



Center for
Ocean and
Society

Ecosystem-based fisheries management in the Baltic

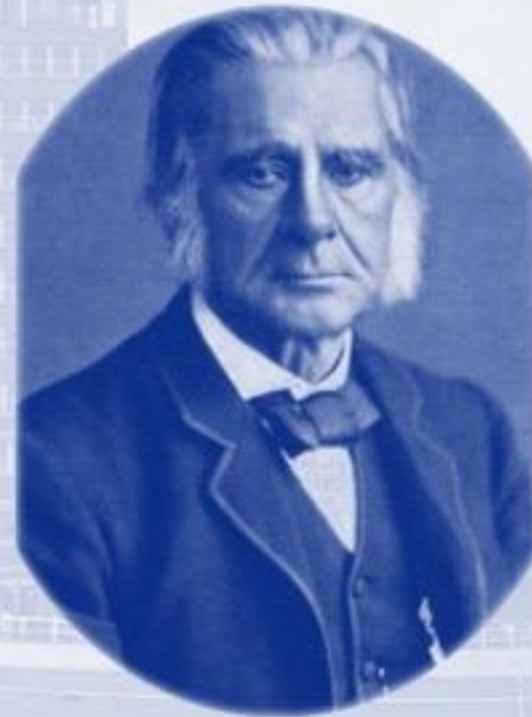
Possible contributions of ecological-economic modeling to advance EBFM

Is there a problem?

Sir Thomas Huxley

I believe, then, that the cod fishery, the herring fishery, the pilchard fishery, the mackerel fishery, and probably all the great sea fisheries, are inexhaustible; that is to say, that nothing we do seriously affects the number of the fish. And any attempt to regulate these fisheries seems consequently, from the nature of the case, to be useless.

Inaugural Address to the Fisheries
Exhibition - 1883

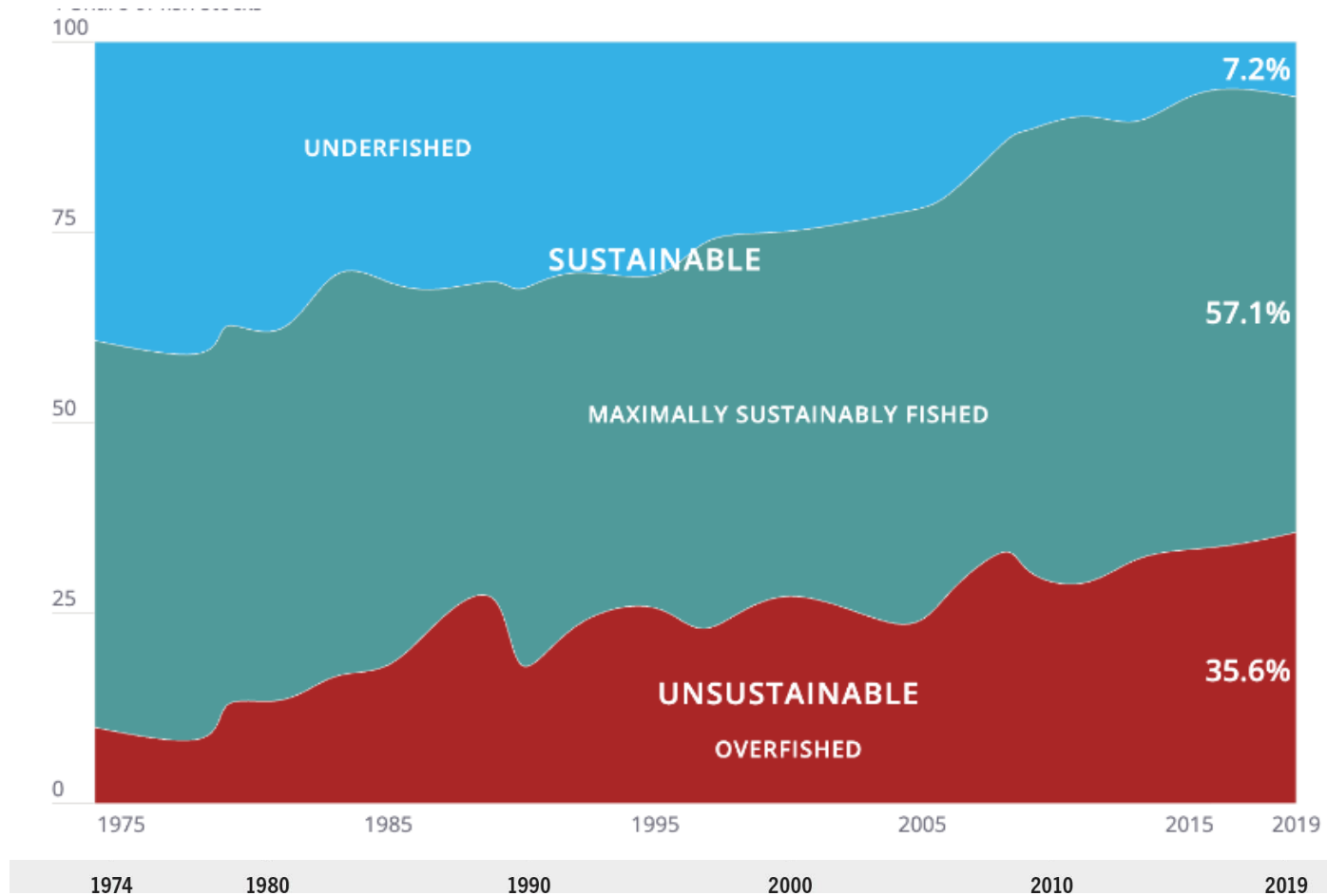


On the way to sustainability?



- Global imperative on sustainable fisheries since 2002 (**Maximum Sustainable Yield** concept)
- Confirmed and reinforced during the Rio+20 conference in 2012
- Needs:
 - Include species interaction
 - Include ecosystem interaction
- Advice is based on biological data - not accounting for economic and social needs and drivers
 - A main reason for failing fisheries management in the past – and ongoing

On the way to sustainability?



Unbroken trend to overfishing in FAO assessment

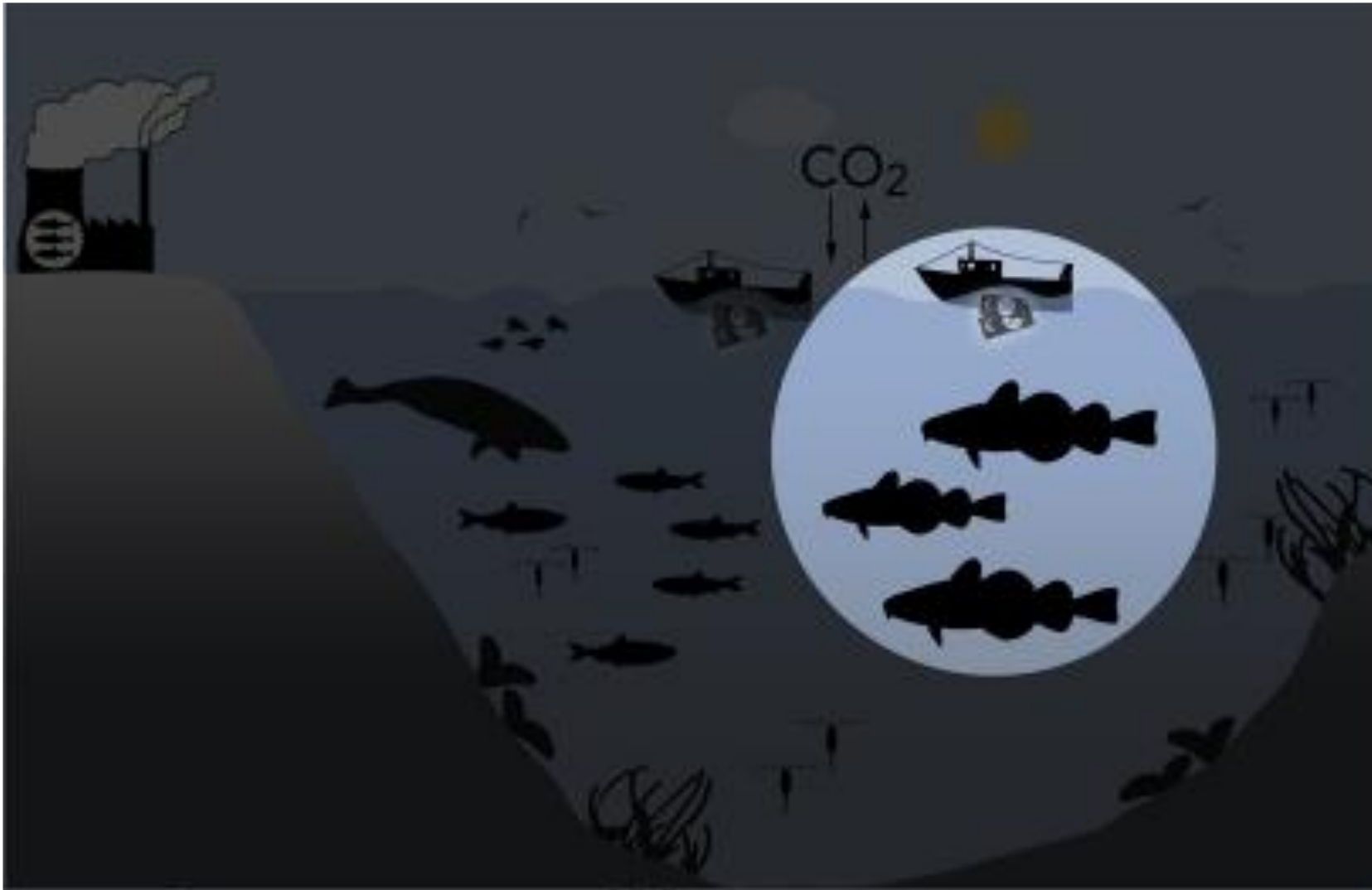
- Strong impacts on ecosystems, biodiversity, economics and social systems

On the way to sustainability?

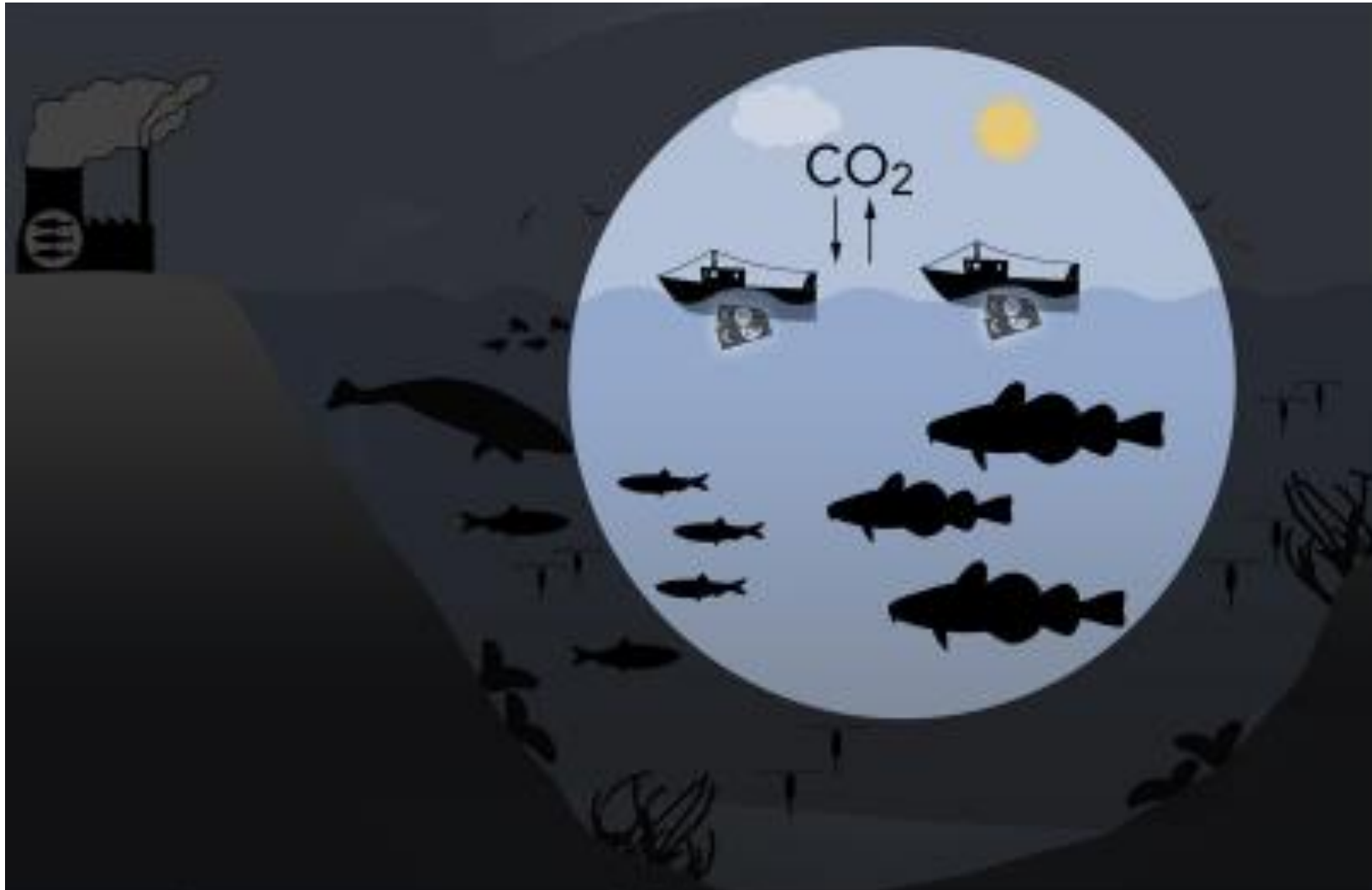


- Global imperative on sustainable fisheries since 2002 (**Maximum Sustainable Yield** concept)
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- Needs:
 - Include species interaction
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 - A main reason for failing fisheries management in the past – and ongoing
- **Successful, commonly accepted fisheries management needs to include economics!**

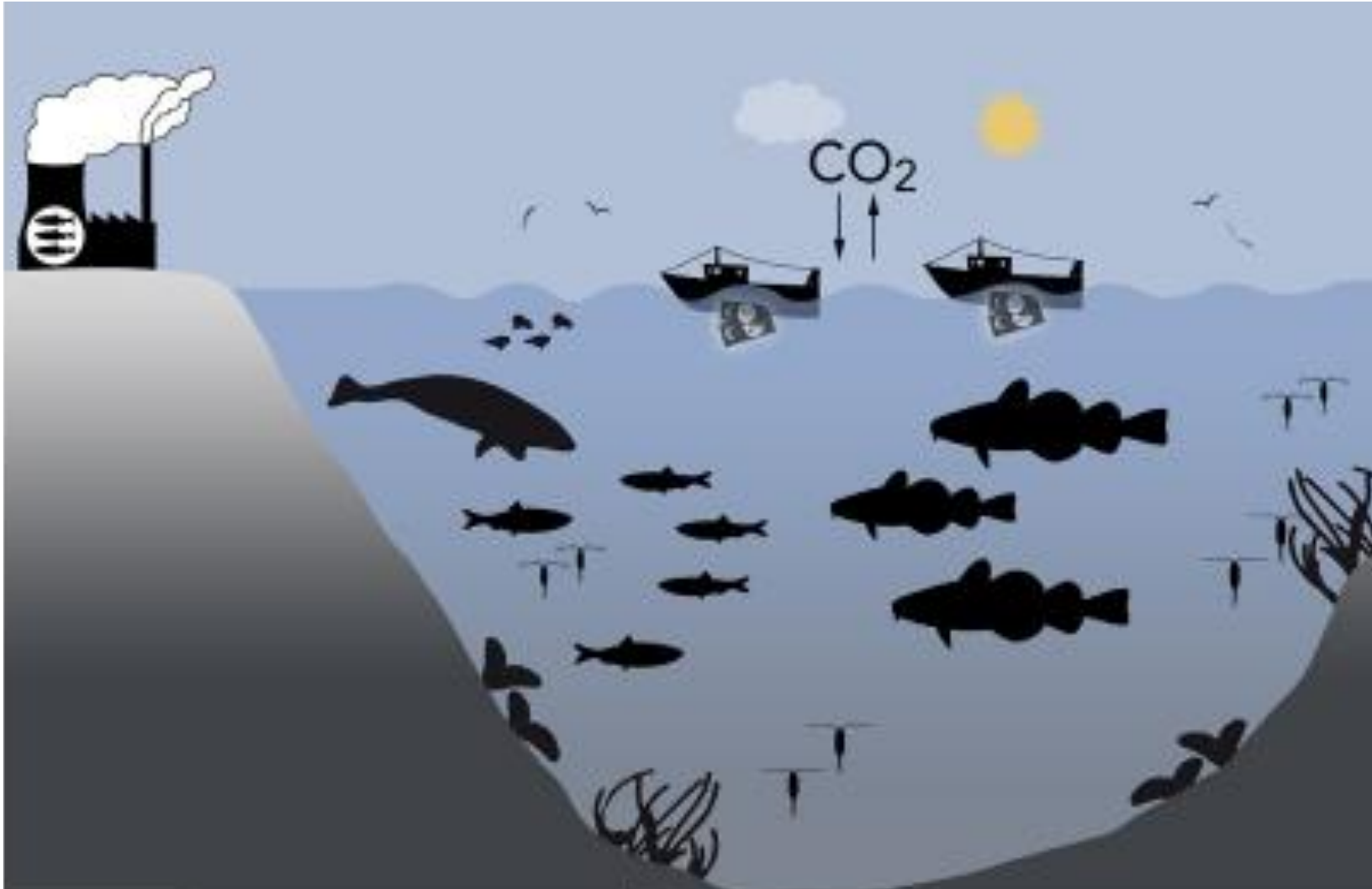
Current state of the art



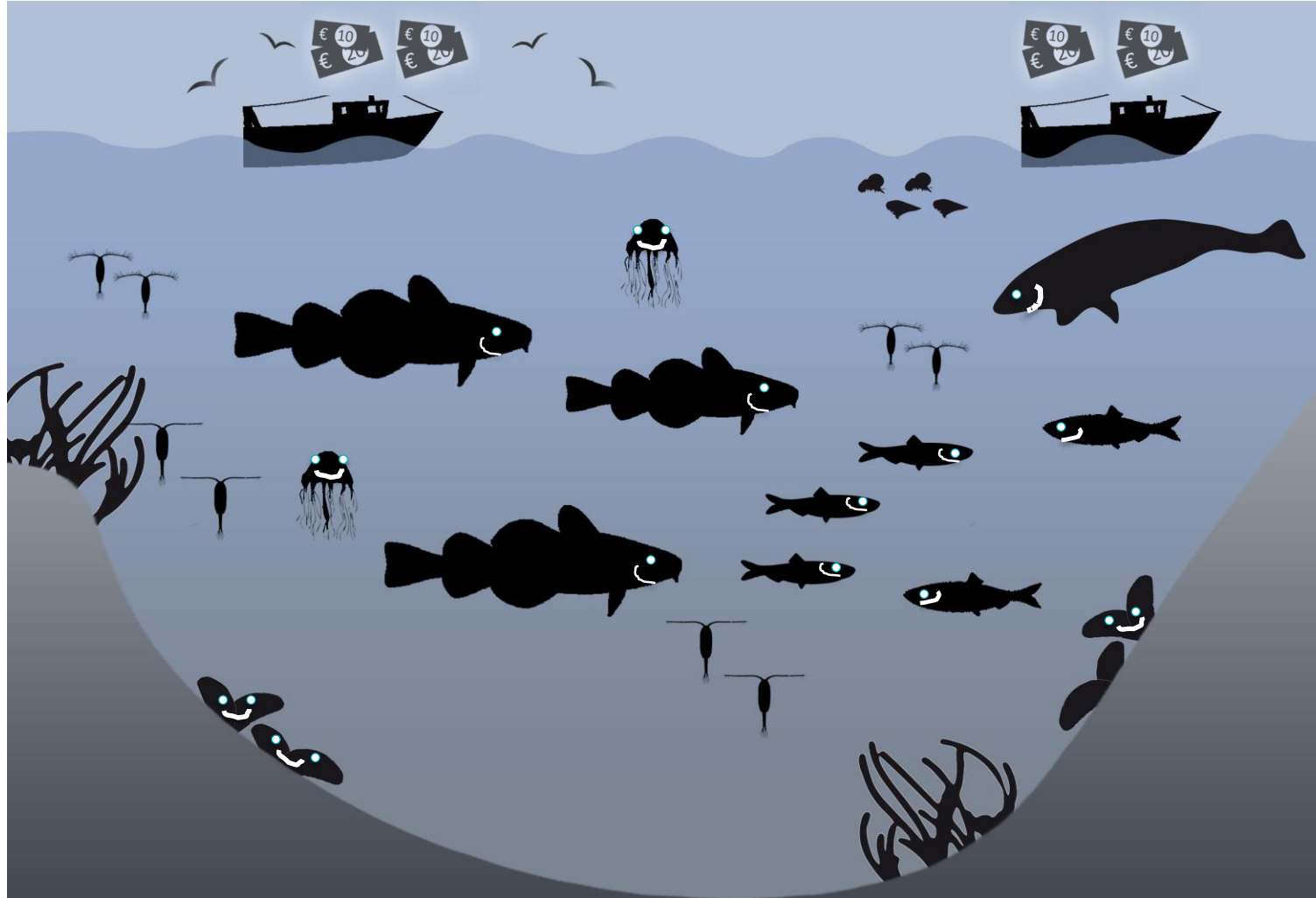
Recent efforts: include env. change & species intercation



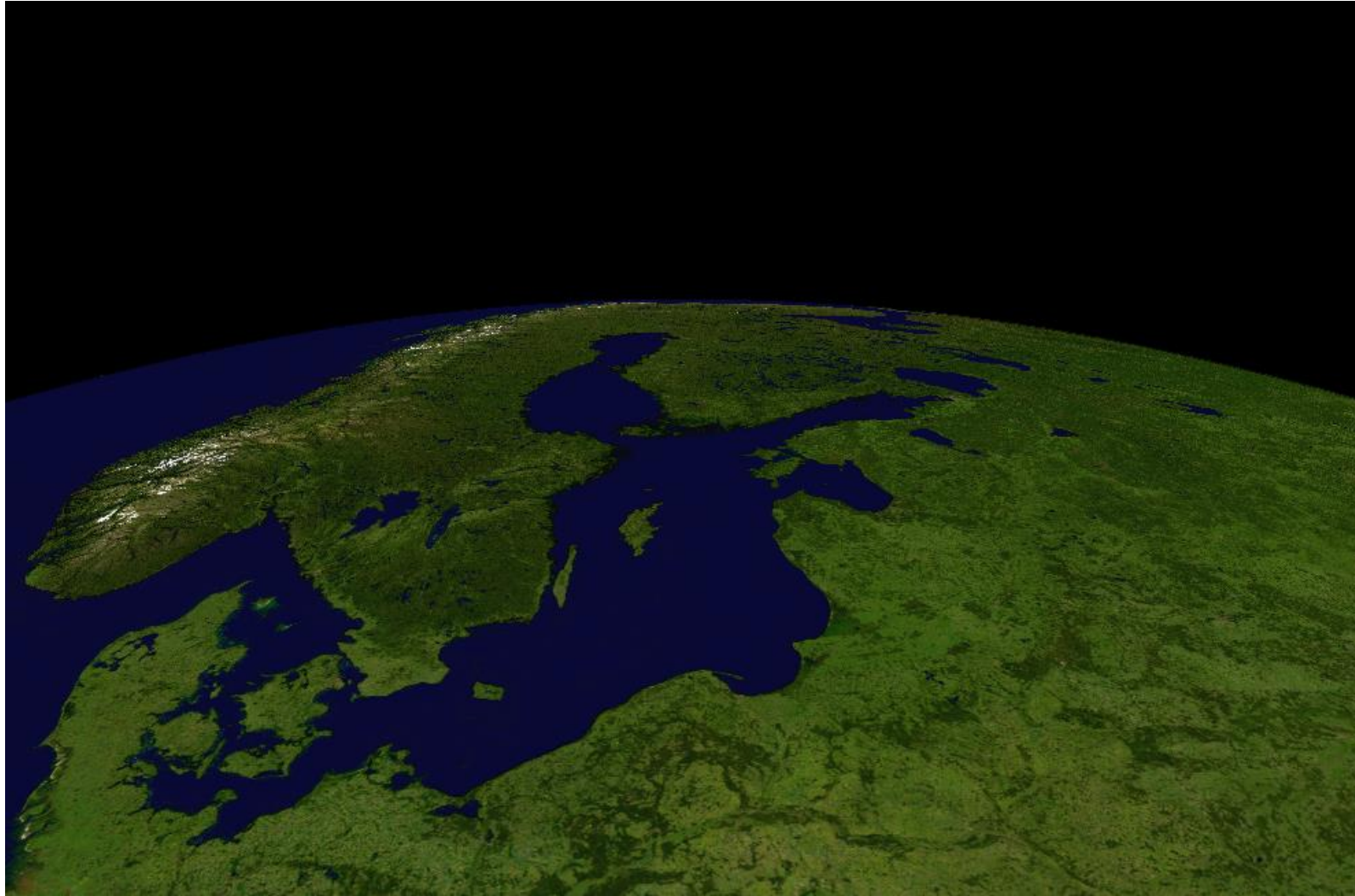
Needed: incl. socio-economics & ecosystem



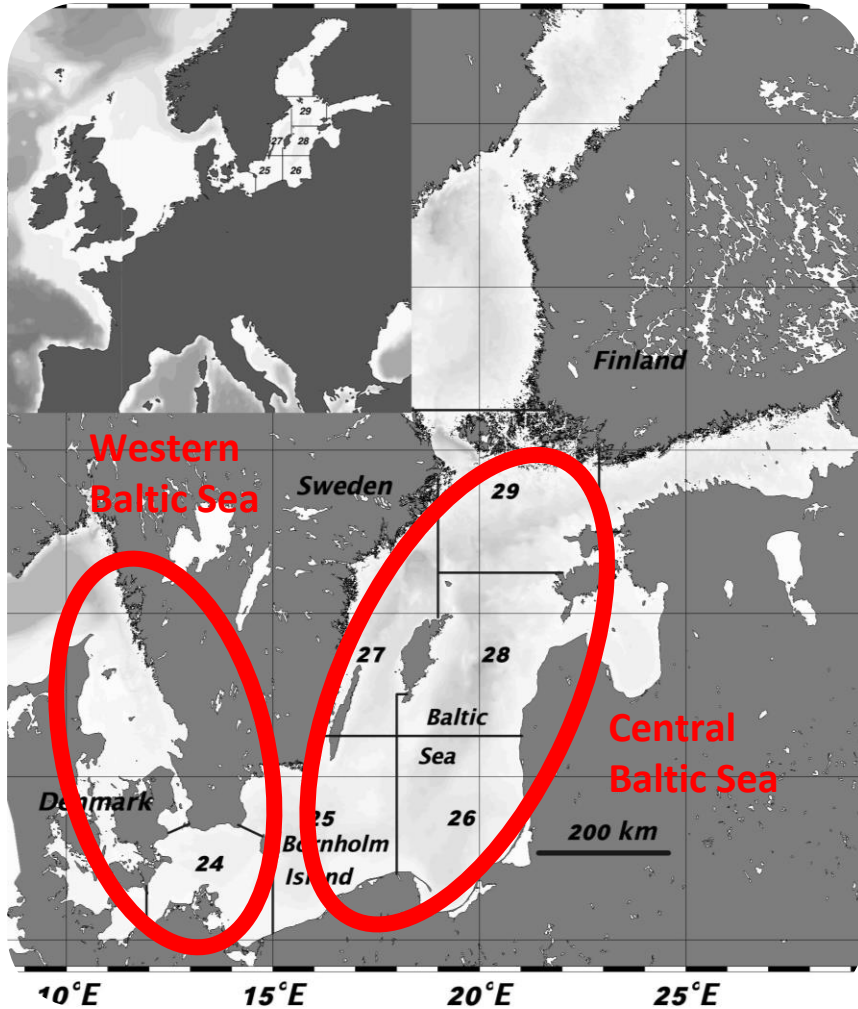
Needed: incl. socio-economics & ecosystem



Baltic Sea Case Study



Baltic Sea – the largest brackish water body of the world

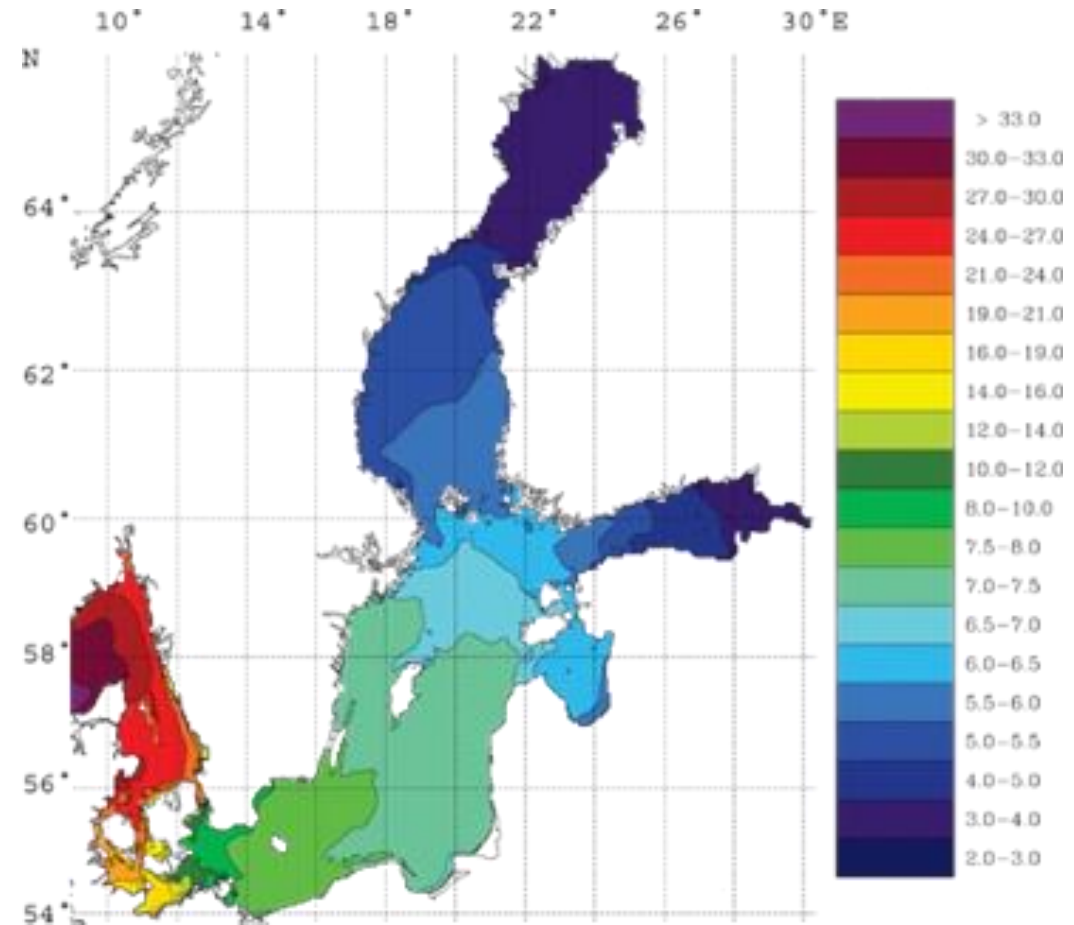


Max. depth:

Arkona Basin: 48 m

Bornholm Basin: 92 m

Salinity at the surface



Gdansk Deep: 112 m

Eastern Gotland Basin: 248 m

Western Gotland Basin: 460 m

Species of interest: a riddle



Sprat

Species of interest

Owner



Her ring

Species of interest

Biscaja



Ostsee



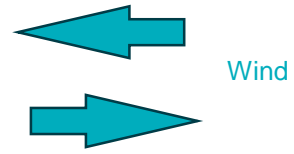
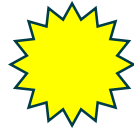
Or

Was soll ich kochen?
Que cuisiner?



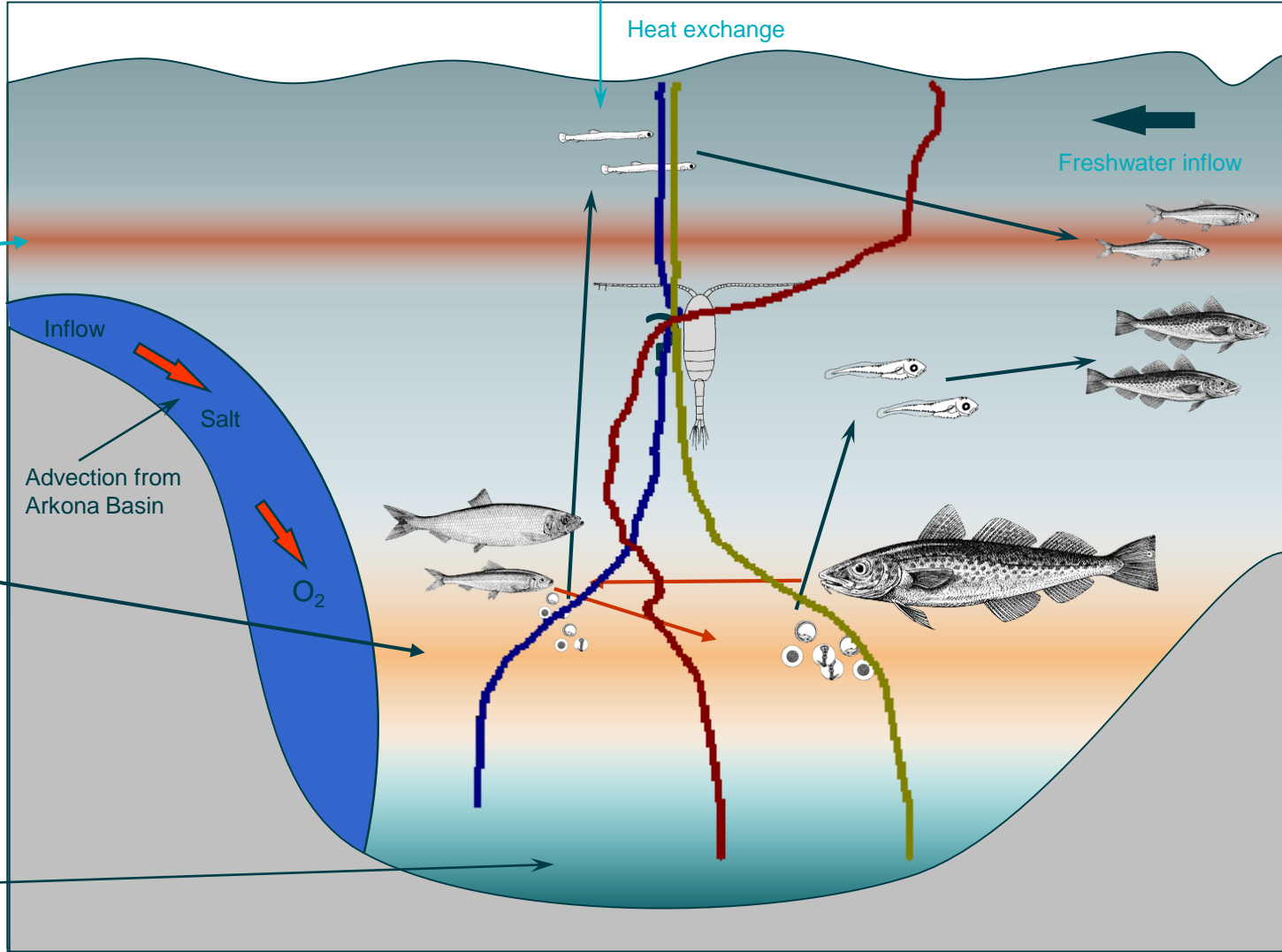
Cabillaud Or Dorsch
Cod

Central Baltic



- Sauerstoff [ml/l]
- Salzgehalt
- Temperatur [°C]

Thermocline



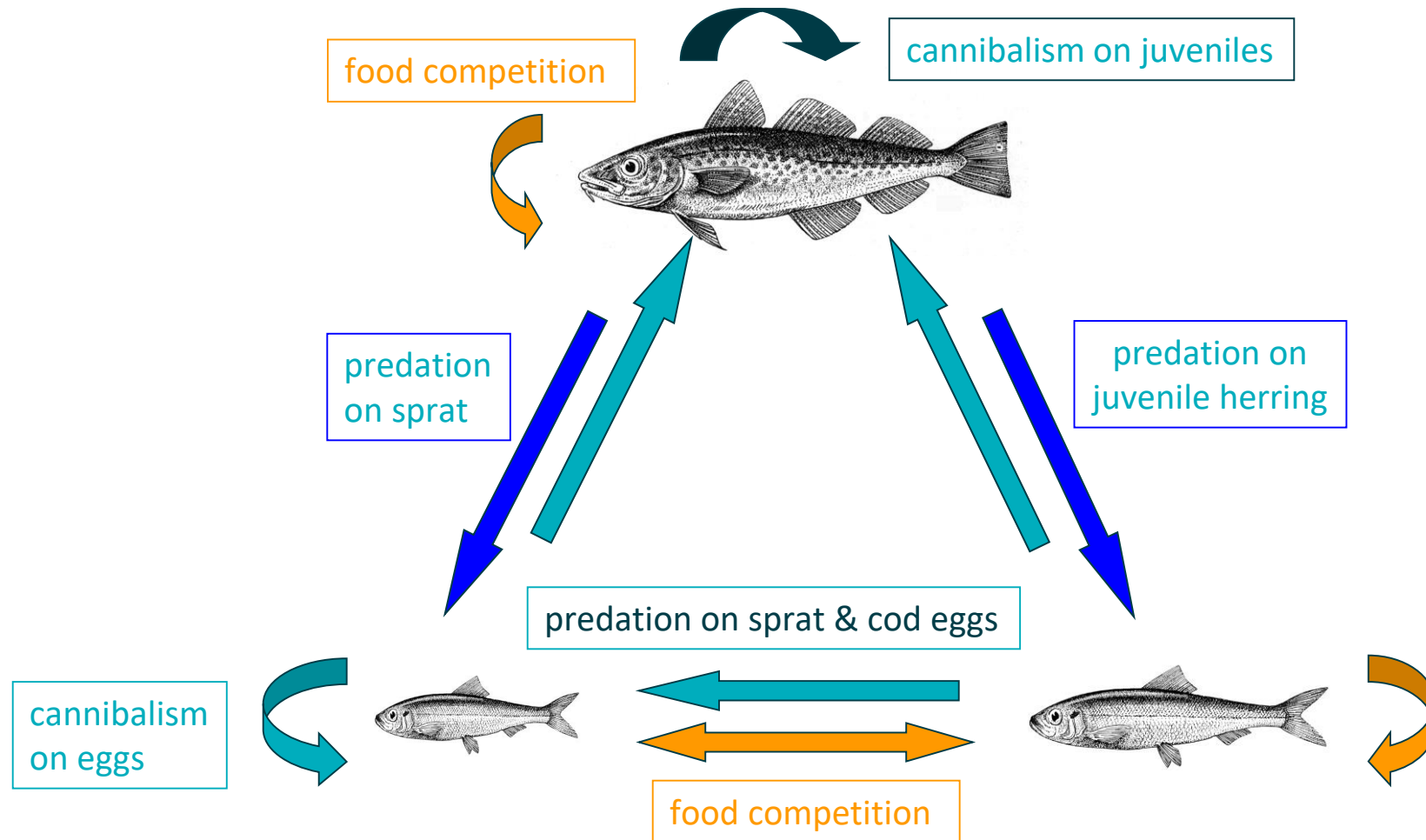
Inflow
Salt
Advection from Arkona Basin
O₂

Halocline

Oxygen minimum zone

5 10 15 20

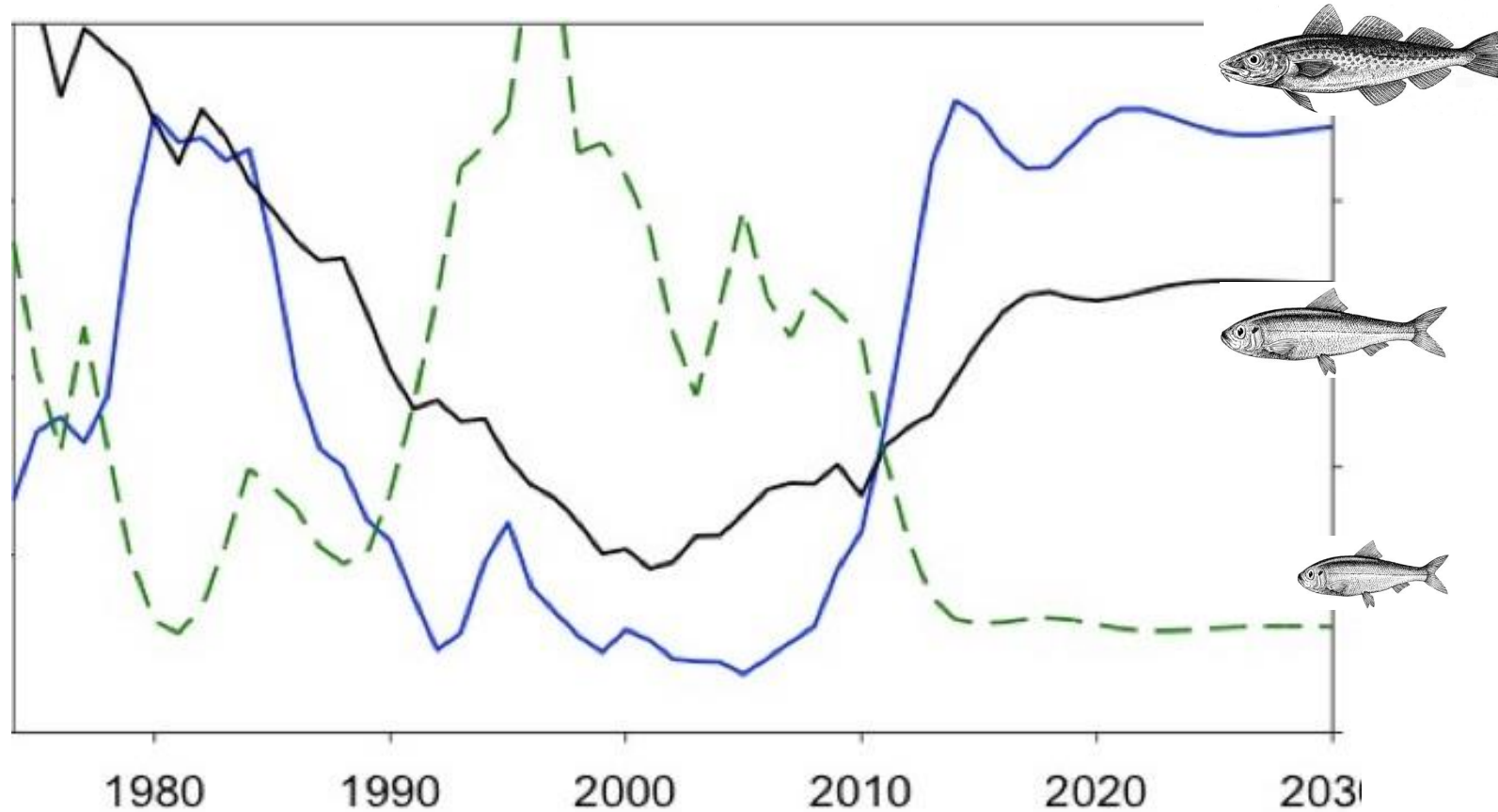
Central Baltic multi-species fishery: three dominant species



Ecological-economic model

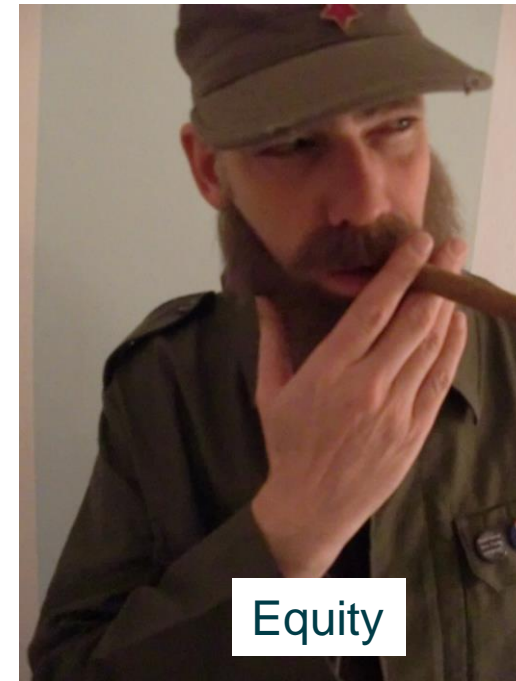
- Combined model for sprat, herring, and cod
- Predation mortality as central interaction (SMS output)
- Age-structured (8 age-classes) to meet standard assessment
- Cost functions dependent on stock size and effort
- Dynamic optimization of F in every fishing period
- Standard objective: Maximize present value of profits
- Desire for catch stability (max. changes 15% per year) built in
- Variation of interest rate & prices possible

Optimal multi-species management: profit maximization



- Incorporation of side conditions needed
- Other objectives, e.g. conservation goals, equity considerations

Multispecies MSY: Trade-offs in management



Wake up! YEAH! Formula!



Multispecies MSY: Trade-offs in management

Objective:

$$V = \sum_{t=0}^{\infty} \rho^t \left(\frac{1}{1-\eta} \Pi^{1-\eta} + (\lambda x_{s0})^{1-\eta} \right)$$

Intertemporal utility of
fishing income:

$$\Pi = \left(\frac{1}{3} \pi_C^{1-\theta} + \frac{1}{3} \pi_S^{1-\theta} + \frac{1}{3} \pi_H^{1-\theta} \right)^{\frac{1}{1-\theta}}$$

ρ Discount factor

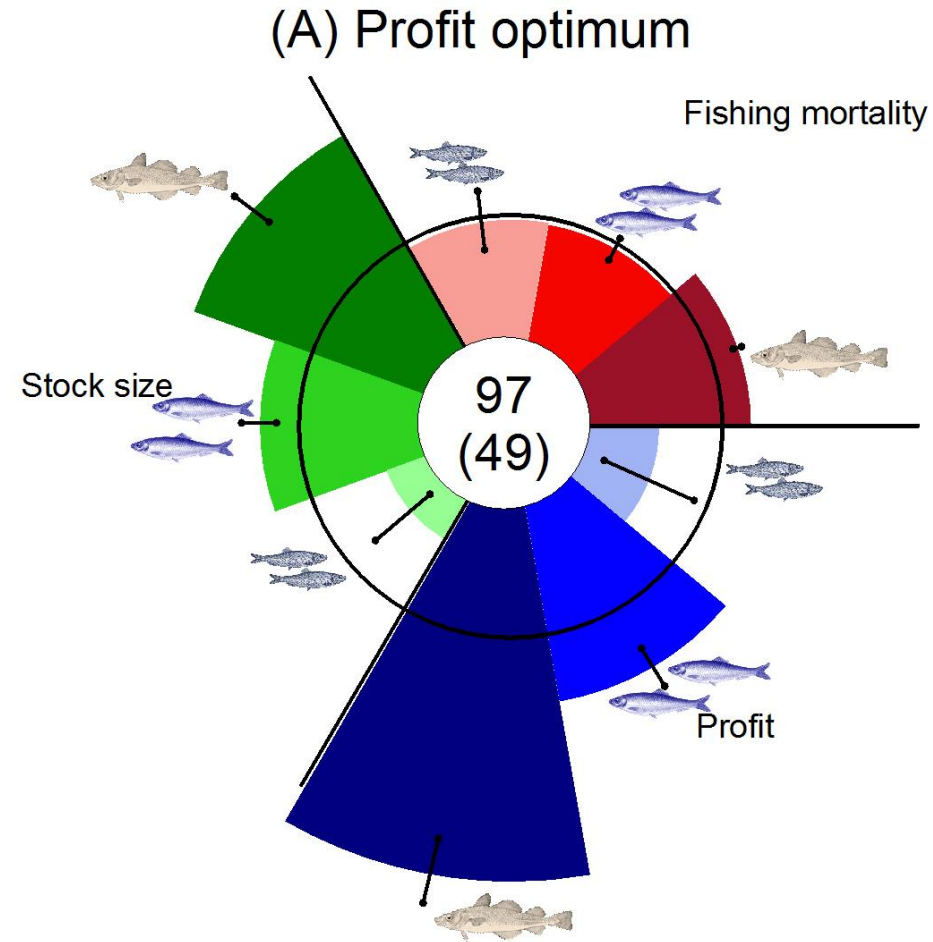
η Representative fisherman's aversion against
intertemporal income fluctuations

$\theta \geq 0$ Social aversion against inequality of incomes
for the three different fisheries

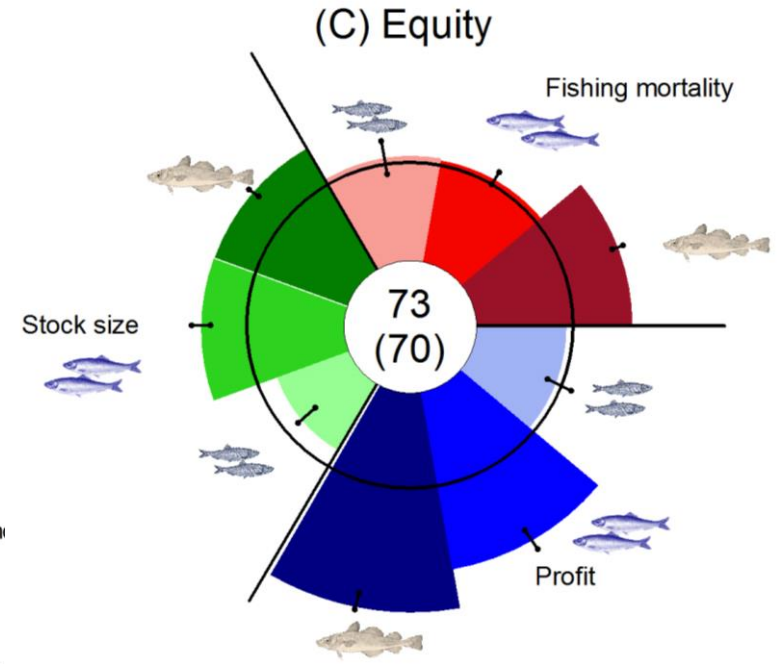
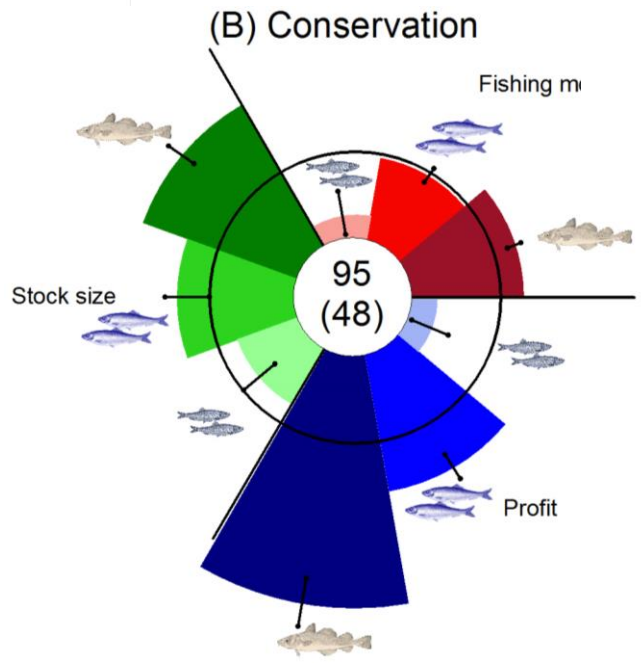
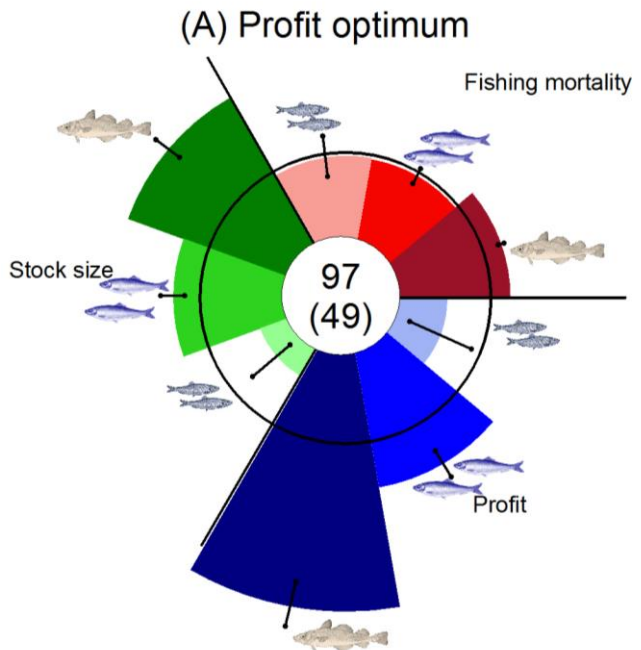
x_{s0} Spawning stock

$\lambda \geq 0$ willingness to pay for sprat ecosystem services

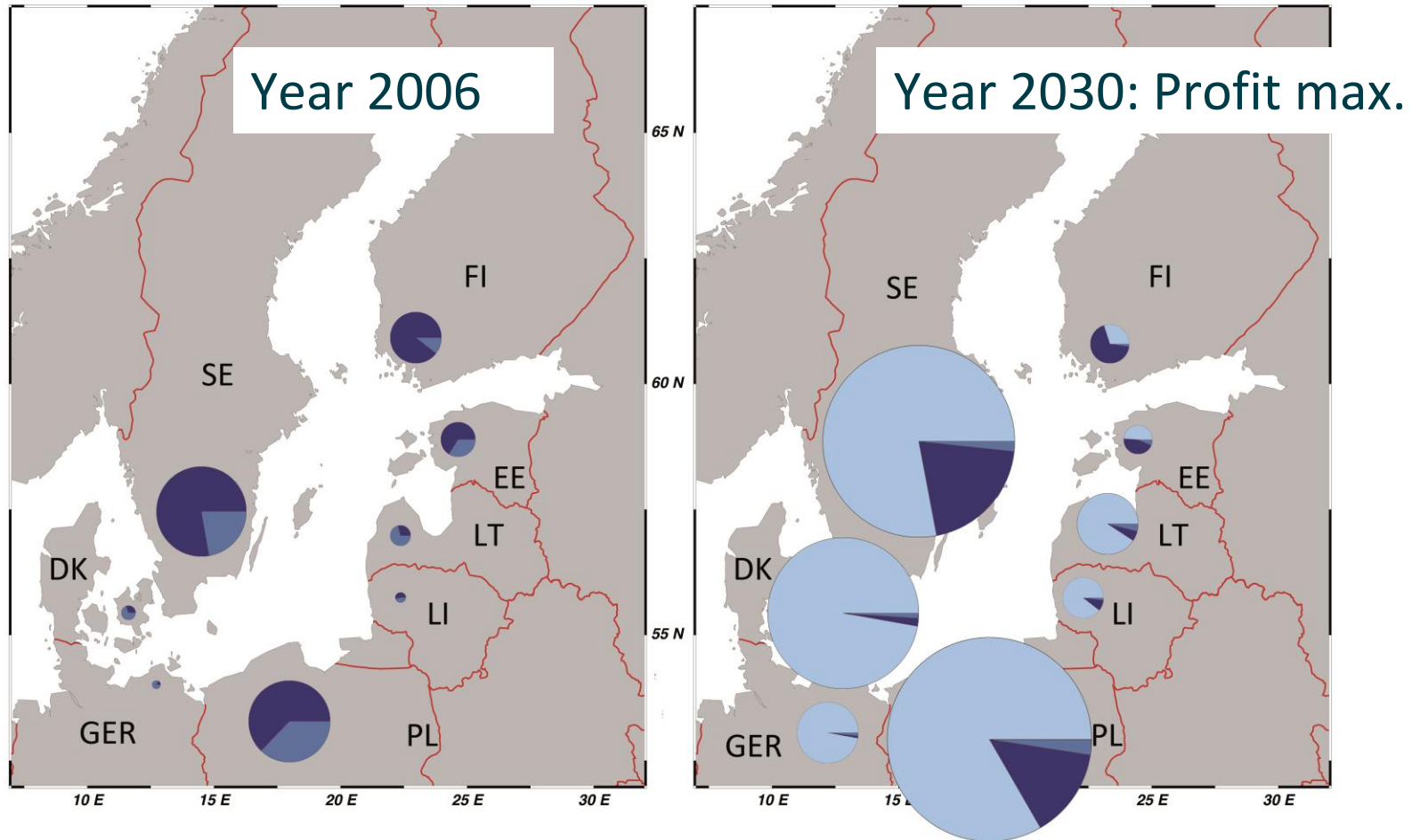
Optimal multi-species management: Profit maximization



Optimal multi-species management:



Regional distribution of profits:



Limitations

- Spatial resolution
 - Current changes in predator-prey overlap?
- Rate of cannibalism in cod
- Food limitation of cod (benthic component)
- Competition between clupeids
- Feed-back from clupeids->cod
- Demand side interactions
- Technological progress
- Environmental change

Baltic Sea is highly stratified



Sprat larvae

Cod larvae

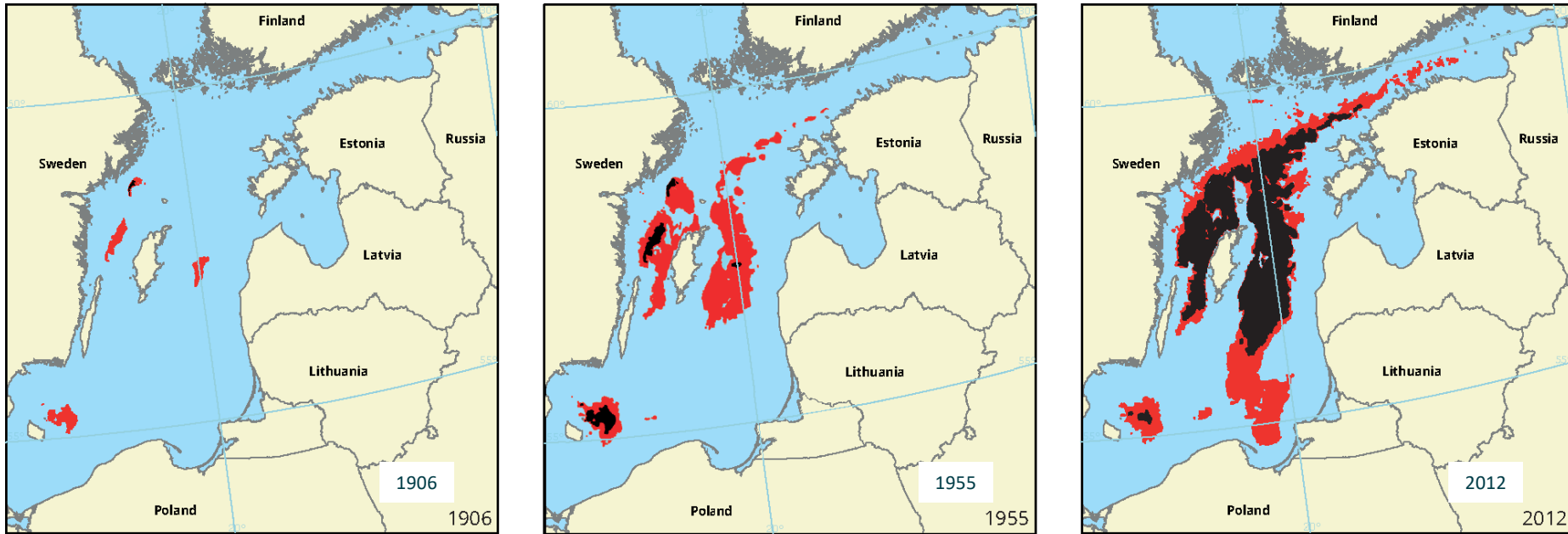
Sprat eggs

Cod eggs

Temp. conditions

Oxygen conditions

Dead zones in the Baltic



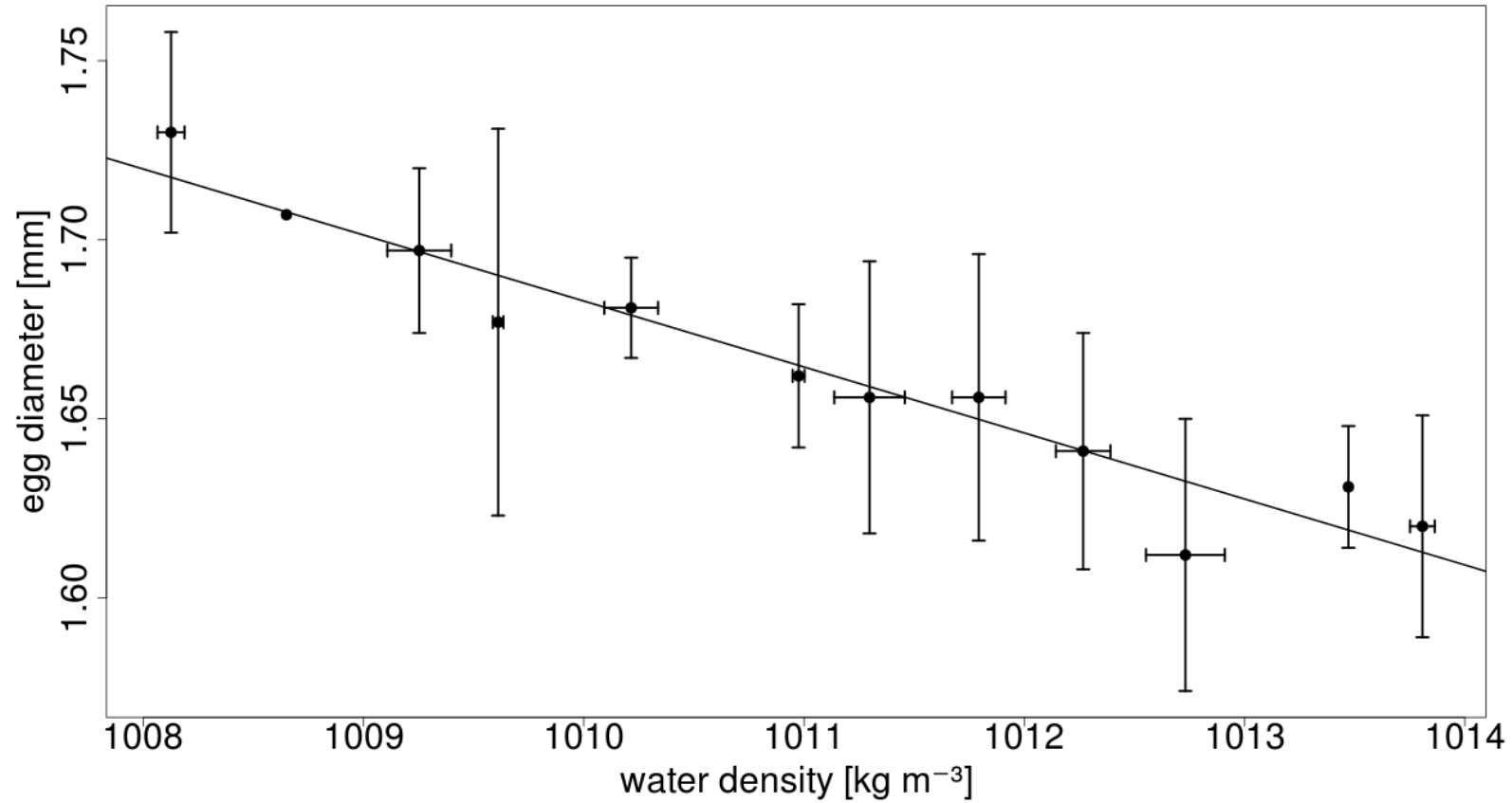
Development of oxygen depletion in the Baltic Sea over time

Estimated bottom concentrations (mg/l)

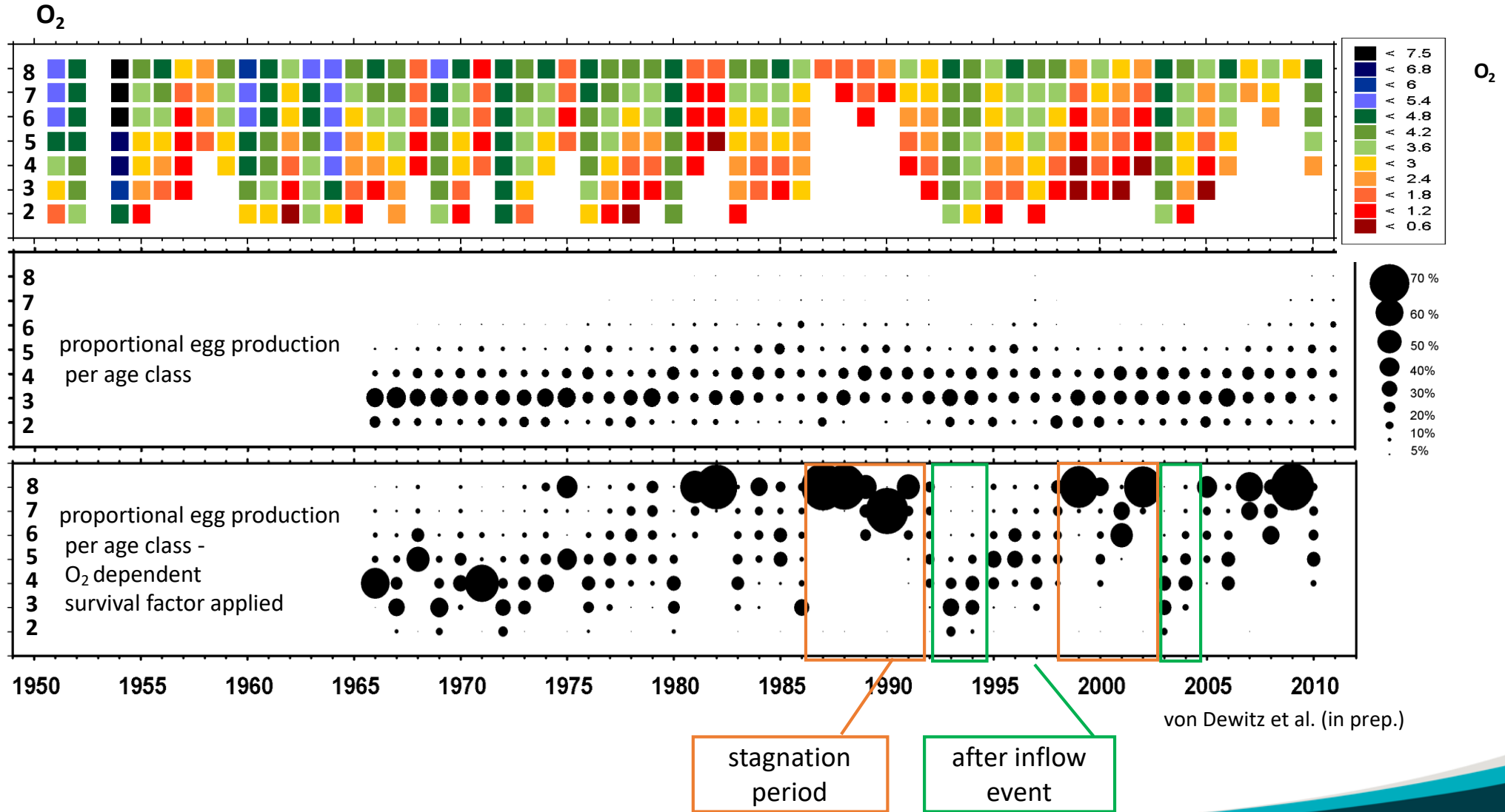


100 km

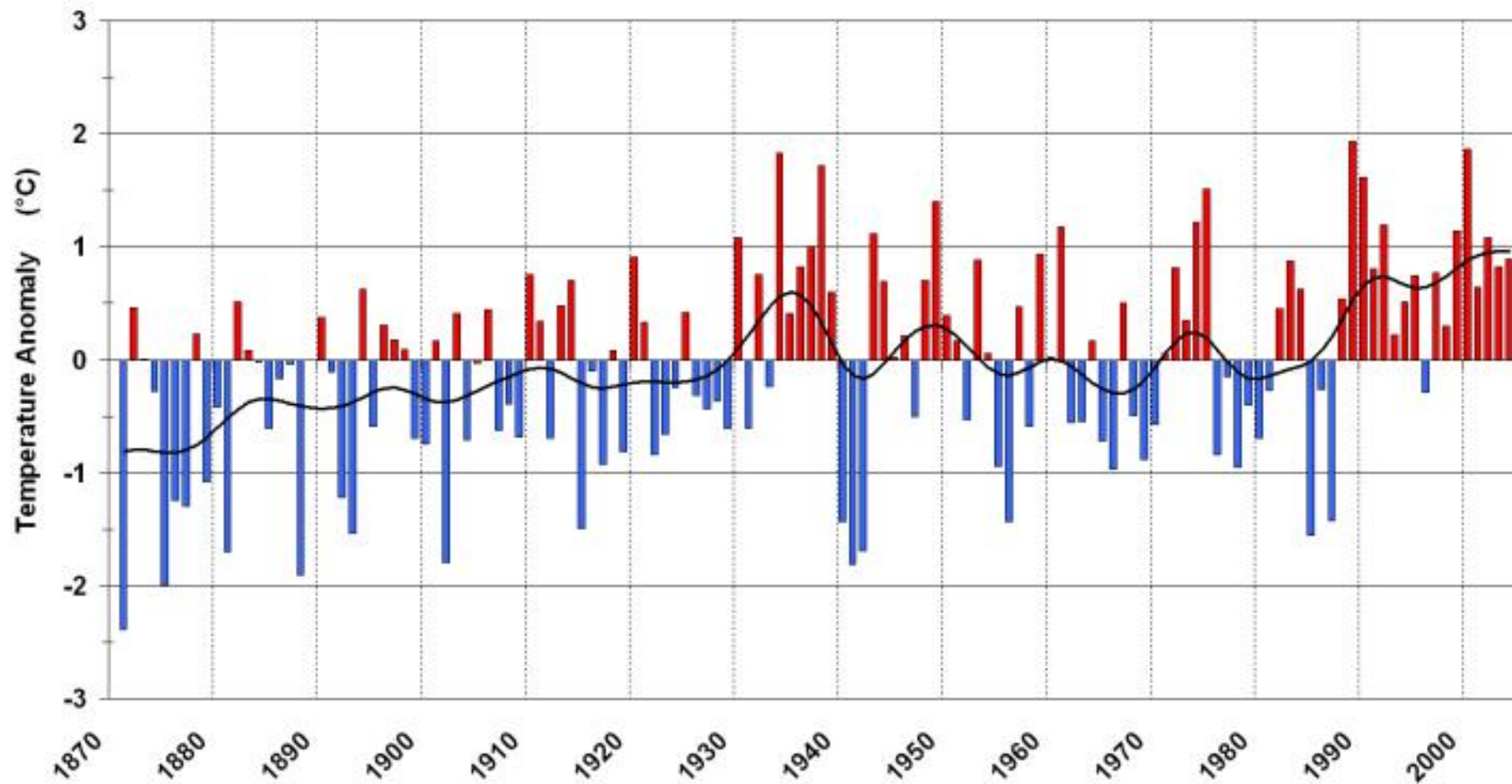
Older cod have larger eggs



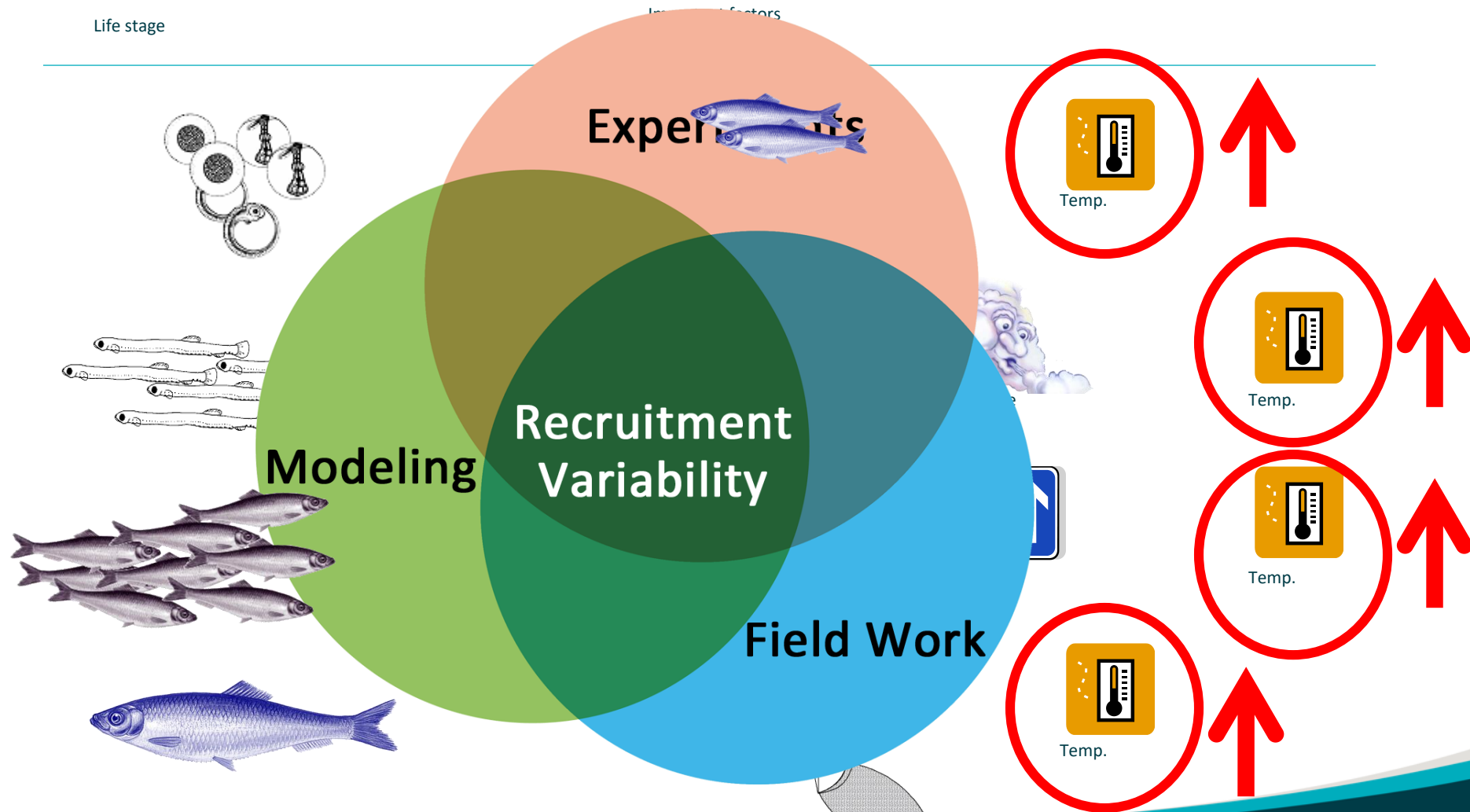
Egg survival: environmental selection



Temperature development in the Central Baltic

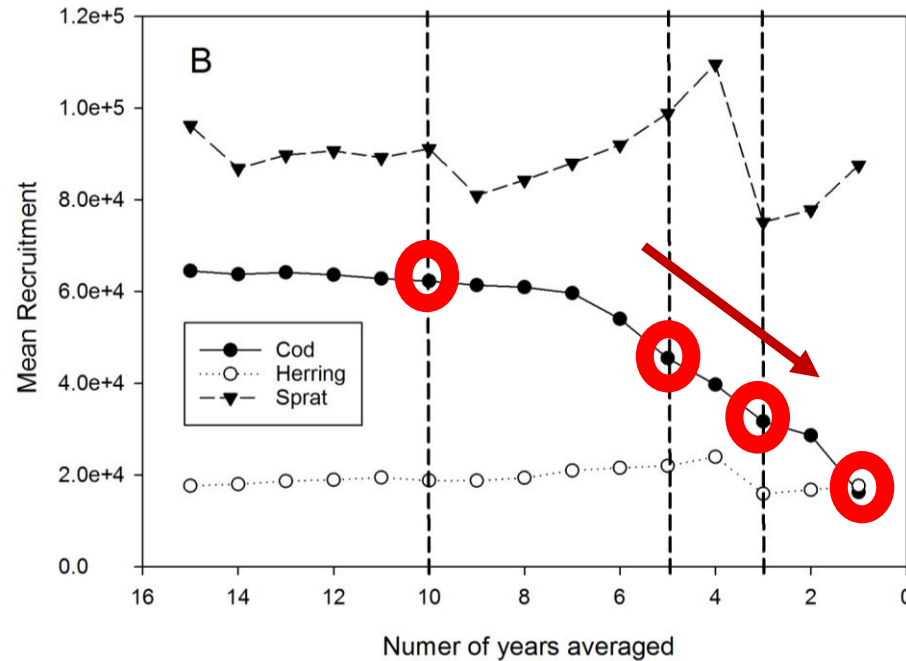


Sprat recruitment variability



Including environmental change

Including environmental change: trends



- Recruitment (R) of herring is stable / decreasing
- R of sprat is highly variable
- R of cod is decreasing
- ICES uses 5y averages for short-term forecast & advice
- New stock productivity and predation rates for cod available

Model?

Model?

What we do NOT use:

End



End

End-to-end model

Model?

What we use:



Model of intermediate complexity
Prof. Martin Quaas

What we do NOT use:



Simplified model

Model!

- Age-structured, multispecies optimization model
- Biological input based on ICES data & predation rates

- Fishing costs are stock-dependant; prices sensitive to supply
- Overall welfare can be separated to producer and consumer surplus
- Analysis of total profits, trade-offs and synergies

- Comparison of situation in 2014 vs 2019
- Long-term targets & short-term advice

Management scenarios



Ähmm, ...
why?

M M E Y

Management scenarios

Scenario 1	Multispecies Maximum Economic Yield (MMEY) - unconstrained
Scenario 2	Multispecies Maximum Sustainable Yield (MMSY) - unconstrained
Scenario 3	MMSY respecting minimum biomass reference points (MMSY B_{lim})
Scenario 4	MMSY respecting minimum biomass reference points and yielding non-negative profits (MMSY B_{lim} econ)
Scenario 5	MMEY respecting minimum biomass reference points (MMEY B_{lim})

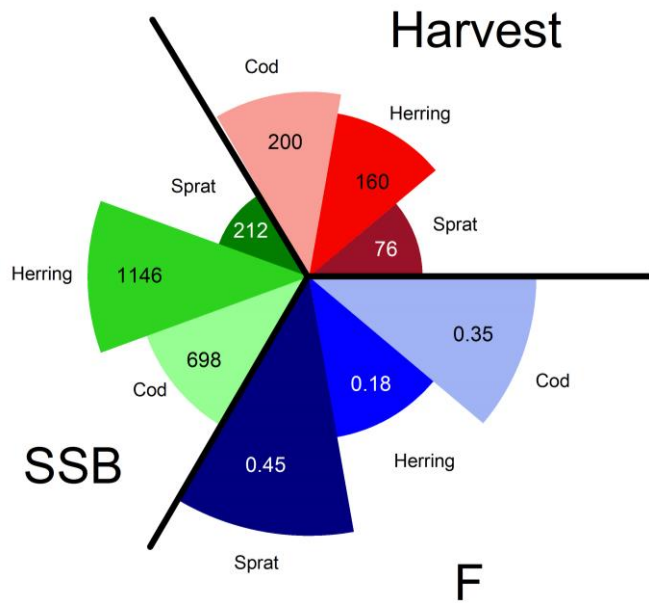
Cod recruitment scenarios

Recruitment level 1	Average R over 10 years (2009-18)
Recruitment level 2 (ICES standard)	Average R over 5 years (2014-18)
Recruitment level 3	Average R over 3 years (2016-18)

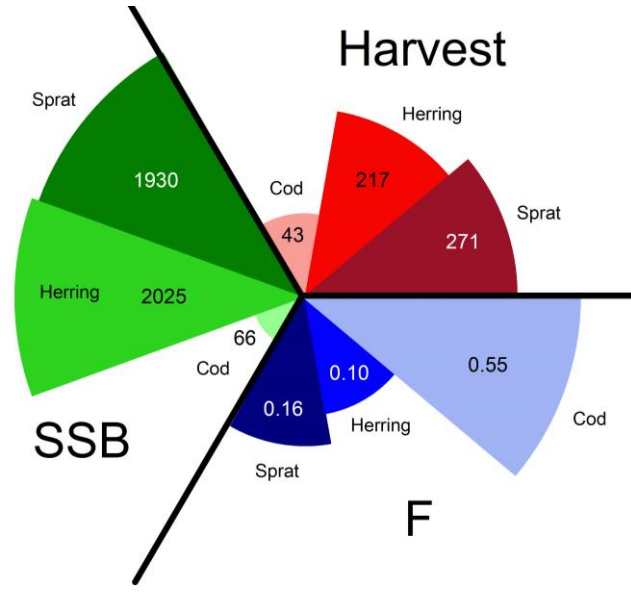
Long-term effects



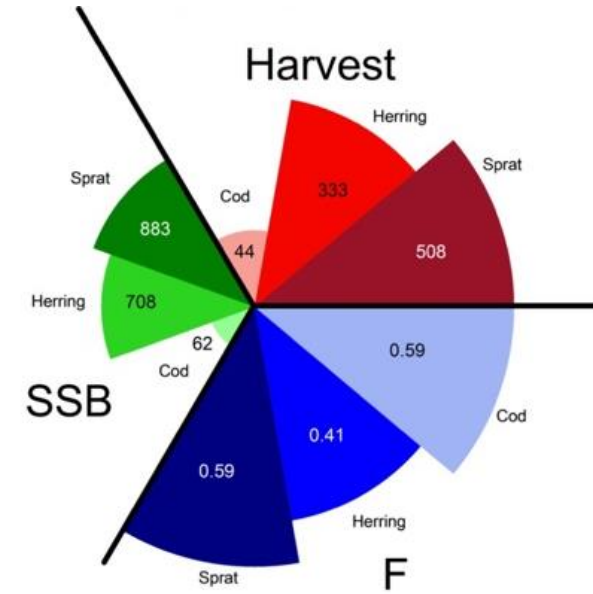
Long-term effects: changed biological input data



2014
MMEY

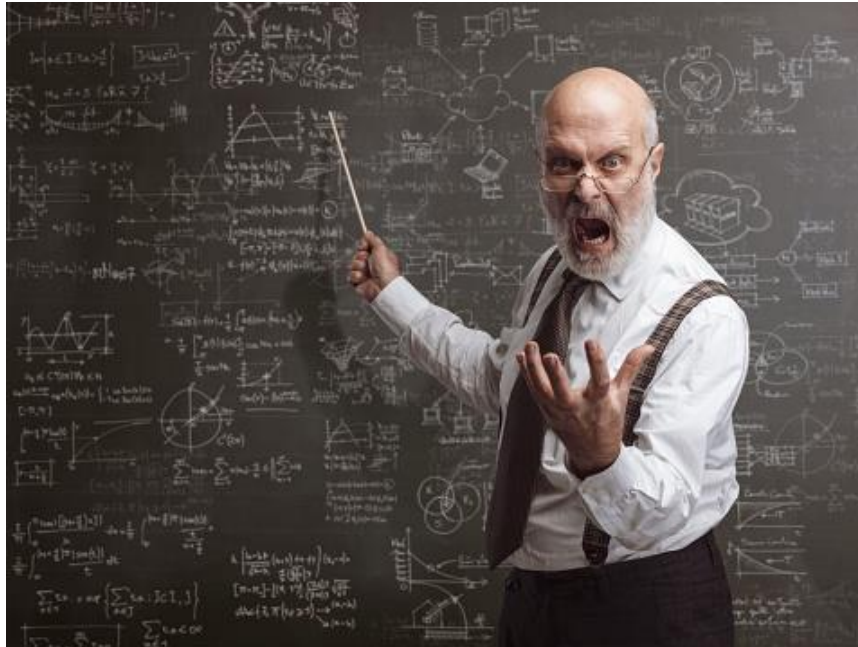


2020
MMEY



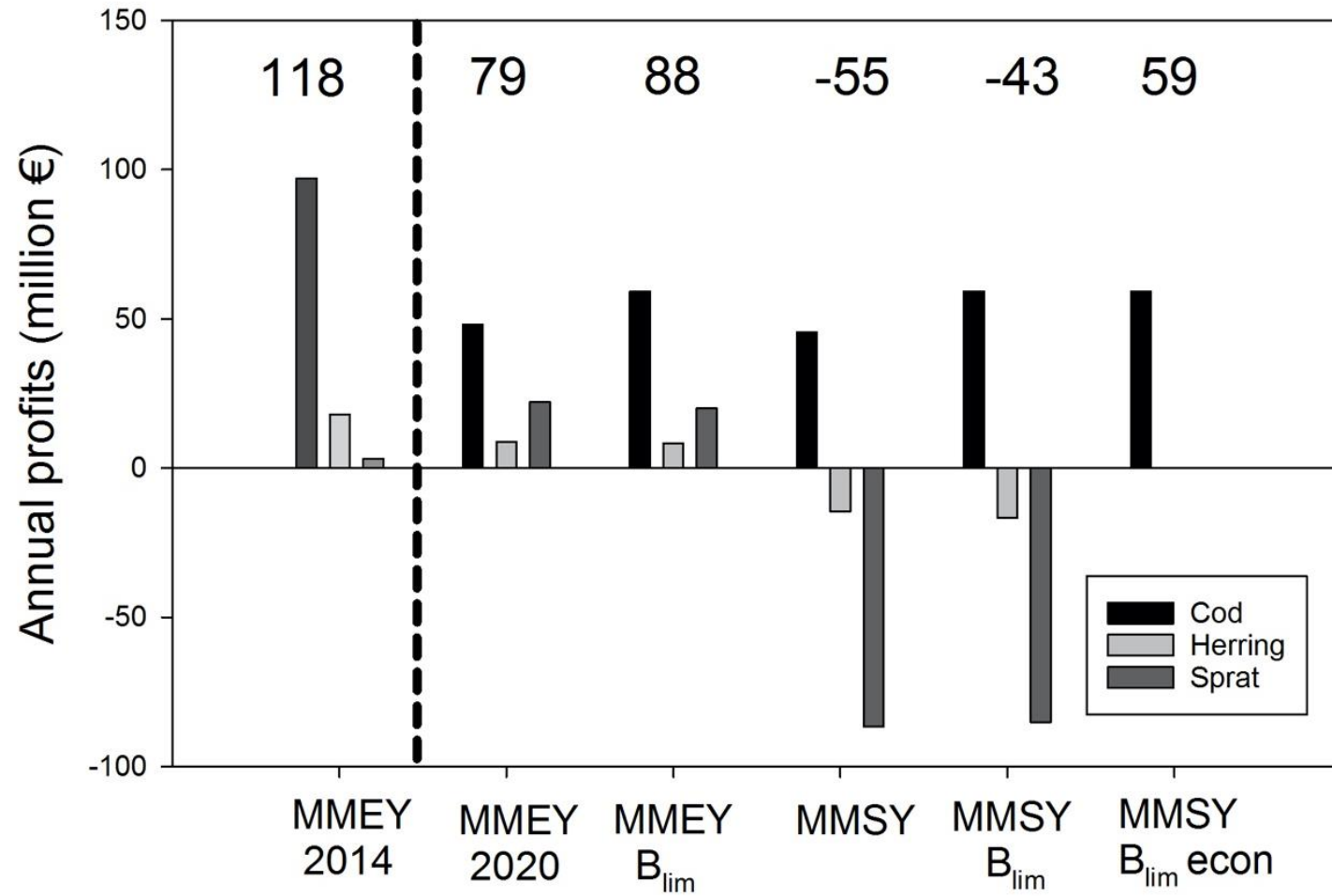
2020
MMSY

What we are also interested in:



Prof it

Annual profits






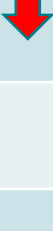
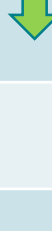
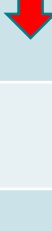
What about ... ?



+

... Alec Guinness

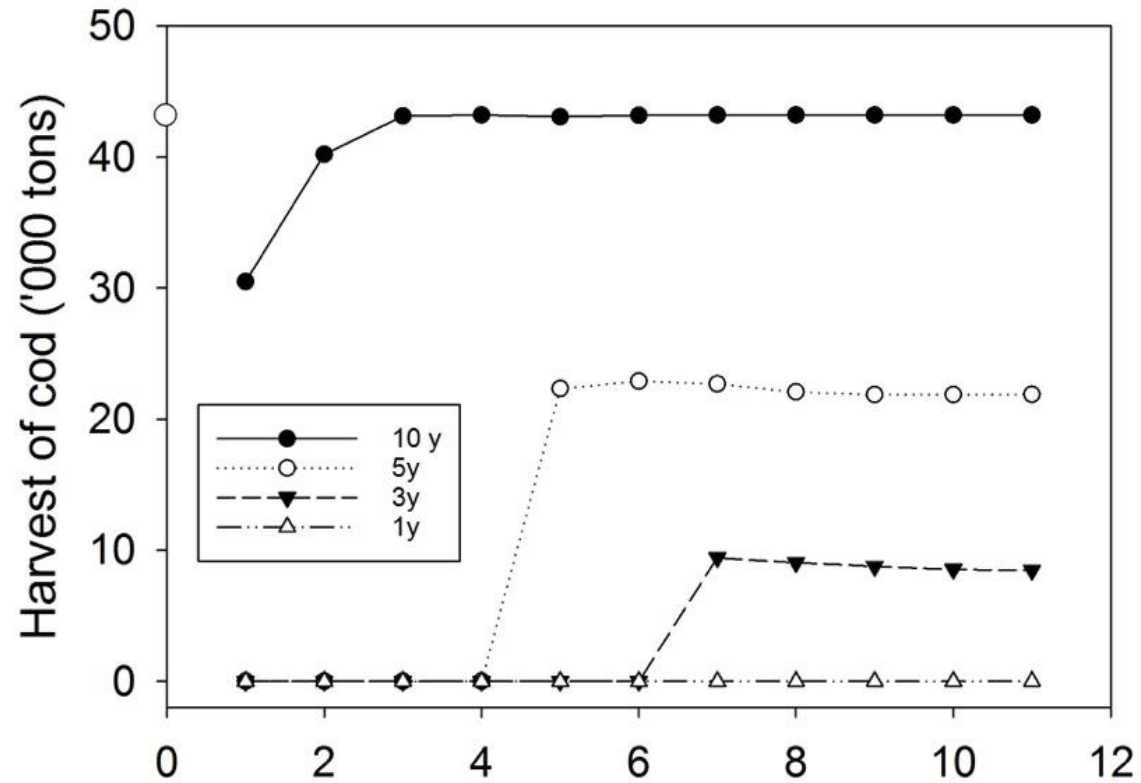
Sir plus Sur plus

	Total Welfare	Producer Surplus	Consumer Surplus
MMEY	397.1 	79.2 	317.9 
MMEY robust	396.8	83.5	313.3
MMEY B_{lim}	391.1 	87.6 	303.5 
MMSY	301.1	-55.5	356.5
MMSY B_{lim}	298.4	-42.6	341.0
MMSY B_{lim} econ	380.9	59.2	321.6

Short-term effects

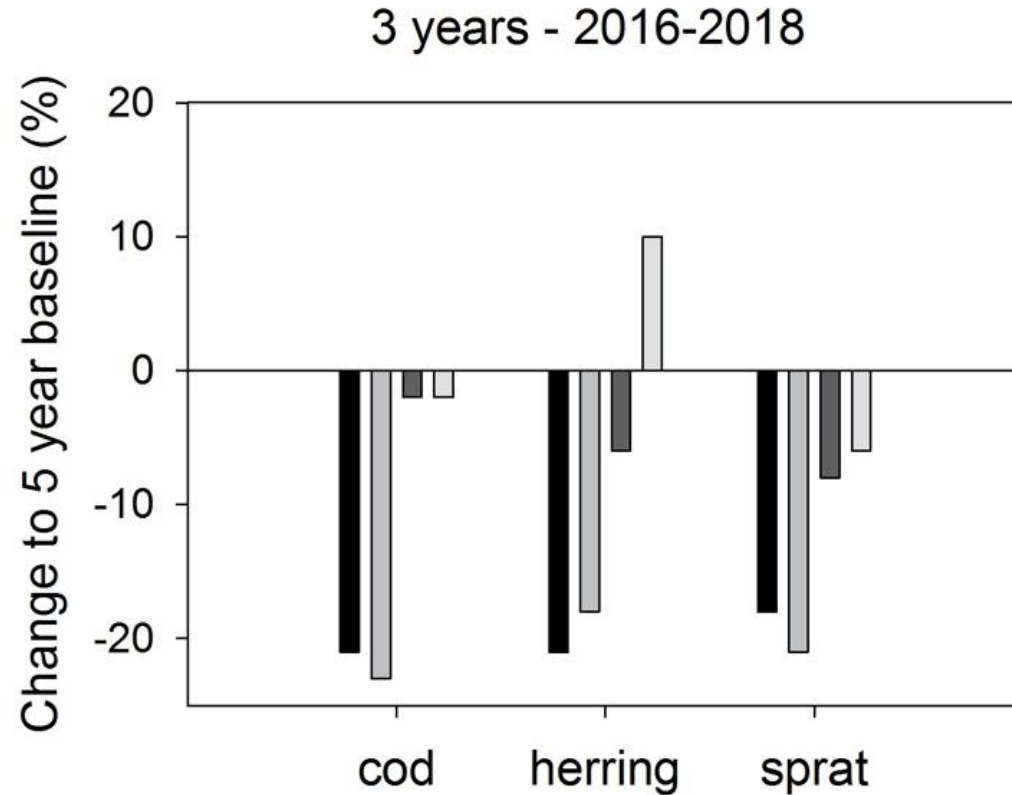


Short-term effects



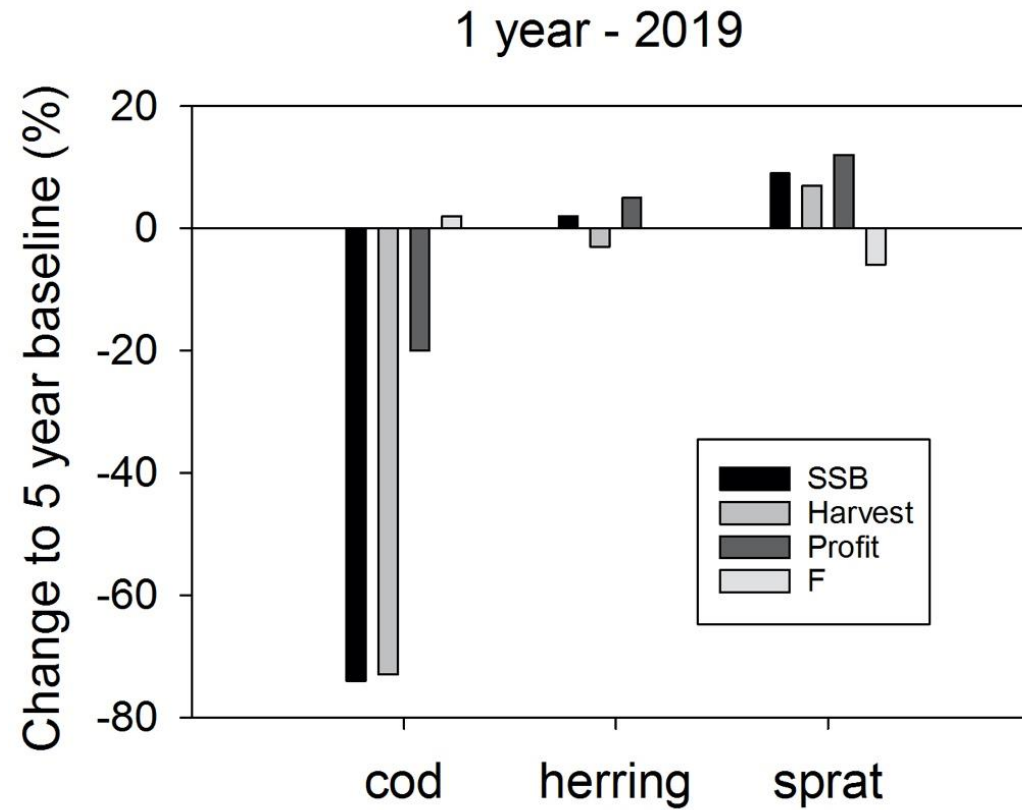
- Closure of cod fishery needed

Effects of varying time span of R averaging



- Varying the timespan of averaging has large effects
- Last 3 years below-average R for all species

Effects of varying time span of R averaging



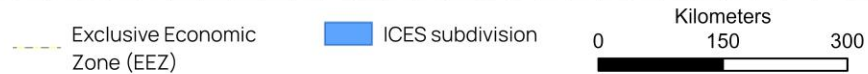
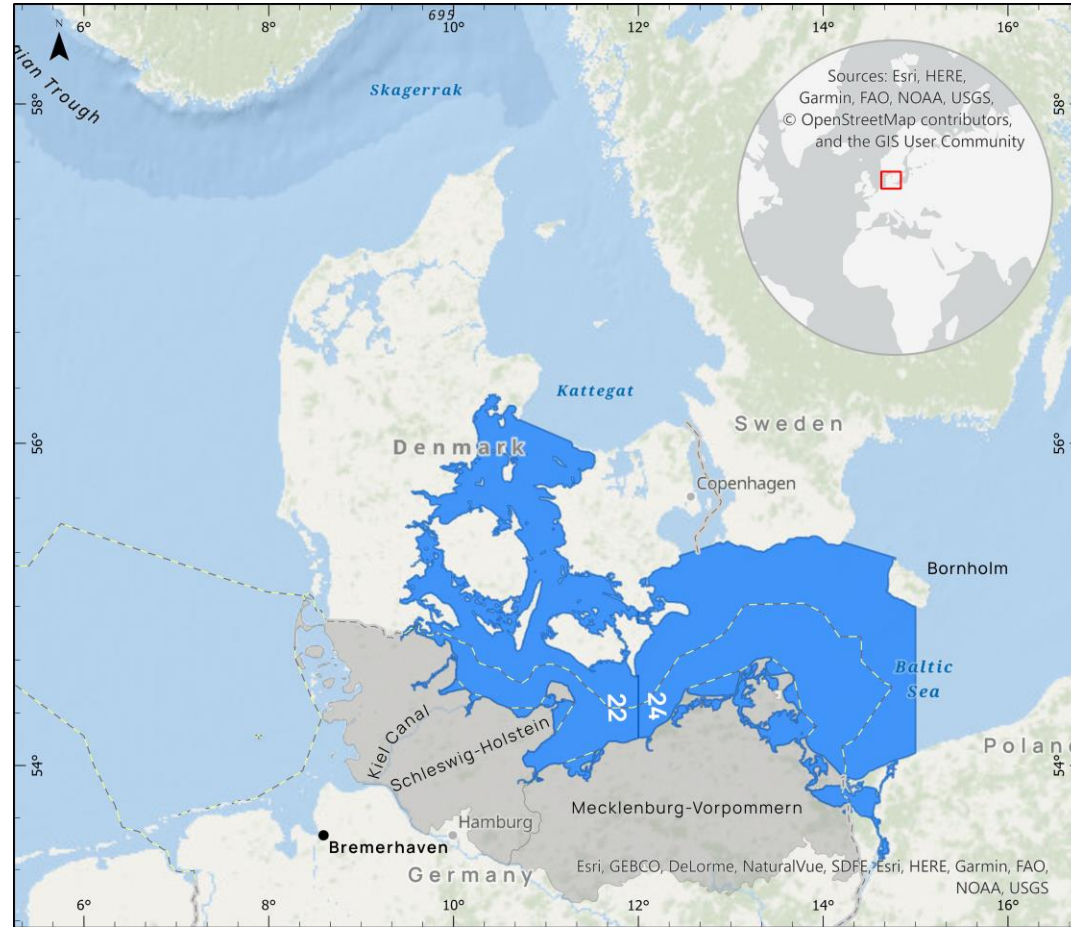
- Simulation with (low) 2019 recruitment of cod
- Last 3 years below-average R for all species

Conclusions Central Baltic

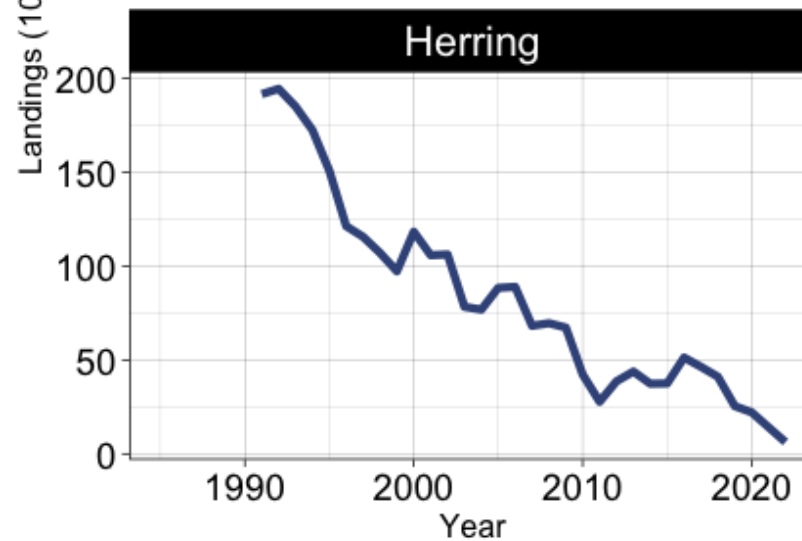
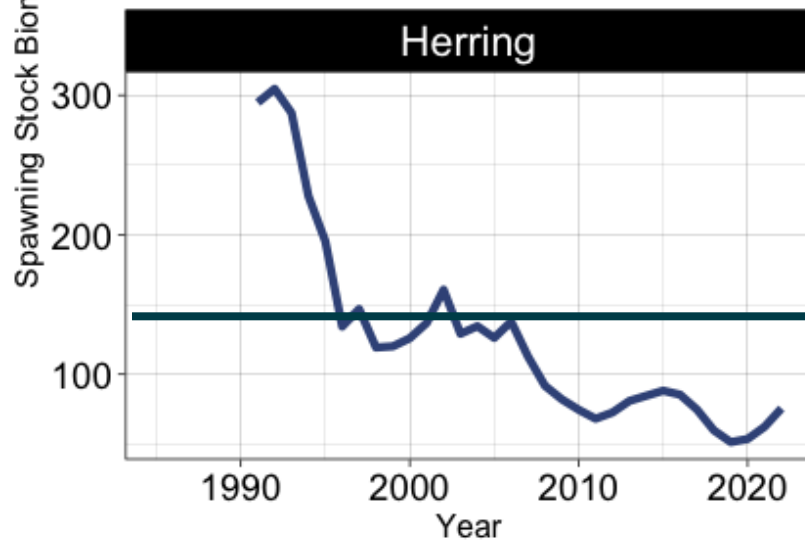
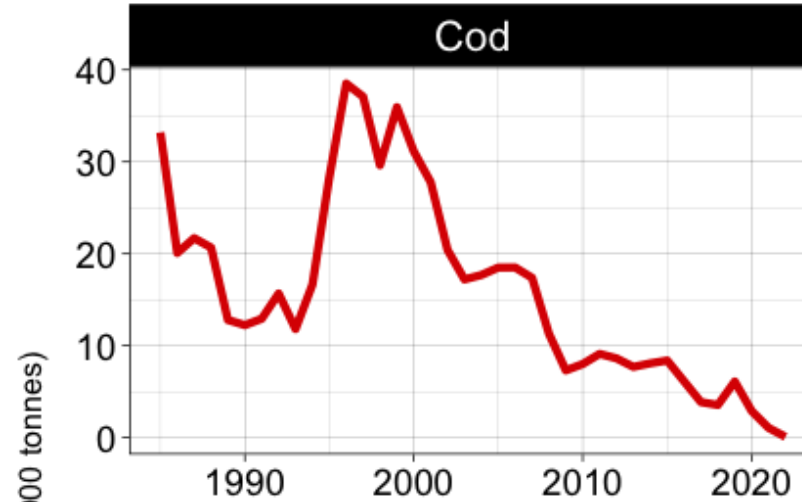
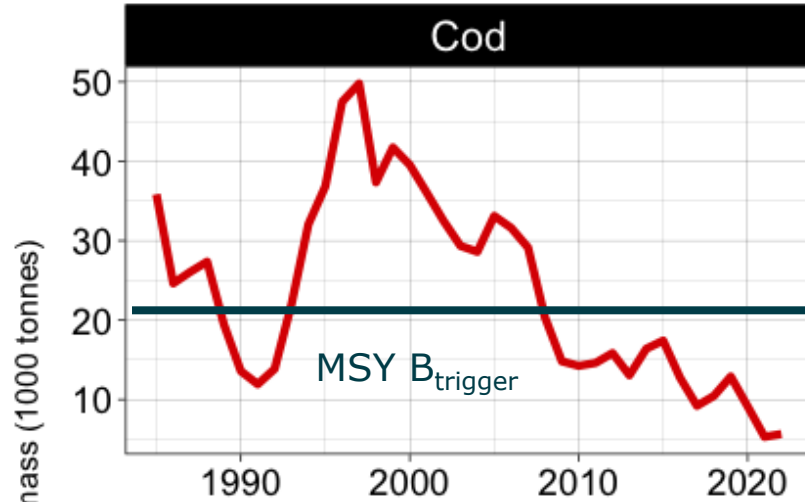


- Management targets need to be adapted
- Synergy between fishery profits and respecting Blim
- If cod stock dynamics further worsen -> Brave New Baltic
- Environmental effects can be included, e.g. in S/R relationship
- This is what we did recently in the Western Baltic ...

The Western Baltic Sea



Cod & herring collapse



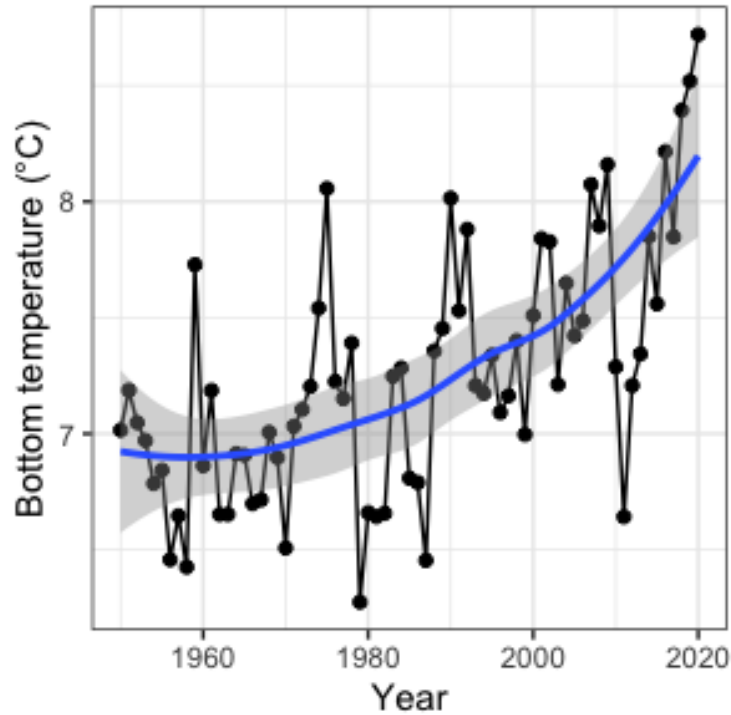
Crisis of the German Baltic fisheries



Fleet development

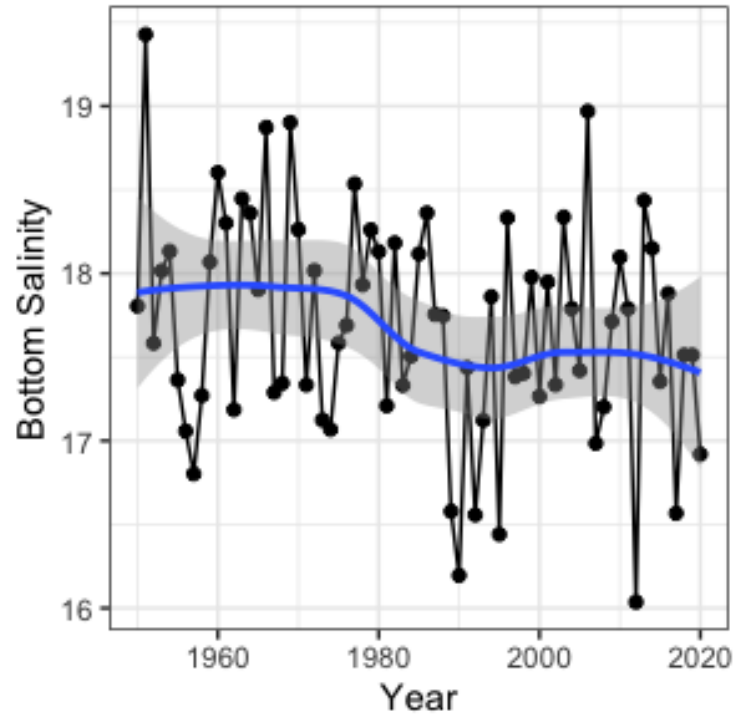


Long-term change in physics

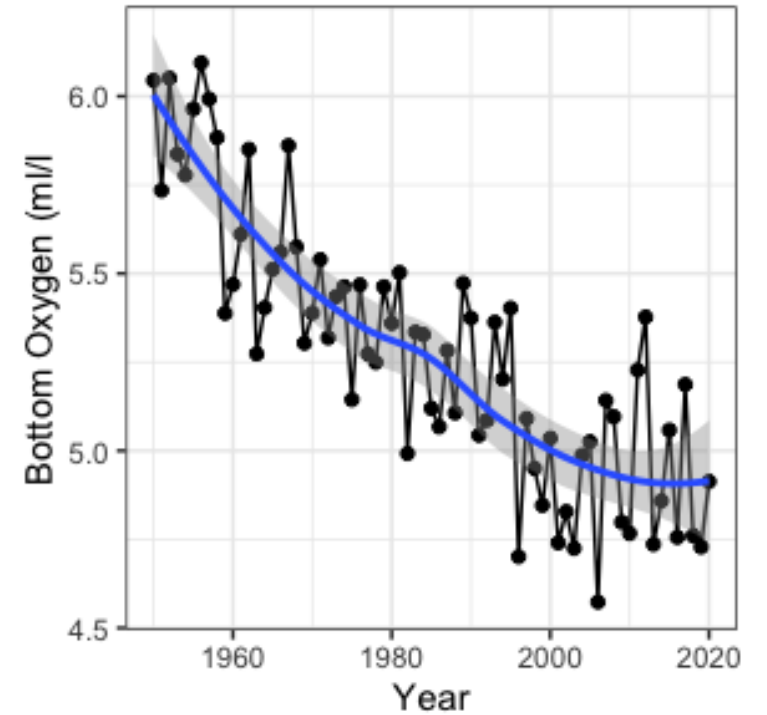


Mean **increase** in SST: 1.3 C°

Mean **increase** in bottom Temp.: 0.89 C°



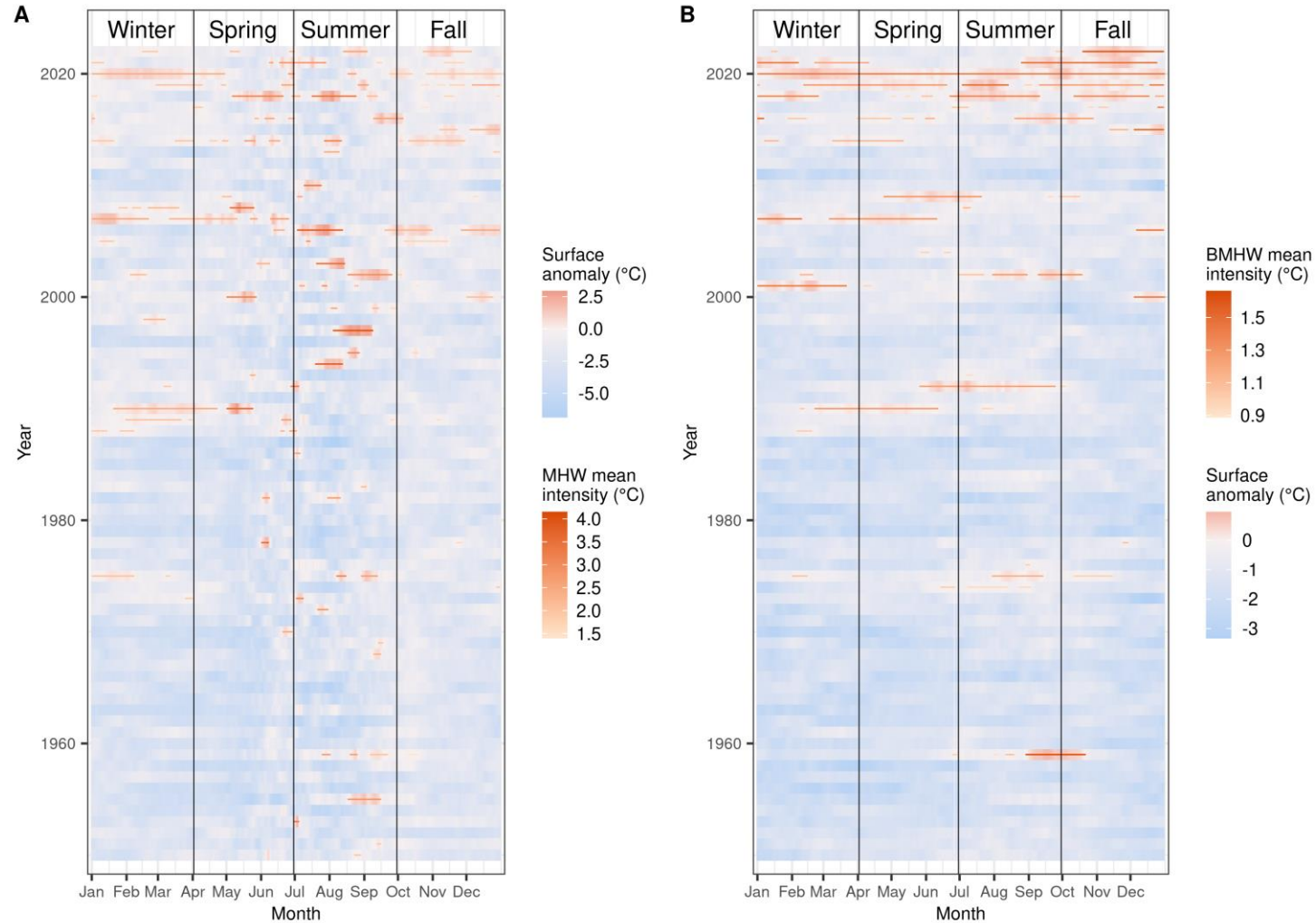
Mean **decrease** in bottom O₂ (ml/L⁻¹): 0.90



Marine heatwaves

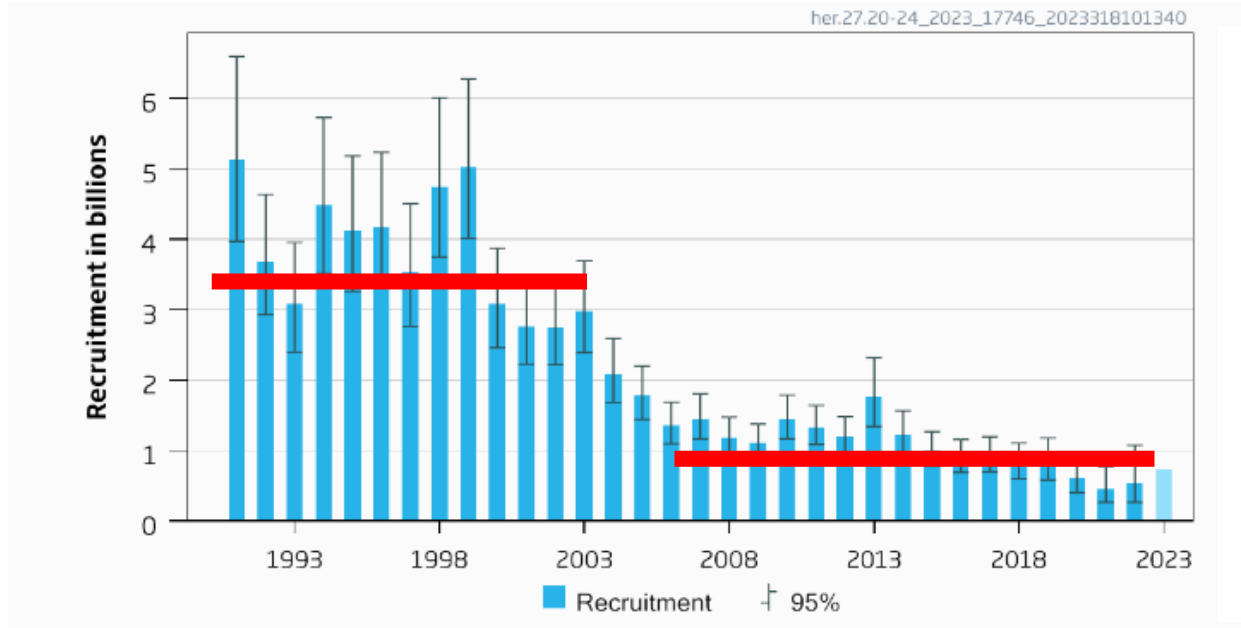
Oberfläche

Boden

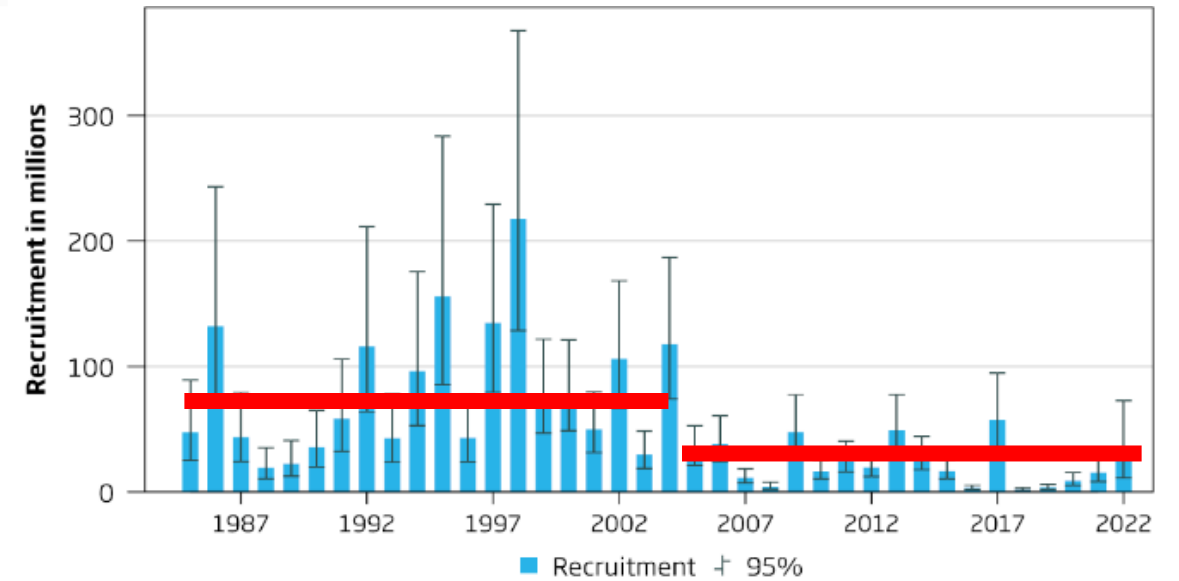


Climate impact on stocks: recruitment

Herring



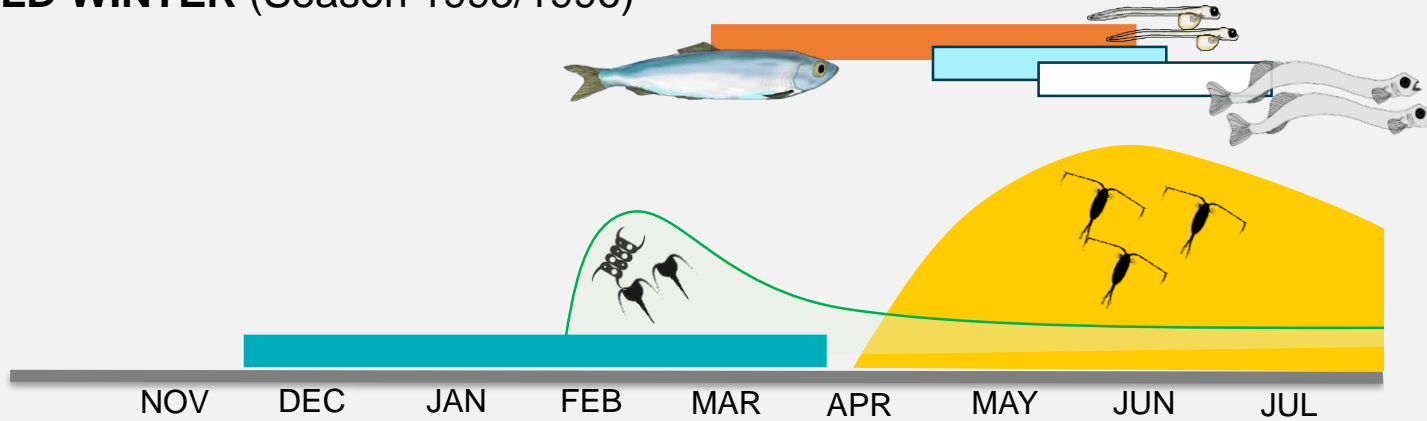
Cod



- Both stocks showed reduced recruitment in recent years

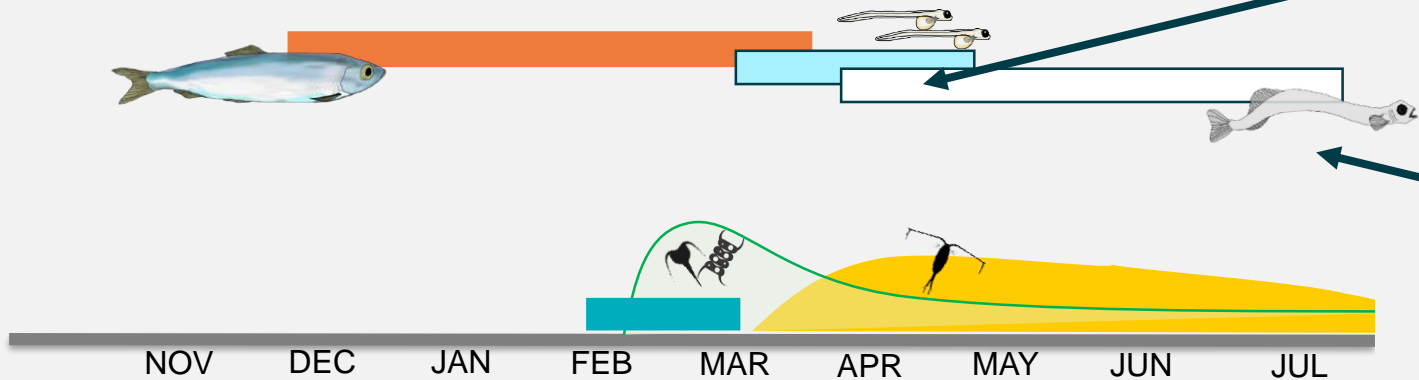
Herring: mismatch between larvae & prey

COLD WINTER (Season 1995/1996)



Bloom dynamics still under study but **substantial decrease in zooplankton biomass since 2013**

WARM WINTER (Season 2019/2020)

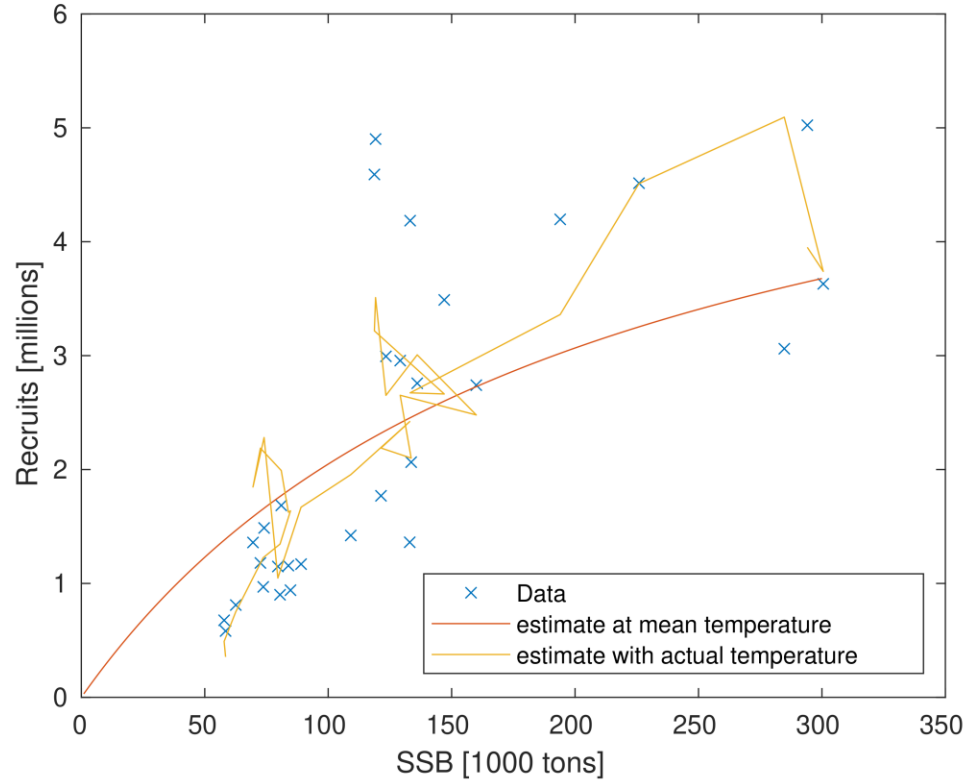


Early larvae may experience **mismatch** with food

Is it too warm for **late larvae**?

■ TEMPERATURES BELOW 4.5°C
 ■ SPAWNERS
 ■ YOLK-SAC LARVAE
 FEEDING LARVAE
■ PHYTOPLANKTON BLOOM
 ■ ZOOPLANKTON BLOOM

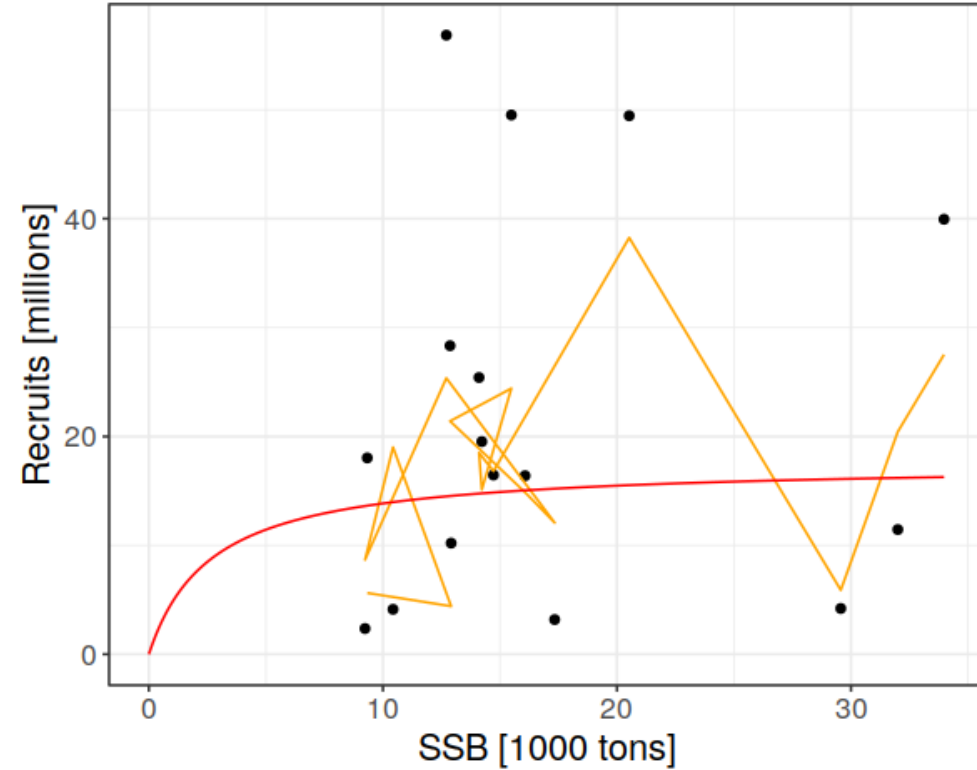
Temperature-dependent Stock-Recruitment



Nonlinear regression model:

$$R \sim ((b1 + b3 * \text{temp_bottom_q4}) * \text{SSB}) / (1 + b2 * \text{SSB})$$

**Herring: bottom temperature,
4th quarter!**

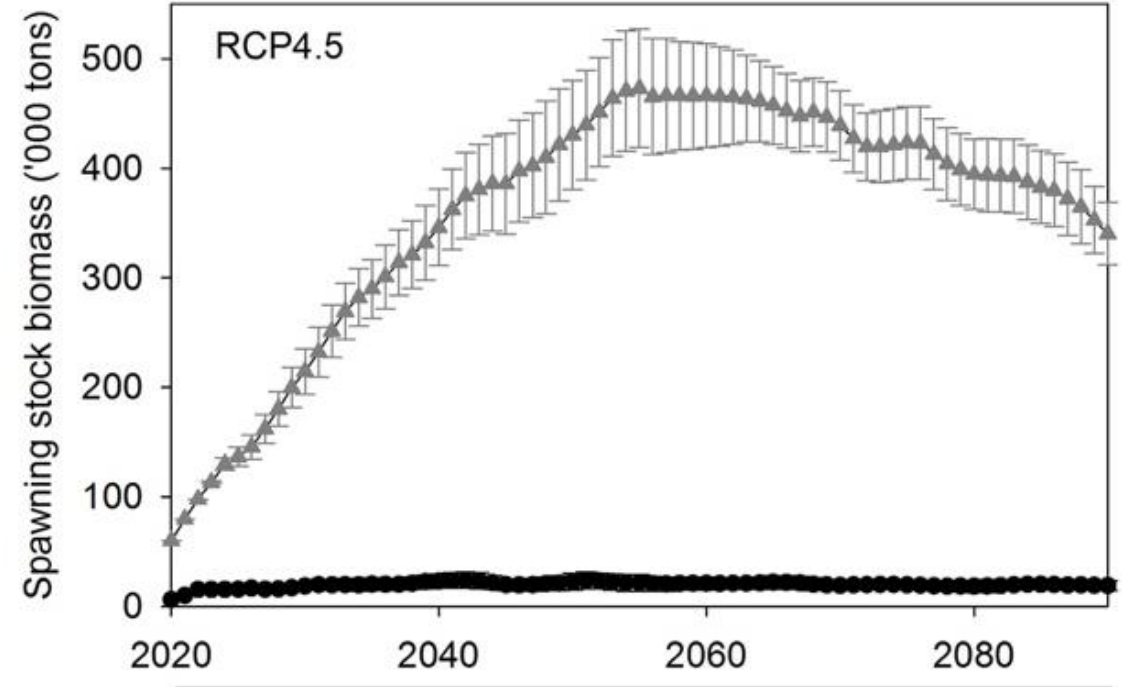
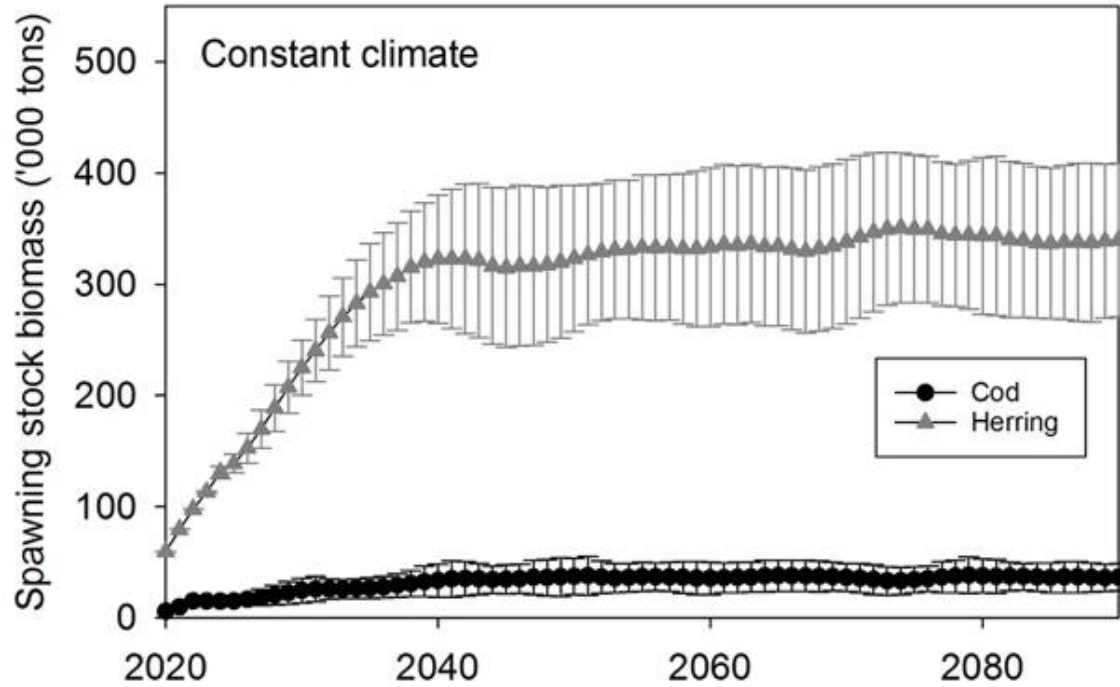


Nonlinear regression model

$$\text{model: } \log(R1) \sim (cc * q3_SST) + \log(ac * \text{SSB}) - \log(1 + bc * \text{SSB})$$

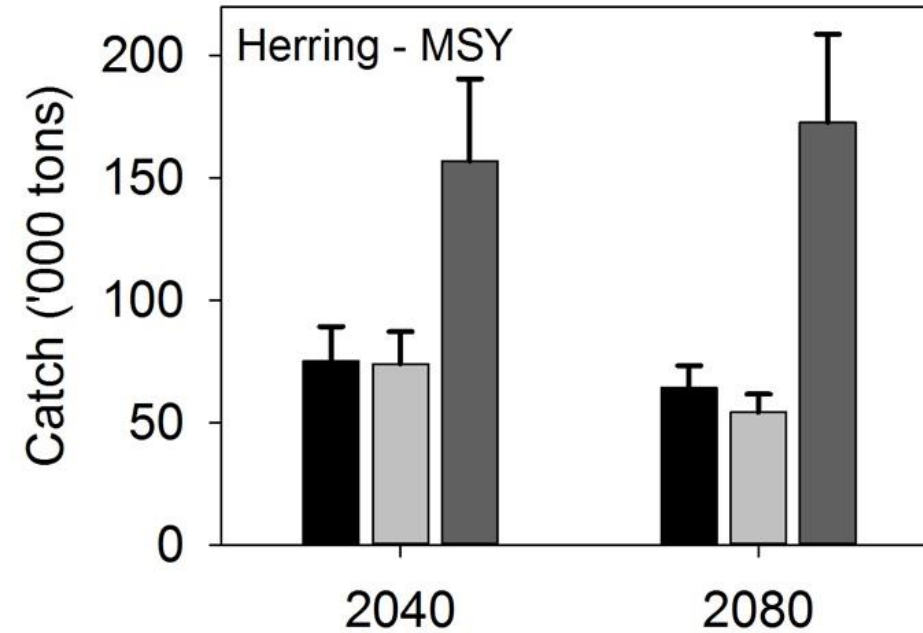
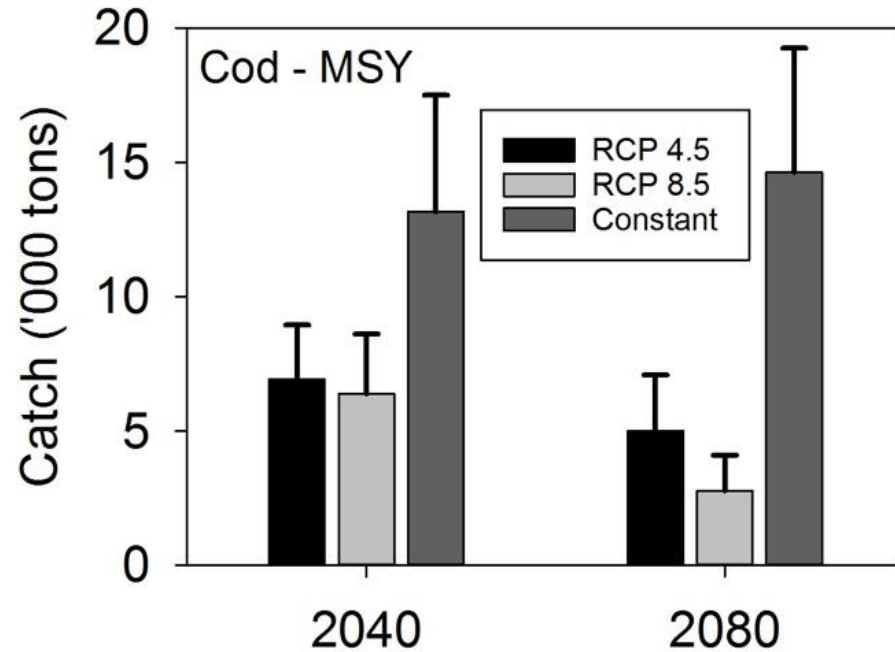
**Cod: Sea surface temperature,
3rd quarter!**

Climate scenarios: Optimal stock size



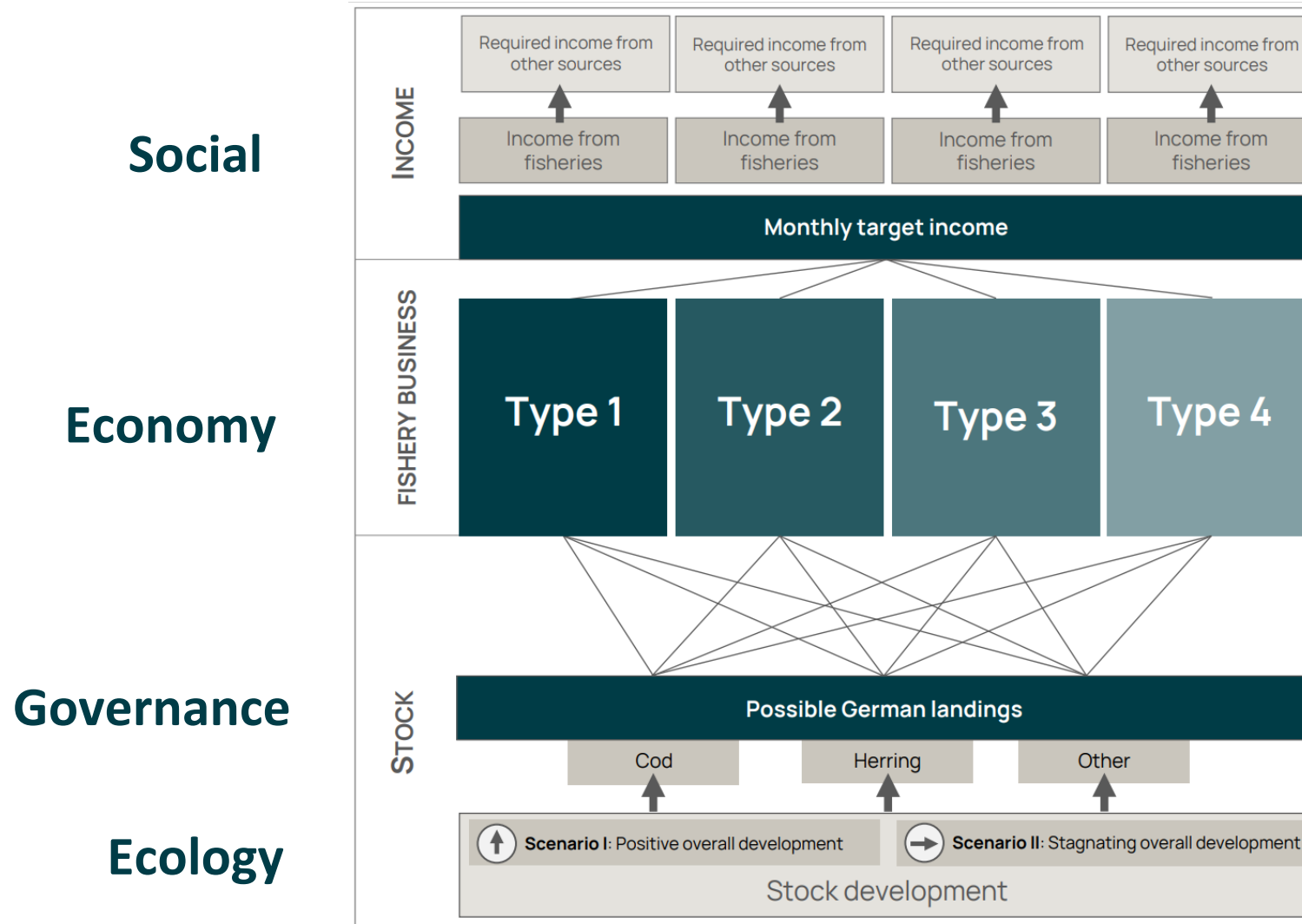
- Under no climate change, cod will slightly recover – but not to former levels
- Herring recovers; under RCP4.5 rebuilding to higher stock size is optimal
- Negative temperature impact from mid-century onwards

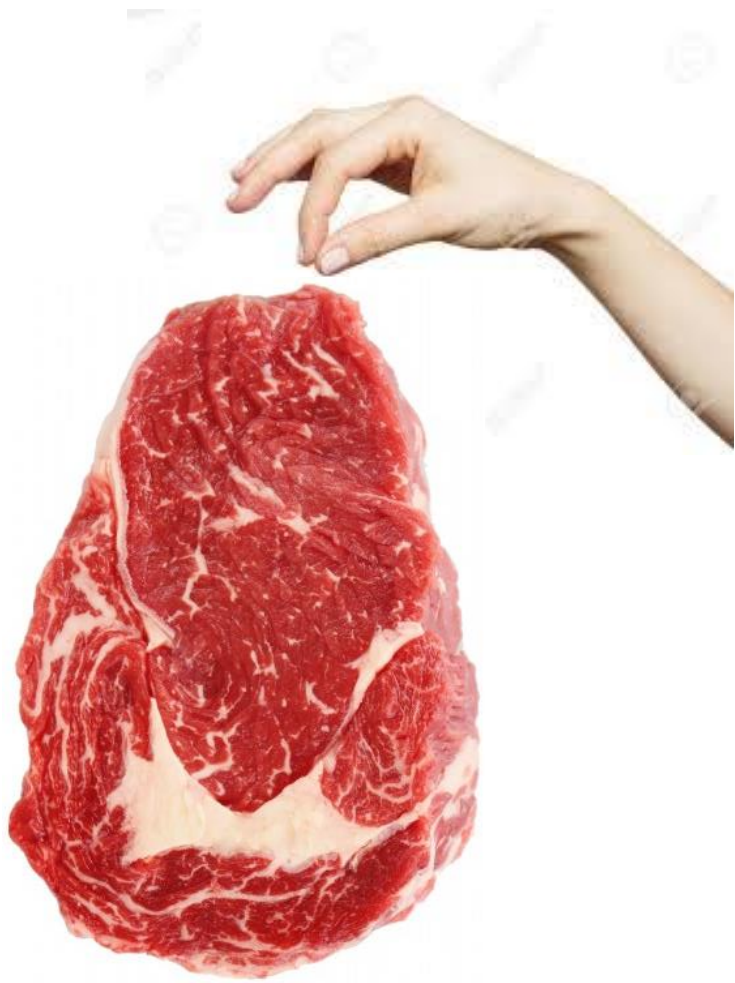
Future catch potential



- Strong climate impact
- Future catch potential for cod is low
- RCPs differ significantly from mid-century onwards

How many fishers the resources may support?





Finally: Fun stuff



1 DAS JAHR 2040

KIEK MOL, MIN DEERN! DAS IST DER PLATZ, AN DEN MEINE ALTE „GERTKUD“ GELEGEN HAT. EIN GUTER KÜTTER WAR DAS NA JA, ALSO FRÜHER SAH DAS HIER BESSER AUS. DIE FISCHEREI HAT SICH SEIT DAMALS JA SO GUT WIE ERLEDIGT...

WAS IST DENN PASSIERT? WIE KONNTE ES ZU DEM HIER KOMMEN, OPA?

2 DAS JAHR 2040

KIEK MOL, MIN DEERN! HIER LAG DAMALS MEIN ALTER KÜTTER, ALS EINER VON VIELEM. ABER VIEL MEHR GAB'S AUCH NICHT... ERREICHLICHERWEISE HAT SICH EINIGES GETAN.

WAS MEINST DU DAMIT? WAR ES DENN DAMALS NICHT GUT, OPA?

UNSERE MEERE AM KIPPPUNKT

VERÄNDERUNGEN IN EINEM ÖKOSYSTEM KÖNNEN SO GENANNT KIPP-PUNKTE AUSLÖSEN. DIESE PUNKTE MARKIEREN DIE GRENZE DER ELASTIZITÄT EINES ÖKOSYSTEMS. IN DER FOLGE „KIPPT“ DAS SYSTEM IN EINEN NEUEN, ÖFTMALS WENIGER PRODUKTIVEN ZUSTAND. AUSLÖSER VON KIPP-PUNKTEN: IN DER OSTSEE SPIELEN VOR ALLEM

- ÜBERSCHÜSSUNG
- VERSCHMÜTZUNG
- EINGEWANDERTE ARTEN
- UND DIE KLIMAERWÄRMUNG EINE GROSSE ROLLE.

KIPP-PUNKTE KÖNNEN DRASTISCHE VERÄNDERUNGEN VERURSACHEN, DIE DIE WEITERE ENTWICKLUNG DES SYSTEMS NEGATIV, ABER AUCH POSITIV BEEINFLUSSEN KÖNNEN. SIE KÖNNEN FÜR DEN POTENZIELLEN WANDEL STEHEN, ABER AUCH FÜR DIE KRAFT DES INTELLIGENTEN HANDELNS. LASSEN SIE UNS INTELLIGENT HANDELN, GEMEINSAM, FÜR EINE NACHHALTIGE, GESUNDE OSTSEE!

UND... WAS HABT IHR GETAN?

KALTENFAHRT STAFT BUTTENFAHRT

ES WAR SCHWER. ES GAB VIEL MISSTRAUEN UNTER DEN LEUTEN UND VIELEN WAR DAS EIGENE INTERESSE AM WICHTIGSTEN SO SIND WIR DANN HIER GELANDET. UNSERE WIPPE KIPPT UNABHÄLTIG UND ENDSCHLIEßLICH AUF DIE SEITE... AUF DER WIR... SIE EIGENTLICH NICHT HABEN WOLLTEN.

DAS HEIßT ES WAR ALLEN KLAR, WAS PASSIEREN WÜRDEN UND ALLE WOLLTEN DAS VERHINDERN! ABER, DIE LEUTE KONNTEN SICH EINWAS NICHT EINIGEN? WIE TRÄURIG!

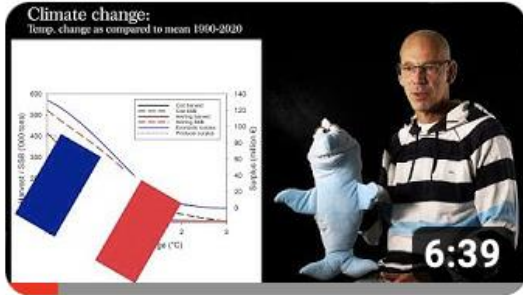
SEUFZ! JA.

DU HAST RECHT. MEERE WERDEN NICHT VON EINER PERSON ODER EINER GRUPPE GERETTET. ALLE MUßEN ETWAS BEITRAGEN. DAZU GEHÖREN AUCH KOMPROMISSE. ZUM GLÜCK HANDELN ALLE VERANTWORTUNGSBEWUSST UND IN VIELEN GESPRÄCHEN GELANG ES ALLE INTERESSEN ZU HÖREN UND ZU VERMITTELN. WIR HATTEN WIRKLICH GLÜCK!

ICH BIN FROH, OPA! HÄTTET IHR DAMALS NICHT DIE RICHTIGE RICHTUNG EINGESCHLAGEN, WÜRDEN WIR HEUTE NICHT SO EINE SCHÖNE ZEIT HABEN?

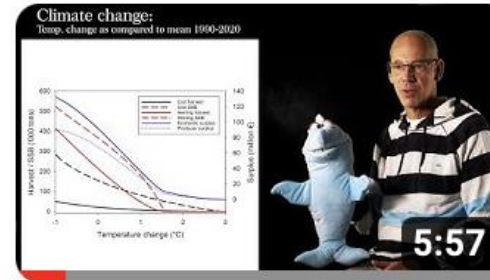
DA HAST DU SCHON WIEDER RECHT!

Finally: Fun stuff



Baltique occidentale, gestion des pêches, changement...

Ocean and Society
125 Aufrufe • vor 1 Jahr



Western Baltic, fisheries management, climate change,...

Ocean and Society
222 Aufrufe • vor 1 Jahr



Playmobil goes Science: Fishing past a tipping point



Brave New Baltic - Optimal multispecies fisheries...

Thanks a lot!!

How many fishers the resources may support?

Szenarienrechner für die deutsche Küstenfischerei

Willkommen Rechner Typen - Hintergrundinfo

Bestands-Entwicklungs-Szenarien:
 Hering: Stagnierende Gesamtentwicklung
 Dorsch: Positive Gesamtentwicklung

Hering: Gesamtfang 6000 Tonnen
 Dorsch: Gesamtfang 6000 Tonnen

Mögliche (deutsche) Anlandemenge (in Tonnen/Jahr):
 Hering: 3312, Dorsch: 1276.2, Andere Arten: 2000

Mögliche Anlandemenge andere Arten (Gesamtbiomasse) z.B. Scholle (in Tonnen/Jahr):
 2.000

Fischerei A Fischerei B Fischerei C Fischerei D

Quote Hering (in %): 63, 20, 12, 5

Quote Dorsch (in %): 48.5, 25, 10, 6.5

