Integrating mark-recapture data within a Bayesian life-cycle model to evaluate spatial structure and population dynamics of sole
A coastal and nursery dependent flatfish : Eastern Channel Sole

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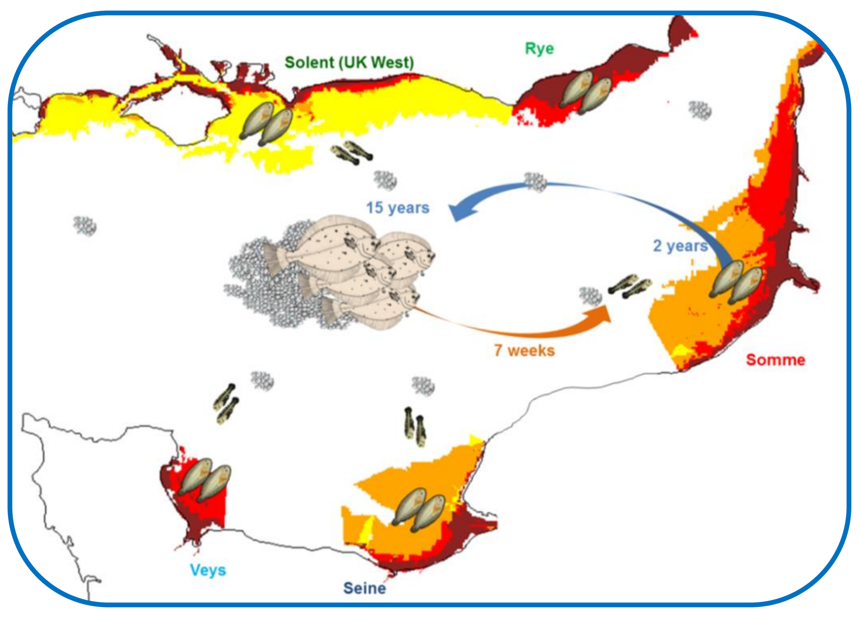
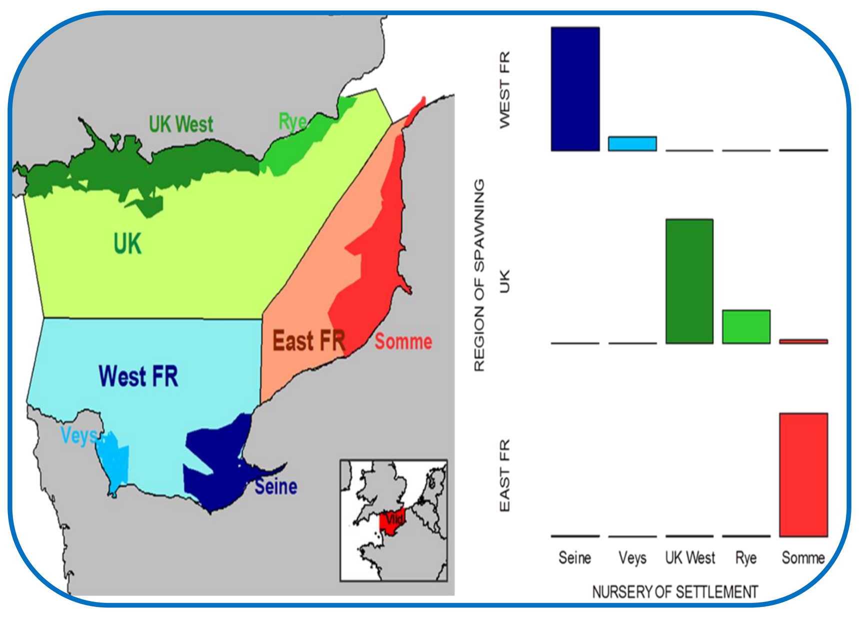
A coastal and nursery dependent flatfish species

Current paradigm for management vs some ecological clues



The sole population in the Eastern English Channel

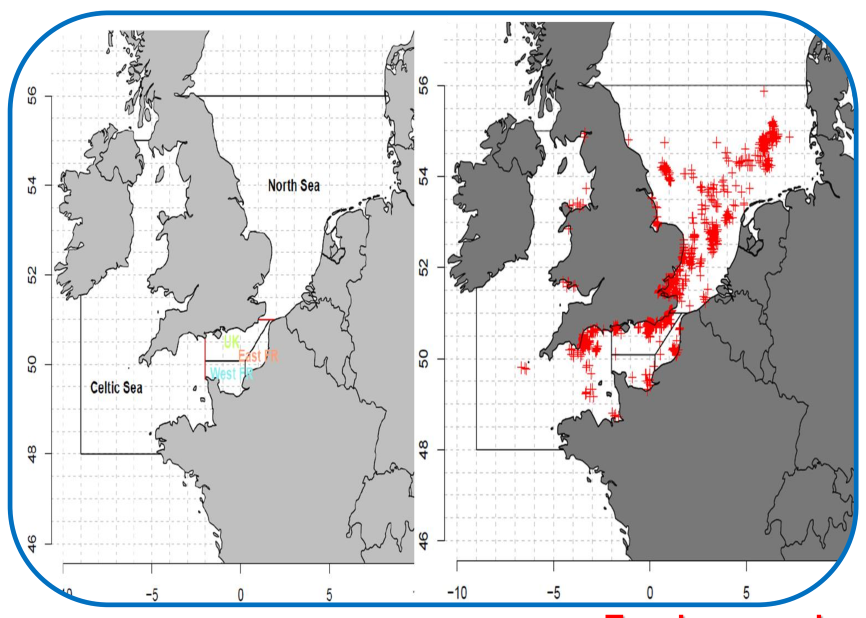
- ❑ **One of the most harvested** flatfish populations
- ❑ **Management** :
  - Considered as an homogeneous single stock
  - Separated from the North sea and the Western Channel stocks

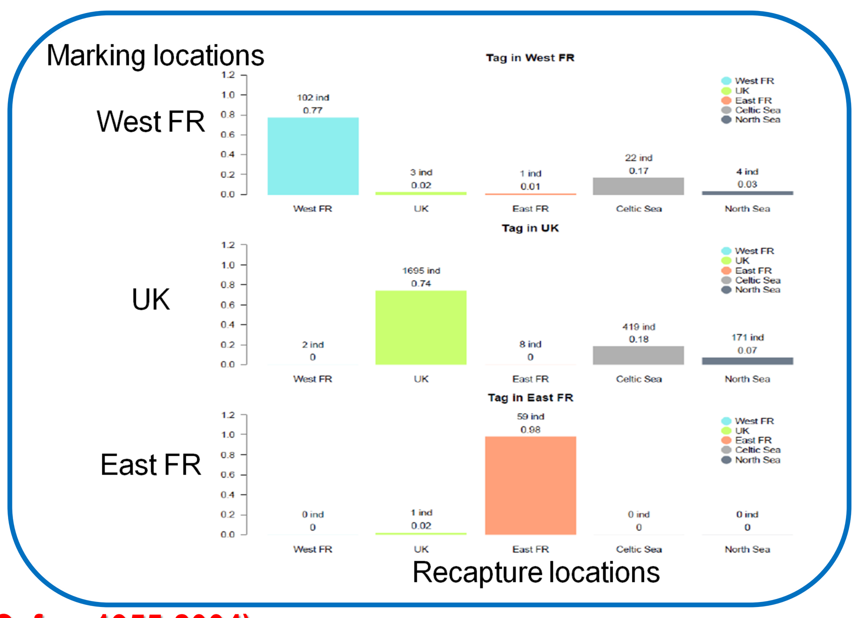


Spatial segregation during early life stages

- ❑ A **metapopulation structure** :
  - Three subpopulations with low connectivity
  - High larval retention within spawning regions
  - Very low connectivity between nursery grounds

Analysing capture-mark-recapture data





Tagging experiments (Cefas, 1955-2004)

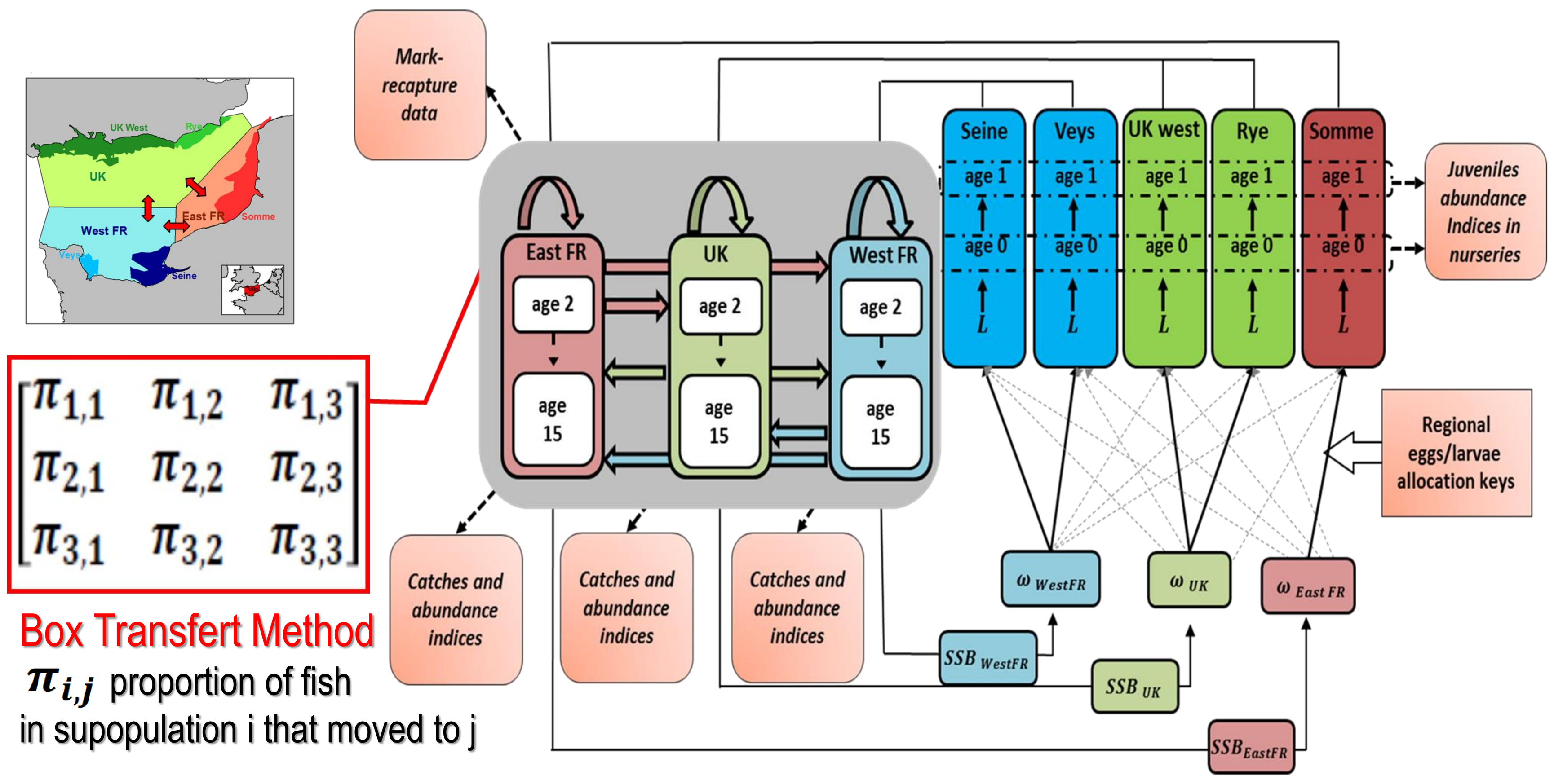
- ❑ Mainly westward **Seasonal movement pattern** (from the ICES management area Ivb to the area VIIe)
- ❑ Very **low connectivity** induced by **the movement of adult fish** between:
  - the potential subpopulations in the EEC
  - The EEC and the North Sea

OBJECTIVES

1) Assess the sensitivity of population dynamics and stock assessments to hypotheses on connectivity
2) Evaluate the contribution and reliability of integrating mark-recapture data in a Bayesian life-cycle model to infer connectivity parameters and population dynamics

Implementing a bayesian integrated life-cycle for adult fish

Allowing adult migrations between the three subpopulations



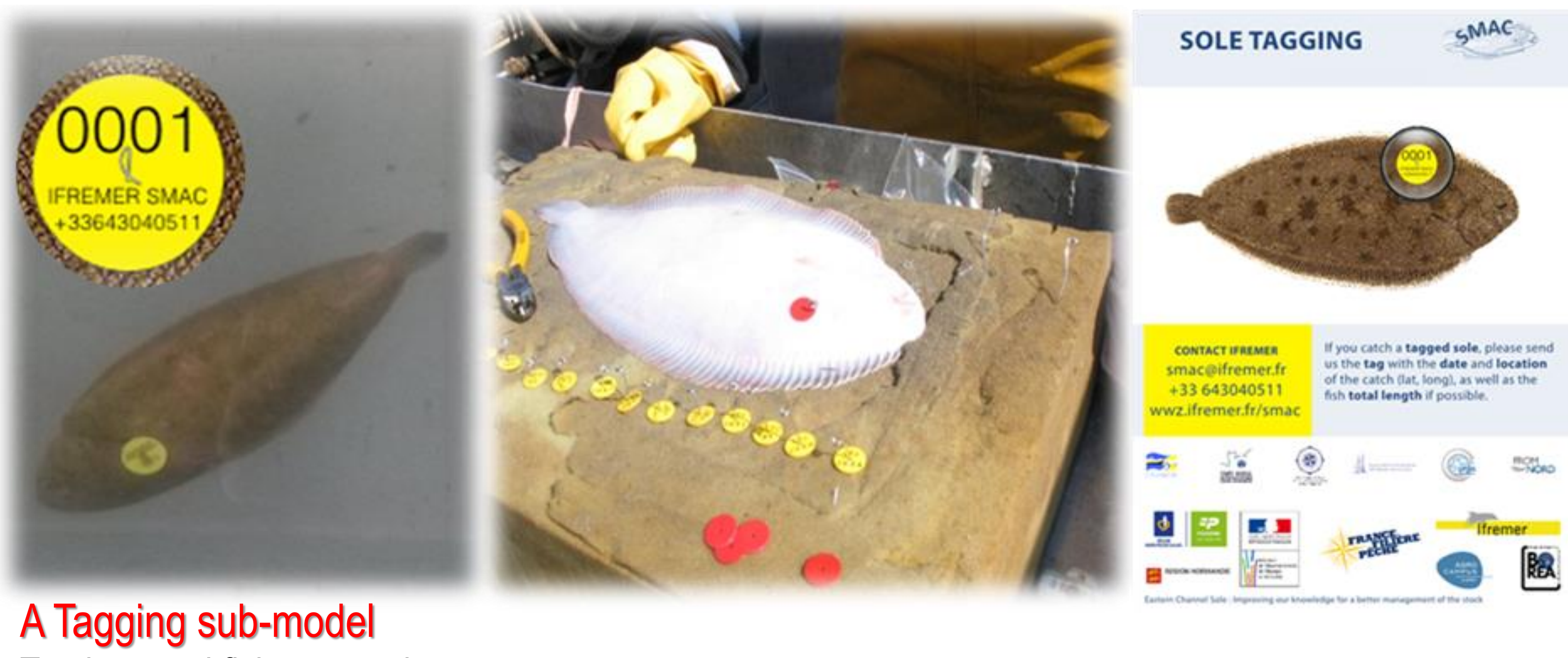
$$\begin{bmatrix} \pi_{1,1} & \pi_{1,2} & \pi_{1,3} \\ \pi_{2,1} & \pi_{2,2} & \pi_{2,3} \\ \pi_{3,1} & \pi_{3,2} & \pi_{3,3} \end{bmatrix}$$

Box Transfert Method

$\pi_{i,j}$ proportion of fish in supopulation i that moved to j

1. Movement is modelled as **isotropic**
2. Movement among the three subpopulations only concern **fish aged over 2 years (adult fish)**
3. Age-structured dynamics with an **annual time step** and accounting for connectivity among the three subpopulations at each life-stage

Integrating mark-recapture data



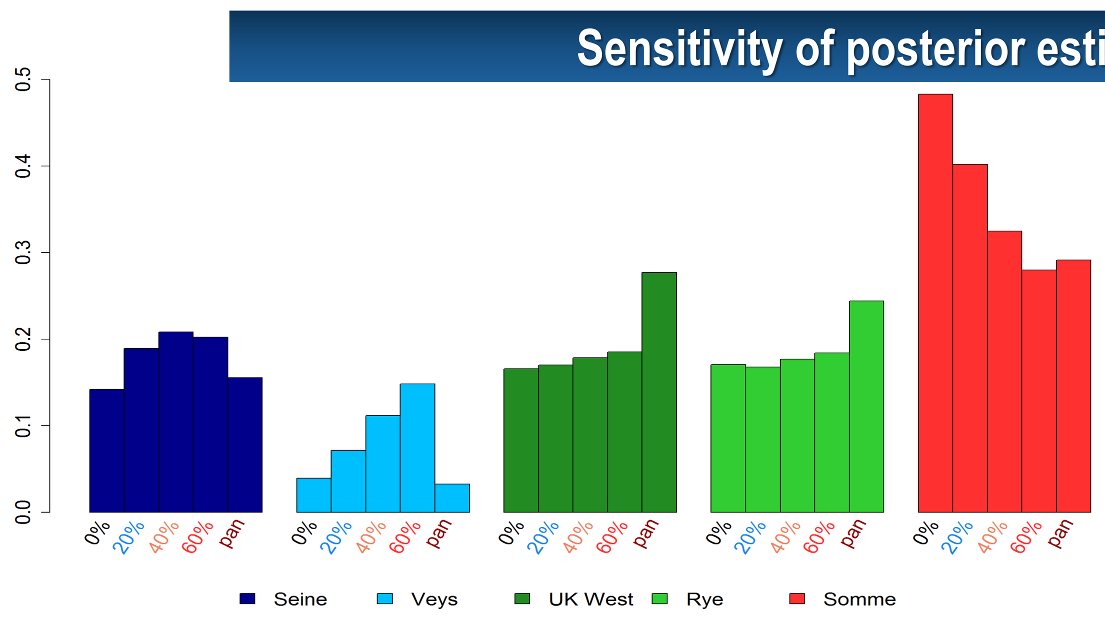
A Tagging sub-model

Track tagged fish among time

1. **Fully mixed** hypothesis: tagged fish follow the same dynamics as untagged fish
2. **Recapture** exclusively by **commercial fisheries**
3. **Recapture rate** is unknown and depends on the **fishing mortality** (estimated using the stock assessment model) and the tag **recapture declaration rate**

Sensitivity to connectiviy levels and performance of estimations

Sensitivity of posterior estimates



Connectivity level →

✓ F_{MSY} (UK) ↗
✓ F_{MSY} (East FR)

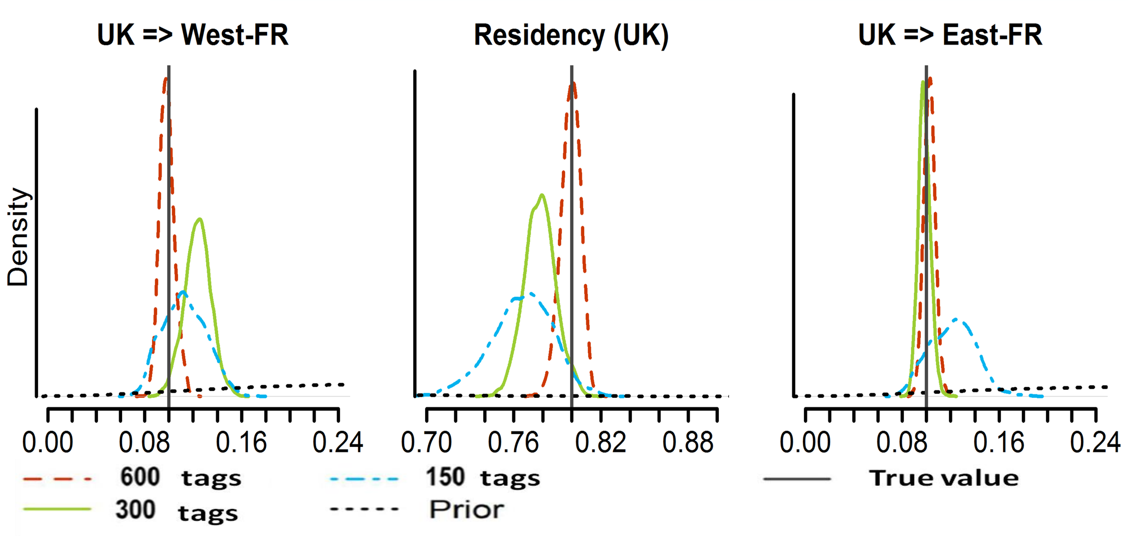
✓ F_{MSY} (West FR) ↘

Ratio		Different connectivity 0%	20%	40%	60%	One single population
F/F_MSY	West FR	1.05	0.69	1.13	1.31	1.81
	UK	1.86	1.96	1.12	0.91	
	East FR	1.96	4.07	3.08	3.00	

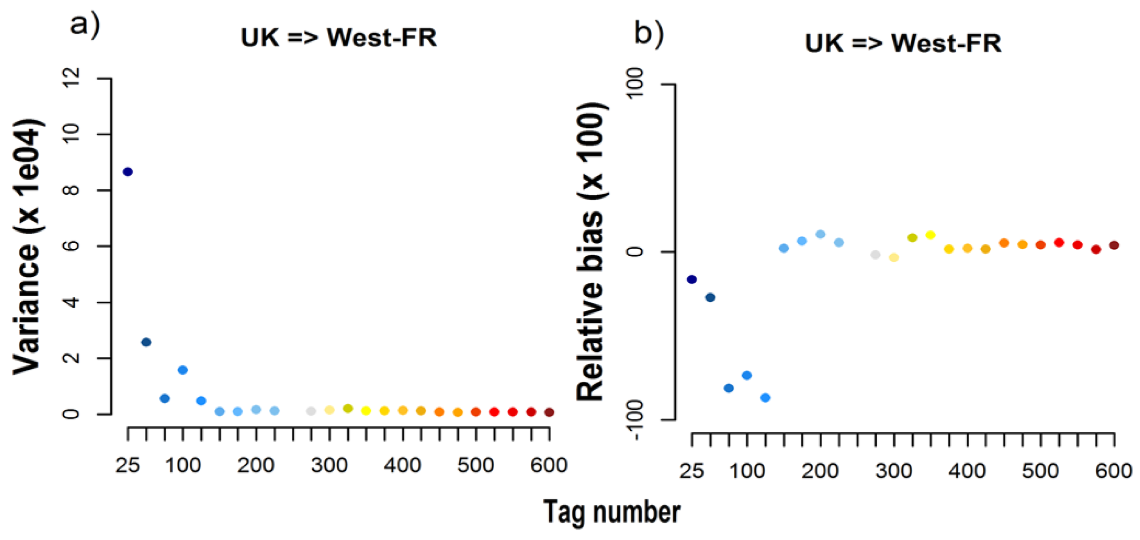
- ❑ Estimates of parameters and contribution to recruitment are **sensitive to connectivity hypotheses**
- ❑ Consistent overall **trend** of parameter estimates **towards the same values as the single population model**

- ❑ Estimates of Spawning-Biomass, Recruitment and Fishing mortality are sensitive to the connectivity level
- ❑ **Management reference points** (SSB_{msy}, C_{msy} and F_{msy}) are sensitive to the level of connectivity. When the connectivity level increases, SSB_{msy} and C_{msy} increase and converge towards values estimated in the model considering one single homogeneous population

A simulation-estimation approach



- ❑ With a **declaration rate of 90%** ,and around **200 tags** released (in each subpopulation), connectivity parameters are estimated with **low bias and uncertainty**
- ❑ /!\ The product **recapture rate x declaration rate** has to be at the maximum level to ensure good inferences



- ❑ Inferences are sensitive to the **number of tags released**
- ❑ The fewer tags, the higher are the relative bias and uncertainty in posterior estimates
- ❑ The necessary number of tags released increases if the declaration rate decreases

Conclusions and perspectives

A Bayesian integrated life-cycle model for adult fish

- ❑ **Exploration of all movement configurations** between a single population and three subpopulations
- ❑ Inferences on key population dynamics parameters **are highly sensitive** to the assumptions made about connectivity
- ❑ **A connectivty level of 20%** appears most consistent with the data (*AICM*) => consistency with the body of knowledge

Foundations for a tag-integrated stock assessment model and good perspectives for SMAC

- ❑ Integration of mark-recapture datasets **to infer connectivity**
- ❑ **Sufficient** tags must be released (SMAC project tagging experiments should provide adequate data, with **200 tags released** per subpopulation, and assuming the product of **recapture rate x declaration rate** at the same level observed on previous tagging programms)
- ❑ **Quality of inferences** are drastically penalised by low or miss-represantated tag-recapture declaration rate