

DEFIPEL

Ifremer

l'institut Agro

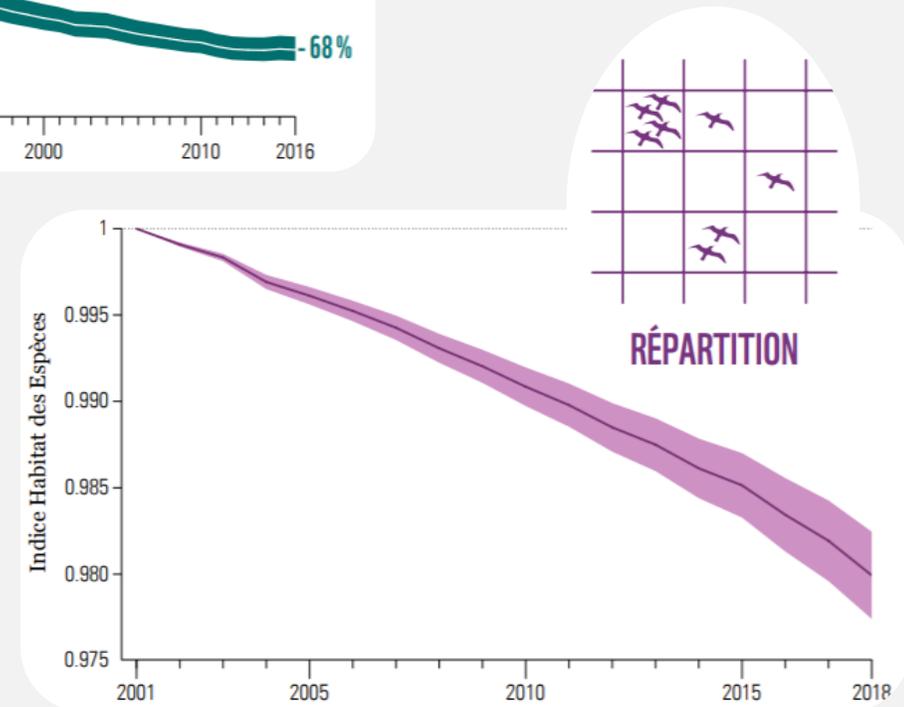
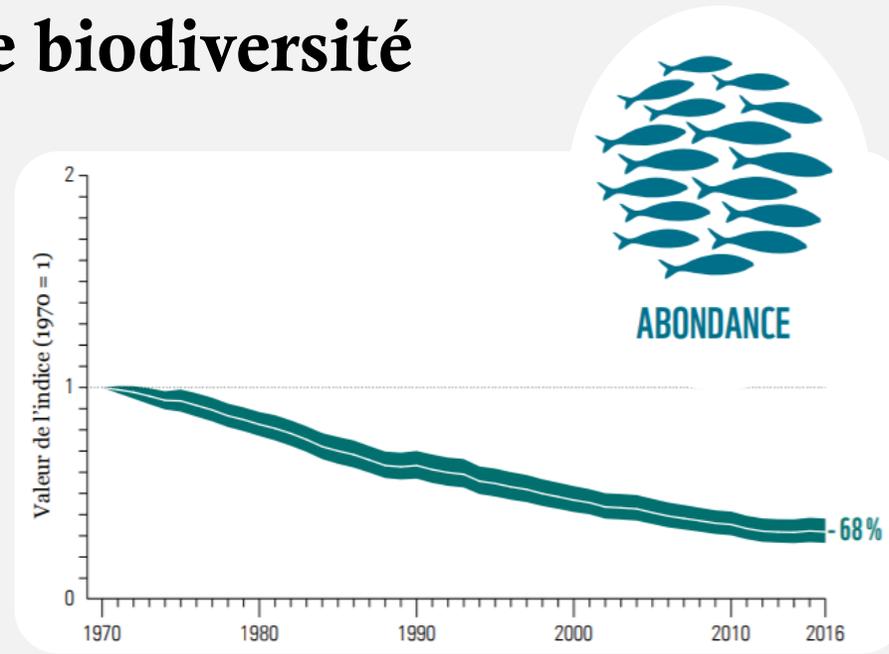
agric agriculture • alimentation • environnement



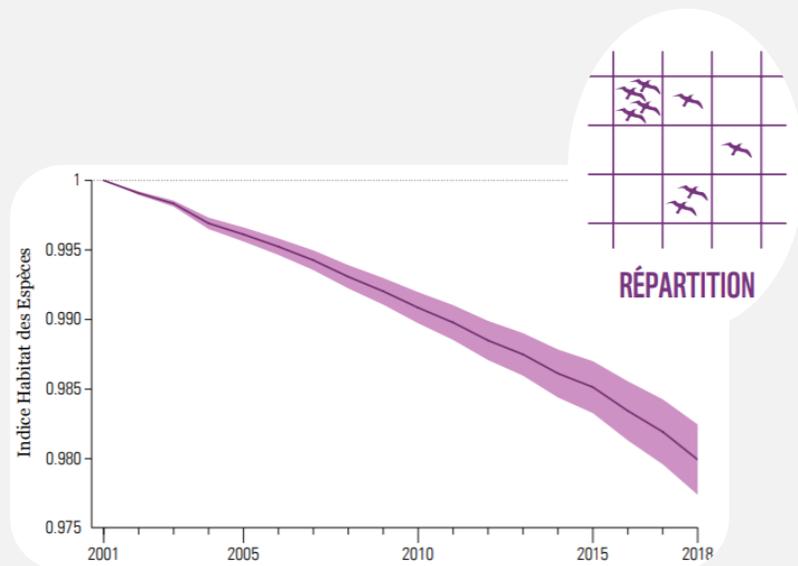
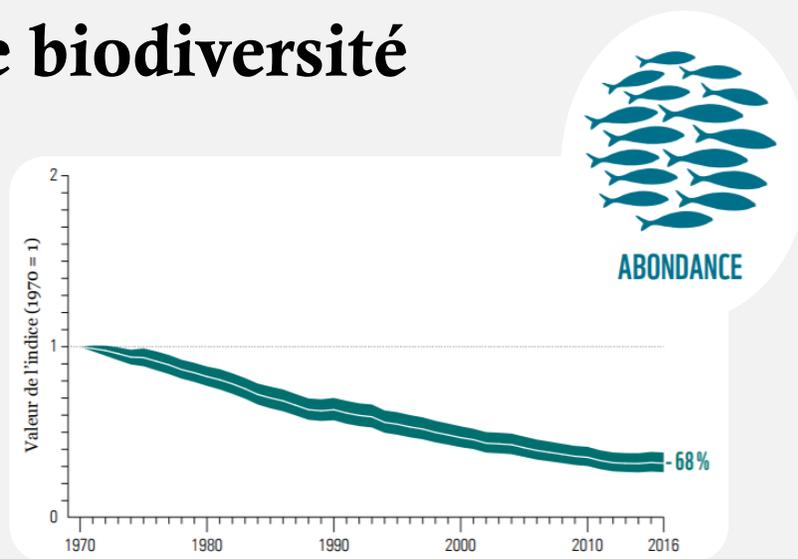
Etude de la diminution de taille et de poids
des anchois et des sardines,
entre le golfe du Lion, le golfe de Gascogne et la Manche :
une approche de modélisation bioénergétique

Clara Menu

Contexte global : perte de biodiversité



Contexte global : perte de biodiversité



FACTEUR DE CHANGEMENT

Pêche



Changement climatique



Pollution terrestre



Pollution des océans



Développement du littoral



Espèces exotiques envahissantes



Infrastructure offshore



Transport maritime



Mariculture (aquaculture d'organismes marins)



Exploitation minière en haute mer



Contexte global : scénarios pour le futur des océans



-  **Production Primaire Nette** : - 4 à 11% d'ici 2100
- Impact sur **distribution et abondance** des espèces marines
- Impact sur **pêcheries**,  du maximum de Potentiel de Capture : -20 à 24% d'ici 2100



Cas d'étude

Petits pélagiques :

- Importance **écologique** (espèces fourrages)
- Importance **économique** (1/4 des captures mondiales)

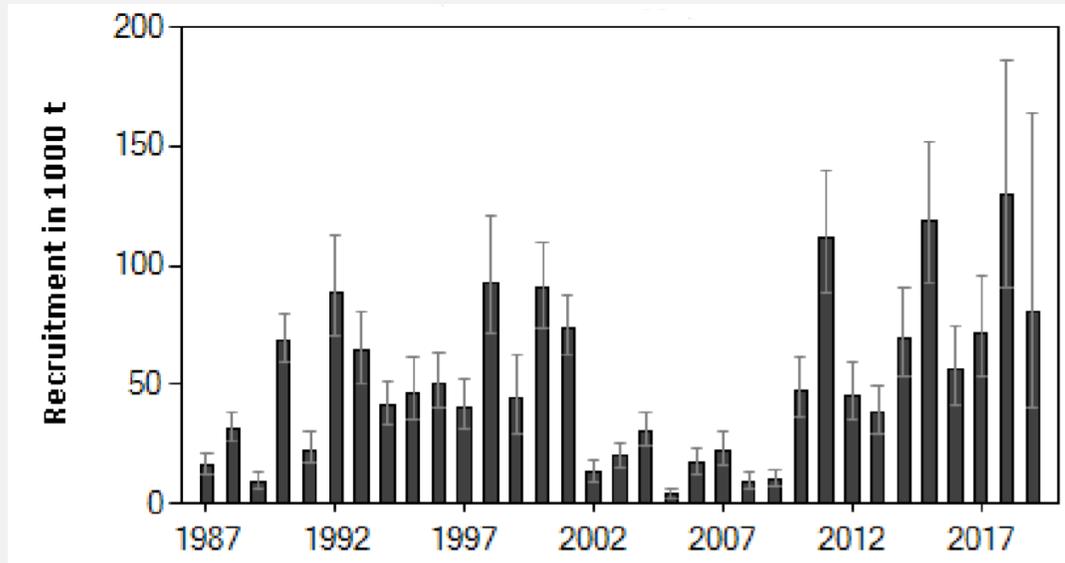


Anchois, *Engraulis encrasicolus*

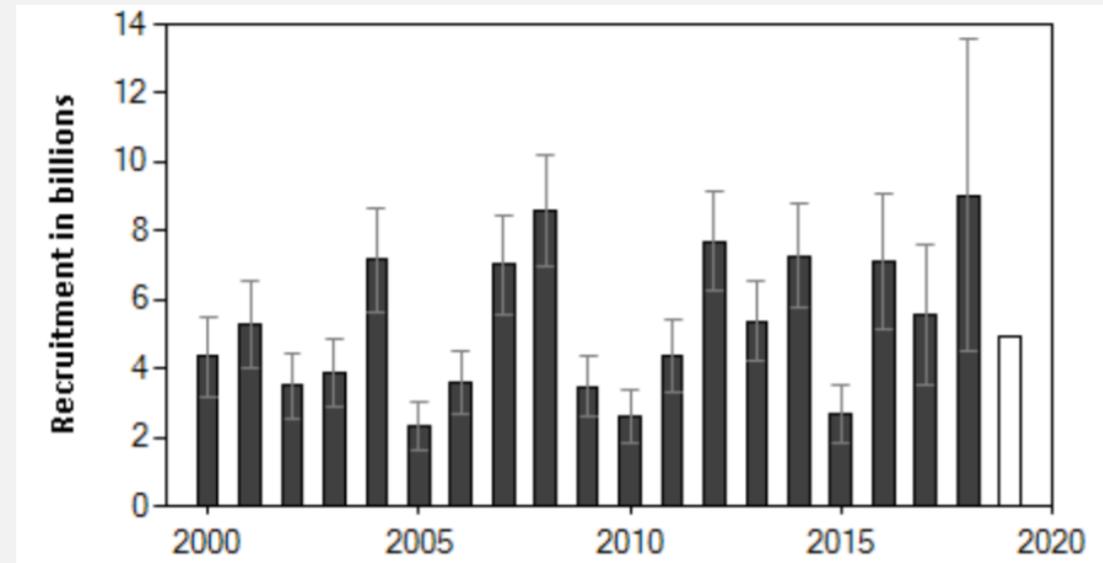


Sardine, *Sardina pilchardus*

Recrutement variable et sensible à l'environnement

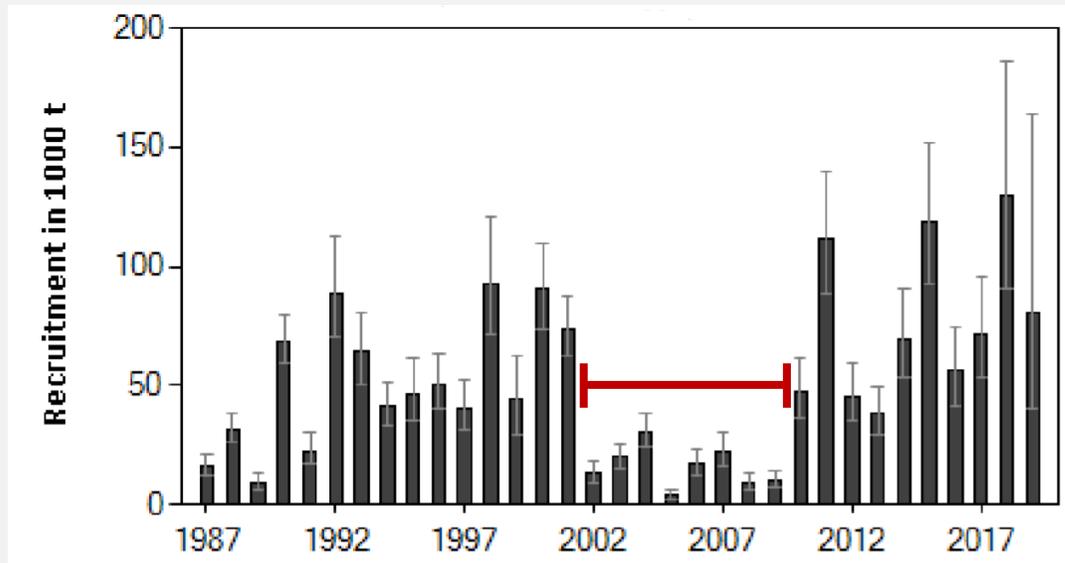


Anchois du golfe de Gascogne (ICES, 2019)

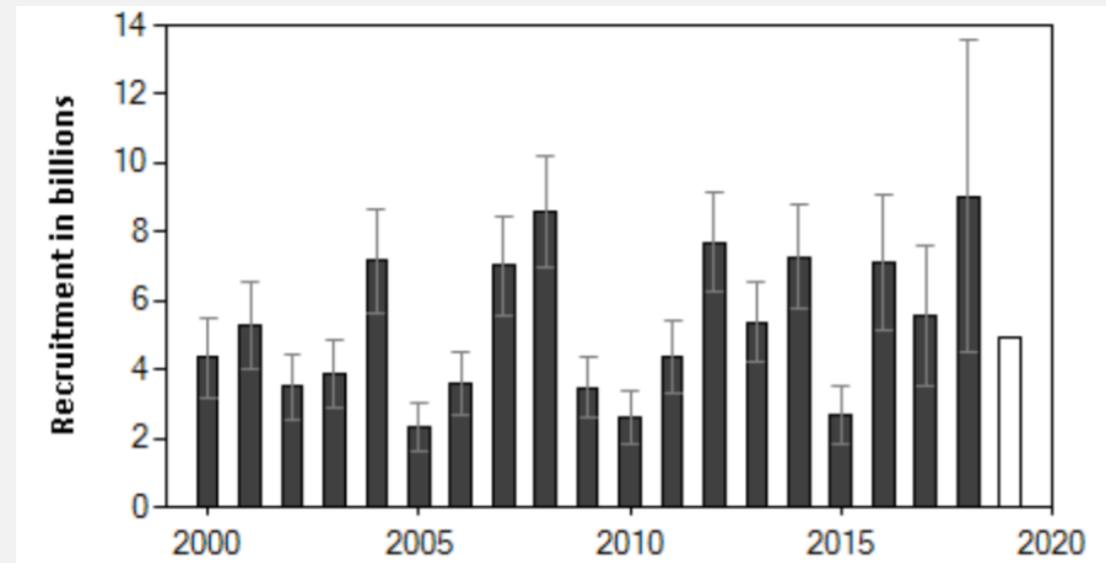


Sardine du golfe de Gascogne (ICES, 2019)

Recrutement variable et sensible à l'environnement

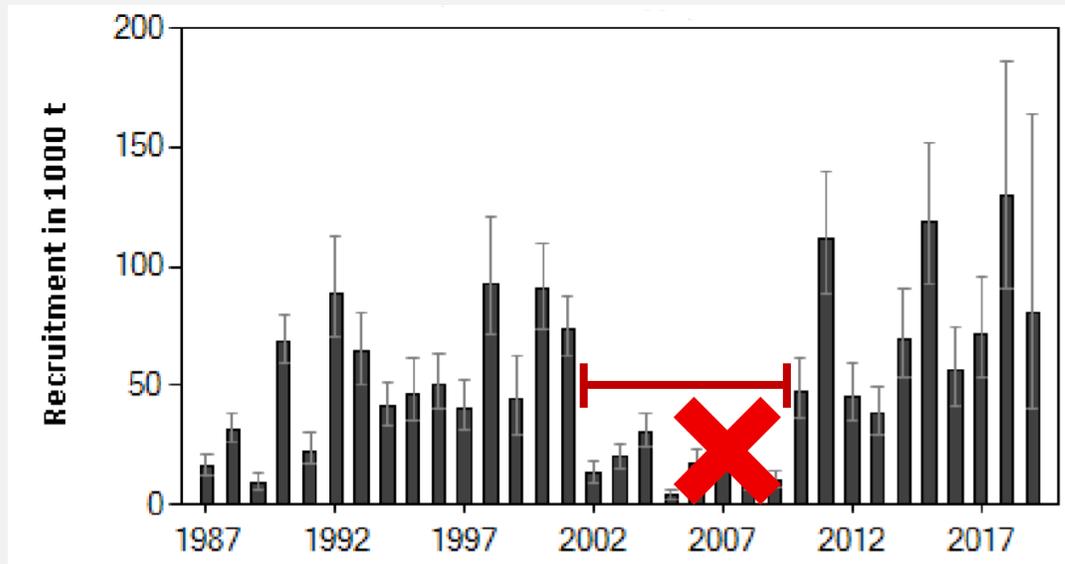


Anchois du golfe de Gascogne (ICES, 2019)

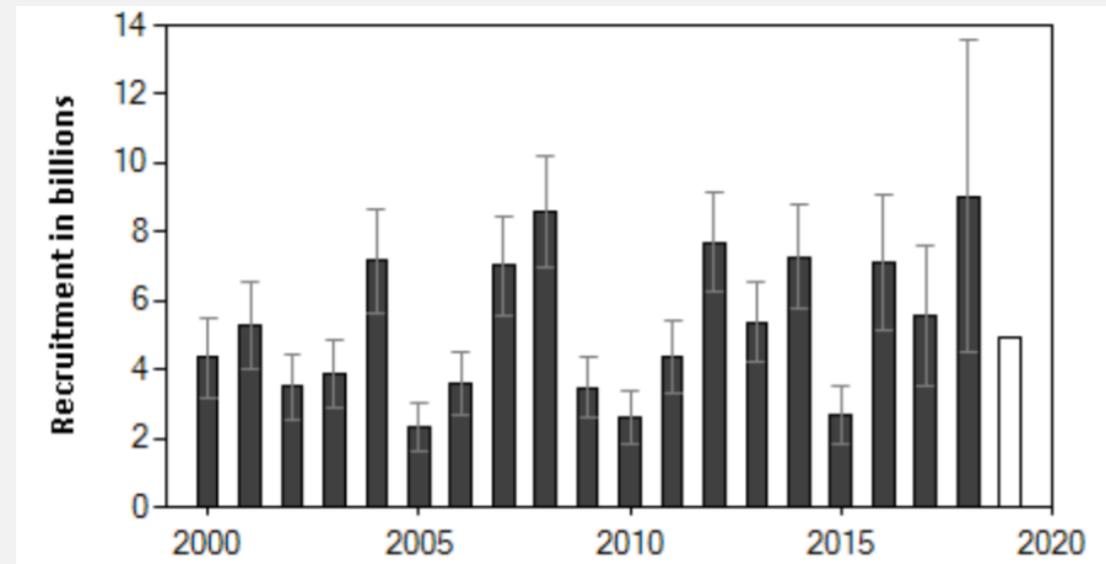


Sardine du golfe de Gascogne (ICES, 2019)

Recrutement variable et sensible à l'environnement



Anchois du golfe de Gascogne (ICES, 2019)



Sardine du golfe de Gascogne (ICES, 2019)

Diminution de taille et de condition

Latitude

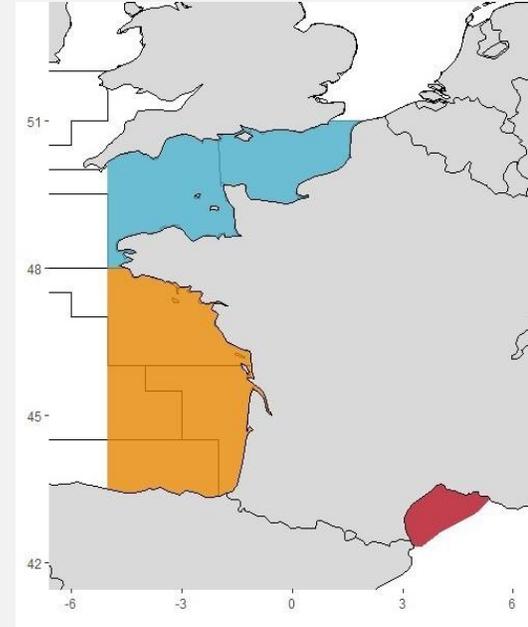
*Golfe de Gascogne**Golfe du Lion*

2000



2020

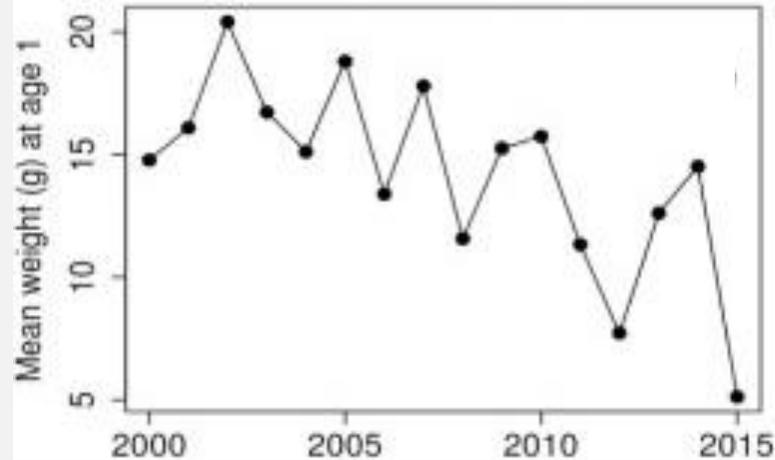
Temps



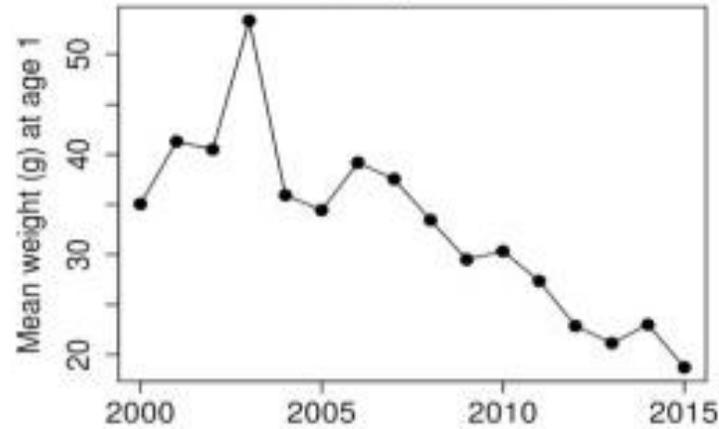
Diminution de taille et de condition



Engraulis encrasicolus

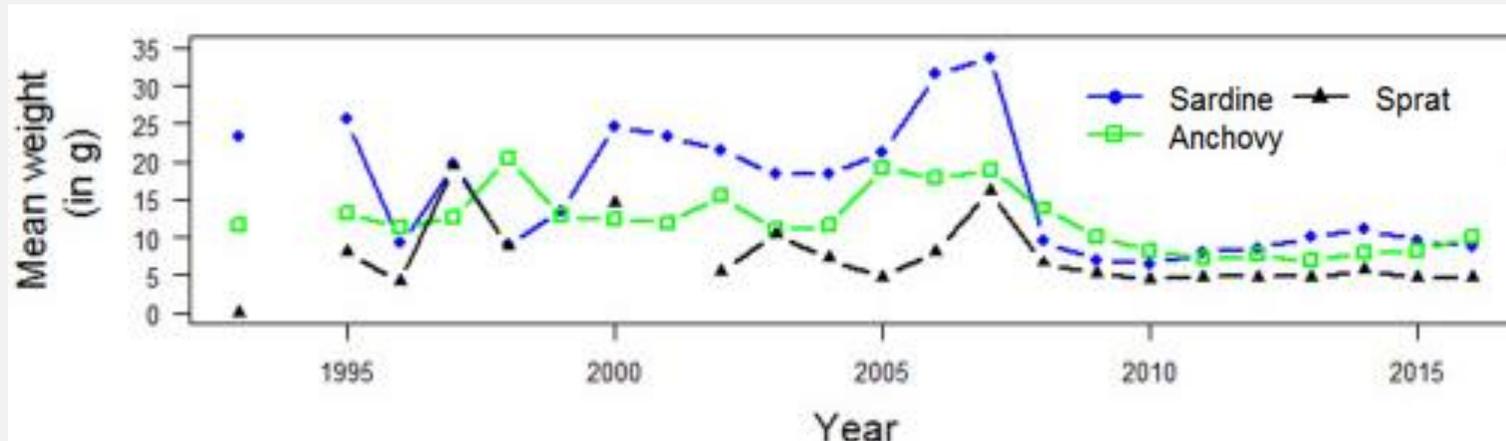


Sardina pilchardus



Golfe de Gascogne

(Doray et al., 2018)

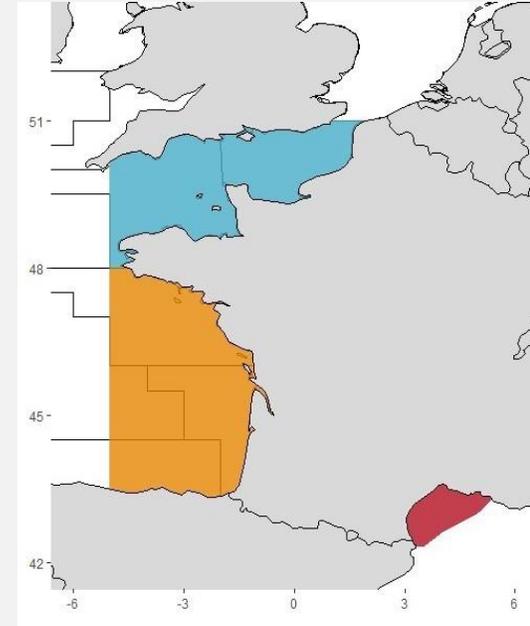


Golfe du Lion

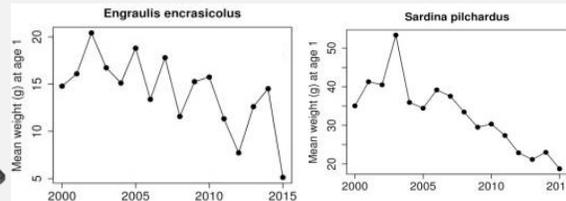
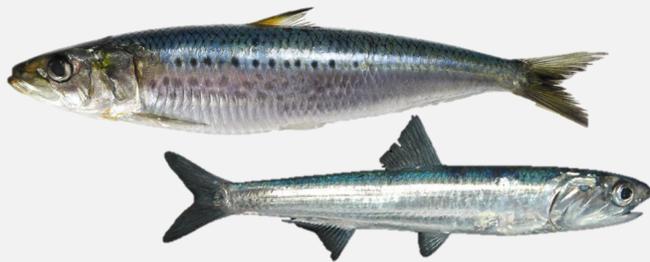
(Saraux et al., 2019)

Diminution de taille et de condition

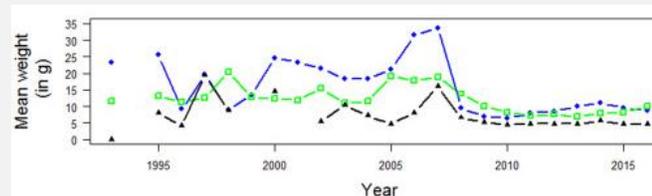
Latitude



Golfe de Gascogne



Golfe du Lion



2000

2020

Temps

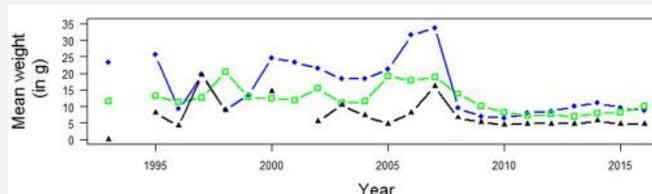
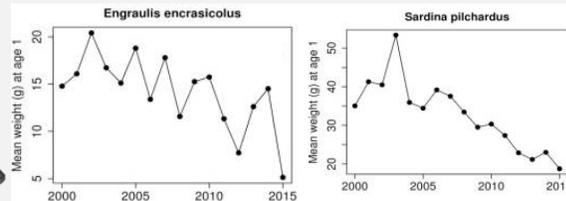
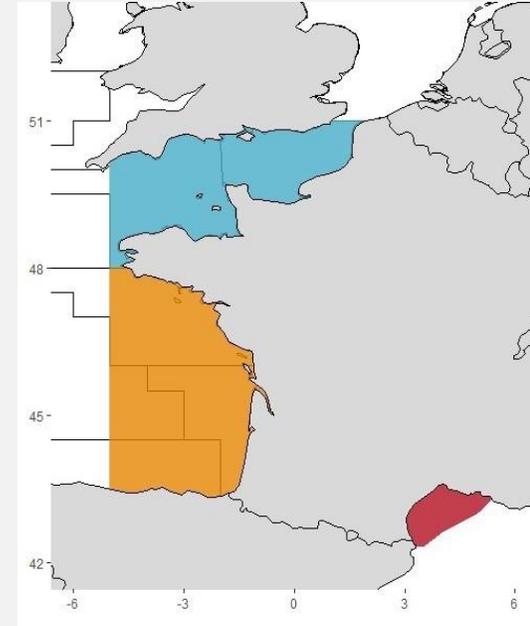
Diminution de taille et de condition

Latitude

Manche

Golfe de Gascogne

Golfe du Lion



2000

2020

Temps

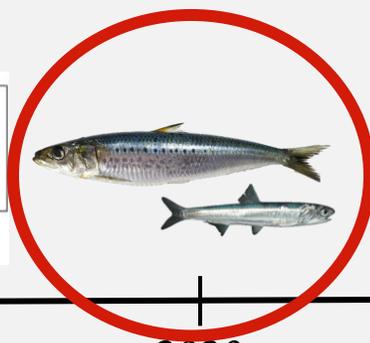
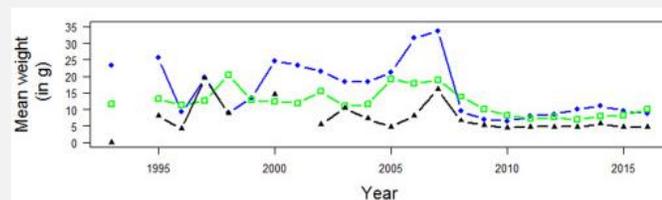
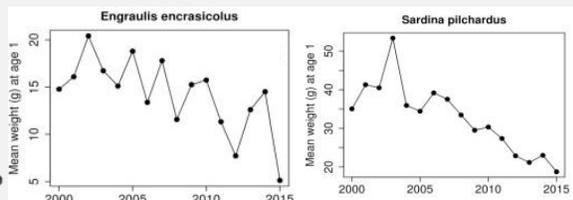
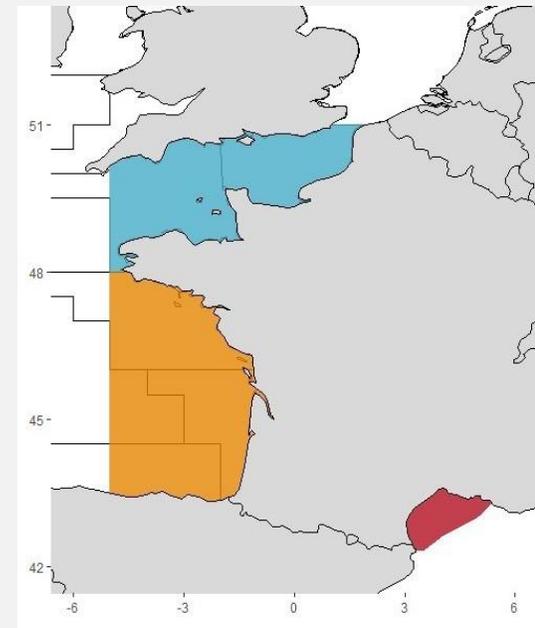
Diminution de taille et de condition

Latitude

Manche

Golfe de Gascogne

Golfe du Lion

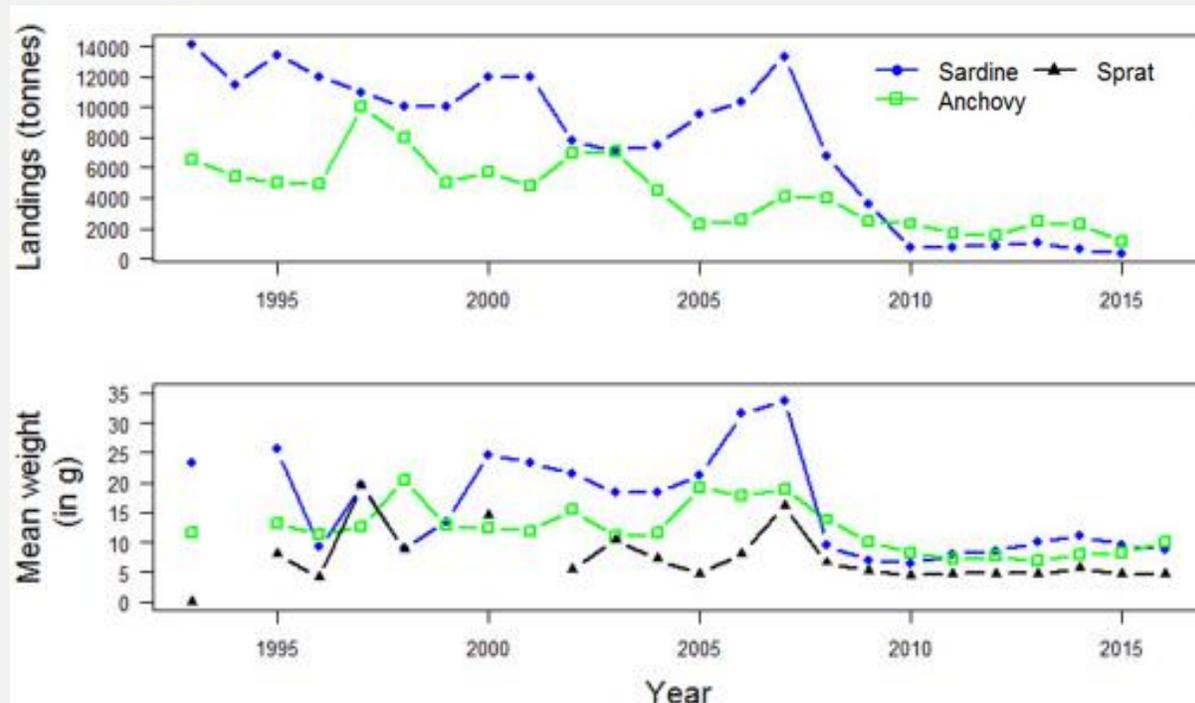


2000

2020

Temps

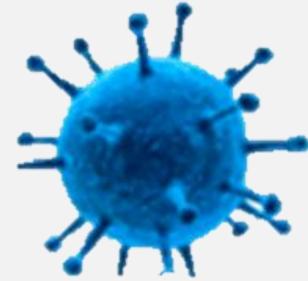
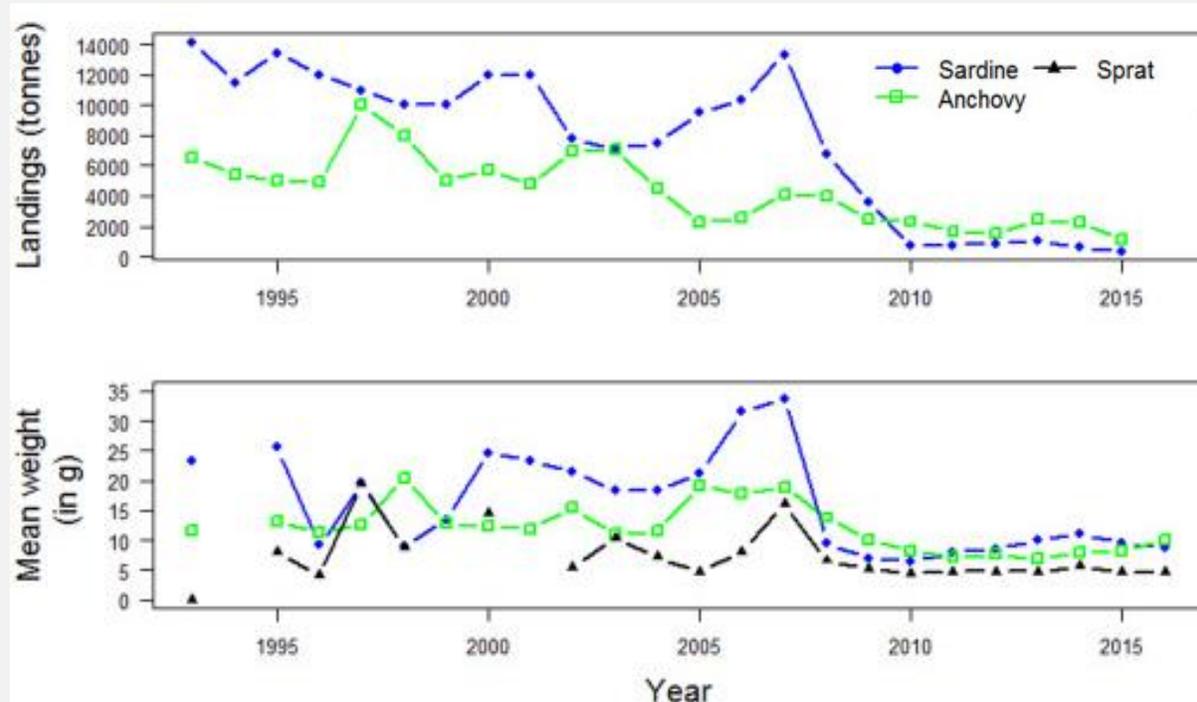
Diminution de taille et de condition



Golfe du Lion

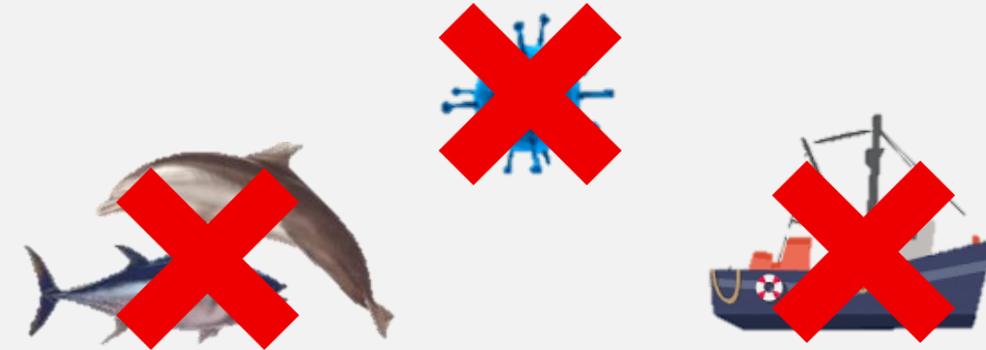
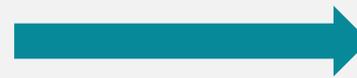
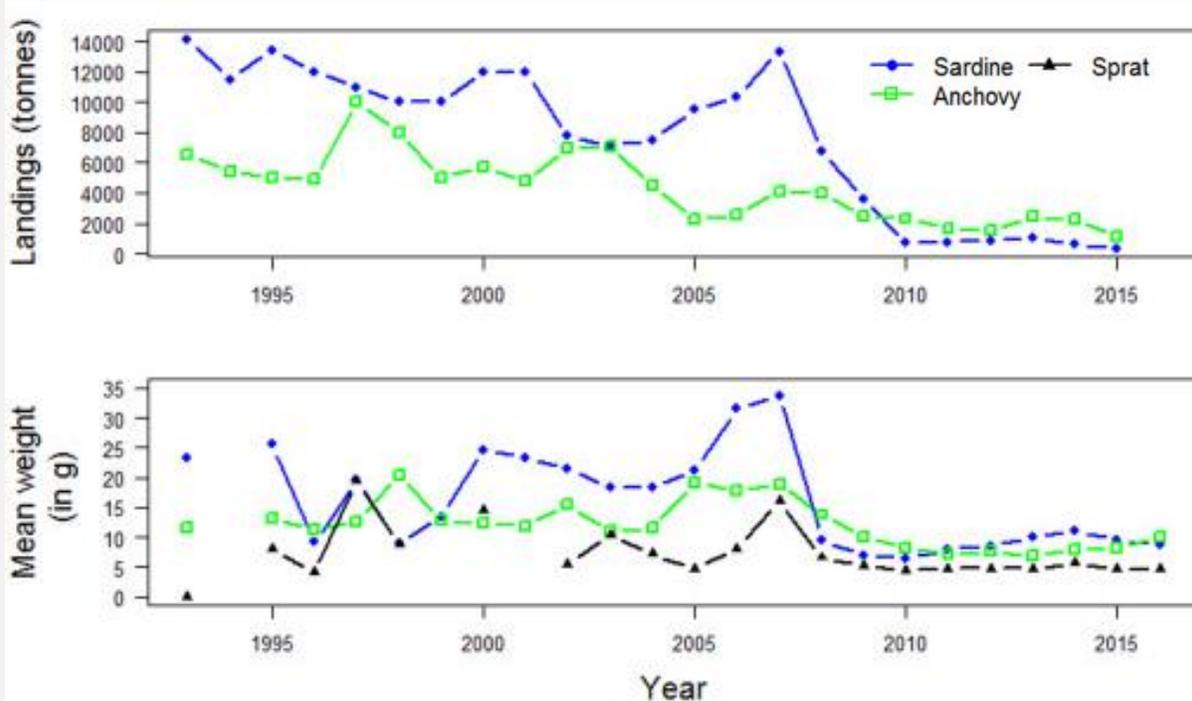
(Saraux et al., 2019)

Diminution de taille et de condition



Golfe du Lion
(Saraux et al., 2019)

Diminution de taille et de condition

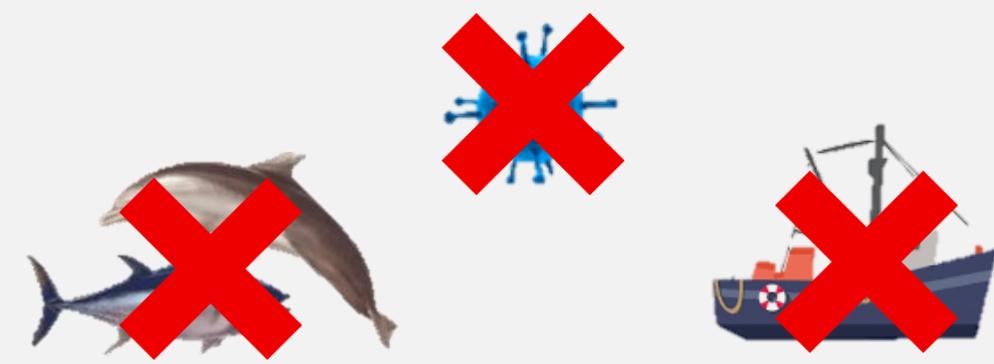
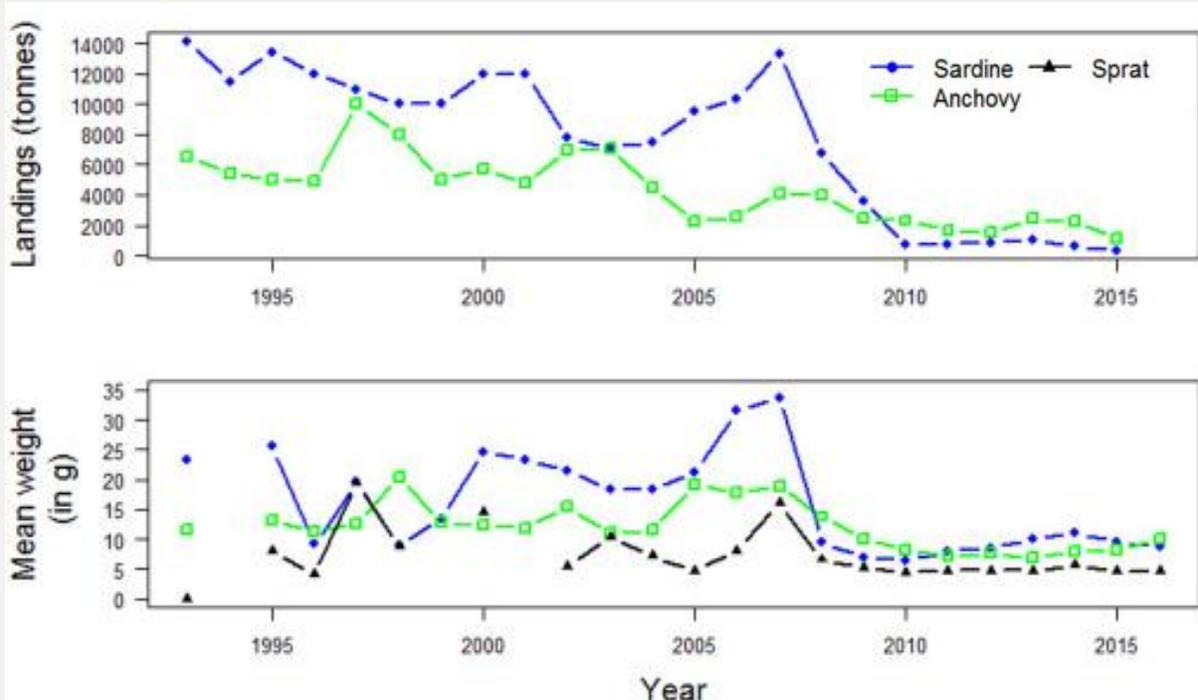


Contrôle bottom-up ?
 (Brosset et al., 2016 ; Saraux et al., 2019)



Golfe du Lion
 (Saraux et al., 2019)

Diminution de taille et de condition



Contrôle bottom-up ?
(Brosset et al., 2016 ; Saraux et al., 2019)

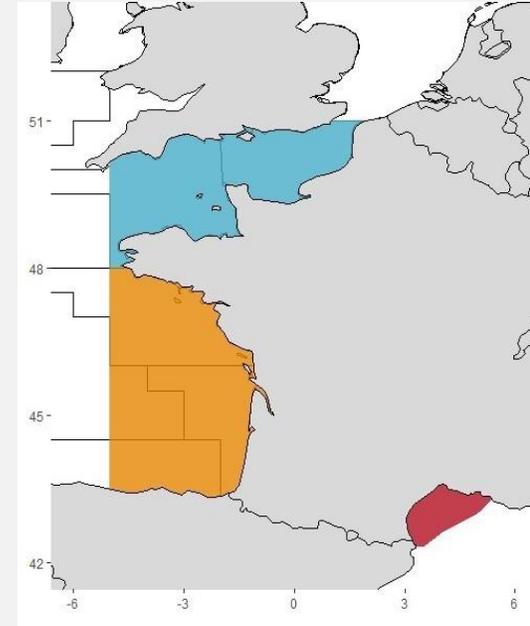
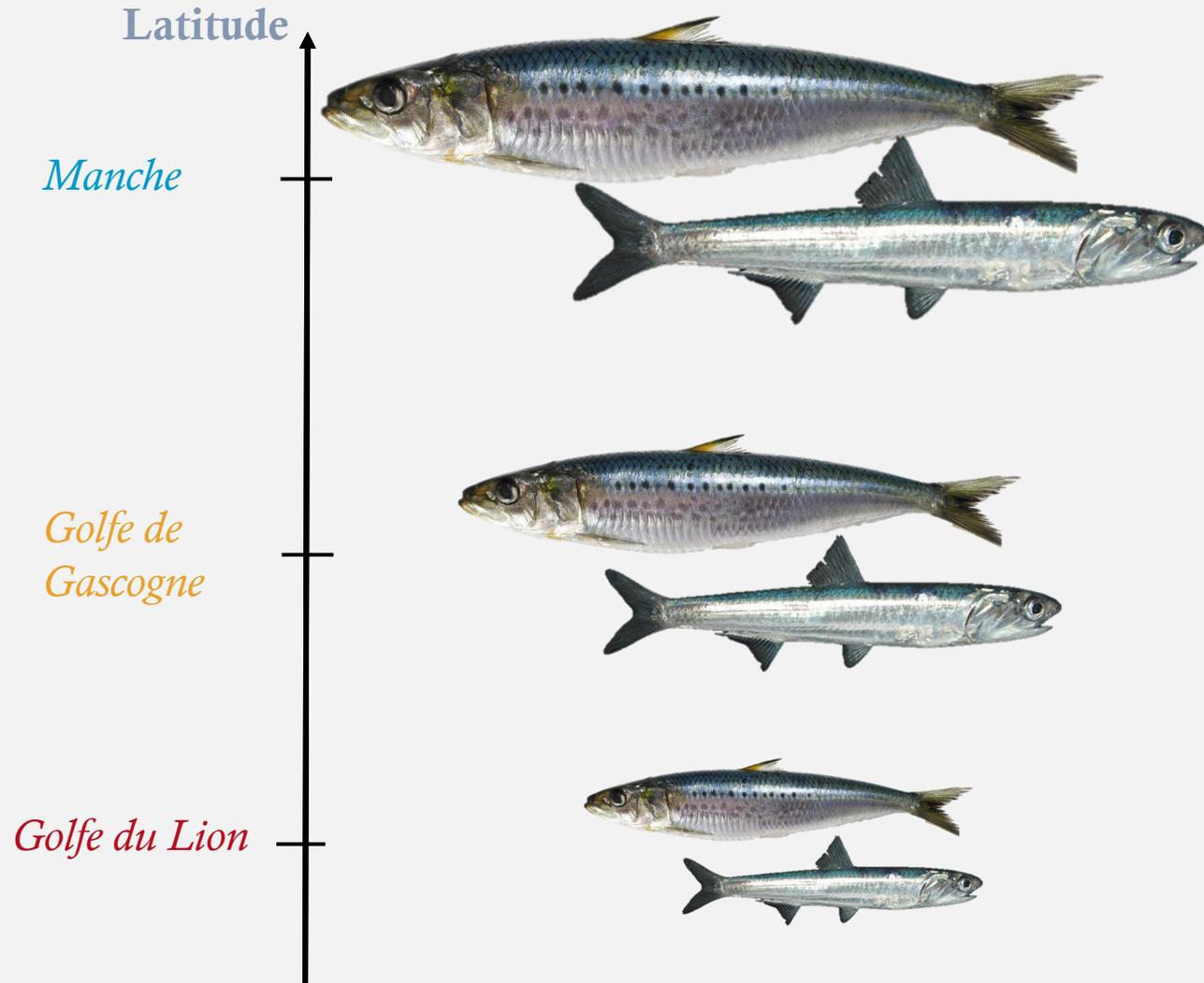


Golfe du Lion
(Saraux et al., 2019)

Golfe de Gascogne
(Véron et al., 2020)

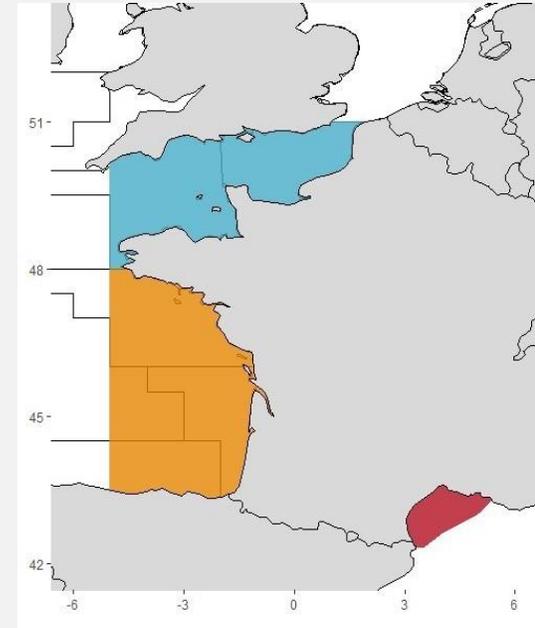
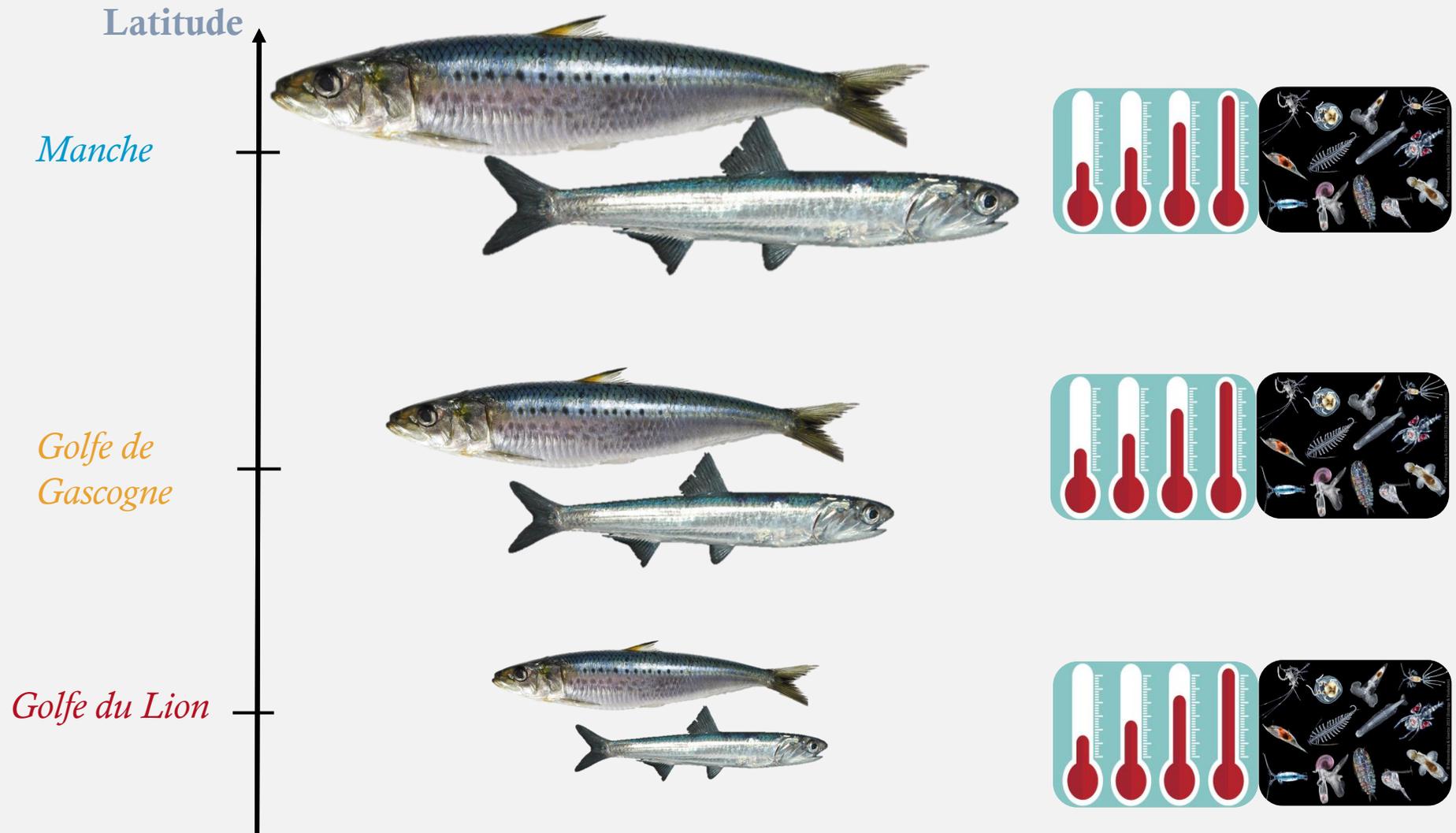
Impact température et Chl-a ?

Variabilité spatiale de taille et de condition



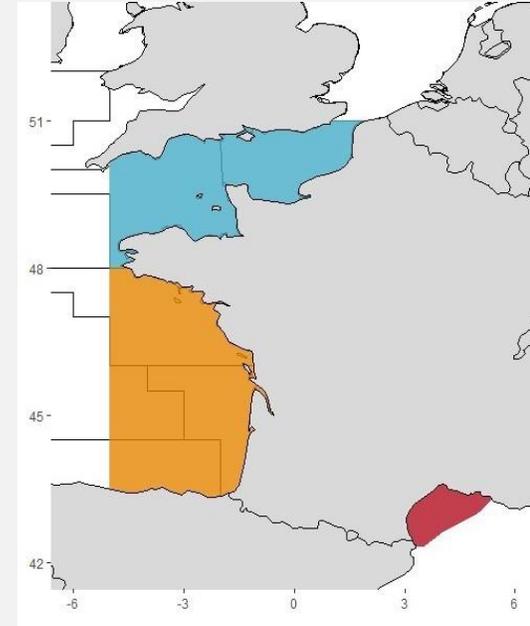
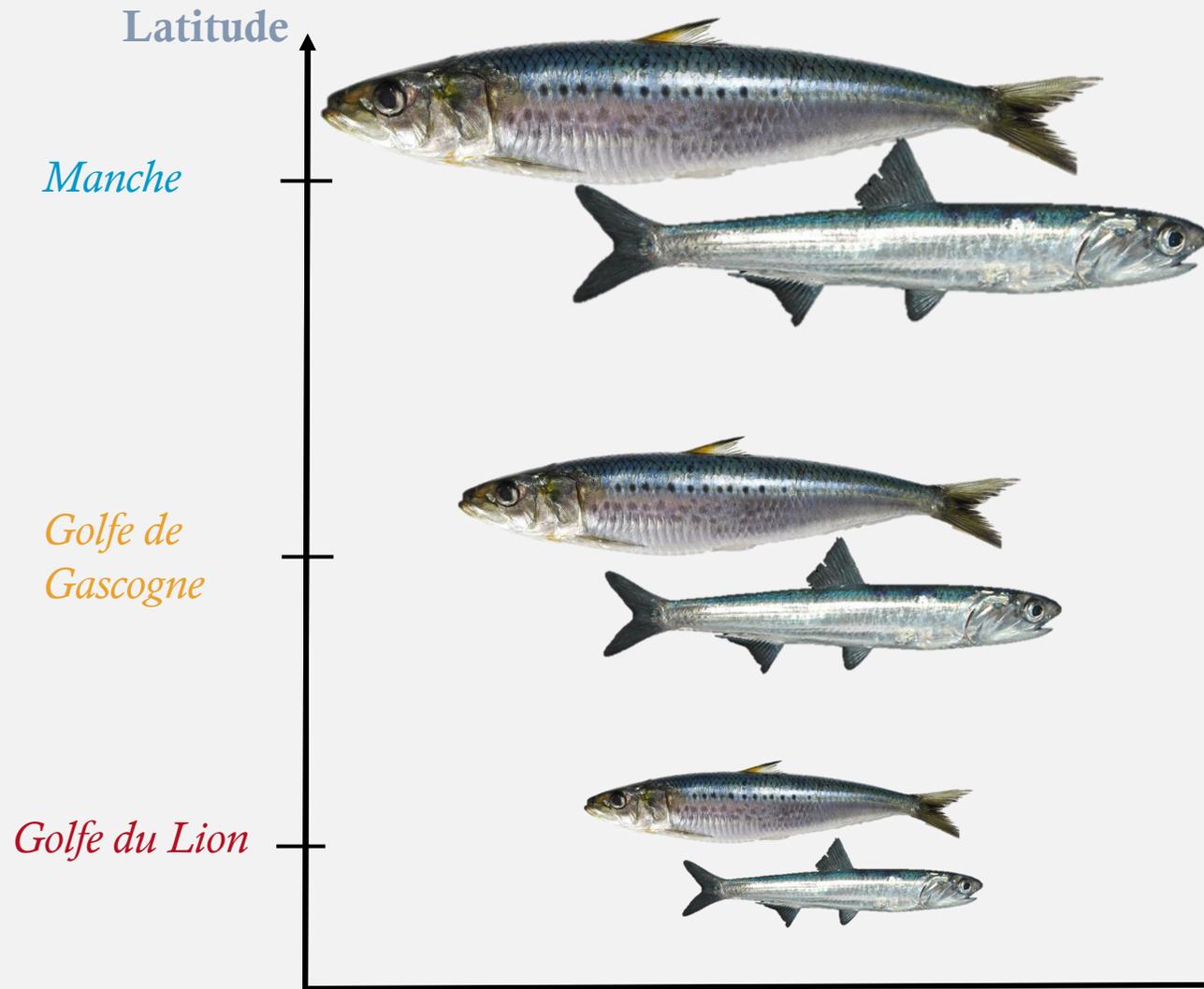
*(Silva et al., 2008 ;
Huret et al., 2019)*

Variabilité spatiale de taille et de condition



(Atkinson and Sibly, 1997;
Kingsolver and Huey, 2008)

Variabilité spatiale de taille et de condition



Changement de l'environnement ?

Problématique

Observation d'une diminution de taille et de condition aux âges des anchois et sardines

Problématique

Observation d'une diminution de taille et de condition aux âges des anchois et sardines

Hypothèse explorée : Changement de l'environnement

Problématique

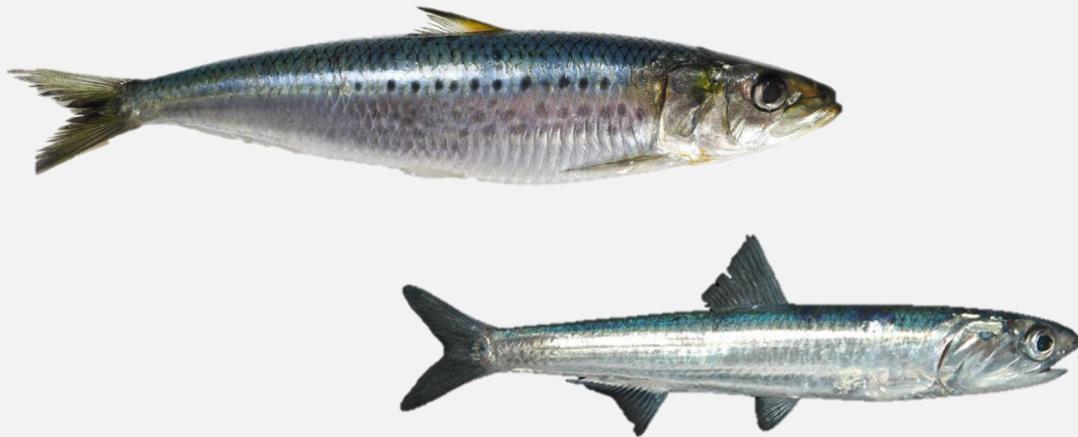
Observation d'une diminution de taille et de condition aux âges des anchois et sardines

Hypothèse explorée : Changement de l'environnement

- **En quelle mesure l'environnement explique-t-il la diminution de taille et de condition des anchois et sardines ?**

Démarche : approche comparative

- 2 espèces



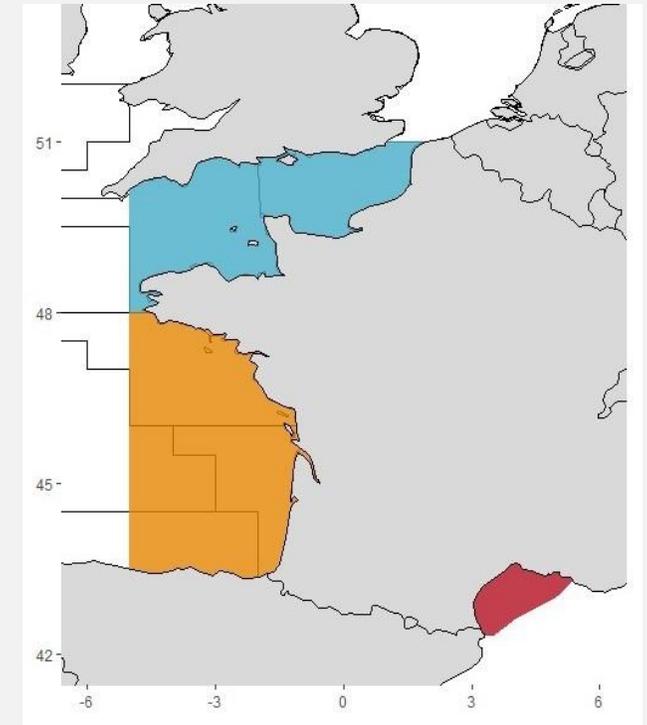
- 3 façades (~ 3 populations)

(Huret et al., 2020)

Manche

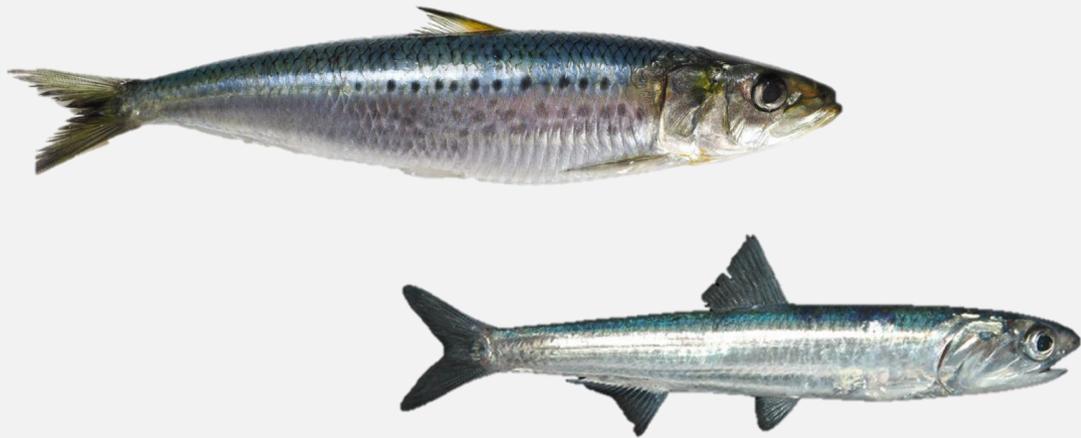
Golfe de
Gascogne

Golfe
du Lion



Démarche : approche comparative

- 2 espèces



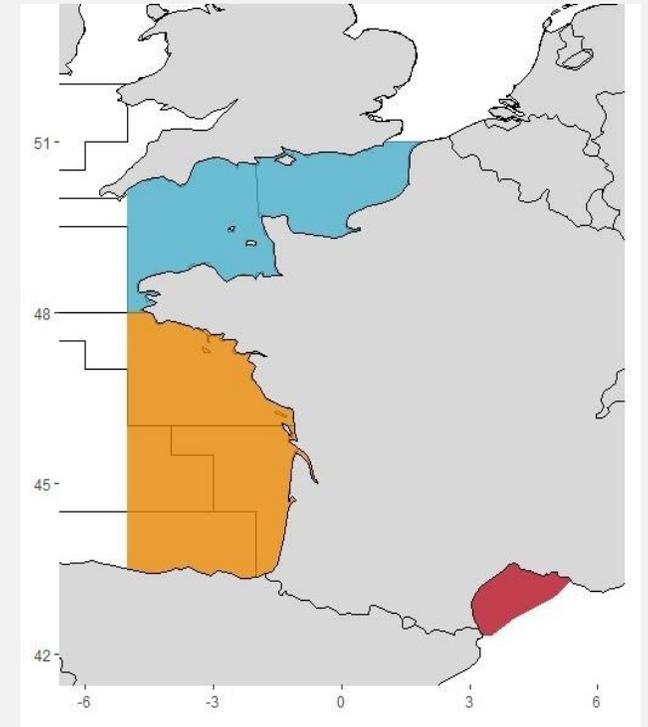
- 3 façades (~ 3 populations)

(Huret et al., 2020)

Manche

Golfe de
Gascogne

Golfe
du Lion



Contraste

Robustesse de nos résultats

Démarche : influence de l'environnement sur le cycle de vie

- Analyse des données (environnement et campagnes)

Variabilité dans nos données ?

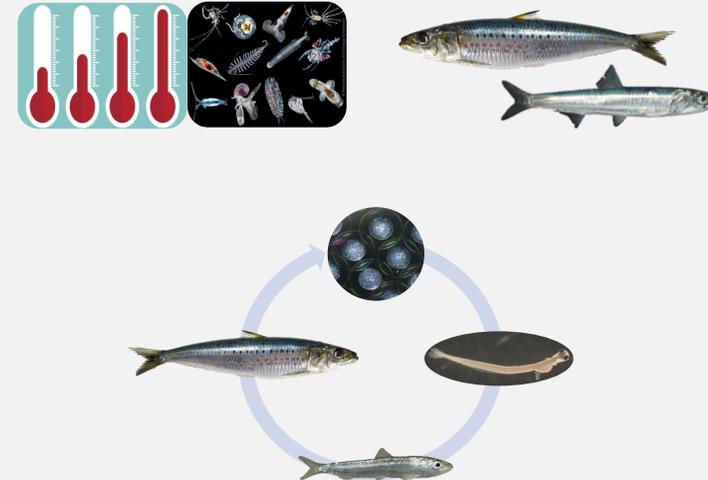
Validité de nos données ?

- Modélisation de l'influence de l'environnement sur développement d'un individu moyen

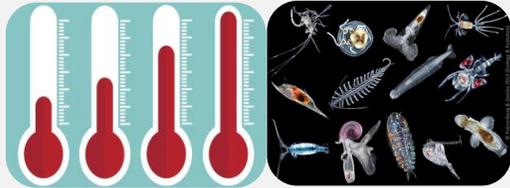
Modélisation bioénergétique

- Approche scénarios

Exploration d'hypothèses (dimension temporelle et spatiale)

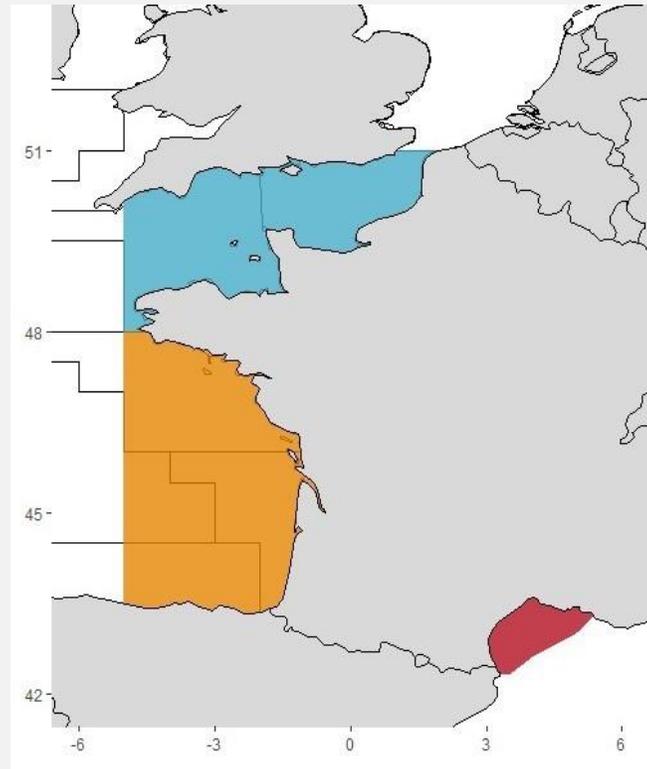


Analyse des données



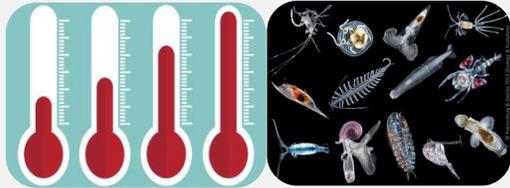
Données d'environnement Modèle POLCOMS-ERSEM

- Spatial
- Temporel
- Zooplancton



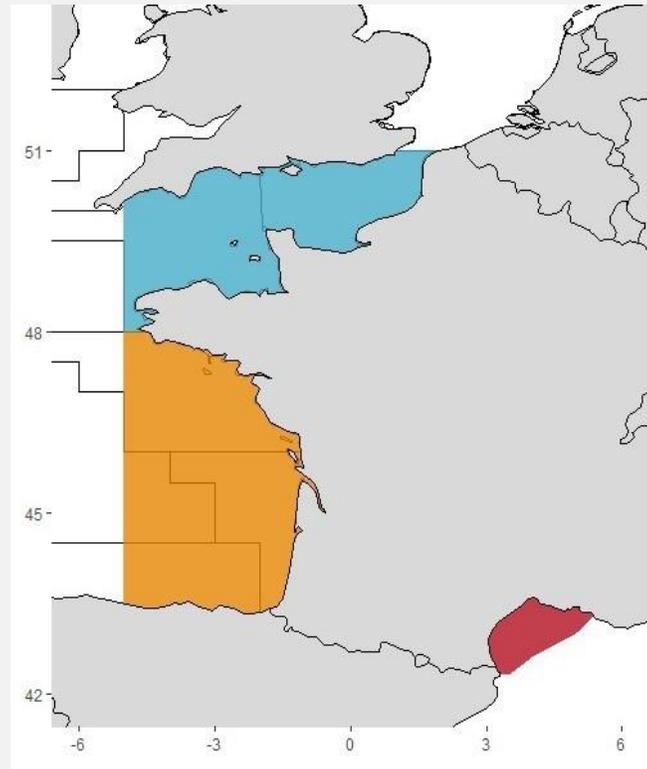
Données de campagnes pélagiques PELTIC, PELGAS, PELMED

Analyse des données



Données d'environnement Modèle POLCOMS-ERSEM

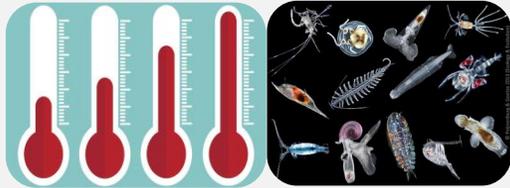
- Données homogènes
- Environnements contrastés



Données de campagnes pélagiques

- Données homogènes
- Données standardisées par des experts locaux (taille et poids)

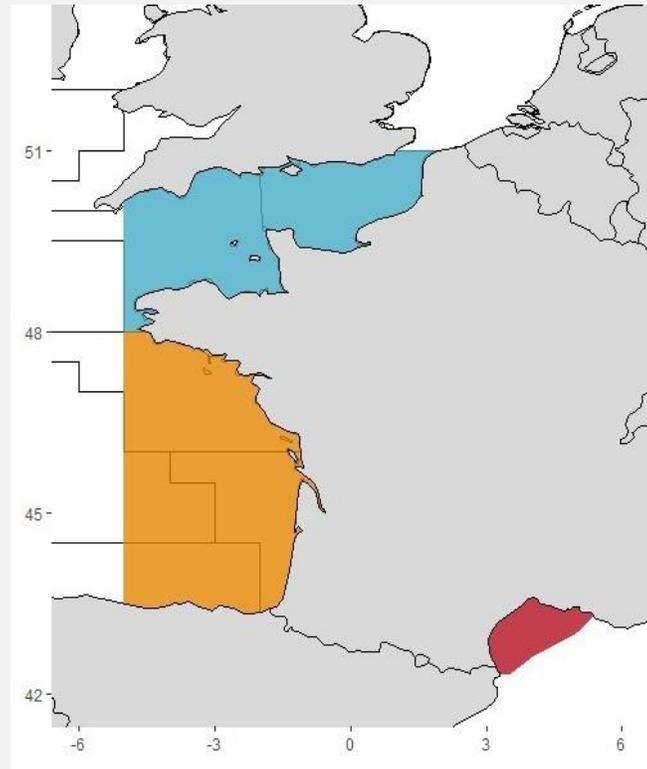
Analyse des données



Données d'environnement Modèle POLCOMS-ERSEM

- Données homogènes
- Environnements contrastés

2000-2015

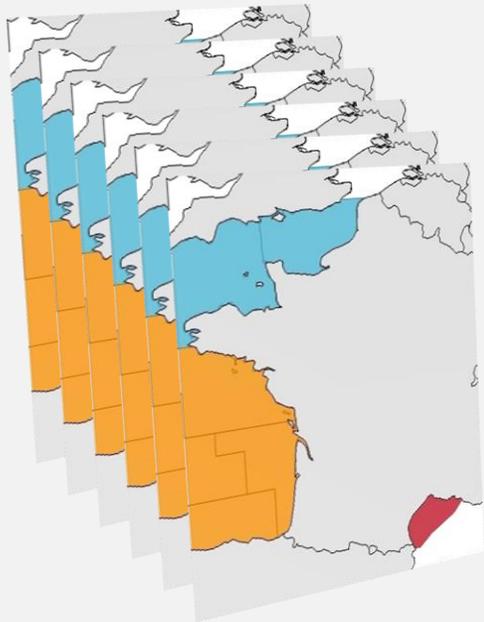


Données de campagnes pélagiques

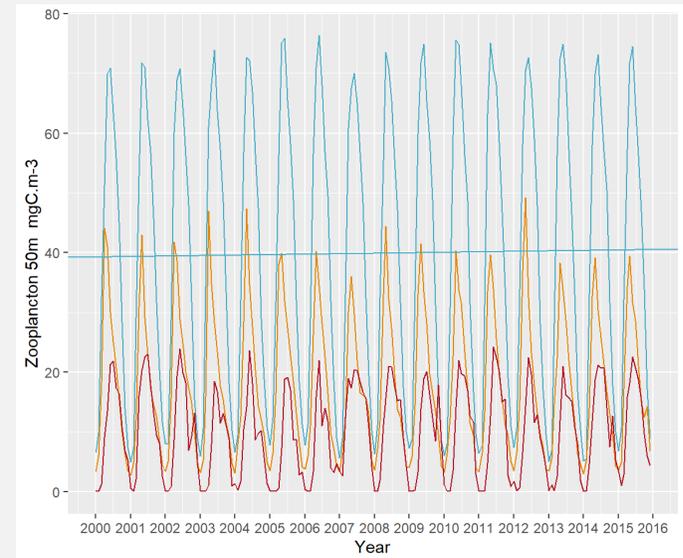
- Données homogènes
- Données standardisées par des experts locaux (taille et poids)

2000-2019

Extraction et analyse des variables de forçage

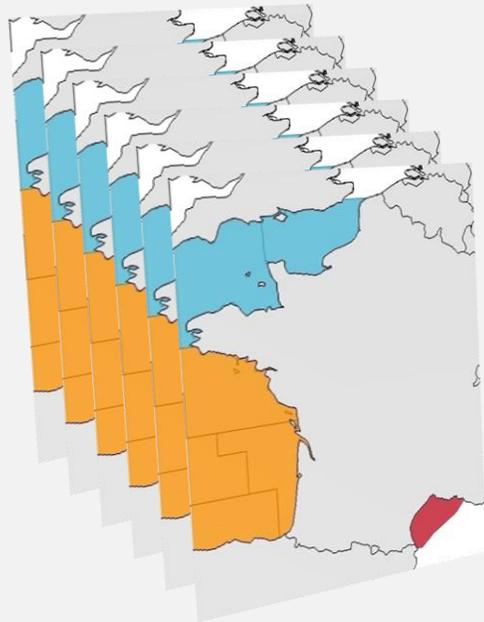
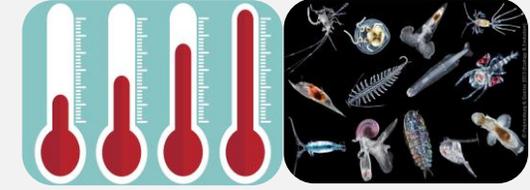


Données 3D

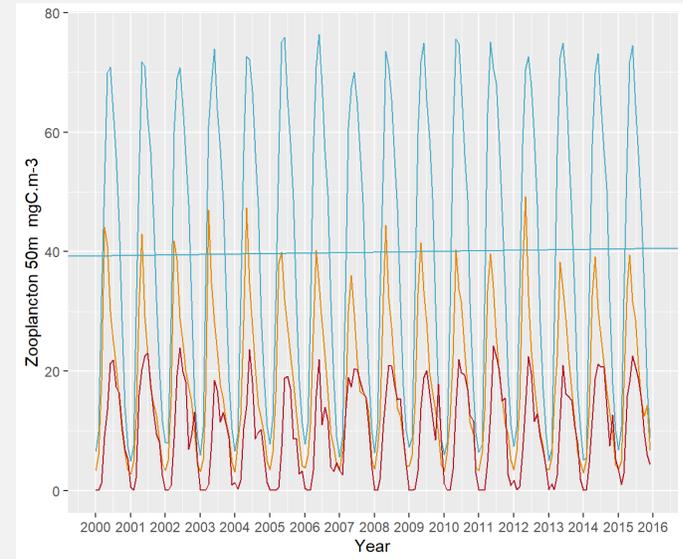


Série temporelle

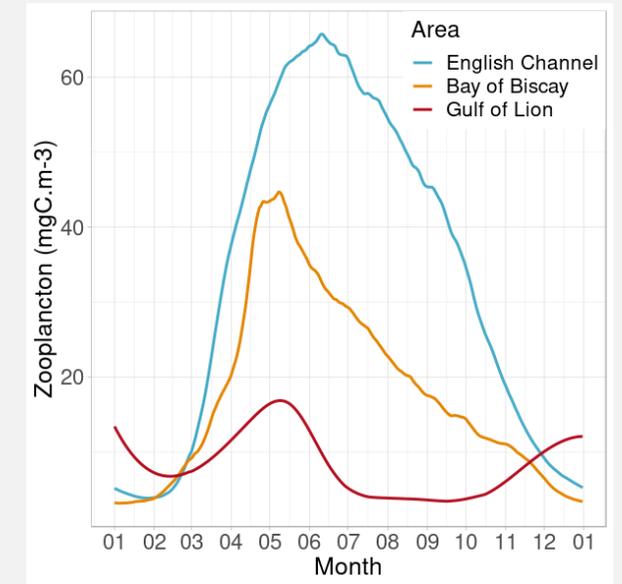
Extraction et analyse des variables de forçage



Données 3D

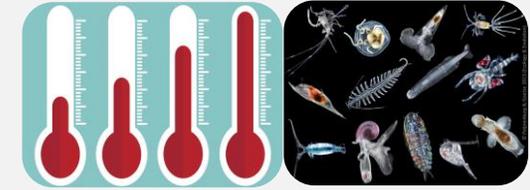


Série temporelle



Climatologies

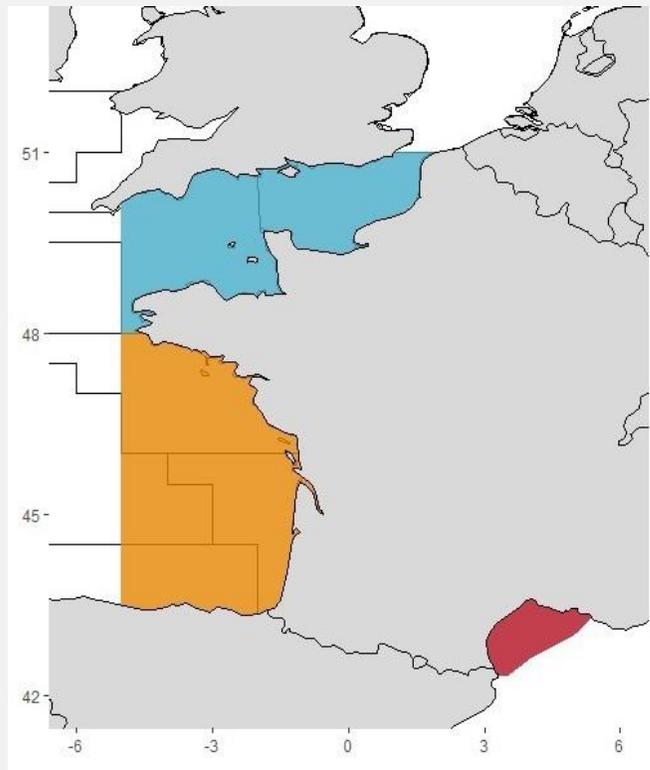
Validité des variables de forçage



Manche

Golfe de Gascogne

Golfe du Lion



Données environnementales
Modèle POLCOMS-ERSEM

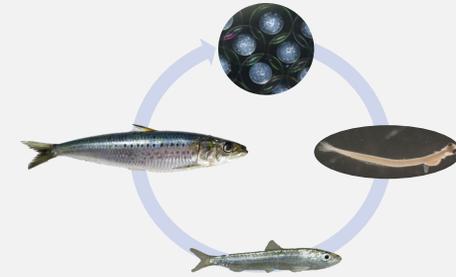


Comparaison



Données satellites

Modélisation de la relation environnement - cycle de vie



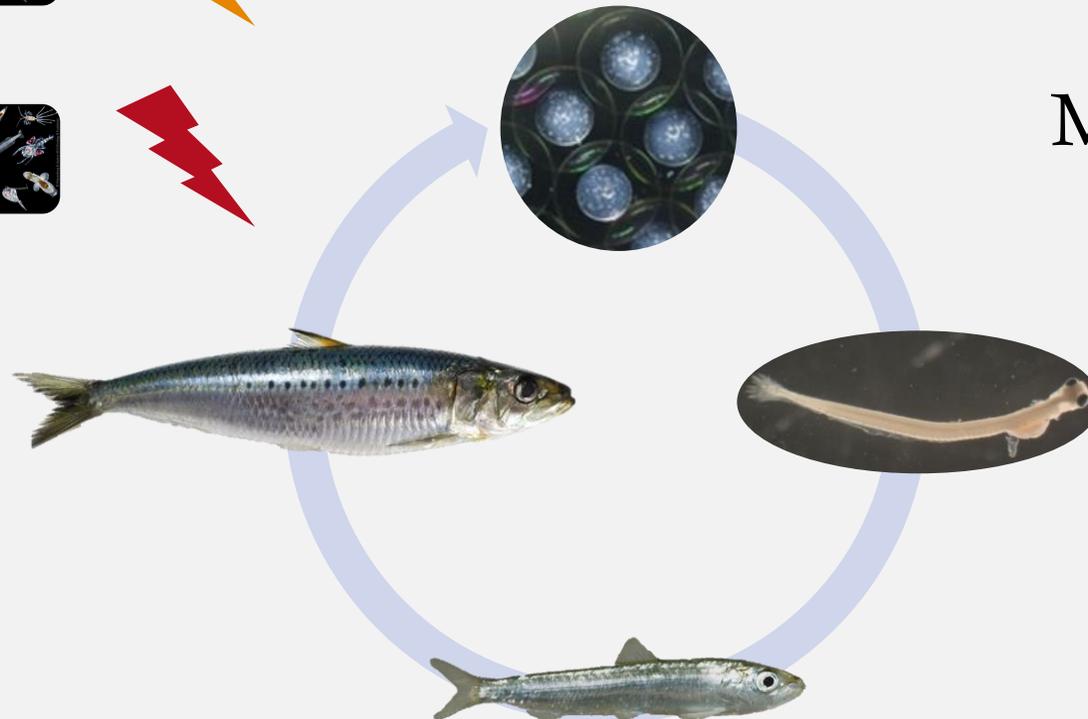
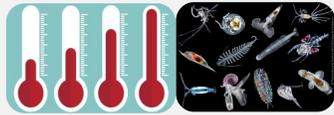
Manche



Golfe de Gascogne

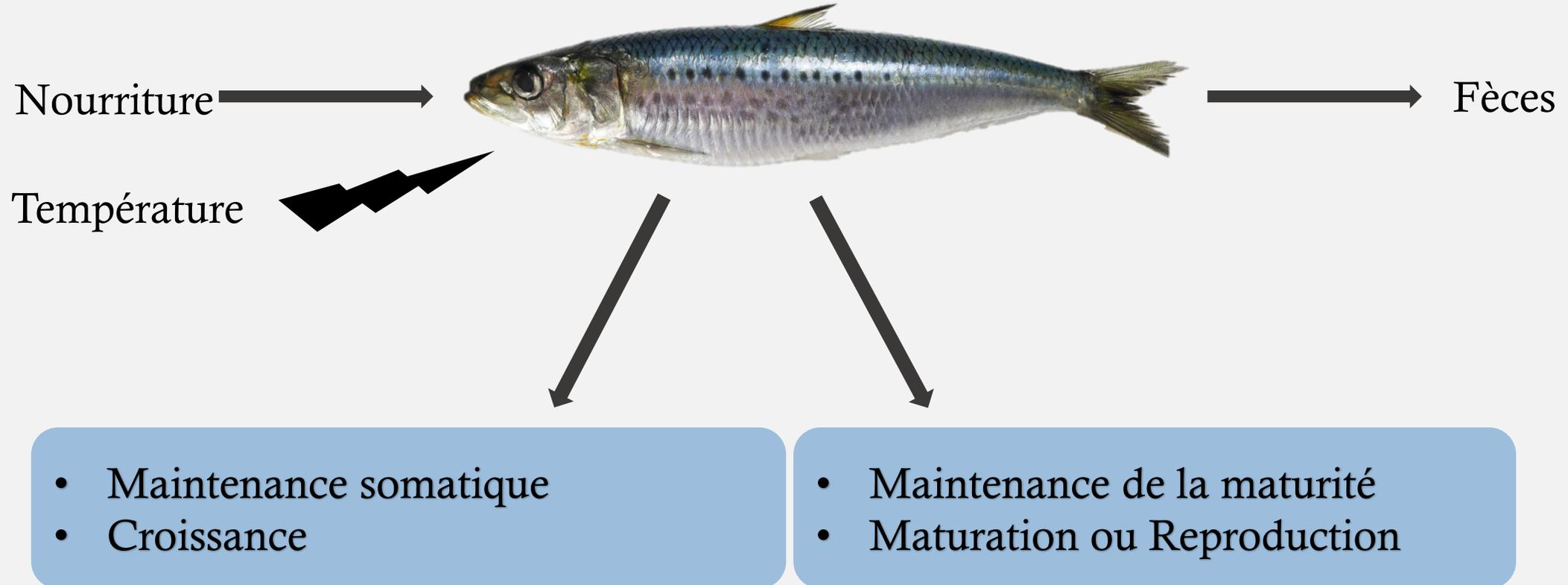
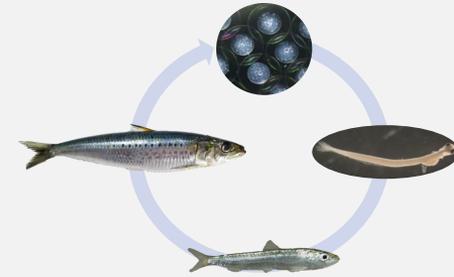


Golfe du Lion



Modèle bioénergétique

Théorie DEB (Dynamic Energy Budget)



Etude des sorties de modèle

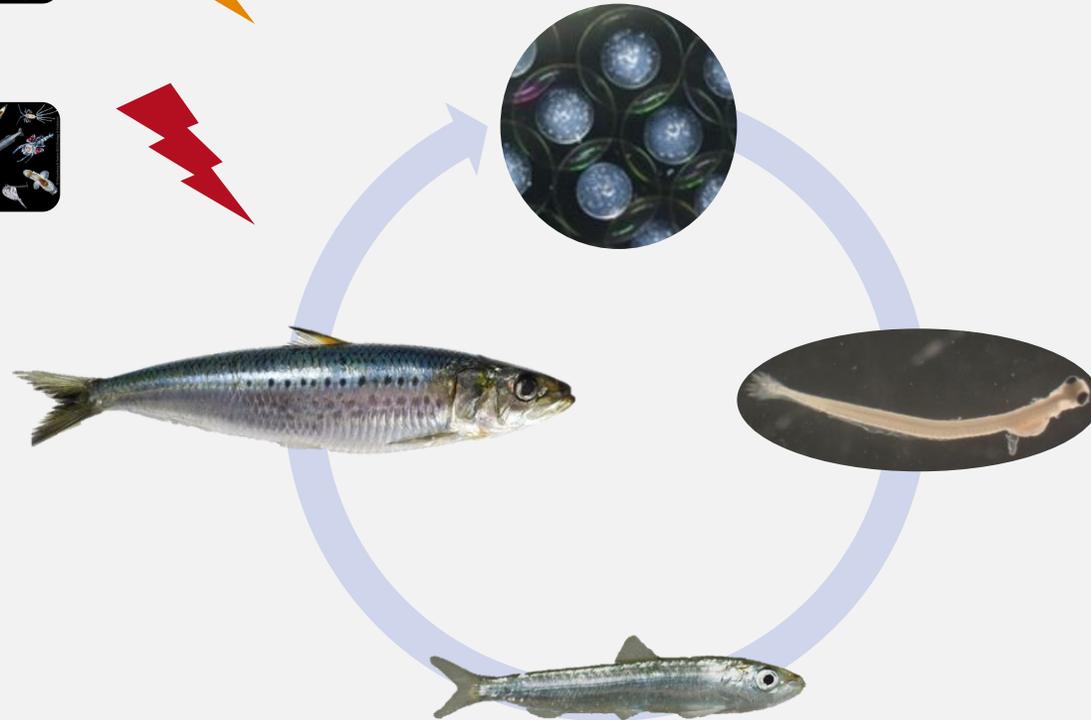
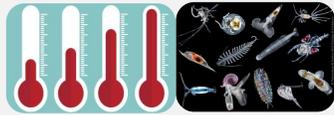
Manche



Golfe de Gascogne



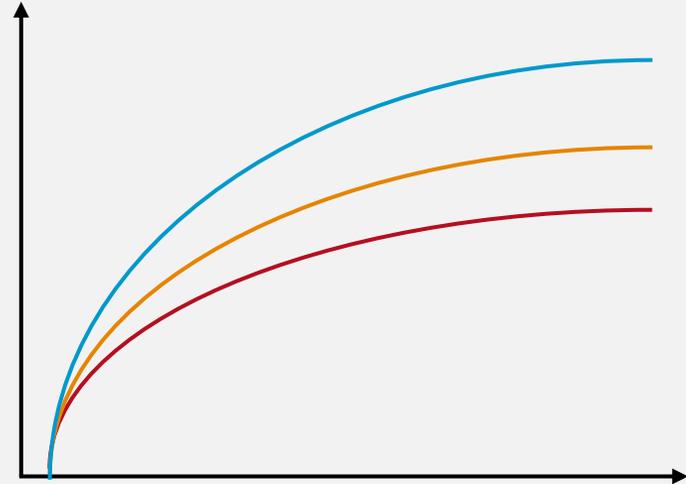
Golfe du Lion



Ajustement : Données de campagnes pélagiques



Taille



Etude des sorties de modèle

Ajustement : Données de campagnes pélagiques



2000-2005 2010-2015

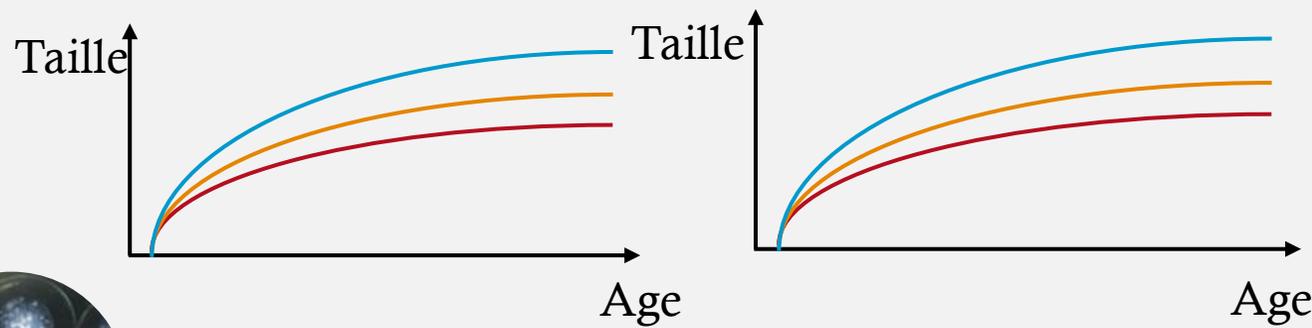
Manche



Golfe de Gascogne

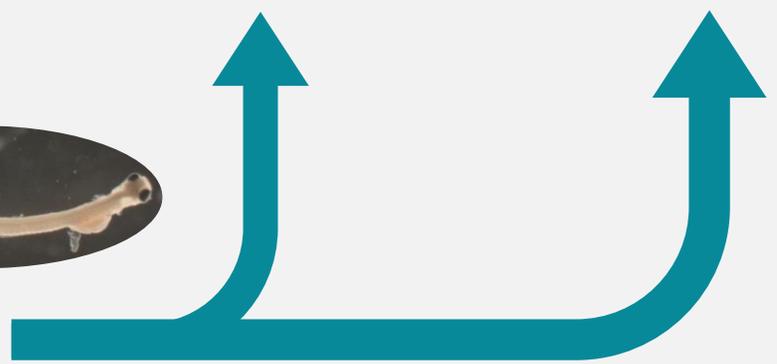
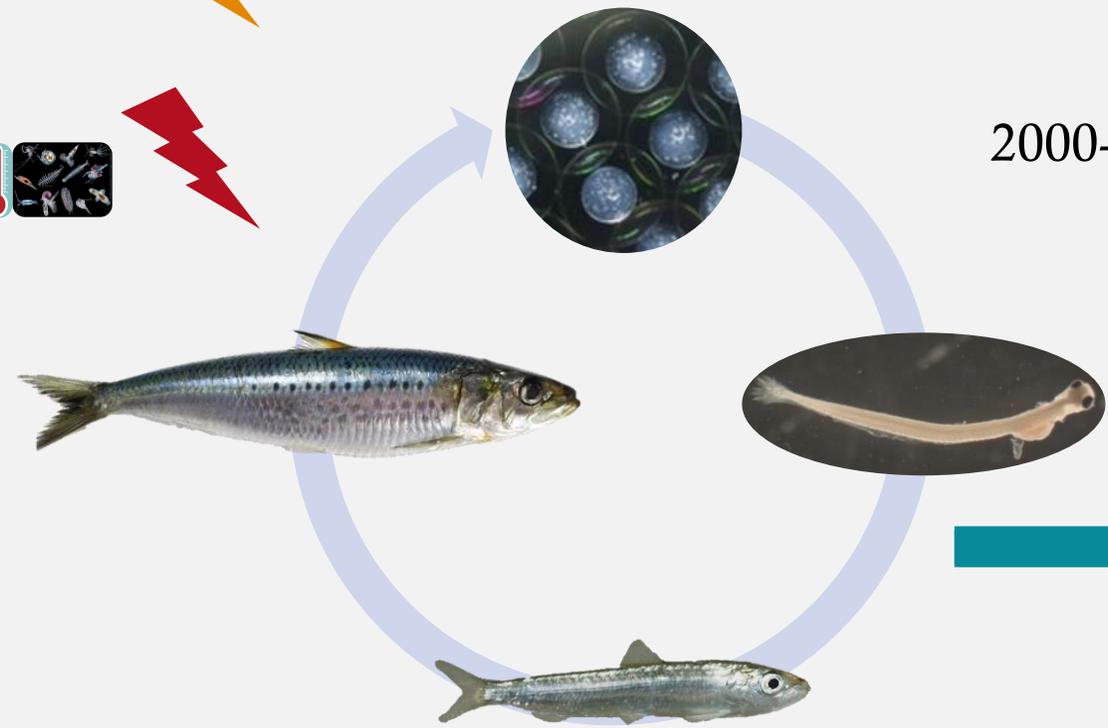


Golfe du Lion

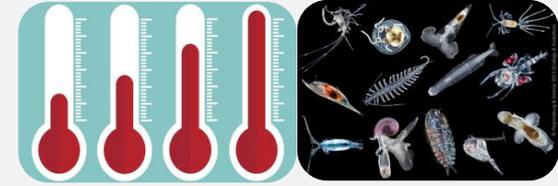


2000-2005

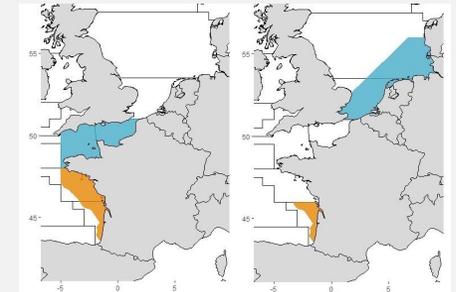
2010-2015



Approche scénarios

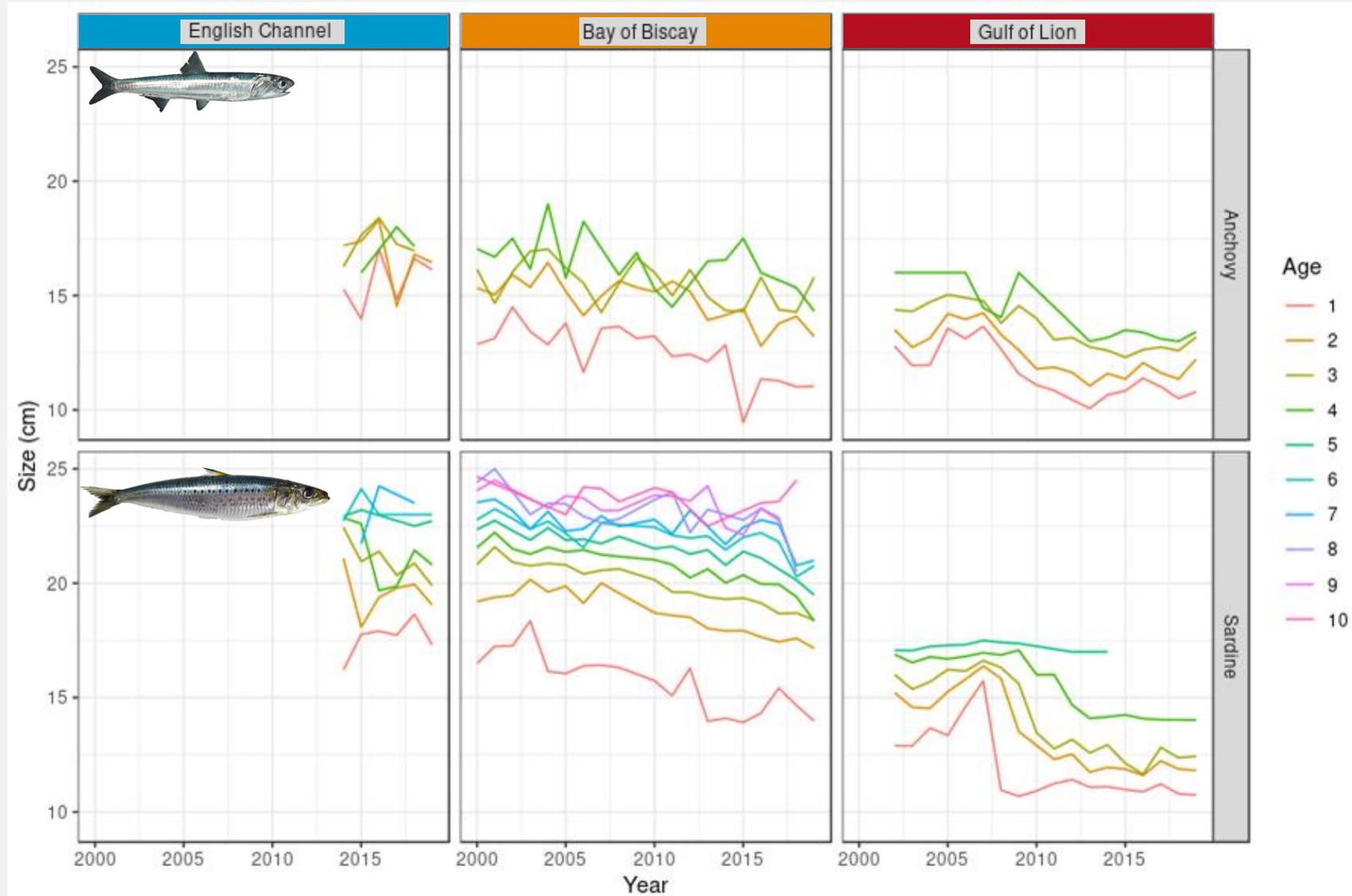


- **SC1** : Amélioration du réalisme des tendances temporelles (zooplancton)
- **SC2** : Spatialisation du cycle de vie



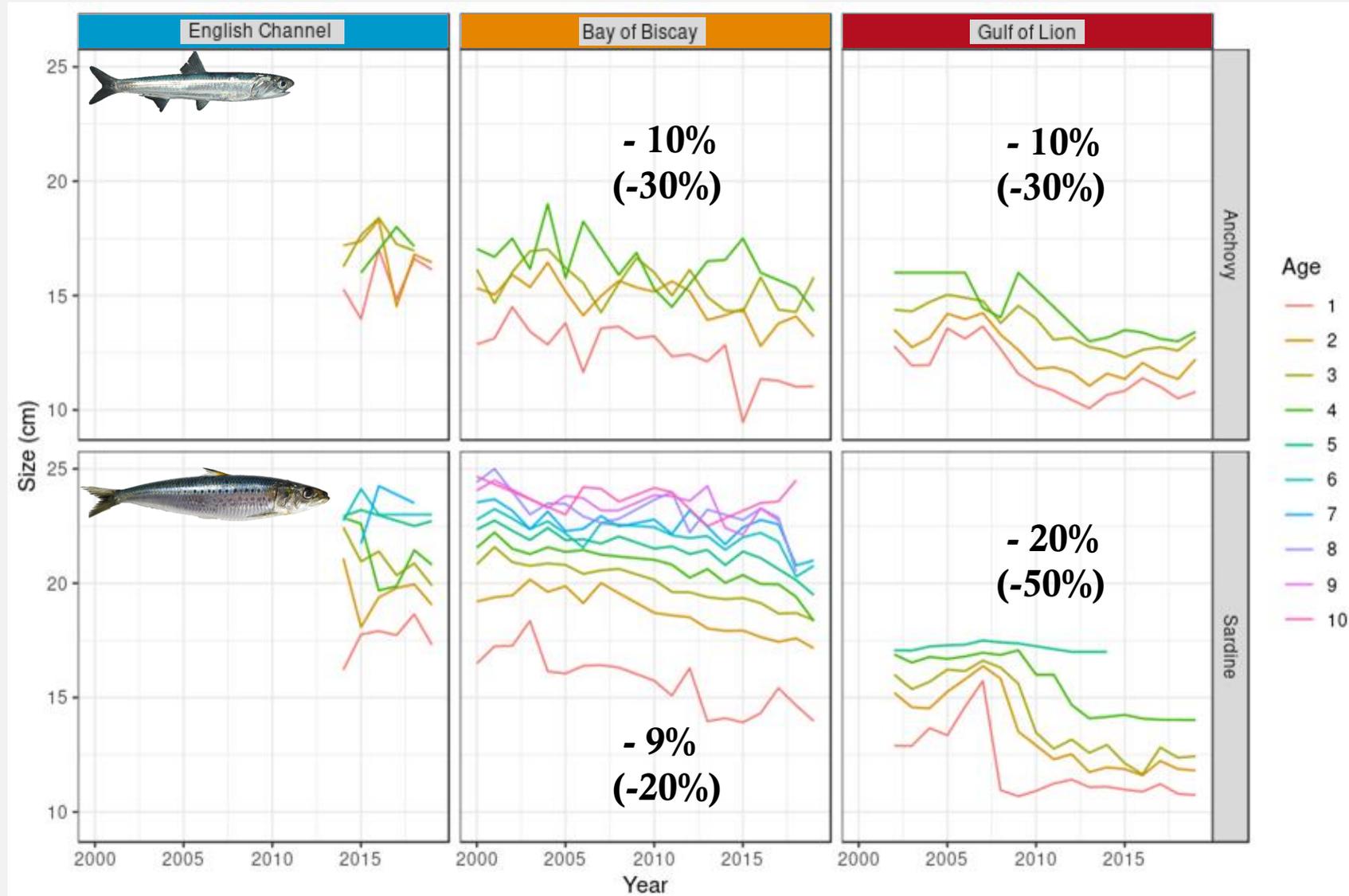


Diminution de taille dans les données de campagnes pélagiques

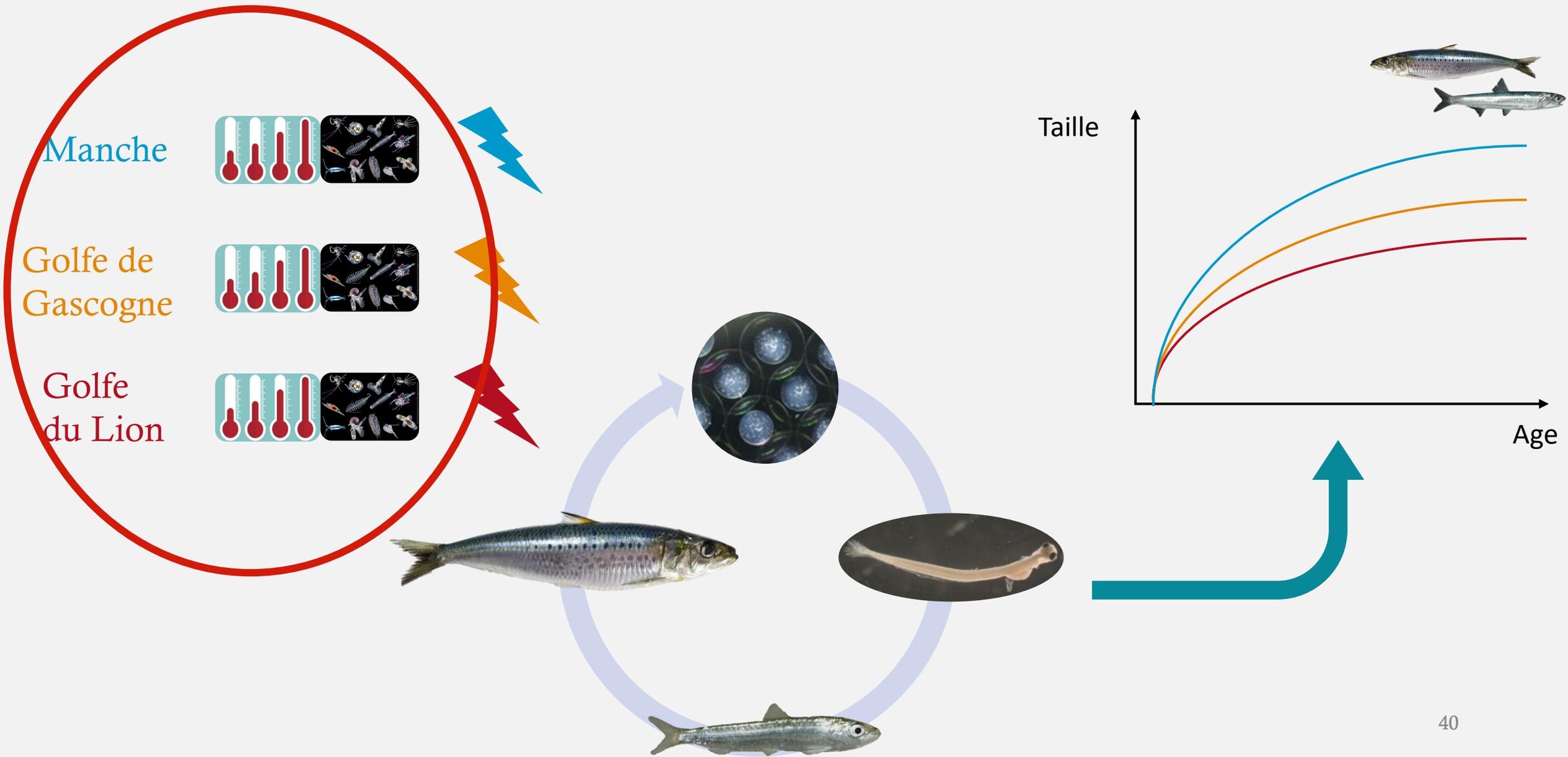




Diminution de taille dans les données de campagnes pélagiques

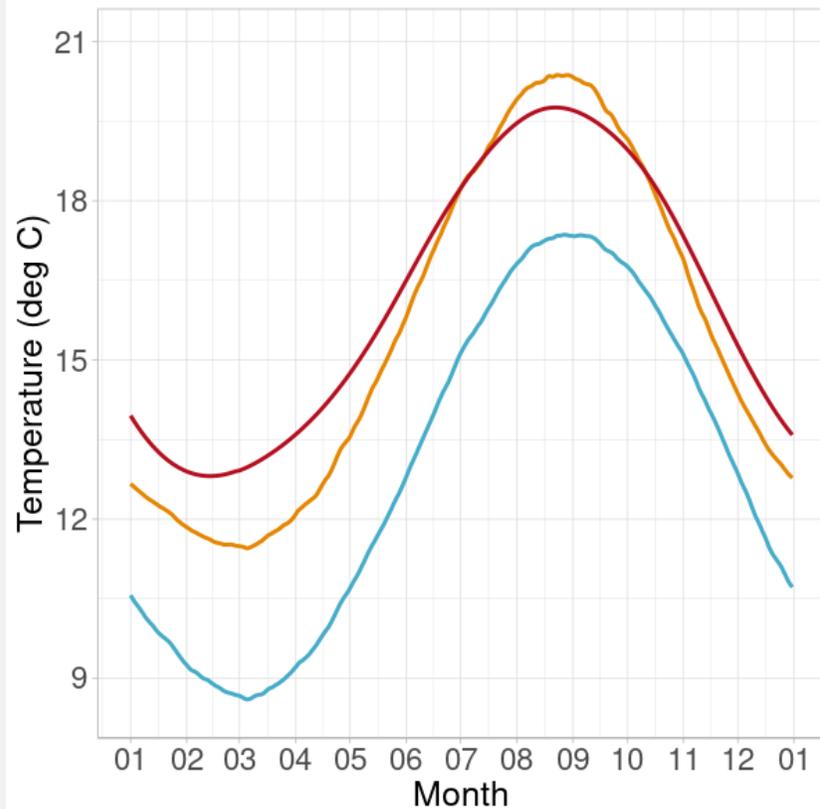


Diminution de
taille
(poids)

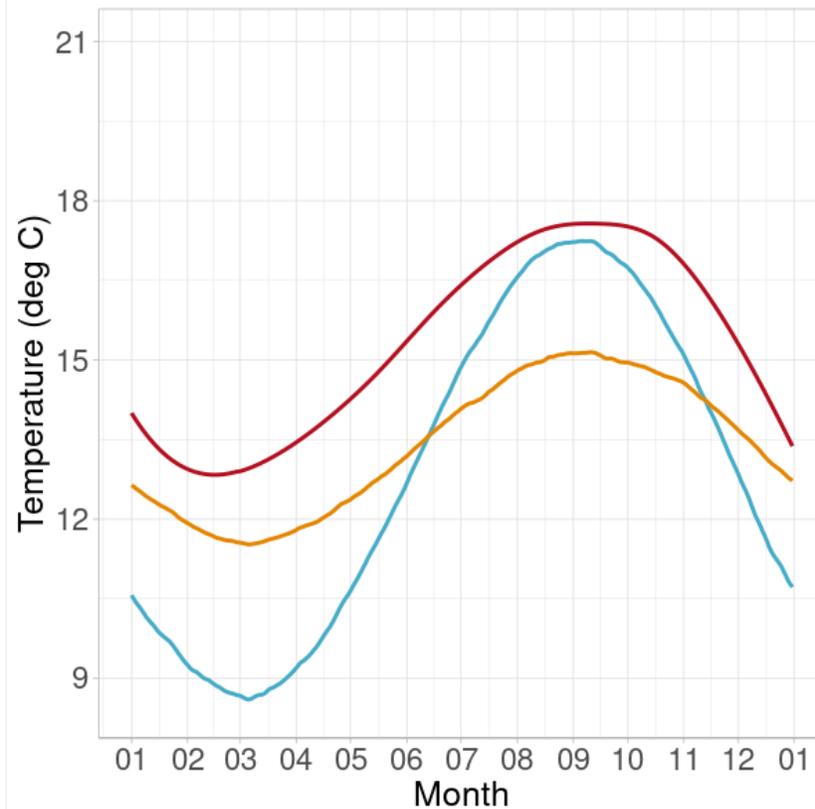




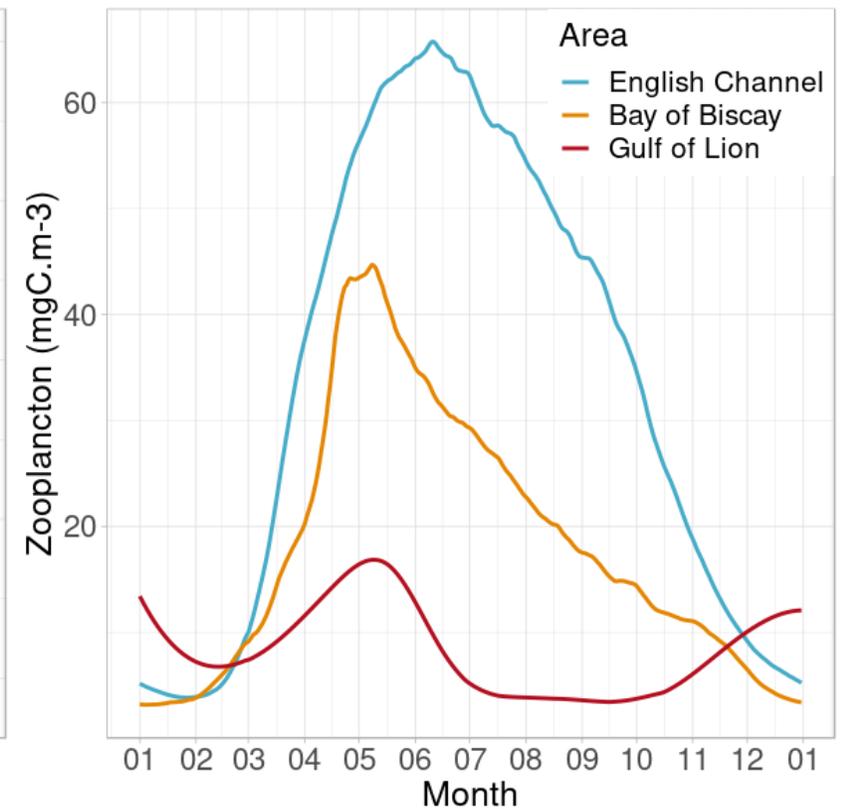
Variabilité spatiale marquée dans nos variables de forçage (proxy d'environnement)



Température (0-30m)



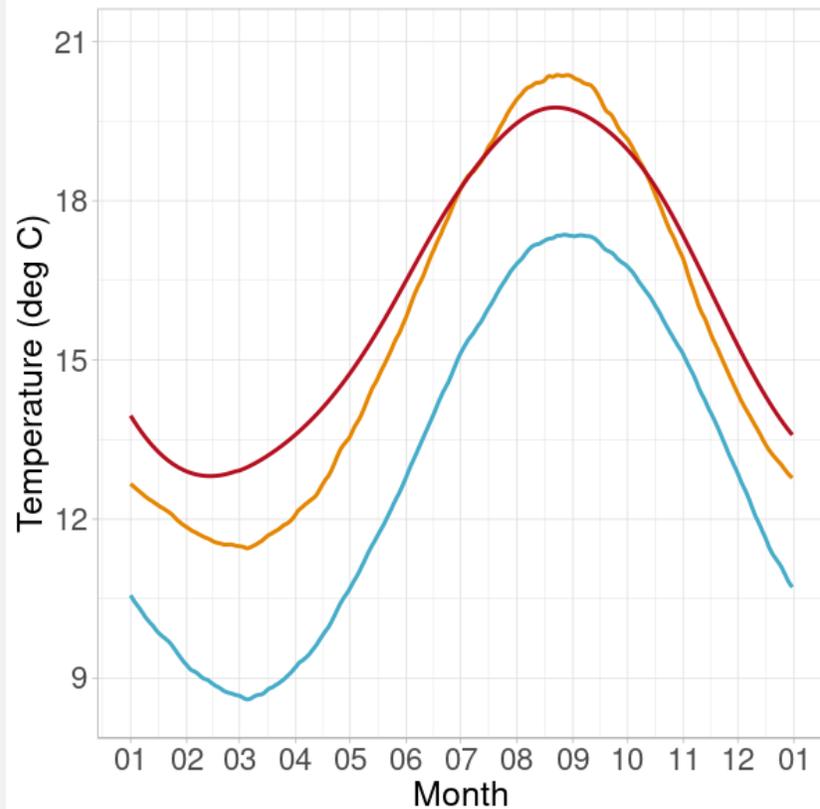
Température (0-150m)



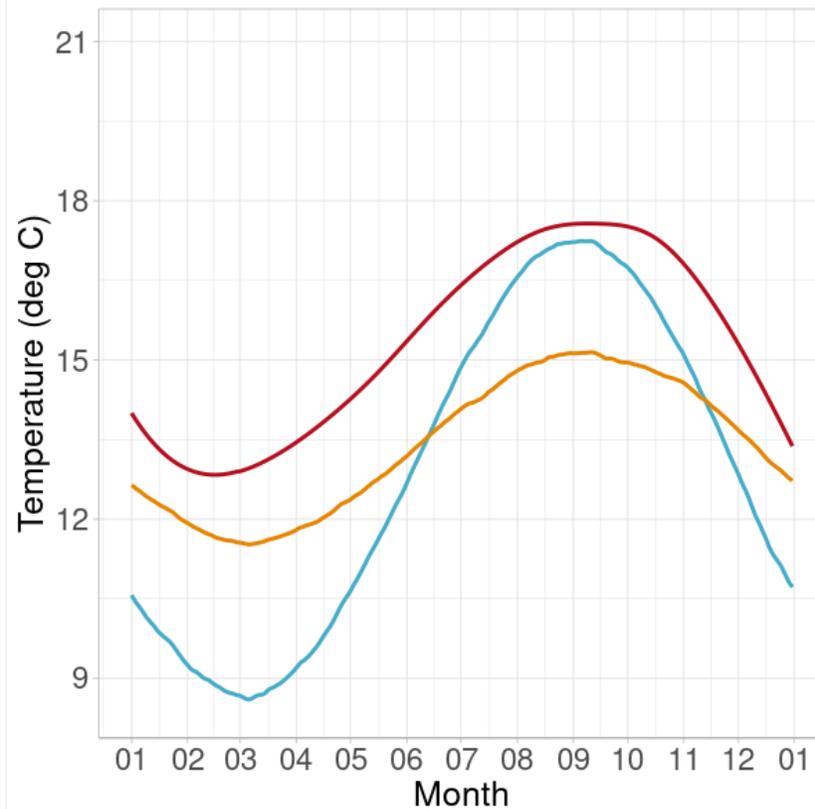
Zooplancton (0-50m)



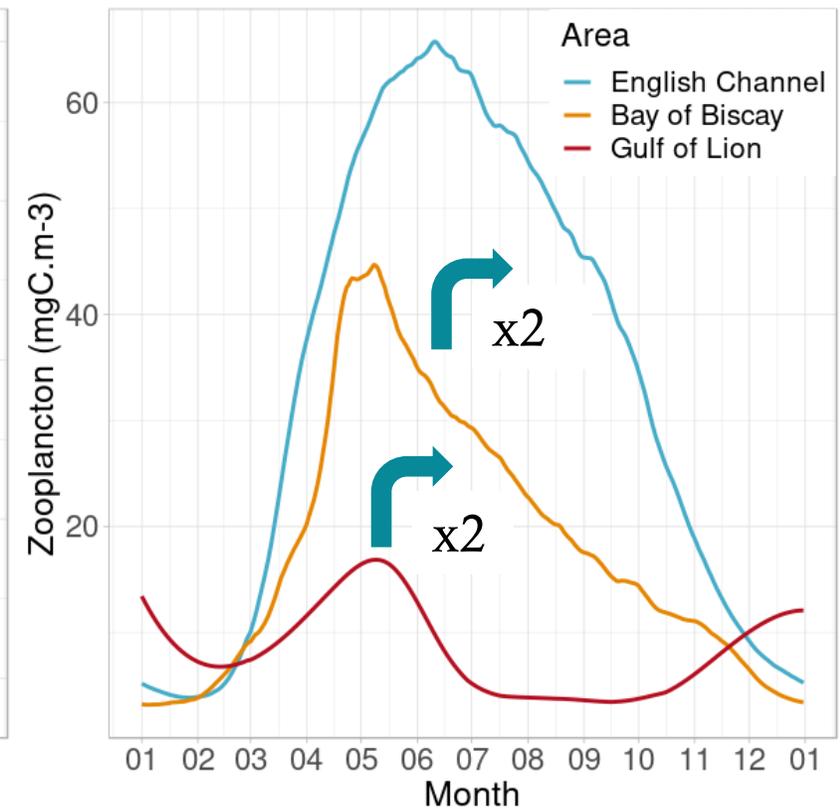
Variabilité spatiale marquée dans nos variables de forçage (proxy d'environnement)



Température (0-30m)



Température (0-150m)

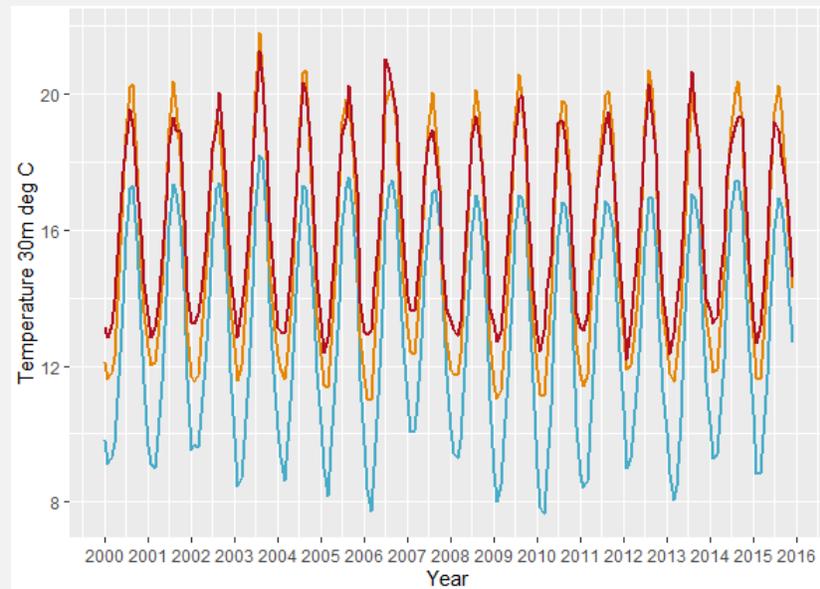


Zooplancton (0-50m)

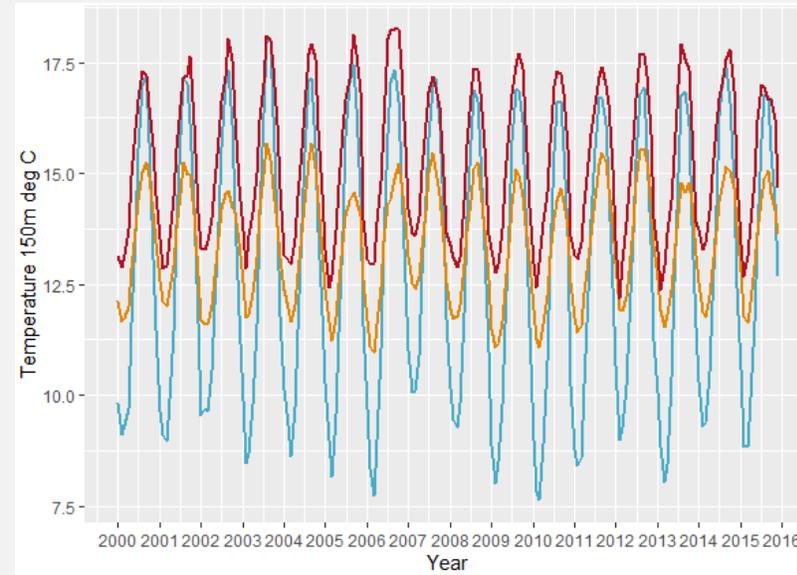


Tendances peu marquées dans nos variables de forçage (proxy d'environnement)

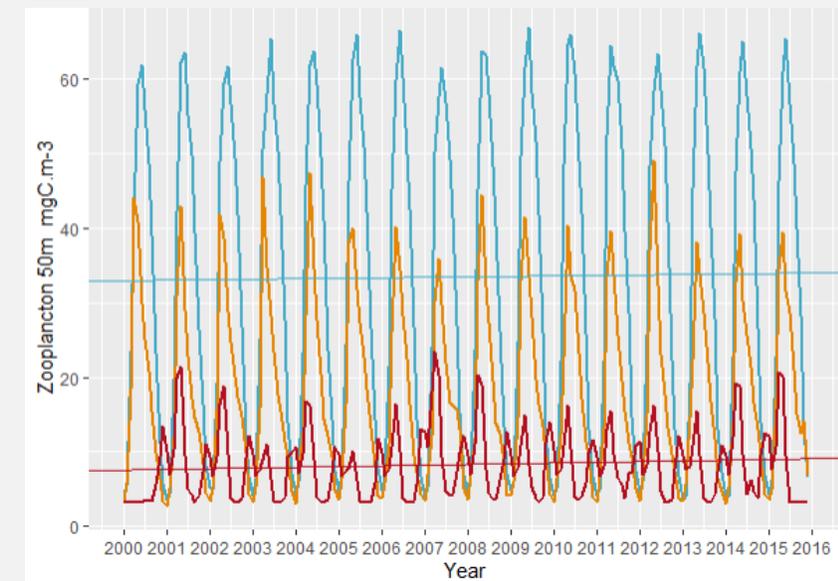
(Gohin et al., 2019)



Température (0-30m)

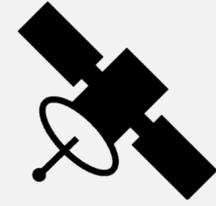


Température (0-150m)

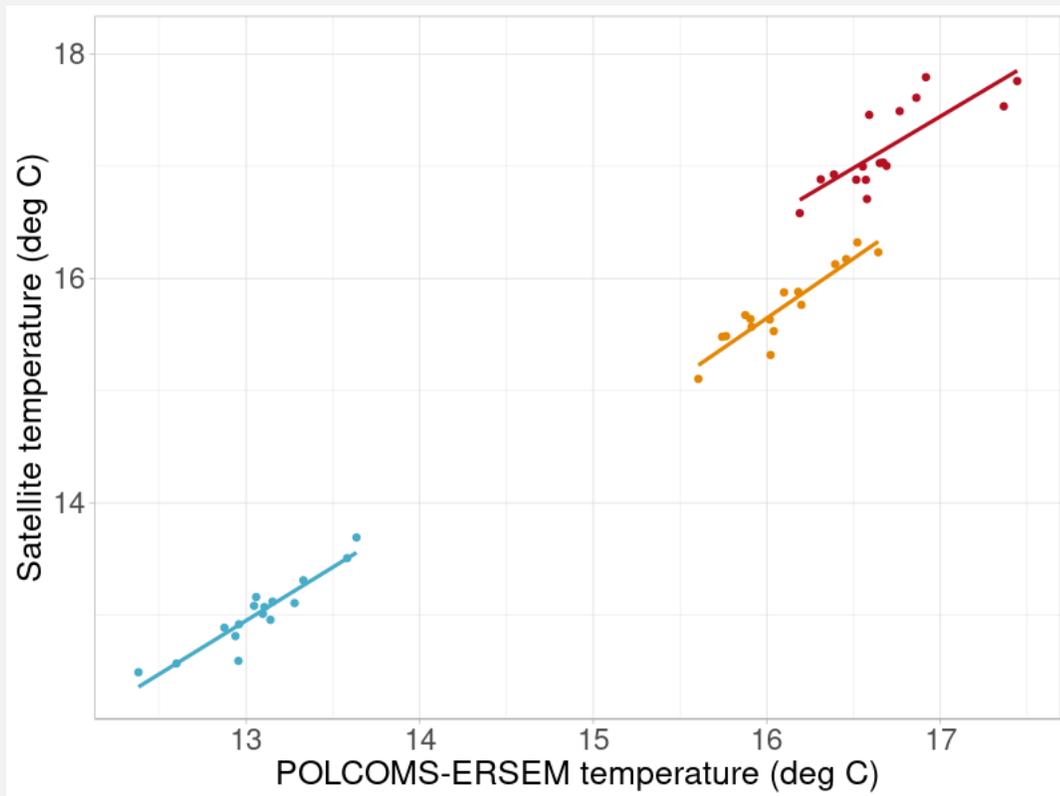


Zooplancton (0-50m)

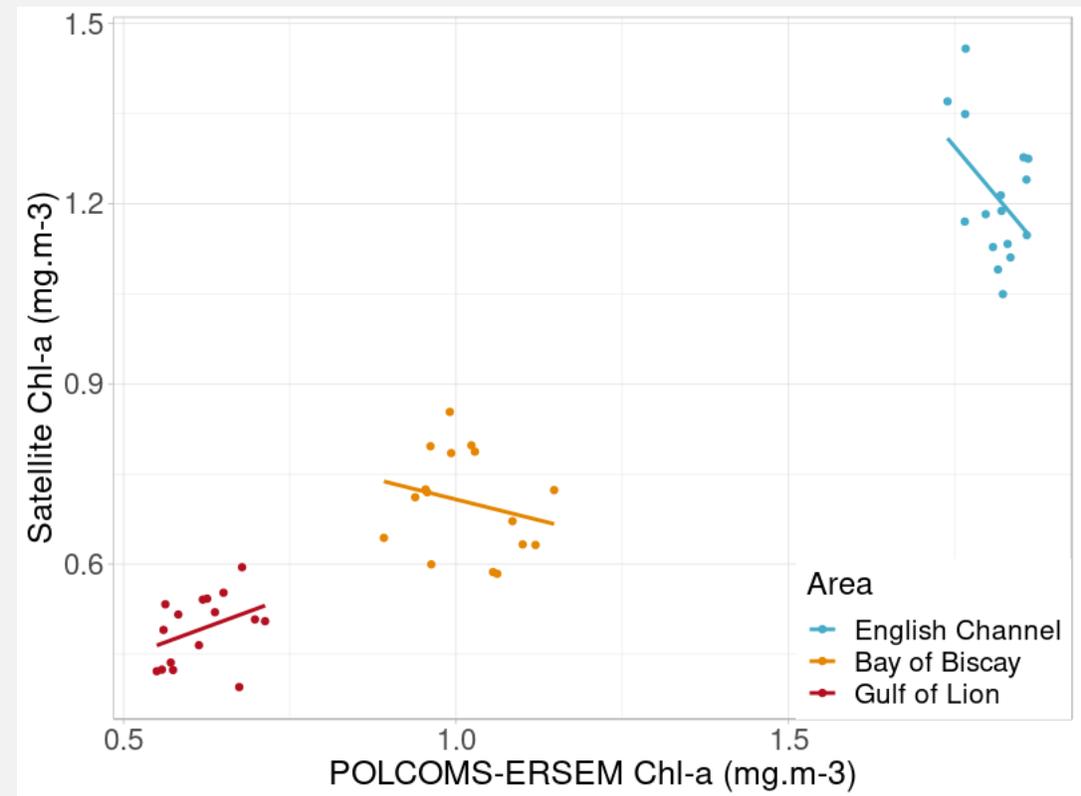
+ 0.08 mgC.m⁻³ par an



Variabilité interannuelle peu marquée dans nos variables de forçage



Température (0-3m)



Chlorophylle-a (0-3m)

Conclusion de l'analyse des données

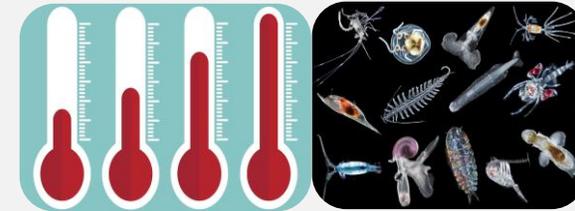
Données de campagnes pélagiques

- **Forte diminution de taille et poids** des anchois et sardine dans le golfe de Gascogne et le golfe du Lion



Données d'environnement (variables de forçage)

- Variabilité **spatiale marquée**
- **Faibles tendances** dans variables de forçage (température et zooplancton)
- Variabilité **temporelle peu corrélée aux données observées** (phyto ➔ zooplancton)



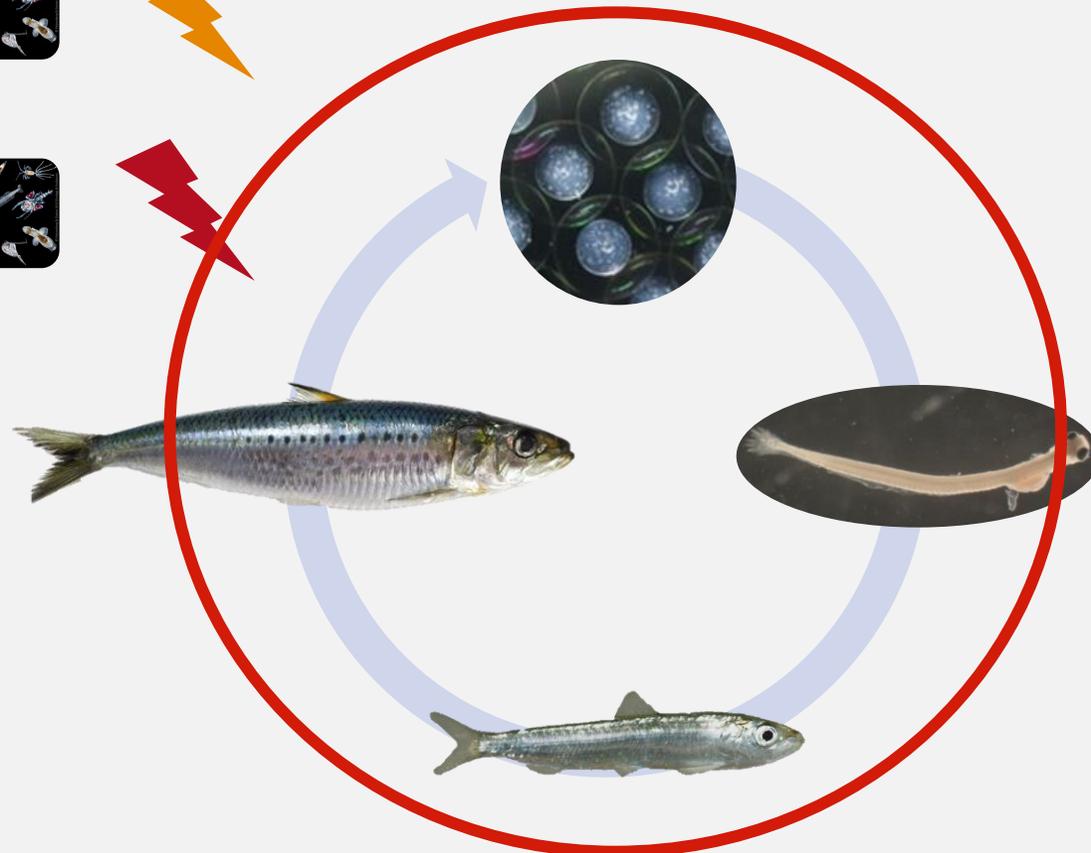
Manche



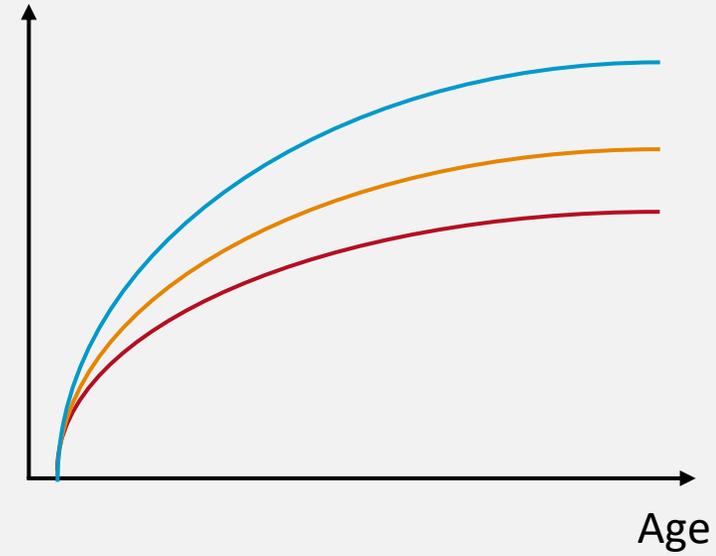
Golfe de Gascogne

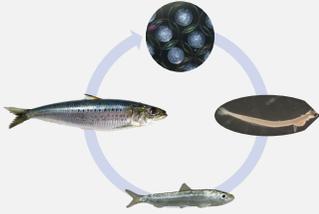


Golfe du Lion

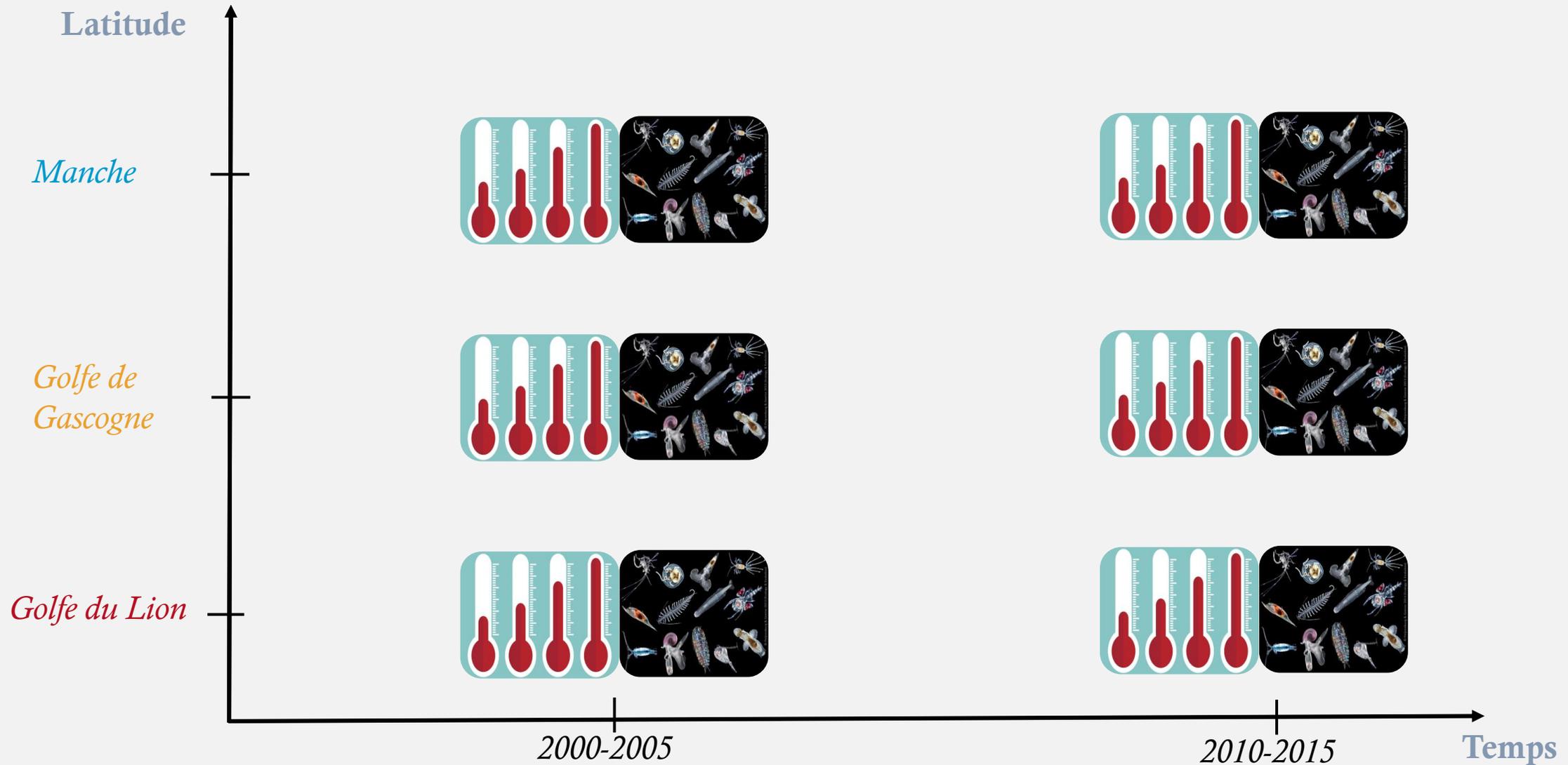


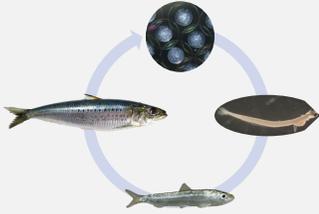
Taille



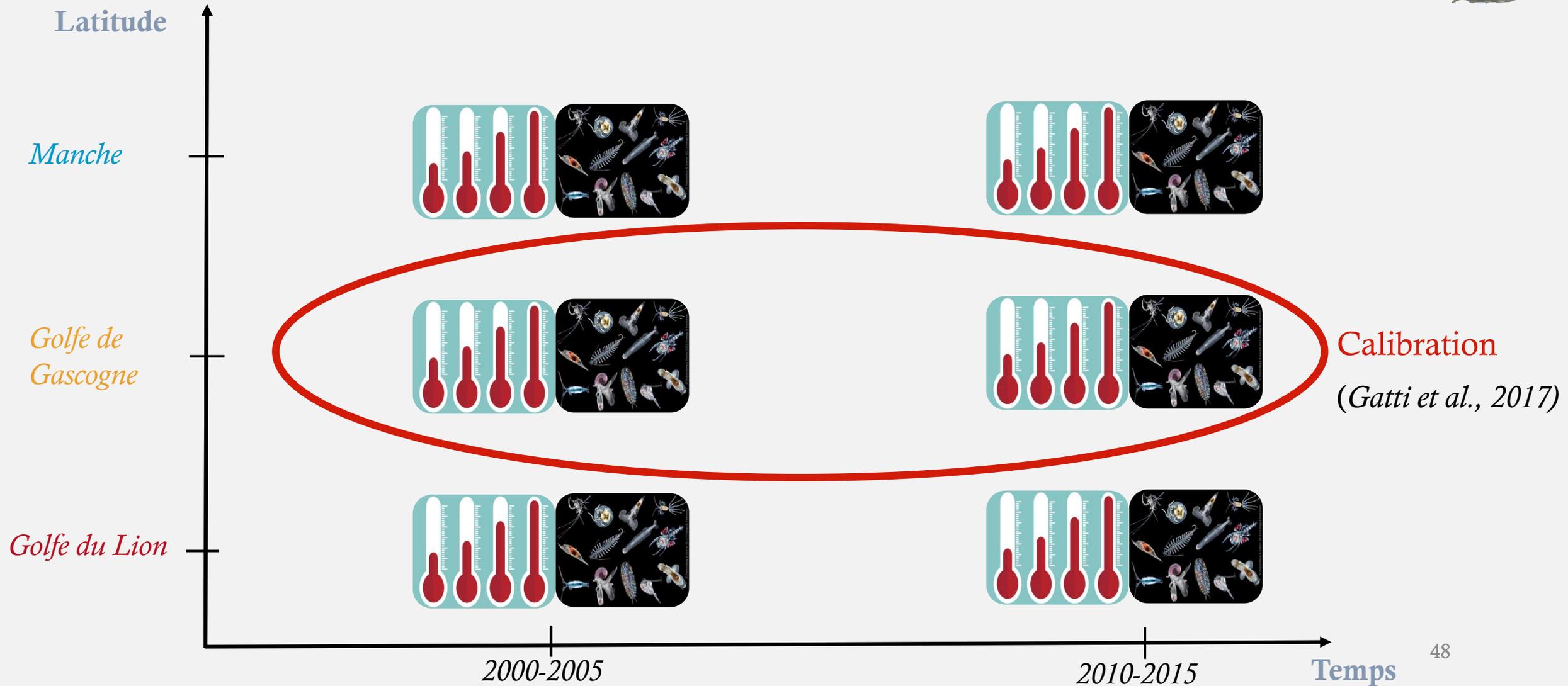


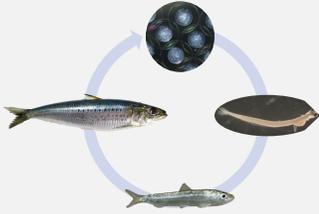
Constitution des données d'entrée du DEB



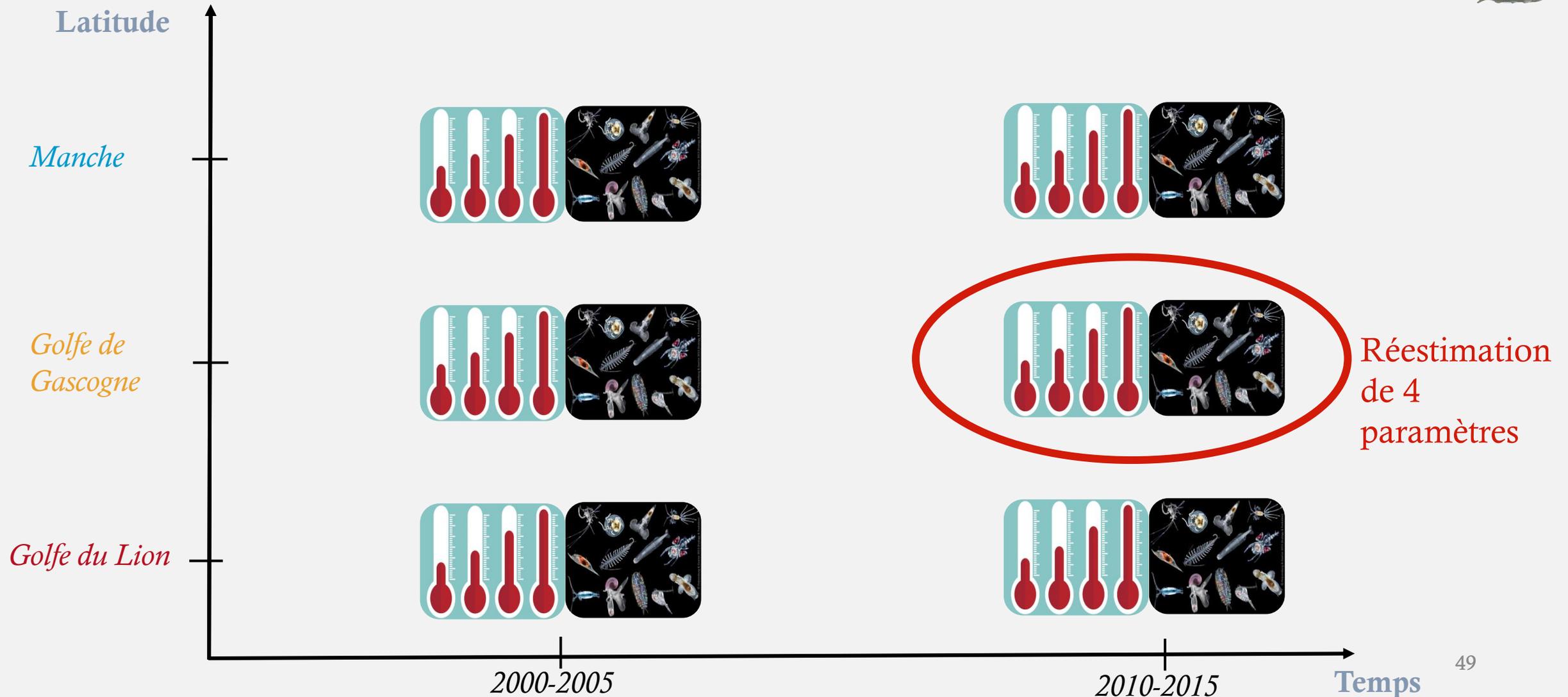


Constitution des données d'entrée du DEB

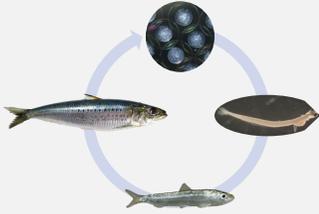




Constitution des données d'entrée du DEB



Calibration du modèle



Parameters	Symbol
<i>Primary DEB parameters</i>	
Maximum assimilation rate	$p\dot{A}_m$
Assimilation efficiency	ae
Volume specific cost for structure	$[EG]$
Volume specific maintenance cost	$[pM]$
Energy conductance	$\dot{\nu}$
Fraction of energy allocated to growth	κ
Maturity maintenance rate coefficient	$\dot{k}_j = \frac{[pM]}{[EG]}$
Maturity threshold at birth	H_b
Maturity threshold at puberty	H_p
Half saturation coefficient for food	K_f
Fraction of energy fixed into eggs	$K_R = \frac{\rho_G}{\rho_R}$
<i>Auxiliary and compound DEB parameters</i>	
Reference temperature	T_{ref}
Arrhenius temperature	T_A
Shape coefficient (adult)	δ
Size at first feeding	l_b
Size at metamorphosis	l_j
Energy in reserve at first feeding	E_b
Energy of eggs	E_0
Relative batch fecundity	R_{bf}
Spawning frequency	\dot{S}_f
Shape coefficient (early larva)	δ_b
Acceleration factor (larvae)	f_{acc}
Density of structure	d_V
Energy density of structure	ρ_V
Energy density of reserve	ρ_E
Energy density of reproduction reserve	ρ_R
Energy density of gametes	ρ_G
Maximum storage density	$[E_m] = \frac{p\dot{A}_m}{\dot{\nu}}$



Idéalement
Physiologie du poisson

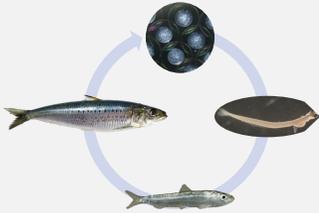
Calibration du modèle

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Réellement

Reflet des données utilisées pour calibration



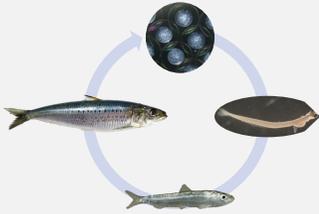
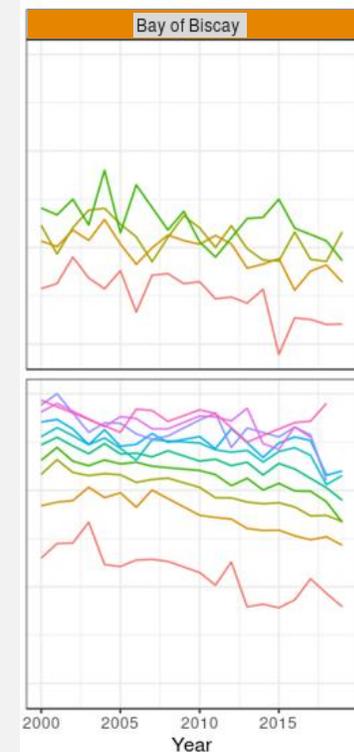
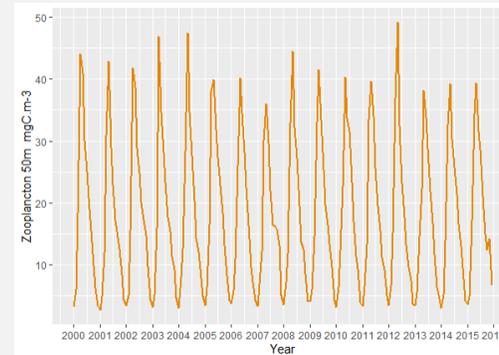
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Energy in reserve at first feeding	E_b
Energy of eggs	E_0
Relative batch fecundity	$R_{b,f}$
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Réellement

Reflet des données utilisées pour calibration

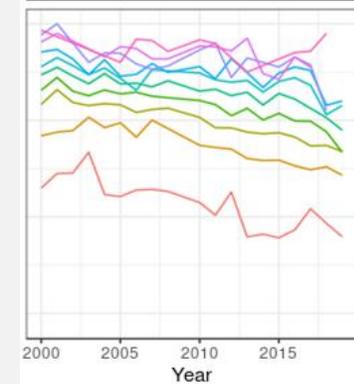
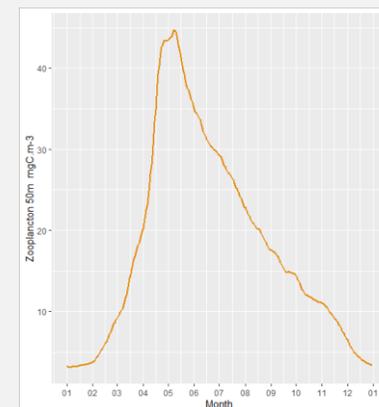
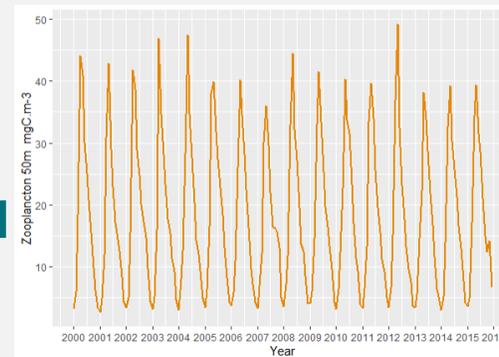
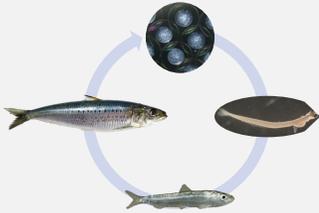


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Réellement
Reflet des données utilisées pour calibration

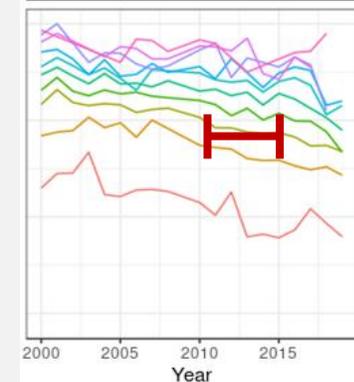
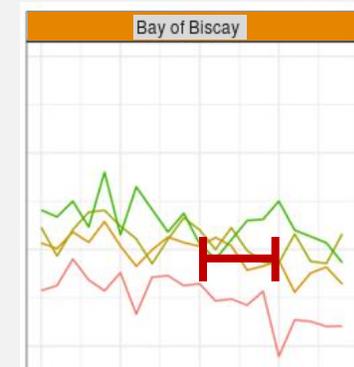
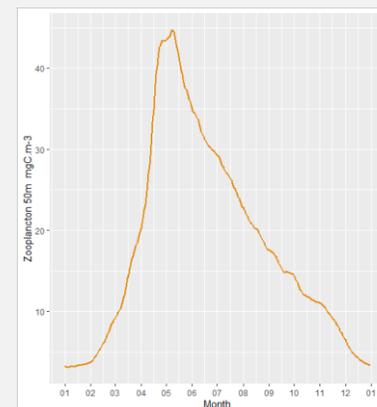
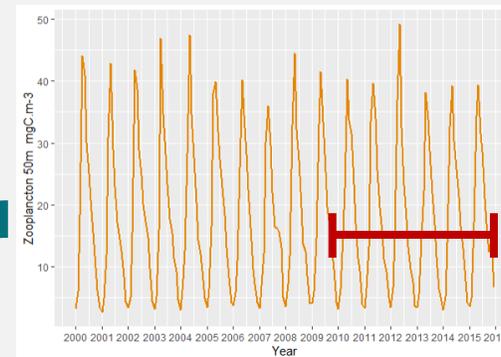
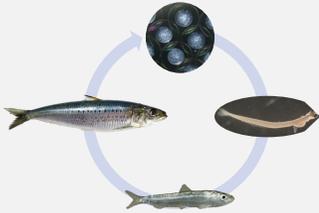
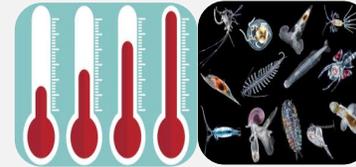


Calibration du modèle

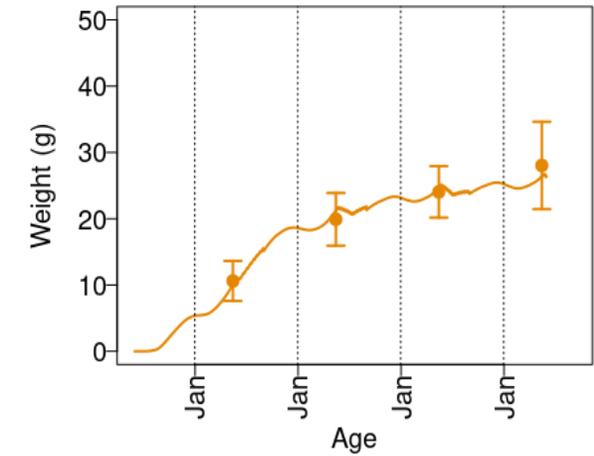
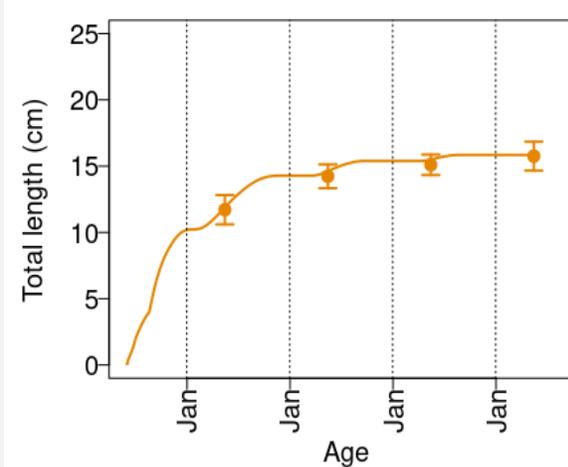
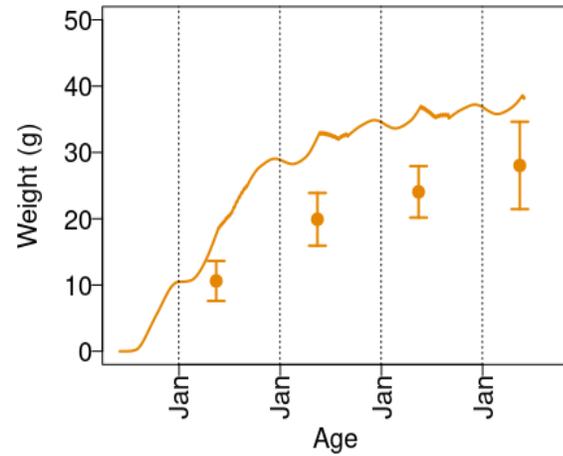
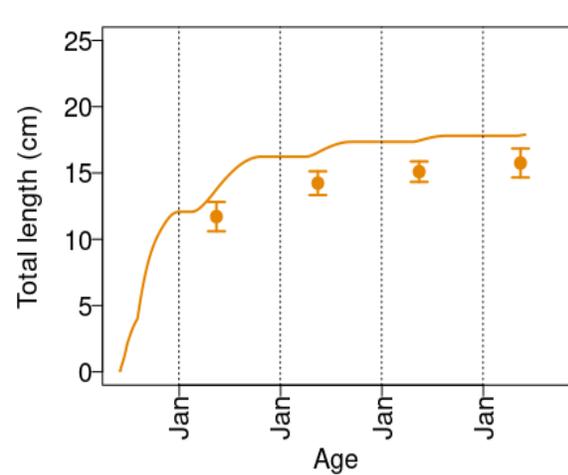
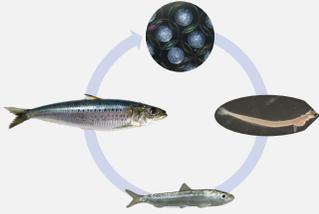
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Energy density of gametes	ρ_G
Maximum storage density	$[E_m] = \frac{p\dot{A}_m}{\dot{\nu}}$



Réellement
Reflet des données utilisées pour calibration



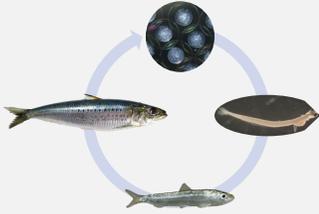
Comparaison de deux calibrations différentes (golfe de Gascogne)



Calibration sur toutes les données disponibles
(Paul Gatti)

Calibration sur les données 2010-2015
(cette étude)

Estimation des paramètres de croissance et assimilation

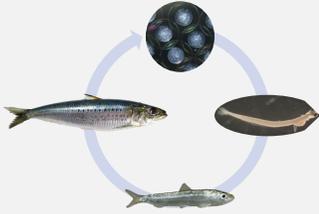


DEB parameters	Symbol	Units
Fraction of energy allocated to growth	κ	-
Maximum assimilation rate	$P\dot{A}_m$	$J\ cm^{-2}\ d^{-1}$
Volume specific maintenance cost	$[P\dot{M}]$	$J\ cm^{-3}\ d^{-1}$
Half saturation coefficient for food	K_f	$gC\ m^{-3}$

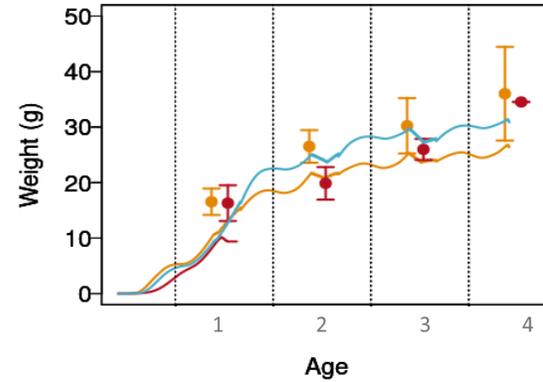
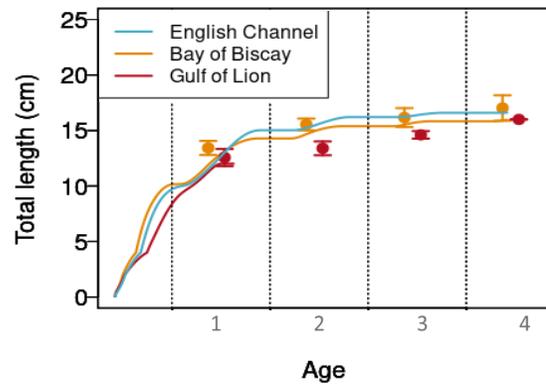
Croissance

Assimilation

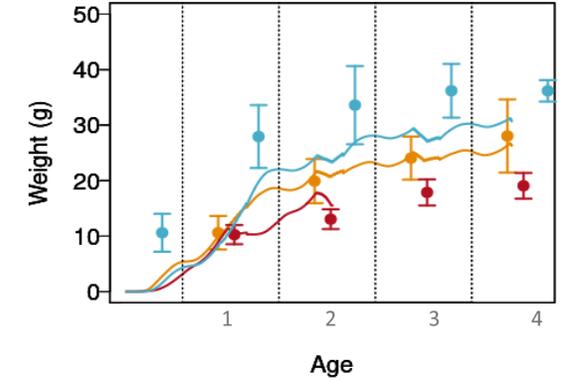
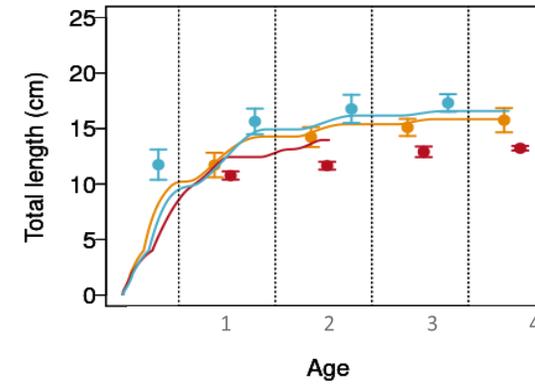
Ajustement du modèle aux données de taille et poids de campagnes



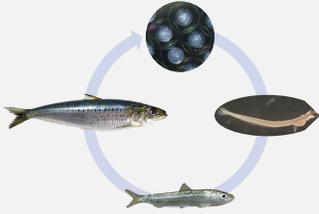
2000-2005



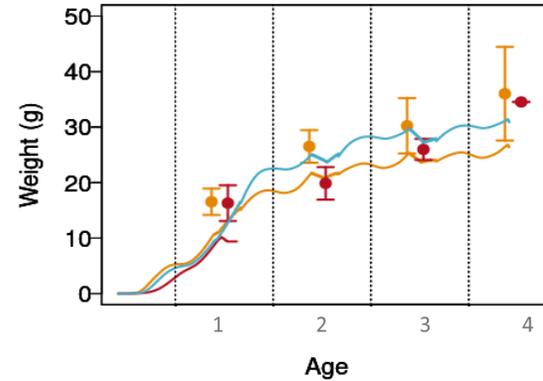
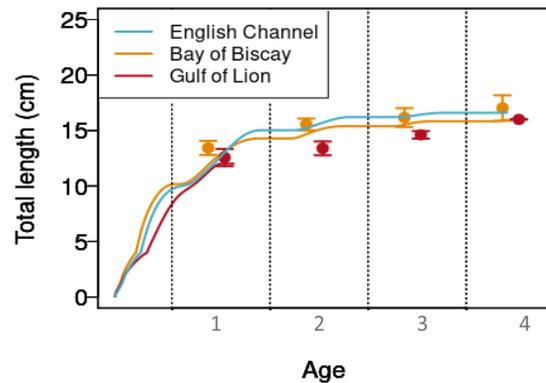
2010-2015



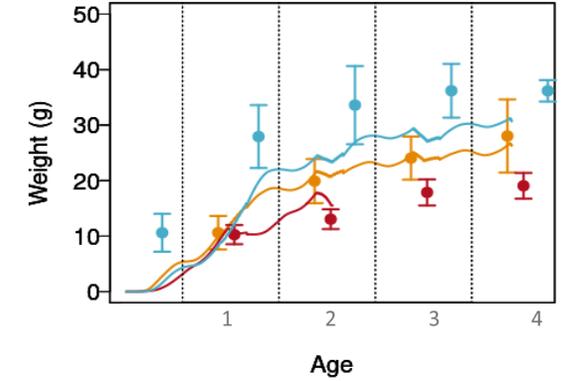
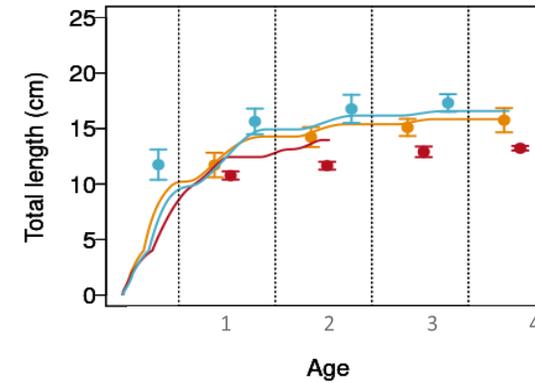
Ajustement du modèle aux données de taille et poids de campagnes



2000-2005

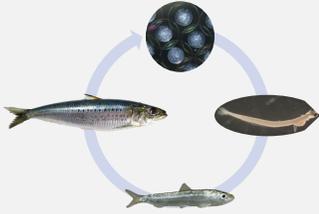


2010-2015

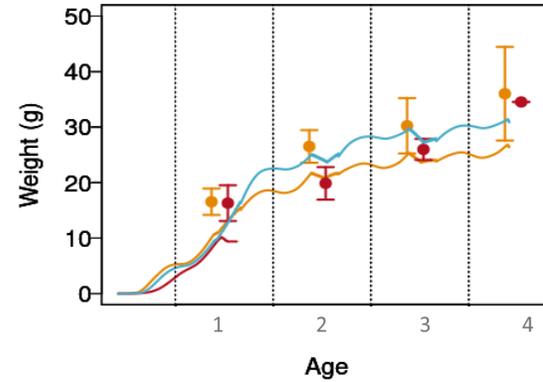
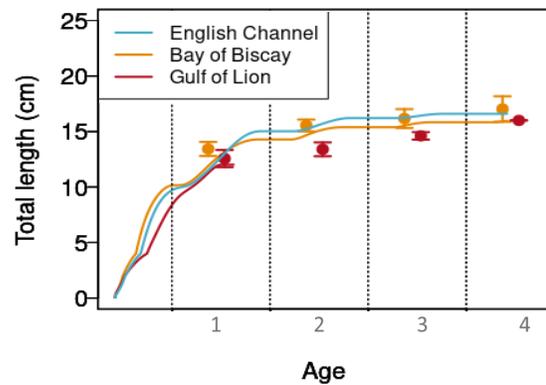


$$NRMSE = \frac{1}{\bar{y}} \sqrt{\frac{\sum_i^n (\hat{y}_i - y_i)^2}{n}}$$

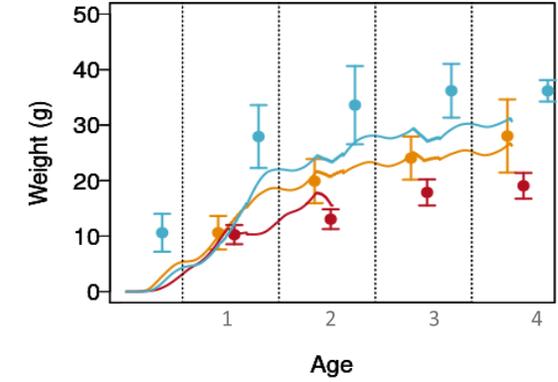
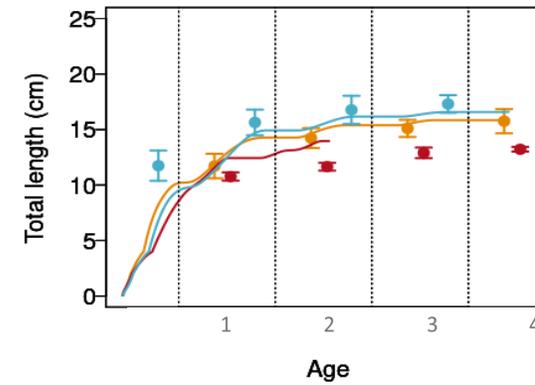
Ajustement du modèle aux données de taille et poids de campagnes



2000-2005



2010-2015

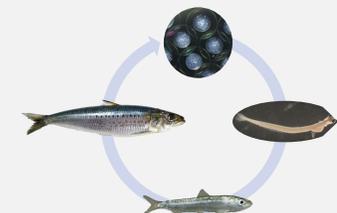


Anchovy				
	Area	Period	Length	Weight
NRMSE	EC	2000-2005	*	*
	BoB	2000-2005	0.08	0.31
	GoL	2000-2005	0.06	0.36

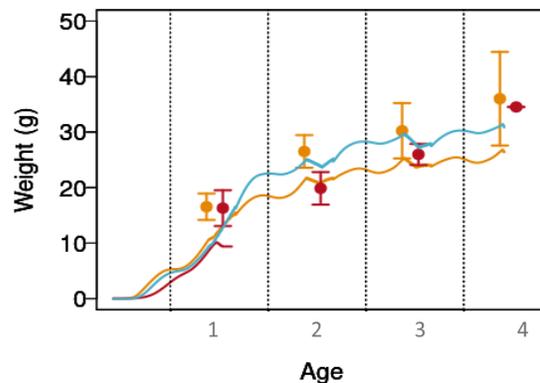
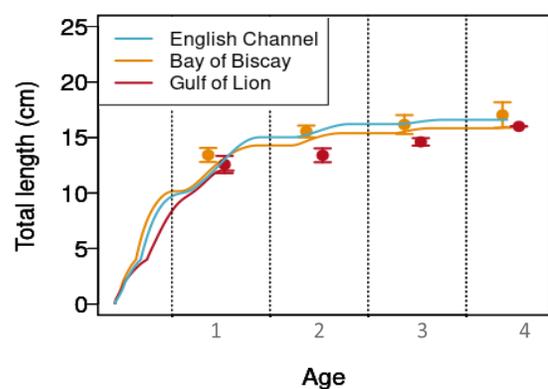
Anchovy				
	Area	Period	Length	Weight
NRMSE	EC	2010-2015	0.07	0.28
	BoB	2010-2015	0.07	0.20
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$$NRMSE = \frac{1}{\bar{y}} \sqrt{\frac{\sum_i^n (\hat{y}_i - y_i)^2}{n}}$$

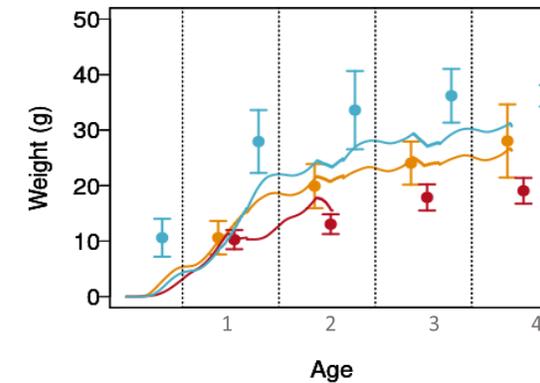
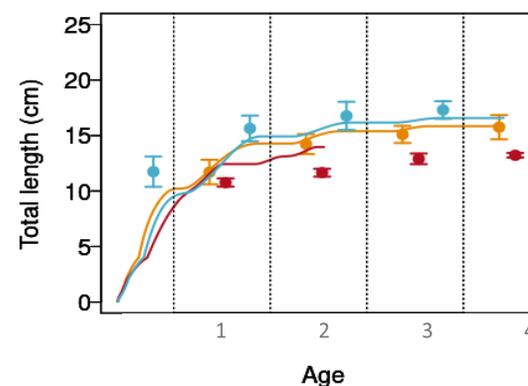
Ajustement du modèle aux données de taille et poids de campagnes



2000-2005



2010-2015

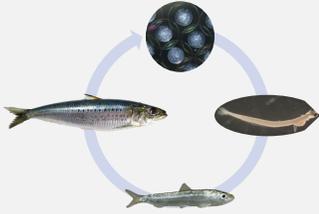


Anchovy				
	Area	Period	Length	Weight
NRMSE	EC	2000-2005	*	*
	BoB	2000-2005	0.08	0.31
	GoL	2000-2005	0.06	0.36

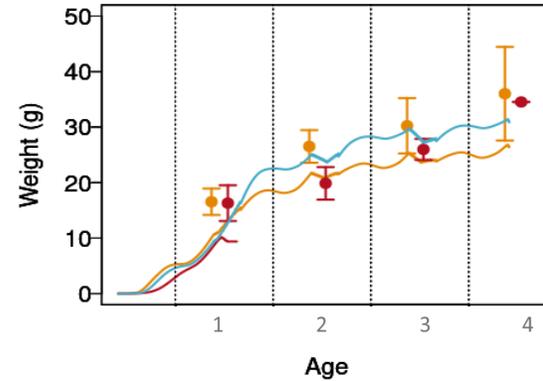
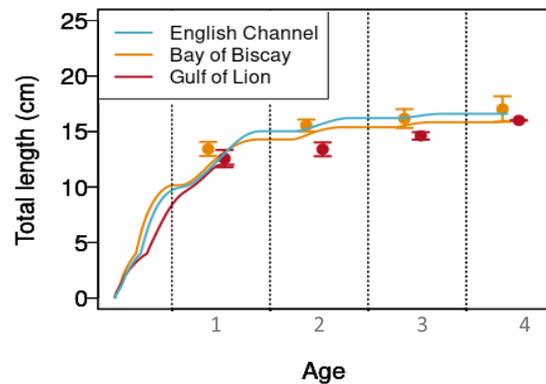
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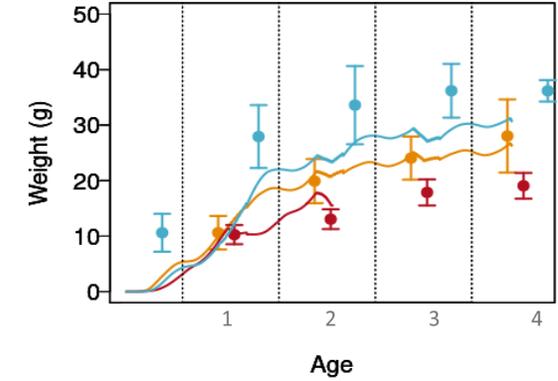
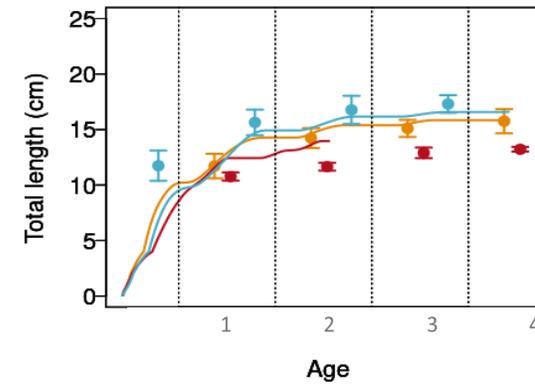
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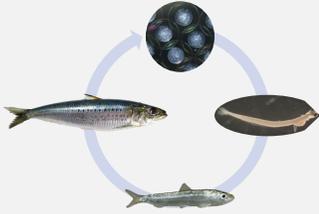


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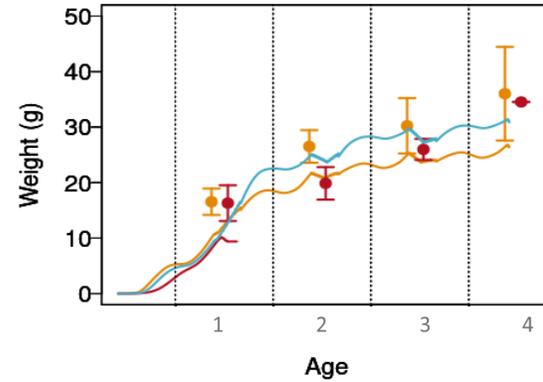
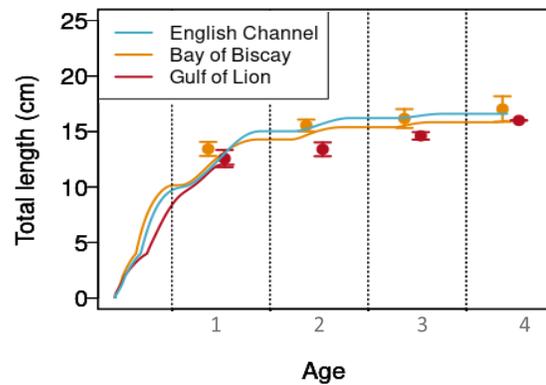
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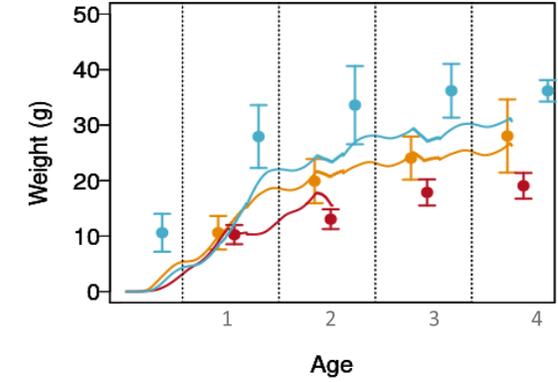
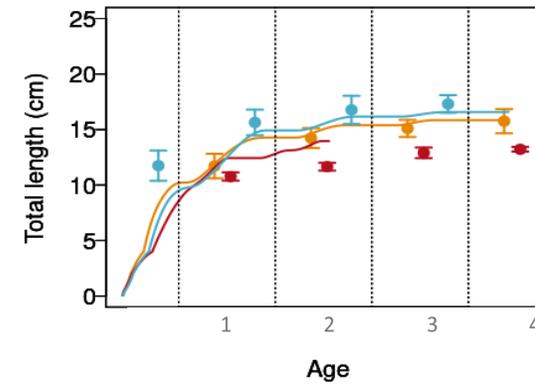
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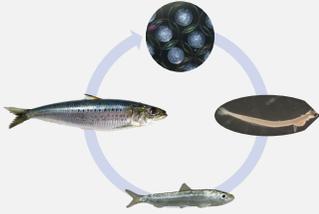


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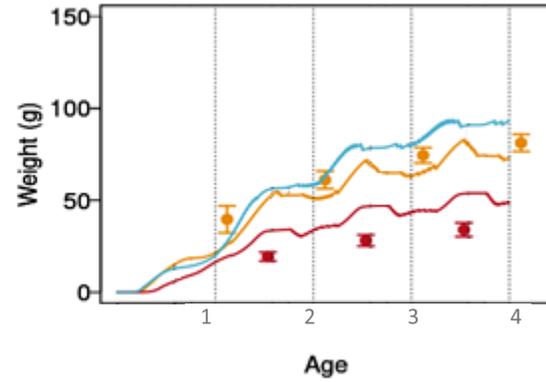
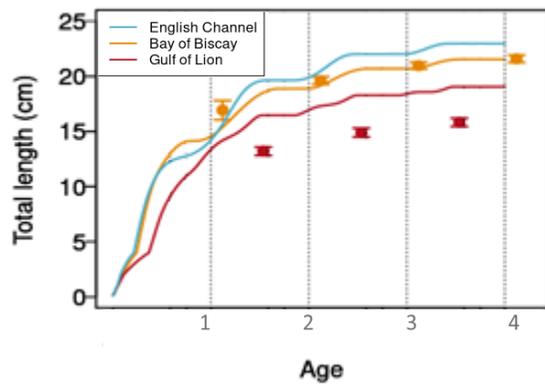
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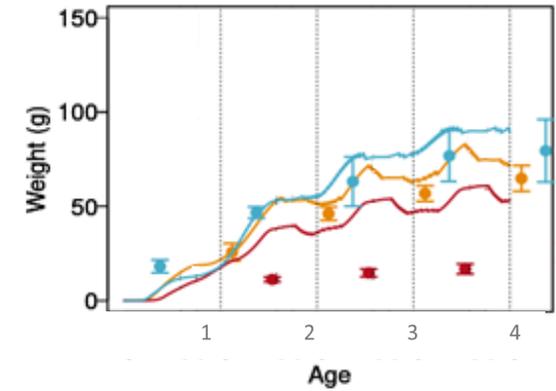
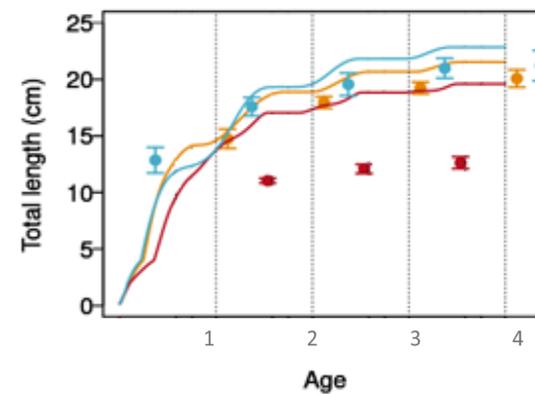
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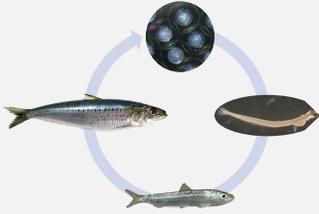
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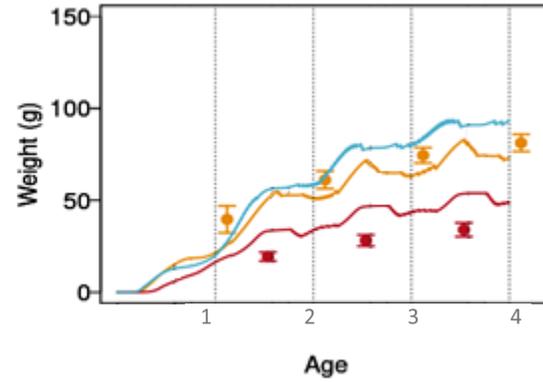
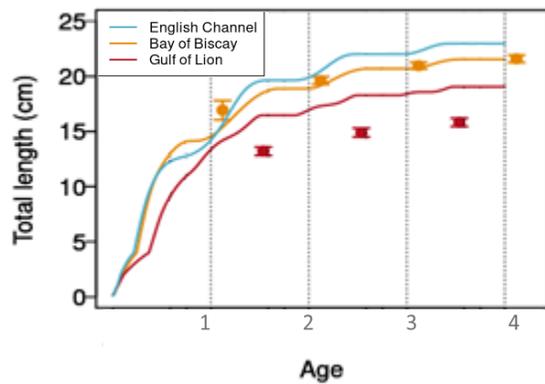
2010-2015



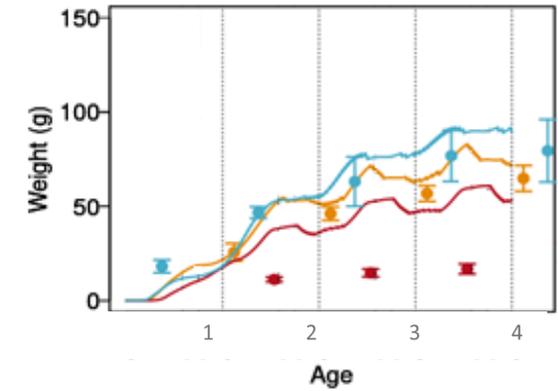
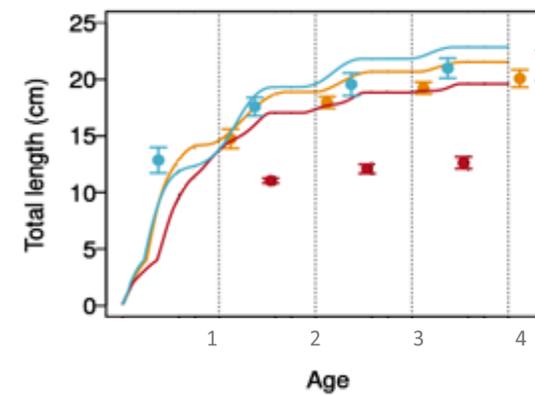
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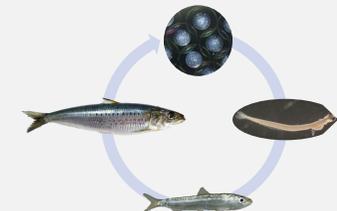
2010-2015



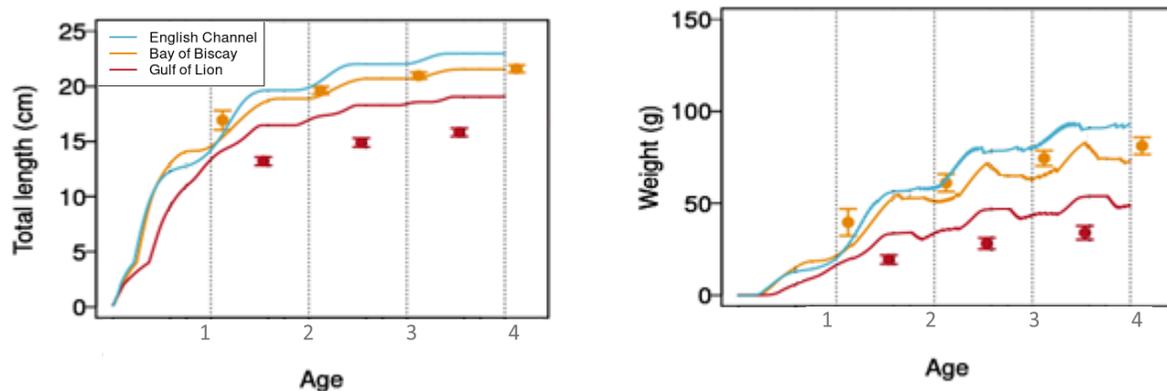
Sardine				
	Area	Period	Length	Weight
NRMSE	EC	2000-2005	*	*
	BoB	2000-2005	0.06	0.21
	GoL	2000-2005	0.23	0.65

Sardine				
	Area	Period	Length	Weight
NRMSE	EC	2010-2015	0.09	0.24
	BoB	2010-2015	0.07	0.15
	GoL	2010-2015	0.54	2.44

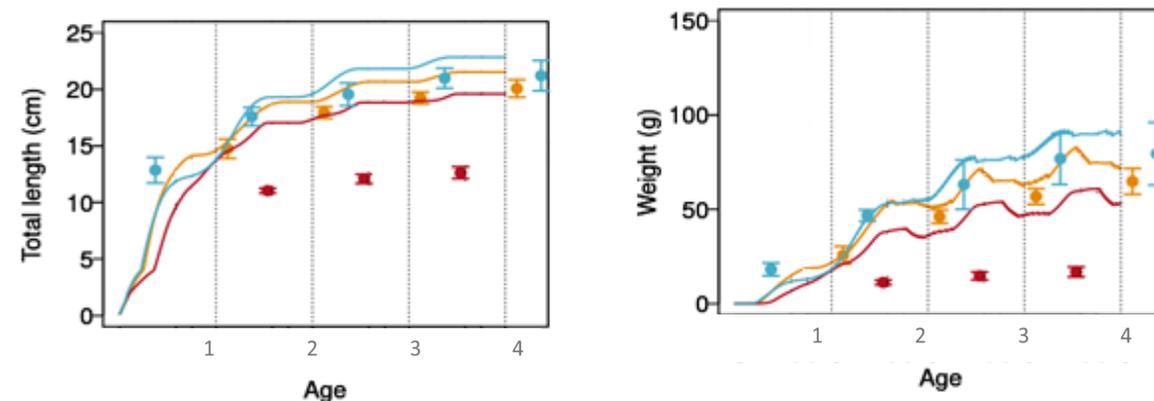
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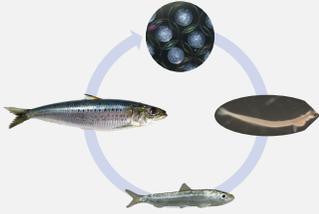
2010-2015



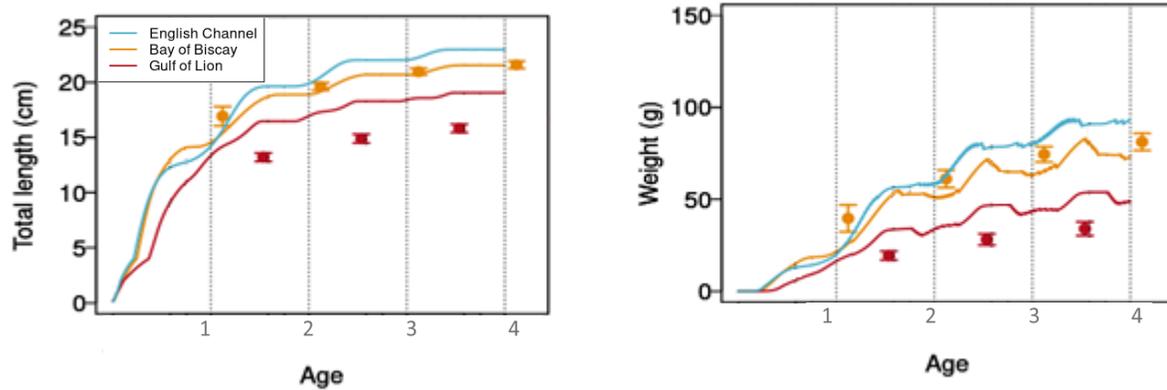
Sardine				
	Area	Period	Length	Weight
NRMSE	EC	2000-2005	*	*
	BoB	2000-2005	0.06	0.21
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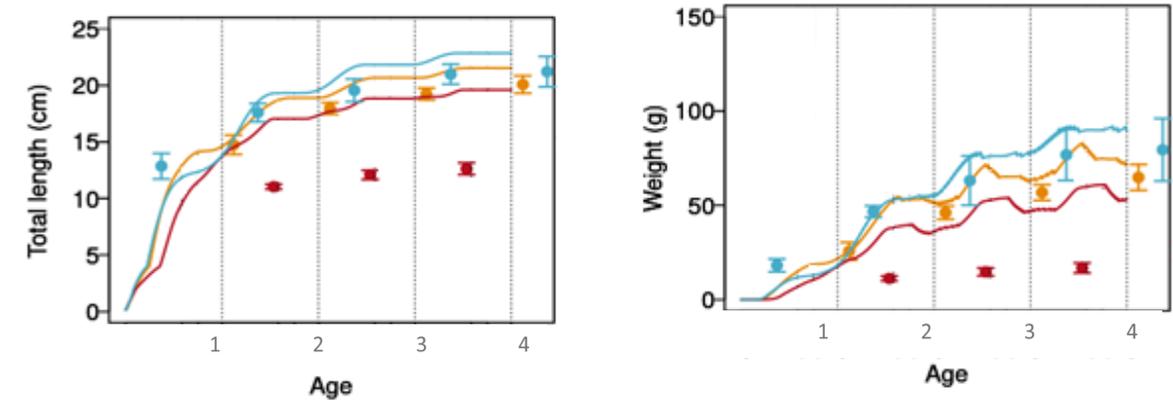
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2000-2005



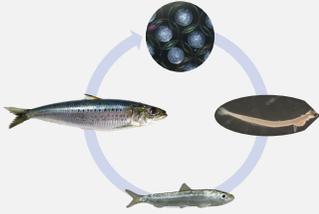
2010-2015



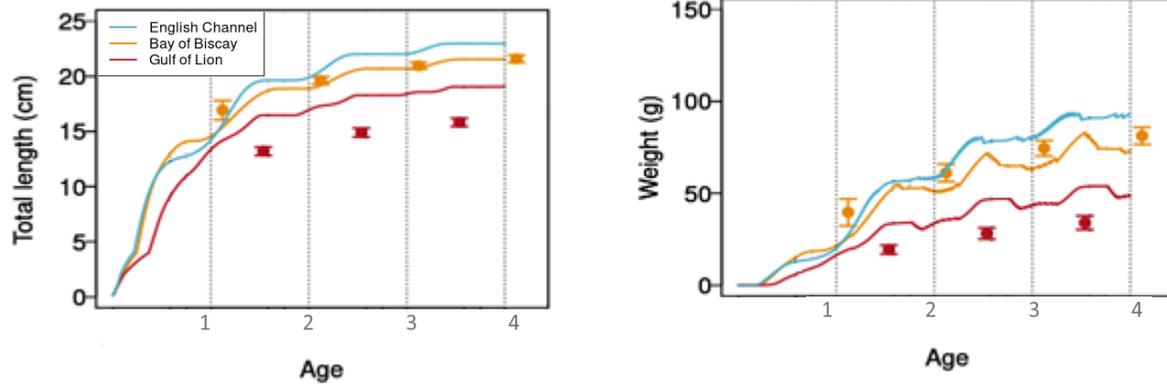
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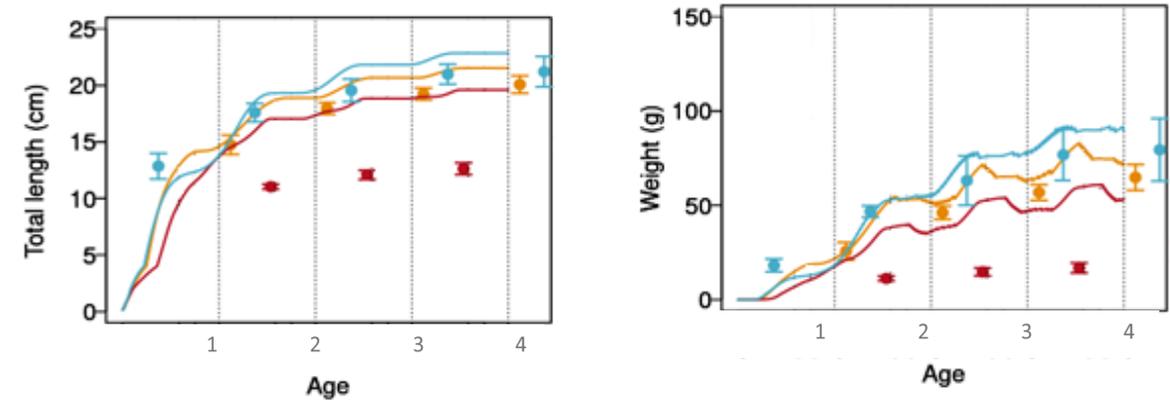
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2010-2015



Sardine				
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Conclusion du cas de référence

Variabilité spatiale : nos proxy d'environnement expliquent en partie la variabilité spatiale de taille

- Ajustement plus faible pour le golfe du Lion
- Sous estimation de la variabilité saisonnière en poids

Conclusion du cas de référence

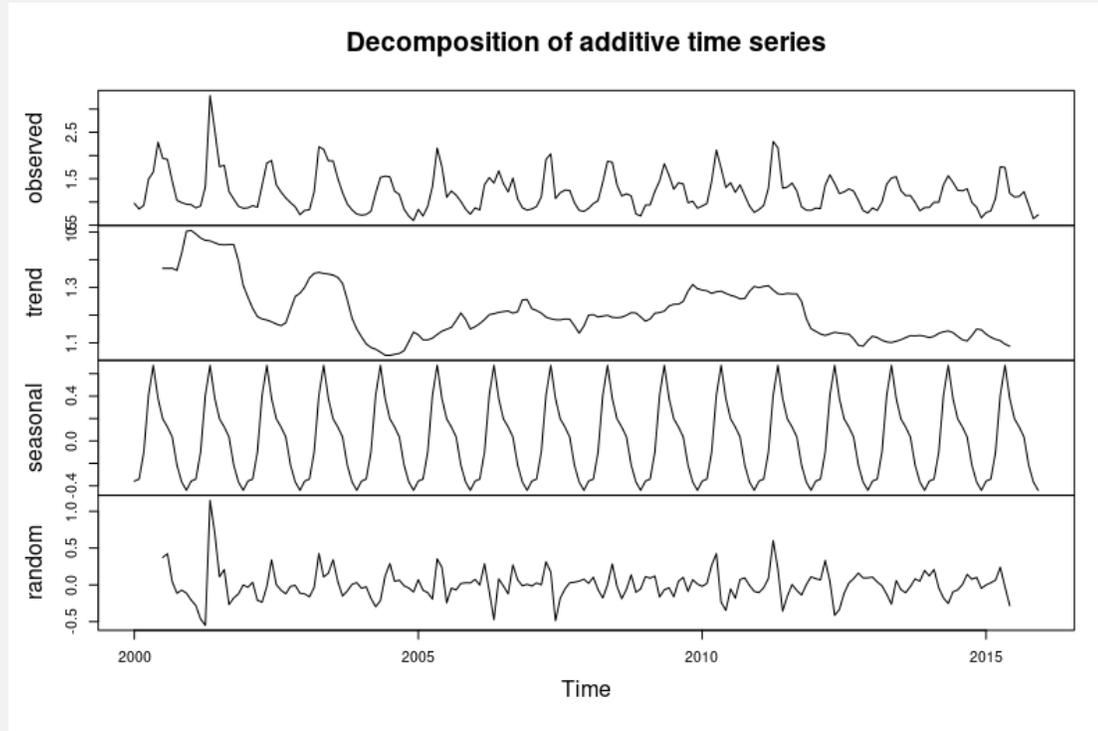
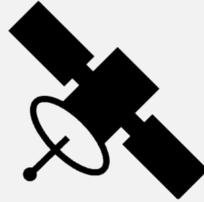
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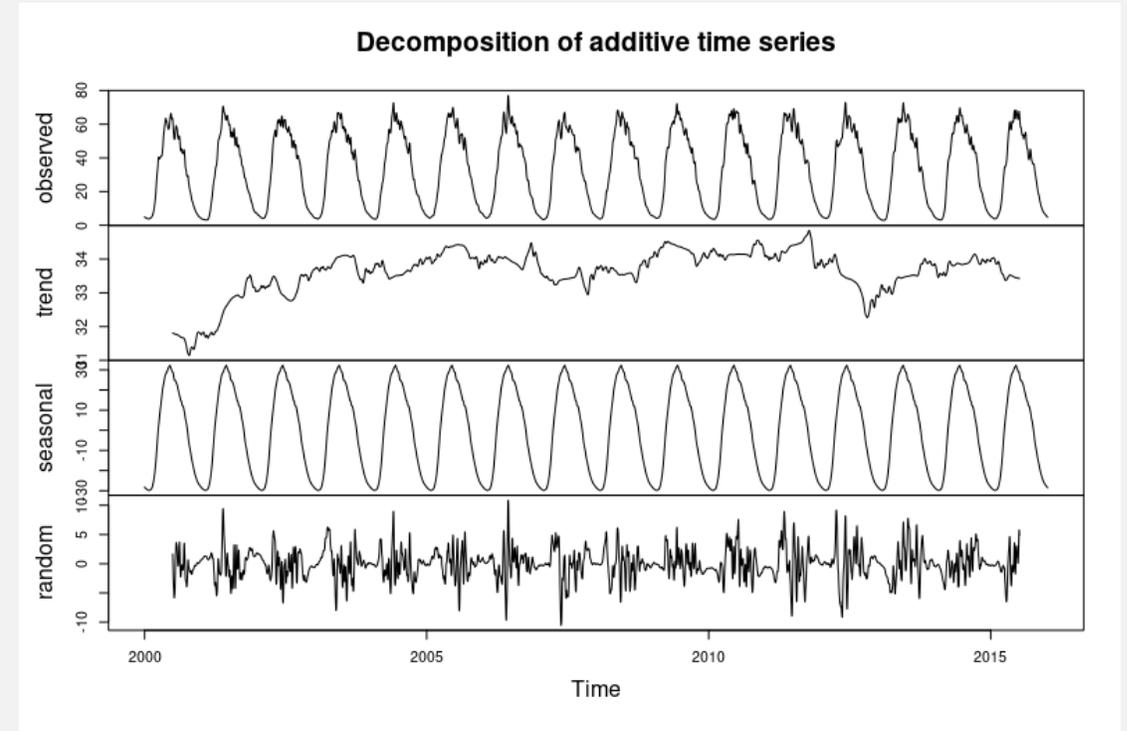
Variabilité temporelle : nos proxy d'environnement n'expliquent pas la diminution de taille au cours du temps

- Faibles tendances dans variables de forçage (température et zooplancton)
- Variabilité temporelle peu corrélée aux données observées (phyto ➔ zooplancton)
- Affiner l'échelle de modélisation

SC1 : Amélioration du réalisme des tendances temporelles

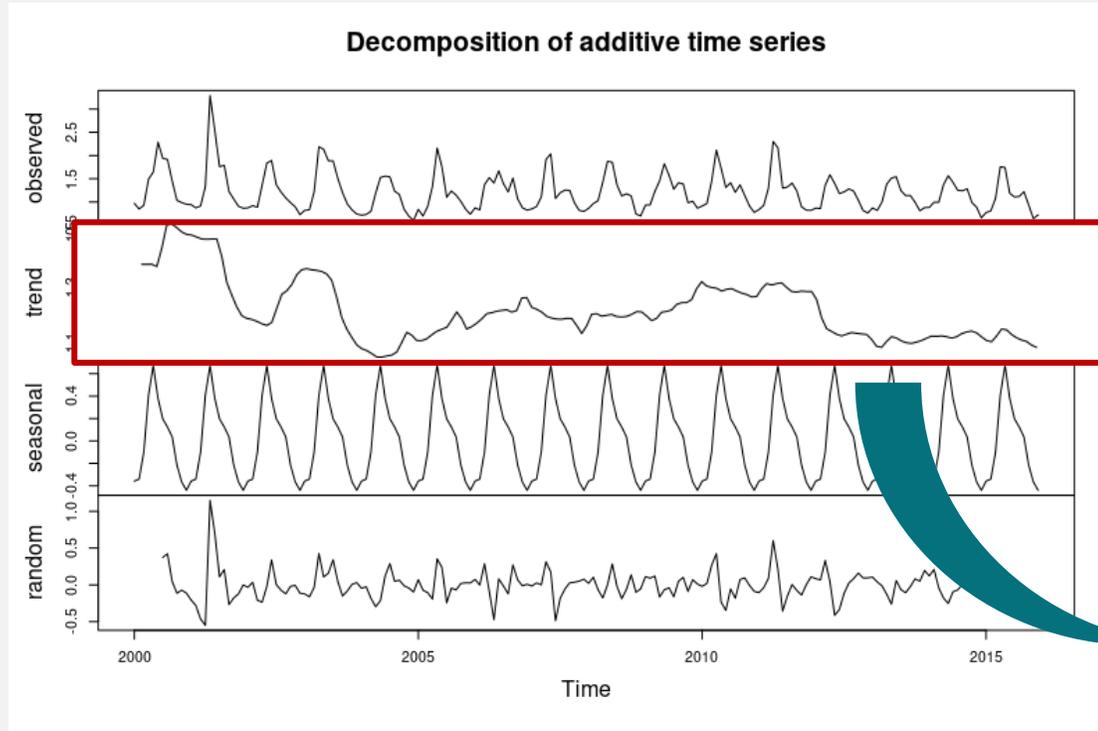
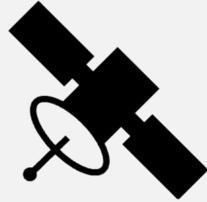


Décomposition de la chlorophylle-a
(satellite)

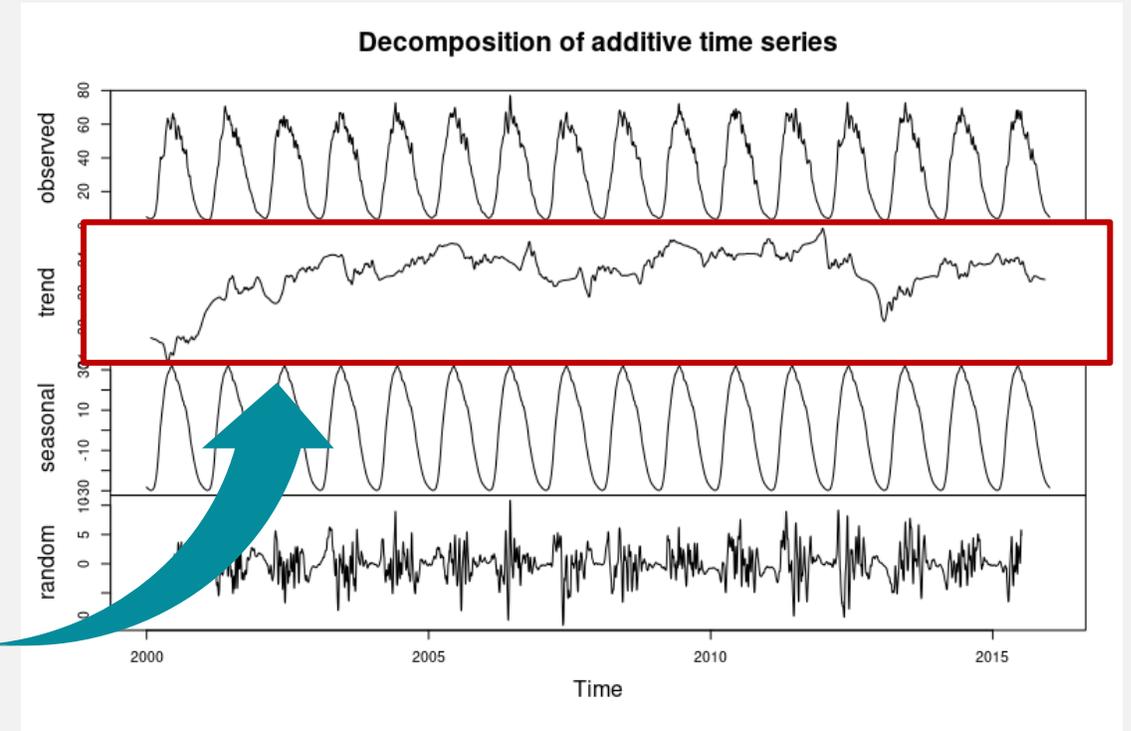


Décomposition du zooplancton
(POLCOMS-ERSEM)

SC1 : Amélioration du réalisme des tendances temporelles

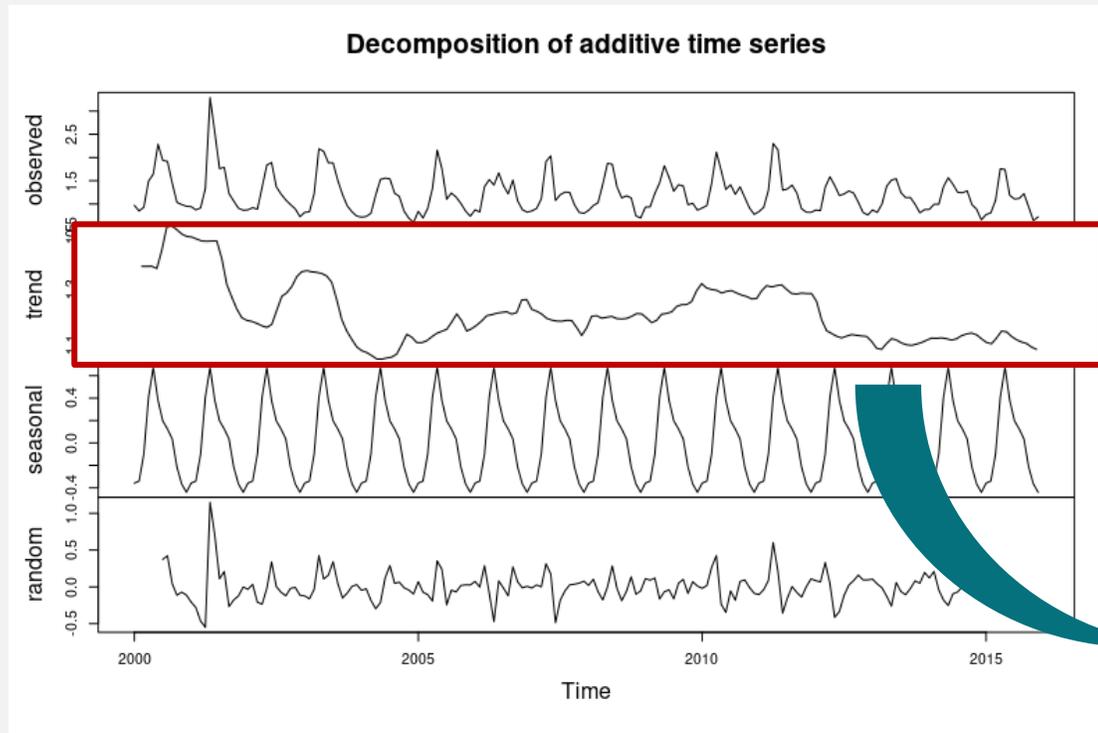
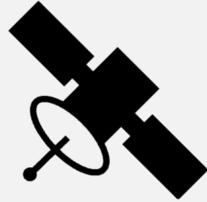


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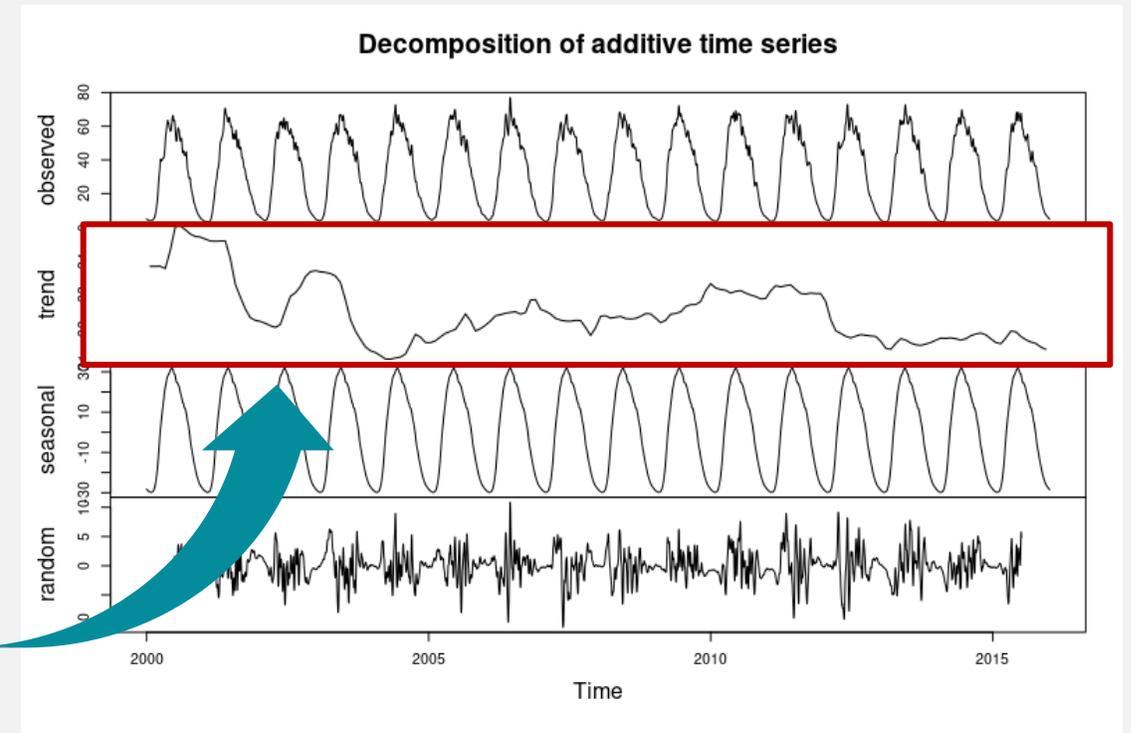


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Décomposition de la chlorophylle-a
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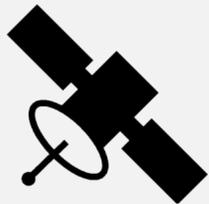
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Très faible impact sur les résultats

$$NRMSE = \frac{1}{\bar{y}} \sqrt{\frac{\sum_i^n (\hat{y}_i - y_i)^2}{n}}$$

	Area	Period	Anchovy		Sardine	
			Length	Weight	Length	Weight
NRMSE						
SC0						
	EC	2000-2005	*	*	*	*
	BoB	2000-2005	0.08	0.31	0.06	0.21
	GoL	2000-2005	0.06	0.36	0.23	0.65
SC1						
	EC	2000-2005	*	*	*	*
	BoB	2000-2005	0.09	0.33	0.06	0.23
	GoL	2000-2005	0.05	0.35	0.24	0.74

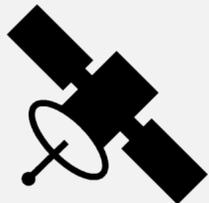


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			Length	Weight	Length	Weight
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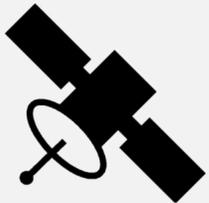


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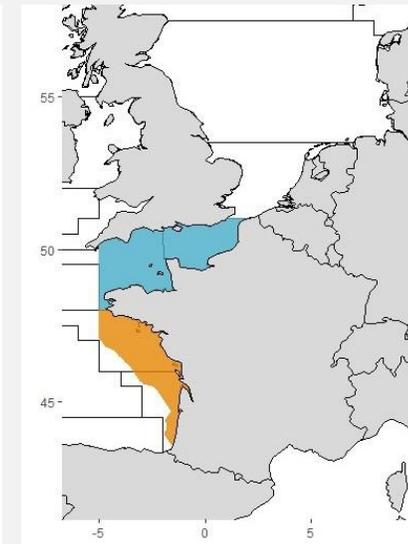
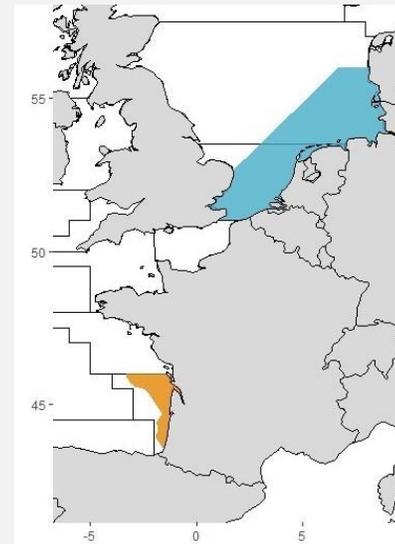
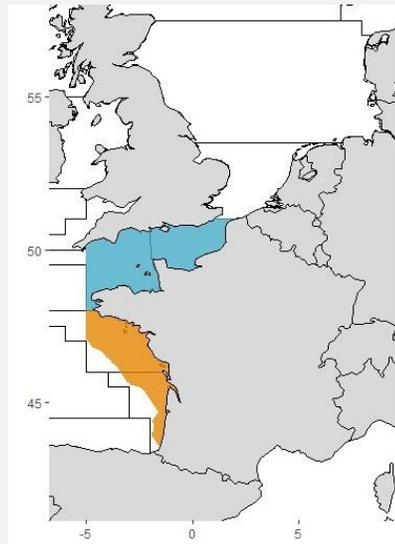
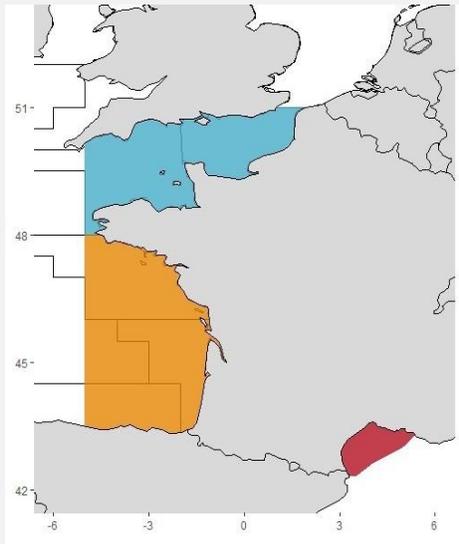
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SC2 : Spatialisation du cycle de vie de l'anchois

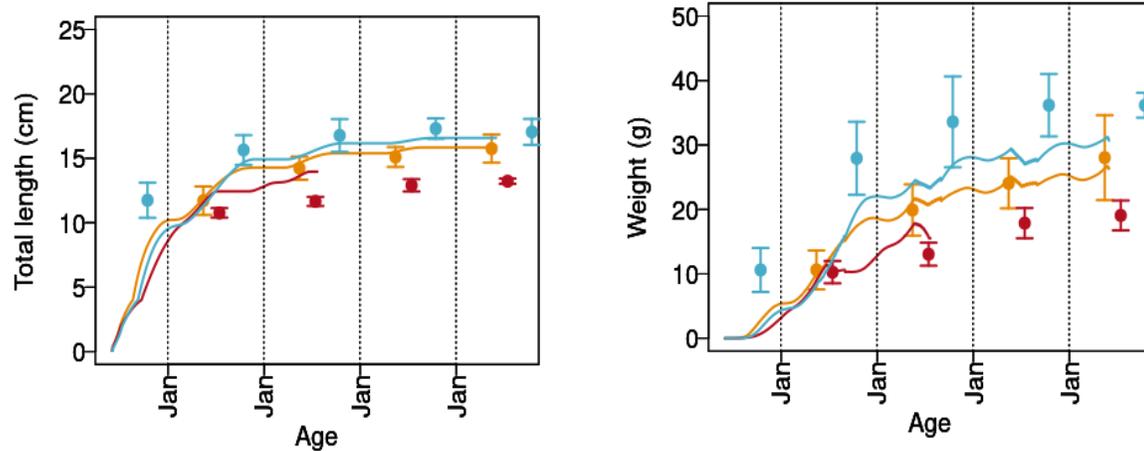
(Huret et al., 2020)



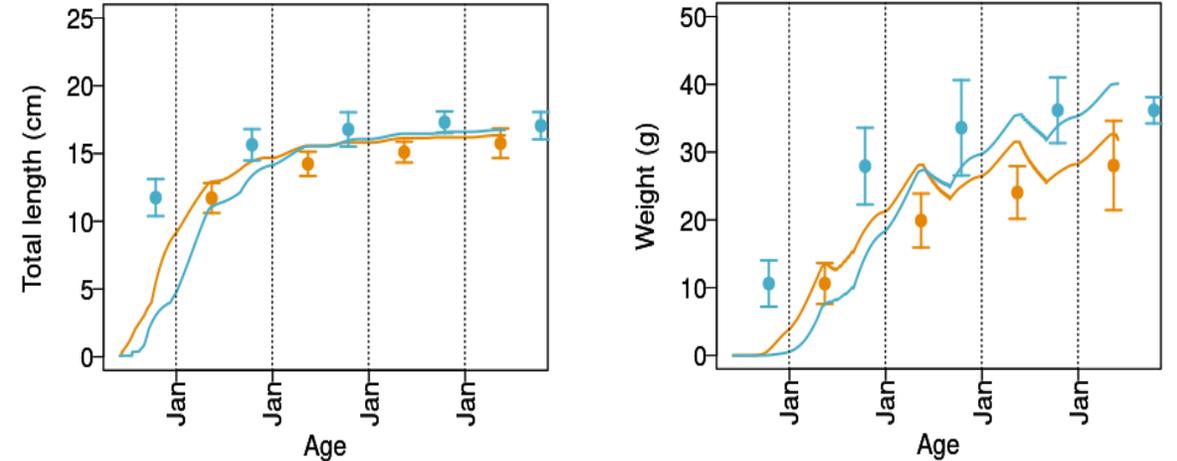
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
English Channel												
North Sea												
Bay of Biscay												
Bay of Biscay South												

SC2 : Spatialisation du cycle de vie de l'anchois

Variations saisonnières de poids plus marquées



SC0 : cas de référence



SC2

Conclusion de l'étude

Nos proxy d'environnement expliquent en grande partie la variabilité spatiale, mais n'expliquent pas la diminution de taille au cours du temps

Conclusion de l'étude

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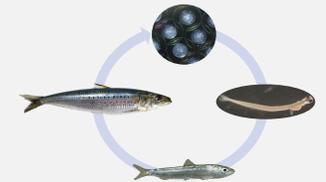
- Variabilité temporelle des données environnement (tendance et validité)



Conclusion de l'étude

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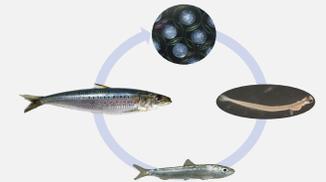
- Variabilité temporelle des données environnement (tendance et validité)
- Calibration (sensibilité spatialisation, adaptation locale)



Conclusion de l'étude

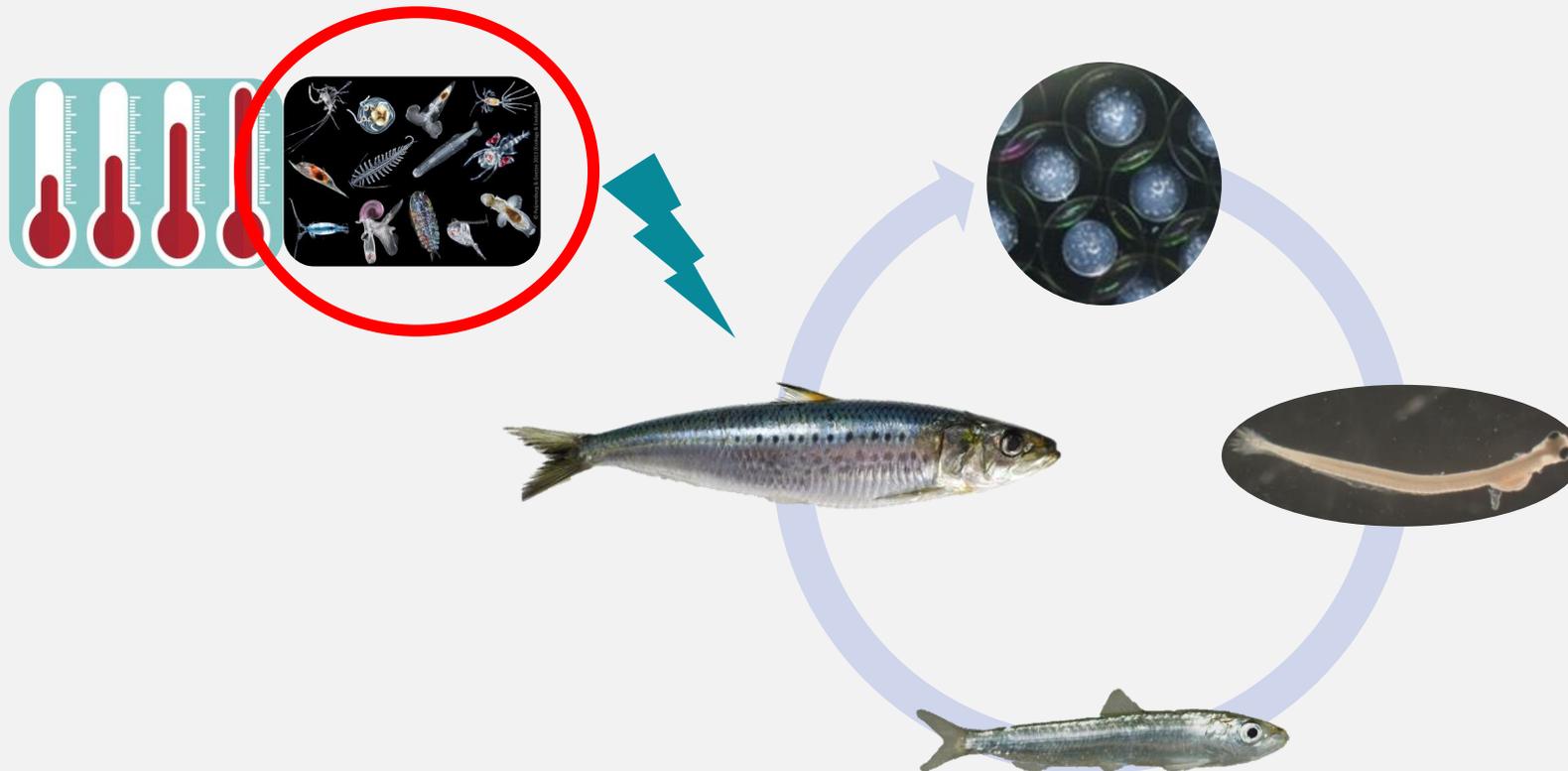
Nos proxy d'environnement expliquent en grande partie la variabilité spatiale, mais n'expliquent pas la diminution de taille au cours du temps

- Variabilité temporelle des données environnement (tendance et validité)
- Calibration (sensibilité spatialisation, adaptation locale)
- Processus non pris en compte



Hypothèses pouvant expliquer la diminution de taille

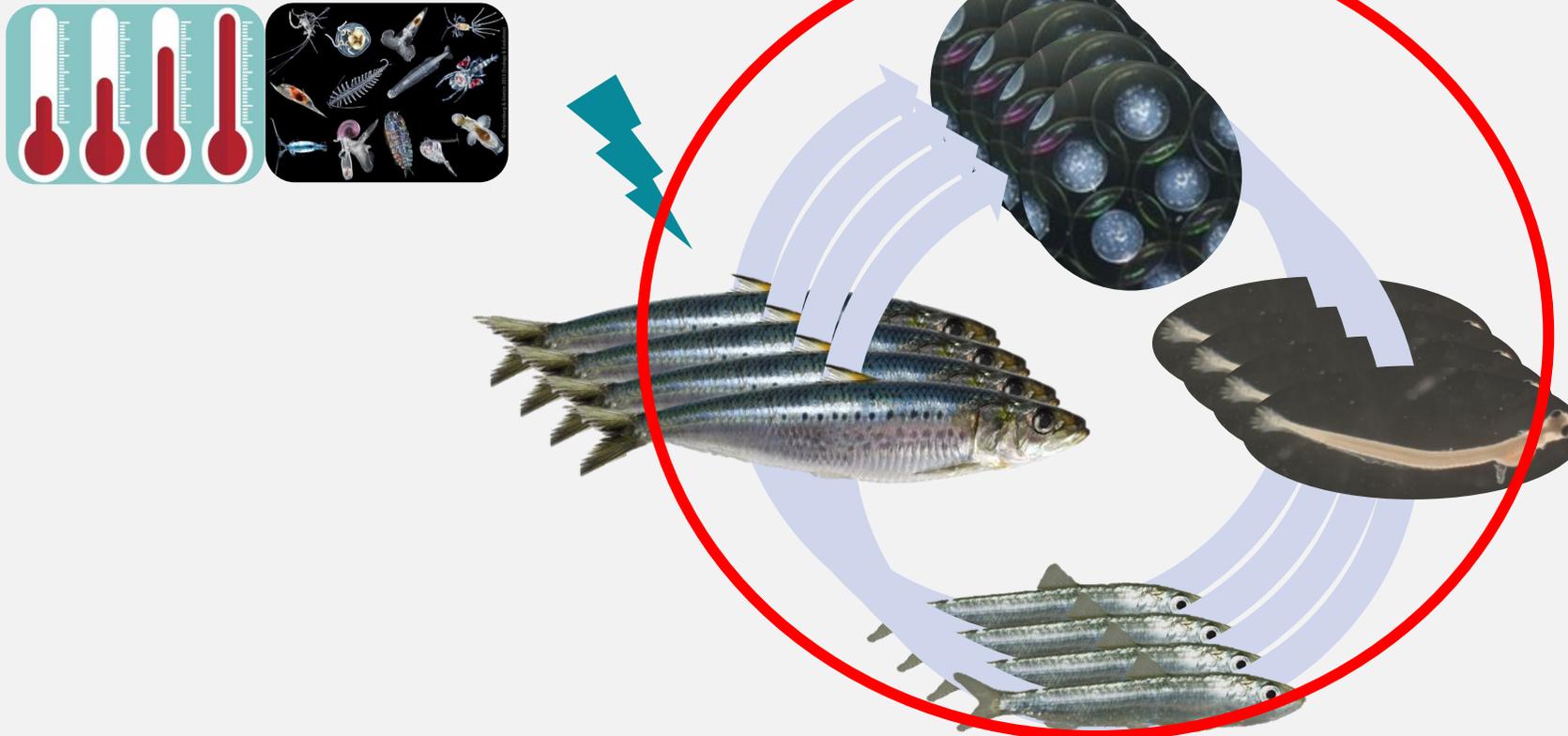
- Un potentiel changement dans les communautés planctoniques (quantité et/ou qualité de la nourriture des petits pélagiques)



*(Brosset et al., 2016 ;
Saraux et al., 2019 ;
Véron et al., 2020)*

Hypothèses pouvant expliquer la diminution de taille

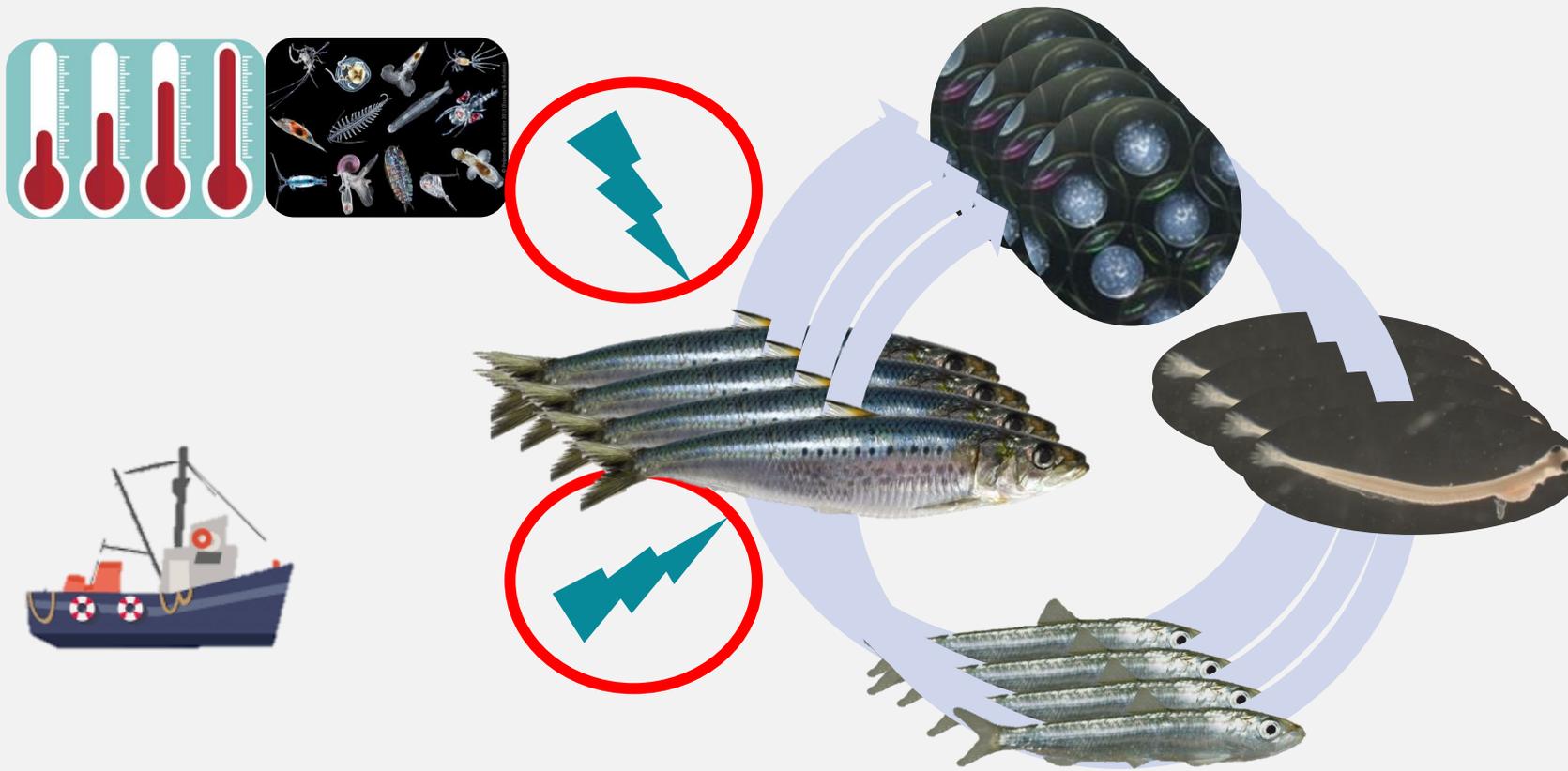
- Un changement dans les processus de densité-dépendance affectant la croissance et/ou la mortalité (échelle population)



Hypothèses pouvant expliquer la diminution de taille

- Une augmentation de la mortalité naturelle ou par pêche, sélective en fonction de la condition énergétique ou de la taille des individus

(Saraux et al., 2019)



Remerciements



Martin
HURET



Jeroen
VAN DER
KOOIJ



Mathieu
DORAY



Tarek
HATTAB

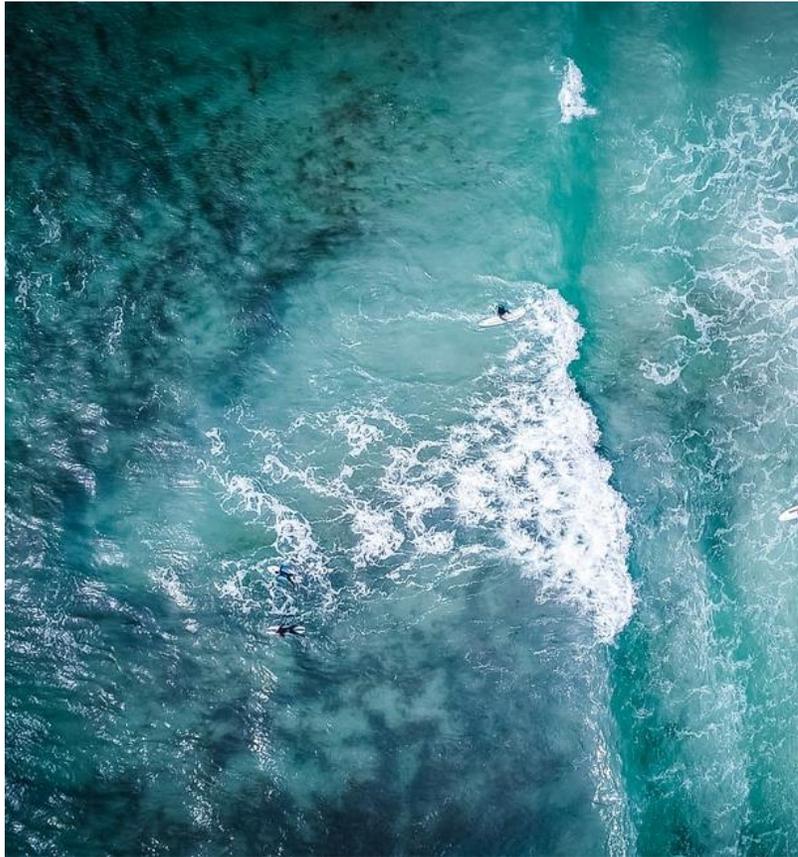


Laure
PECQUERIE



Cedric
BACHER





Merci pour votre attention



l'institut Agro
agriculture • alimentation • environnement



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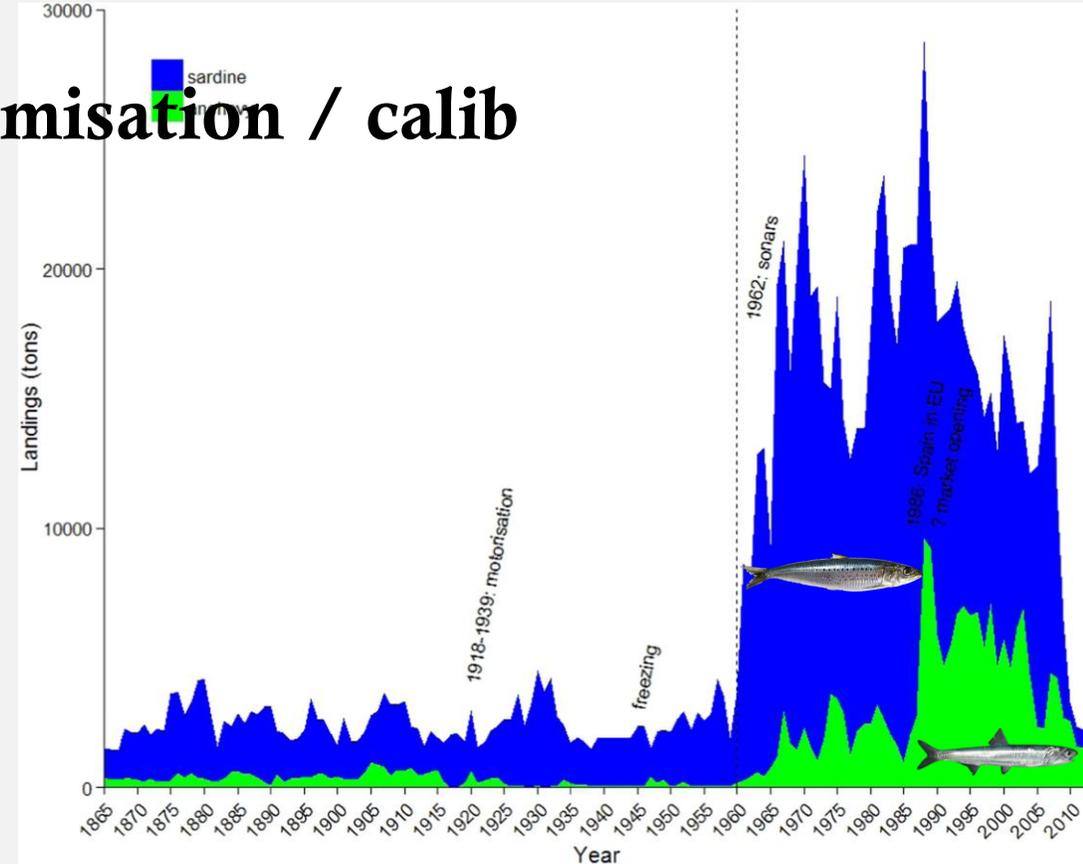
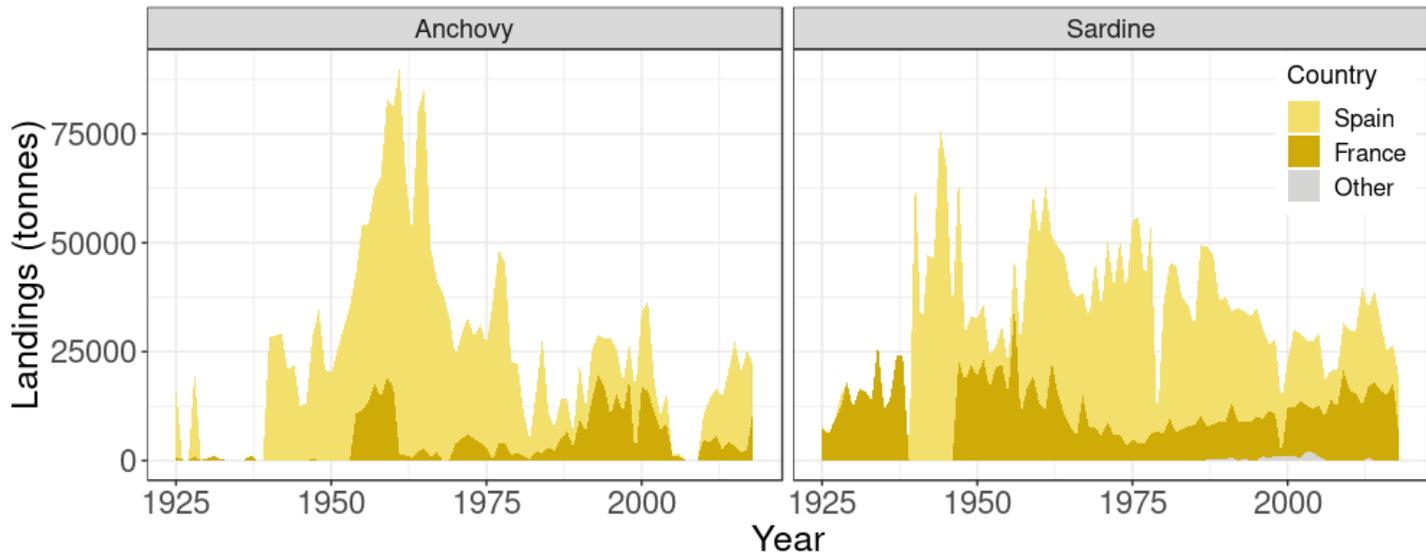


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Captures anchois et sardine

Faire slide sur méthode optimisation / calib

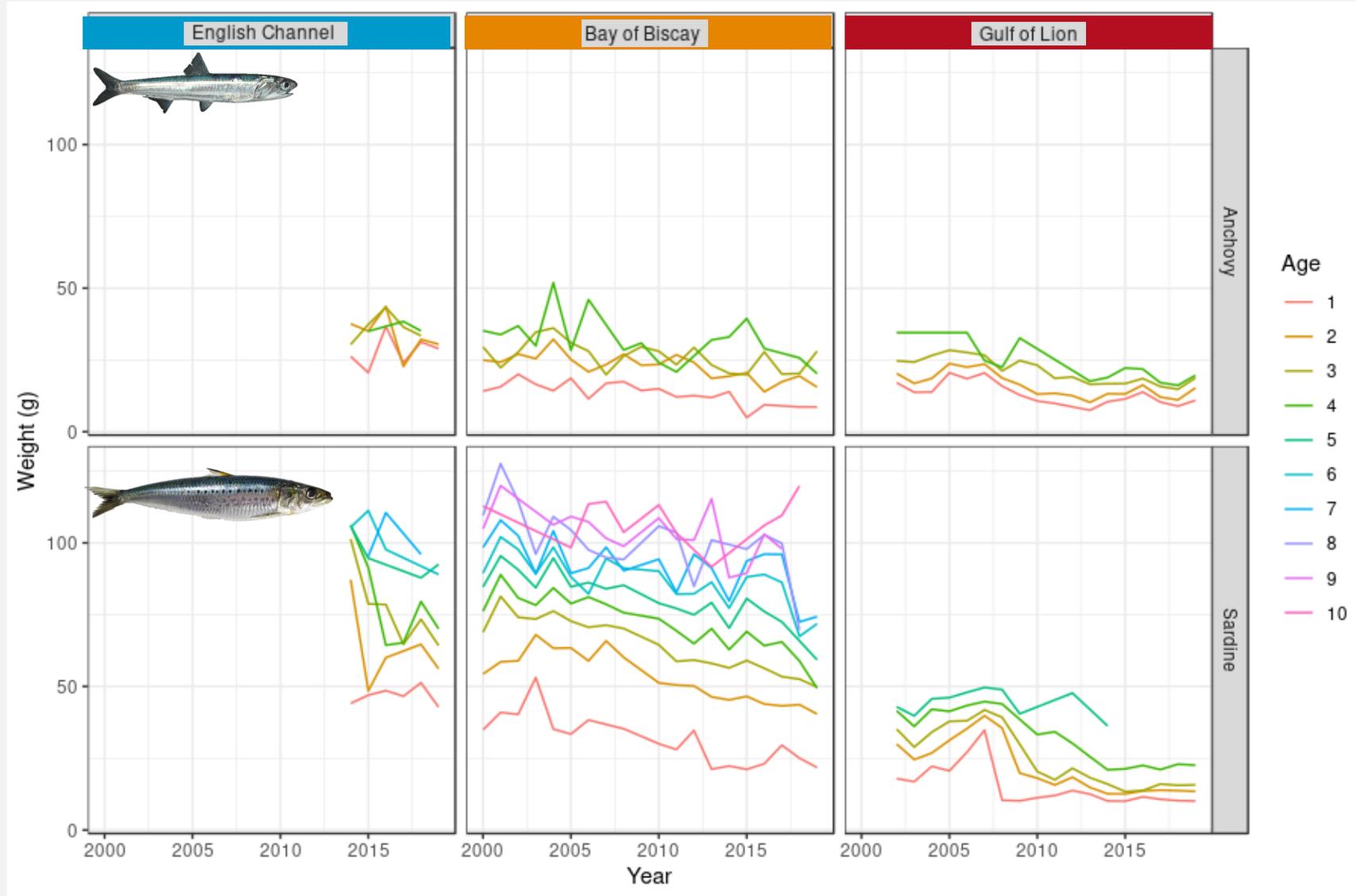


Golfe de Gascogne

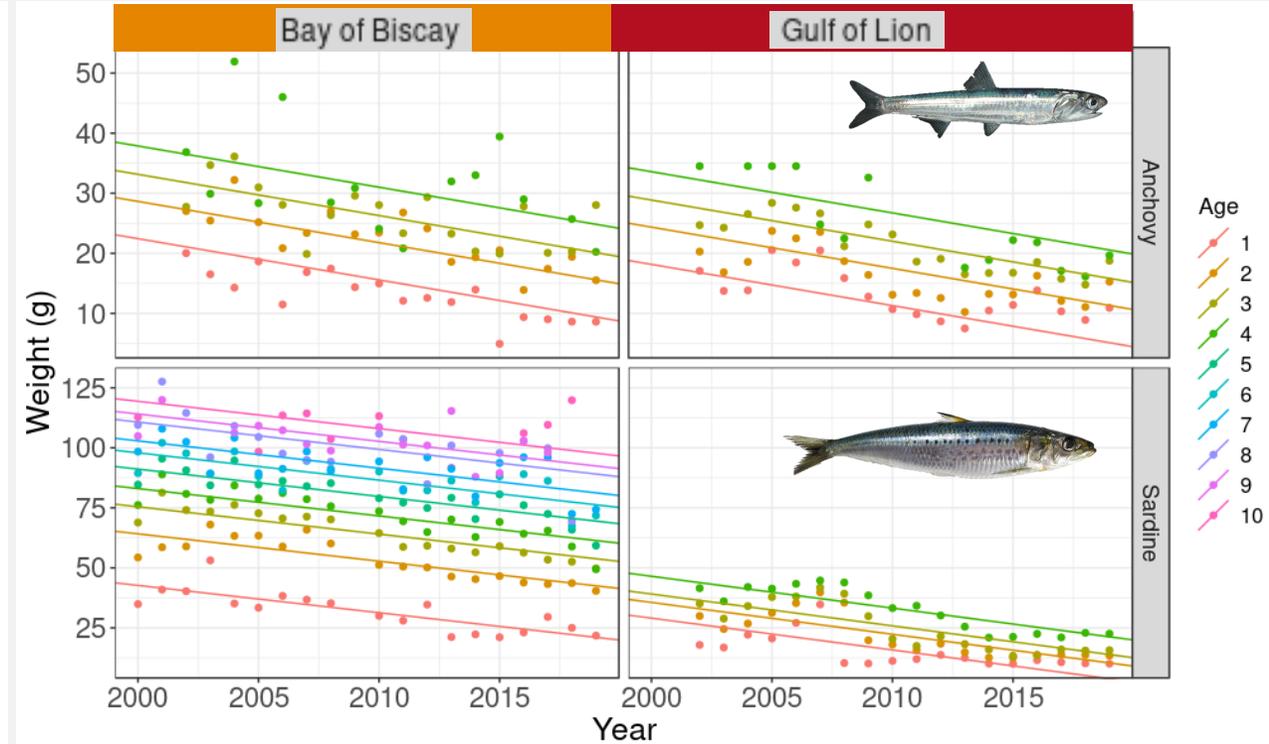
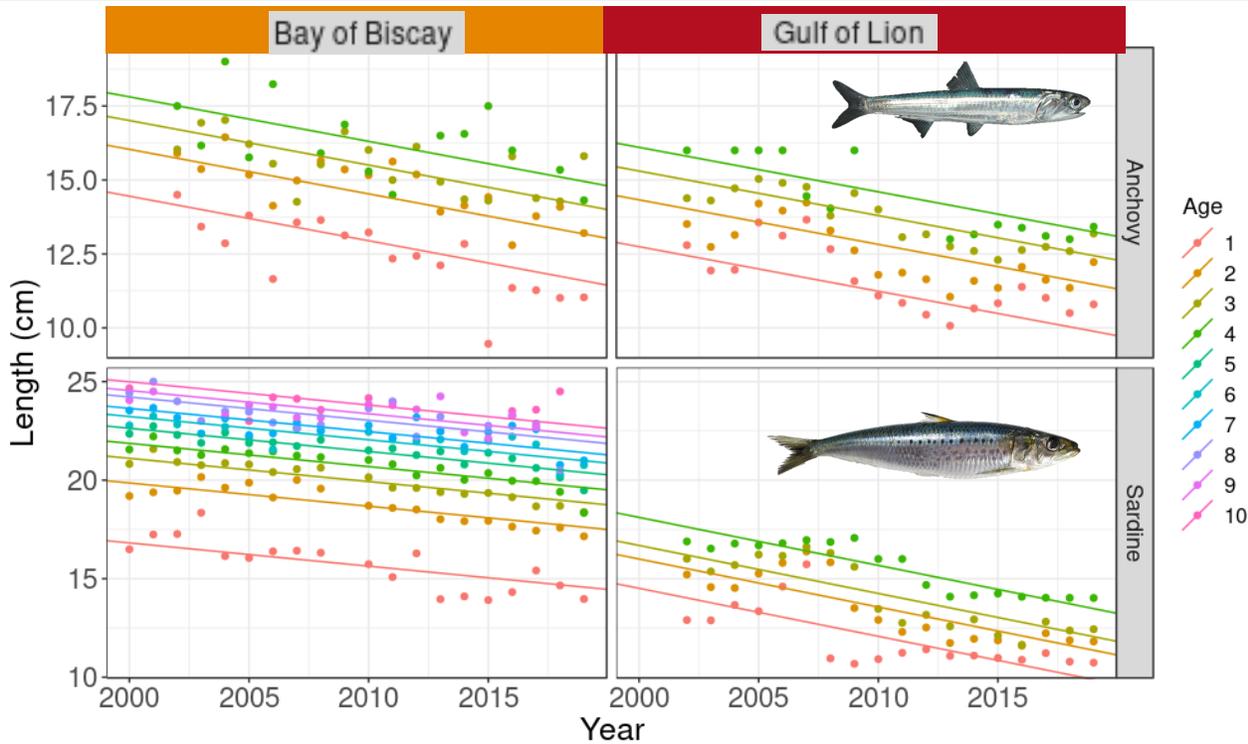
Golfe du Lion



Diminution de poids dans les données de campagnes pélagiques



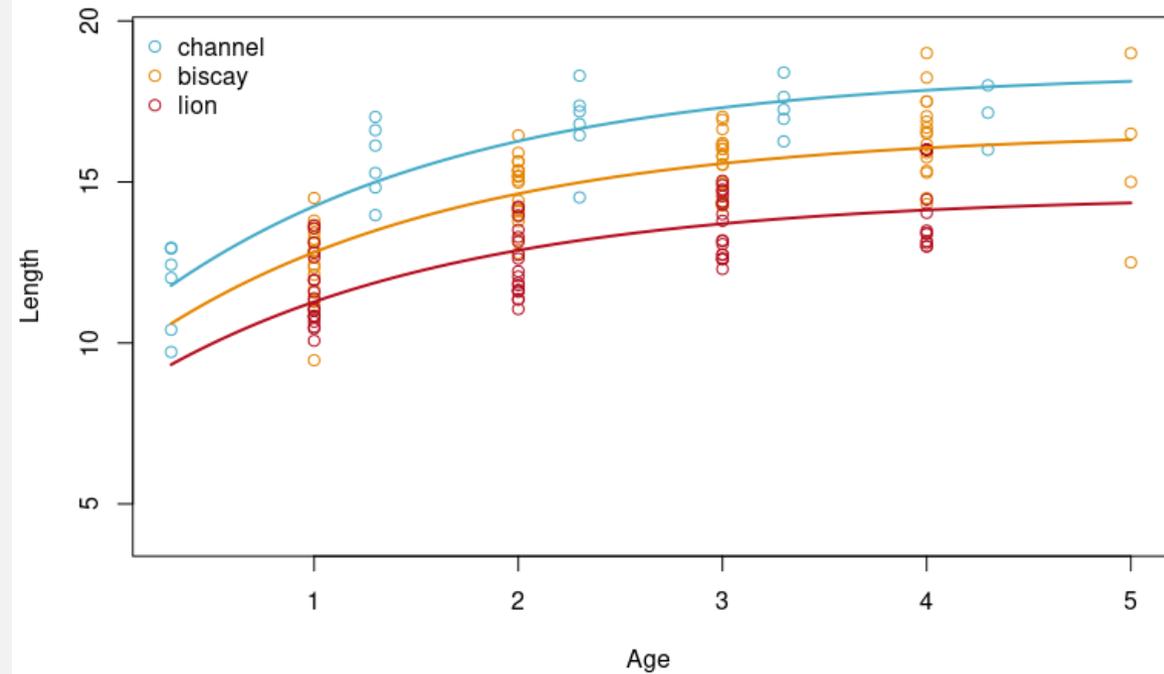
Diminution de taille et poids (1m)



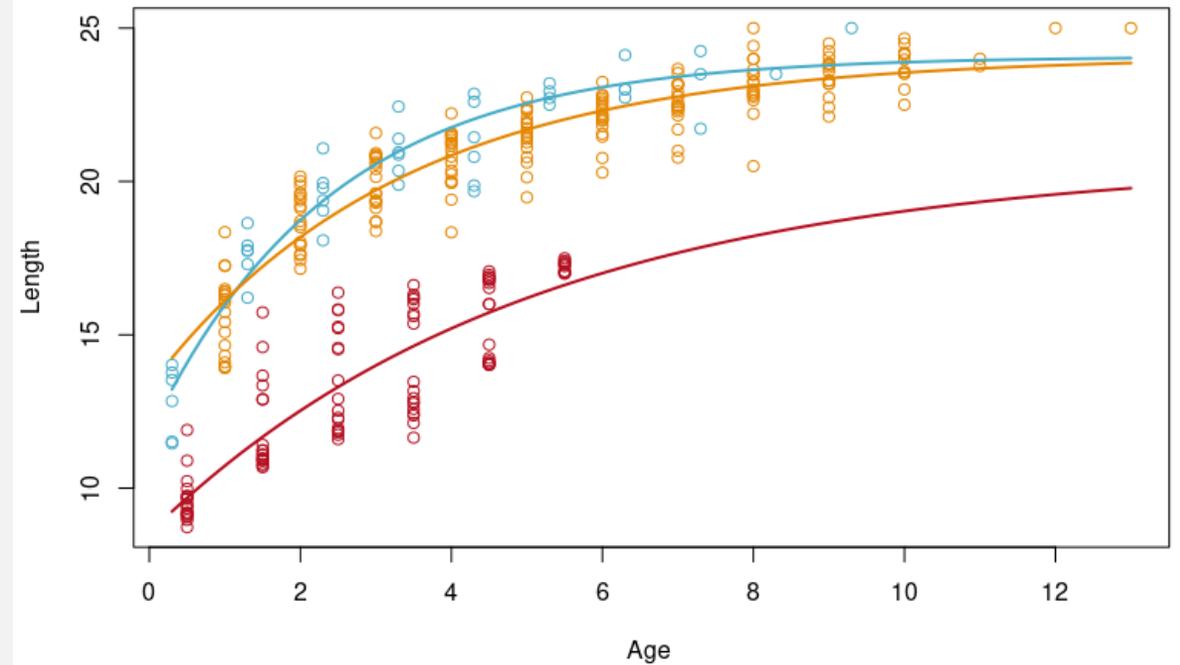
Différences significatives des Linf par zone



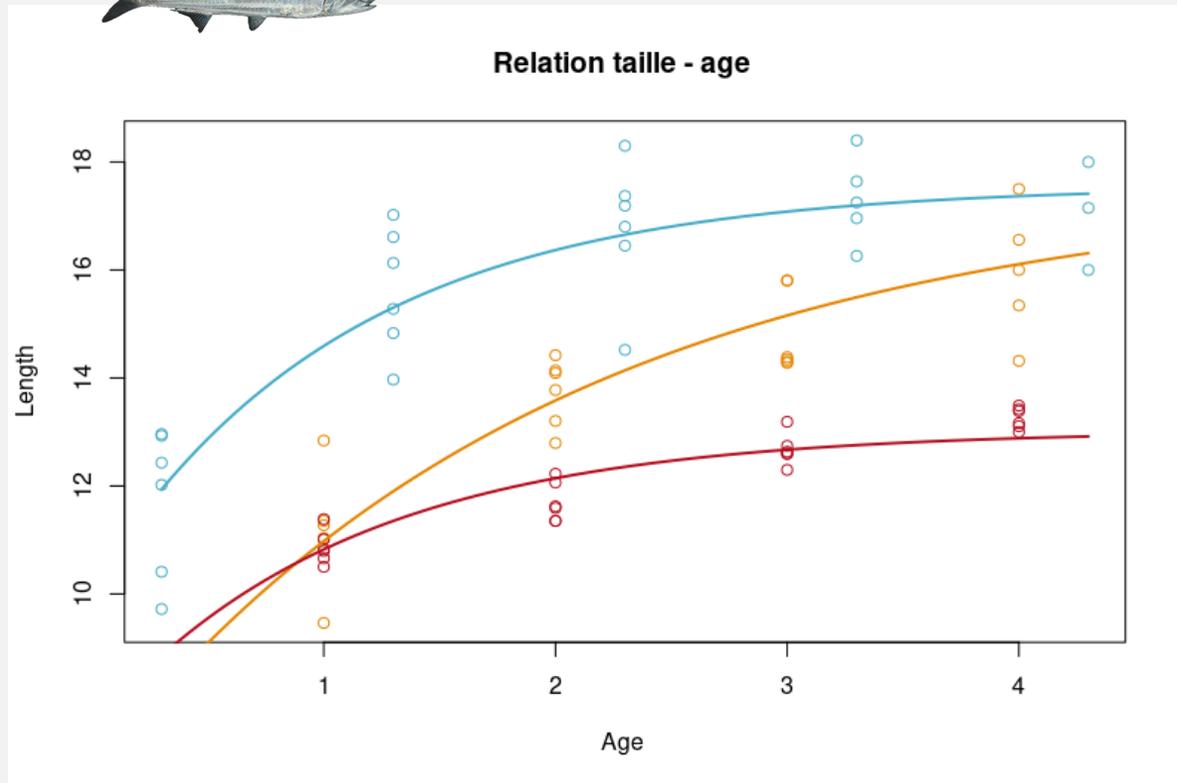
Relation taille - age



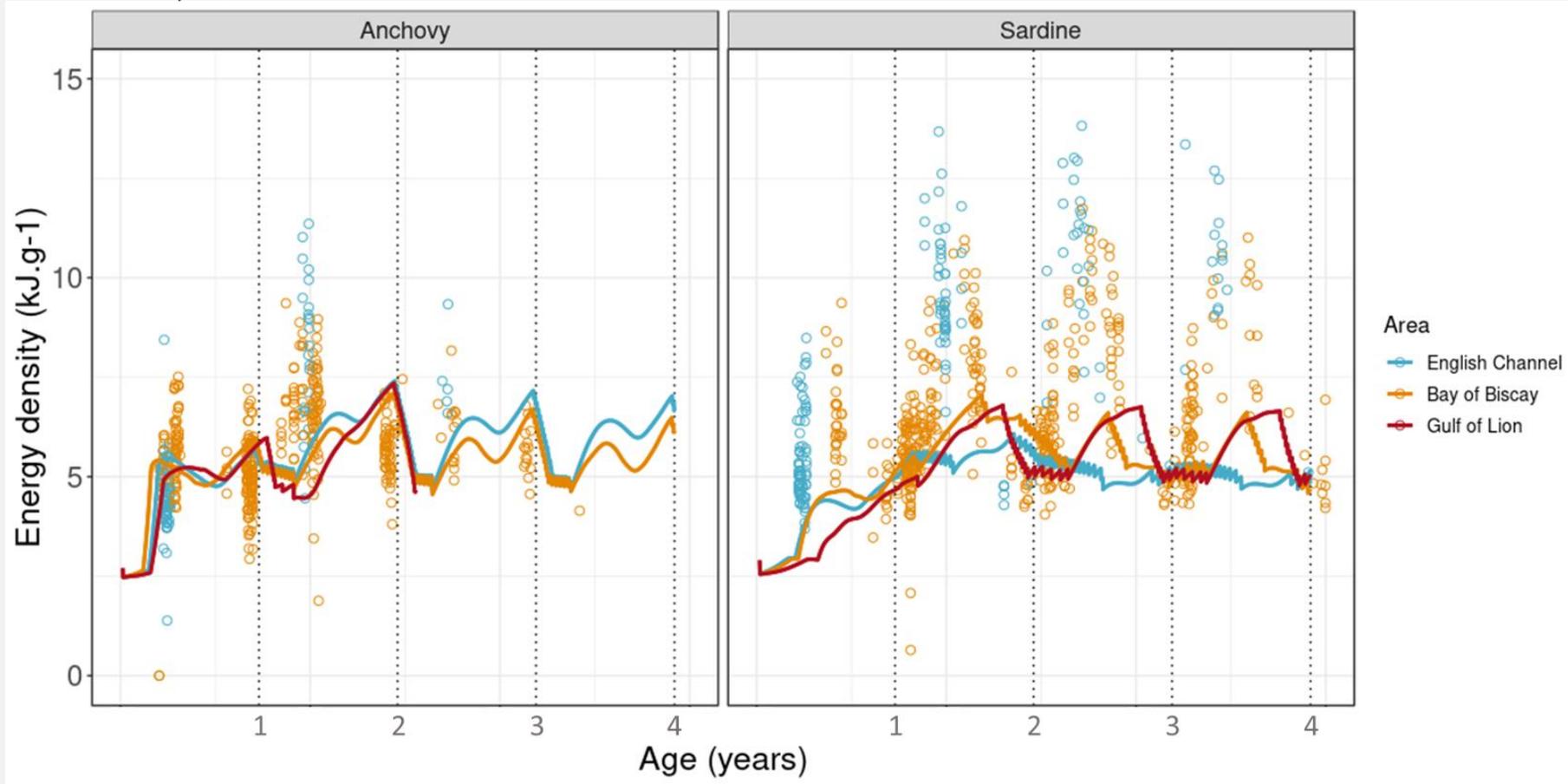
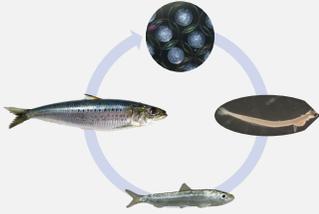
Relation taille - age



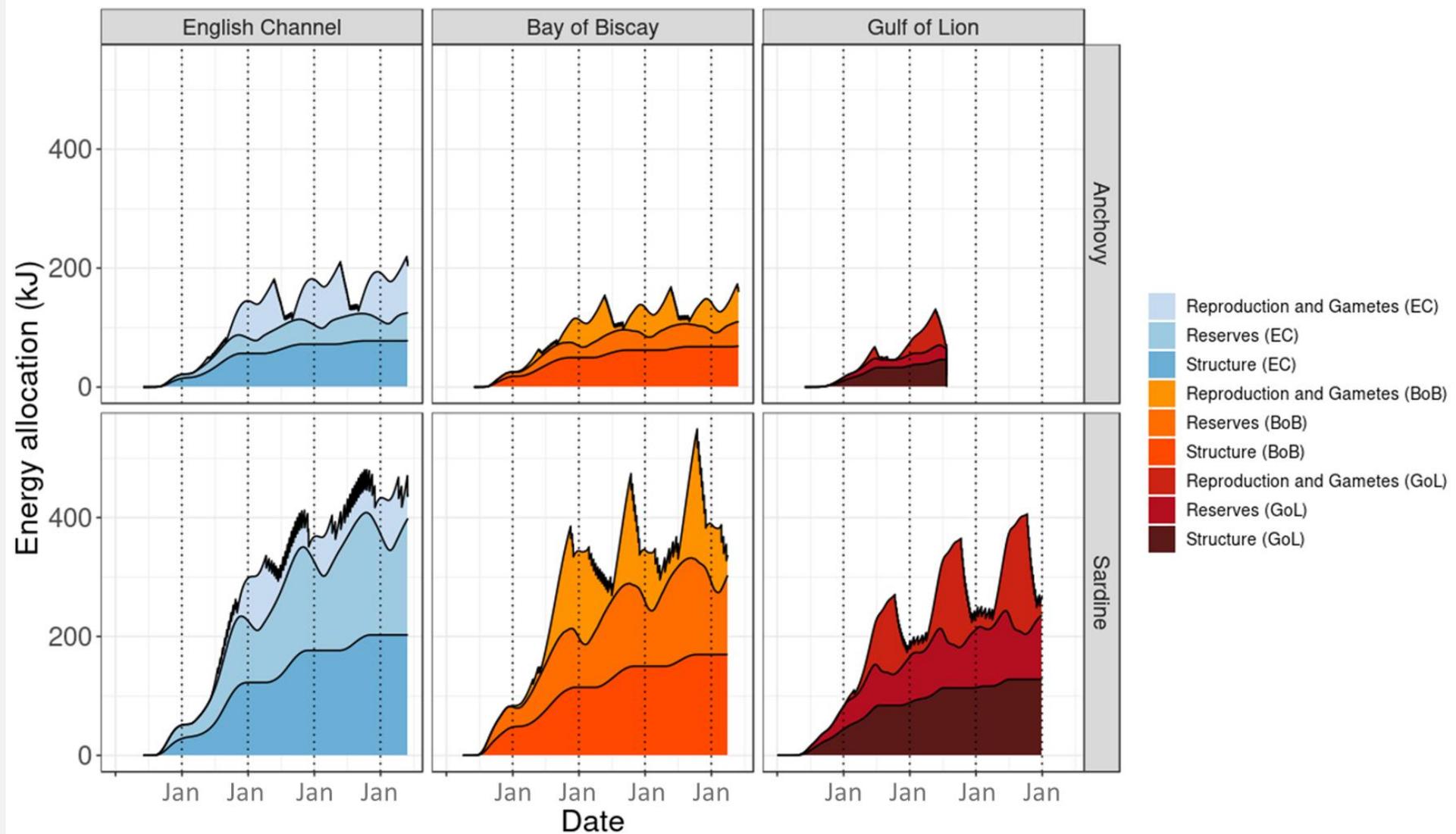
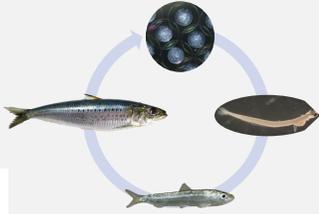
Différences significatives des L_{inf} par zone (fin de période)



Ajustement du modèle aux données de densité énergétique



Allocation d'énergie



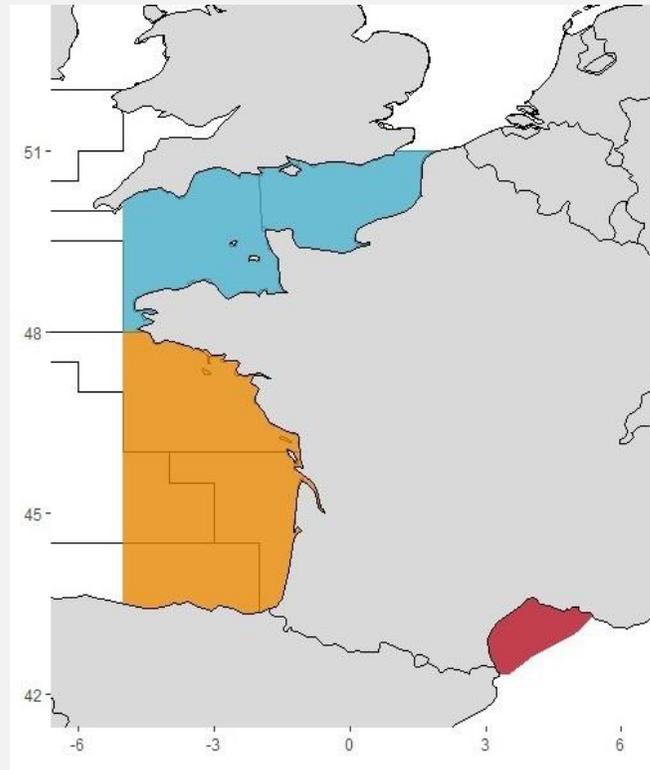
Données de campagnes pélagiques



Manche
PELTIC

Golfe de Gascogne
PELGAS

Golfe du Lion
PELMED



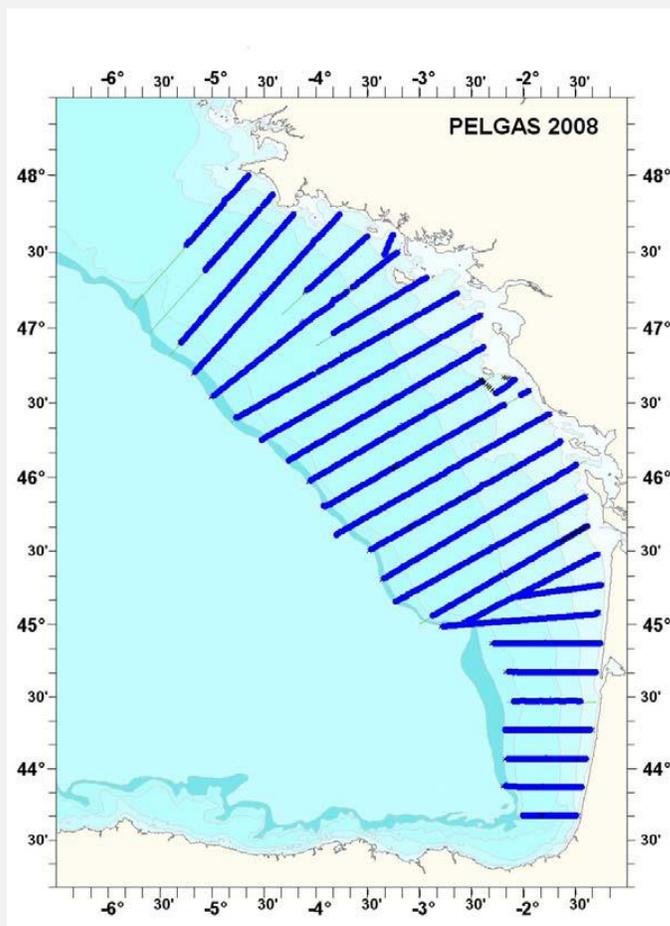
Données homogènes :

- Campagnes pélagiques
- Données standardisées par des experts locaux (taille et poids)

Données de campagnes pélagiques



Golfe de Gascogne
PELGAS



Données homogènes :

- Campagnes pélagiques acoustiques
- DIRE COMMENT STANDARDISEES