ICES/PICES
6TH ZOOPLANKTON PRODUCTION SYMPOSIUM
"NEW CHALLENGES IN A CHANGING OCEAN"
SCANDIC BERGEN CITY, BERGEN, NORWAY
9–13 MAY 2016

Bioenergetics modeling of the annual consumption of zooplankton by NEA mackerel, NSS herring and blue whiting

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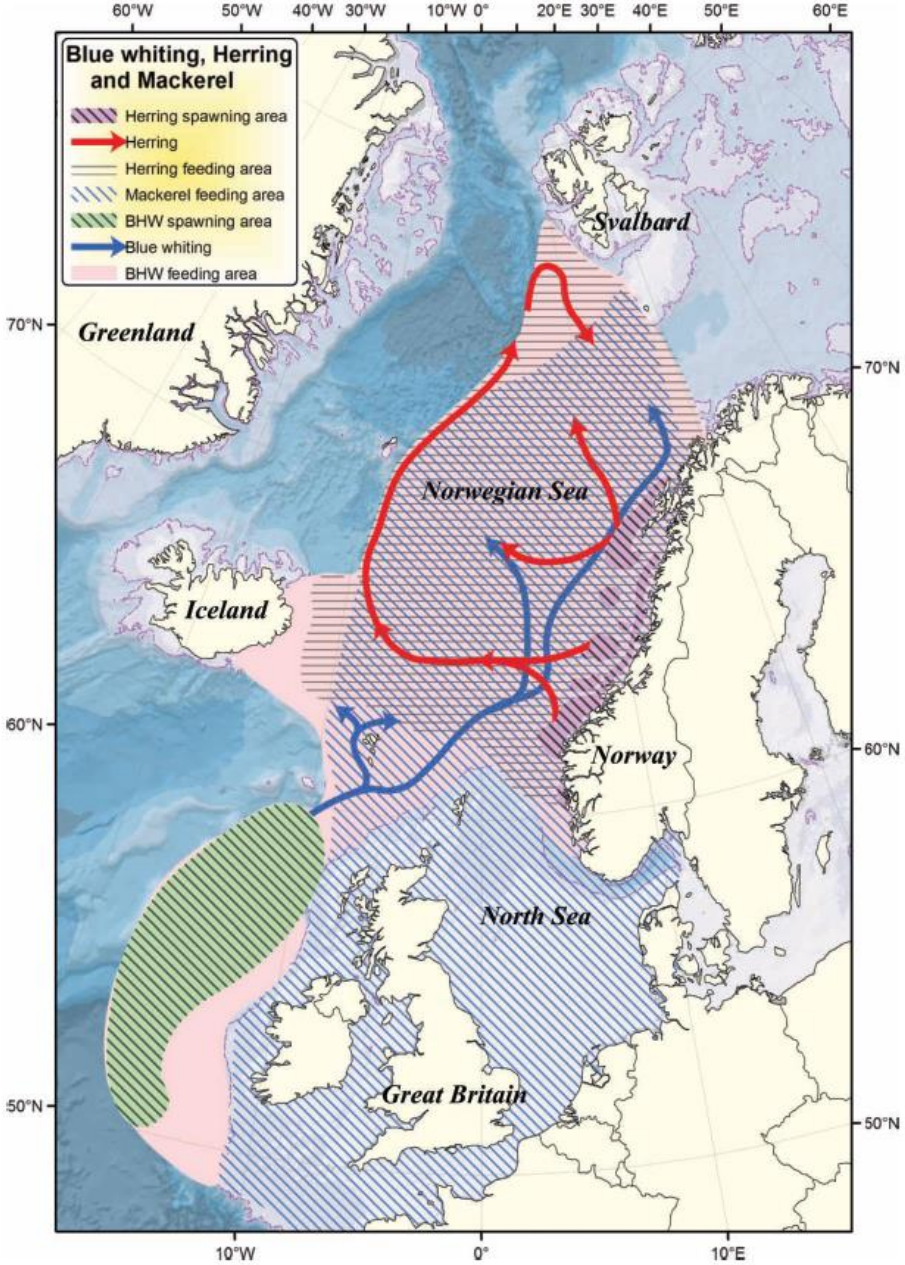
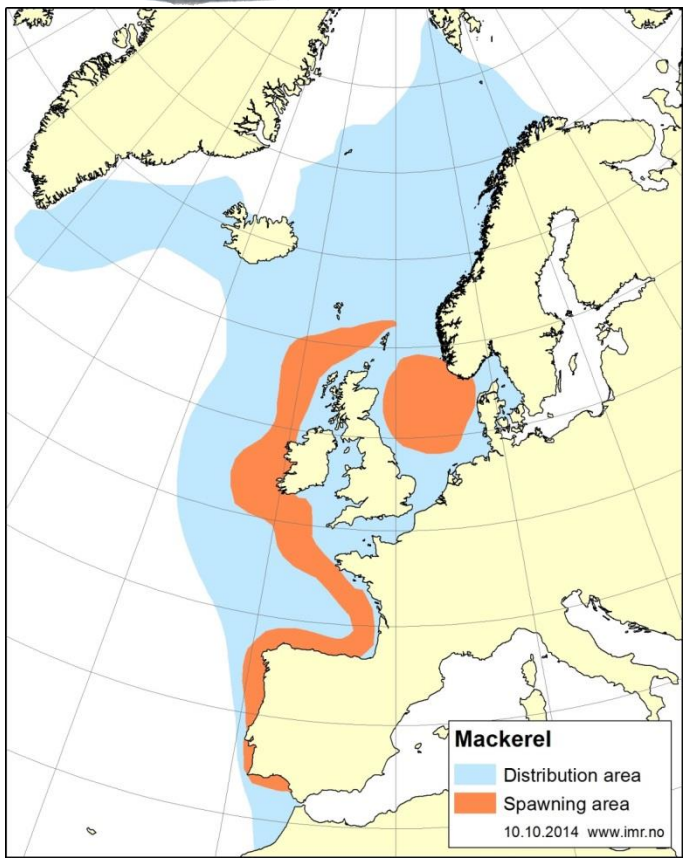

Blue whiting, Herring and Mackerel
Herring spawning area
Herring
Herring feeding area
Mackerel feeding area
BHW spawning area
Blue whiting
BHW feeding area
Svalbard
Greenland
Norwegian Sea
Iceland
Norway
North Sea
Great Britain
60°W
50°W
40°W
30°W
10°W
0°
20°E
30°E
40°E
50°E
60°E
70°N
60°N
50°N
10°W
0°
10°E


Mackerel
Distribution area
Spawning area
10.10.2014 www.imr.no

Research (2014-15, IMR)

Data available: May/July 2005 - 2010

PLOS ONE

RESEARCH ARTICLE

Feeding Ecology of Northeast Atlantic Mackerel, Norwegian Spring-Spawning Herring and Blue Whiting in the Norwegian Sea

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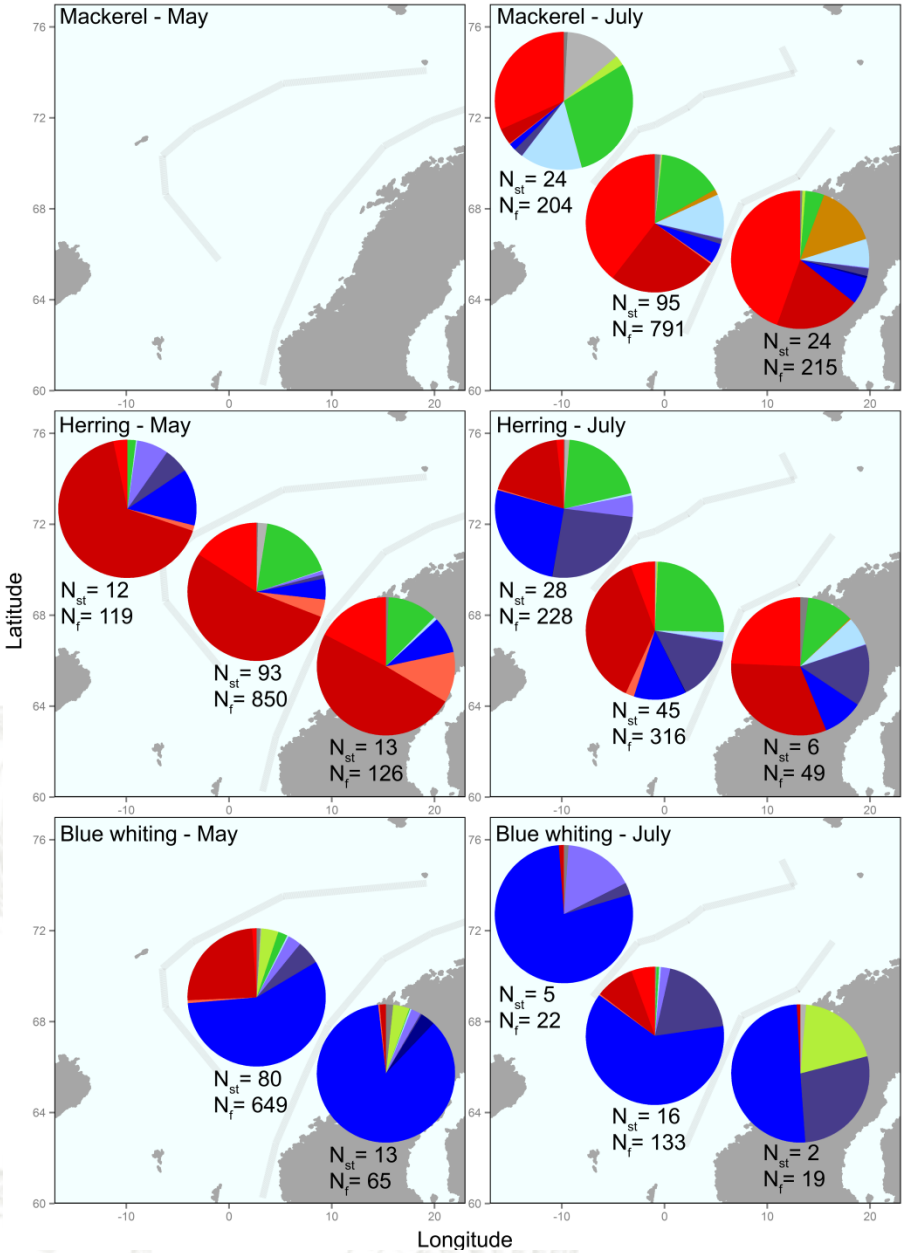
Diet composition

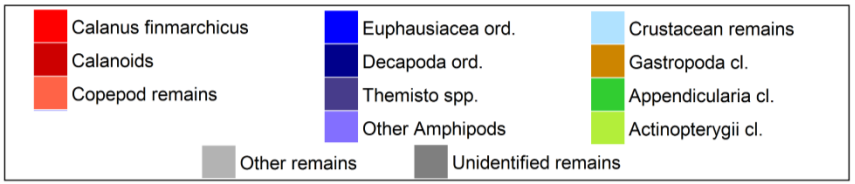


- diet ≈
- calanoids ↑
  + appendicularians
  + euph. & amph. (her)

especially ↑ in summer?

- diet ≠
- euph. & amph. ↑
  calanoids ↓

Atlantic water mass

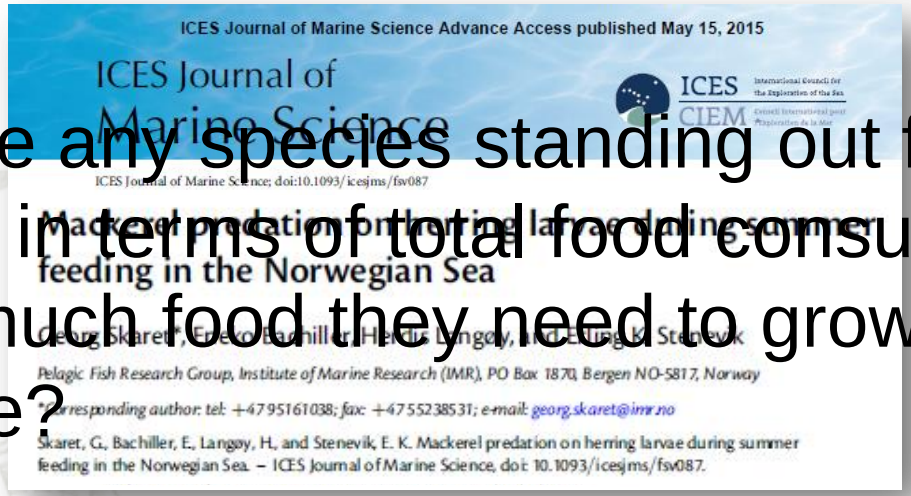


Background (feeding ecology)

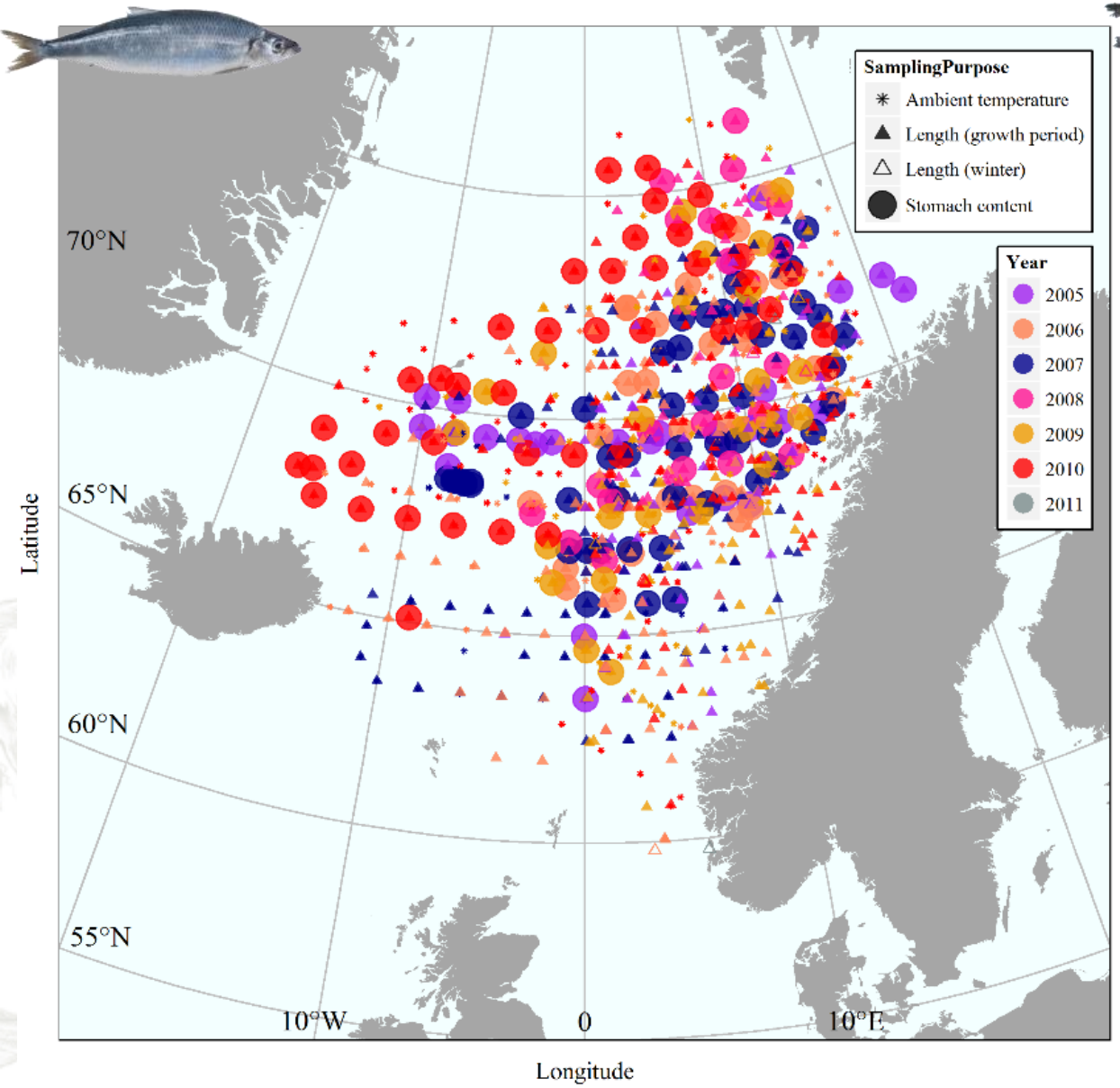
- FI and SFD ↑ in Arctic waters
- The three species adapt their feeding to different conditions over the Norwegian Sea both in May and July
- Trophic interactions
  - Blue whiting: spatial overlap↓ diet similarity ↓ (large prey↑)
  - Mackerel – herring: spatial overlap↑ diet similarity↑
    - Herring feeding activity is **still high** in summer
  - Opportunistic predation of mackerel on herring larvae ↑

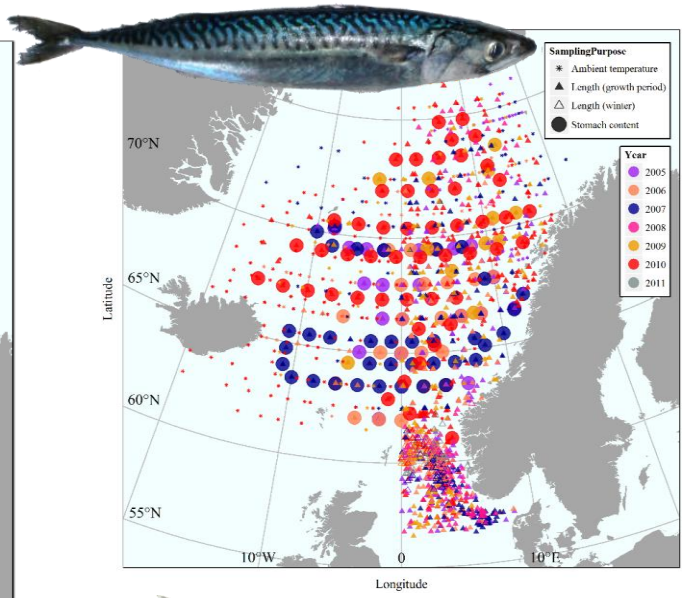
But…

- Is there any species standing out from the others in terms of total food consumption?
- How much food they need to grow & survive?



Sampling


SamplingPurpose
Ambient temperature
Length (growth period)
Length (winter)
Stomach content
Year
2005
2006
2007
2008
2009
2010
2011
70°N
65°N
60°N
55°N
10°W
0
10°E
Latitude
Longitude


SamplingPurpose
Ambient temperature
Length (growth period)
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Year
2005
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70°N
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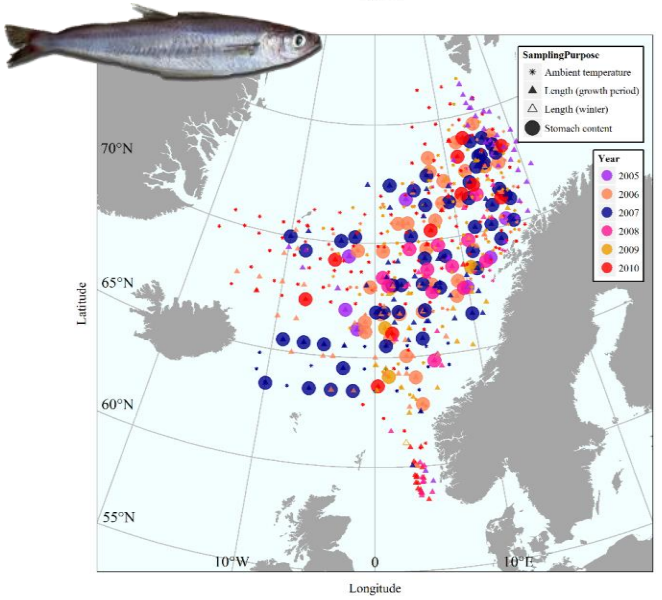
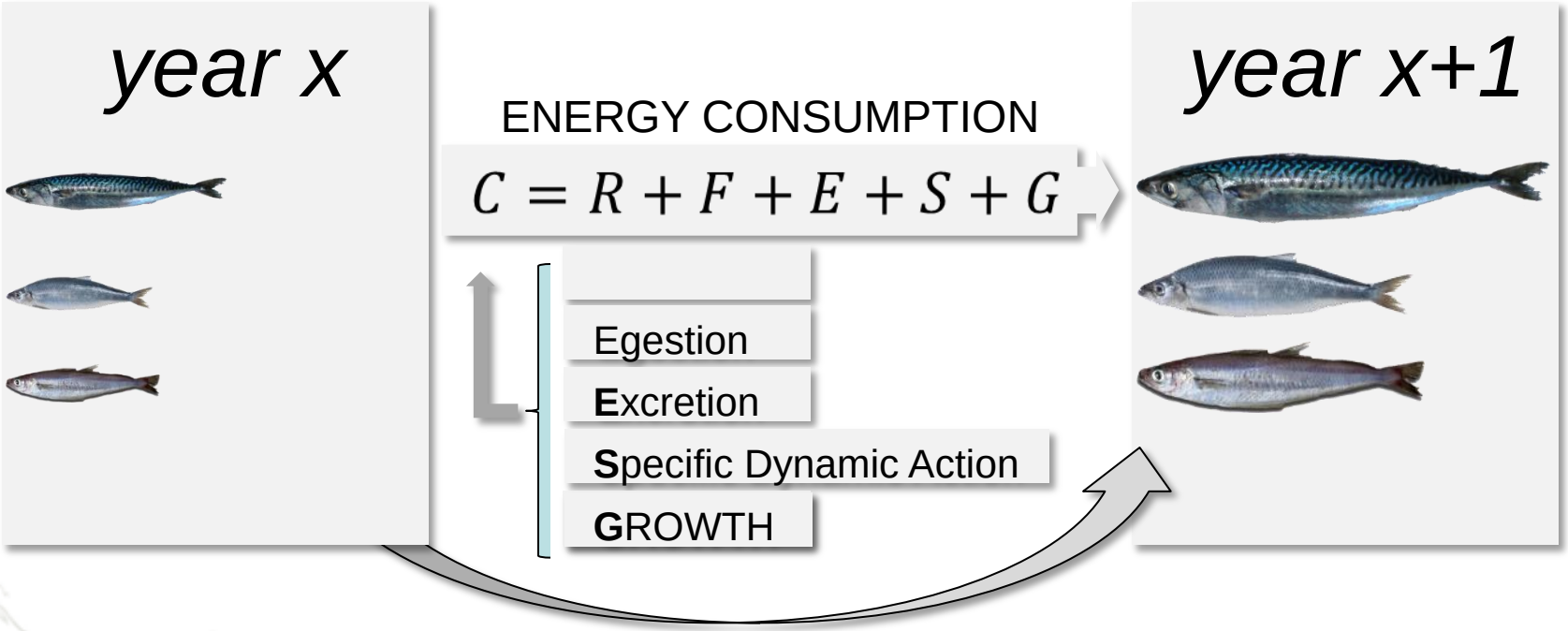
55°N
10°W
0
10°E
Latitude
Longitude


SamplingPurpose
Ambient temperature
Length (growth period)
Length (winter)
Stomach content
Year
2005
2006
2007
2008
2009
2010
70°N
65°N
60°N
55°N
10°W
0
10°E
Latitude
Longitude

Bioenergetics consumption model

- Energy requirements: swimming, feeding, growing, metabolism...

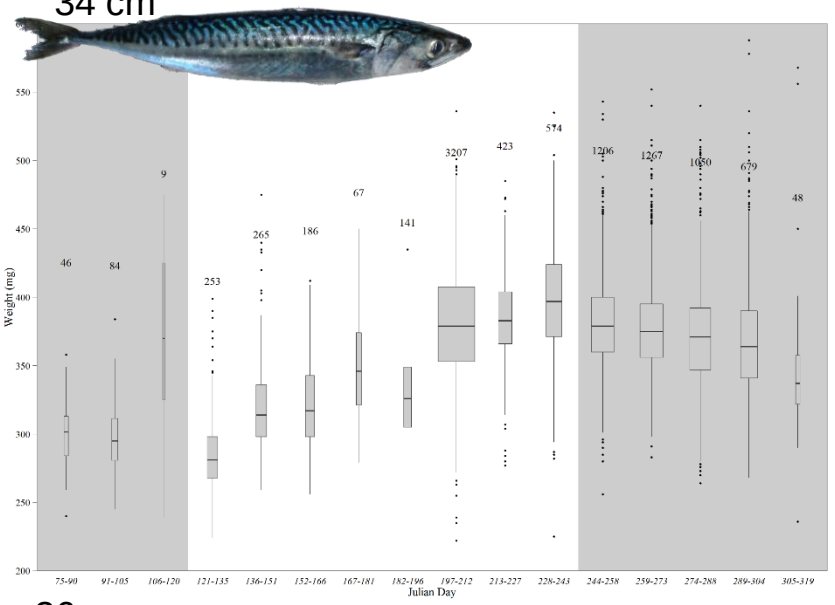


- Integrating C over time...
  - We can derive annual consumption estimates for different (7) prey groups, **based on observed growth + other parameters**

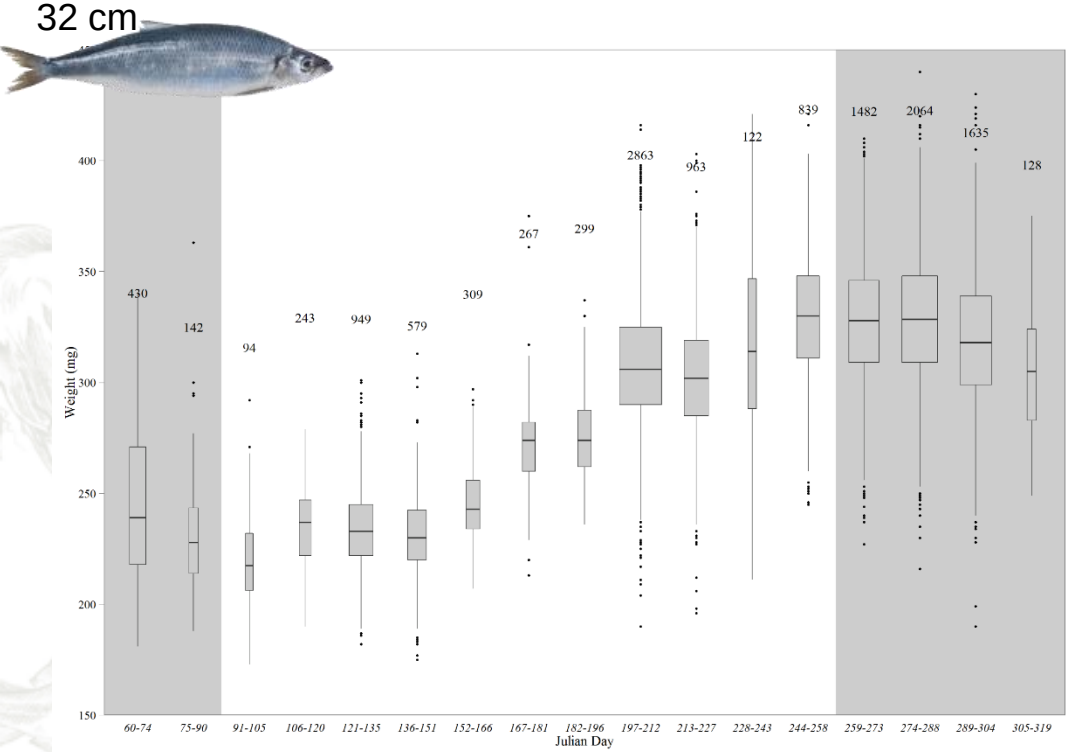
Data range definition

Species	Length range (cm)	Feeding (W growing) period
mackerel	25 - 45	May 01 – August 31
herring	28 - 38	April 01 – September 15
blue whiting	15 - 40	April 01 – September 30

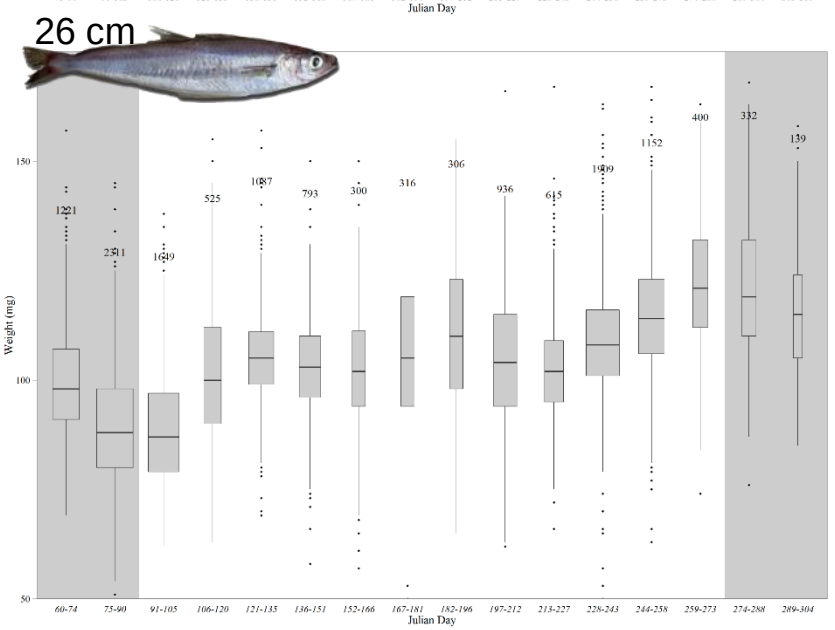
34 cm



32 cm



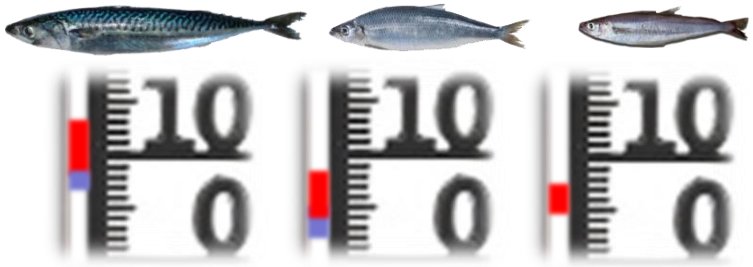
26 cm



Model input

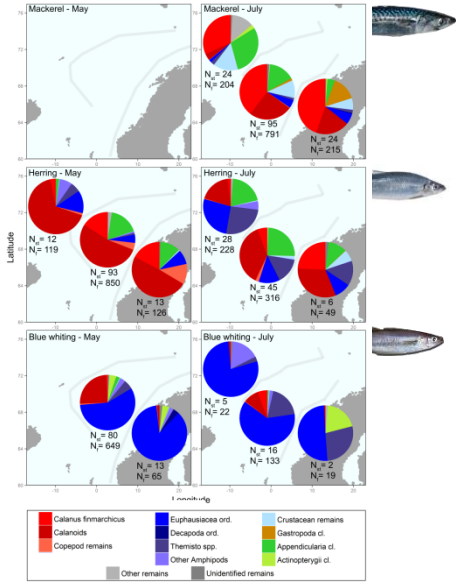
- Swimming speed

- Ambient T
  - her/bwh: Acoustics + CTD
  - mac: CPUE + CTD (10m)



- Diet composition (7 prey groups)
  - % prey (May & July, 2005-10)

    Linear interpolation

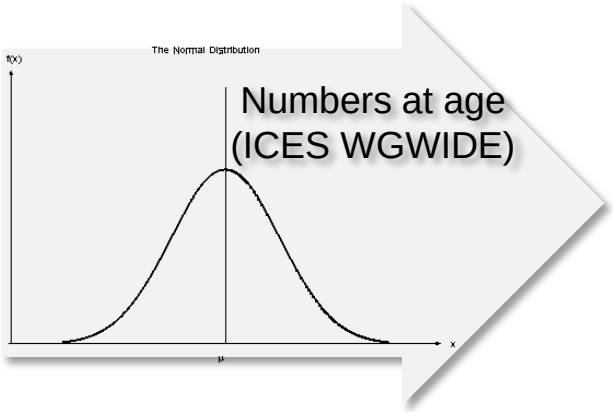


  - Energy Density (prey)

Model input

- Abundance distribution per length group (winter)
  - Model: length specific ▸ stock as number of indiv. per 1 cm length group

Winter length at age (0.1 cm) measurements



Numbers at age (ICES WGWIDE)

New length distribution: ABD per 1 cm group (scaled to the total biomass)

$$ABD'_L = \sum_{L_{min}}^{L_{max}} ABD_L \left(\frac{B_{ICES}}{\sum_{L_{min}}^{L_{max}} W_{L,t=91} ABD_L} \right)$$

We make a transition from the assessment data (number at age and weight at age)
into: *length at age*. This way we obtain ***number at length***.

Model input

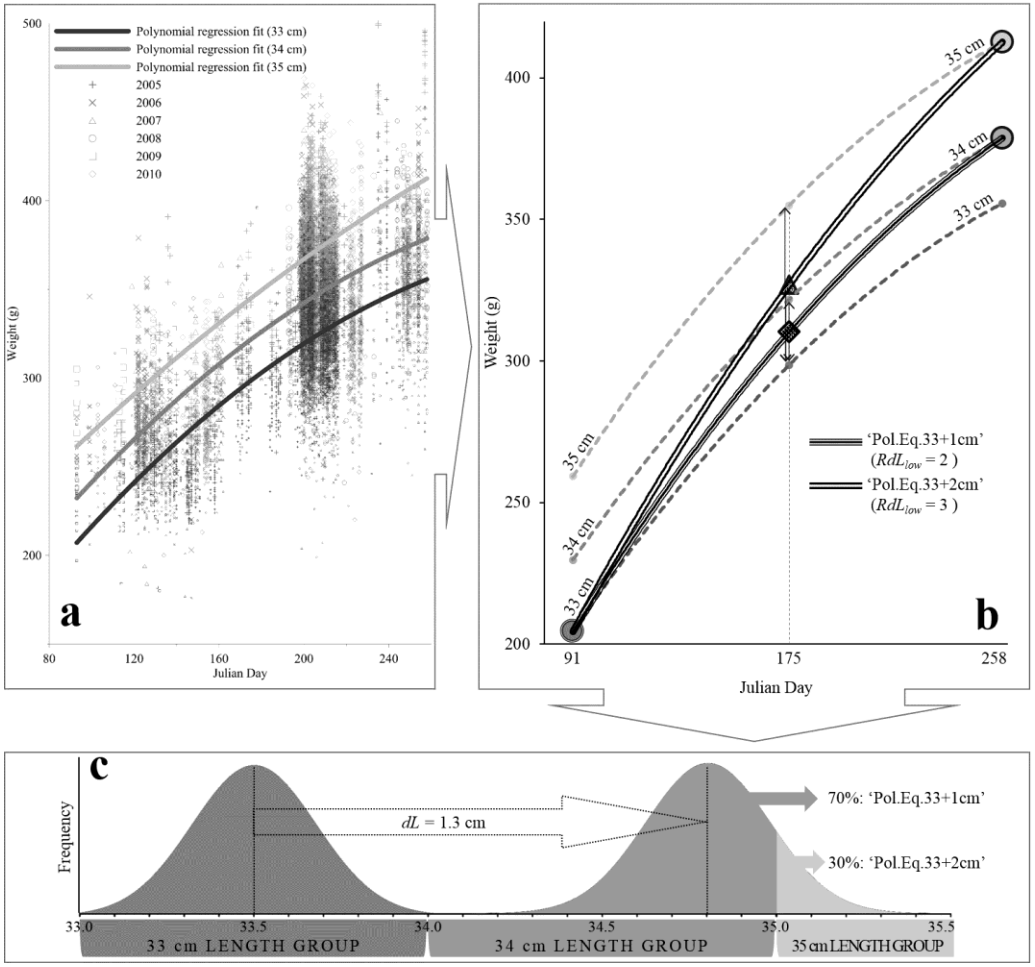
- Somatic growth (feeding period)

  – Growth during the feeding season is the combined effect of length growth and changes in weight-at-length

$$W_t = at^2 + bt + c$$

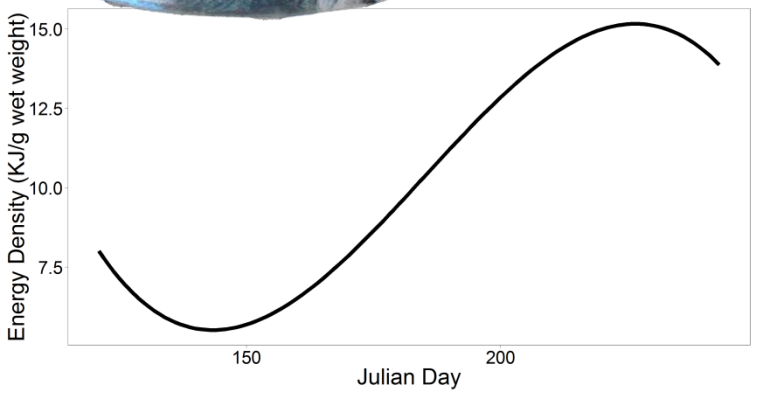
  – Length increment per year: Hamre et al. (2014)

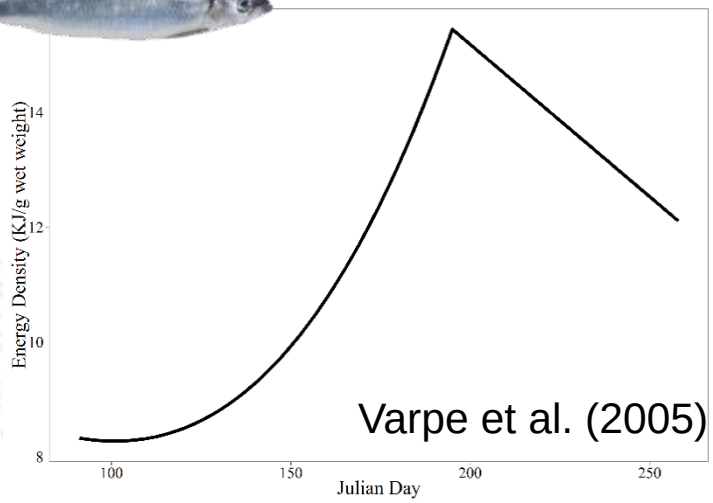
$$dL = k(L_{max} - L_s)$$



Model input

- Fish grow in 3 dimensions
  - Length
  - Weight (fat & muscle)
  - **Energy Density**



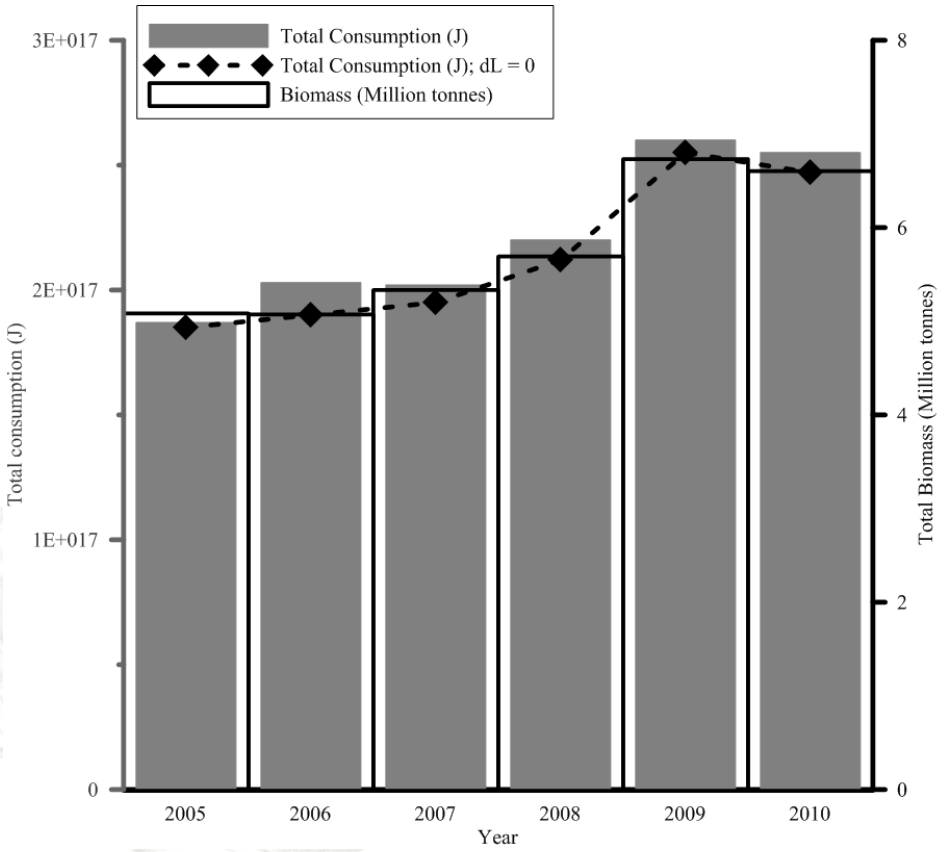


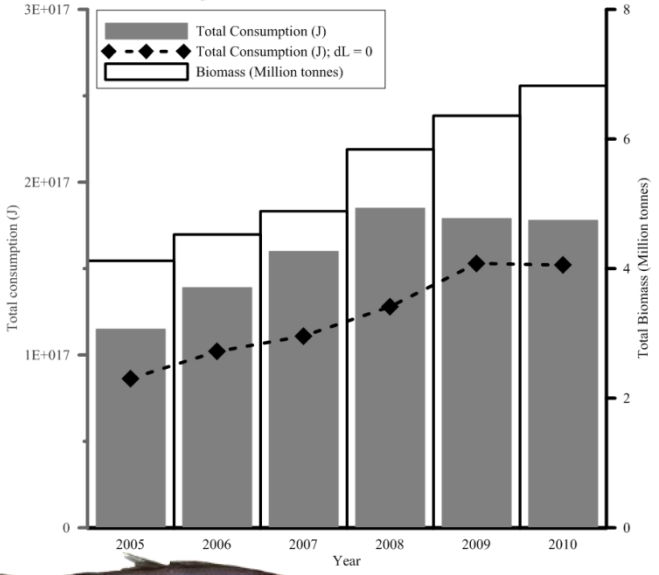
Varpe et al. (2005)

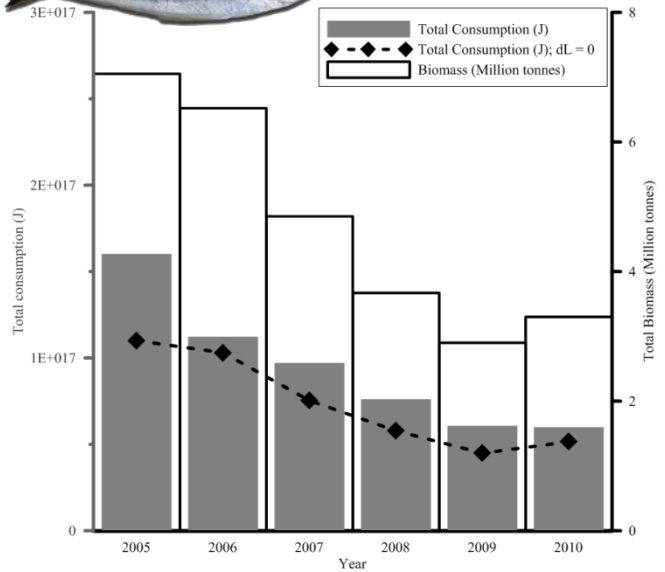
Fixed value (cod, literature) ***but…***

+ Fraction of Energy **accumulated in liver** (Dumke 1986)

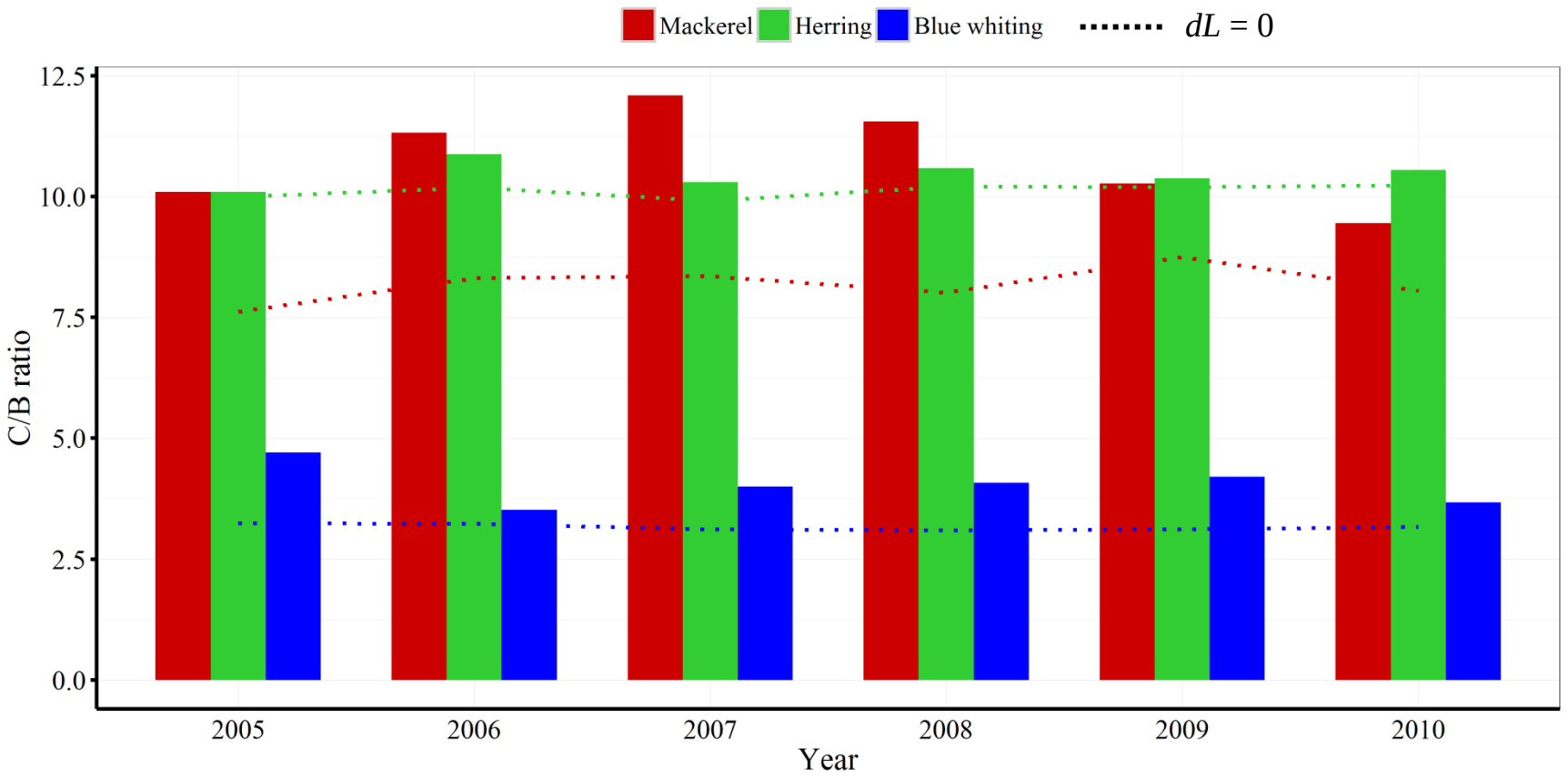
Results: Total E consumption & Biomass



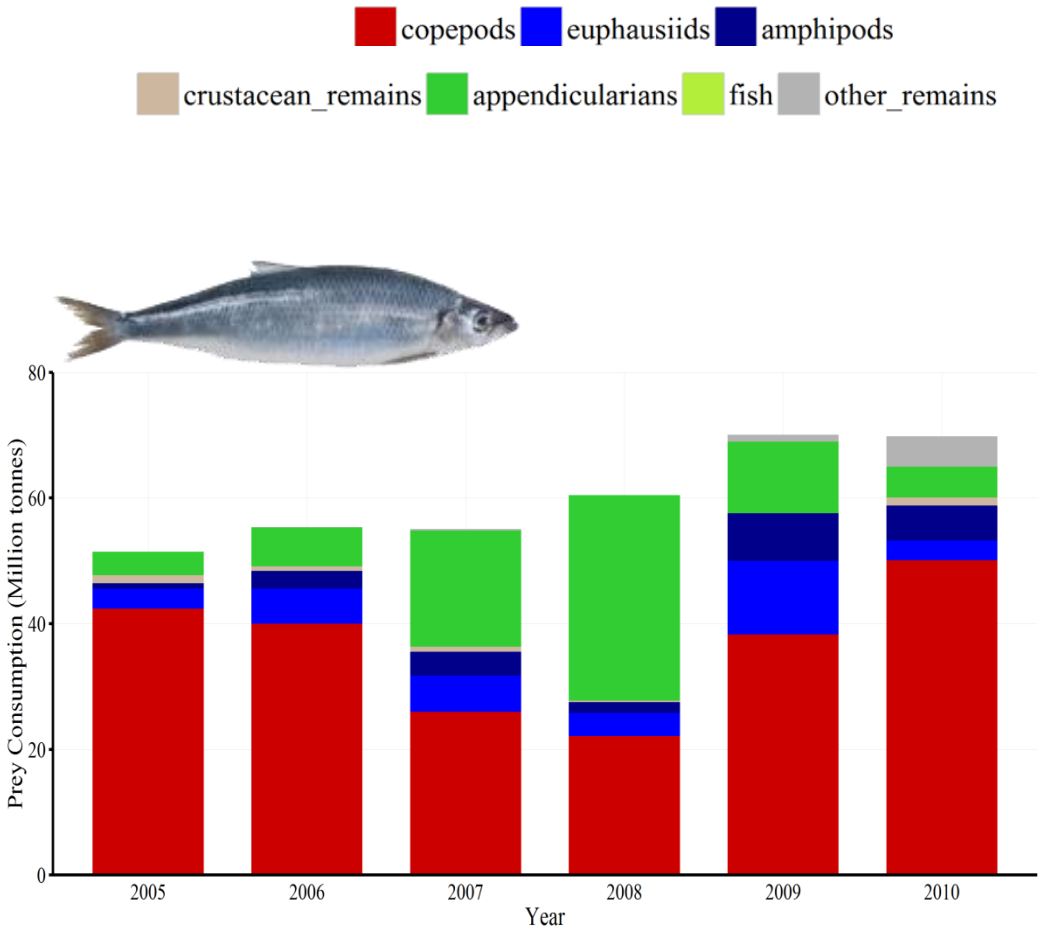


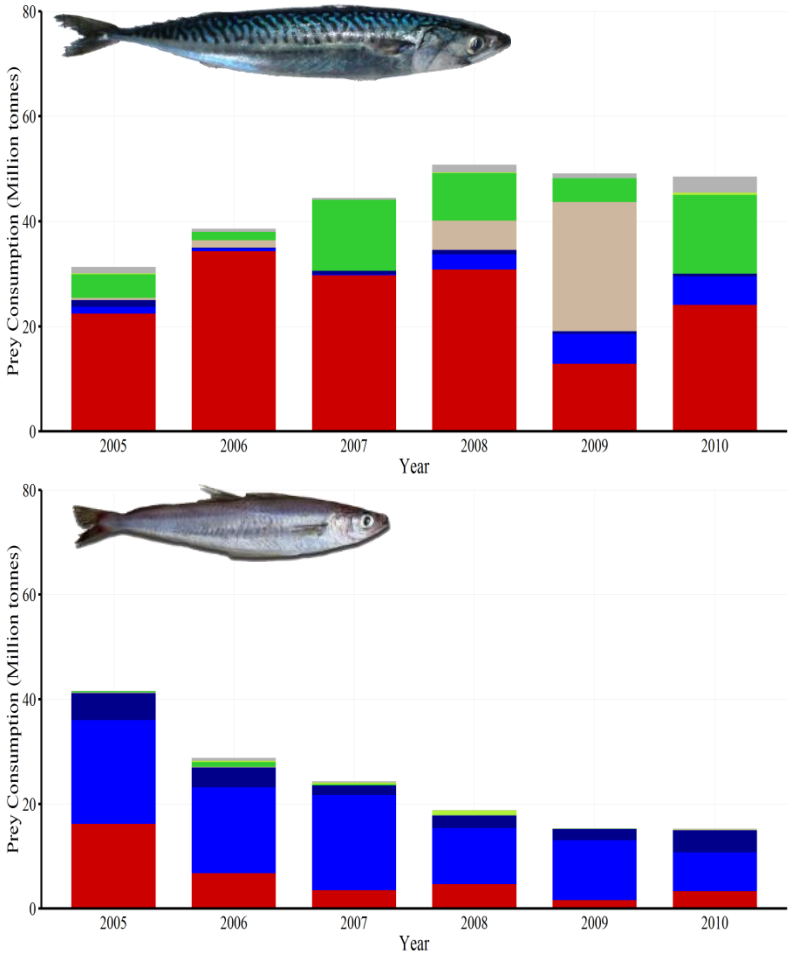


Results: Consumption / Biomass ratio



Results: Prey consumption estimates





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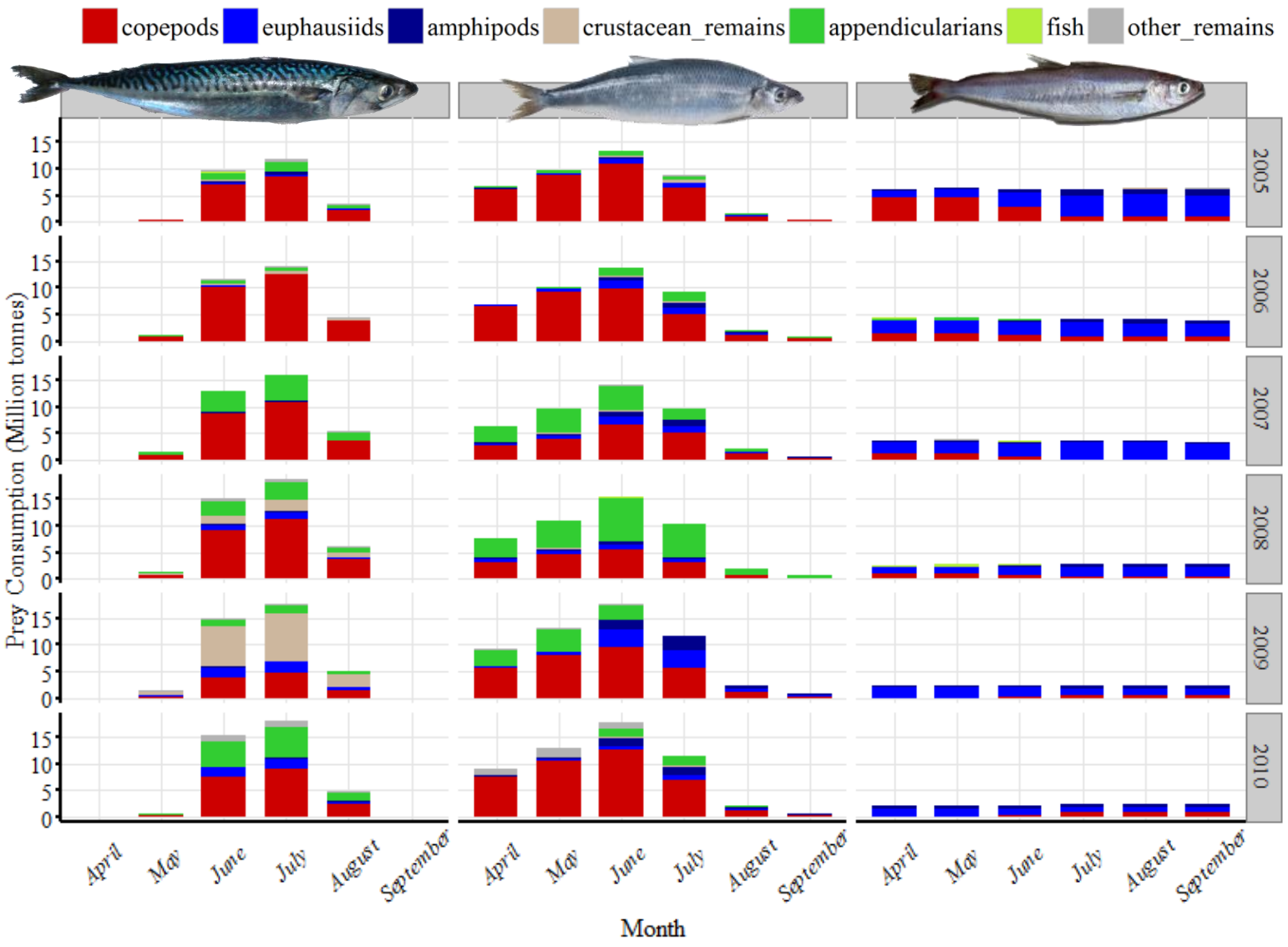
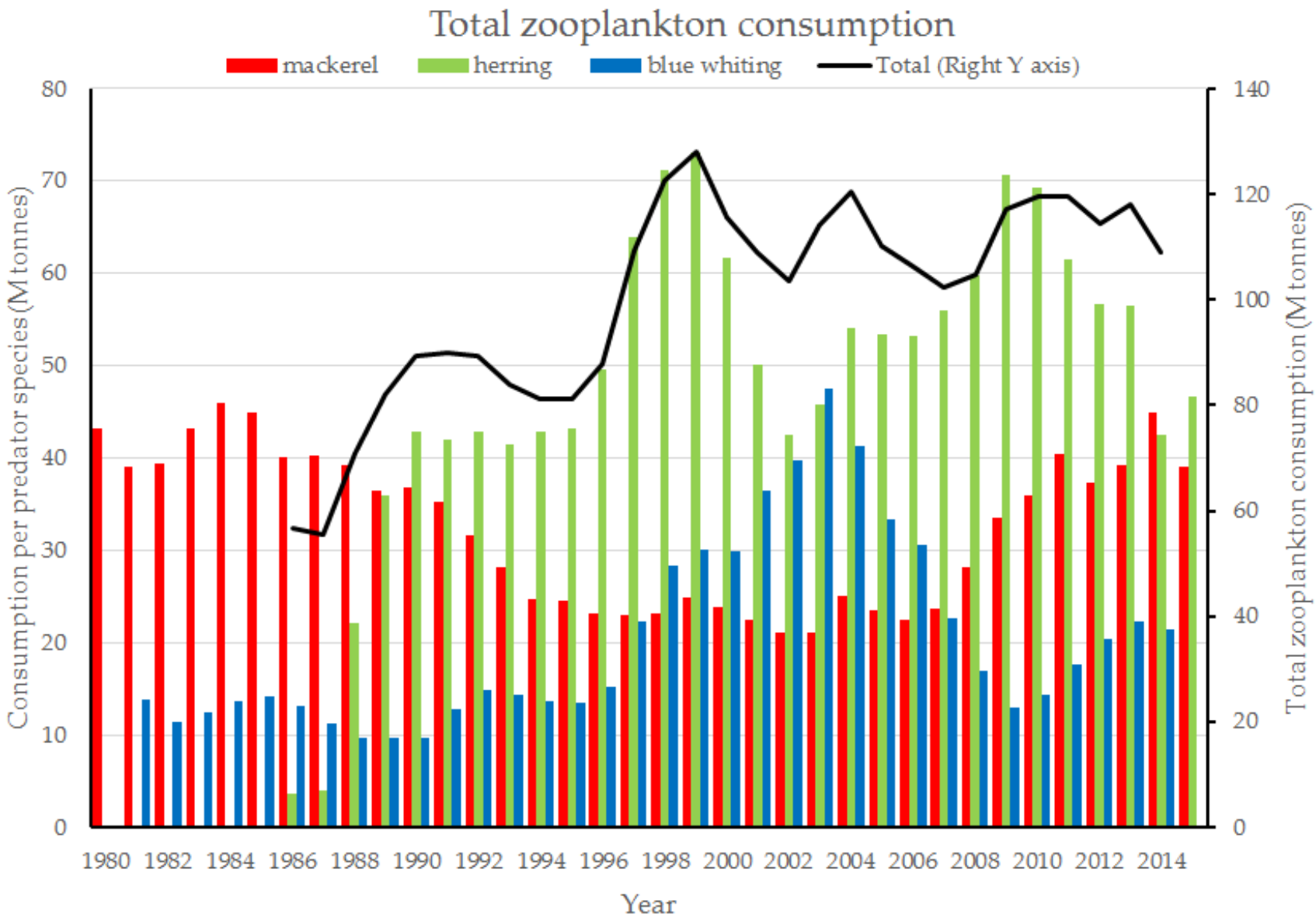


From average C/B ratios (2005-10)…



Consumption estimates: main findings

- The three species are consuming around 110 Million tonnes of zooplankton each year! But...
  - Total zooplankton biomass? (accurate estimates & sampling tool assessment)
  - Part of the stock is feeding outside the Norwegian/Nordic Seas... (spatial variability?)
- Mean peak of feeding: herring in June; mackerel in June/July; blue whiting quite constant throughout the feeding season.
  - Herring still feeds effectively in July
  - Inter-annual variations (consumption & diet composition)
- Total consumption of prey is higher by herring (longer feeding period) than for mackerel, but...

  Cons/bio ratio: mac ≈ her!! (both >>> bwh)
- Appendicularians (mac & her): more relevant than in diet composition analysis!

Consumption estimates: next steps

- Spatial differences in zooplankton consumption could also offer new insights of the feeding efficiency...

  Why the CF of mackerel is decreasing? Are they consuming less quality food, or is it due to more competition? If so, then IGP effects could increase...

- Zooplankton biomass estimates? Sampling tools?
- Consumption estimates as input for ecosystem models, in order to assess the potential impacts due to trophic interactions (e.g. top-down control).

Acknowledgments

W5 conveners

ICES ZPS2016 & AZTI (travel fund)

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Thank you for your attention