



ALMA MATER STUDIORUM  
UNIVERSITÀ DI BOLOGNA

# Trophic networks, climate change and resource management in Northern Europe (Baltic Sea)

**Michele Casini**

Department of Biological, Geological  
and Environmental Sciences (BiGeA)

# Outline

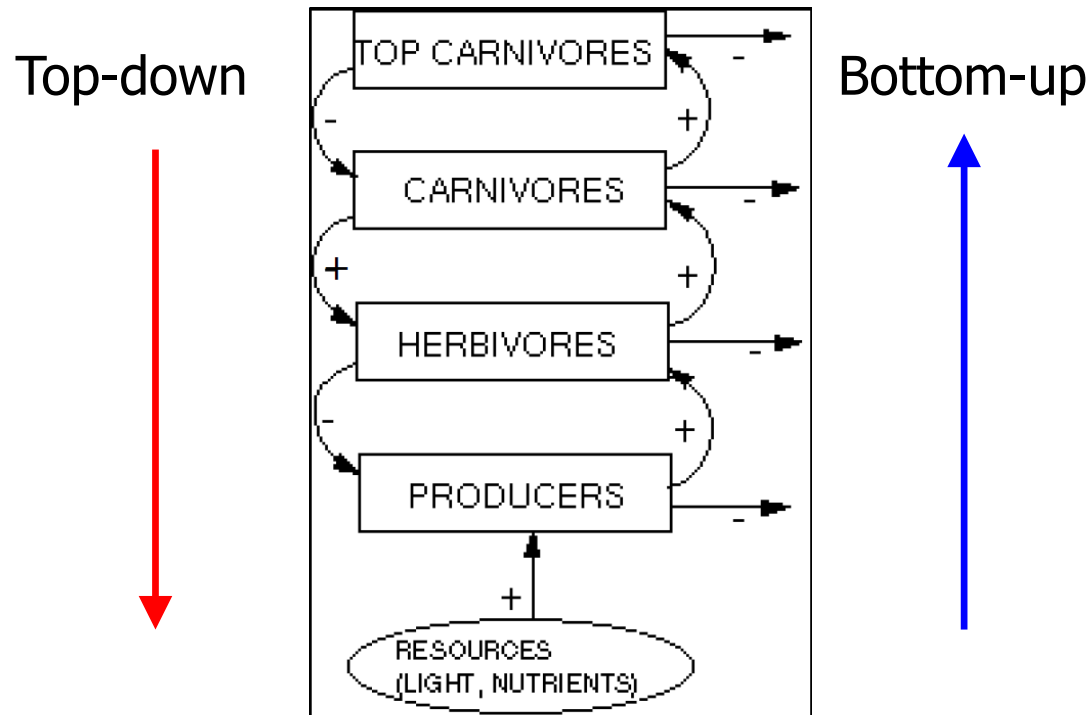
- General introduction about ecosystem functioning
- Baltic Sea biological/physical characteristics
- Baltic cod biological changes, potential causes and effects
- Recent project for a better management of the Baltic cod
- Ecosystem-based (fisheries) management
- Management options



# Changes in the populations, community and ecosystem



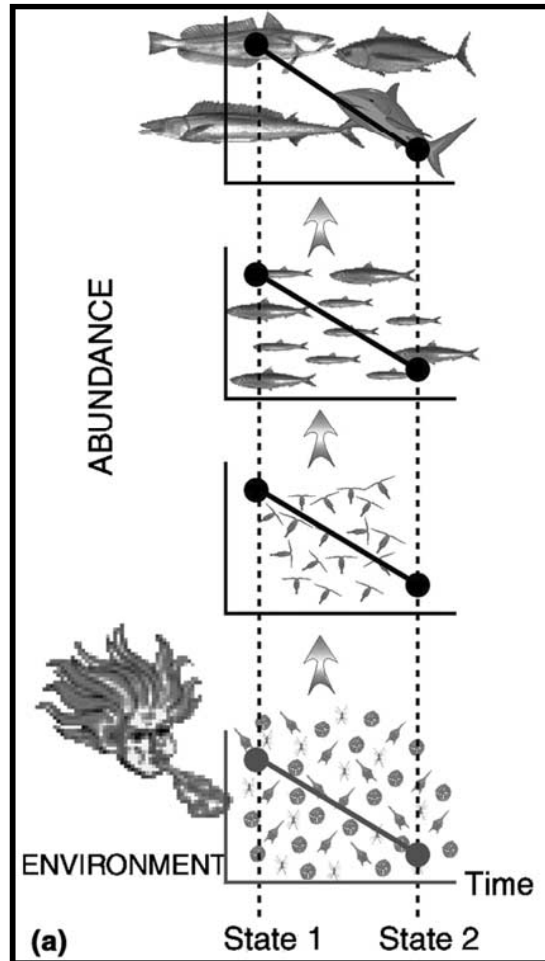
# Top-down vs Bottom-up trophic control



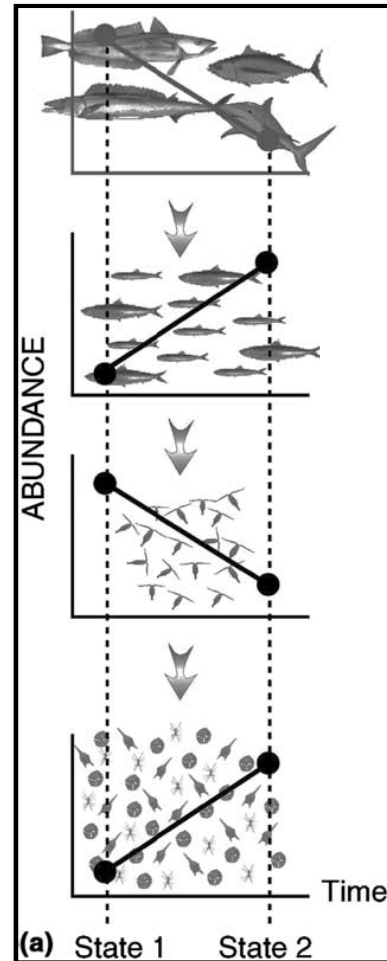


# Top-down vs Bottom-up trophic control

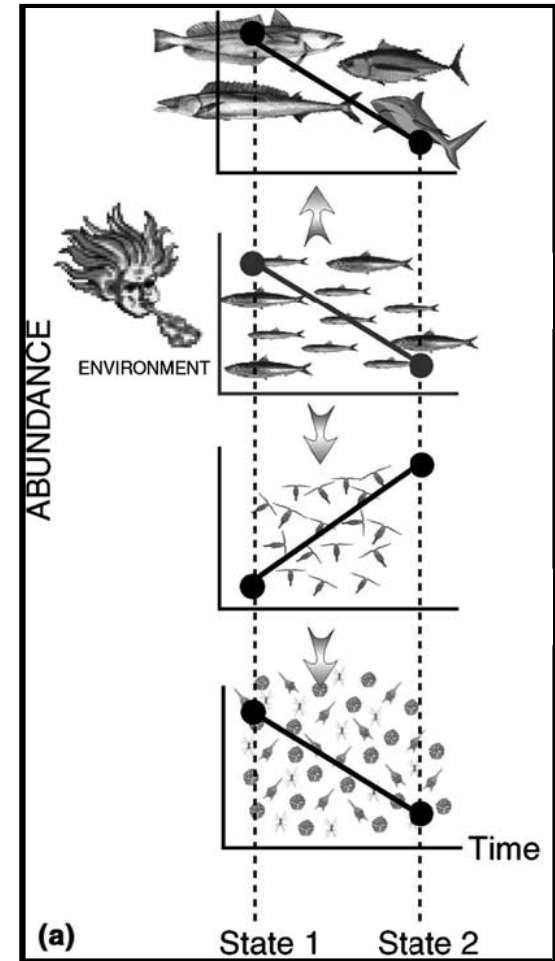
Bottom-up



Top-down



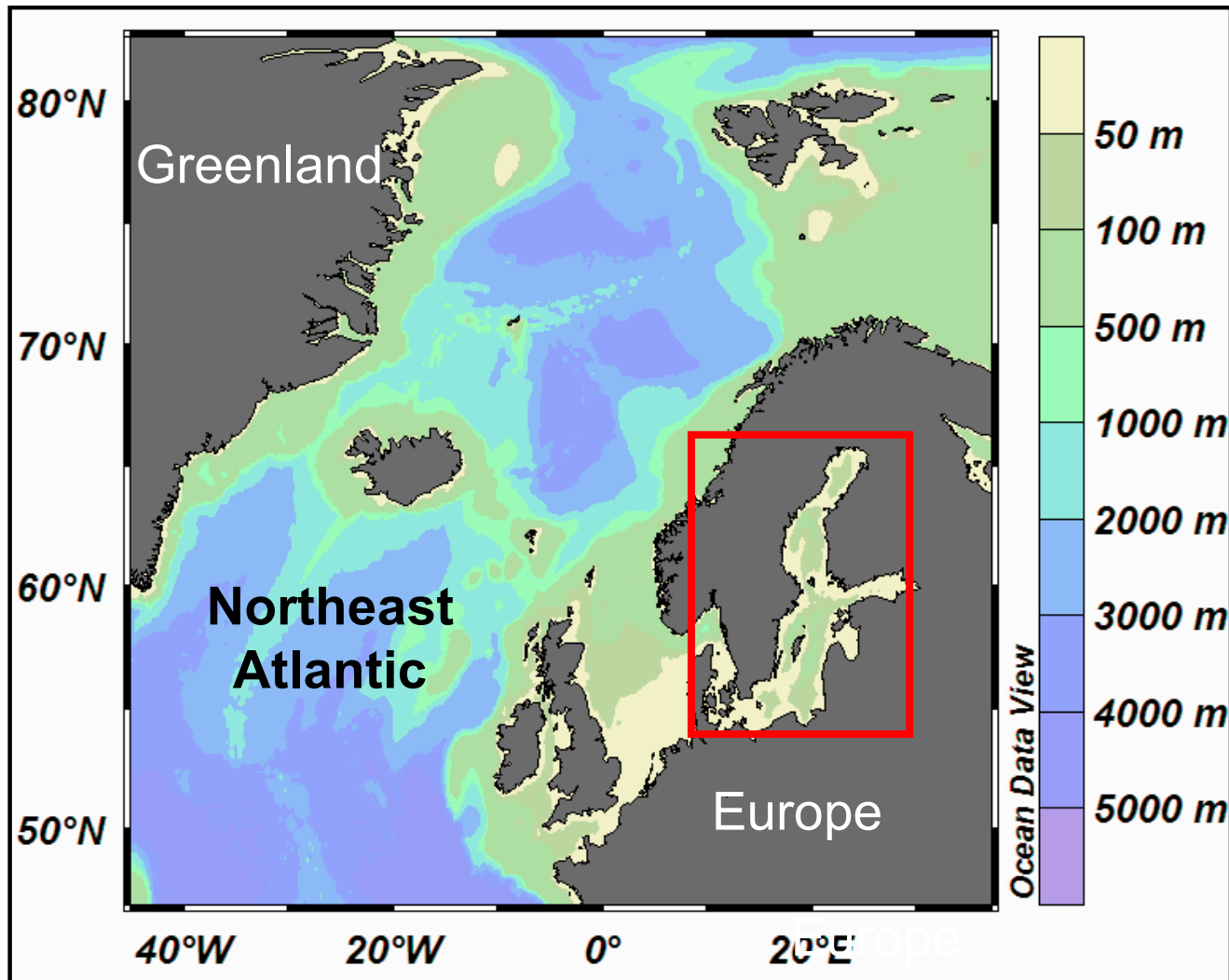
Wasp-waist



From Cury and Shannon (2004)

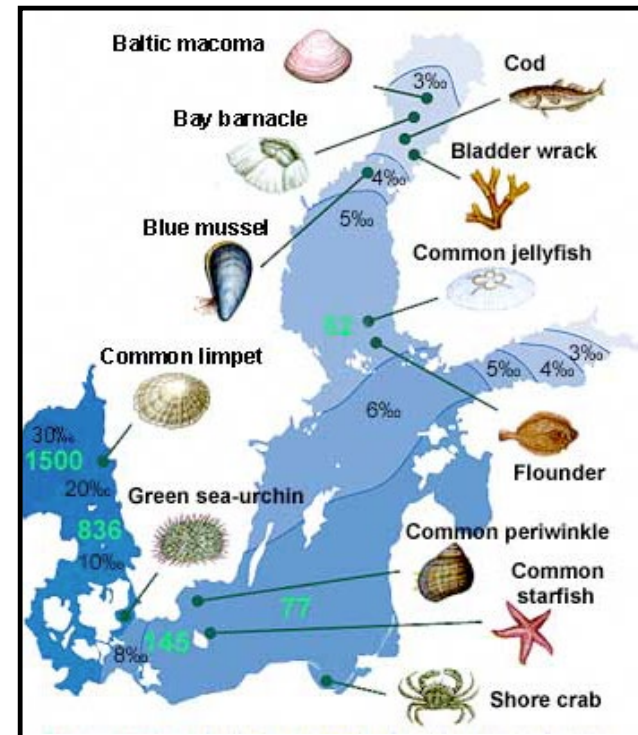


# Baltic Sea: focus area



# Baltic Sea: low biodiversity

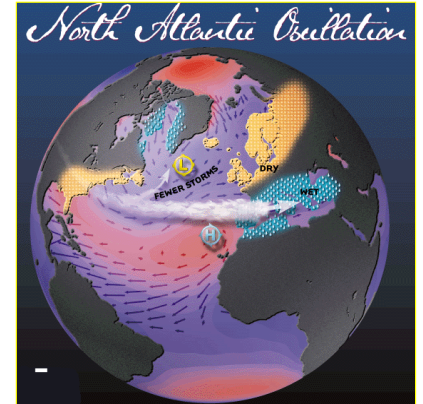
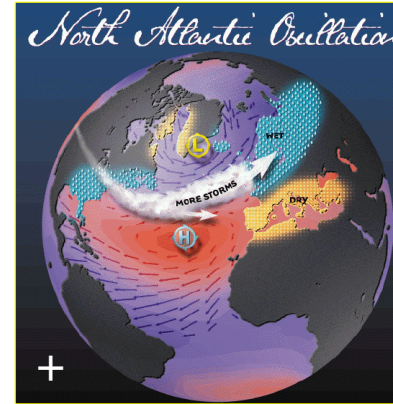
- Very strong linkages between the biological components: changes in one component strongly affect the others
- Many species are at the limit of their distribution range: sensitive to even small changes in external pressures



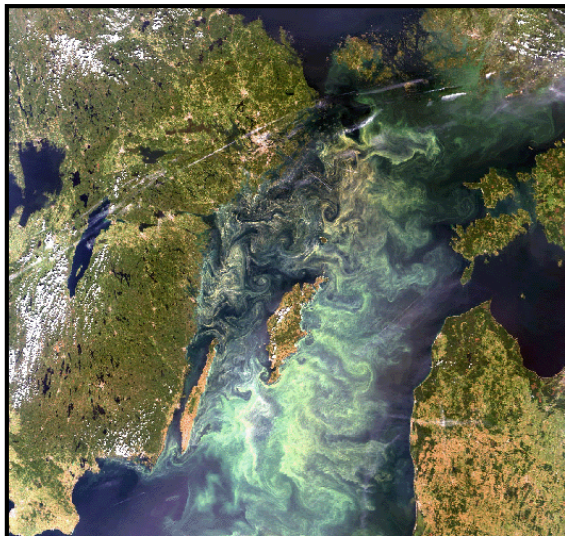
# Baltic Sea: multiple pressures



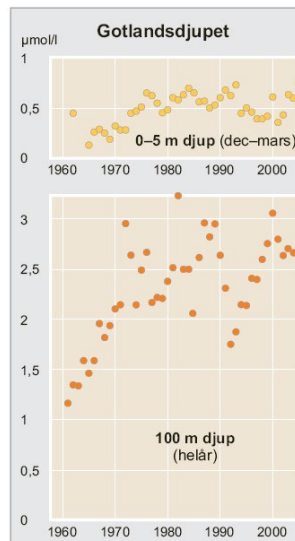
Fishery



Climate / hydrography



Eutrophication

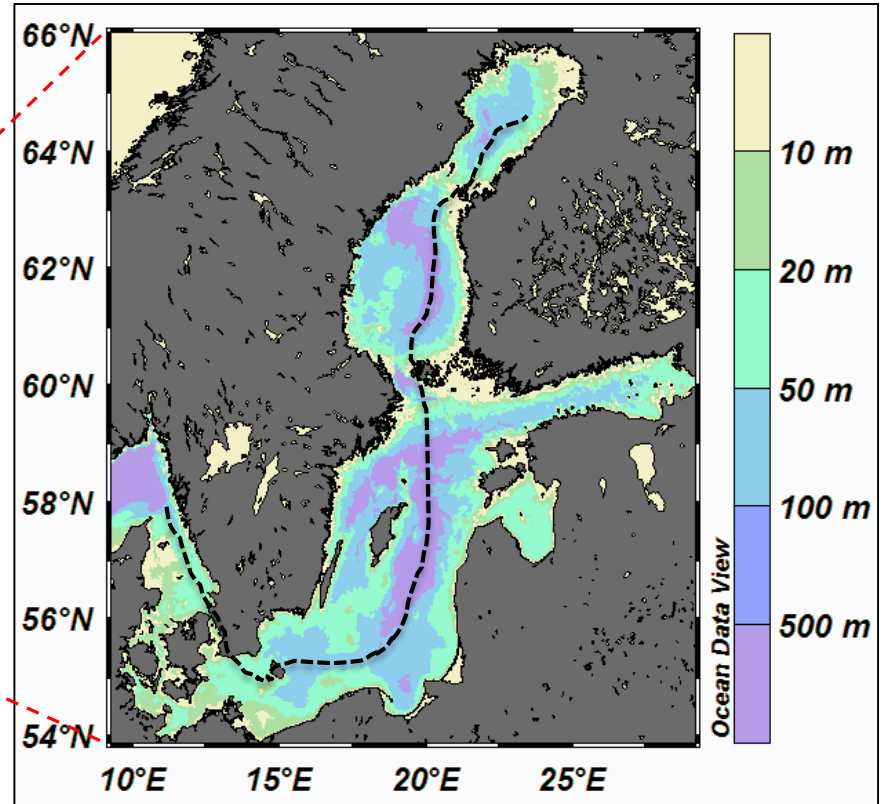
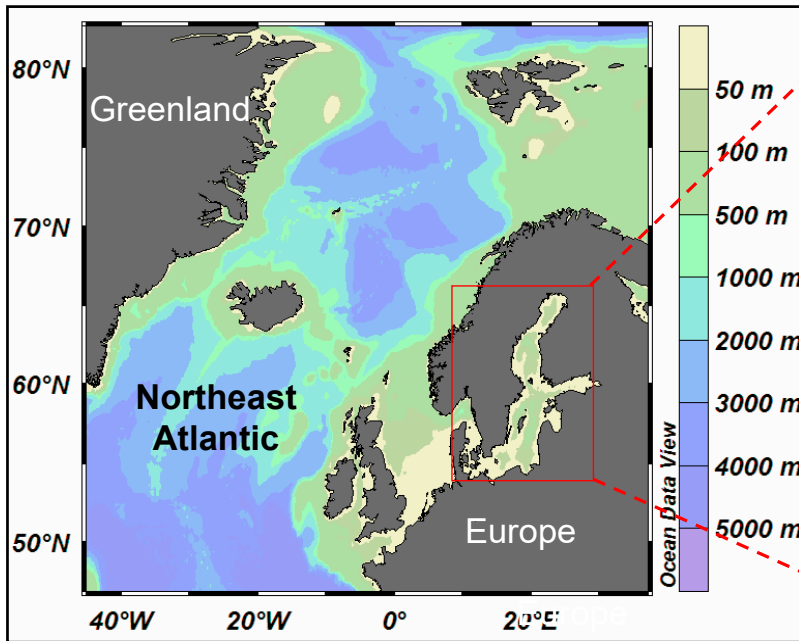


Pollution

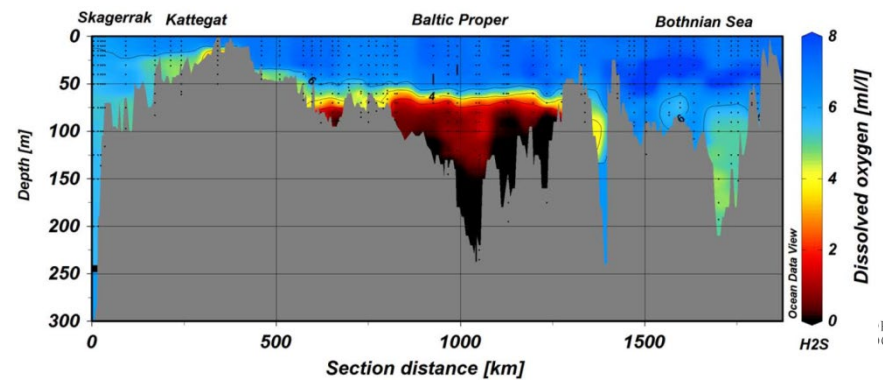




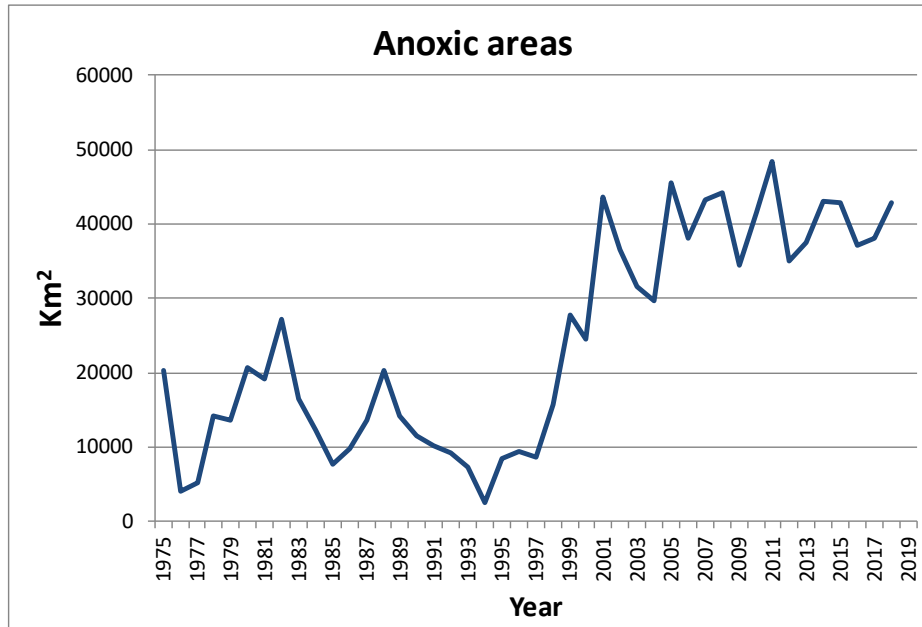
# Baltic Sea: anoxia and hypoxia



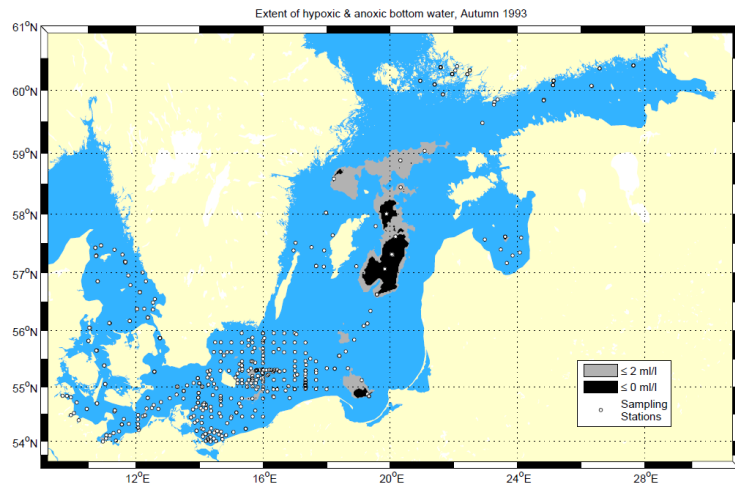
Large hypoxic areas



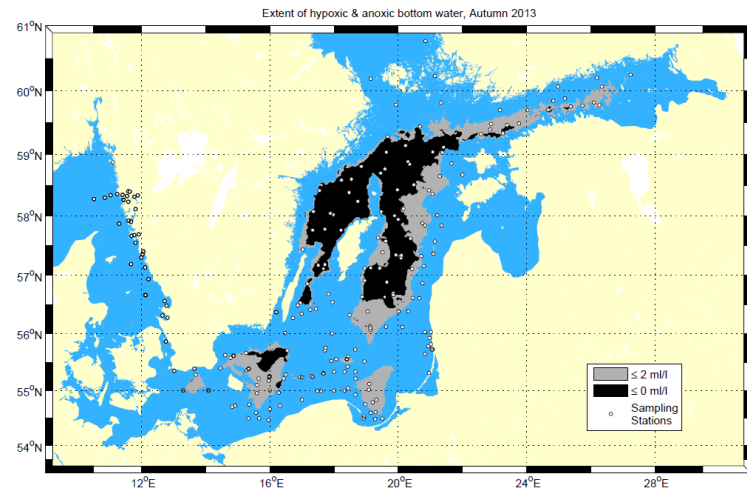
# Baltic Sea: anoxia and hypoxia



SMHI (2019)



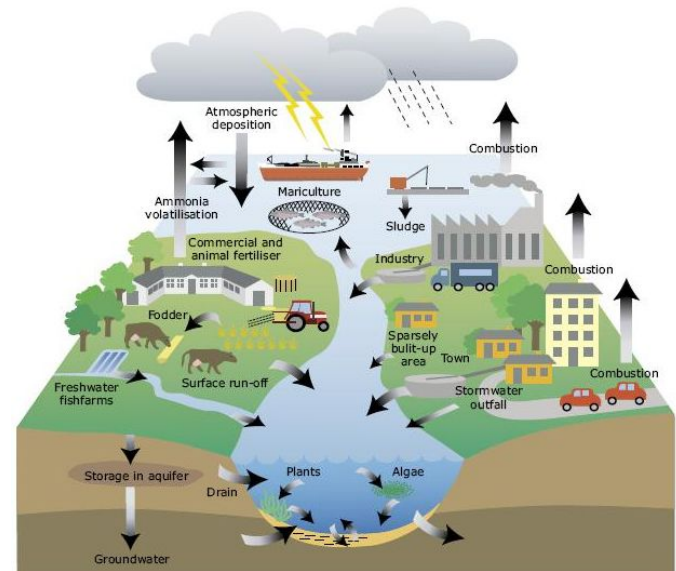
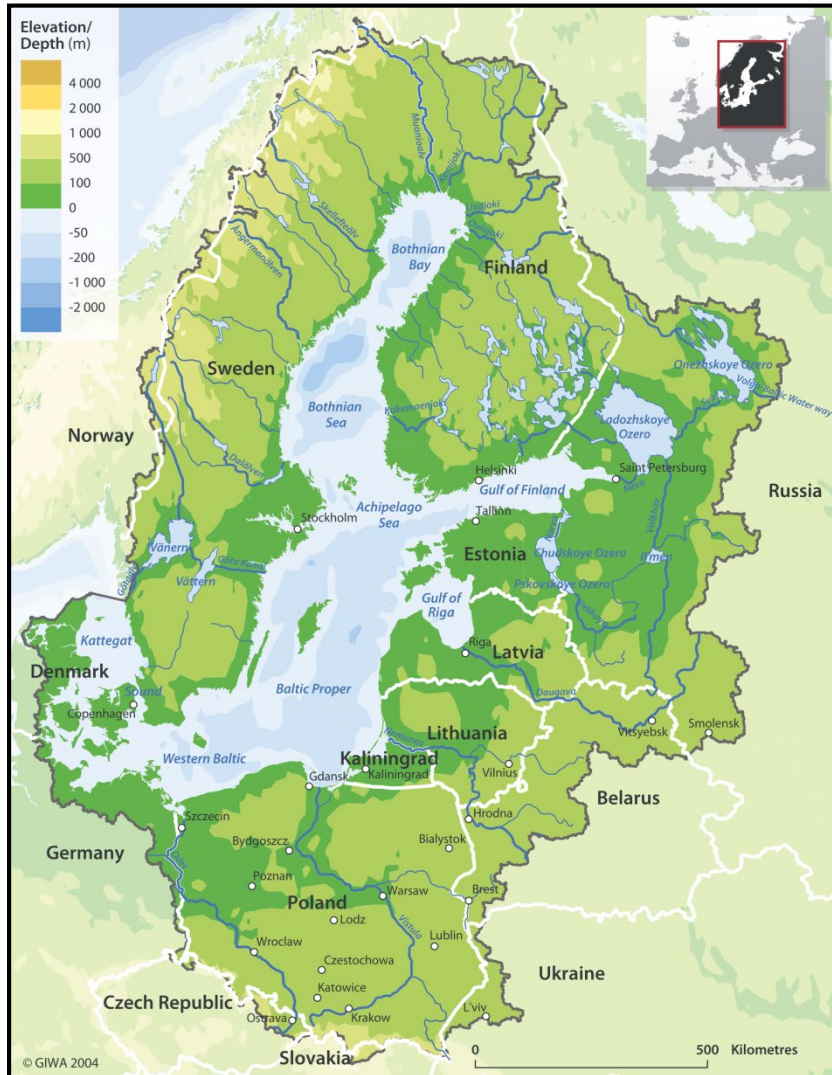
1993



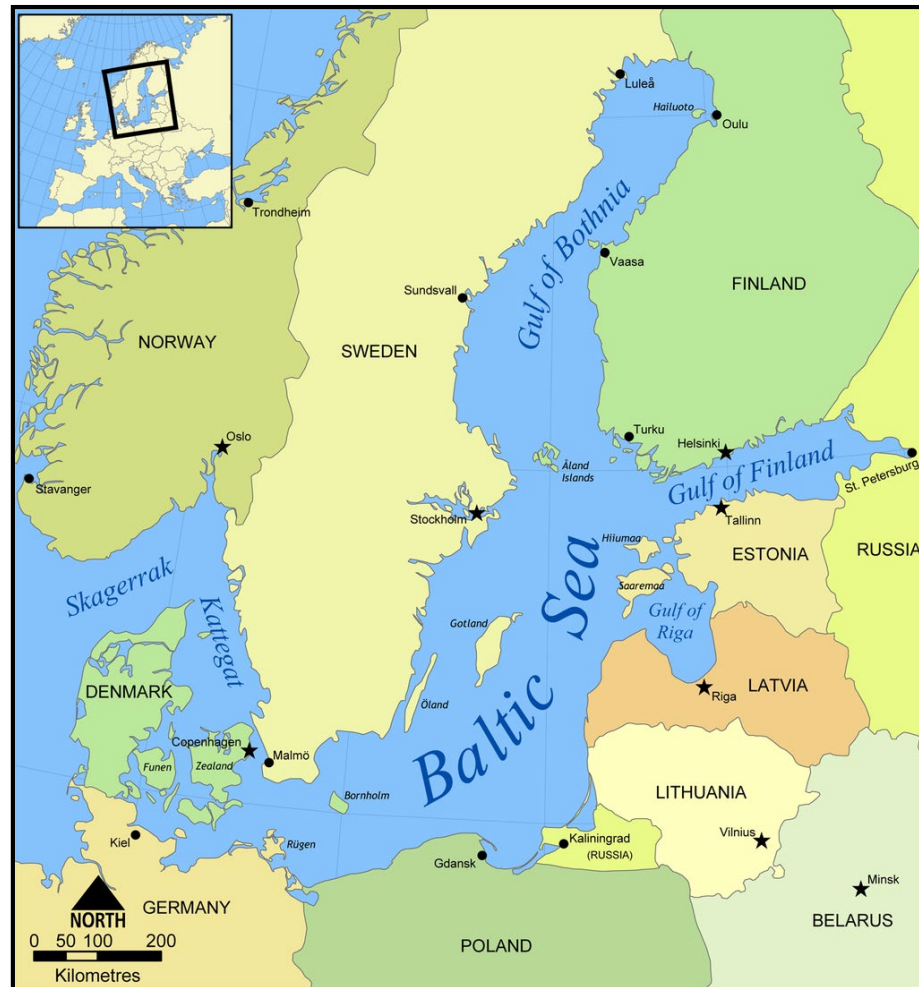
2013



# Baltic Sea: catchment area

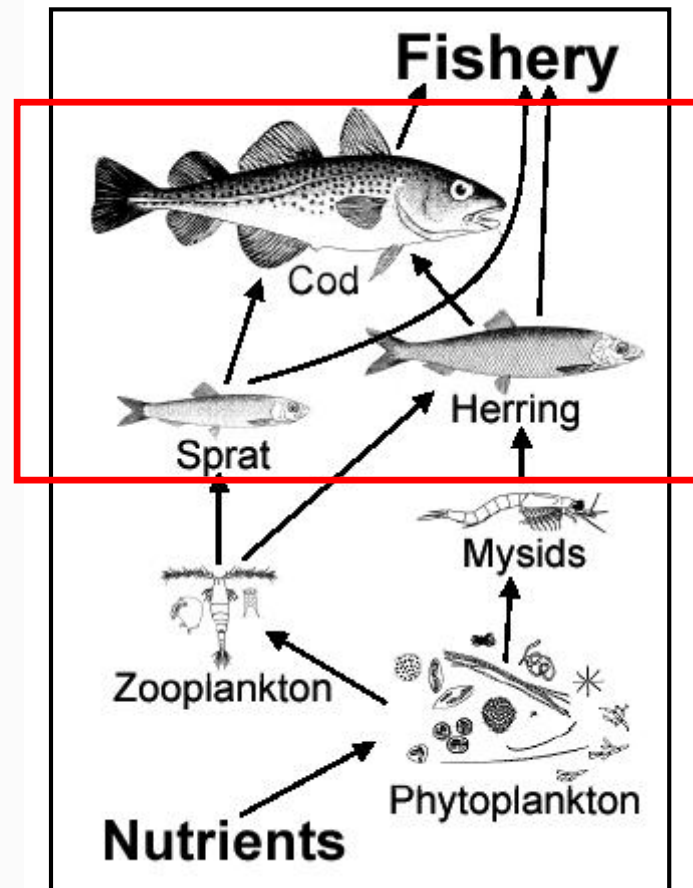
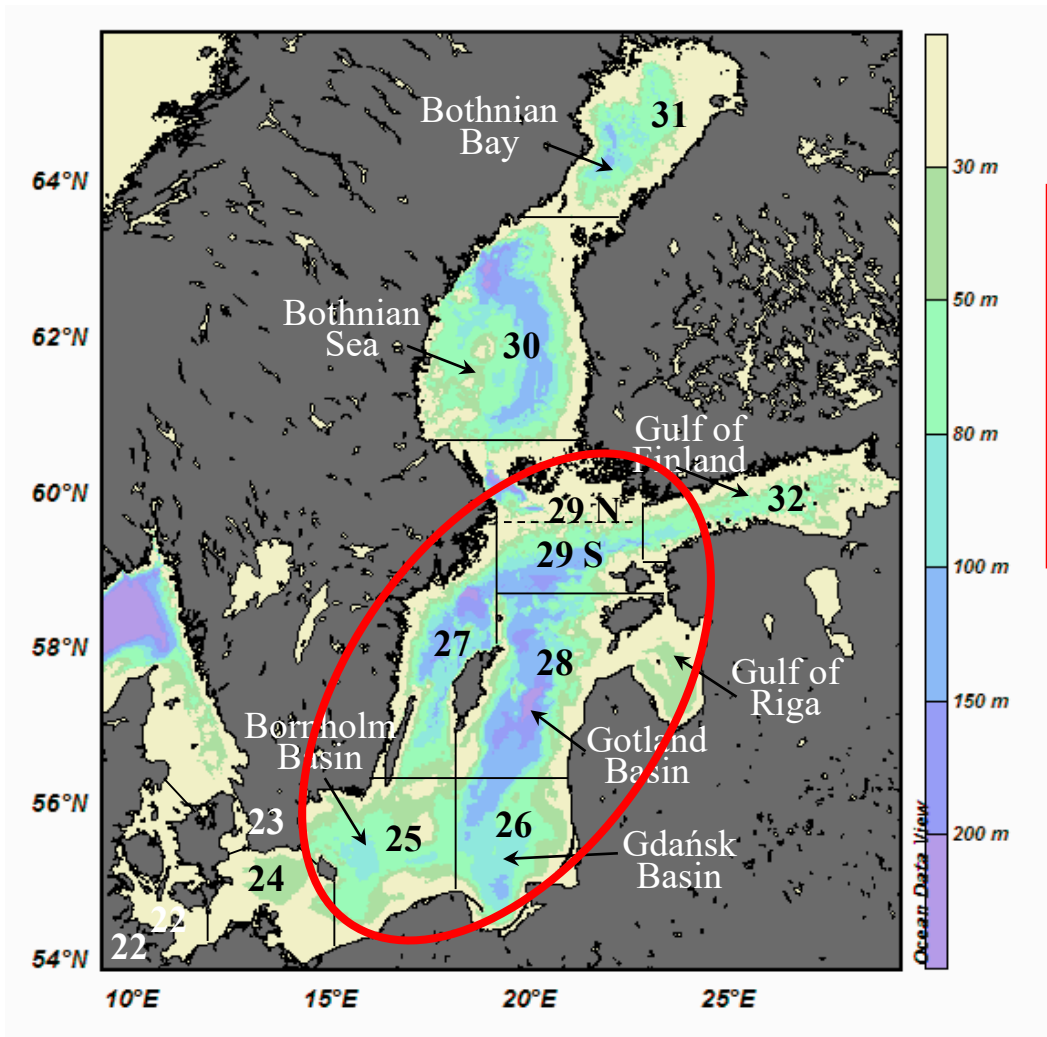


# Baltic Sea: complex political situation

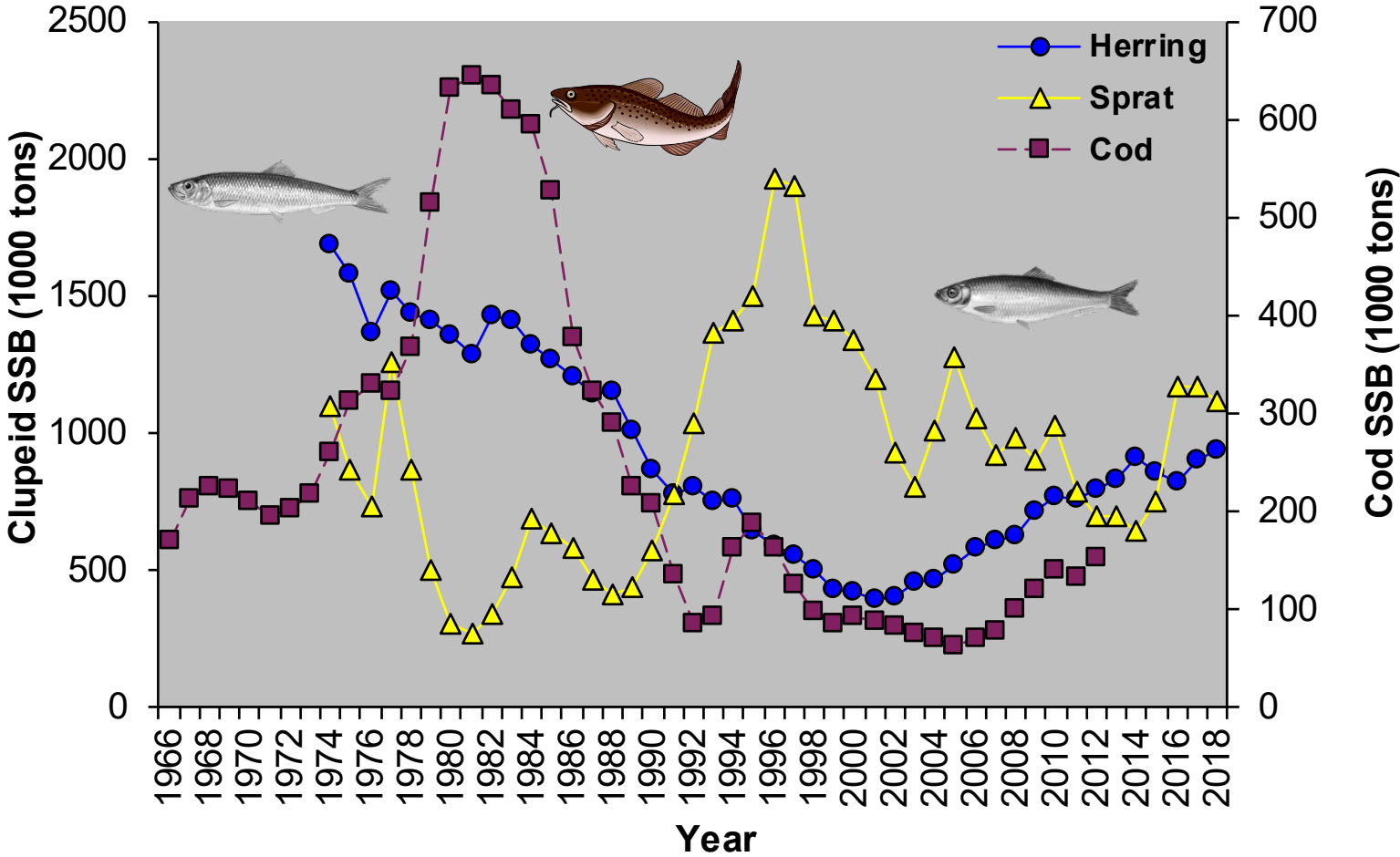




# Baltic Sea: simplified food-web



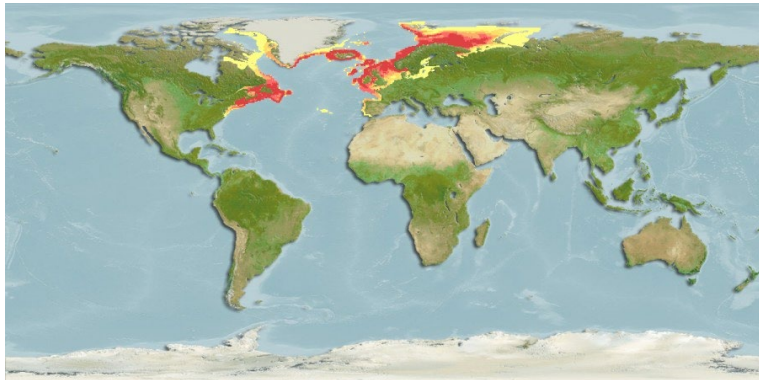
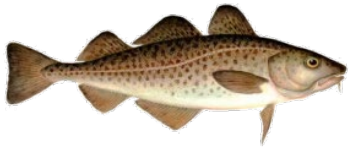
# Changes of the main fish populations



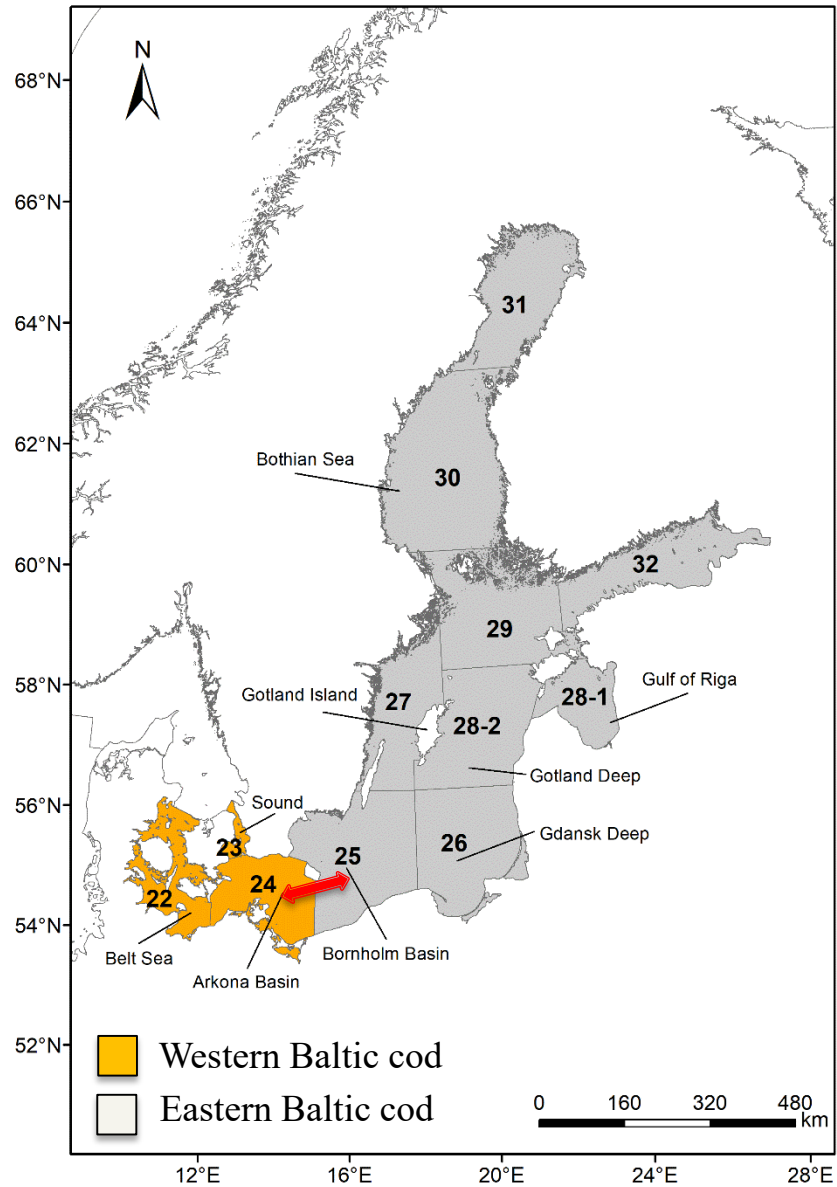
ICES WGBFAS (2019)  
Stock assessment



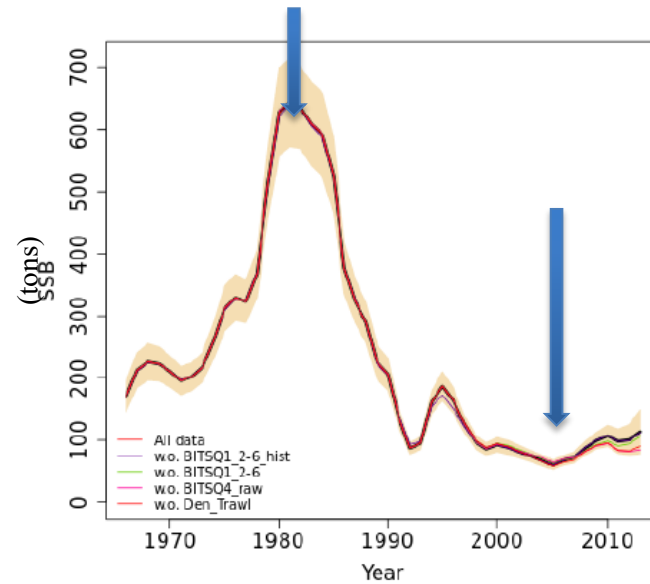
# The Baltic cod stocks



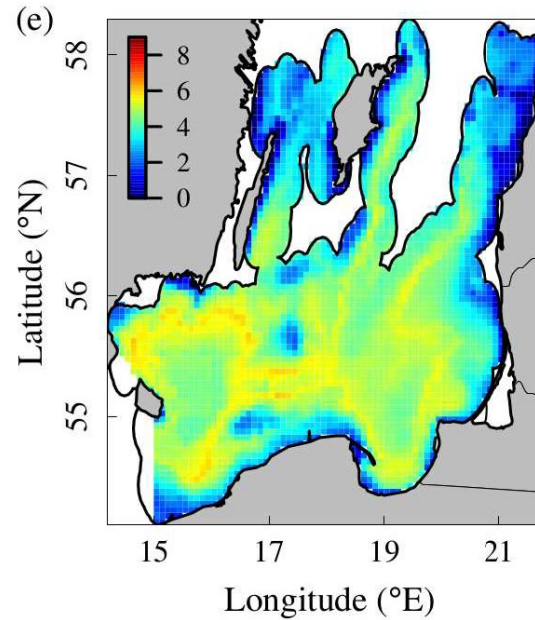
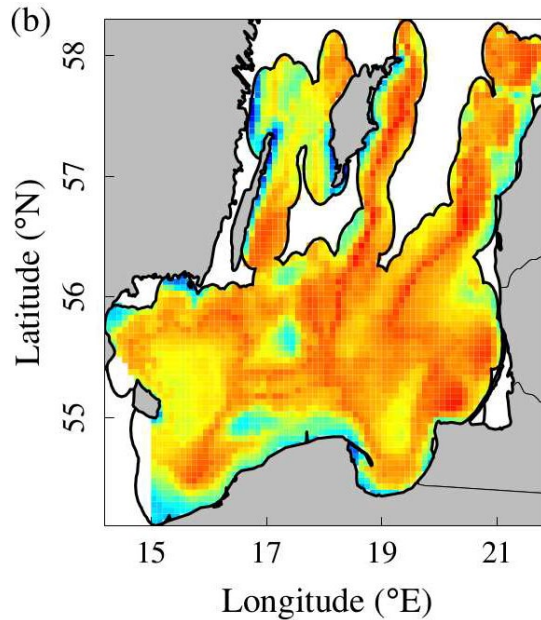
FishBase



# Contraction of the spatial distribution

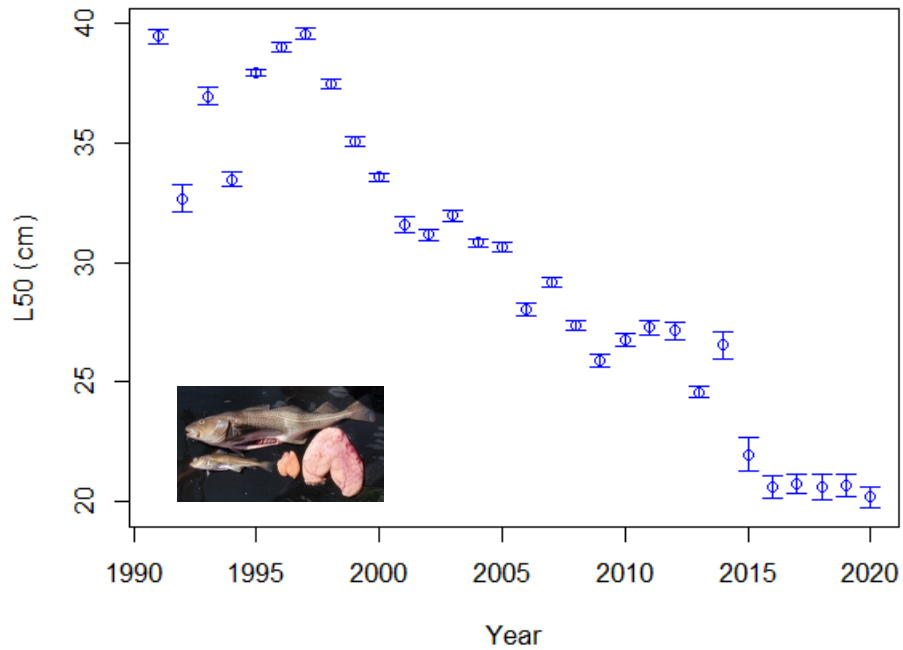


ICES, 2014

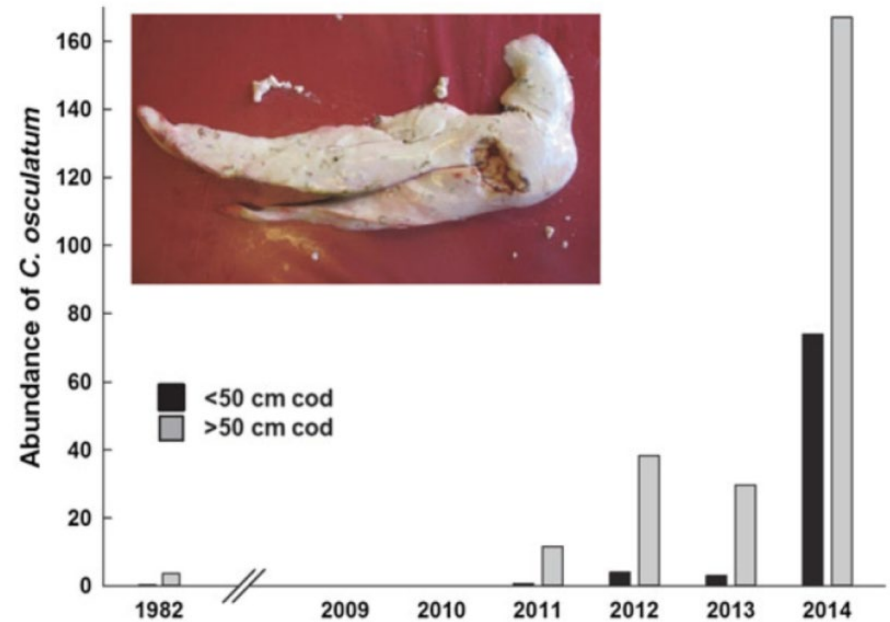


Bartolino et al. (2017)

# Decline in size at maturity and increase in parasites



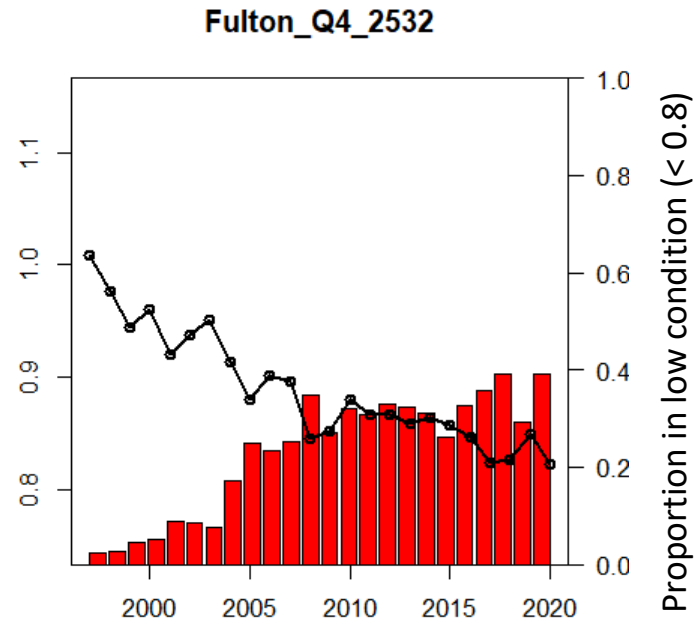
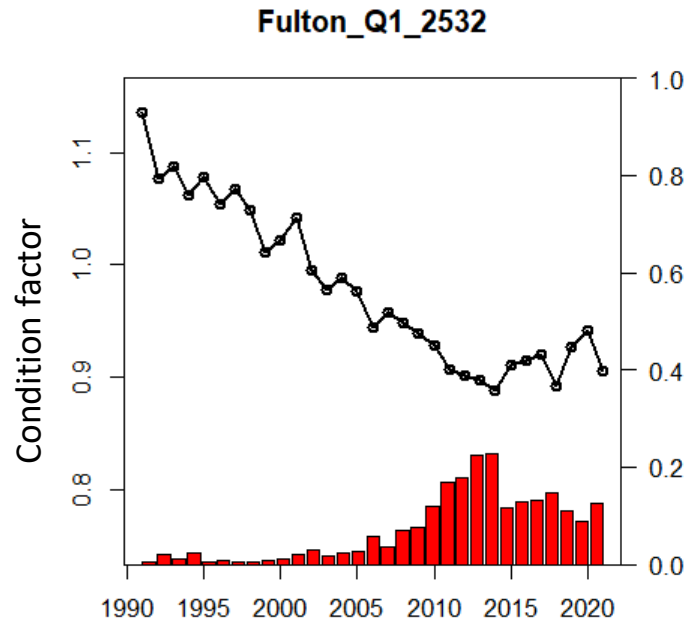
Köster et al. (2016), updated in ICES (2021) WGBFAS



Eero et al. 2015



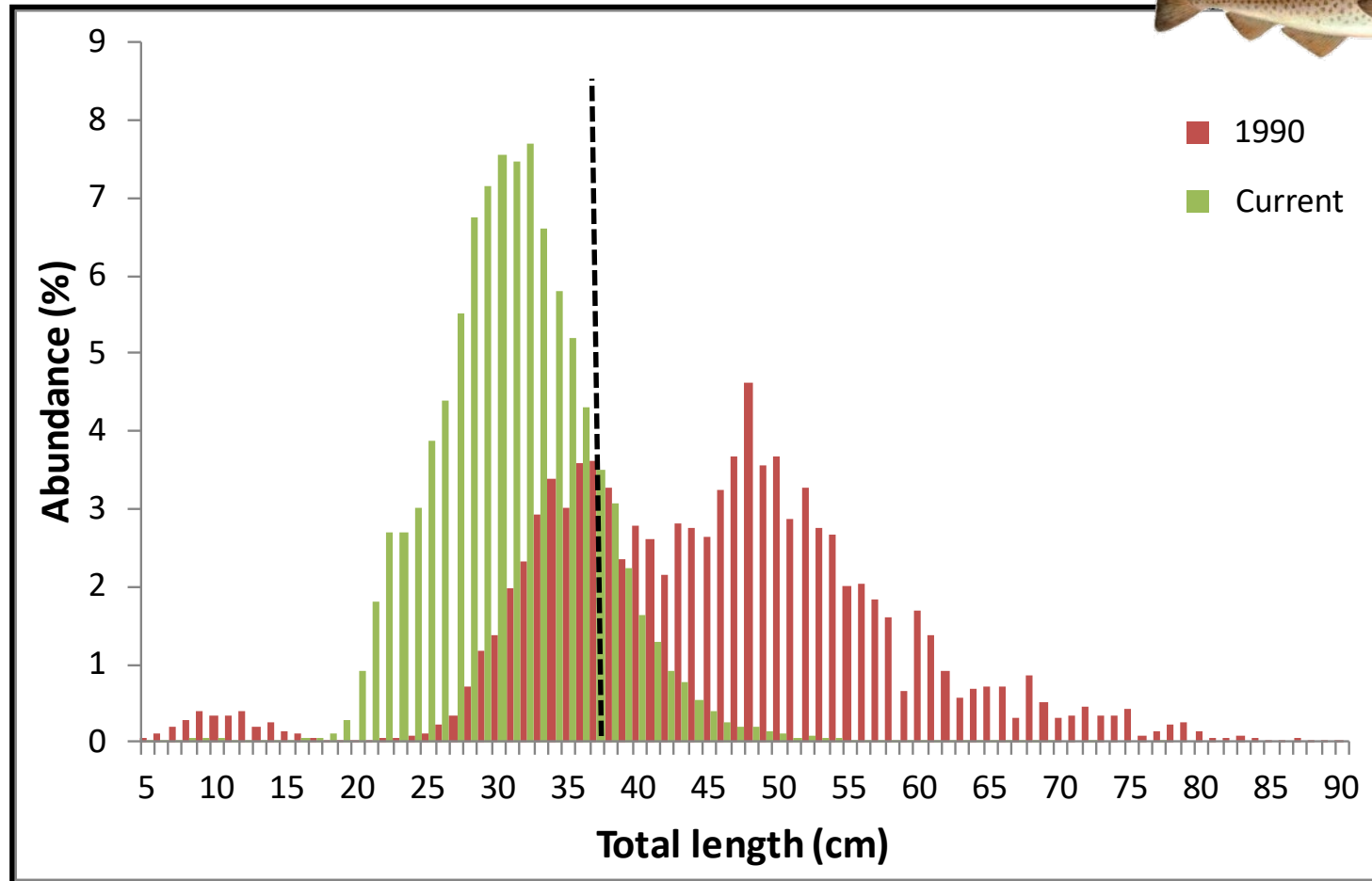
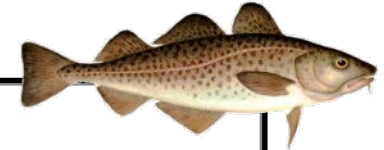
# Decrease in condition: Fulton's K



*ICES (2021) WGBFAS*



# Disappearance of large cod





# Disappearance of large cod



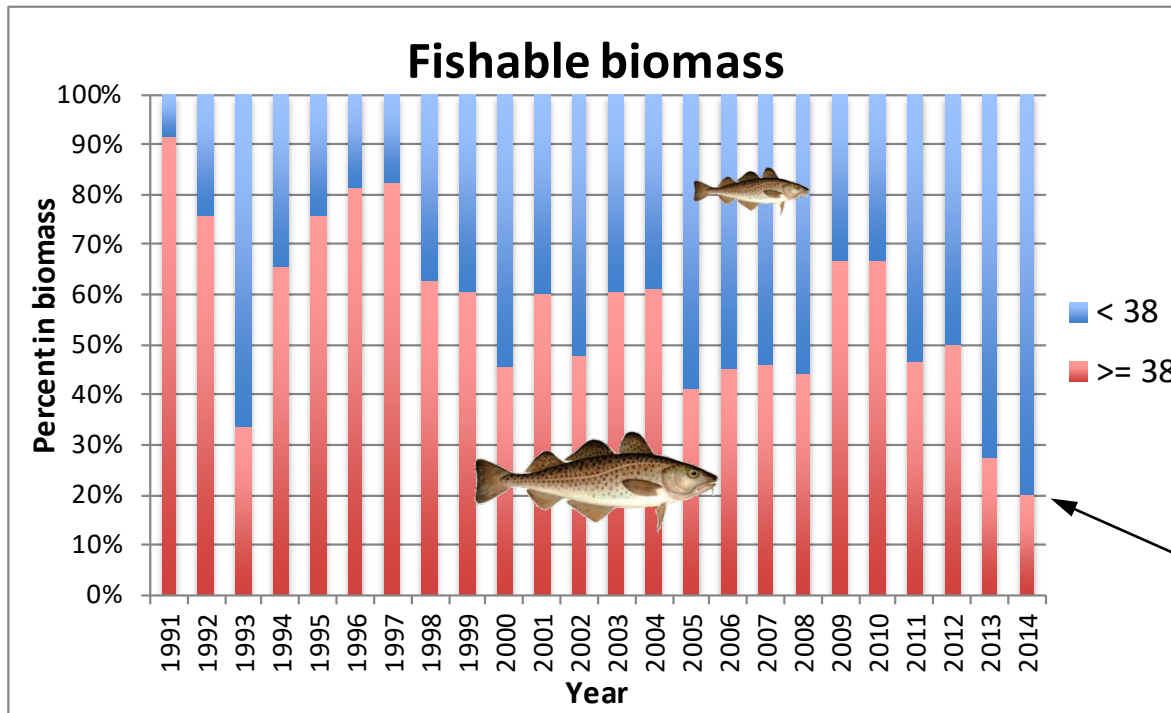
Once upon a time....





# Effects of small cod size: the fisheries perspective

A



B

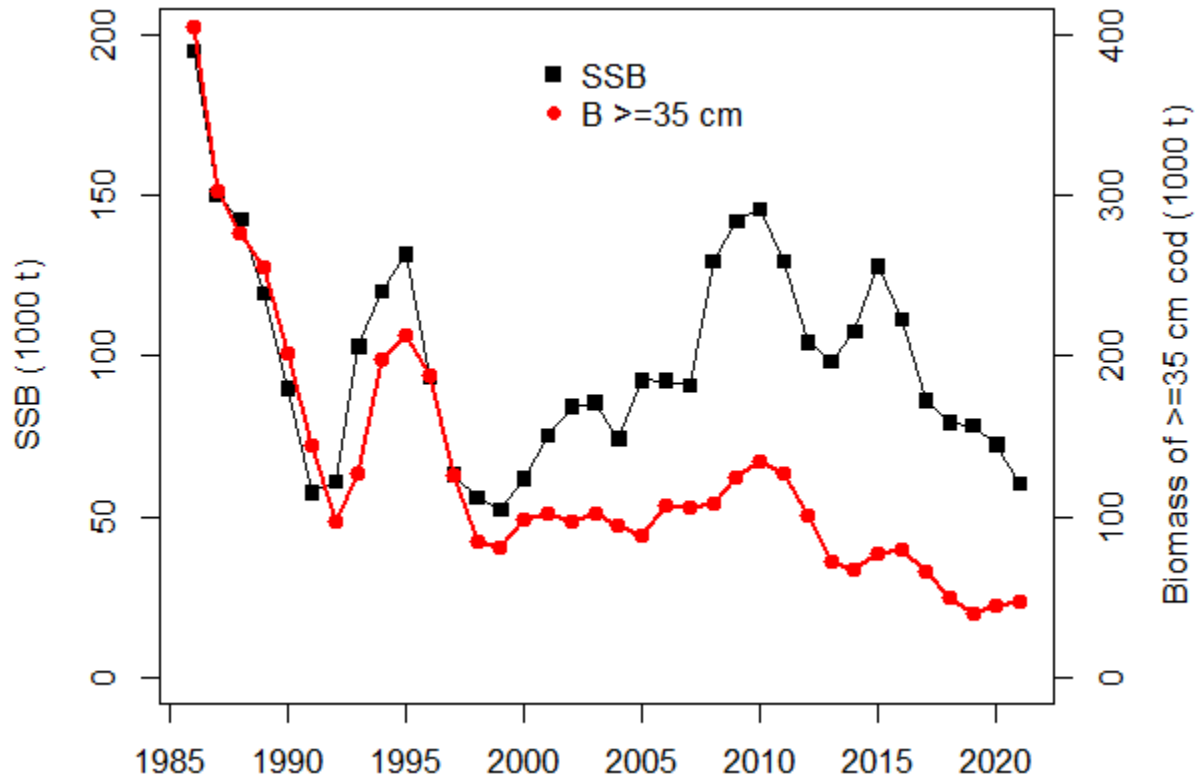


20% in biomassa  
7% in abbondanza

- Catture difficili da vendere
- Aumento dei rigetti
- I pescatori non riempiono le loro quote



# Effects of small cod size: the fisheries perspective

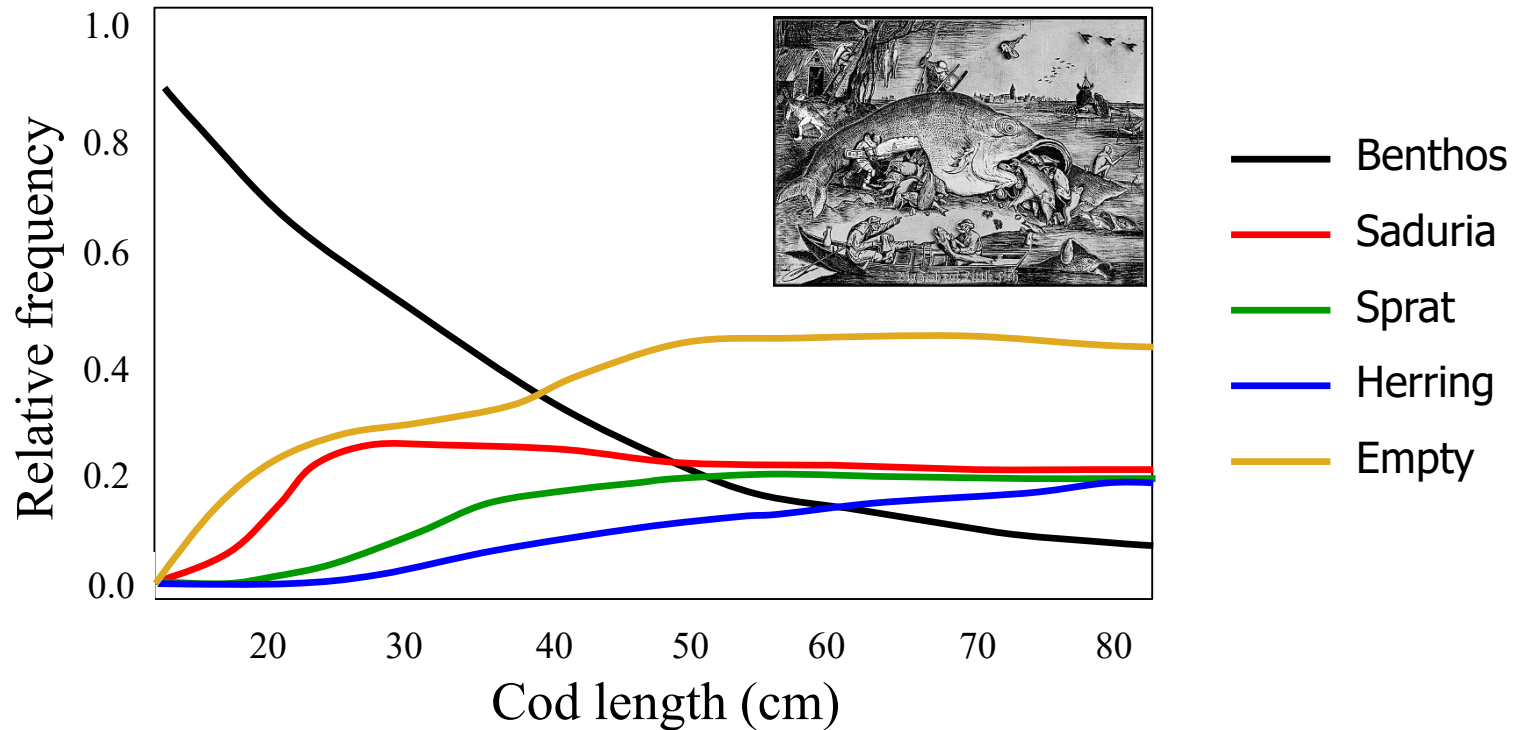


ICES (2021)

- Catture difficili da vendere
- Aumento dei rigetti
- I pescatori non utilizzano le loro quote



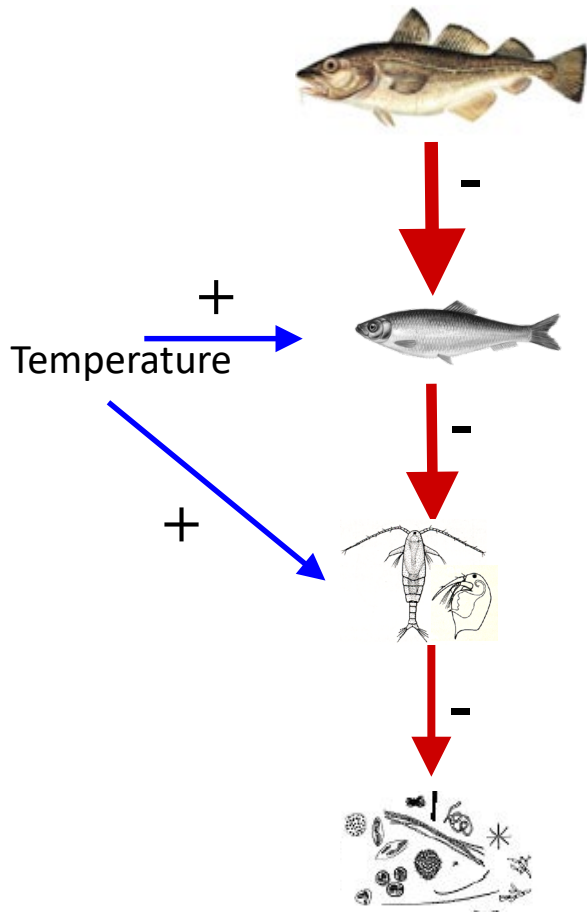
# Effects of small cod size: the ecosystem perspective



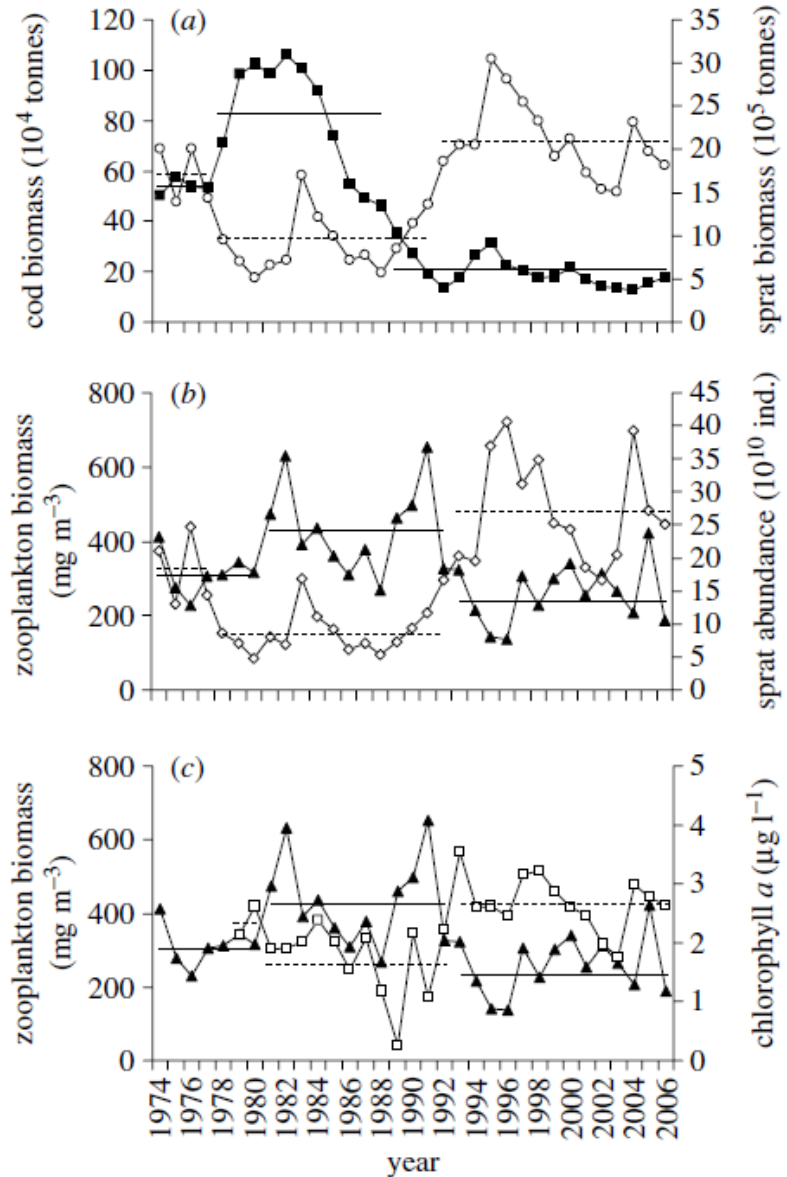
Predation pressure on forage fish is reduced when cod is small



# Indirect effects of changes in fish community



Trophic cascade



Casini et al. (2008)



# Indirect effects of changes in fish community

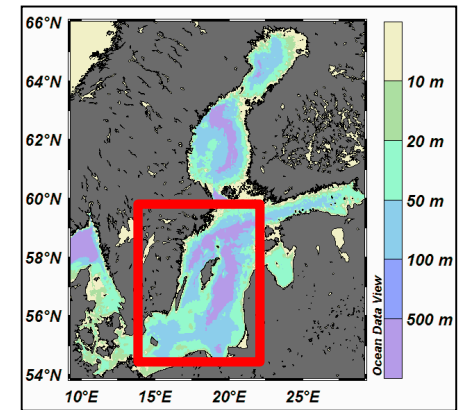
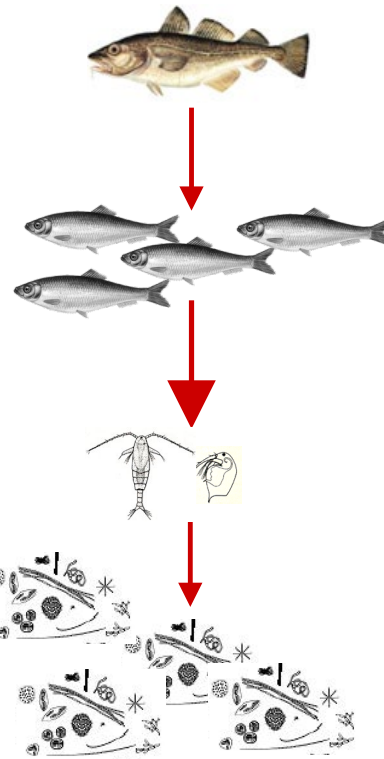
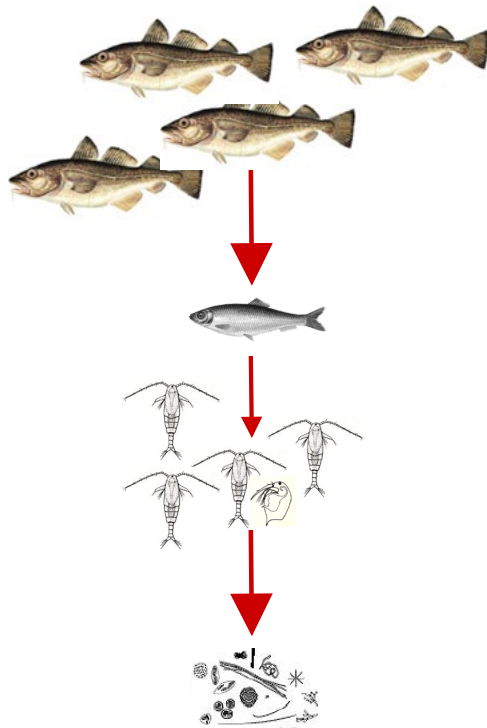
Overexploitation



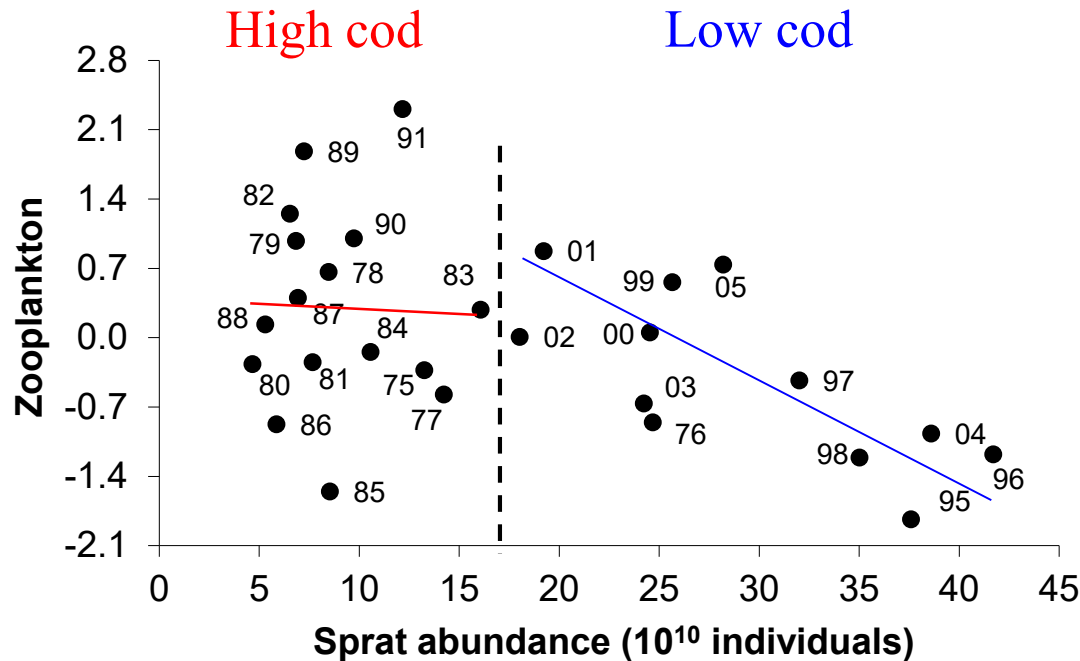
Hydrological changes  
(oxygen, salinity)

From 1990s

1980s



# Indirect effects of changes in fish community



Break-point =  
~ 17 \* 10<sup>10</sup> sprats

*Casini et al. (2009)*

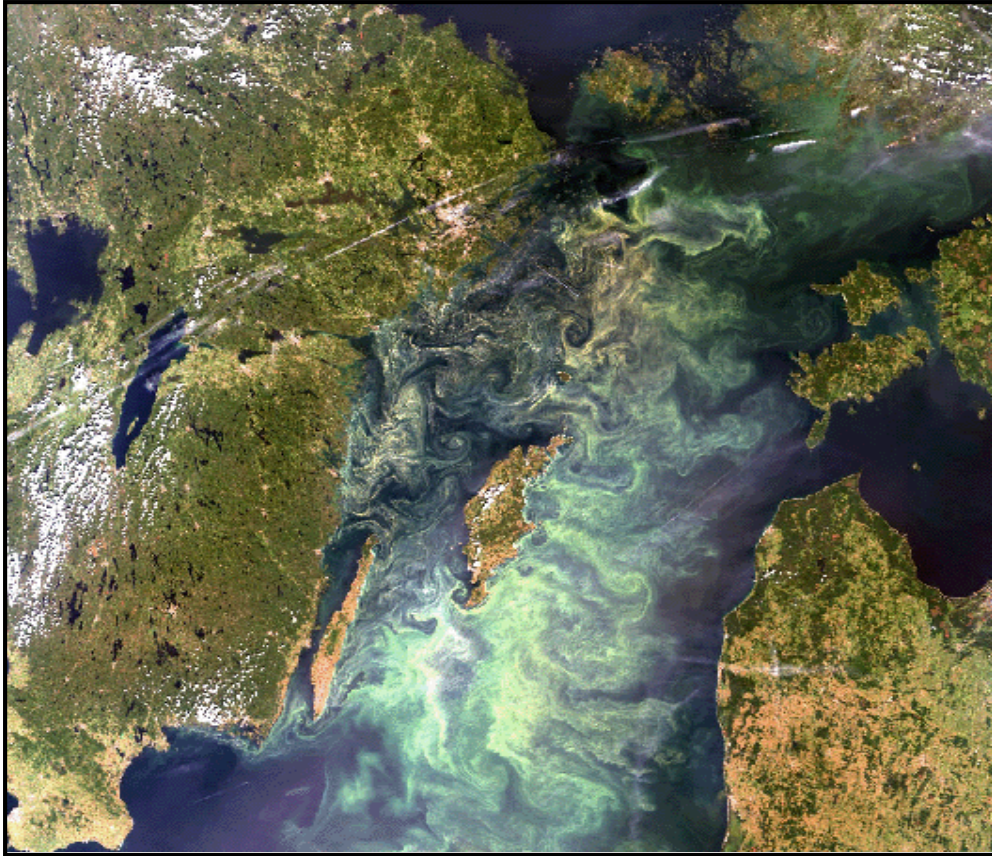
The predation effects of sprat on zooplankton seems to be evident only when the sprat stock is above a certain threshold

...we come back to this....





# Indirect effects of changes in fish community



Algal blooms are not only due to nutrients emissions, but also to overexploitation of the resources at the top of the food chain

Summer bloom of cyanobacteria in the central Baltic Sea (satellite image from NASA reworked by SMHI)

*Cover, Proceedings of the Royal Society B (2008, issue 1644)*



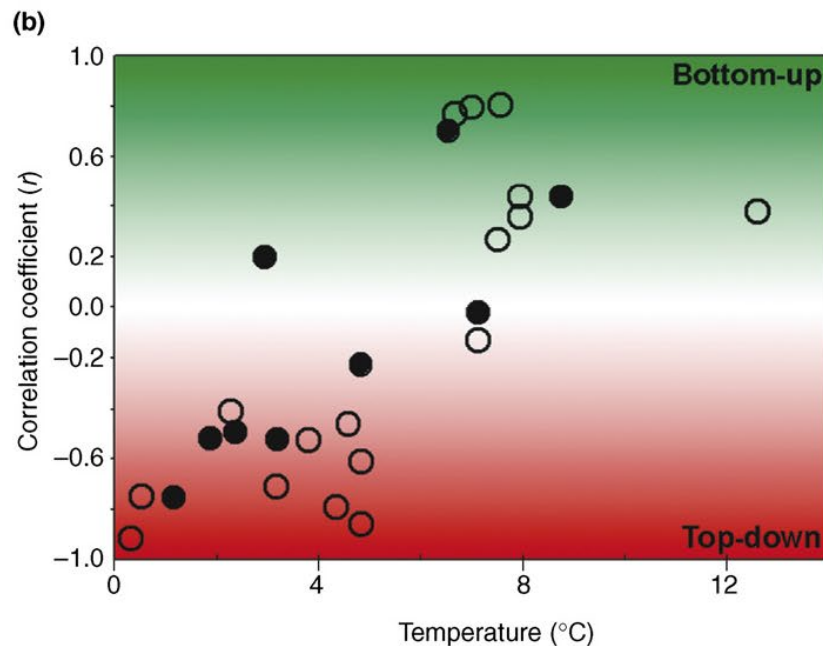
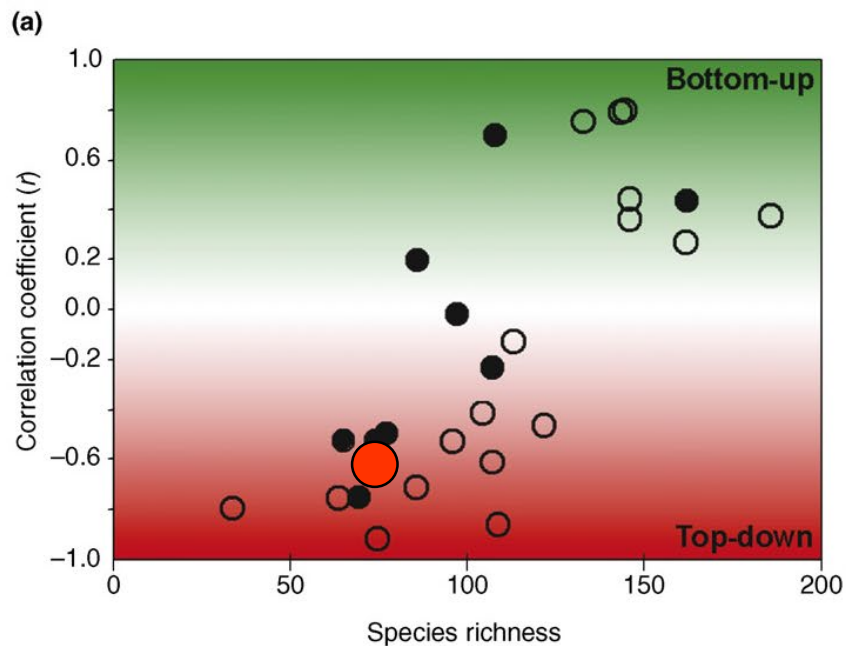
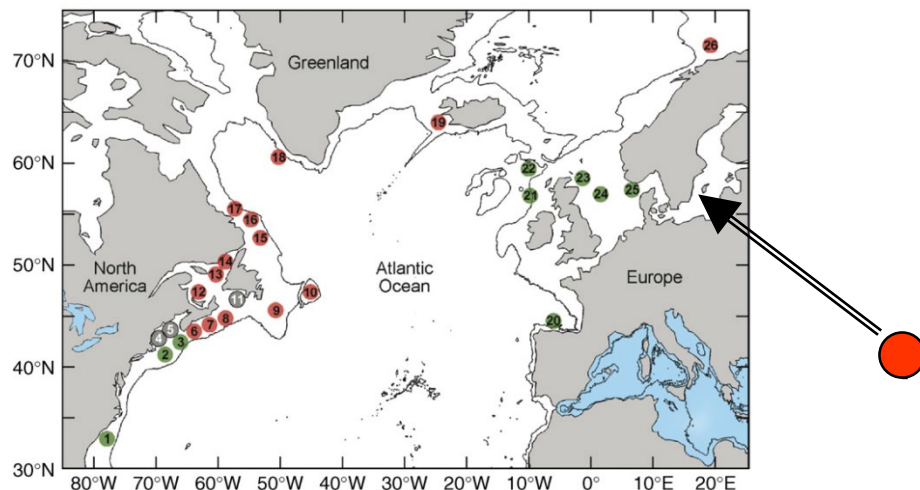
European Parliament

Presented at the European Parliament 2011



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# Top down vs bottom up control: putting the Baltic on map





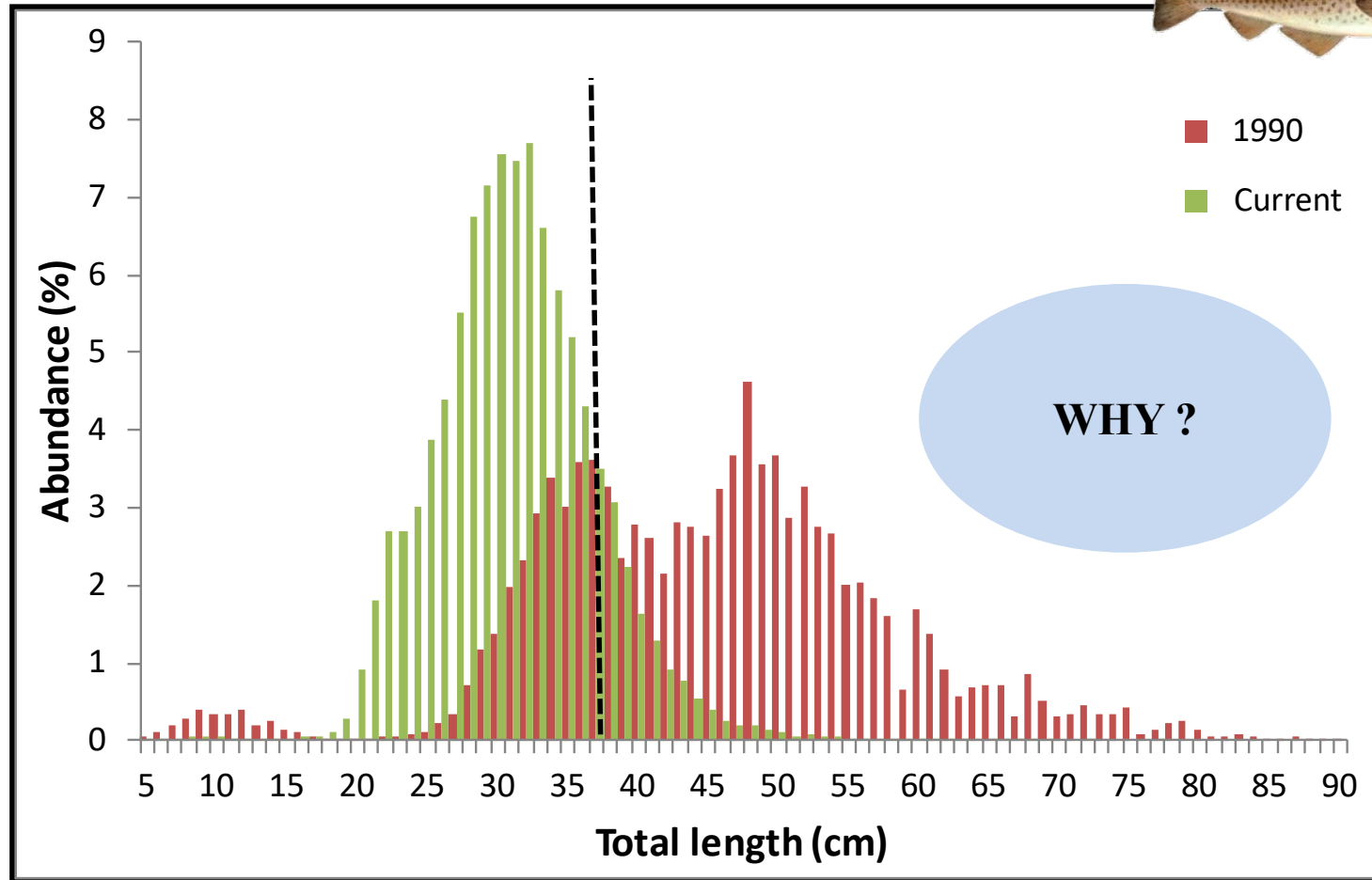
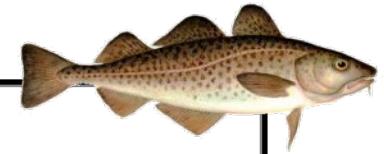
New project  
in support to management:

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Has Baltic cod growth rate changed?



# Disappearance of large cod



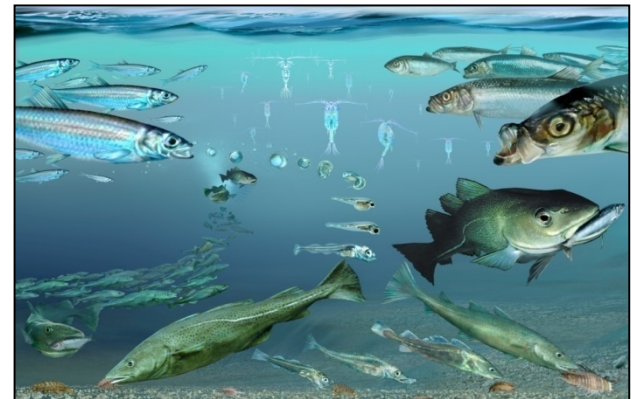
# Disappearance of large cod

## WHY?

- High size-selective fishing pressure?
- High natural mortality?
- Decrease in individual growth rates?
  - If yes, when during the lifetime?
  - If yes, what are the causes?
- Can we do anything about it?



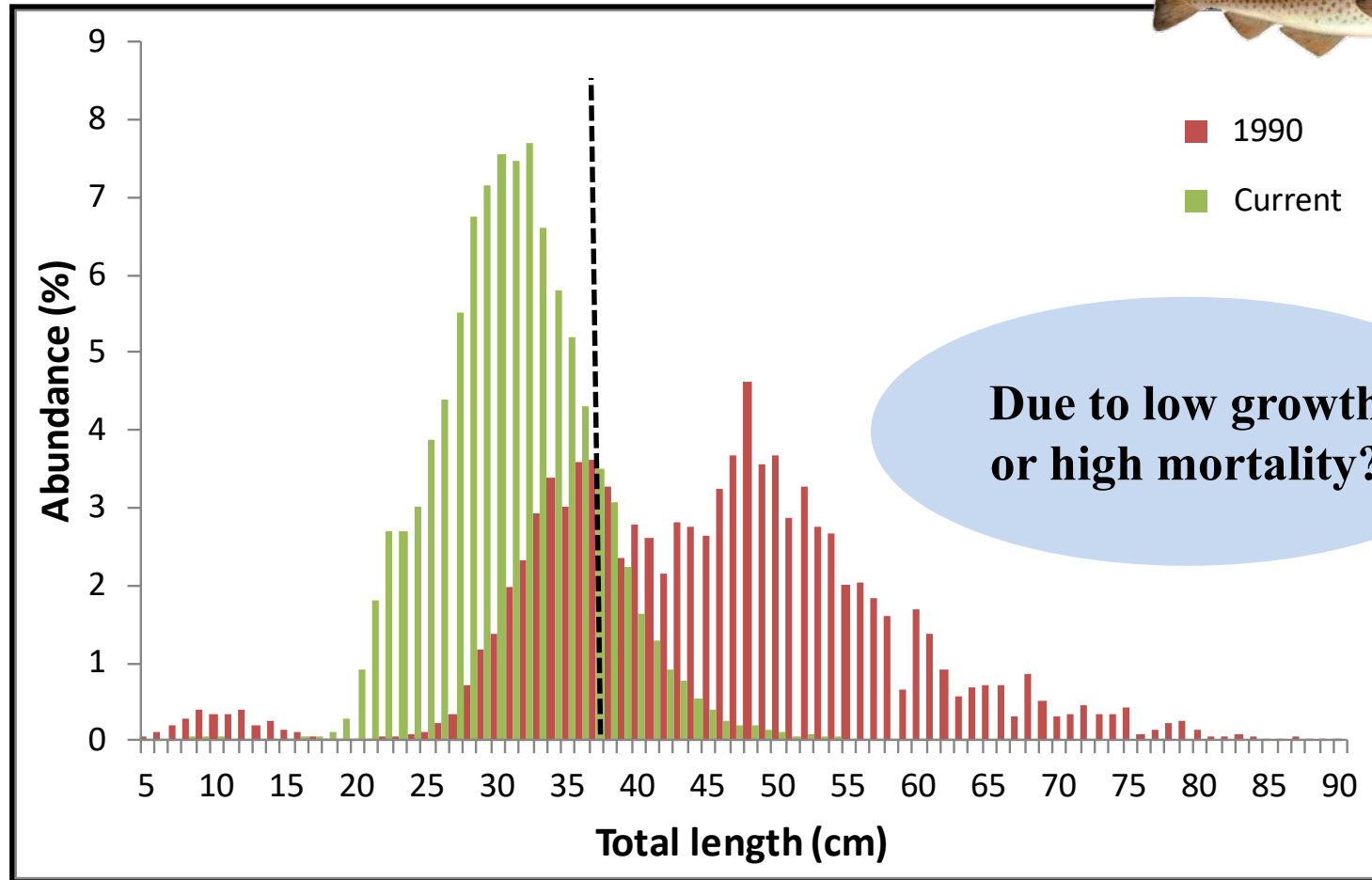
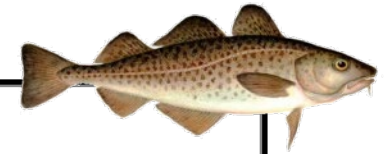
*Photo Magnus Andersson*



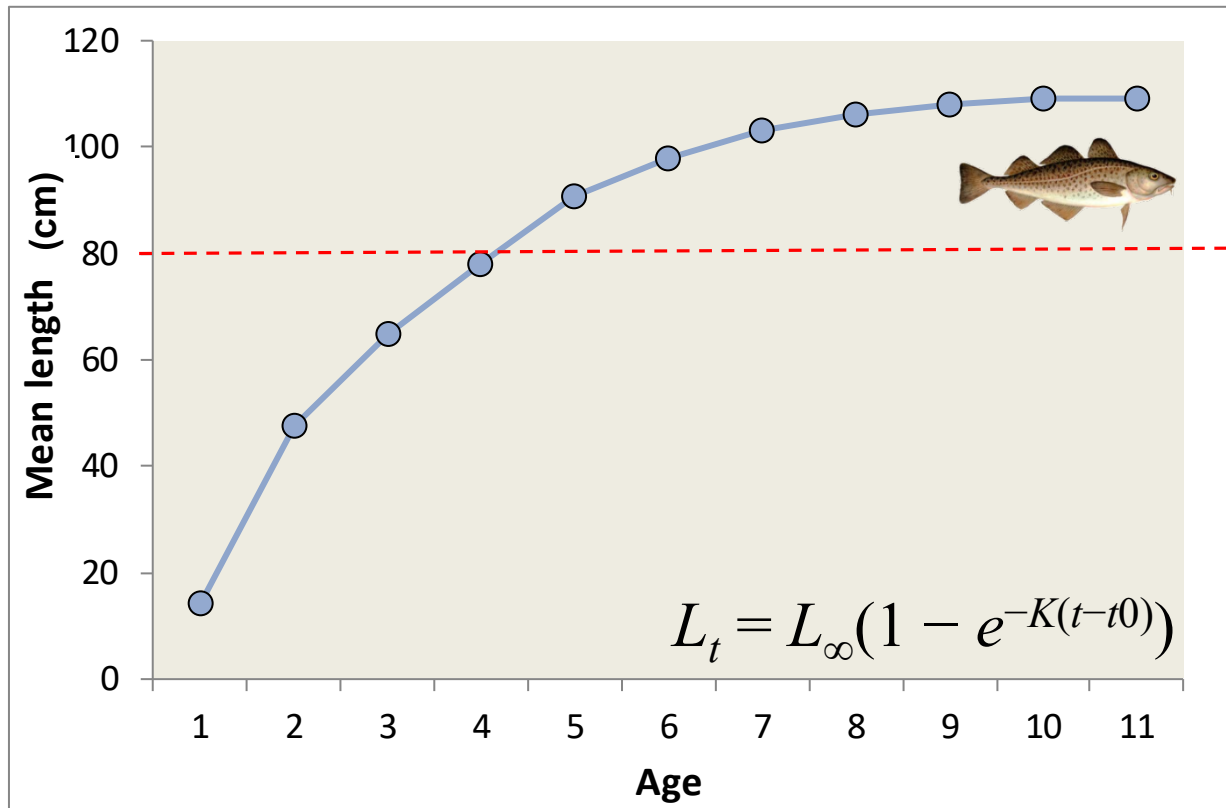
*© G. Gorick and DTU Aqua*



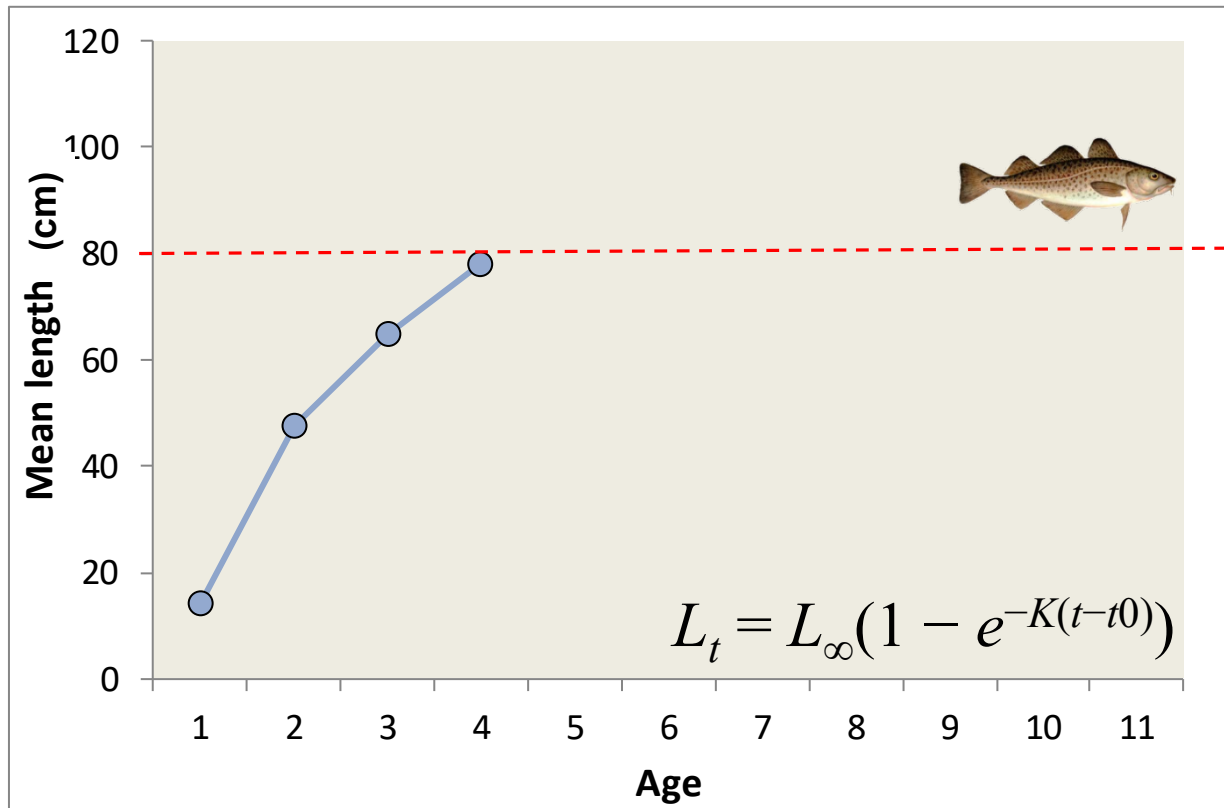
# Disappearance of large cod



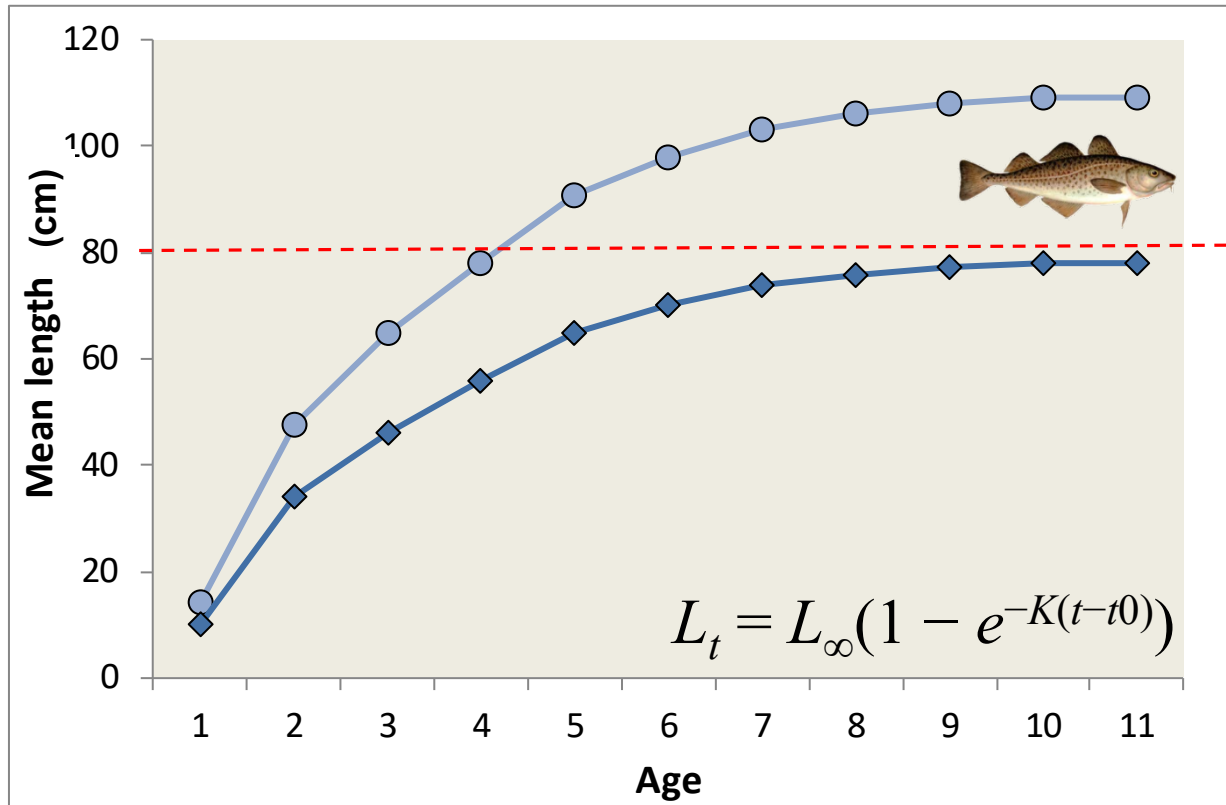
# Disappearance of large cod



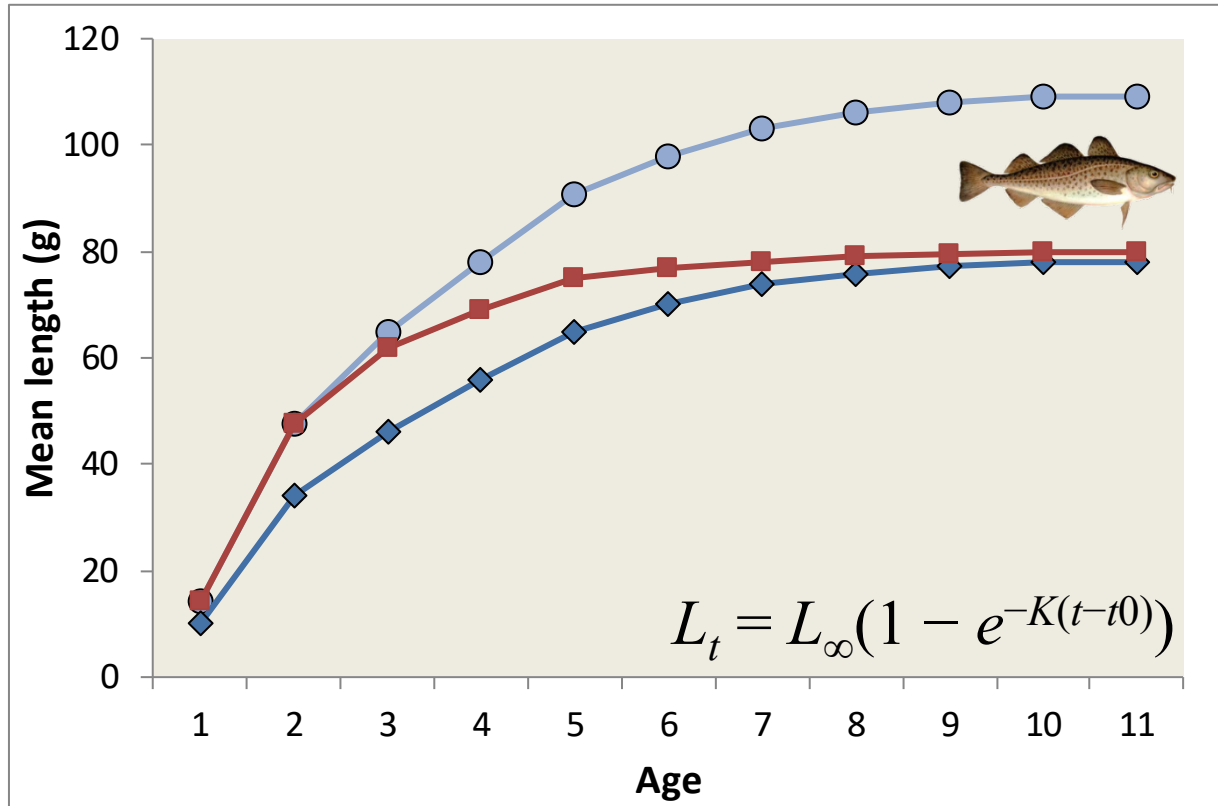
# Disappearance of large cod



# Disappearance of large cod

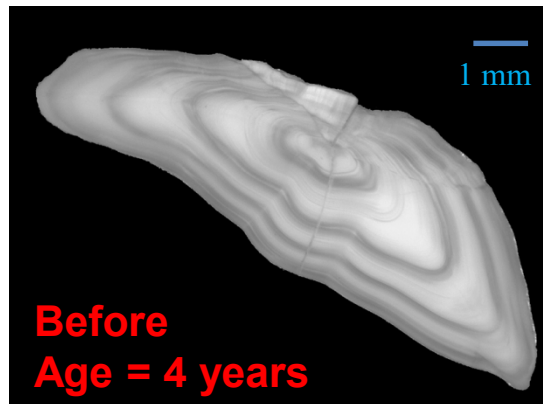


# Disappearance of large cod





# Disappearance of large cod



Otoliths:  
ear stones

*Photo Karin  
Hüssy*

- Difficult to determine age with ordinary otoliths reading
- Has growth decreased or fish just die?

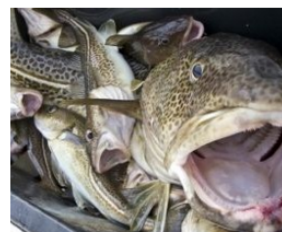


# Otoliths readability and stock assessment

- Growth and mortality unknown
- No analytical assessment 2012-2018
- ICES advice uncertain
- Management problematic
- MSC suspended



## Eastern Baltic cod fisheries lose MSC approval



December 17, 2015, 11:38 am

[Undercurrent News](#)

Marine Stewardship Council (MSC) certification for all five cod fisheries in the Eastern Baltic Sea has been suspended.

Independent assessment of the fisheries has shown that eastern Baltic cod stocks no longer meet the robust requirements of the MSC fisheries standard. This means that cod caught in the area from Dec. 17 can no longer be bought or sold with the MSC eco-label.

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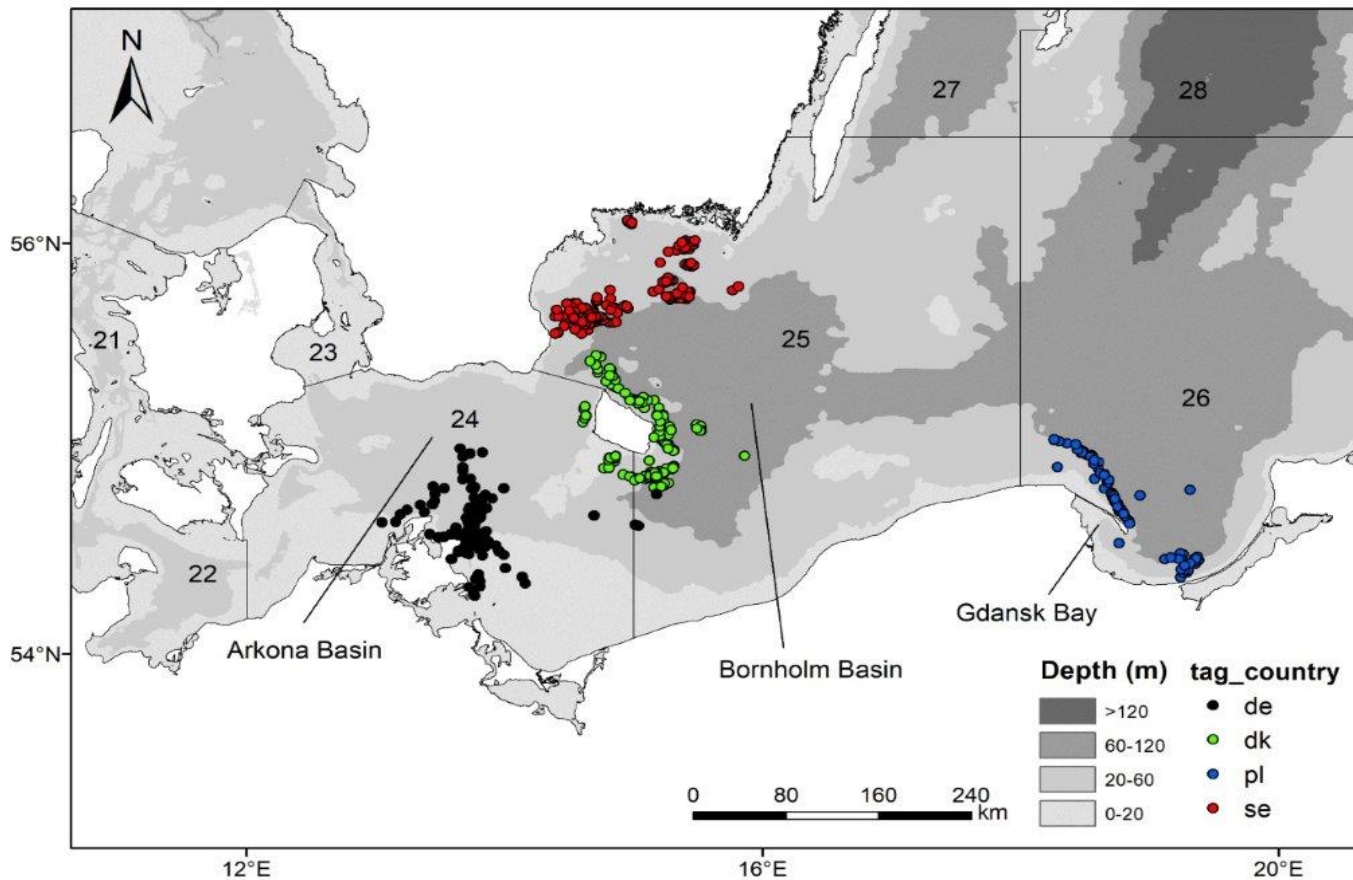
[Oceana: Baltic cod 'in peril'](#)

[Concern for overfished Baltic cod as EC cuts quotas 20%](#)

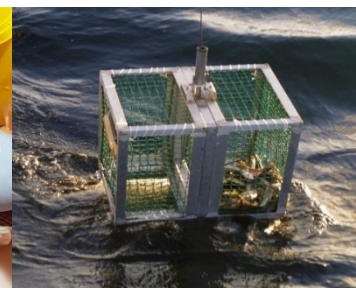
[EU whitefish quota utilization at 75.7% in 2014](#)

"The reason for suspending the fisheries is that the 2015 benchmark stock assessment provided no advice on stock status or reference points, and is not robust or appropriate for a harvest control rule; this

# The tagging experiment

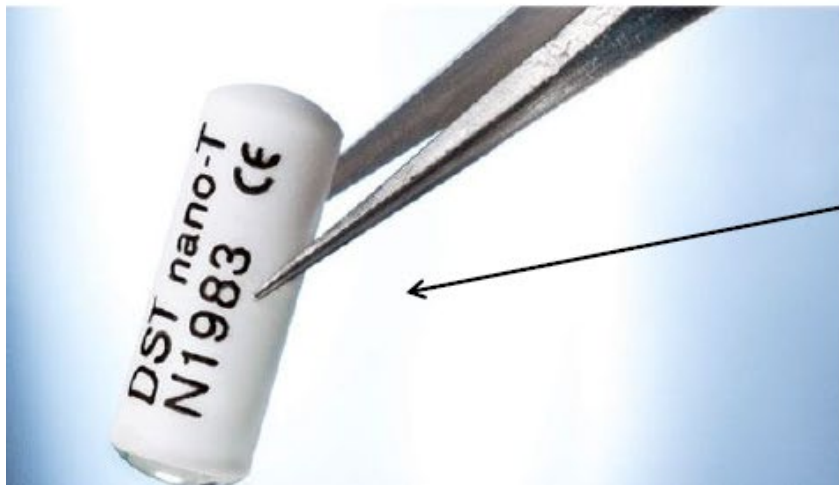
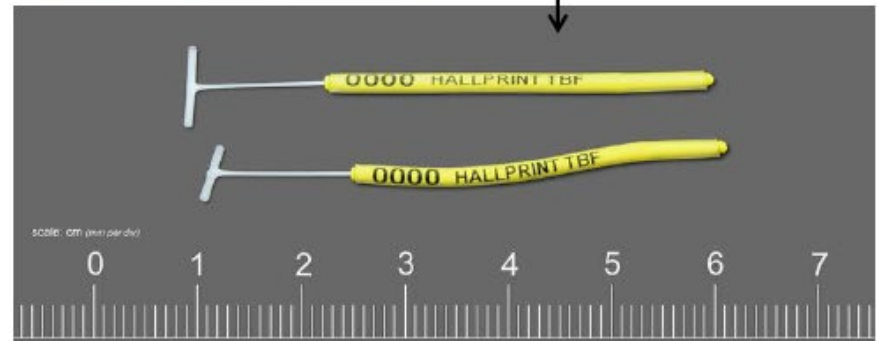
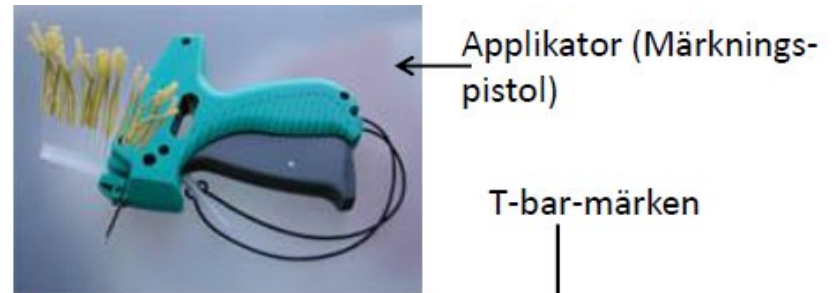


TABACOD project  
(2016-2019)  
[www.tabacod.dtu.dk/](http://www.tabacod.dtu.dk/)





# External tagging



## Datalagrande märke

Finns i olika storlekar, det vi kommer att använda är 25.4 mm x 8.3 mm och väger 1.9 g. Endast fiskar längre än 25 cm kommer att märkas med detta märke.

# External tagging



*Photo Monica Mion*



Tag and release study



# Involvement of the fishermen and industry



## 1. Spara torsken HEL (inte rensad)

Frys ner den (på is går bra en kortare period) och förvara i hamn /hemma, så att vi kan hämta den för att mäta storlek, bestämma kön och ta ut hörselstenar.

## 2. Notera fångstdatum, tid och position, redskapstyp

Helst GPS position

## 3. Vänligen kontakta

SLU Aqua | Phone: +46 (0)104784030 | annelie.hilvarsson@slu.se  
För hämtning av fisk och utbetalning av belöning m.m.

Det här märknings-återfångstprojektet (TABACOD-Tagging Baltic Cod) kommer ge information om ålder, tillväxt och rörelsemönster hos Östersjötorsk. Det kommer öka vår förståelse om torskens biologi och ge viktig information för bättre beståndsuppskattning och ICES rådgivning.

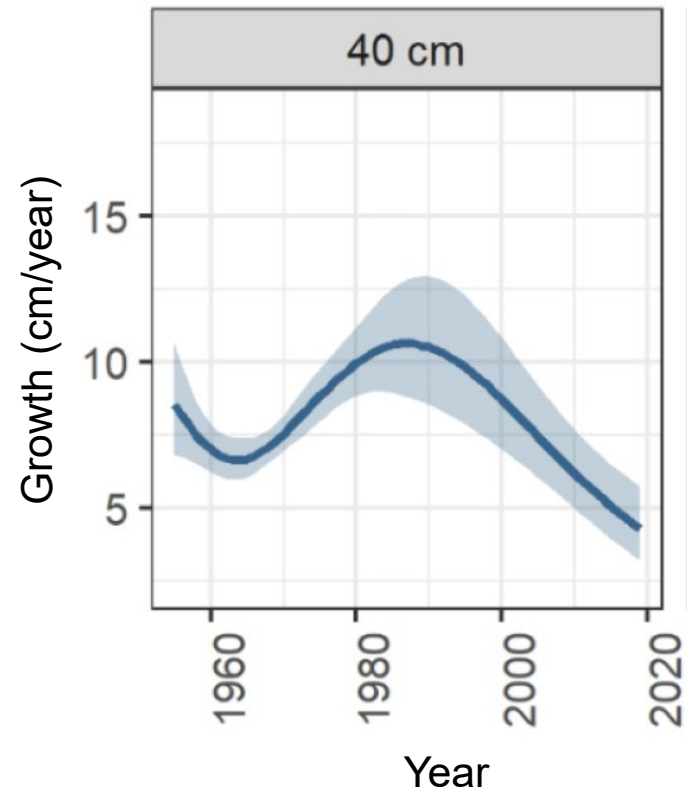
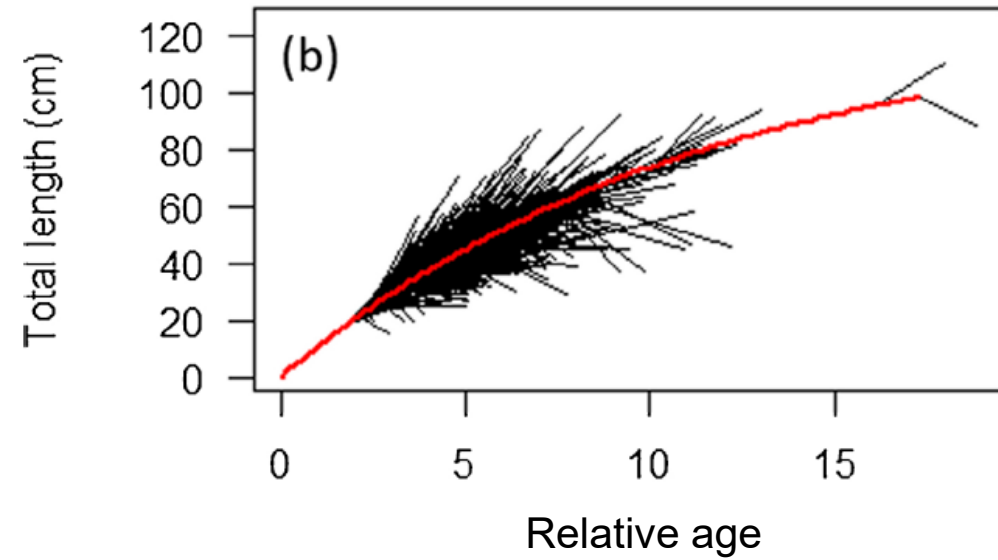
Ert samarbete är grunden för att det här forskningsprojektet ska lyckas!  
Tack för din insats!



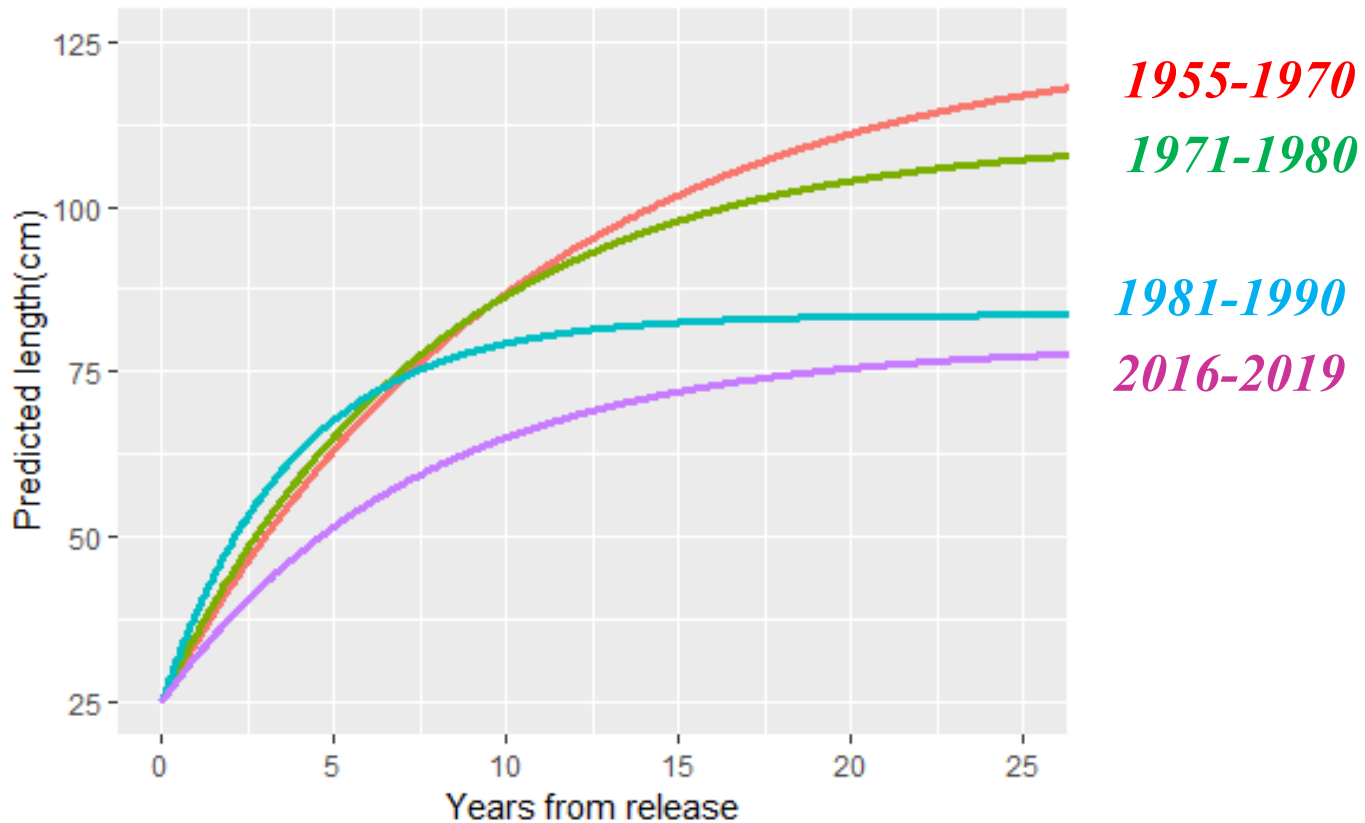
För mer detaljer  
om märkningsstudien:  
[www.tabacod.dtu.dk](http://www.tabacod.dtu.dk)



# Estimation of growth with tagging historical data



# Estimation of growth with tagging historical data

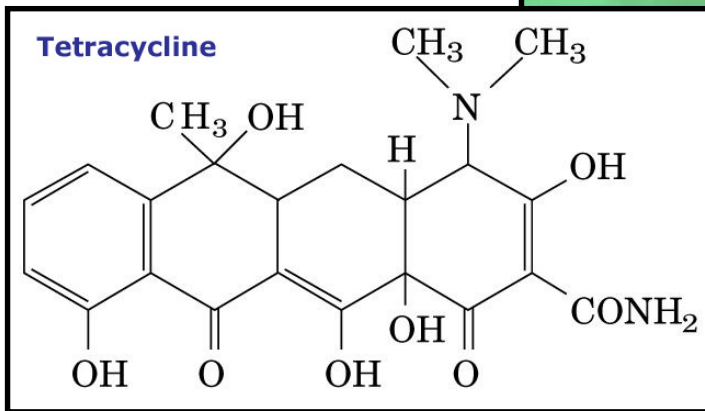
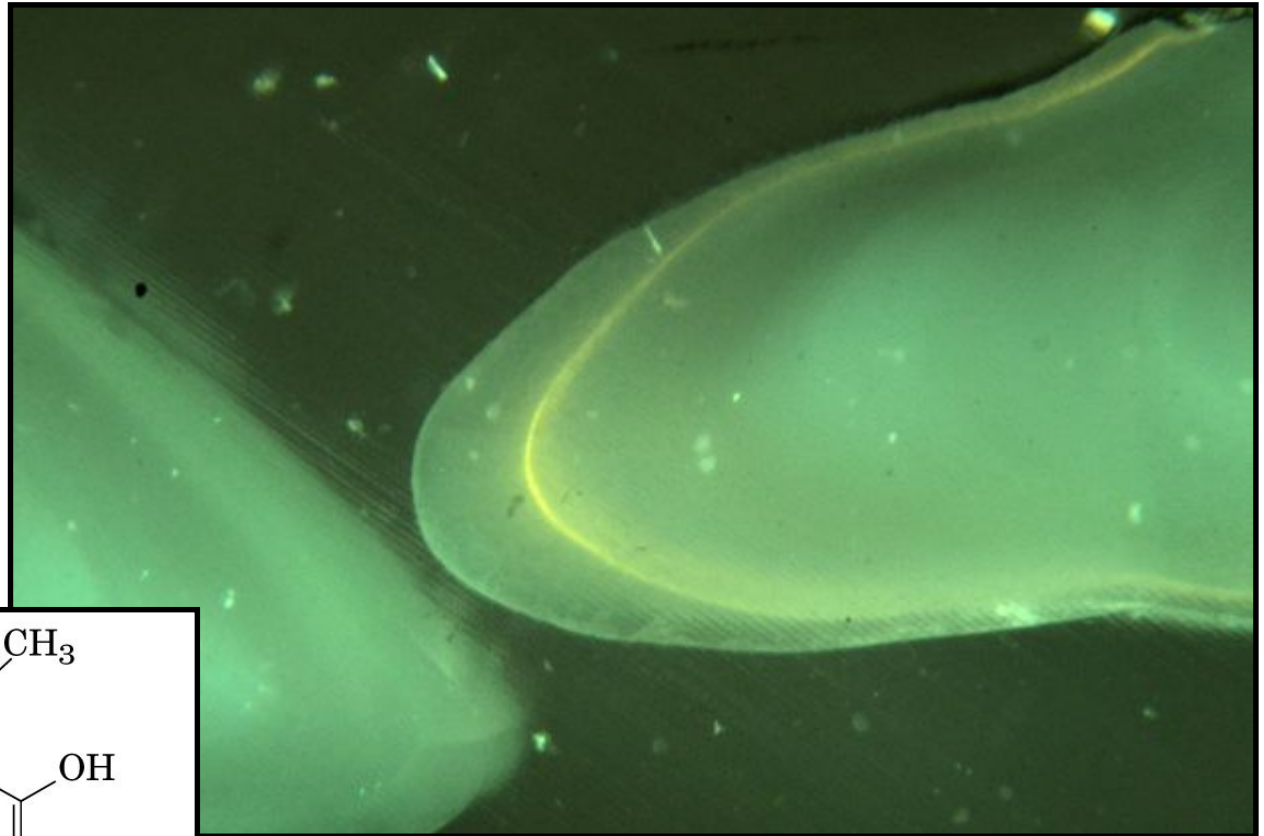


*Mion et al. (2020, 2021)*





# Internal tagging

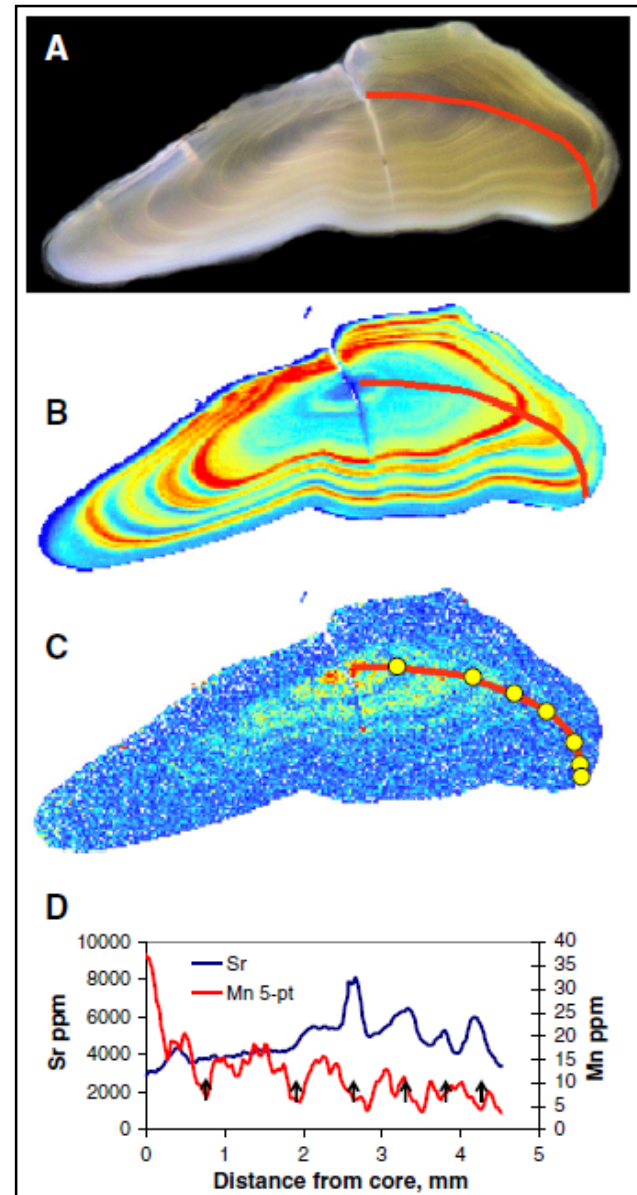
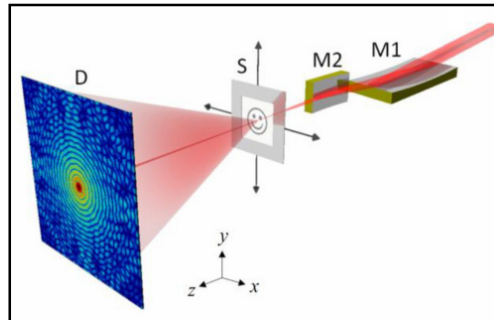


# New method to age fish from otoliths?

X-ray fluorescence microscopy



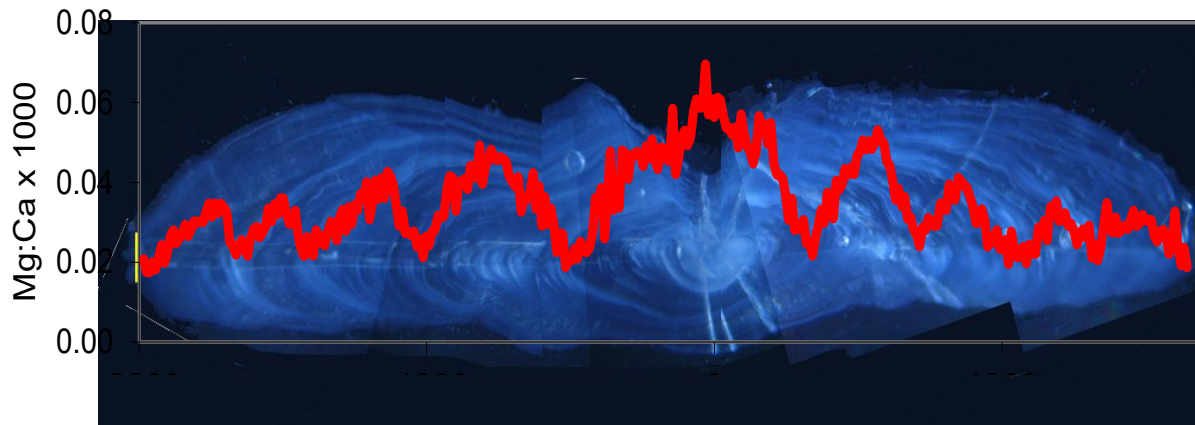
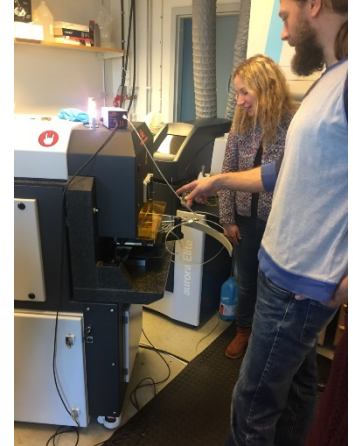
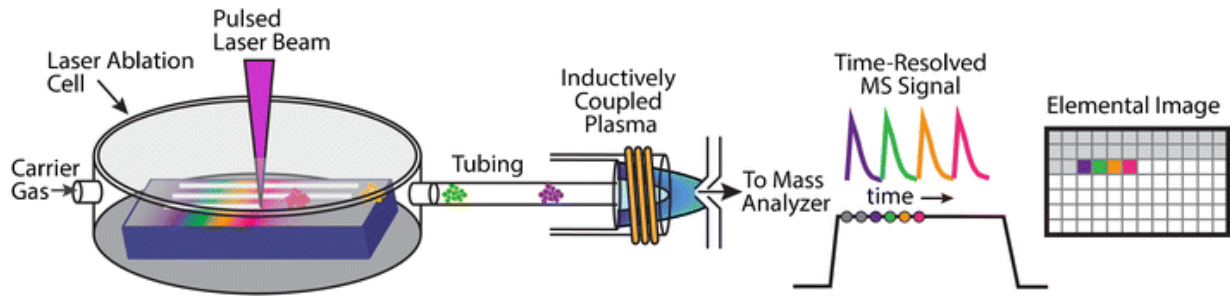
Synchrotrone at Cornell, USA



*Limburg et al. (2014)*

# New method to age fish from otoliths?

Laser ablation-inductively coupled plasma-mass spectrometry (LA-ICPMS)



Flounder

# Horizontal movements

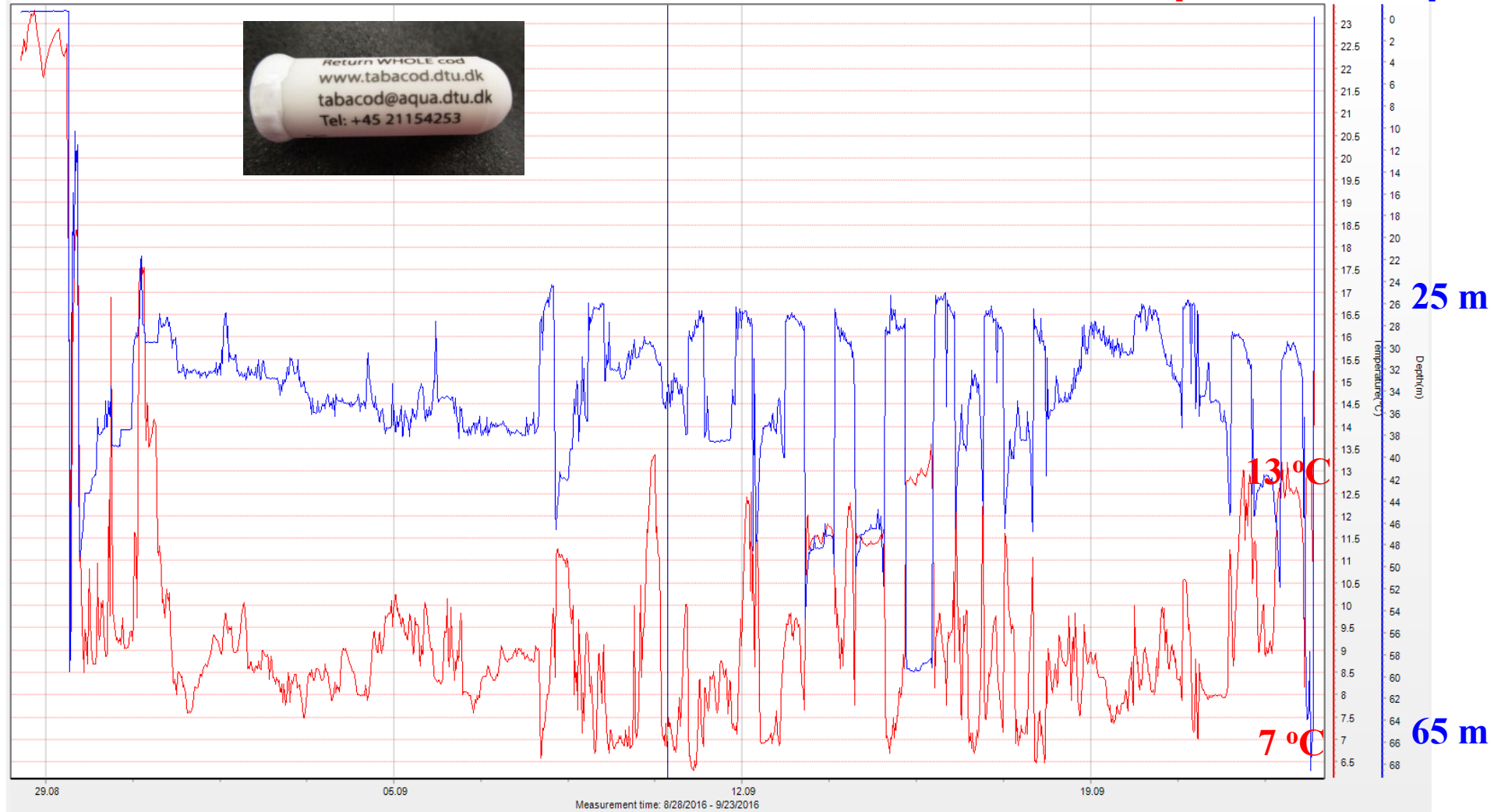




# Habitat experienced and vertical movements

1B1650DAT

Temperature Depth

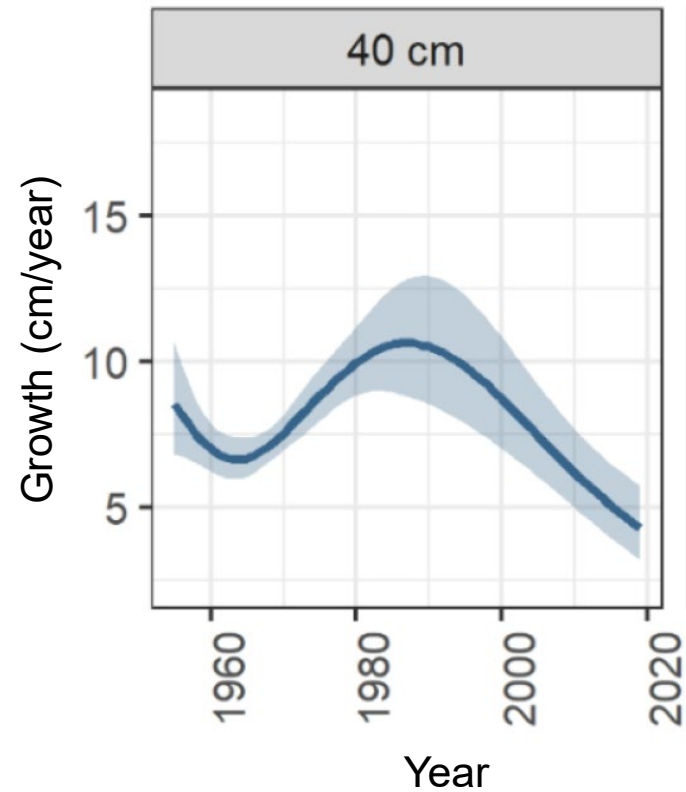


Why has the Baltic cod  
growth rate changed?



# Why a decrease in cod growth?

- Lack of food
- Competition
- Physiological stress
- Selective fishing



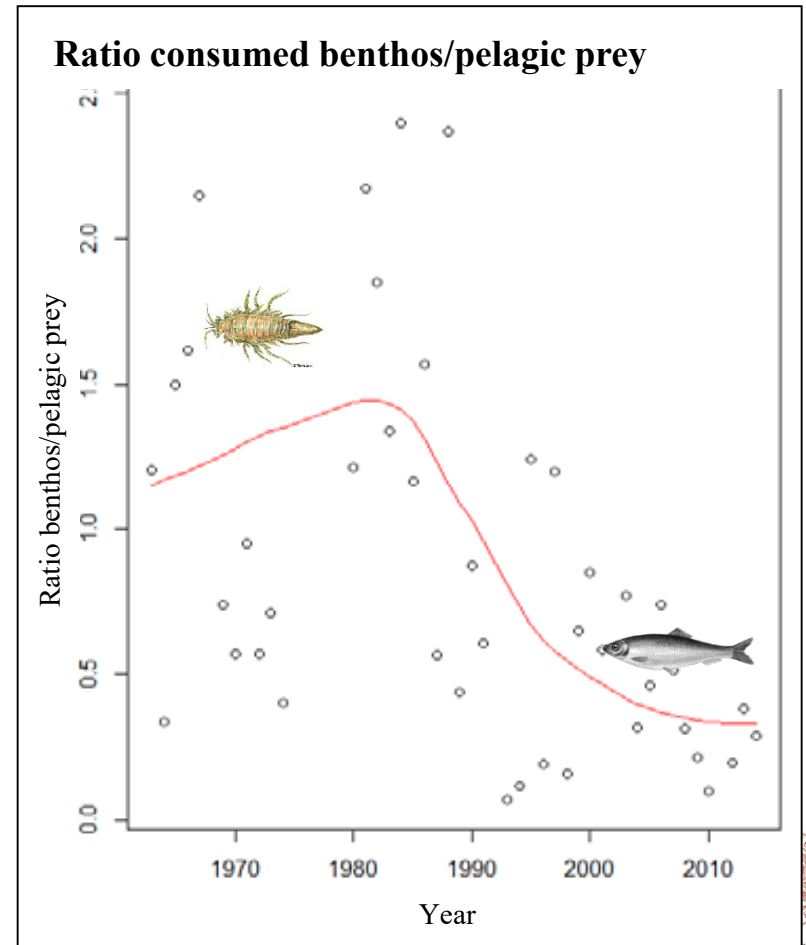
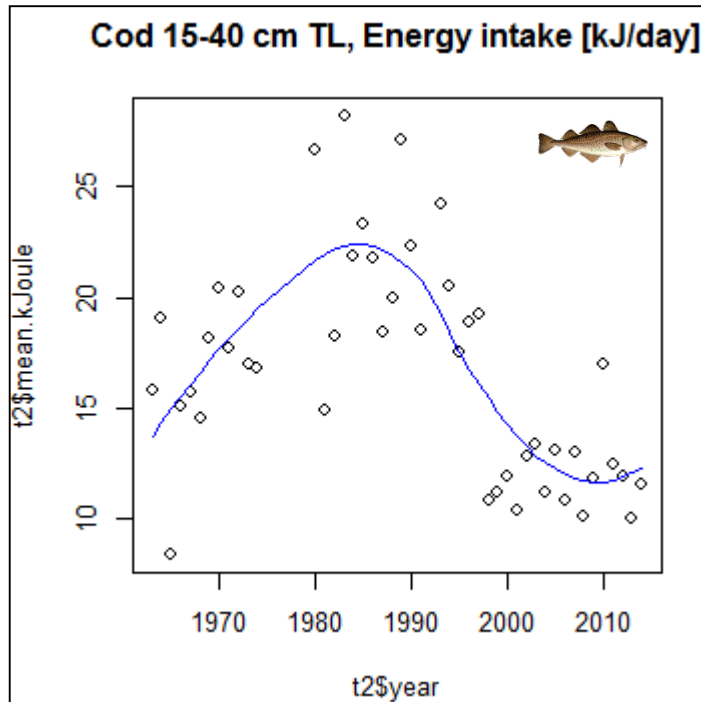
*Mion et al. (2020)*





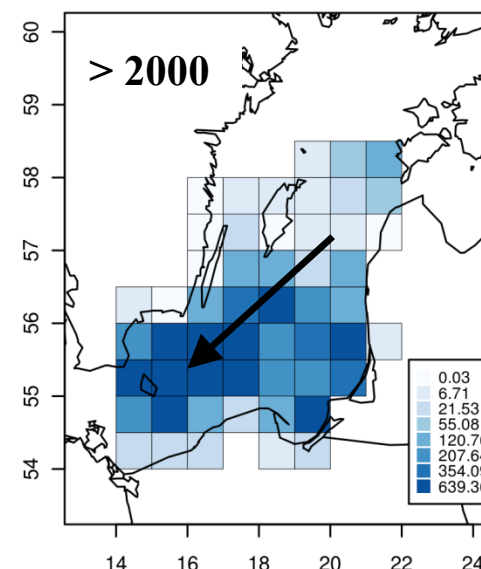
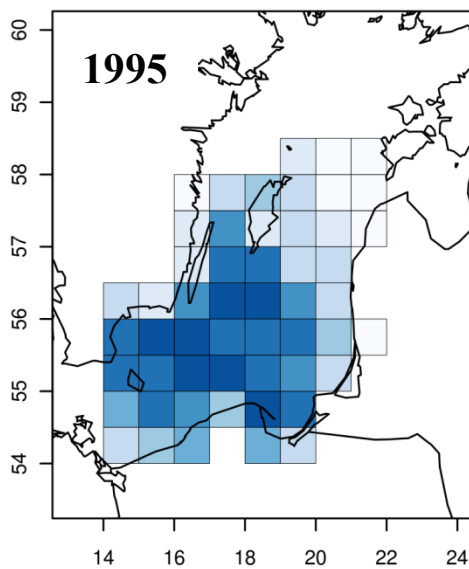
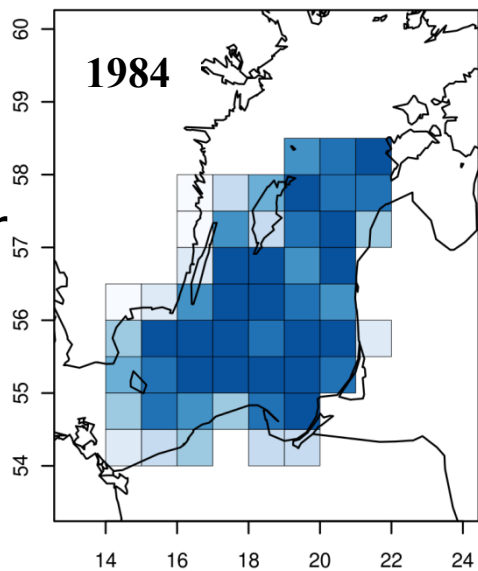
# Why a decrease in cod growth: they eat less

Change in the prey composition and total energy intake of cod

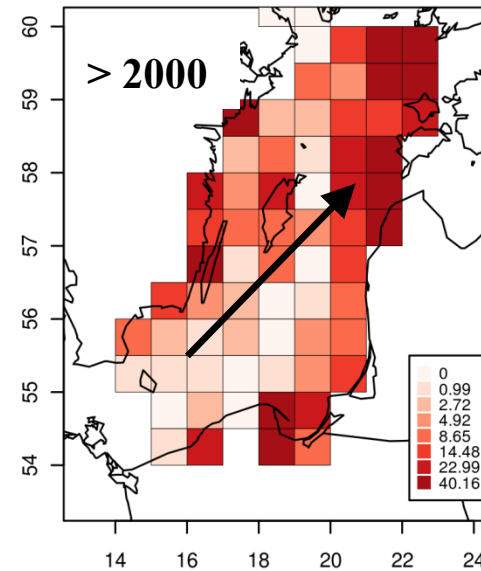
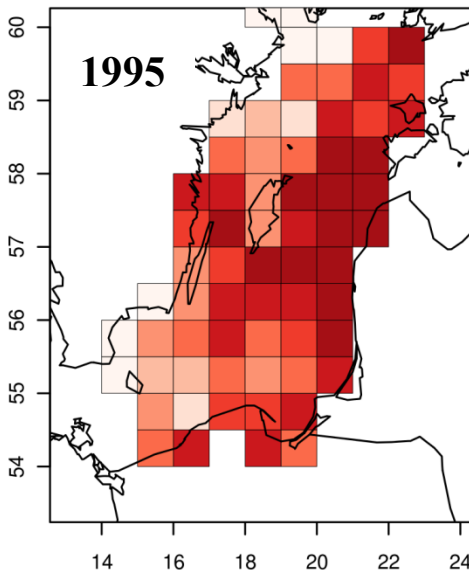
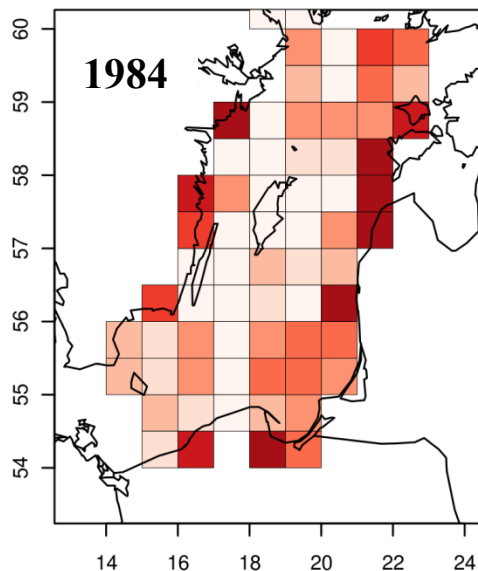


# Why a decrease in growth: spatial mismatch with the prey?

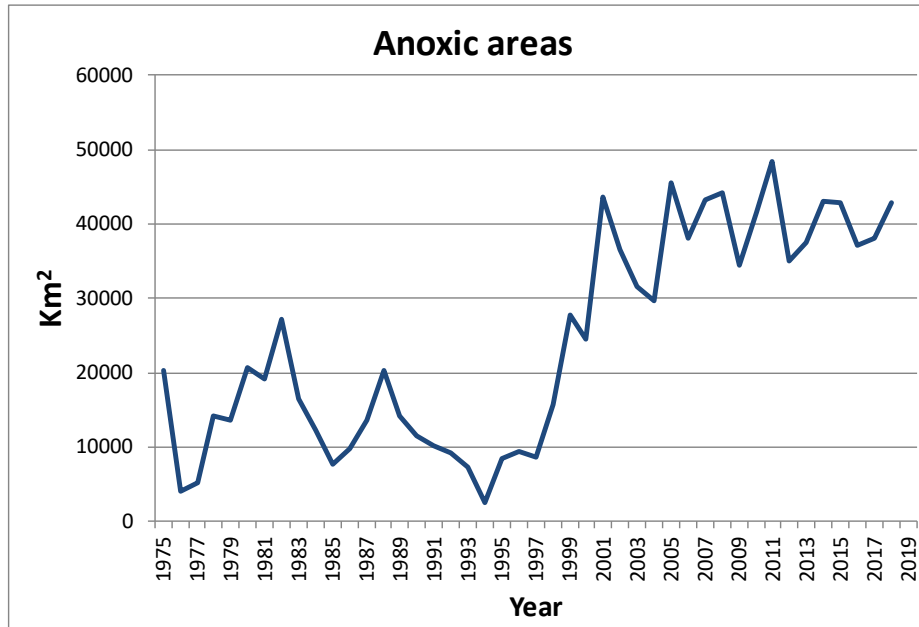
Predator  
Cod



Prey  
Sprat

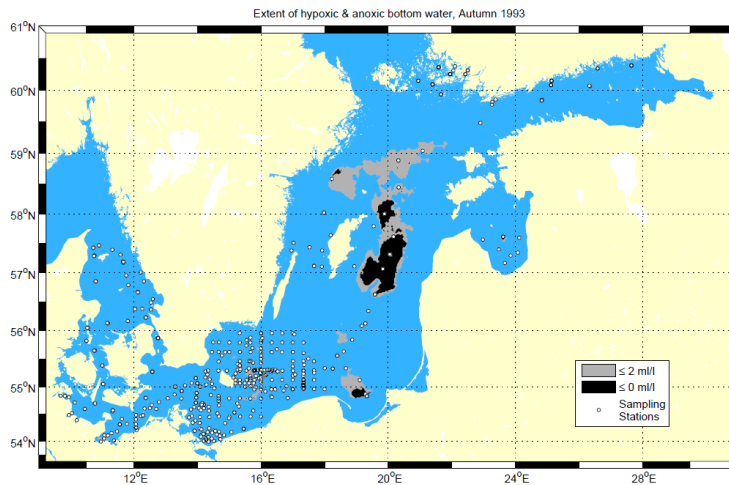


# Why a decrease in growth: anoxic waters?

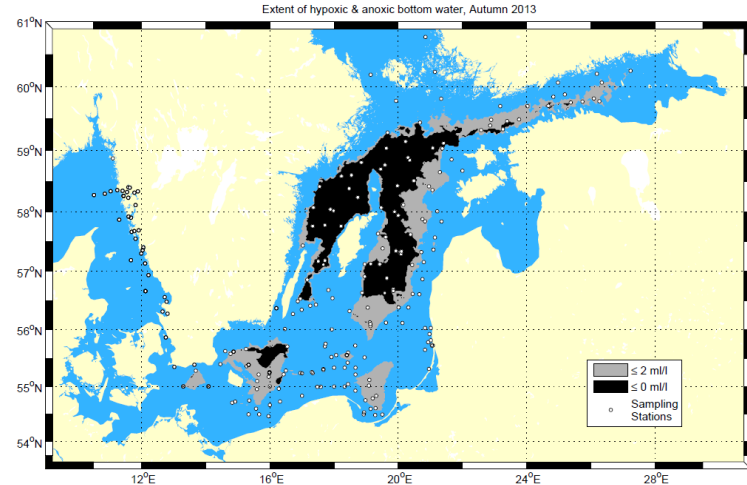


- Potentially affecting:
- (Reproduction)
  - Distribution
  - Benthic prey availability
  - Feeding behaviour

SMHI (2019)



1993

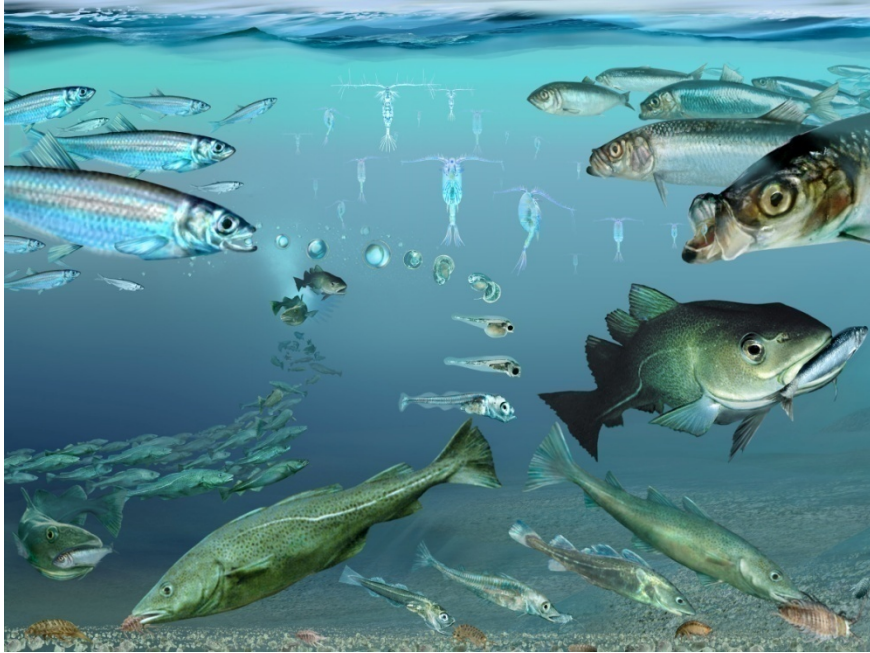


2013

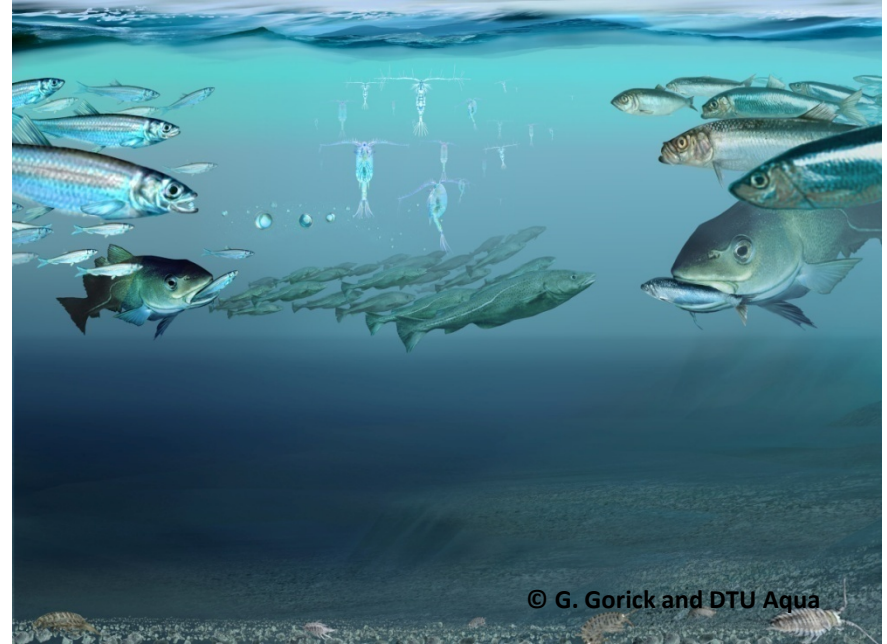


# Why a decrease in growth: anoxic waters?

## The Baltic offshore ecosystem



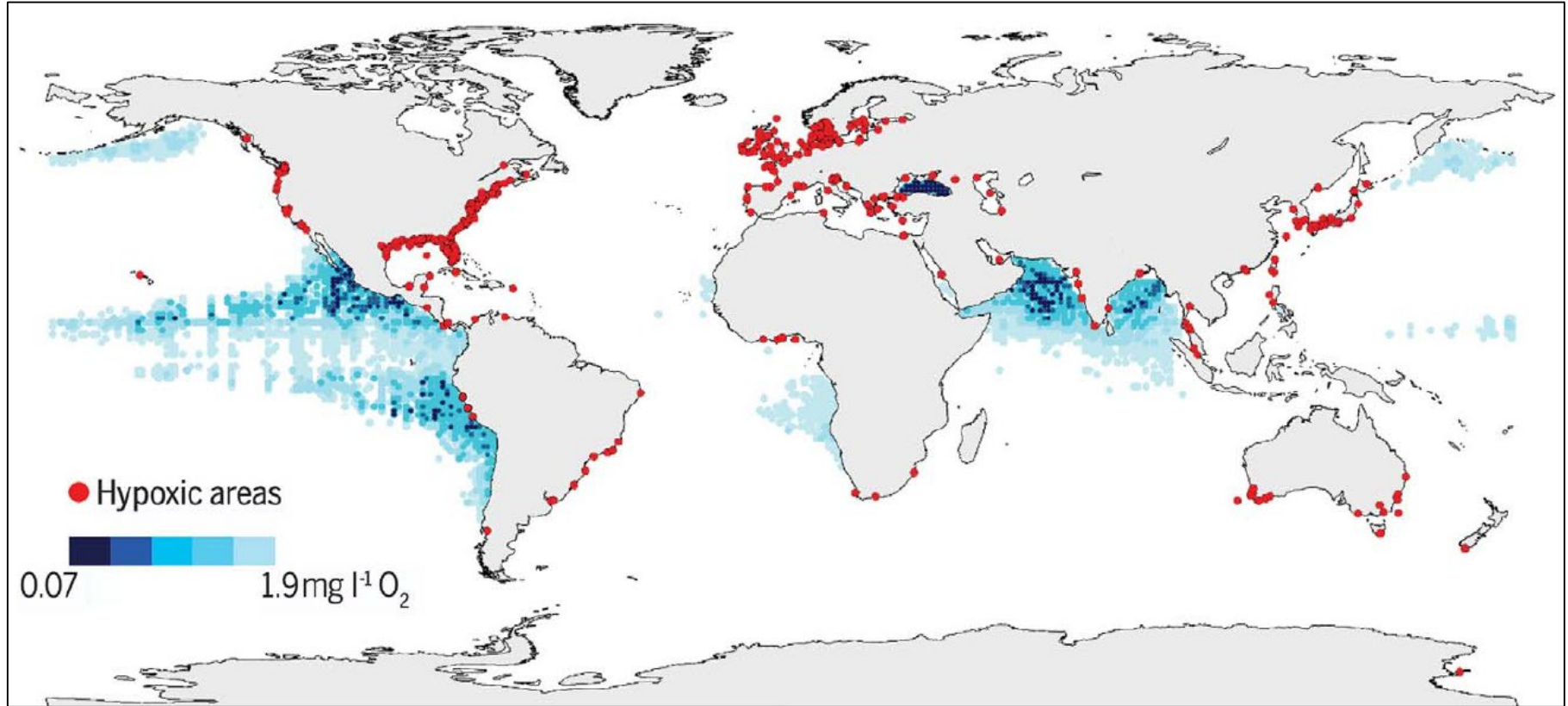
Before



Now



# Why a decrease in growth: anoxic waters?

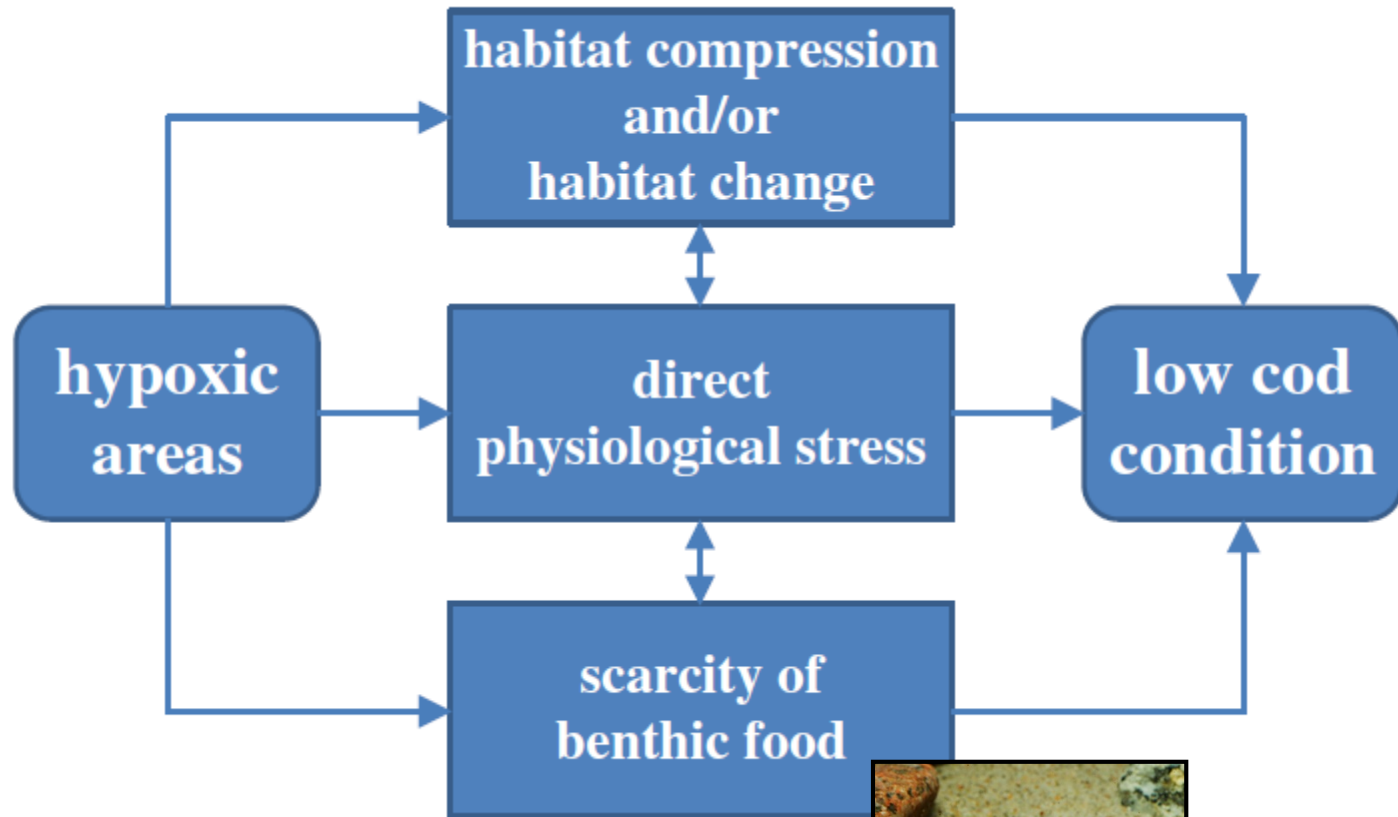


*Breitburg et al. (2022)*

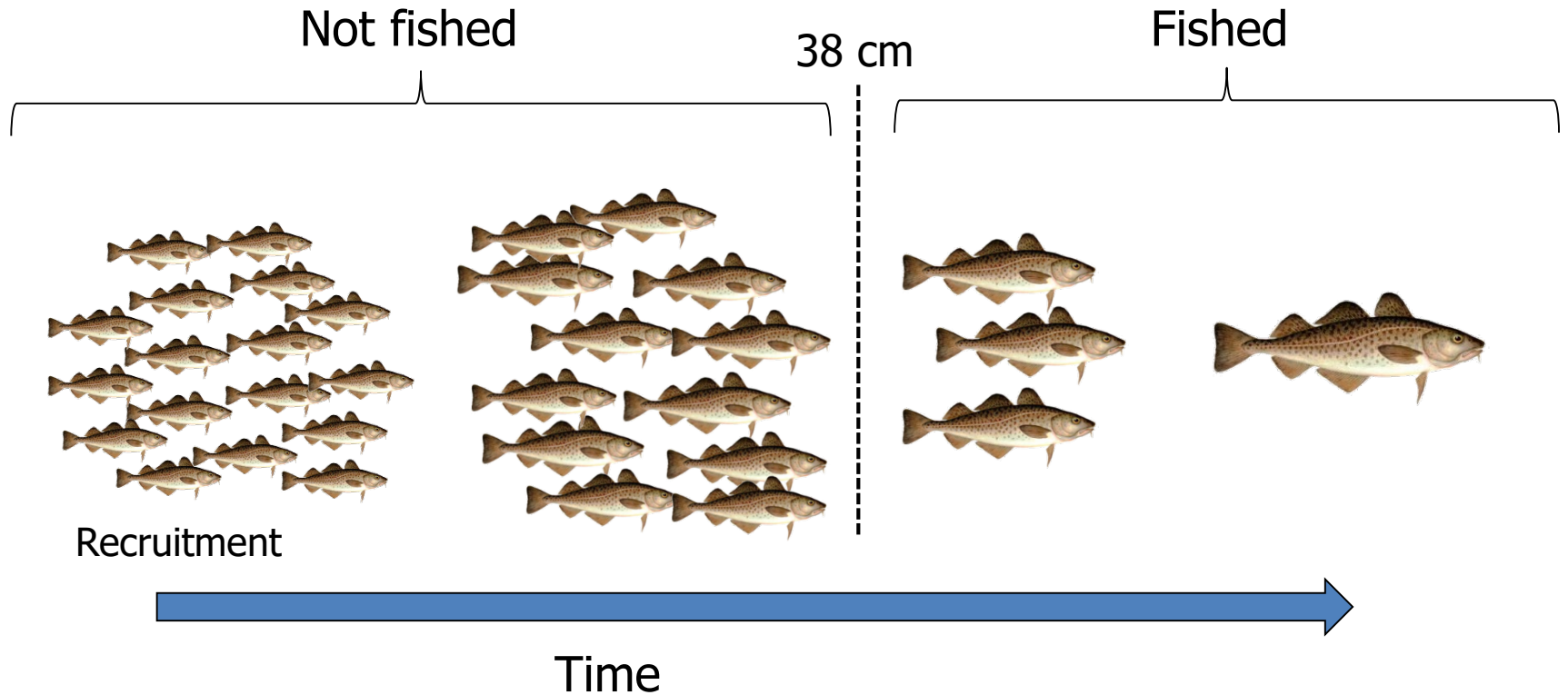




# Why a decrease in growth: anoxic waters?



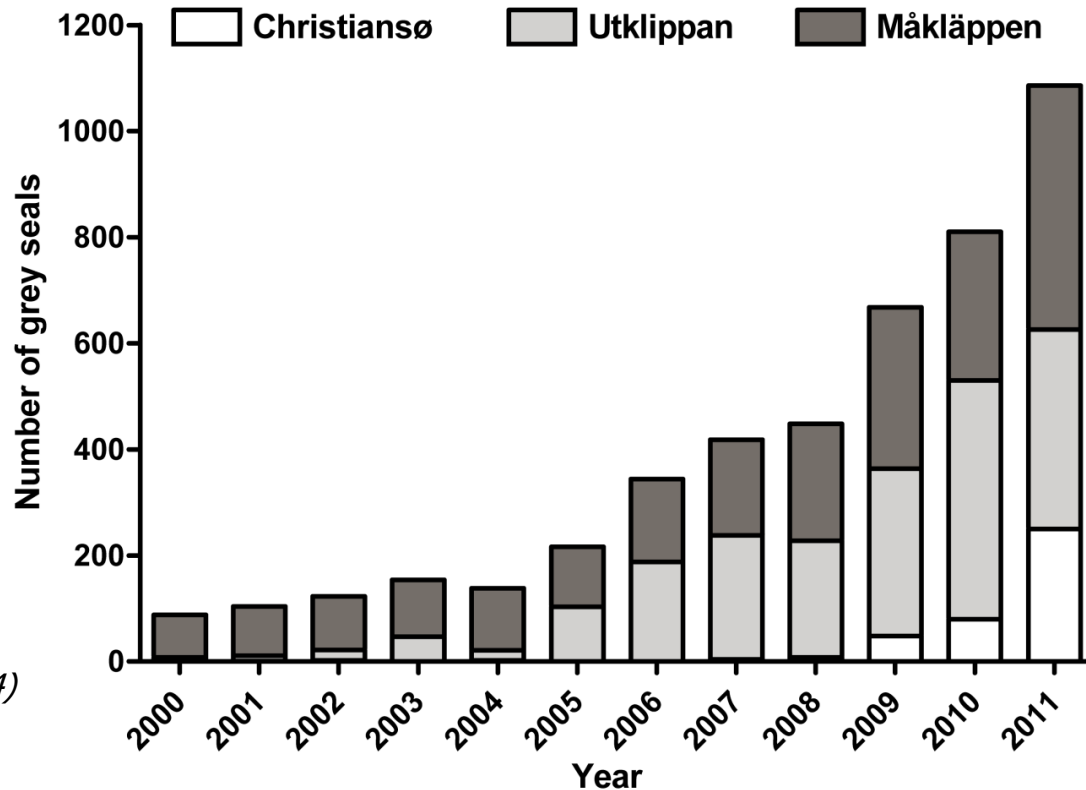
# Why a decrease in cod growth: selective fishing?



Results: increased competition in small fish!



# Why a decrease in growth: seals?



Haarder et al. (2014)



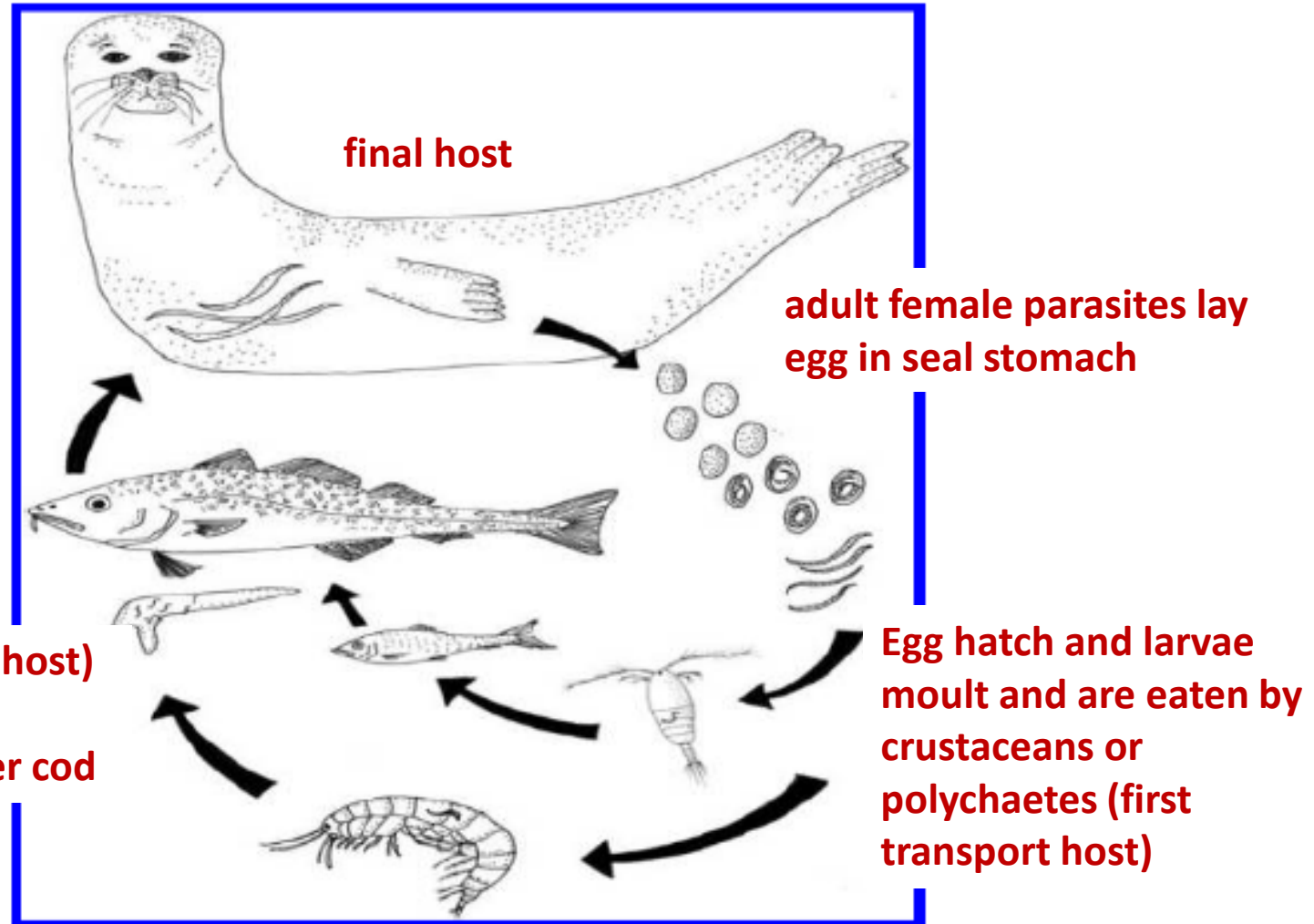
Increased cod mortality due to predation and parasites?  
Decreased condition/growth due to parasites?

*Contracaecum osculatum*  
- "liver worm" -



# Why a decrease in growth: seals?

Parasite life cycle



*Haarder et al. (2014)*

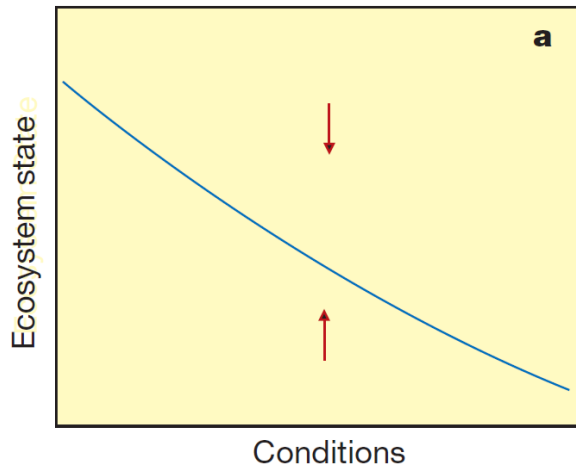


# Populations and community recovery: is it possible?

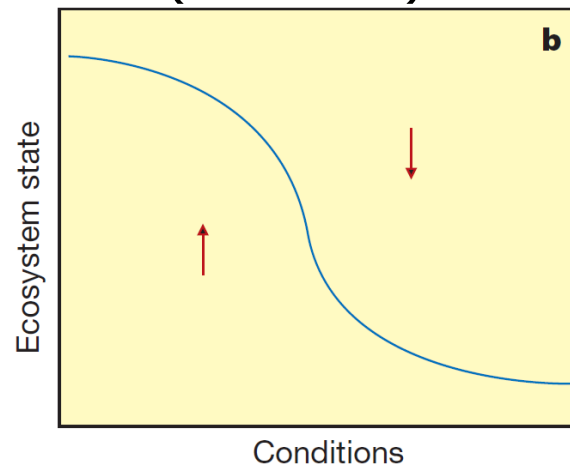


# Ecosystem response to changes in external pressures

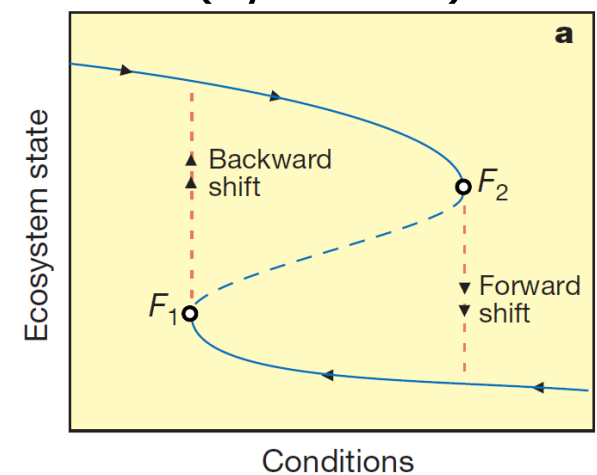
## Smooth



## Abrupt (threshold)



## Discontinuous (hysteresis)

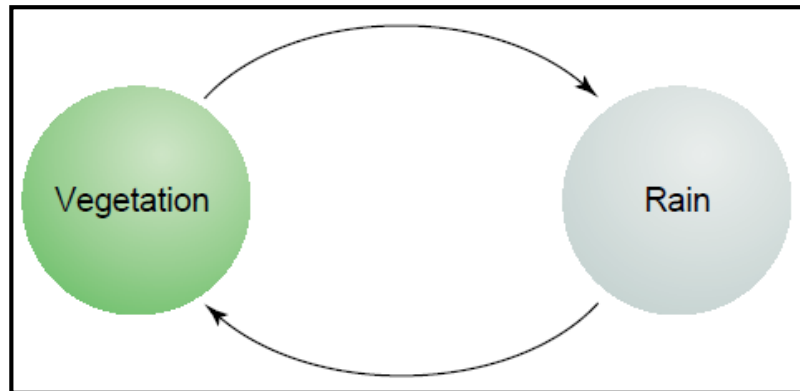


*Scheffer et al. (2001)*

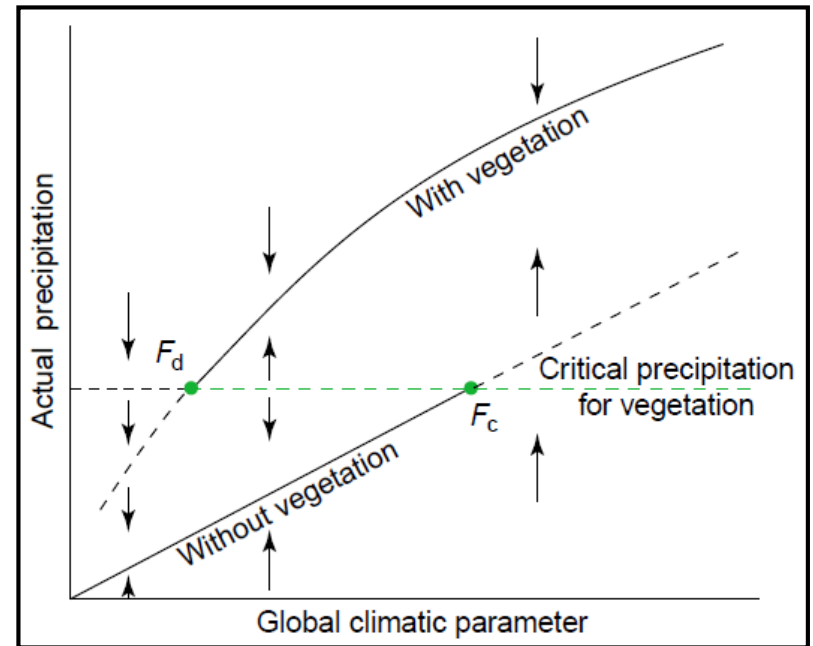
## Alternative Stable States (ASS)



# Mechanisms of Alternative Stable States



Positive feedback between  
vegetation and rainfall



*Scheffer et al. (2003)*



# Examples of Alternative Stable States

(a) (i)



(b) (i)



(c) (i)



Before

(ii)



(ii)



(ii)



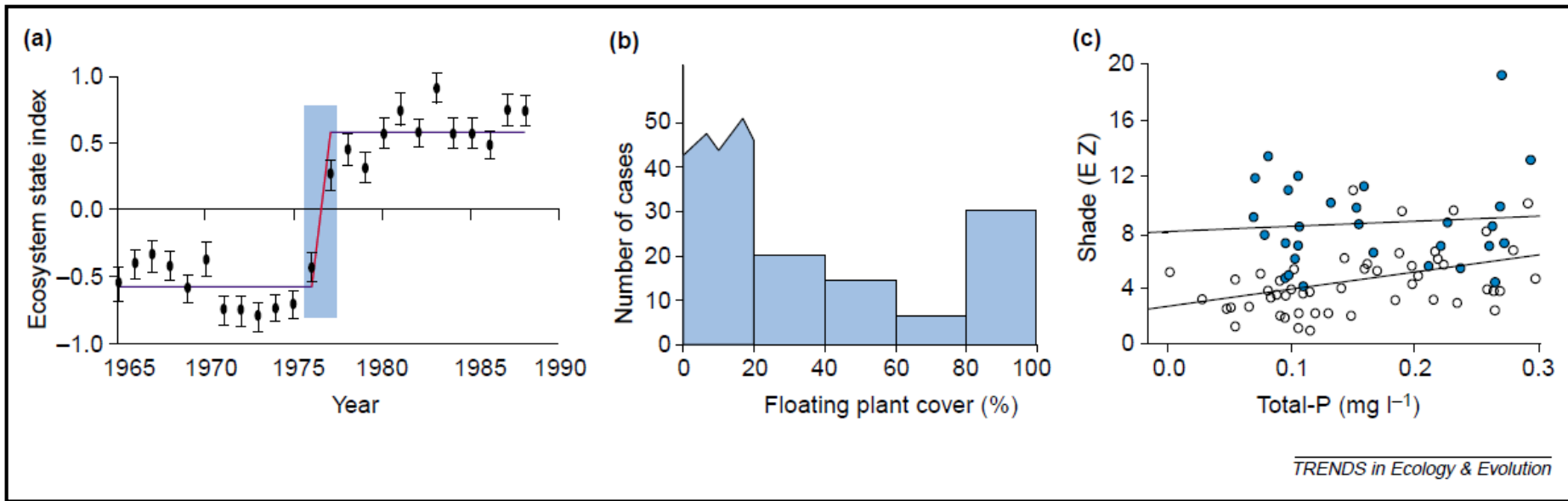
After

*Hughes et al. (2005)*





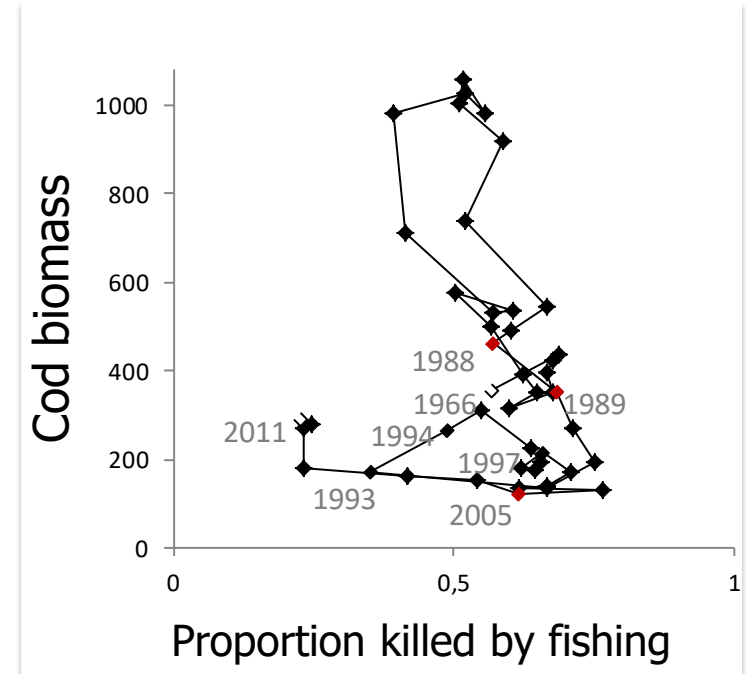
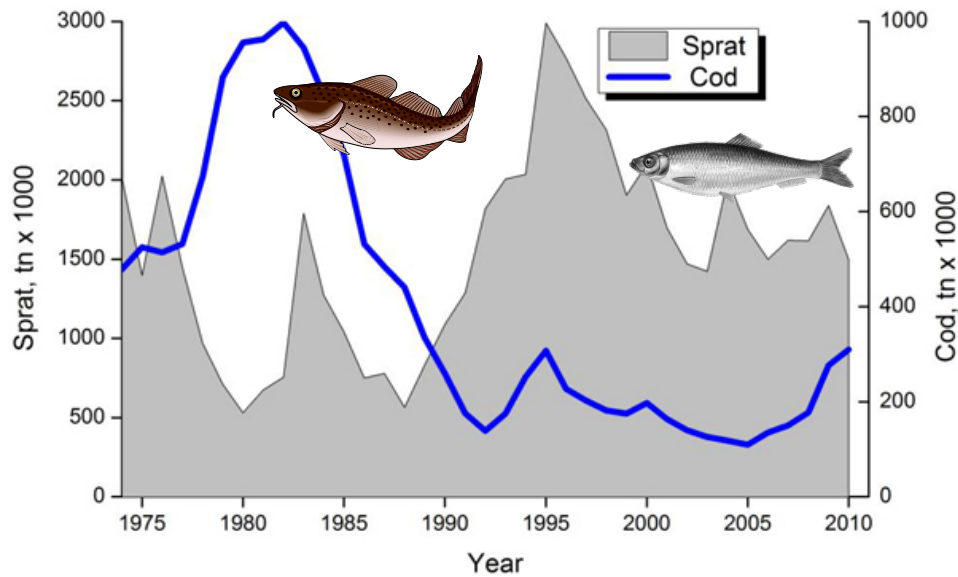
# Hints of Alternative Stable States from field data



*Scheffer et al. (2003)*



# Are there Alternative Stable States (one cod and one sprat dominated) in the Baltic sea?



Gårdmark et al. (2015)

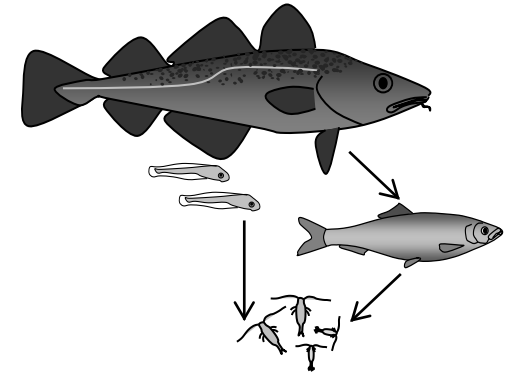


# Predator-prey interactions

## 1 Prey compete with predator early life stages

*Competitive cultivation-dependensation*

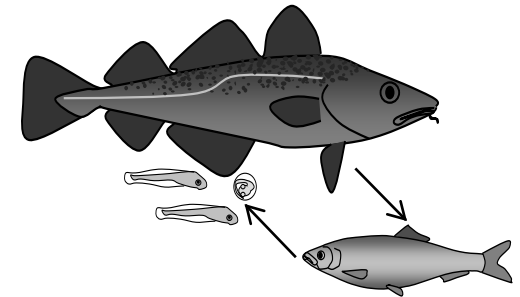
*Walters & Kitchell (2001)*



## 2 Prey predate on predator early life stages

*Predatory cultivation-dependensation*

*Gårdmark et al. (2015)*

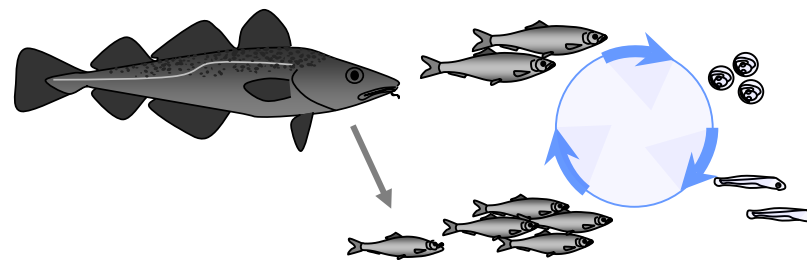
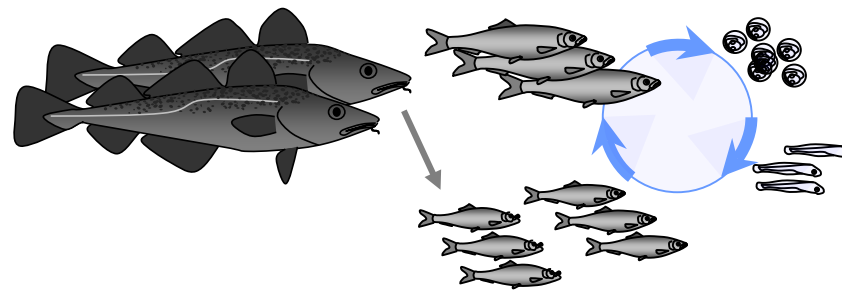


# Predator-prey interactions

## 3 Predation-induced competitive release of prey

*Abundance overcompensation*

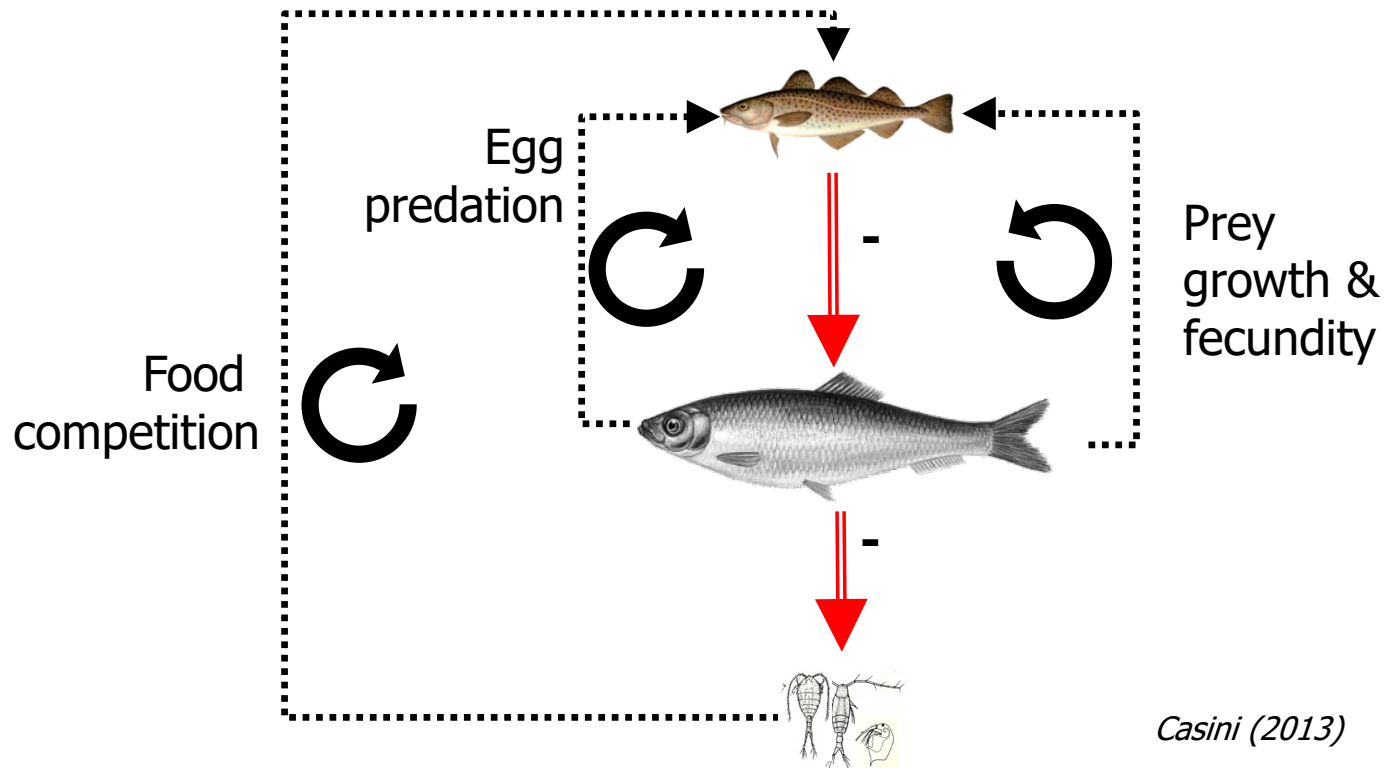
*de Roos & Persson (2002)*



*Gårdmark et al. (2015)*



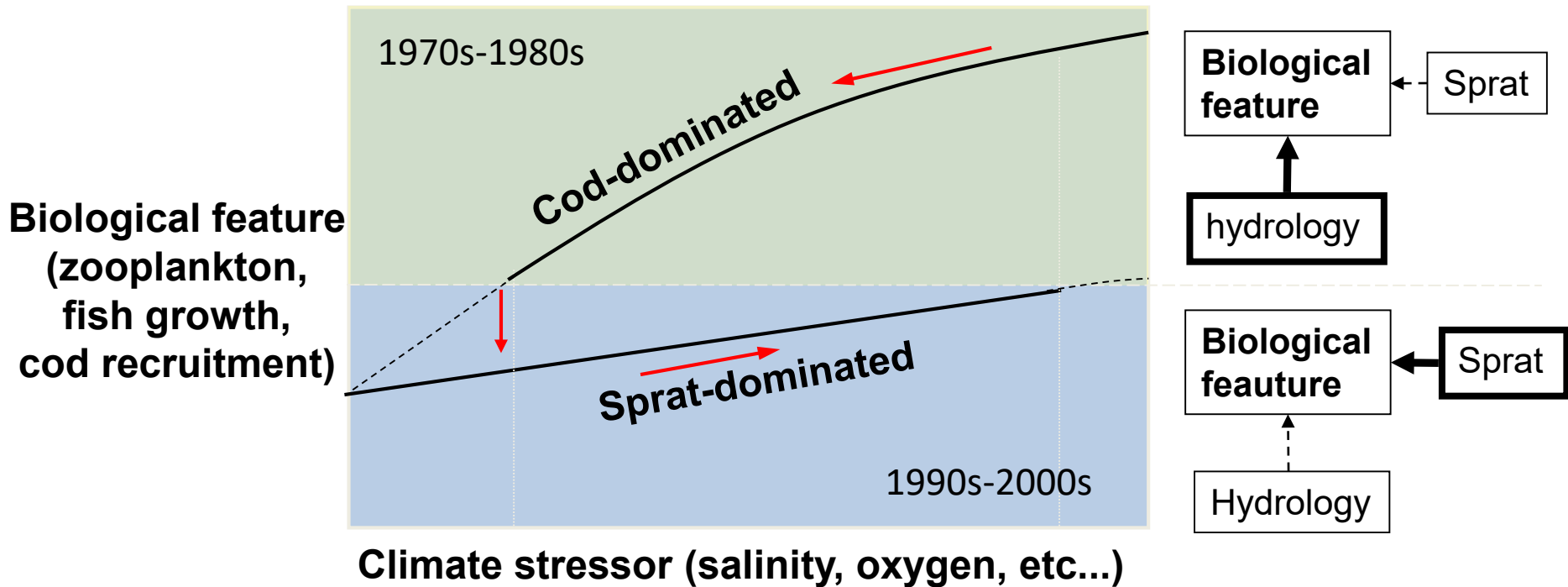
# Predator-prey interactions



Prey-to-Predator feedback loops



# Schematic representation of the potential Alternative Stable States in the Baltic Sea

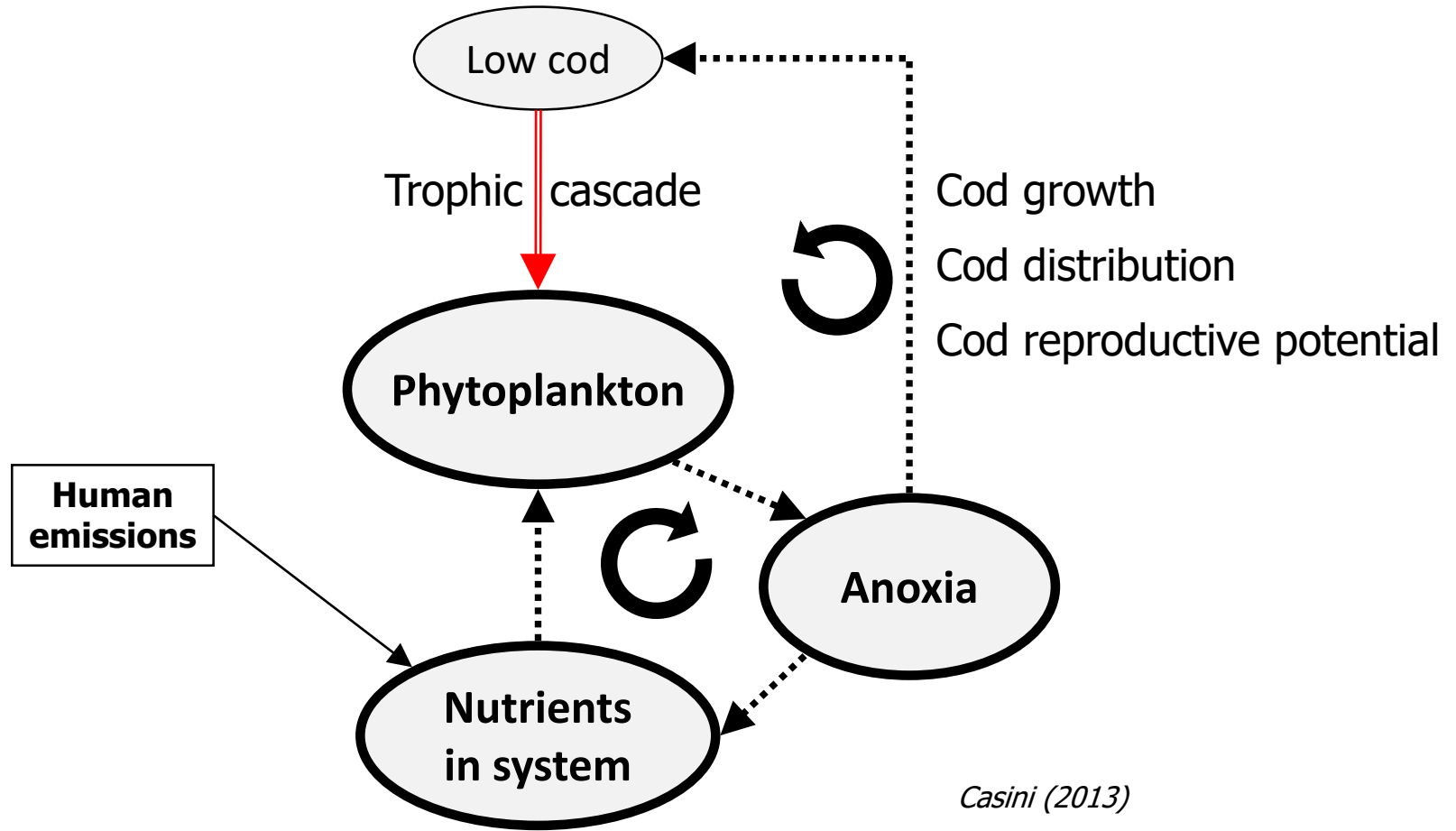


*Casini et al. (2010)*





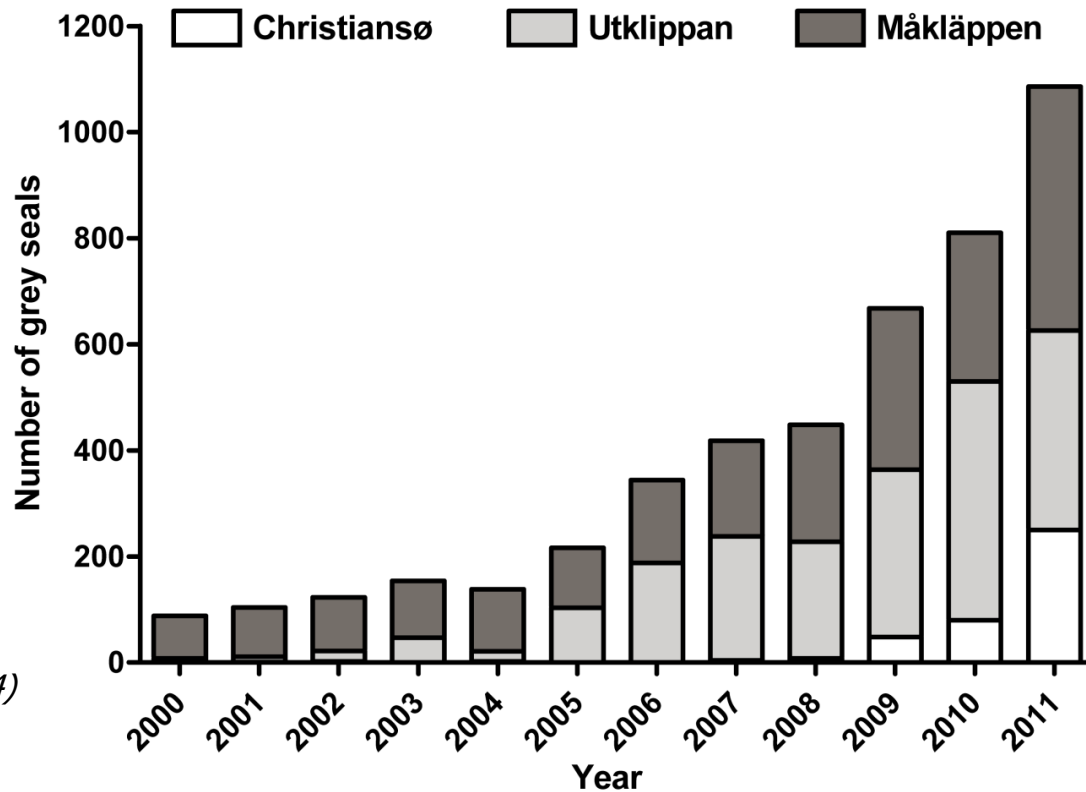
# Ecosystem interactions



Ecosystem feedback loops



# Other components changed in the Baltic Sea



Haarder et al. (2014)

*Contracaecum osculatum*  
- "liver worm" -

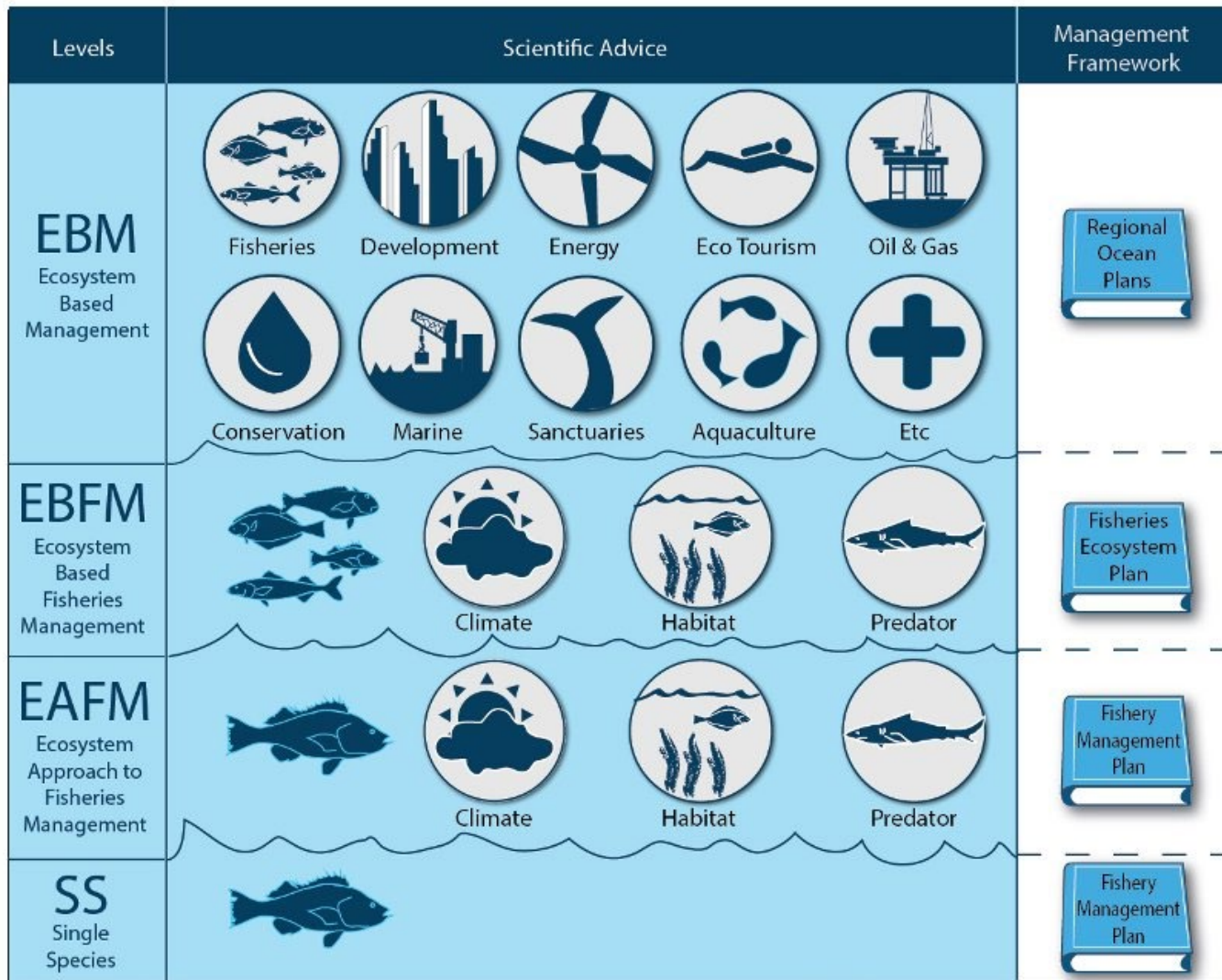
Increased cod mortality due to predation and parasites?



# Options for an “ecosystem-based fisheries management”



# Different levels of managements



From a single-species management to an **ecosystem approach to management**

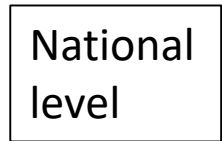
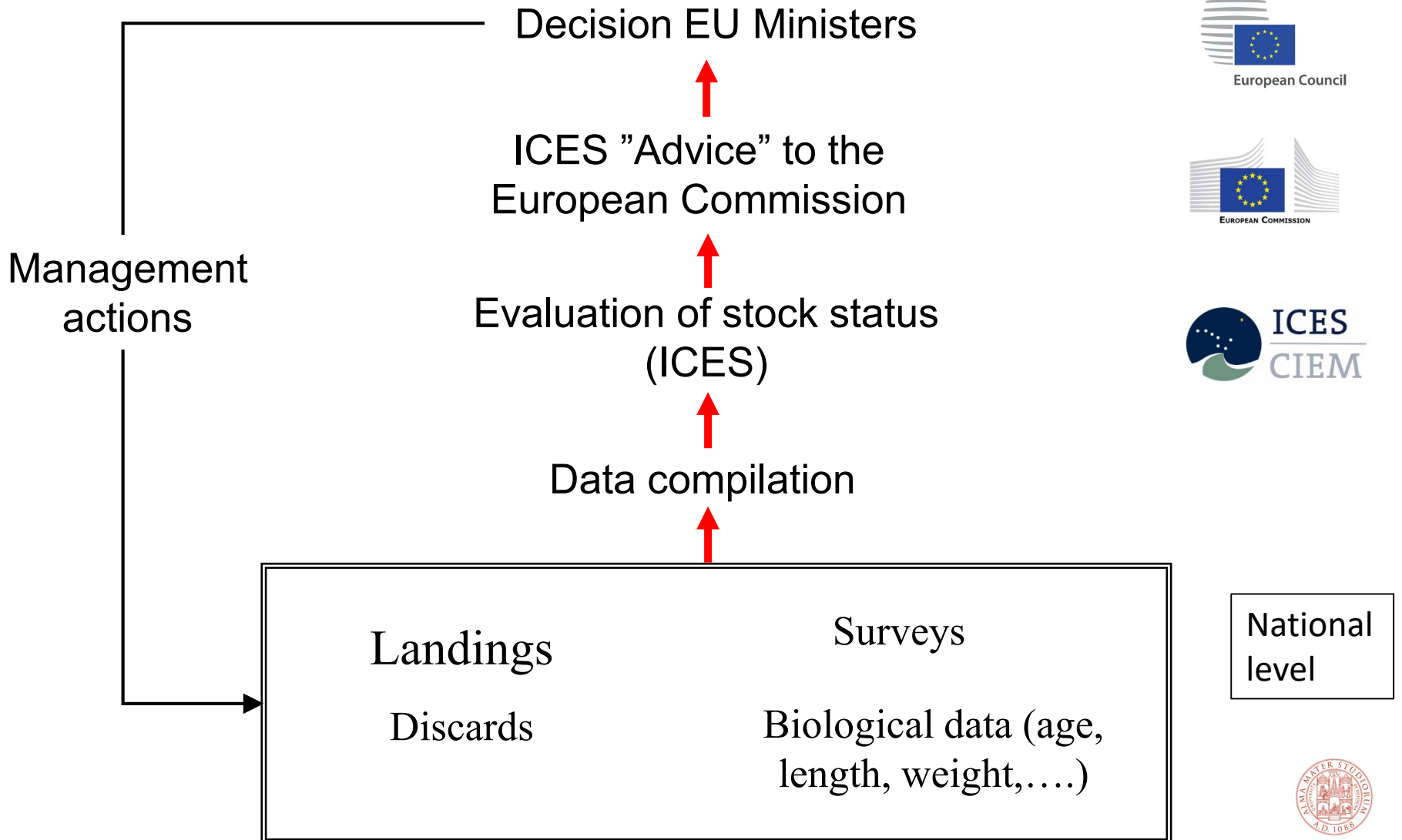
...or at least this is the aim...

# The International Council for the Exploration of the Sea

ICES provides the European Commission with an annual evaluation of the stock status and with scientific advice on how to manage the fishery



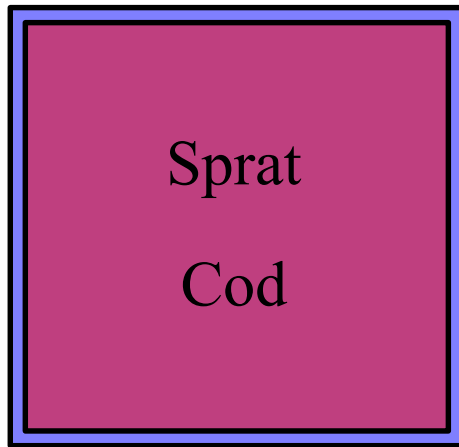
# Annual cycle of stock evaluation and management



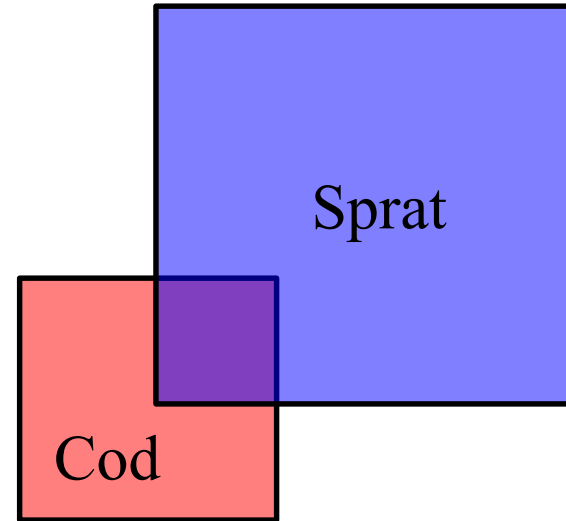


# Option for management (1)

Current management dilemma: **should we decrease fishing pressure on sprat in the southern Baltic Sea?**



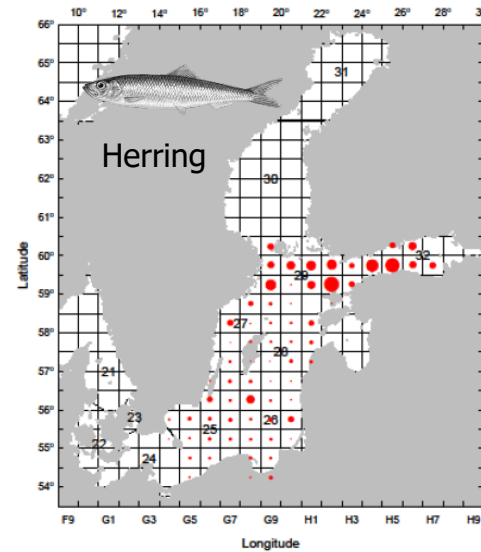
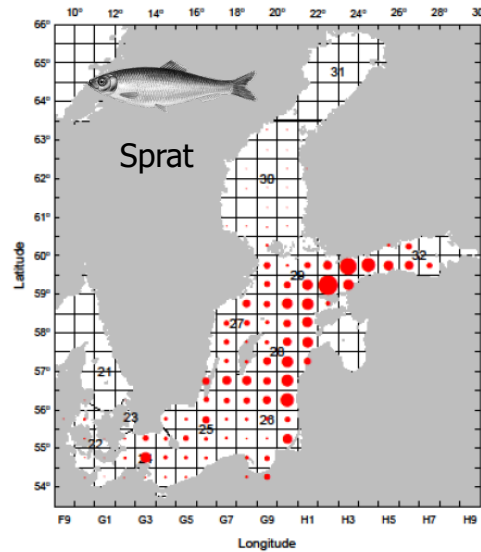
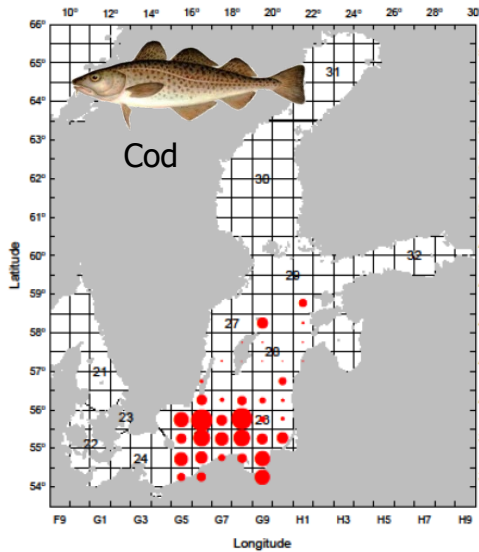
< 1990



> 1990



# Option for management (1)



ICES Advice (2018)

ICES Advice on fishing opportunities, catch, and effort  
Baltic Sea Ecoregion  
spr.27.22-32



Published 31 May 2018  
<https://doi.org/10.17895/ices.pub.4375>

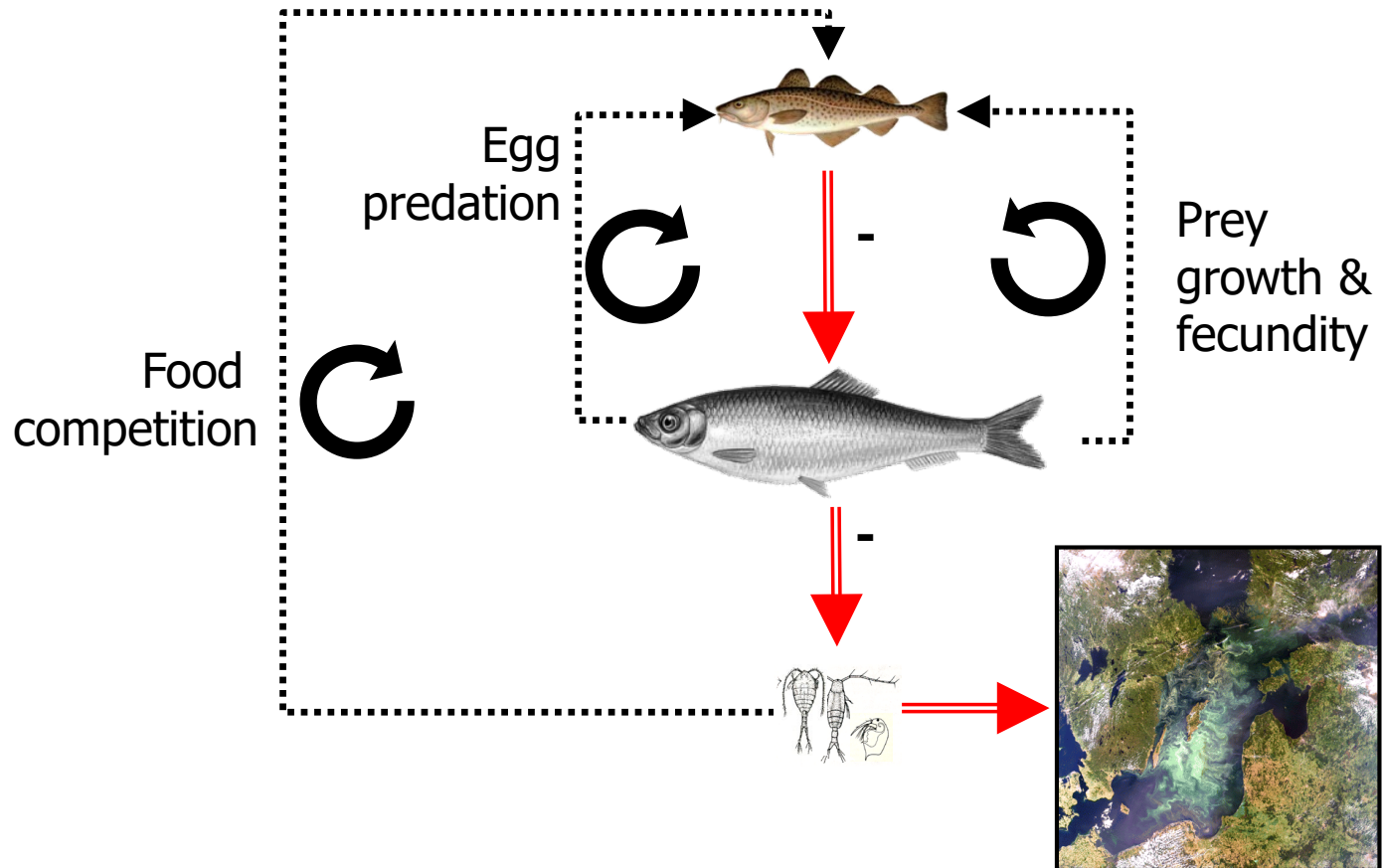
## Sprat (*Sprattus sprattus*) in subdivisions 22–32 (Baltic Sea)

### ICES advice on fishing opportunities

ICES advises that when the EU multiannual plan (MAP) is applied, catches in 2019 that correspond to the F ranges in the plan are between 225 752 tonnes and 311 523 tonnes. According to the MAP, catches higher than those corresponding to  $F_{MSY}$  (301 125 tonnes) can only be taken under conditions specified in the MAP, whilst the entire range is considered precautionary when applying the ICES advice rule.

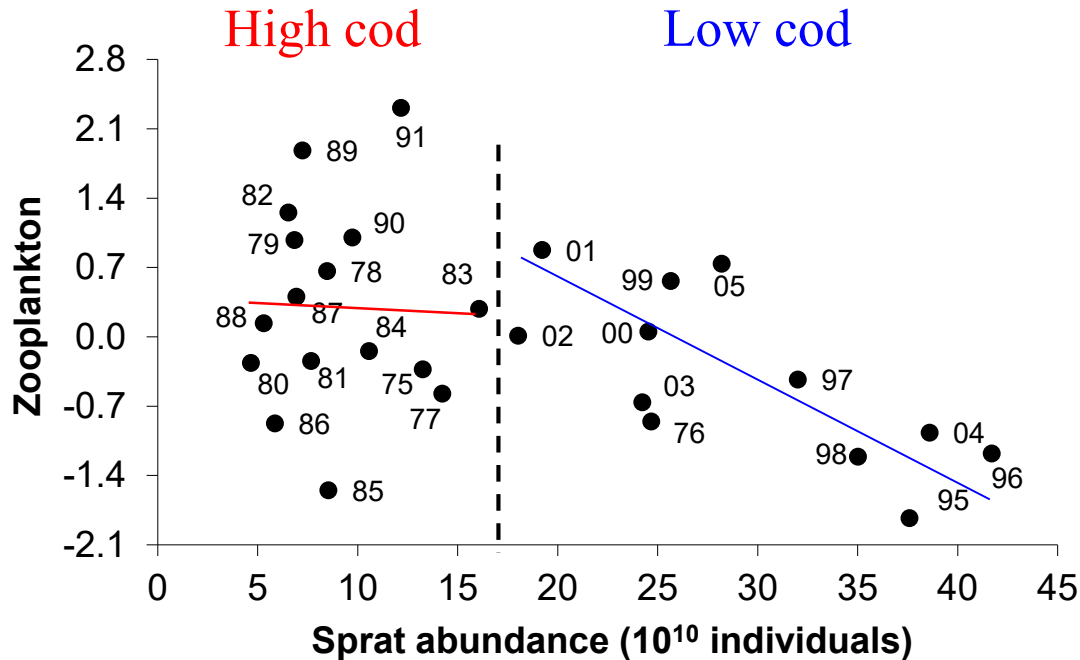
ICES advises that a spatial management plan is considered for the fisheries that catch sprat.

## Option for management (2)



Or is it better to increase fishing for pelagic fish in the southern Baltic?

## Option for management (2)



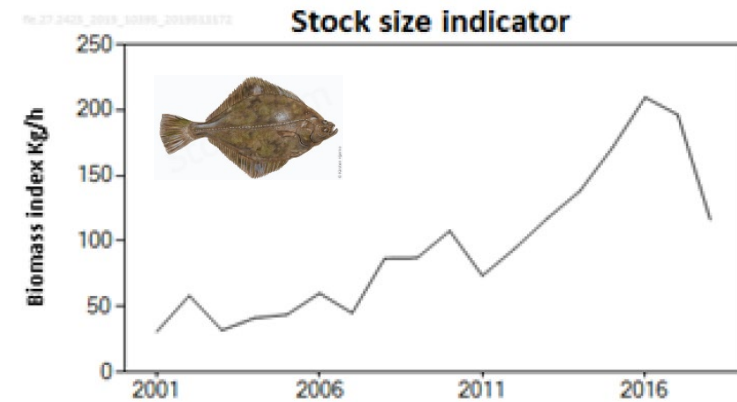
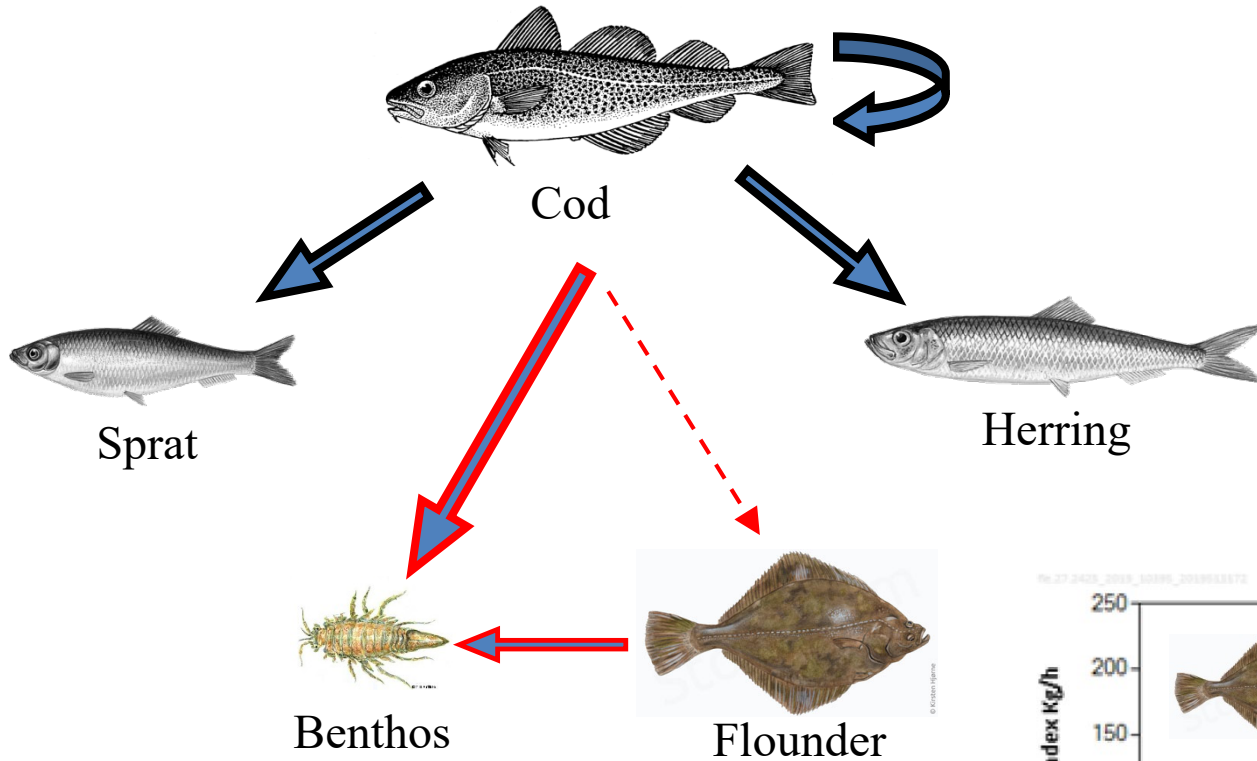
Break-point =  
~ 17 \* 10<sup>10</sup> sprats

*Casini et al. (2009)*

Set a minimum abundance/biomass limit for sprat (escapement biomass)? (EC 2012, ICES WKMULTBAL 2012)



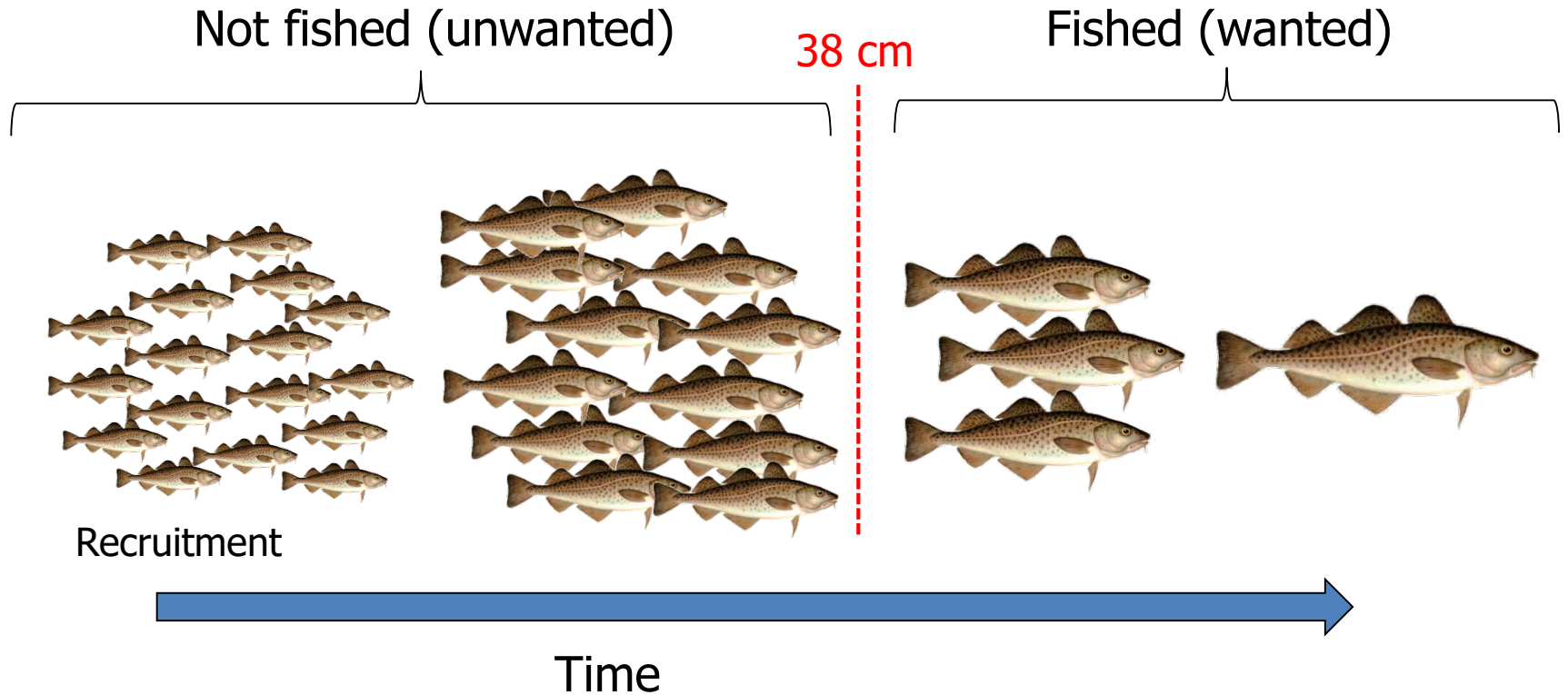
# Option for management (3)



Should we increase fishing on flounder?

ICES Advice (2019)

# Option for management (4)

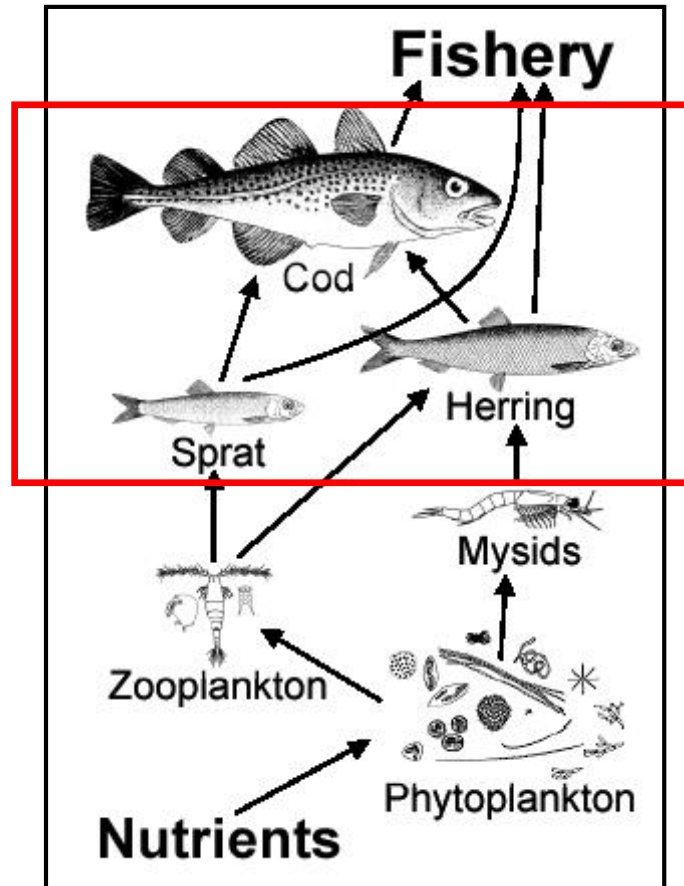


Reduce the minimum landing size (now conservation size)?



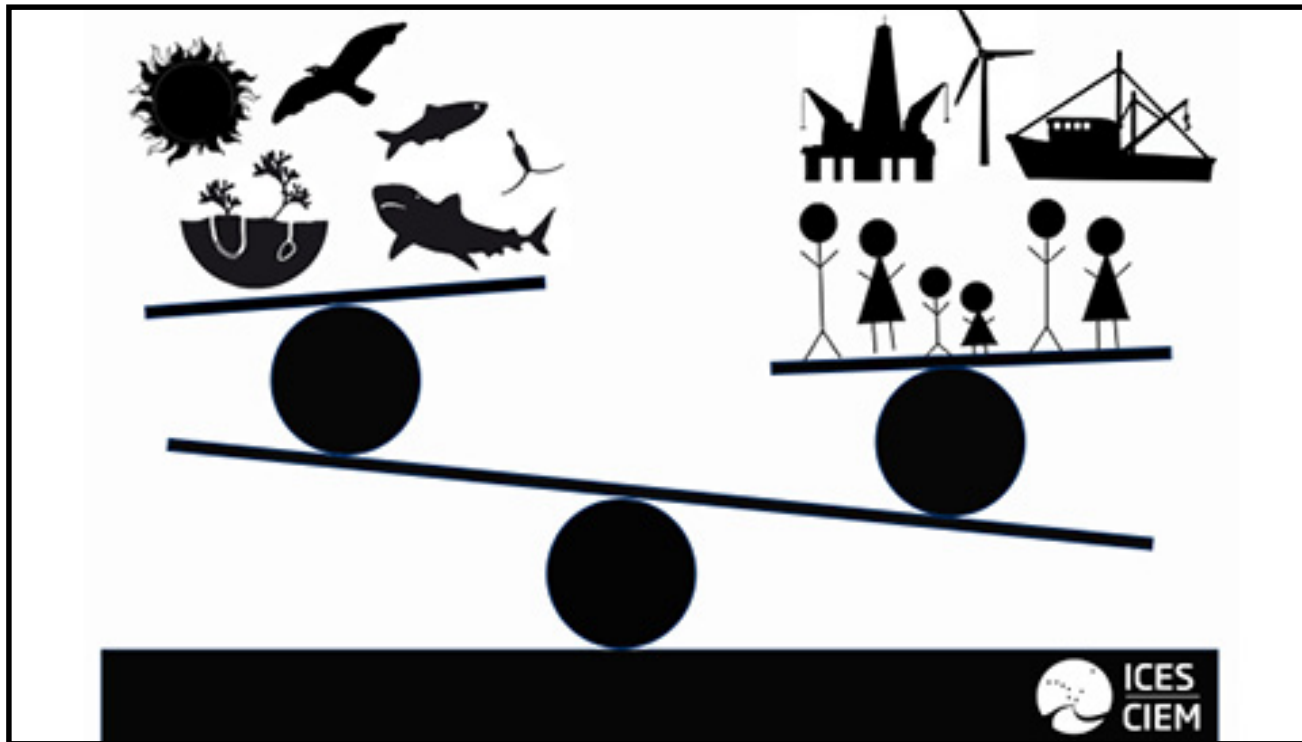


# Baltic Sea (still simplified) food-web



# Ecosystem approach to management

It is a great scientific and political challenge since it shows the trade-offs among the societal interests and needs



# Summary

- The Baltic is a very sensitive sea (closed, brackish, low diversity)
- Multiple climate and anthropogenic forces
- 9 bordering countries (1 not EU)
- Cod is in a distressed situation
- Cod stock has become constituted by smaller and thinner fish, with large ecosystem and economic effects
- The reasons are still unknown hampering management: still need of basic biological knowledge about growth and mortality
- The inclusion of ecosystem considerations into management is key
- Cod is at the center of the current public debate around the Baltic Sea, but other components should not be forgotten





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