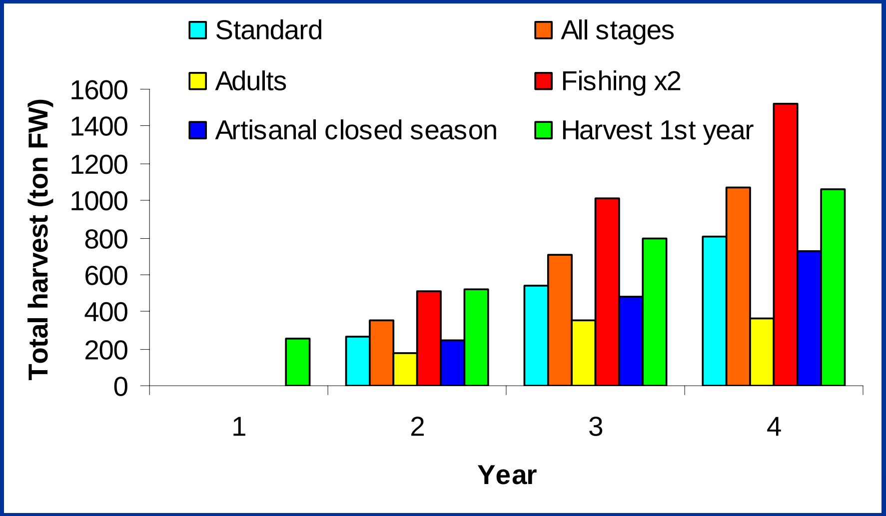
The biomass decreases from the juvenile stage to the adult stage stabilizes through the simulated years

Juvenile abundance increases during the recruitment period and decreases through mortality and shrimp transition to consecutive stages resulting in a decrease of shrimp abundance from the first to the last stage

Abundance peaks in the first half of the year, corresponding to the period of higher catches

Shrimp model – Results II





- Fishing pressure removes about 6% of the total biomass. This suggests that the available stock of *P. indicus* allow higher catch rates
- The extension of the closed season to the artisanal fishery does not significantly affect the total harvest
- Because the catch is not limiting the stock , double fishing originates a linear increase of the total catch
- The harvest of *P. indicus* from the first year forward results in a 50% increase of shrimp total harvest in the second year followed by a smaller increase in years 3 (32%) and 4 (24%)

Final considerations

- The coupling between the physiological and the demographic processes proved to be an useful approach to simulate biomass dynamics of this exploitable resource

- Calculate the potential *P. indicus* stock in Maputo Bay based on simulations of the different development stages

- Evaluate the abundance and biomass for each stage as well as classify areas and periods of maximum abundance

- Analyse the impact of different development scenarios on the shrimp population and based on the results select the management options that give better results in order to maintain a sustainable fishery