PREFACE-PIRATA-CLIVAR Tropical Atlantic Variability Conference

28th November – 1st December 2016, UPMC, Paris, France

Session 3

Population traits in Small pelagic fish model

Emergence from interactions between turbulent environment and individual behaviors in Upwelling Systems

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Plan

I - Introduction

- Basic principles of the Evol-DEB model
- Emergeant population traits for round sardinella in North-West Africa

2 - Processes responsible for the population traits emerging from the model

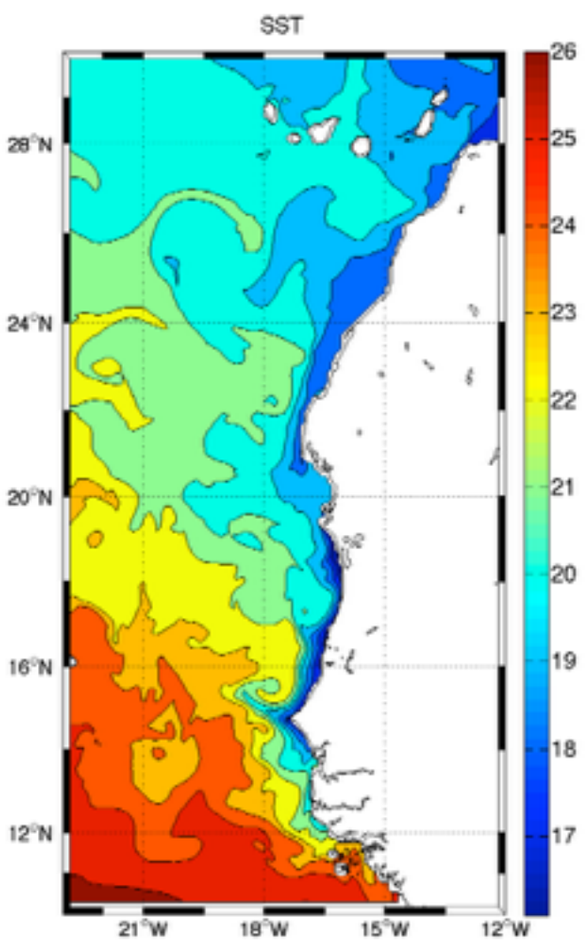
- Parameters tested in sensitivity analysis
- Processes identified

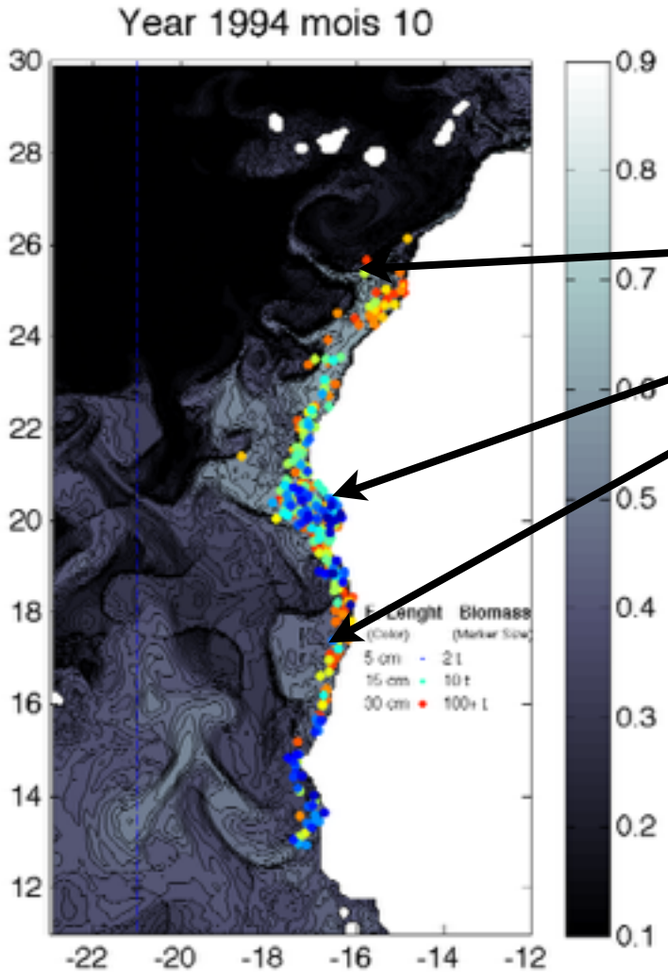
3 - Implications for Climate change impacts

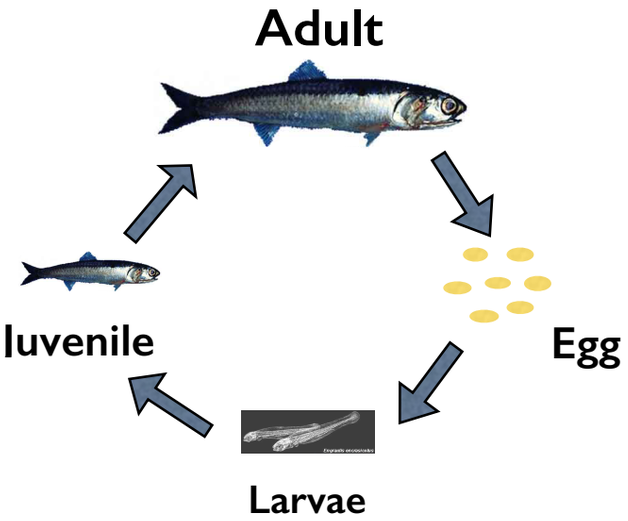
- IPCC AR5: Suggested Climate Change in Canary Current
- Potential effects on round sardinella distribution

Basic principles of the Evol-DEB model

The biophysical model







Submodels for each individual:

- Energy Budget
- Early life dynamics
- Adult migrations

Hydrodynamic
(ROMS)

Bio-geochemical
(ROMS-PISCES)

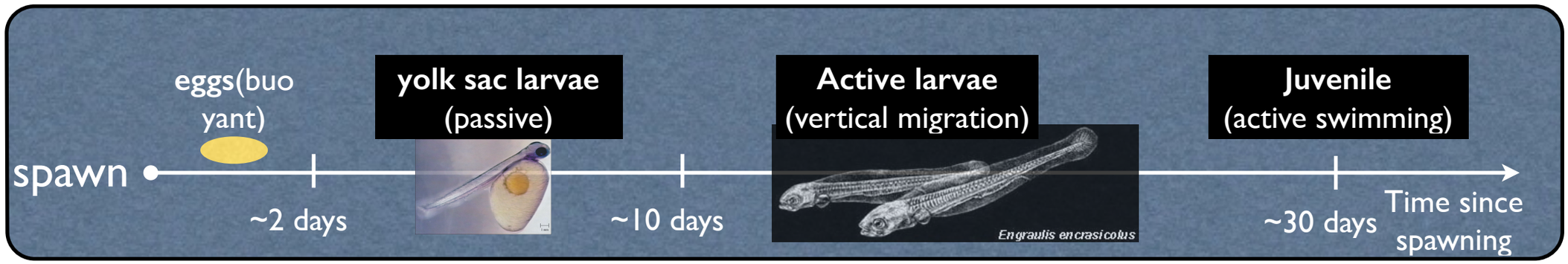
Life-cycle
(Evol-DEB)

6 km, 32 vertical levels, daily archived simulation (1980-2009)
Auger et al. (2015) (AGRIF-2 ways)

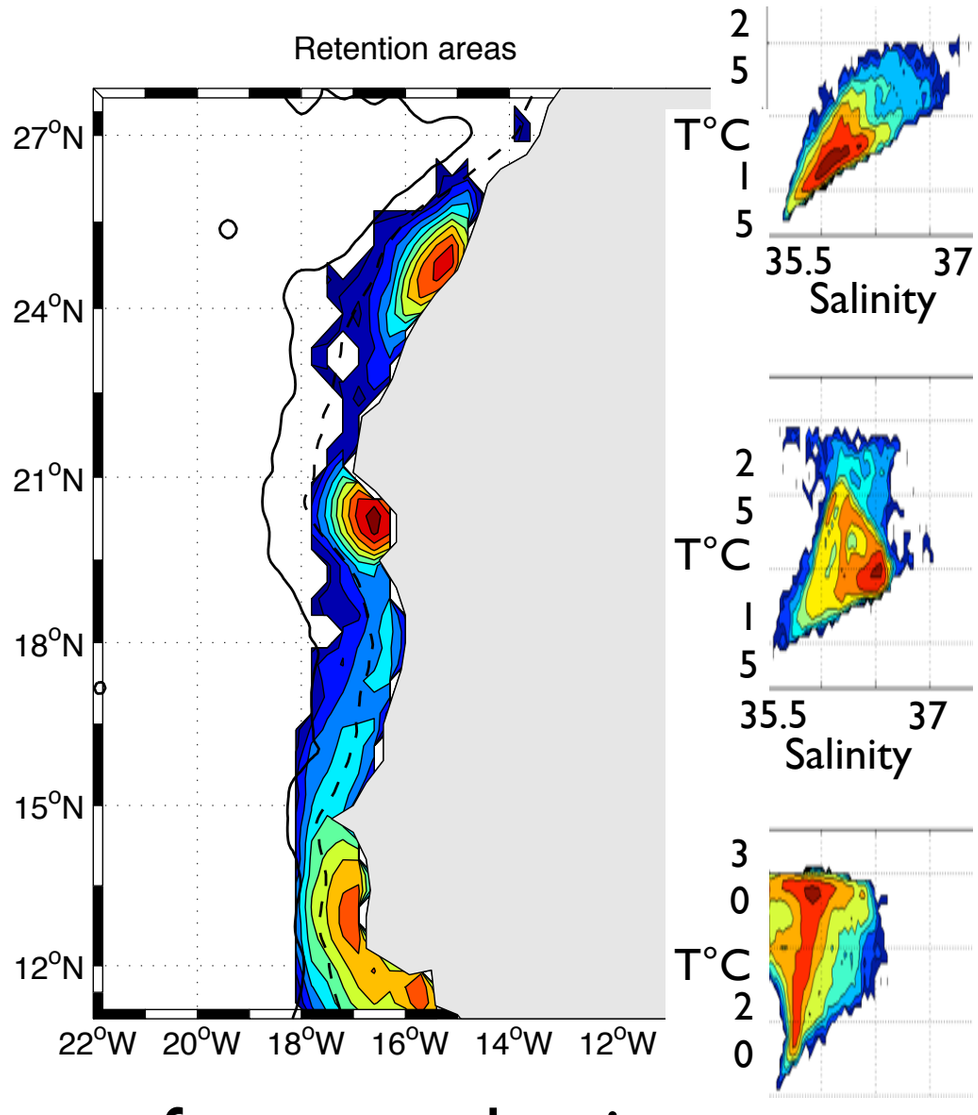
~1000 individuals
Time step = 1 h

Basic principles of the Evol-DEB model

Submodel : Early-life stage



- Buoyant egg
- Neutral yolk-sac larvae
- Diurnal Vertical Migrations of active larvae
- Progressively increasing horizontal swimming capacities (~ Body length/s)

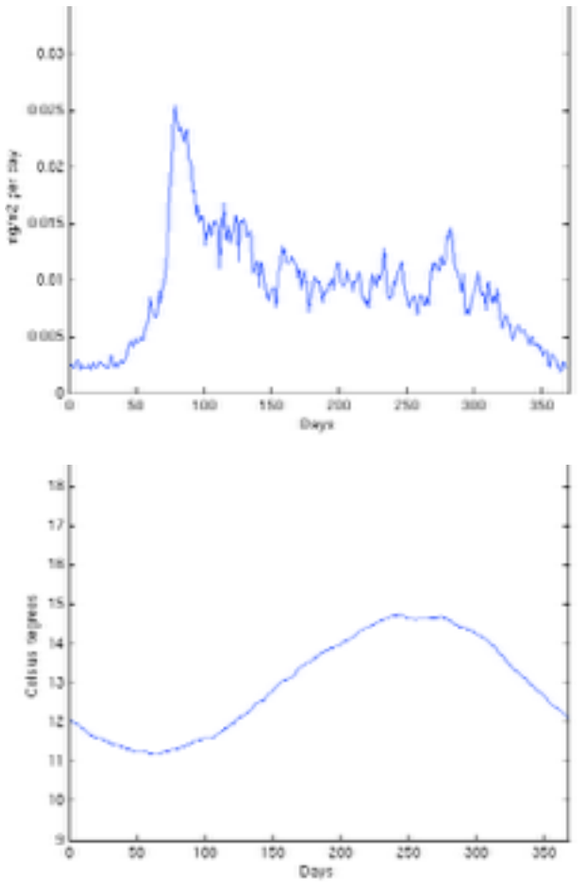


Hot spots for reproduction success

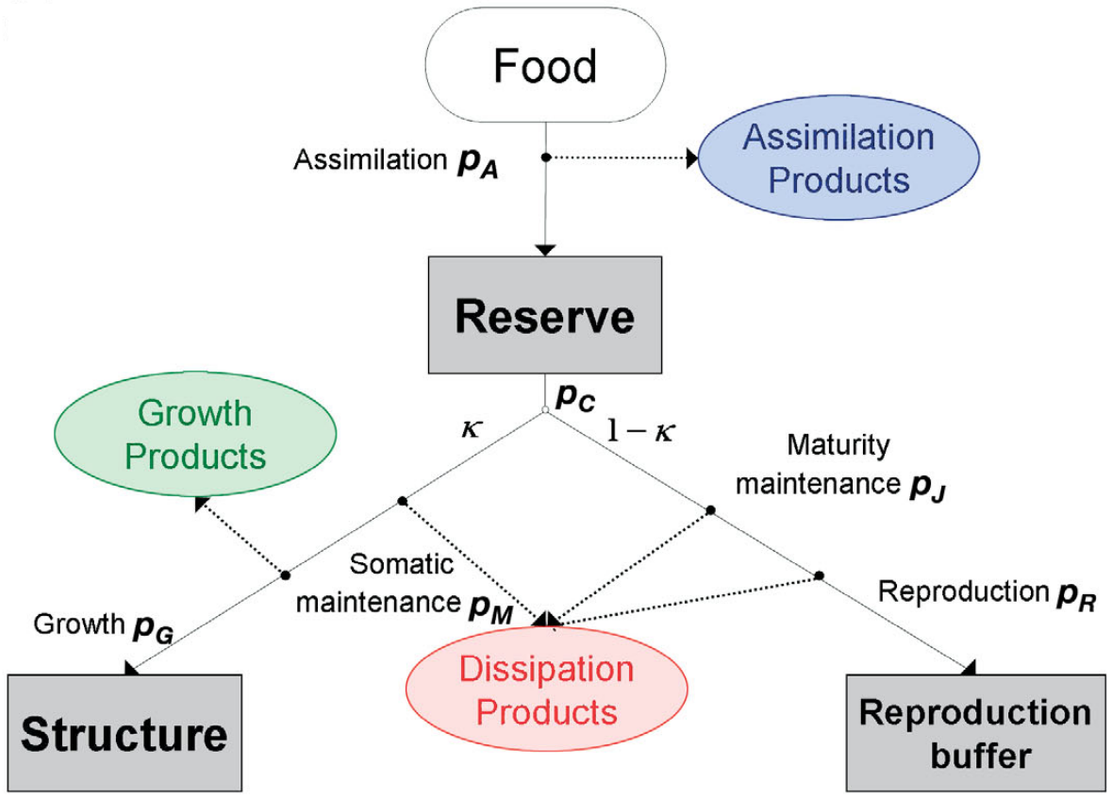
Basic principles of the Evol-DEB model

Submodel : **Bioenergetic**

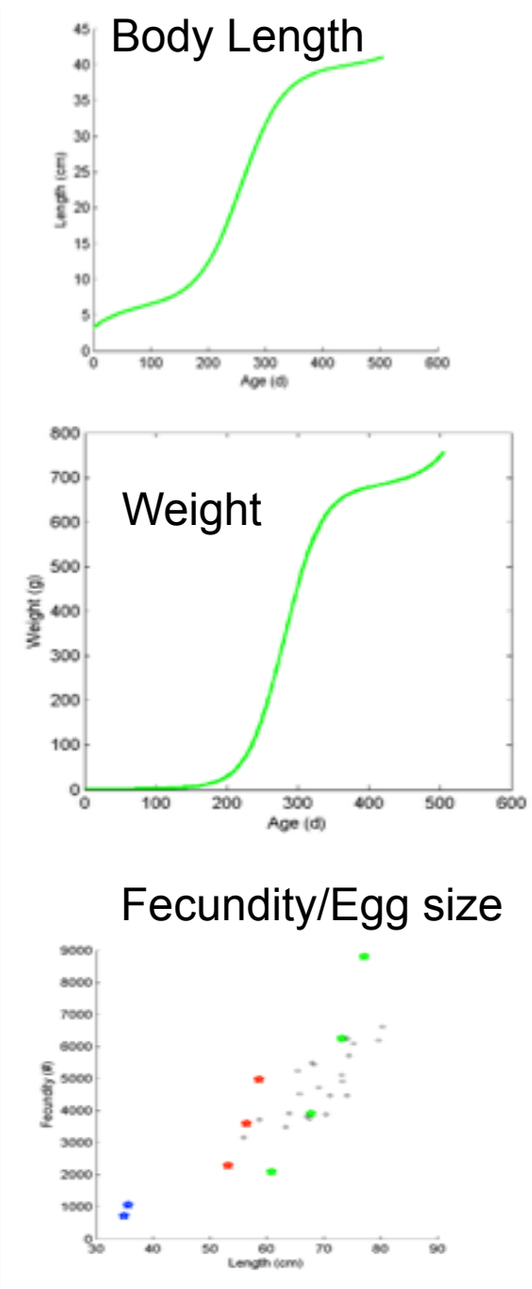
—> The Dynamic Energy Budget (DEB) :



INPUT



DEB MODEL



OUTPUT

Each individual grow and mature according to environnemental conditions

Basic principles of the Evol-DEB model

Submodel : Horizontal movement

- Advection + Swimming

$$\begin{cases} X_{(t+1)} = U_{(x,y,z,t)} \cdot dt + V_{swim_1(t)} \cdot dt \\ Y_{(t+1)} = V_{(x,y,z,t)} \cdot dt + V_{swim_2(t)} \cdot dt \end{cases}$$

- Swimming algorithm: « Kinesis »:
  (~ random walk within the « habitat »)

$$\begin{cases} V_x(t) = f_x + g_x \\ f_x = V_x(t-1) \cdot H_1 \cdot e^{-0.5(\Delta Q/\sigma Q)^2} \\ g_x = \varepsilon_x \cdot (1 - H_2 \cdot e^{-0.5(\Delta Q/\sigma Q)^2}) \end{cases}$$

- Habitat quality index: Trade-off between local mortality and growth index)

$$\begin{cases} Q = \delta + (1\text{-}\delta)G - \delta M \\ \text{G = growth index} \\ \text{M = mortality index} \end{cases}$$

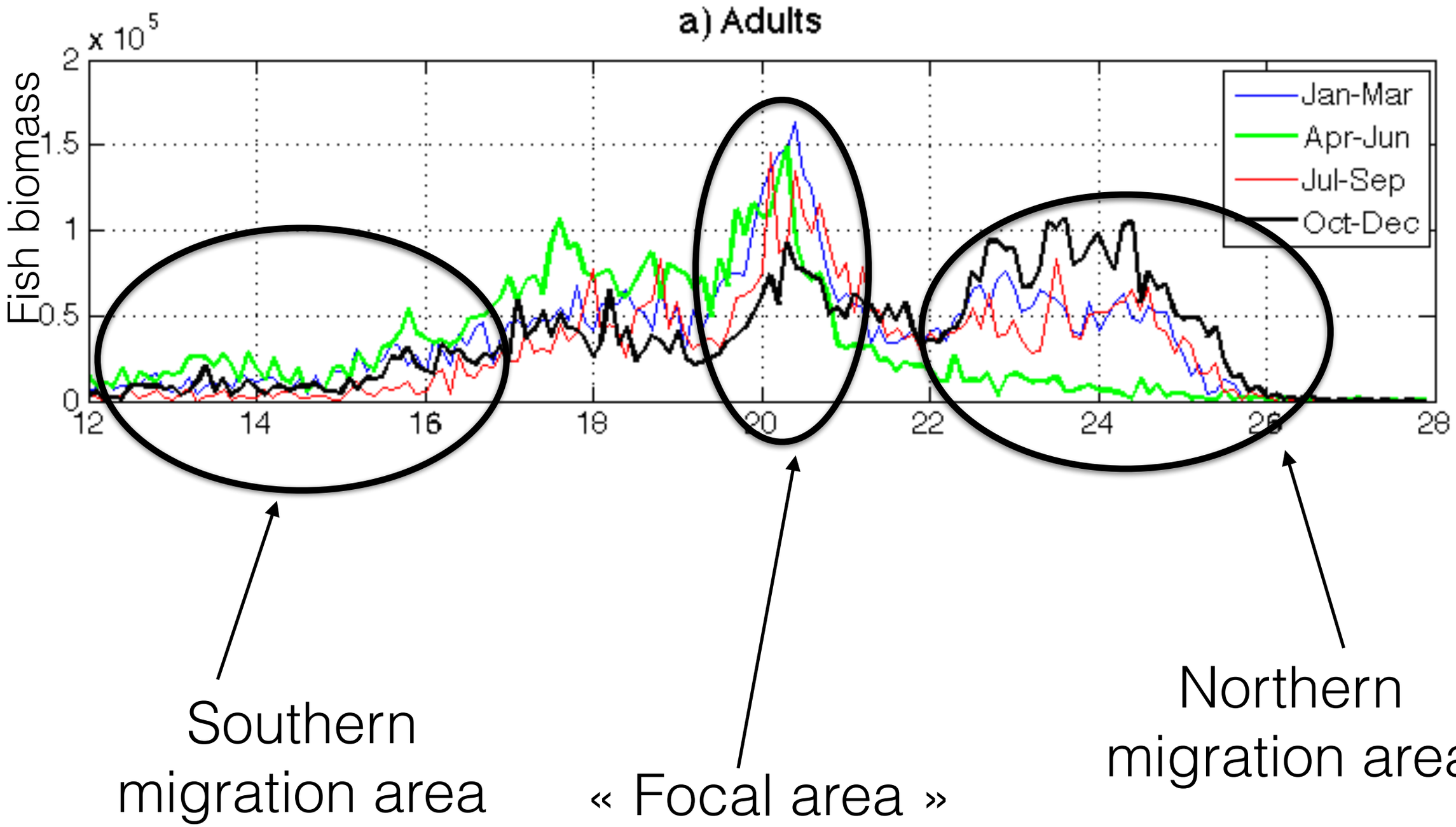
- Growth index: Food x Temperature preference

$$f = \frac{X}{X+X_k} \qquad I_T = e^{-\frac{(T-T_{nat})}{2\sigma^2}}$$

Target Temperature

Emergeant population traits for round sardinella in North-West Africa

Latitudinal population structure



Consistent with the fish landings in Senegal and Mauritania

Emergeant population traits for round sardinella in North-West Africa

Seasonal variability: Model Vs Data

No Data

IMROP CPUE

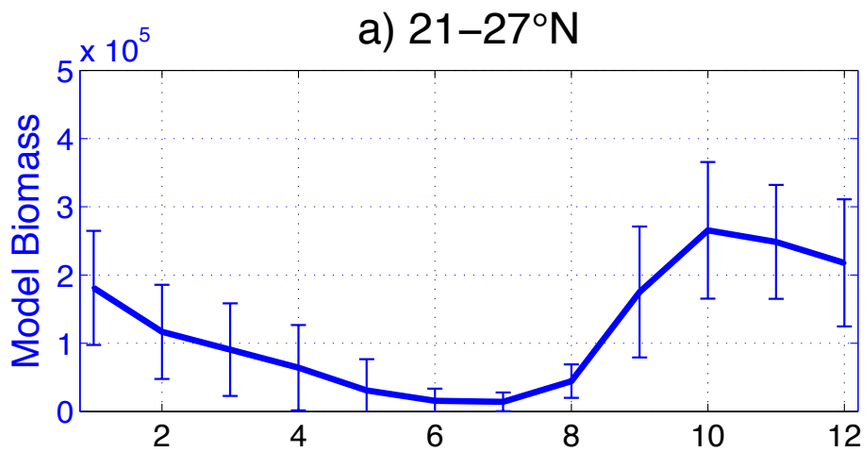
R = 0.8

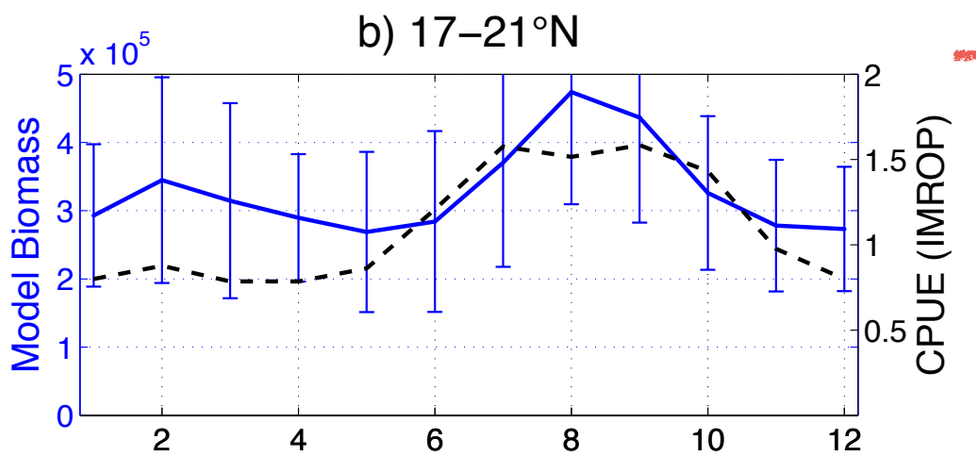
P < 0.005

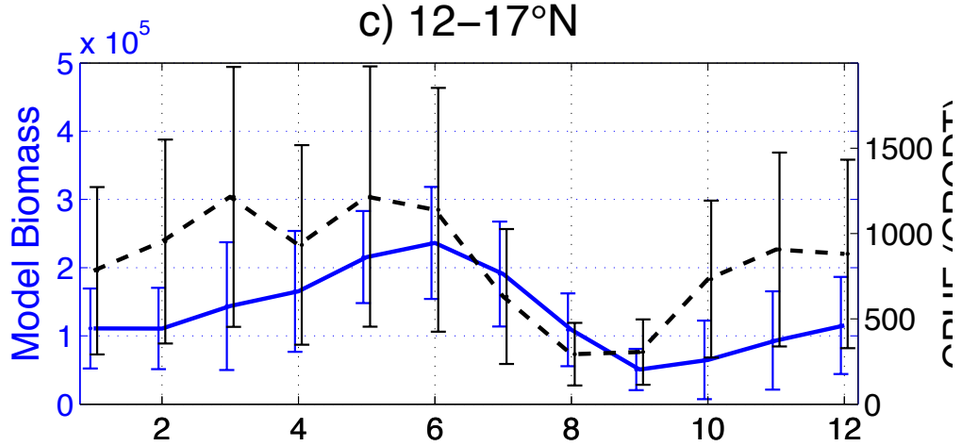
CRODT CPUE

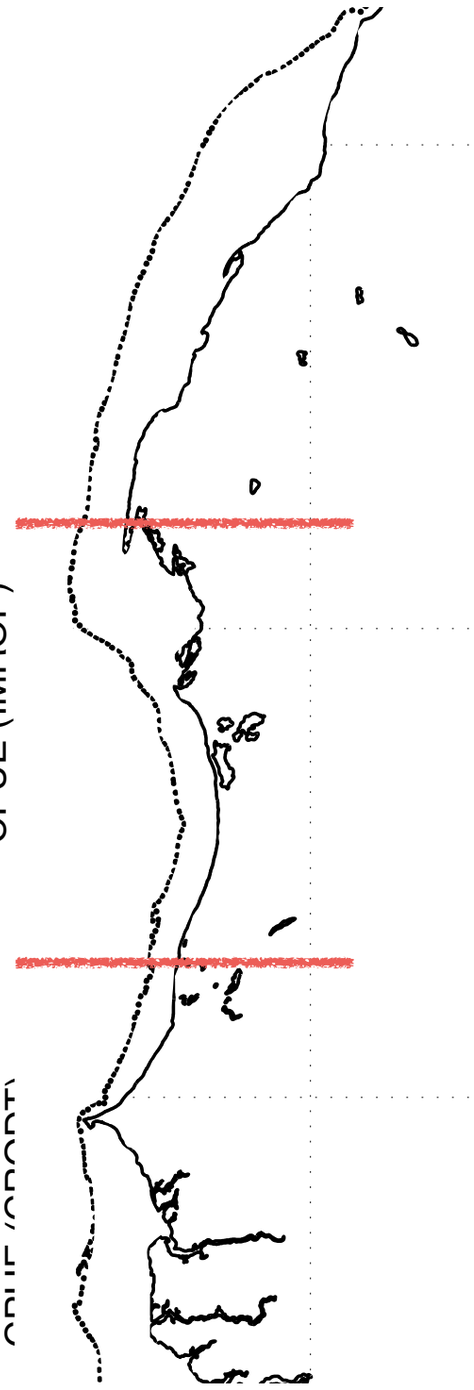
R = 0.6

P < 0.05



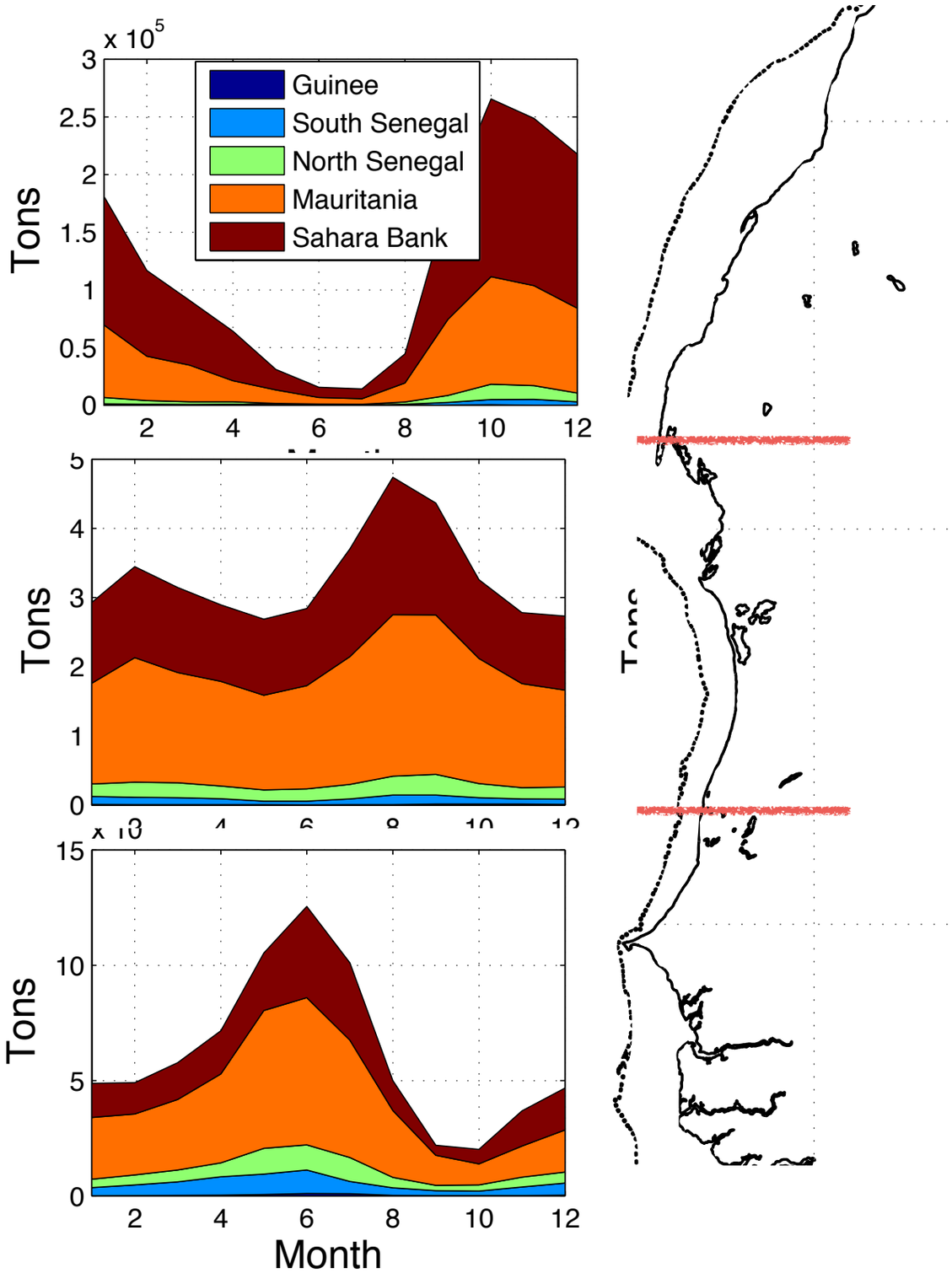






Emergeant population traits for round sardinella in North-West Africa

Seasonal variability: contribution of each area (Model)



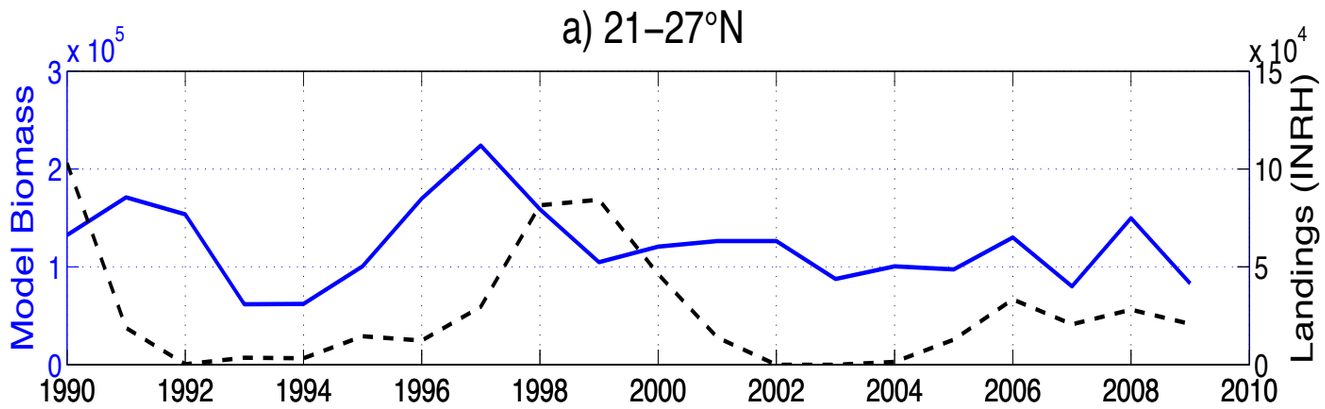
Emergeant population traits for round sardinella in North-West Africa

Inter annual variability: Model Vs Data

INRH Landings

R = 0.4

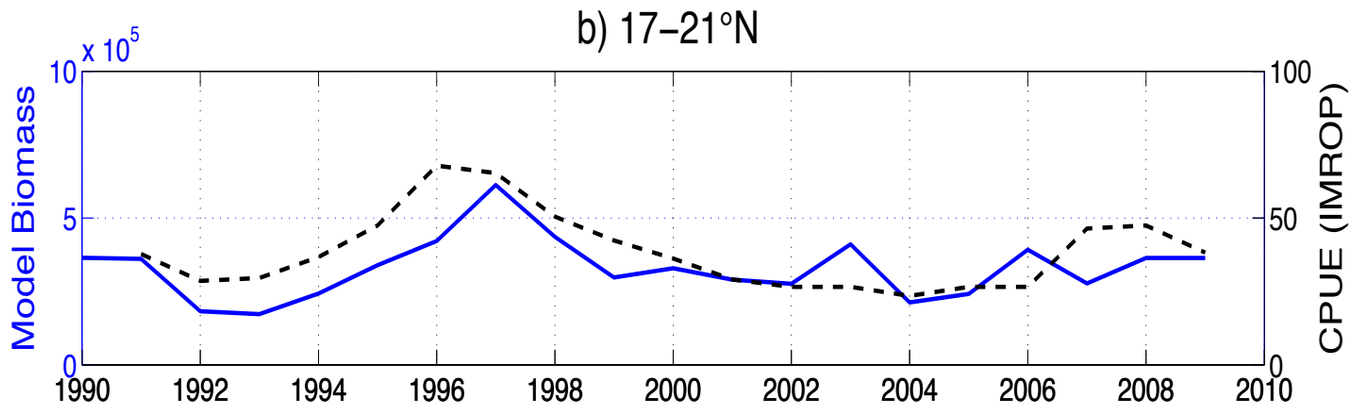
Lag = -2



IMROP CPUE

R = 0.7

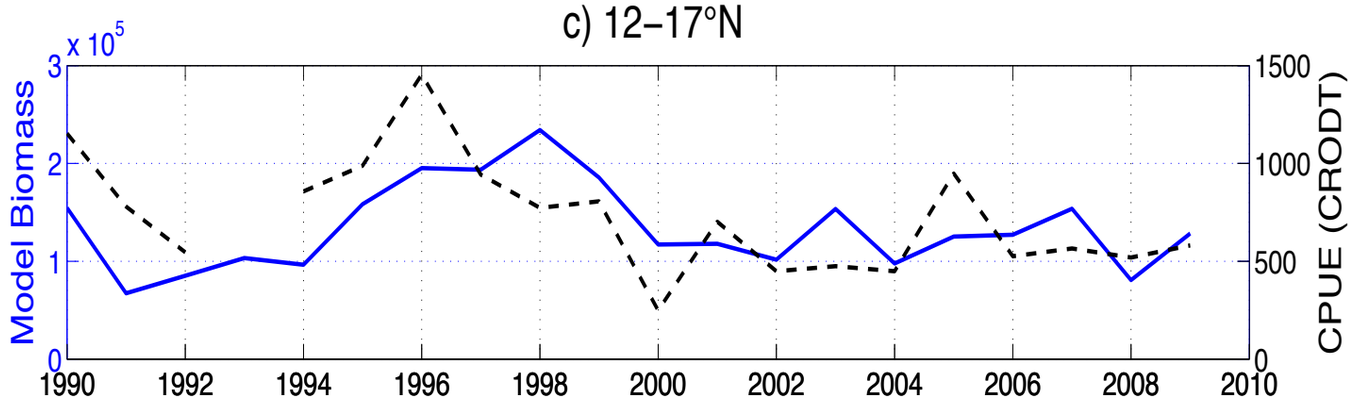
P < 0.005

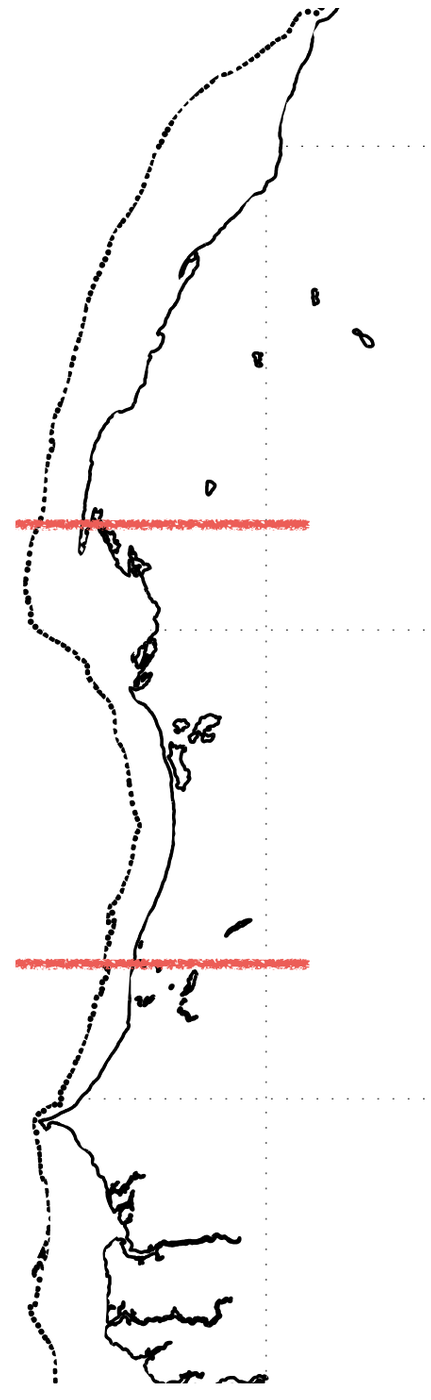


CRODT CPUE

R = 0.5

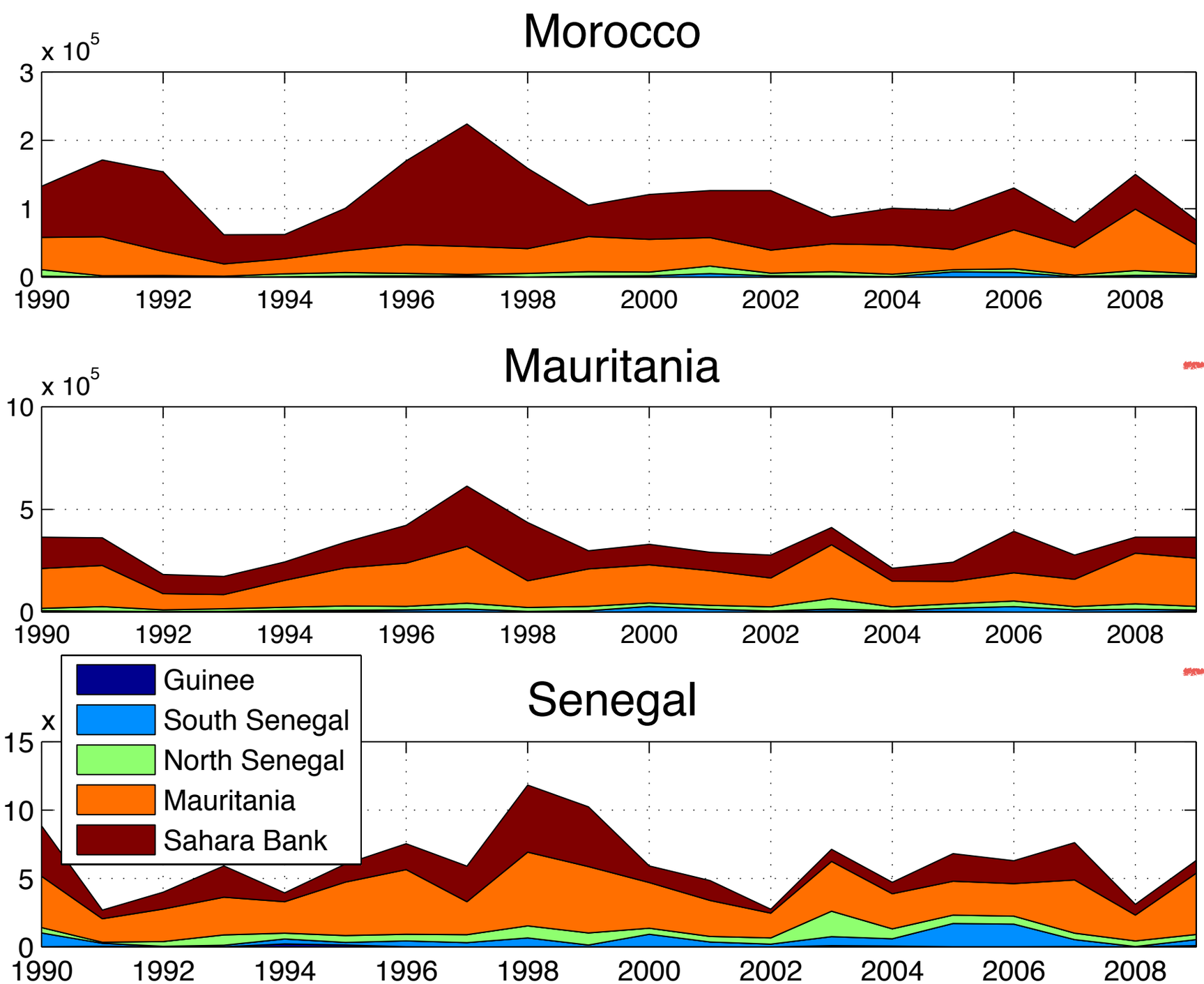
P < 0.05

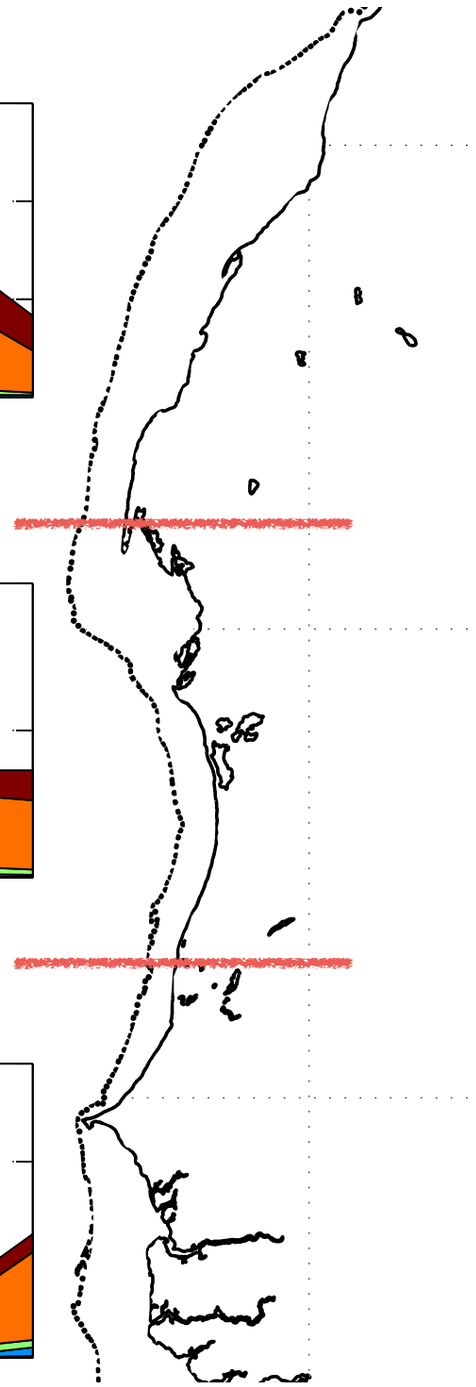




Emergeant population traits for round sardinella in North-West Africa

Inter annual variability: contribution of each area (Model)





Model Processes responsible for the population traits

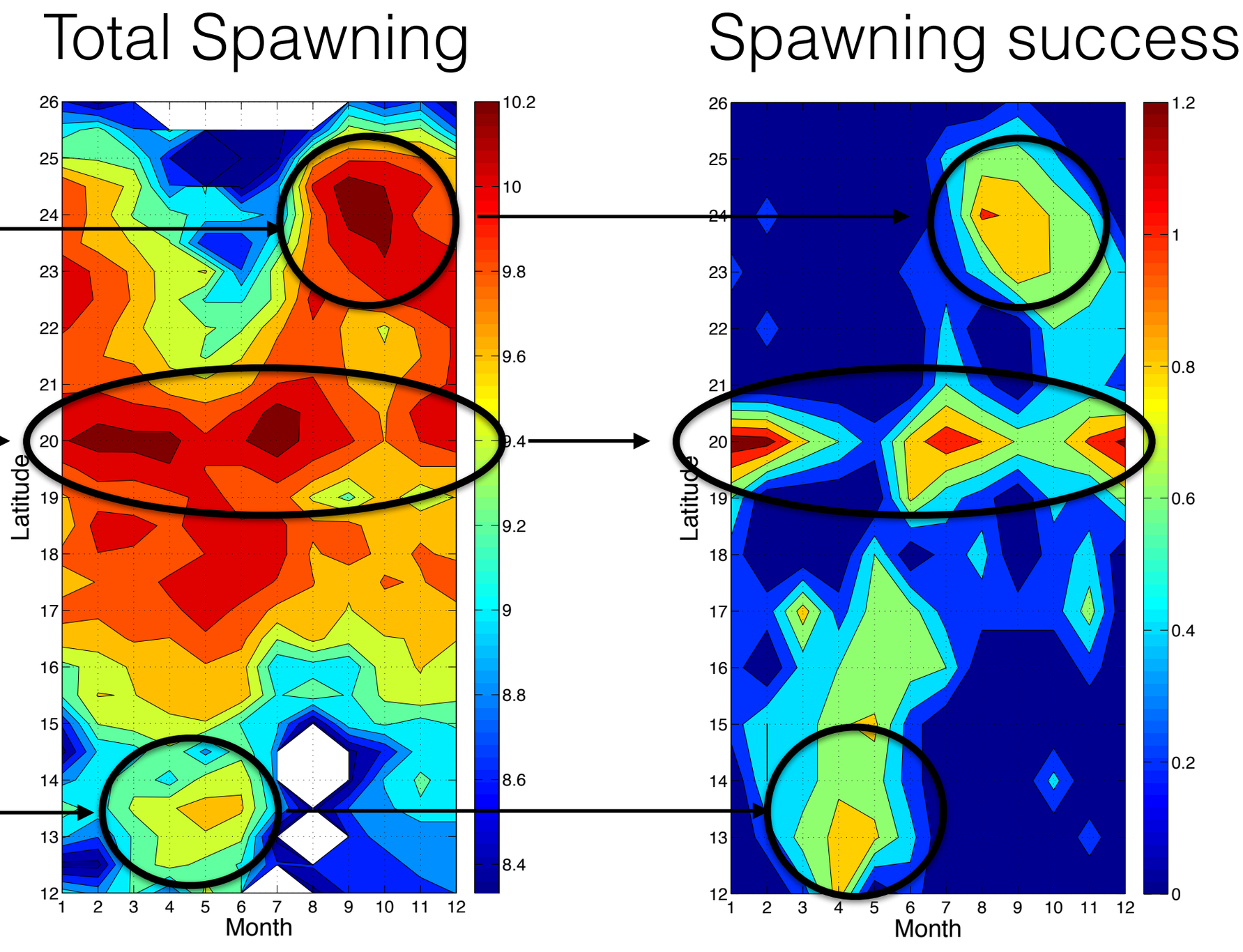
Larval retention patterns

3 main nursery area:

Sahara Banc
Oct-Nov

Banc d'Arguin
~all year

Southern Senegal
~ March-May



Model Processes responsible for the population traits

Coastal Current Advection

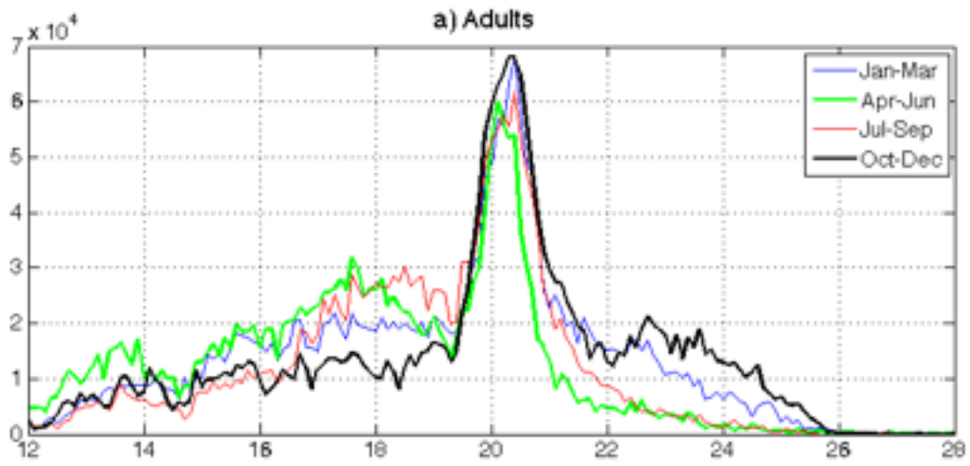
Canary current (Upwelling jet)—> shift population southward

Mauritanian current—> shift population northward

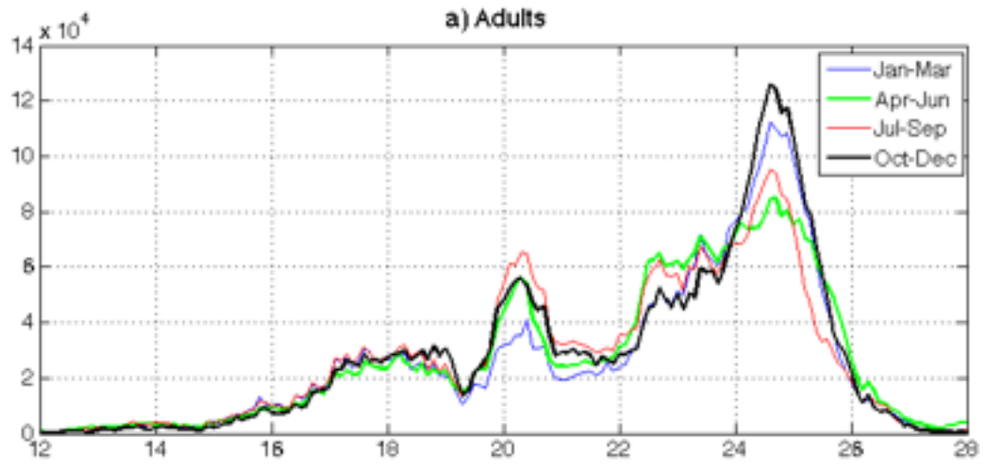
Sensitivity test 1:

Removing the advection component on individual movement

—> shift the focal area



With advection



Without advection (IFD)

Model Processes responsible for the population traits

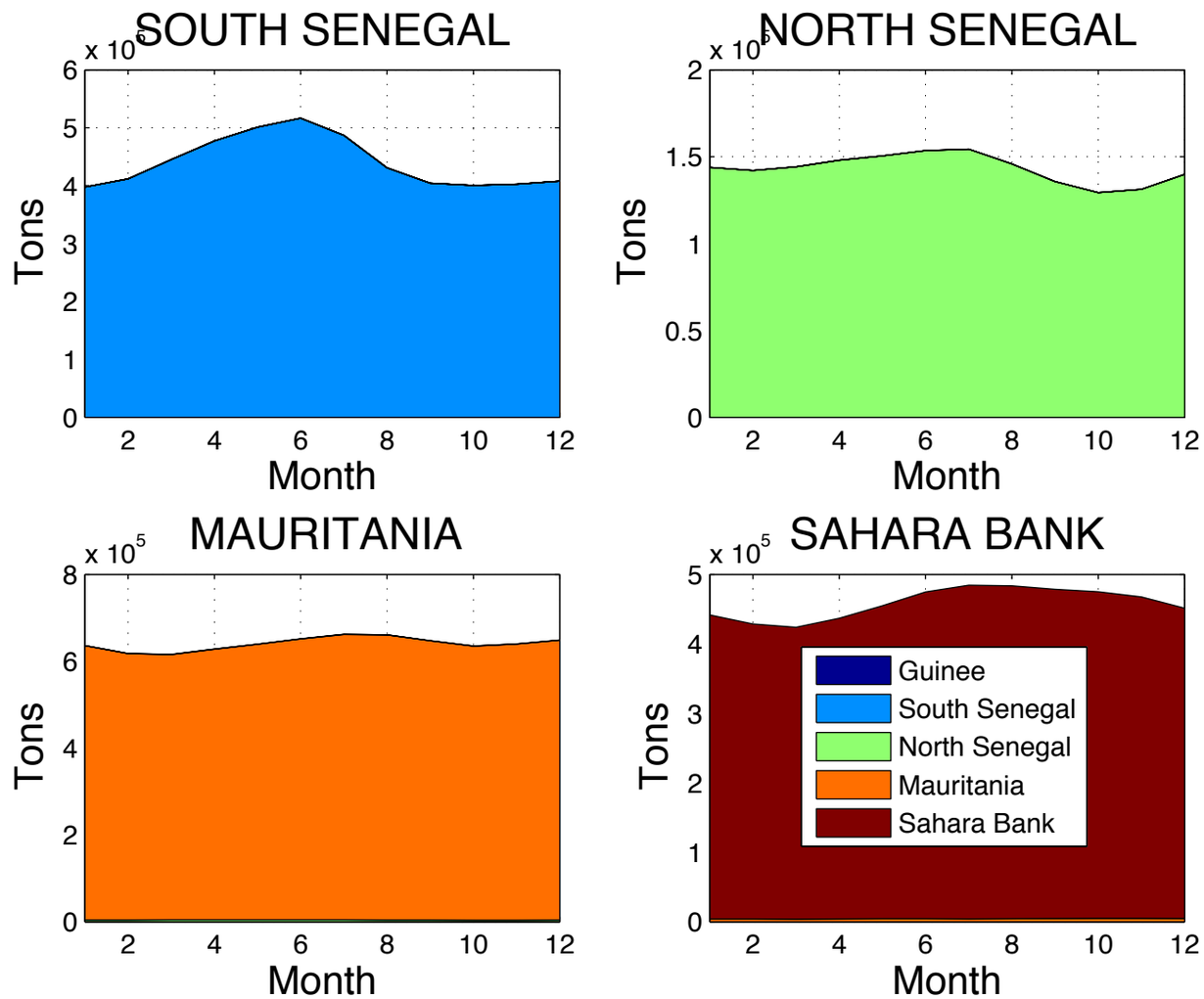
Coastal Current Advection Vs Swimming Behavior

Sensitivity test 2:

No Advection -
Neutral swimming behavior

(Habitat = continental shelf,
whatever temperature and food)

—> No migration
—> Variability = Recruitment



Model Processes responsible for the population traits

Coastal Current Advection Vs Swimming Behavior

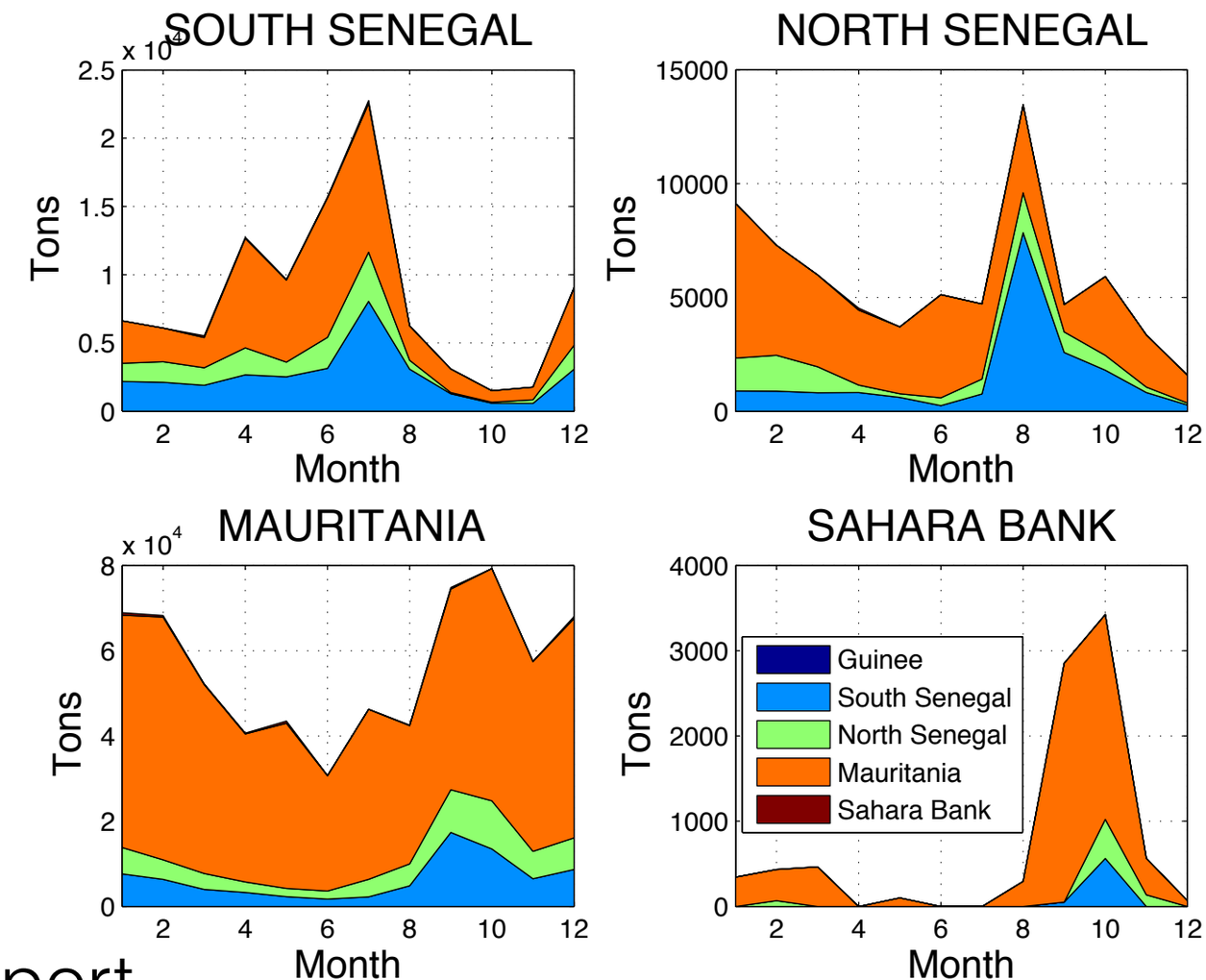
Sensitivity test 3: Neutral swimming behavior + Current advection

(Habitat = continental shelf, whatever temperature and food)

—> Transport Mauritania to Senegal month 4-7, opposite 9-11

—> Sardinella expelled from Sahara Bank

—> Variability = Recruitment+transport



Model Processes responsible for the population traits

Coastal Current Advection Vs Swimming Behavior

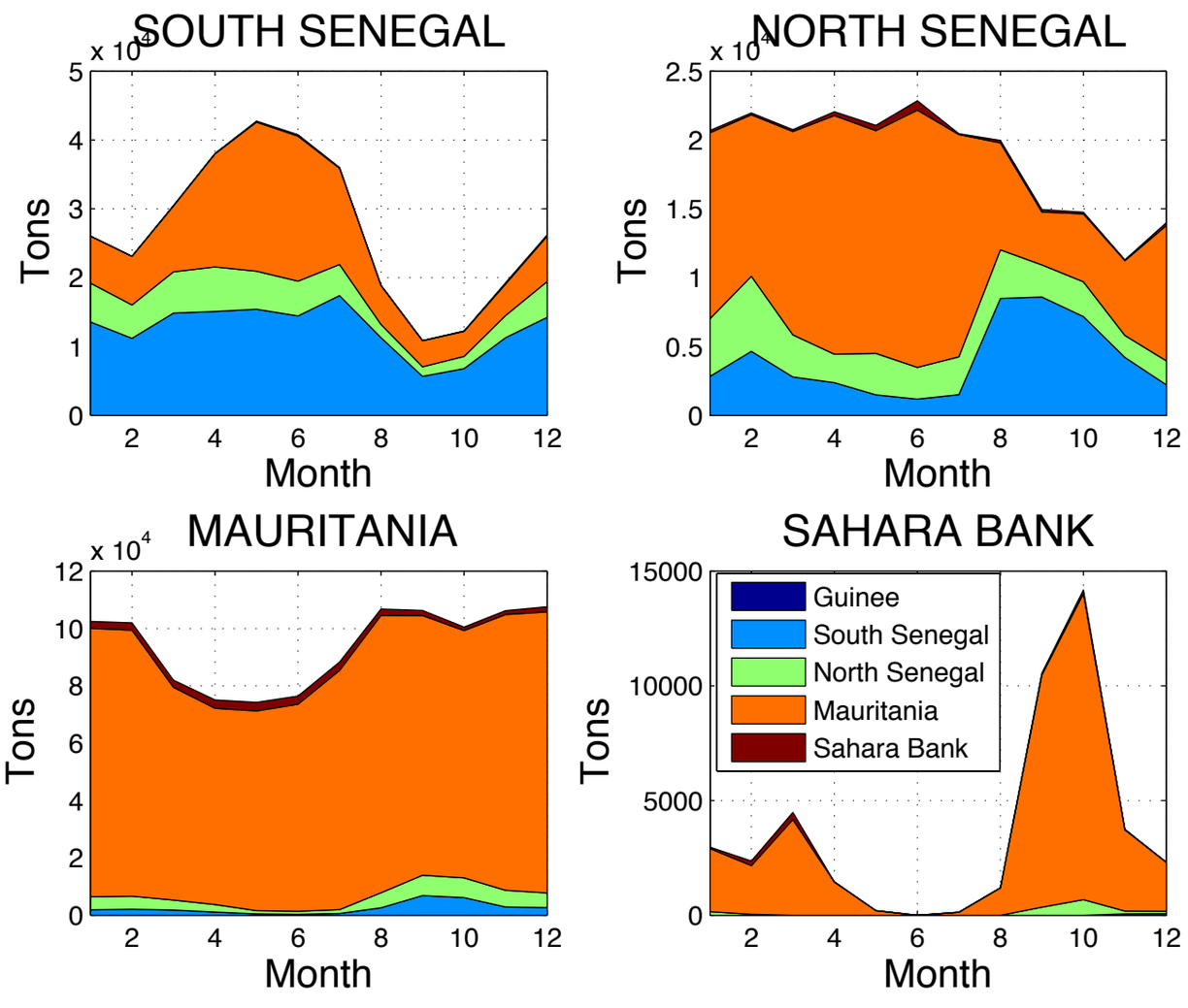
Sensitivity test 4:

Active swimming behavior
+ Current advection

(Habitat = continental shelf with food)

Seek for high food plankton concentrations
—> upstream movement

—> Seek for food = increased presence in Sahara Banc



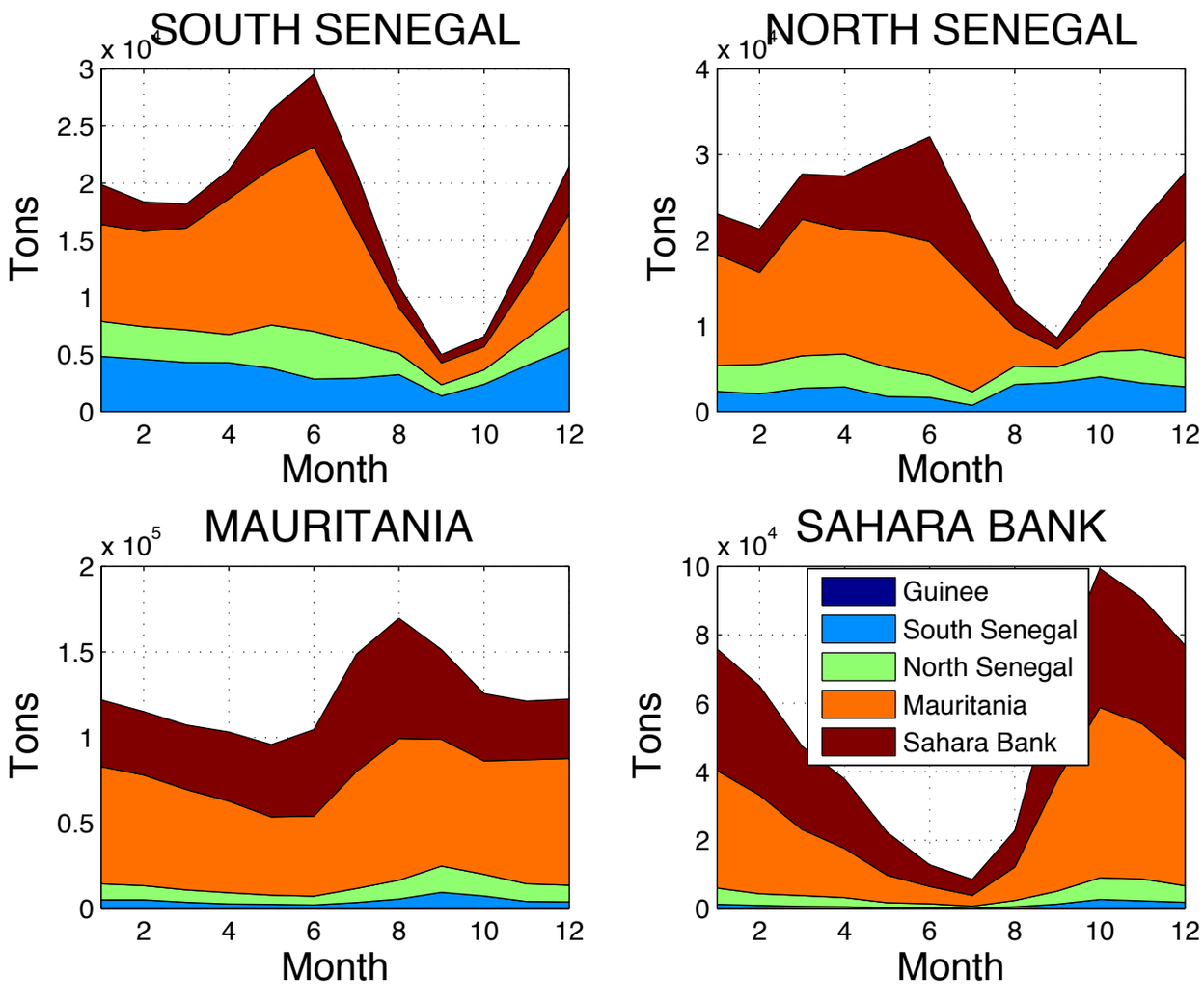
Model Processes responsible for the population traits

Coastal Current Advection Vs Swimming Behavior

Sensitivity test 4: Active swimming behavior + Current advection

Seek for natal temperature ranges

—> Spawning on Sahara Bank

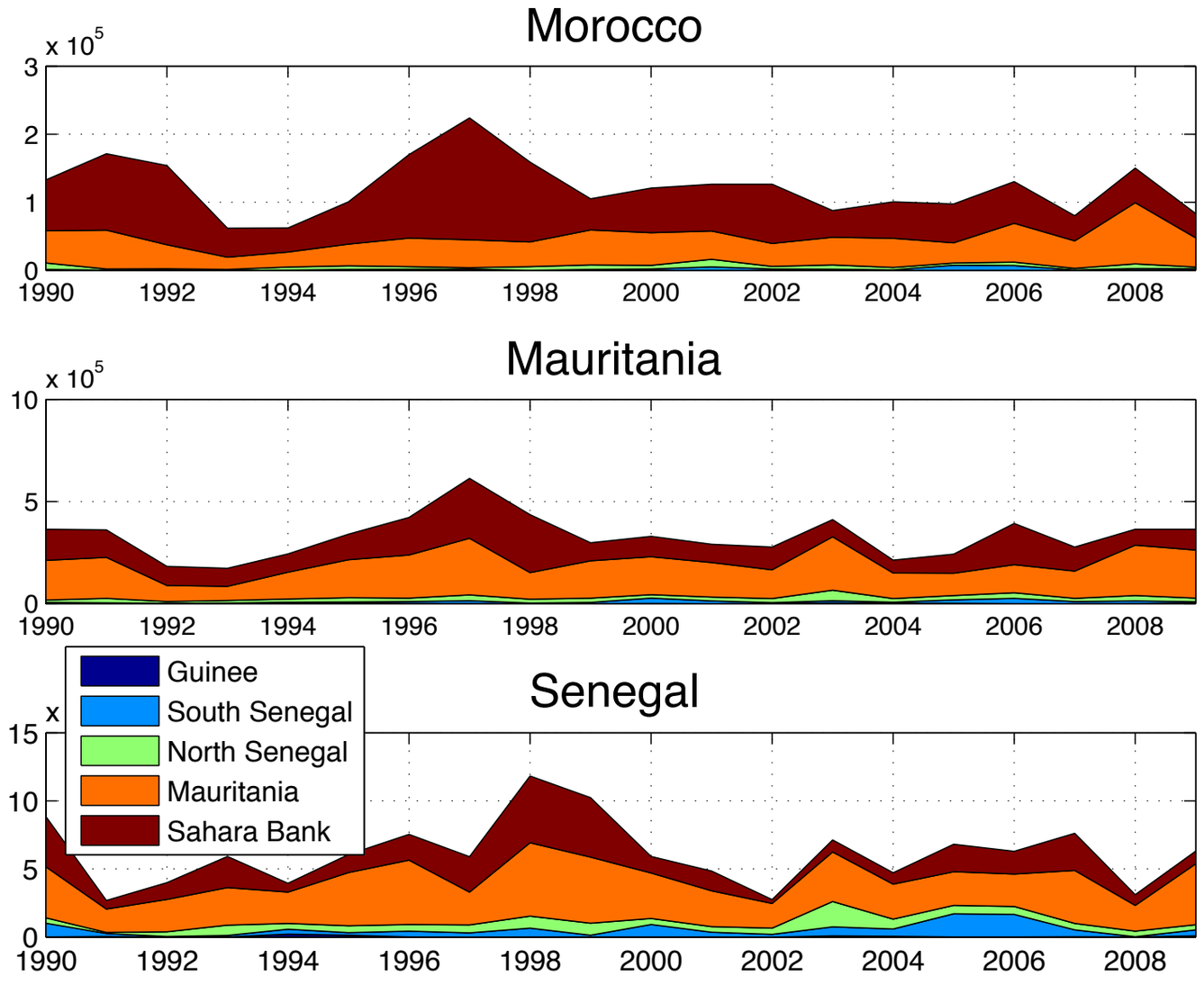


Model Processes responsible for the population traits

Coastal Current Advection Vs Swimming Behavior

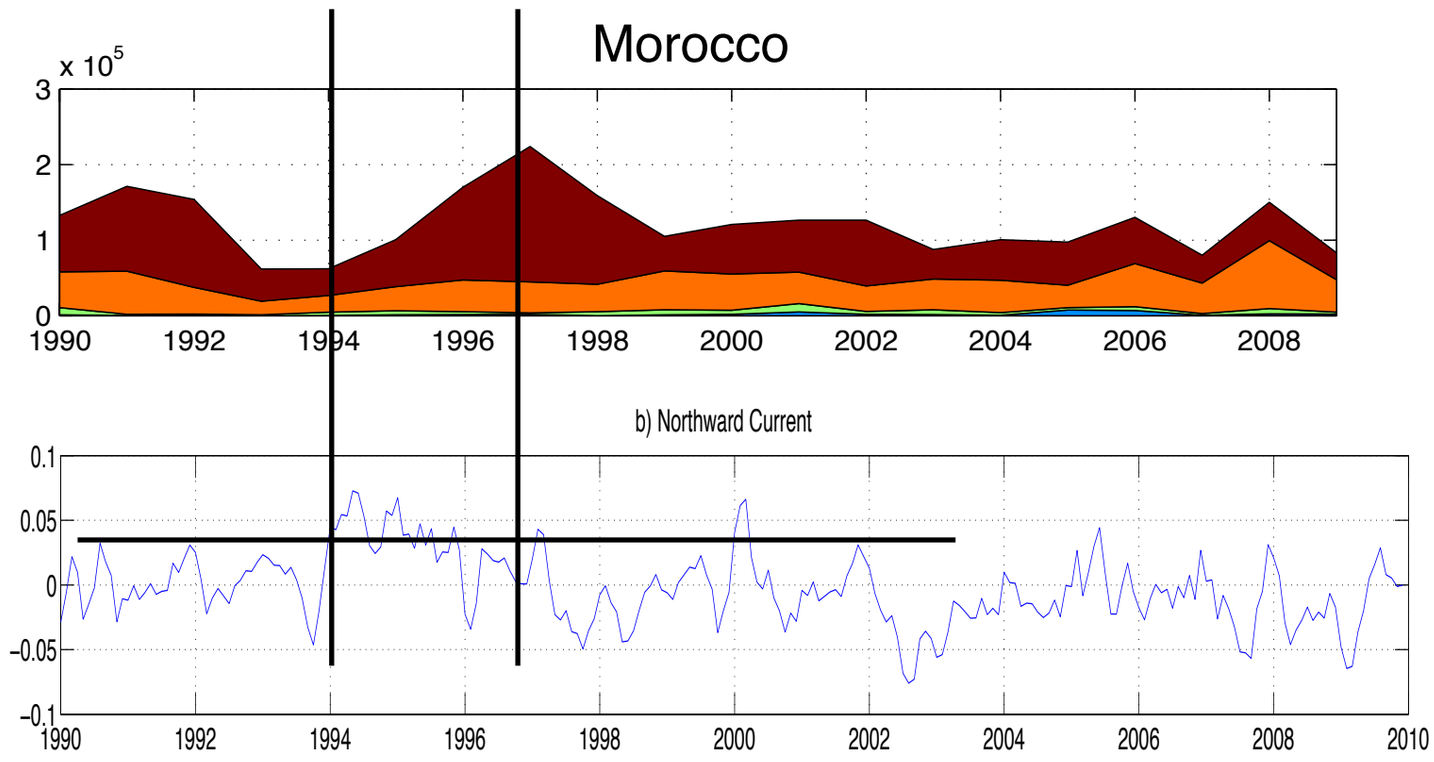
Sensitivity test 4:

—> inter-annual variability due to variable size of the « home population » of the Sahara Banc



Model Processes responsible for the population traits

Coastal Current Advection Vs Swimming Behavior

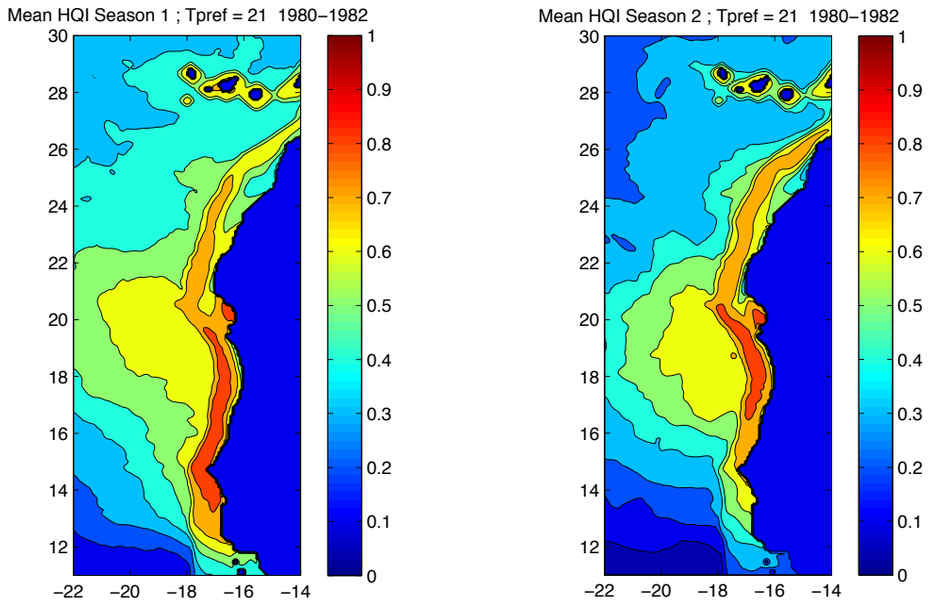


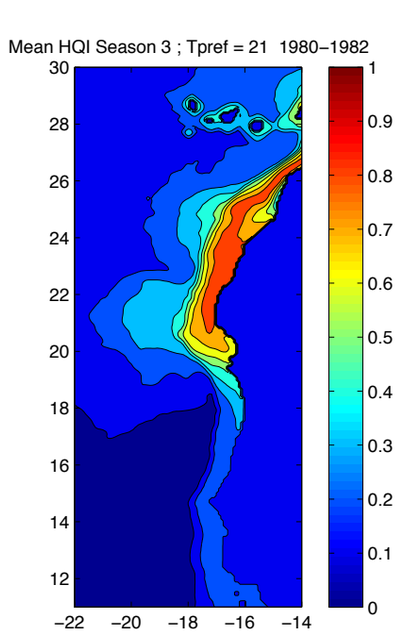
—> Weakening of the southward upwelling jet in 1994

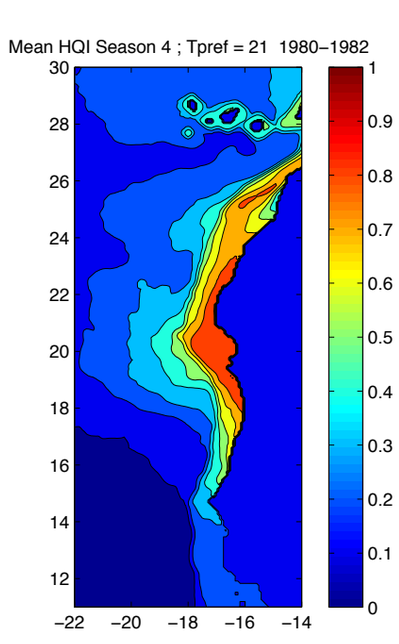
—> Increasing reproduction on the Sahara Banc

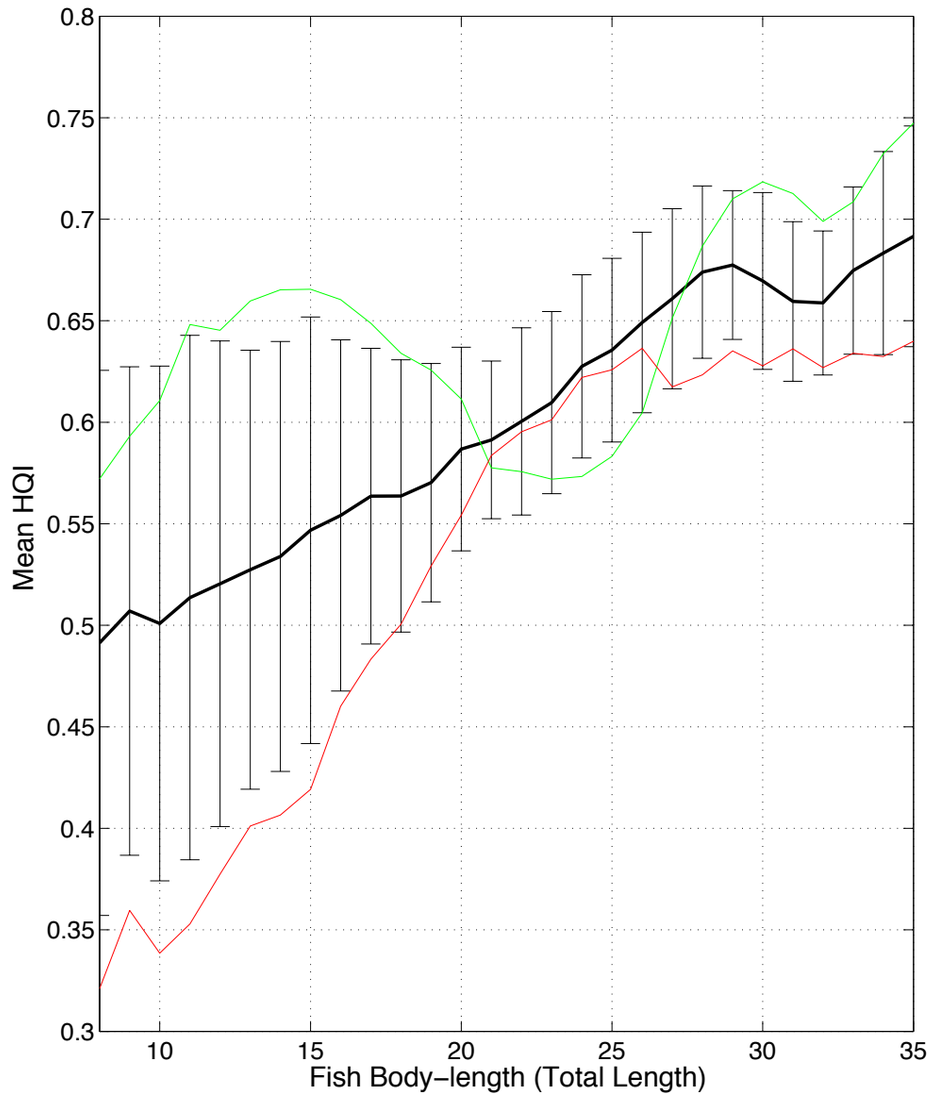
Model Processes responsible for the population traits

Sahara Banc: good habitat but difficult to reach because of current





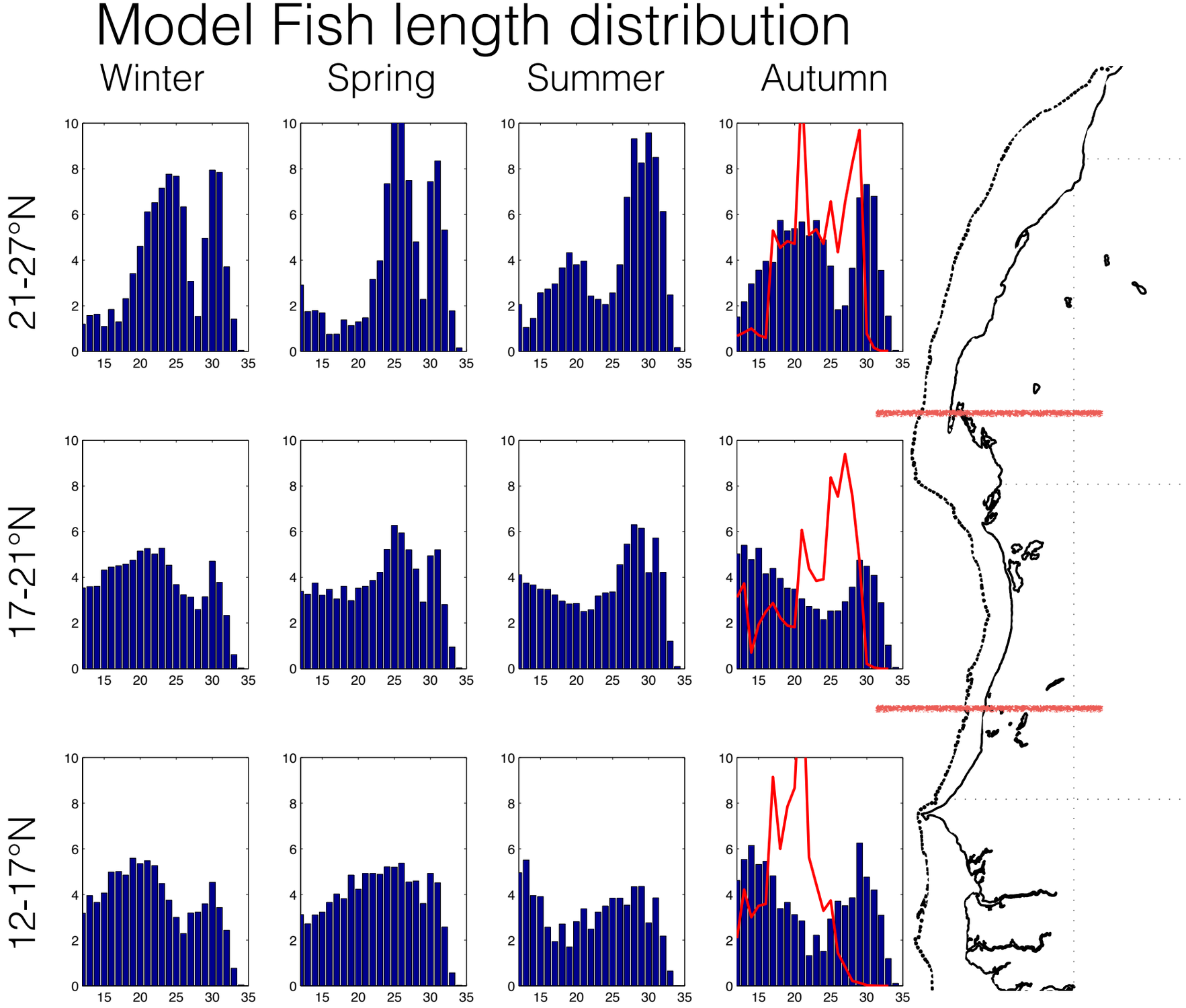




Larger individuals perform better in reaching preferred habitat

Emergeant population traits for round sardinella in North-West Africa

Coastal Current Advection Vs Swimming Behavior



—> Bigger fish are better swimmer, thus more present in the north

Processes responsible for the population traits

Summary
3 main processes in interaction:

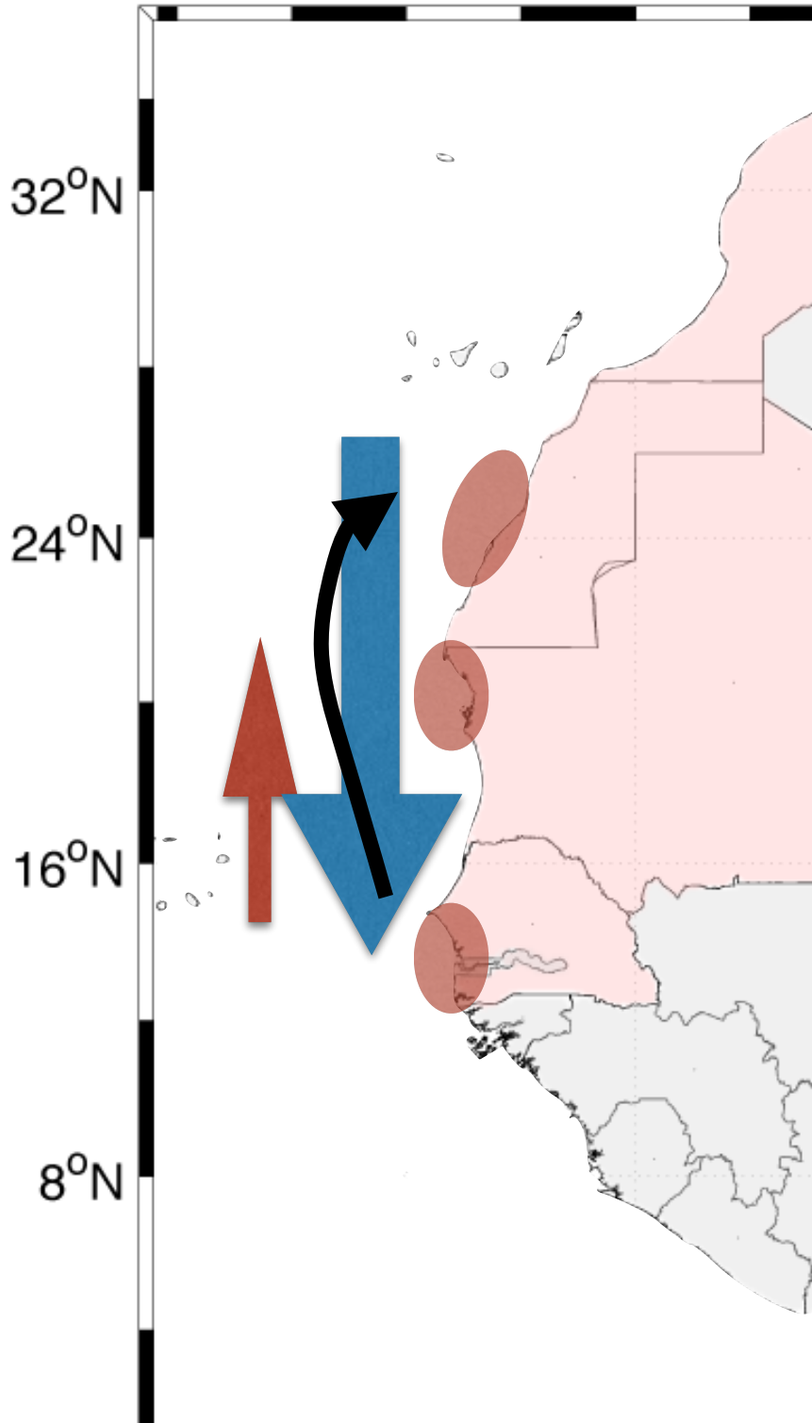
1) Larval retention patterns
—> recruitment

2) Coastal current advection
—> latitudinal shift

Summer Winter

3) Swimming behavior
—> Target Habitat Quality
—> Spatial size pattern

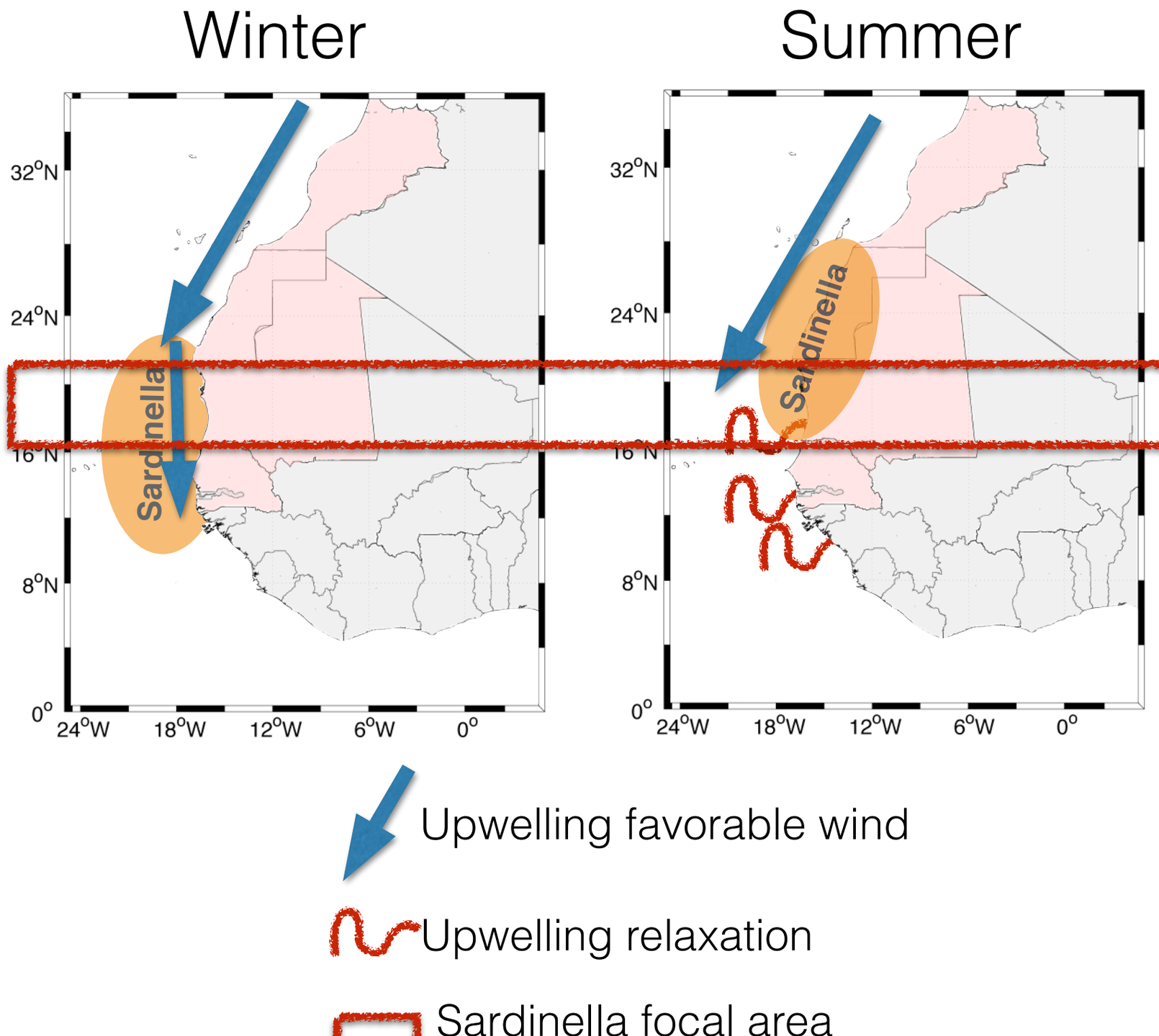
Summer



Effect of Climate change on Sardinella in the Canary Current

Current Model

- Focal area ~ 17-21°N (Permanent upwelling area)
- Summer: —> 27°N (except if upwelling too strong)
- Winter —> 10°S



Effect of Climate change on Sardinella in the Canary Current

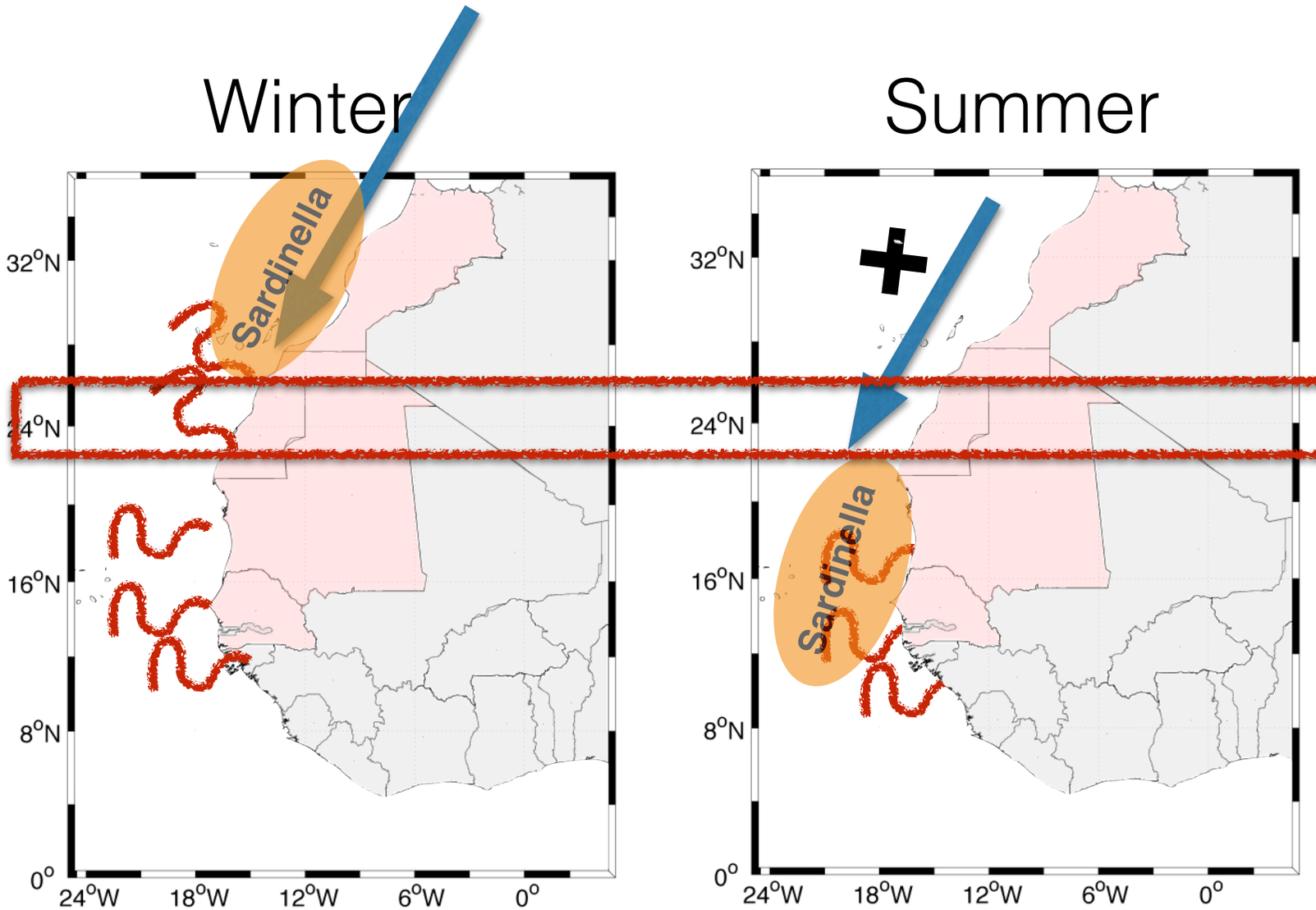
IPCC AR5:

- Intensification of upwelling winds in the poleward portion of the CUS in summer

- Intensification of subtropical anticyclone

—> Northward shift of the permanent upwelling area?

- —> If the northward shift of permanent upwelling area exceed ~4°, the focal area off Mauritania might disappear



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Mali
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Sénégal
Banjul
Gambie
Guinée Bissau
Bissau
Bamako
Niamey
Ouagadougou
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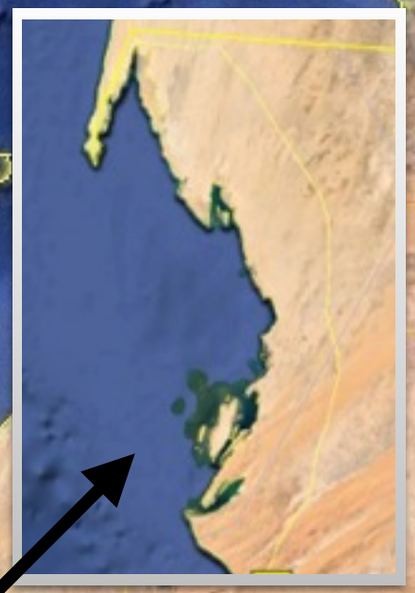
Benin
Guinée
Conakry
Freetown
Sierra Leone
Togo
Côte d'Ivoire
Abuja
Nigeria



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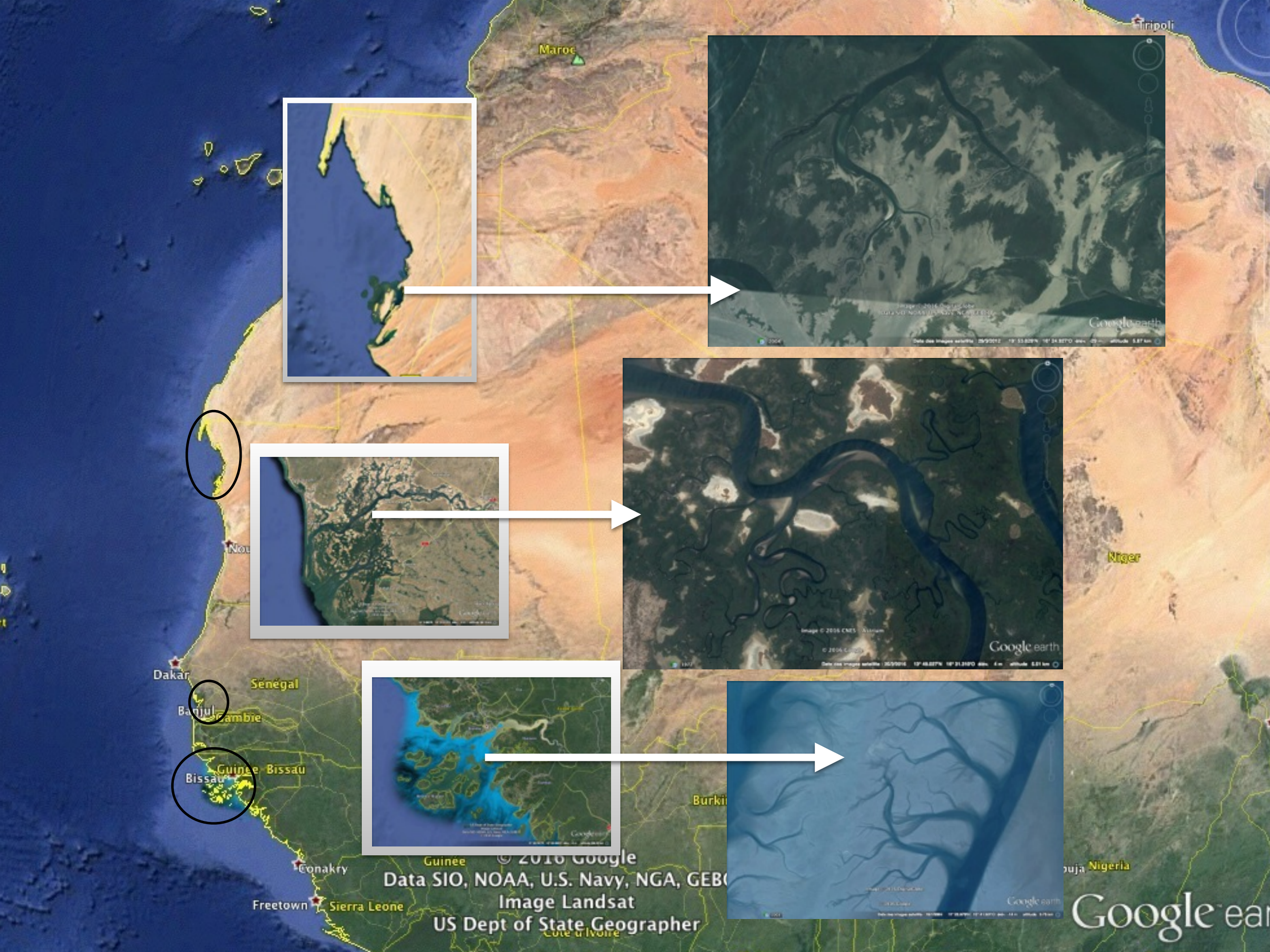
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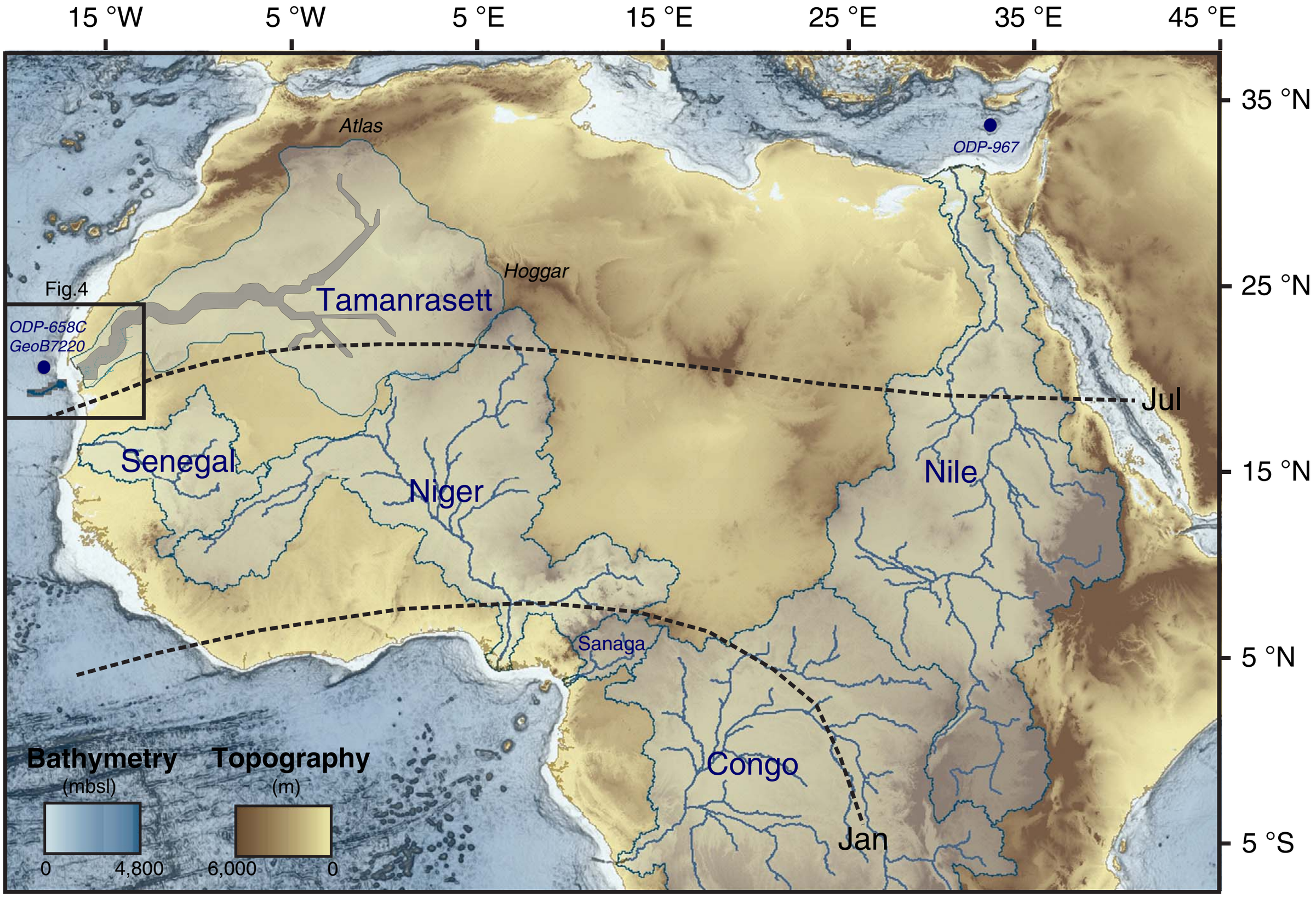
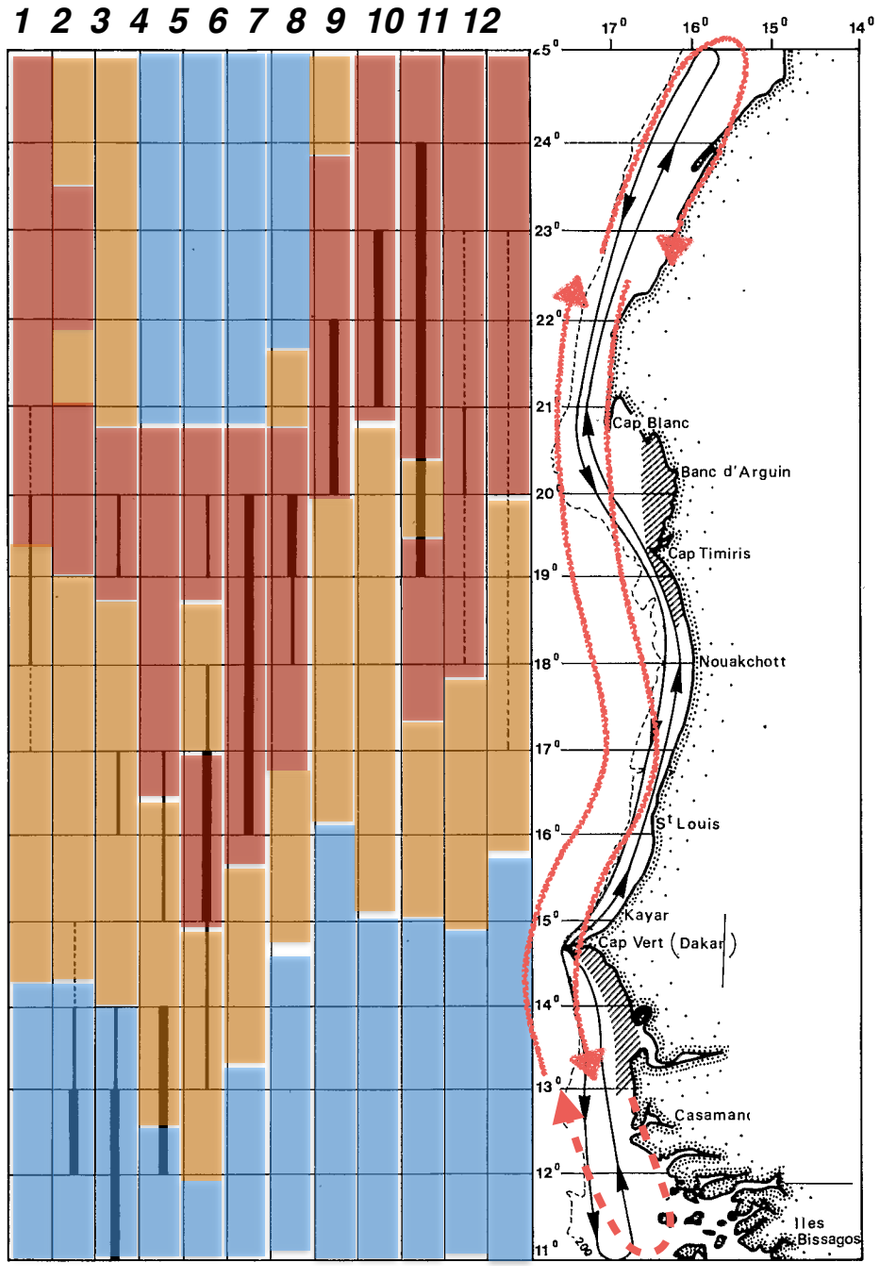
African humid periods triggered the reactivation of a large river system in Western Sahara

Skonieczny et al., 2015



a) Historical Vs Model migration scheme



Mean seasonal fish concentration (Historical/Model)

Low Medium High

Historical hypothesis for adult seasonal trajectory:

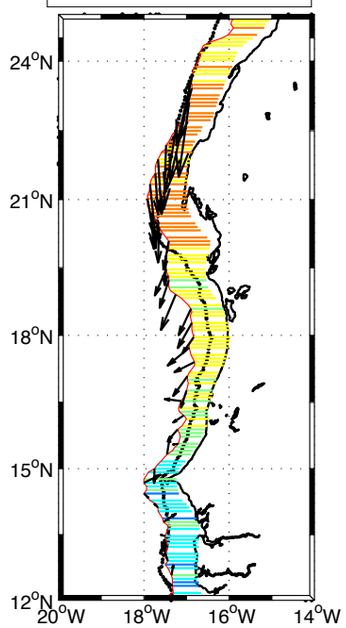
(Boely et al. 1979)

(Corten et al. 2012)

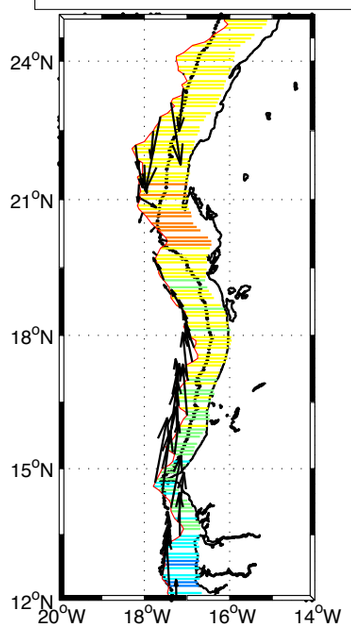
Nursery

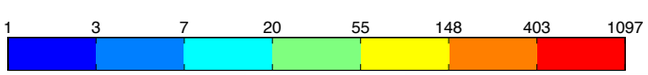
b) Model migration steps and LEK seasons

b.1) « Noor » *(Months 1-4)*

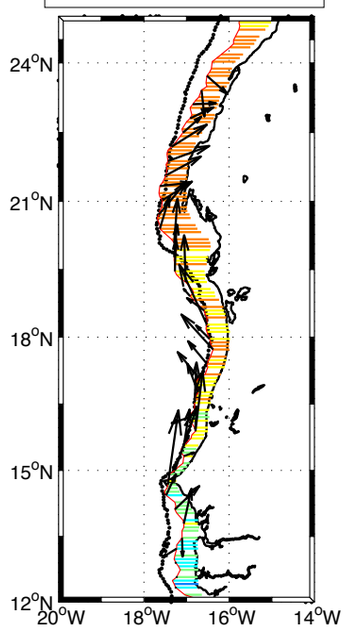


b.2) « Cooroon » *(Months 5-6)*

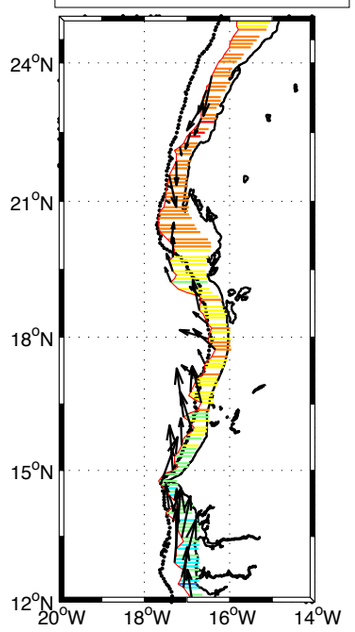




b.3) « Nawet » *(Months 7-10)*



b.4) « Lolli » *(Months 11-12)*



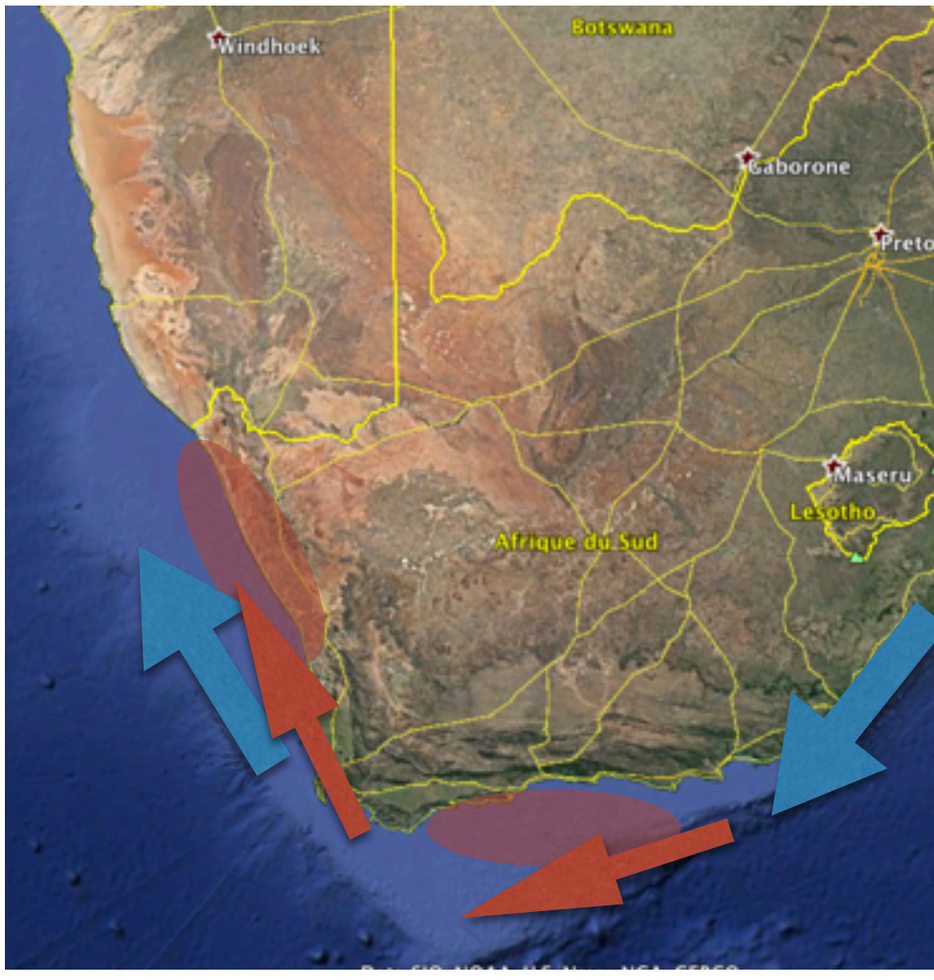
Average direction of fish movement (Model)

Looking at others EBUS small pelagic fish

1) Larval retention

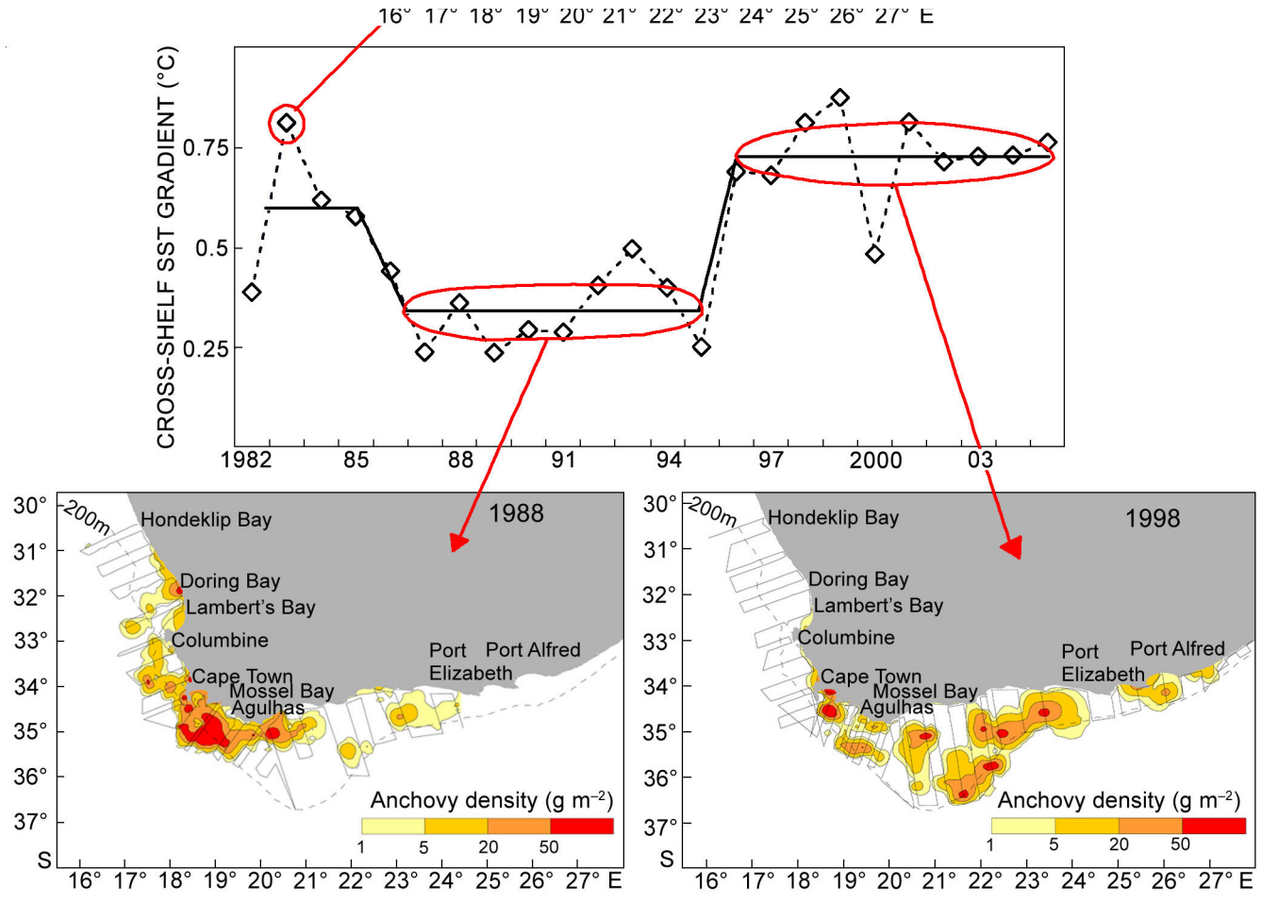
2) Coastal current advection

3) Swimming behavior



Looking at others EBUS small pelagic fish

Southern Benguela



Roy et al., 2007