Pêches et Océans Canada   Fisheries and Oceans Canada

Effect of hypoxia on cod bioenergetics

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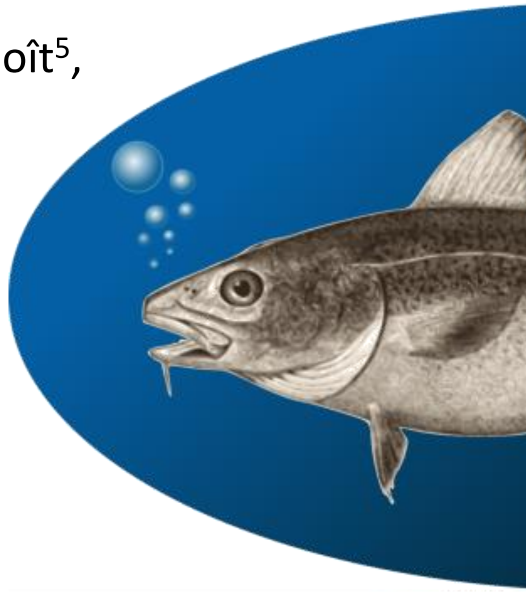
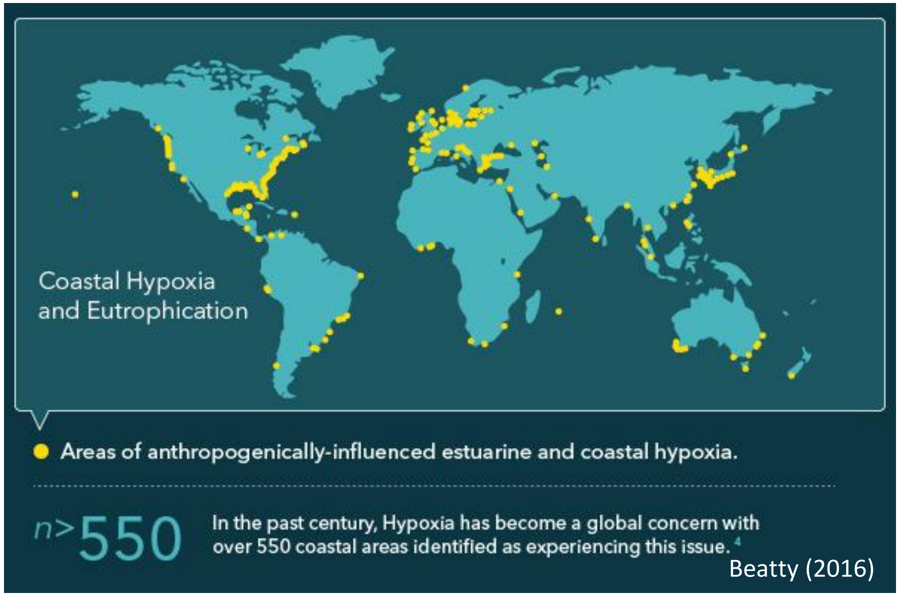


DEB2019 1-12 April 2019 / Brest (France)

Introduction

Hypoxia in coastal marine systems is a growing phenomenon around the world, accelerated as a result of human activities. It is defined as a reduction of dissolved oxygen saturation levels (% DO sat.).



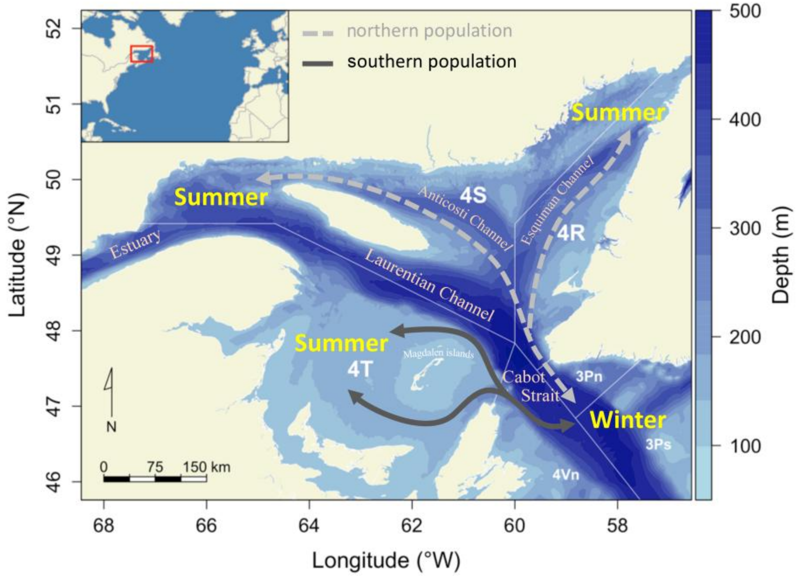
Effects of hypoxia at the physiological level include:

- Disturbance of the phenology (e.g. spawning time)
- Reduced growth
- Limitation of reproductive success
- Increased vulnerability to diseases

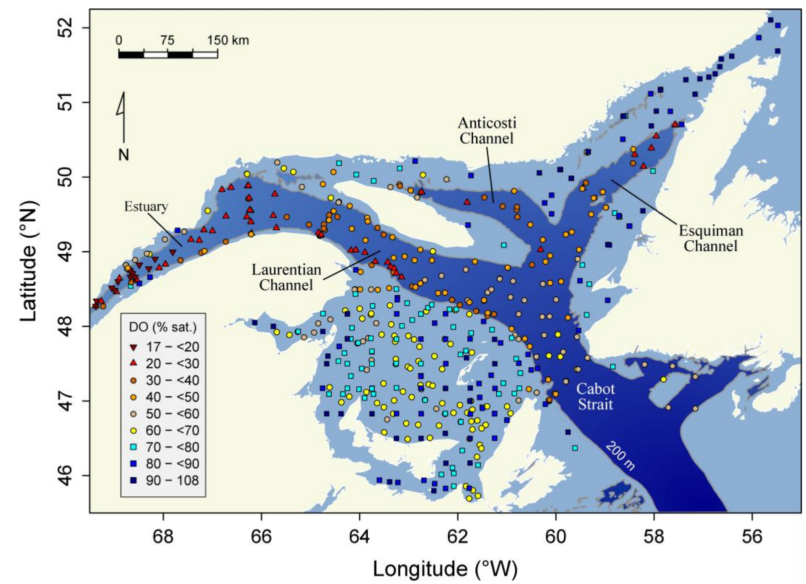
→ Mortality outbreaks

Introduction

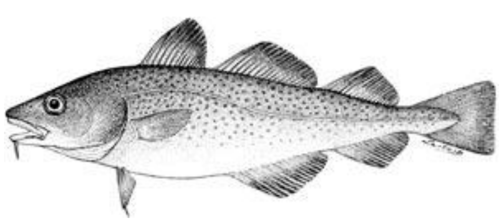
The **Atlantic cod** is an iconic species facing important challenges from its changing **environment**, **human activities** and, in some populations, intense **predation**.



2 populations: north and south (different migration and residency patterns)

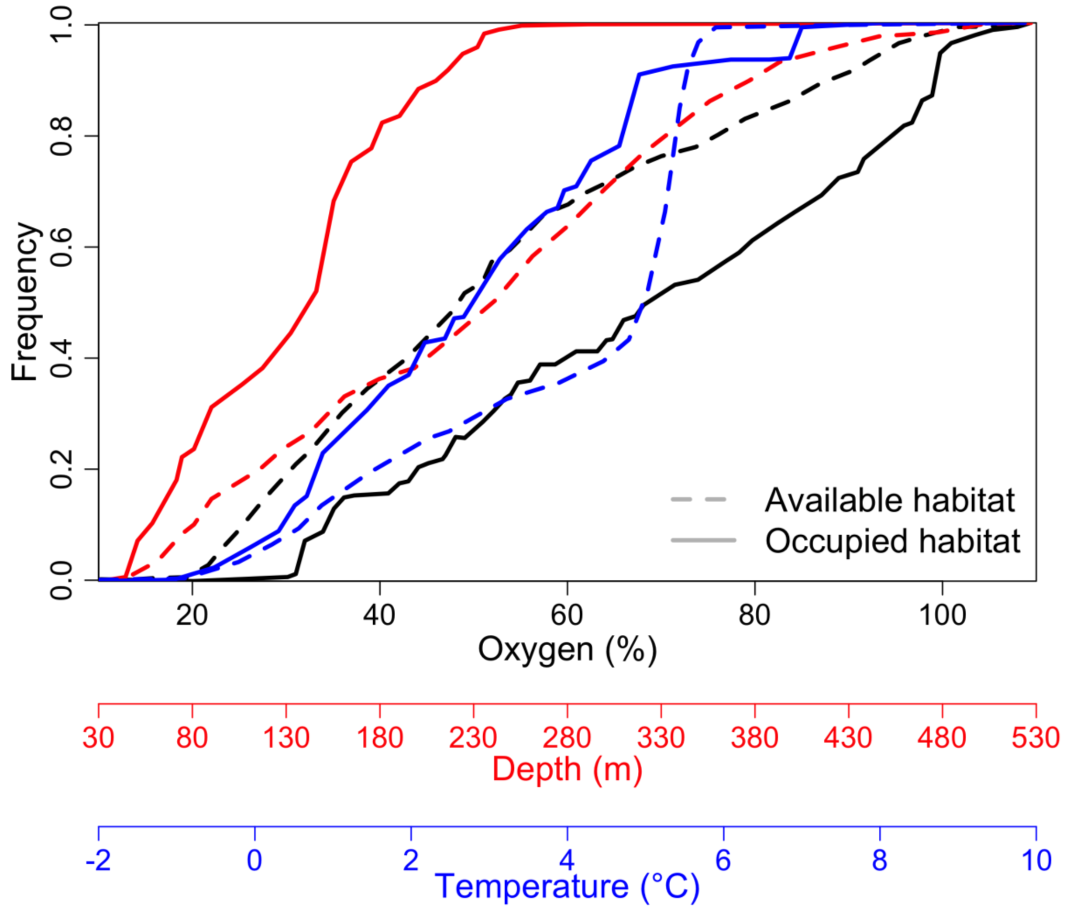


DO (% sat.) in the Gulf of Saint Lawrence



Introduction

Realized habitat of Atlantic cod in the northern Gulf of Saint Lawrence (nGSL).



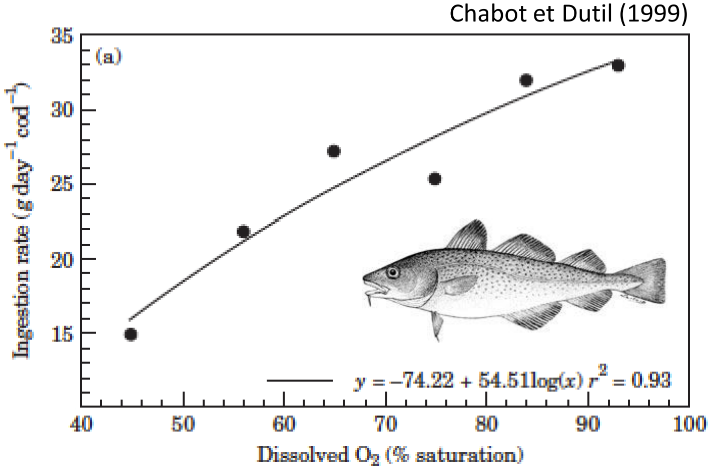
Modeling hypoxia

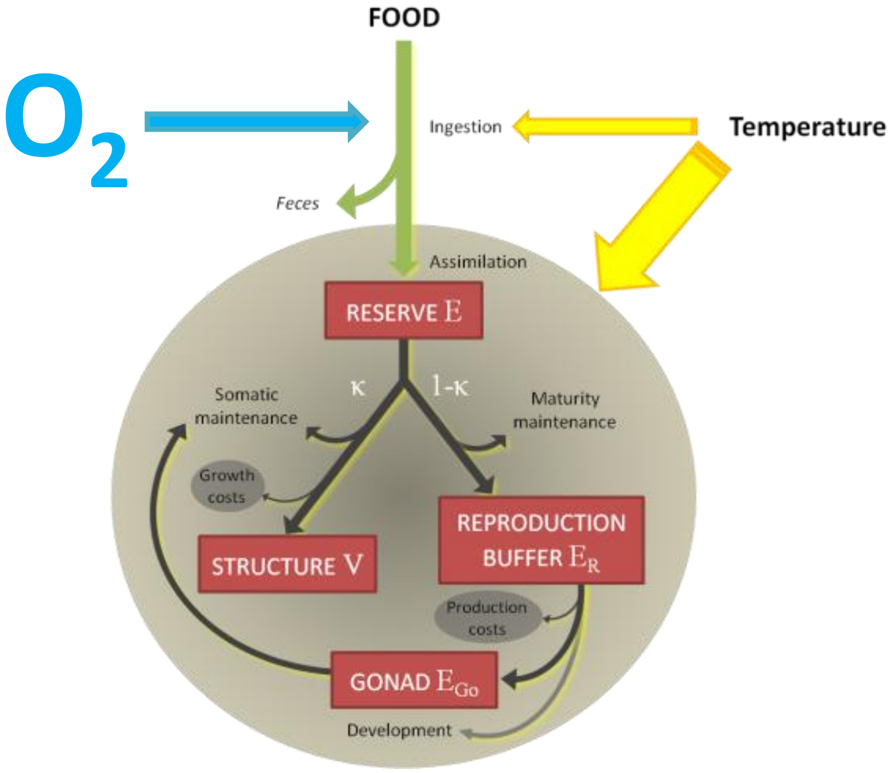
Dynamic Energy Budget theory:

- Mechanistic and generic approach
- Full life cycle
- Scale transfer (population)
- Multi-stressor perspective

Thomas et al. (2018) identified that the main effect of hypoxia on the metabolic response of cod was on **ingestion**.

Chabot et Dutil (1999)





Thomas et Dutil (2019)

DO correction factor of ingestion

$$c_{DO}(t) = \begin{cases} \alpha \dfrac{DO(t) - DO_{crit}}{DO(t) - DO_{crit} + \beta}, & \text{if } DO(t) > DO_{crit} \\ 0 & , \text{if } DO(t) \leq DO_{crit} \end{cases}$$

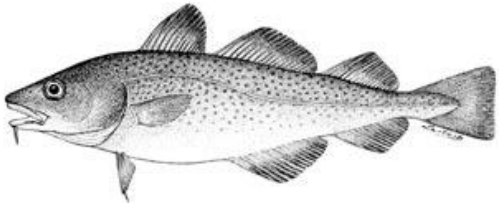
Objectives

Quantify the effect of hypoxia in two populations of Atlantic cod in the Gulf of Saint Lawrence

1) Disentangle the importance of **environmental variables**:
   - Temperature,
   - Food availability
   - DO saturation

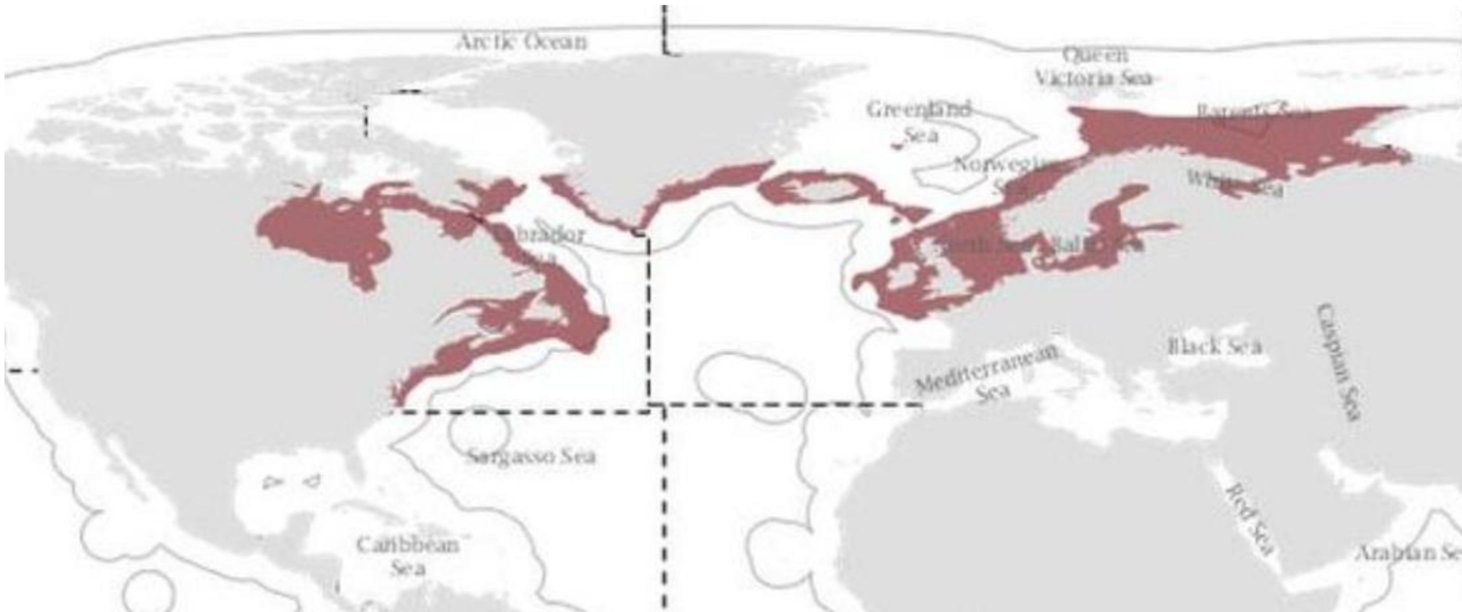
   on the energy buget of cod from each population

2) Investigate potential effects of hypoxia on **life history traits**



Methods

Many identified **stocks** with contrasted life-history traits (Brander, 2005)



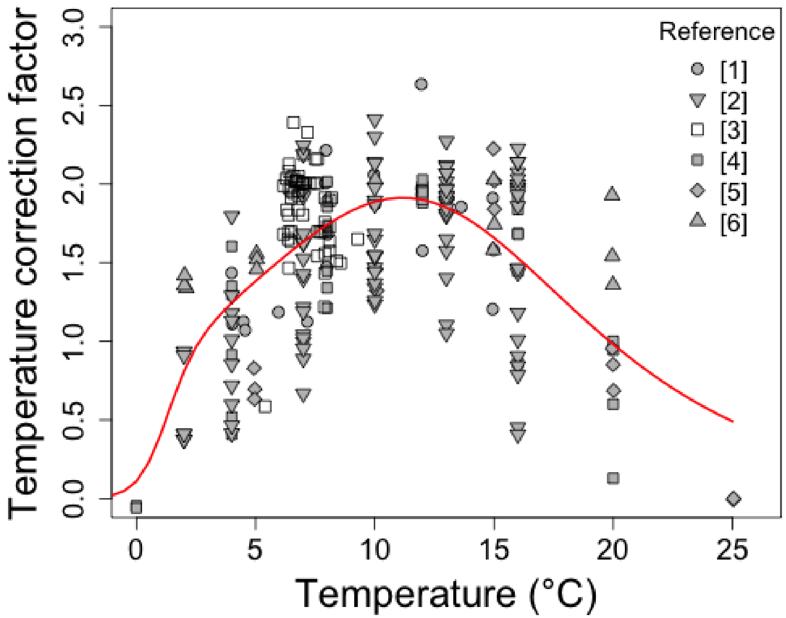
Arcto-Norwegian
Baltic
Celtic Sea
Greenland
Faroese Islands

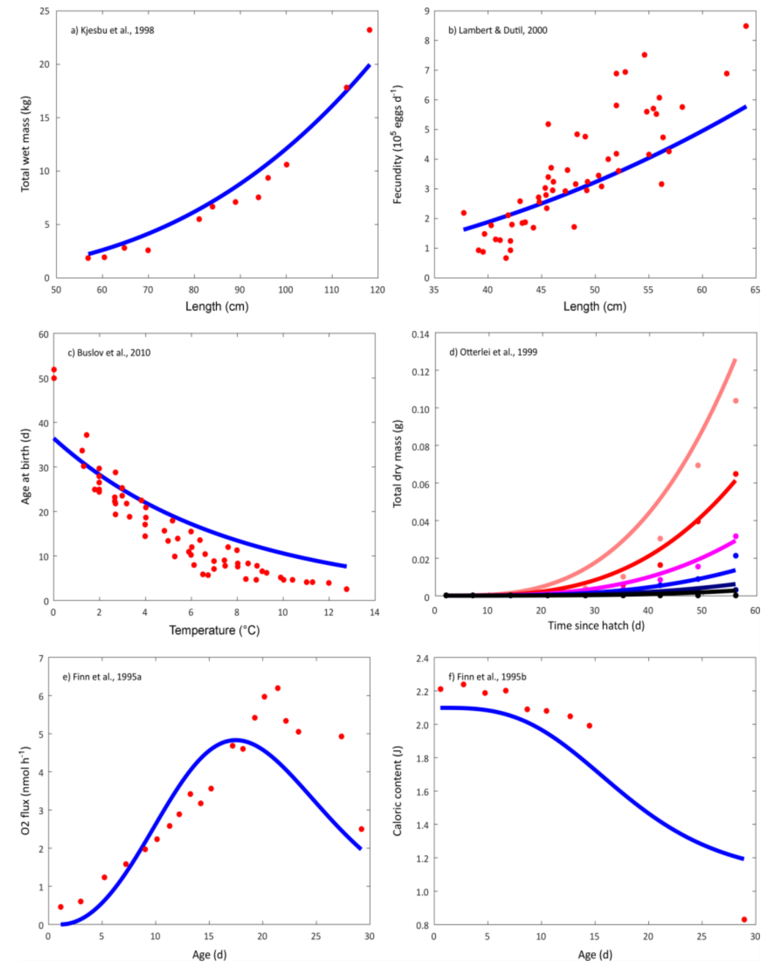
Iceland
Irish Sea
North Sea
Scotland
Scotian Shelf

Northern Gulf of Saint-Lawrence
Southern Gulf of Saint-Lawrence
Southern Grand Bank
Southern Newfoundland
Northern Newfoundland and Labrador
Gulf of Maine and Georges Bank

Methods

Re-estimation of parameters for our populations



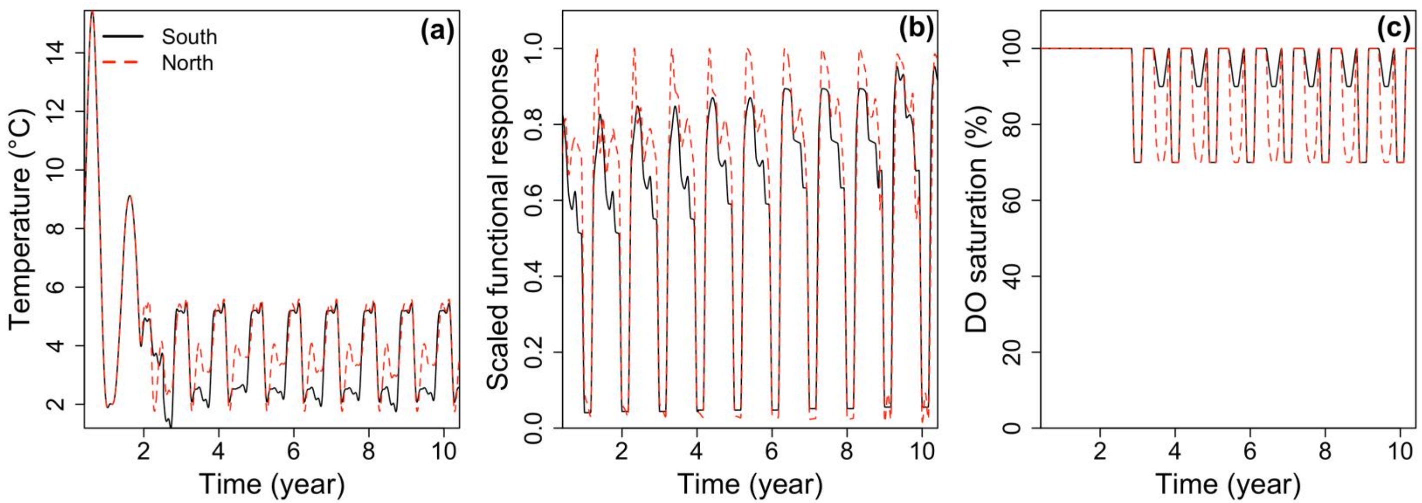


Data

Annual monitoring surveys conducted in the nGSL since **1990** and in the sGSL since **1971**, providing:

- Length
- Wet mass
- Stomach content
- Temperature

Additional data for sGSL cod from a physiological condition monitoring conducted annually since 1992 (typically monthly in April and June–October) and January surveys of cod overwintering grounds in 1994 and 1995.



Modeling scenarios

Scenario S1: Reference scenario without implementing DO effect

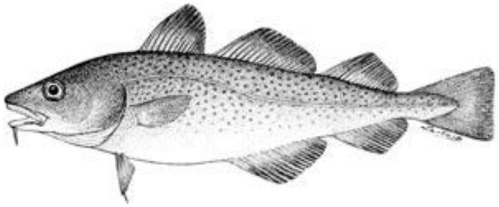
stomach content data already incorporate this effect

Scenario S2: Quantification of the temperature effect

imposing same temperature forcing to each population
keeping other variables untouched

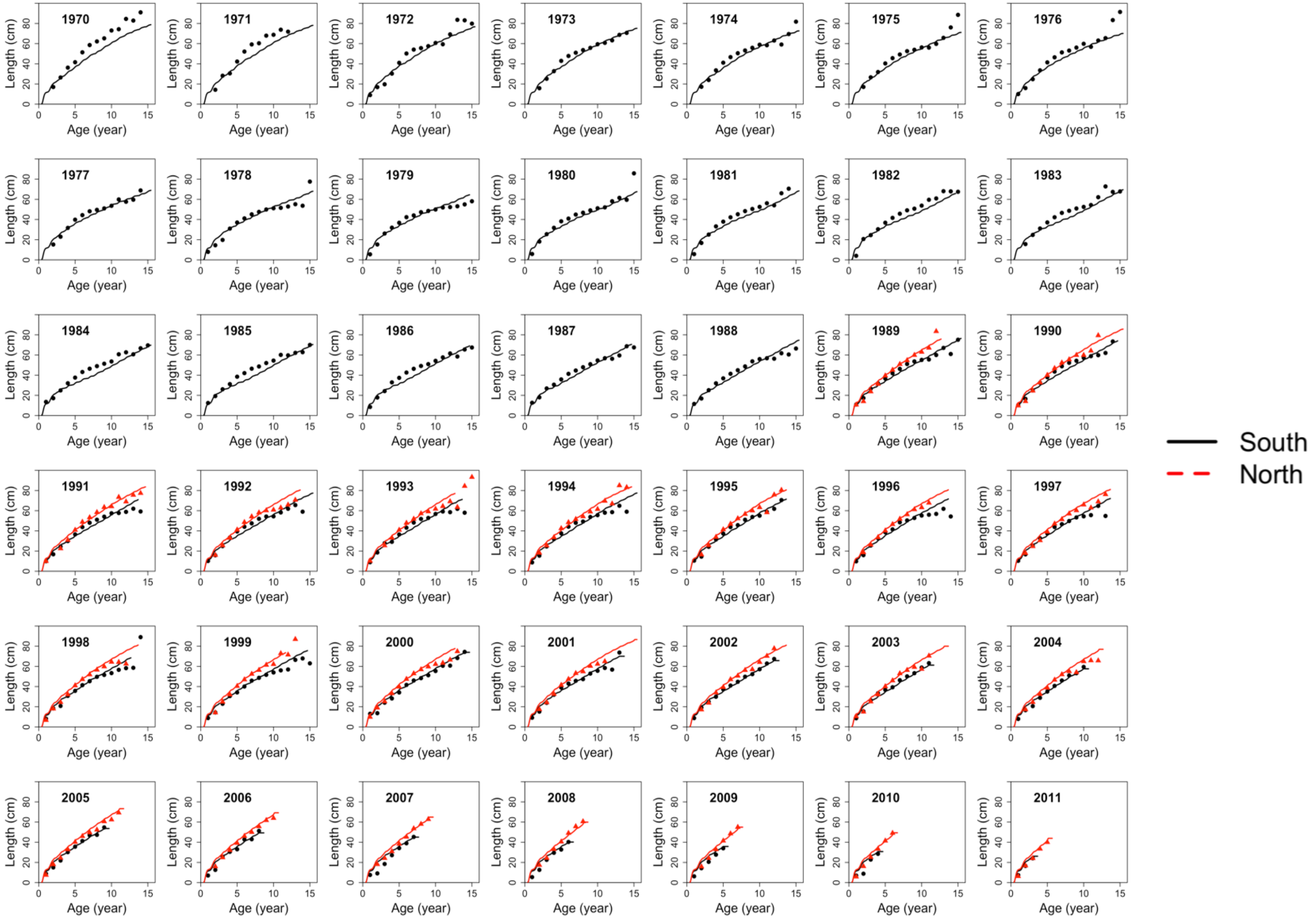
Scenario S3: quantification of the DO effect on growth

by removing the DO effect on ingestion, estimate the potential gain in growth
ingested food is corrected by $1/c_{DO}$

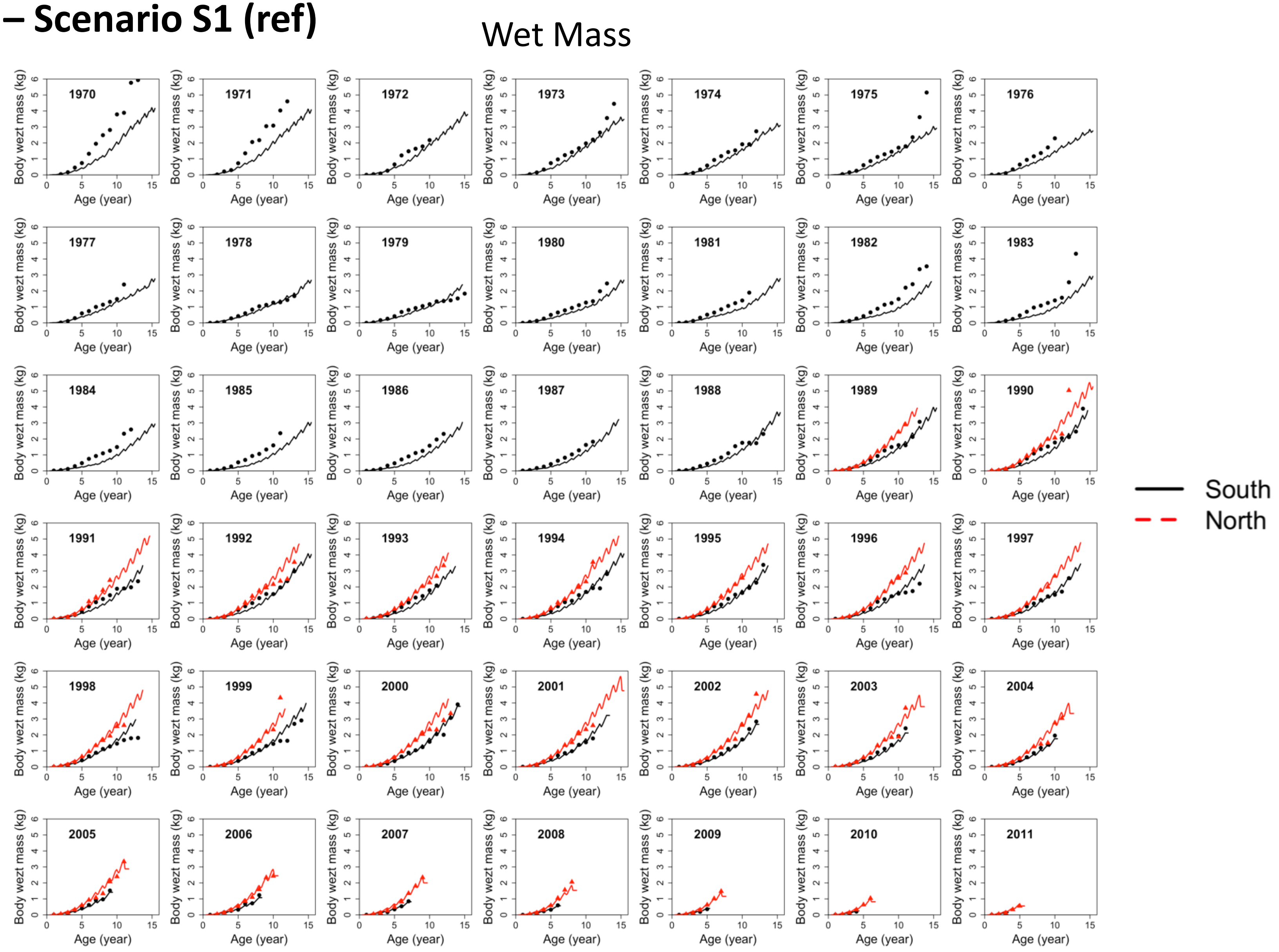


Results – Scenario S1 (ref)

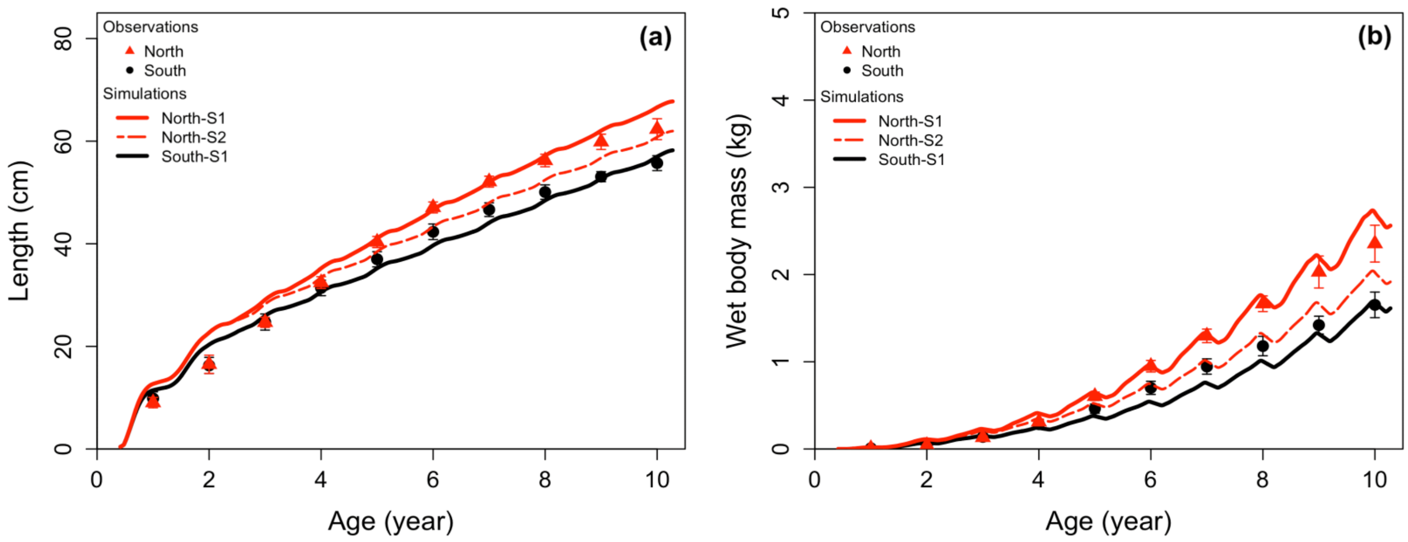
Length



Results – Scenario S1 (ref)



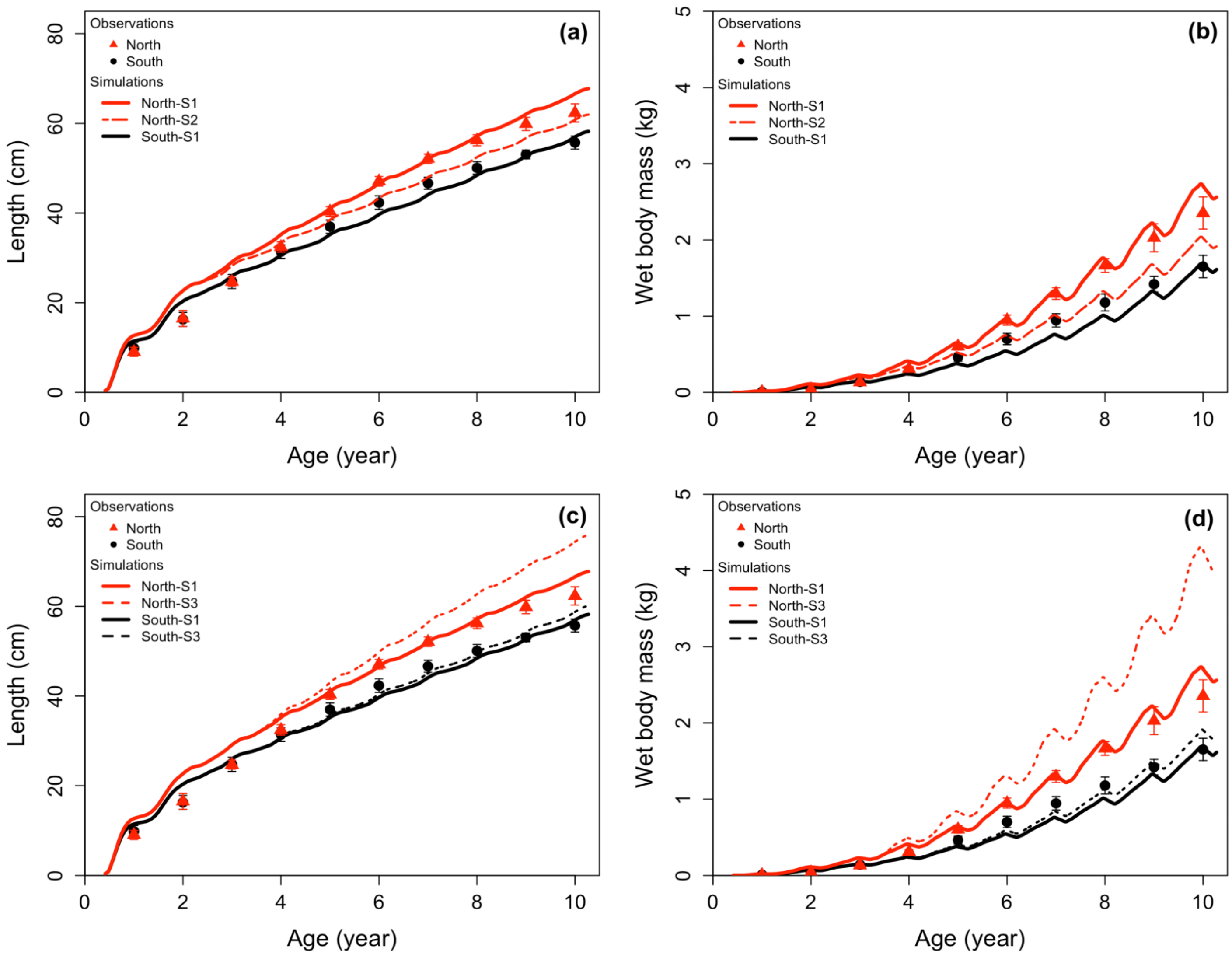
Results



Good predictions from the model in reference scenario (S1)

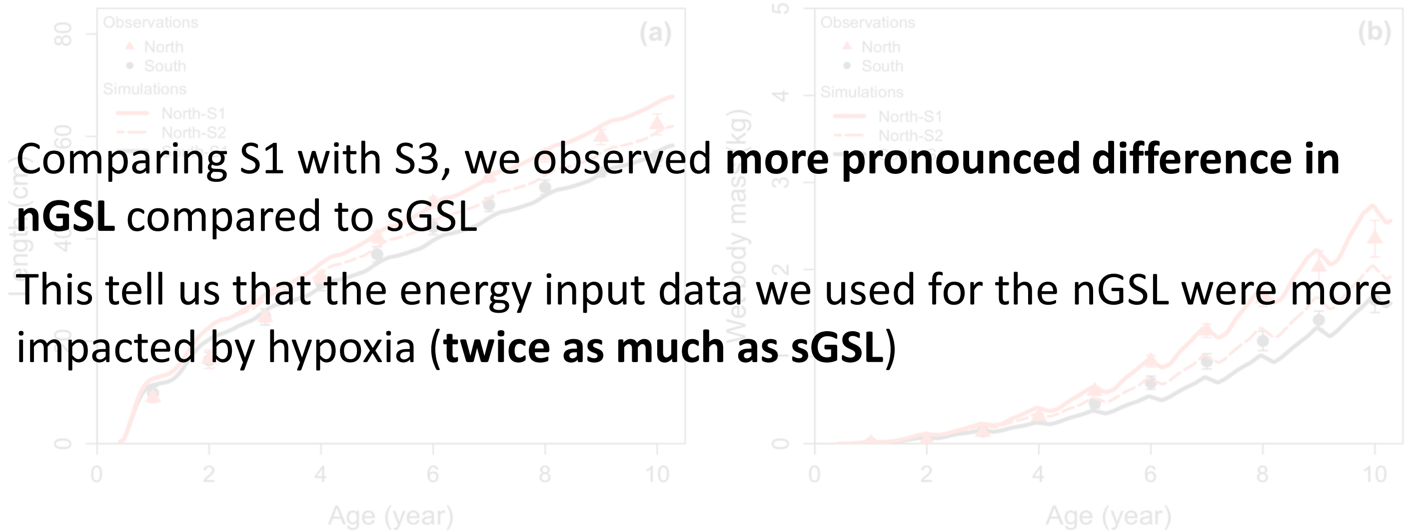
From comparing S1 with S2 scenario we found that temperature explained 48% of the difference in length between populations and 59 % of the difference in mass

Results



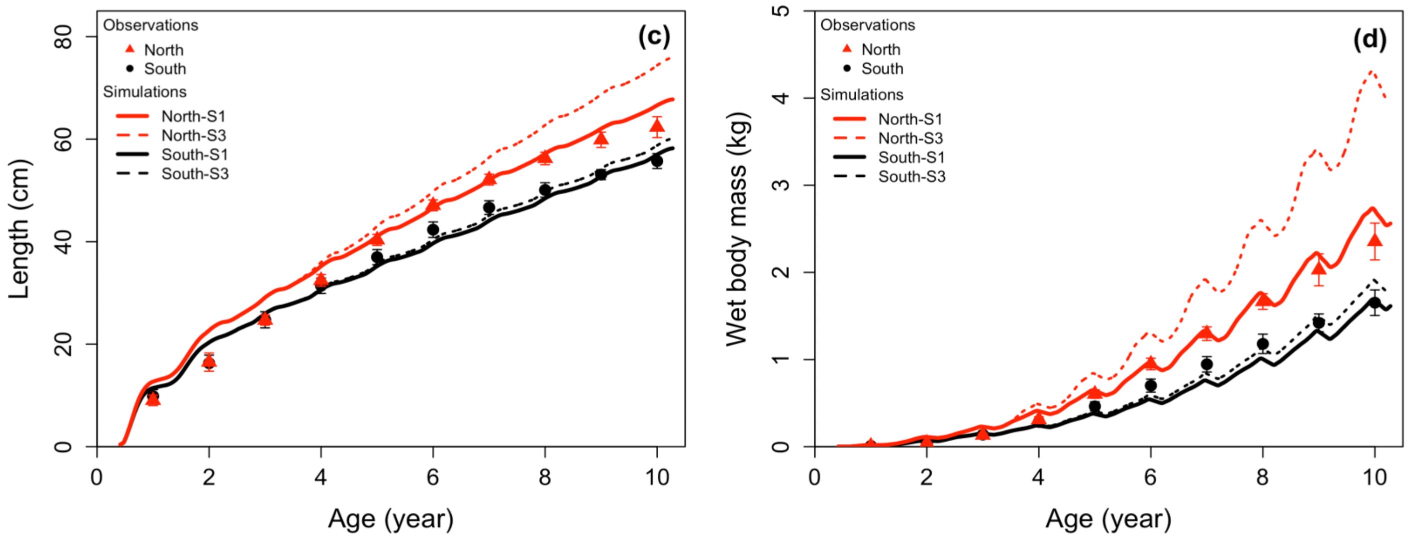
(a)
(b)
(c)
(d)
Observations
North
South
Simulations
North-S1
North-S2
North-S3
South-S1
South-S3
Length (cm)
Wet body mass (kg)
Age (year)

Results

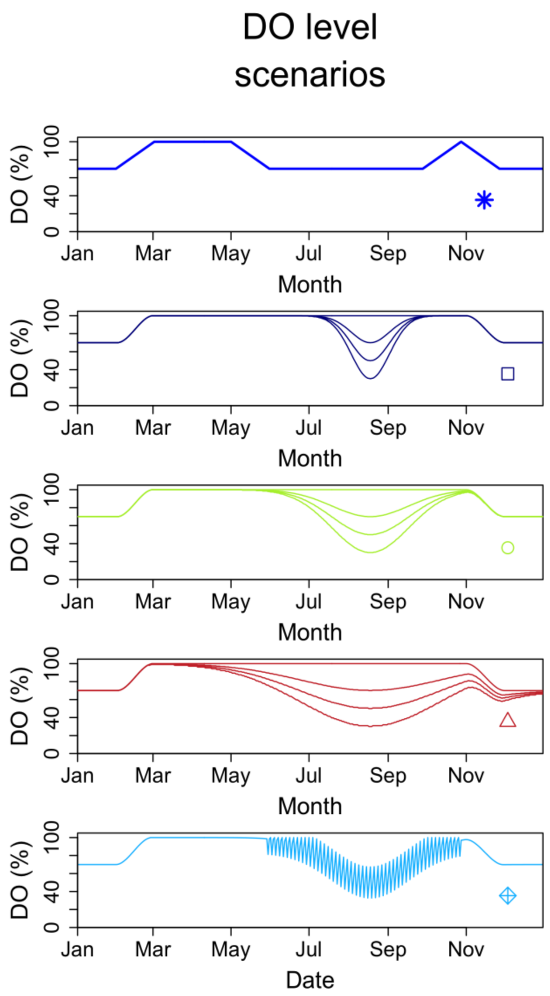


Comparing S1 with S3, we observed **more pronounced difference in nGSL** compared to sGSL

This tell us that the energy input data we used for the nGSL were more impacted by hypoxia (**twice as much as sGSL**)



Impact of hypoxic conditions on cod life-history traits



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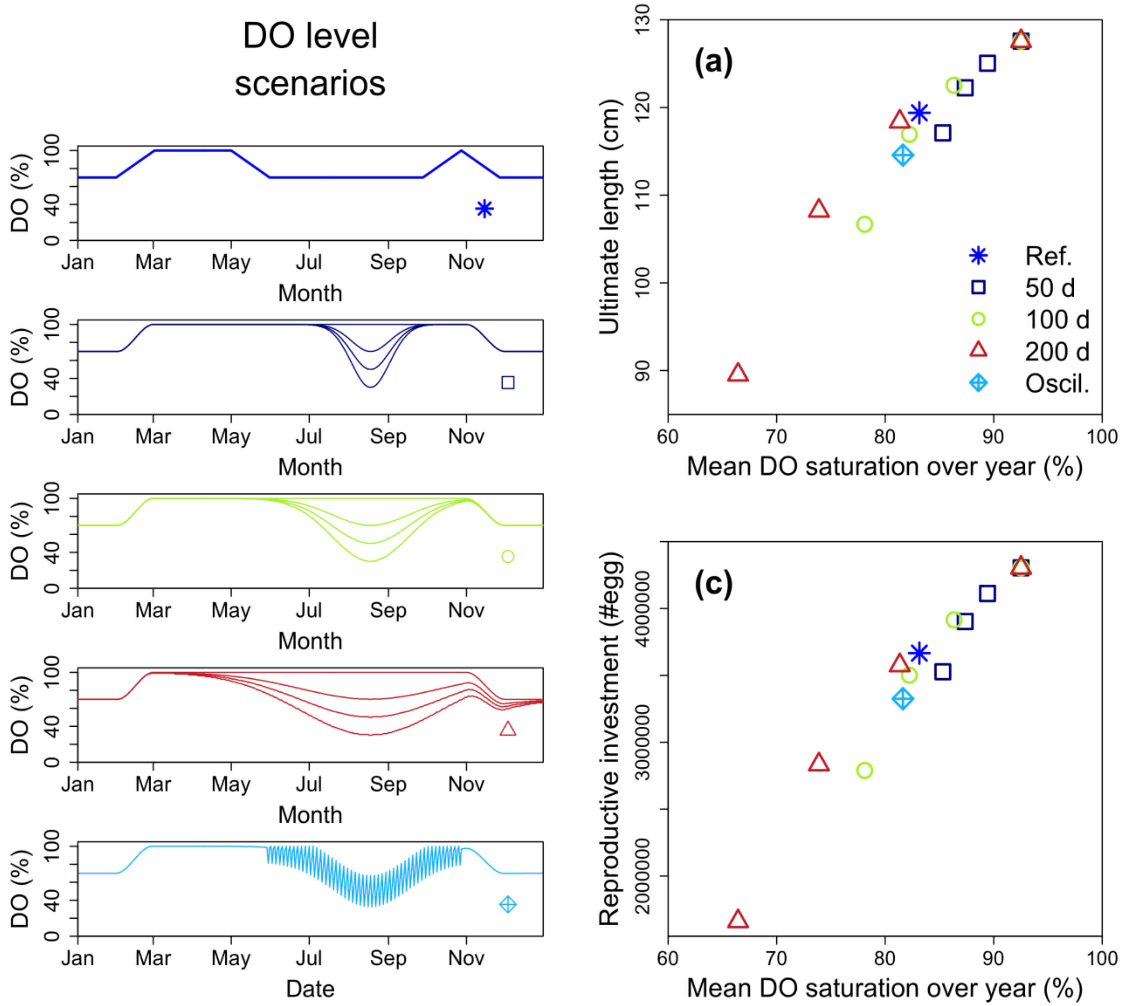

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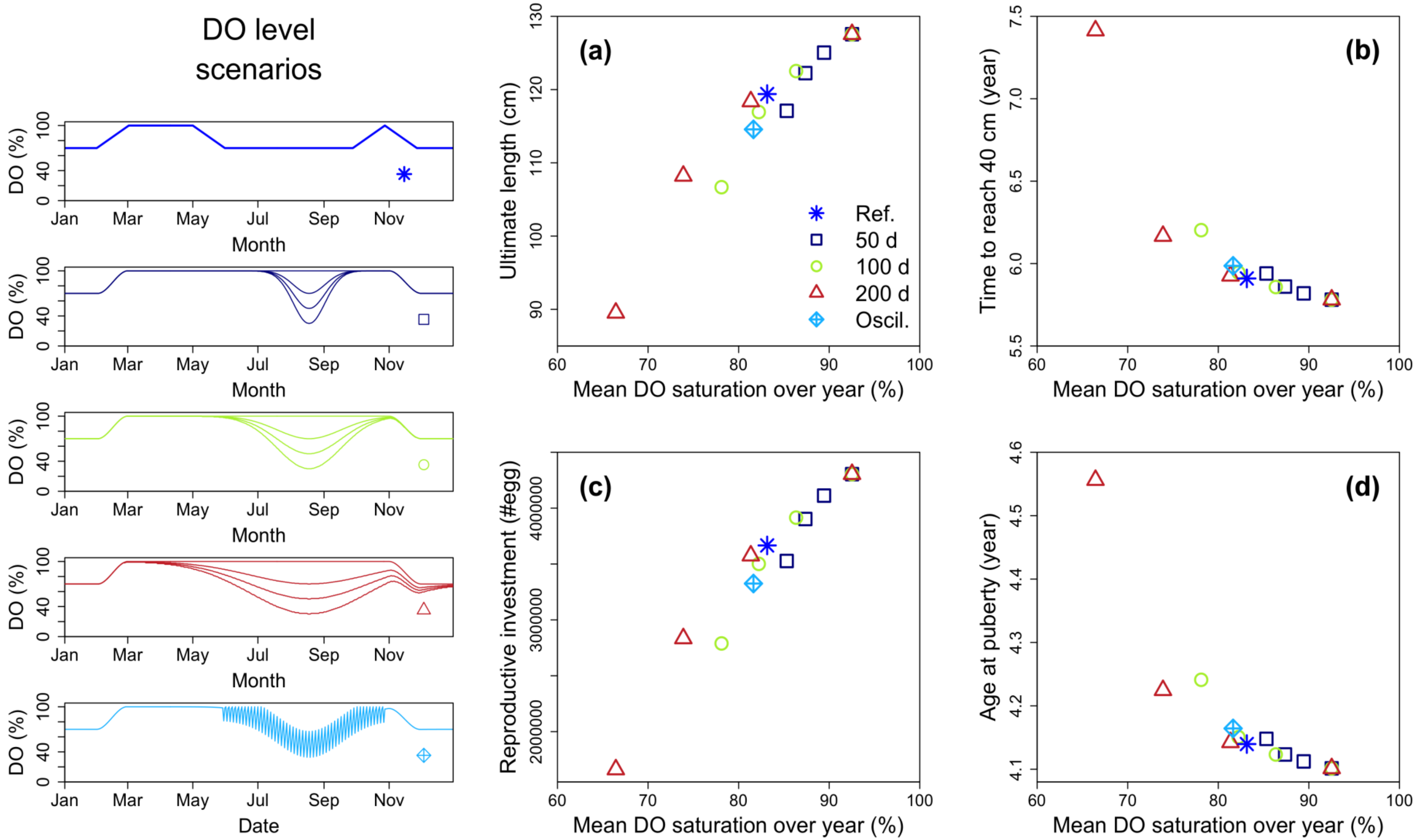

Conclusions

Contrasted effects of Temperature and hypoxia

in the nGSL population.

- Temperature seems to explain about half of the difference between populations
- More data needed to ascertain the effect of DO
- Other pressures should be considered (predation, evolution from fishing pressure)

Conclusions

Contrasted effects of Temperature and hypoxia in the nGSL population.

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Further investigations

Tracking of individuals equipped with loggers

- High-resolution of individual trajectories of experiences conditions
- Comparison of different behaviours (migratory vs. resident, coastal vs. deep dwellers)

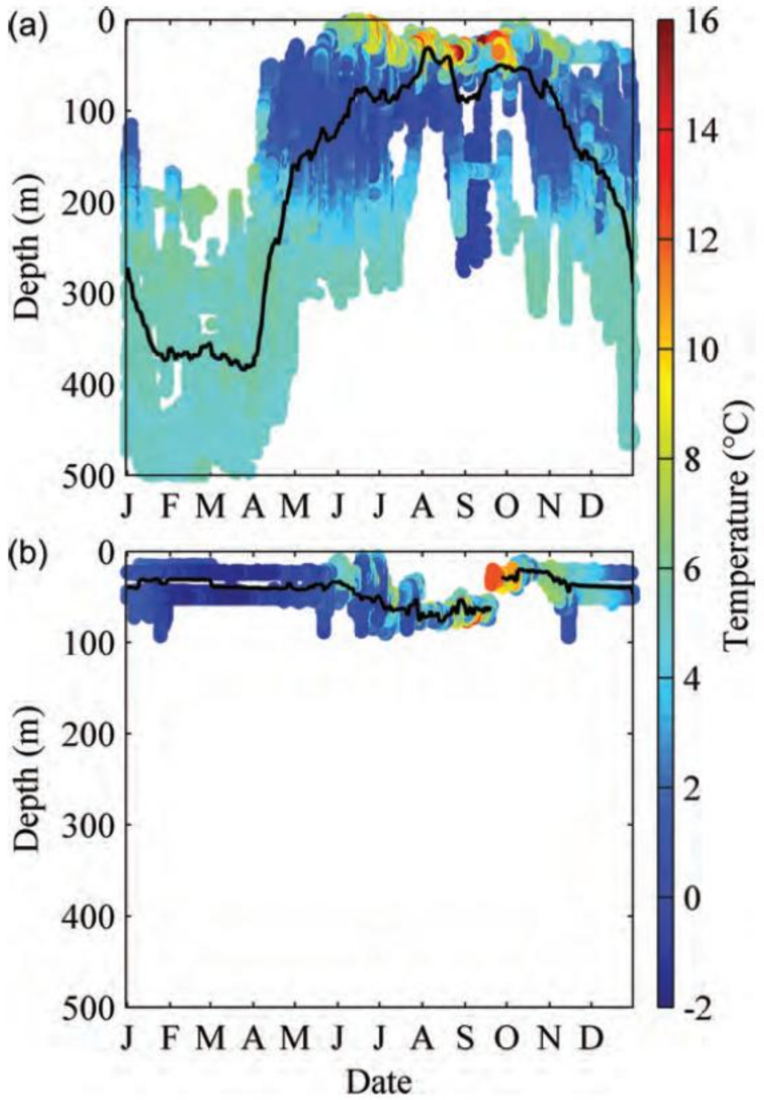
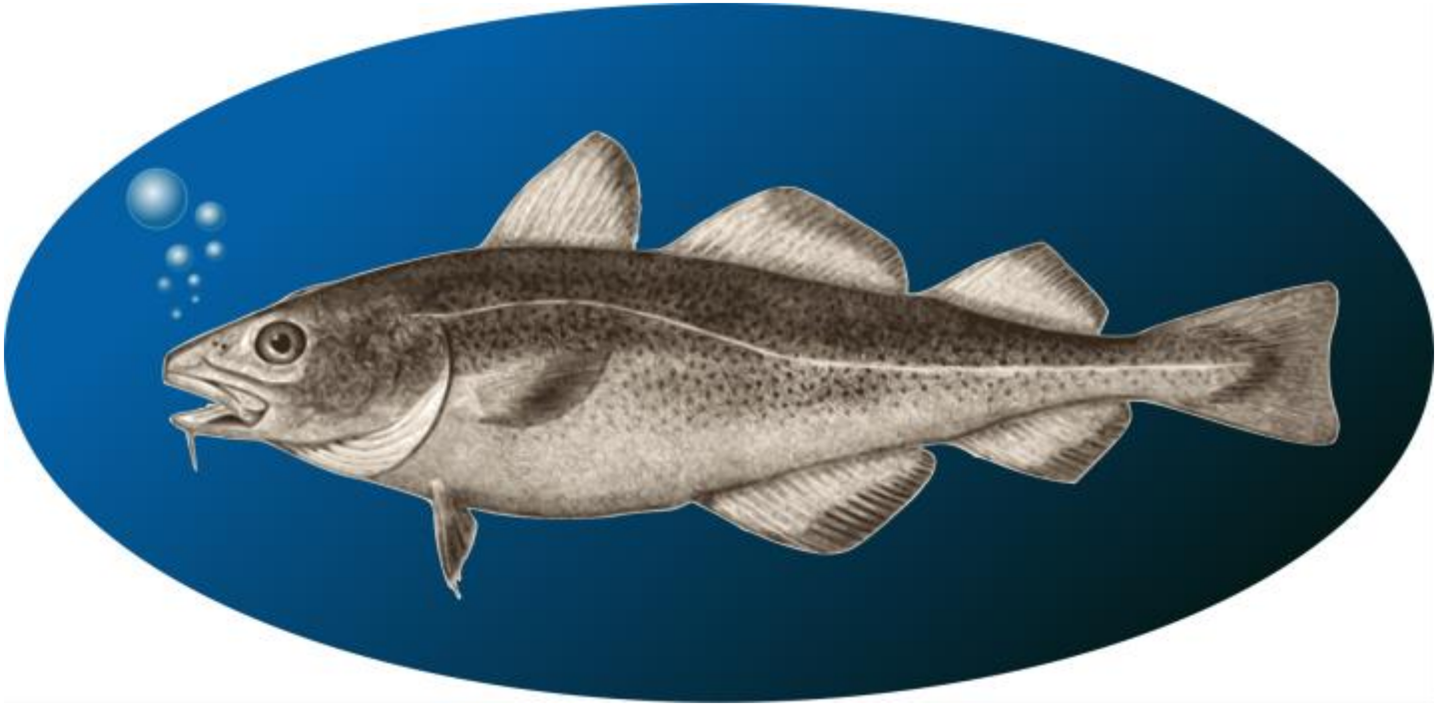


Figure 5. Depth and temperature profiles for (a) migratory cod ($n = 10$), and (b) resident cod ($n = 3$). Black lines show average depth.

Le Bris et al. 2013

Thank you!



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Seasonal stomachal content v Length