Spatial population dynamics of round sardinella off North-West Africa

Emergent patterns from interactions between turbulent environment and individual behaviors in an Eastern-Boundary Upwelling System

Timothee Brochier
Pierre-Amaël Auger,
Laure Pecquerie, Eric Machu, Xavier Capet,
Modou Thiaw, Baye Cheikh Mbaye, Cheikh-Baye Braham,
Omar Ettahiri, Najib Charouki, Patrice Brehmer

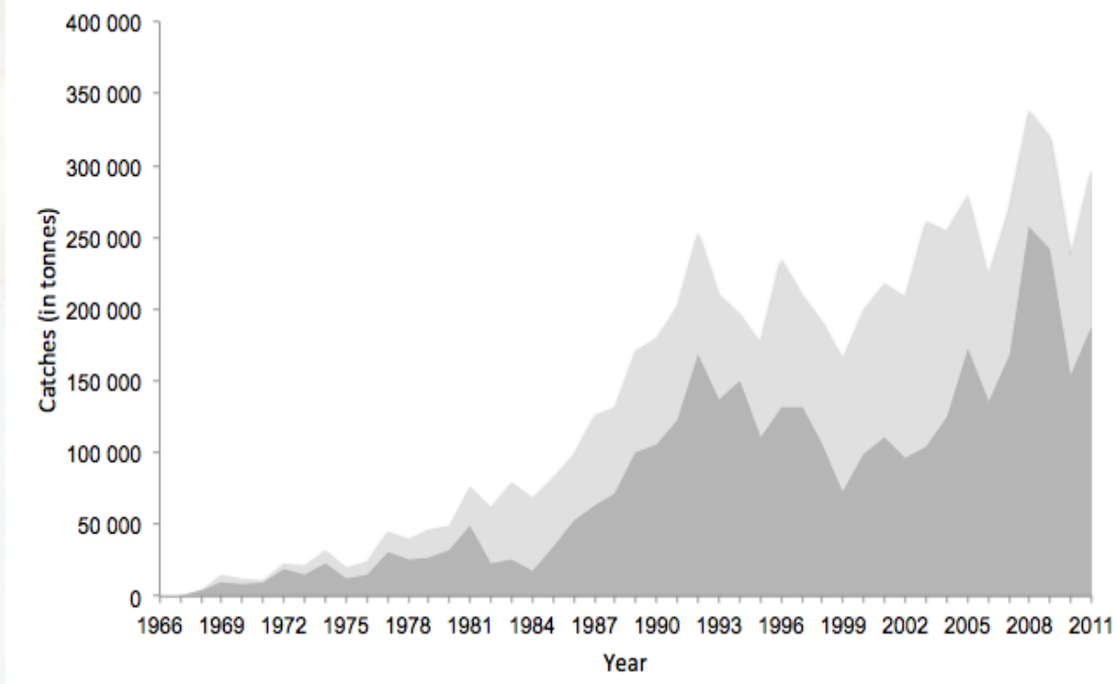
Context: Round sardinella in North West Africa

- Key species for regional food security
  (Failler, 2014)

- Support large fisheries
  (~70% of total Senegalese landings;
  ~80% of SPF landings in Mauritania
  (Braham et al., 2014, Thiaw et al., in press)

- Increasing landings
  + EU fishing
  agreements, illegal fishing

- Transboundary migrations



Source: Fishbase.org

→ Need for regional management

Research question: Do we understand the spatial dynamics of the population?

Objective and approach

Objective

- To developp a **mechanistic model** to explore the **different drivers** of the *Sardinella aurita* **migrations**

Modelling approach: EVOL-DEB model

- **Multi-disciplinary team**: physics, biogeochemistry, bioenergetics, fisheries biology, social sciences (artisanal fishermen knowledge)

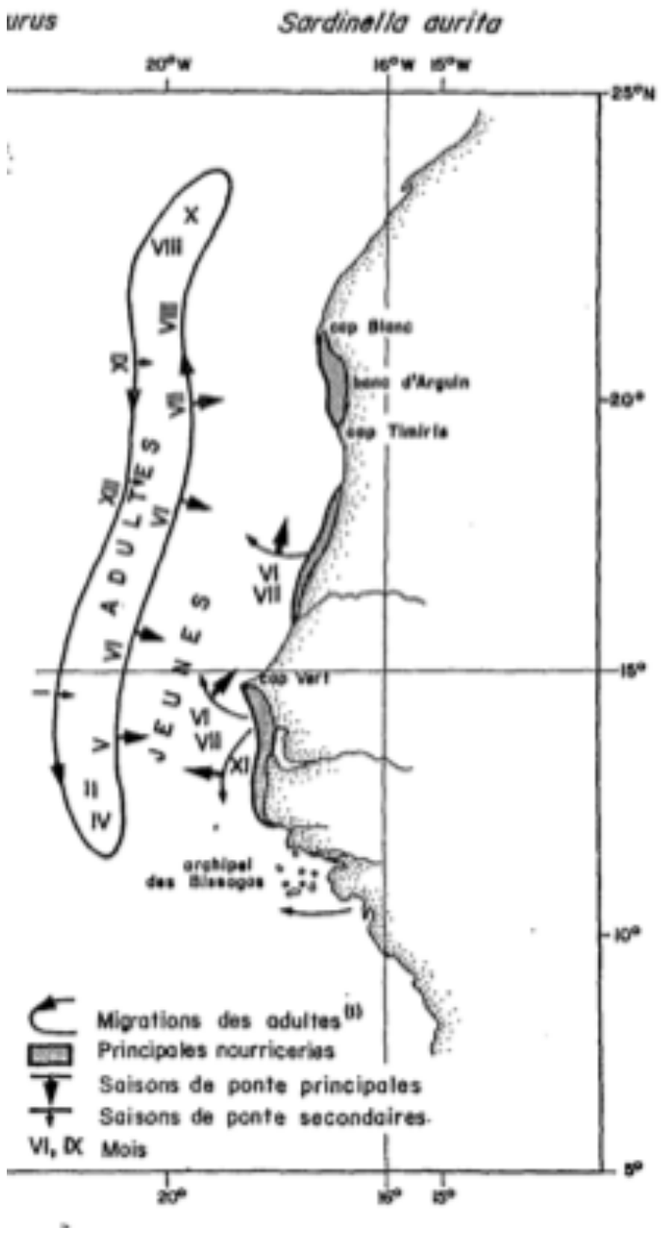
- **IBM approach**: Mechanisms at the individual level → emergent patterns at the population level

- Environment model (physics/biogeoxhemistry) provides **forcing variables** (**currents, temperature, plankton concentrations**); no coupling/feedback

- Key assumption: **water-mass homing** → Temperature experienced during larval stage impact adult movement. **Environmental preferences** may **evolve** within the population.

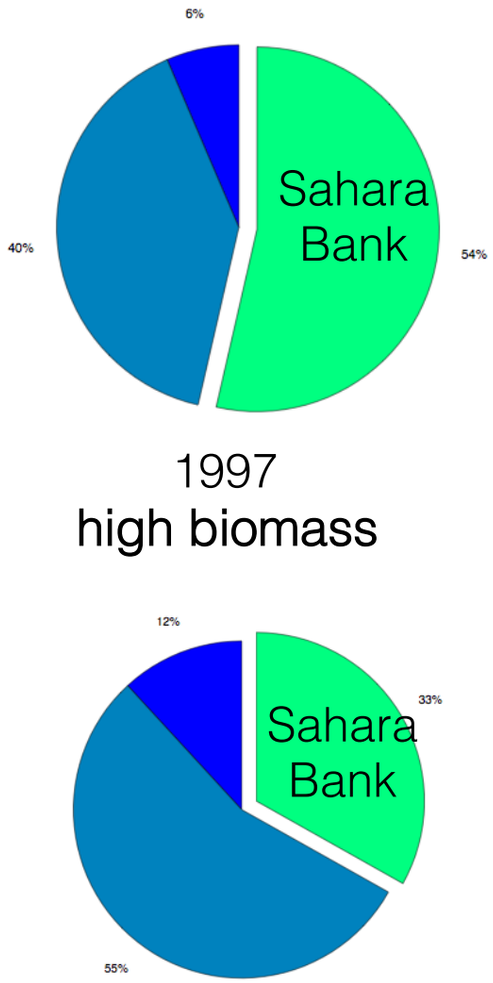
Data / Knowledge available

- General migration pattern (Boely and Fréon 1979)
- Interannual and seasonal scales: Fisheries-dependent data (Senegal / Mauritania, Morocco)
- Size structure: Fisheries-independent data, Surveys RV Nansen
- Growth/weight/Fecundity data: Senegal CRODT, IFAN

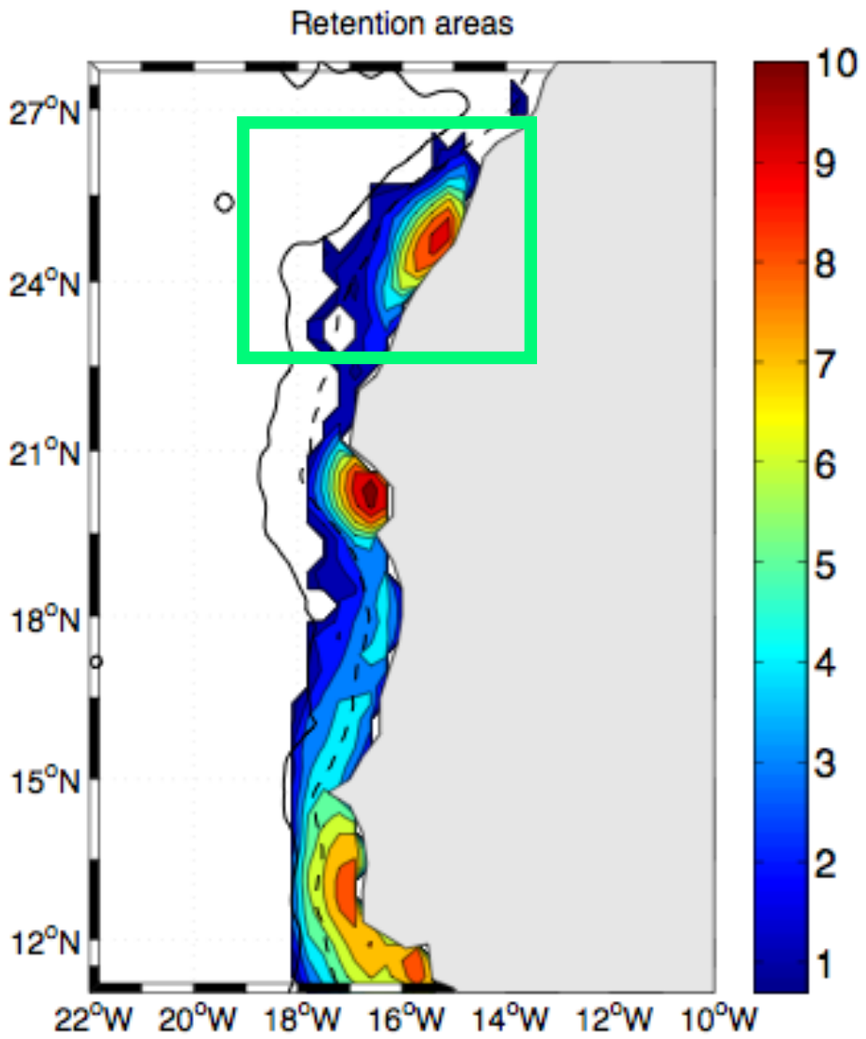


S. aurita migrations (Boely and Fréon, 1979)

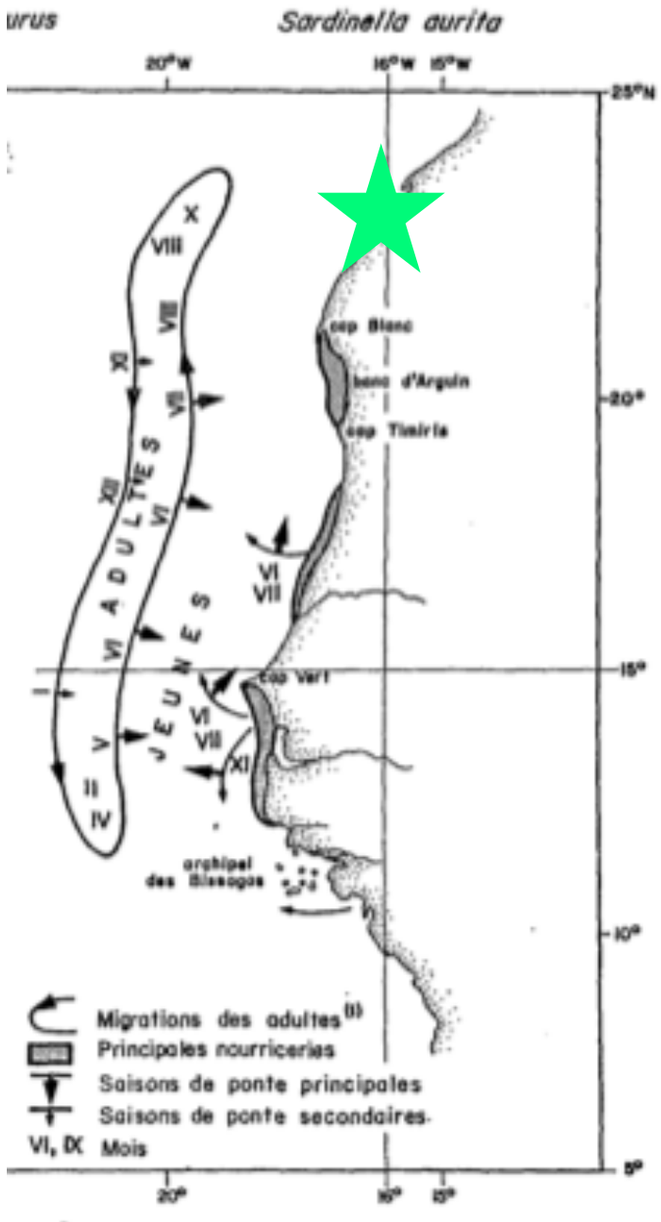
And a first look of what we learned so far…



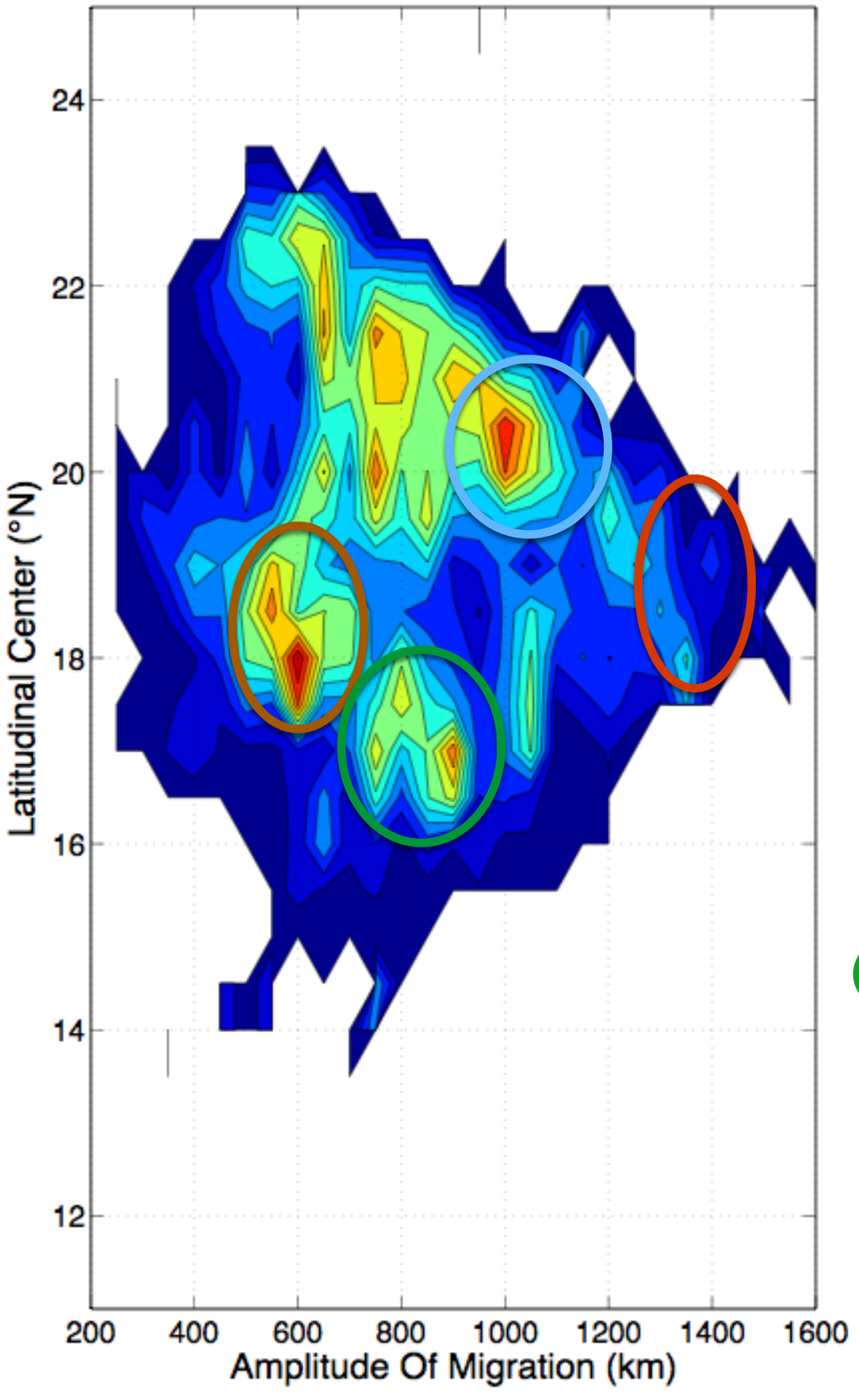
Share of the population biomass origin

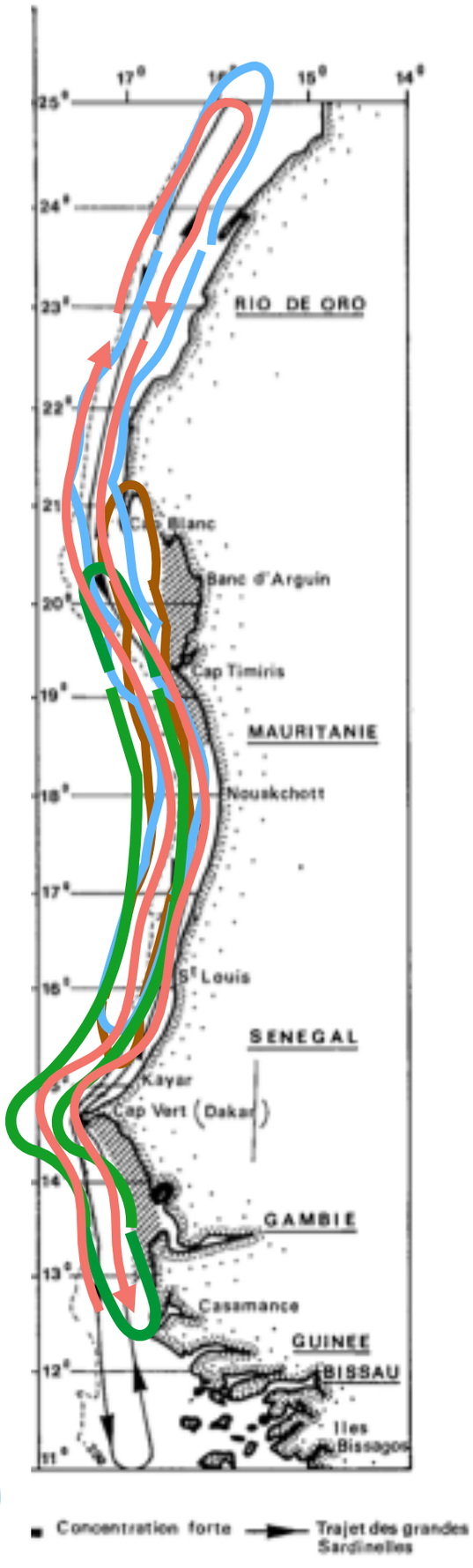


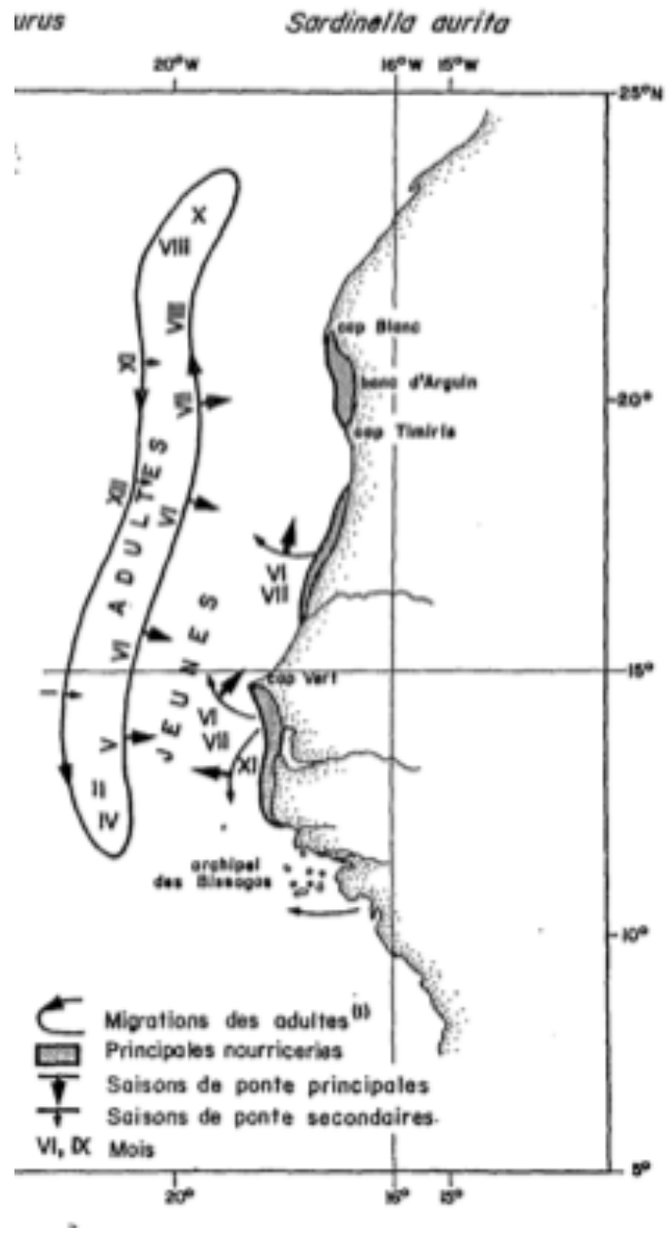
Hot spots for reproduction success



S. aurita migrations (Boely and Fréon, 1979)



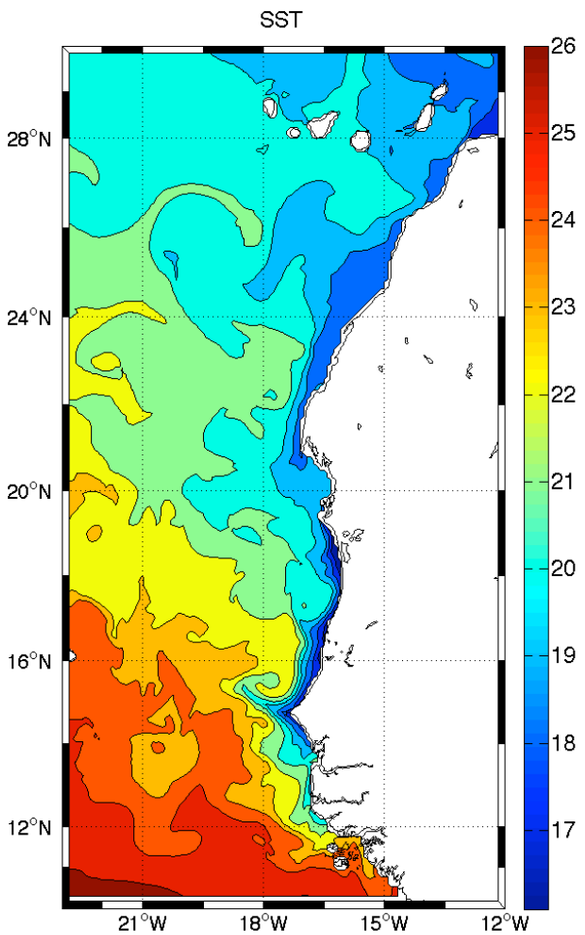




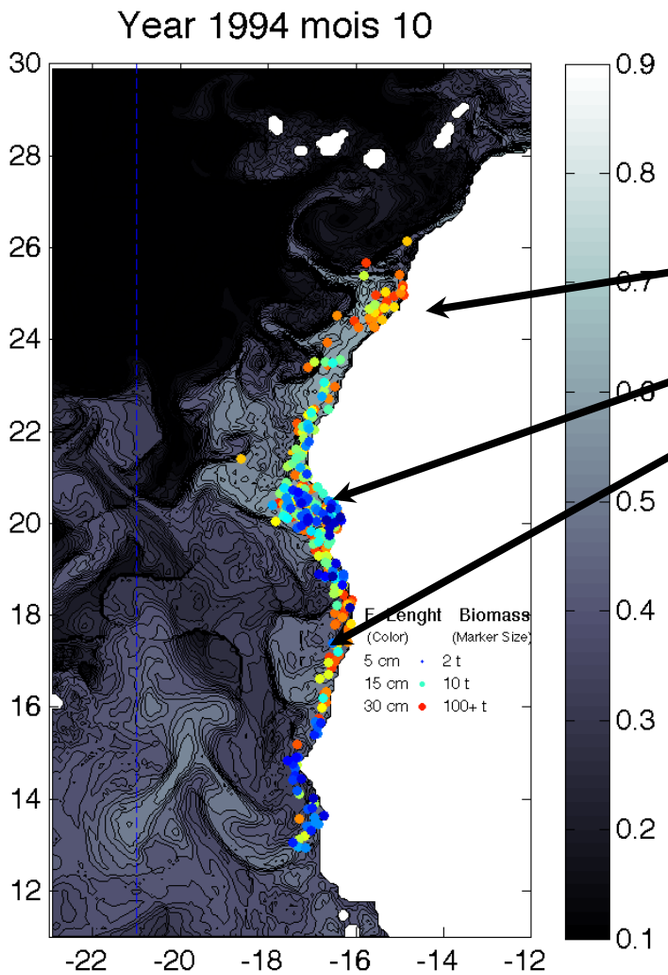
S. aurita migrations
(Boely and Fréon, 1979)

Basic principles of the Evol-DEB biophysical model

Environmental modeling

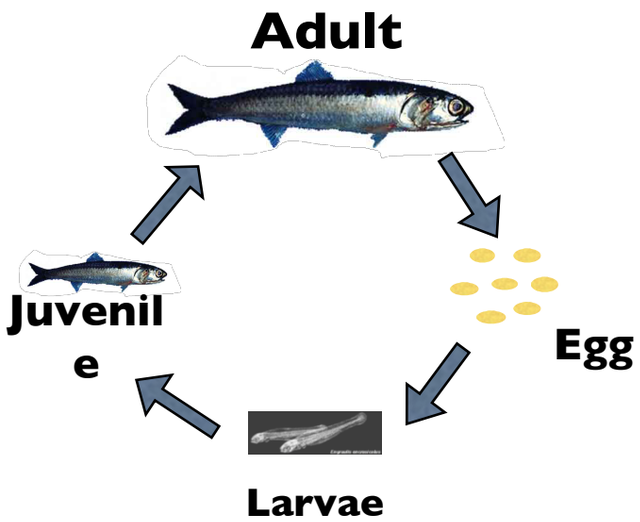


Hydrodynamic
(ROMS)



Bio-geochemical
(ROMS-PISCES)

Life-cycle modeling



3 Submodels for each individual:

- Early life dynamics
- DEB (Dynamic Energy Budget)
- Adult migrations

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

~1000 super-individuals
Time step = 1 h

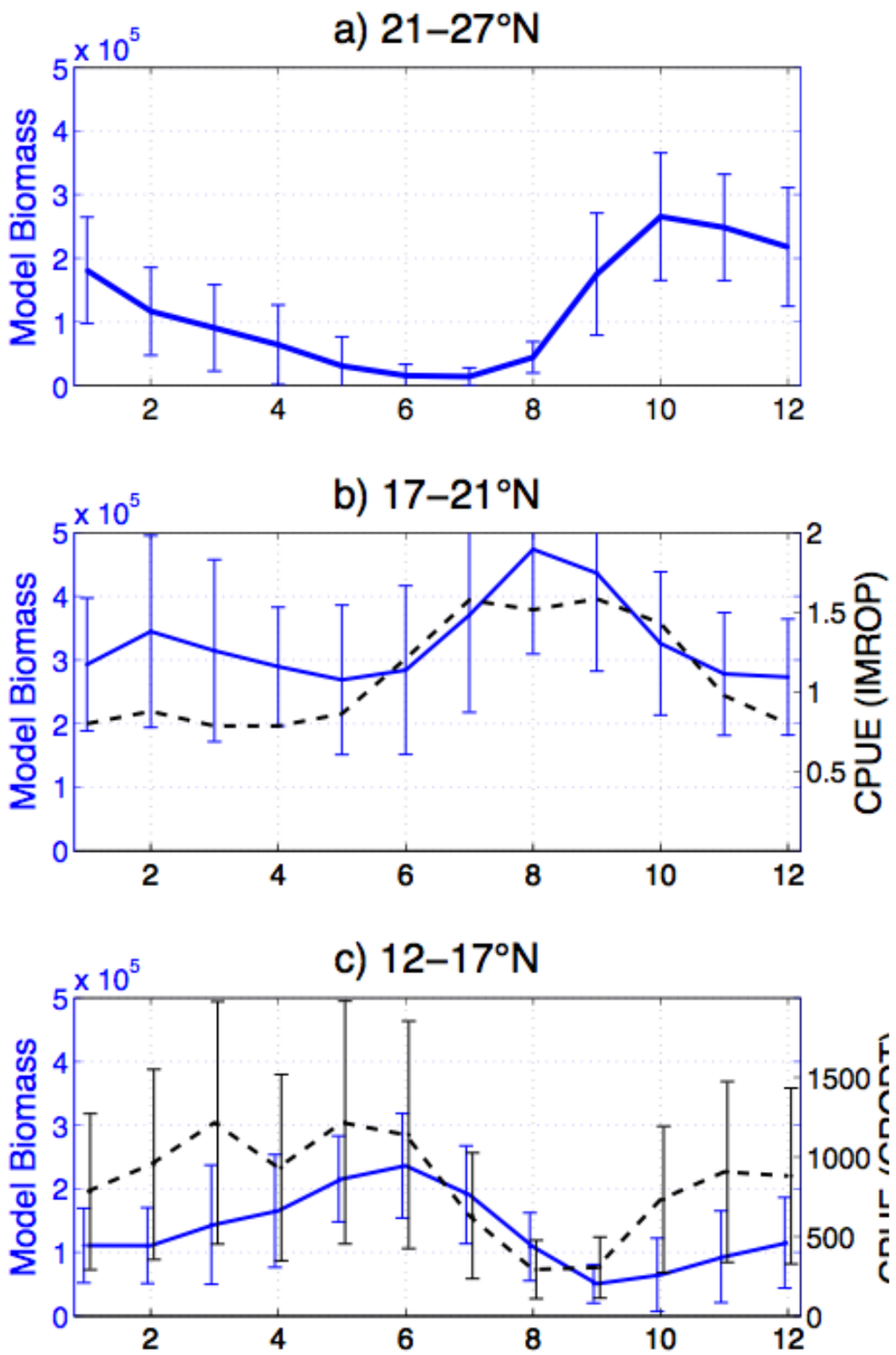
Emergeant population traits for round sardinella in North-West Africa

Seasonal variability: Model Vs Data

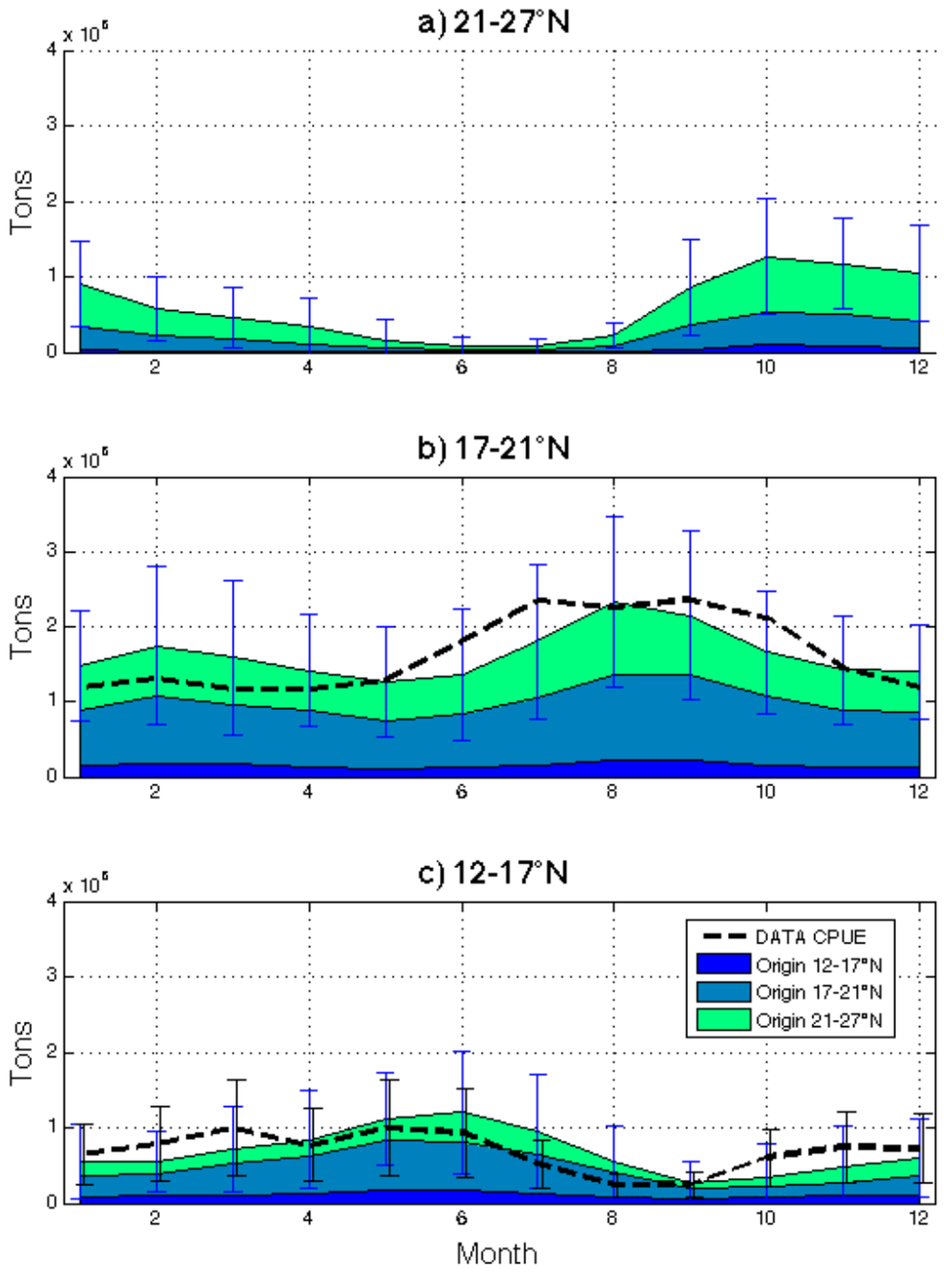
No Data

IMROP CPUE
R = 0.8
P < 0.005

CRODT CPUE
R = 0.6
P < 0.05



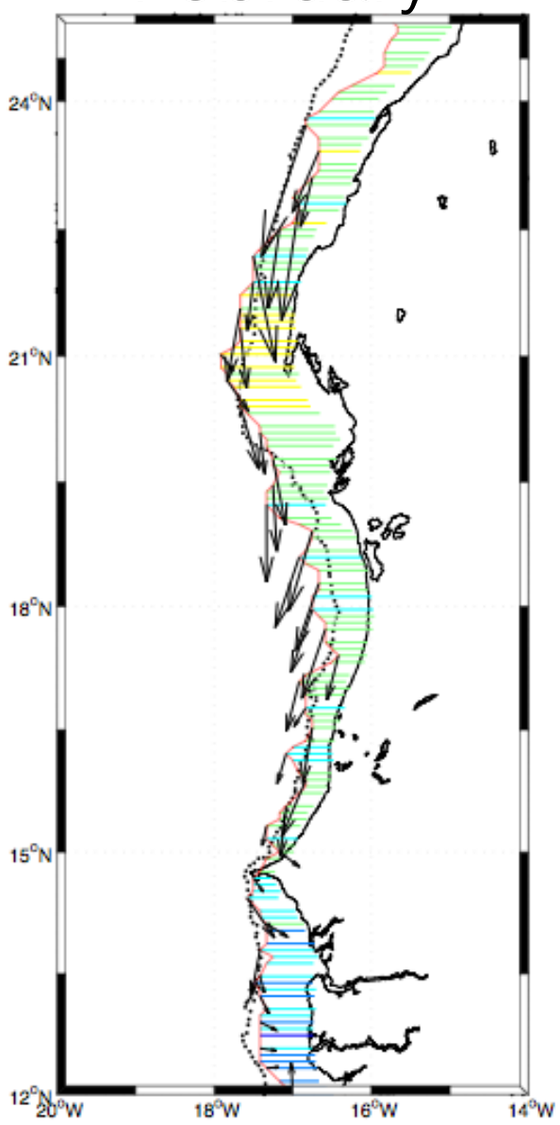
Seasonal variability: contribution of each area (Model)



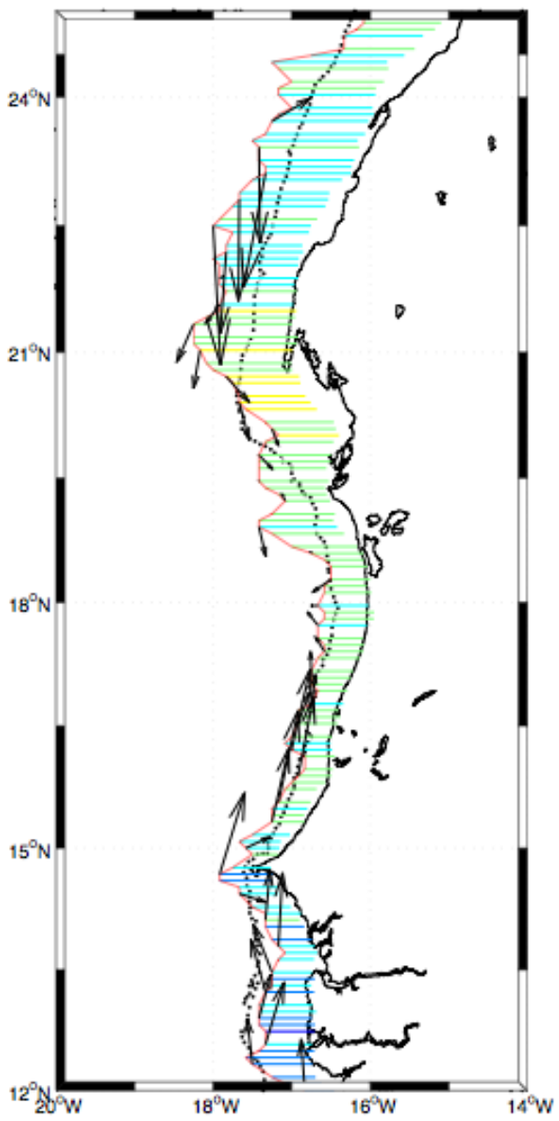
Emergeant population traits for round sardinella in North-West Africa

Average Dynamic of fish migration

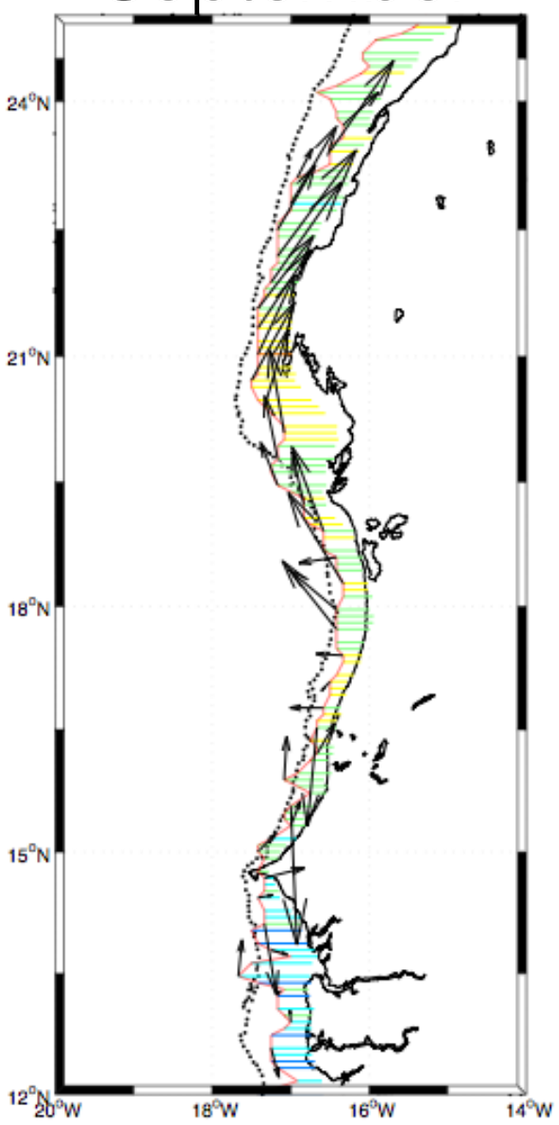
February



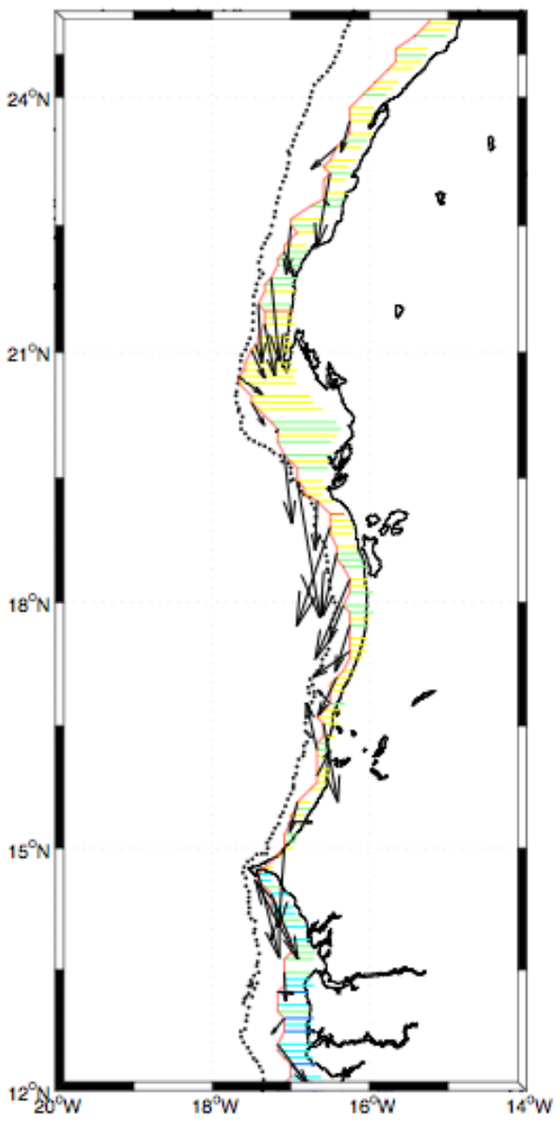
June



September



November



Emergeant population traits for round sardinella in North-West Africa

Inter annual variability: Model Vs Data

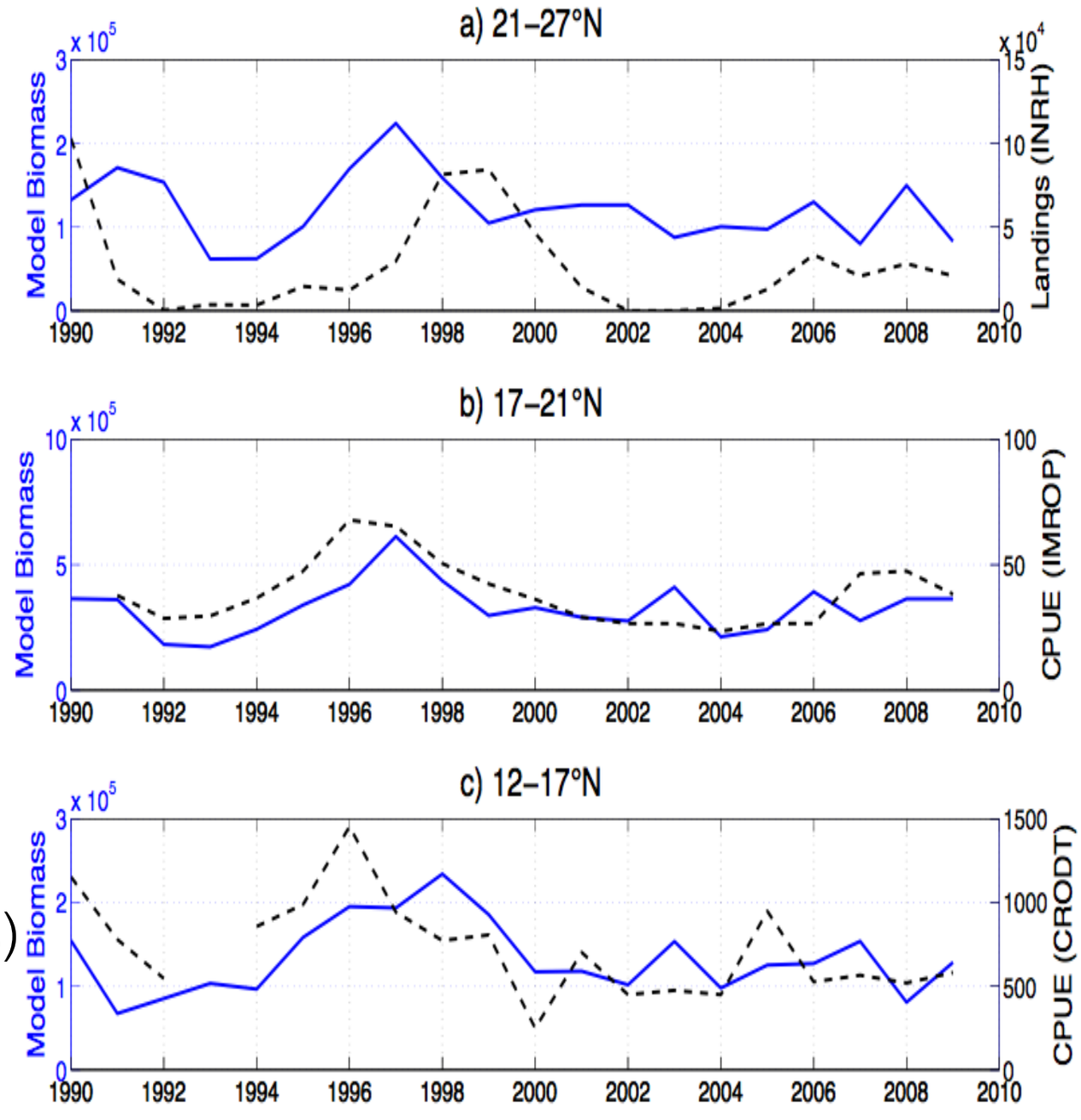
INRH Landings

IMROP CPUE
(Braham et al. 2014)

R = 0.7
P < 0.005

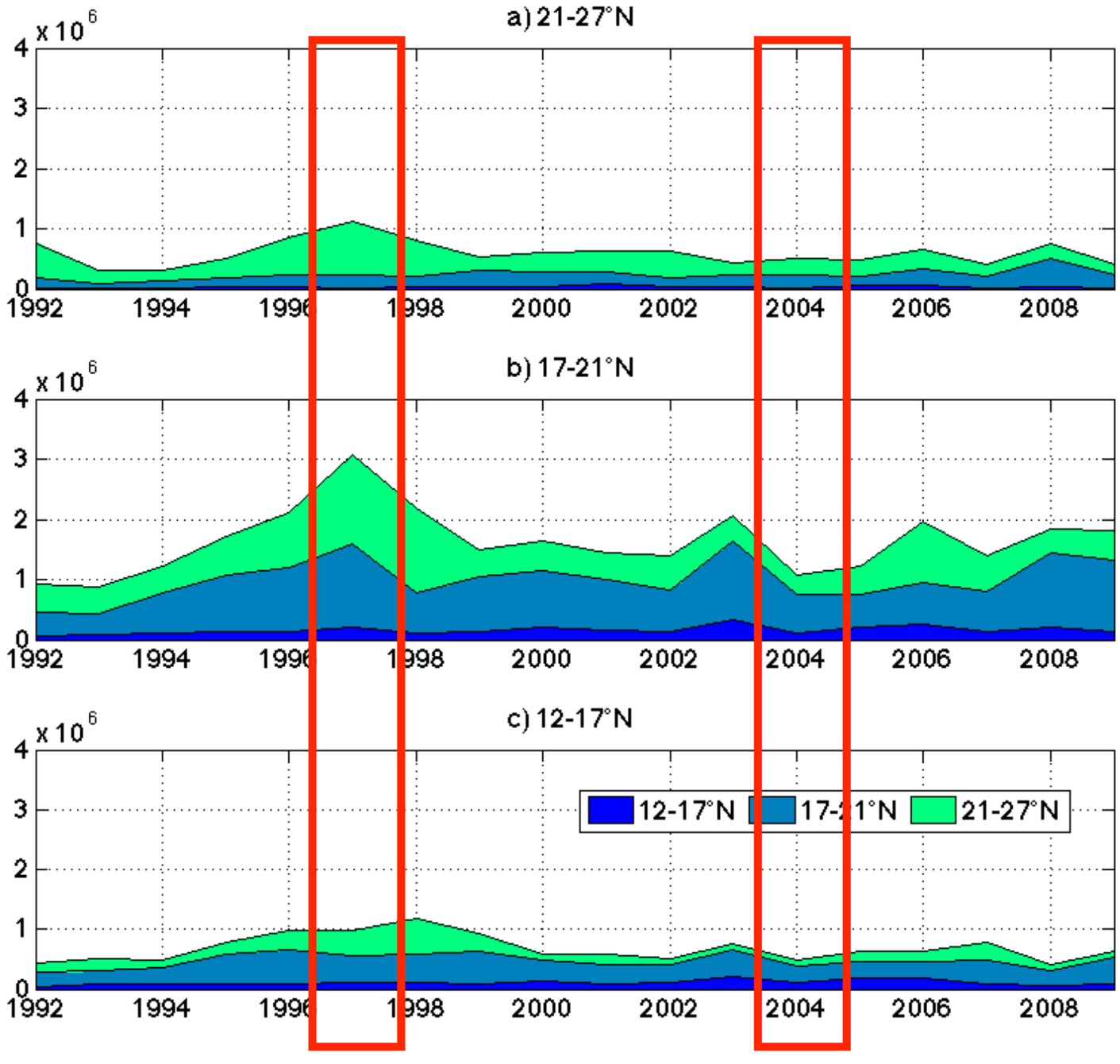
CRODT CPUE
(Thiaw et al. in press)

R = 0.5
P < 0.05



Emergeant population traits for round sardinella in North-West Africa

Inter annual variability: contribution of each area (Model)



Processes responsible for the population traits

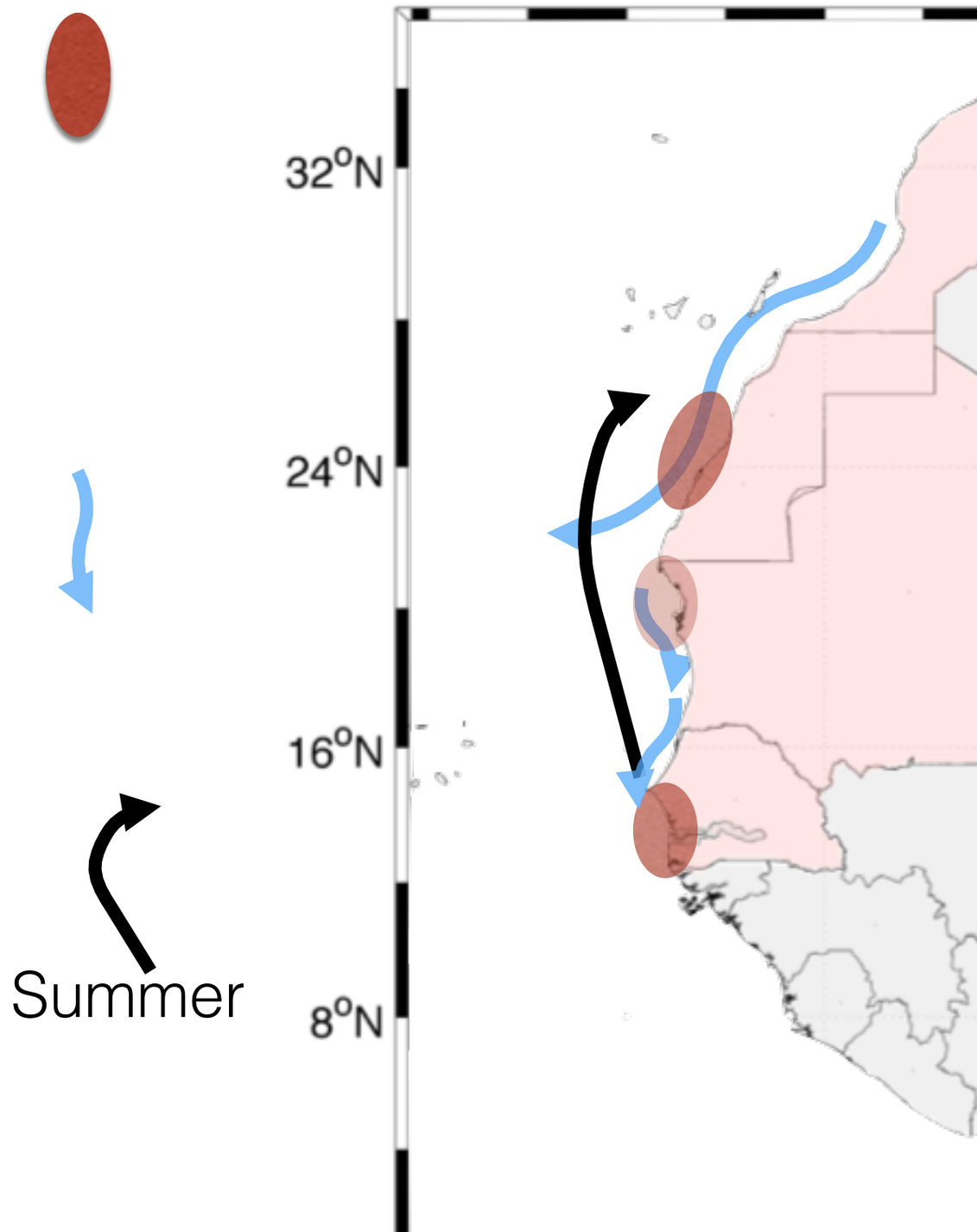
3 main processes in interaction:

1) Larval retention patterns
recruitment
—> natal homing (temperature preference)

2) Coastal current advection
→ Seasonal latitudinal shift

(Variability of Canary Current intensity)

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



Model Processes responsible for the population traits

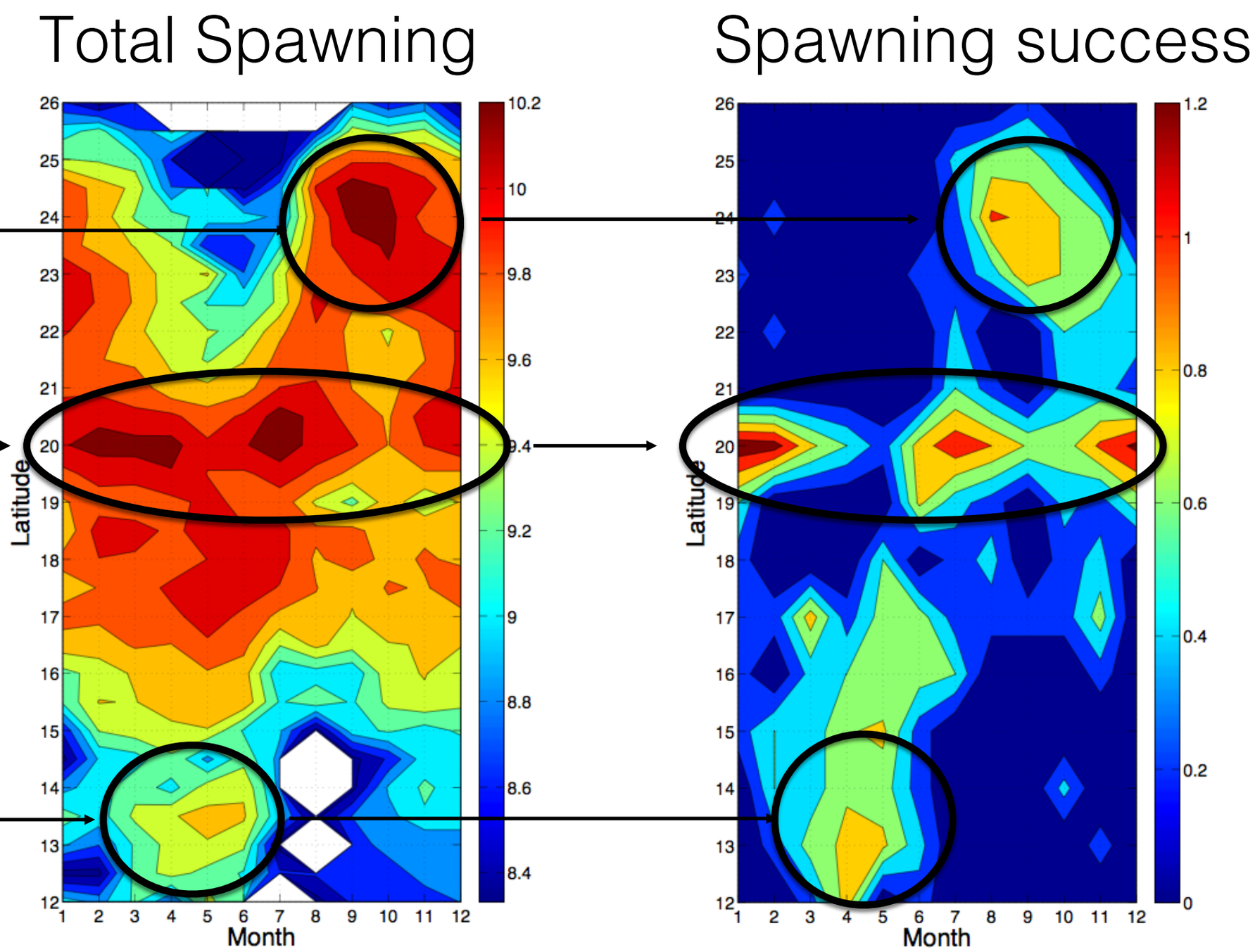
1) Larval retention patterns

3 main nursery area:

Sahara Bank
Oct-Nov

Banc d'Arguin
~all year

Southern Senegal
~ March-May

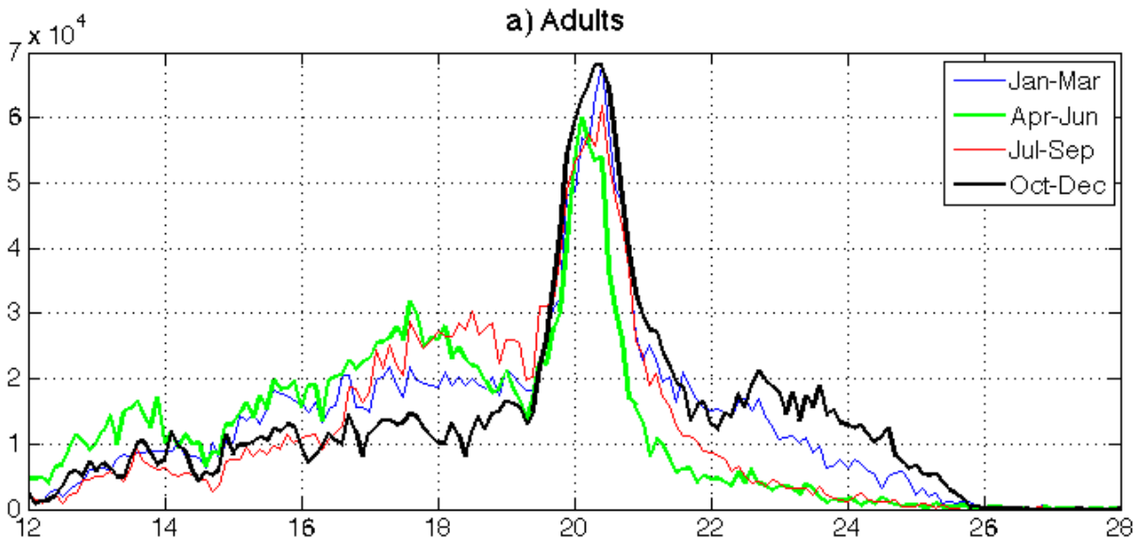


Model Processes responsible for the population traits

2) Coastal Current Advection

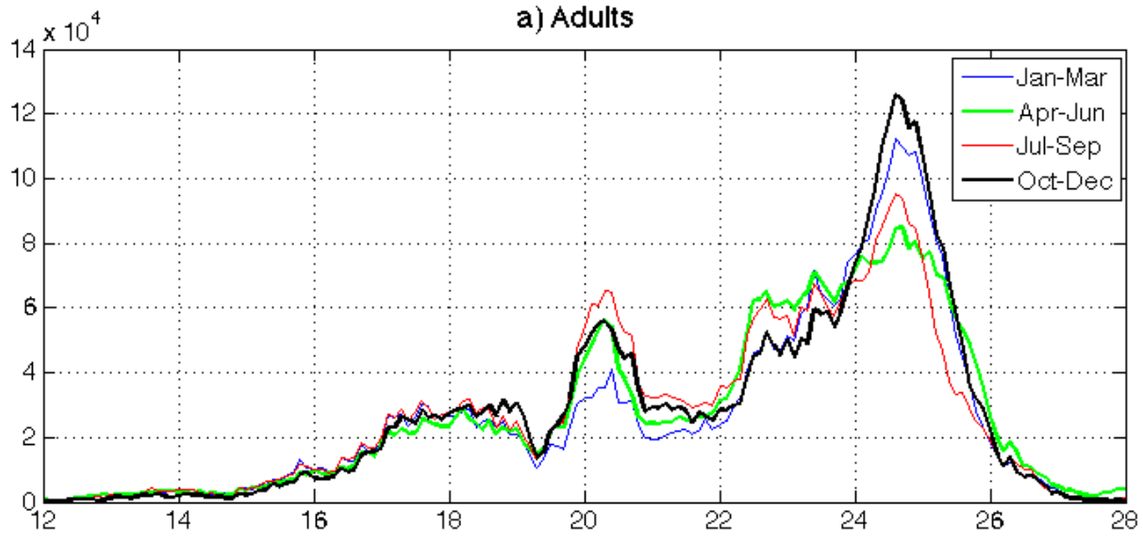
Test : removing the advection

south → north



With advection

south → north



Without advection (IFD)

—> Without advection, the abundance maximum is on the Sahara Bank

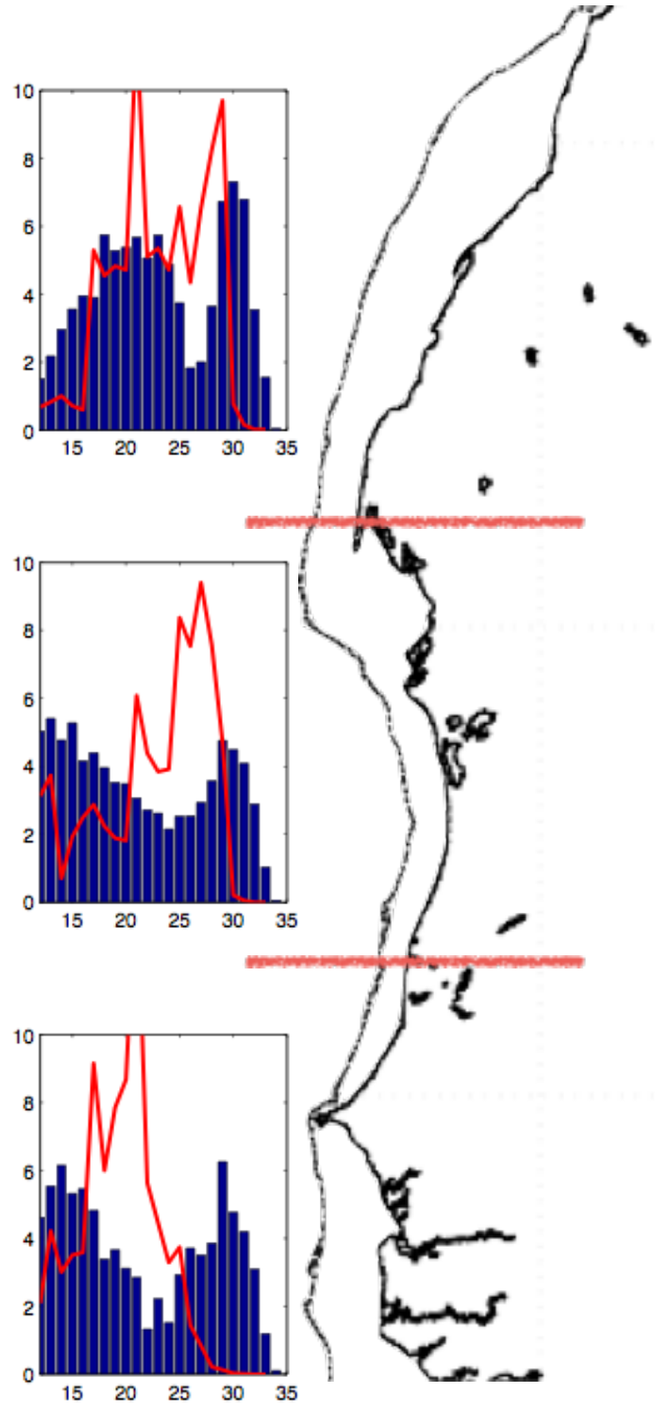
—> The advection shifts the abundance maximum southward

Emergeant population traits for round sardinella in North-West Africa

3) Swimming Behavior

—> Counteracts advection

—> Large fish body-length are more frequent in the northern part of the domain, where the current is more intense



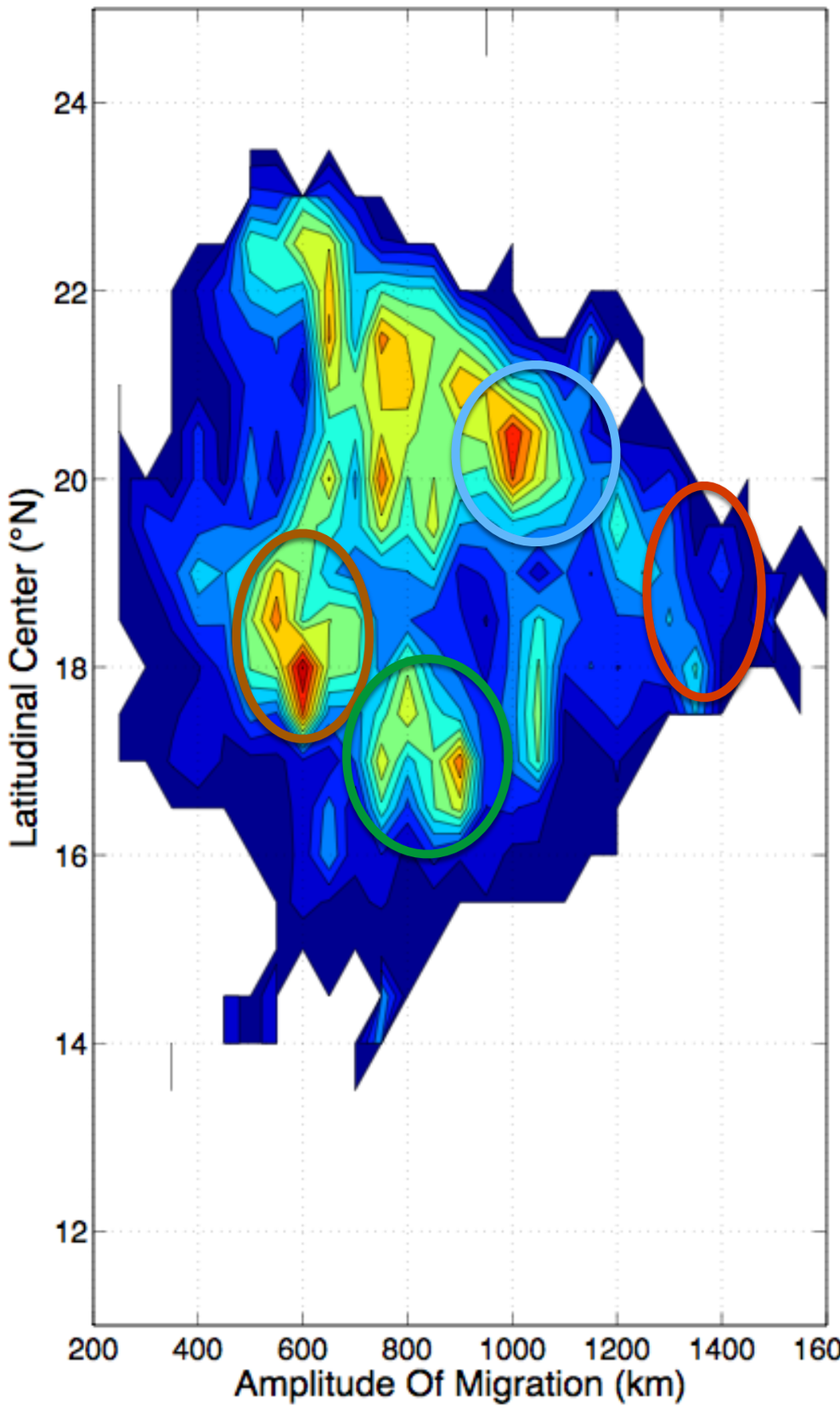
Mean Fish length distribution in autumn
(blue=model; red = data (NANSEN - 1996-2004)

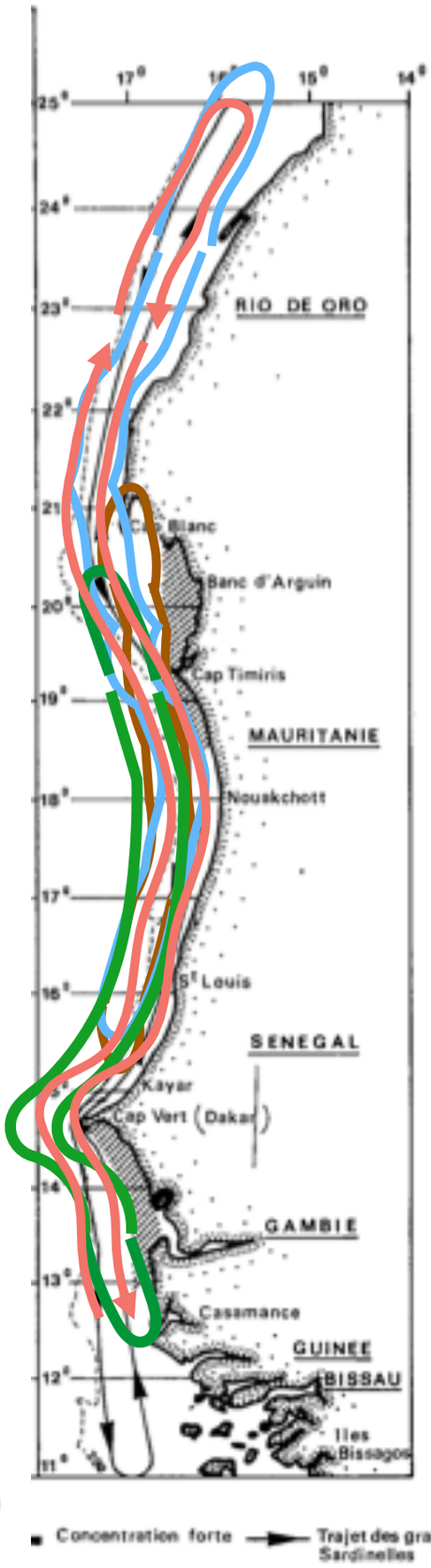
CONCLUSIONS

1. **A finer understanding of migratory scheme** for the round *sardinella* in North-West Africa :

Diversity of migration route among super-individuals : variable amplitude of migration and barycenter

« Focal area » off Mauritania





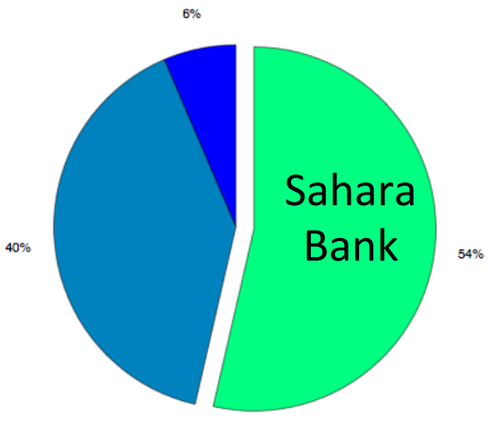
CONCLUSIONS

2. **A new hypothesis for the environmental driver** for the round sardinella abondance inter-annual variability off North-West Africa

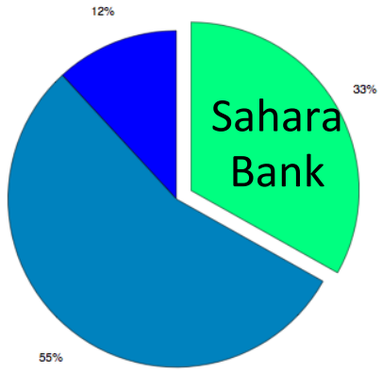
The key role of the **intermittent Sahara Bank nursery**:

—> High recruitment in periods of low upwelling winds

—>Spawning amplified by natal homing

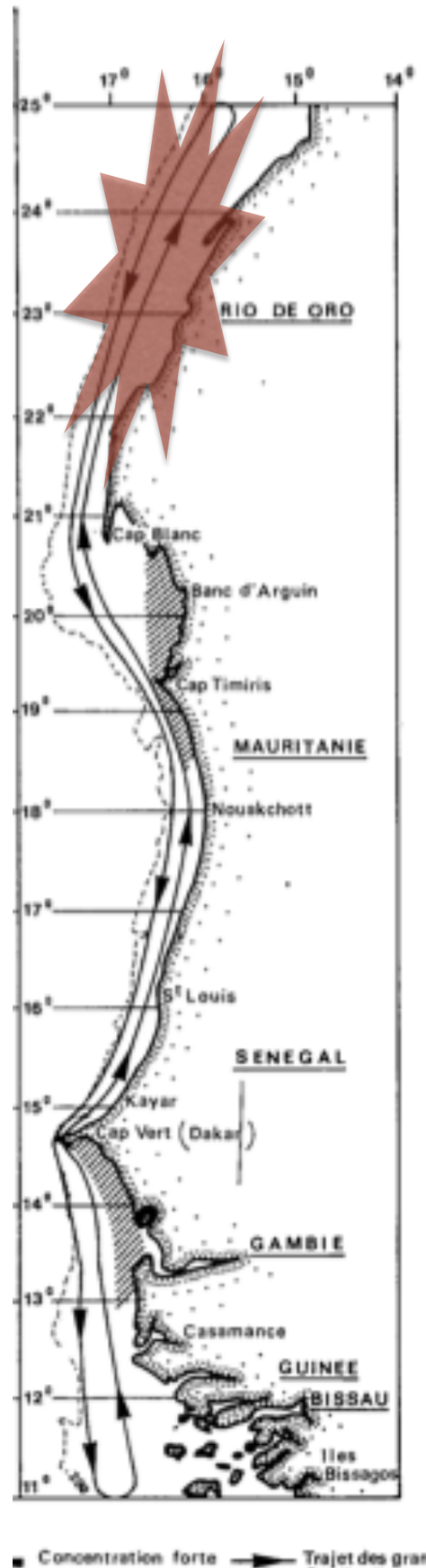


1997
(high biomass)



2004
(low biomass)

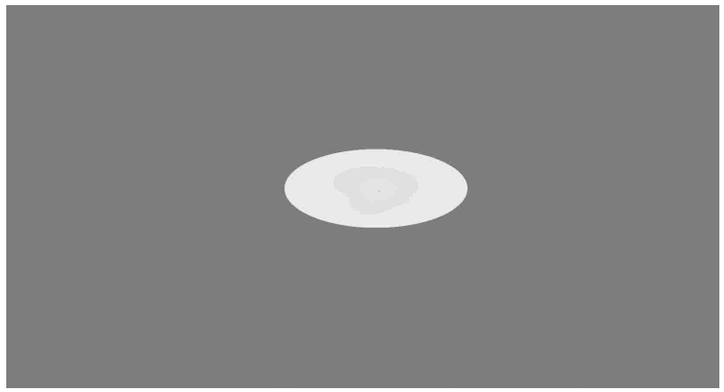
Share of the population biomass origin



PERSPECTIVES

1 - Validation of connectivity patterns at the individual scale:

Compare with individual life history (Otoliths, condition index)



Pecquerie *et al*. 2012

Otolith DEB model
(opacity, growth, $\delta^{13}C$, $\delta^{18}O$)
<->
Otolith data

2 – Climate change scenarios (IPCC AR5):

e.g. Impact for the current development of fish meal factories in Mauritania?

3 – **Comparison with other EBU systems**

(where do we go for the next SPF conference?)