ICAWA

A Bioeconomic modeling of Sardinella fisheries in Senegal

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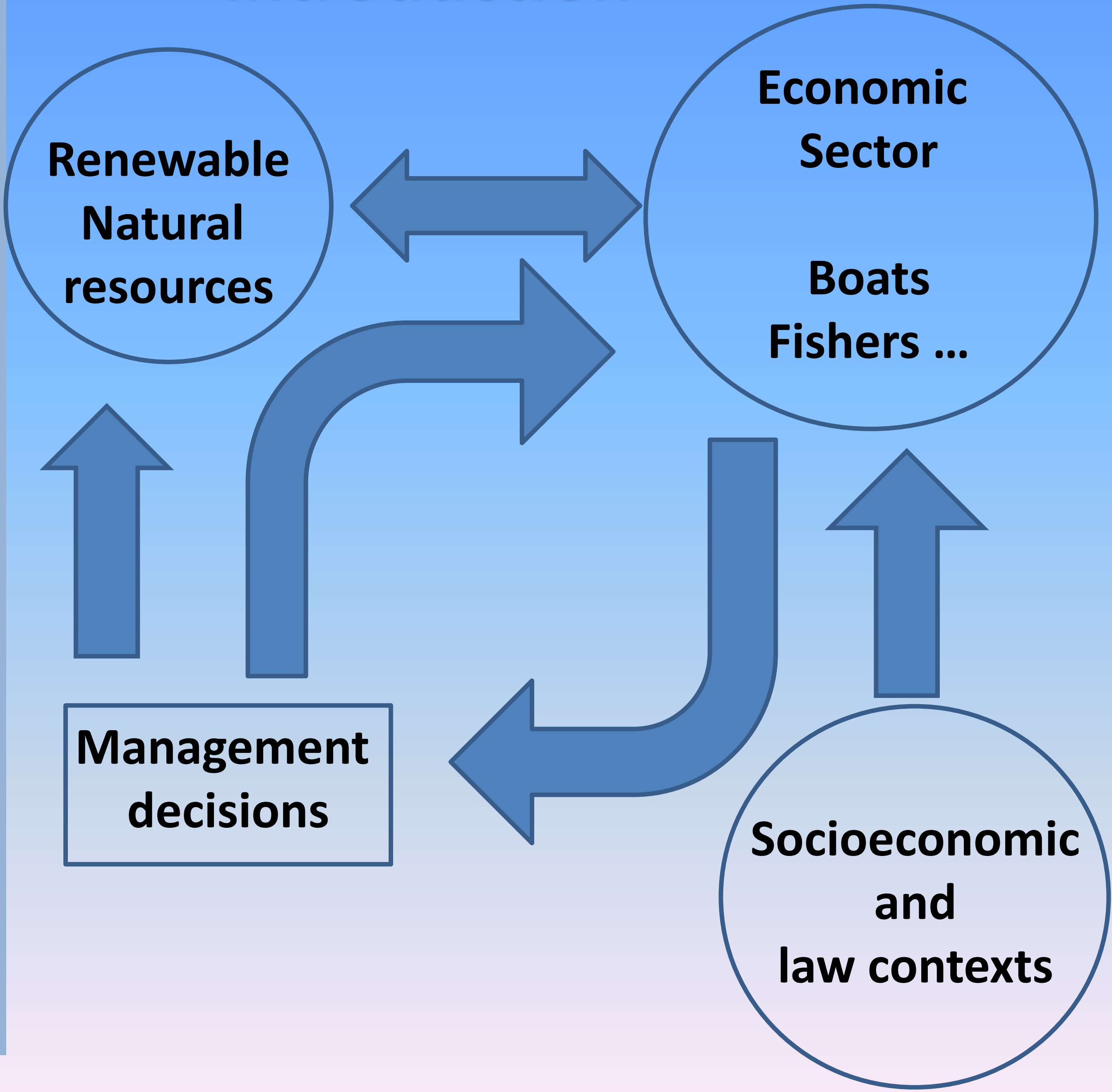
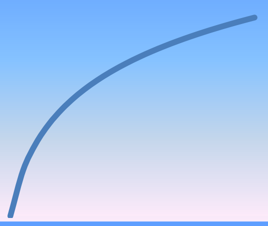
Introduction

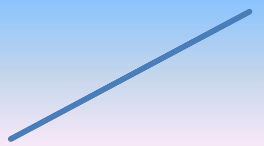
- A simplified representation of the fishery system
- Understanding the system dynamics
- Support management : how to achieve a better state of the system according to a collective point of view



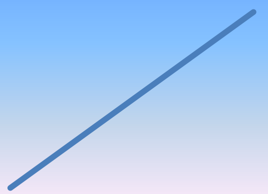
Effort



National and International demand

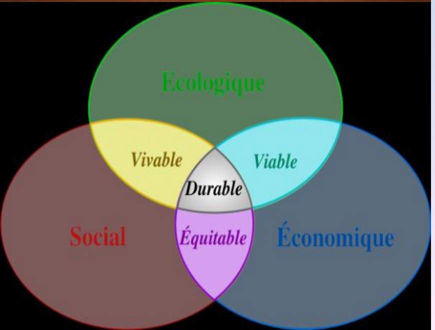


fishmeal demand



Introduction

- Major role of small coastal pelagic for national and regional food security (fresh and processed products)
- Increasing pressure on resource due to growth in small scale fishing effort but also from foreign (legal and illegal) exploitation
- Increasing demand on national and regional markets (fresh and processed product)
- Increasing international demand for fishmeal, major Input for aquaculture industry. Limits (quotas) in the Peruvian industrial had direct consequences on other fishing zones, and, among them, West Africa.



Introduction

- Necessity of better fishing effort regulation, with many possible regulation tools.

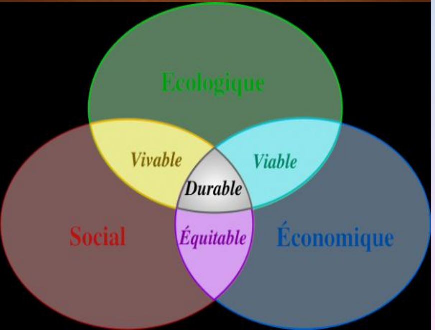
- Test the impacts of different management options (licenses, quotas, taxes, MPAs, seasonal closures, share of resources allowed for foreign boats)

- Consequences of changes in economic context (prices, input costs, new markets)

- What is the best management strategy according to a wide diversity in goals and constraints ?

Introduction

- Goals:
  - Understand and model the dynamics of this fishery
  - Test management scenarios
  - Implement a management tool

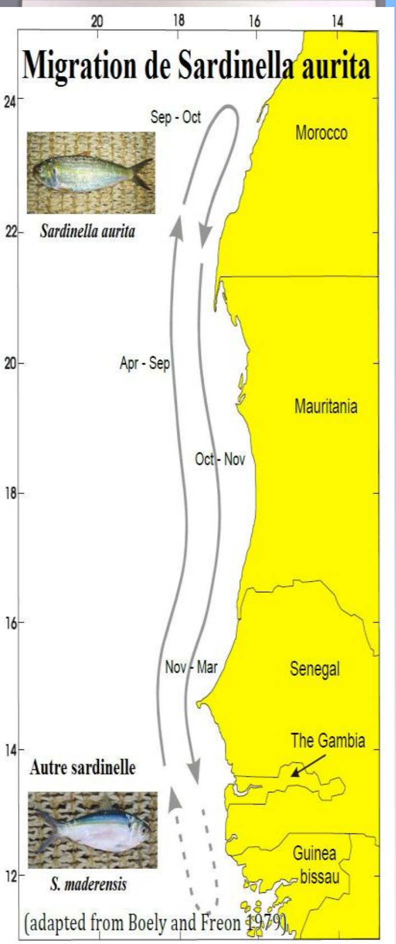


Methodology

An overview of the sardinella bioeconomic model

- Biological and economical data:
  - Literature,
  - CRODT,
  - DPM,
  - FAO,
  - AWA Survey
  - A VPA was conducted with catch and biological data (input for the model)

Methodology



RESOURCES

- Two main species : round sardinella (*S. aurita*) and flat sardinella (*S. maderensis*)
- Migrating stocks (mainly for *S. aurita*) shared between neighboring EEZs (Mauritania, Senegal and Guinea Bissau (?)
- Seasonal spatial repartition varying among species
- Great sensitivity of population dynamics to environment parameters (upwelling, CC)

Methodology

FLEETS

- Fishing methods: artisanal purse seine , artisanal encircling gillnet, industrial pelagic gear (?)
- The fleet have differences in costs , catchability and in targeted markets.
- Fleets : sets of boats, defined by fishing methods and specific costs.
- Fleets will be spatially redistributed a each time step. Spatial fleet behavior modeling is exposed later.

Methodology

MODELING CHOICES

- Time step : month
- Simulation length : up to 20 years
- Age structured model (month)
- Two species (*S aurita and S. maderensis)*
- Multi gears (Purse seines, encircling gillnets, industrial gears targeting sardinellas)

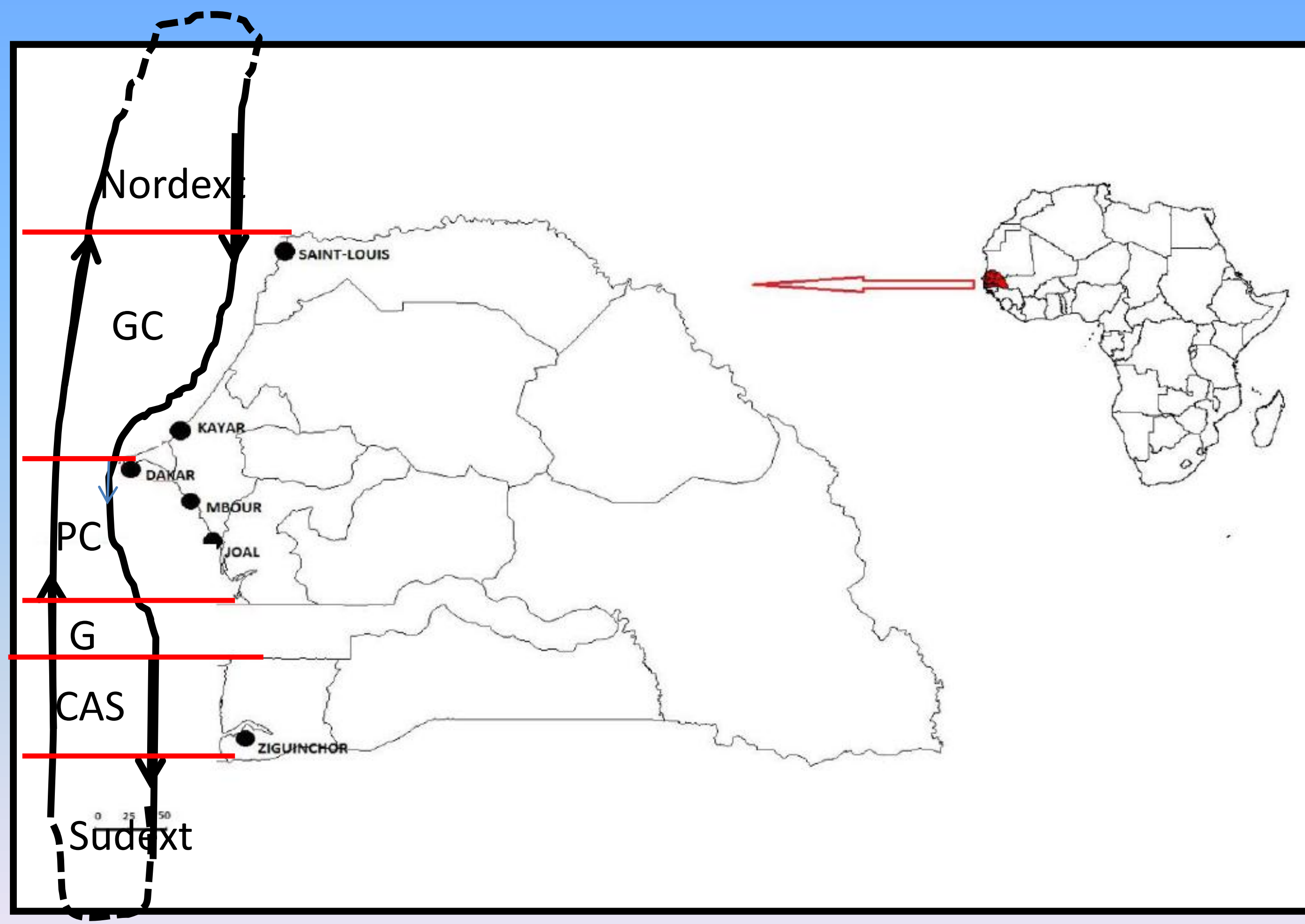
Methodology

MODELING CHOICES

Spatially explicit model : resources and fleets are redistributed a each time step

Exploitation is only modeled in Senegal

In external zones, exploitation is exogenous (forced)



Methodology

MODELING CHOICE

- **Market** :Fishery is price taker (constant prices). Exogenous prices are defined by species

- **Cost functions** specified by fleet
  - Fixed costs : insurance, depreciation, maintenance, fishing license fees…
  - Variable costs :
    - energy, food (linked to time at sea)
    - labor (linked to yield value)

Methodology

Control variables

- **Policy parameters**
  - Initial fleet numbers (with possibility of effort multiplier varying during simulation)
  - Licenses
  - Spatial/seasonal closures
  - Limits in landed quantities
  - Taxes /subsidies
  - …..
- **Economic parameters**
  - Costs
  - Markets parameters (price)
  - …….

Methodology

- **Resources parameters**
  - Structured by age (age class = month)
  - Catchability defined par species and gears
  - Von Bertalanffy growth curves
  - Natural mortality constant per species
  - Spatial monthly repartition per species is due to migration between zones and fishing effort in zones
  - Monthly migration matrix defining exchanges between zones

Methodology

Spatial and temporal resource behavior

Number of fish in a cohort :

$$N_{i,c,z,t} = R_{i,c,z} \qquad t = tr_c$$
$$N_{i,c,z,t} = 0 \qquad t < tr_c$$
$$N_{i,c,z,t} = N_{i,c,z,t-1} - D_{i,c,z,t-1} + M_{i,c,z,t-1} - X_{i,c,z,t-1} \qquad t > tr_c$$

Mortality in number

$$D_{i,c,z,t} = N_{i,c,z,t} \cdot (1 - e^{-Z_{i,c,z,t}})$$

Mortality

$$Z_{i,c,z,t} = F_{i,c,z,t} + Mortn_i(a_{c,t})$$

Methodology

Effort time dynamic

- For each end of year there are investment or disinvestment

$$\mathbf{IVT_{e,\,a} = PROFCF_{ea}.txi} \qquad \mathbf{PROFCF \geq 0}$$

$$\mathbf{IVT_{e,\,a} = PROFCF_{ea}.txi1} \qquad \mathbf{PROFCF < 0}$$

- New UP=$NUP_{e,\,a} = IVT_{e,\,a} / PrUP_e \qquad a = a1, a2..., a20$

- Total UP zone

$$UP_{e,\,a} = UP_{e,\,a-1} + NUP_{e,\,a-1} \qquad a = a1, a2..., a20$$

$$UP_{ea} \leq MaxUP_e$$

Methodology

Spatial and temporal resource behavior

Fishing mortality:

$$F_{i,\,c,\,zsen,\,t} = \sum_e Ff_{i,\,c,\,e,\,zsen,\,t} \qquad z \in \{Nordext, G, Sudext\}$$

$$F_{i,\,c,\,z,\,t} = \sum_e Ffix_z$$

$$z \in \{Nordext, G, Sudext\}$$

With

$$Ff_{i,\,c,\,e,\,z,\,t} = Fla_{e,\,z,\,t}.q_{e,\,i}$$

Migration

$$FMM_{i,\,c,\,ori,\,dest,\,nmois,\,t} = N_{i,\,c,\,z,\,t}.ParamMigr_{i,\,ori,\,dest,\,nmois} \qquad si\ t >= tr_c$$

$$FMM_{i,\,c,\,ori,\,dest,\,nmois,\,t} = 0 \qquad t < tr_c$$

$$nmois = mois1, mois2..., mois12 \qquad mois = 1, 2, ..., 12$$

Methodology

Fleets spatial behavior : a free ideal distribution approach

- Fleet redistribution at every time step depend to the attractiveness of the zones who is based on resources abundance in the past in the zones.

$$ATRZ_{zsen,t} = \frac{\sum_i [(BIZS_{i,zsen,t-1} + BIZS_{i,zsen,t-12})*ParFerm_{zsen,t}]}{\sum_{i,zsen}[(BIZS_{i,zsen,t-1} + BIZS_{i,zsen,t-12})*ParFerm_{zsen,t}]}$$

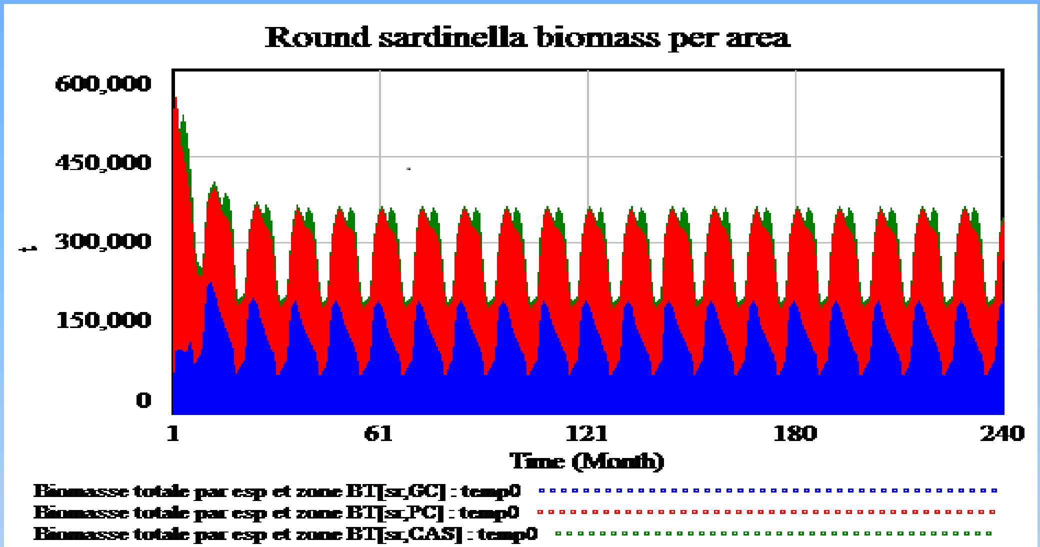
- The fleet can now redistributed between zones

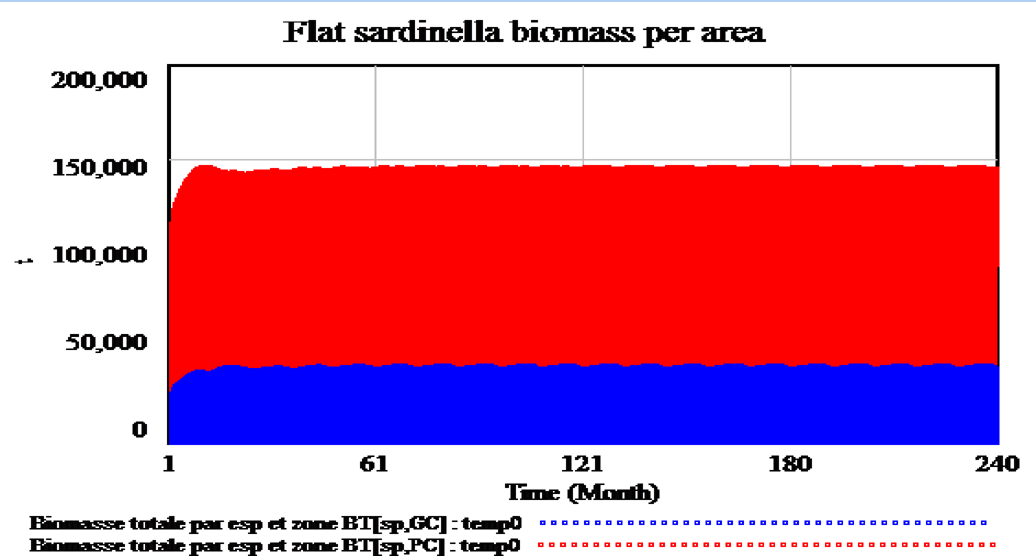
$$UPZ_{e,zsen,t} = UP_{e,t}.ATRZ_{zsen,t}$$

Results: Model outputs

Biomass per species per area

- High variability for round sardinella
-
- Biomass flat sardinella high in PC



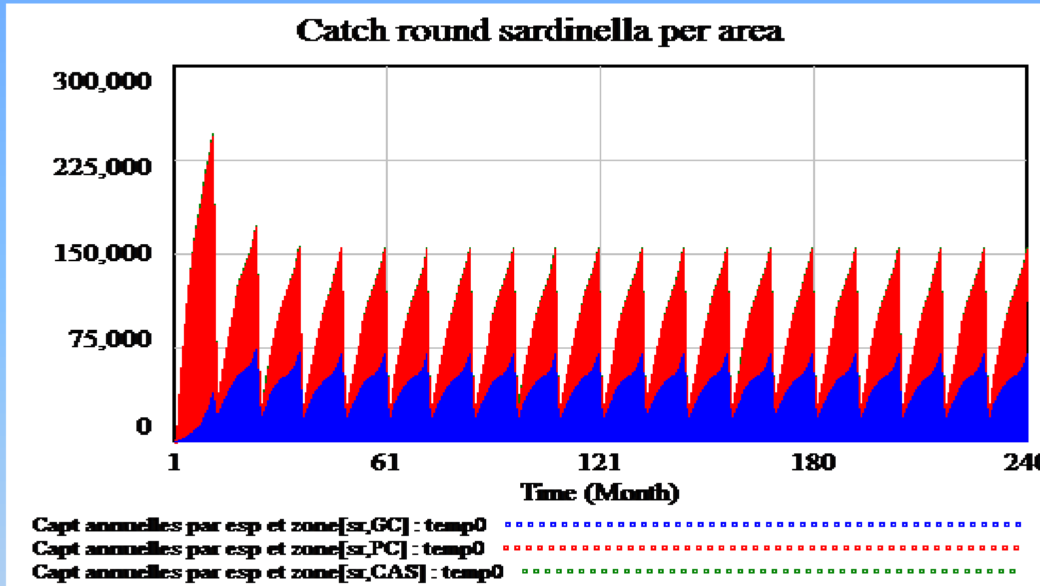


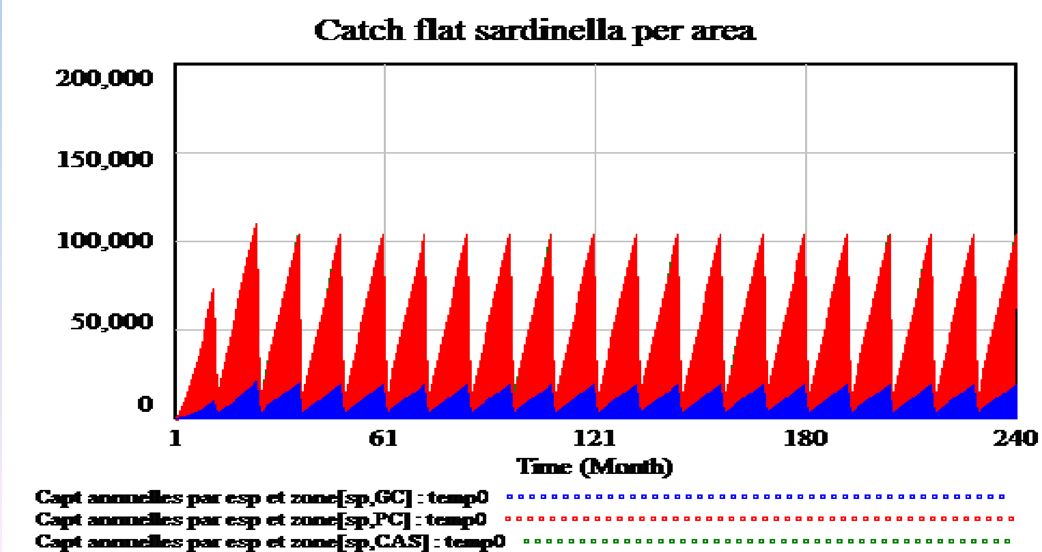
Results: Model outputs

Catches per species per area

- about 150,000 tons ≈ observed catches (aurita)
- About 100,000 tons ≈ observed catches (maderensis)
- Variablity
- Catch PC > GC > Cas

Catches per species per area

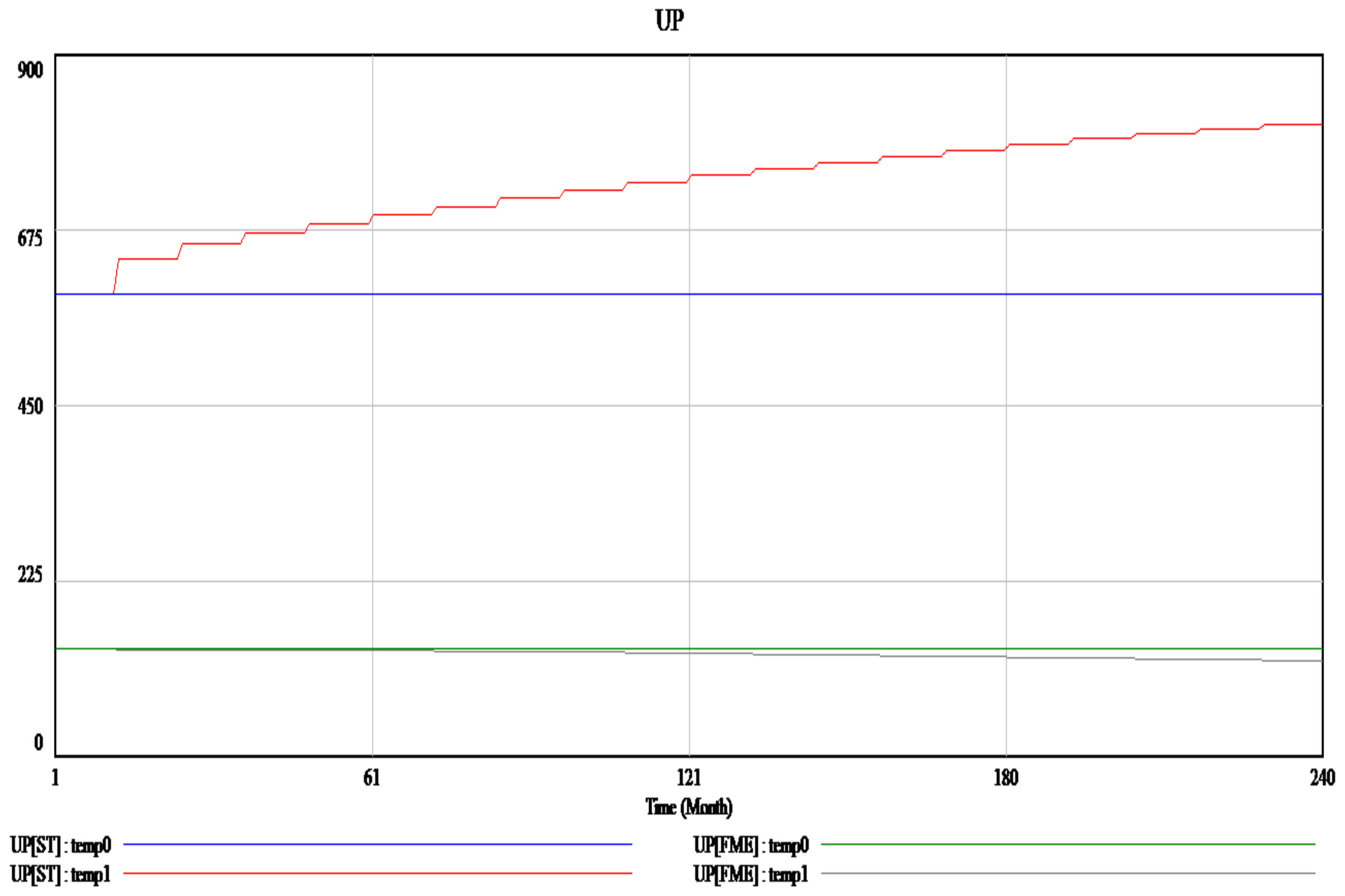




Results: Model outputs

Simulation1: Endogenous effort (fishing effort depends on the profit) vs constant effort

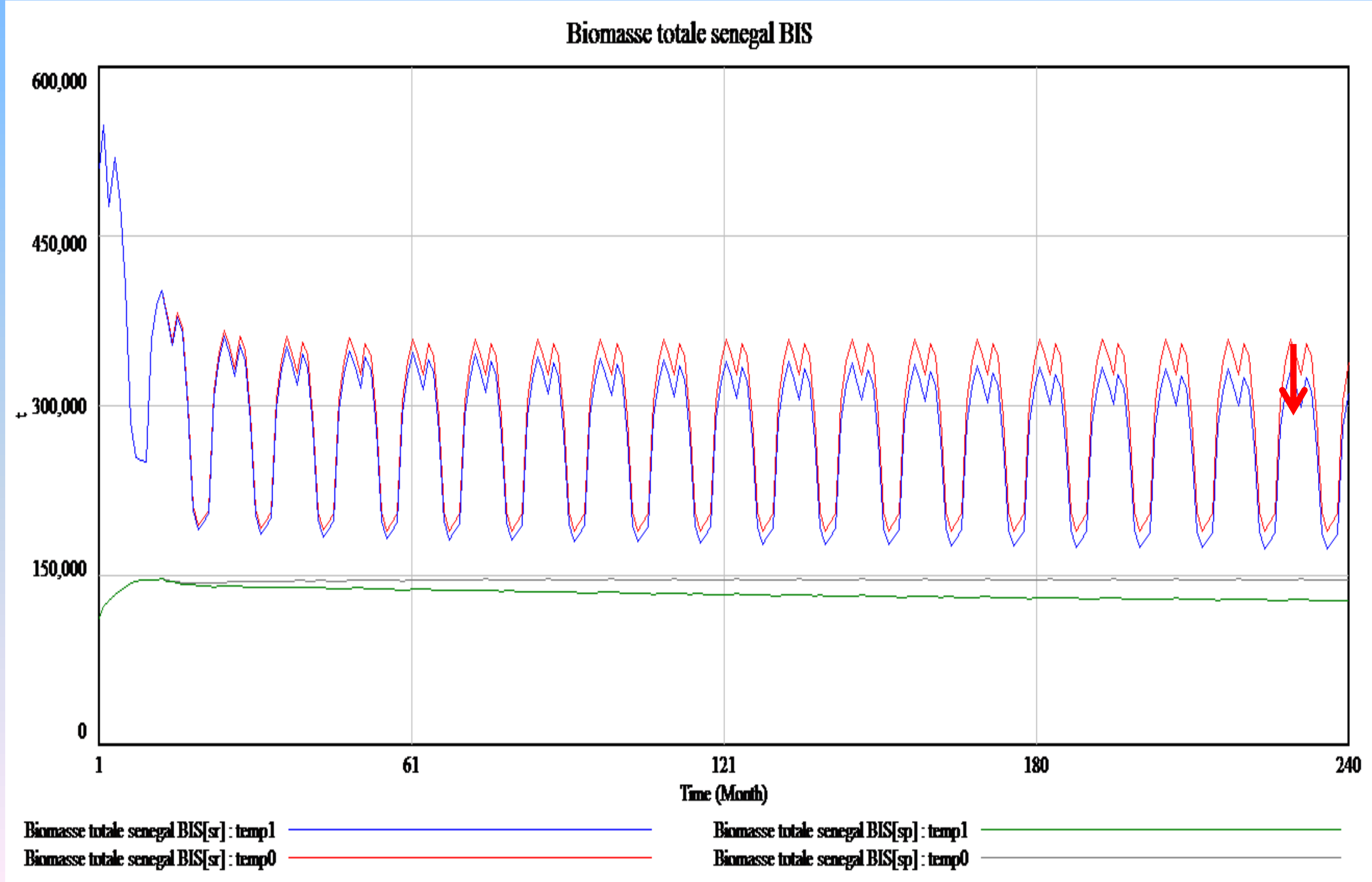
- UP increase



Results: Model outputs

Simulation1: Endogenous effort (fishing effort depends on the profit) vs constant effort

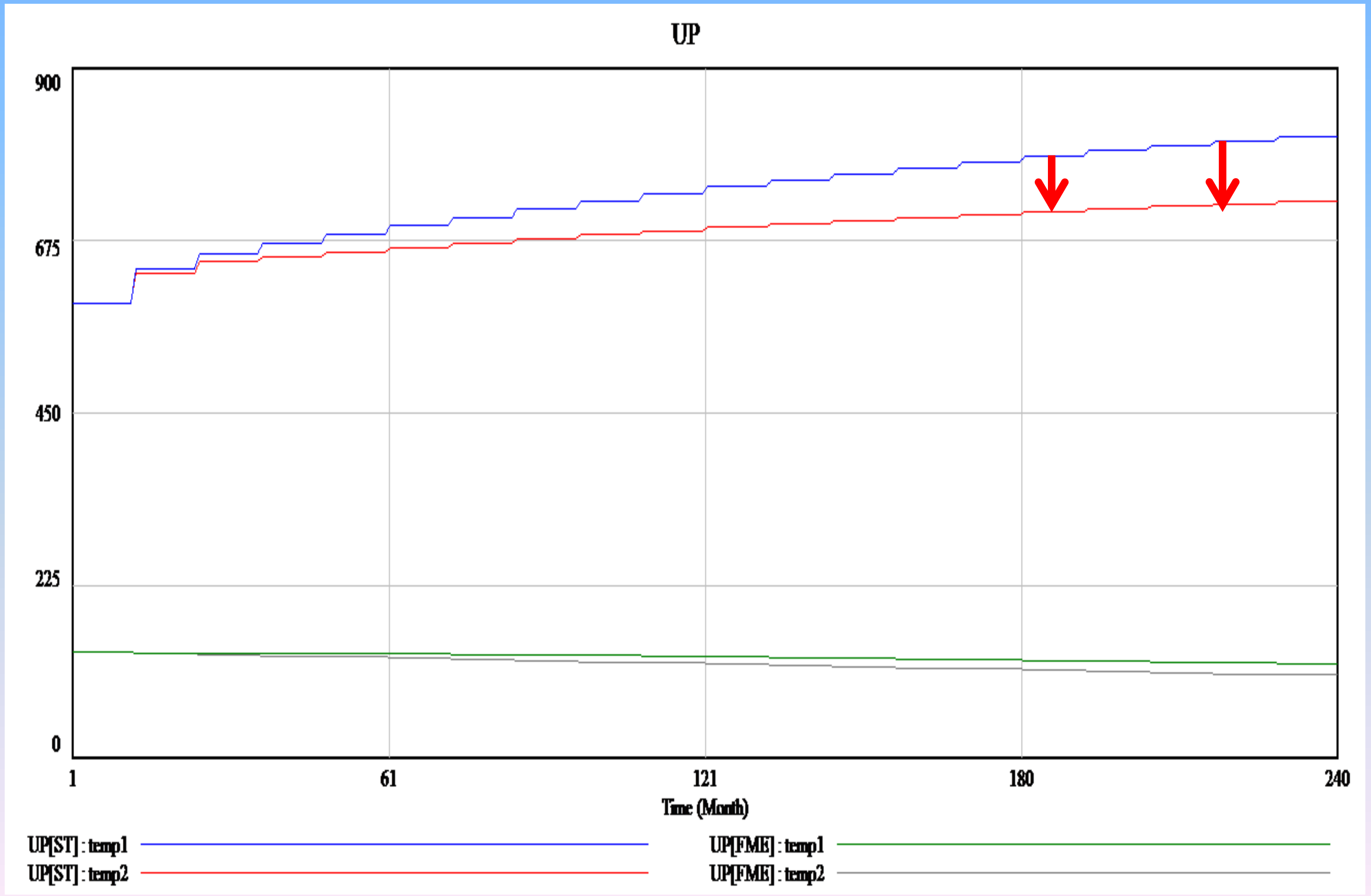
- Income and rent decrease



Results: Model outputs

Simulation2: Tax increase (licenses)+ endogenous effort vs endogenous efforts only

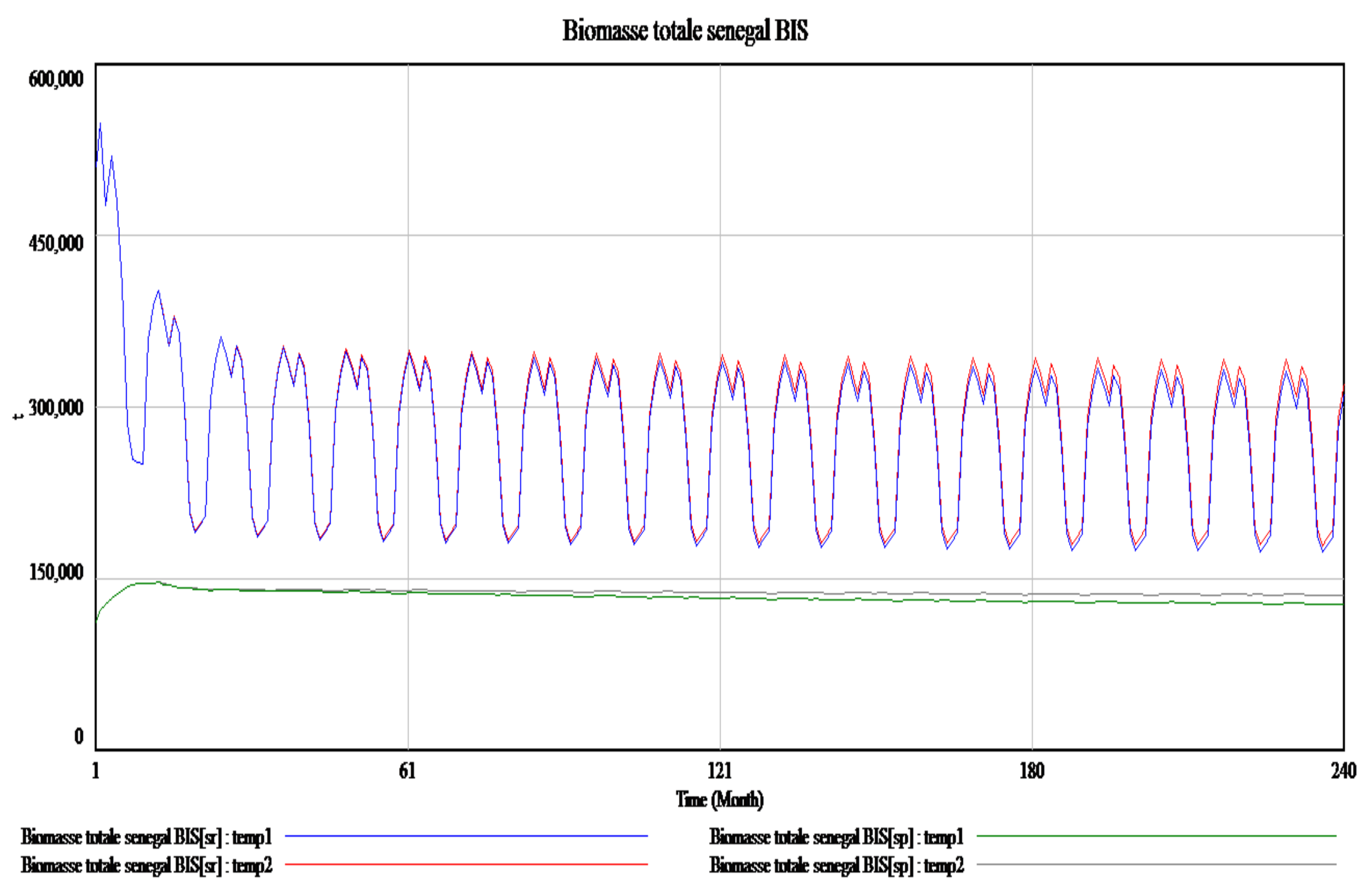
- Result: UP decrease



Results: Model outputs

Simulation2: Tax increase (licenses)+ endogenous effort vs endogenous efforts only

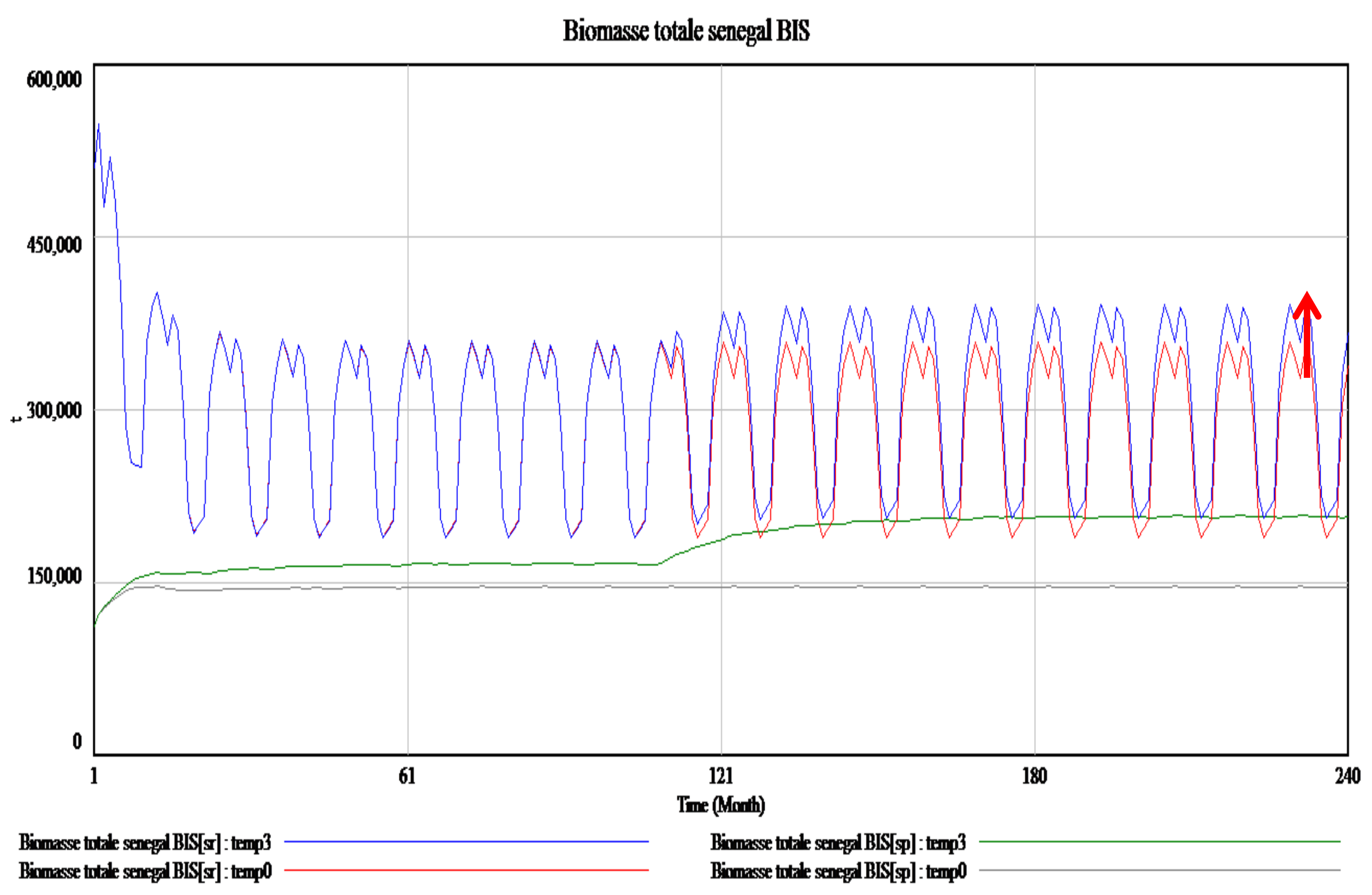
•Result: income decease and rent and biomass increase



Results: Model outputs

Simulation3: Forced effort (reduction of 30% after 10 years) vs Reference situation

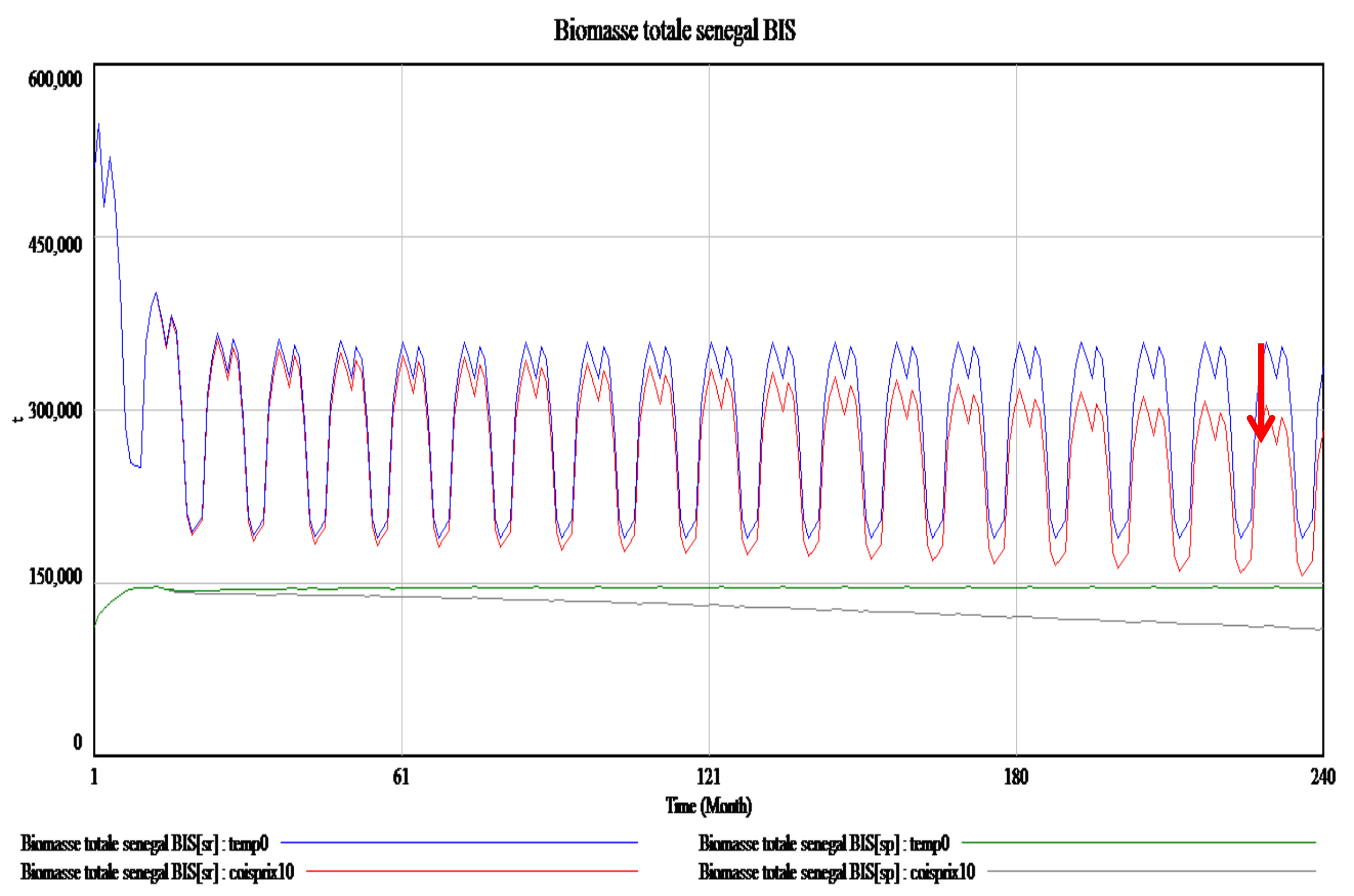
- Income rent and biomass increase



Results: Model outputs

Simulation4: 3% annual growth rate of the price vs Reference situation

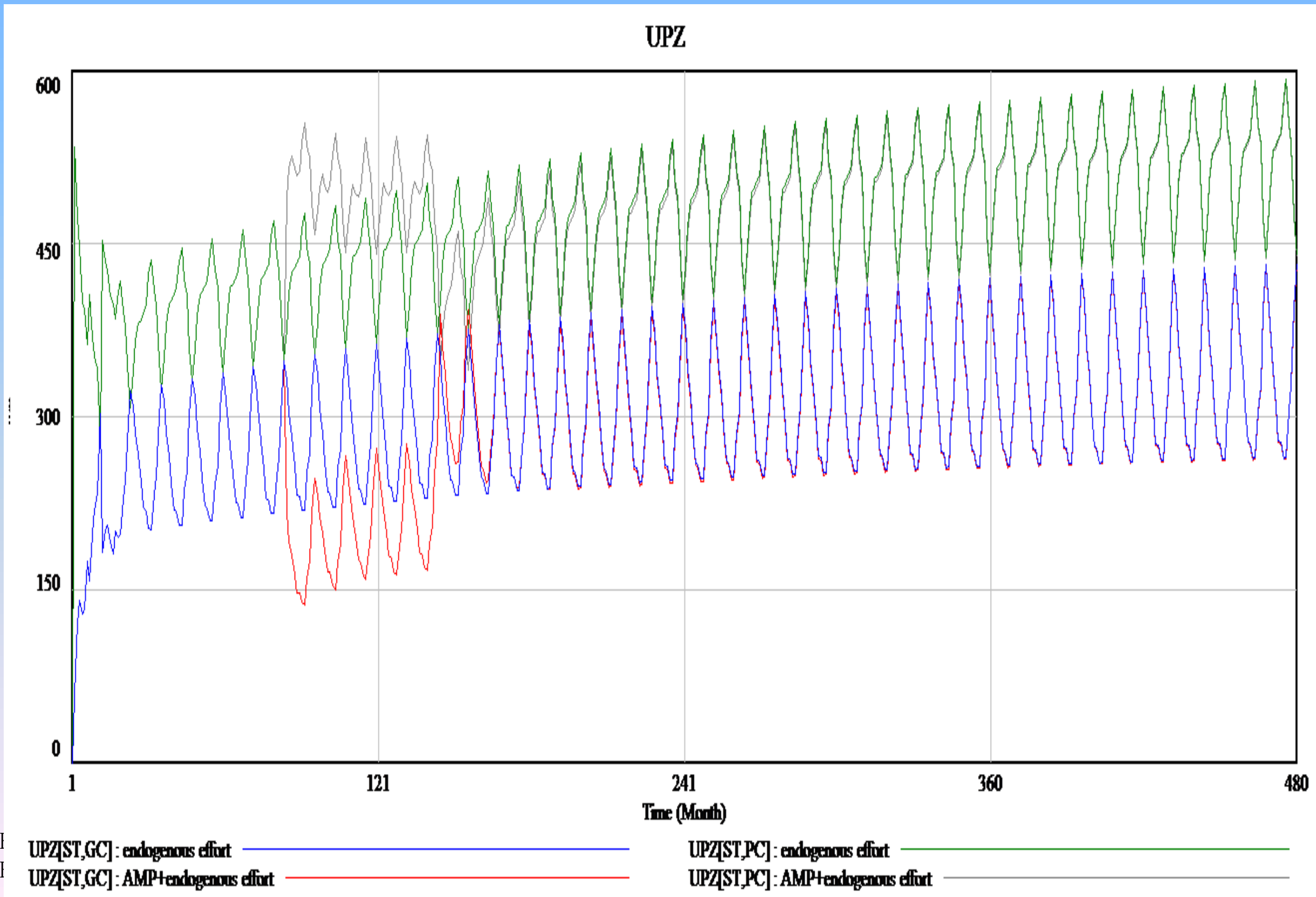
•Income and rent increase, biomass decrease.



Results: Model outputs

Simulation5: Closing a fishing area (50% of GC) with endogenous effort

Fishing effort moved in order area



Conclusion

- The model is calibrated and runs well

- Spatial behavior of resource and fleet is quite realistic

- The results of the model are fairly close to results observed

    - Between 92 and 96 % for the catch

    - Positive profits for ST and zero profits see negative for FME as observed previous studies

    - Rent positive but very low (≈0) for the FME

Conclusion

- Open access: endogenous effort: Bad for fisheries
    - Profit, rent, biomass decrease

- Tax with open access: better to tax fisheries with endogenous effort
    - UP and profit decrease but rent increase

- Reduction in fishing effort: Good for this fishery
    - Profit, rent, and biomass increase

- Increase of demand or the price: bad for open access fisheries
    - Profit, rent Up increase and biomass go down

- Closing area with open access is not better because fishing effort moves in other areas

Conclusion

- The model run only with Senegalese data. It would be better to have the data of all the countries that sharing the resources

- The model is very sensitive to the catch of external areas

- It would be better for the sustainability of the exploitation of this resources to strengthen cooperation between countries (CSRP).

Perspectives

- Test the stock-recruitment relations (Because recruitment is independent of biomass in the model)
- Making scenario involving several managements policies
- Introduce uncertainly in the model on biological and economical parameters (Monte Carlo simulation)
- Include the data of other country if possible

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