Decrease in quality of small pelagic fish : Bottom-up control and consequences for the fishing industry and a top predator in the Bay of Biscay



Martin Huret

F. Daurès, M. Doray, A. Favreau, S. Lehuta,
J.-B. Romagnan, J. Spitz, M. Travers-Trolet



Size shrinking in fish

Global Change Biology
celebrating 20 years
Global Change Biology (2014) **20**, 1023–1031, doi: 10.1111/gcb.12514

OPINION

Warming temperatures and smaller body sizes: synchronous changes in growth of North Sea fishes

ALAN R. BAUDRON[1], COBY L. NEEDLE[2], ADRIAAN D. RIJNSDORP[3] and C. TARA MARSHALL[1]

LETTERS
PUBLISHED ONLINE: 30 SEPTEMBER 2012 | DOI: 10.1038/NCLIMATE1691
nature climate change

Shrinking of fishes exacerbates impacts of global ocean changes on marine ecosystems

William W. L. Cheung[1]*, Jorge L. Sarmiento[2], John Dunne[3], Thomas L. Frölicher[2], Vicky W. Y. Lam[1], M. L. Deng Palomares[1], Reg Watson[1] and Daniel Pauly[1]

nature ecology & evolution
ARTICLES
https://doi.org/10.1038/s41559-020-1171-0
Check for updates

Fish body sizes change with temperature but not all species shrink with warming

Asta Audzijonyte[1,2]✉, Shane A. Richards[3], Rick D. Stuart-Smith[1], Gretta Pecl[1,2], Graham J. Edgar[1], Neville S. Barrett[1], Nicholas Payne[4] and Julia L. Blanchard[1,2]

RESEARCH ARTICLE
Global Change Biology WILEY

Temperature impacts on fish physiology and resource abundance lead to faster growth but smaller fish sizes and yields under warming

Max Lindmark[1] | Asta Audzijonyte[2,3] | Julia L. Blanchard[3] | Anna Gårdmark[4]

nature climate change
ARTICLES
https://doi.org/10.1038/s41558-021-01123-5
Check for updates

Historical warming consistently decreased size, dispersal and speciation rate of fish

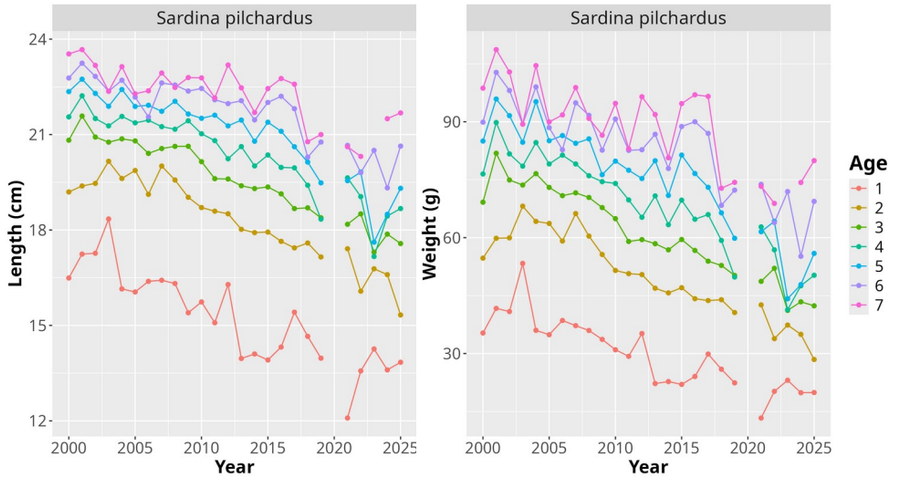
Jorge Avaria-Llautureo[1]✉, Chris Venditti[2], Marcelo M. Rivadeneira[1,3,4], Oscar Inostroza-Michael[5], Reinaldo J. Rivera[6], Cristián E. Hernández[5,7] and Cristian B. Canales-Aguirre[8,9]

RESEARCH ARTICLE
Journal of Applied Ecology BRITISH ECOLOGICAL SOCIETY

Bigger juveniles and smaller adults: Changes in fish size correlate with warming seas

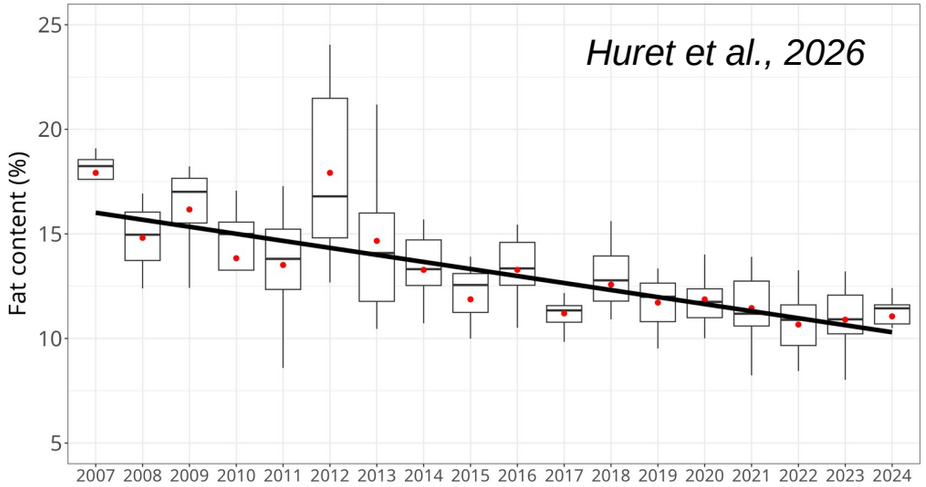
Idongesit E. Ikpewe | Alan R. Baudron | Aurore Ponchon | Paul G. Fernandes

In the Bay of Biscay

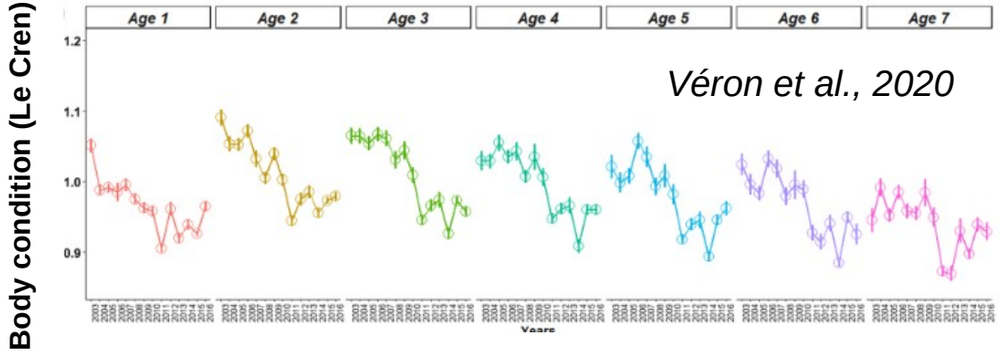


Updated after Doray et al., 2018

Can industry monitoring of fat content







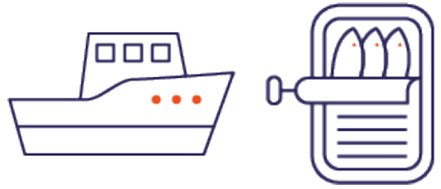
Length-at-age
Weight-at-age
Body condition (Le Cren)

Fat/energy content OMEGA 3

General decrease in FISH QUALITY

Outline

1. What impacts on the fishing industry ? → focus on sardine

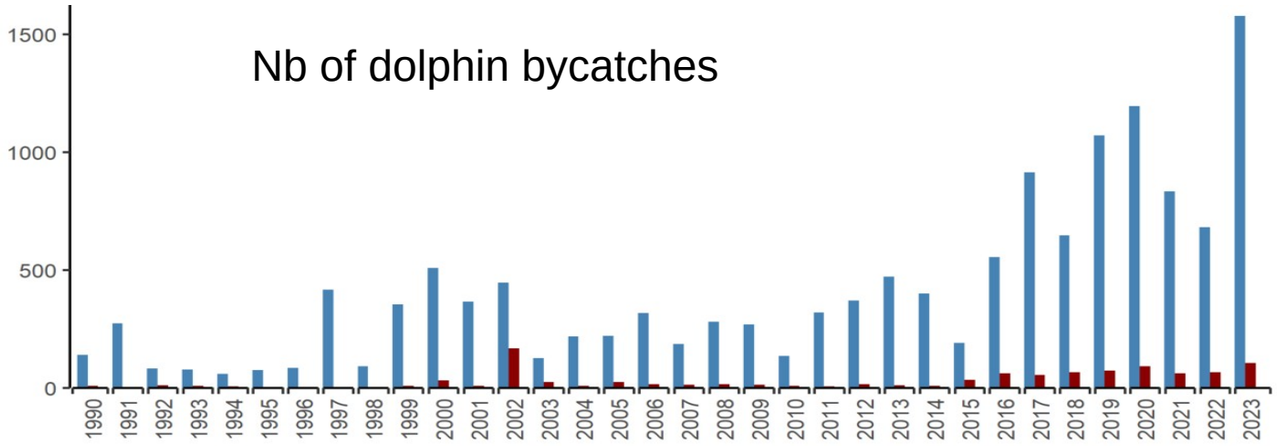


2. What impacts on a top predator ? → Case of the common dolphin

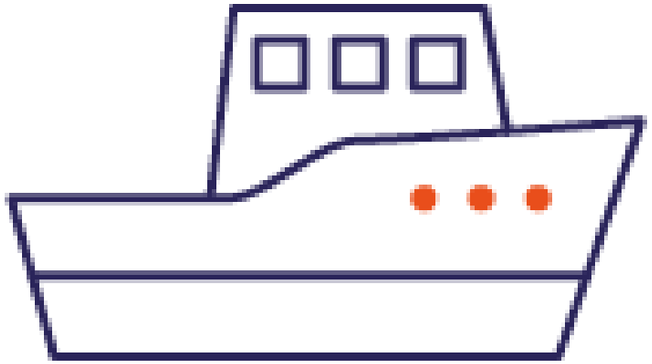


Delphinus delphis





1. Impact of the decrease in sardine quality on the fishing industry



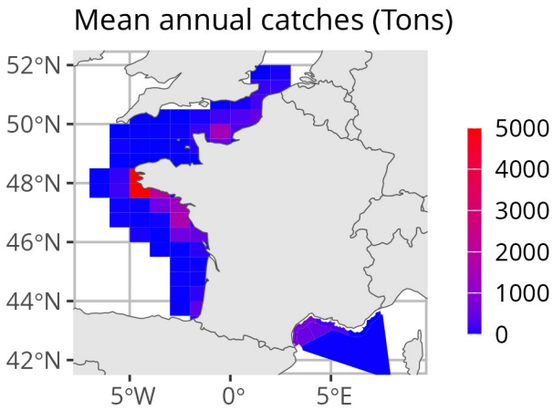


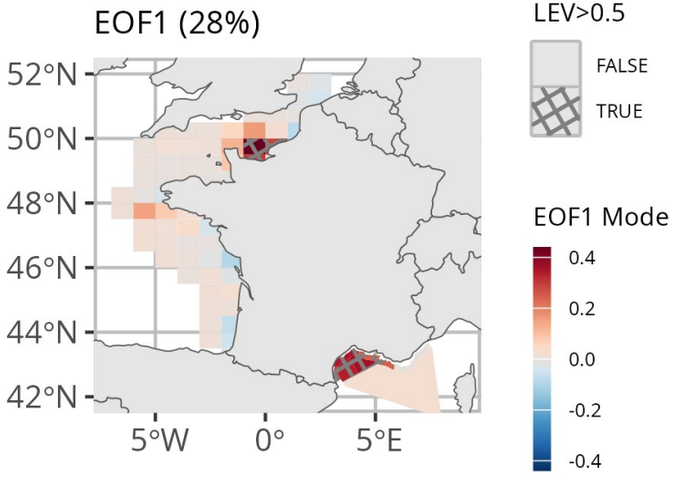
Spatio-temporal dynamics of the fishery

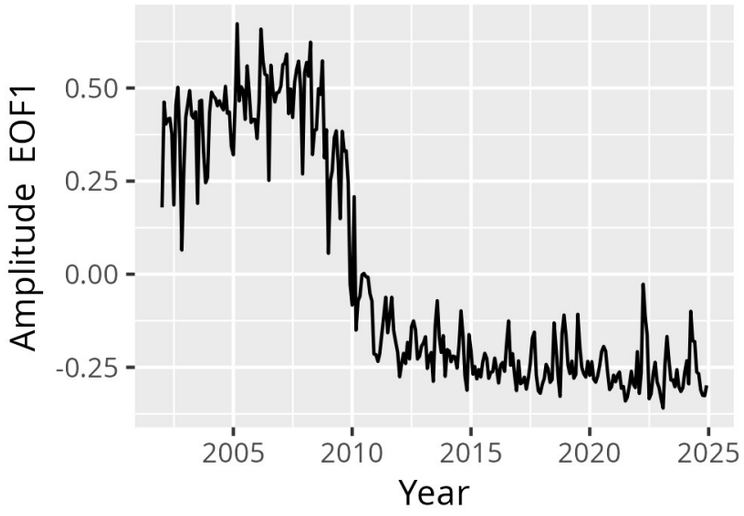


- Data : spatially explicit catches from IFREMER SACROIS product
  - ➔ Monthly maps

- Method : space-time analysis - Empirical Orthogonal Functions (EOF)
  - ➔ extract the main patterns of temporal variability from a series of maps
  - ➔ follow their temporal magnitude
  - ➔ map the corresponding spatial patterns

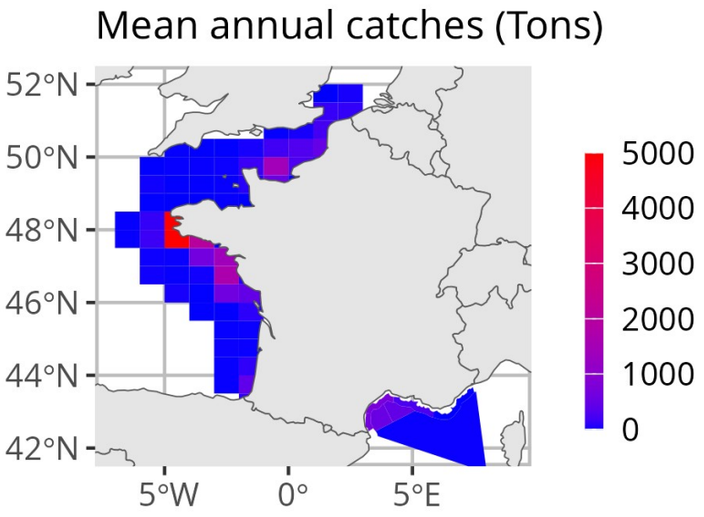


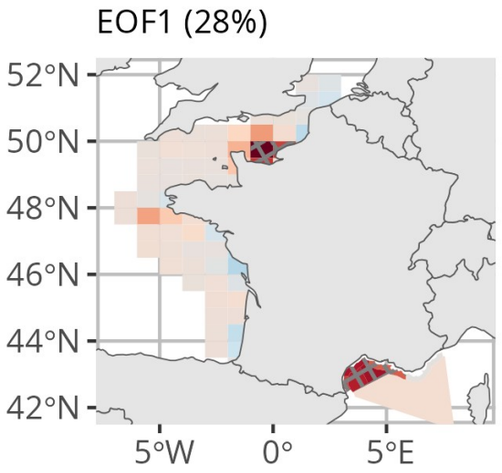


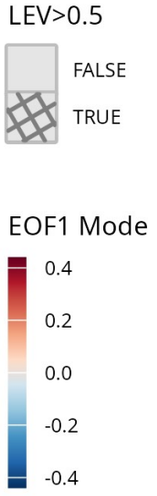


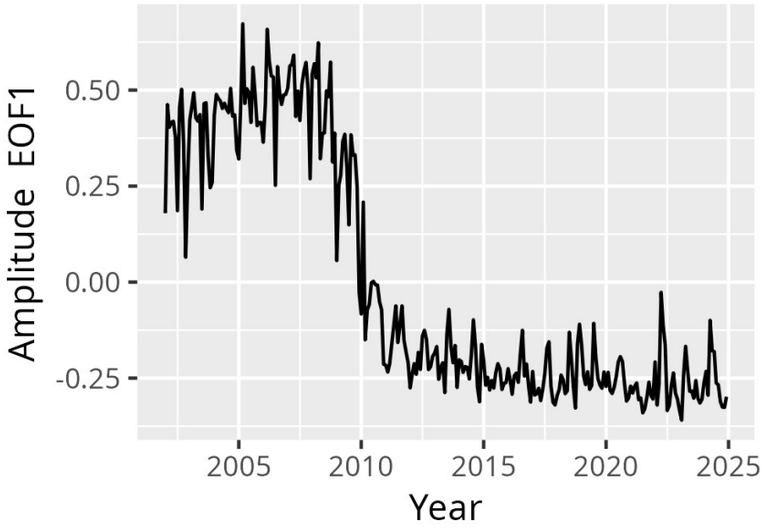
Spatio-temporal dynamics of the fishery

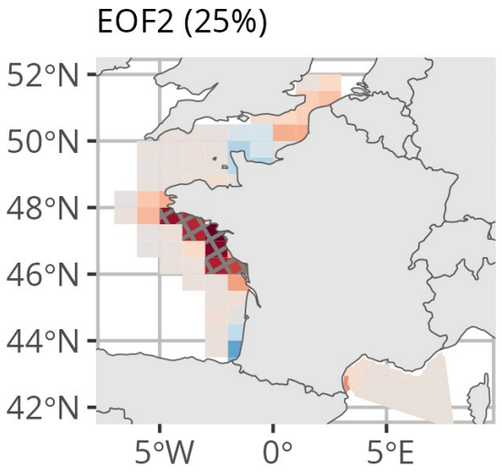


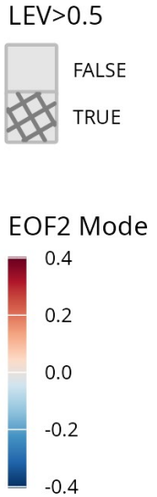


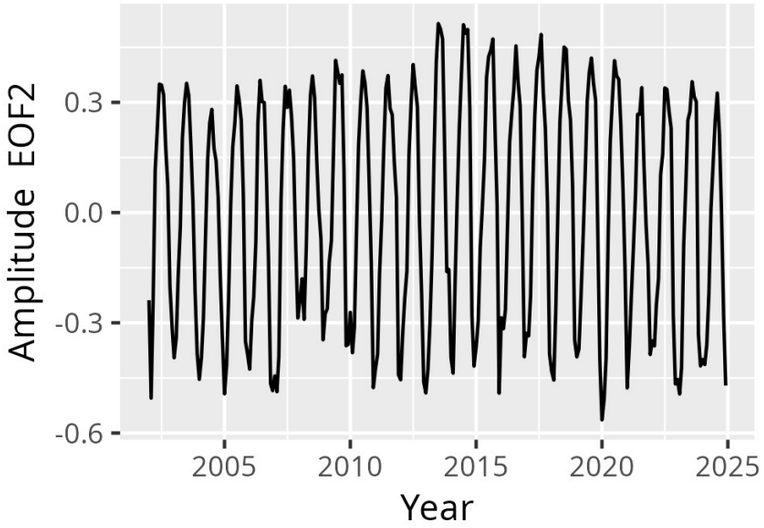




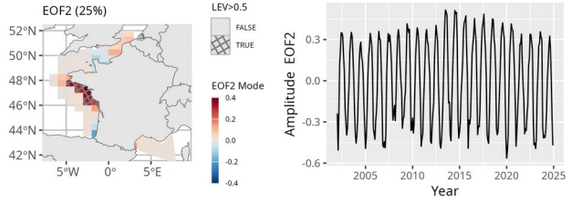


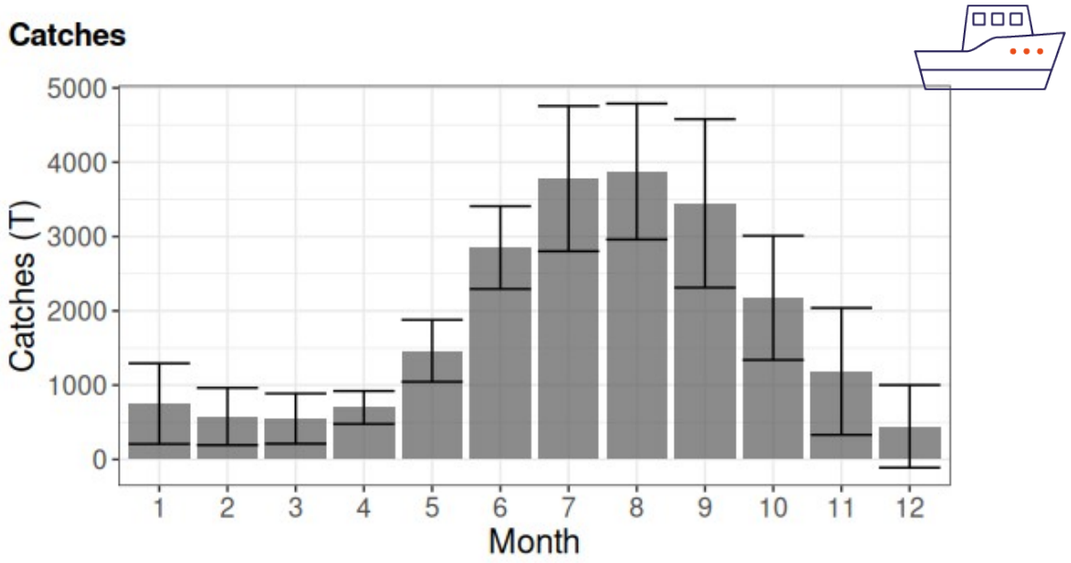




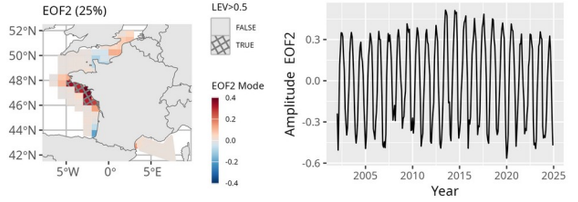


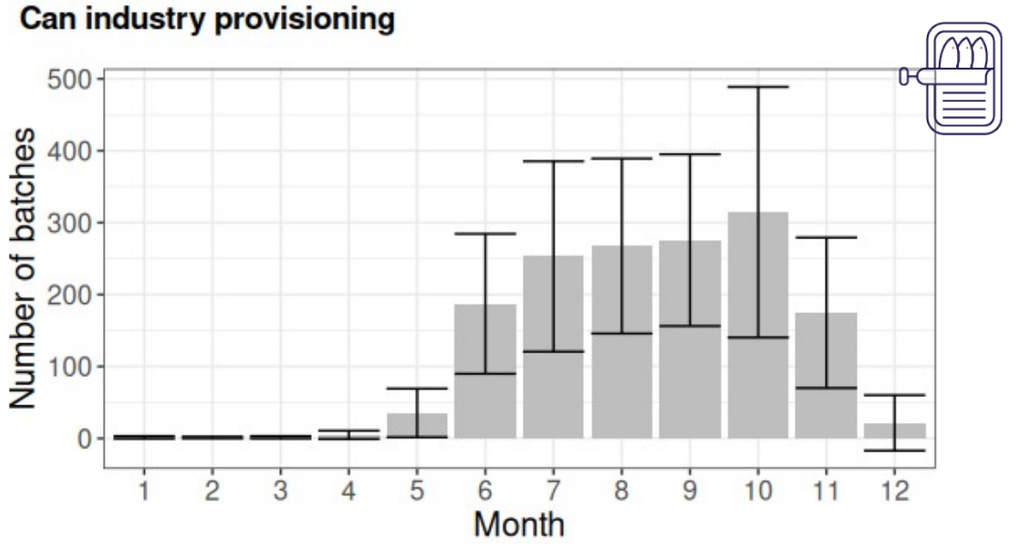
Drivers of the seasonal variability

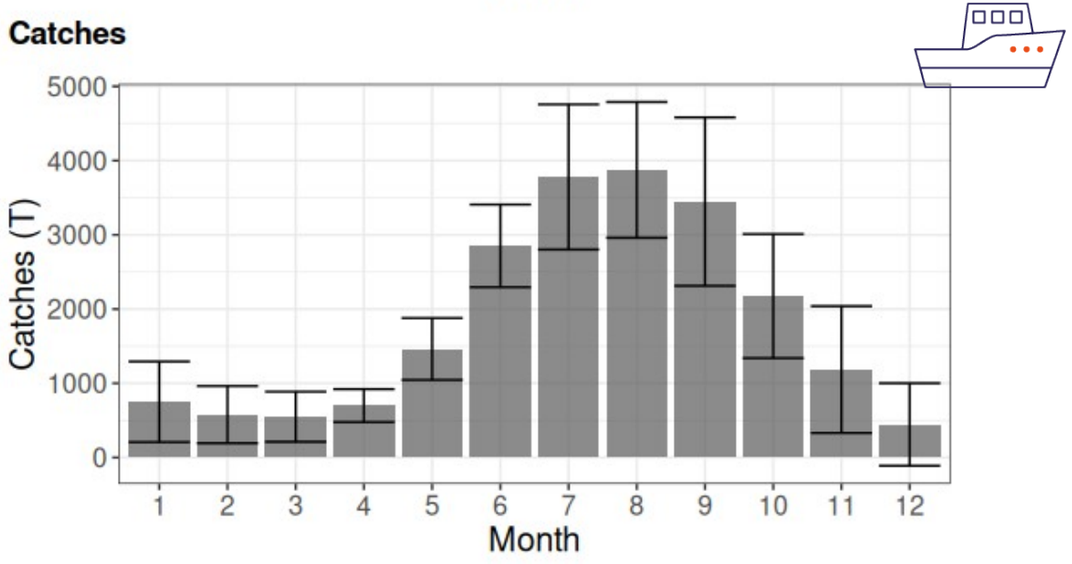




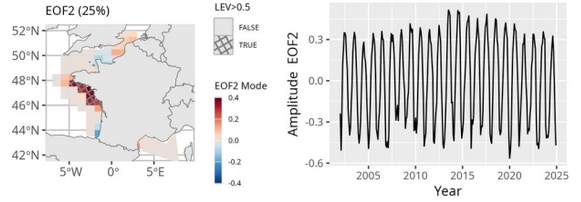
Drivers of the seasonal variability





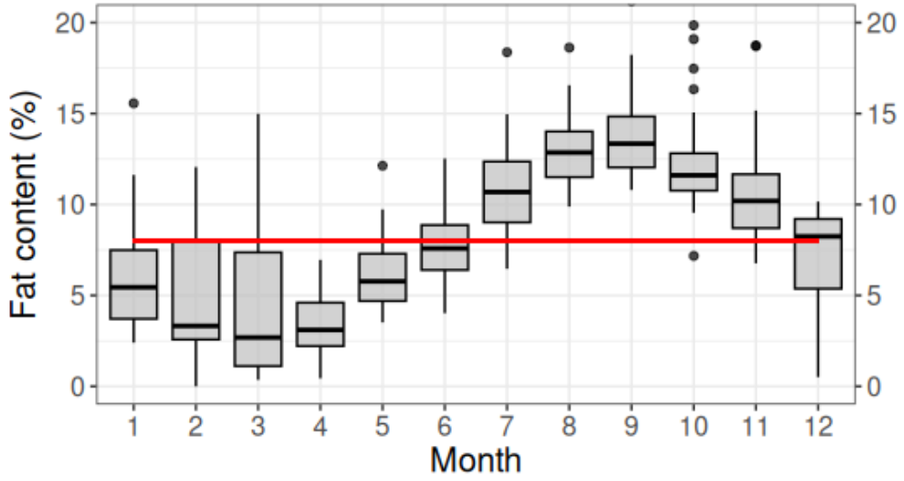


Drivers of the seasonal variability





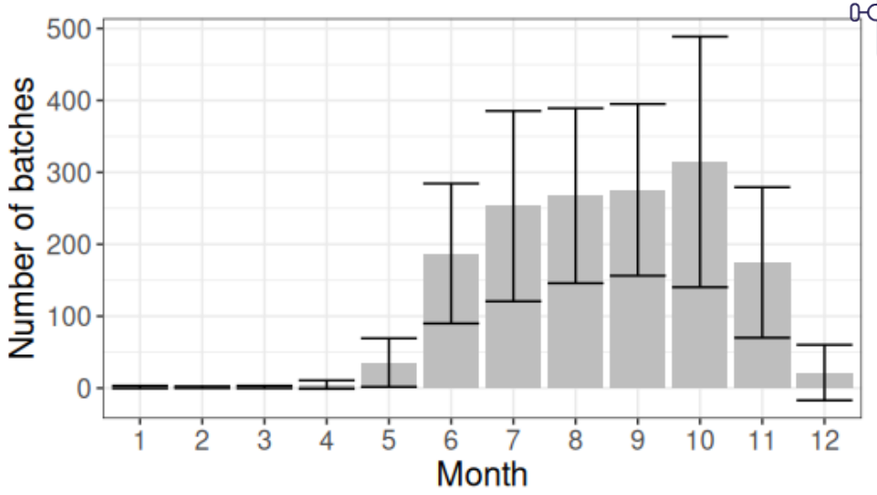
Fish Fat content





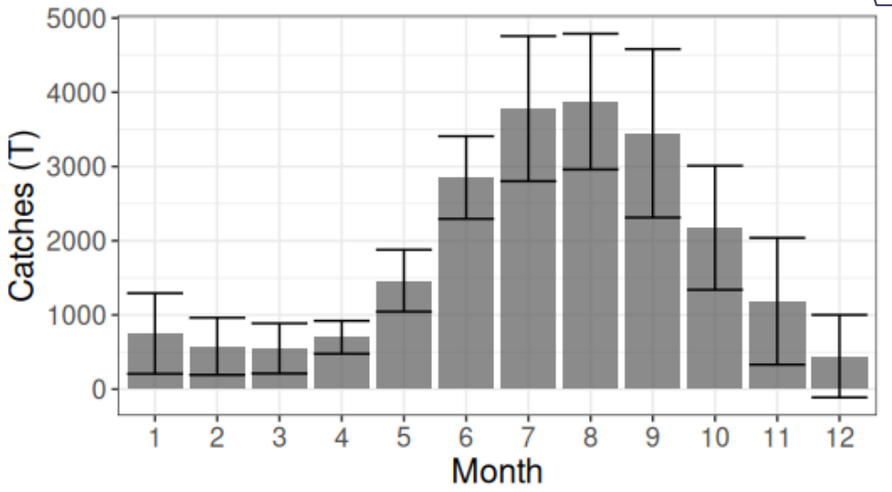
Can industry provisioning



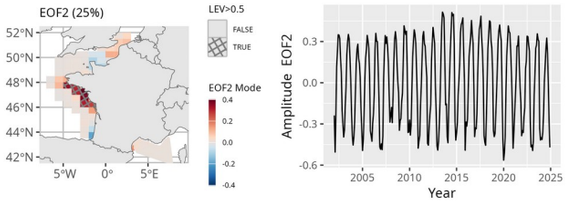


Catches



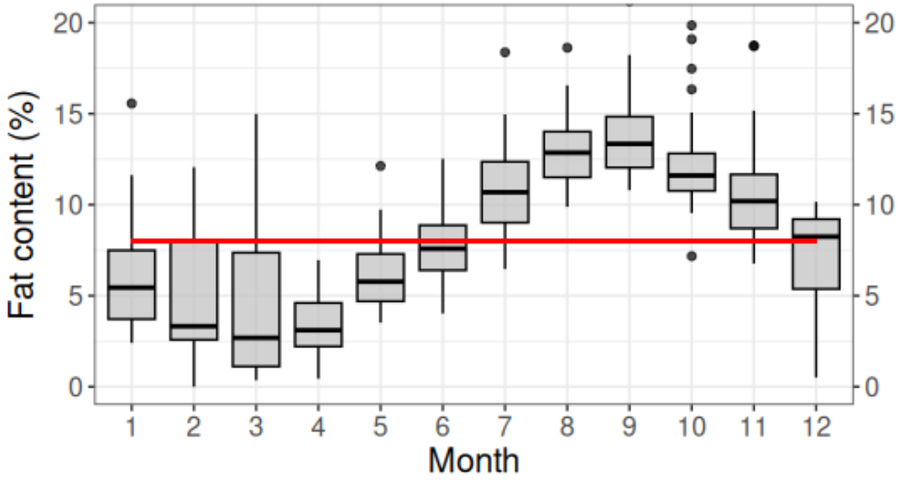


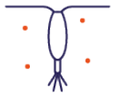
Drivers of the seasonal variability



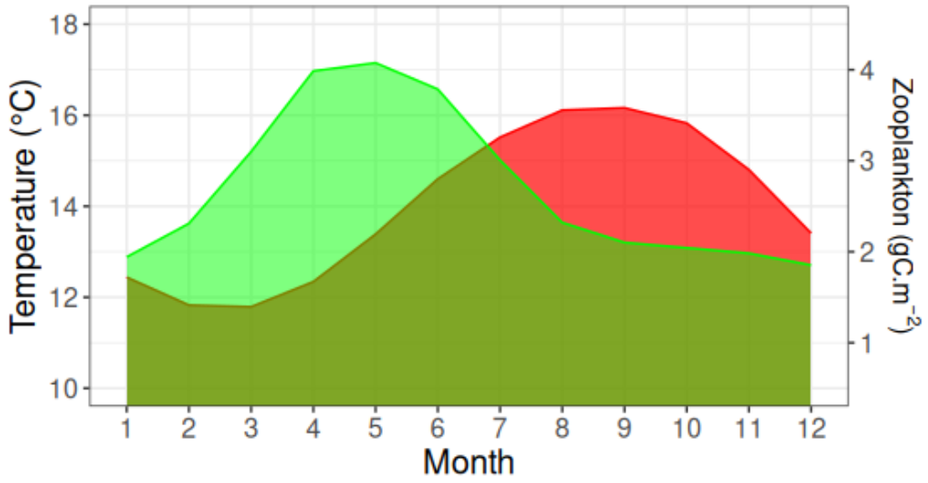


Fish Fat content



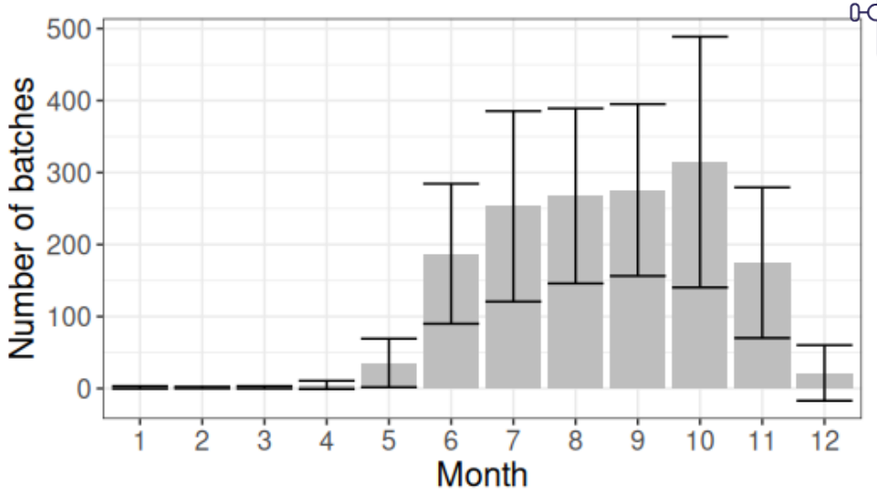


Habitat



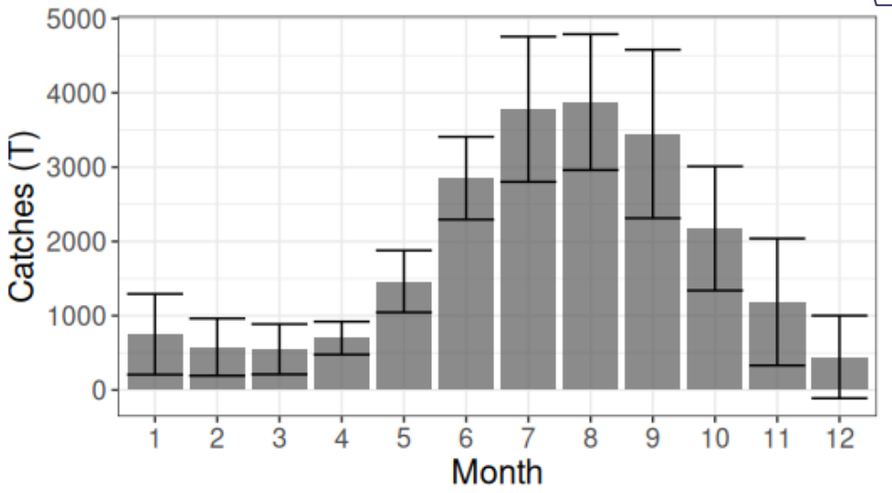
Can industry provisioning



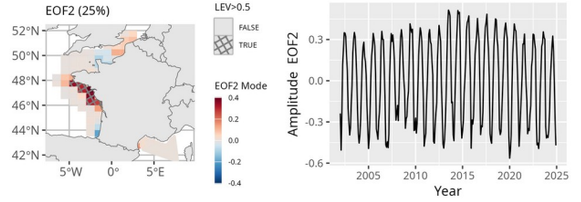


Catches



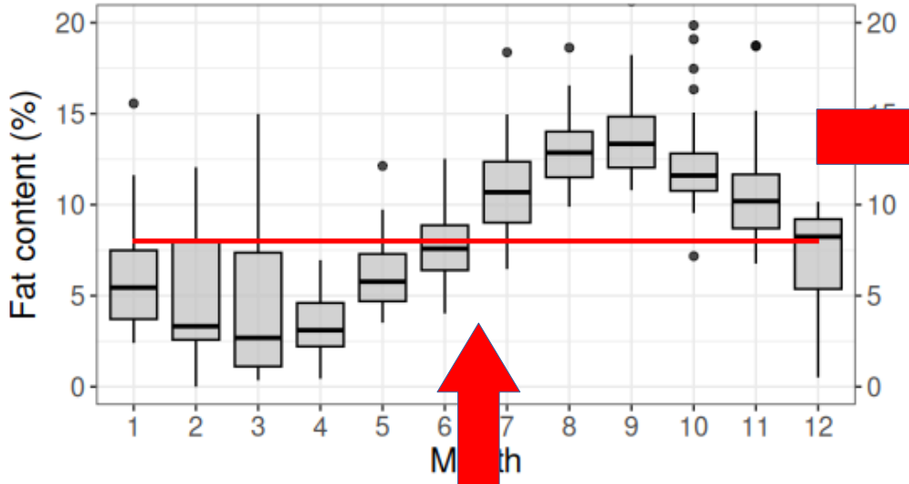


A strong bottom-up control



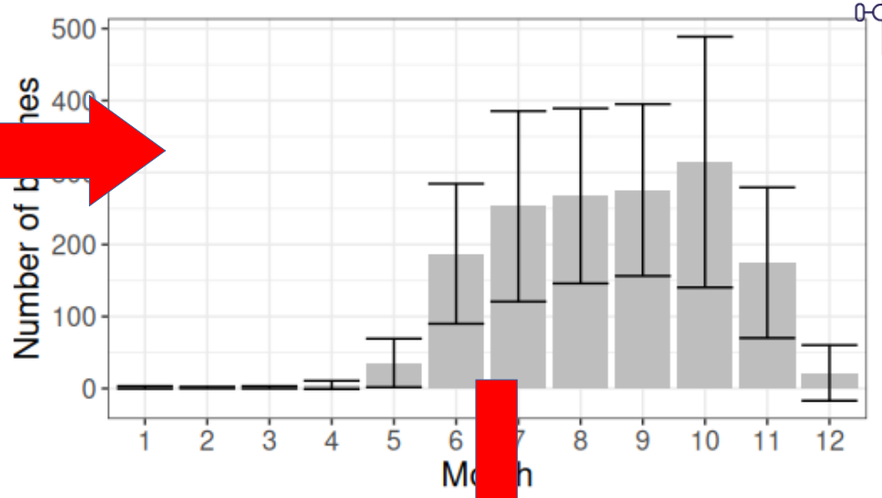


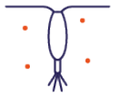
Fish Fat content



Can industry provisioning







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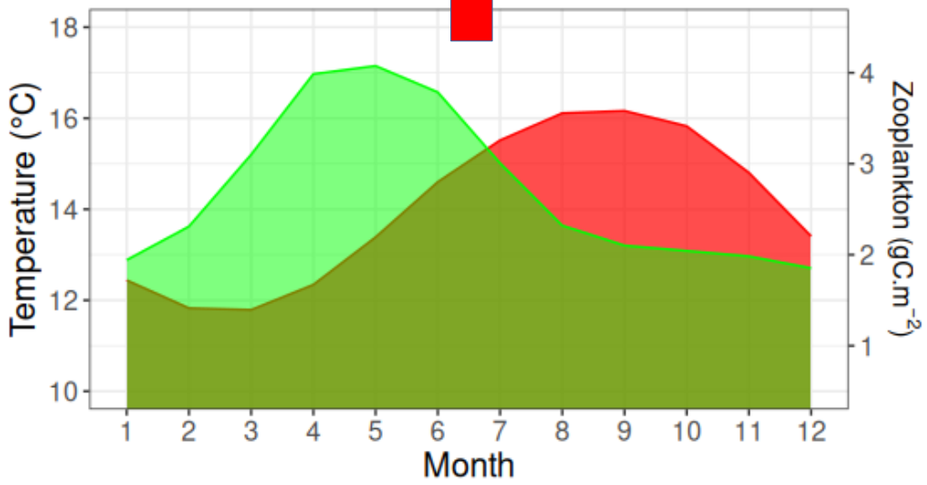

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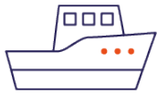
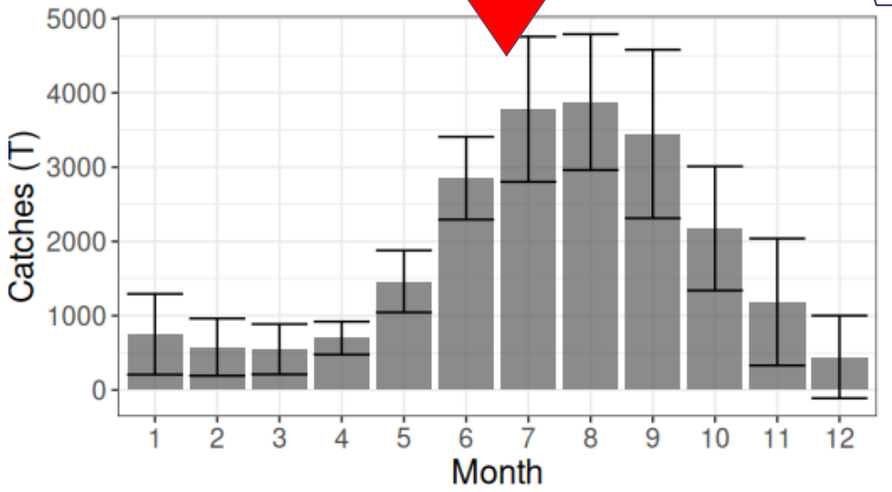
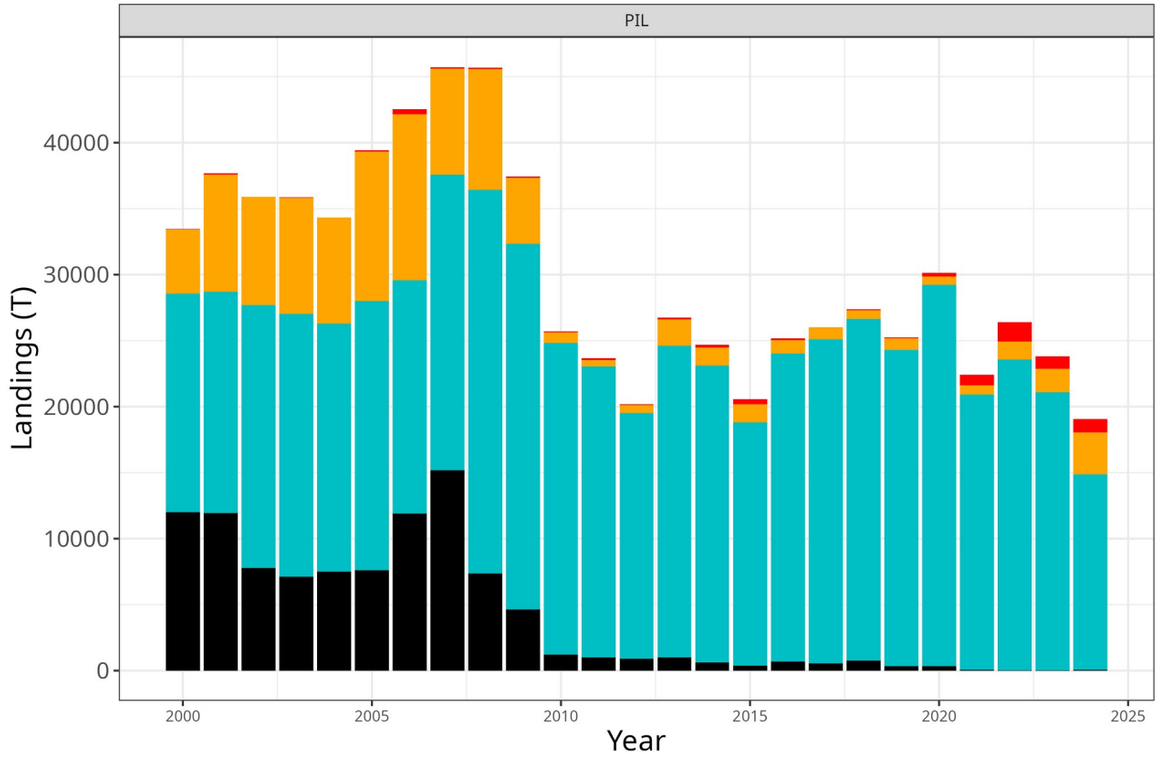
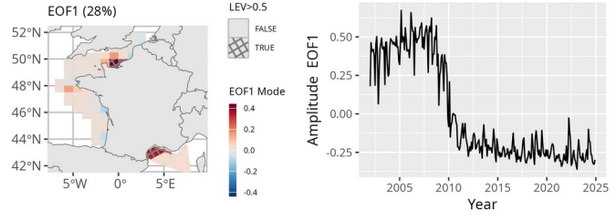


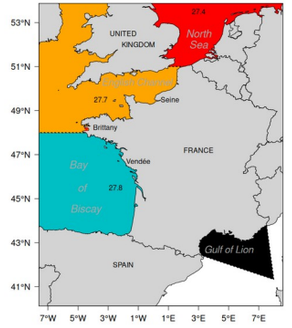


Drivers of the interannual variability



Southern North Sea
English Channel
Bay of Biscay
Gulf of Lions





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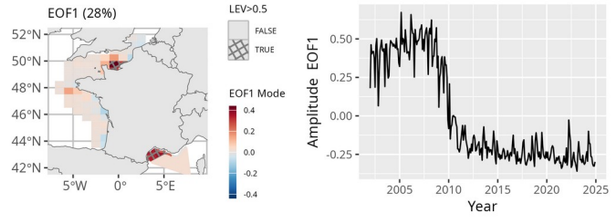

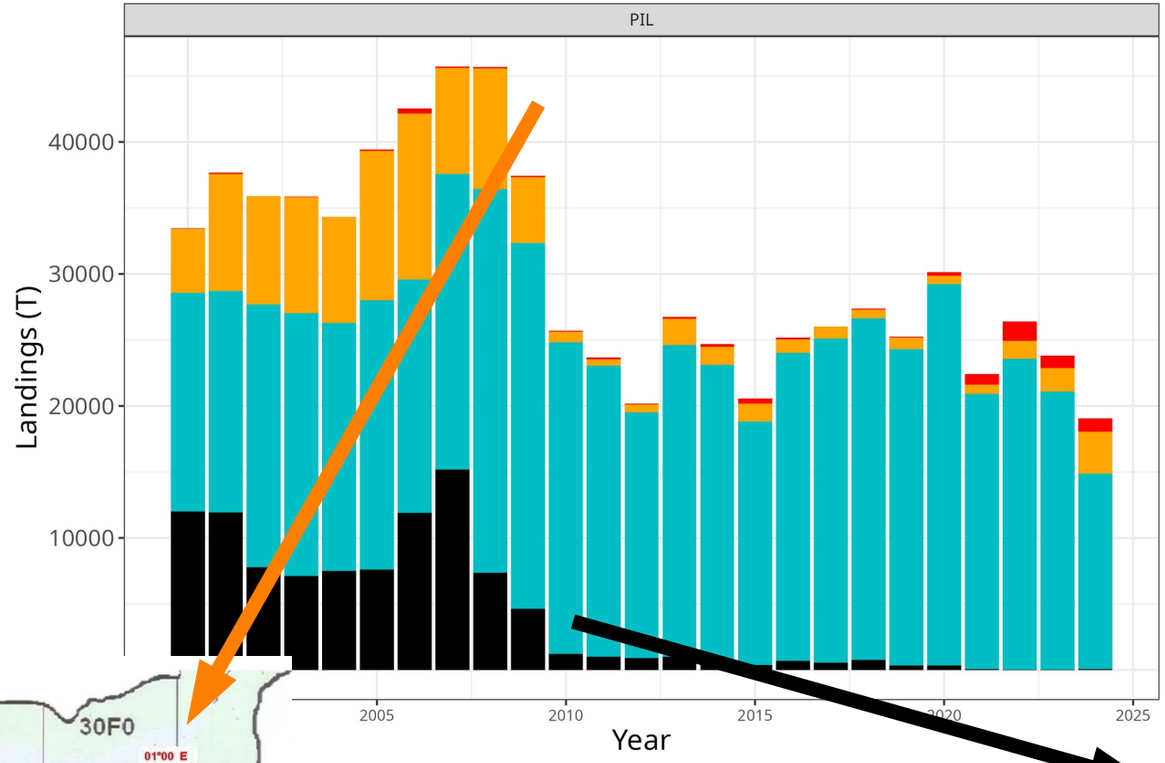

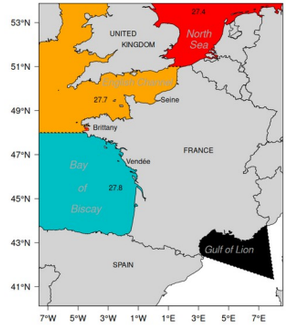

Southern North Sea
English Channel
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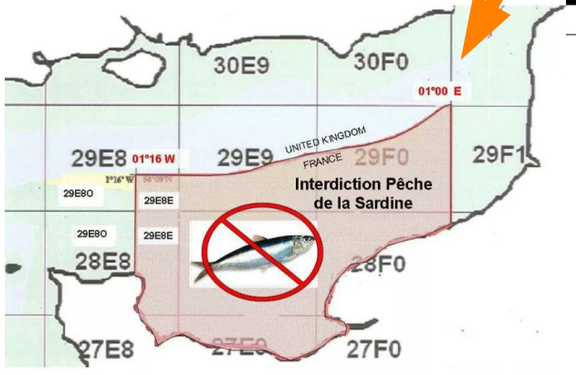

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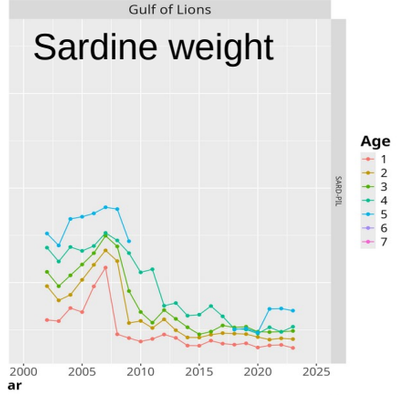
Deep-Sea Research Part II

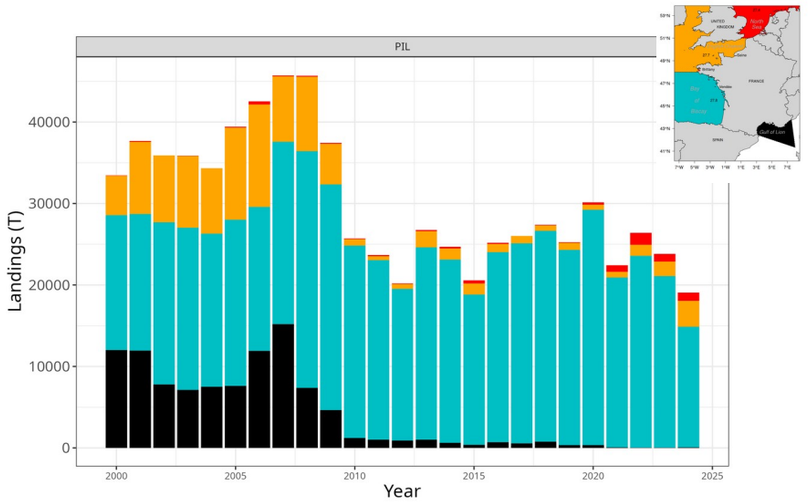
journal homepage: www.elsevier.com/locate/dsr2

Small pelagic fish dynamics: A review of mechanisms in the Gulf of Lions

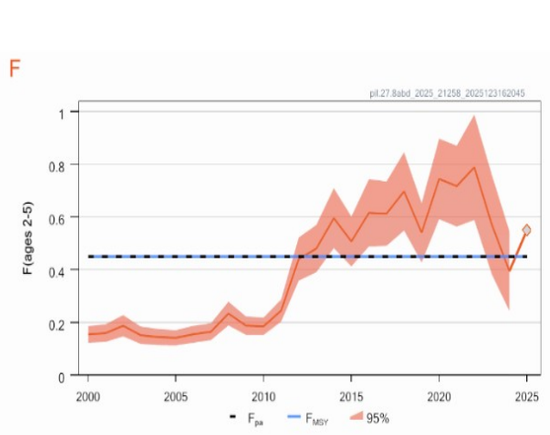
Claire Saraux[a,*], Elisabeth Van Beveren[a,b], Pablo Brosset[a,b], Quentin Queiros[a], Jean-Hervé Bourdeix[a], Gilbert Dutto[c], Eric Gasset[a], Cyrielle Jac[a], Sylvain Bonhommeau[a,d], Jean-Marc Fromentin[a]

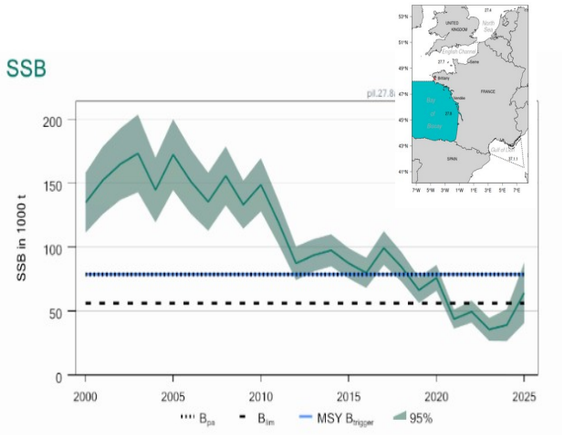


A fragilised social-ecological system



- Fishing/provisioning relying on Biscay only
- Biscay stock at maximum level of exploitation



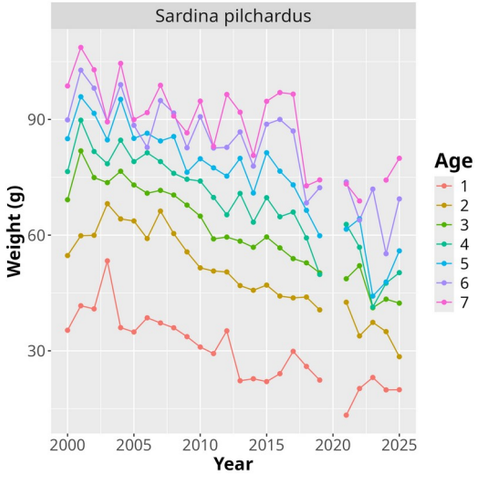


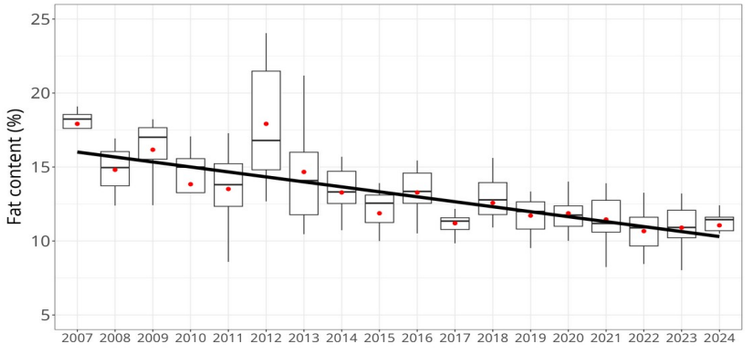
A fragilised social-ecological system



- Fishing/provisioning relying on Biscay only
- Biscay stock at maximum level of exploitation

- Quality (size, fat) is decreasing, most likely under bottom-up (climate) control





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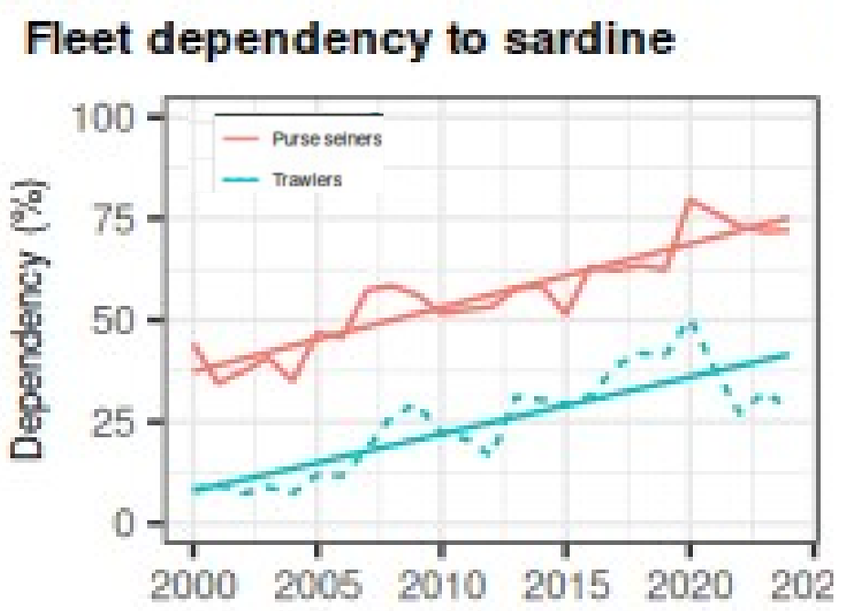
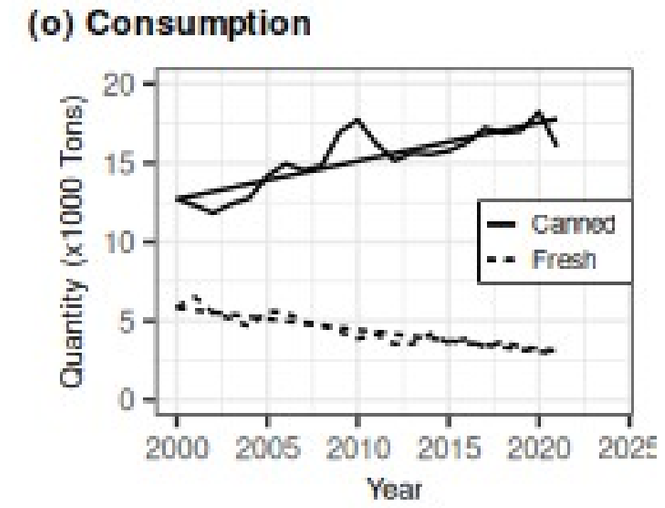


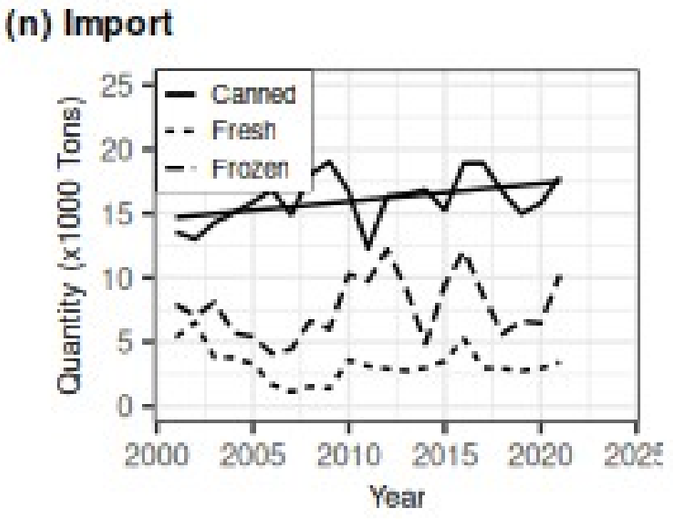
- Fishing/provisioning relying on Biscay only
- Biscay stock at maximum level of exploitation

- Quality (size, fat) is decreasing, most likely under bottom-up (climate) control

- Increased dependency to sardine, throughout the year
- Less and less alternative species

A fragilised social-ecological system





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- Increased dependency of fishers to the canning industry
- Increased dependency to import

Summary (1) - What impacts on the fishing industry ?

- **Fish quality** (more than quantity) has driven both the **seasonal and interannual variability** of the sardine french fishing industry over the last 25 years

- **Decrease in fish quality** (size, fat, pollutant) **has strongly weakened the fishing industry**



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Aquatic Living Resources

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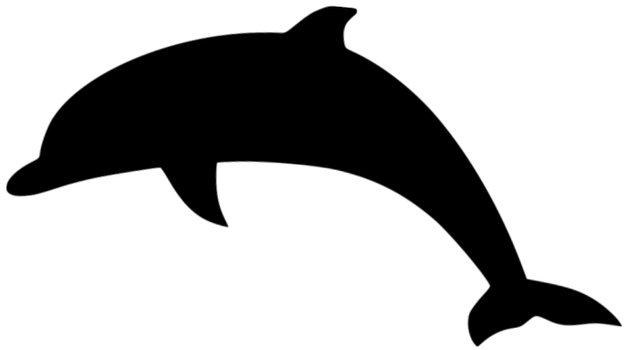
Special Issue - Small pelagic fish in changing social-ecological systems

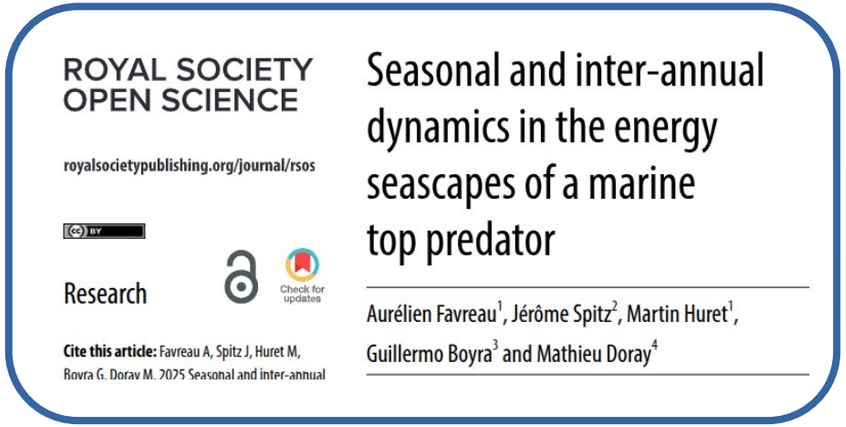
RESEARCH ARTICLE OPEN ACCESS

Fish quality jeopardises the French small pelagic social-ecological system

Martin Huret[1,*], Fabienne Daurès[2], Mathieu Doray[3], Tarek Hattab[4], Jean-Baptiste Romagnan[5], Morgane Travers-Trolet[5], Caroline Cailliau[6] and Sigrid Lehuta[5]

2. Impact of the decrease in SPF quality on a top predator : the common dolphin







Favreau et al., Submitted. MEPS
Long-term changes in small pelagic fish community reshape **the prey profitability and foraging seascape** for common dolphins.

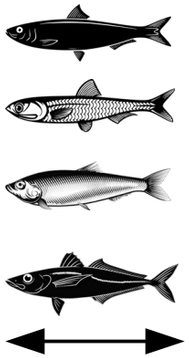
2.1. What evolution of the **energy seascape** from the SPF community ?

2.2 What change in the **foraging seascape** of common dolphin ?

Data description

Species

- Sardine (*Sardina pilchardus*)
- Anchovy (*Engraulis encrasicolus*)
- Sprat (*Sprattus sprattus*)
- Horse mackerel (*Trachurus trachurus*)



~ 70 - 80 % of dolphin's diet *Meynier et al, 2008*

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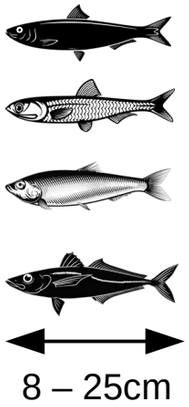
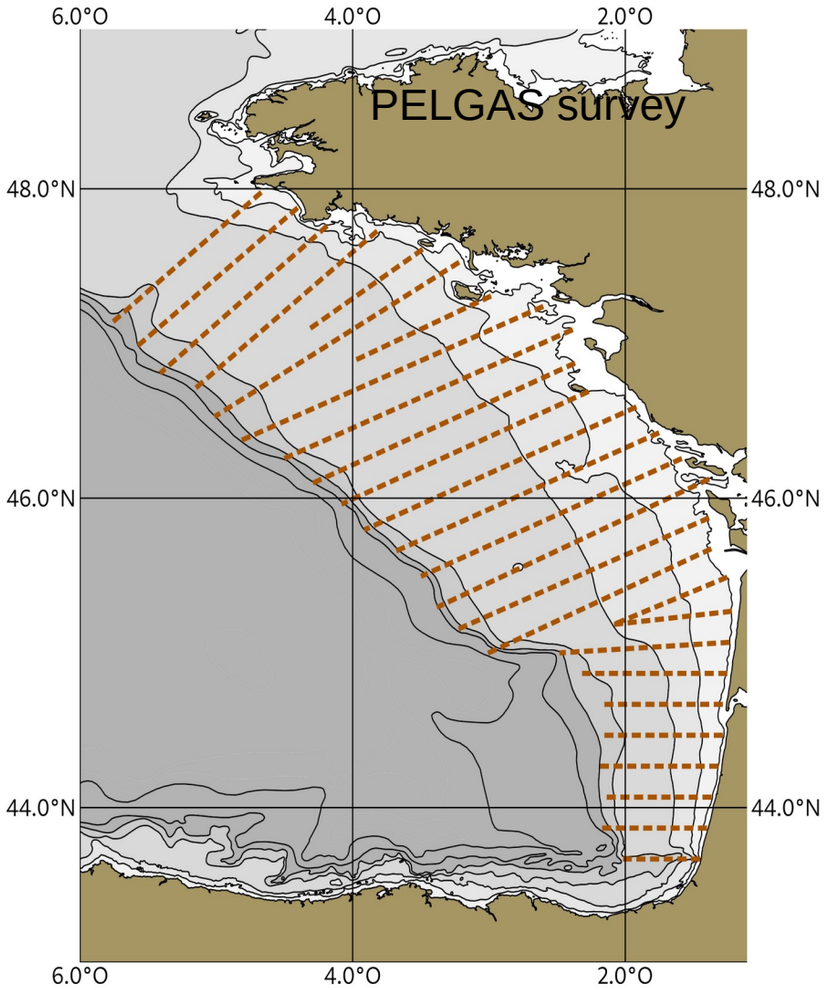


~ 70 - 80 % of dolphin's diet *Meynier et al, 2008*

- **Abondance**, **weight** and **length,** spatially explicit
  - PELGAS survey : spring 2000 – 2023
  - *JUVENA : Autumn 2009 – 2023*

- **Energy density** from calorimetry
  - Sardine : ~1000 individuals
  - Anchovy : ~500 ind.

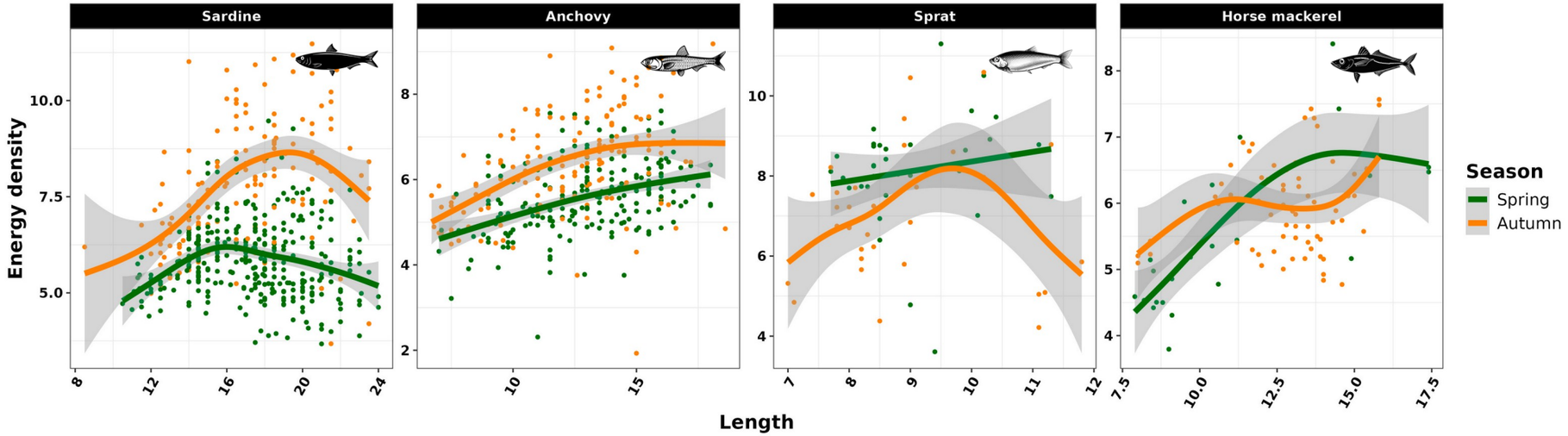


Doray et al, 2018

Methods : from biomass distribution to energy seascapes

Energy density





Methods : from biomass distribution to energy seascapes

Trawling → EDSU

Energy density	x	Mean individual weight





Methods : from biomass distribution to energy seascapes

Trawling → EDSU

Energy density x Mean individual weight





Individual energy



Methods : from biomass distribution to energy seascapes

Trawling → EDSU

Energy density x Mean individual weight

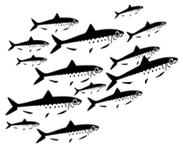


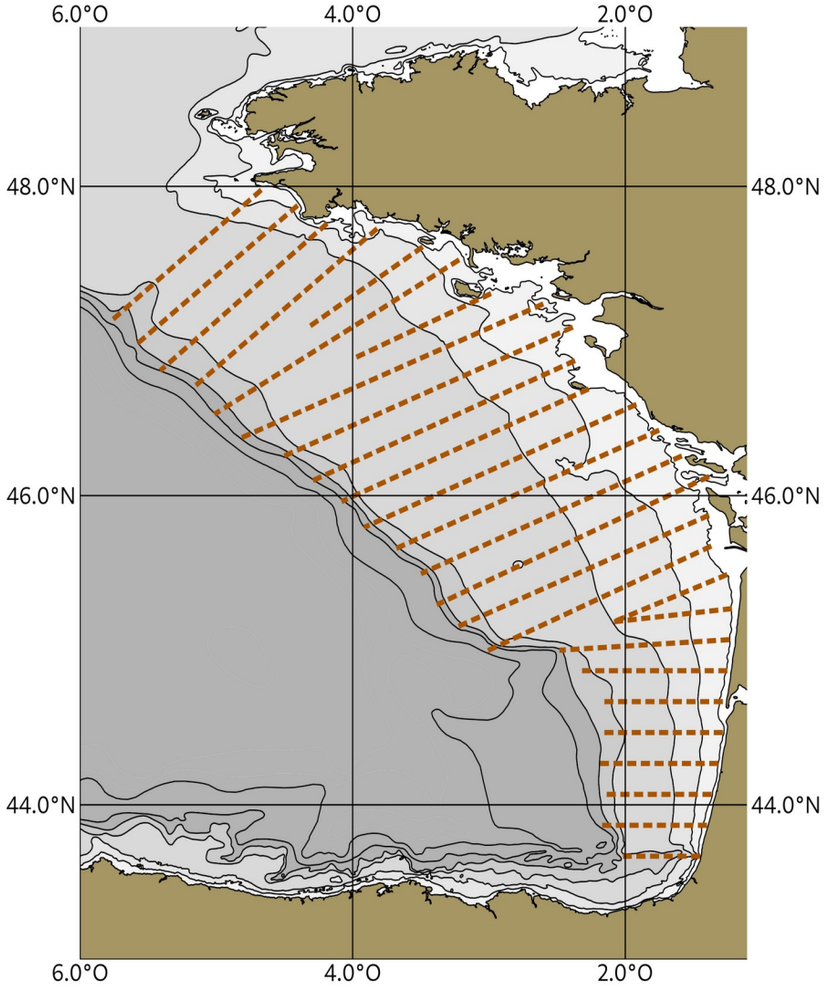


Acoustics by EDSU

Individual energy x Abundance







Doray et al., 2018, 2021

Methods : from biomass distribution to energy seascapes

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Energy density x Mean individual weight

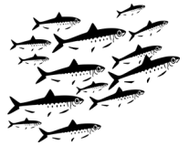




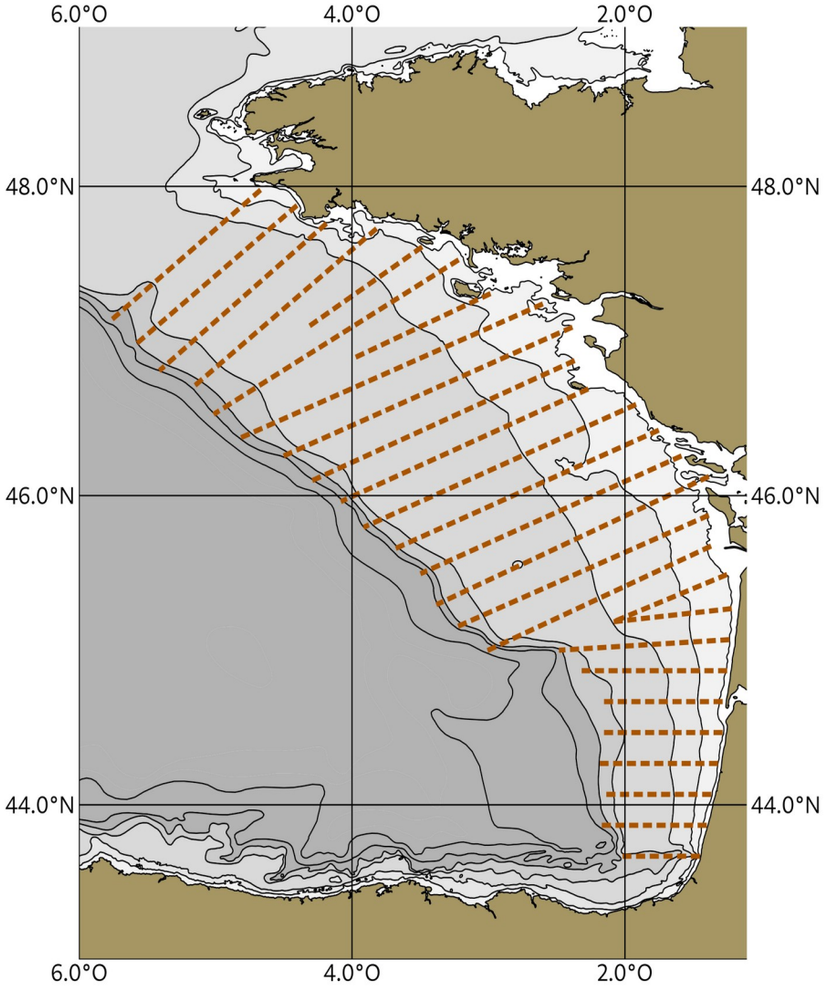
Acoustics by EDSU

Individual energy x Abundance





Spatialised total energy



Methods : from biomass distribution to energy seascapes

Trawling → EDSU

Energy density x Mean individual weight

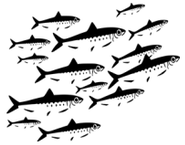




Acoustics by EDSU

Individual energy x Abundance





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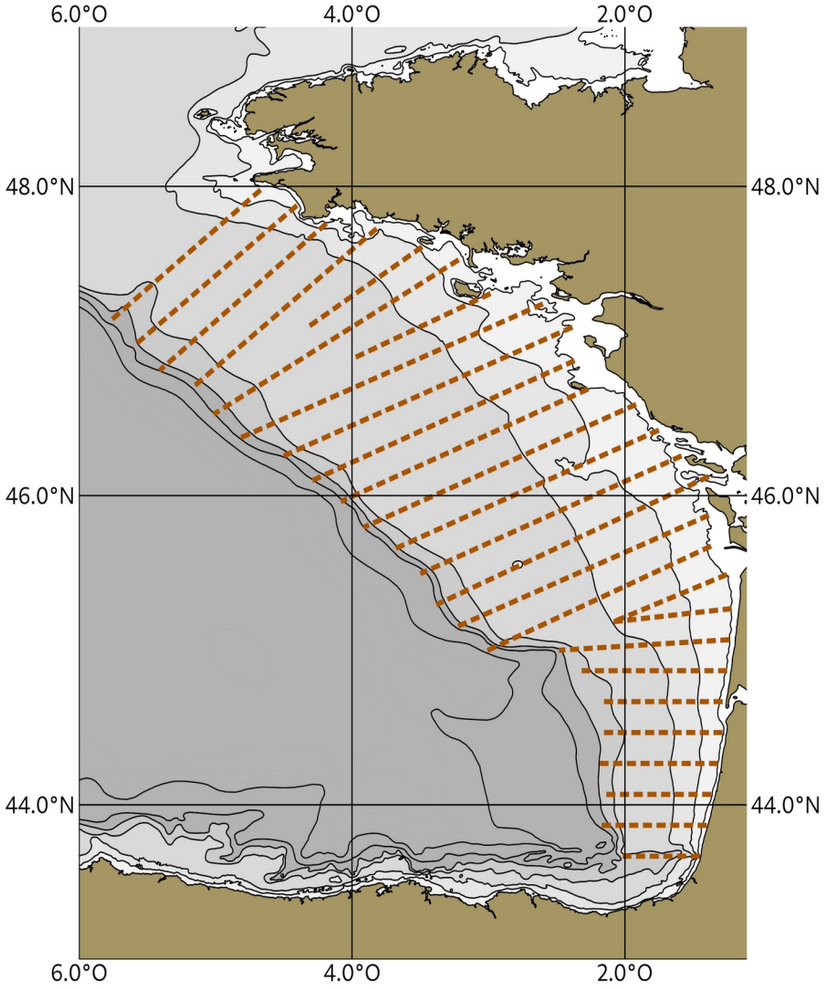
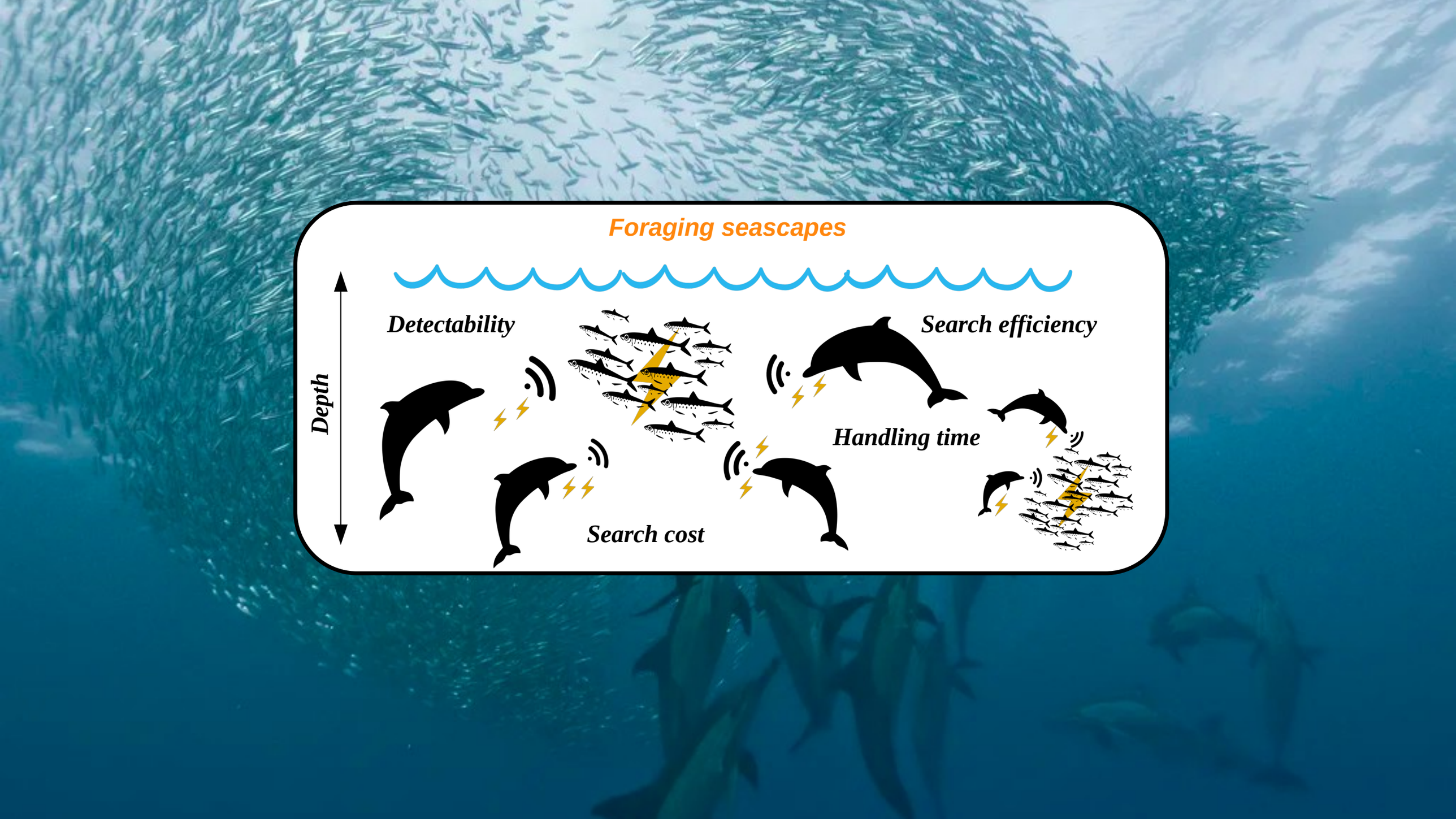


➔ **Individual, population and community scale indicators**


Foraging seascapes
Depth
Detectability
Search efficiency
Handling time
Search cost

Methods : The foraging seascapes

Definition of **profitability** (Optimal Foraging Theory) :

$$Profitability\left(kJ\,.\,s^{-1}\right)=\frac{Encounter\ rate*Prey\ energy}{1+Handling\ time*Encounter\ rate}-Search\ cost$$

Dolphin traits
Prey traits

$$Encounter\ rate=Search\ efficiency*Detectability*Prey\ density$$

Adapted from *Stephens & Krebs (1986)*

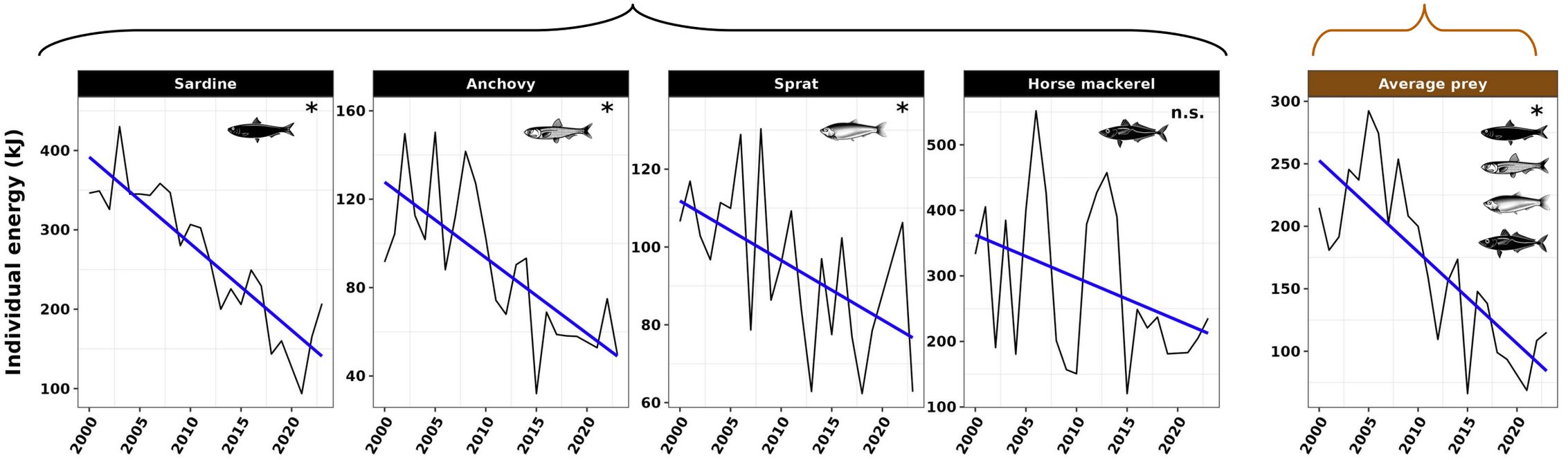
➔ *How has the profitability change over time and space ?*

Energy seascape : decrease of individual energy



Mean individual in the populations

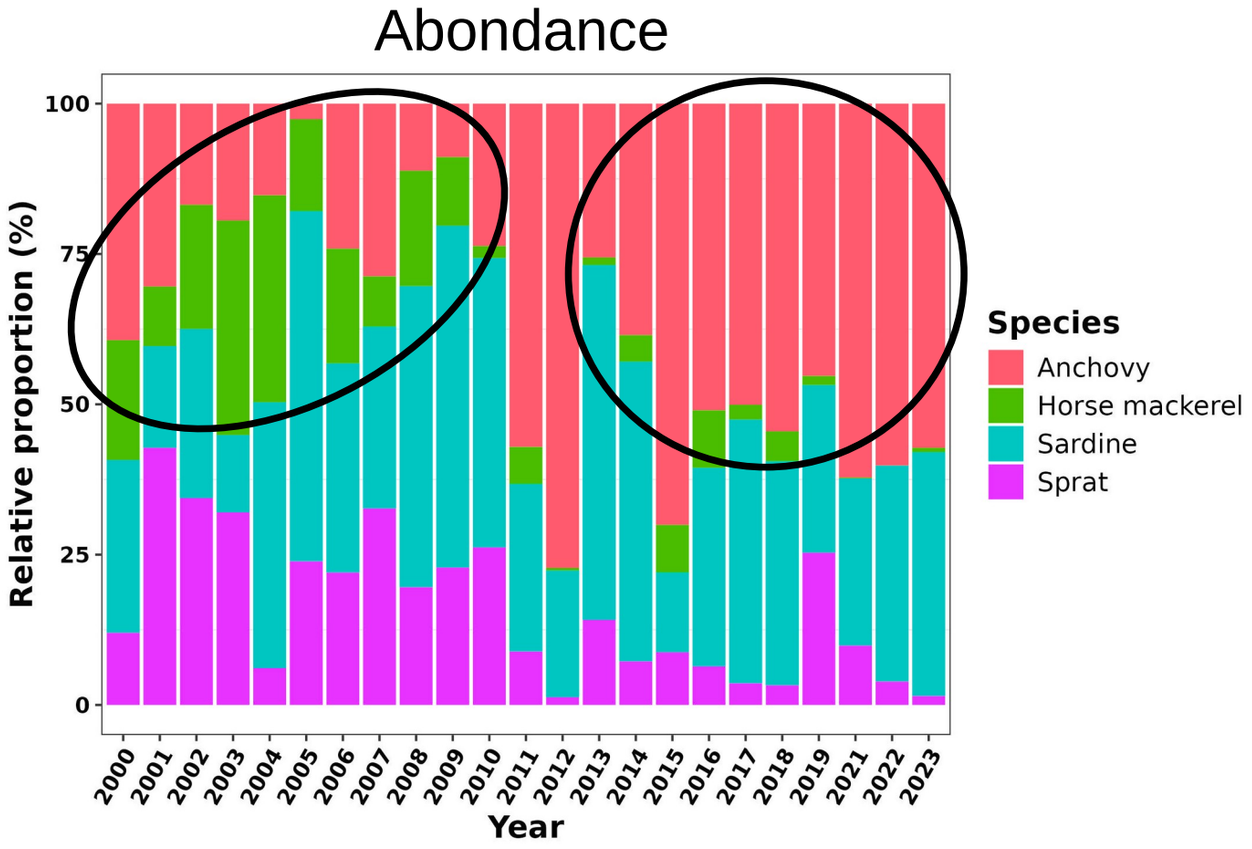
In the community



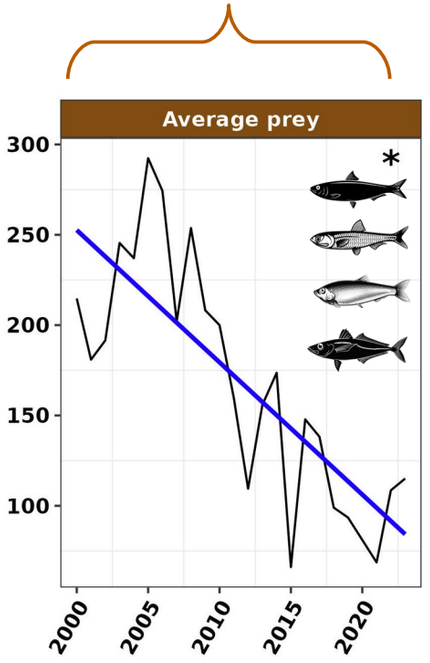
Mean individual among the SPF community

- Individual energy divided by 2.5
- Double effect : decrease in size/energy by species and increase of less energetic species

Energy seascape : decrease of individual energy



In the community



Mean individual among the SPF community

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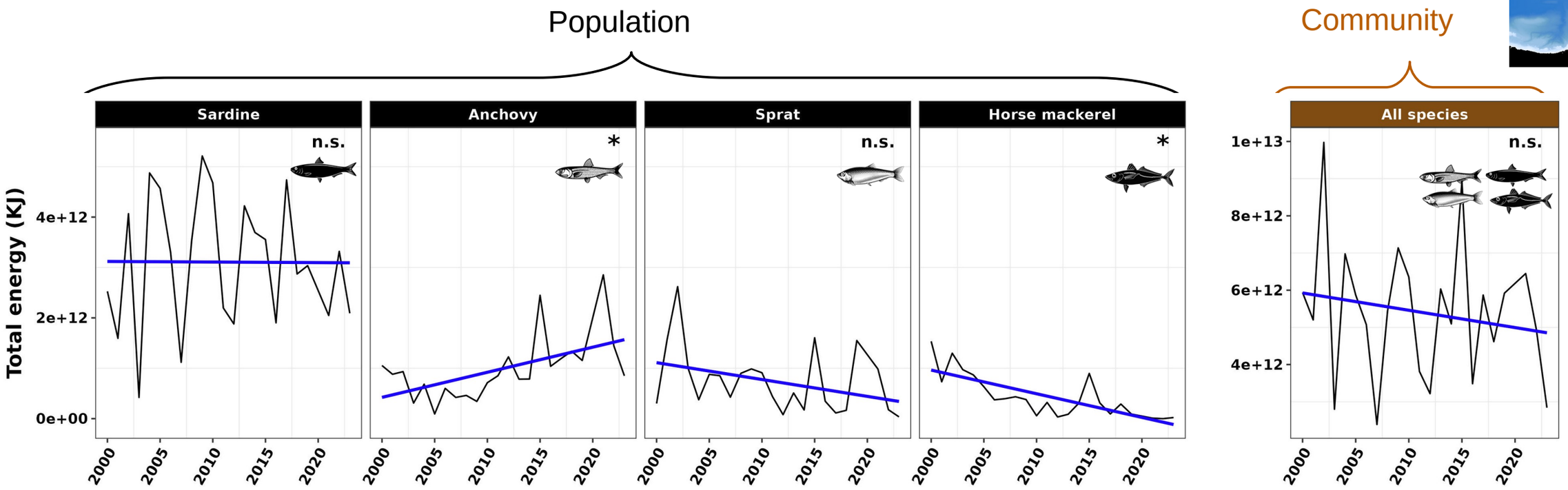
Energy seascape : ~stable total energy





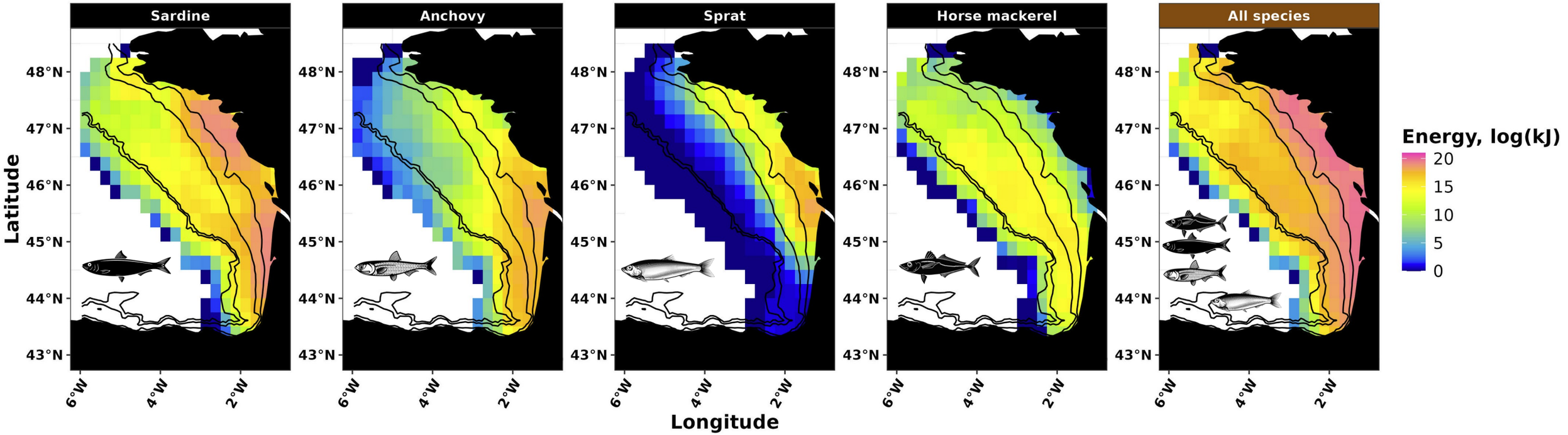
At population scale

- Different trends among species

At community scale

- Stability of the total energy available for dolphins

Energy seascape : average



At population scale

- Different distribution among species

At community scale

- Mostly coastal but a secondary energy peak along the continental slope

Energy seascape : space-time variability

Population scale

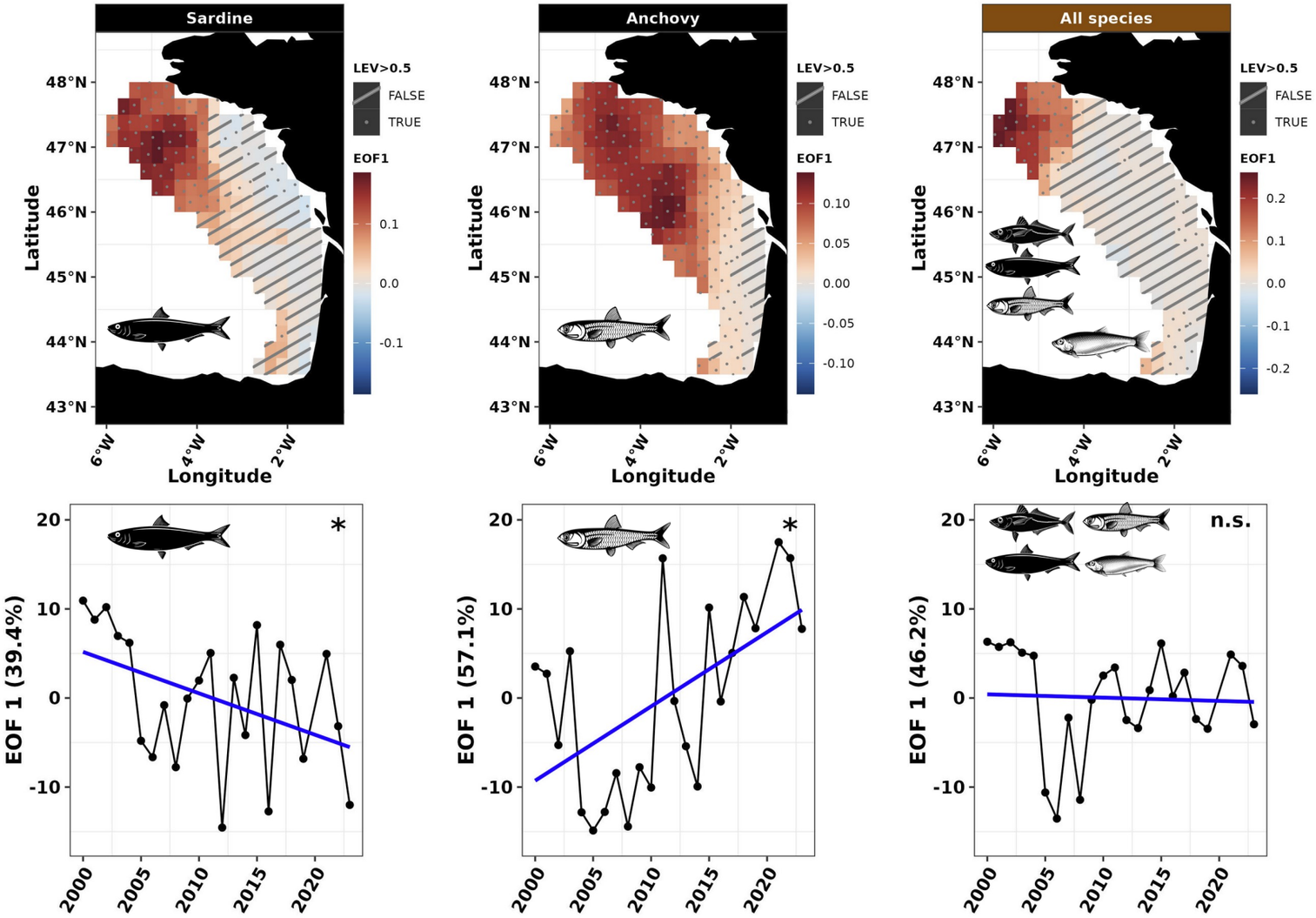
- Decrease of energy from sardine in the northwest
- Increase of energy from anchovy in the northwest

Community scale

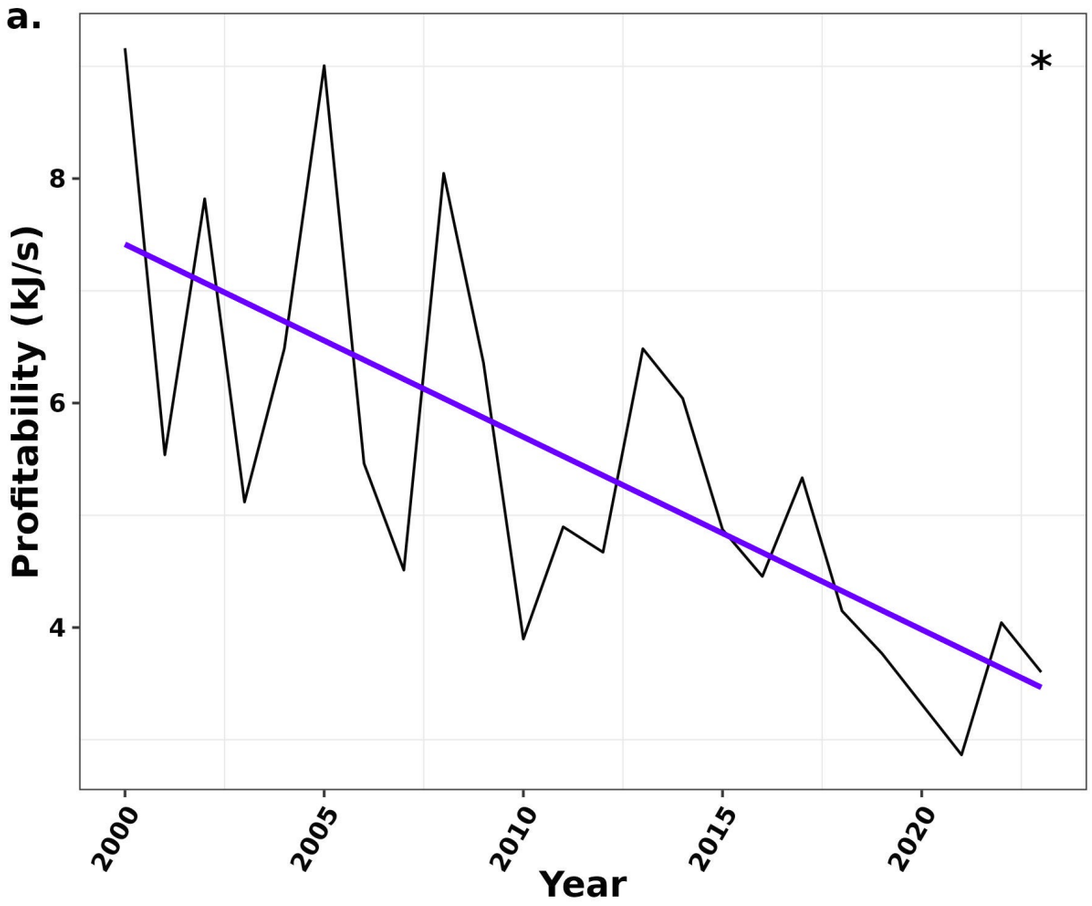
- No big change nor trend from 2000 to 2023

→ Compensation between sardine and anchovy

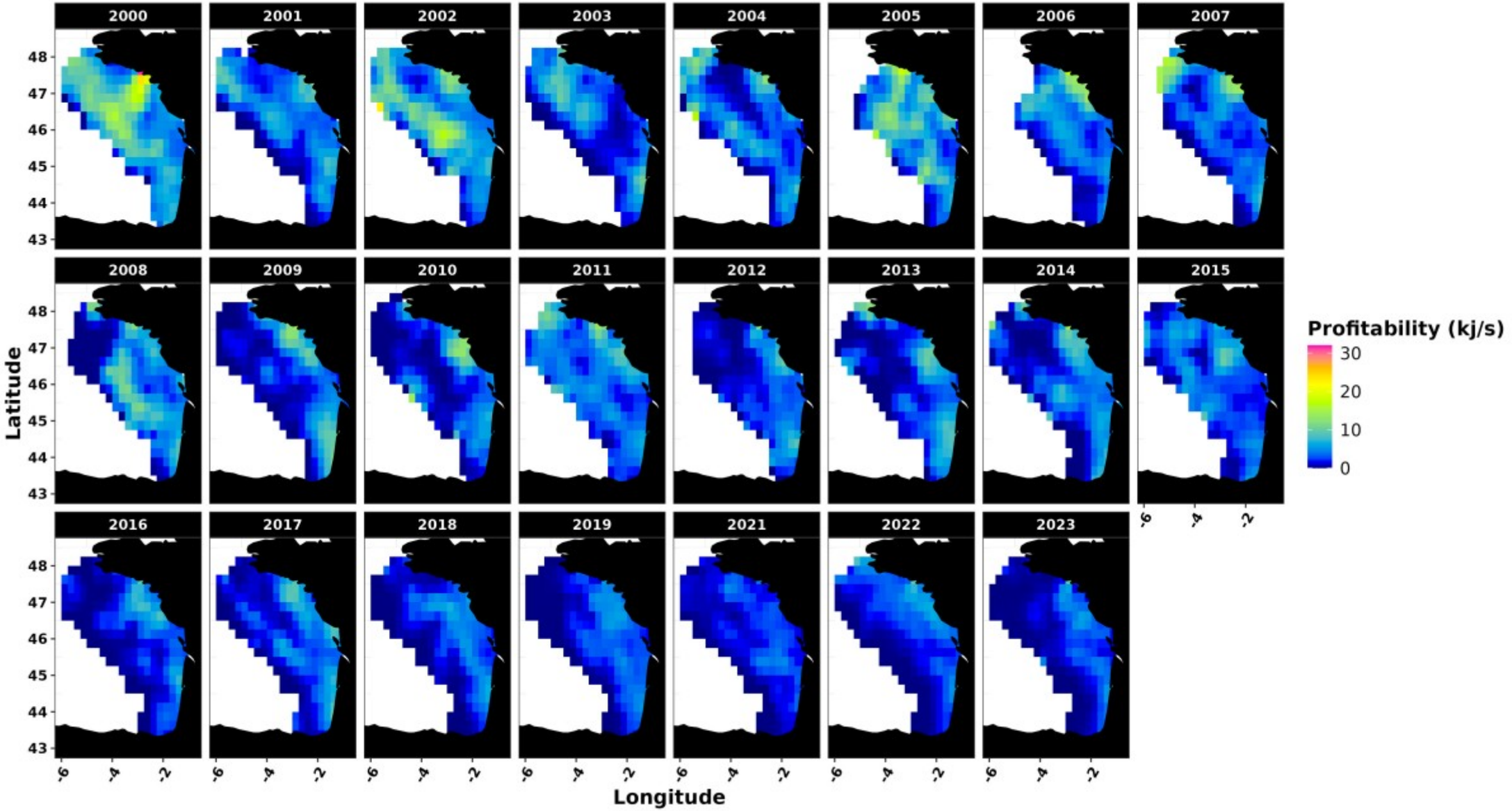
Empirical Orthogonal Functions (EOF)



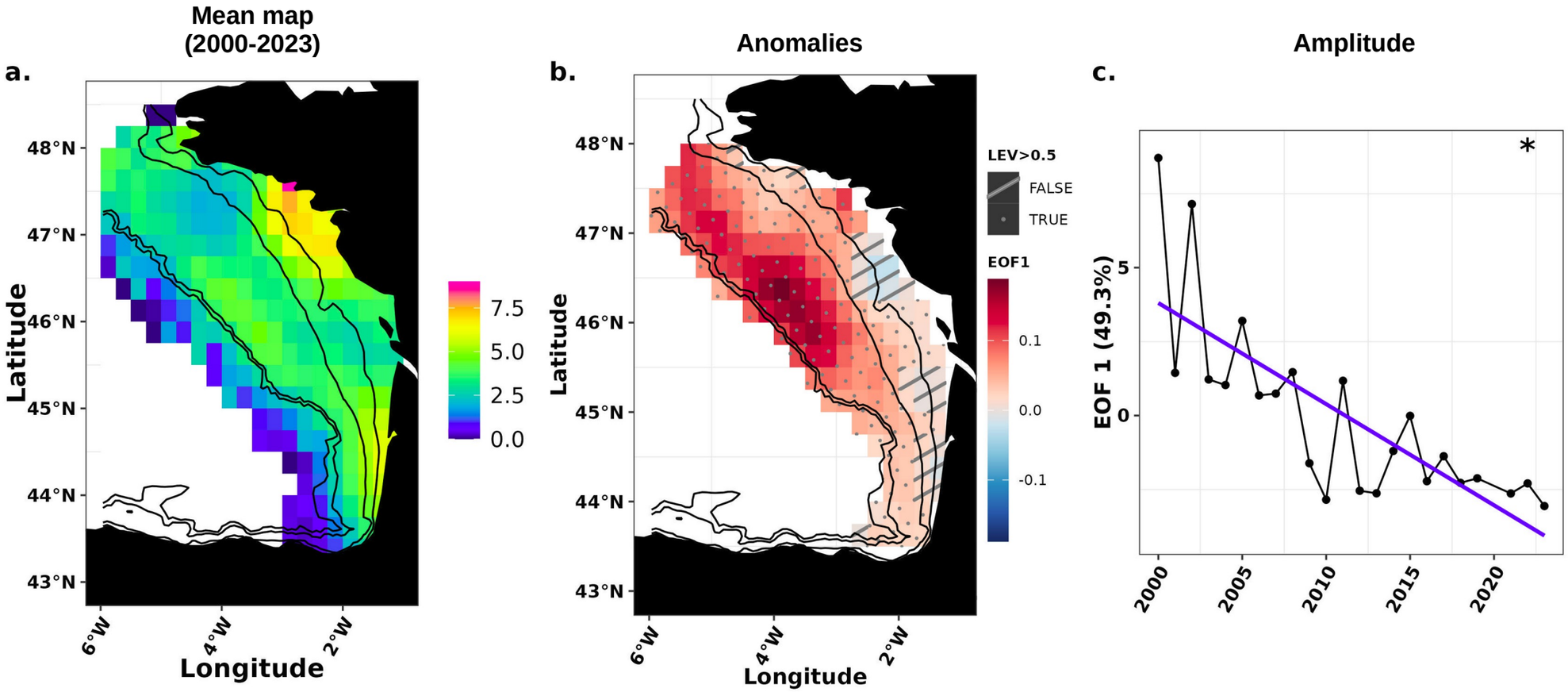
Foraging seascape : evolution of the profitability



Foraging seascape : space-time variability in profitability



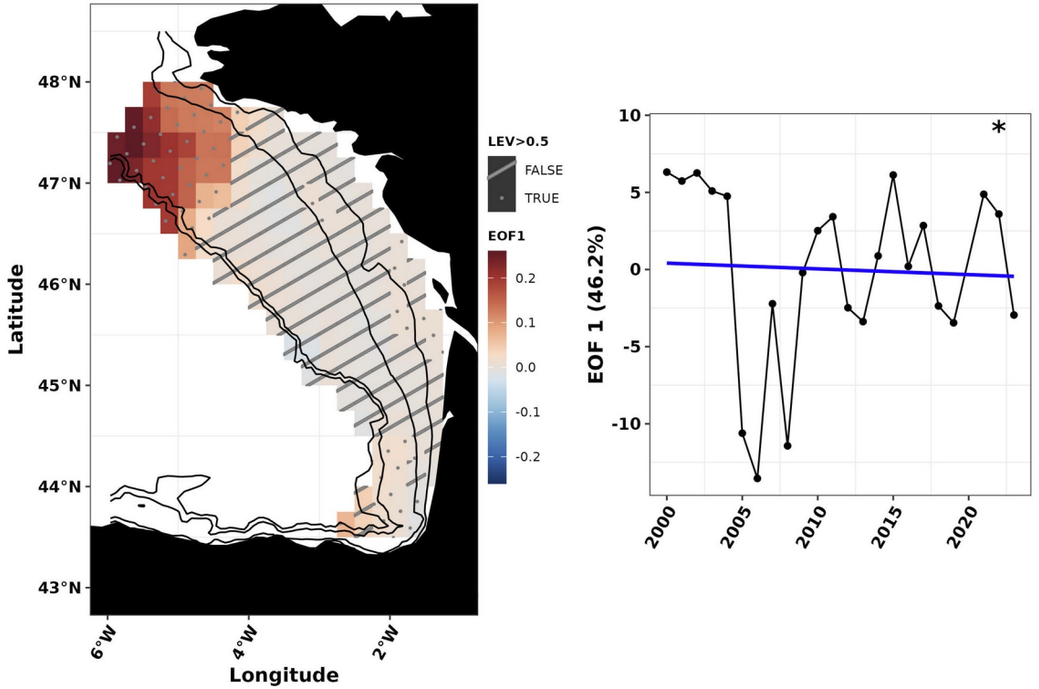
Foraging seascape : space-time variability in profitability



- Large decrease in offshore profitability
- Small anchovies have replaced large sardines but are less profitable

Summary (2) - What impacts on common dolphin ?

Total energy from SPF



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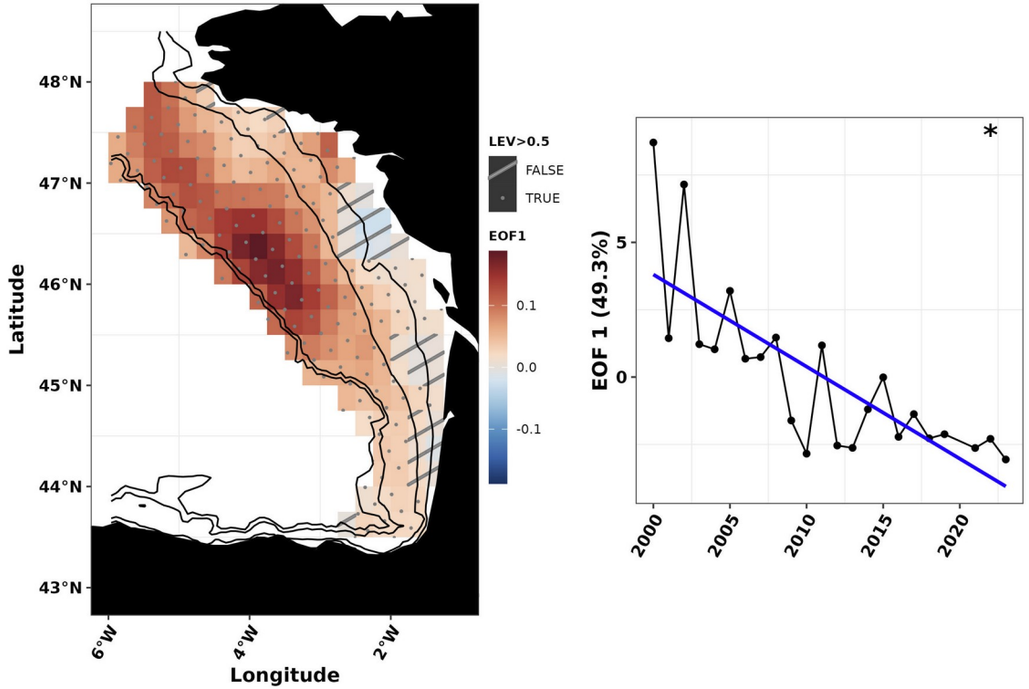
Profitability for dolphin



- **No trend in total energy available** → compensation between species
- **Decrease in profitability** (+ increase in nb of prey to ingest) → decrease in size and energy content, and shift to species of smaller sizes within the SPF community

- A potential explanation for the **increase in dolphin bycatches** : more presence along the coast where fishing activity is highest

General conclusion

- Decrease in SPF quality (size, energy content, community composition)
  - More fish to ingest daily to sustain energetic needs for top predators
  - More fish in a can → increased processing cost
  - ➔ Decrease in the profitability of SPF prey field for the predators and also for the market

- Issues on food security and equity in access to essential nutrients among predators (human included), and among human communities

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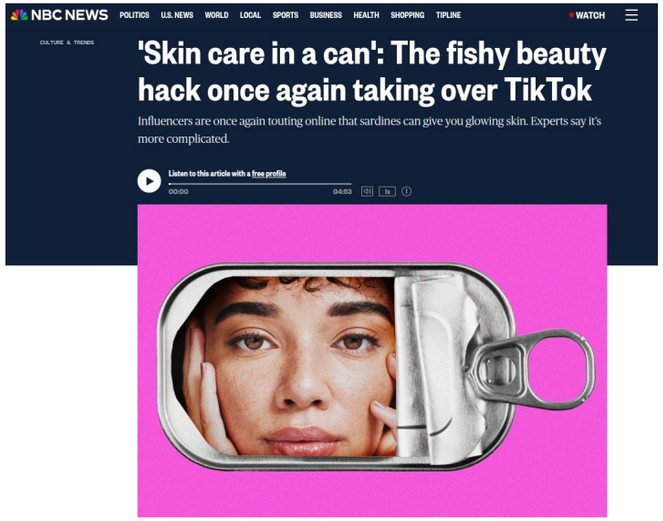
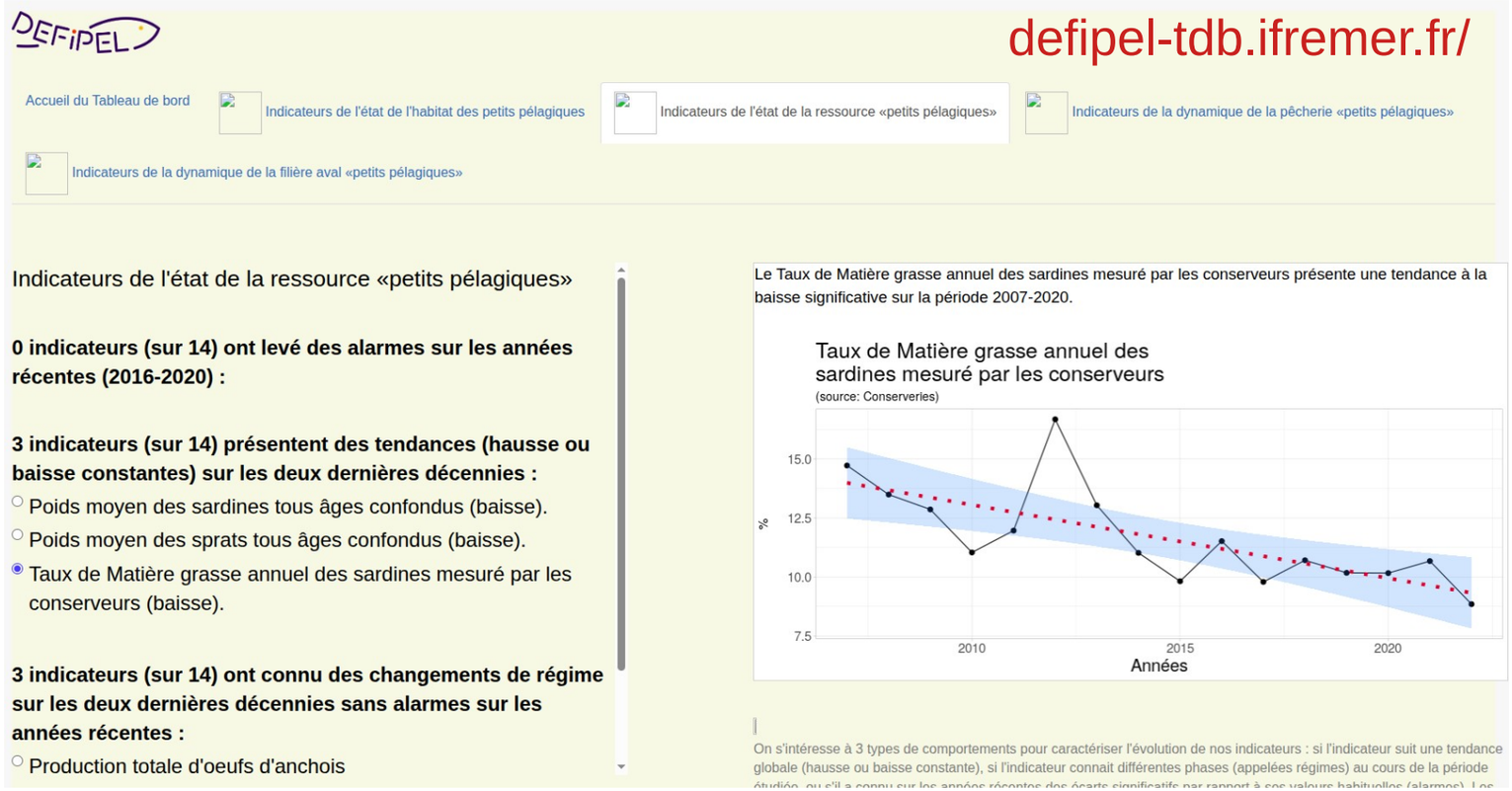
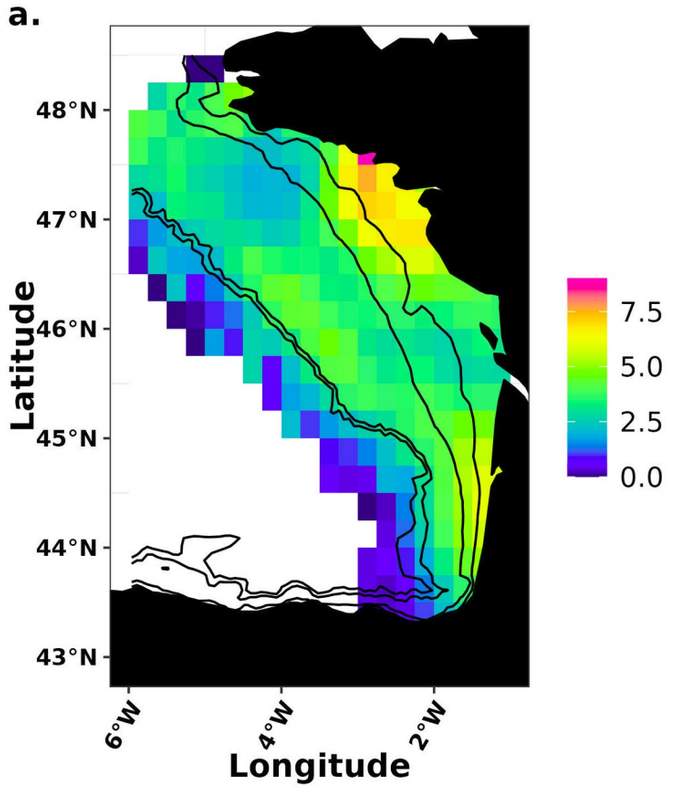


Towards actionable science



Profitability ($kj.s^{-1}$)



Dashboard to share information and consensus with stakeholders

Travers-Trolet et al., 2026

RESiPEL
Résilience de la filière petits pélagiques

Risk mapping for dolphin bycatches



Thank you for your attention



Aquatic Living Resources

Special Issue - Small pelagic fish in changing social-ecological systems

