What can we learn about mortality and survival of *Calanus finmarchicus* from monitoring data?

An example from the PMZA

Stéphane Plourde

Collaborators:

Pierre Pepin (NWAF) & Erica Head (BIO) (PMZA)

Frédéric Maps (ISMER) & Pierre Joly (Station Rimouski-GSL)

- **Describe the long-term stage-specific mortality patterns in *C. finmarchicus* using data collected as part of the Atlantic Zone Monitoring Program (AZMP) with the Vertical Life Table appraoch (VLT)**

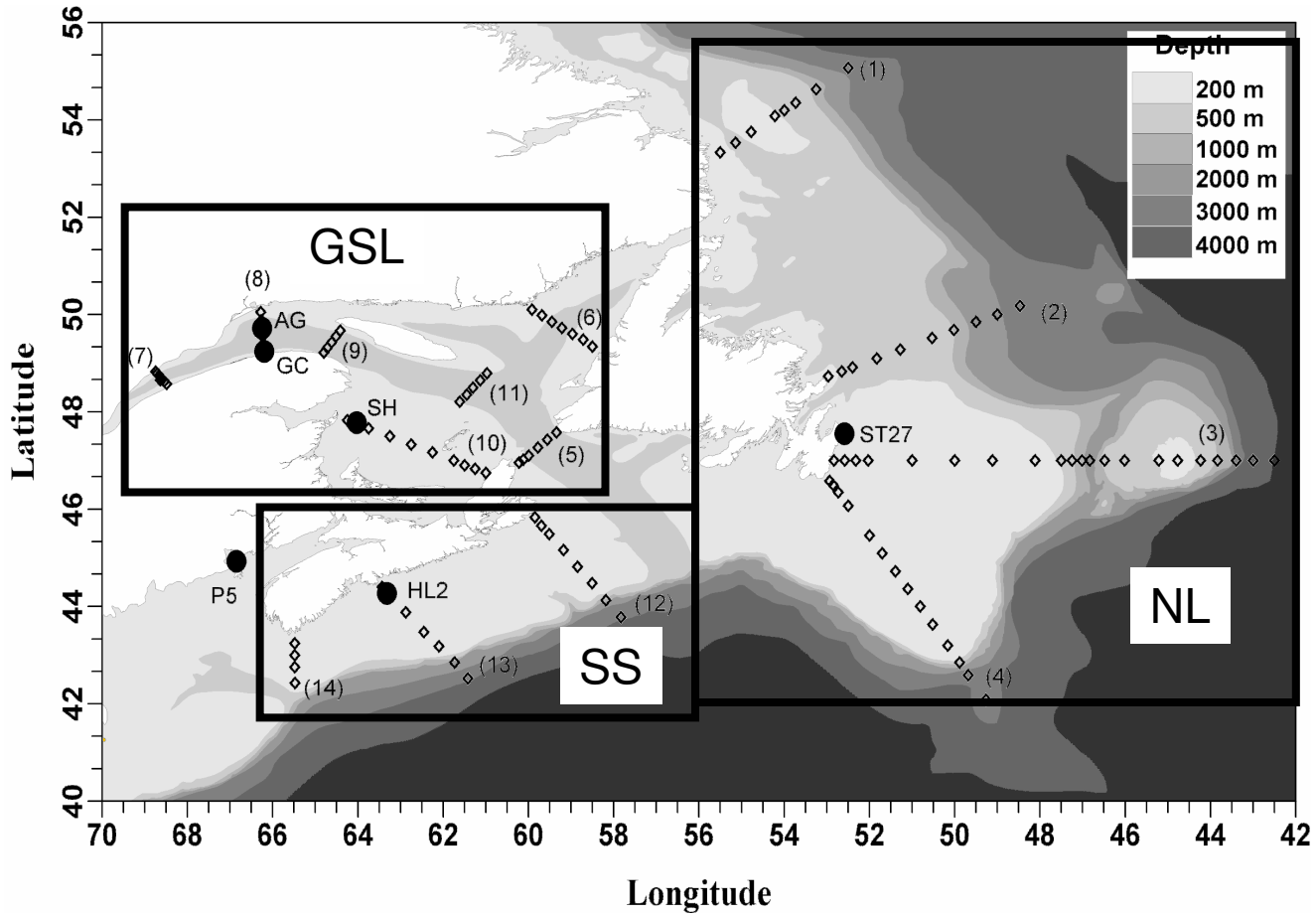
- **Describe and compare long-term stage-specific mortality and survival in *C. finmarchicus* (1) in the Gulf of St. Lawrence (GSL), Newfoundland shelf (NL) and Scotian Shelf (SS) and (2) during different seasons**

- **Build climatologies of 'survival trajectory' of *C. finmarchicus* population in different regions and during different seasonal: representation of the effect of mortality X temperature on population dynamics**

- **Describe long-term seasonal pattern in mortality in egg-N3**

- **Describe potential relationships between daily mortality vs environment: temperature, phytoplankton biomass (proxy food), *C. finmarchicus* C6f (cannibalism, density-dependent processes)**

S. Plourde, P. Pepin, E Head (accepté) ICES Journal of Marine Science



Mortality and survival of *Calanus finmarchicus* AZMP 2000-2006

- **AZMP lines visited in April (SS, NL), June-July (GSL-NL) and in October-November (GSL, NL, SS) from 2000 to 2006 (n= 1892)**

- **Zooplankton sampled with a 0.75-m, 200-µm mesh net from bottom (or 1000 m) to surface**

- **Abundance of C1 to C6 of *C. finmarchicus***

- **Environmental variables at each station: temperature (0-50 m) et Chl *a* (0-25 m)**

- **Development time (DT): estimated from temperature (0-50 m)**

- **VLT and environmental data: applied to data averaged on each line to gain robustness (but n= 204); similar than than using min of 6-10 replicates to obtain reliable mortality estimates (Asknes & Ohman 1996)**

-**PopEpr: estimated with region-specific functional relationships Epr vs Chl *a* in GSL (Plourde et al. 2008) and on NL-SS (Head unpublished)**

- **Examination of population structure among regions (not shown):**

    - **Data SS (April) and June-July (GSL-NL): population 'Growth' season**

    - **Data GSL-NL-SS in OCtober-November: Fall season**

Equations Vertical Life Table (VLT) (Ohman et al. 2002)

$$\frac{A_i}{A_{i+1}} = \frac{\exp^{mD_i} - 1}{1 - \exp^{-mD_{i+1}}}$$

- **Joint mortality in sucessive stages**

$$\frac{A_{C1}}{PopEpr} = \frac{\exp^{-mD_{egg-N6}}\left[1 - \exp^{-mD_{C1}}\right]}{m}$$

- **Mortality Egg-C1 using PopEpr**

$$m = \frac{\ln\left[\frac{A_{C5}}{A_{C6}} + 1\right]}{D_{C5}}$$

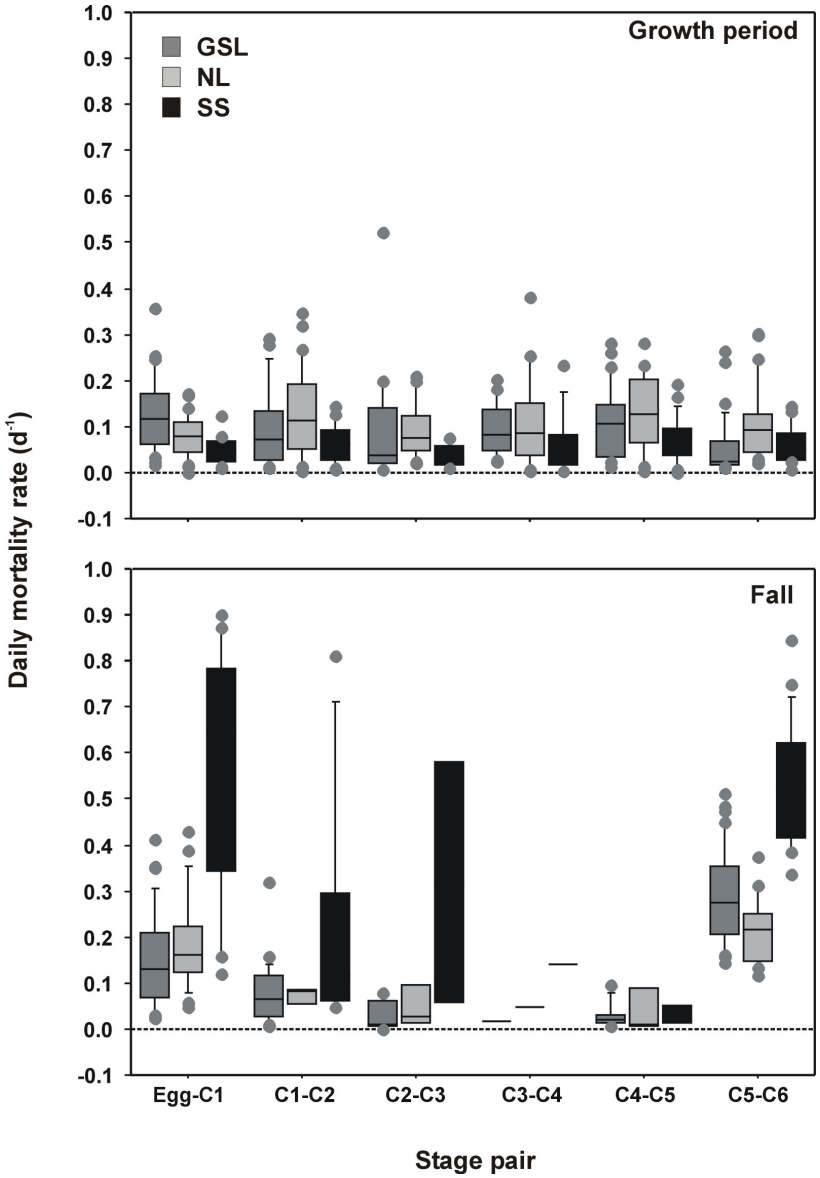
- **Mortality C5-C6**

$$S_{i+i+1} = \exp(-m_{i,i+1} \times D_{i,i+1})$$

(Hirst et al. 2007)

- **Proportion surviving through each stage pair: integration of daily mortality rate during development**

Mortality and survival of *Calanus finmarchicus* AZMP 2000-2006



- **Mortality rates different among 'Growth period' and Fall (Mann-Whitney, $p<0.0001$)**

- **Mortality varied among regions within each season (Kruskall-Wallis, $p<0.0001$)**

- **Mortality rates very high in Fall on SS, in particular in egg-C1 and C5-C6**

- **Mortality in C4-5 and C5-6: effect of C5 in diapause**

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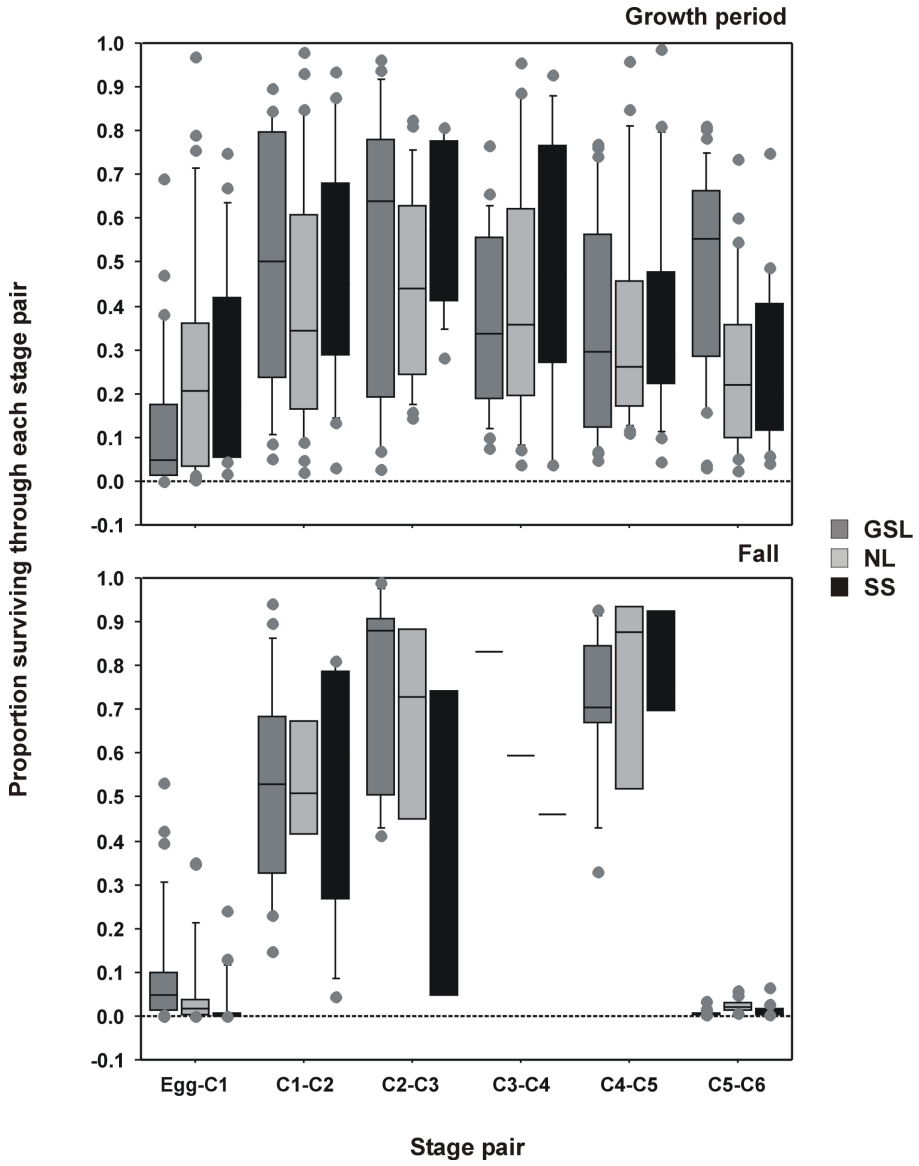

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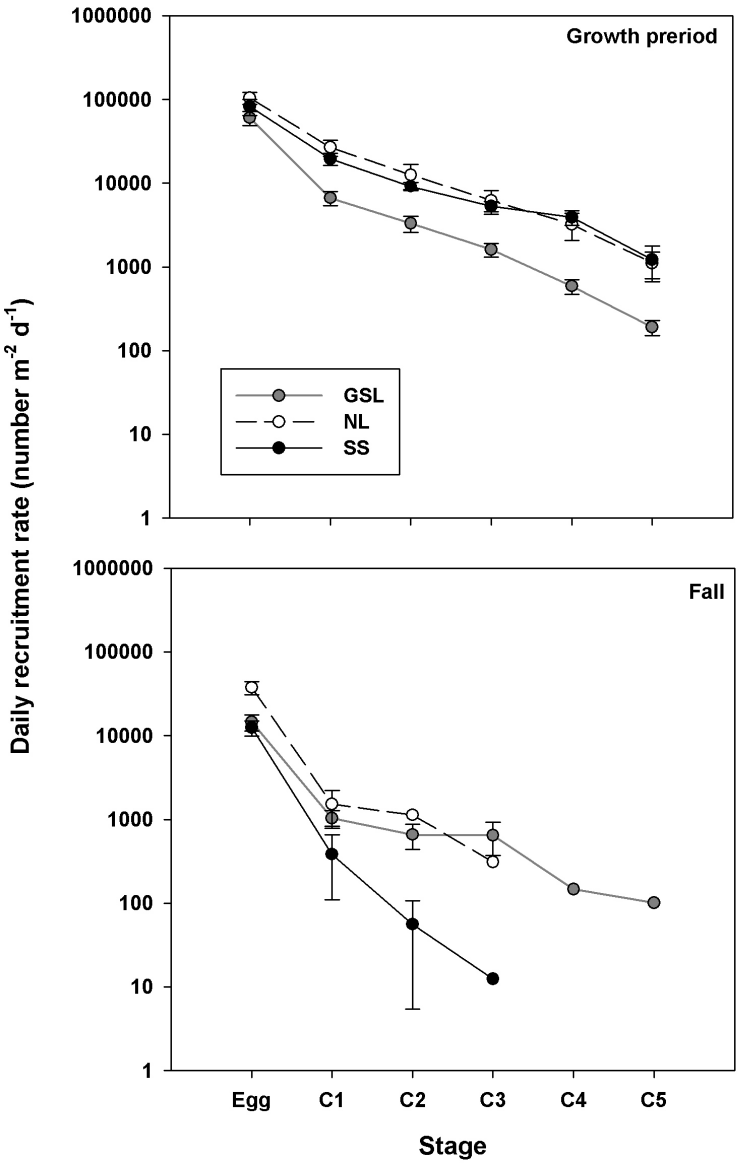


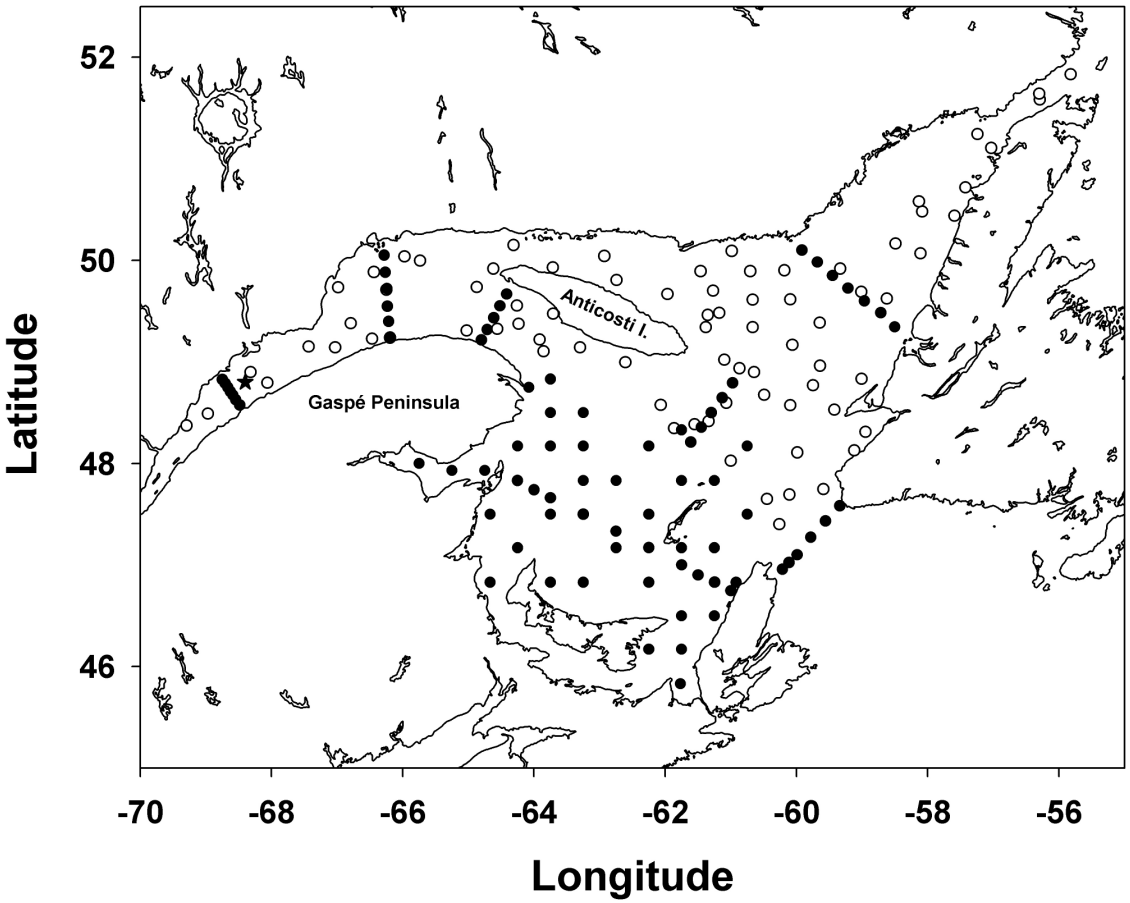
- PopEpr X survival egg-C1= C1 m^{-2} d^{-1}
- C1 m^{-2} d^{-1} X survival C1-C2= C2 m^{-2} d^{-1}
- etc…..
- 'Survival trajectories' in regions and seasons
- Representation of how a population model would work (stage-specific daily recruitment= transfert functions)

- 'Growth period': lower survival egg-C1 in GSL= lower recruitment than on NL and SS
- Trajectories C1-C5: similar in GSL, NL, SS

- Fall: low survival egg-C1 in all regions
- SS: very low survival and recruitment to C3

- Population losses: > during egg-C1
- Could be very important to determine the overall success of the population

S. Plourde, F. Maps, P. Joly (2009) Journal of Plankton Research 31 (4): 371-388

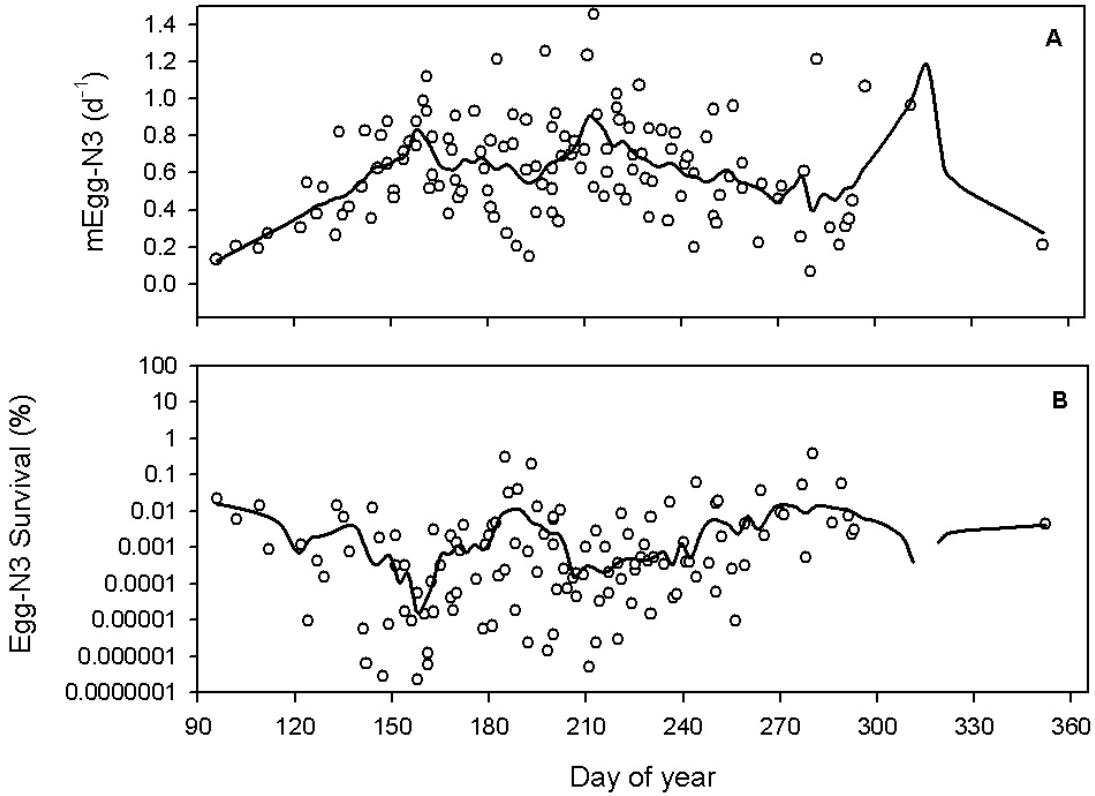


- **Long-term seasonal pattern in mortality egg-N3 at Rimouski station: fine mesh samples (73-µm) (7 years)**

- **Environnement: temp (0-30 m), chl a (0-50 m), C6f m^{-2}**

- **Also (not shown): Spatial pattern mortality-N6 in GSL in June (filled circles) and August (open circles)**

Mortalité et survie de *Calanus finmarchicus* STN Rimouski 1994-2006 and GSL 2006



-**Lowess fit used to described seasonal climatology**

- **mortality egg-N3 not constant, varies with time with resulting 3 orders of magnitude changes in survival egg-N3**

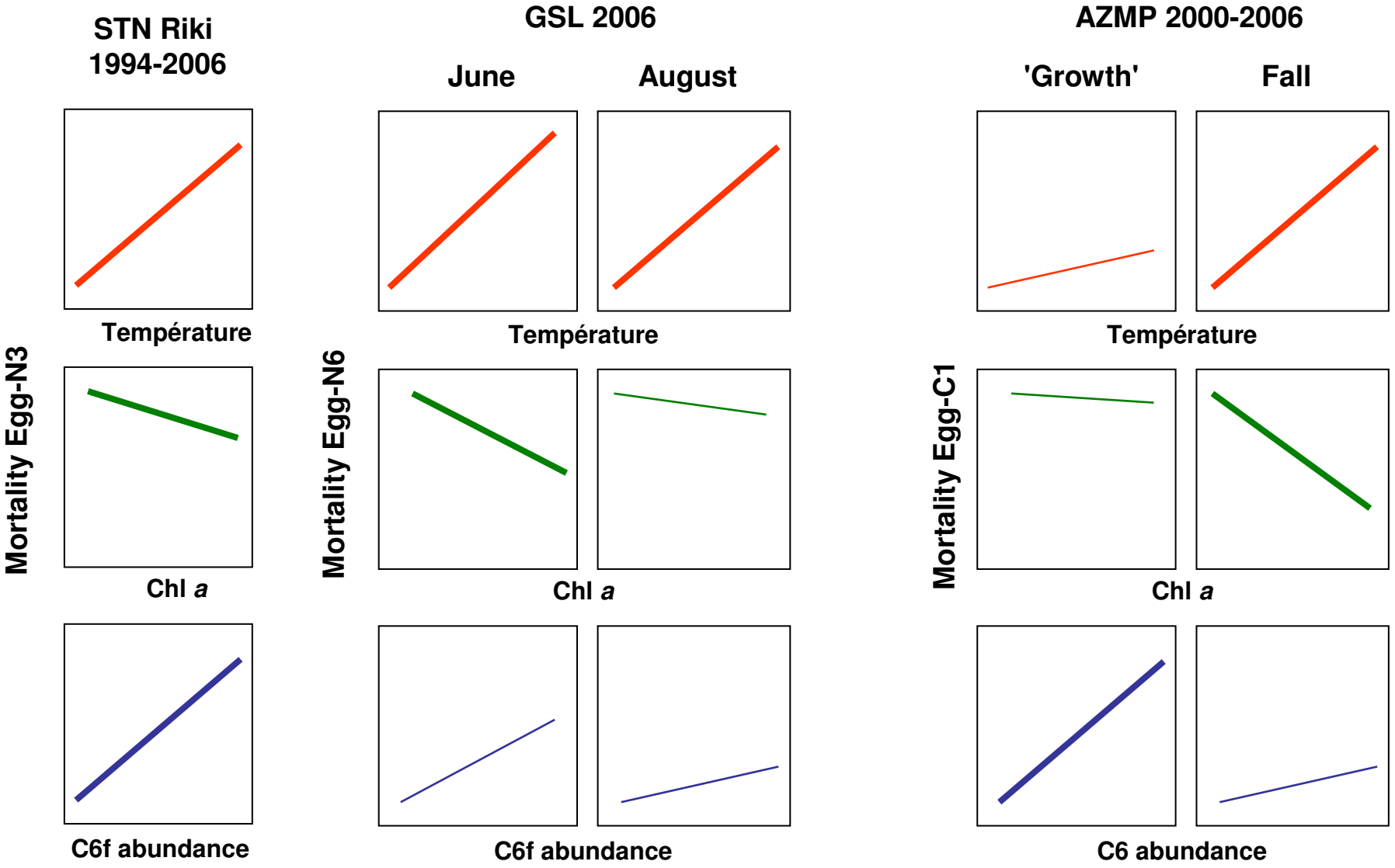
AZMP 2000-2006: Daily mortality rate vs temperature

Stage	r^2	*p*-value	*a*	*b*
Egg-C1	0.700	<0.0001	0.033	0.214
C1-C2	0.074	0.003	0.074	0.074
C2-C3	0.172	<0.0001	0.033	0.159
C3-C4	0.177	0.0007	0.048	0.110
C4-C5	0.171	<0.0001	0.050	0.100
C5-C6 Growth	0.659	<0.0001	0.015	0.253
C5-C6 Autumn	0.802	<0.0001	0.137	0.105

- **Significant relationship mortalité vs temperature in all stage pairs**

- **High R^2: egg-C1 et C5-C6**

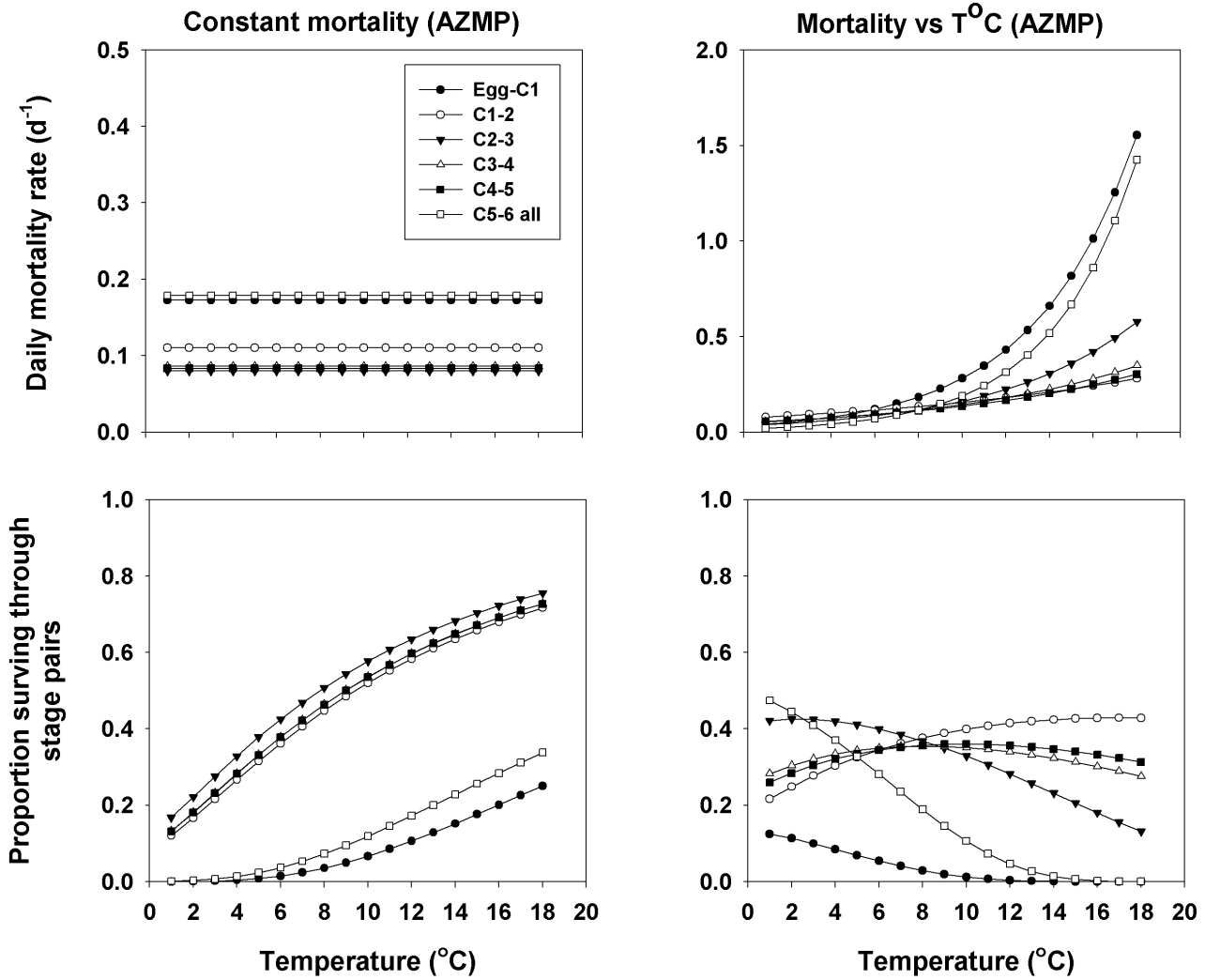
Summary of different multiple linear regression models (all p< 0.05)



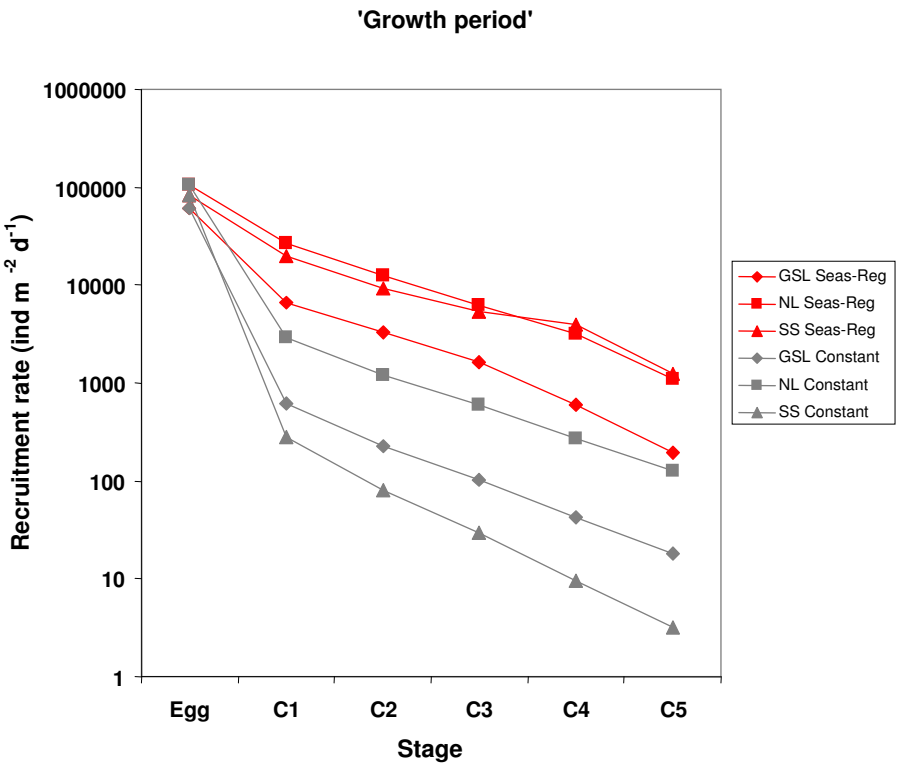
Data source: Plourde et al. (2009) JPR 31 (4): 371-388

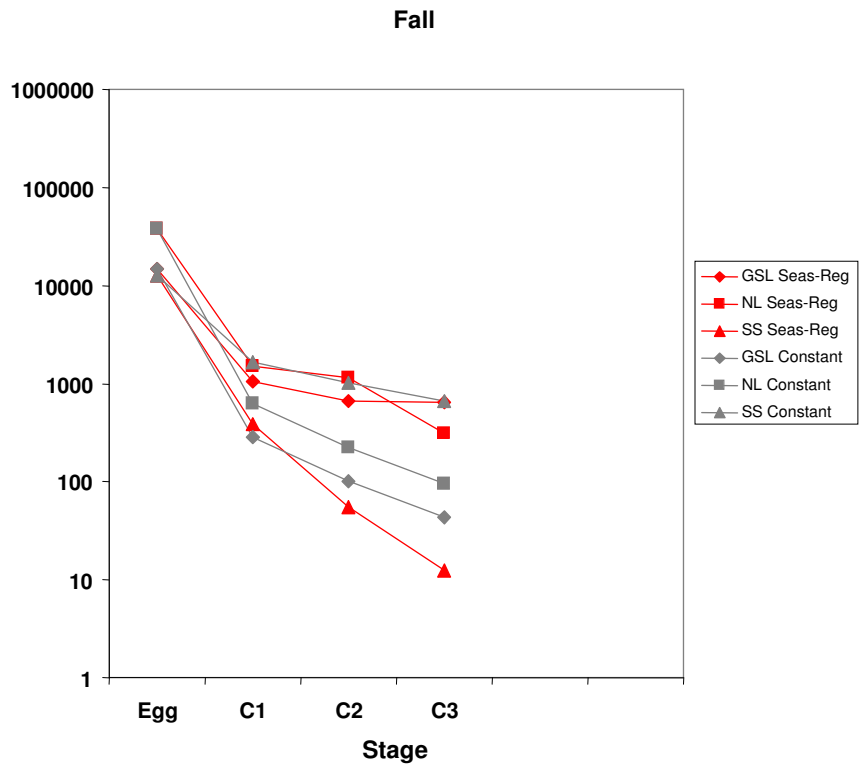
Plourde et al. (accepted) ICESJMarSci

Using averaged (constant) mortality vs temperature-dependent mortality: results in very different survival

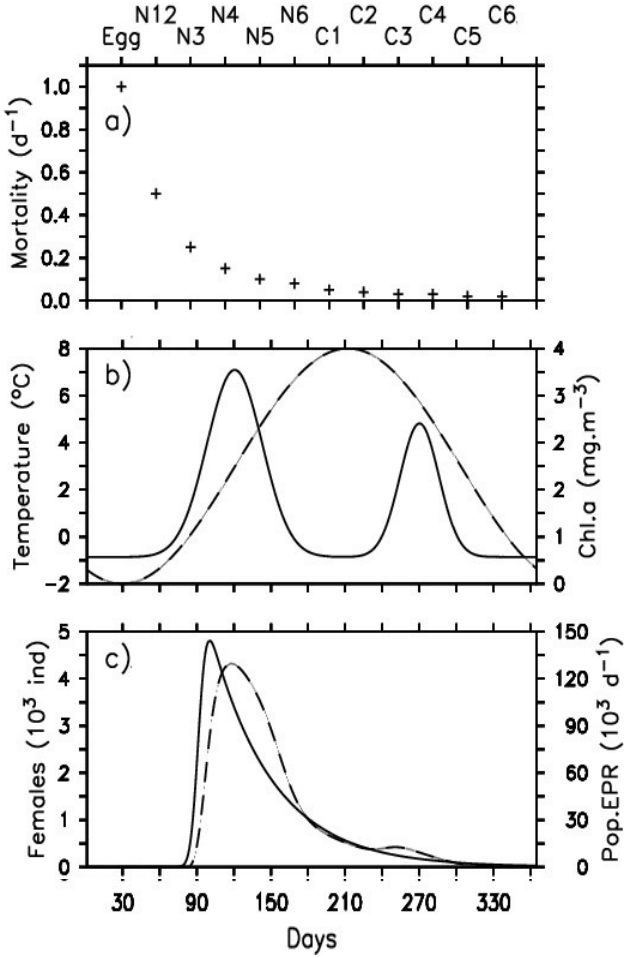


Using averaged (constant) AZMP mortality (grey) vs region-seasonal specific mortality (red) from AZMP: results in very different survival trajectory





Impact de l'utilisation de fonctions mortalité vs environnement: exemple mortalité œufs-N3 (Stn Riki) (Plourde et al. 2009)



Constant mortality all stages

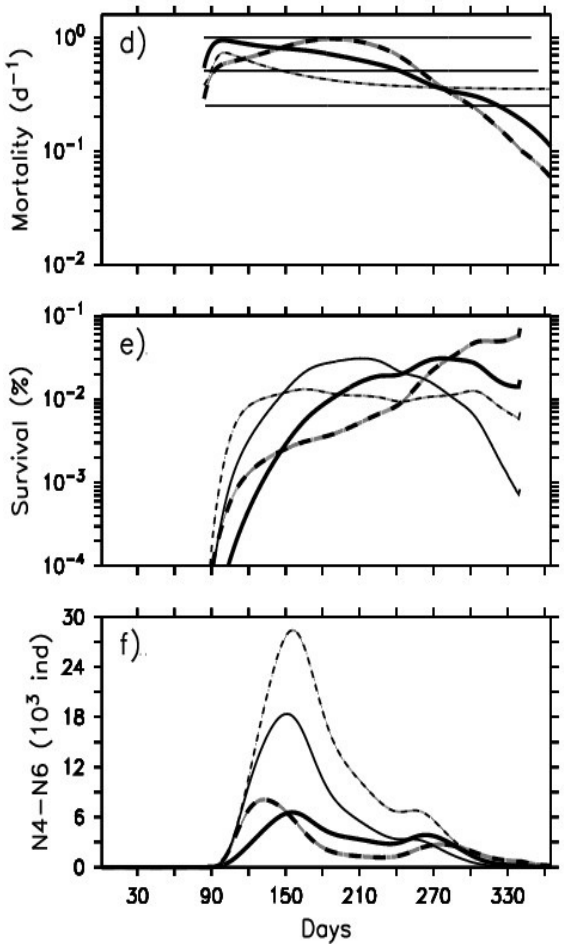
mEgg-N2 vs C6f (Ohman et al. 2002)

mEgg-N3 vs Chla-C6f (Plourde et al. 2009)

mEgg-N3 vs Chla-C6f-T°C (Plourde et al. 2009)

- **different mortality formulations in early stages resulted in marked different population response**

- **inclusion of temperature: modification of the timing of max N4-6 by 3-4 weeks (change in ontogeny)**



S. Plourde proposed work: Pan-Regional study of mortality and survival of *C. finmarchicus* using long-term monitoring data

- **Describe and compare long-term stage-specific mortality and survival in different regions in the north Atlantic using a similar approach (development stages, VLT): necessary for comparability**

-**Describe relationships between daily mortality vs environment: temperature, phytoplankton biomass, *C. finmarchicus* C6f (cannibalism, density-dependent processes)**

  - **Region-specific functional relationships or 'universal' functions?**

  - **Deep basins vs continental shelves?**

  - **Northeast vs Northwest Atlantic?**

- **Criteria for selection of data sets**

  -**Multiyear data sets of *C. finmarchicus:* spatial surveys and/or fixed monitoring sites**

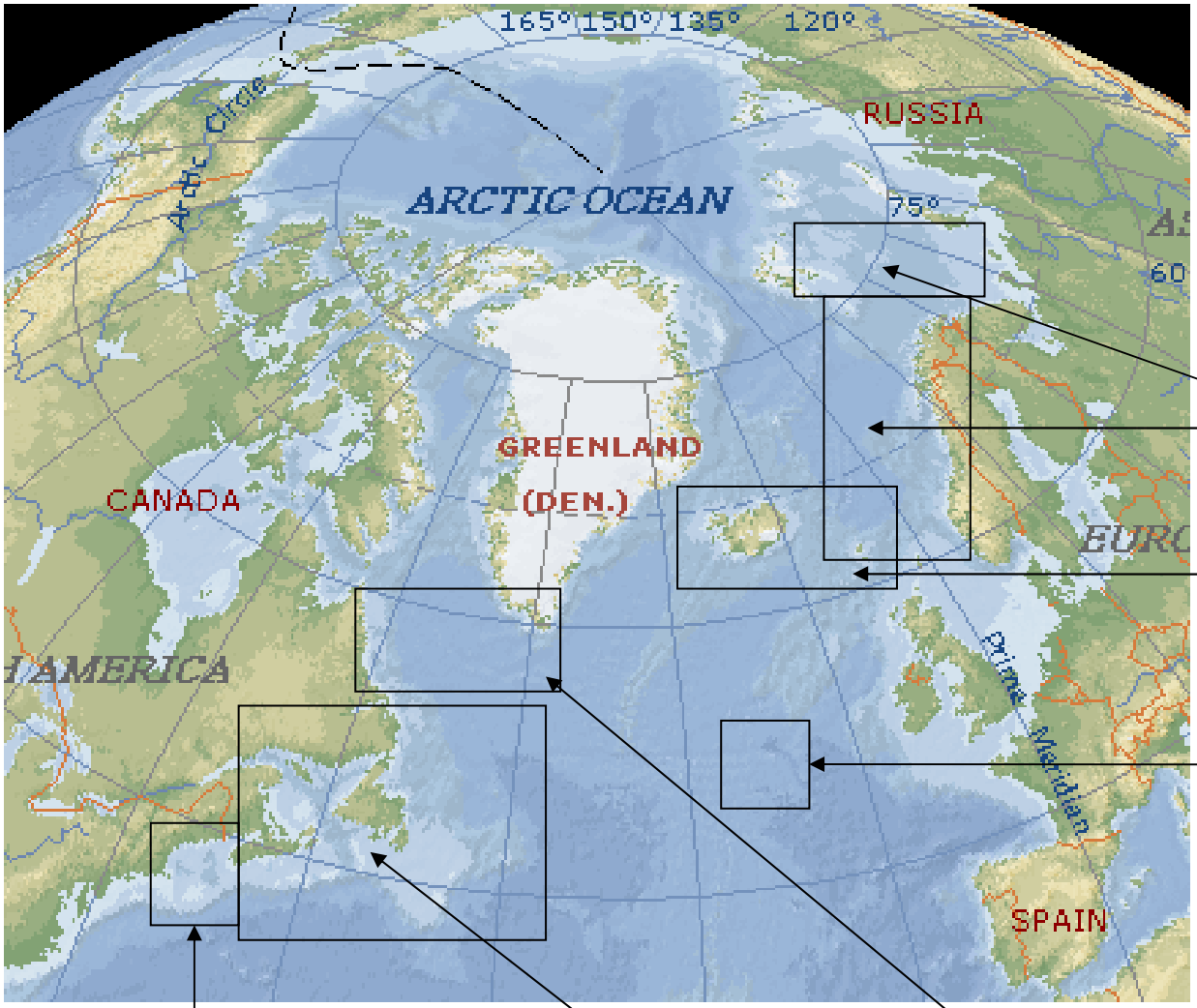
  -**Mesh size: 158-µm or 200-µm (abundance of C1 to C6)**

  -**Need for environmental data associated to *C. finmarchicus* data base**

    - example: I am not sure…. but no Chl a during USGLOBEC broadscal surveys on GBank. Use of satellite data?

Mortality and survival of *Calanus finmarchicus*

Potential data sets



Norwegian Sea and Barents Sea (Melle et al.)

Iceland (Gislason et al)

Station India (Irigoien, Harris)

Georges Bank-GoMaine (Ohman, Durbin, Runge, etc…

AZMP (Plourde, Pepin, Head, Johnson)

Labrador Sea (Head et al)