Precarious livelihoods in changing oceans

Salmon, sandeels, plankton, and people

Neil Banas
Strathclyde U, Glasgow, UK
neil.banas@strath.ac.uk

together with
Emma Tyldesley
Aislinn Borland
Agnes Olin
Charlotte Regan
Maria Bogdanova
Colin Bull
Jon Emery
Ruedi Nager
Øystein Varpe
Sarah Wakelin
David Johns
and many others!

THE MISSING SALMON ALLIANCE

Likely Suspects Framework

UKRI Natural Environment Research Council

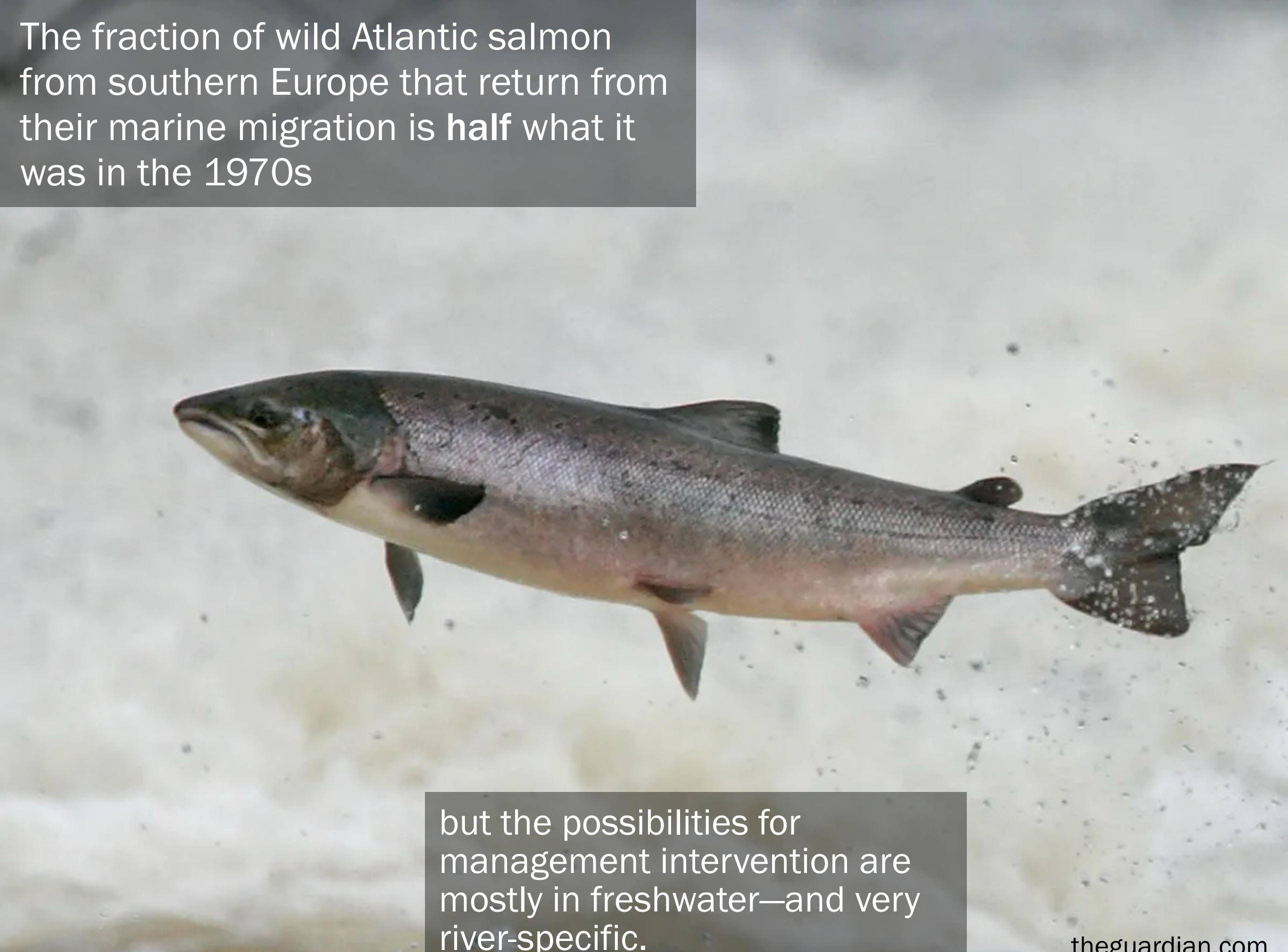
Ecowings
(part of Ecowind)

MARINE ALLIANCE FOR SCIENCE AND TECHNOLOGY FOR SCOTLAND

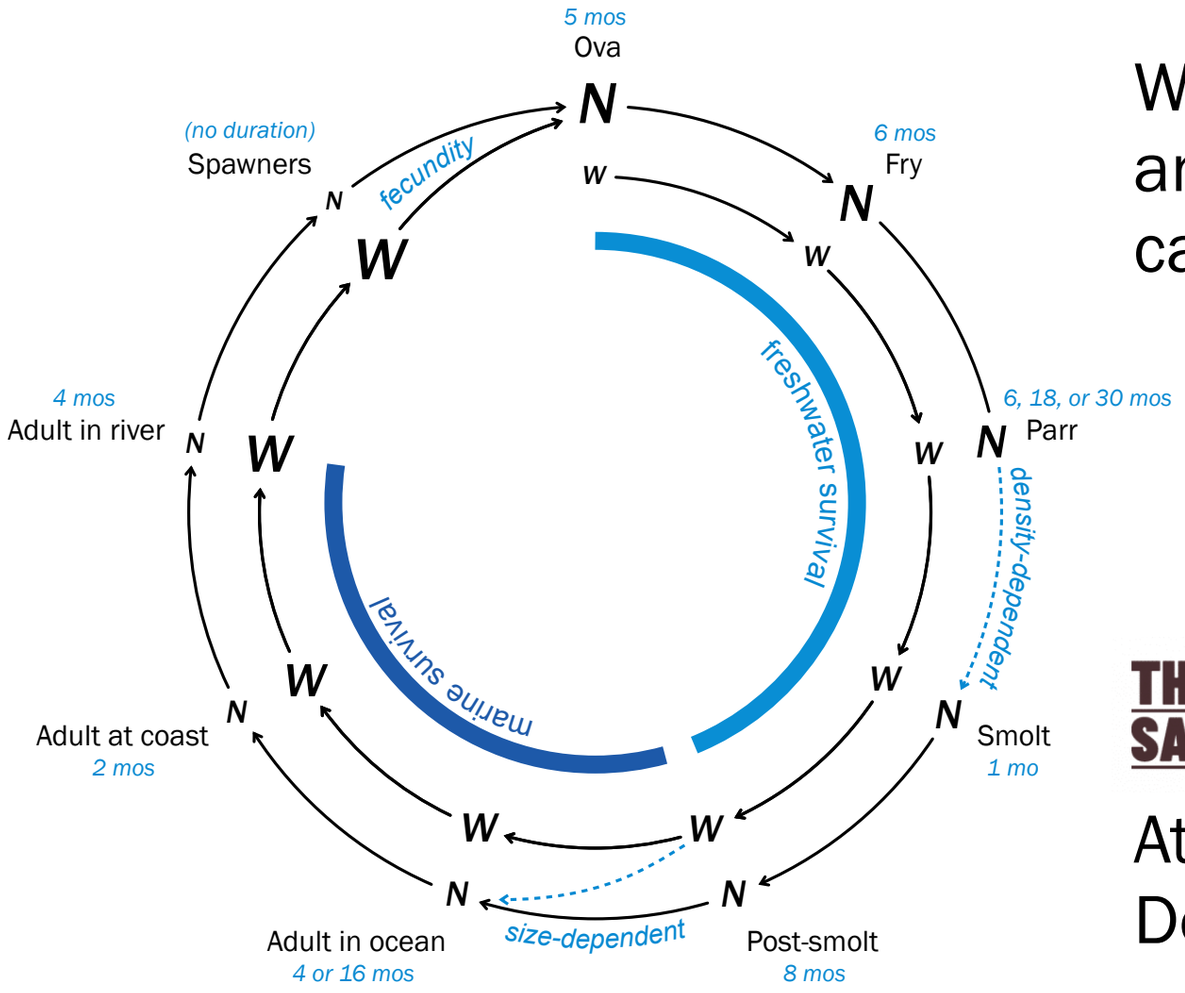
Working Group on Migration and Prey Energyscapes

- **The setting: "conservation oceanography"**
  (salmon, seabirds, plankton)
- A coarse-grained picture of despair
- The problem (if that's what it is) of scale
  (matsutake mushrooms, social anthropology)
- Fine-grained stories about resilience

The fraction of wild Atlantic salmon from southern Europe that return from their marine migration is **half** what it was in the 1970s



but the possibilities for management intervention are mostly in freshwater—and very river-specific.

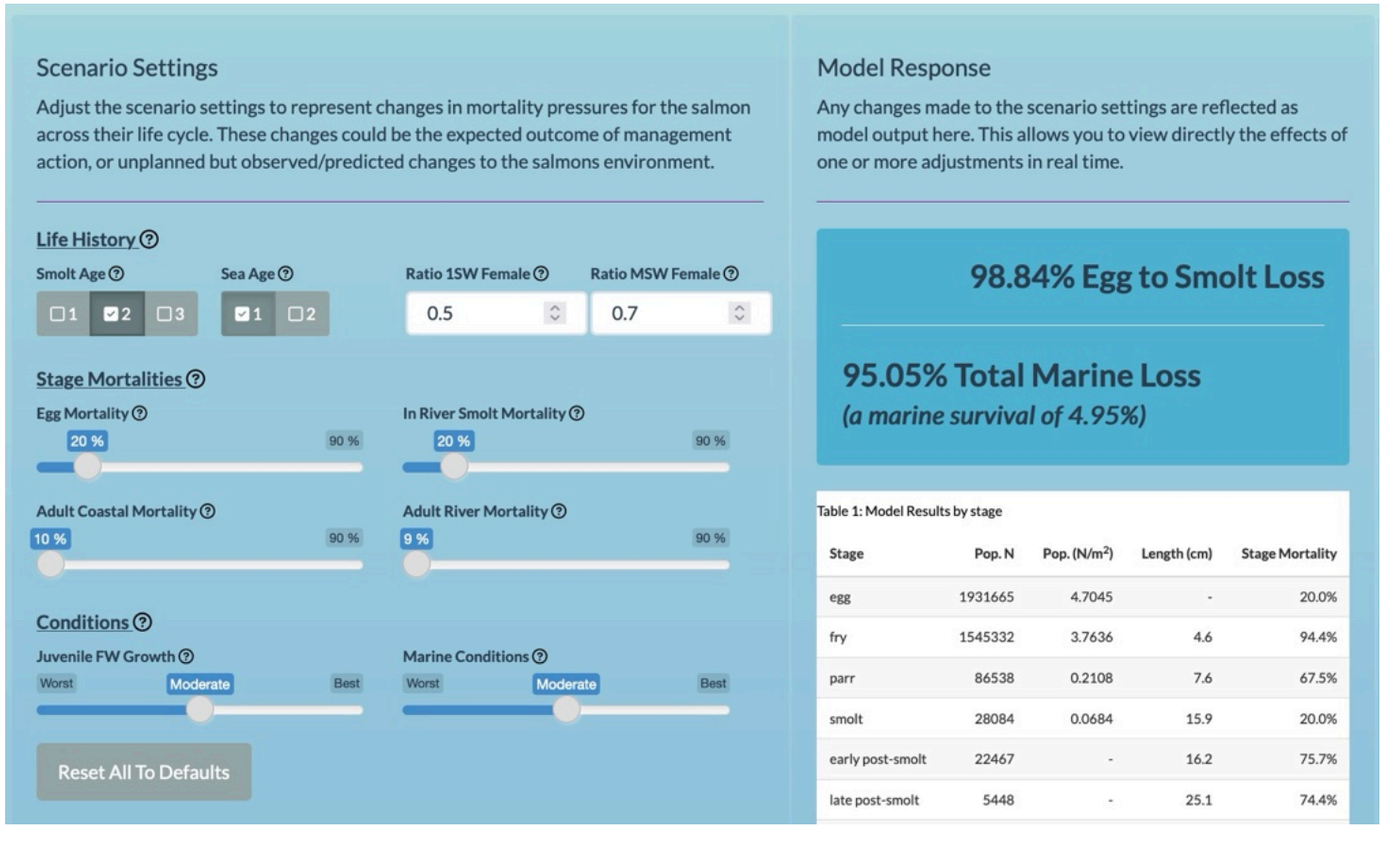


Whole-life-cycle model of salmon growth and survivorship, including size-dependent carryover effects from river to ocean to river

THE MISSING SALMON ALLIANCE

Atlantic Salmon Managers Decision Support Tool

shiny.missingsalmonalliance.org/salmonDST



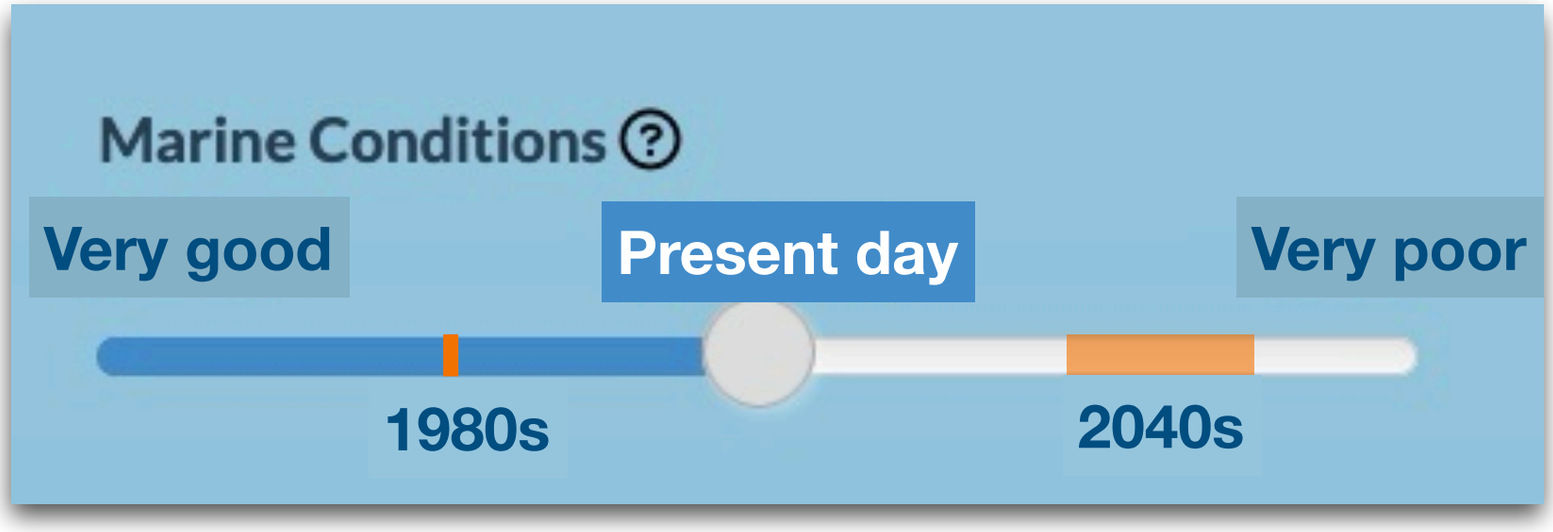
A mockup of a new selector for marine scenarios (in development 2025–26).

How do we inform managers building a specific river scenario how fast the marine baseline is shifting?

THE MISSING SALMON ALLIANCE

Atlantic Salmon Managers
Decision Support Tool

shiny.missingsalmonalliance.org/salmonDST



A simplified food chain for Southern European salmon post-smolts

further reading:
Haughland et al. 2006,
Utne et al. 2022

size

post smolts

FORAGE FISH

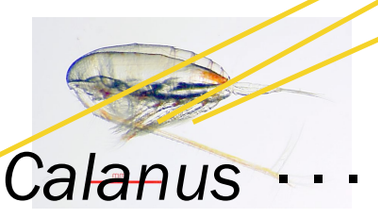
blue whiting

sandeels

ZOOPLANKTON

Oithona · · · *Pseudocalanus*

small copepods · · · *Calanus* · · ·



euphausiids

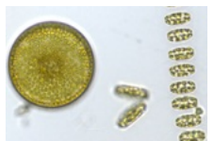
amphipods

appendicularians

phytoplankton

bacteria · · · diatoms

other
protists



The UK's breeding seabirds have declined 25% since the 1980s—in Scotland, **49%**

nature.scot

Atlantic puffin

black-legged kittiwake

On Scotland's North Sea coast, the sandeels that many seabirds rely on to feed their chicks are getting **smaller.**

Burthe et al. 2012

Why is this happening, and is it going to continue?

Keith Mutch / nature.scot

North Sea kittiwakes,
puffins, guillemots, ...

post smolts

FORAGE FISH

blue whiting

sandeels

ZOOPLANKTON

Oithona · · · *Pseudocalanus*

small copepods · · · *Calanus* · · ·

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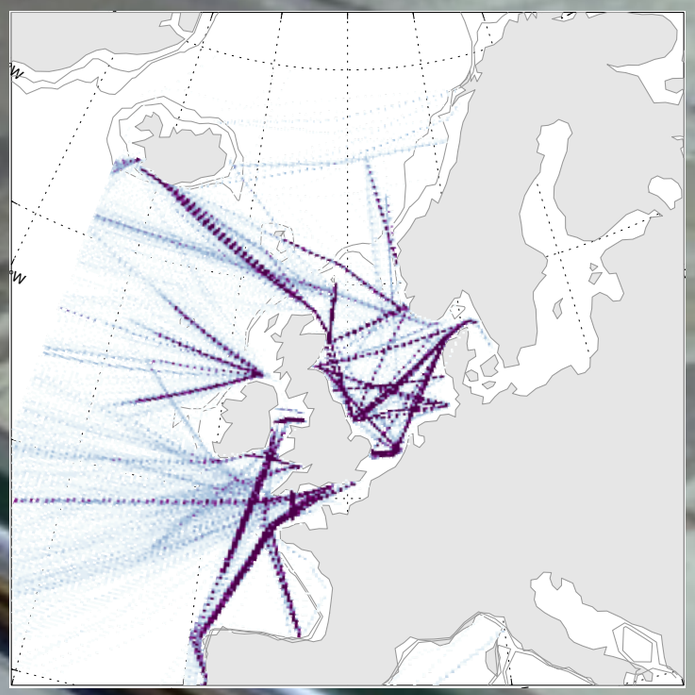
other
protists

- The setting: “conservation oceanography”
- **A coarse-grained picture of despair**
- The problem (if that’s what it is) of scale
- Fine-grained stories about resilience

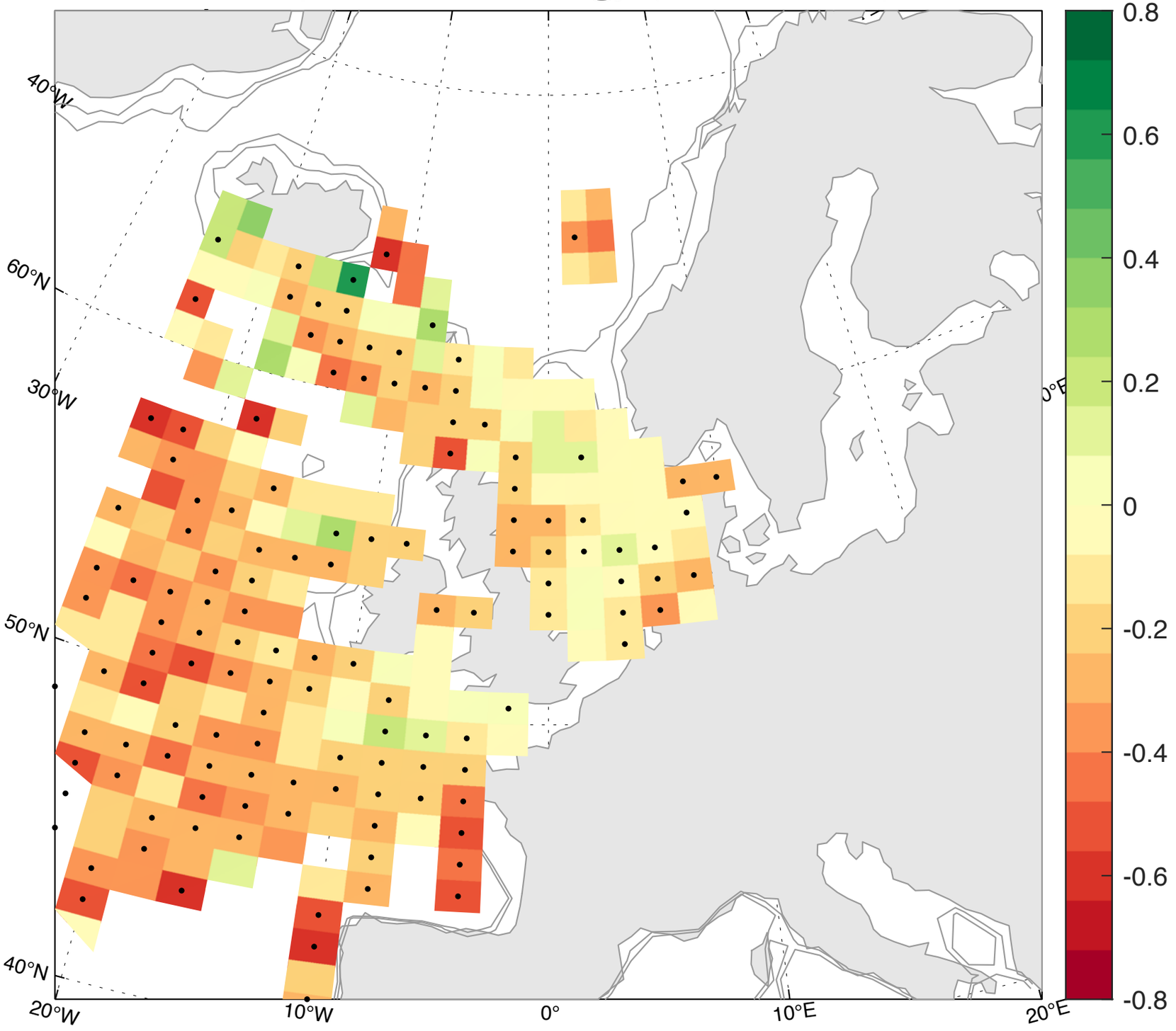
Continuous Plankton Recorder surveys on ships of opportunity, 1960s onward: zooplankton captured on lengths of treated silk



Marine Biological Association

Fractional change per decade in zooplankton energy (ZE, kJ m^{-2})

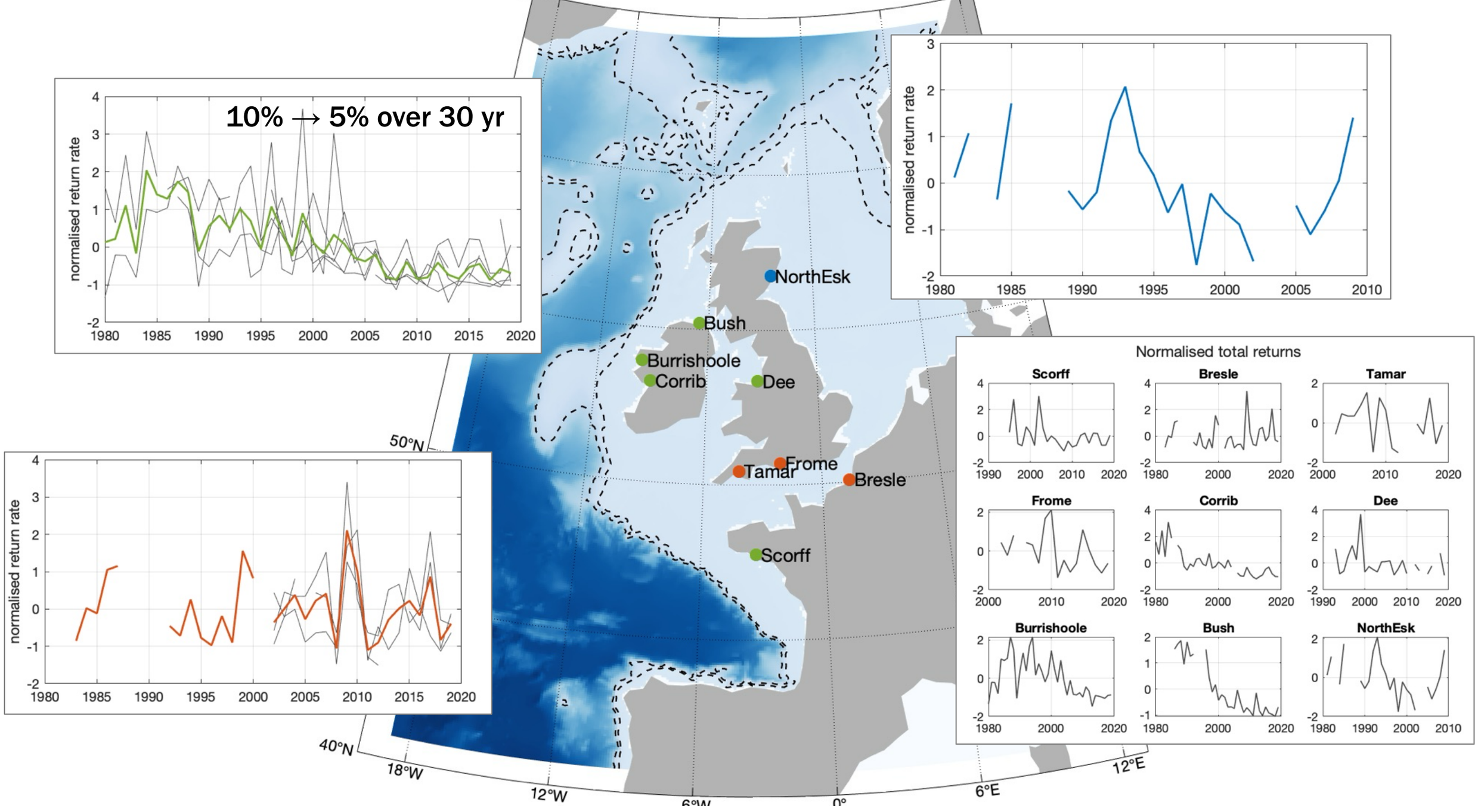
$$\log_{10}(ZE + 1) \sim a + \boldsymbol{b} \cdot \text{year}$$



Only showing 40+ year spans, before 1980 – after 2000

· p<0.05

(Tyldesley et al. *ICES JMS*, 2024)



Salmon marine return rates fall into regional clusters—

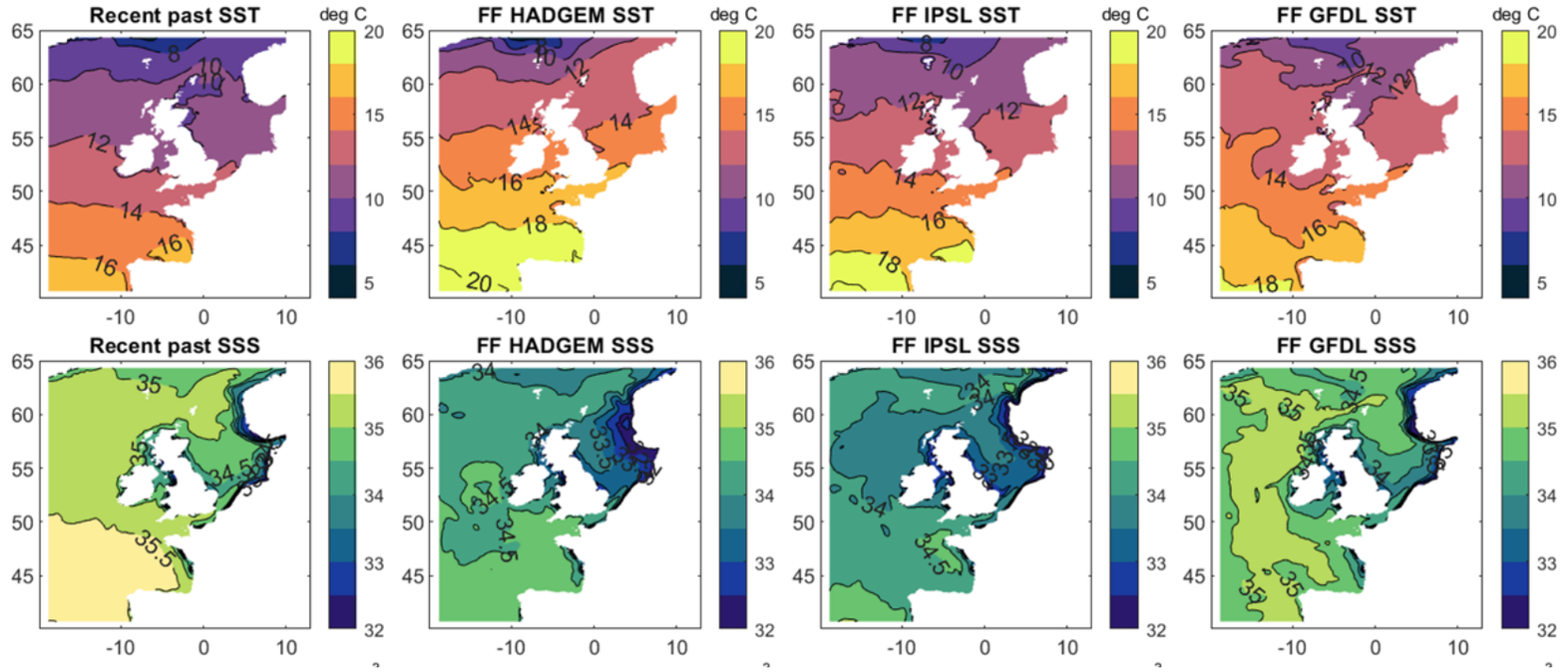
and **west river returns** correlate best with ZE in the adjacent NE Atlantic, while **North Sea river returns** correlate best with ZE in the North Sea

(Tyldesley et al. *ICES JMS*, 2024)

(Tyldesley et al., in prep)

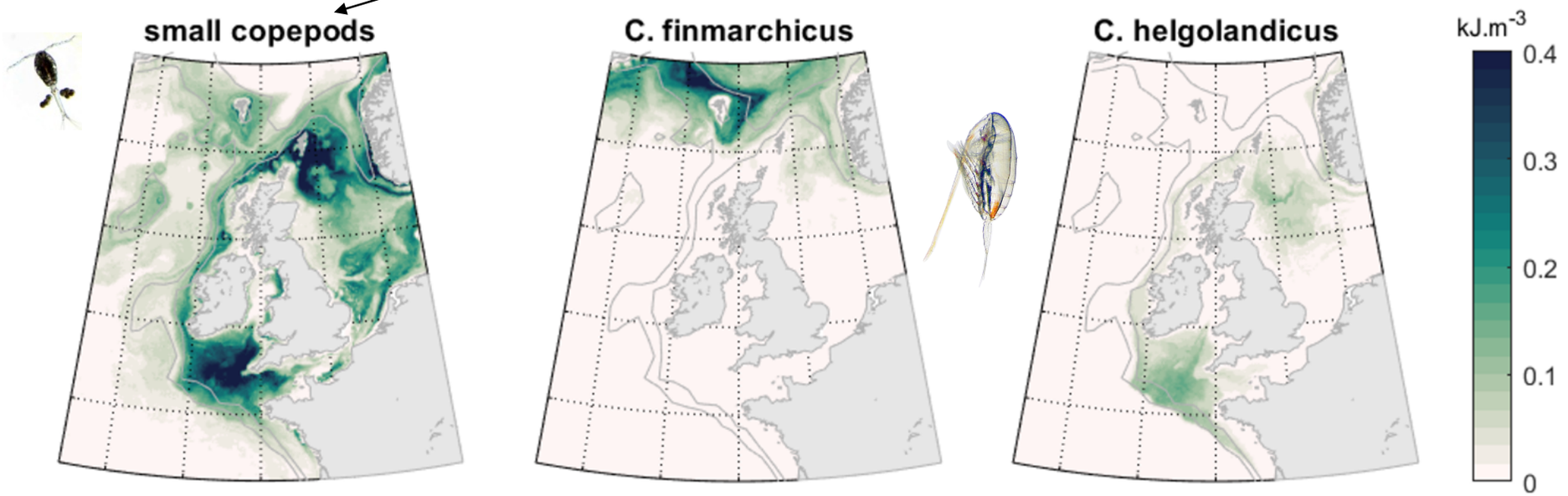
Surface temperature

Surface salinity



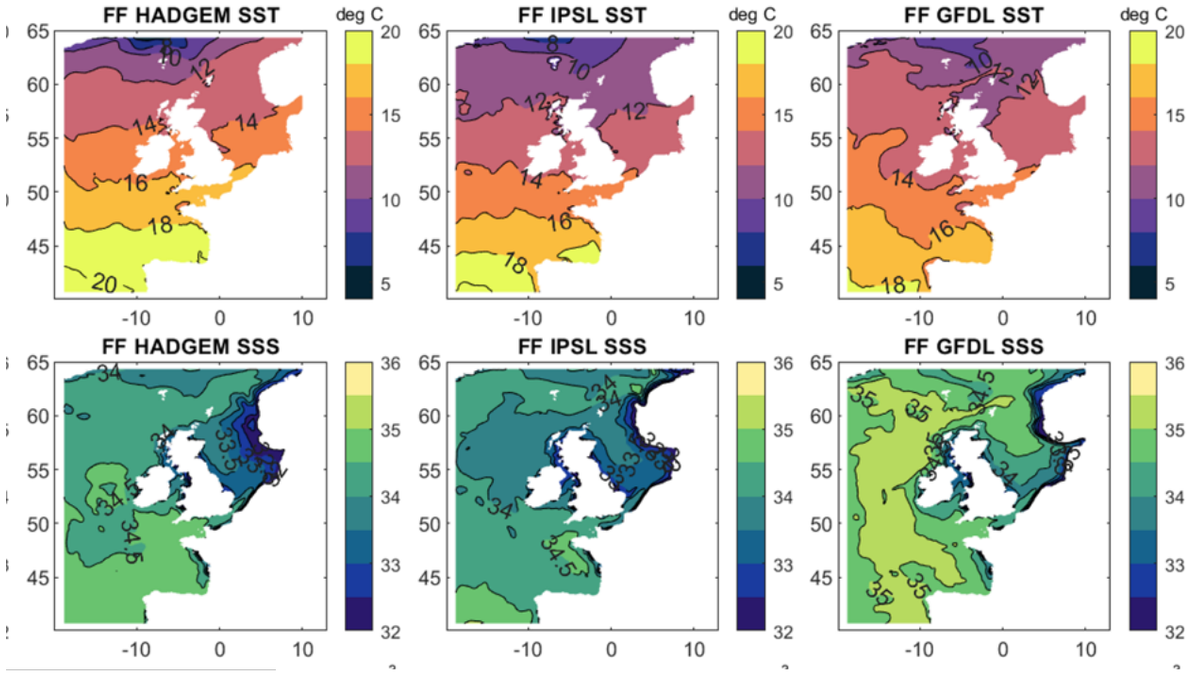
25-year AMM7 reanalysis

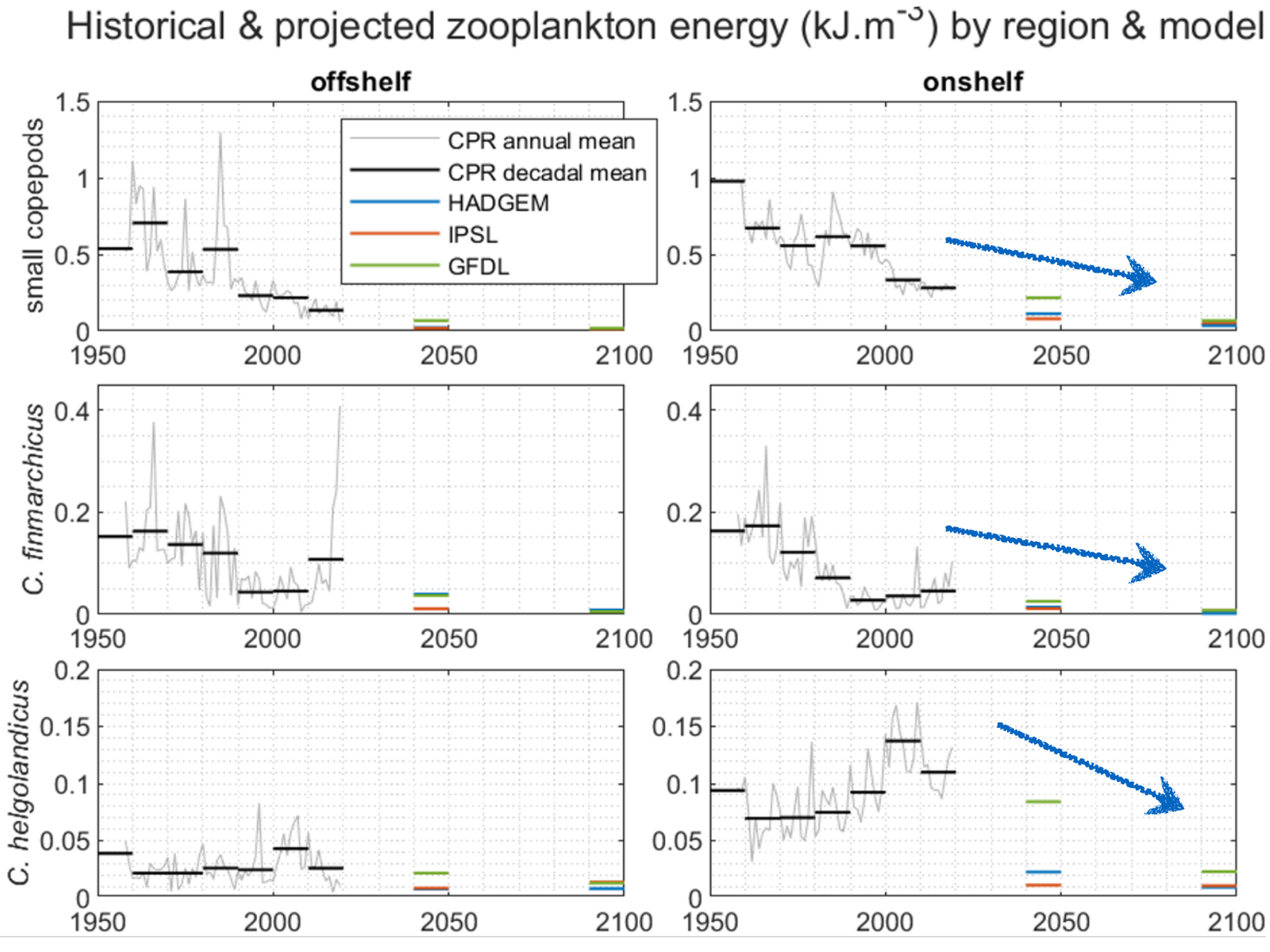
Three downscaled projections (shown: RCP8.5 2090s)



Random forest model for three copepod groups in Continuous Plankton Recorder data (predictors: physics, SPG index, bloom metrics, nitrate, yearday, depth)

(Tyldesley et al., in prep)





The random-forest copepod model suggests continuing huge declines in the “energetics of the ocean”.

It would be great to find reason to think this is not the end of the story.

- The setting: “conservation oceanography”
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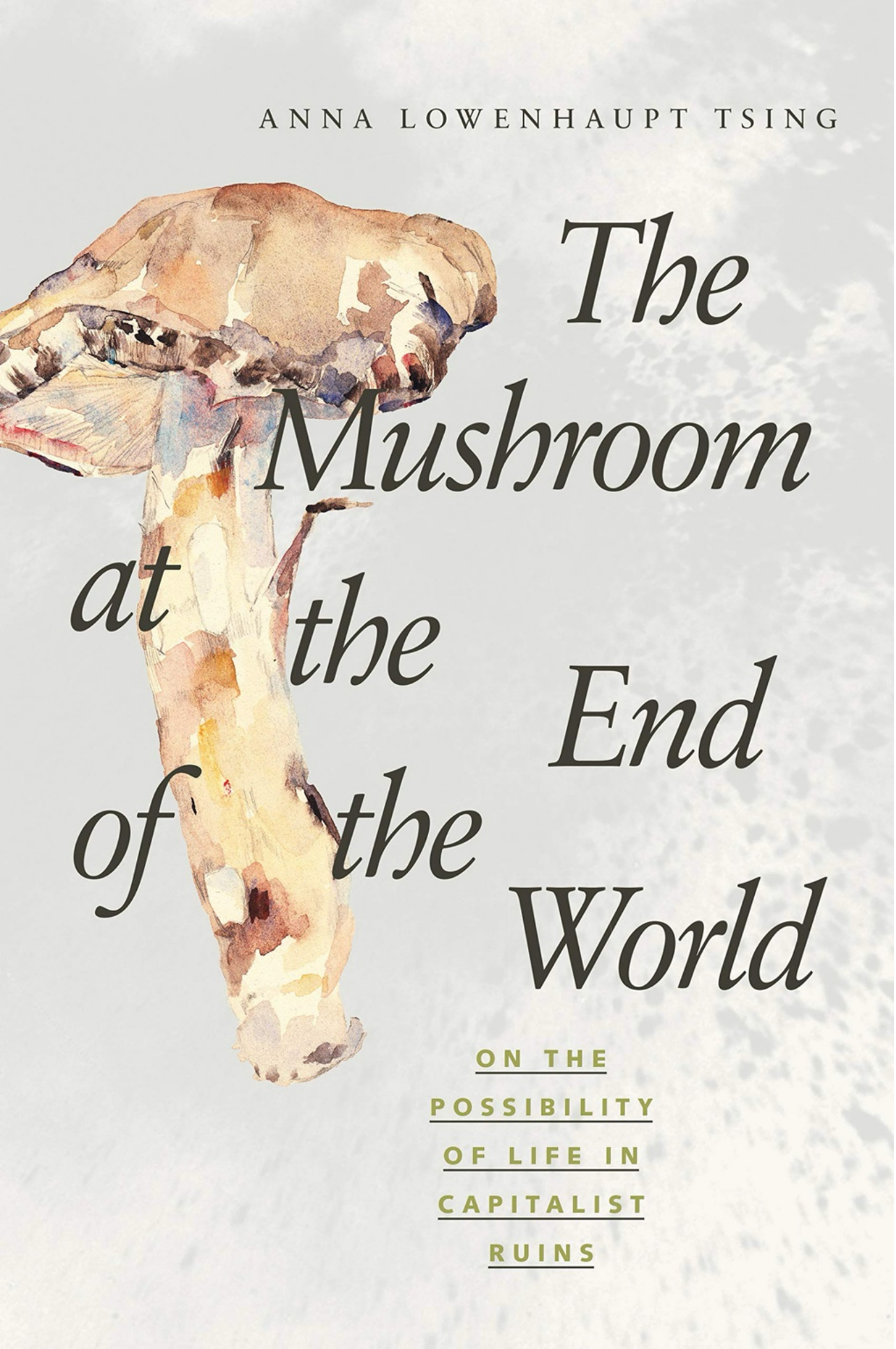
- **The problem (if that’s what it is) of scale**
- Fine-grained stories about resilience



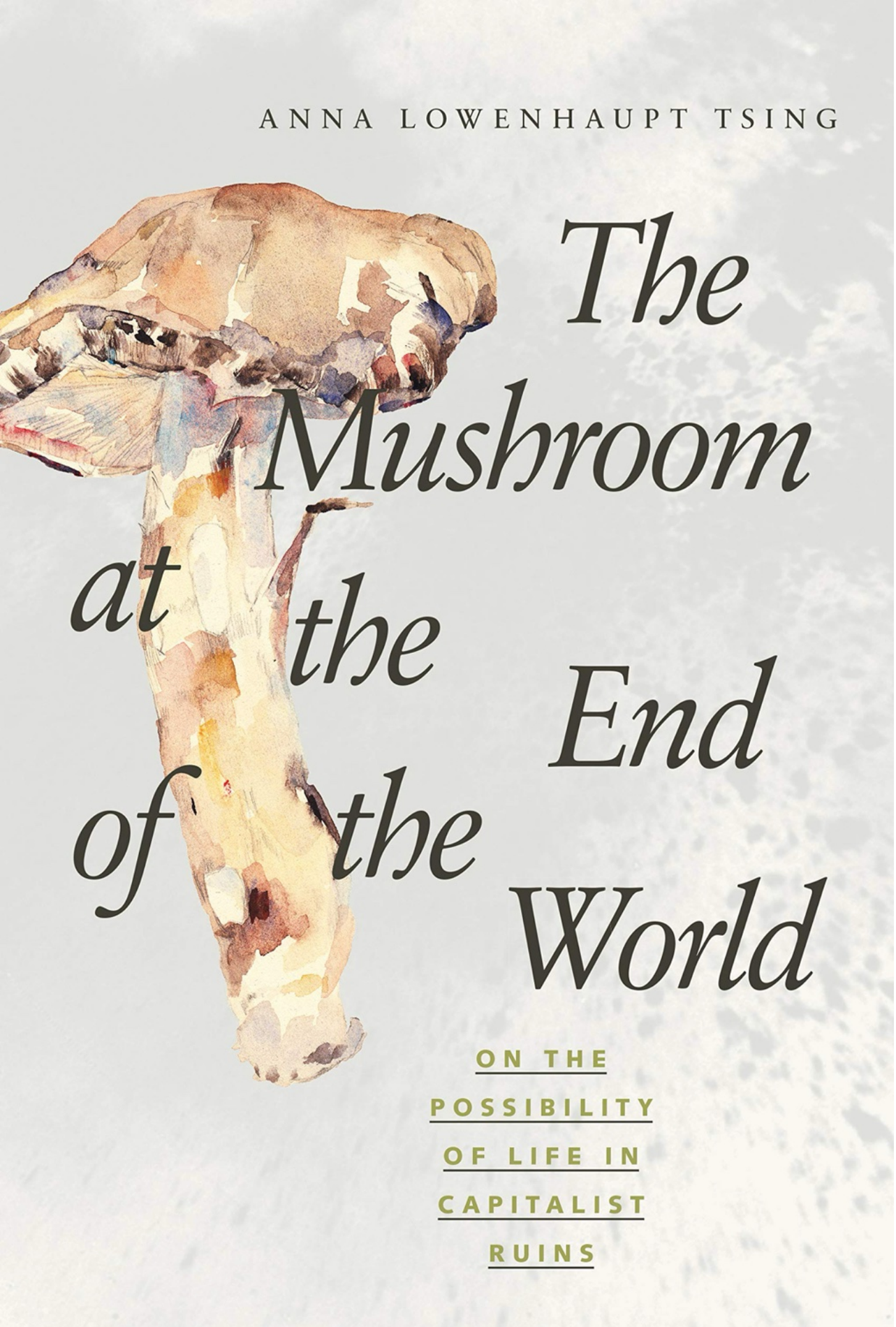
Matsutake mushrooms *grow wild in disturbed pine forests, such as ruined, clear-cut land in the US Northwest*

They are foraged by marginal, often ephemeral communities

make their way into long global supply chains

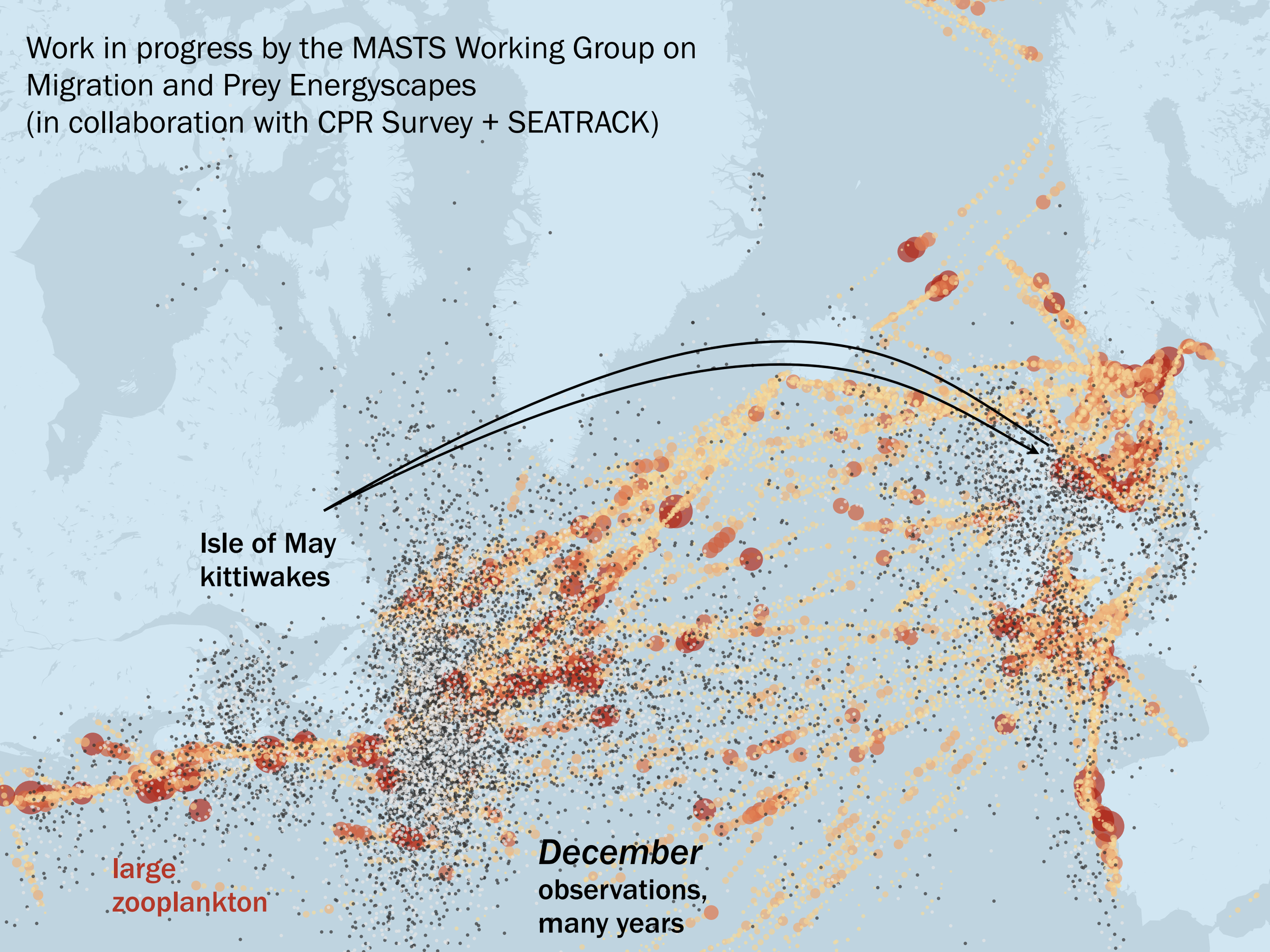
and end up as neatly packaged, high-value commodities in Japan

This book has become a modern classic in environmental humanities



"But we have a problem with scale. A rush of stories cannot be neatly summed up. Its scales do not nest neatly; they draw attention to interrupting geographies and tempos. These interruptions elicit more stories. This is the rush of stories' power as a science. Yet it is just these interruptions that step out of the bounds of most modern science, which demands the possibility for infinite expansion without changing the research framework."

Work in progress by the MASTS Working Group on
Migration and Prey Energyscapes
(in collaboration with CPR Survey + SEATRACK)

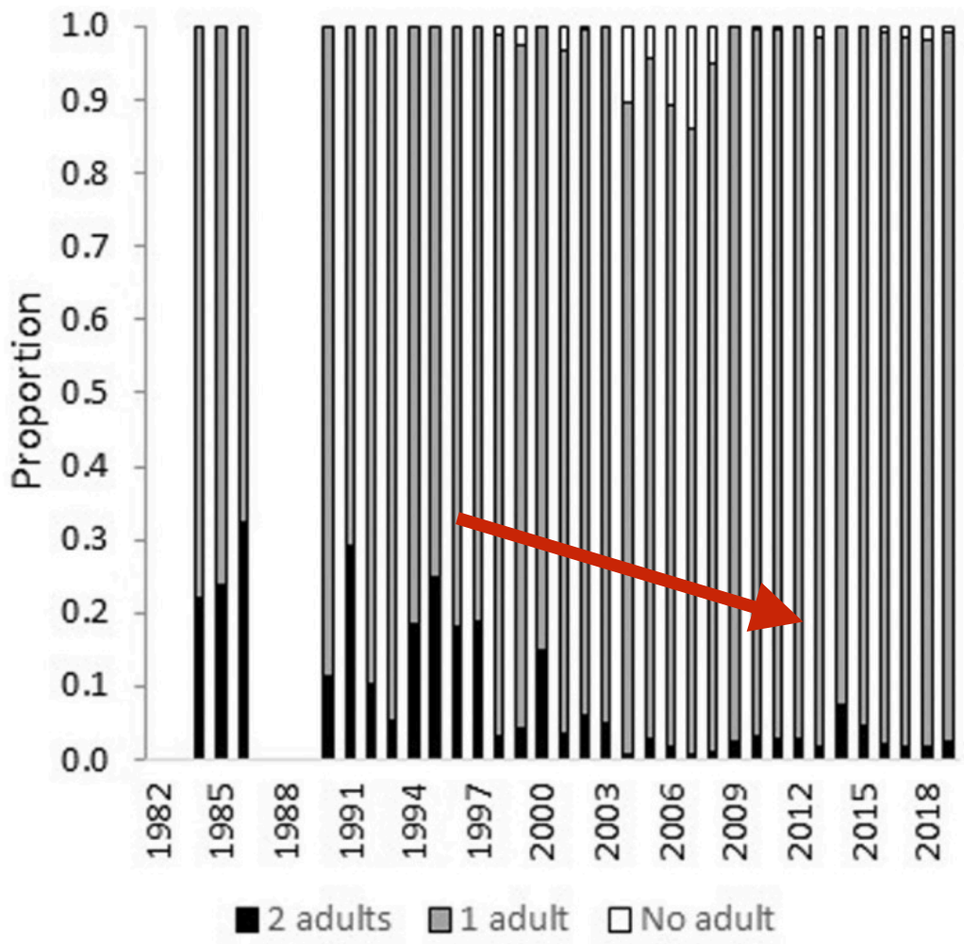


In seabirds as in humans, *food insecurity* has to be understood through the lens of **family life and household economics**

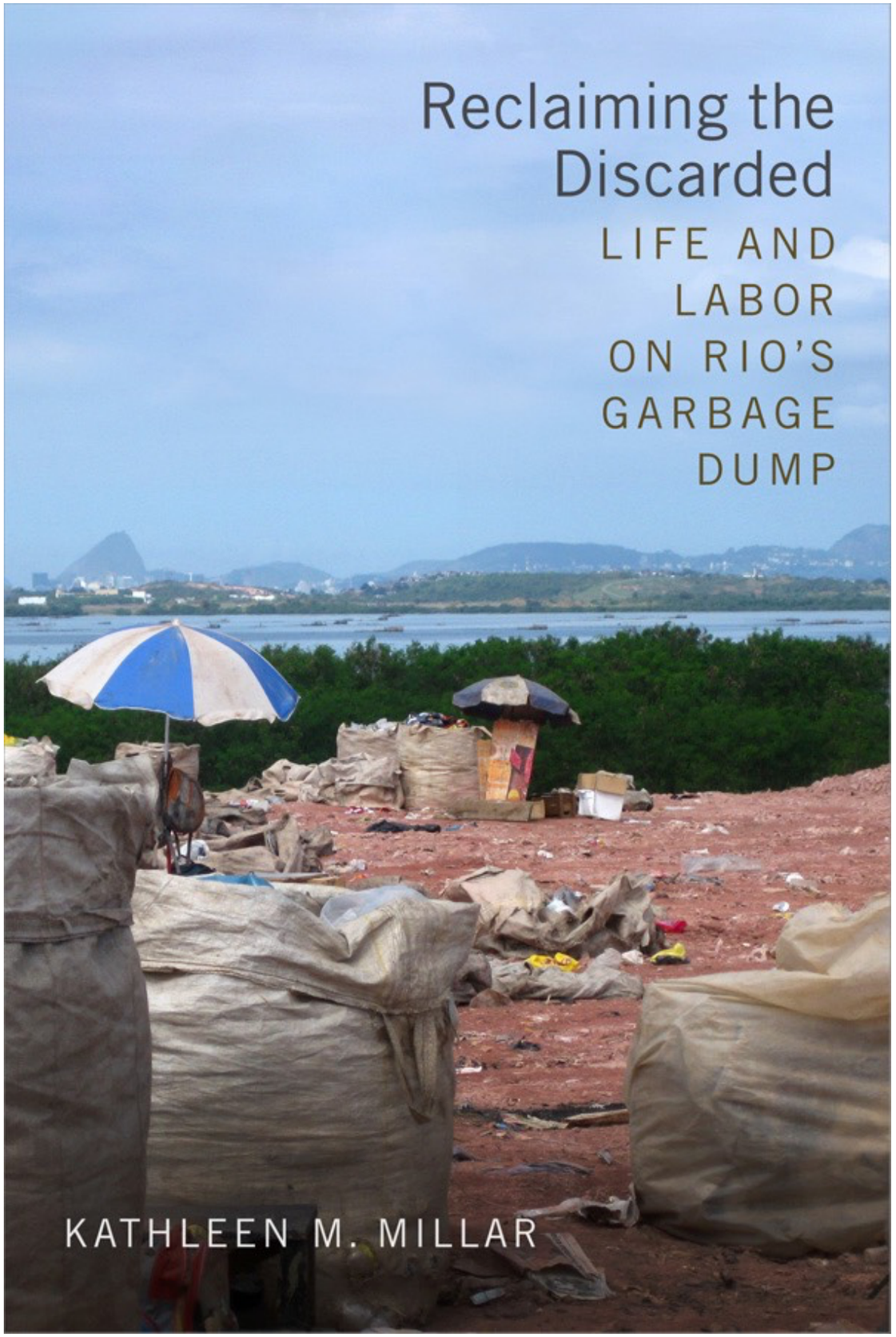
Increased parental effort fails to buffer the cascading effects of warmer seas on common guillemot demographic rates

Sarah Wanless[1] | Steve D. Albon[2] | Francis Daunt[1] | Blanca Sarzo[3,4] | Mark A. Newell[1] | Carrie Gunn[1] | John R. Speakman[5,6] | Michael P. Harris[1]

guillemot parent and chick



(guillemots spending less time with their chicks as food gets harder to find)



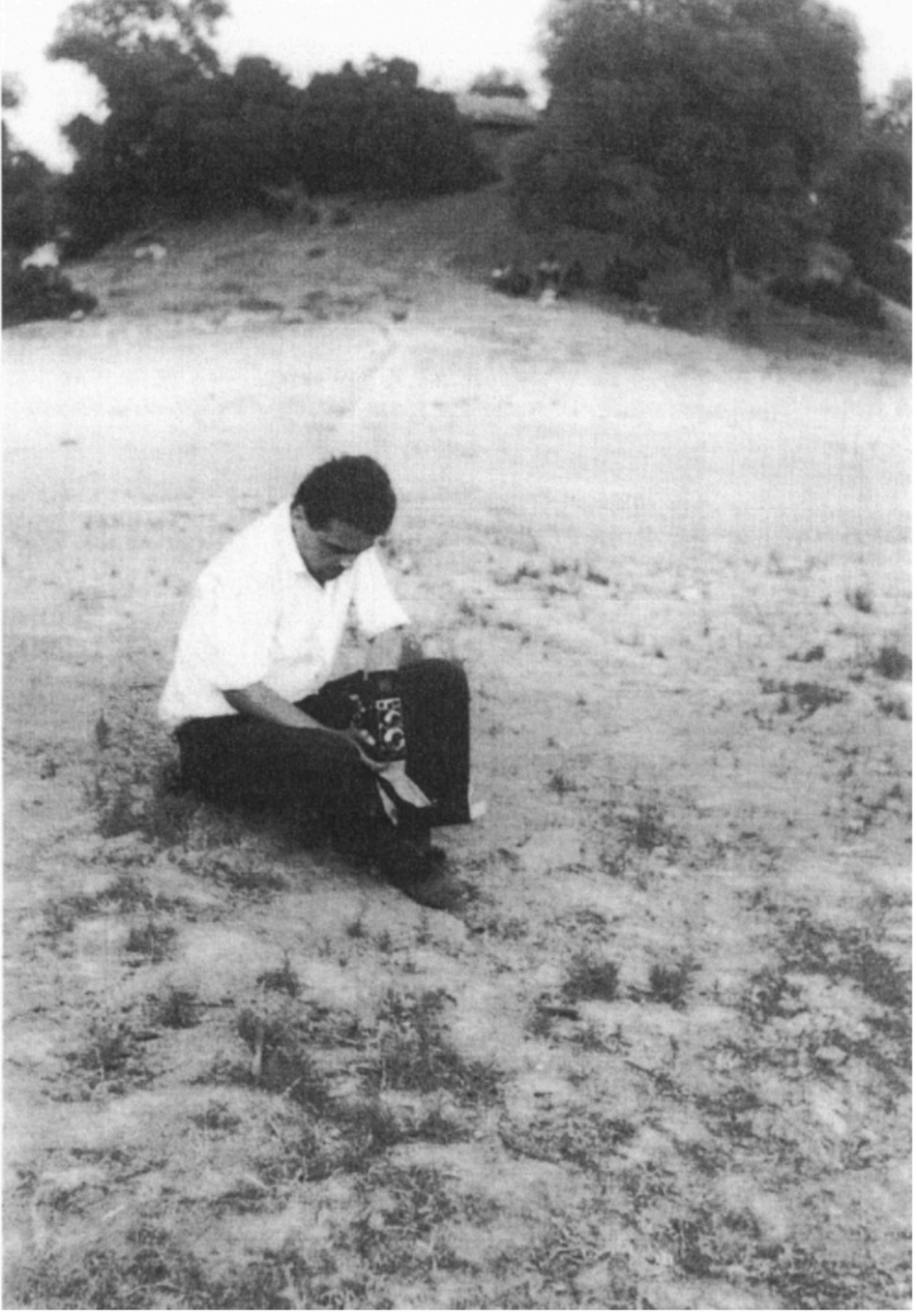
(Why do garbage pickers come to the dump? Why do they stay?)

Salmon post-smolts have a hugely varied diet (normal for a highly mobile marine predator)

Table 3. Percentage frequency of occurrence (O%) and percentage by mass (M%) of prey organisms found in post-smolt stomachs from the southwest area in 1995, 1996, and 1997. The forage ratio with and without empty stomachs is given for each year.

	Southwest area					
	1995		1996		1997	
Prey organism	O%	M%	O%	M%	O%	M%
Pisces (total)	97.6	98.3	60.4	80.5	83.0	81.9
Clupea harengus	41.5	11.2				
Maurolicus muelleri	2.4	0.3				
Gadidae, unidentified	4.9	3.1				
Gadus morhua			3.8	6.8		
Phycis blennoides			15.1	15.4		
Micromesistius poutassou	53.7	63.9				
Scorpaenidae			9.4	3.5		
Ammodytes spp.	43.9	15.4	18.9	46.9	27.7	44.7
Pisces, unidentified	17.1	4.4	30.2	8.0	55.3	37.2
Invertebrata (total)	34.1	1.7	83.0	16.1	42.6	10.5
Crustacea (total)	34.1	1.7	83.0	16.1	42.6	10.5
Copepoda (total)	12.2	0.2	69.8	6.9	14.9	0.2
Anomalocera patersoni						
Calanus finmarchicus			58.5	4.3		
Copepoda, unidentified	12.2	0.2	13.2	2.6	14.9	0.2
Caligoida	4.9	0.0				
Isopoda			1.9	0.2	4.3	0.3
Amphipoda (total)	9.8	0.1	9.4	5.2	6.4	0.3
Hyperiidae, unidentified	9.8	0.1	9.4	5.2	6.4	0.3
Euphausiacea	14.6	0.8	28.3	3.4	23.4	9.2
Decapoda	19.5	0.6	13.2	0.4	21.3	0.4
Crustacea, unidentified					2.1	0.1
Unidentified and miscellaneous			17.0	3.4	27.7	7.6

(Haughland et al. 2006)



"…everything is stamped with precariousness. No regular timetable, no fixed place of work; the same discontinuity in time and space. The search for work is the one constant factor in an existence swept to and fro by the whim of accident…. The whole of life is lived under the sign of the provisional."

Pierre Bourdieu (1963), describing rural displacement in 1950s Algeria

often cited as the origin of "precarity" as in "precarious employment"

"…everything is stamped with precariousness. No regular timetable, no fixed place of work; the same discontinuity in time and space. The search for work is the one constant factor in an existence swept to and fro by the whim of accident…. The whole of life is lived under the sign of the provisional."

Pierre Bourdieu (1963)

but also basically the definition of foraging!

Dependence on a diversity of unpredictable, patchy resources (= foraging) is often summarised as **"the portfolio effect"**

REVIEWS REVIEWS REVIEWS

The portfolio concept in ecology and evolution

Daniel E Schindler[1*], Jonathan B Armstrong[2], and Thomas E Reed[3]

Biological systems have similarities to efficient financial portfolios; the emergent properties of aggregate systems are often less volatile than their components. These portfolio effects derive from statistical averaging across the dynamics of system components, which often correlate weakly or negatively with each other through time and space. The "portfolio" concept when applied to ecological research provides important insights into how ecosystems are organized, how species interact, and how evolutionary strategies develop. It also helps identify appropriate scales for developing robust management and conservation schemes, and offers an approach that does not rely on prescriptive predictions about threats in an uncertain future. Rather, it presents a framework for managing risk from inevitable perturbations, many of which we will not be able to understand or anticipate.

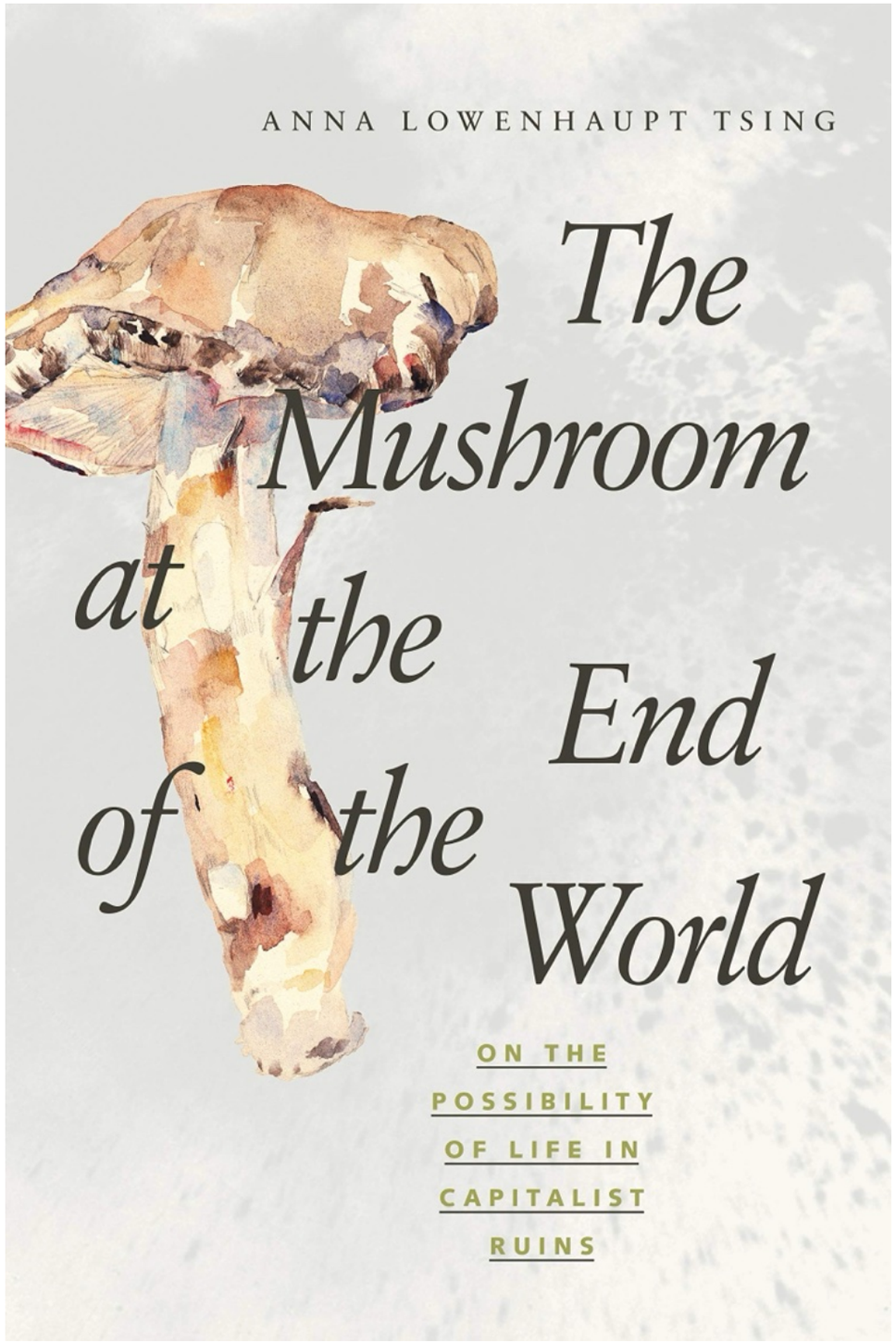
Front Ecol Environ 2015; 13(5): 257–263, doi:10.1890/140275

(Schindler et al. 2015; see also Den Boer 1968)

As a metaphor, the **diversified investment portfolio** is very similar to **employment in a gig economy**

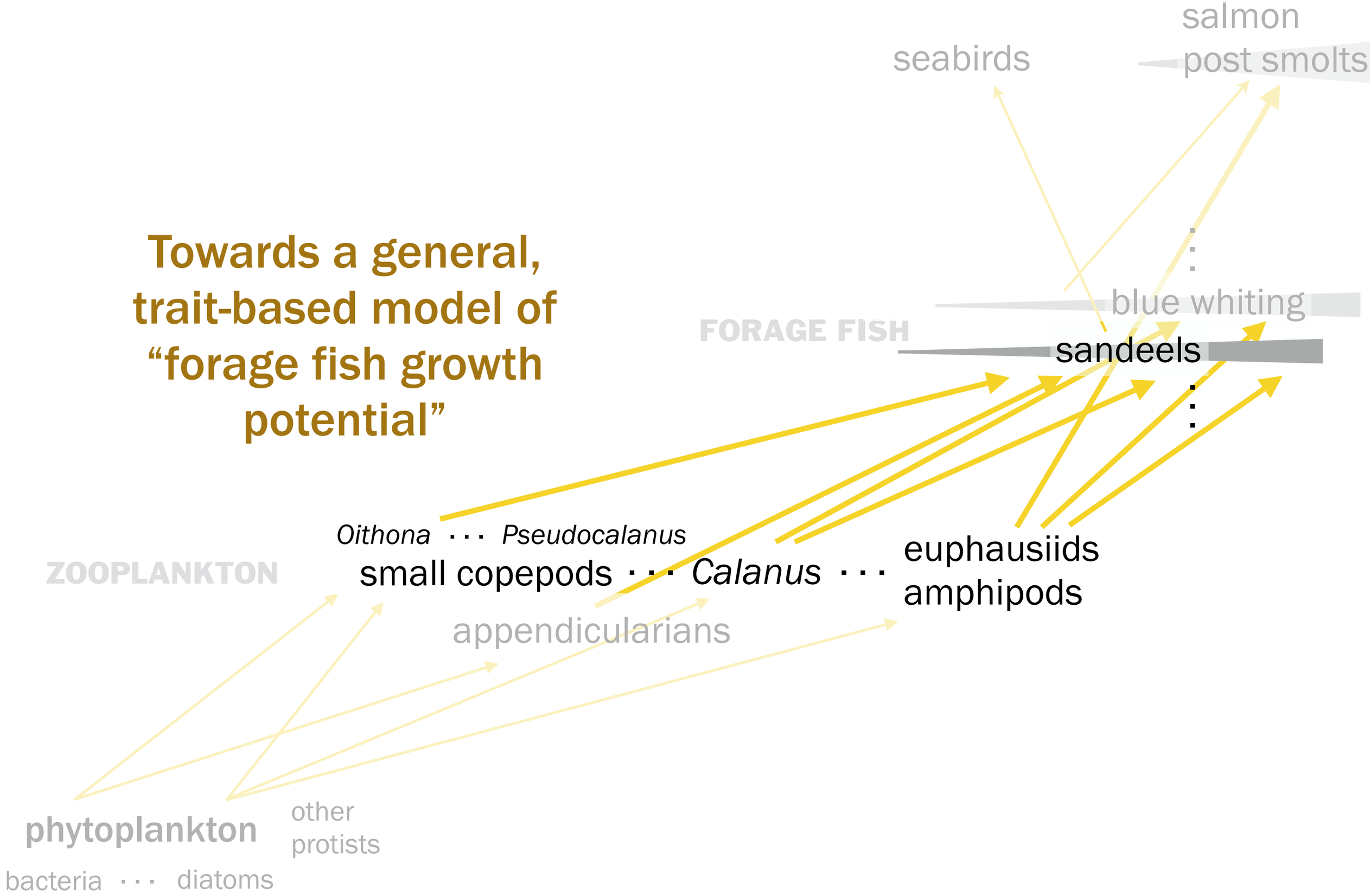
but they suggest exactly opposite hypotheses regarding resilience or vulnerability in a changing environment!

- The setting: “conservation oceanography”
- The problem (if that’s what it is) of scale
- A coarse-grained picture of despair
- **Fine-grained stories about resilience** (maybe)



"We hear about precarity in the news every day. People lose their jobs or get angry because they never had them. Gorillas and river porpoises hover at the edge of extinction.... But most of the time we imagine such precarity to be an exception to how the world works. It's what "drops out" from the system. ... What if precarity, indeterminacy, and what we imagine as trivial are the center of the systematicity we seek?"

Towards a general, trait-based model of "forage fish growth potential"



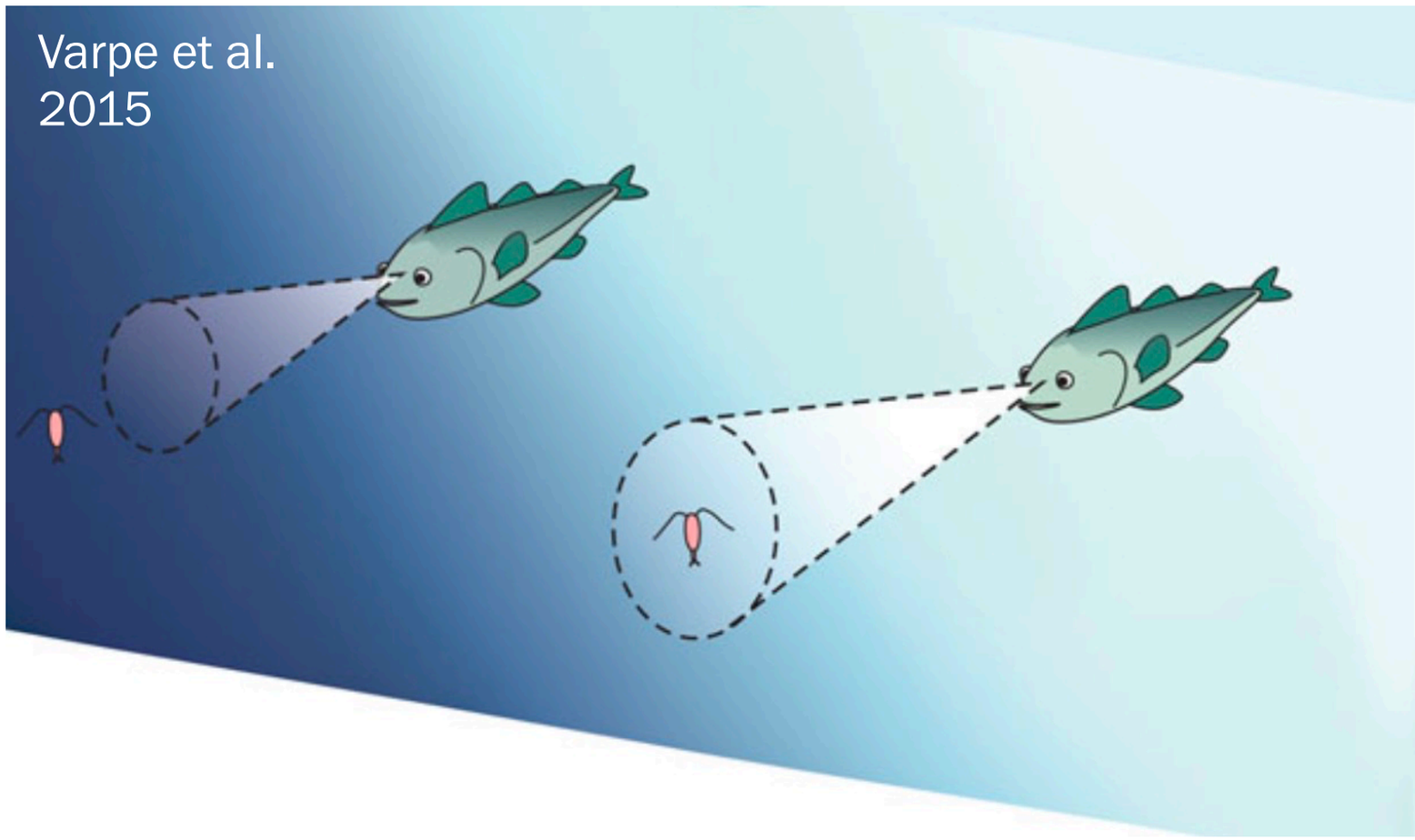
Diet of a origami sandeel

orgamiplankton.org

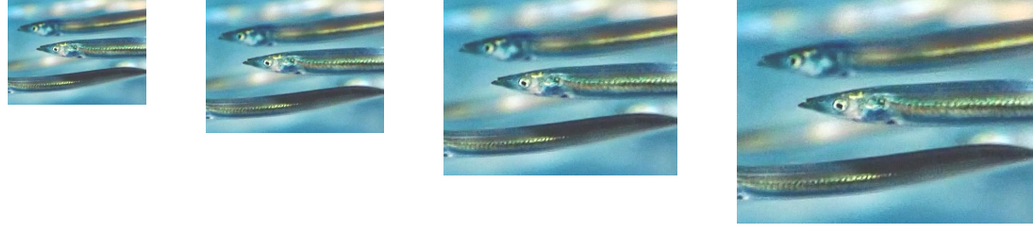
The **zooplankton index** shown earlier simply adds together everything we believe sandeel and other small pelagic fish like to eat.

In many contexts, it doesn't matter if zooplankton production is “packaged” as relatively few large individuals or a larger number of small individuals—

but from a sandeel or polar cod's point of view, it matters a lot!



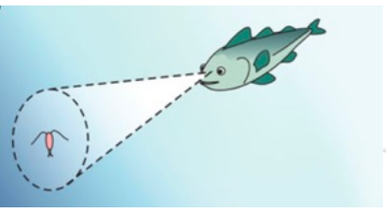
A model of first-summer growth in sandeels (Olin et al., *MEPS*, in press)



zooplankton from CPR data → sandeel growth model → *predicted length in first summer*

(breeding kittiwakes rely on both age 0 and age 1 sandeels at different points in the seasonal cycle—but age 0 growth also predicts the likelihood of surviving to become an age 1)

A model of first-summer growth in sandeels, taking into account



maximum intake rate within a given search class *c*, feeding on *k* prey types (3.5)

$$i_{max,c} = \frac{\sum_k \lambda_{k,L,I}\phi_k n_k E_k}{1 + \sum_k h_e \lambda_{k,L,I}\phi_k n_k}$$

abundance; energy content; effective handling time; search rate (Eq. 3.8); capture probability (Eq. 3.12)

prey diversity
(Olin et al. 2022)

visual search
(Aksnes and Utne 1997)

max hourly ingestion rate (3.7)

$$i_{max} = \sum_c p_c i_{max,c}$$

proportion of time spent in each search class *c* (Eq. 3.6)

optimal prey selection
(Visser and Fiksen 2013)

if there is space (Eqs. 3.13 and 3.15) feed at max rate

energy ingested in a given hour (3.16)

$$i_h = \begin{cases} i_{max}, & (g_{max} - g)\delta_{food} \geq i_{max} \times (1\text{h}) \\ (g_{max} - g)\delta_{food}/(1\text{h}), & (g_{max} - g)\delta_{food} < i_{max} \times (1\text{h}) \end{cases}$$

if gut is full (Eqs. 3.13 and 3.15) fill up remaining space (Eq. 3.14)

behaviour + gut fullness

daily assimilated energy (3.3)

$$A = \begin{cases} \epsilon \sum_{h=1}^{h_{active}} i_h, & \epsilon \sum_{h=1}^{h_{active}} i_h - (M_{feed} + M_{SDA}) > 0 \\ 0, & \epsilon \sum_{h=1}^{h_{active}} i_h - (M_{feed} + M_{SDA}) \leq 0 \end{cases}$$

only feed if metabolic costs associated with feeding (Eqs. 3.19 and 3.20) are met

a partial bioenergetic budget
(van Deurs et al. 2015)

(Olin et al., *MEPS*, in press)

maximum intake rate within a given search class c, feeding on k prey types (3.5)

$$i_{max,c} = \frac{\sum_k \lambda_{k,L,I} \phi_k n_k E_k}{1 + \sum_k h_e \lambda_{k,L,I} \phi_k n_k}$$

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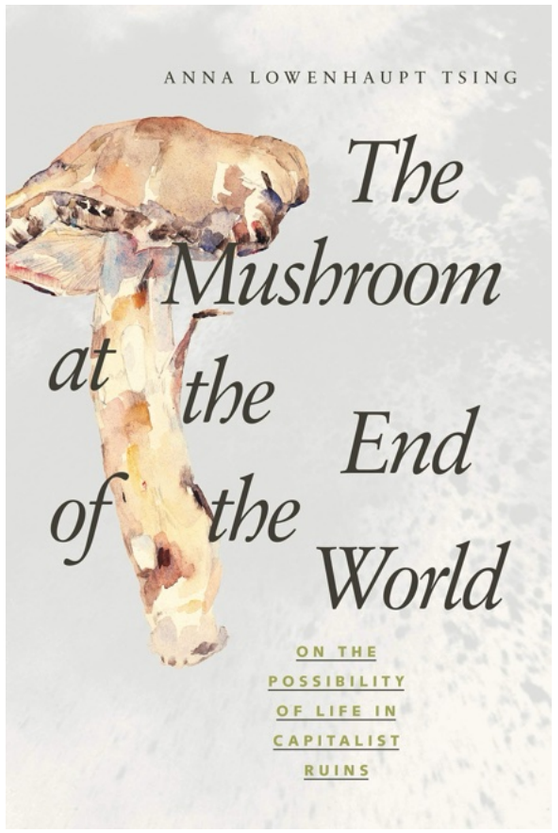
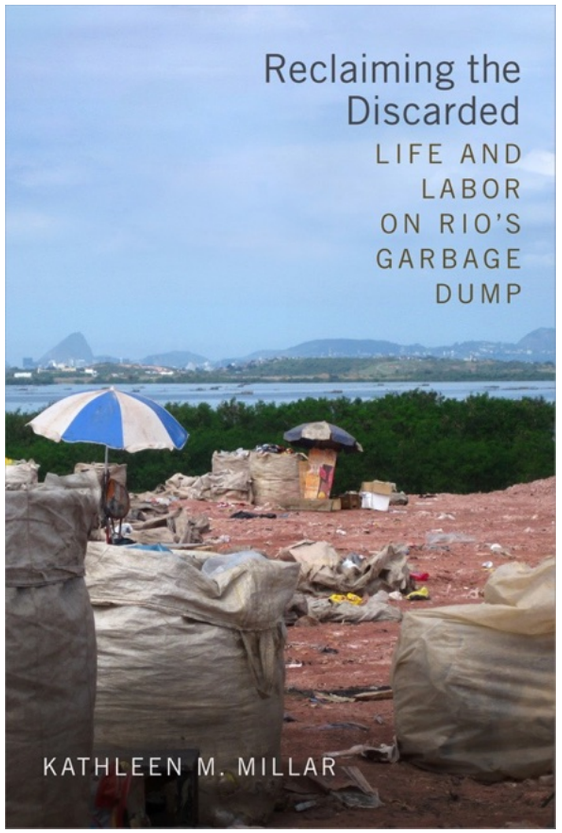
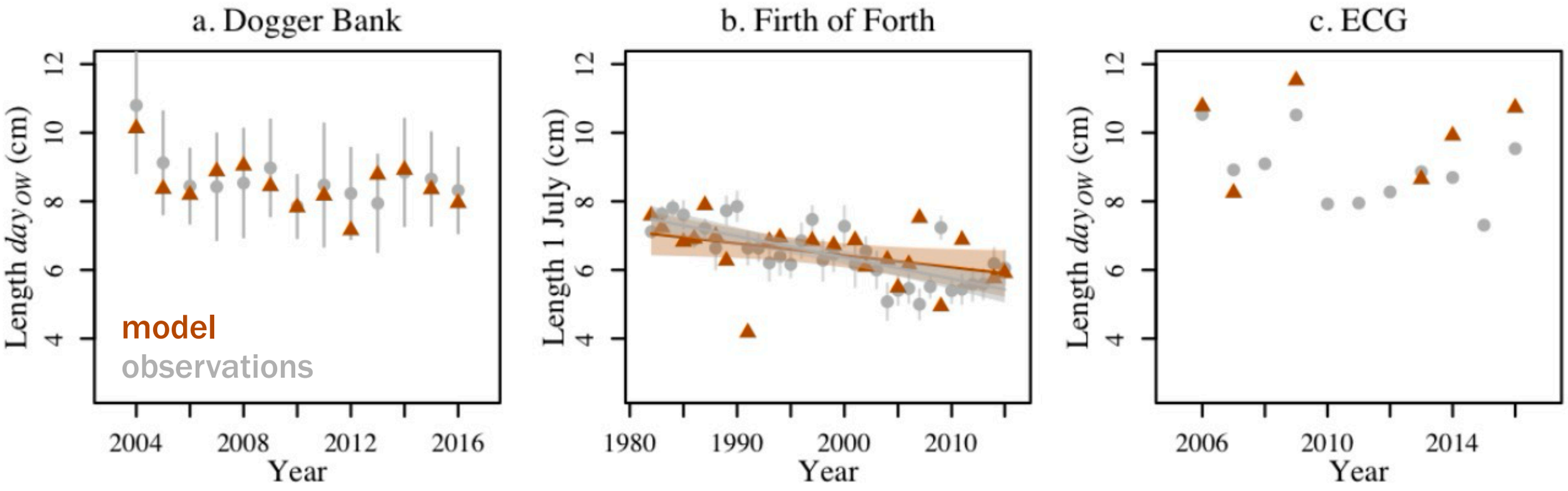




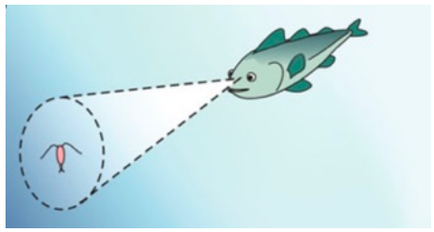
zooplankton from CPR data → **sandeel growth model** → *predicted length in first summer*

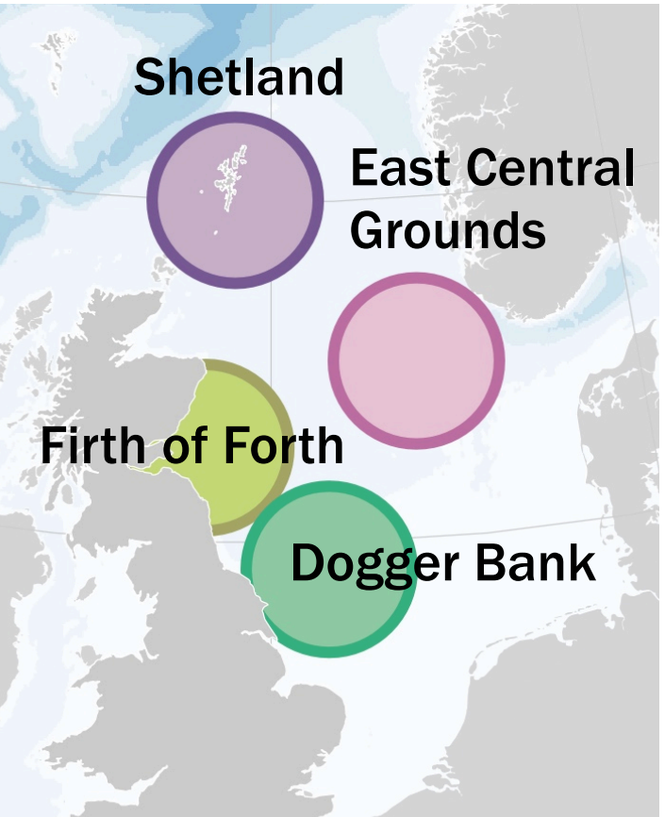


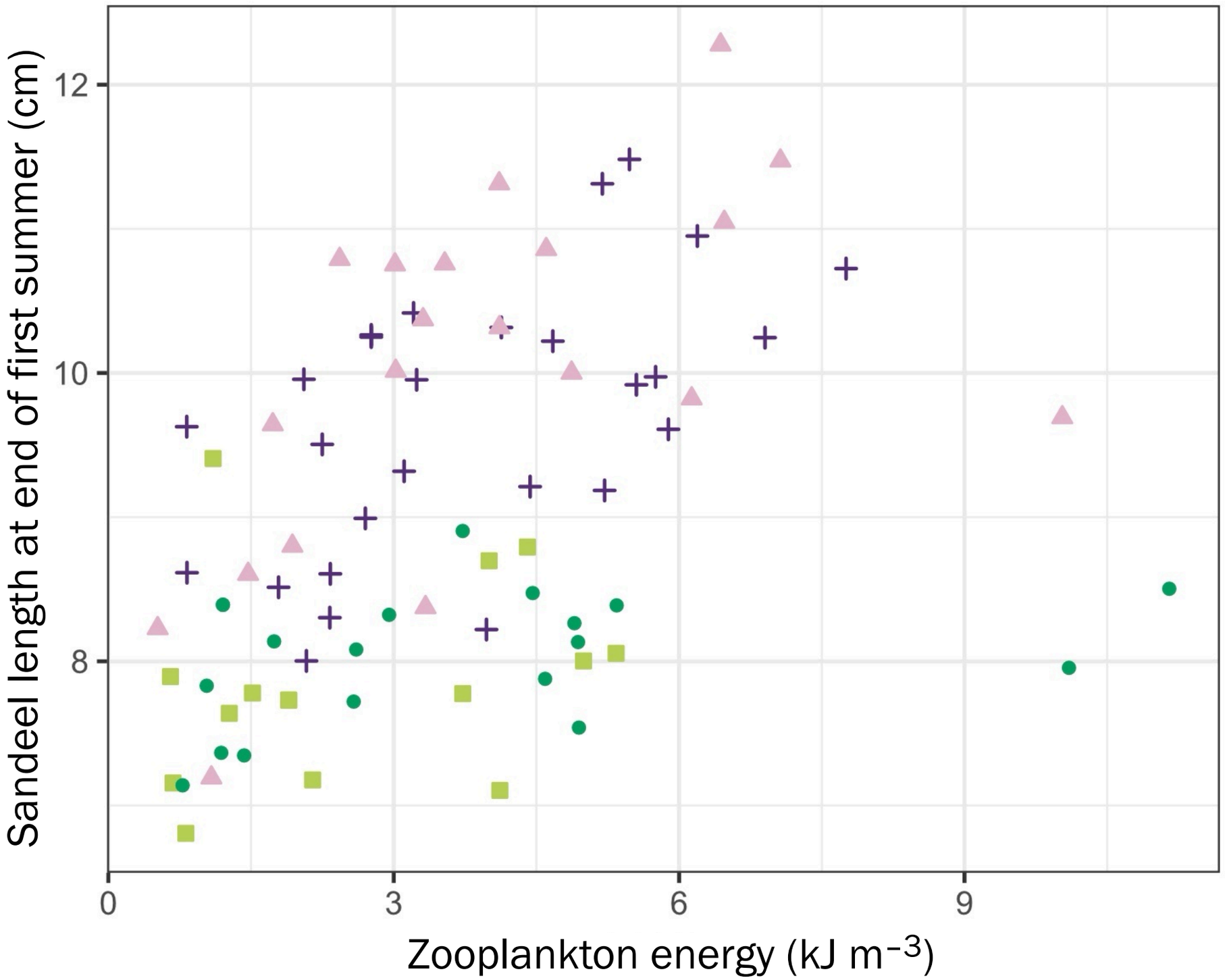
Among North Sea regions, the model correctly picks the places where sandeels in their first summer are particularly small and getting smaller

(Olin et al., *MEPS*, in press)

The sandeel growth model takes the same ingredients as the ZE index—
but its output is much more complex than ZE, and a better match with data







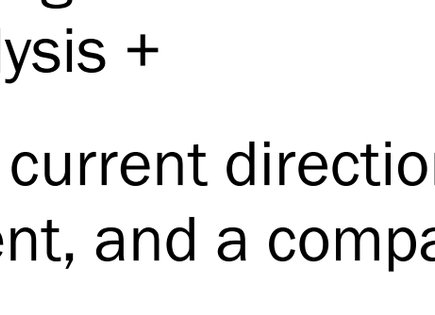
(Olin et al., *MEPS*, in press)

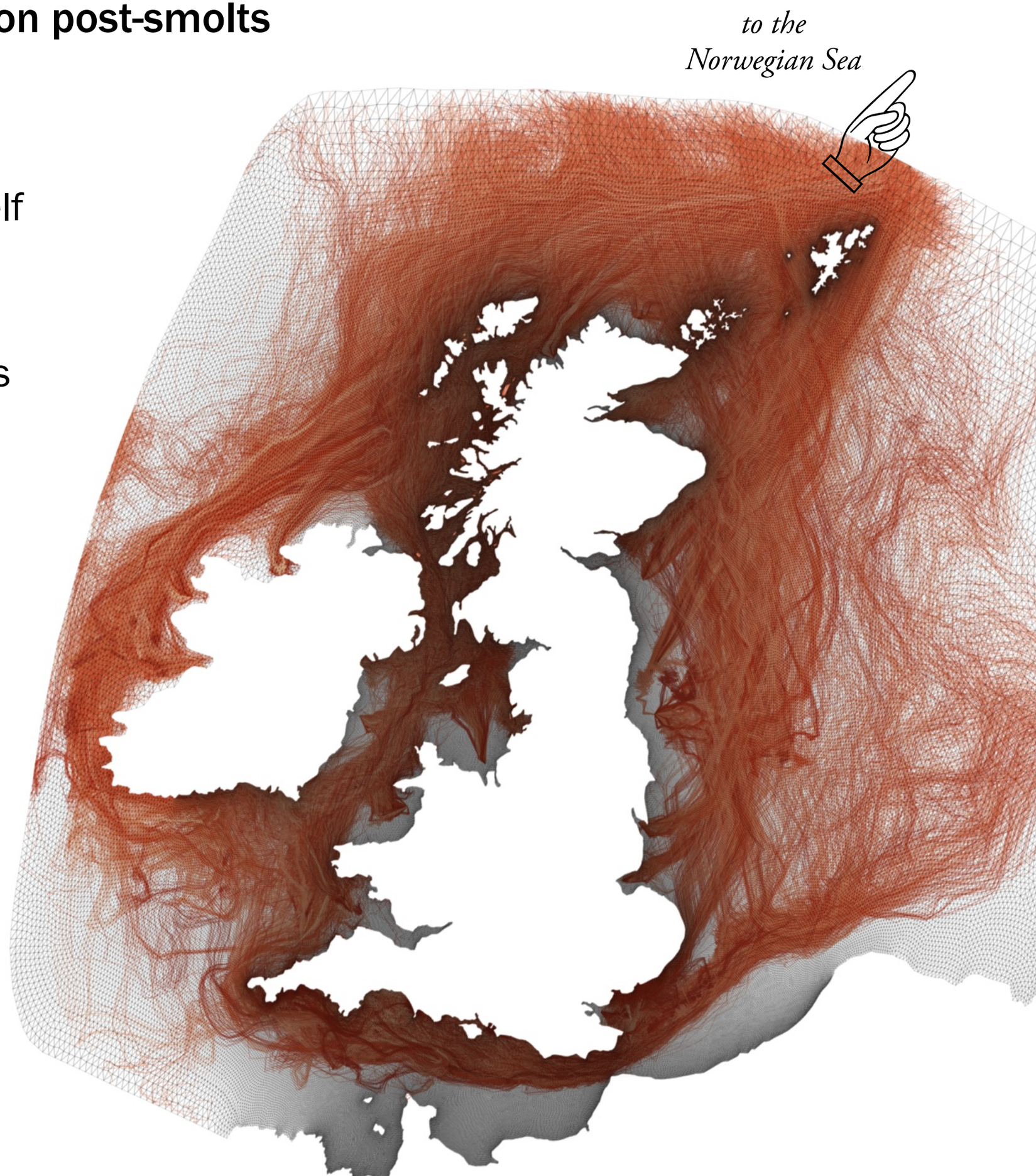
Simulated migration of salmon post-smolts from UK and Irish rivers

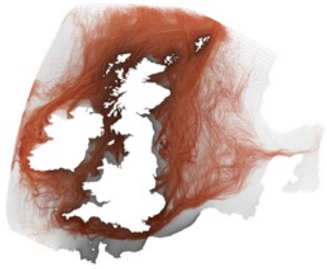
Particle tracking in Scottish Shelf Model Reanalysis +

orientation to current direction, salinity gradient, and a compass bearing

(Borland et al., *ICES J Mar Sci*, 2024)

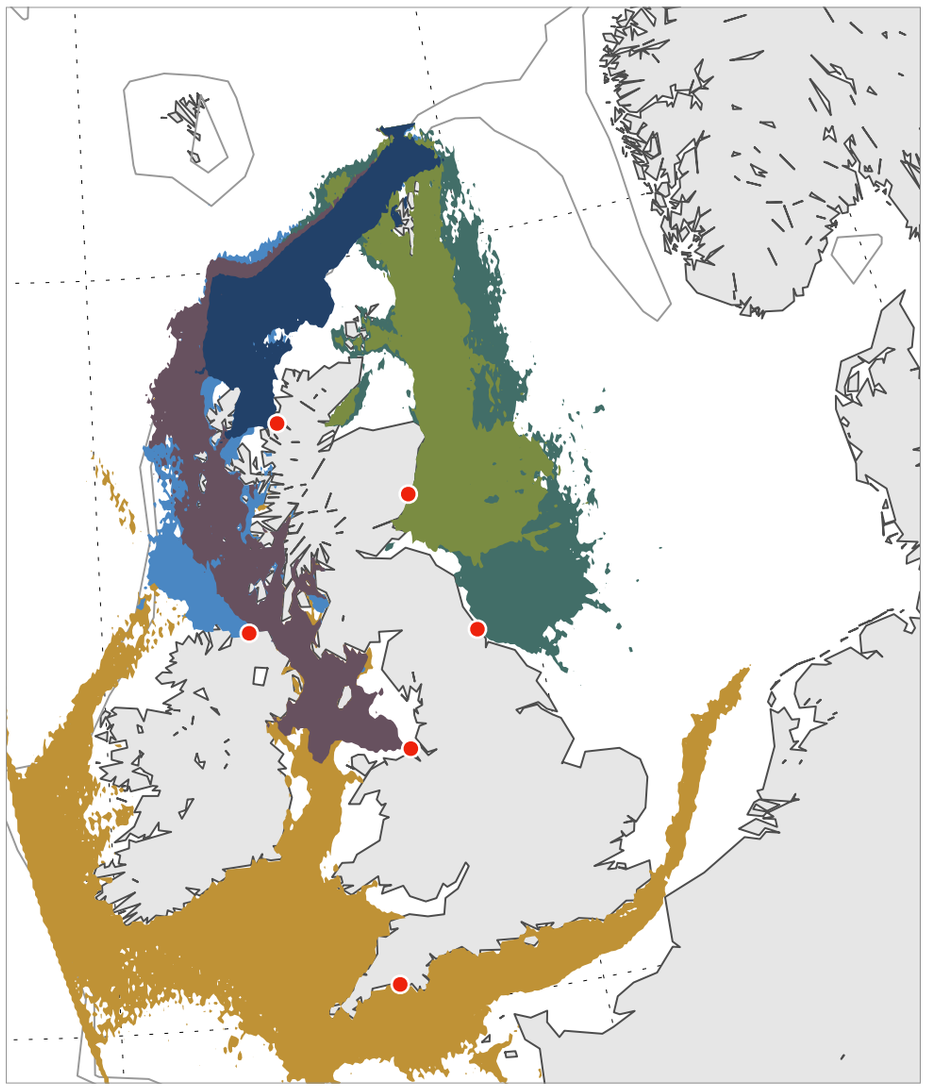






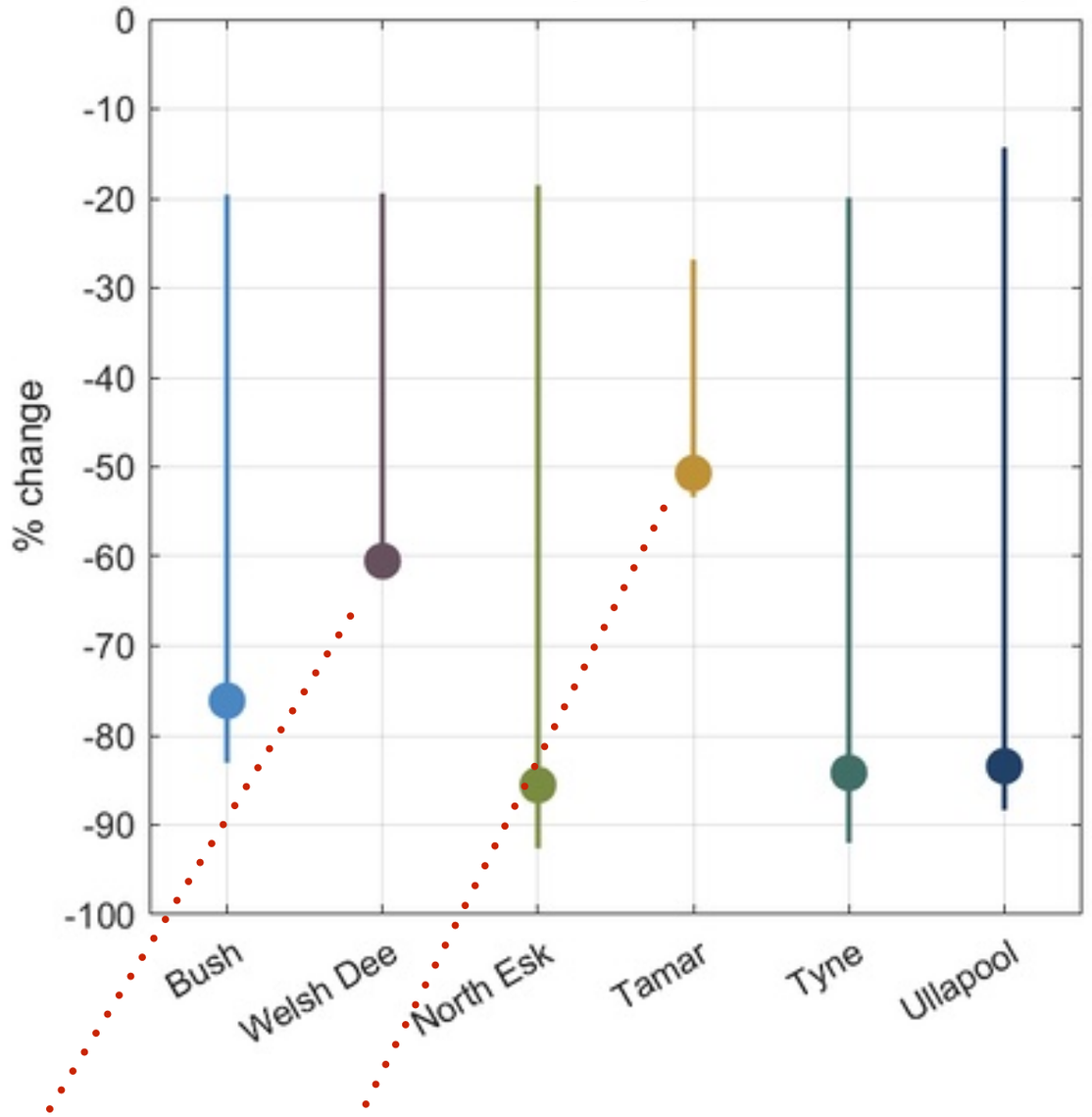
Early marine spatial footprint for 6 rivers

(filled areas = 80% of occupancy in first 60 days at sea)



% declines in total zooplankton energy, 2040s vs. recent past

(*Calanus* spp. + small copepod spp., three downscaled projections, RCP8.5)

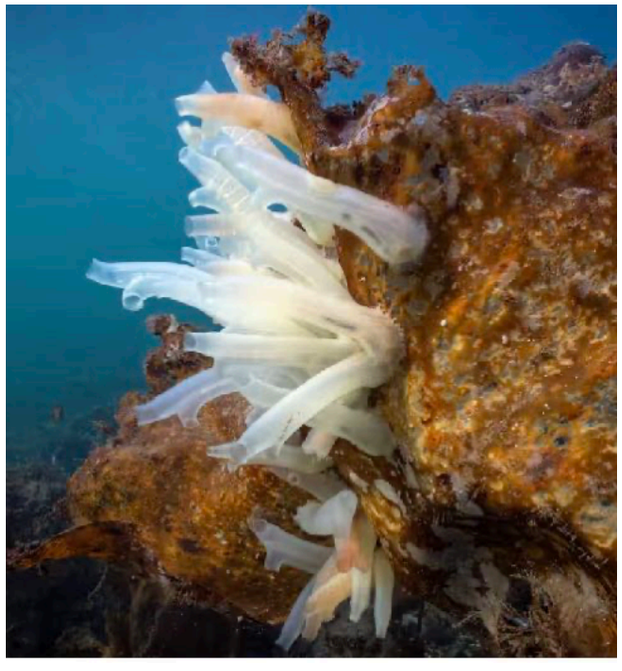


Softer future declines in shelf seas where the most energy-rich zooplankton were never especially prominent in the first place

How flexible and creative are sandeels willing to be about what they eat?

Together with Conny Jaspers (DTU) we have started exploring the extent to which North Sea fish are happy to eat “future plankton” instead of “20th-century plankton”

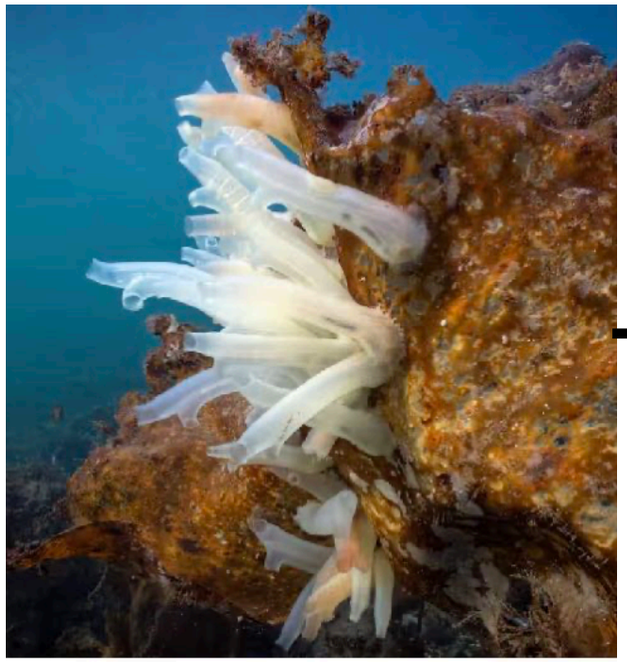
Oikopleura (tiny, planktonic, on the rise while other species decline)



Ciona (invasive, grows on rocks and pilings, good for water quality)

two examples of **gelatinous tunicates**

How flexible and creative are ~~sandeels~~ we and sandeels willing to be about what ~~they~~ we eat?



‘It should not taste marine-like’: Would you eat a burger made from processed sea squirts?

Odd-looking creatures called ciona are naturally rich in protein and one company aims to farm and process them for the table

A prototype burger made from ciona mince. Photograph: pronofa.com

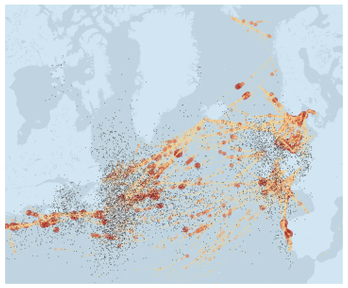
(*The Guardian*, 12 Nov 2024)

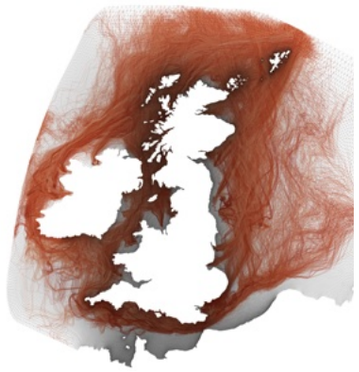
“harvesting” ⟷ “foraging”

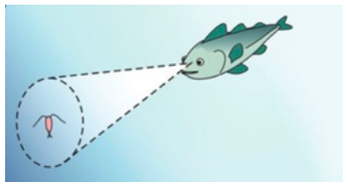
straightforward responses to straightforward resources

ecology as macroeconomics (“maximum sustainable yield”, “net production”, …)

- resource patchworks (space/time/species)
- behavioural plasticity
- ambiguity between trash and treasure
- search, sensing, information constraints
- balancing gain and risk







Neither tales of progress nor of ruin tell us how to think about collaborative survival. It is time to pay attention to mushroom picking. Not that this will save us—but it might open our imaginations.”
—Anna Tsing