Analyzing environmental and fishing effects on the short lived-species: the case of exploited stocks of octopus and shrimps in Senegalese waters

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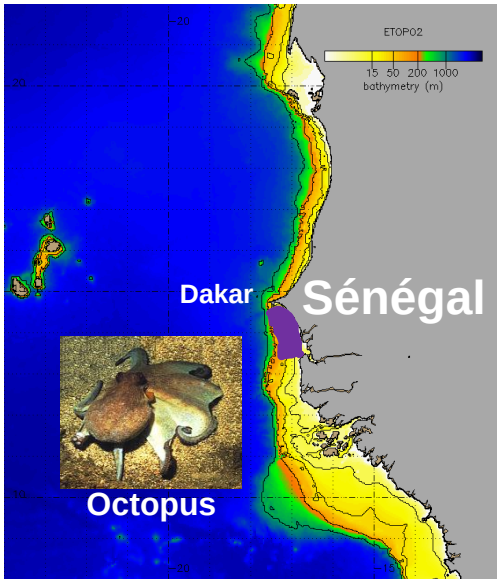
CASE STUDY

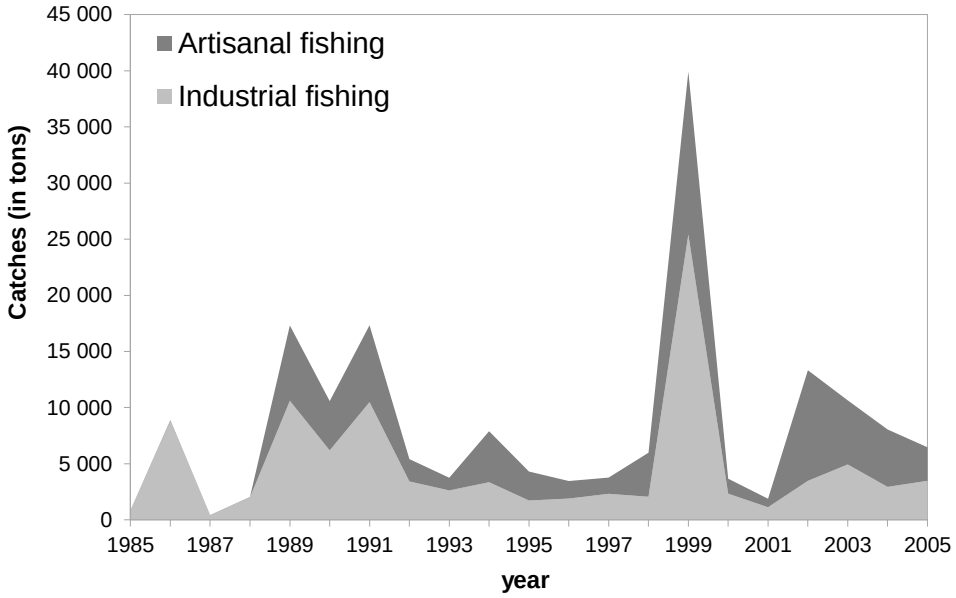
- **Octopus stock: south of Dakar (Petite Côte)**
  - **The stock is composed by a single annual cohort.**



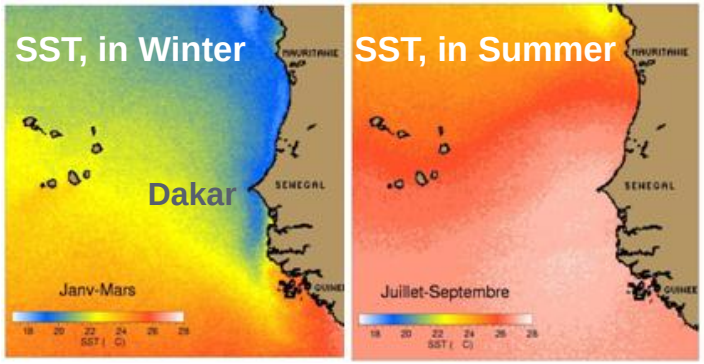
Special jigging hand line for fishing Octopus

« Turluttes »

- **High variability of production from year-to-year**

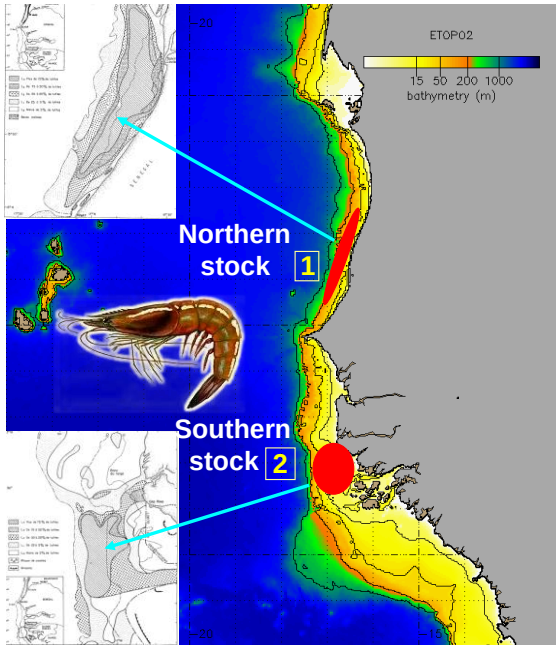


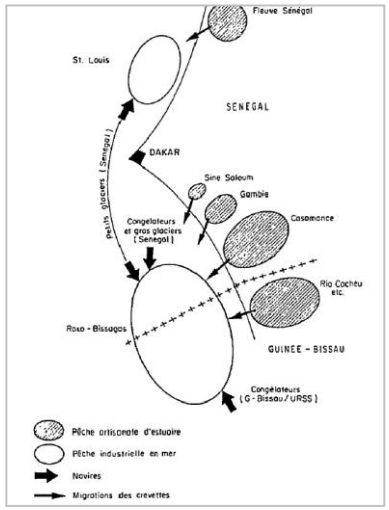
- **Potential impact of seasonal upwelling?**



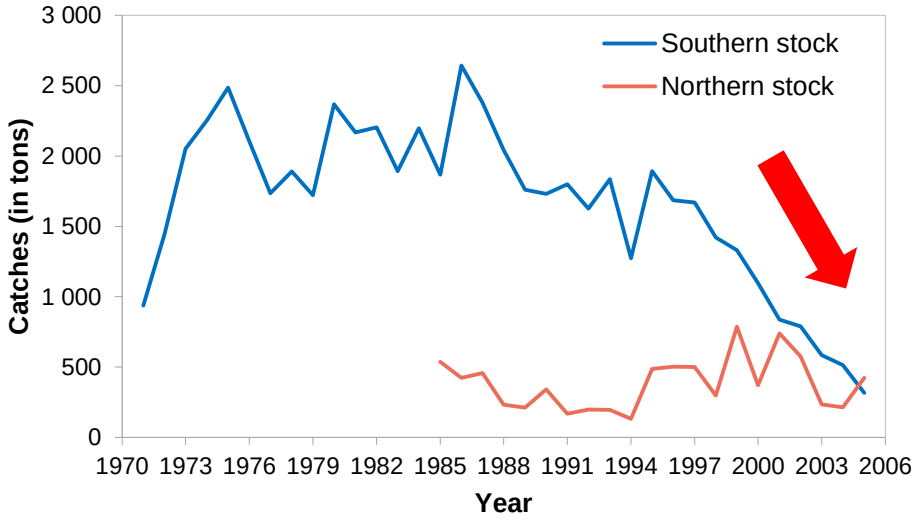
CASE STUDY

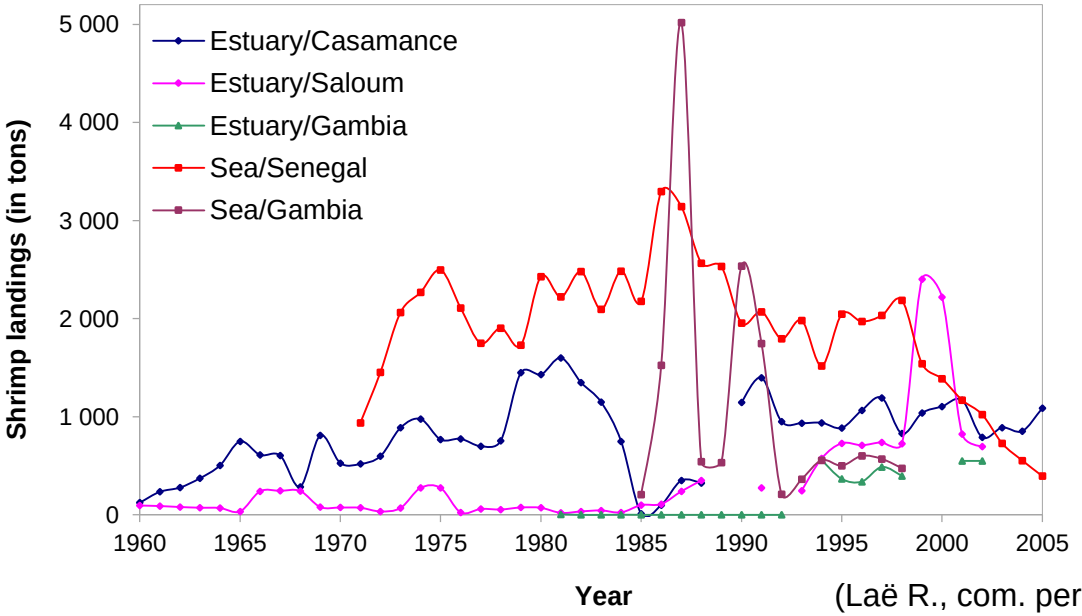
- **Two shrimp stocks in Senegal**





- **Trends of shrimp catches**





(Laë R., com. pers.)

MODELS FOR SHORT-LIVED SPECIES

Characteristics of short-lived species

- Biology: short life cycle, rapid growth, post spawning mortality (Octopus) and high rates of natural mortality associated with the early stages of life (*Lhomme, 1981*; *Garcia et Le Reste, 1986; Jouffre et al., 2002*).

- Extremely dependant on variability of environment

- Stocks present rapid and unstable dynamics

  - their potential production varies widely from year-to-year (Caverivière et al., 2002; Thiaw et al., 2009; Thiaw et al., 2011).

  - marked variability in catches for most fisheries of short-lived species (Wang et al., 2003).

➔ Specific modeling strategy for population dynamics and stocks assessment

Principle Objective

To understand the population dynamics of octopus and shrimps in order to improve the scientific bases of specific fisheries management plan.

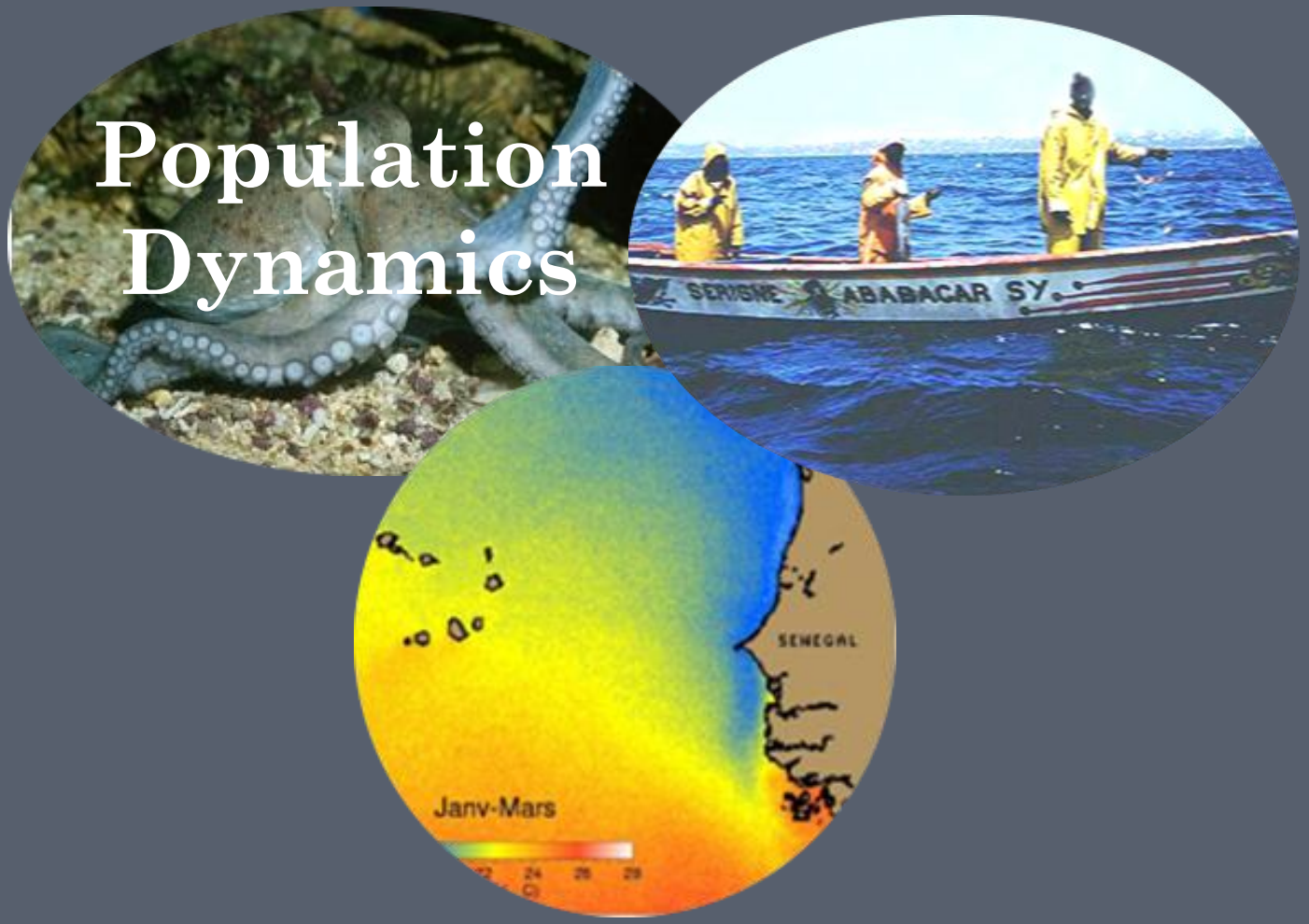
OUTLINE

Three scientific questions:

Three parts:

What is the variability of the recruitment and biomass of short-lived species stocks?	Monthly cohort analysis Linear model
What is the part of the variability of octopus abundance linked to the environment (upwelling)?	Seasonal decomposition analysis Correlations between recruitment and environmental factors
In this variability context, what is the diagnosis on the stocks status?	Surplus production models

1. STOCK DYNAMICS AND VARIABILITY



MONTHLY COHORT ANALYSIS MODEL

Monthly catches

(CRODT, 1985-2005)

Abundance index

(GLM CPUE 1996-2005)

Terminal fishing mortalities ($F_{i, T,}$ $F_{I-1, t}$)

Catch per category

(Sampling 1996-2005)

Catch-at-age

Cohort analysis model

Recruitment R

Abundance N

Fishing mort. F

Mean weight at age

(Jouffre et al., 2002)

Natural mortality

Pre-processing

Input variables

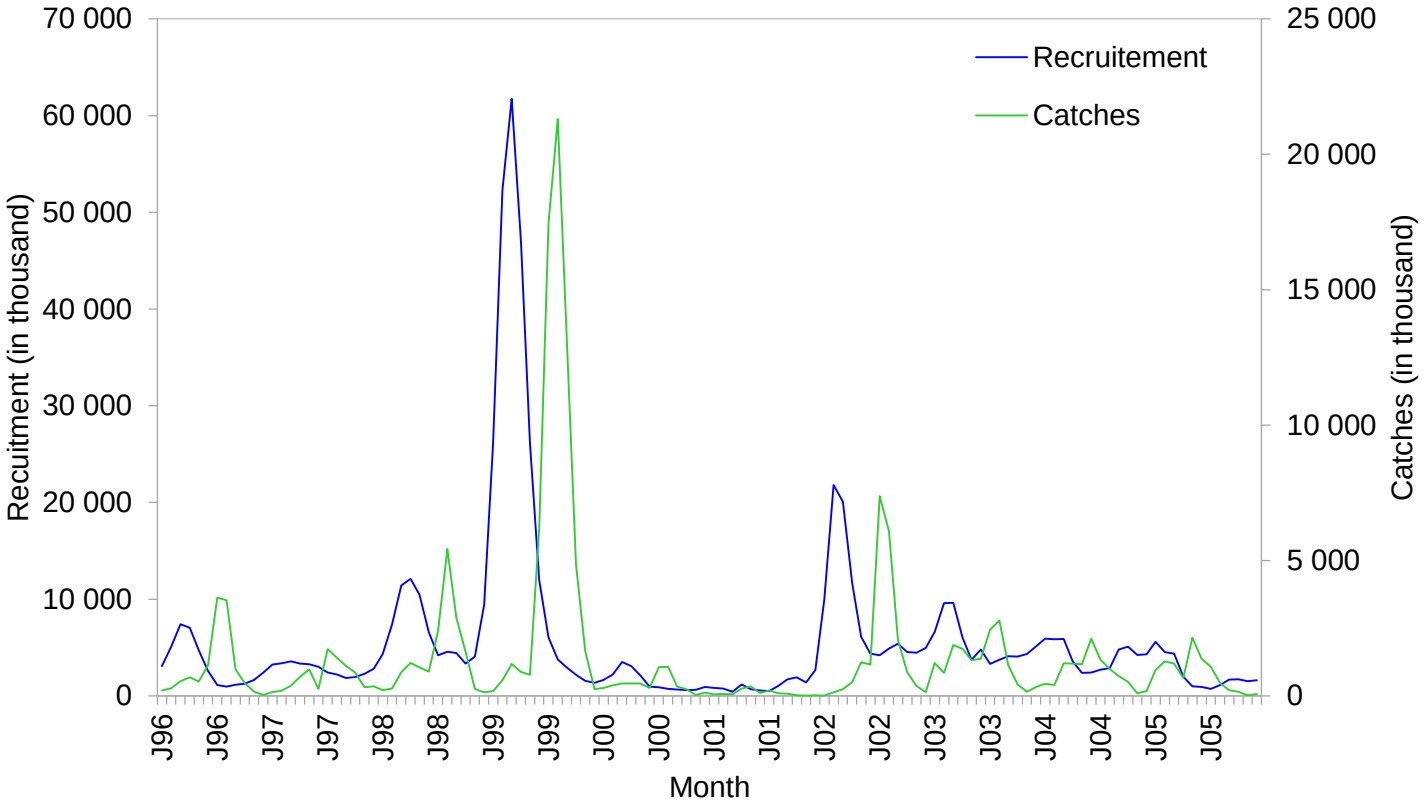
Cohort analysis model

Outputs

Sensibility of the model to the parameters $F_{i, T}$ and $F_{I-1, t}$ was tested.

1.1. POPULATION DYNAMICS OF OCTOPUS

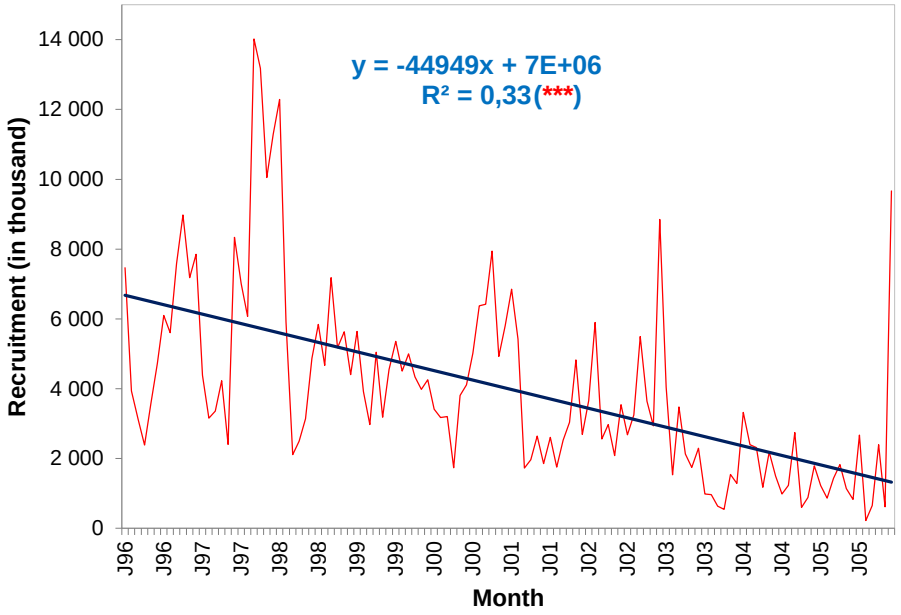
- **Octopus recruitment**



Seasonal and year-to-year variability of recruitment and catches.

1.2. DYNAMICS OF SOUTHERN SHRIMP STOCKS

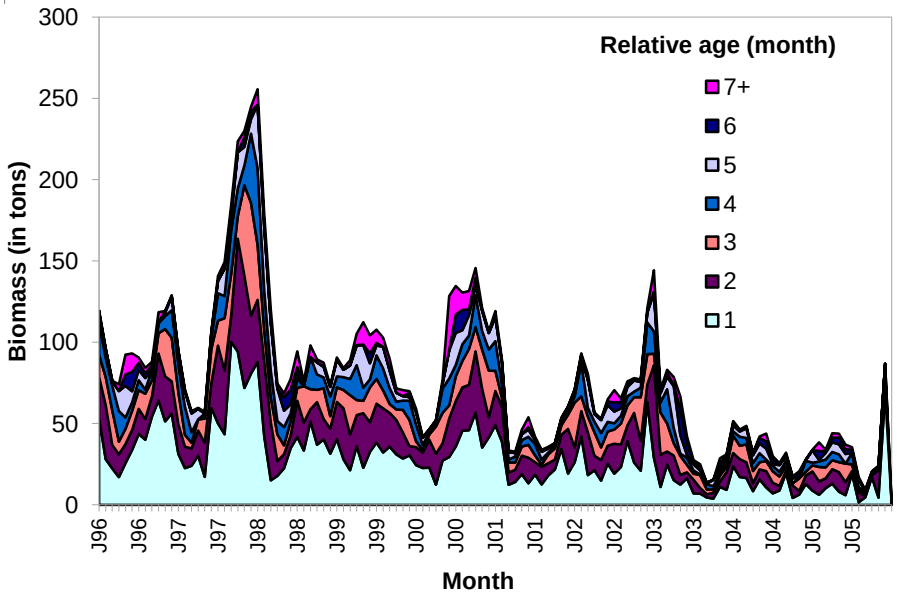
- **Estimation of the recruitment**



Trend of recruitment:

- **Seasonal variability** (main peak at the end of the rainy season)
- **Year-to-year variability**
- **Clear trend to decrease**

- **Estimation of biomass stock**



Trend of biomass:

- **Seasonal and year-to-year variability**
- **Decrease over the 1996-2005 period**
- **Decrease in shrimps length**

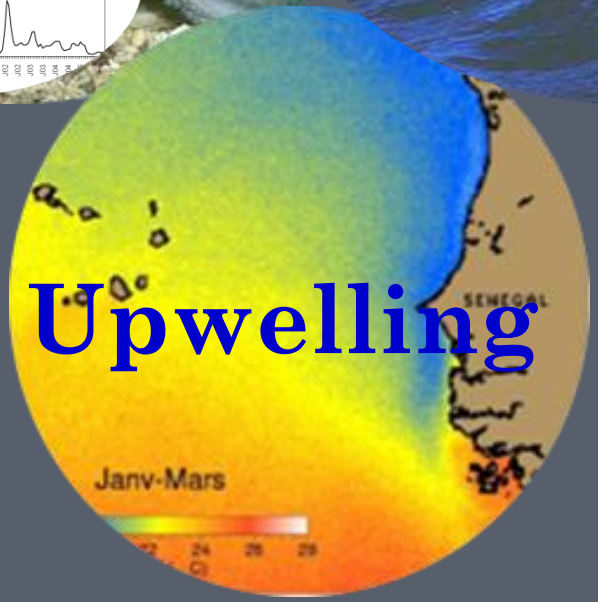
SUMMARY OF STOCKS DYNAMICS

- High variability of recruitment and biomass from year-to-year
  - Recruitment and biomass highly change between years and seasons. For Octopus stock, there is no trend. For the southern shrimp stock, results indicate also a high variability with a clear decrease over the period.
- Markedly interannual and seasonal exploitation pattern
  - Fishing mortality changes from year-to-year according to the yearly recruitment and abundance.
- What relationship between environment and recruitment variability?
  - Even in this context of high seasonal and year-to-year variability of octopus recruitment, what is the part of this variability linked to the environment?

2. ENVIRONMENTAL EFFECTS ON RECRUITMENT

Population Dynamics

High variability of recruitment



Upwelling

3. ENVIRONMENTAL EFFECTS ANALYSIS

Biological data

- **Monthly recruitment of Octopus** estimated by the cohort analysis (1996-2005)

Environmental data

- **Monthly coastal upwelling index** (CUI, $m^3/s/m$) from NOAA website (1985-2005)
- **Monthly sea surface temperature** (SST, °C) from AVHRR satellite data (1985-2005)

Seasonal decomposition of Time Series (Census II Method, Makridakis et al., 1983)

$$R_t = p_t + s_t + u_t$$

Pt: smoothed mean: **Trend component**

st : Mean by month: **seasonal component**

Ut : Residuals: **short-term disturbance**

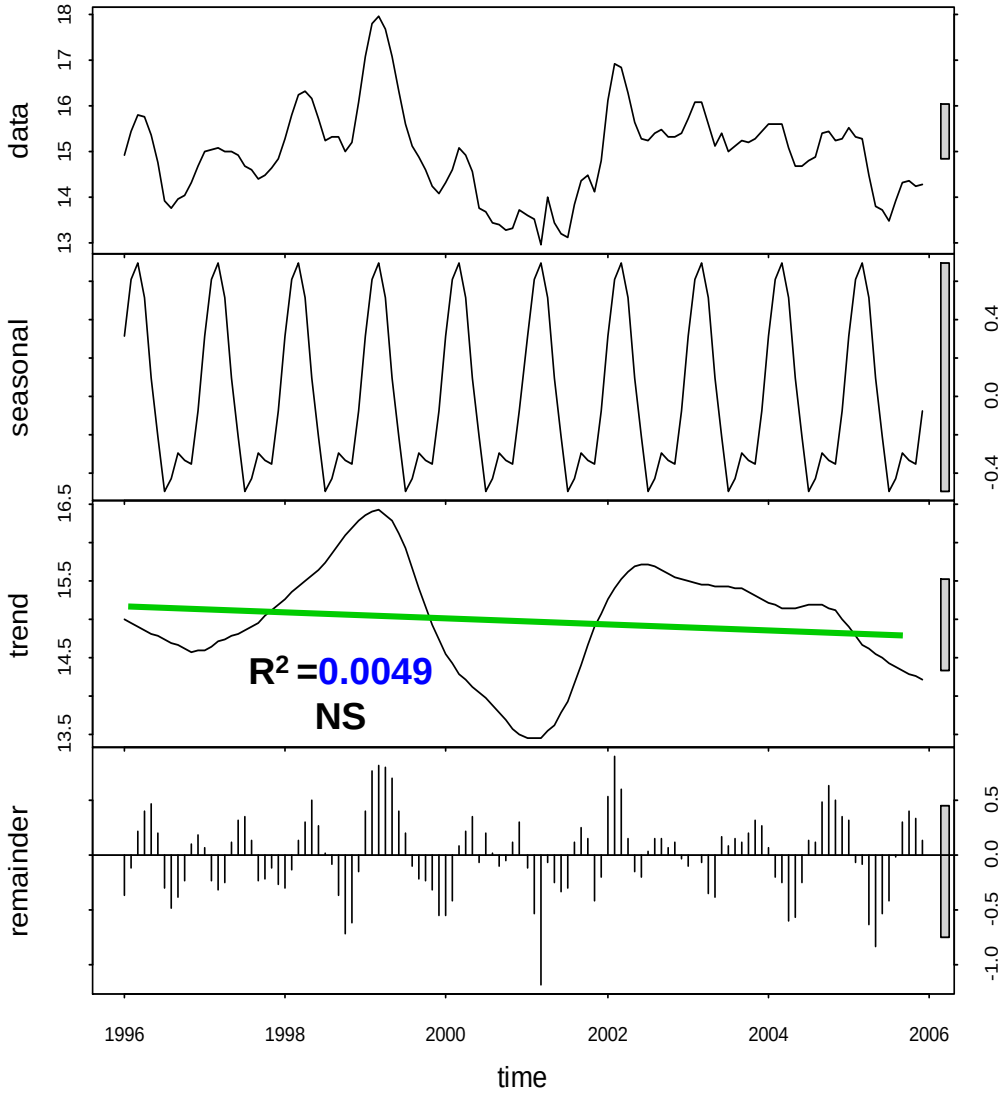
Application to

1. Monthly recruitment
2. Sea surface temperature
3. Coastal upwelling index

→ **Values without seasonal effect**

SEASONAL DECOMPOSITION OF ENVIRONMENT

Octopus recruitment



Input variable: recruitment from VPA

Seasonal component:

- **Main recruitment : March**
- **Secondary: September**

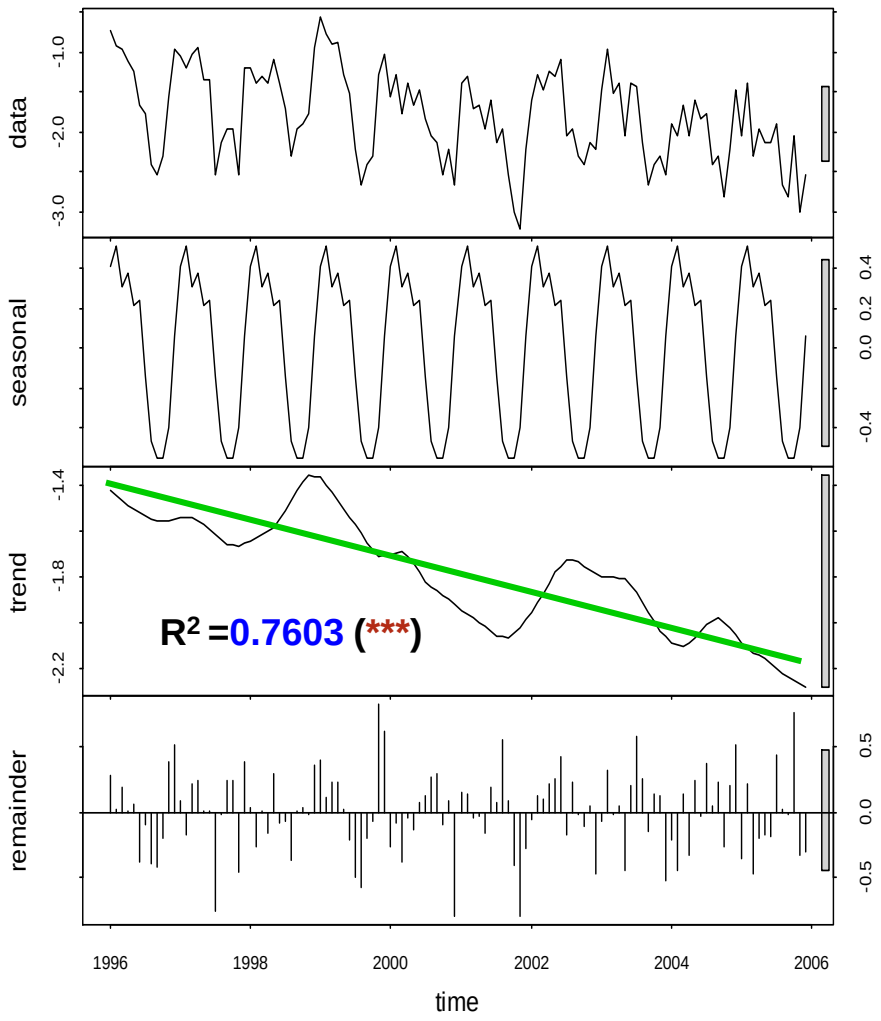
Trend:

- **Maximum: 1999 and 2002**
- **Minimum: 2001**

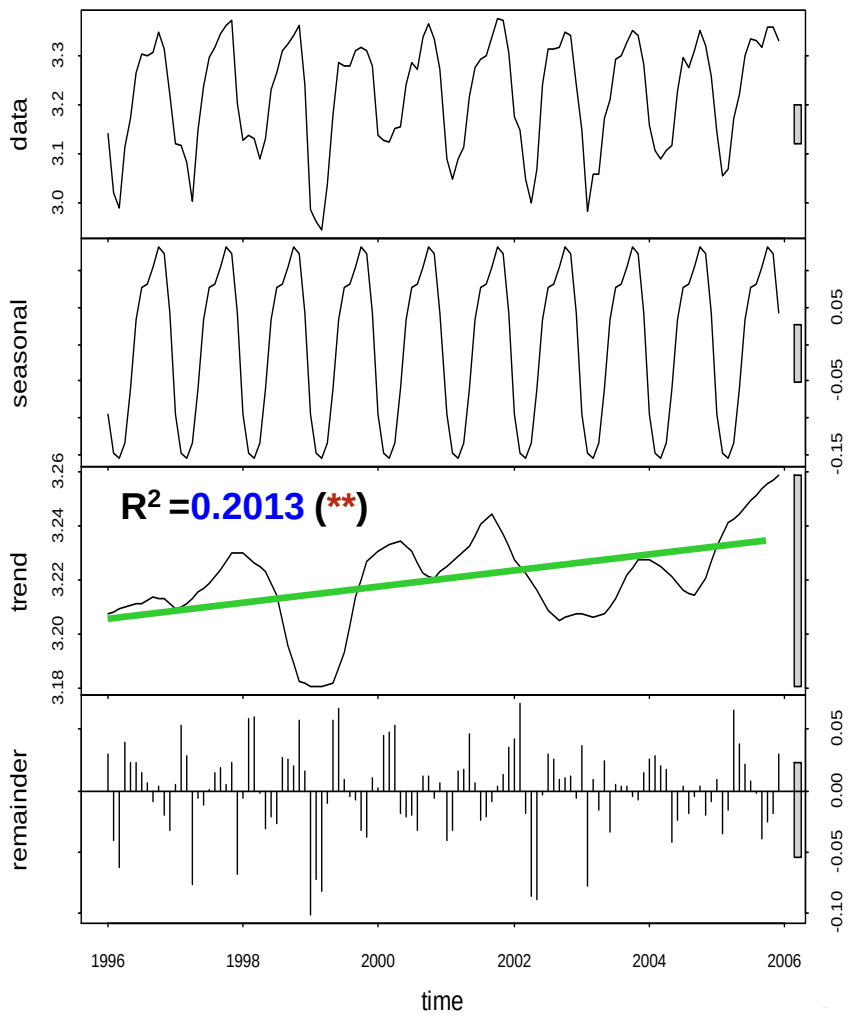
Residuals

SEASONAL DECOMPOSITION OF ENVIRONMENT

Coastal upwelling index

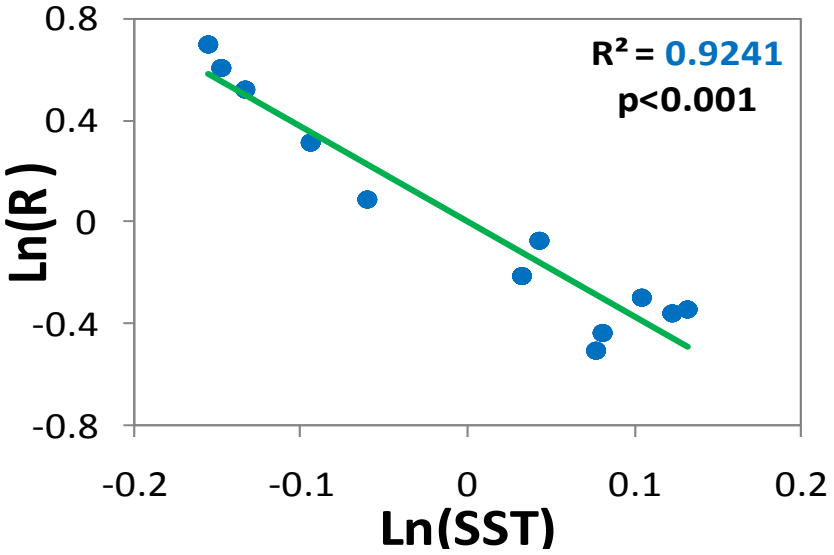


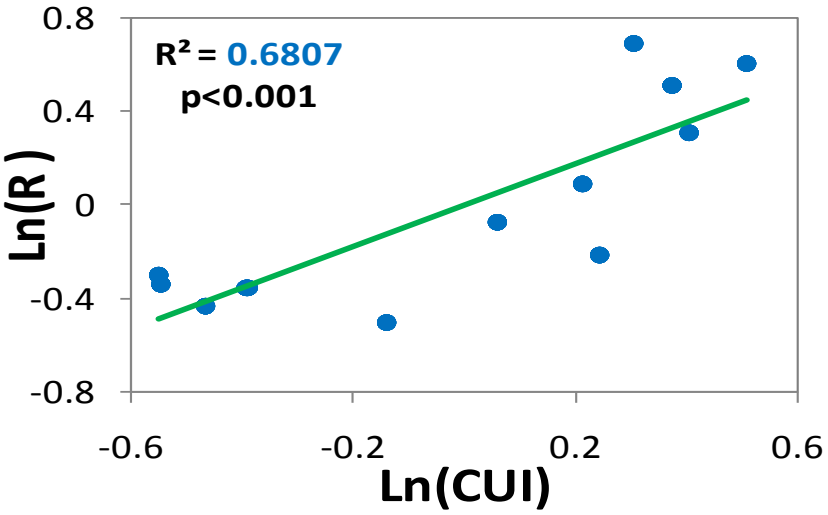
Sea surface temperature



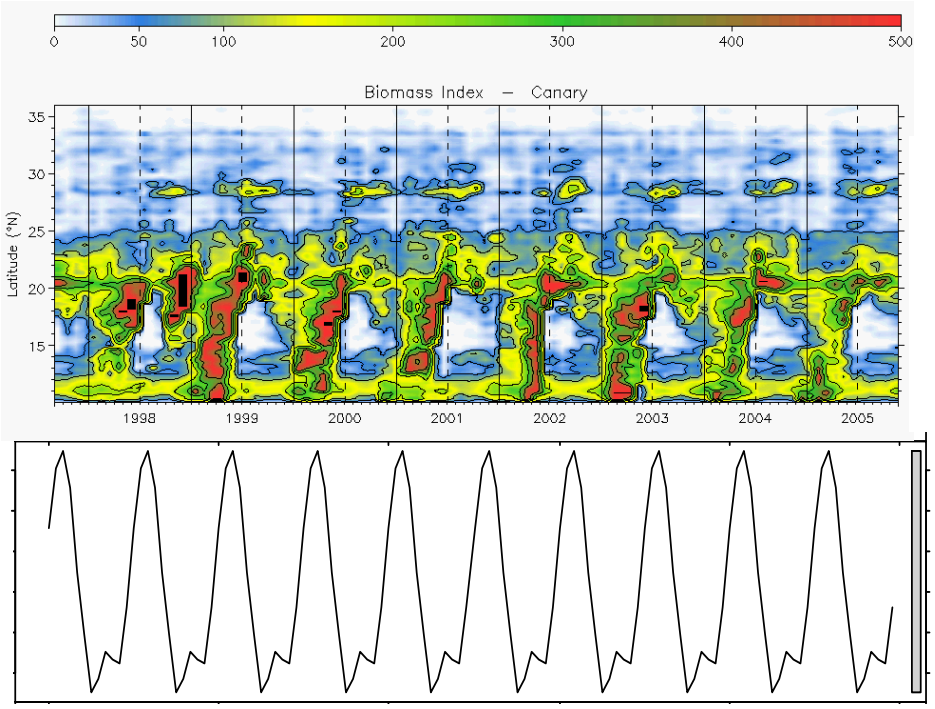
SEASONALITY OF RECRUITMENT AND UPWELLING

Seasonal component





Seasonal variability of upwelling

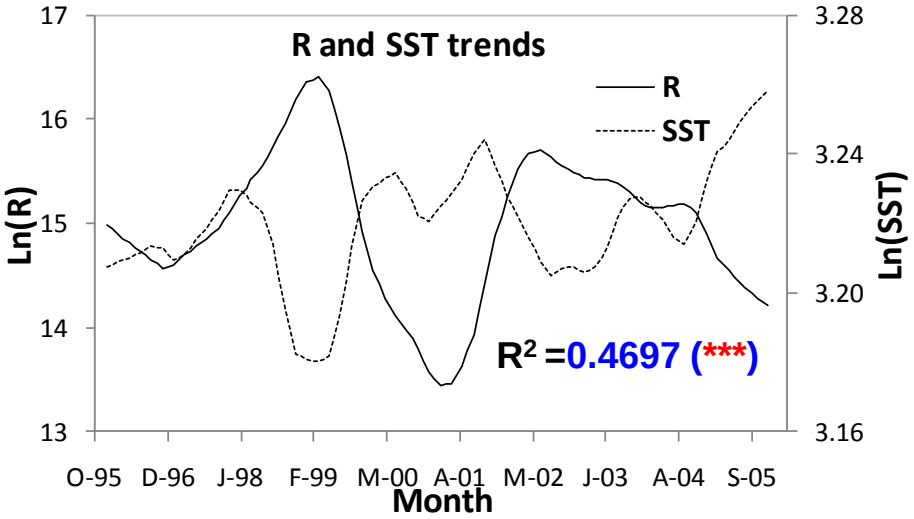


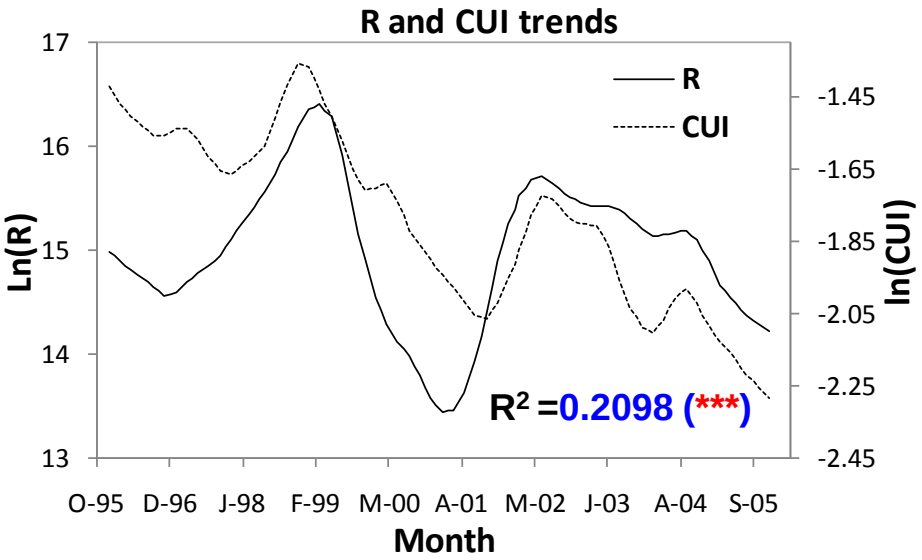
Seasonal variability of octopus recruitment

High seasonality of recruitment and upwelling

ENVIRONMENTAL EFFECTS ON RECRUITMENT

Trend



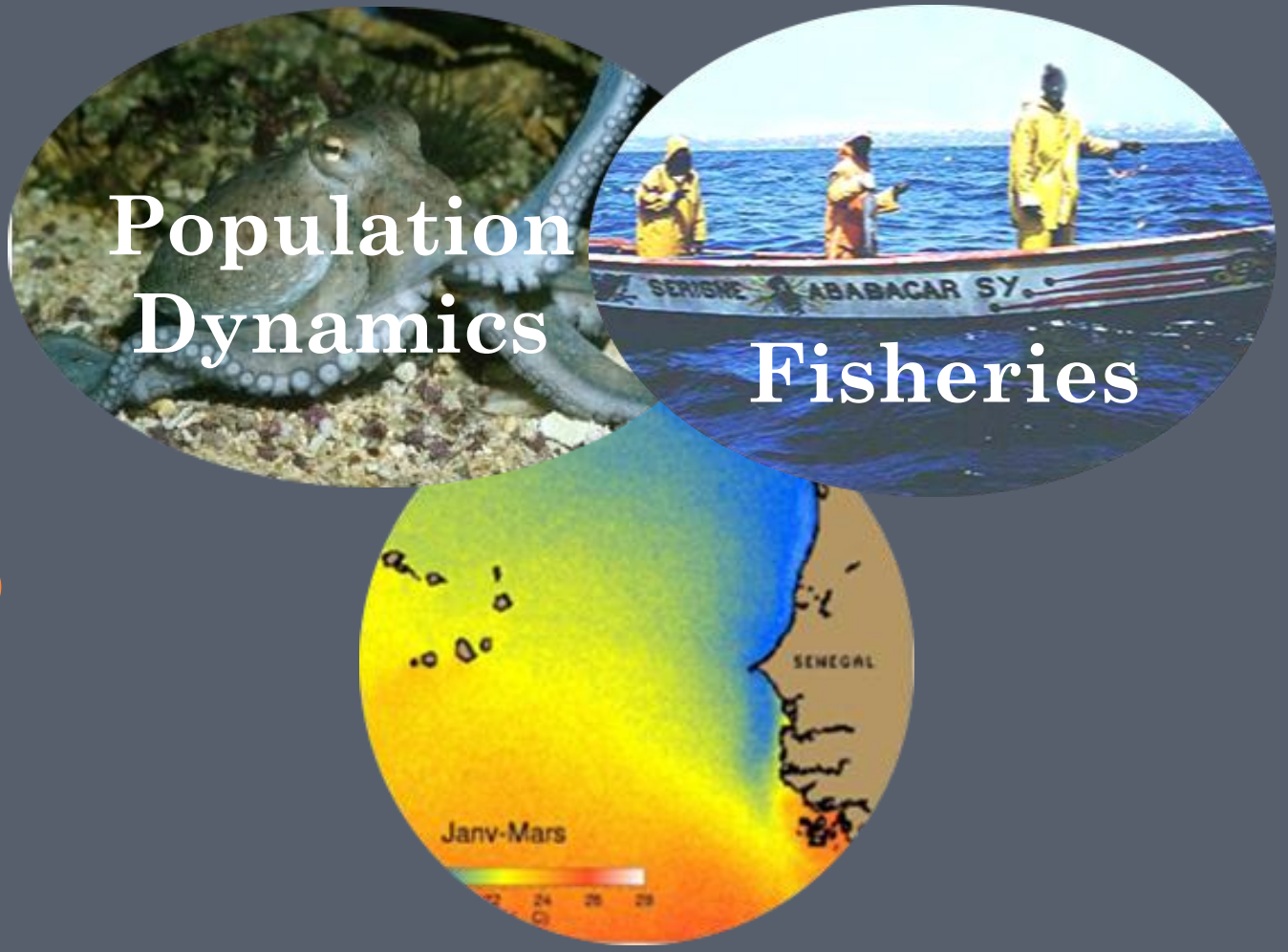


Year-to-year variability of recruitment due to upwelling intensity.

3. ENVIRONMENTAL EFFECTS ON STOCKS RECRUITMENT

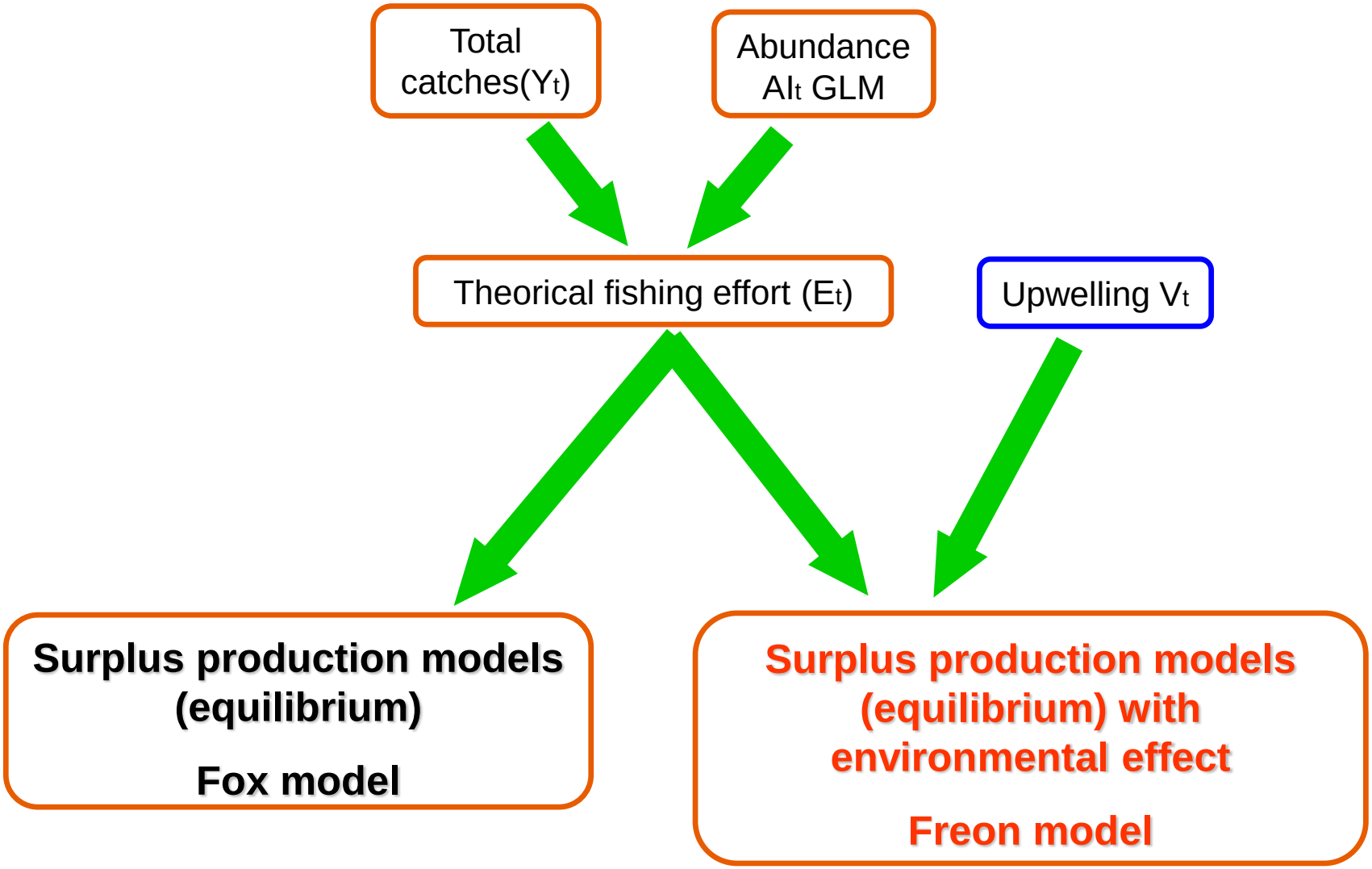
- Interannual variability of recruitment due to environment
  - Two peaks of recruitment each year. The success of the yearly recruitment is significantly related to the upwelling intensity.
- What evolution of the stock on the long term?
  - The upwelling intensity significantly decreased over the 1996-2005 period: what will be the long term effects on the Senegalese octopus stock?
- Even in this environmental variability, what status of Octopus and shrimp stocks?
  - Even in this high environmental variability, what is the fishing impact on the abundance of Octopus and shrimp stocks?

4. FISHING EFFECTS AND EXPLOITATION PATTERN



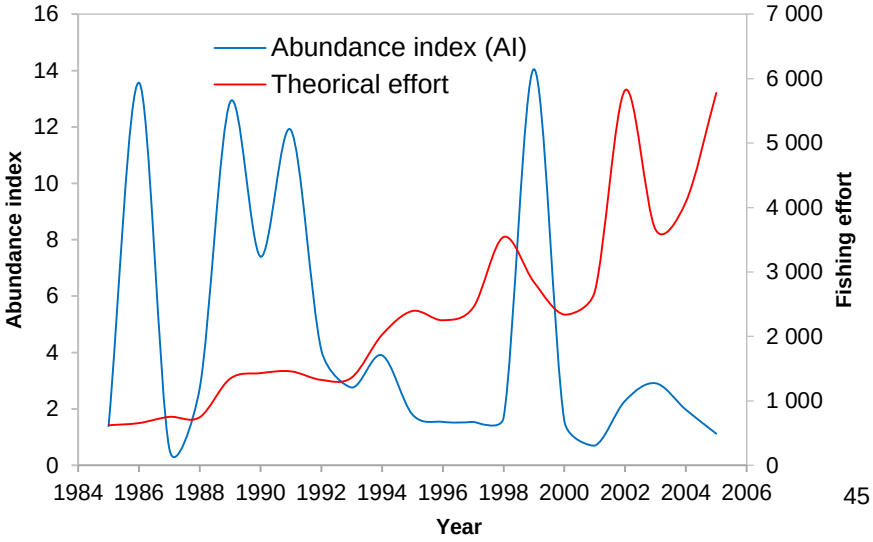
SURPLUS PRODUCTIONS MODELS

- **Fishing impact** (Fox, 1970)
- **Fishing and upwelling impacts** (Freon, 1991)



FISHING EFFECTS ON OCTOPUS STOCK

Abundance\Fishing effort



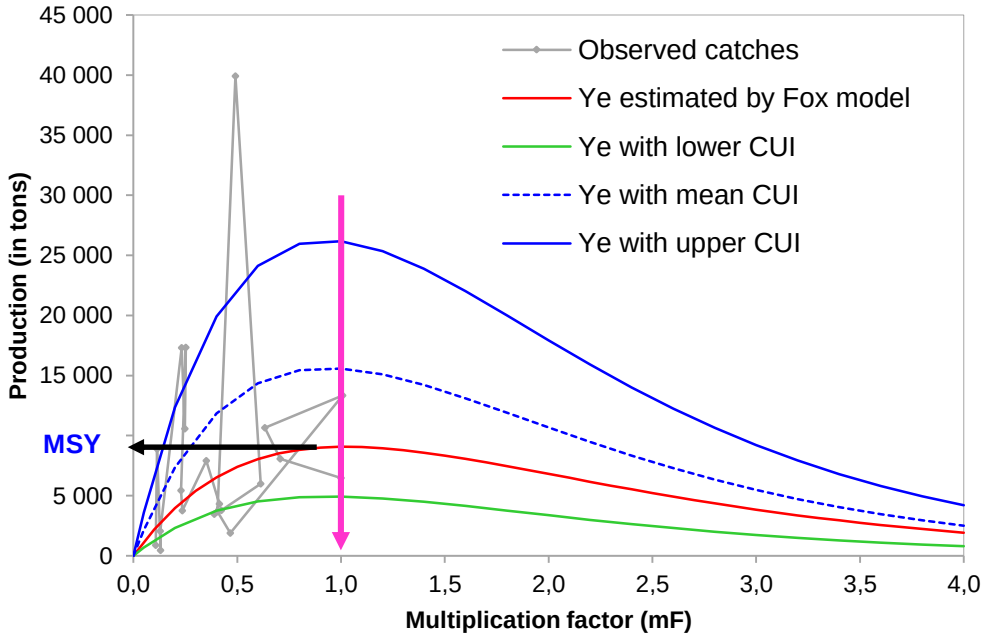
Abundance of Octopus stock:

- **High year-to-year variability without trend**
- **Maximum: 1986, 1989, 1991 and 1999**

Fishing effort

- **High increase**

Observed catches and catches equilibrium curves

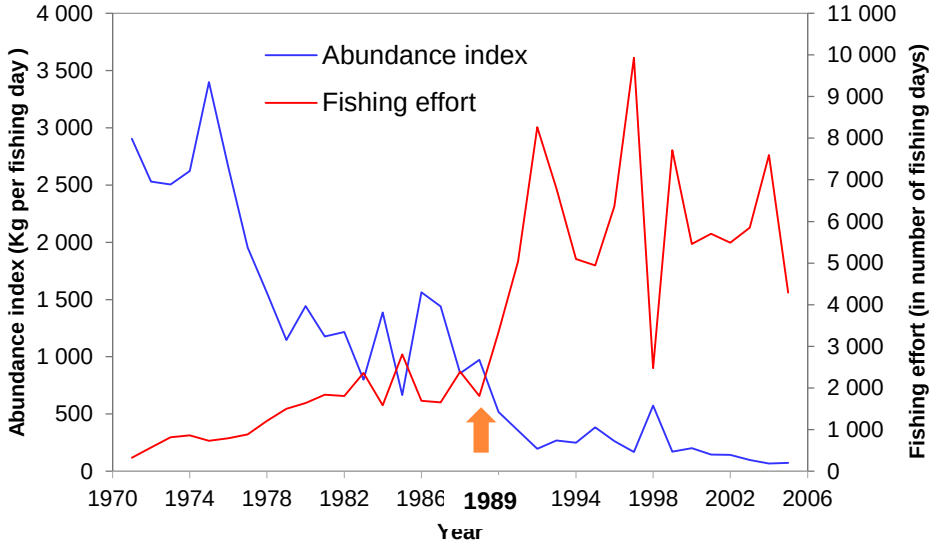


Diagnosis of Octopus stock

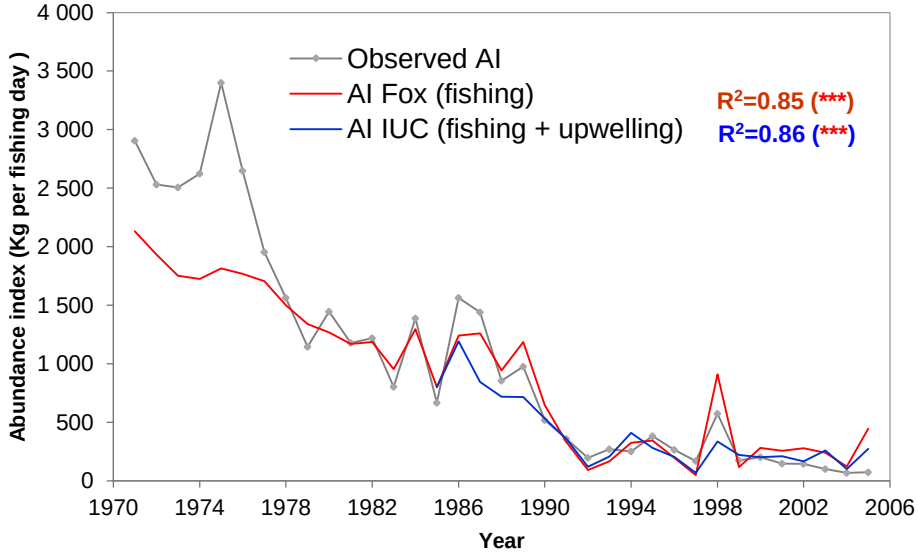
- **Stock is close to full exploitation**
- **Annual catch is strongly affected by the upwelling intensity**
- **MSY changes according to the upwelling intensity**

FISHING EFFECTS ON SOUTHERN SHRIMPS STOCK

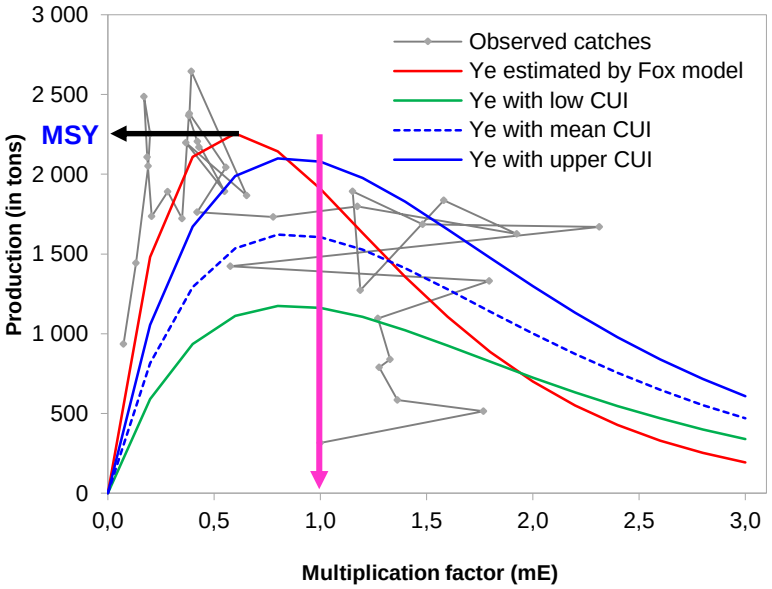
Abundance\Fishing effort



Abundance\Fishing effort\Upwelling



Observed catches and catch equilibrium curves predicted by the two models



Southern shrimp stock is significantly overfished (for the Fox model, MSY = 2 250 tons) and MSY changes according to the upwelling.

SUMMARY OF STOCKS DIAGNOSES

- **Diagnosis of octopus stock**
  - Exploitation patterns remain relatively constant.
  - Octopus stock is fully exploited or close to overexploitation
- **Diagnosis of shrimp stocks**
  - **Northern shrimps stock**
    - Stock is overexploited.
    - The driving force of abundance seems to be the upwelling intensity.
  - **Southern shrimps stock**
    - Stock is strongly overexploited and less affected by environment.
- **High variability of MSY depending of upwelling intensity**
  - For short-lived species, MSY varies according to the upwelling intensity.

Conclusion

- What is the variability of the recruitment and biomass of short-lived species stocks?
  - Populations' dynamics of Octopus and shrimp stocks are variable from year-to-year, thus drawing away a high year-to-year variability of catches.
- What is the part of the variability of Octopus abundance linked to the environment (upwelling)?
  - Upwelling intensity influences the Octopus population dynamics.
  - Time series approach is a useful tool to study these relationships.
- In this variability context, what is the diagnosis on the stocks status?
  - Coastal upwelling explains a large part of the year-to-year variability in the abundance of octopus and shrimp stocks. Octopus stock is fully exploited or close overfished and shrimp stocks are overfished.
- Consequences for the Management
  - Necessity of taking into account of environment, fishing and the dynamics of populations, each being an essential component towards the implementation of improvement plan of octopus and shrimp stocks.

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