Impact of present and future temperature conditions in North Atlantic fisheries: an elasticity analysis approach

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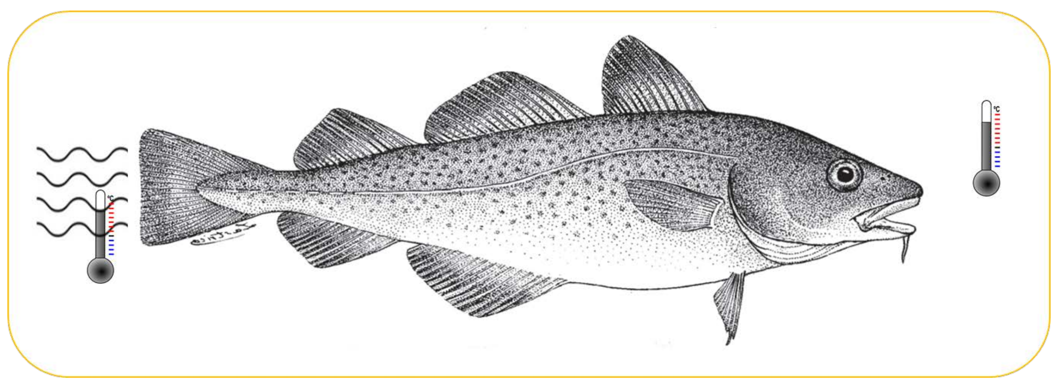
Context

Most marine fish species express life-history changes across temperature gradients.



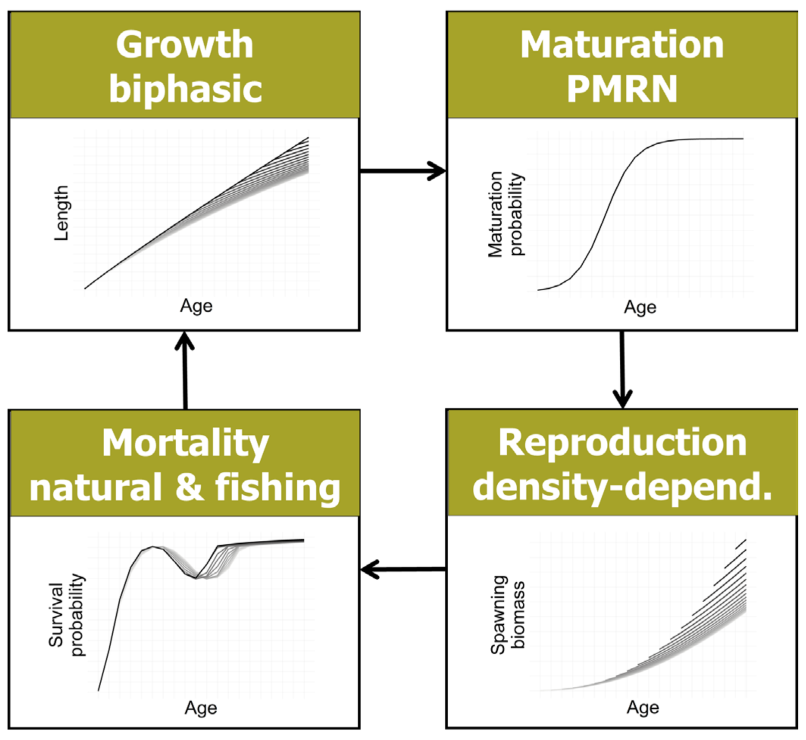
This study investigates the role of life-history determinants in the response of fish stocks to ocean warming.

Methods

We utilize the **data on life-history parameters** of 41 commercially exploited marine stocks gathered by the Working Group on Fisheries-induced Evolution (WGEVO) of the International Council for the Exploration of the Sea (ICES).

Region:	Atlantic Ocean (Northeast, Northwest)		
Species	#	Species	#
Cod	8	Sole	5
Haddock	4	Herring	4
Sandeel	3	Plaice	2
Saithe	2	Whiting	2
American plaice	1	Blue whiting	1
Capelin	1	Mackerel	1
Four-spot megrim	1	Horse mackerel	1
Norway pout	1	Sardine	1
Seabass	1	Sprat	1
Turbot	1		

The **bioenergetic age-, size-, and stage-specific model** of an annual stock life cycle (fitted to the data) enables predictions out of the sample of observed temperatures and with no assumption on the independence of the life-history processes.



Elasticity analysis allows to assess the response of a matrix of stock characteristics to temperature change across spatially explicit emissions scenarios and across a wide range of temperature-effect scenarios, in which the effect of warming is mediated through life-history parameters.

$$\Delta y(N^*(x)) = \frac{\varepsilon y(N^*(x))}{\varepsilon T}\Delta T, \text{ where } \frac{\varepsilon y(N^*(x))}{\varepsilon T} = \sum_{i=1}^{k} \frac{\varepsilon y(N^*(x))}{\varepsilon x_i}\frac{\varepsilon x_i}{\varepsilon T}$$

Proportional change in characteristic of equilibrium ($y(N^*(x))$) in response to SST change

Temperature-elasticity of characteristic $y(N^*(x))$

Proportional change in SST

Temperature-elasticity of life-history parameter x_i

Initial life-history parameter-elasticity of characteristic $y(N^*(x))$

The scenarios for $\frac{\varepsilon x_i}{\varepsilon T}$ are based on a literature review, identifying the range of likely outcomes for each parameter.

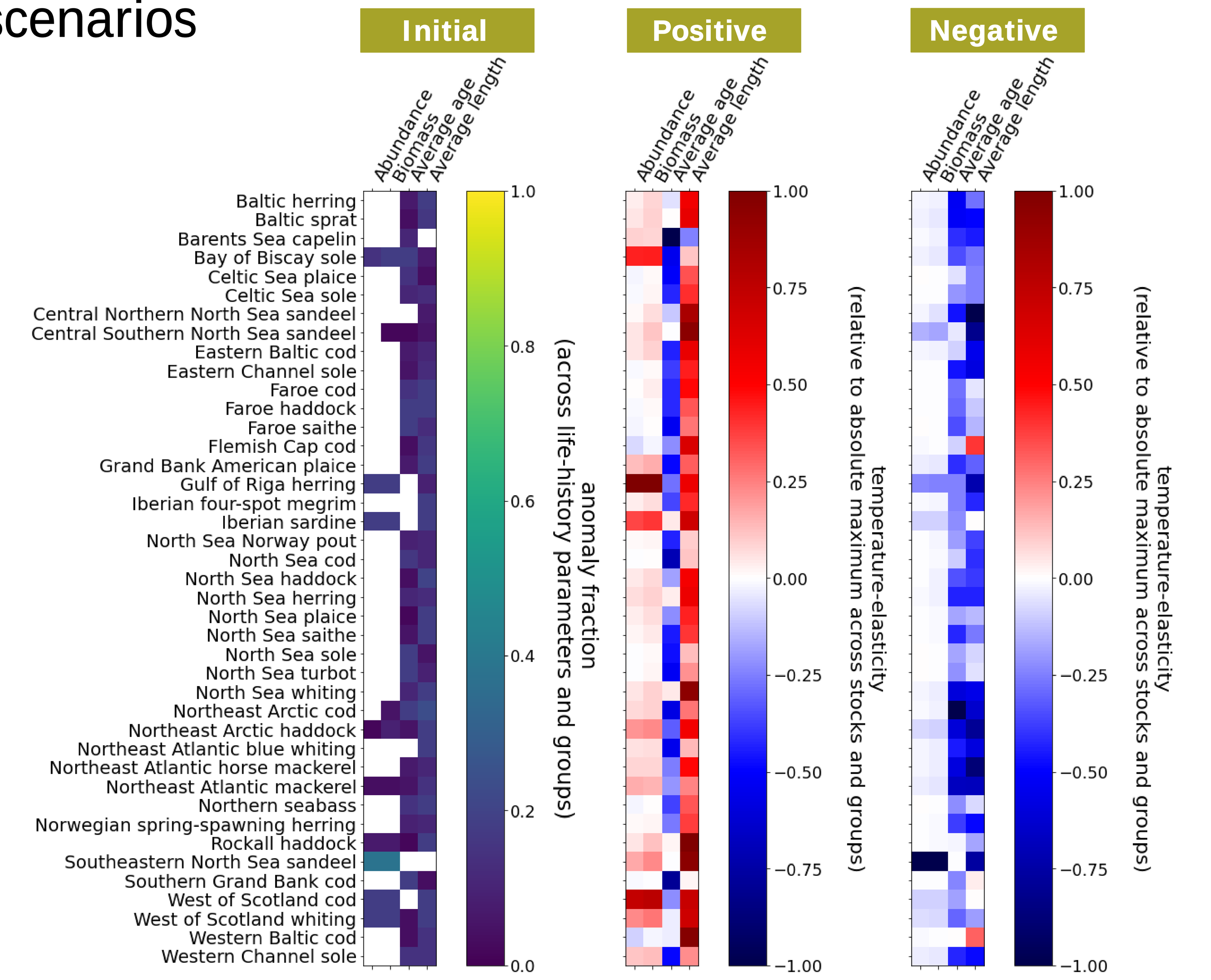
Positive scenario	Negative scenario
Warming enhances population growth	Warming reduces population growth

Main results

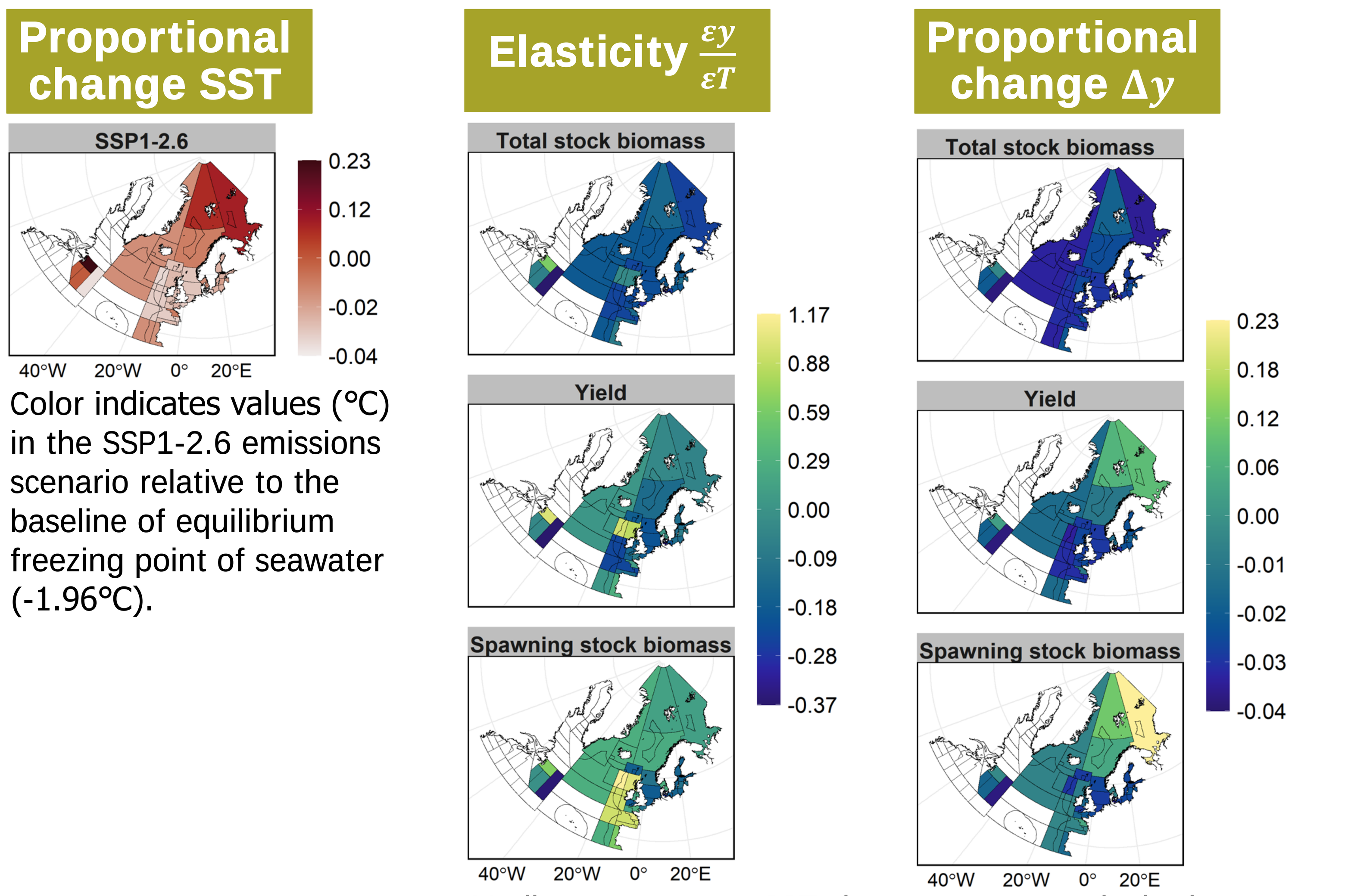
- Life-history parameters in scenarios are less susceptible for change

Scenario	Std	$Q_{99} - Q_1$	IQR
Initial	13.05	80.58	0.63
Positive	1.9	6.55	0.04
Negative	2.19	11.23	0.07

- There are varied responses to parameter perturbations across fish stocks, which influence their asymmetric responses in temperature-effect scenarios



- Compared to other territories of the North Atlantic, fisheries in the Norwegian and Barents Seas are exposed to larger changes in biomass characteristics



Color indicates values (°C) in the SSP1-2.6 emissions scenario relative to the baseline of equilibrium freezing point of seawater (-1.96°C).

Median response to SST change across stocks in the fishing areas. Values are estimated for the middle point in the temperature-effect scenario range and the SSP1-2.6 emissions scenario. Color indicates values of elasticity/proportional change of biomasses.

Summary: Through the systematic elasticity analysis, we can quantify the ecological response to warming in the North Atlantic and identify the role of life-history determinants in the response.

References: 1. ICES (2018). Report of the Working Group on Fisheries-Induced Evolution (WGEVO). https://doi.org/10.17895/ices.pub.8091; 2. Matsumura, S., Arlinghaus, R., & Dieckmann, U. (2011). Assessing evolutionary consequences of size-selective recreational fishing on multiple life-history traits, with an application to northern pike (*Esox lucius*). Evolutionary Ecology, 25: 711–735. https://doi.org/10.1007/s10682-010-9444-8

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