Prey-predator interactions between the myctophid *Bentosema glaciale* and calanoid copepods in the Labrador Sea

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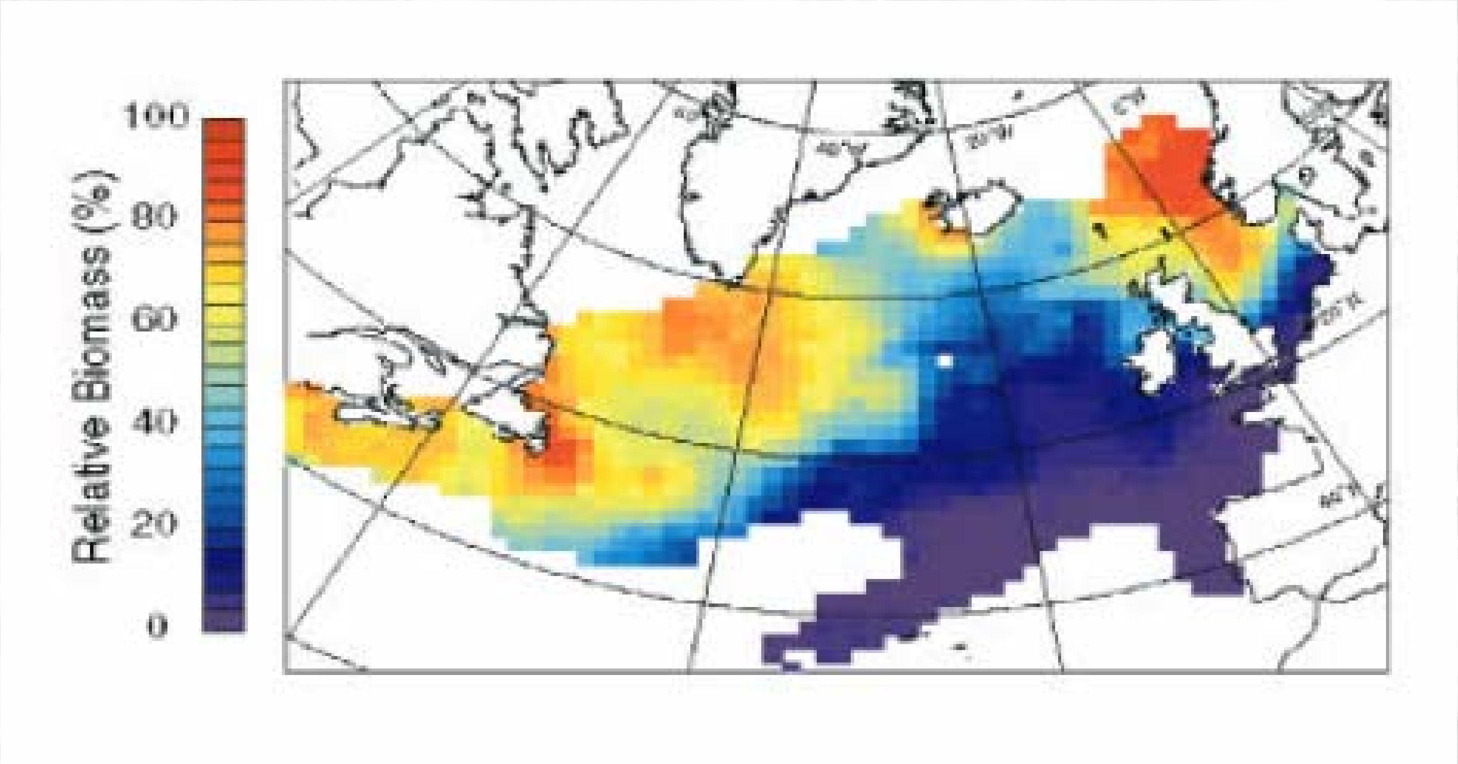
- Throughout the North Atlantic, copepods of the genus *Calanus* are dominant players in the zooplankton community
- *C.finmarchicus* is most important both numerically and in terms of integrated production



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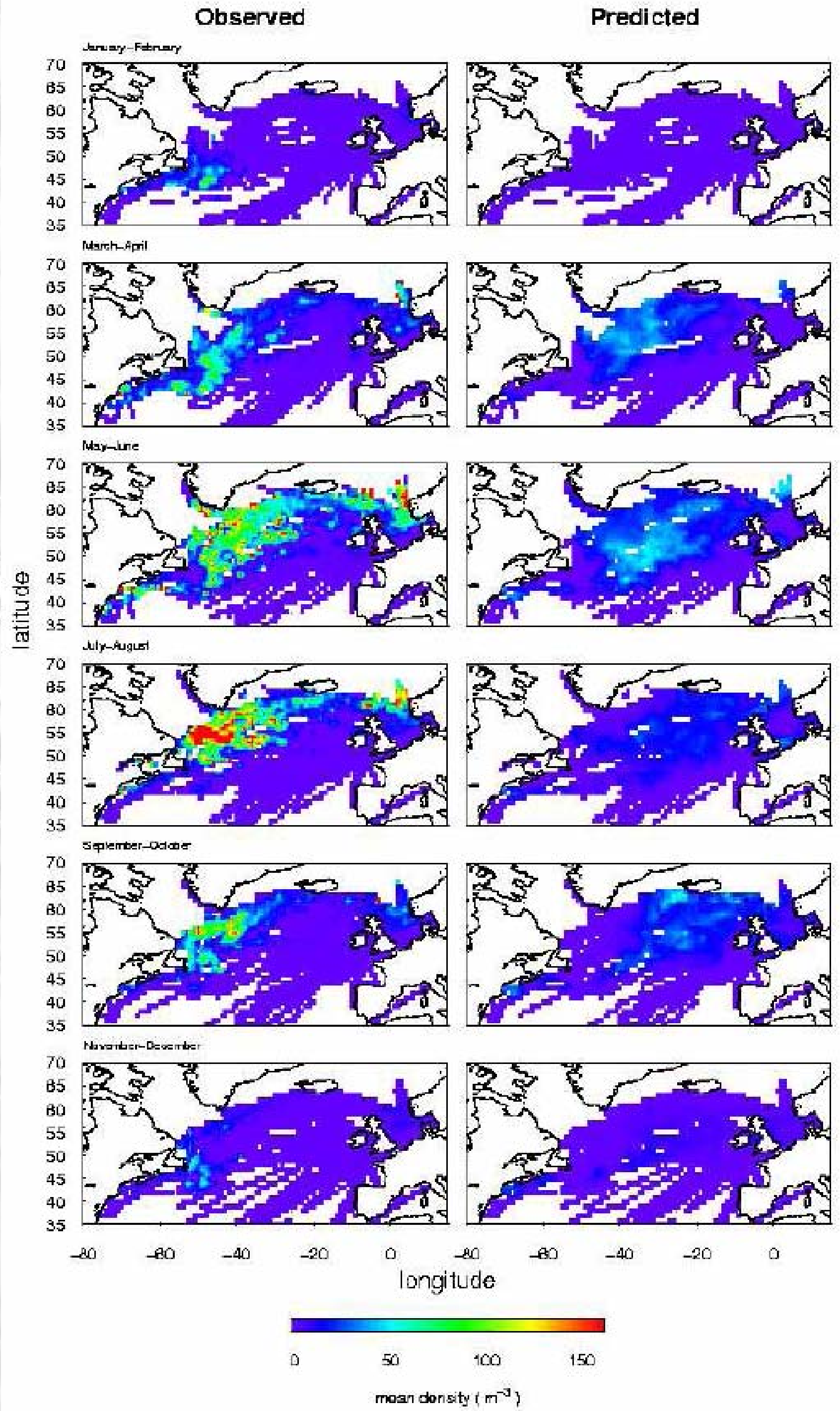
Previous modeling of *C.finmarchicus* had shown that paramaterization based on conditions in the Eastern Atlantic yielded inaccurate results, particularly in the Labrador Sea

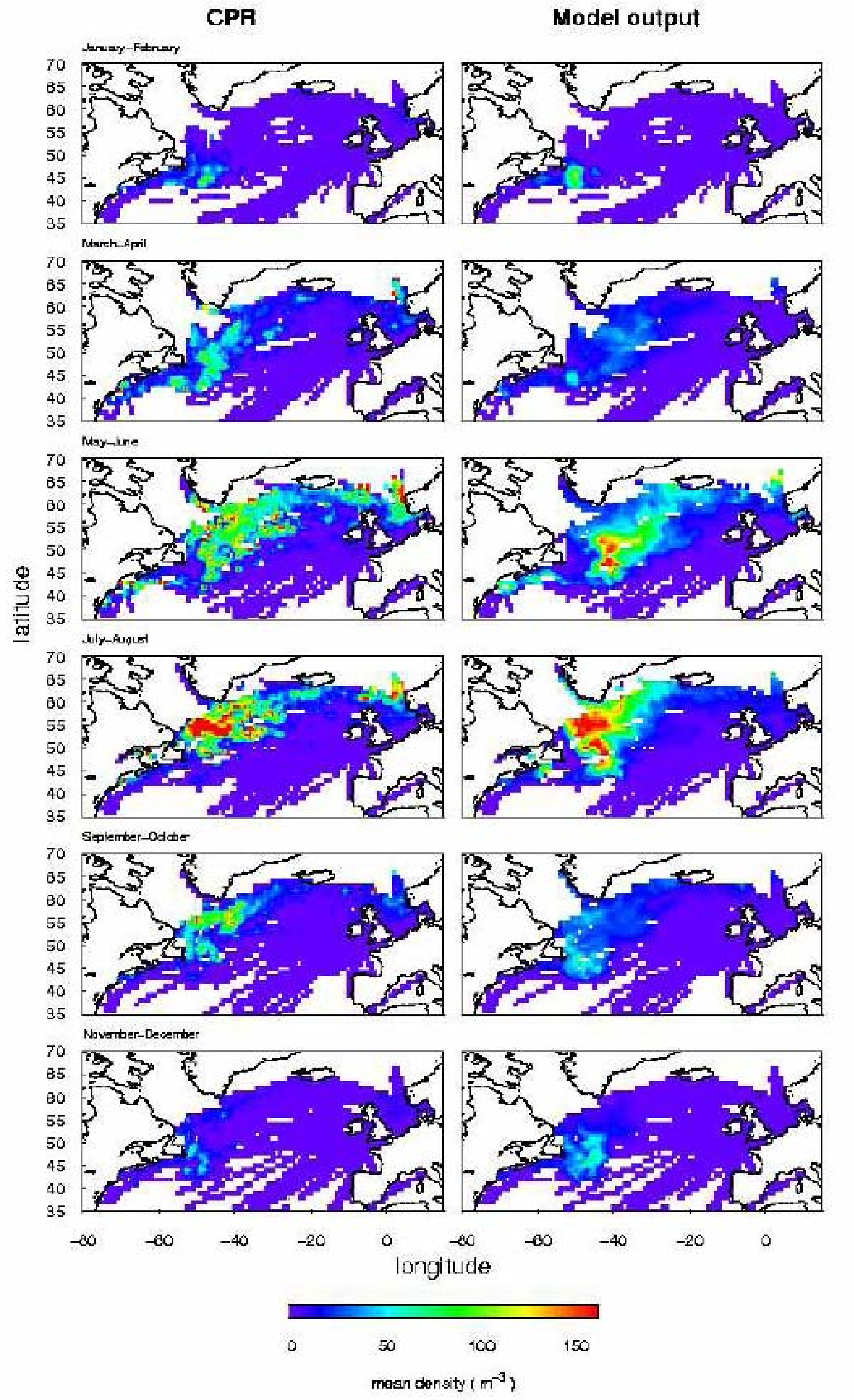


Speirs et al. (2006)

Previous modeling of *C.finmarchicus* had shown that paramaterization based on conditions in the Eastern Atlantic yielded inaccurate results, particularly in the Labrador Sea

The introduction of temperature-dependent mortality term yielded more realistic seasonal pattern in the spatial distribution

Speirs et al. (2006)



- The assumption of a temperature-dependent mortality term in modeling *C. finmarchicus* appears reasonable but there are few data on which to base this decision

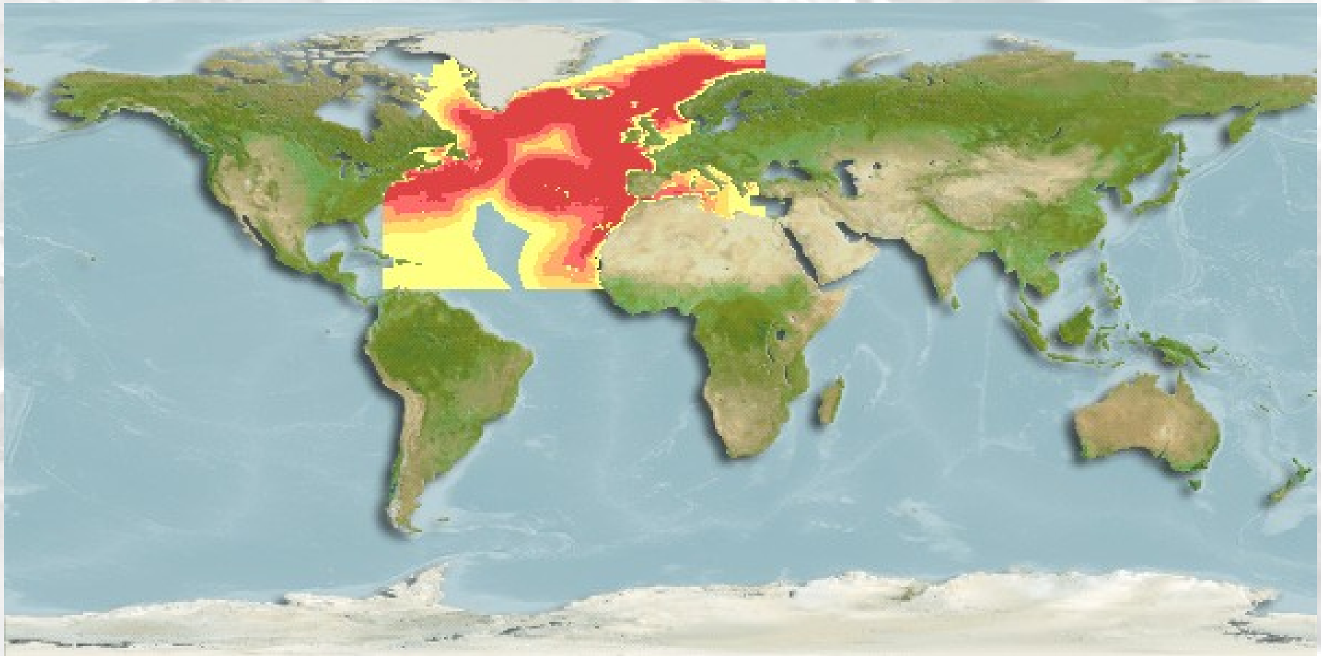
- To achieve strong predictive capacity requires strong causal relationship

- Under the assumption that the primary cause of mortality is predation, and with limited knowledge of the sources of mortality in sub-Arctic ecosystems, we turned our attention to the potential role of the Deep-Scattering Layer (DSL)

- Within the region, and other similar ecosystems, a major component of the DSL consists of myctophids, with *Benthosema glaciale* being a dominant species (Sameoto 1989; Bagoeine et al., 2001) and evidence indicated they could have a significant impact on the zooplankton community

Benthosema glaciale

Pelagic
Non-migratory
Depth range 0 - 1100 m
Planktivorous
Max length ~ 10 – 11 cm
High probability of occurrence throughout the North Atlantic



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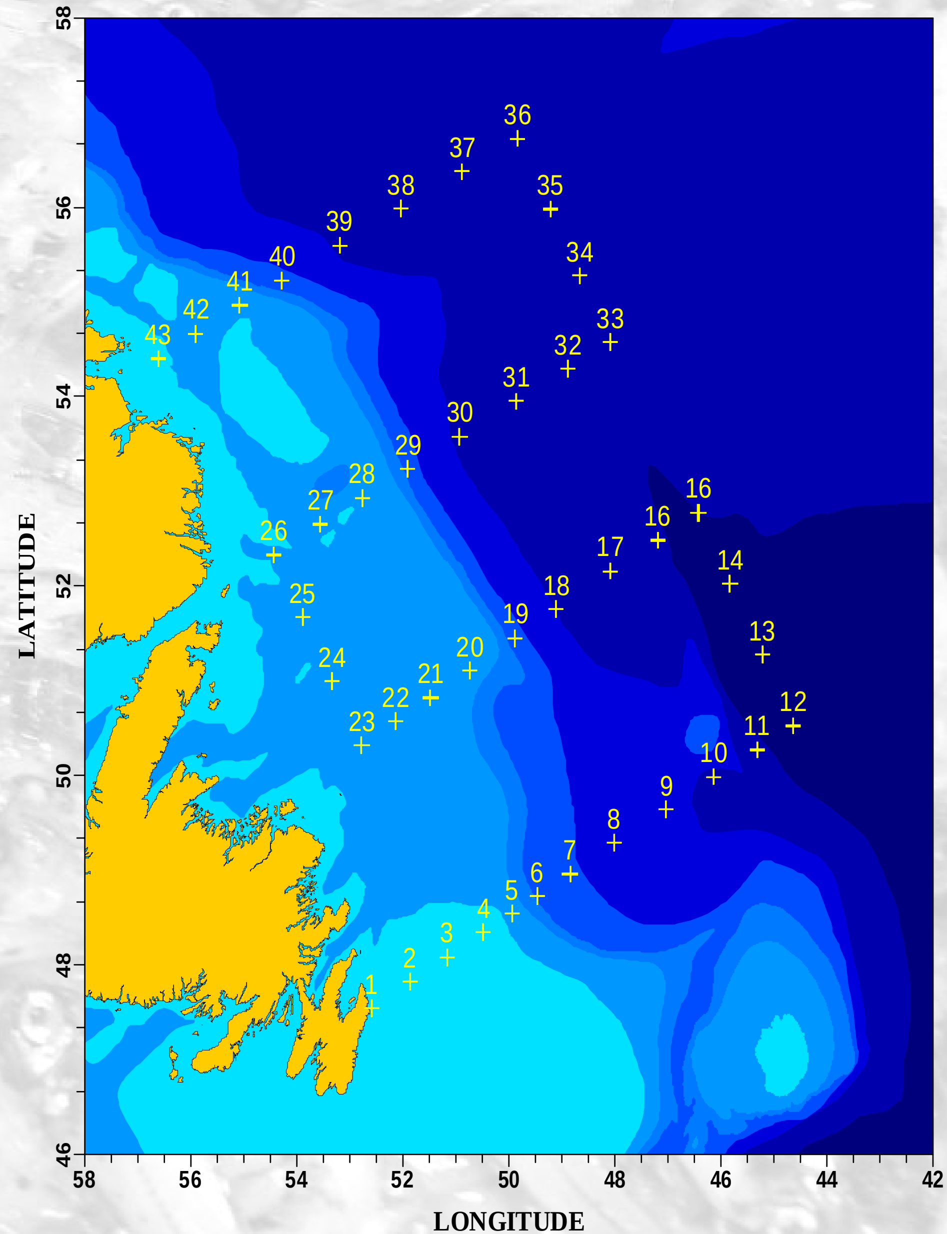
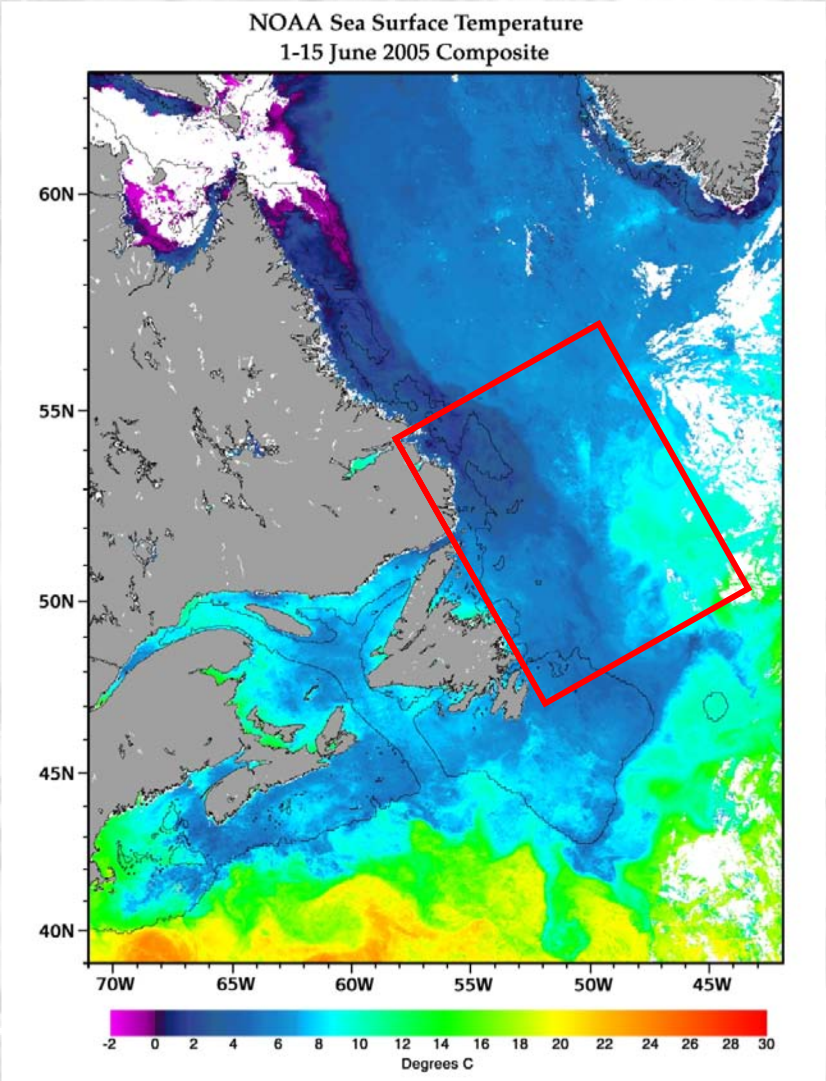
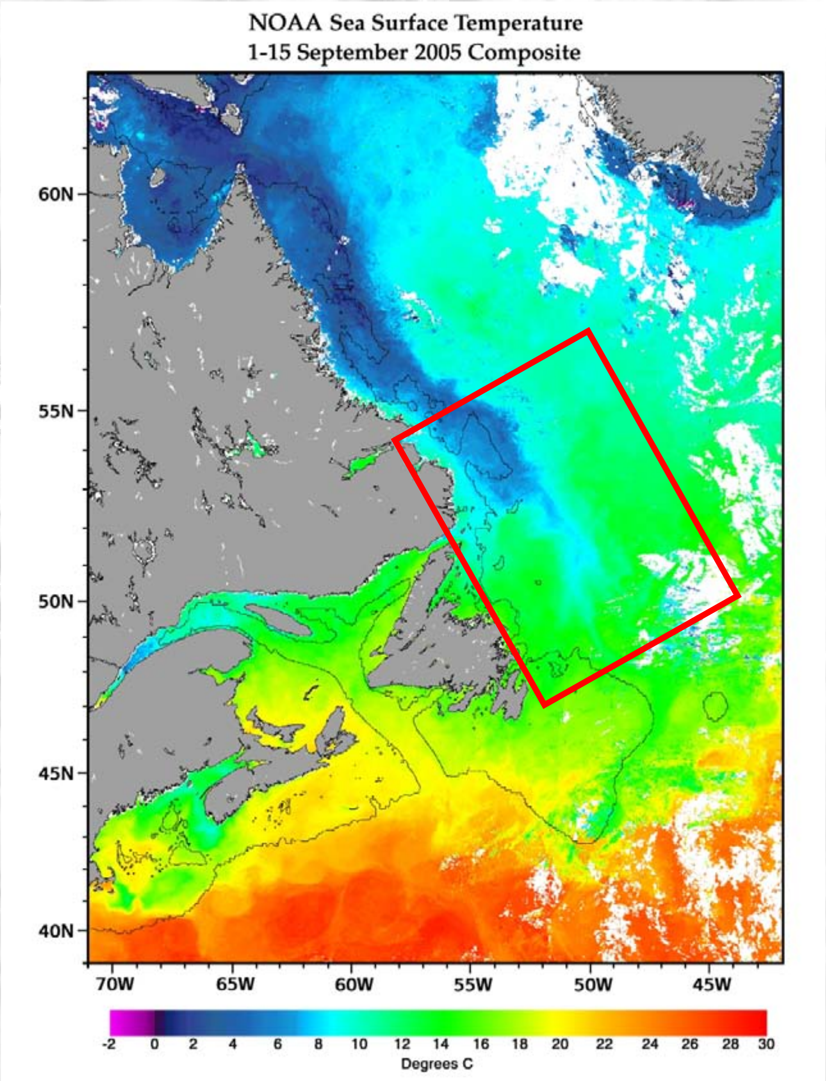
Observation program

- Completed two exploratory surveys of NL Shelf and Labrador Sea (June, August – Sept 2006)
  - Zooplankton collections (integrated and vertically stratified samples) to measure condition (lipids), egg production
  - Hydroacoustic surveys to determine distribution of potential predators (planktivorous fish)
  - Stomach sampling program to estimate predator consumption rates (some depth stratification)
- Focus on deep water and areas of potential cross shelf transport

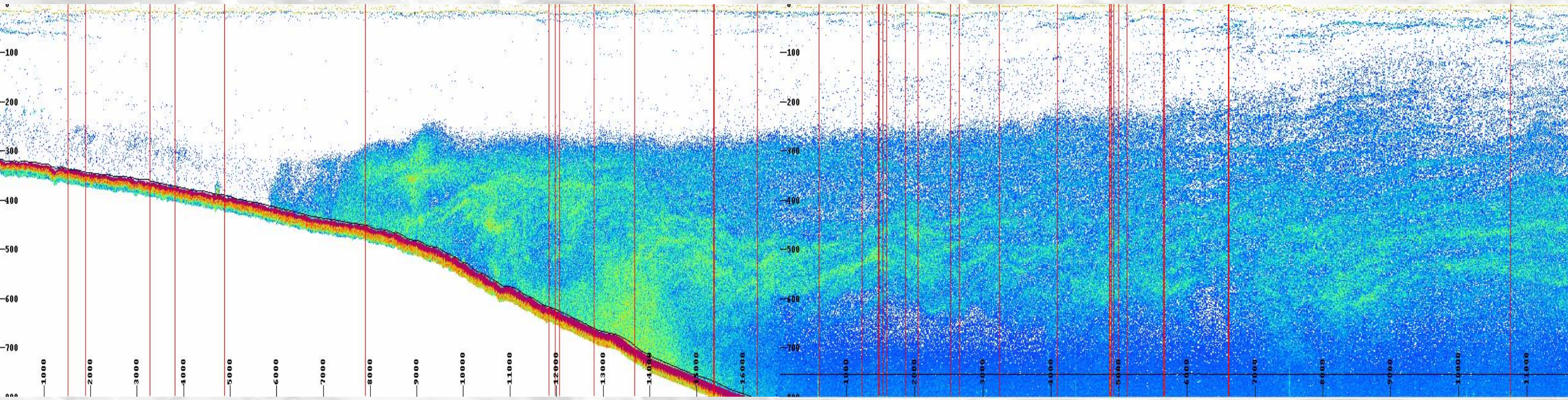


Observation program

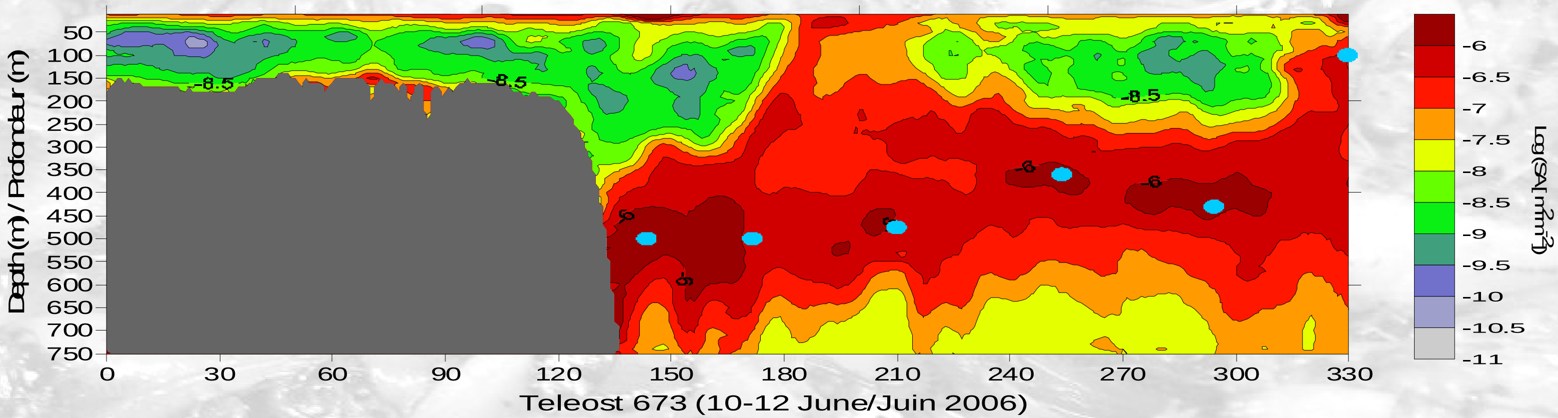


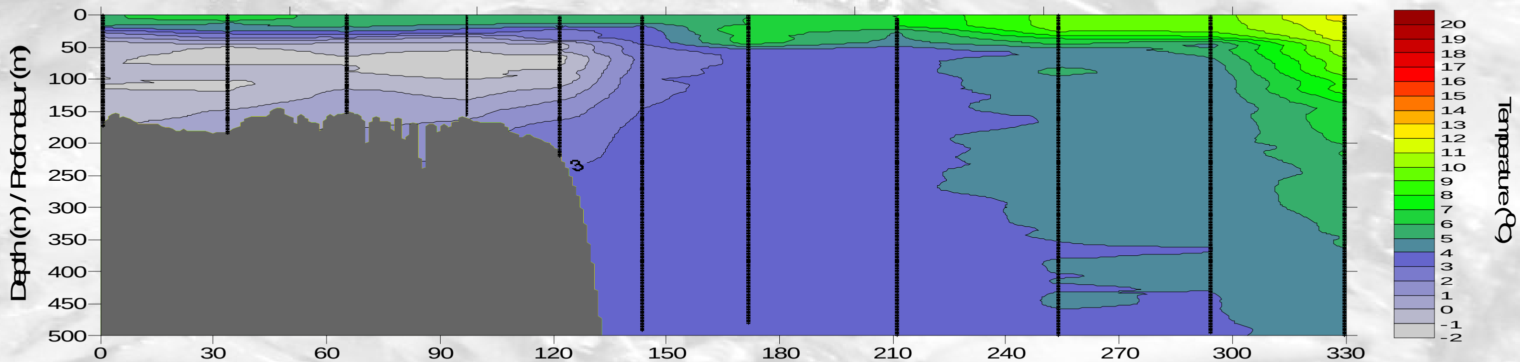


Observation program



Observation program





Near surface scattering layer present on NL Shelf and in Labrador Sea – consists principally of amphipods with some medusae

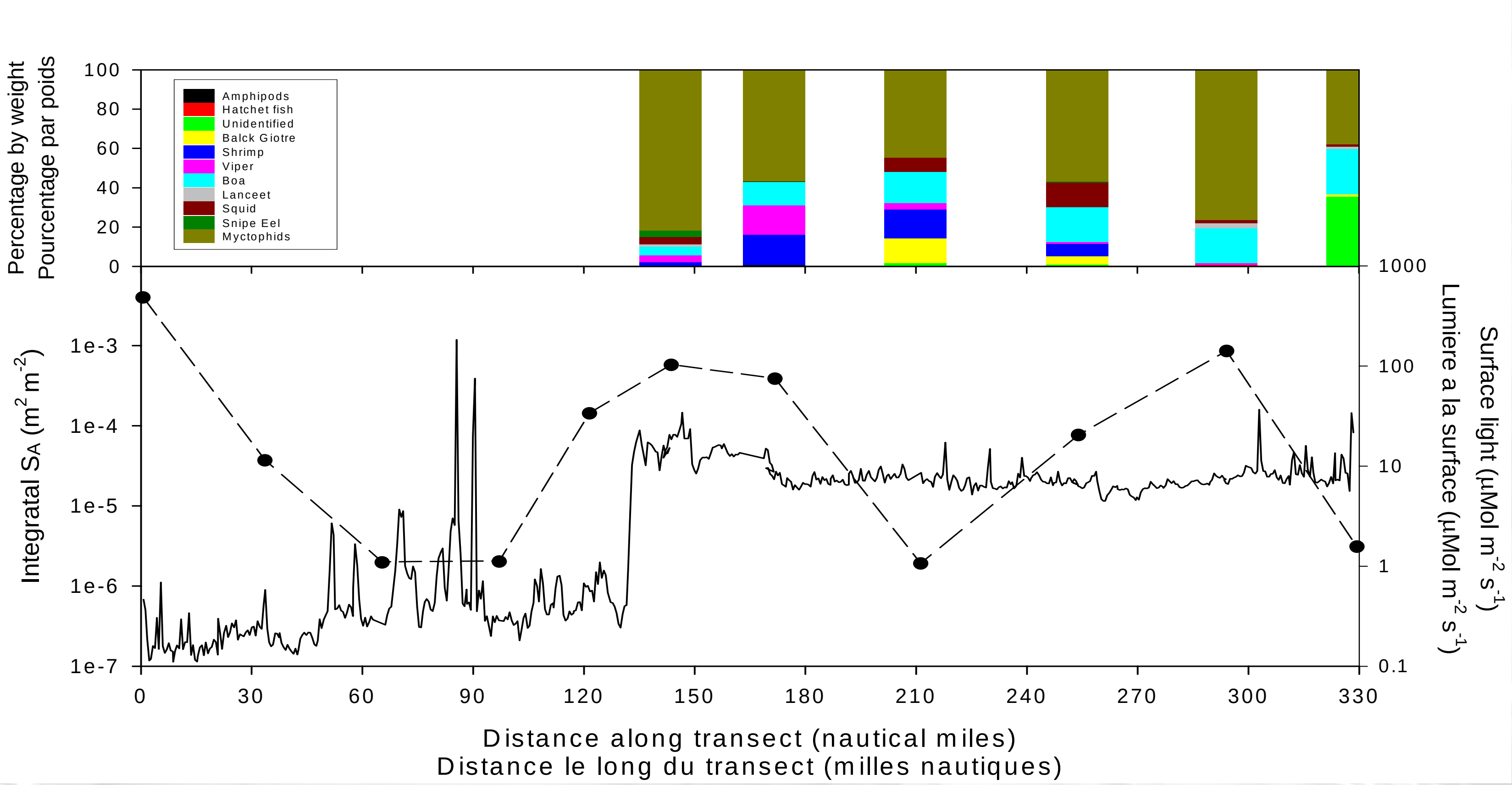
Deep scattering layer (DSL) is present throughout Labrador Sea

Average temperature at 400-500 m ~ 4°C

Observation program

Deep scattering layer (DSL) – 50-70% of biomass consists of myctophids

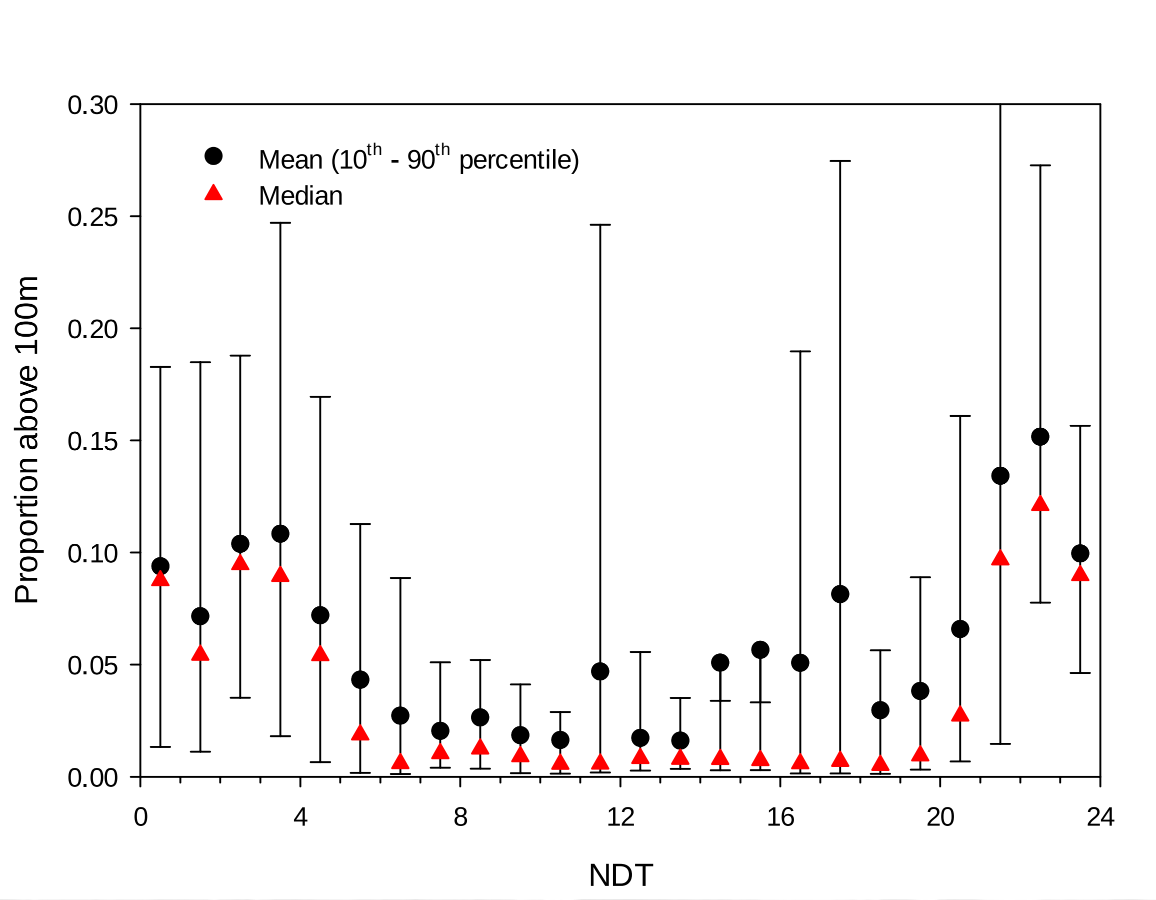
Background integrated Sv in Lab Sea ~ 10 – 80 times that found on NL Shelf



Abundance estimates

- Range of target strength measurements for myctophids
  - MacLennan and Forbes (1987) – TS = -61.7 dB
  - Torgersen and Kaartvedt (2001) – TS (modal) -63 -58 dB
  - Valinassab (2000) – TS = -60 -55 dB
  - Benoit-Baird and Au (2003) – TS = -44.8 dB
- Range of densities ~ 8 – 53 fish m^{-2}
- Range of biomass ~ 15 – 190 mt km^{-2}

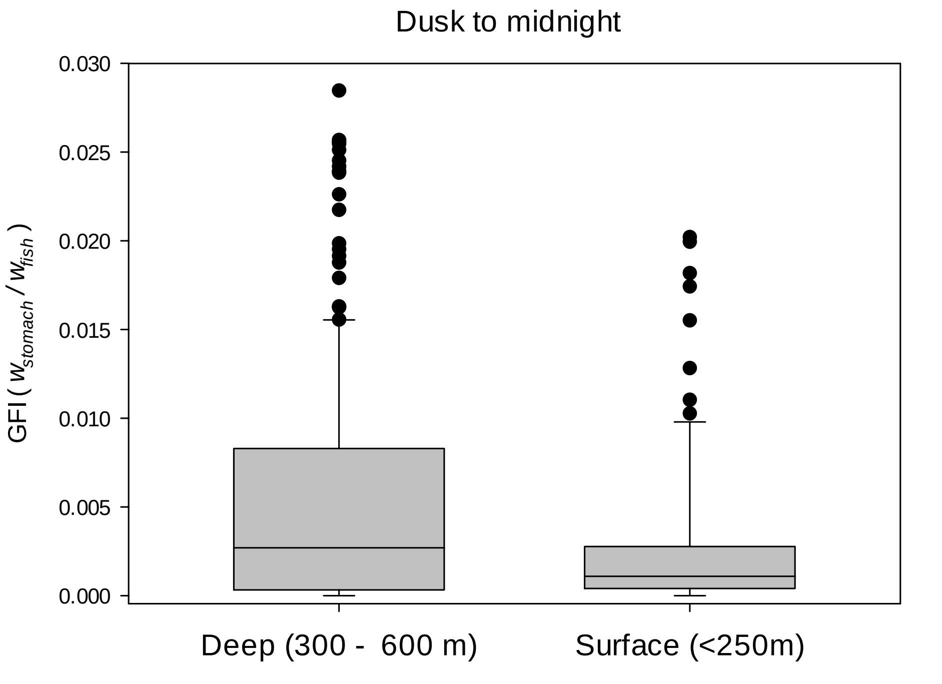
Observation program

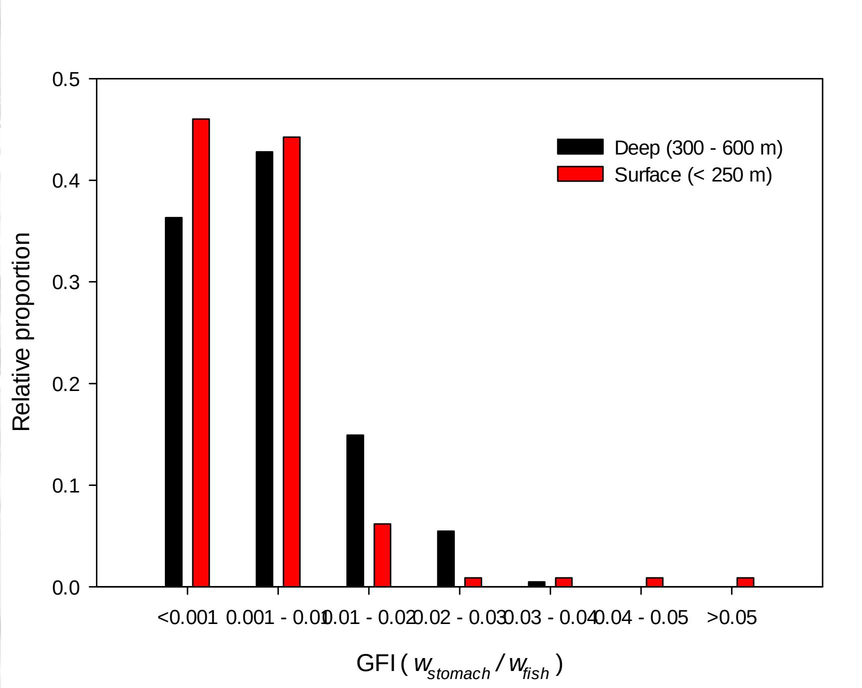


Extensive diurnal vertical migration of DSL but only in a fraction of DSL (10-25% of integrated Sv)

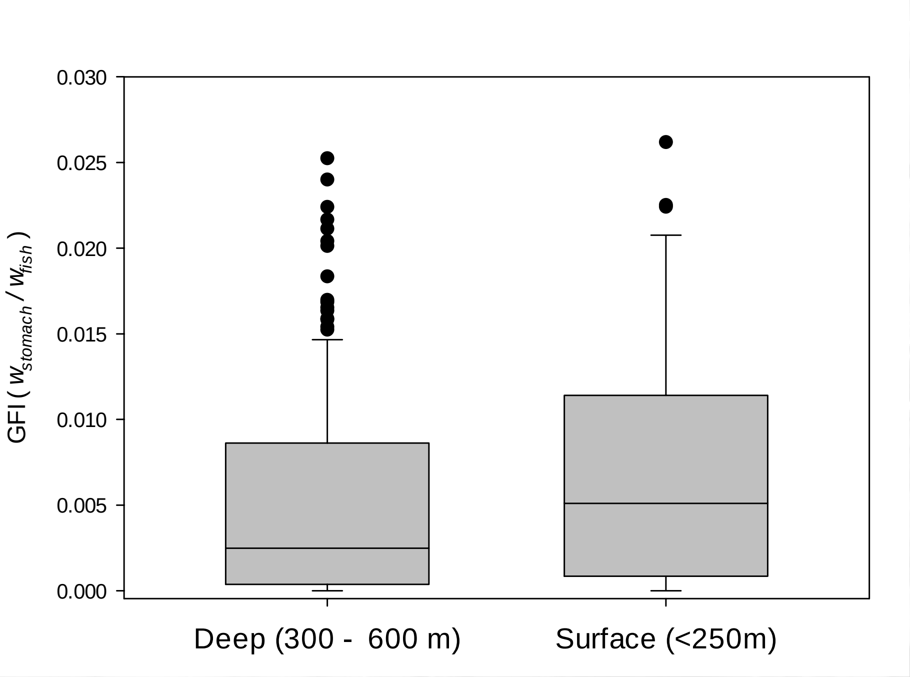
Difficult to determine whether there is replacement of individuals in upper layer

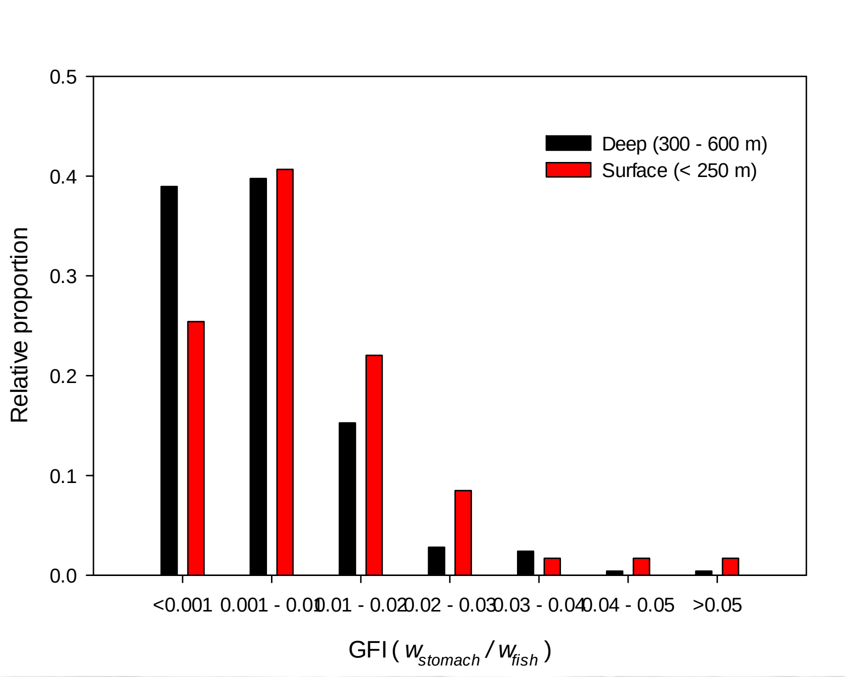
Dusk to midnight



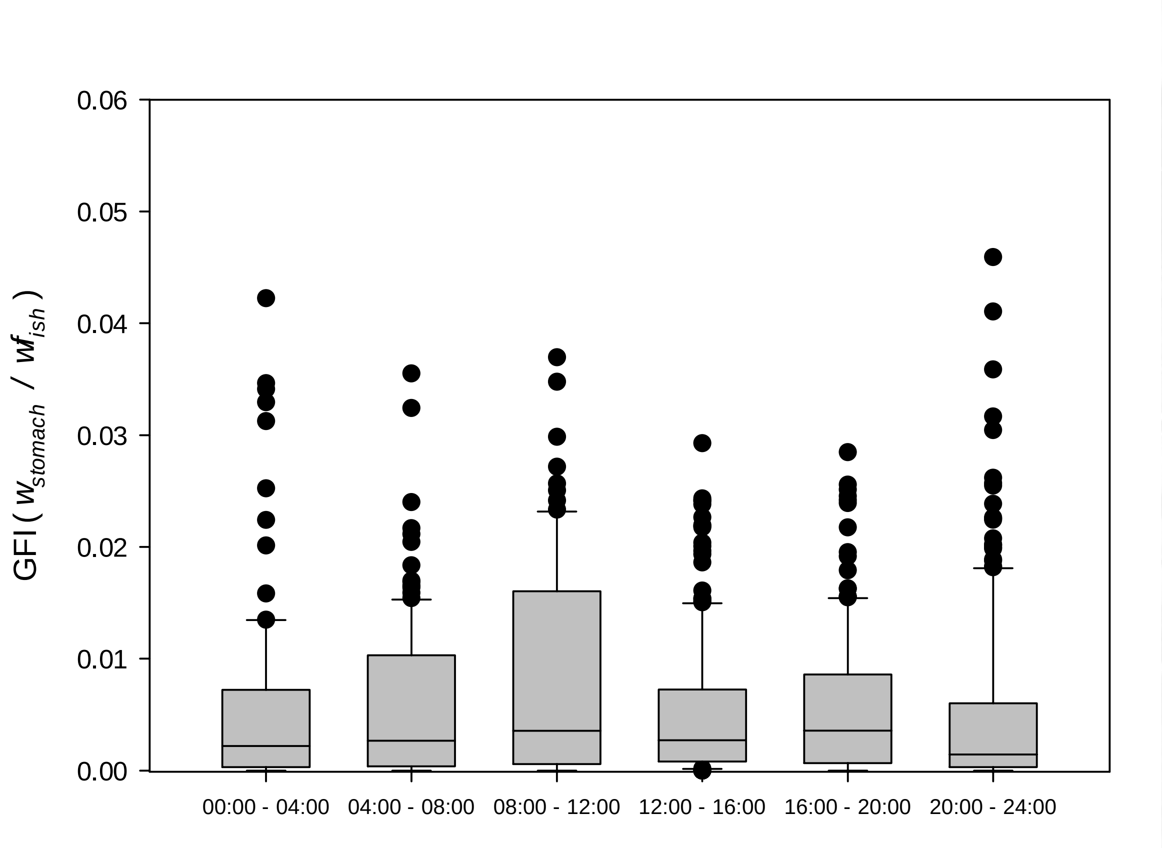


Midnight to dawn



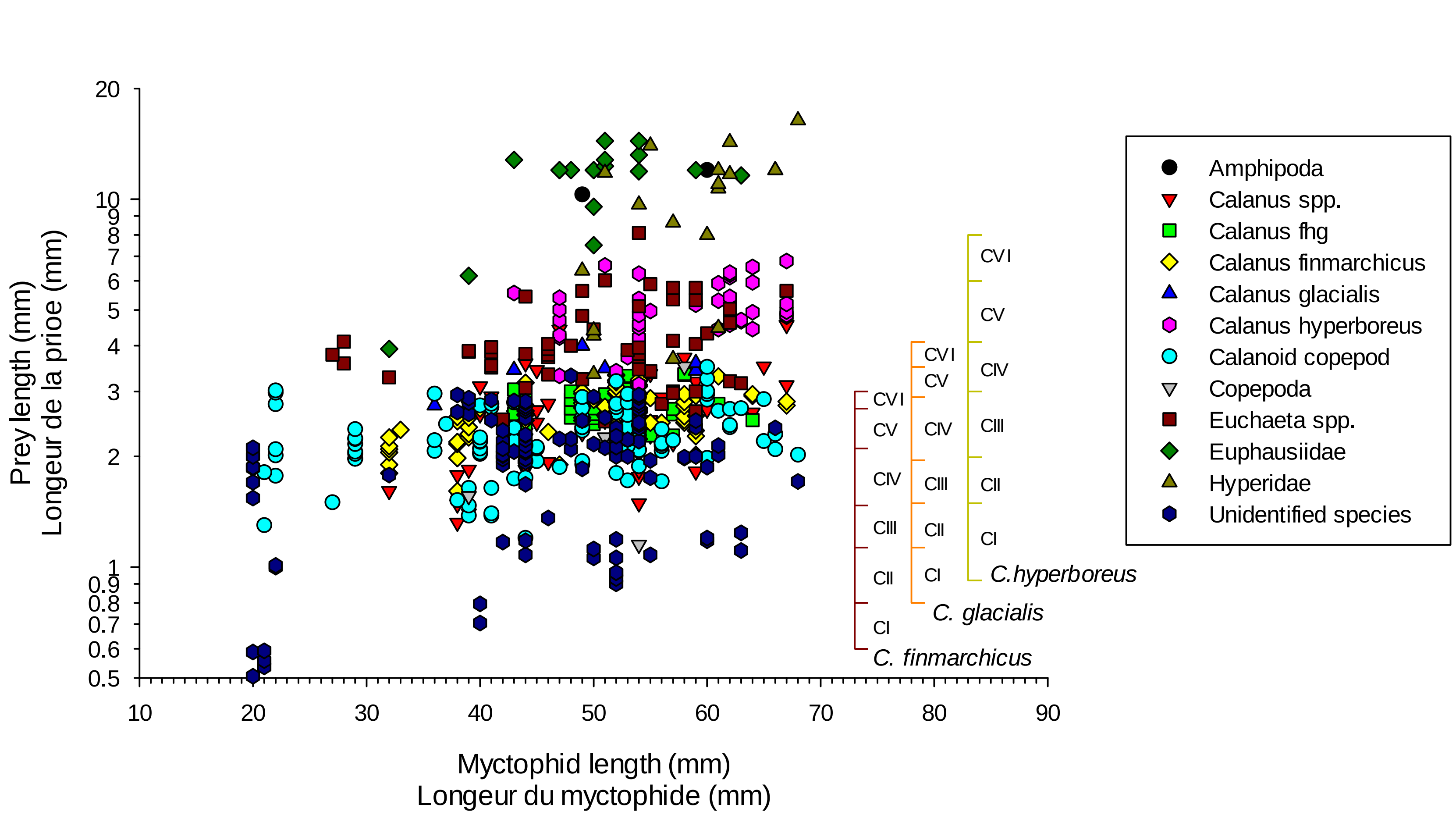


Diurnal cycle (300 – 500 m)

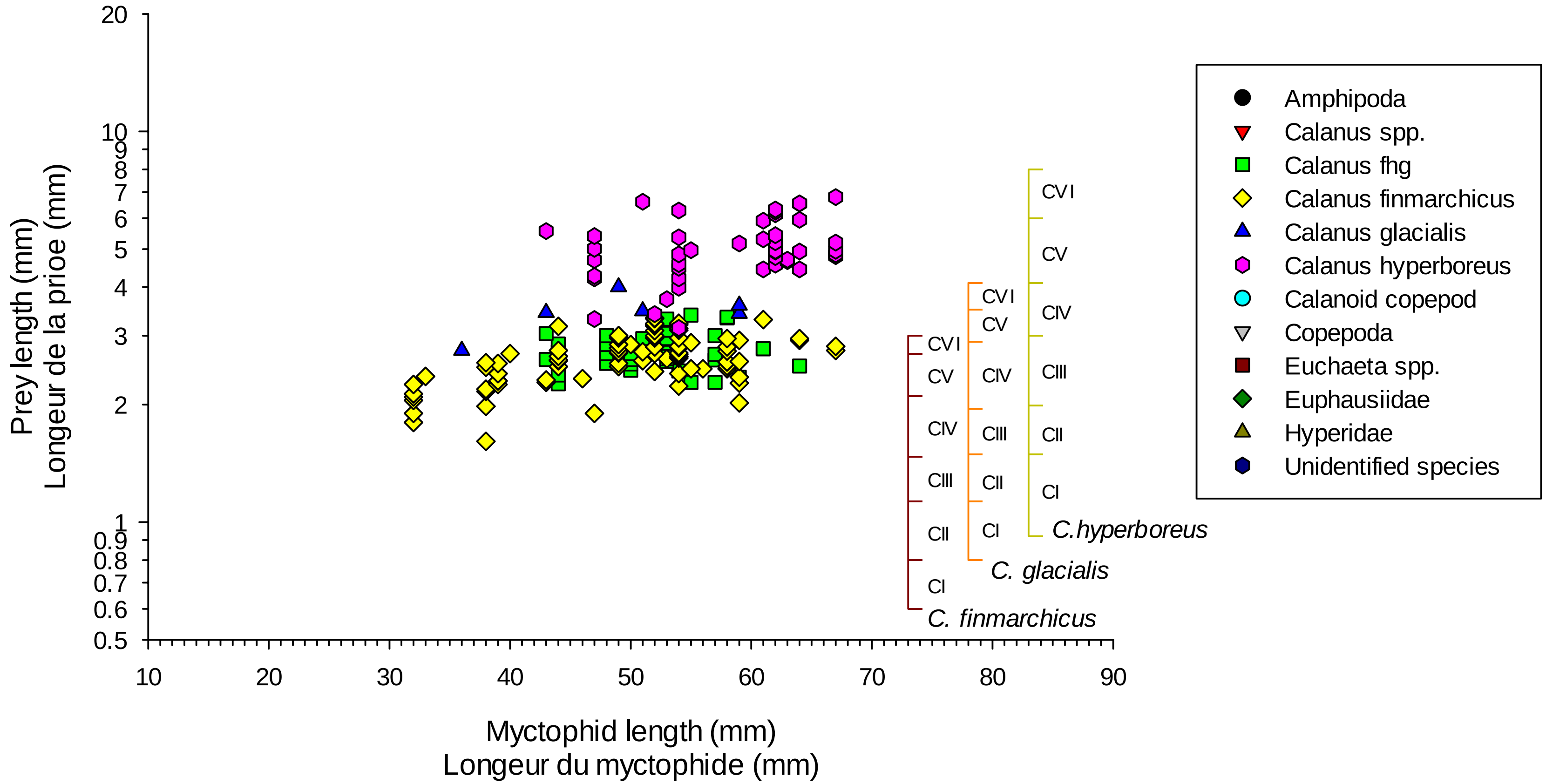


Vertical migration motivated by hunger level

Relative proportion of migrants suggests that turnover rates ~ 4 – 8 d



Prey length (mm)
Longeur de la prioe (mm)
Myctophid length (mm)
Longeur du myctophide (mm)
Amphipoda
Calanus spp.
Calanus fhg
Calanus finmarchicus
Calanus glacialis
Calanus hyperboreus
Calanoid copepod
Copepoda
Euchaeta spp.
Euphausiidae
Hyperidae
Unidentified species
C. finmarchicus
C. glacialis
C.hyperboreus
CVI
CV
CIV
CIII
CII
CI


Prey length (mm)
Longeur de la prioe (mm)
20
10
9
8
7
6
5
4
3
2
1
0.9
0.8
0.7
0.6
0.5
10
20
30
40
50
60
70
80
90
Myctophid length (mm)
Longeur du myctophide (mm)
CVI
CV
CIV
CIII
CII
CI
C. finmarchicus
C. glacialis
C.hyperboreus
Amphipoda
Calanus spp.
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Calanus hyperboreus
Calanoid copepod
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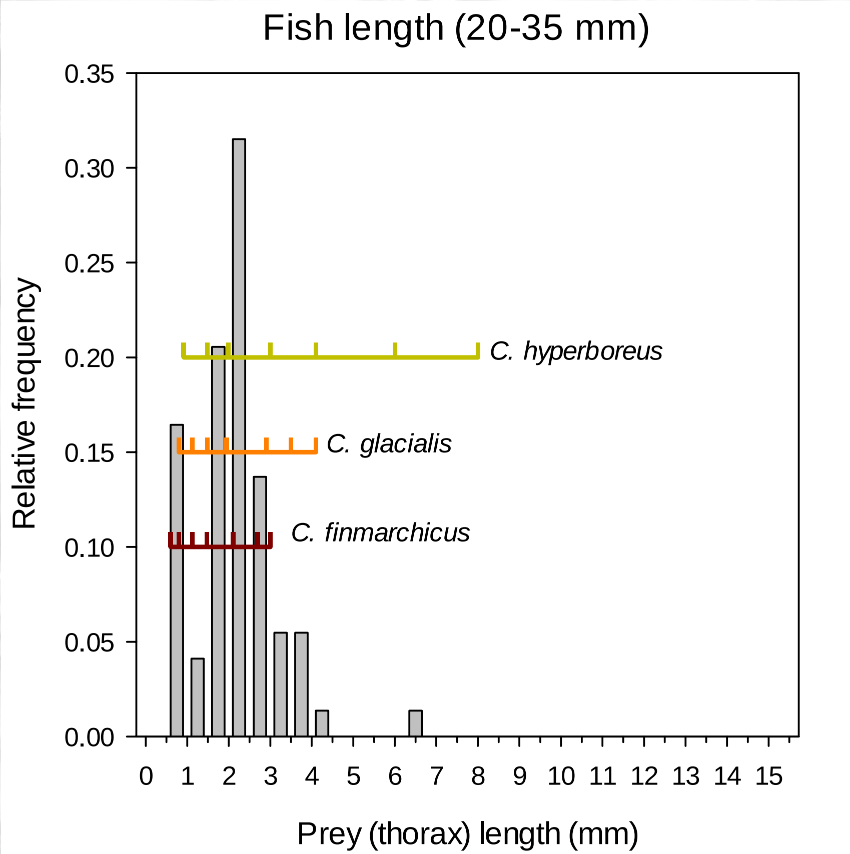
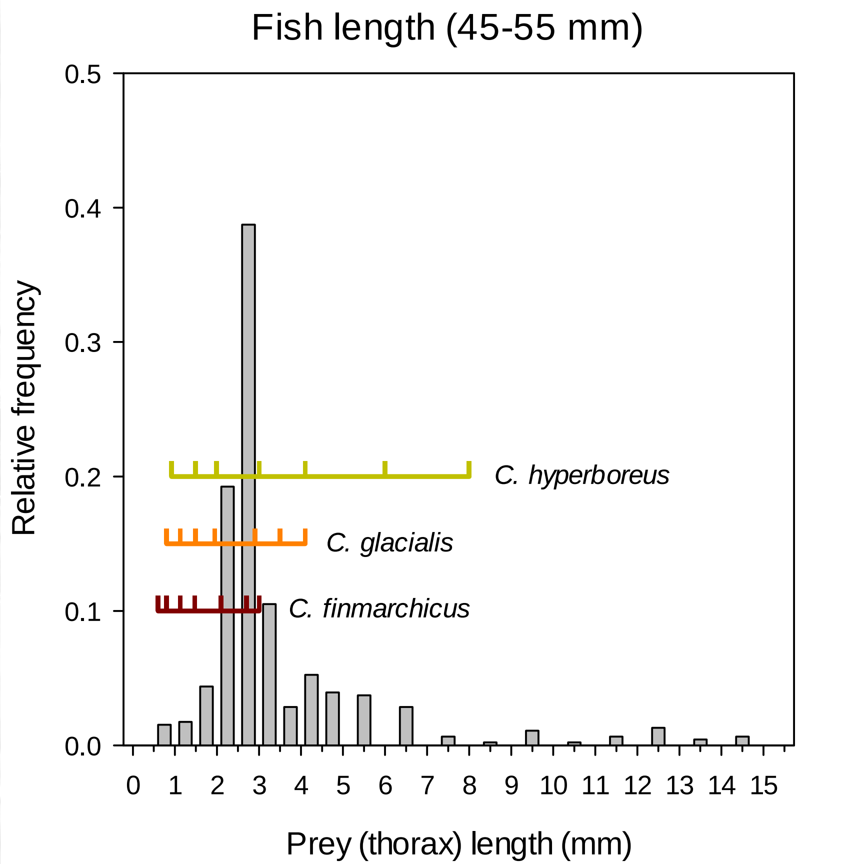

Fish length (20-35 mm)
Relative frequency
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Prey (thorax) length (mm)
C. hyperboreus
C. glacialis
C. finmarchicus


Fish length (45-55 mm)
Relative frequency
0.5
0.4
0.3
0.2
0.1
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Prey (thorax) length (mm)
C. hyperboreus
C. glacialis
C. finmarchicus

Analytical results – stomach contents

- Generalized linear model (Poisson error structure)
- Number of prey per fish
  - Fish length ($P < 0.001$)
  - Time of day ($P < 0.001$) [highest after dawn – lowest at dusk]
  - Positively affected by temperature (0-100m) ($P < 0.001$) Q_{10}~2.2
  - Temperature effect significant for fish sampled in surface layer and not significant for fish in deep layer

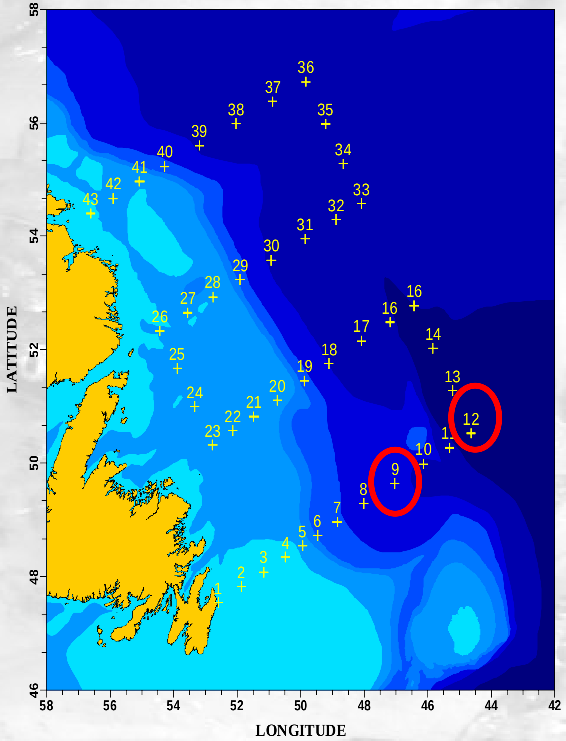
- General linear model (log-transformed GFI)
- GFI
  - Time of day ($P < 0.05$) [highest midnight to midday]
[lowest midday to midnight]
  - Negatively affected by temperature (300-500) ($P < 0.001$) for fish sampled in deep layer Q_{10}~1
  - No significant effect of temperature for fish sampled in surface layer

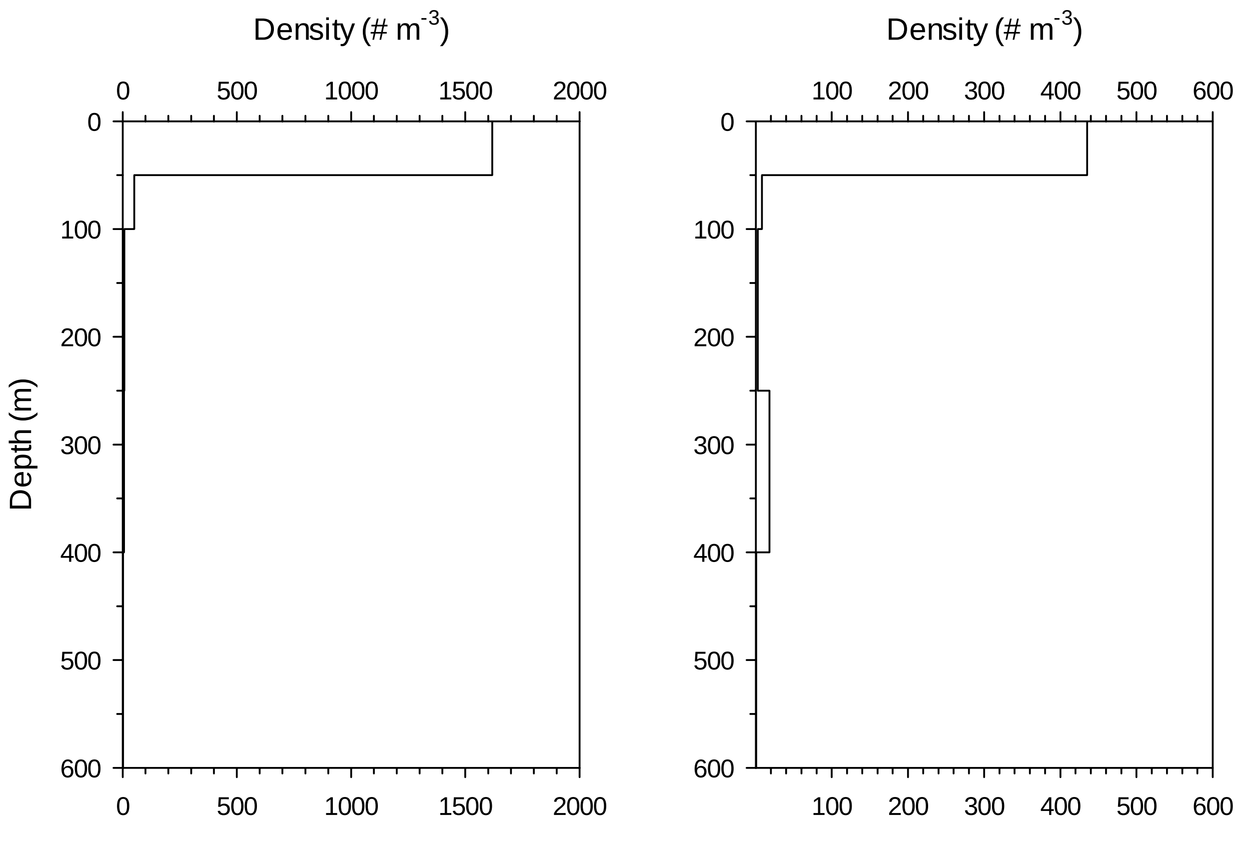
Analytical results – stomach contents

- General linear model (log-transformed prey length)
- Prey length
  - Significantly positively related to fish length ($P < 0.001$)
  - Not significantly affected by temperature ($P > 0.1$)
  - Significantly related to time of day ($P < 0.001$) [larger prey more frequent in stomach sampled midday to dusk]
  - Significant seasonal (June *vs* September) effect ($P < 0.001$) [probably a reflection of differences in availability – few larger copepods in August relative to June]

Vertical distribution of *C. finmarchicus*

Similar distributions for sister species





Analytical results – Mortality estimate

- Range of analytical assumptions
  - Fish density ~ 8 – 53 m^{-2}
  - Mean number of prey per fish (surface feeders) ~ 2 – 10
  - Turnover rate ~ 0.10 – 0.25 d^{-1}
  - Proportion of prey *C. finmarchicus* CIII-CVI ~ 0.6
  - *C. finmarchicus* density ~ 10,000 – 30,000 m^{-2}
  - Total consumption ~ <1 – 100 m^{-2}
  - Mortality 0.00004 – 0.008 d^{-1}

Summary and Conclusions

- The deep-scatter layer (DSL) is widely (and almost uniformly) distributed through the western Labrador Sea, with an overall biomass 8 – 190 mt km^{-2}
- On average, 70% of the biomass consists of *Benthosema glaciale*
- Preferred temperature range: 3.7 – 4.1°C
- Only 10 – 25% of the DSL migrates to surface waters daily
- *B. glaciale* that migrate to the surface appear to be motivated by hunger
- Digestion time / turnover rate ~ 4 – 10 days

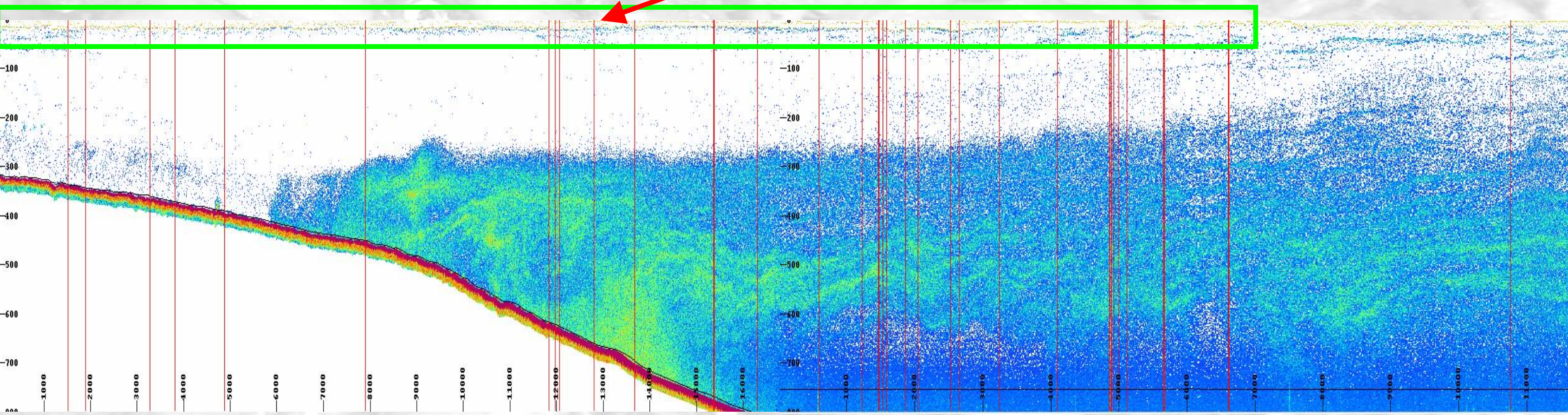
Summary and Conclusions

- Calanoid copepods make up 80% of the prey found in the stomachs
- Late stage *C. finmarchicus, C. glacialis* and *C. hyperboreus* are more prevalent in the stomachs than earlier stages of each species
- In contrast to expectations, measures of feeding activity (number of prey, GFI) are not equally affected by environmental temperature –
  - numbers of prey in surface feeders are positively affected by temperature (Q_{10} ~ 2.2)
  - GFI of fish in either surface or deep layers is negatively affected by temperature(Q_{10} ~ 1)
- Overall impact of *B. glaciale* on *C. finmarchicus* results in mortality rates < 1% d^{-1}

Issues for further research

- Analysis of feeding patterns in *B. glaciale* requires further assessment
  - Role of hunger in motivating activity and feeding pattern
  - Effect of local prey availability on feeding activity (numbers, biomass, selection)
  - Metabolic activity in cold environments???
- Other sources of mortality for *Calanus* in the region?

~100% Themisto libellula



In the Gulf of St. Laurence, A. Marion (University du Quebec, Rimouski) estimated that *T. libellula* could ingest ~2 % of the mesoplankton community, and exert a predation rate of ~3% d^{-1} on *C. finmarchicus* (CIV – CVI).

***B. Glaciale* may play a role in dynamics of *C. finmarchicus* but role of invertebrate predators needs to be investigated (greater overlap, turnover rates, local density)**


Thank you