Cod in the Celtic Sea ecosystem: Environmental niche and a few insights from food-web modeling

Pierre-Yves Hernvann – June 12th 2024 – NWWAC Webinar

Research conducted during PhD studies (2016-2019)

Funds

Diploma deliverance

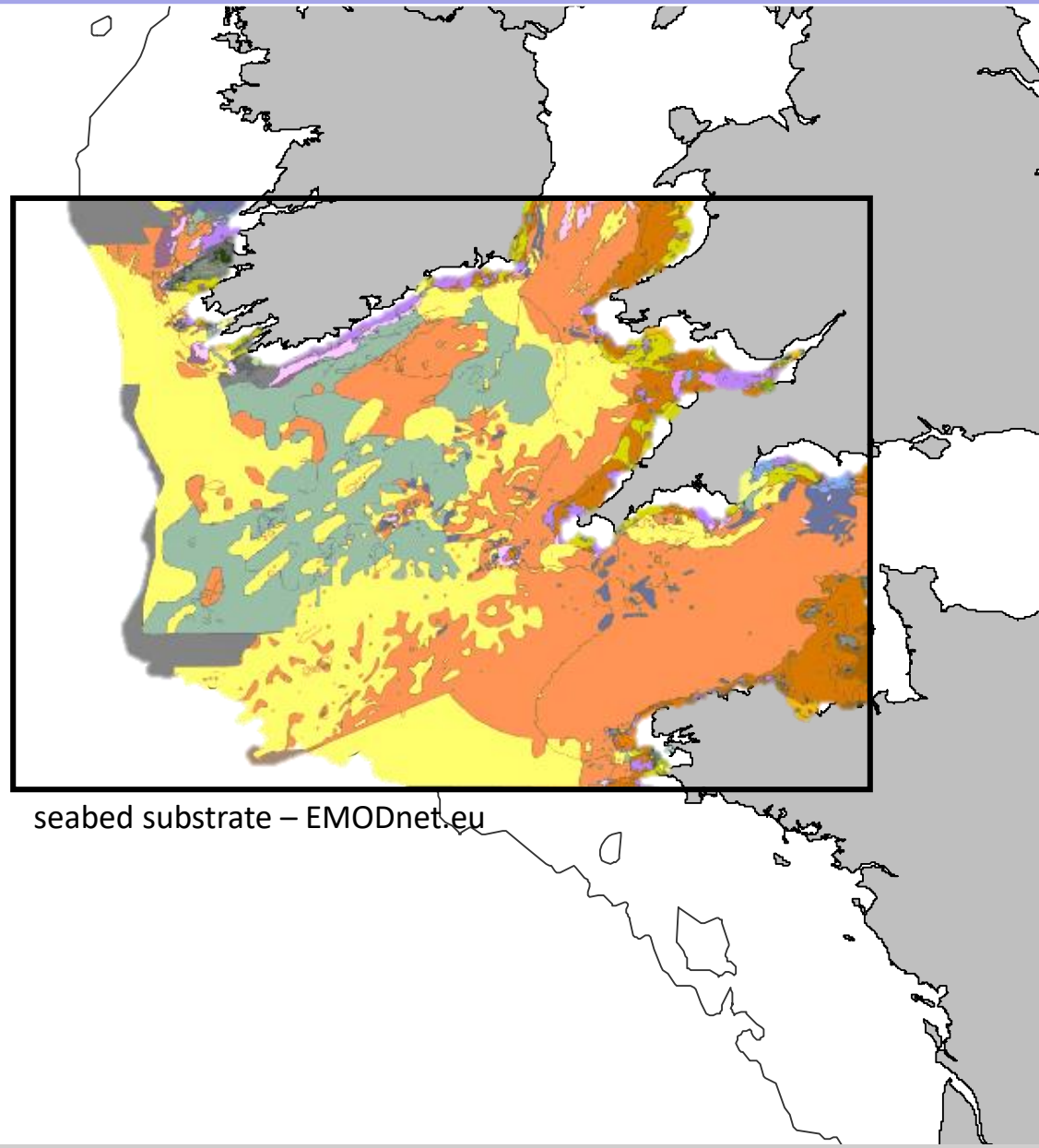
PhD Supervision

D. Gascuel M. Robert, D. Kopp

Collaborations

THE CELTIC SEA CASE STUDY

- European shelf ecosystem
- Great variety of habitat



seabed substrate – EMODnet.eu

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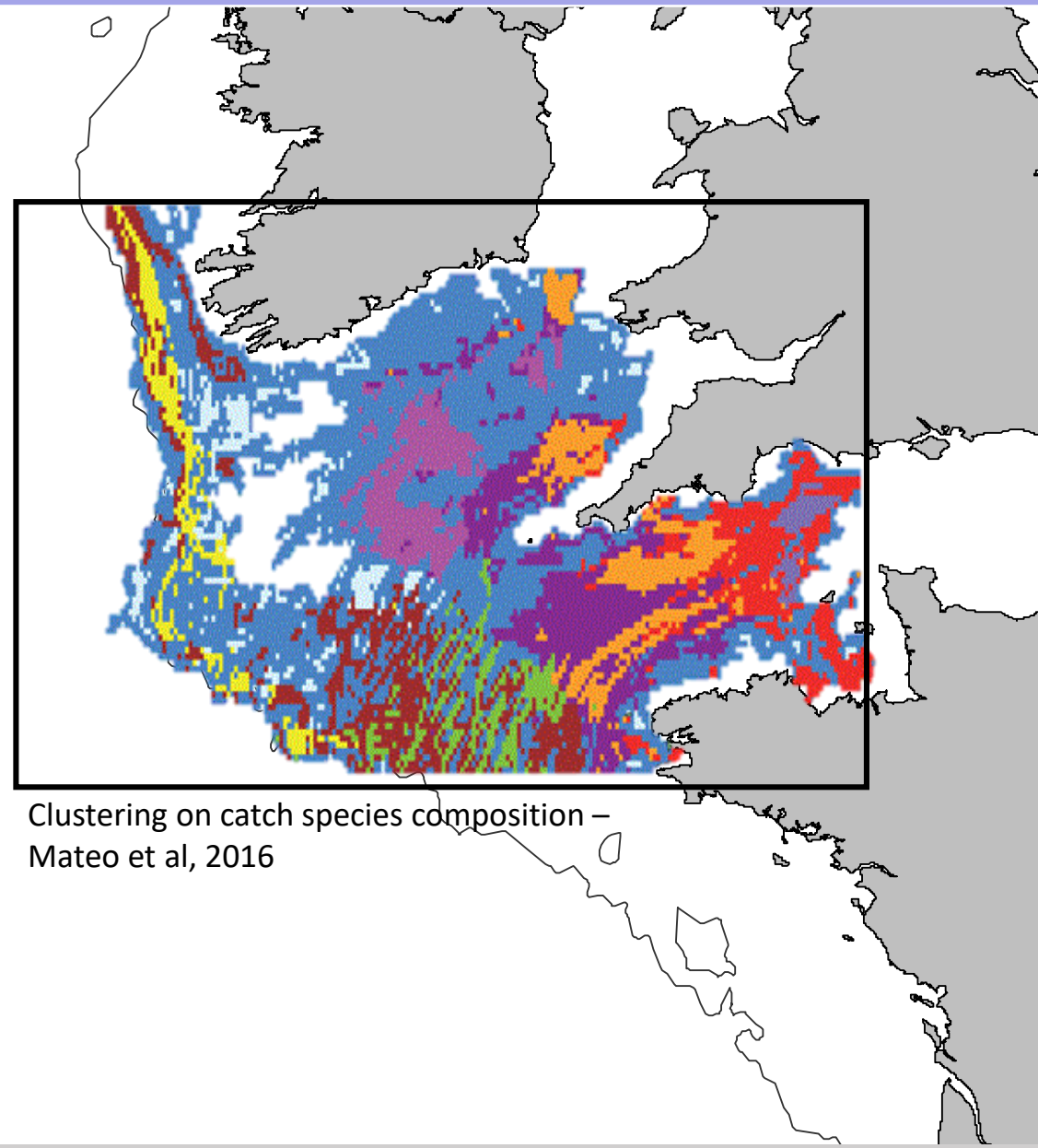
- Great variety of habitat
- Great diversity of species



Clustering on catch species composition – Mateo et al, 2016

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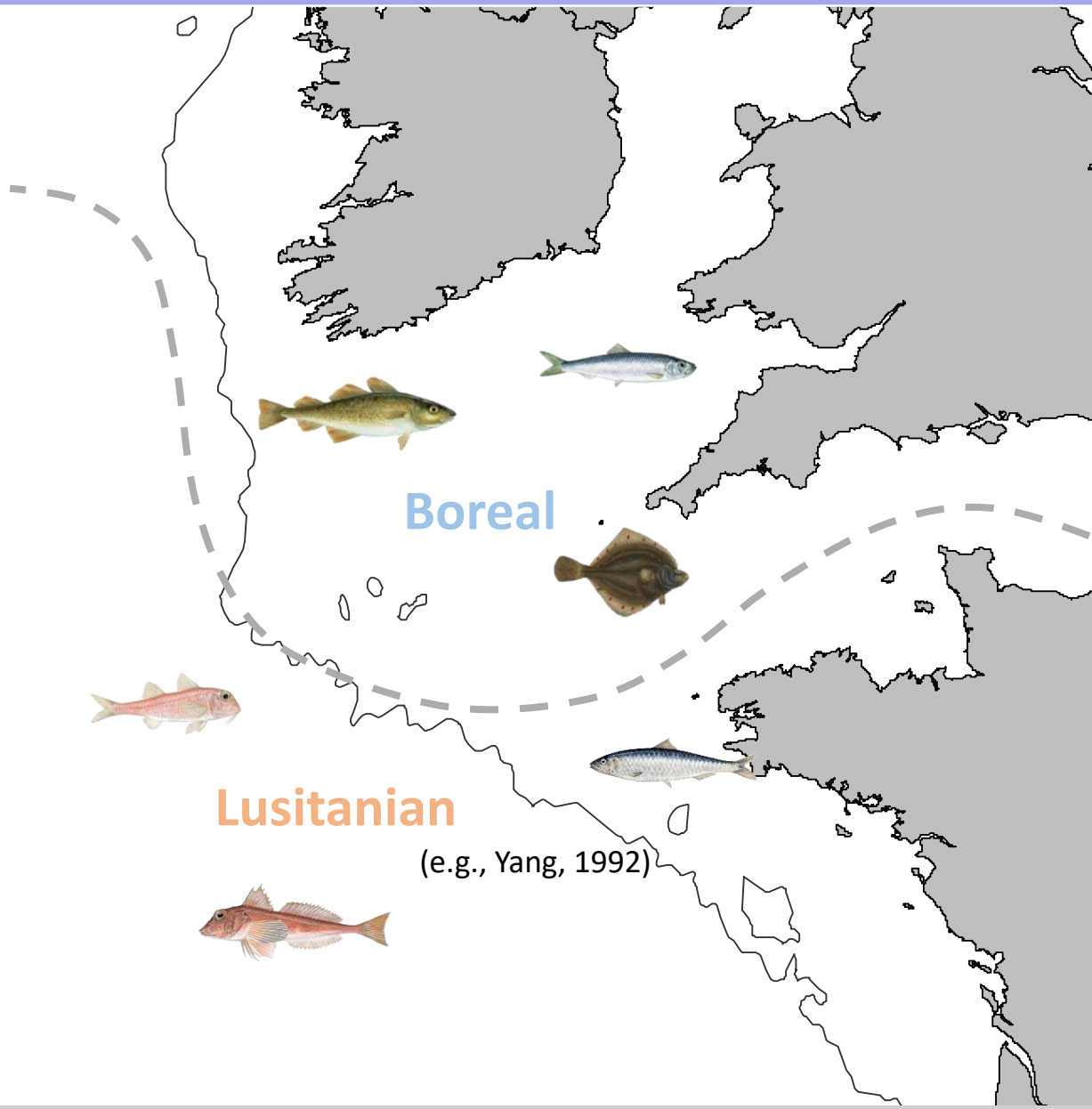
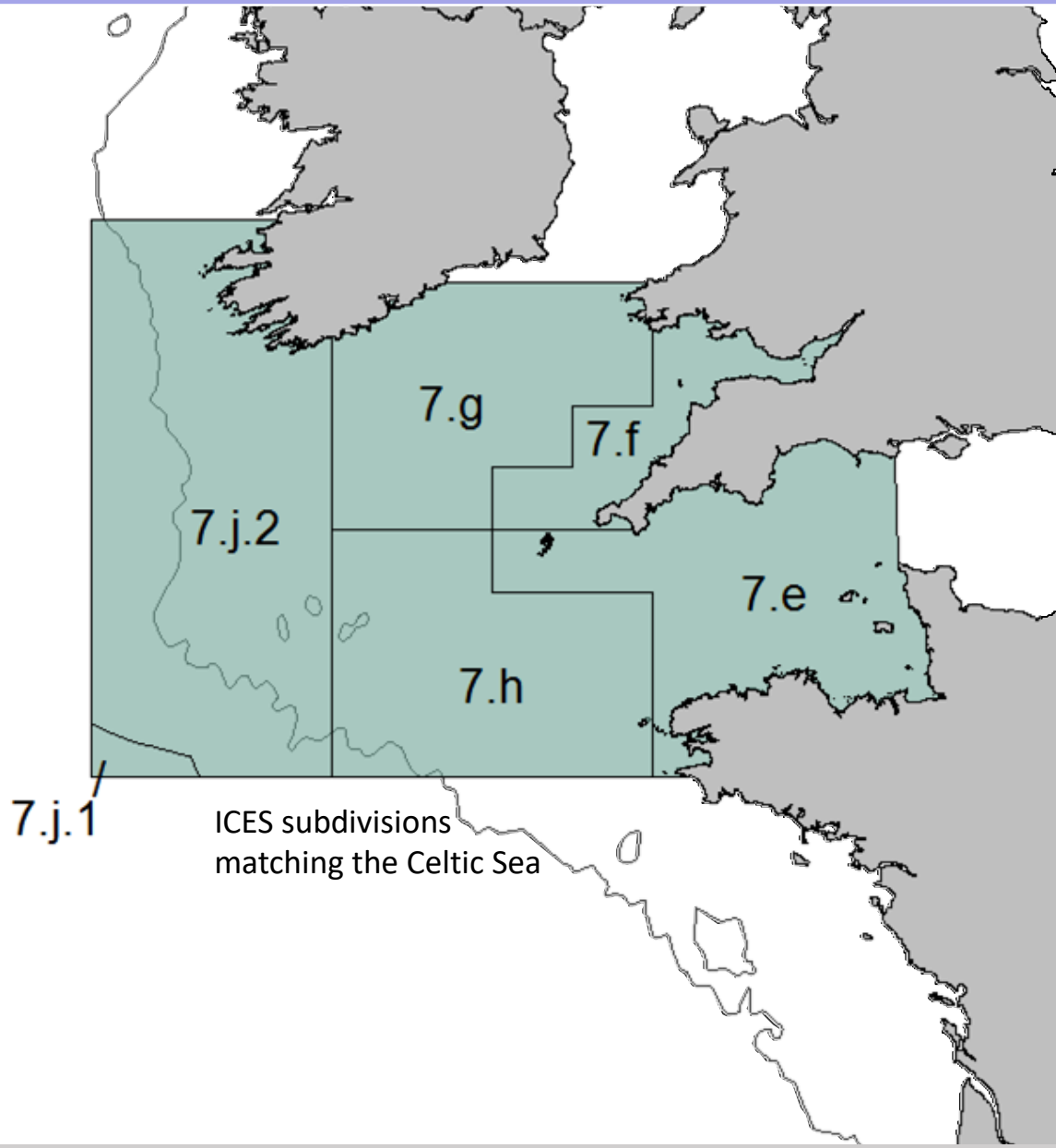
- Great diversity of species
- At a biogeographic boundary



THE CELTIC SEA CASE STUDY

- European shelf ecosystem
- Great variety of habitat
- Great diversity of species
- At a biogeographic boundary
- Crucial for European fisheries

+ + = 340,000 t (average - 2010s)



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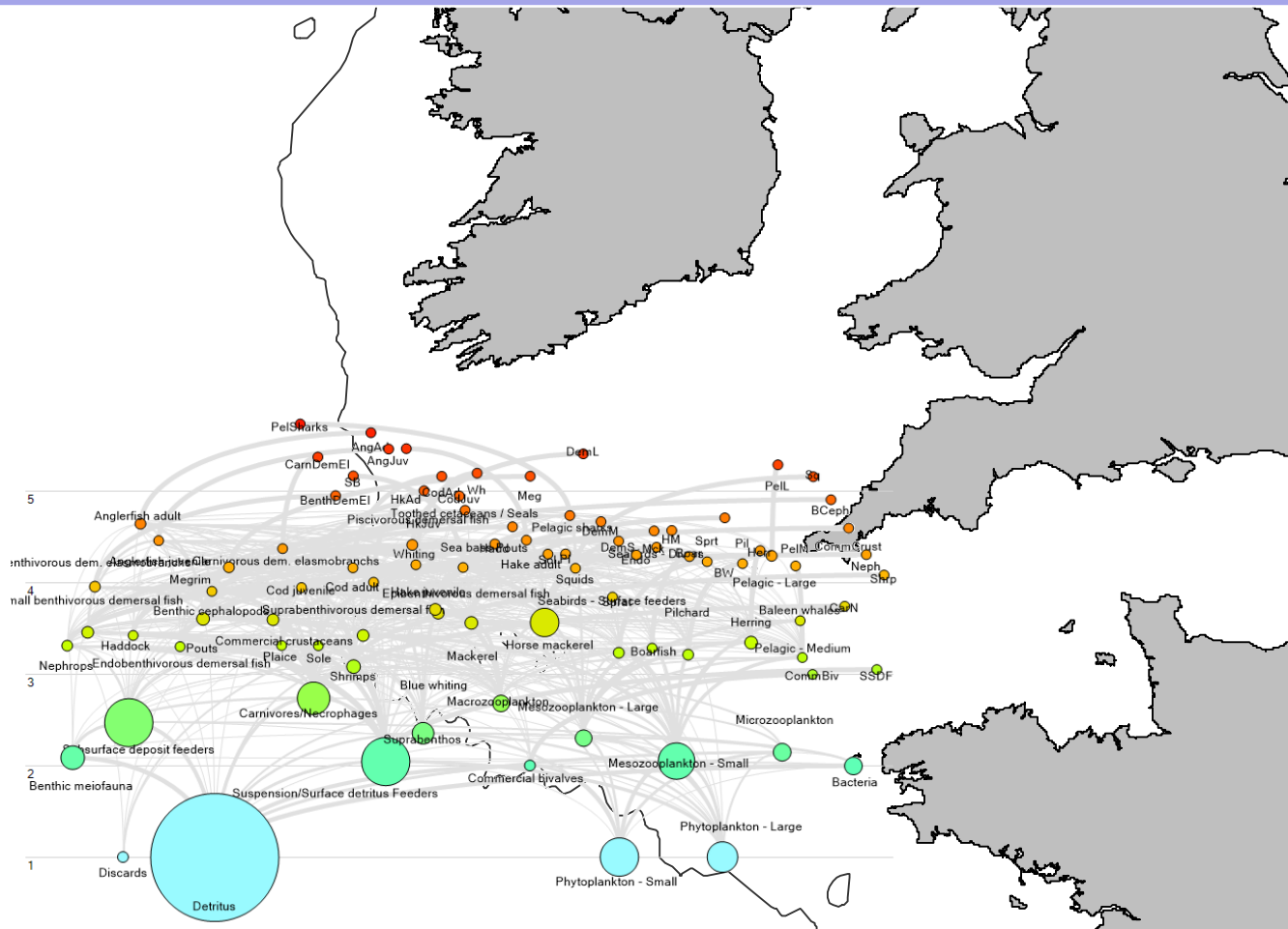
- Crucial for European fisheries
- Trophic modeling of the Celtic Sea ecosystem

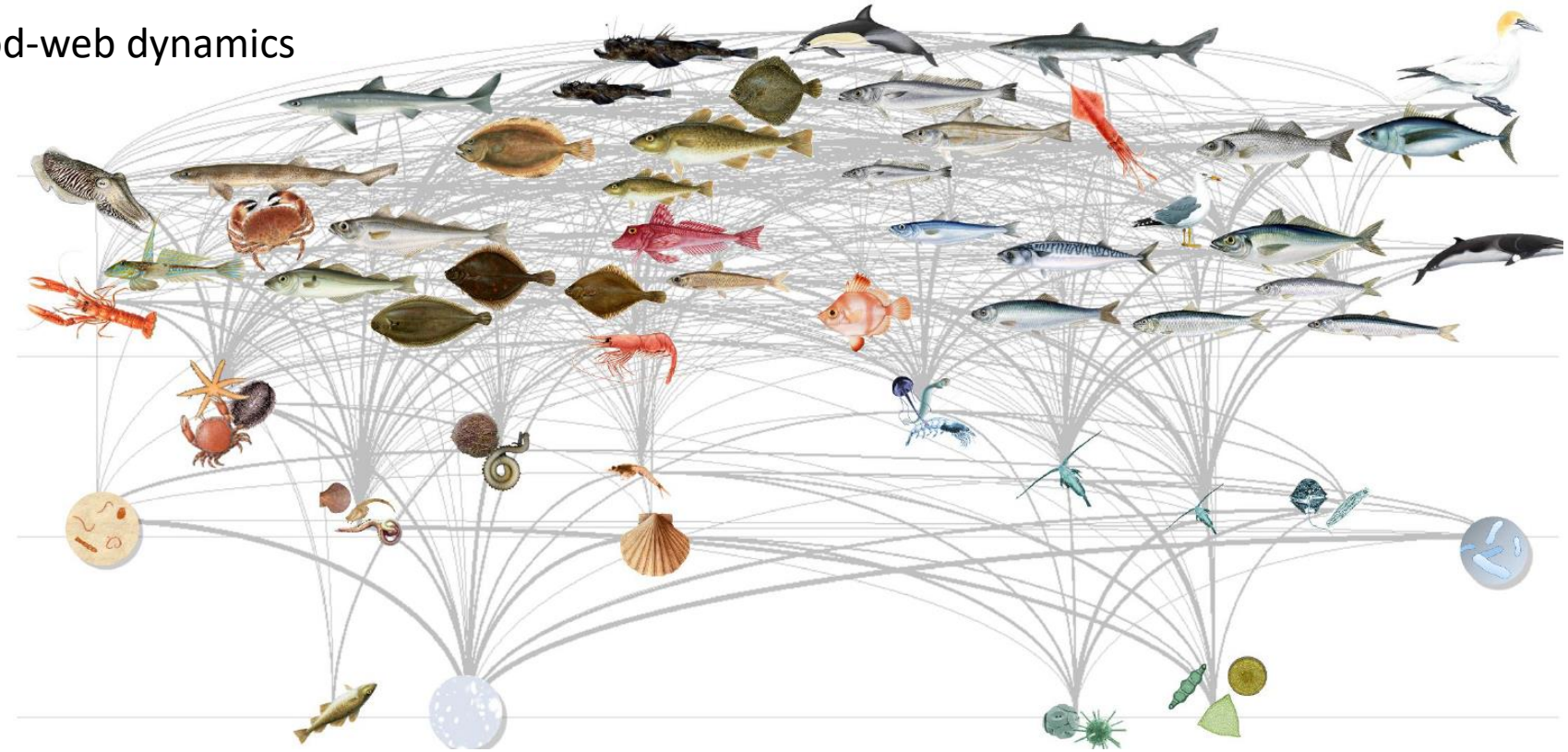


Trenkel et al. 2004, Guenette et Gascuel 2008, Moullec et al. 2017, Hernvann et al. 2020

THE CELTIC SEA FOOD-WEB MODEL

- A pre-existing Ecopath with Ecosim model for the Celtic Sea
  Moullec et al (2017)

- A mass balance representation of food-web dynamics



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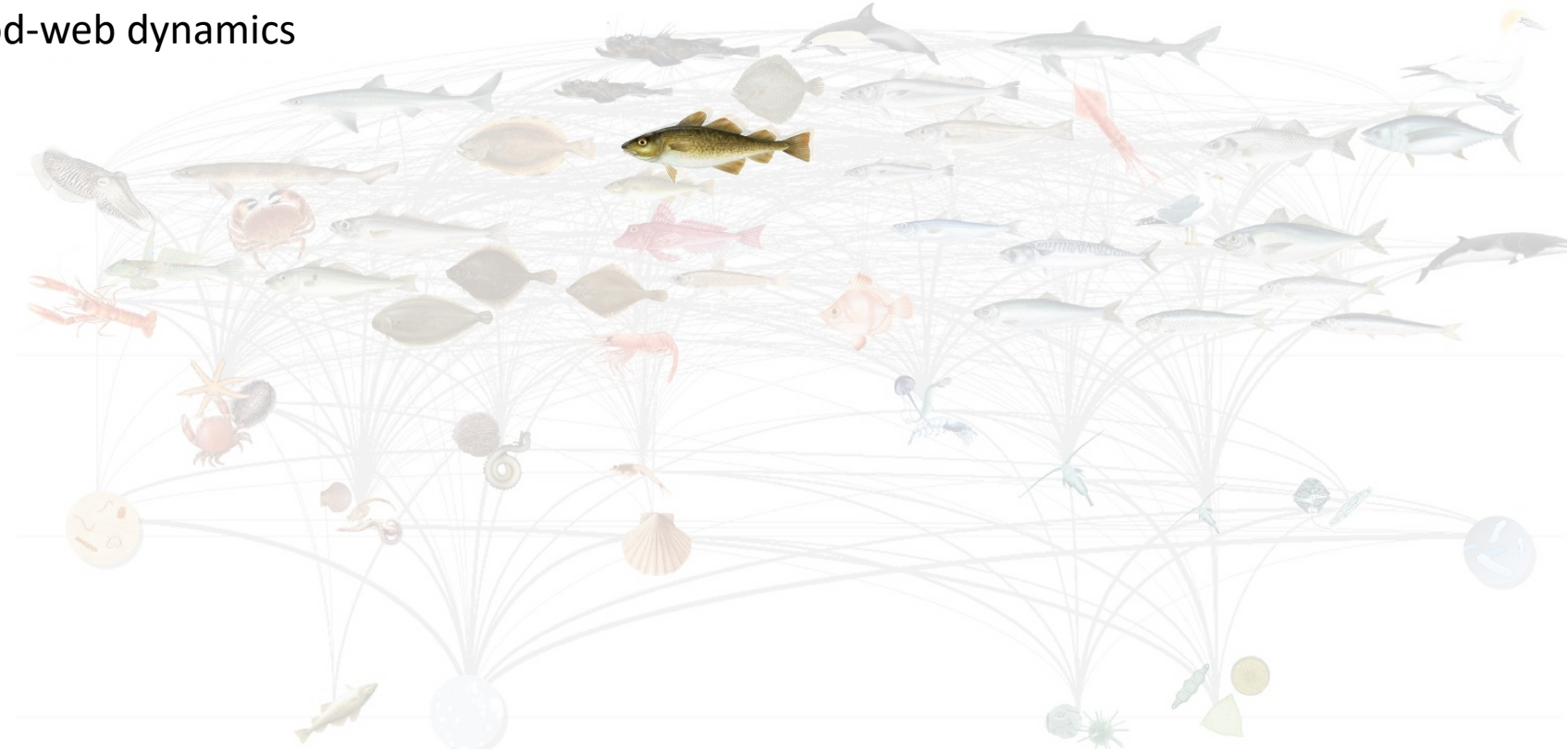

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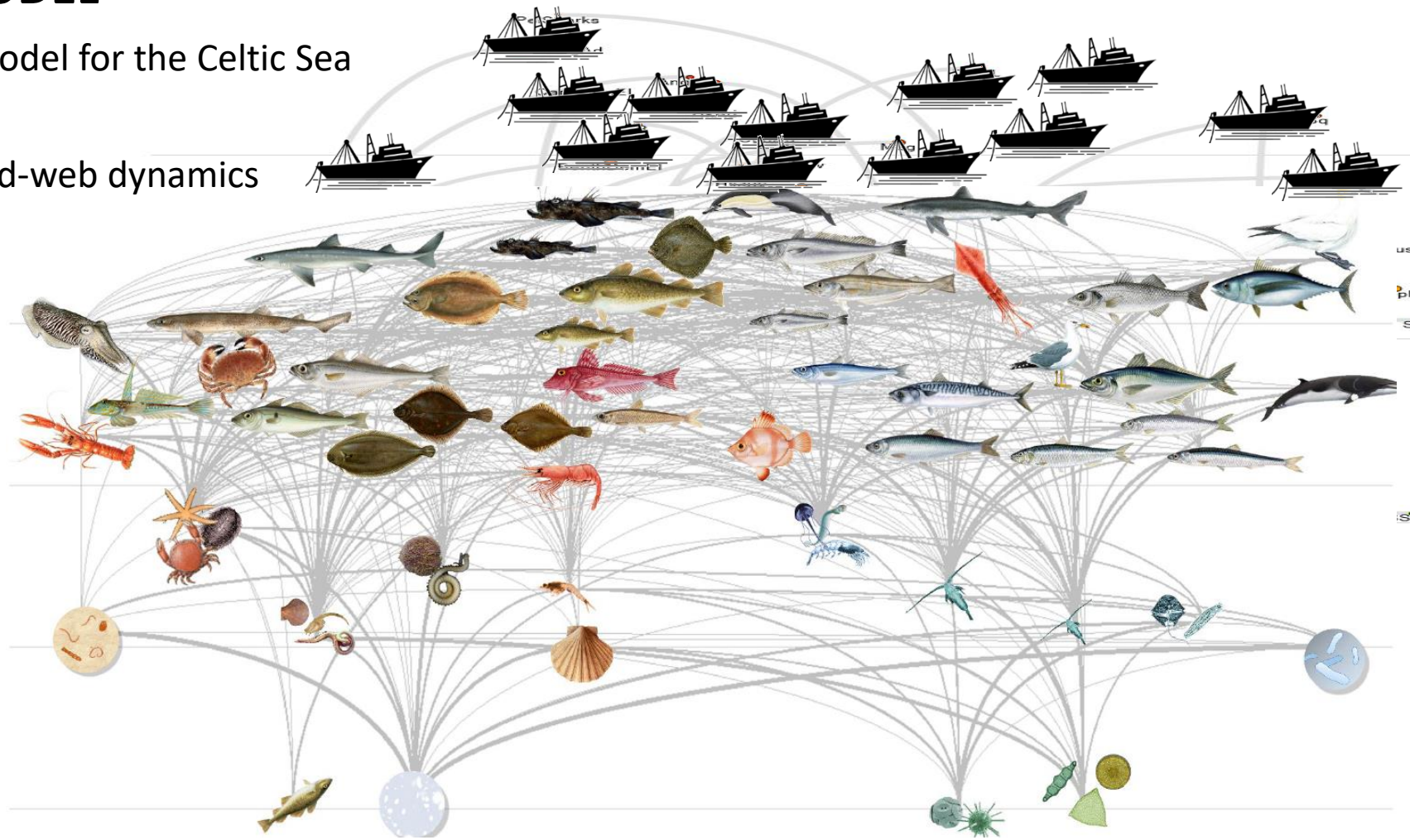

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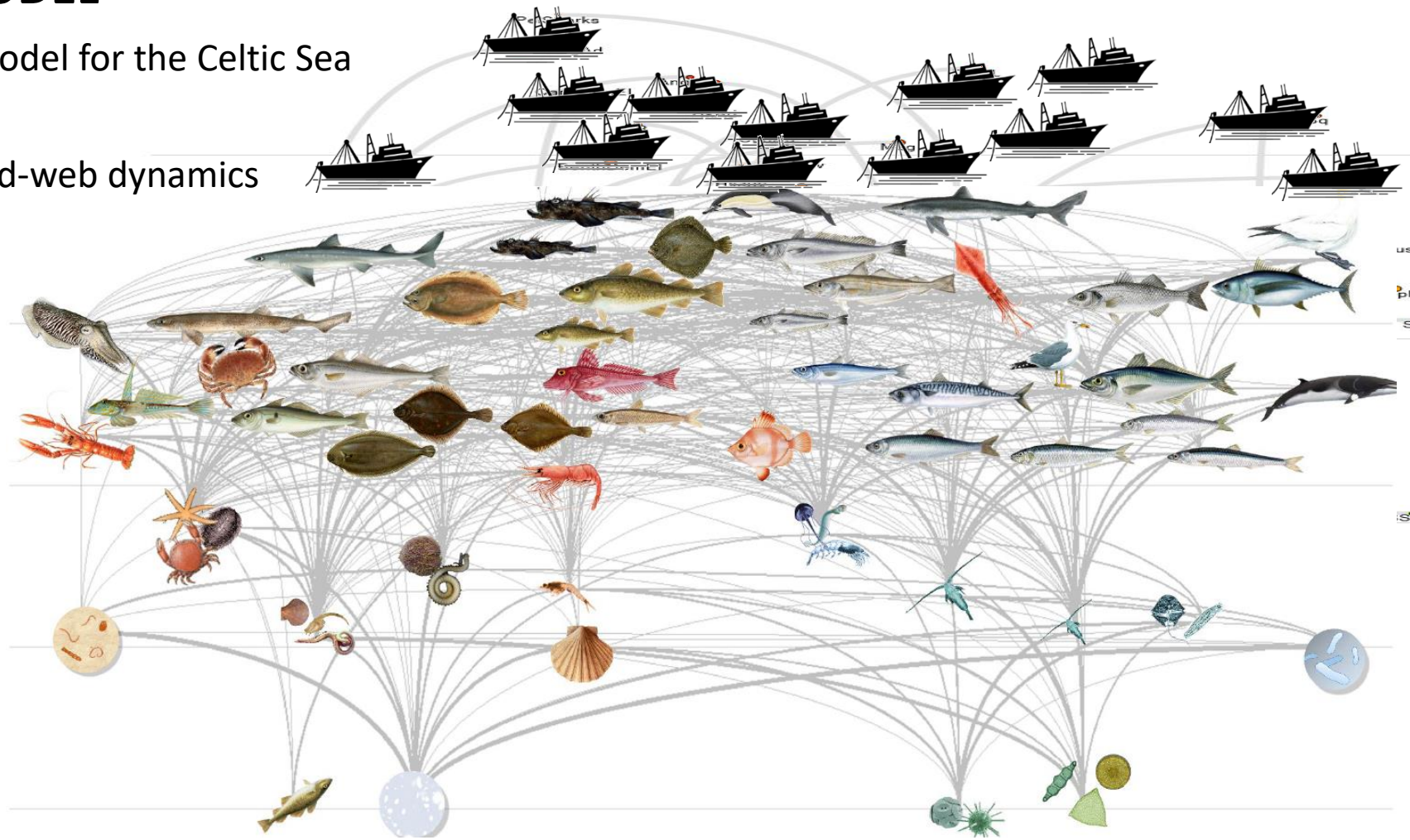

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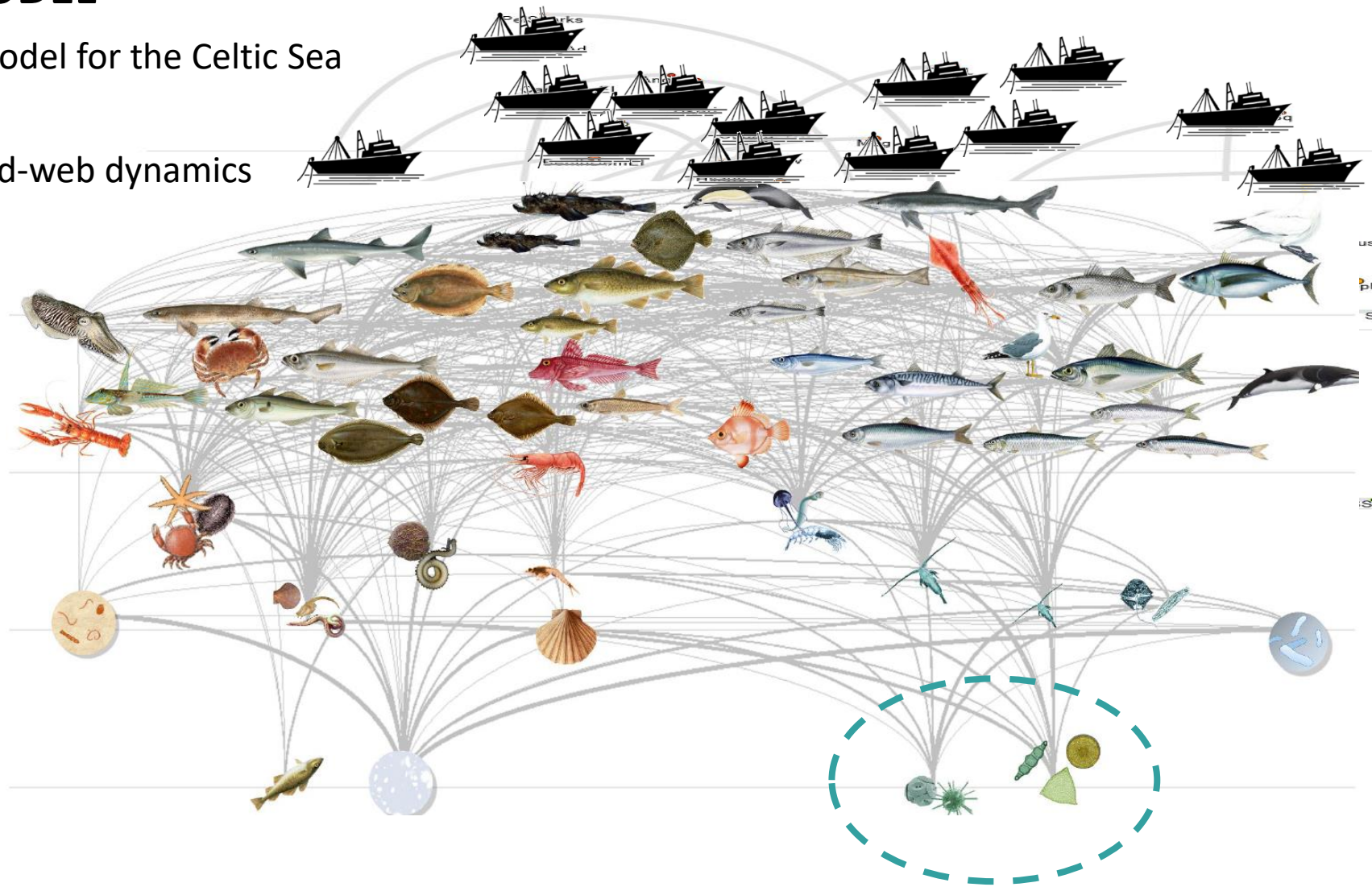
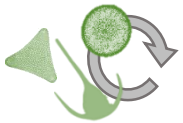


✓ Low Trophic Levels



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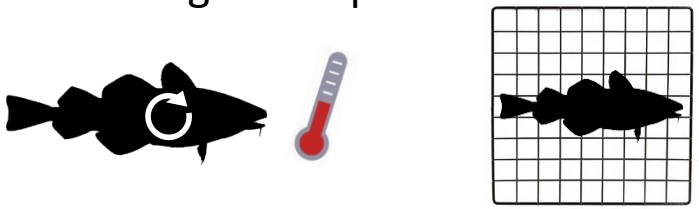
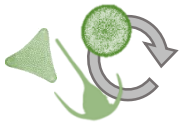


Christensen et al., 2014; Corrales et al. 2018; Bentley et al. 2017 …

  - ✓ Low Trophic Levels



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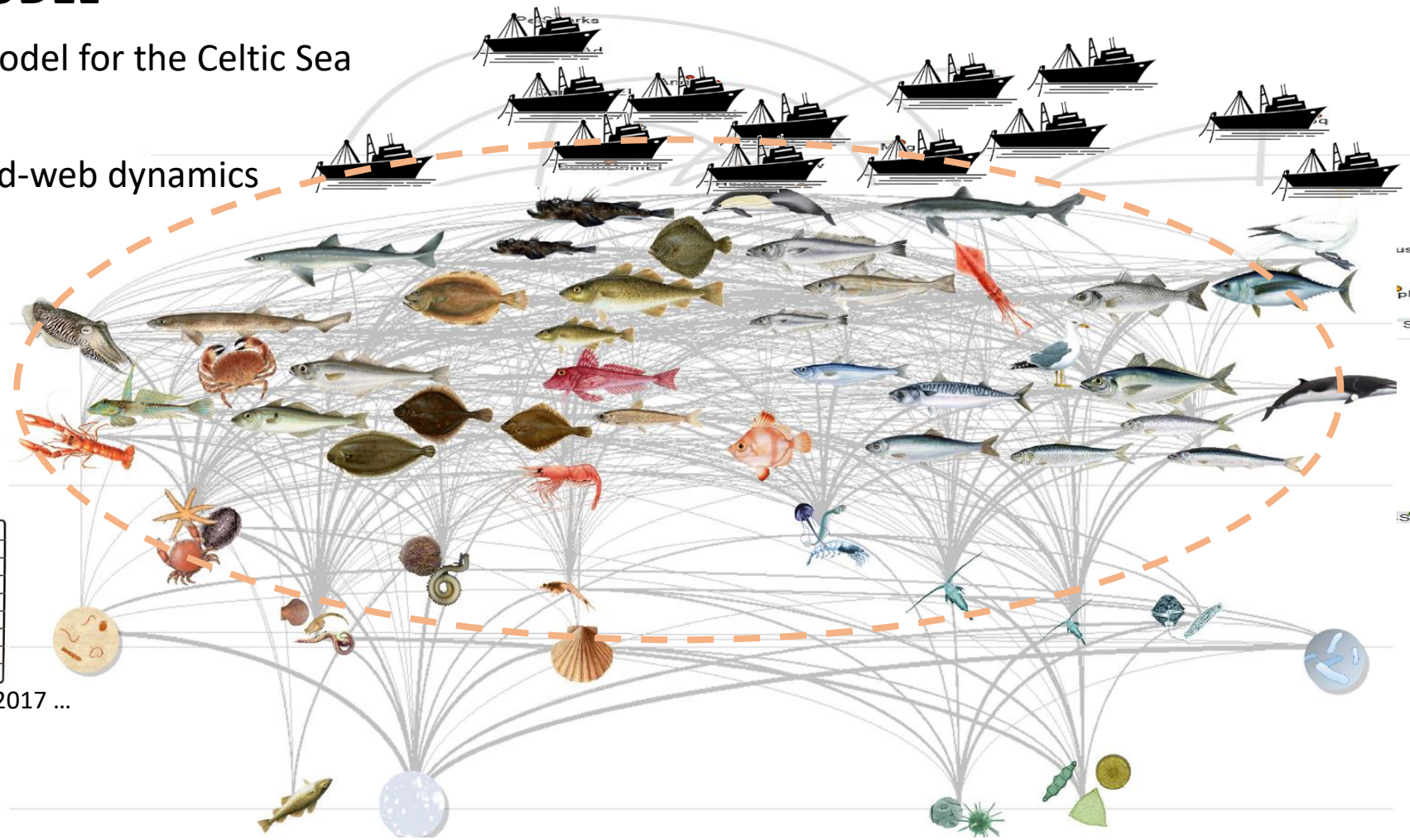

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  - ✓ Low Trophic Levels

Christensen et al., 2008

Understand the relative effects of environment and fishing on the Celtic Sea dynamics in the past

… To better predict the response of the ecosystem to future climate change

AN OCEANOGRAPHIC FUTURE THAT WE CAN FORESEE

- Increasing availability of forecast products worlwide

  e.g. Copernicus Europe's eyes on Earth — Climate Change Service

- Benefits to … global scale studies FISH-MIP FISHERIES & MARINE ECOSYSTEM MODEL INTERCOMPARISON PROJECT

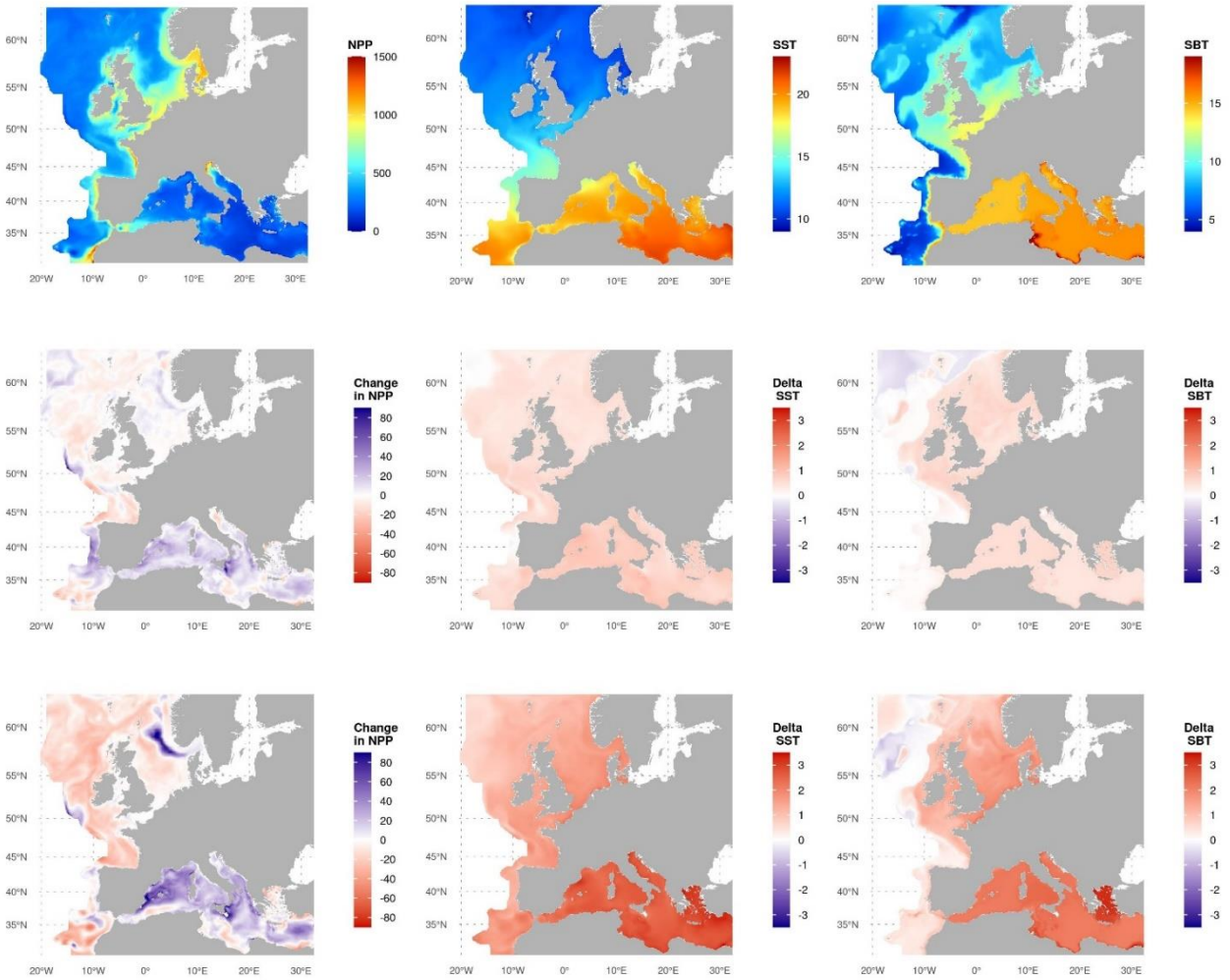
  … regional studies CERES

  … local studies (IBM, Pardo et al. 2019)

- Exemple of the POLCOMS-ERSEM model
  (Holt and James, 2001; Butenschön et al., 2016)

  Physics

  Low-TL (plankton, benthos)

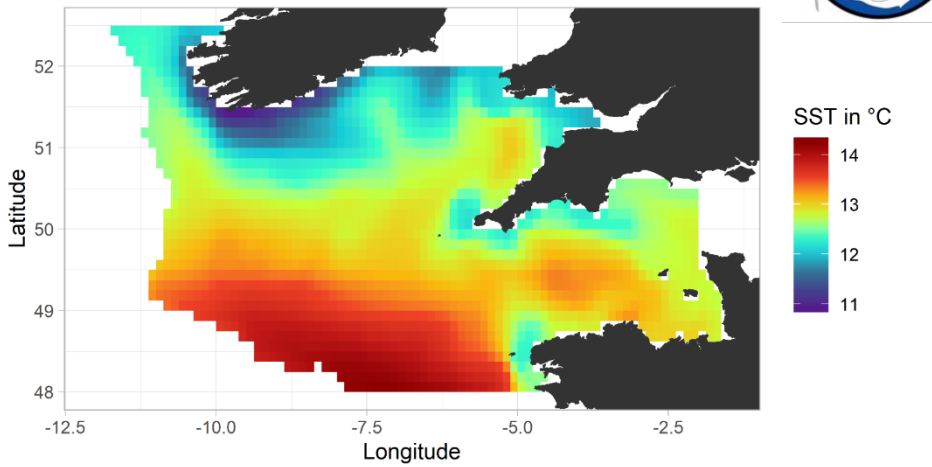


(Kay, Du Pontavice, pers. Comm.)

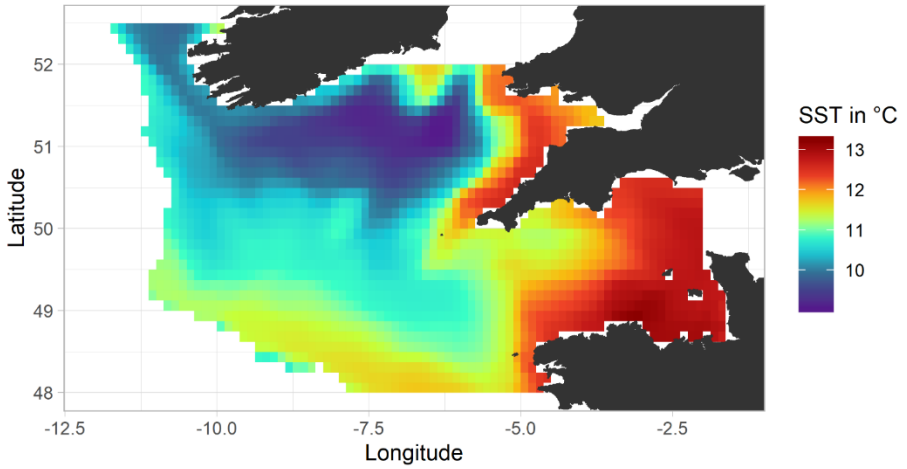
WHAT POLCOMS-ERSEM TELLS US ABOUT THE CELTIC SEA

- Whatever the RCP scenarios:

Sea **surface** temperature 2010s



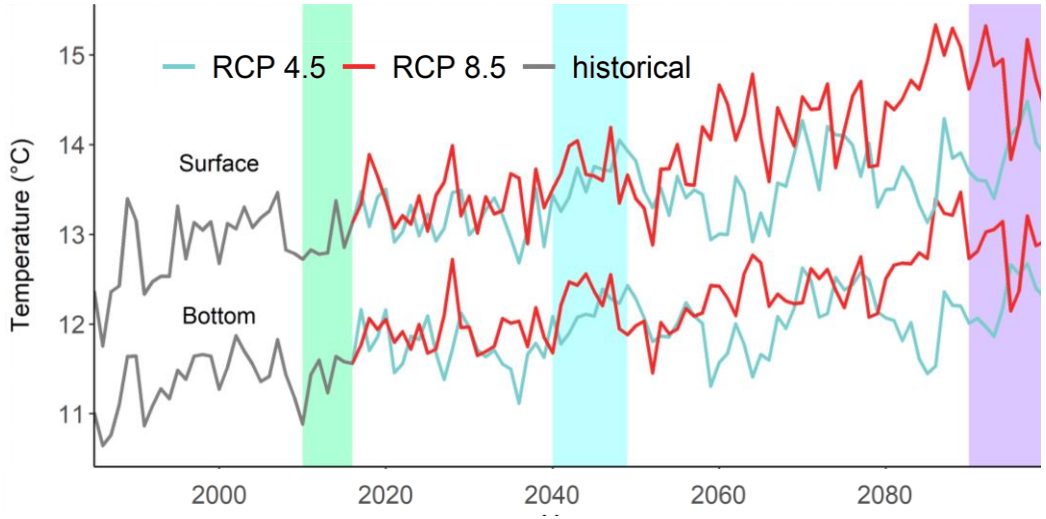
Sea **bottom** temperature 2010s



Outputs of the POLCOMS-ERSEM model
(Holt and James, 2001; Butenschön et al., 2016)

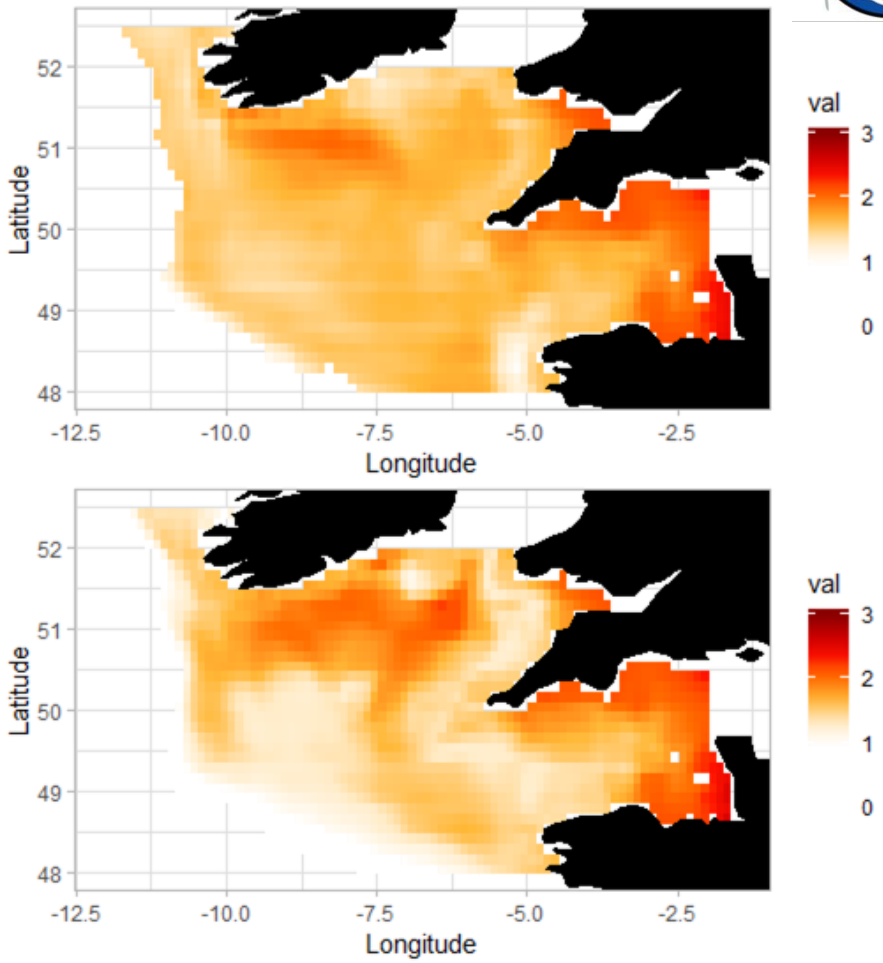
WHAT POLCOMS-ERSEM TELLS US ABOUT THE CELTIC SEA

- Whatever the RCP scenarios:
  - ✓ Increase in surface and bottom temperature
  - ✓ Large increases in already warm areas



Sea **Surface** temperature 2010s-2090s change RCP 8.5

Sea **Bottom** temperature 2010s-2090s change RCP 8.5



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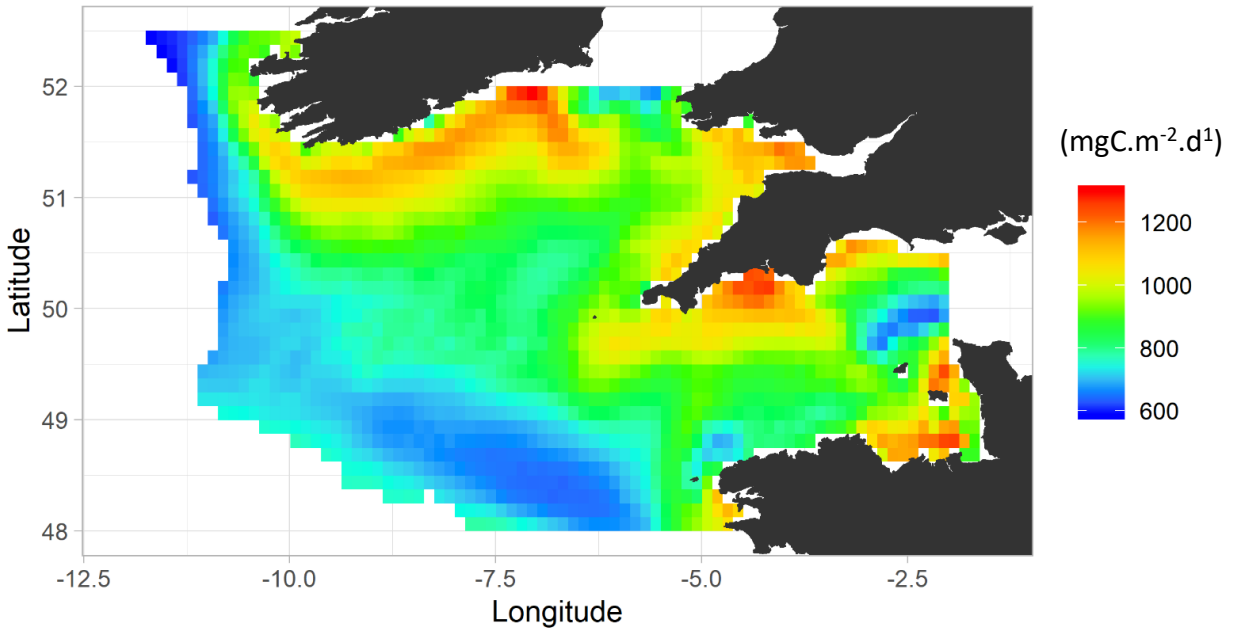

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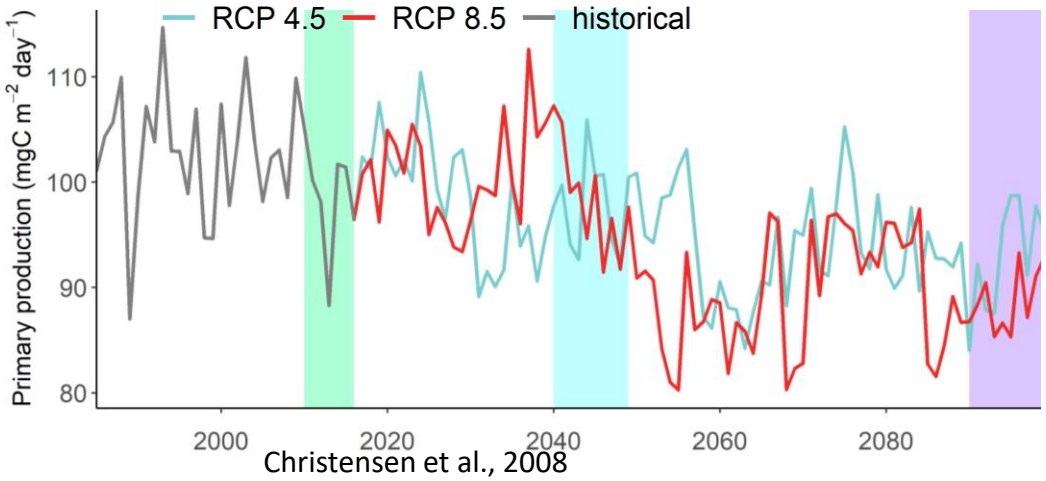
WHAT POLCOMS-ERSEM TELLS US ABOUT THE CELTIC SEA

- Whatever the RCP scenarios:

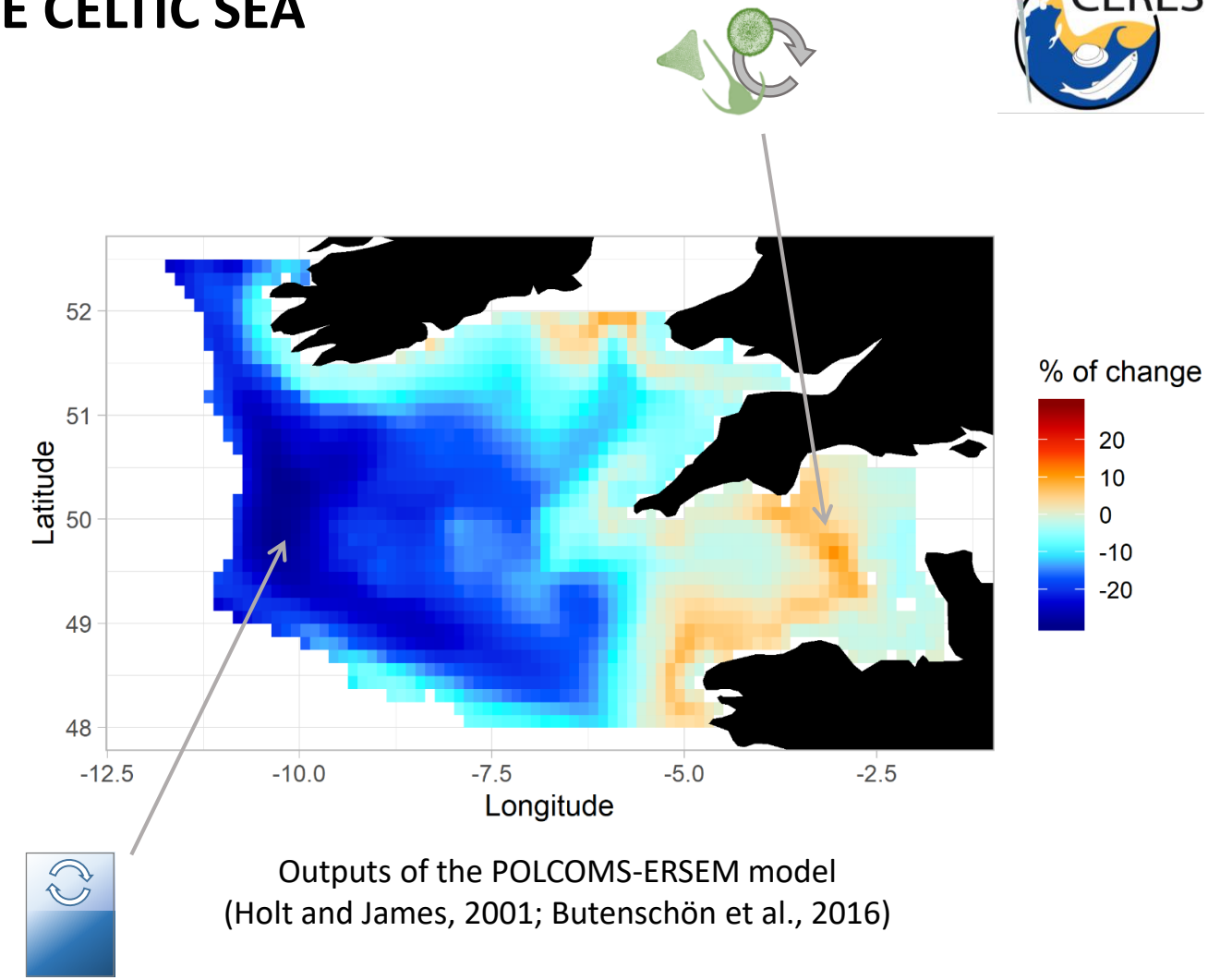
  ✓ Decline in the Primary Production

  ✓ Steeper decline offshore

Stratification enhancement ↘ PP
vs
Warming ↗ plankton productivity



Christensen et al., 2008



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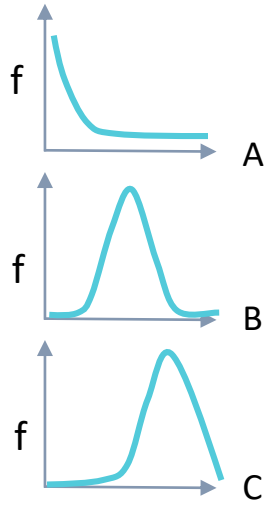
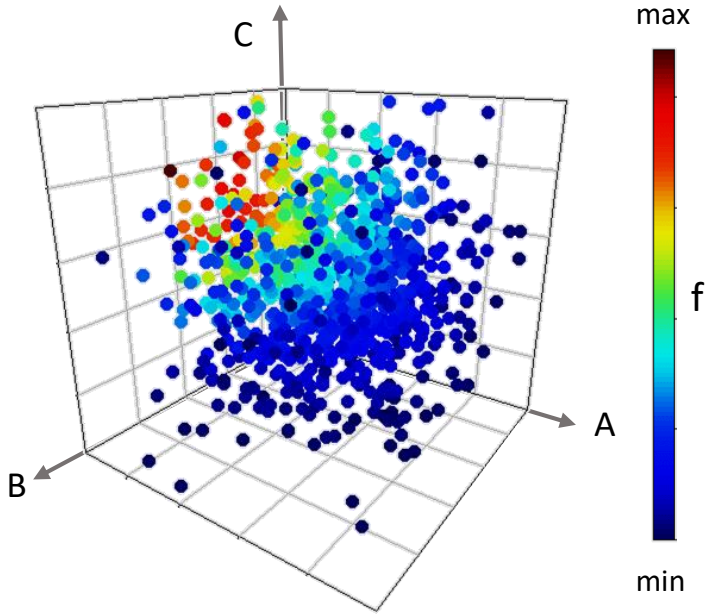
INFORMING THE ENVIRONMENTAL RESPONSE OF HIGH TROPHIC LEVELS

- Concept of the environmental niche (*senso* Grinnell):
  - ✓ Subset of environmental conditions in which the functional group can maximize its fitness
  - ✓ One specific response per environmental variable
    - → Niche as a multidimensional space





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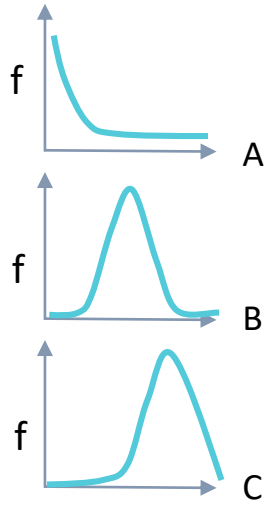
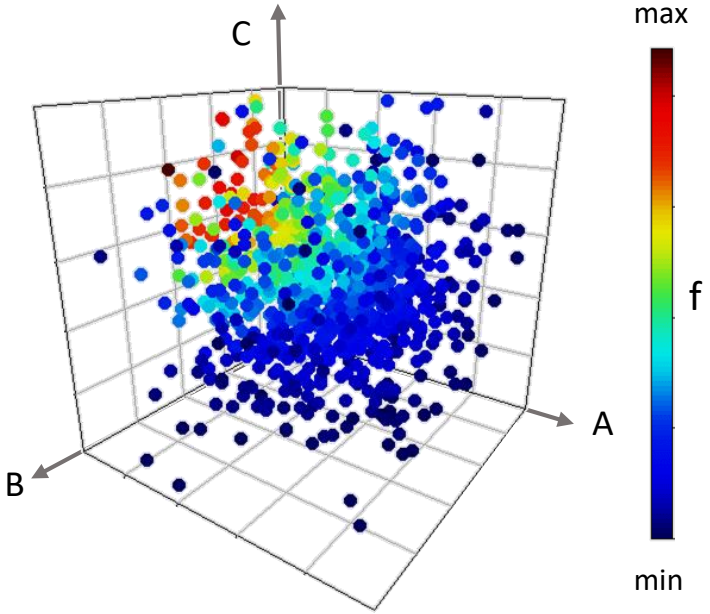
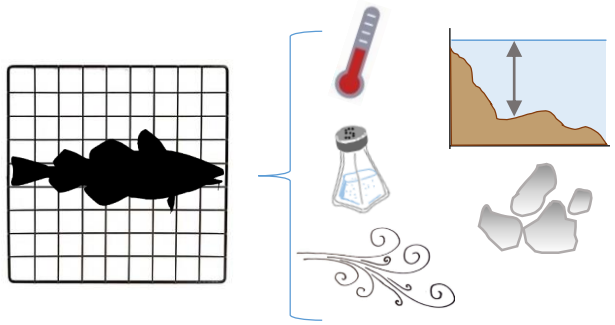




- Environmental conditions affect fish productivity and spatial distribution (Christensen et al, 2014)



PREDICT SPECIES RESPONSES TO WARMING

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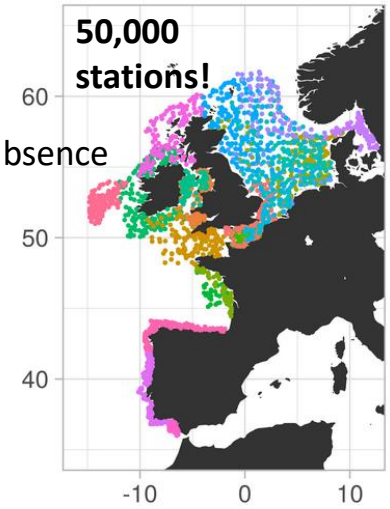
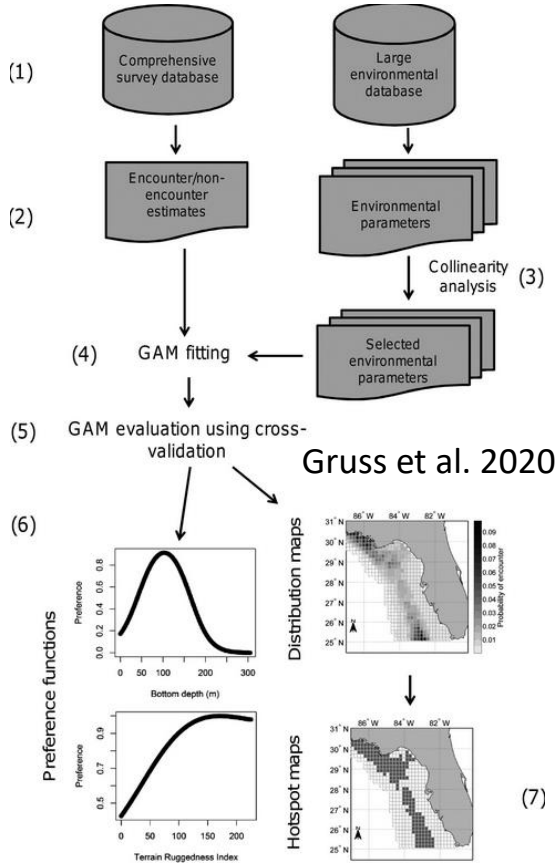
  (Hernvann et al. 2020, Gruss et al. 2020)

- NW European shelf survey





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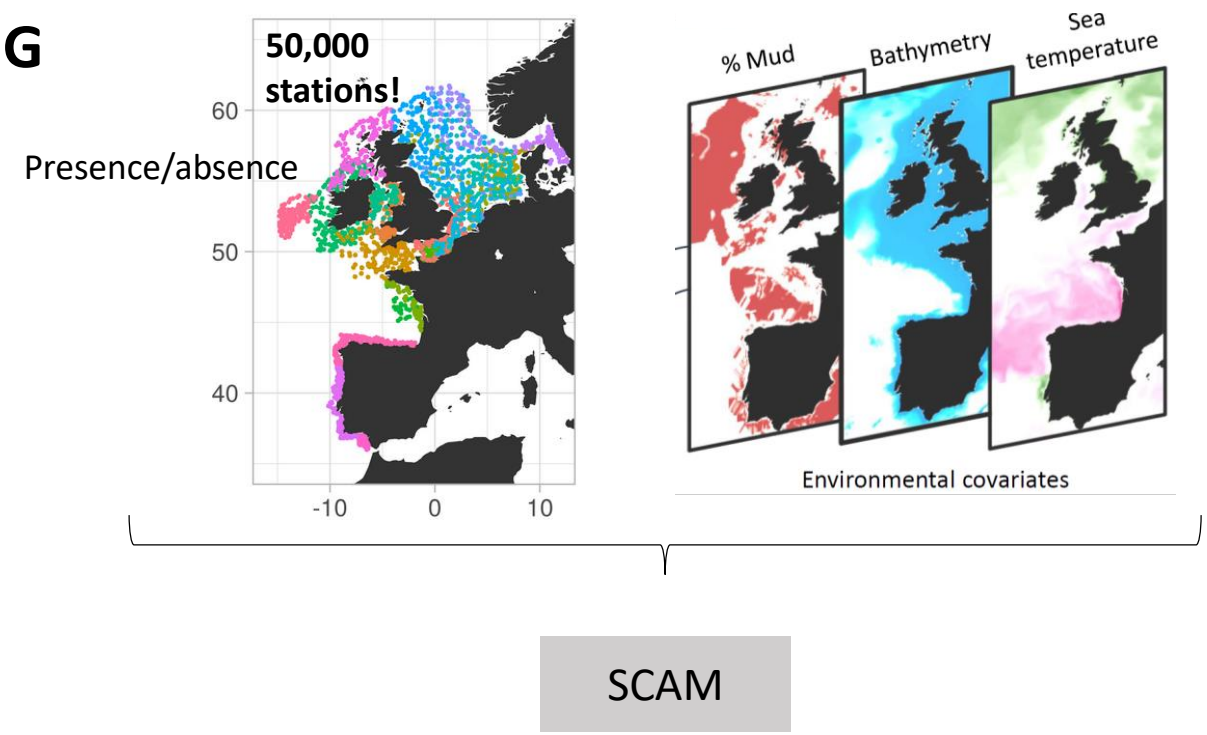

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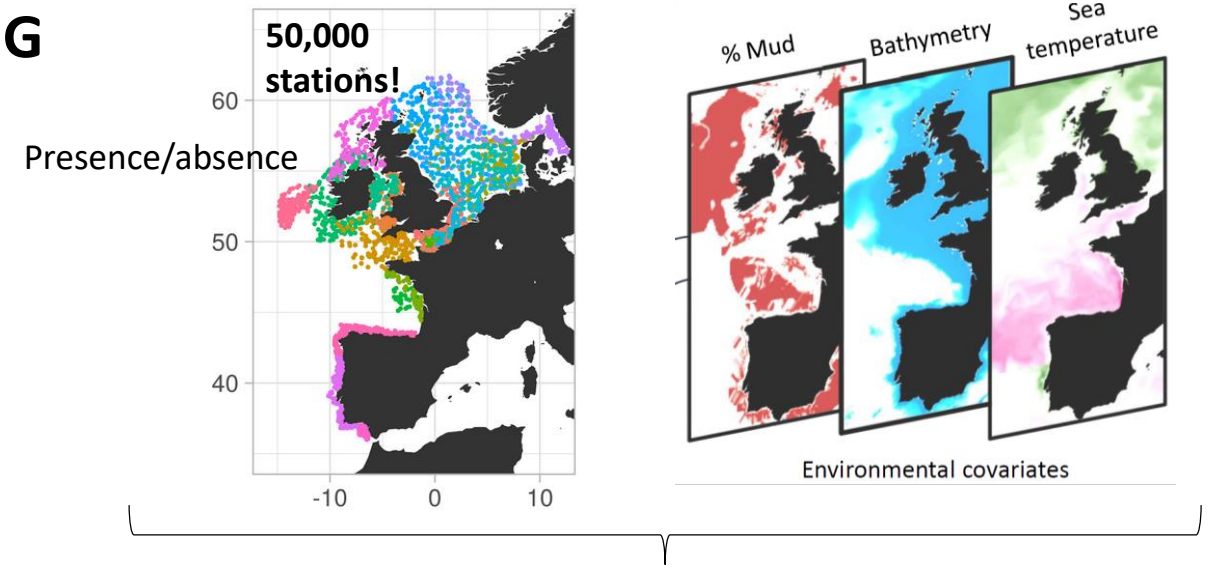
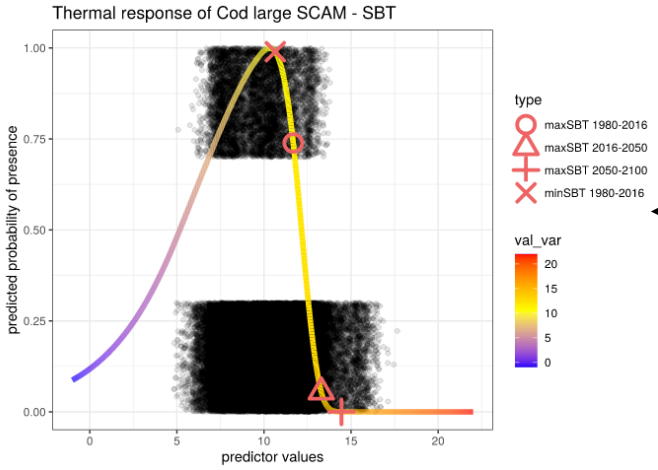
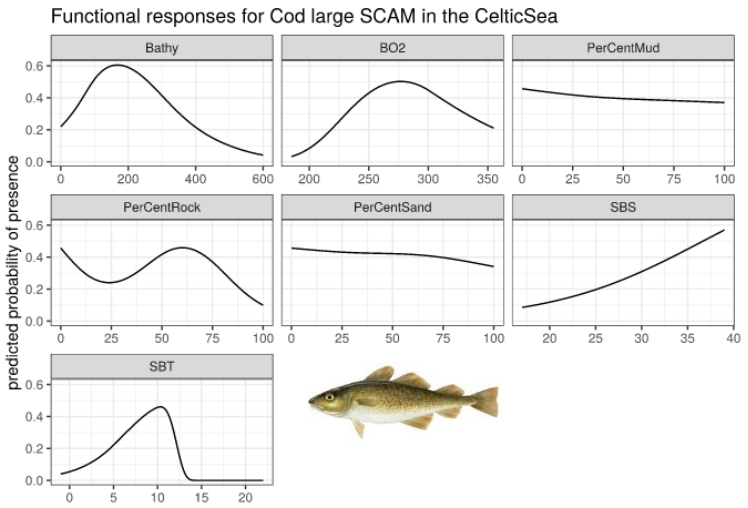
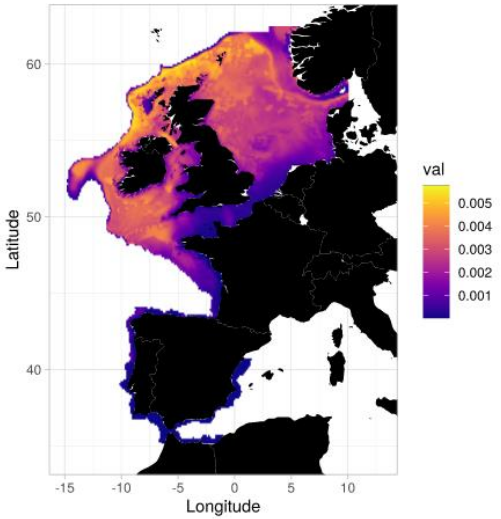
- More realistic/constrained functional responses





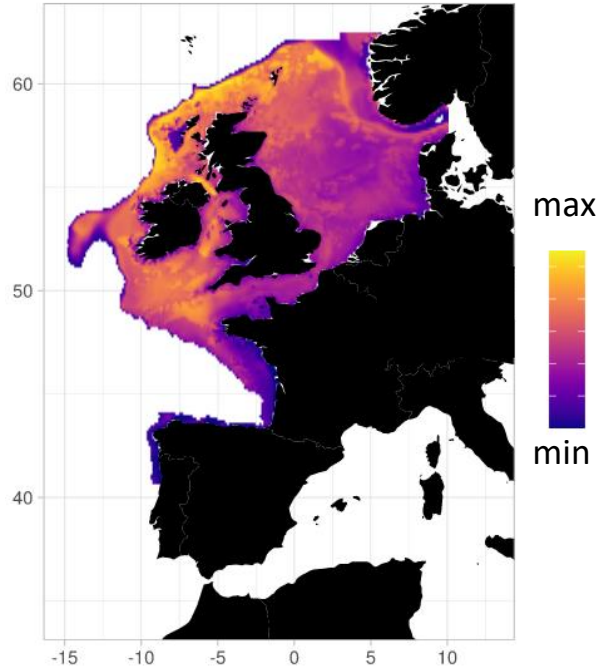


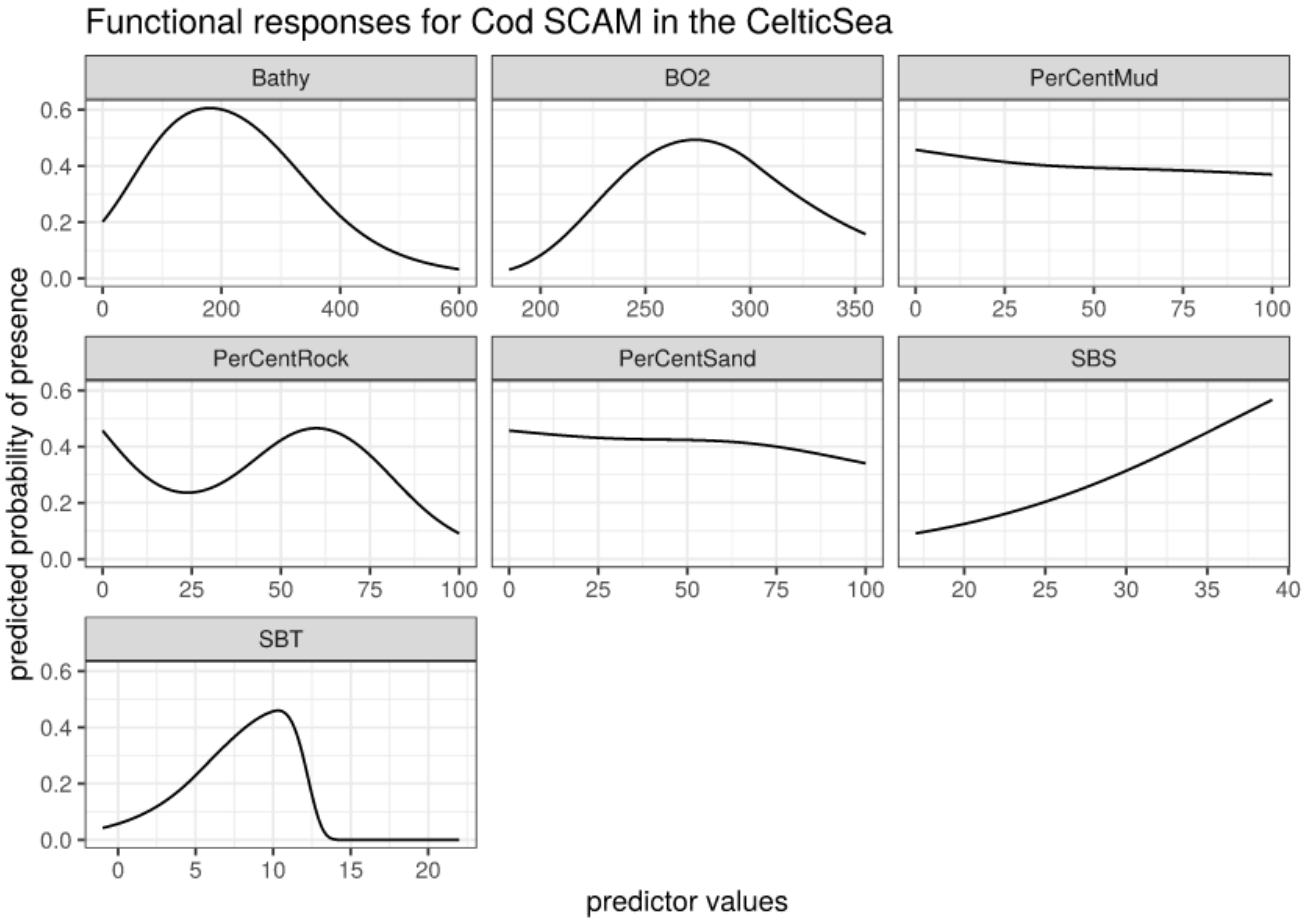


ENVIRONMENTAL RESPONSE OF COD'S PRODUCTIVITY AND DISTRIBUTION

- The environmental niche of cod is determined by…
  - ✓ Bathymetry
  - ✓ Seabed substrate
  - ✓ Physico-chemical conditions

- …and determines its historical distribution





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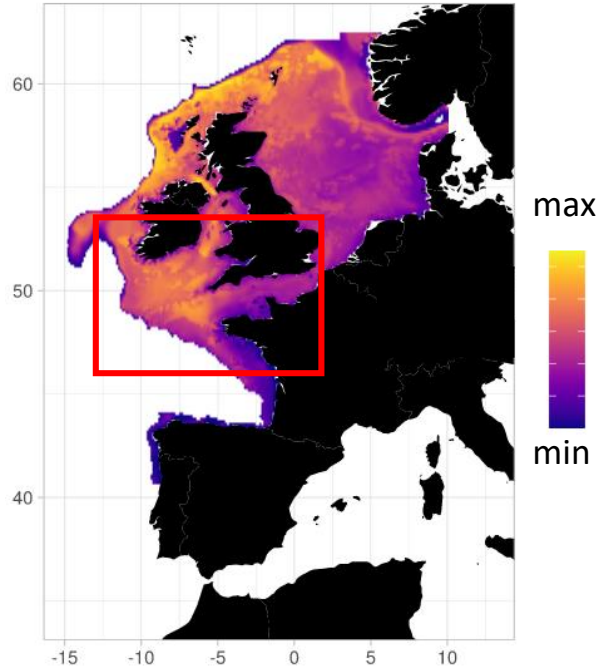

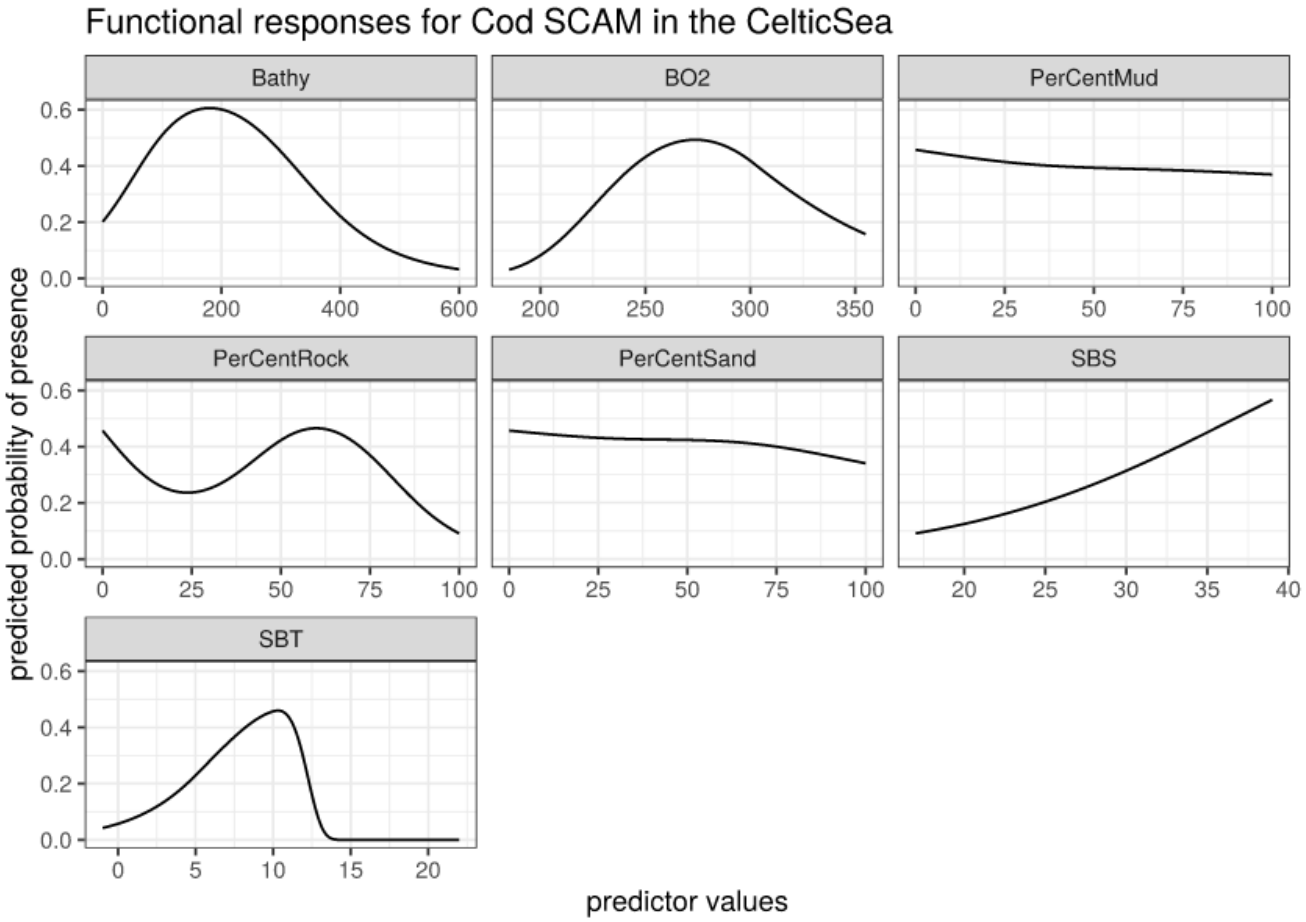

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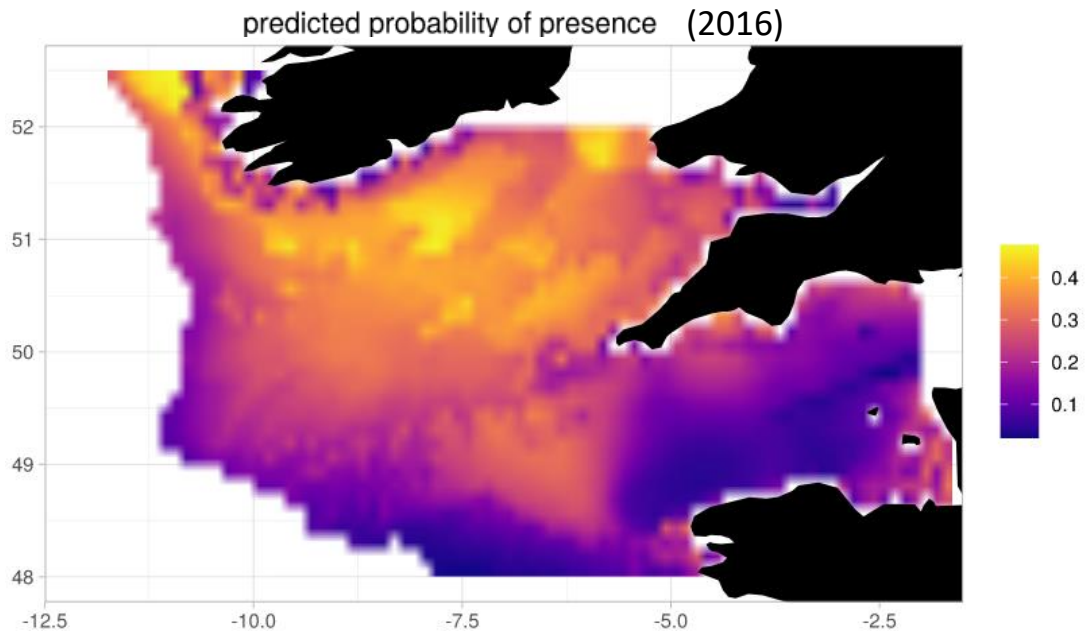

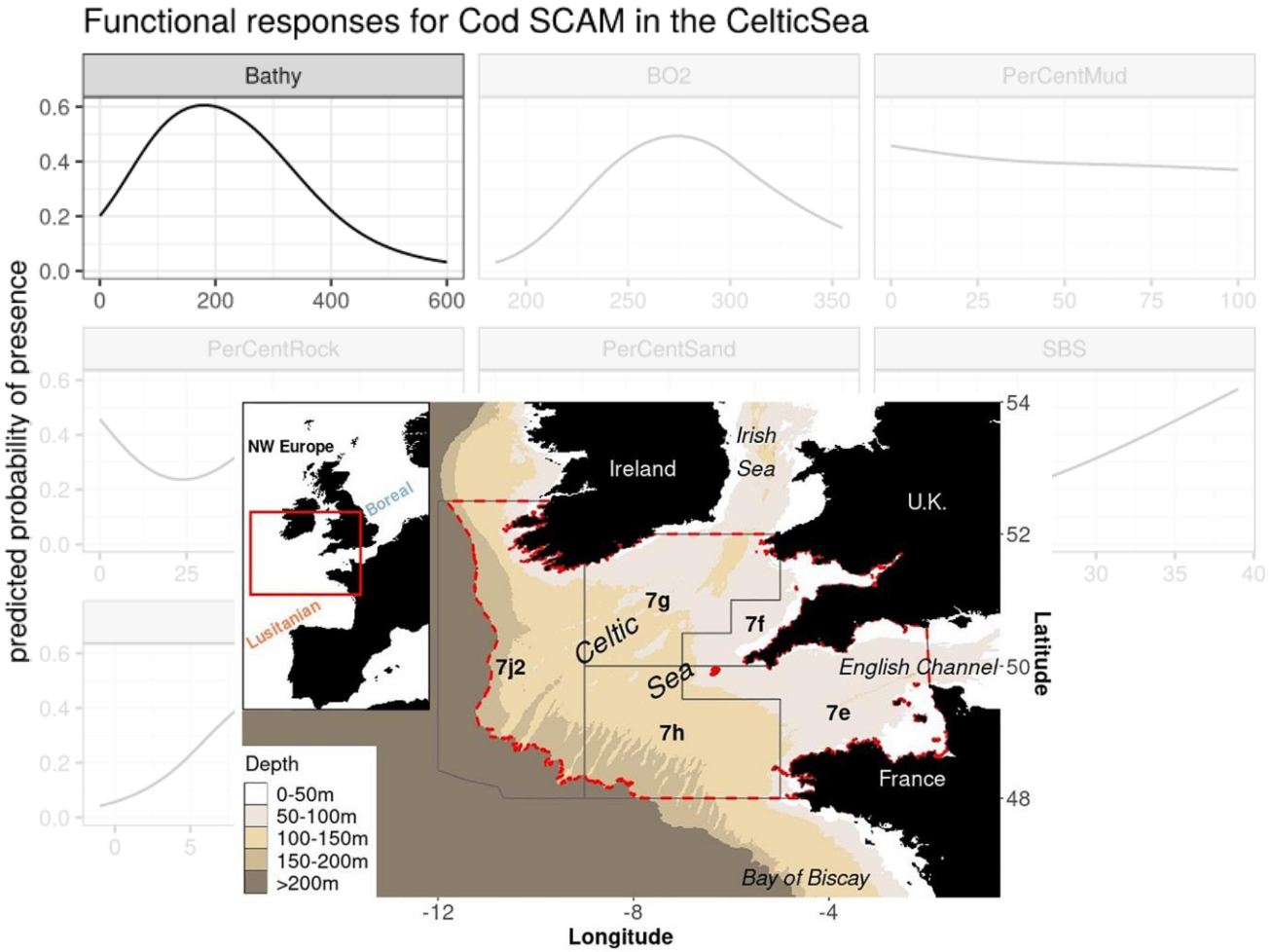

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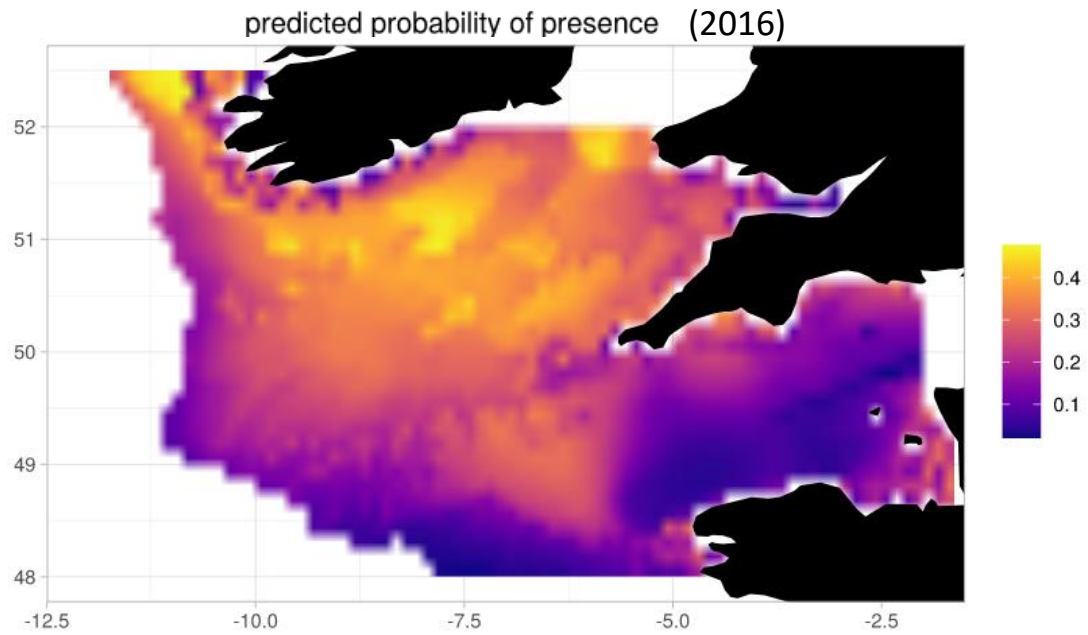

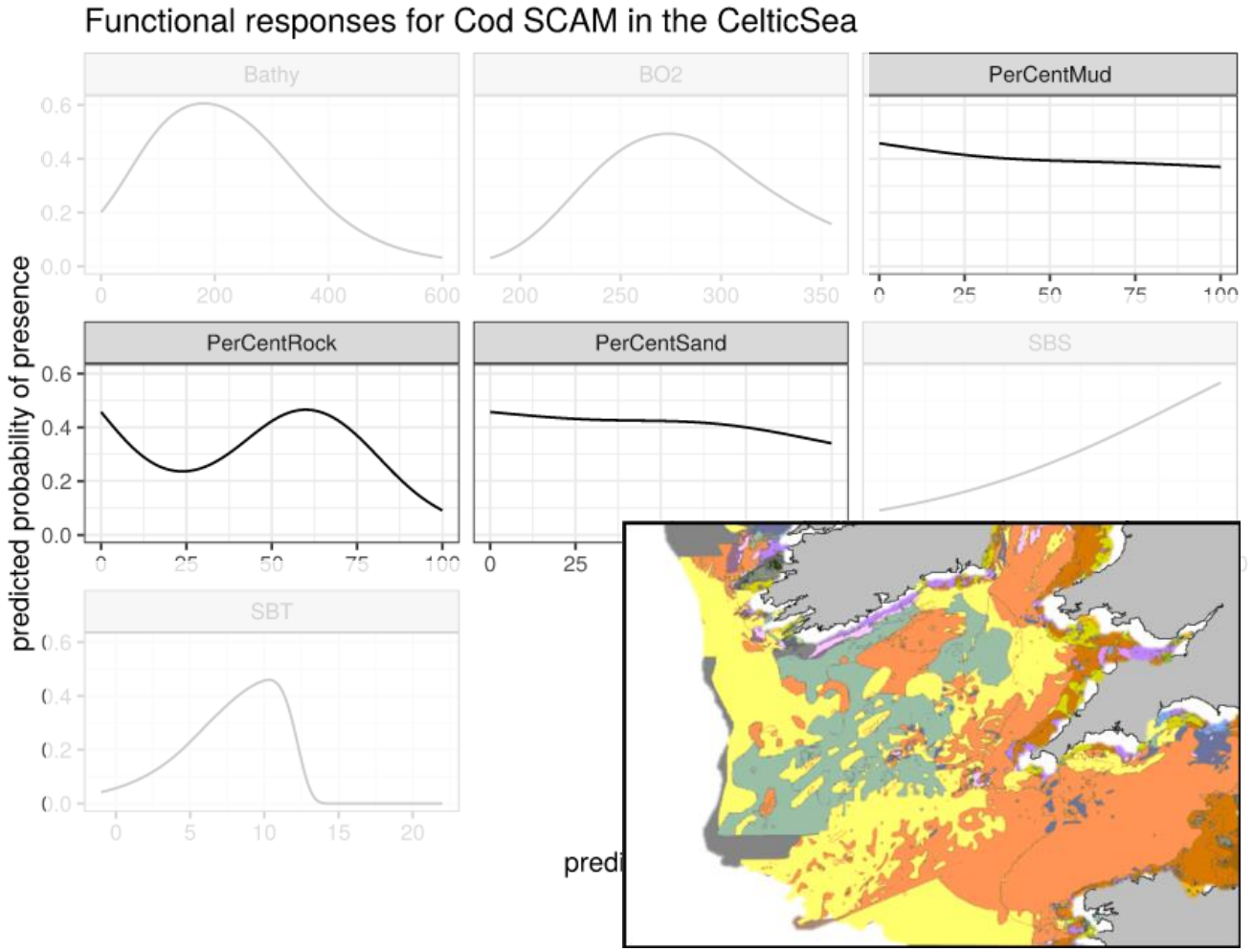

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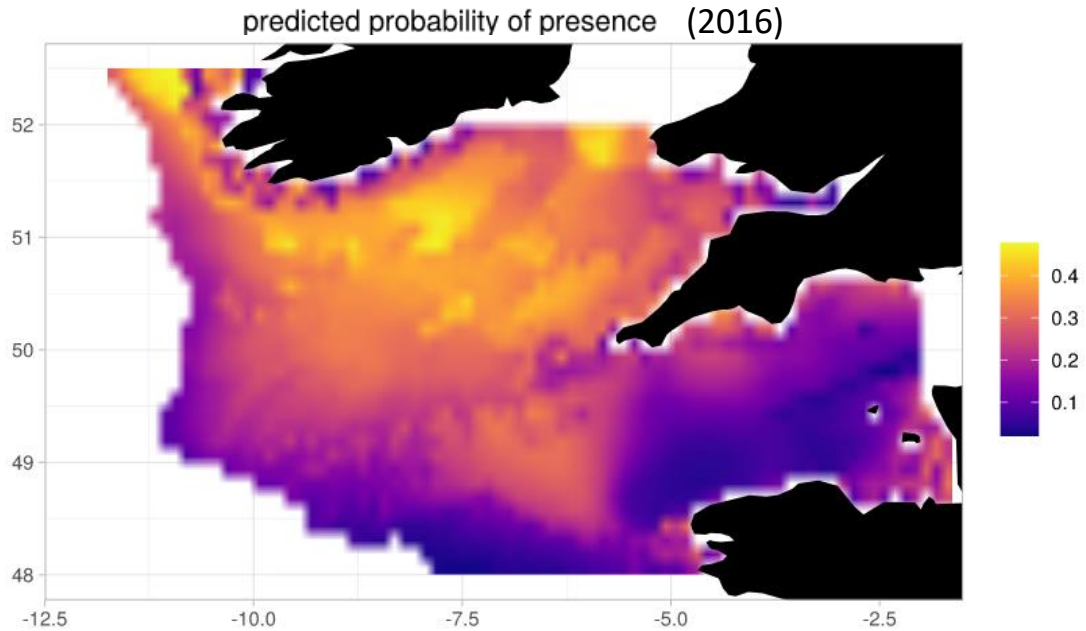
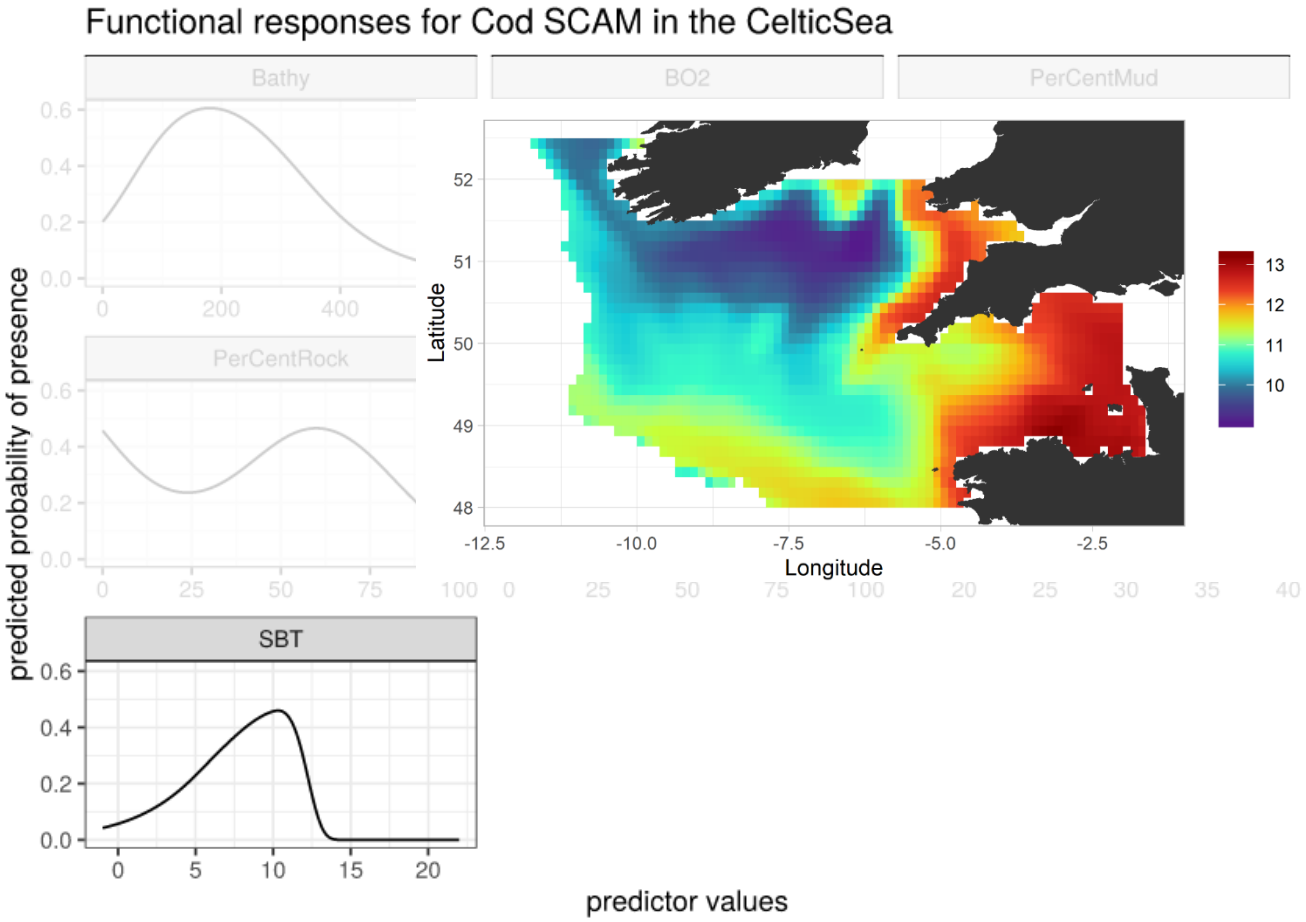




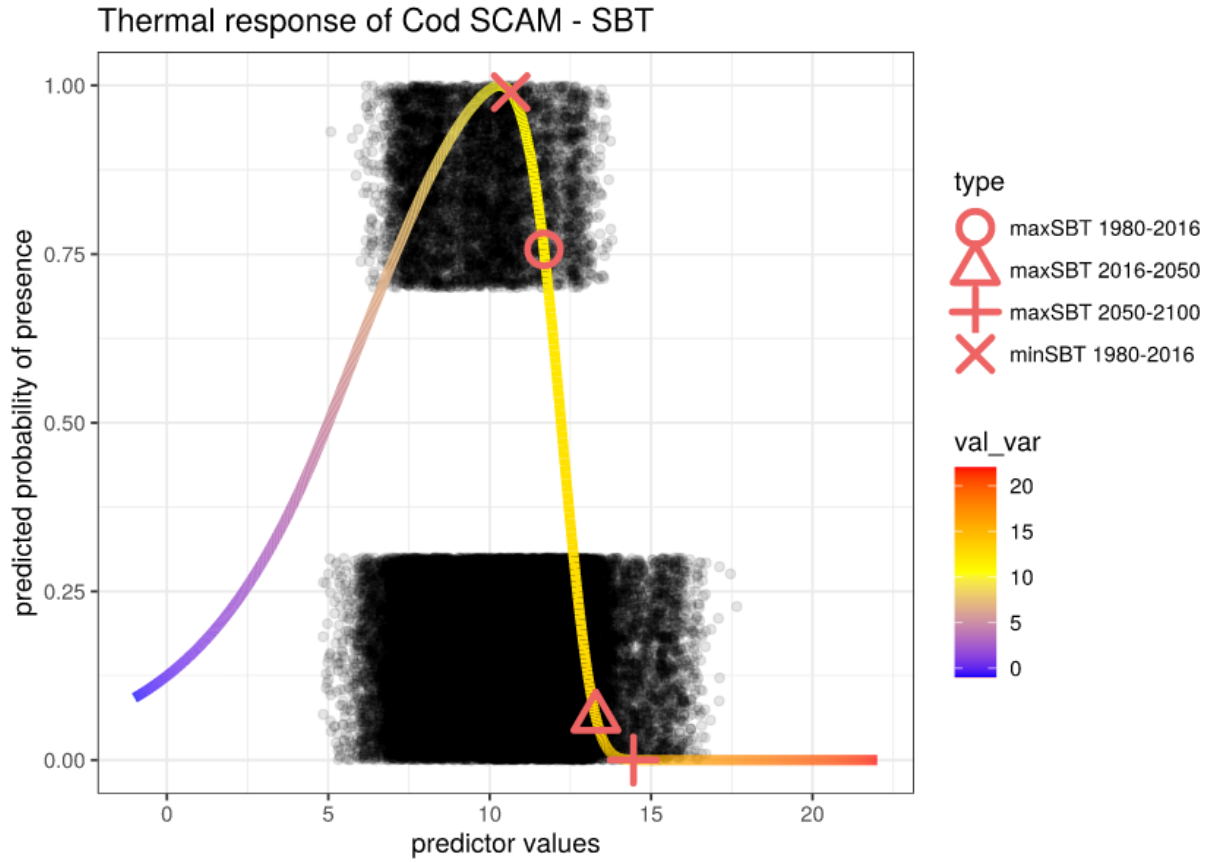
ENVIRONMENTAL RESPONSE OF COD'S PRODUCTIVITY AND DISTRIBUTION

- The environmental niche of cod is determined by…
  - ✓ Bathymetry
  - ✓ Seabed substrate
  - ✓ Physico-chemical conditions
- …and determines its historical distribution
- Thermal conditions are a strong constrain to cod's niche

/!\ This response isn't the thermal physiological window of cod

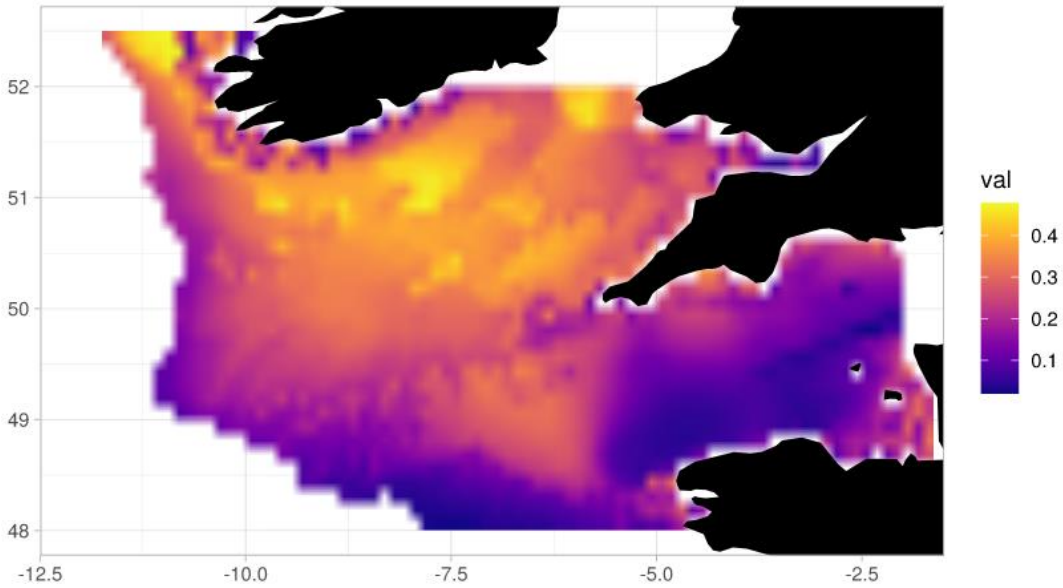
…but it reflects the physiology in some way

…It integrates information on multiple biological/temporal scales

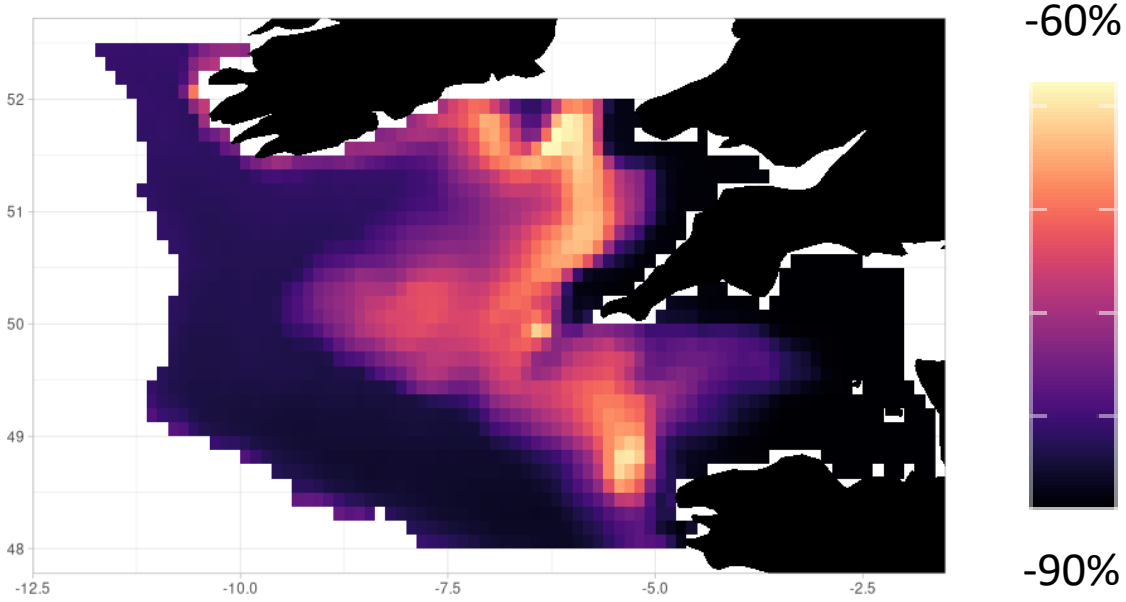


PAST AND FUTURE CHANGES IN THE NICHE OF COD IN THE CELTIC SEA

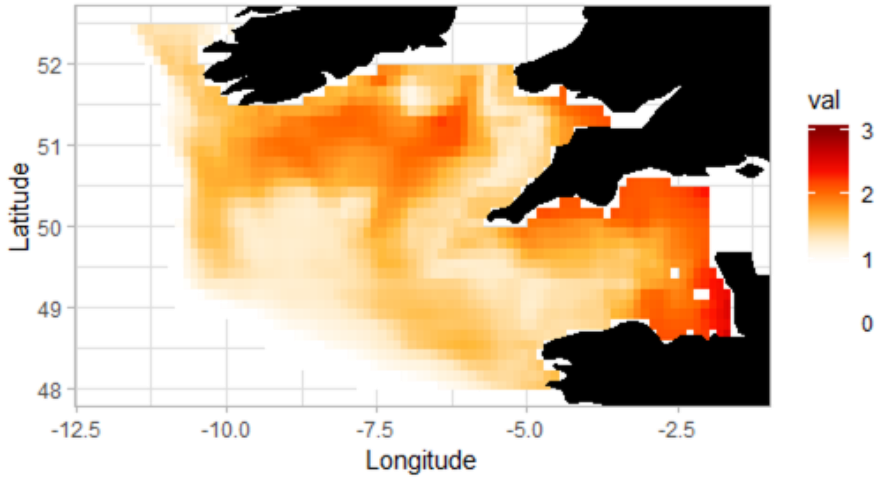
Probability of presence in 2016



Relative difference to 2016



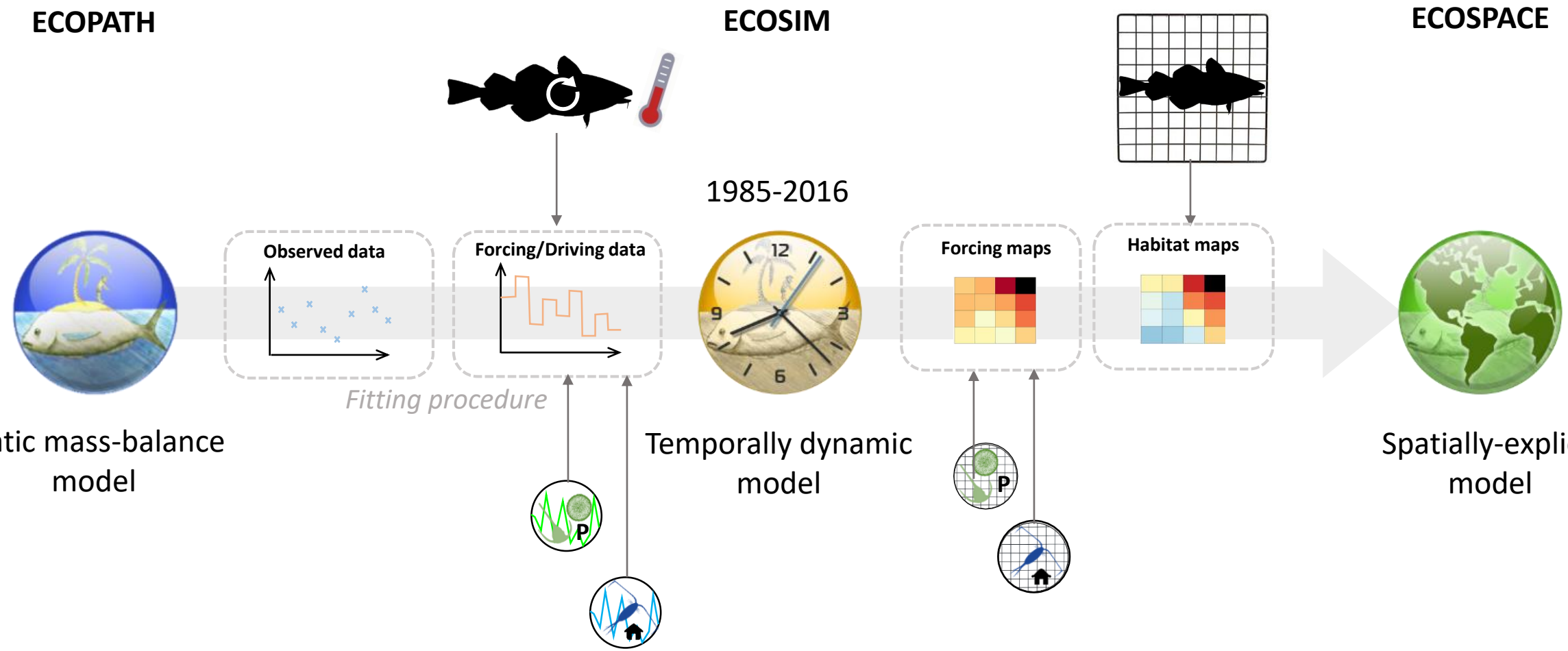
Sea **Bottom** temperature 2010s-2090s change RCP 8.5



RECENT PAST

1985-2016

RECENT PAST: INTEGRATING ENVIRONMENT TO FIT THE FOOD-WEB MODEL



FISHING IS STILL THE MAIN DRIVER OF ECOSYSTEM CHANGES OVER 1985-2016

- The Ecosim model fit can be used to investigate the main drivers of the overall ecosystem dynamics

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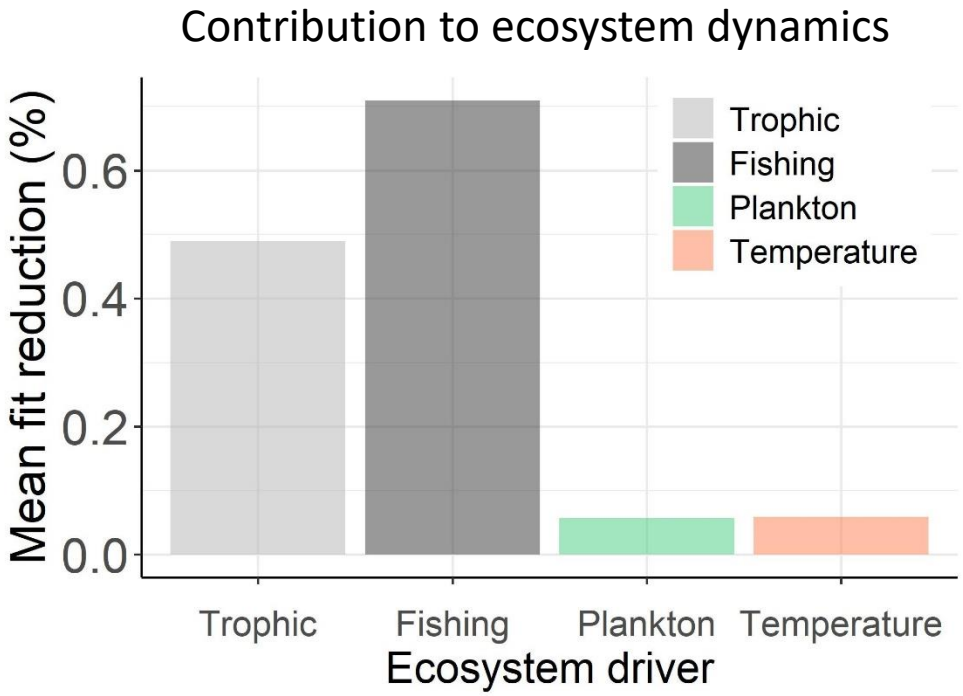

Hernvann et al. (2021)

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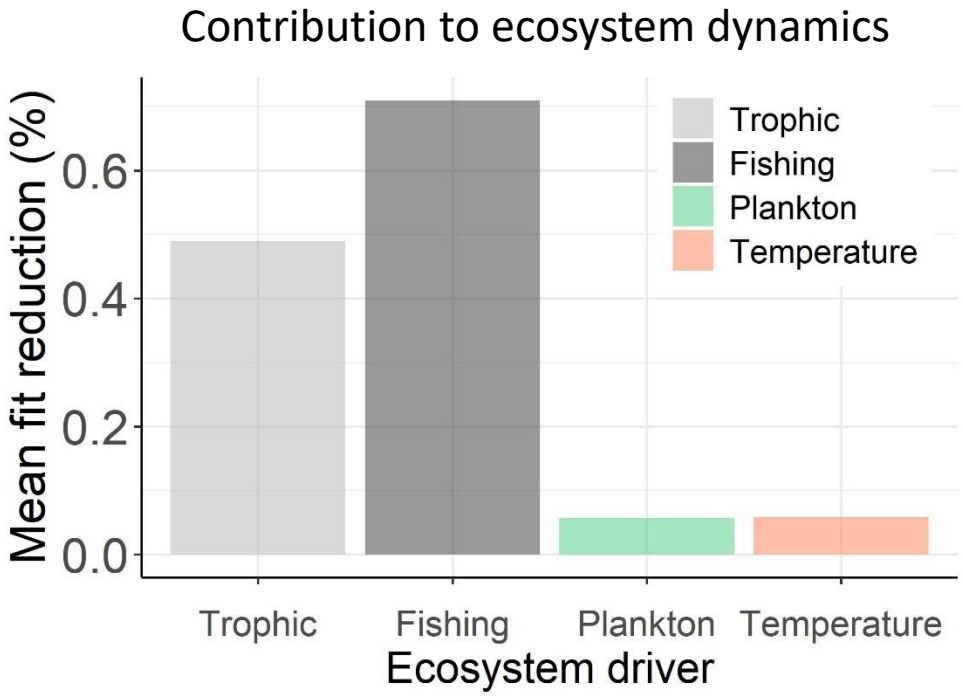

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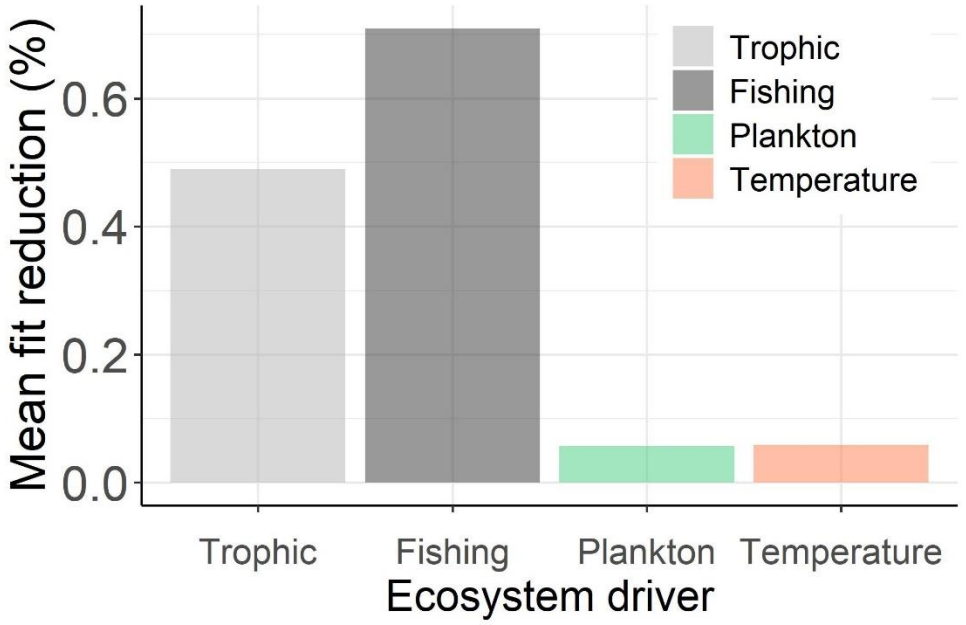
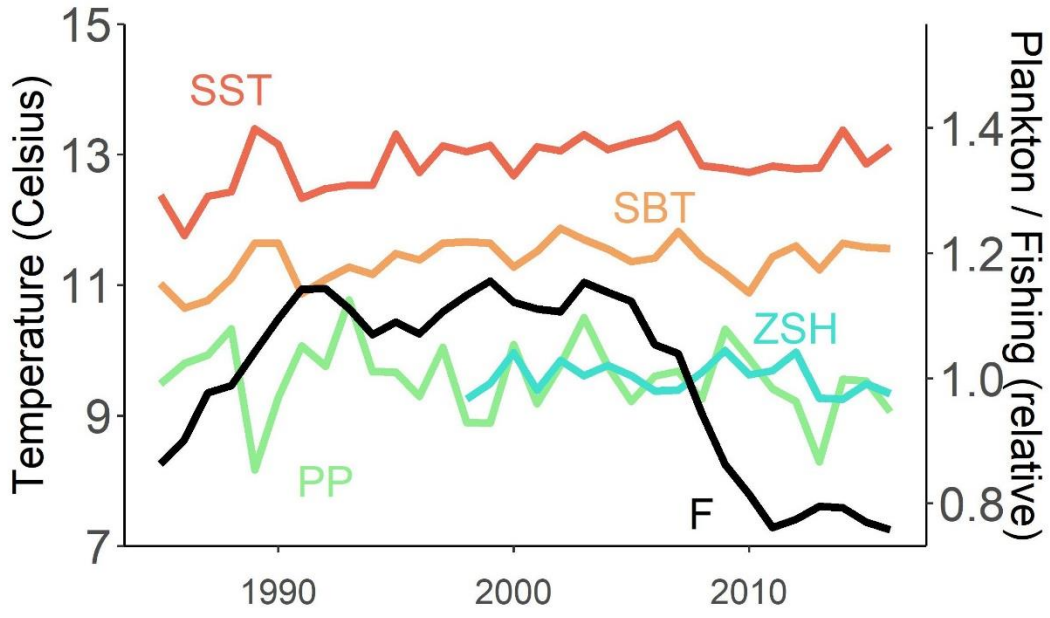
Contribution to ecosystem dynamics



Hernvann et al. (2021)

Environmental changes



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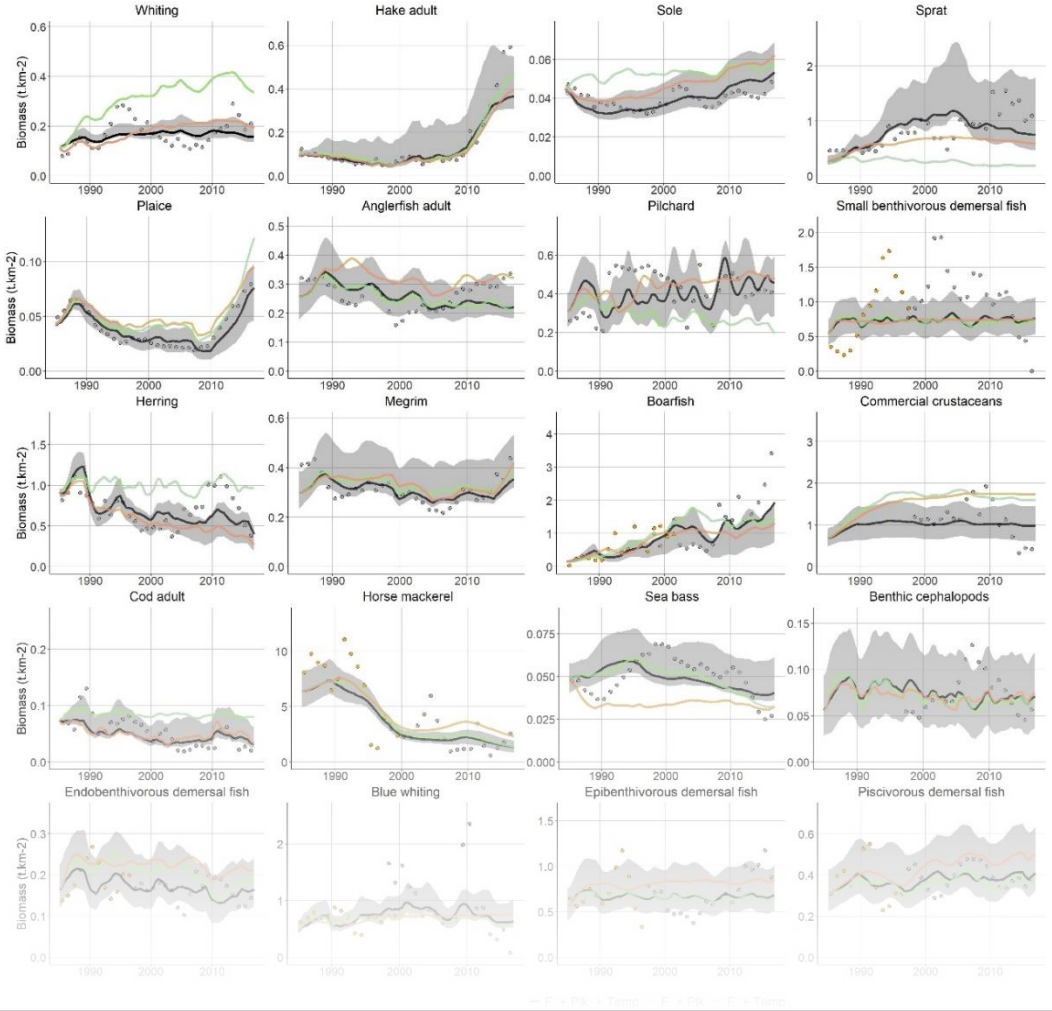
BUT COD'S DYNAMICS ARE INFLUENCED BY THE ENVIRONMENT OVER THE RECENT PAST

- The Ecosim model fit can be used to assess…
  - ✓ The ability of the model to reflect species dynamics
  - ✓ The effect of the ecosystem drivers on one species

Fit to time-series of observations



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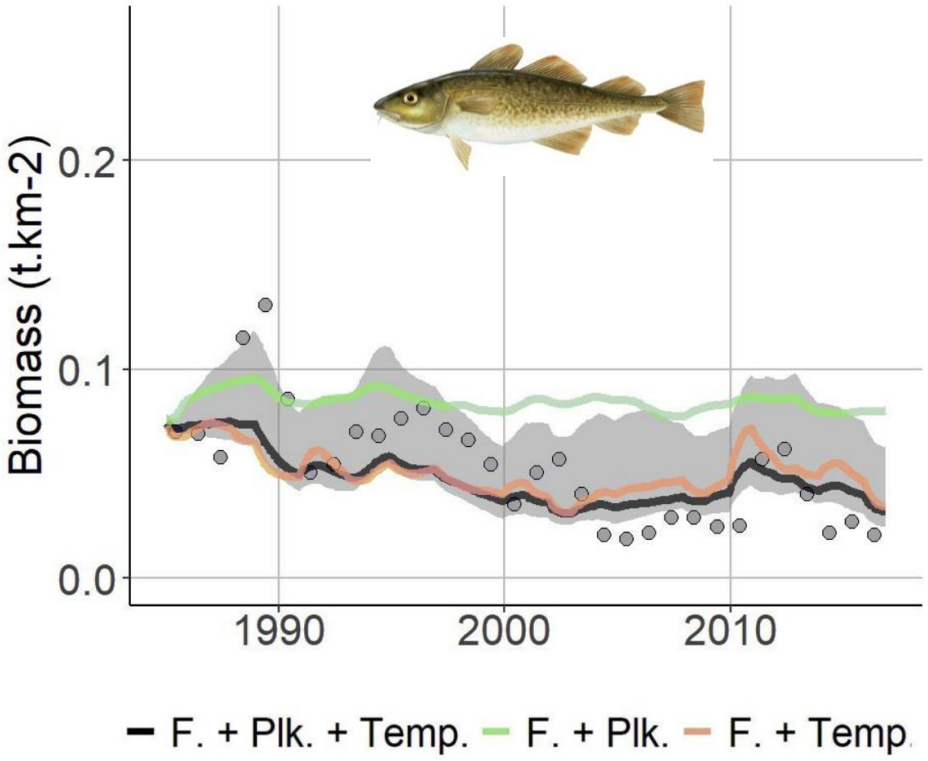
- ↘ in cod biomass isn't captured when temperature is excluded from the model
- Timing of the ↘ matches the early warming

Fit to cod (adult) biomass



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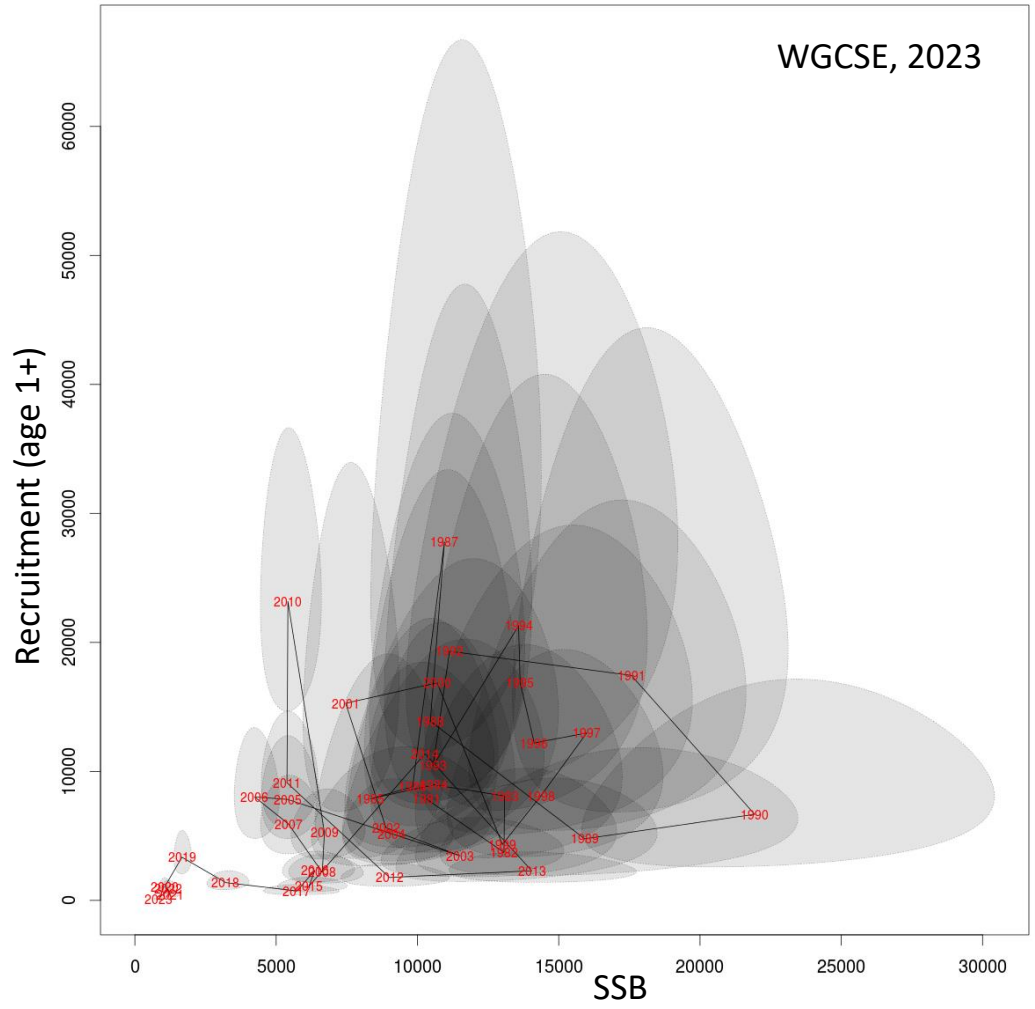
Stock-recruitment plot from the 2023 assessment



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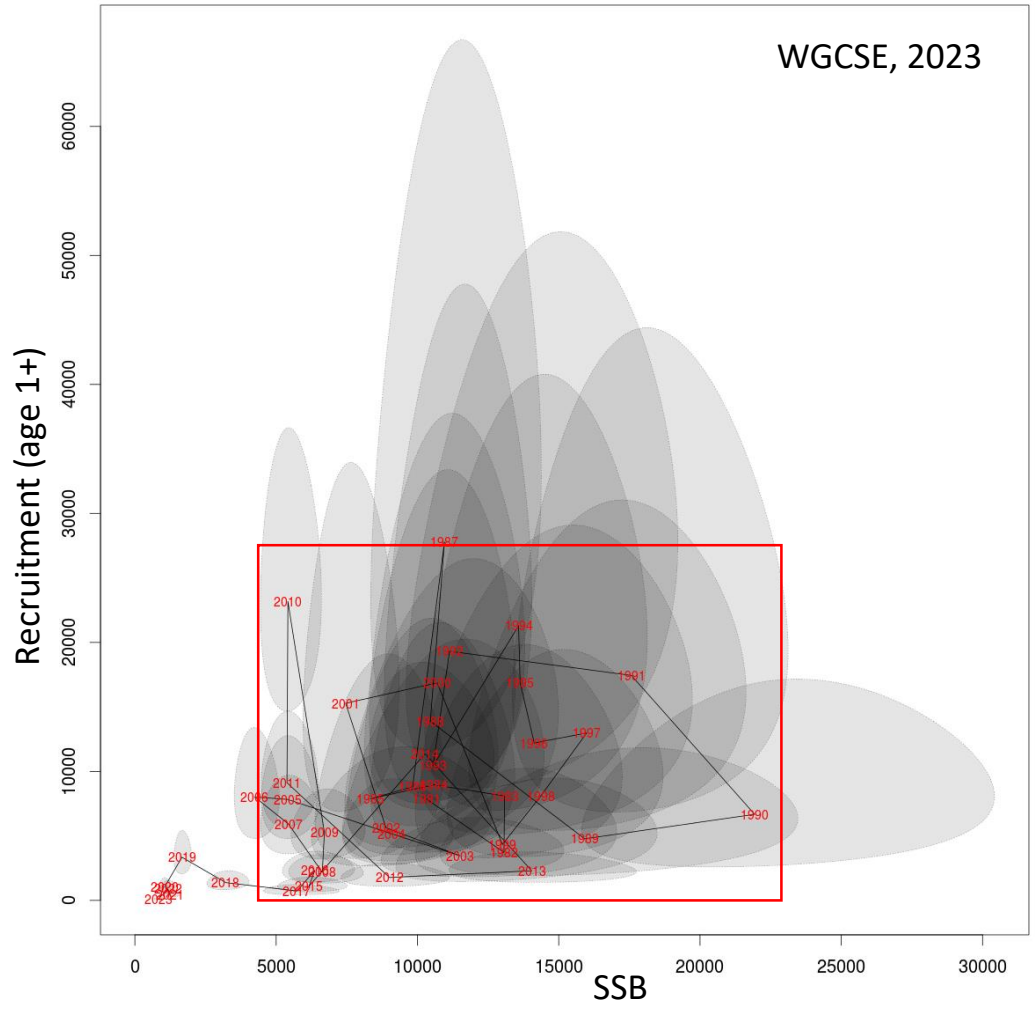

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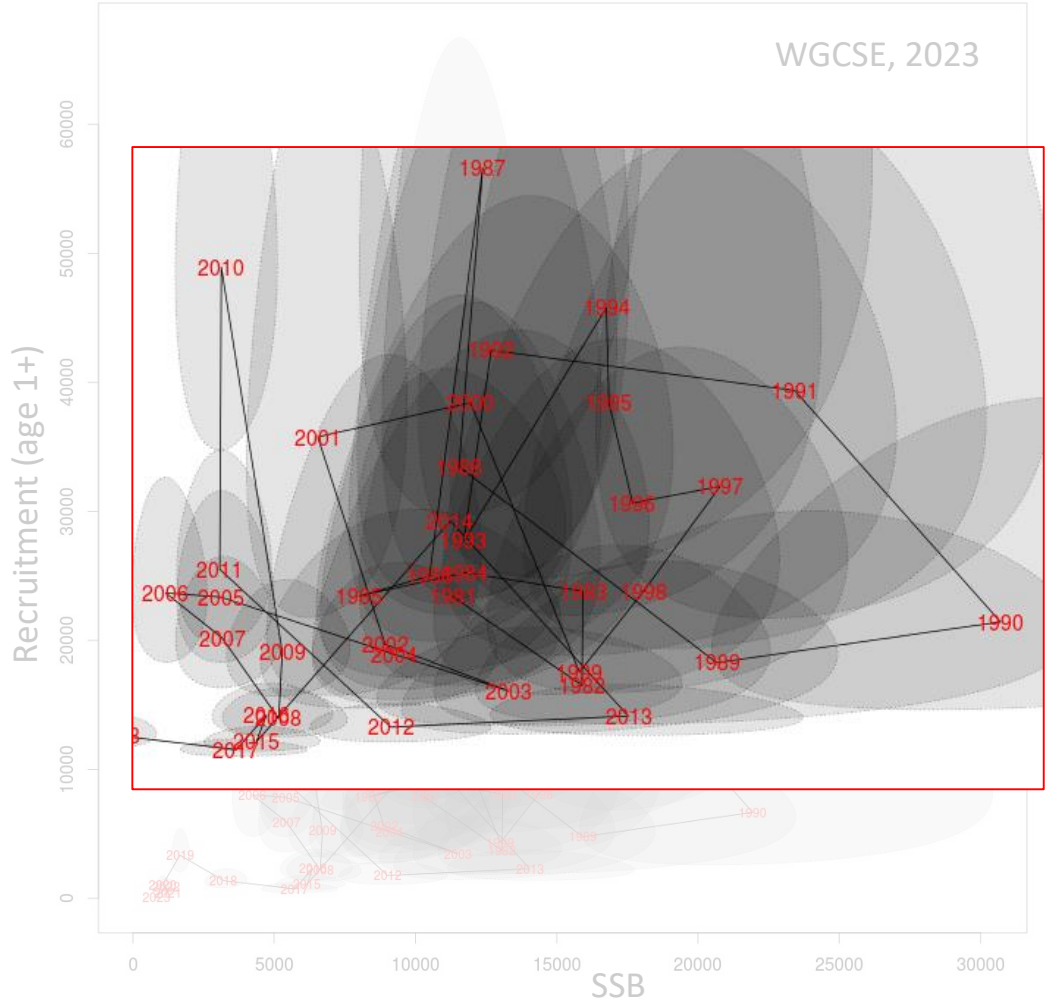

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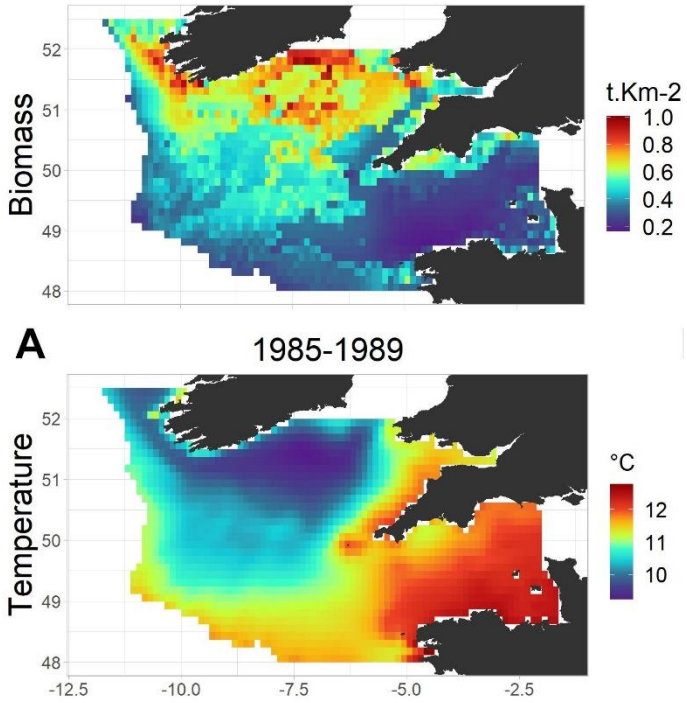

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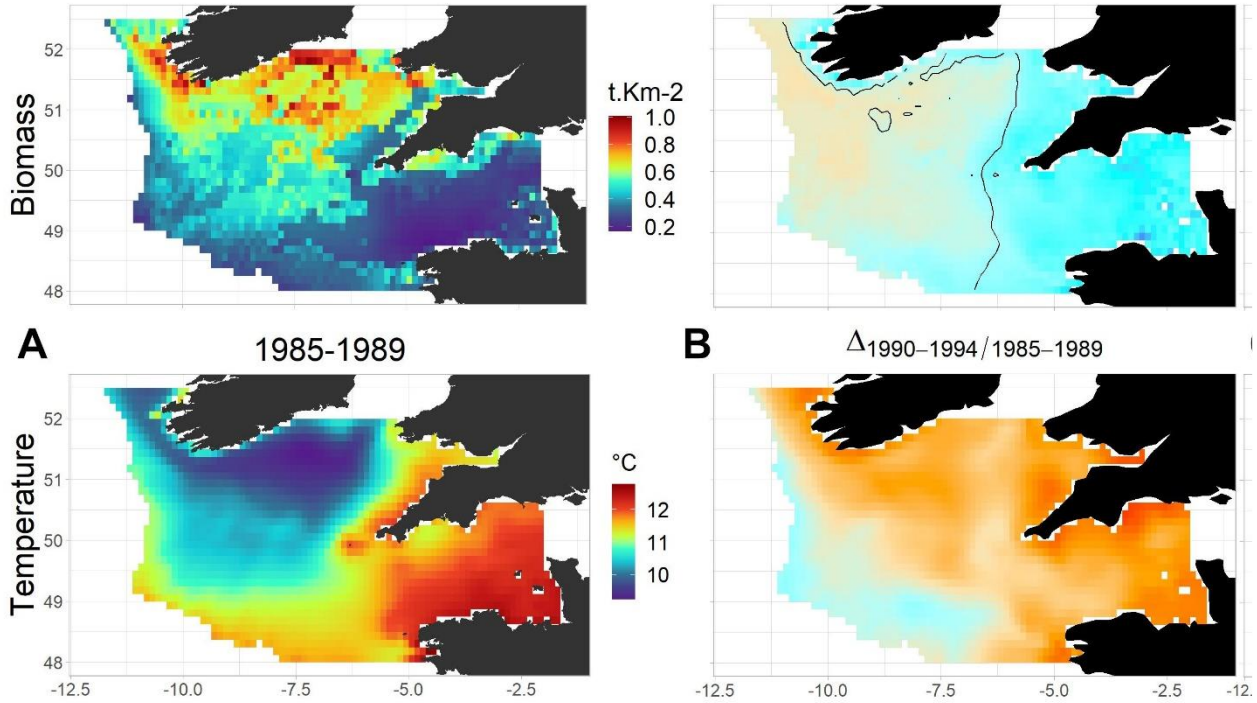
- Contraction of biomass in colder areas, especially in the mid-1990s

Change in the relative biomass distribution of demersal Boreal species



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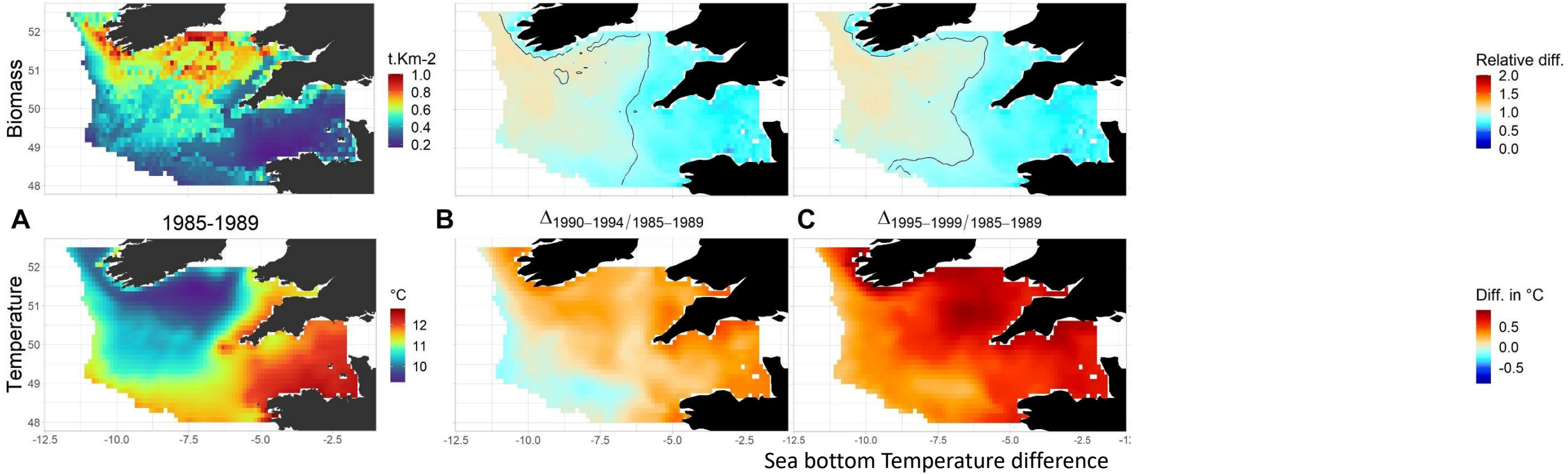

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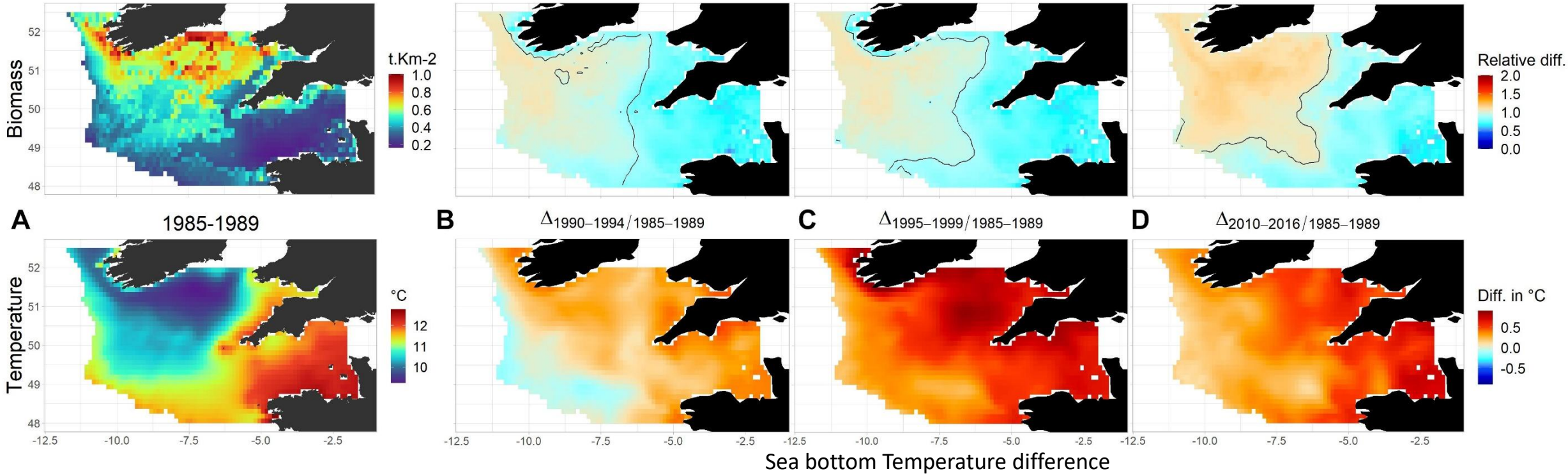
BUT COD'S DYNAMICS ARE INFLUENCED BY THE ENVIRONMENT

- Changes in cod's biomass distribution of reflects patterns affecting demersal Boreal species
- Contraction of biomass in colder areas, especially in the mid-1990s
- Driven by an overall warming, stronger in warmer areas

Change in the relative biomass distribution of demersal Boreal species

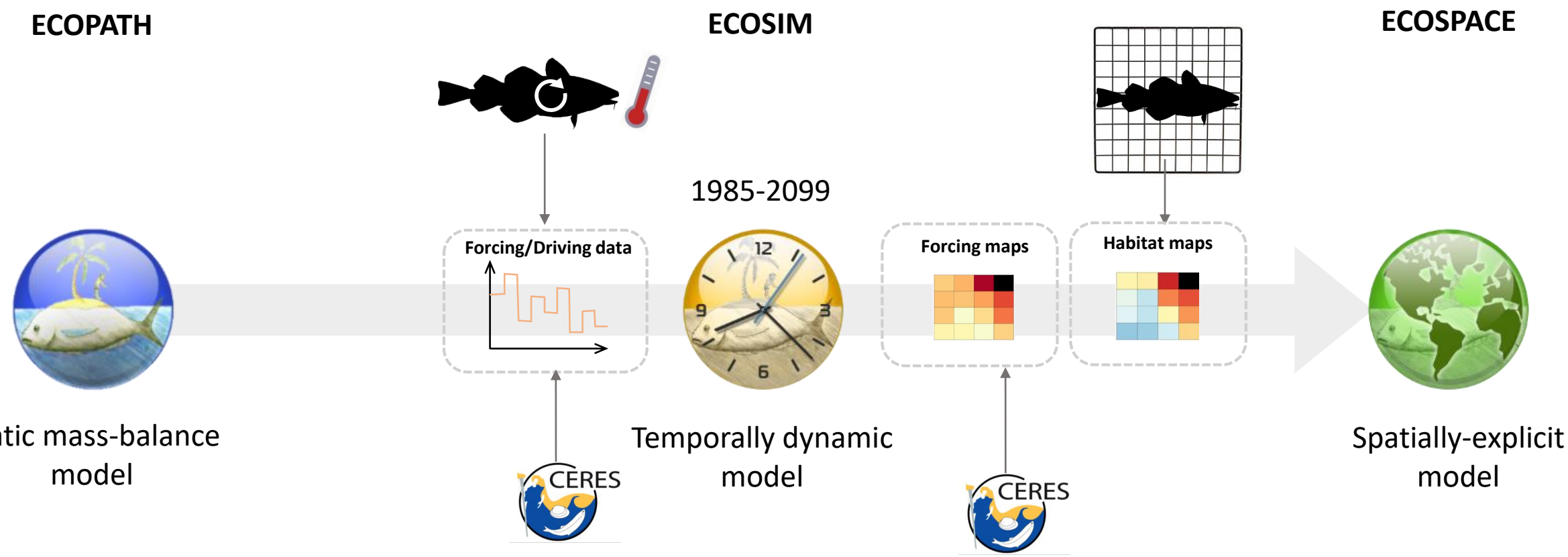


Sea bottom Temperature difference

FUTURE

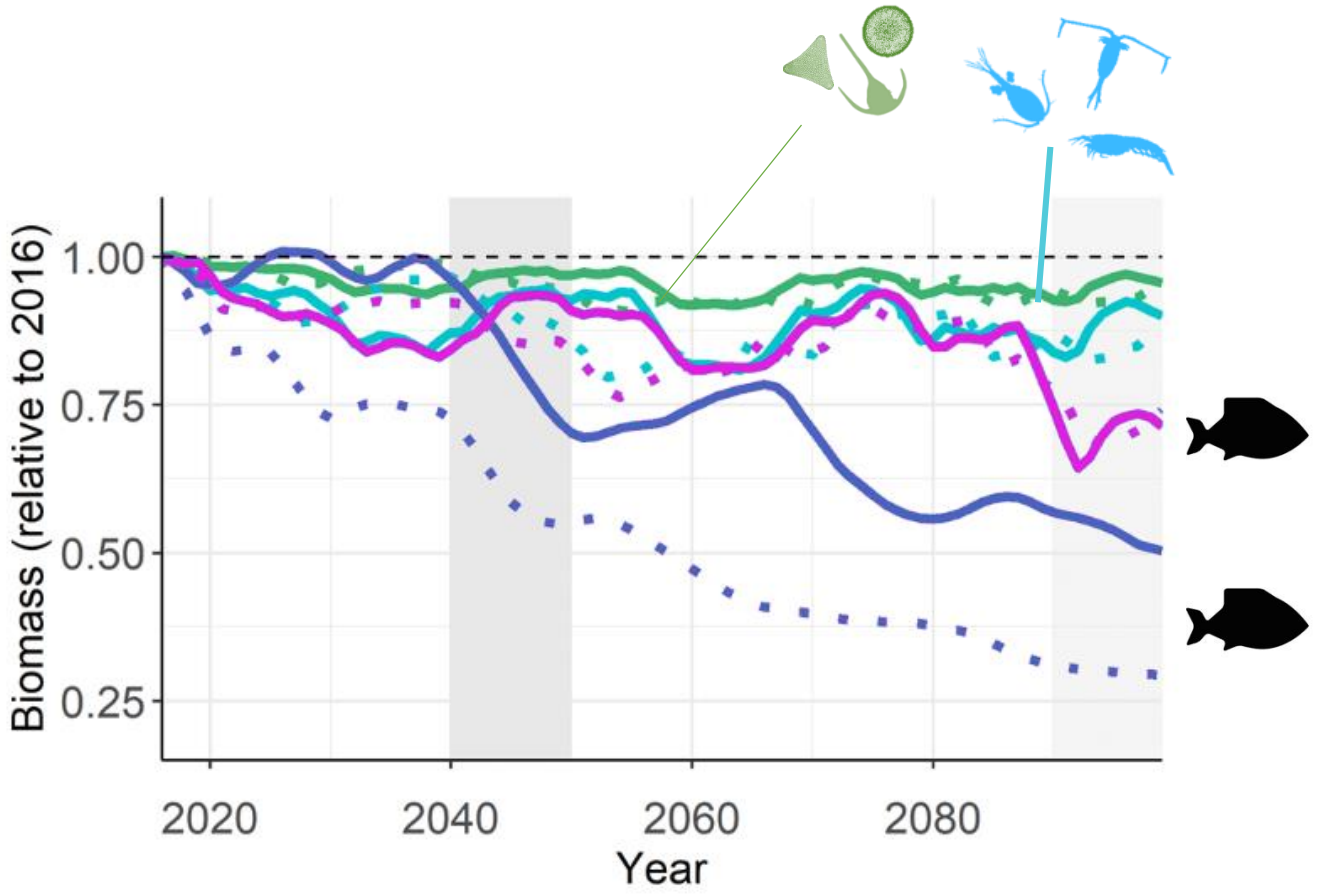
2016-2099

FUTURE: INTEGRATING PRIMARY PRODUCTION AND TEMPERATURE PROJECTIONS



FUTURE DEBOREALIZATION OF THE CELTIC SEA

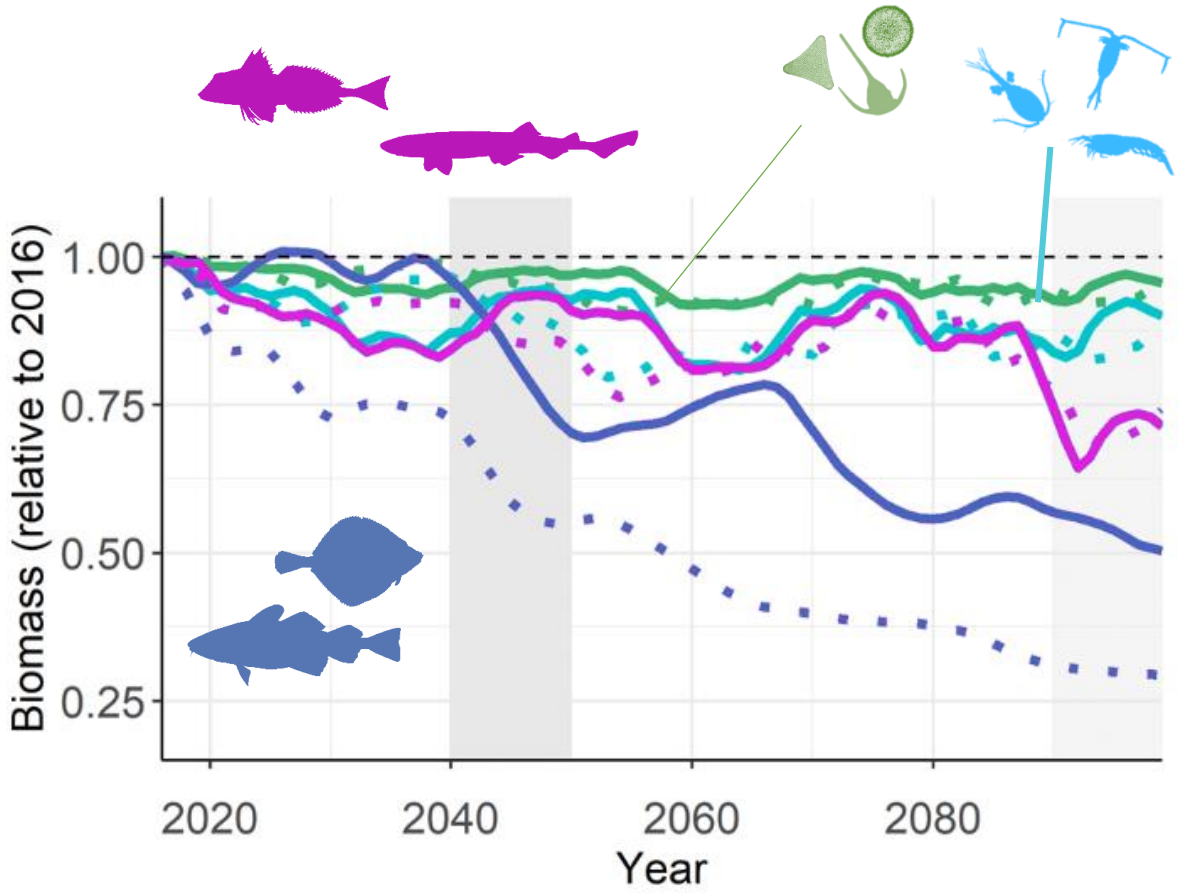
- The decline in the Primary production is amplified through the food web



Biomass trends according to TL and thermal preferenda

FUTURE DEBOREALIZATION OF THE CELTIC SEA

- The decline in the Primary production is amplified through the food web
- The biomass declines for most functional groups, whatever their thermal preferendum
- A larger decline for Boreal than for Lusitanian species….



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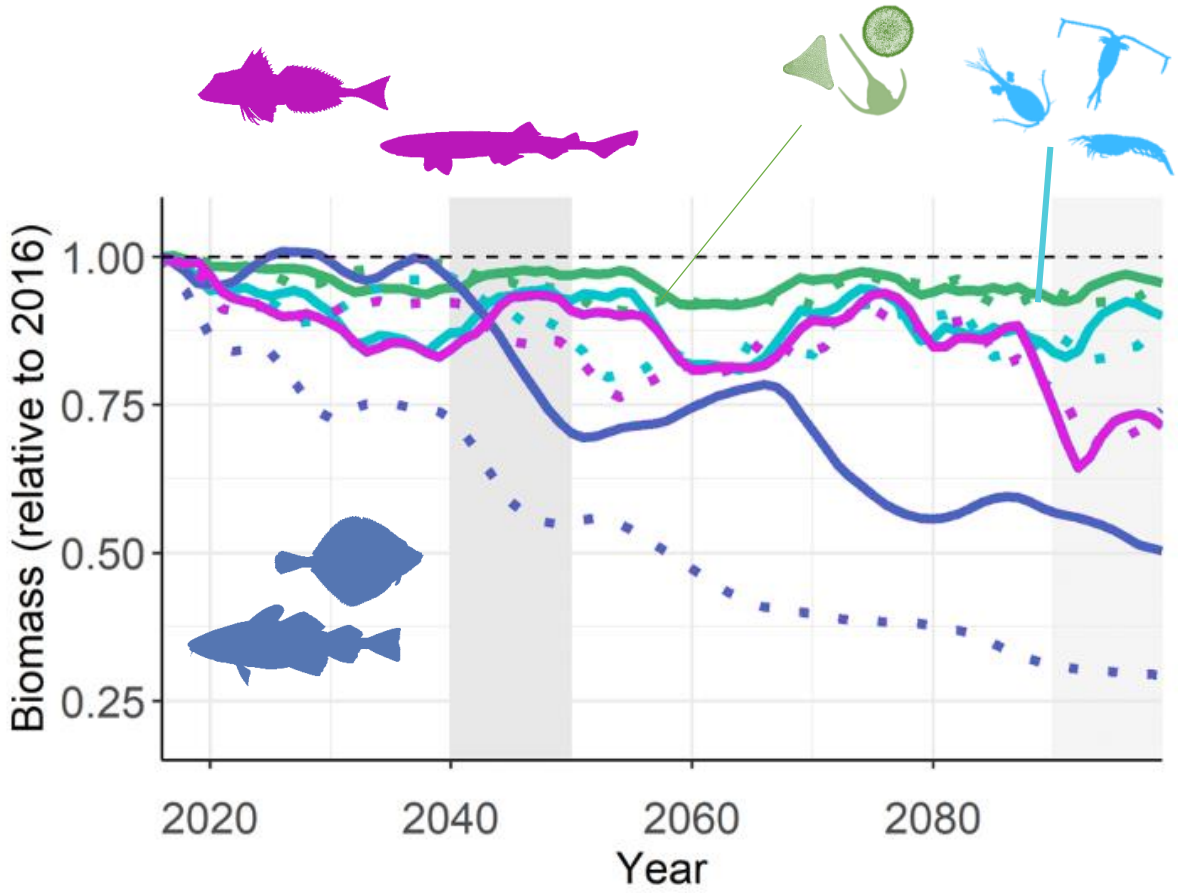

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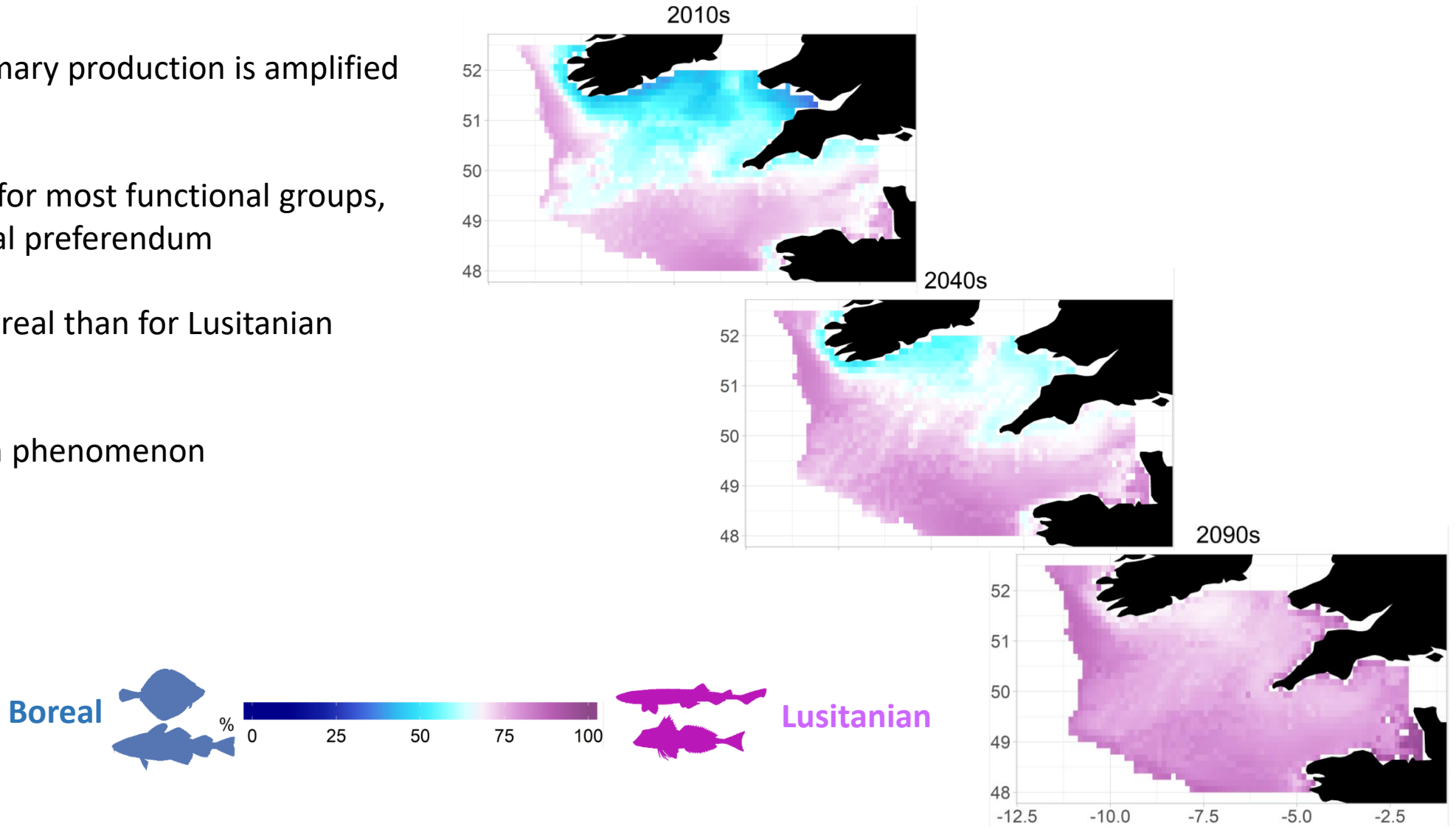
  → A deborealization phenomenon



OUR RESULTS SUGGEST / TAKE HOME MESSAGES

- As a result of the reduction in its environmental niche, cod will be one of the first/most commercial stocks negatively affected by climate change in the Celtic Sea
  - ✓ Productivity and biomass will decrease
  - ✓ Spatial distribution will contract
  - ✓ Consequences of climate change on cod will worsen with time
  - ✓ …and depend on the severity of climate change

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/!\ The niche is here estimated from an ad-hoc methodology, applied to aggregated biological and temporal scales

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/!\ EwE food-web model have a coarse biological resolution – Need of comparisons with other approaches (physiological, spawning, early life stages development, density dependence etc)

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/!\ The food-web model used for climate change projections needs more work…!

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/!\ Fisheries dynamics to be refined

- ❑ Climate change projections under a *status quo* scenario on fishing mortality
- ❑ Still an over-simplistic representation of fleets in the model
- ❑ Spatial distribution of fishing effort is still homogeneous

AN UPDATE TO THE CELTIC SEA FOOD-WEB MODEL

- Potier et al. *in prep* [PhD 2021-2024]

  Historical fit updated : 2003-2020

- A new realistic definition of fleets

  ✓ Clustering based on Fisheries Dependent Information (FDI) database (STECF, 2020)

HAC clusters	Fleet code	Country	Mainly exploited functional groups	Target species assemblages	Main fishing gears
1	ESP DEF lines	Spain	Hake	Demersal fish	Lines
	FRA DEF dorm	France	Hake, piscivorous demersal fish, seabass, anglerfish, benthivorous demersal fish		Passive fishing gears: lines and nets
	IRL DEF GNT	Ireland	Piscivorous demersal fish and hake		Nets
	UKM DEF dorm	UK	Piscivorous demersal fish, hake, mackerel		Passive fishing gears: lines, nets
2	FRA MOL OTB	France	Commercial bivalves, Benthic cephalopods, squids, benthivorous demersal elasmobranch and piscivorous demersal fish	Mollusks	Bottom otter trawl
	UKM MOL OTB/OTT	UK	Benthic cephalopods		Bottom otter
3	FRA SPF OTM	France	Ho her		
	IRL SPF PTR/OTM	Ireland	He ma		
	OTH SPF OTM	Others	Ho		
	UKM SPF PTR/OTM	UK	Ma		
4	FRA SPF PS	France	Sa		
	UKM SPF GNT	UK	Sa		
5	FRA CRU GNT/FPO	France	Co		
	IRL CRU FPO	Ireland			
	OTH CRU FPO	Others			
	UKM CRU FPO	UK			
6	FRA MOL FPO	France	Ne		
	UKM MOL FPO	UK	Ne SS		
7	FRA MOL DRA	France	Co		
	IRL MOL DRA	Ireland			
	UKM MOL DRA	UK			
8	FRA CRU OTT	France	Me		
	IRL CRU tr	Ireland	No		
	UKM CRU OTB/OTT	UK	Norway lobster, cod		Otter twin trawl and bottom otter trawl
9	ESP LPF lines	Spain	Large pelagic fish, pelagic sharks	Large pelagic fish	Lines
	FRA LPF PTR	France	Large pelagic fish		Pair trawls
	IRL LPF PTR	Ireland	Large pelagic fish		Pair trawls
	OTH LPF SEN	Others	Large pelagic fish, mackerel, horse mackerel		Seines
	UKM LPF lines	UK	Large pelagic fish		Lines
10	ESP DEF OTB	Spain	Anglerfish, piscivorous demersal elasmobranch, benthivorous demersal elasmobranch, hake, squids	Demersal fish	Bottom otter trawl
	FRA DEF tr	France	Megrim, Anglerfish, piscivorous demersal elasmobranch, benthivorous demersal elasmobranch, piscivorous demersal fish, blue whiting, cod		Active arts: seines and trawls
	IRL DEF tr	Ireland	Whiting, cod, piscivorous demersal fish, endobenthivorous demersal fish, anglerfish		Active arts: seines and trawls
	OTH DEF TBB	Others	Sole, plaice, benthivorous demersal elasmobranch, piscivorous demersal fish		Bottom beam trawl
	UKM DEF tr	UK	Sole, plaice, benthivorous demersal elasmobranch, anglerfish, piscivorous demersal fish, endobenthivorous demersal fish		Active arts: seines and trawls

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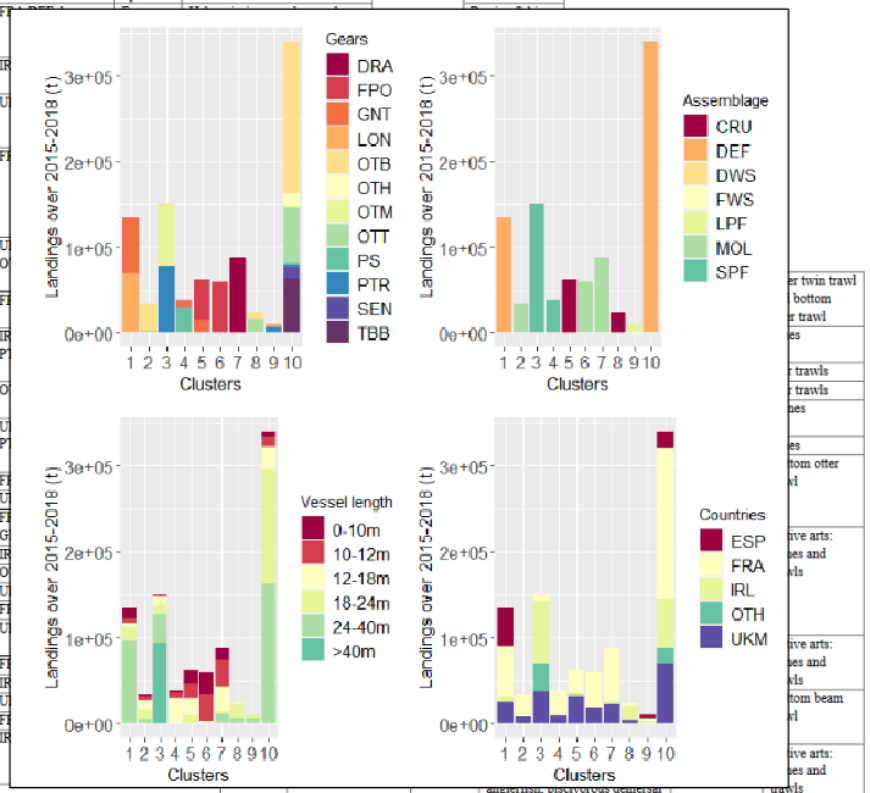

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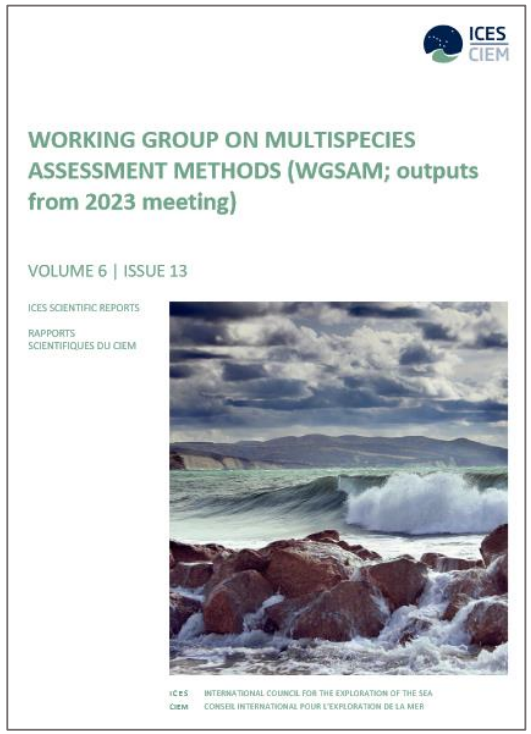
WGSAM



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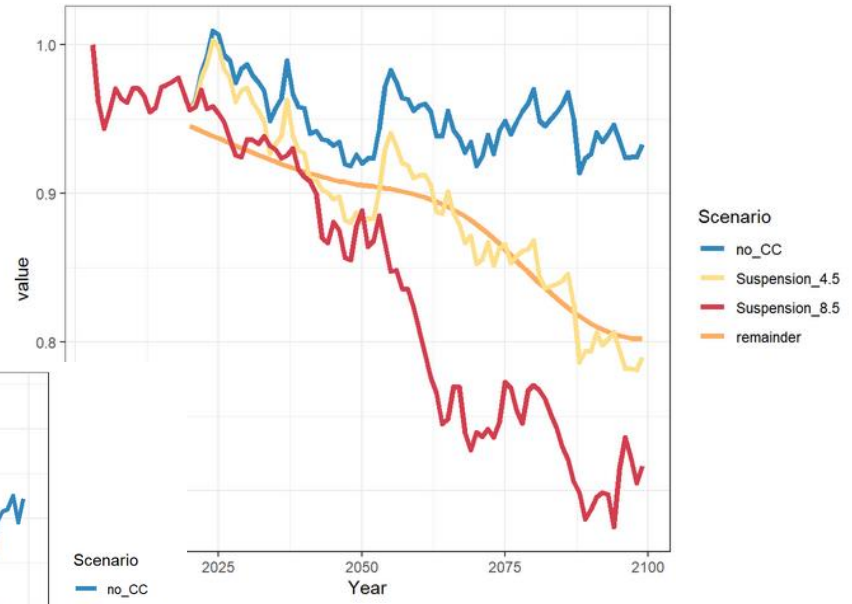
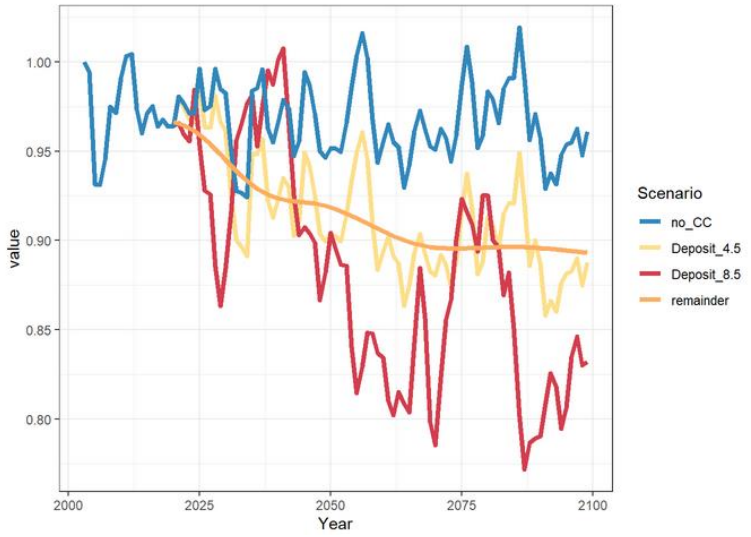
- Additional pertinent bottom-up drivers of cod dynamics?

Suspension feeders rel. biomass



Deposit feeders rel. biomass



Pierre-Yves Hernvann – June 12th 2024 – NWWAC Webinar

pierre.yves.hernvann@gmail.com