

# The effect of climate variability on *Sardinella aurita*'s population off North-West Africa

investigated with an individual based biophysical model

Timothée Brochier(a), Pierre-Amaël Auger(b), Laure Pecquerie(c), Eric Machu(b), Baye Cheikh Mbaye(d), Modou Thiaw(e), Patrice Brehmer(a)

(a) - IRD, ISRA-CRODT, Dakar Sénégal

(b) - IRD, LPO, Brest, France

(c) - IRD, LEMAR, Brest, France

(d) -LPAO-SF, Dakar

(e) - CRODT, Dakar

# Summary

## 1. Introduction

- *Sardinella aurita* in West African Waters

## 2. Methods

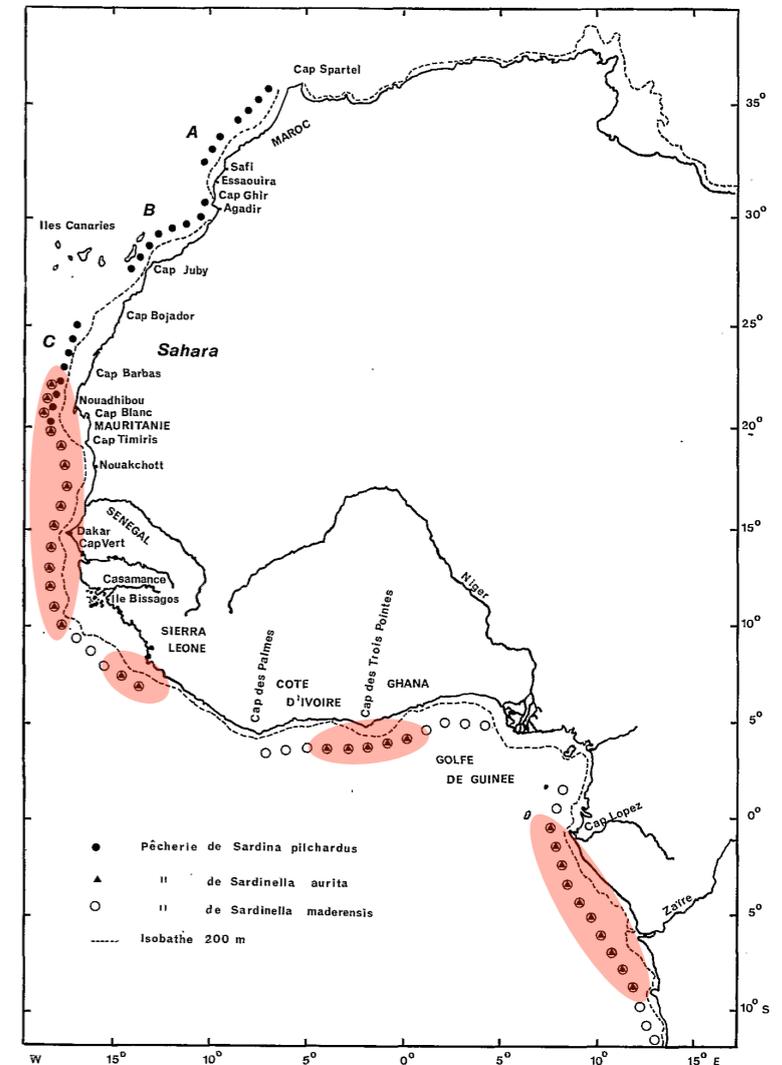
- The biophysical model

## 3. Results

- Biomass predictions in the EEZs

## 4. Discussion

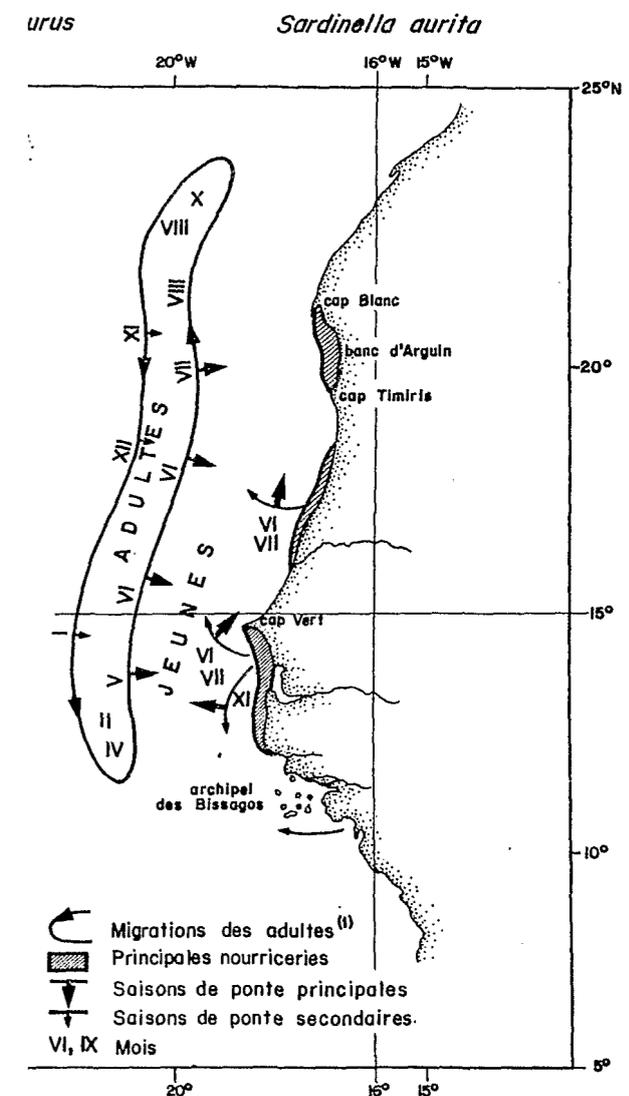
- Comparing periods of low and high fish biomass



**Main *S. aurita* fisheries in West Africa (Binet, 1988)**

# Introduction

- **North-West Africa : Coastal Upwelling System**
  - Permanent upwelling from 21 to 37°N
  - Seasonal (winter) upwelling from 12 to 21°N
- **Round sardinella (= *Sardinella aurita*):**
  - Central rôle in the tropic net ('wasp-waist ecosystem')
  - Targeted by both industrial and artisanal fisheries
  - Food security: major proteins source for sub-Saharan populations
  - Seasonal migration (north-south)



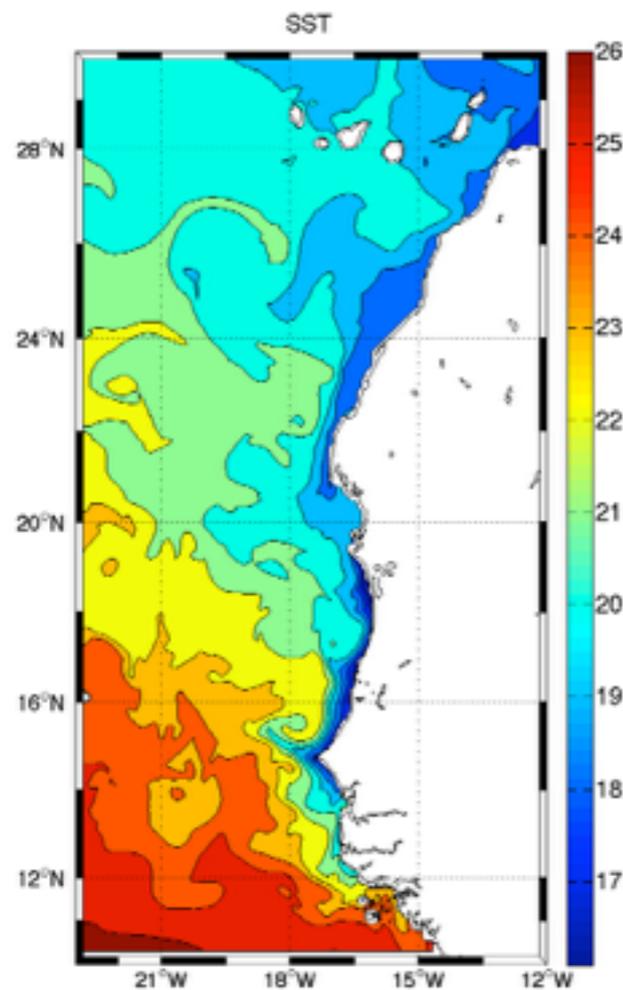
*S. aurita* migrations  
(Boely and Fréon, 1979)

# Methods : biophysical modeling approach

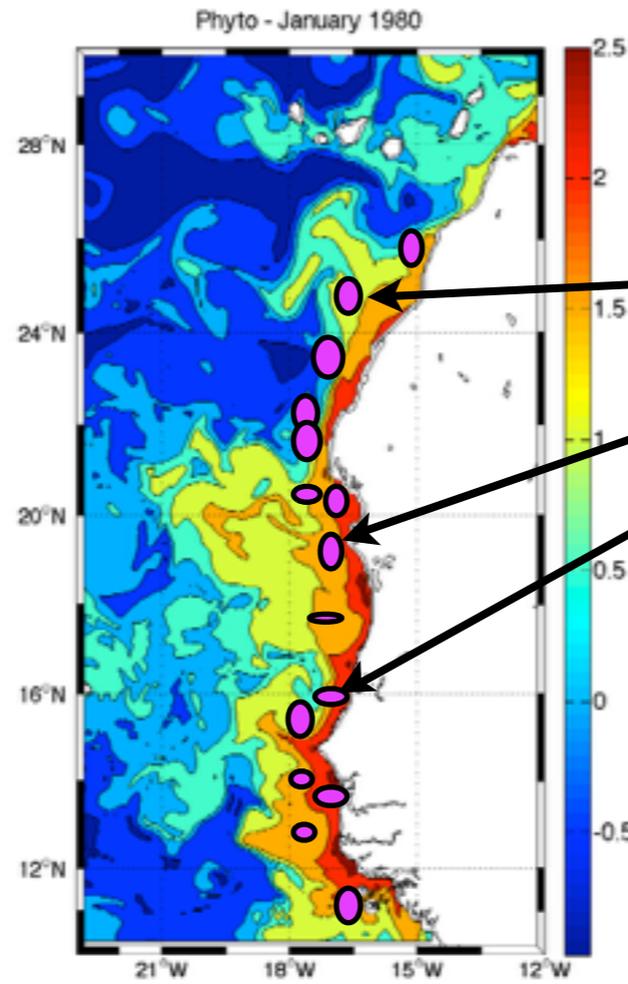
3D Environment from 1980 to 2009

+

Individual Based Model for Sardinella :



Hydrodynamic  
(ROMS)



Biogeochemical  
(ROMS-PISCES)

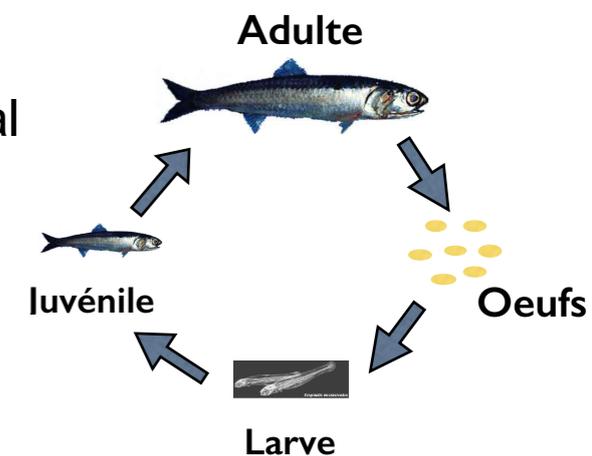


● = Schools

➡ *Monospecific,  
Full life cycle model*

Processus :

- Larval dispersal
- Energy budget
- Swimming
- Spawning

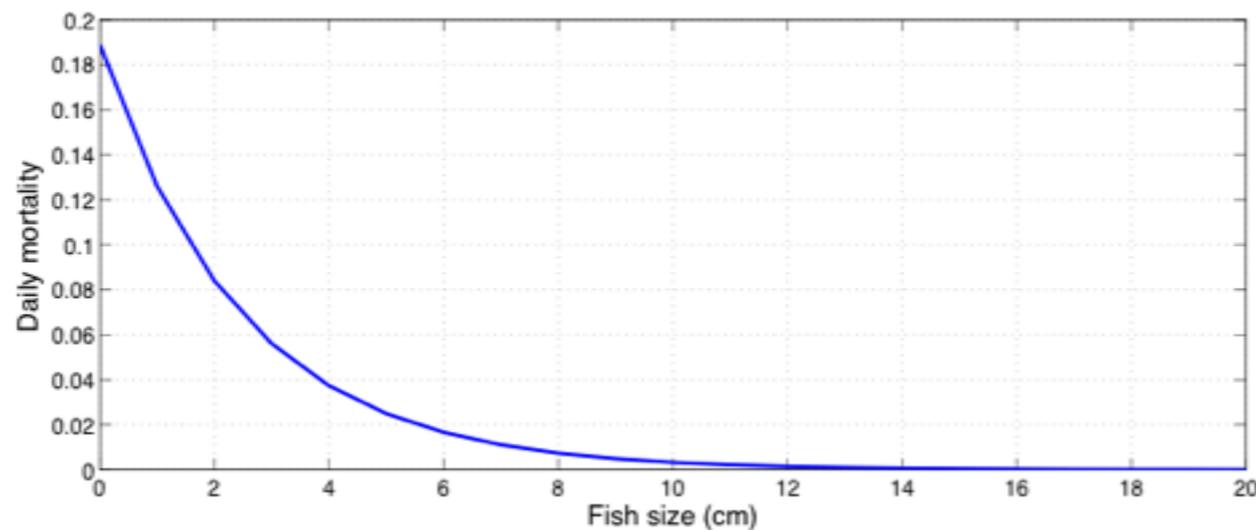


ROMS-PISCES 3D simulation of the upwelling system  
(AGRIF-2 ways, 1980-2009)

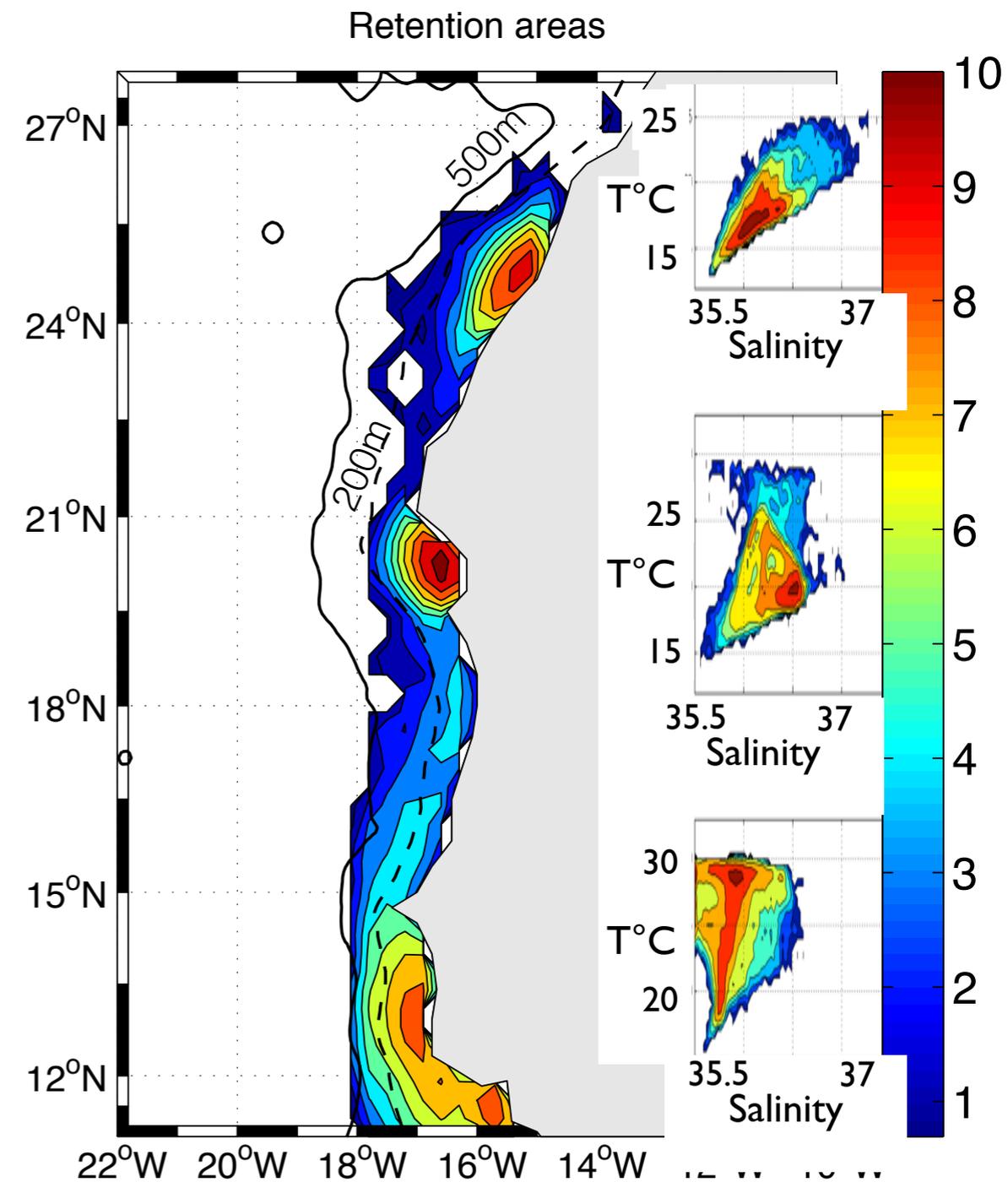
Auger P.A., Machu E., Gorgues T. (IRD, Brest)

# Methods : early life stage modeling

- Larval survival = retention in coastal areas
- Lethal temperature for *S. aurita* larvae = 15°C
- Rapid growth reduce mortality predation mortality



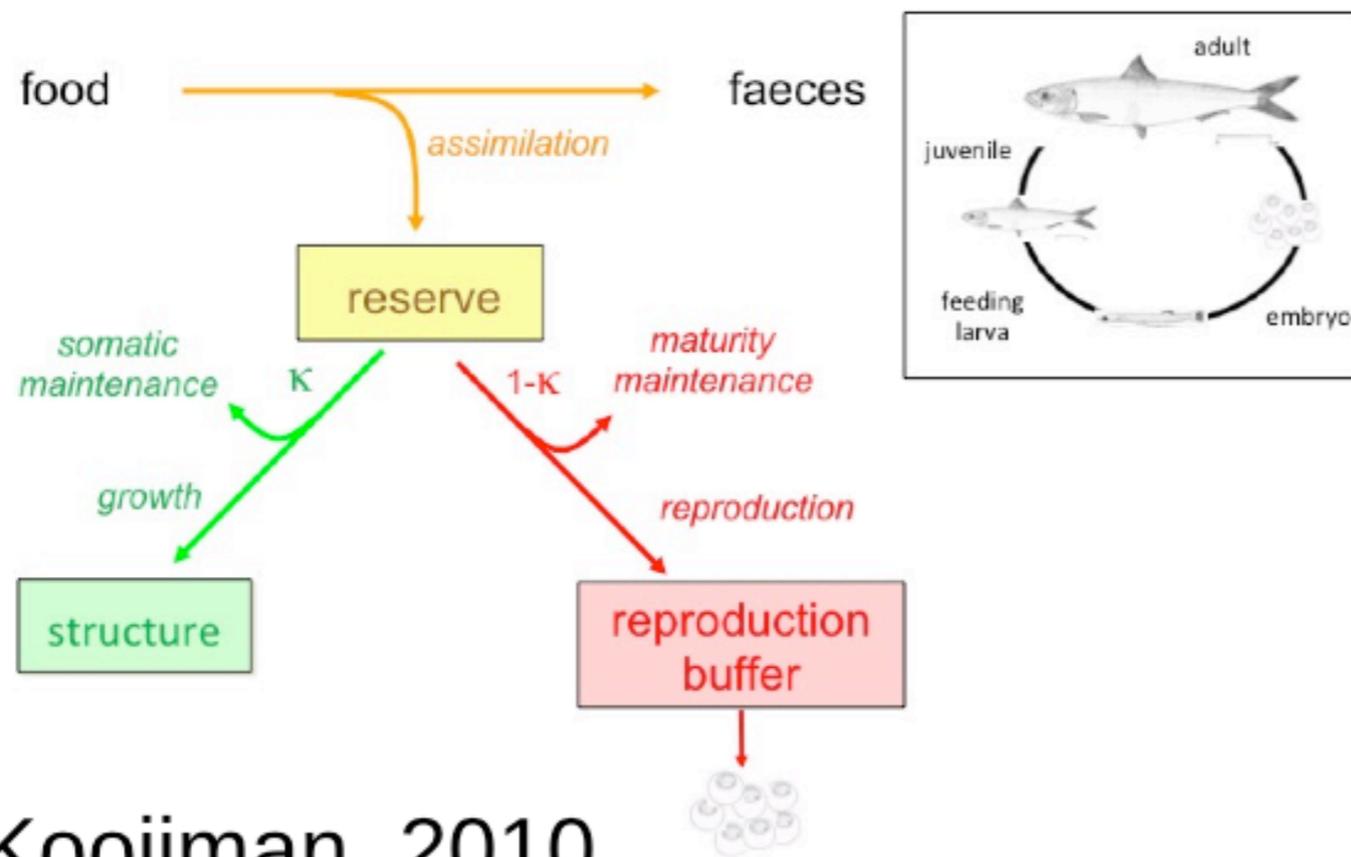
Size-dependant mortality



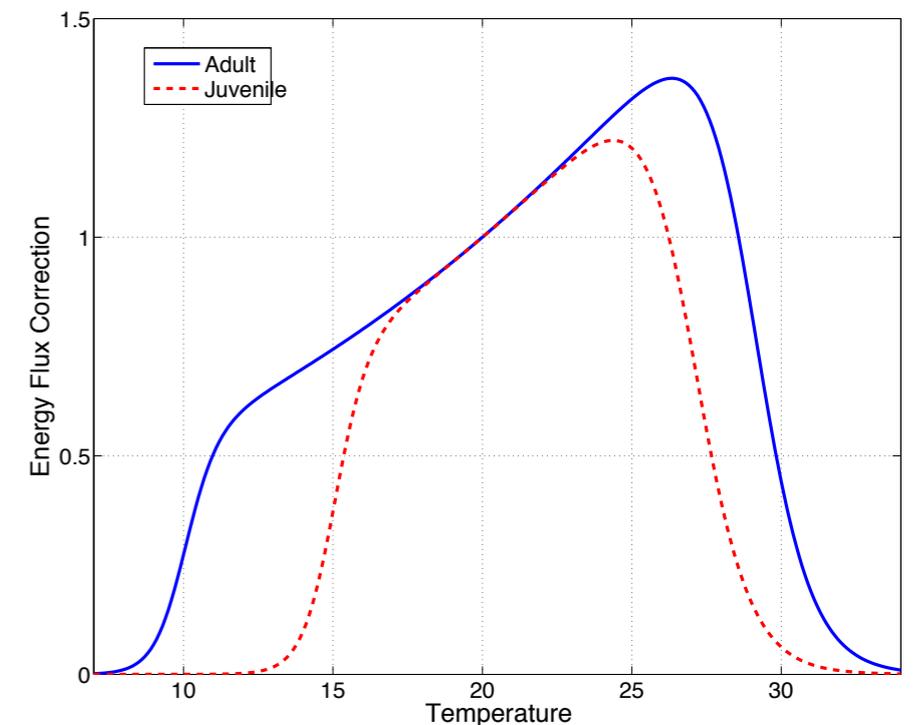
# Methods: bioenergetics

## Dynamic Energy Budget (DEB)

Input : Food and Temperature



Kooijman, 2010

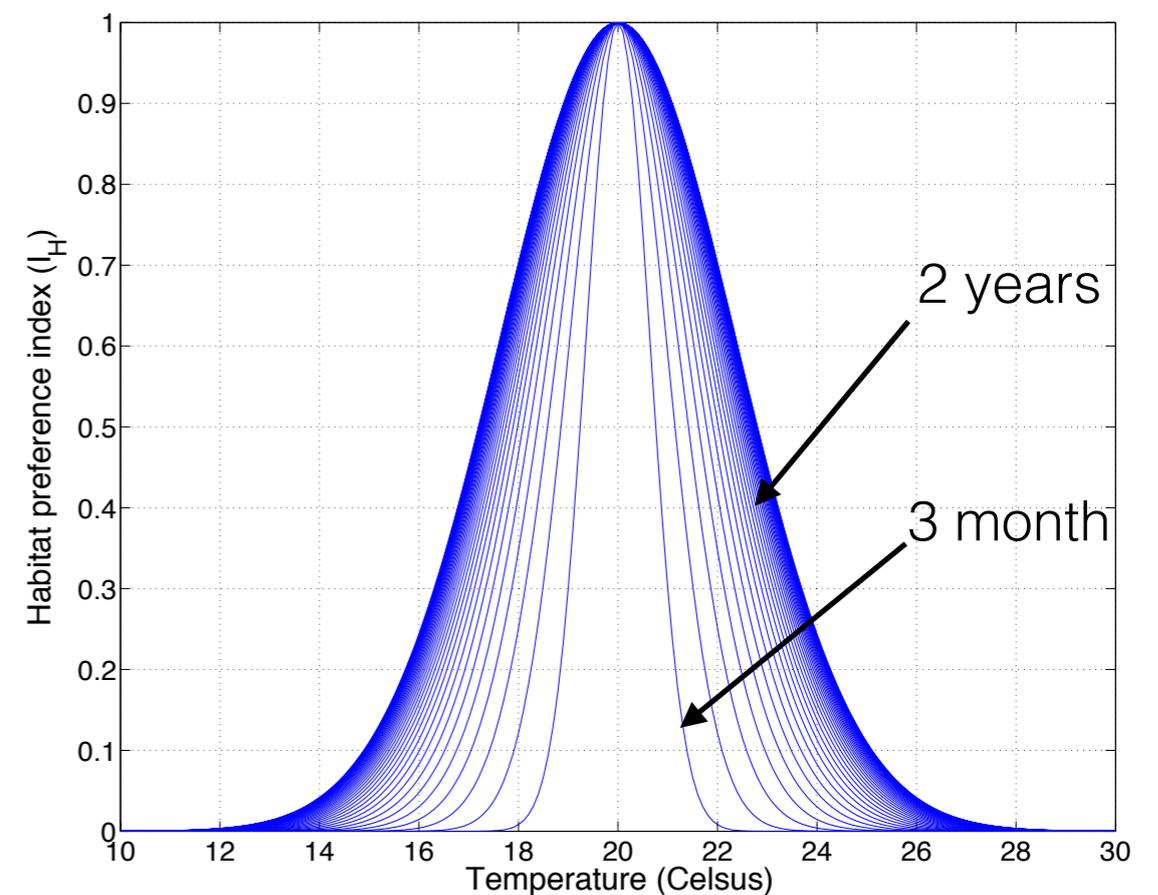


Temperature flux corrections for the bio-energetic model

# Methods: swimming

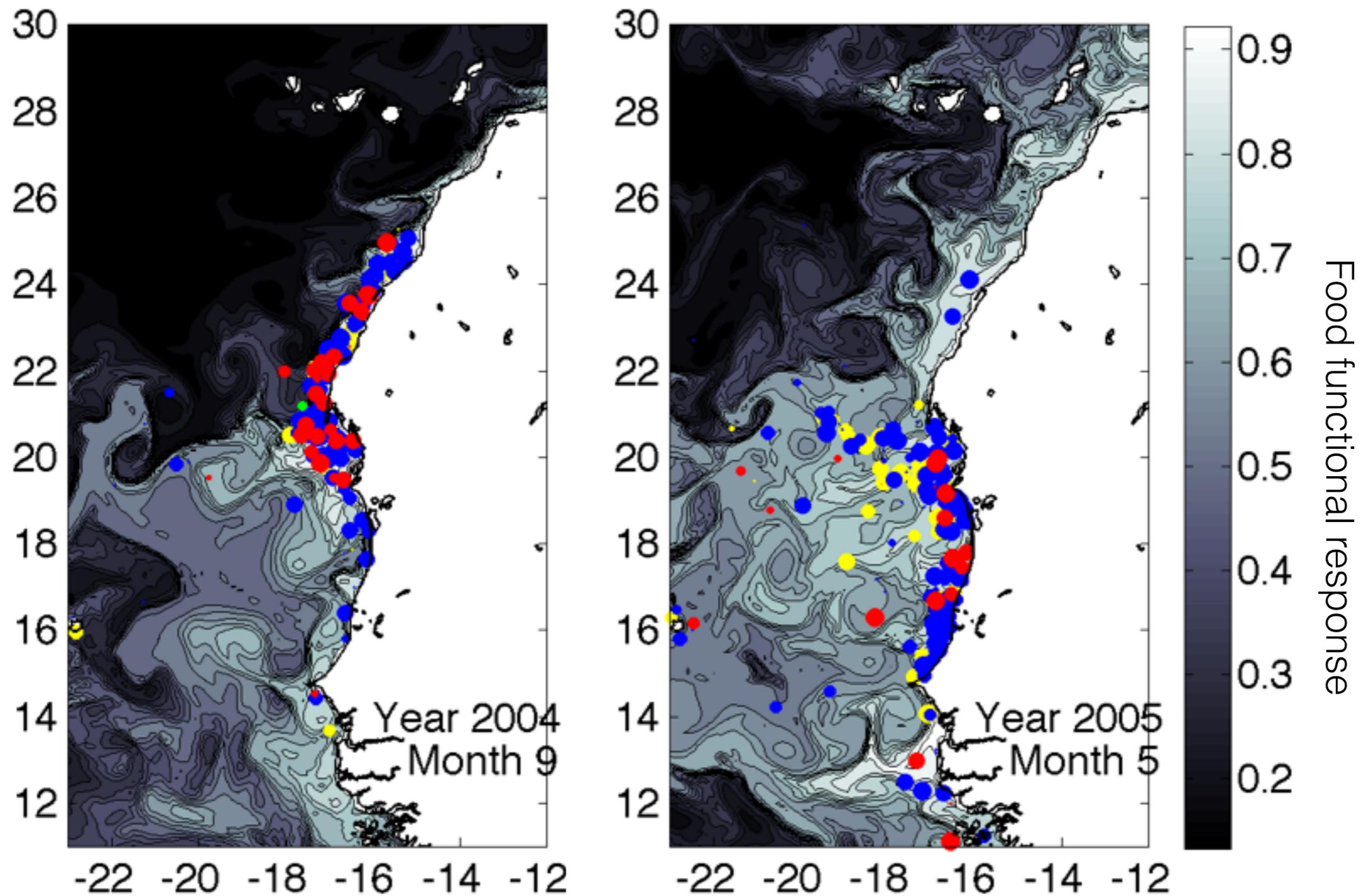
- Movement algorithm: random + inertial component (**Kinesis**)
- Habitat quality index: Temperature x Food - Mortality
- Food : functional response
- Mortality : offshore predation
- Temperature : imprinting (natal temperature)

- ➔ ● Natural selection for temperature preferences



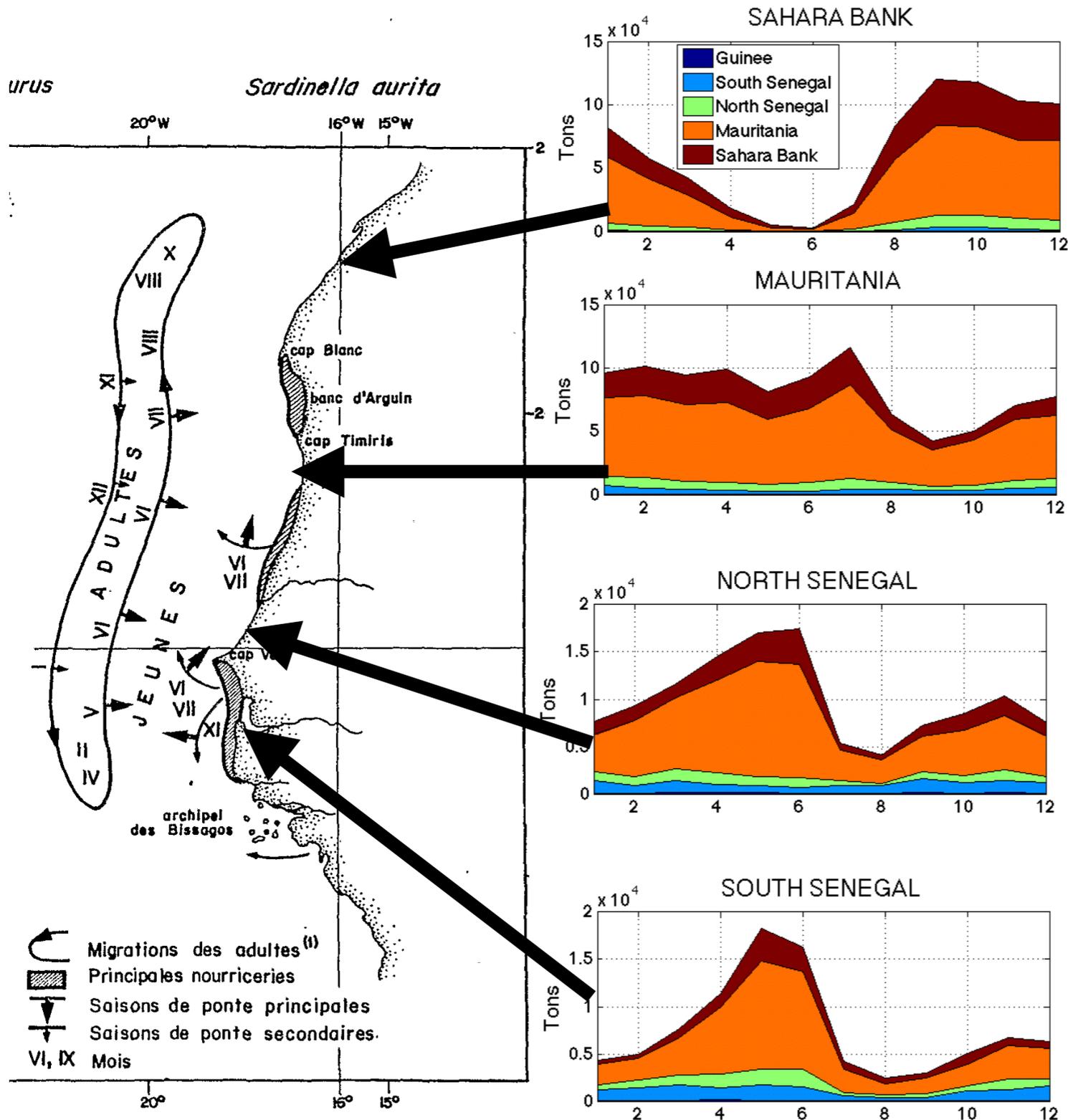
Temperature tolerance depending on age for a fish born in 20 degree water

# Example of fish distribution

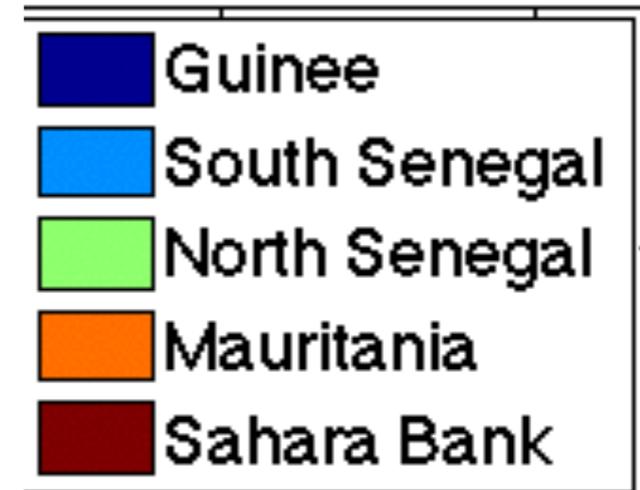


Red = fish born in Senegal -  
Blue = fish born in Mauritania

# Results : seasonality



Fish born in

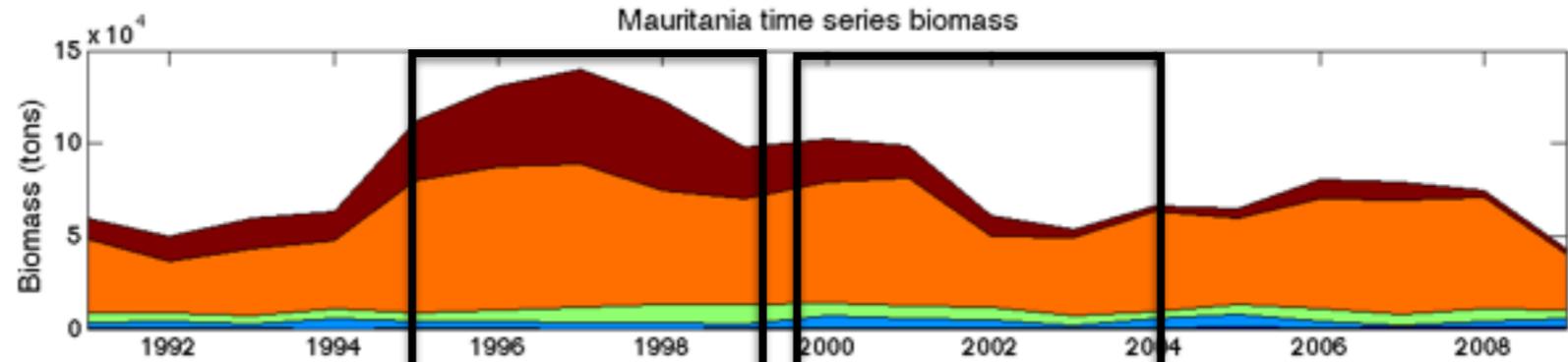


—> Fits with migratory scheme described in 1979 from landings data

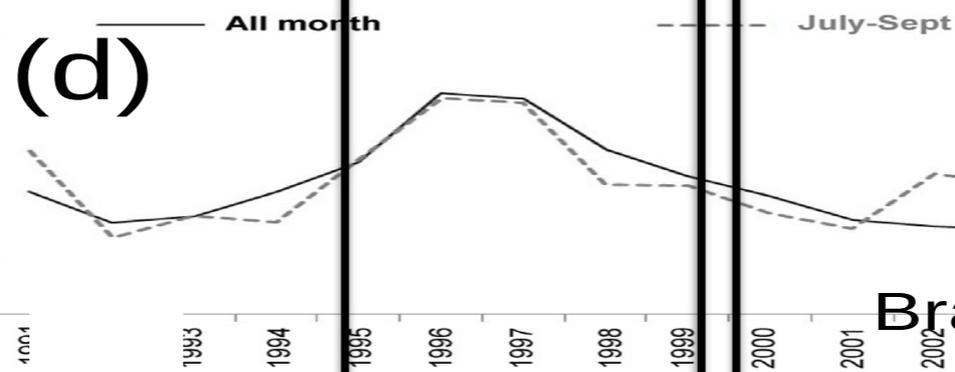
*S. aurita* migrations  
(Boely and Fréon, 1979)

# Results : time series

Model  
Mauritania

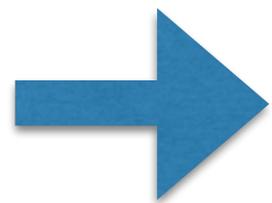
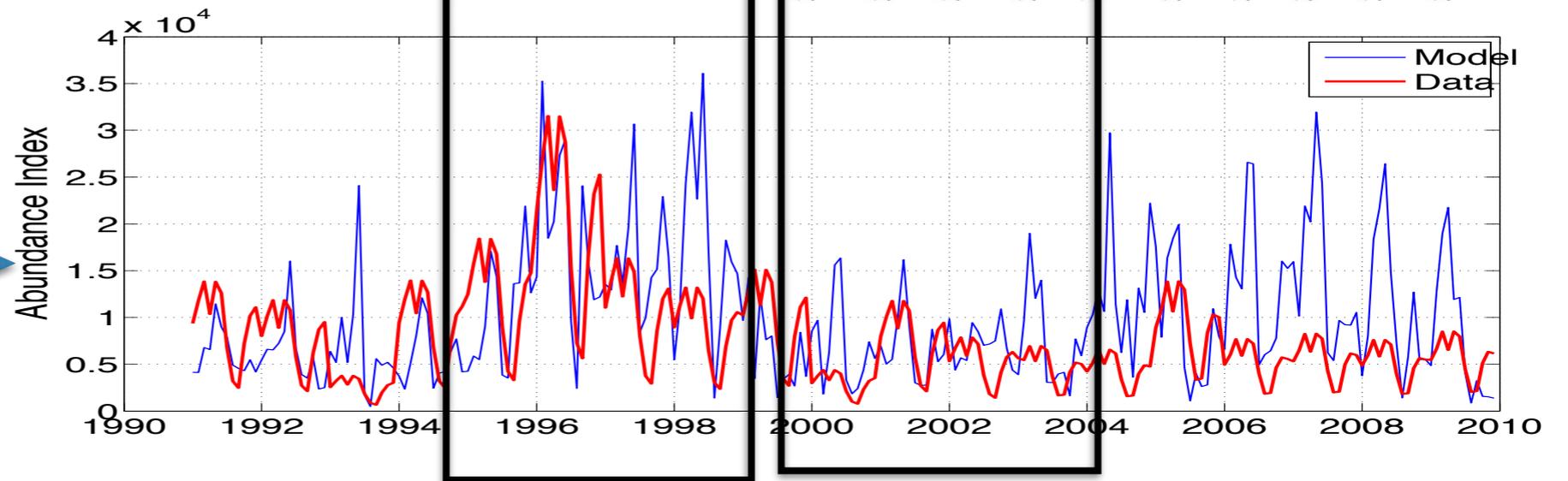


CPUE from  
IMROP



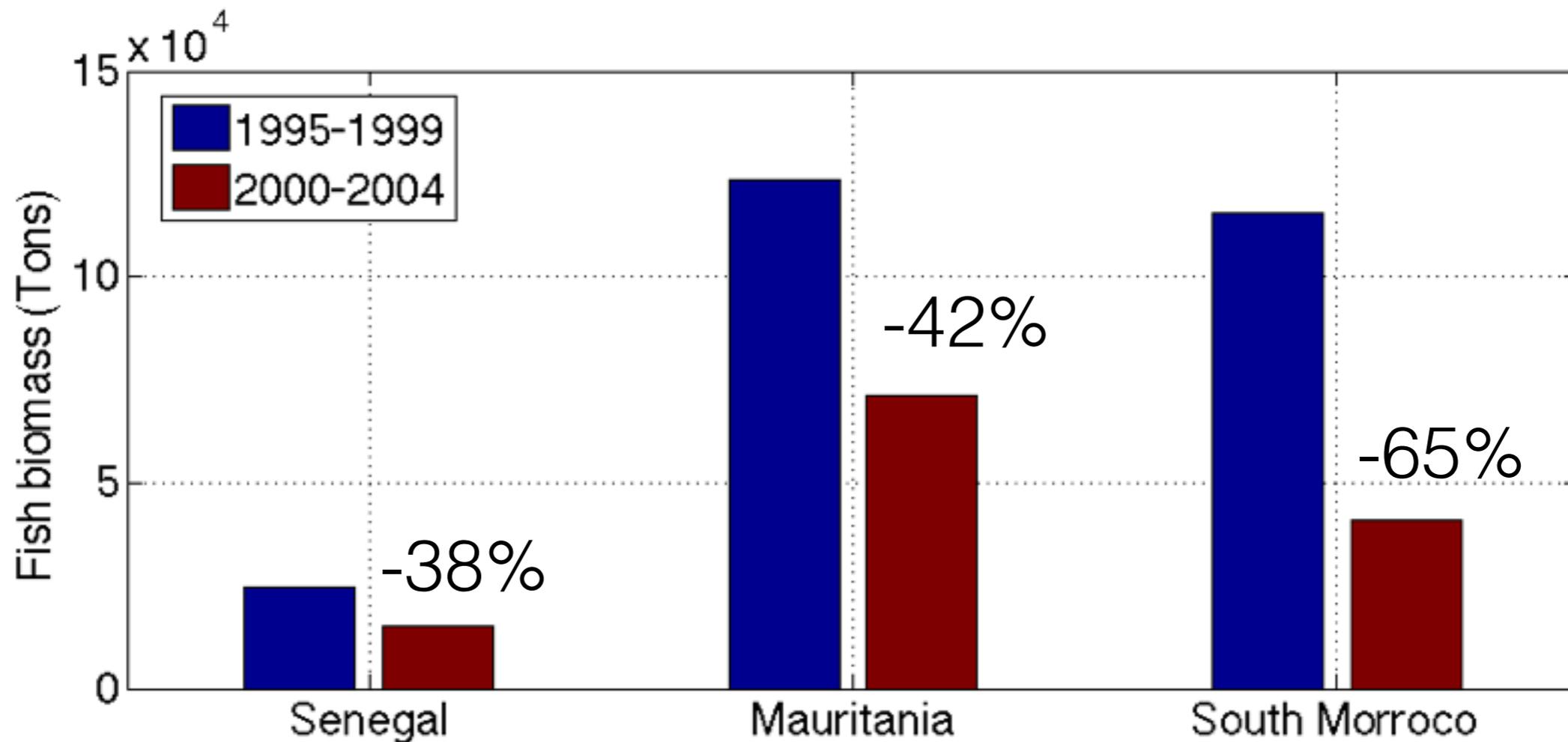
Braham et al. 2014

Model Senegal  
Vs  
CPUE  
from CRODT

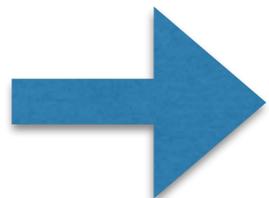


Comparons les périodes 1995-1999 et 2000-2004

# Comparing Low and High *S.aurita* biomass periods

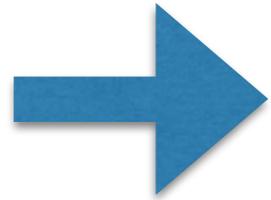


## Mean annual biomass per country

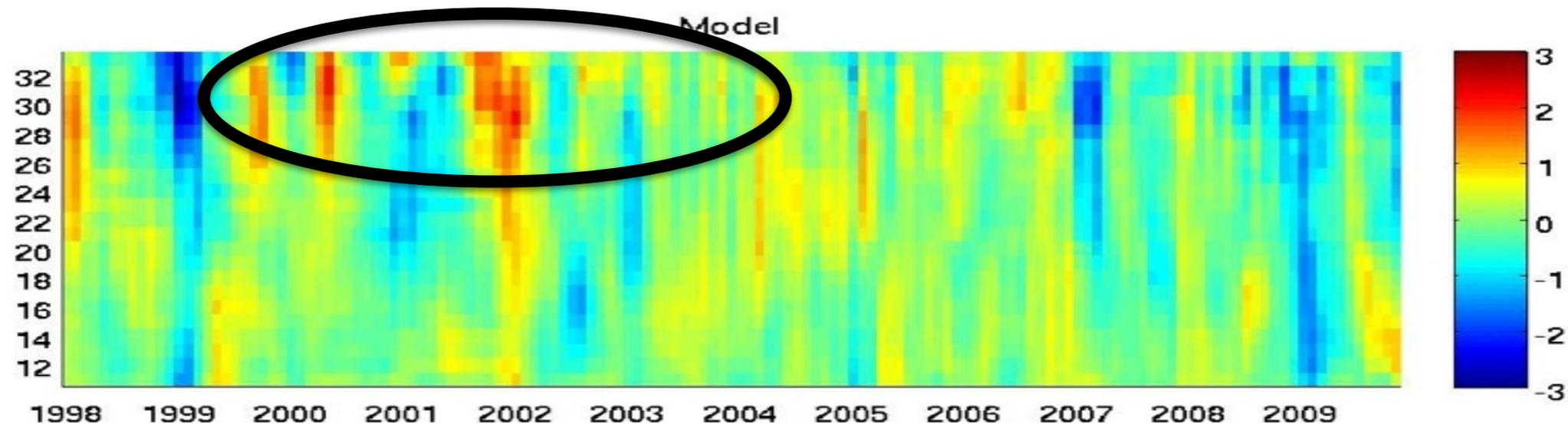


Predicted biomass reduction due to decrease in recruitment or in fish growth?

# Comparing Low and High *S.aurita* biomass periods



Stronger upwelling favorable wind during 2000-2004 :



Along shore wind (ROMS forcings)

—> **Impact on the continental shelf :**

Decrease in annual mean SST :

**Senegal : -0.1°C**

**Mauritania : -0.4°C**

**South Morocco : -0.5°C**

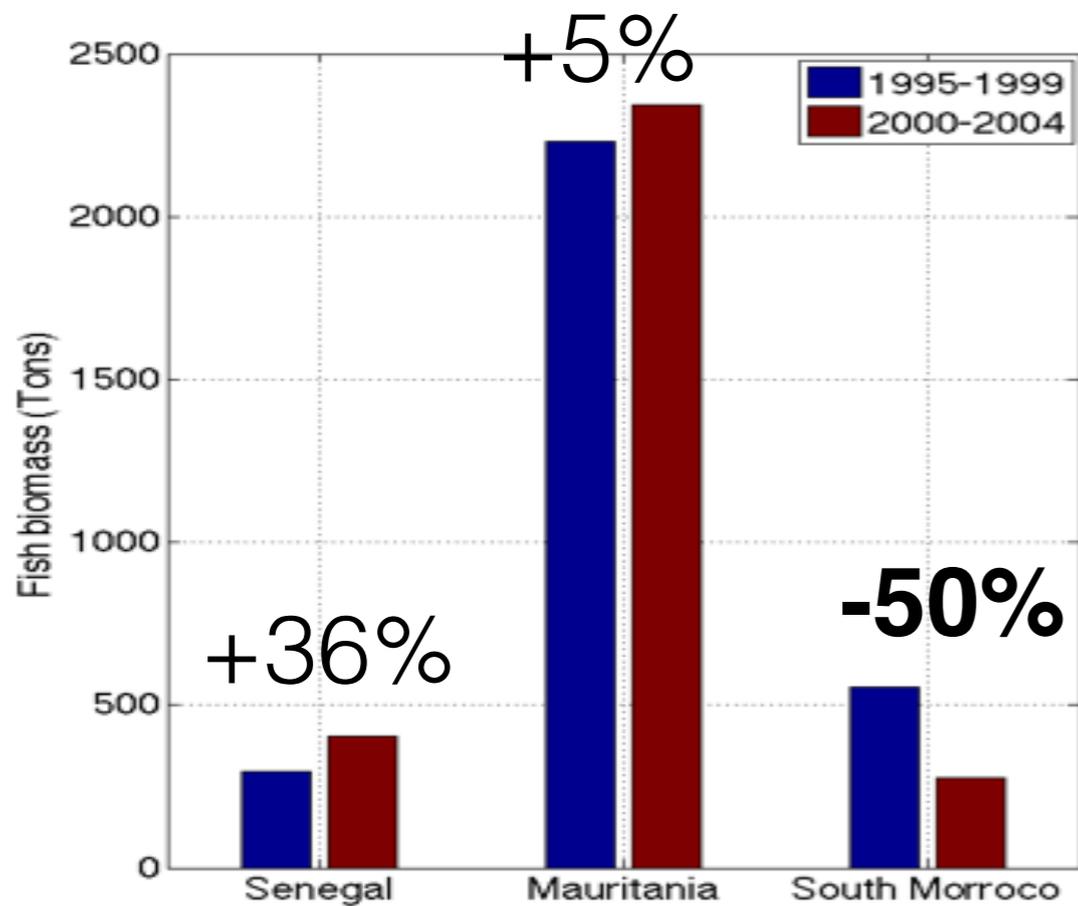
Increase in annual mean plankton biomass :

**Senegal : +9%**

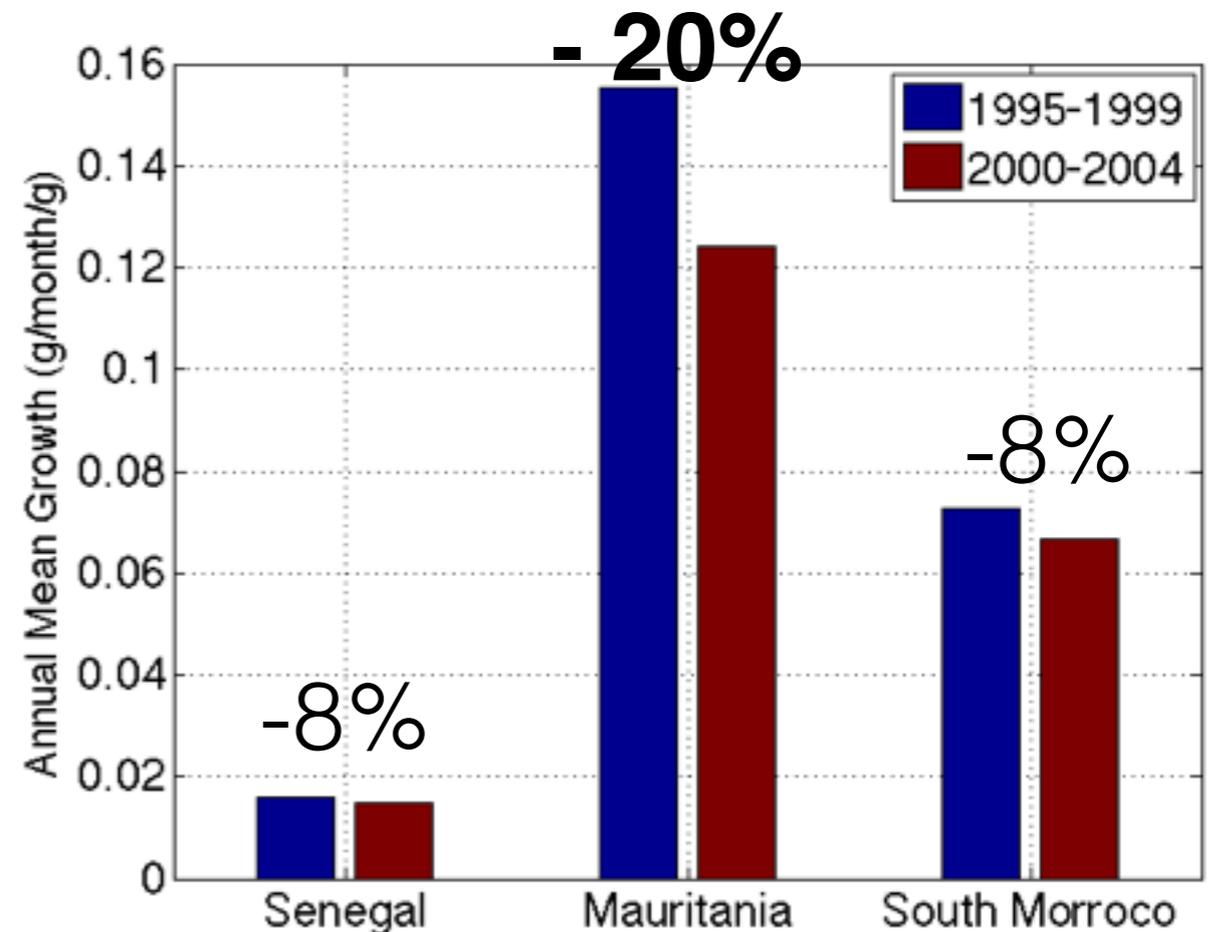
**Mauritania : + 20%**

**South Morocco : +14%**

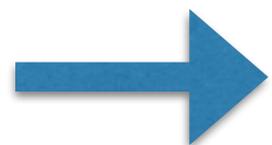
# Comparing Low and High *S.aurita* biomass periods



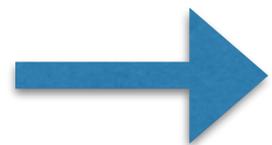
Mean annual recruitment



Mean annual Growth

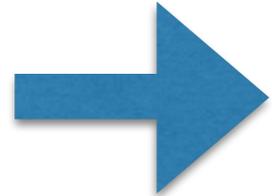


Lower recruitment in Morocco during 2000-2004



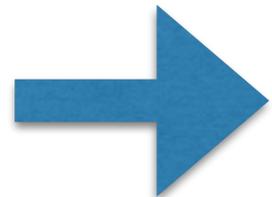
Lower growth during 2000-2004

# Conclusions



L'intensification de l'upwelling en 2000-2004 pourrait avoir eu un effet négatif sur la reproduction de *S. aurita* au Sud Maroc

Par le jeu des migrations, la diminution du succès de reproduction au Maroc entraîne la diminution des biomasses de *S. aurita* en Mauritanie et au Sénégal



Il faudra comparer d'autres exemples de périodes d'upwelling contrasté pour s'assurer de la robustesse de ce résultat

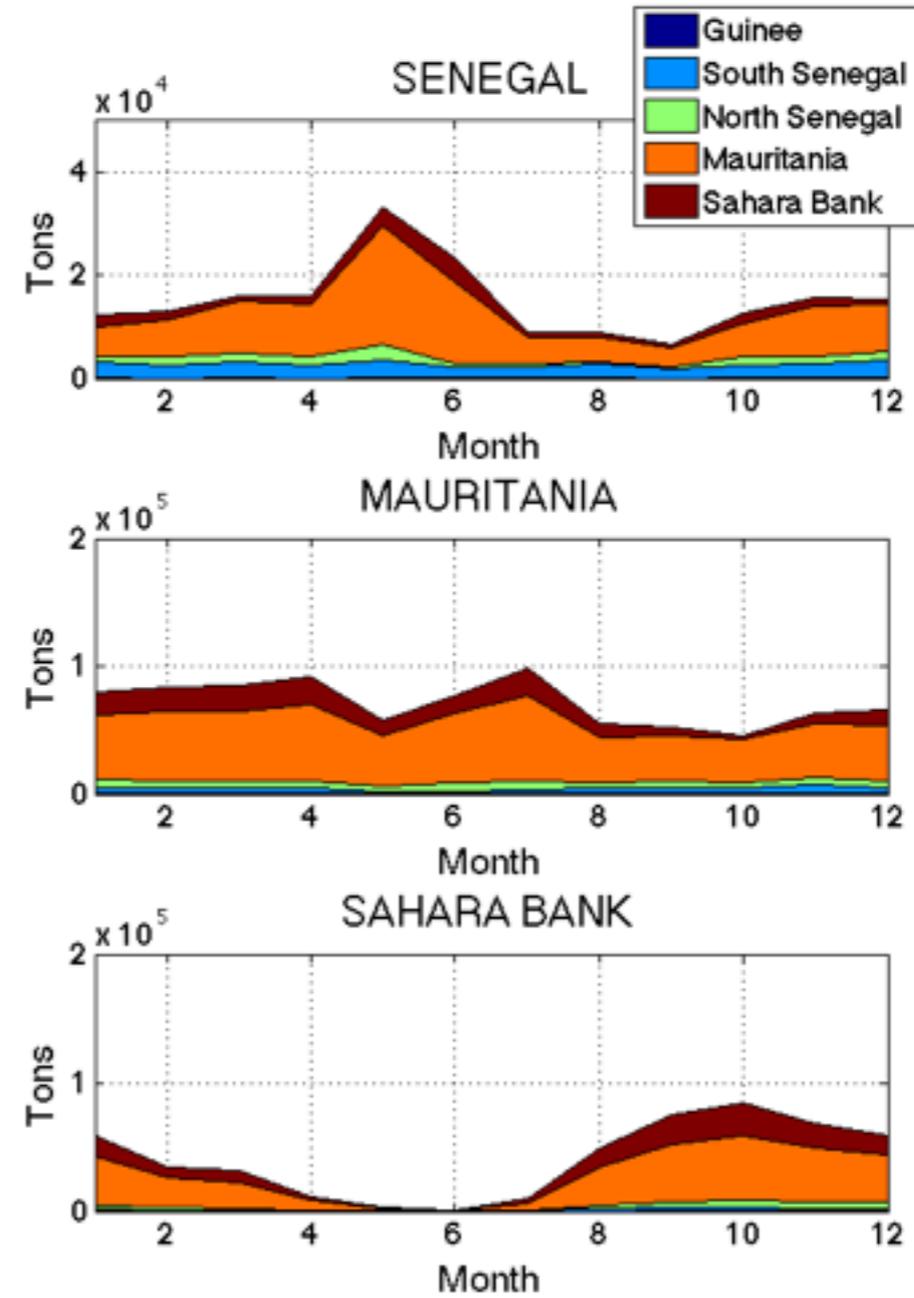
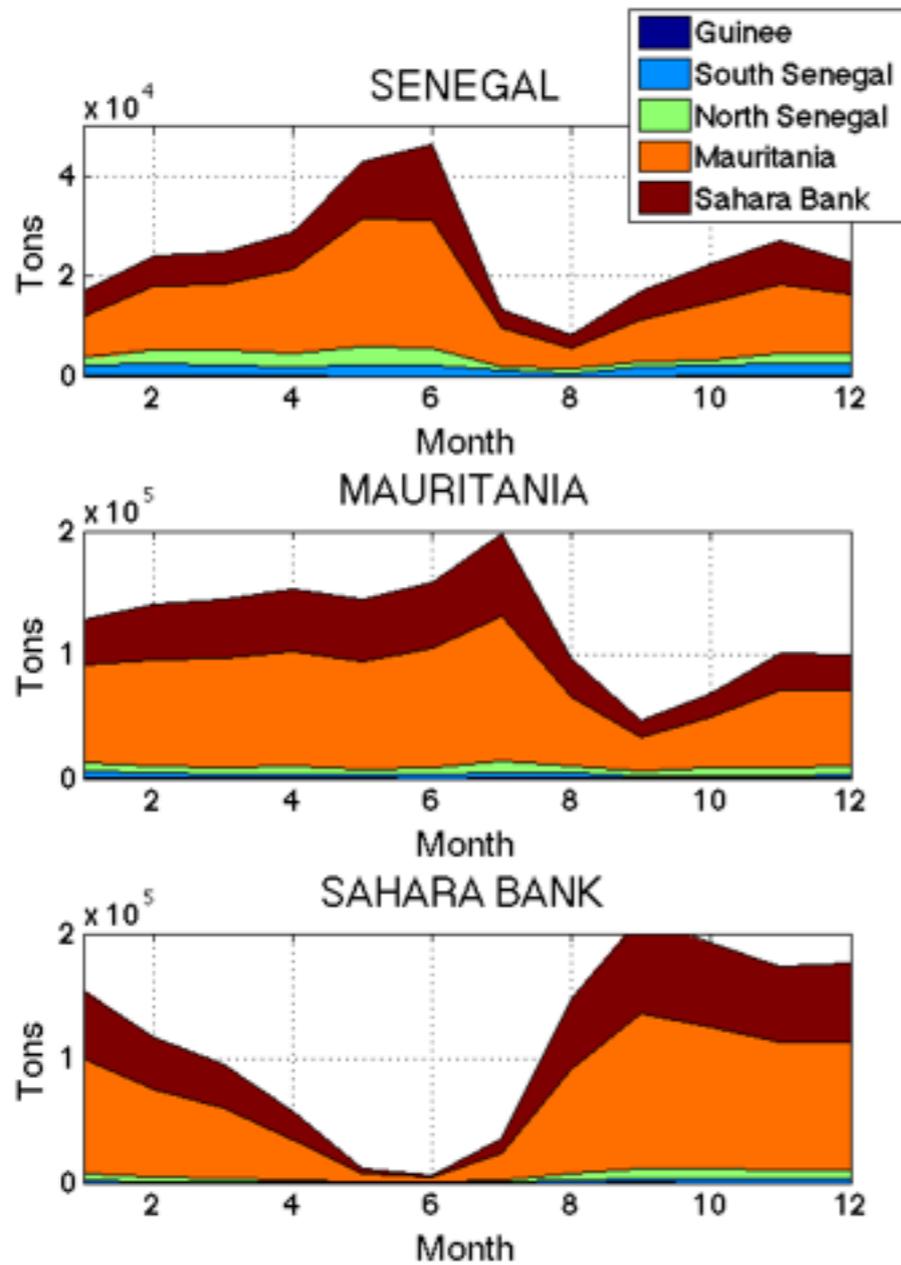
**Des études de terrain et du data-mining sont nécessaire pour valider la théorie proposée.**

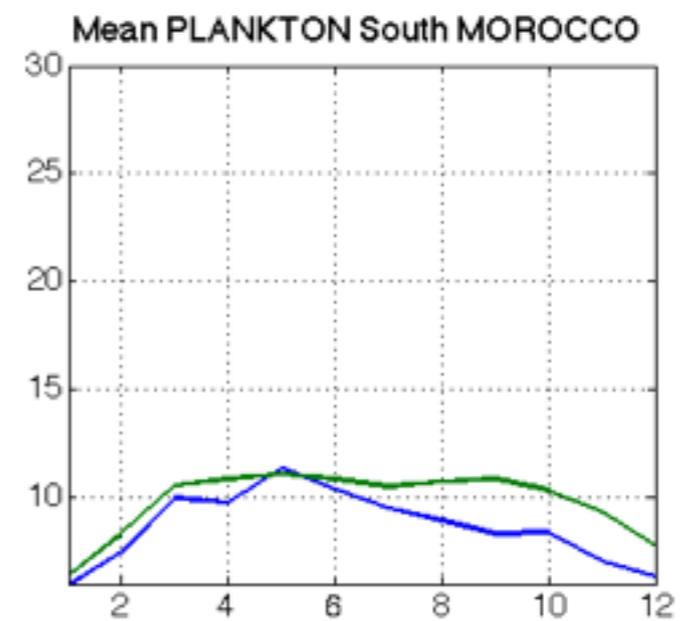
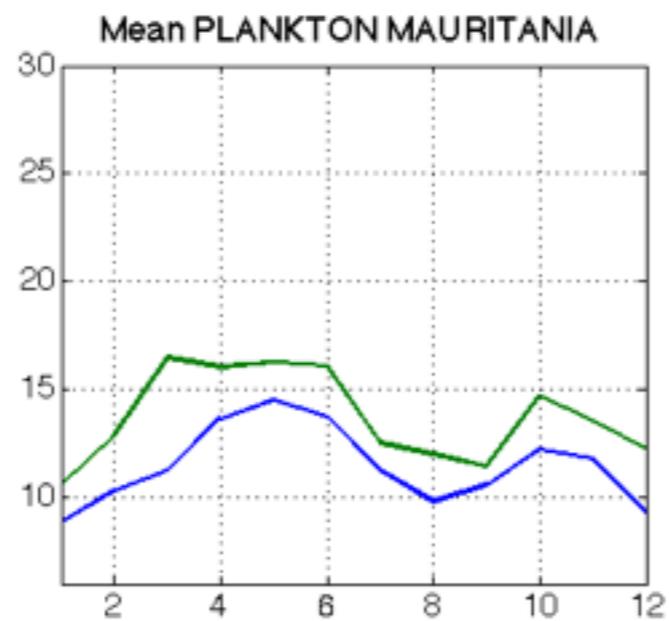
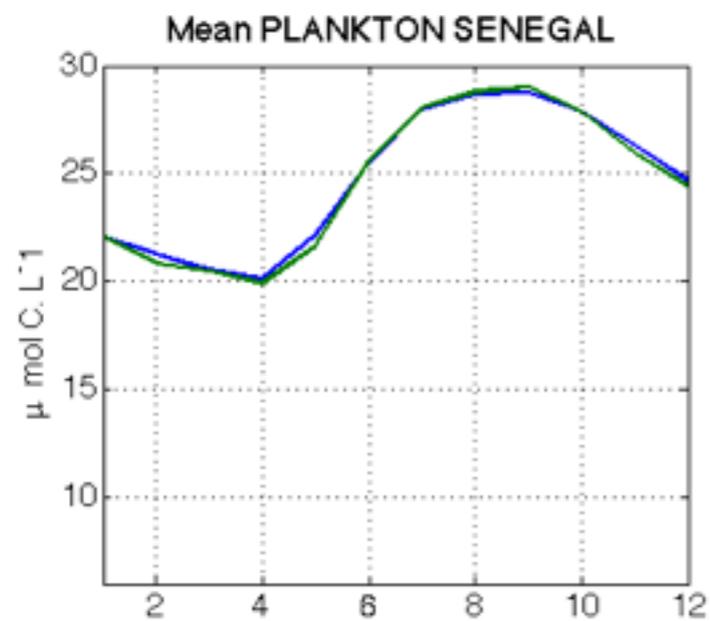
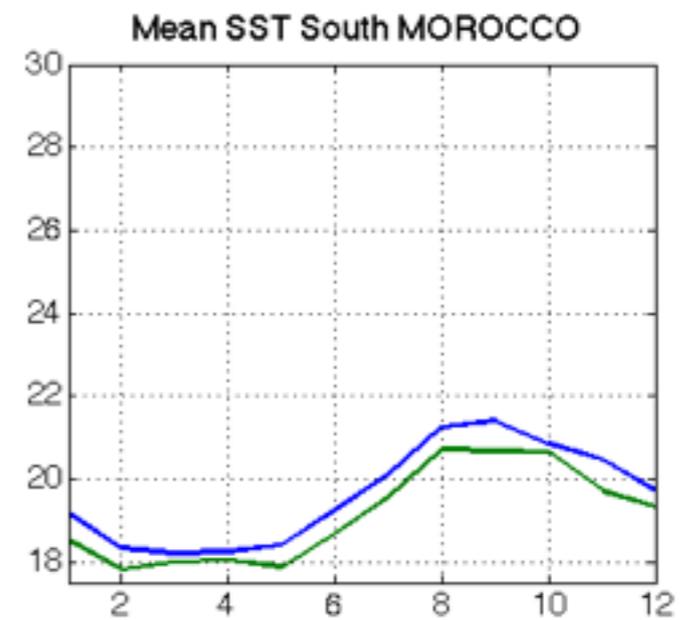
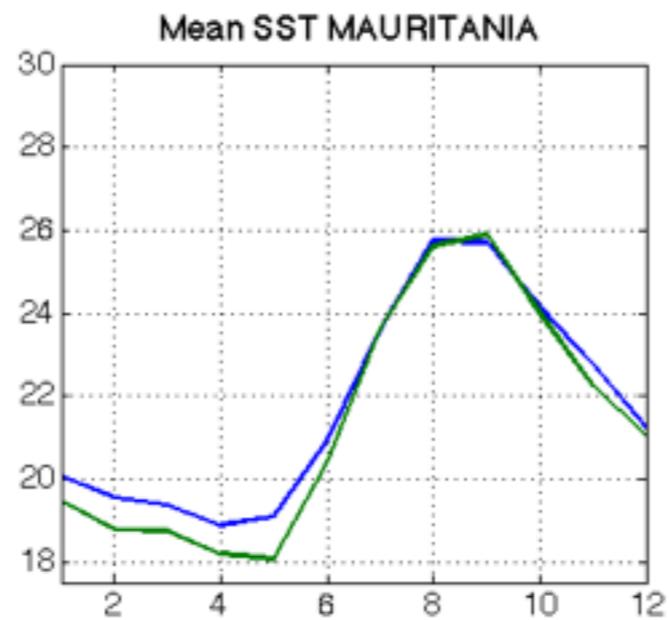
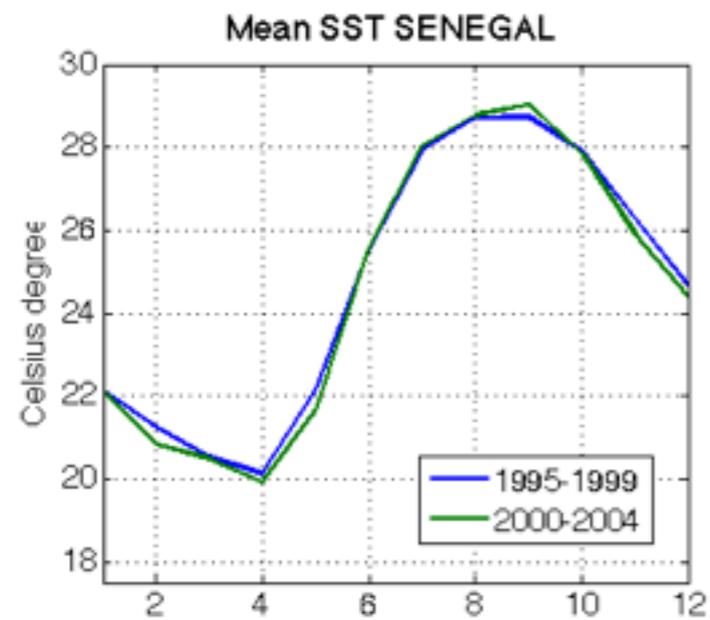
**Le présent modèle théorique pourrait ensuite permettre d'évaluer l'impact des projections climatiques**

# Comparing fish biomass seasonality

**1995-1999 :**  
(High biomass)

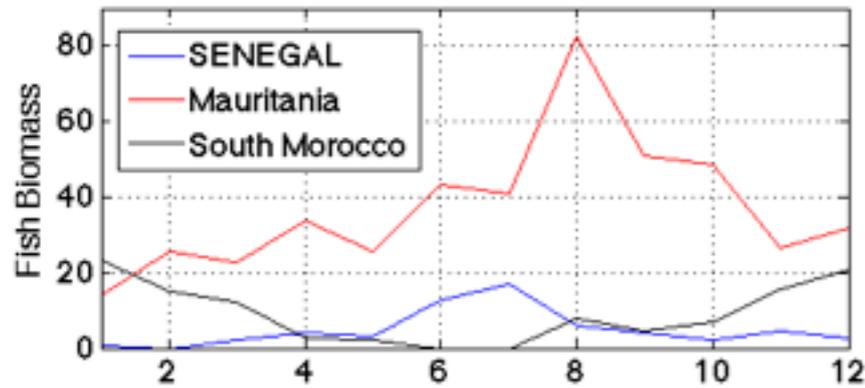
**2000-2004 :**  
(Low biomass)



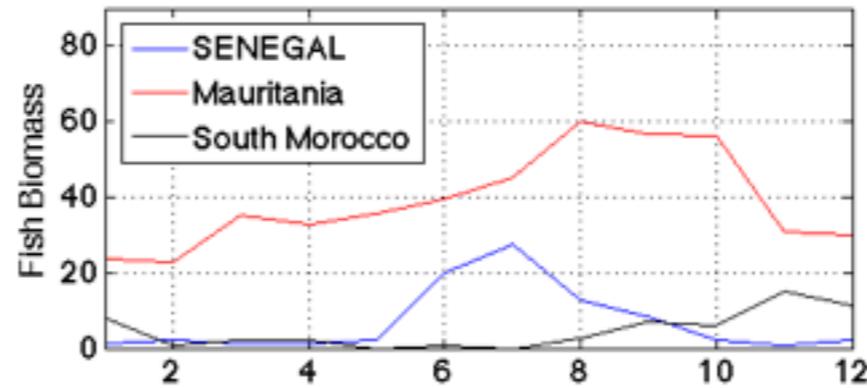


# Recruitment

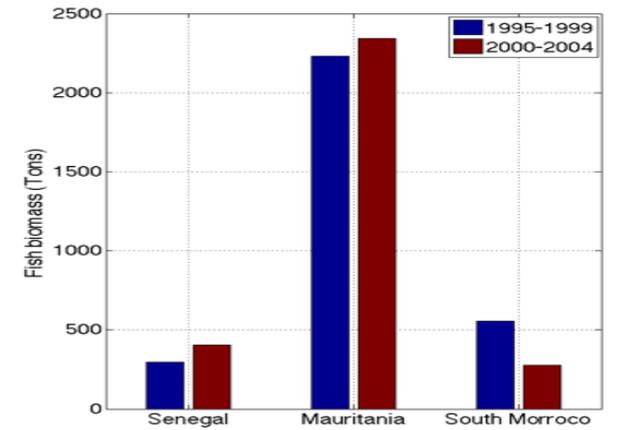
Seasonality during 1995-1999



Seasonality during 2000-2004

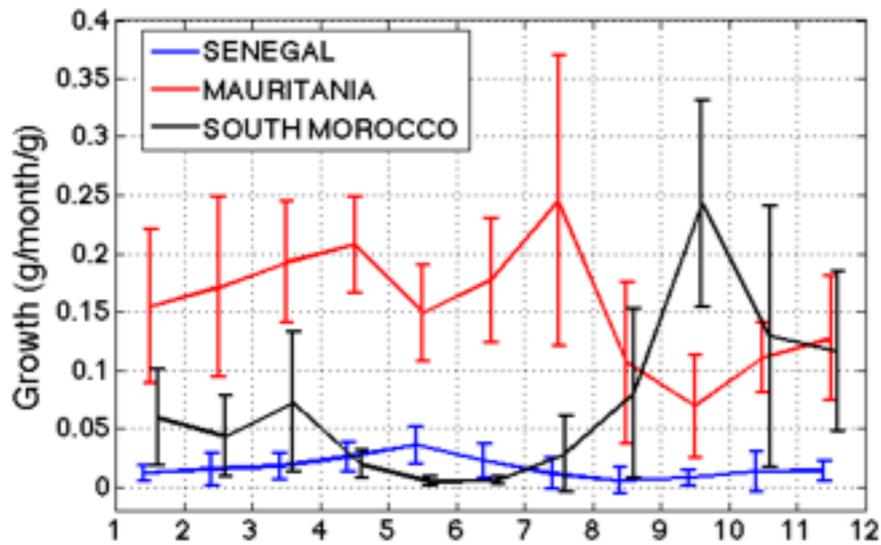


Annual Mean

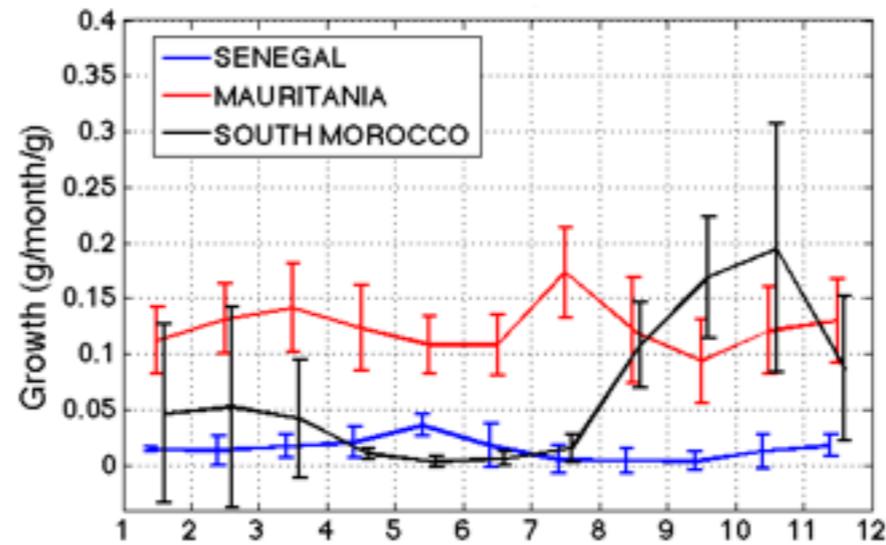


# Growth

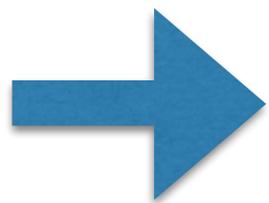
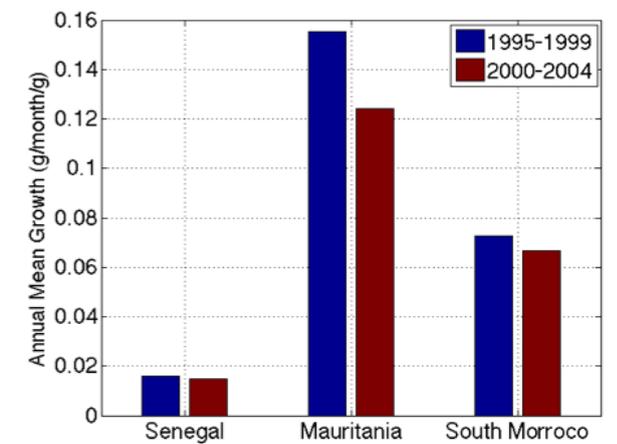
Seasonality during 1995-1999



Seasonality during 2000-2004



Annual Mean



Lower recruitment **and** growth in Morocco during 2000-2004