Revealing the link between prey availability during the larval stage and recruitment strength in small pelagic fish

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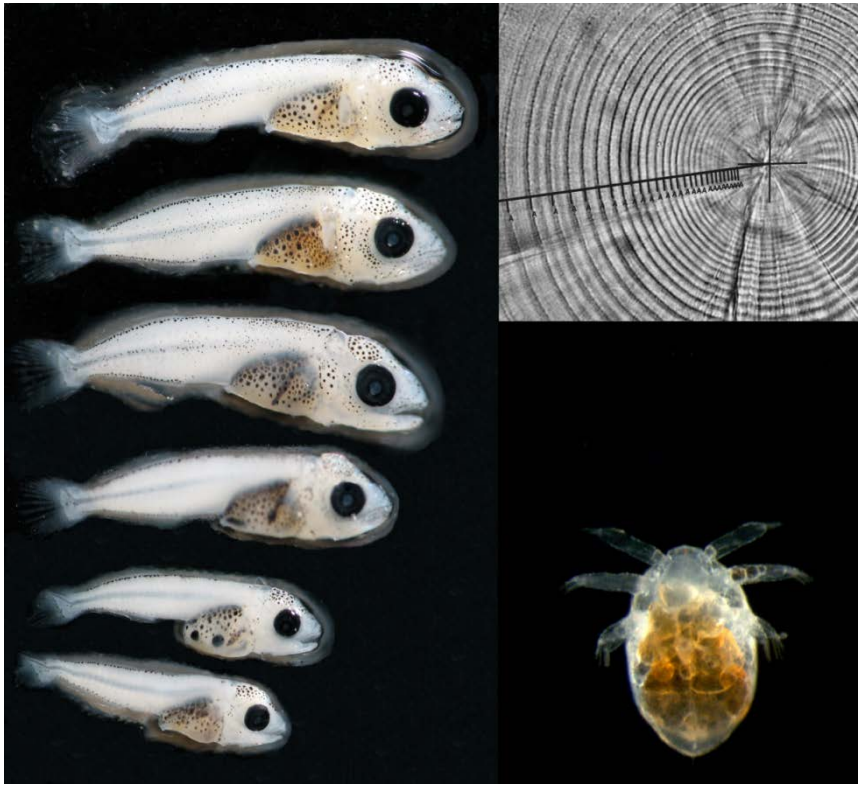
International symposium on the drivers of dynamics of small pelagic fish resources

March 6th, 2017



UQAR SMER
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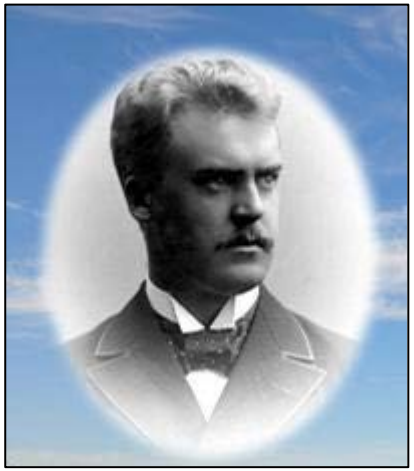
Canada Research Chair in Fisheries Ecology

Outline of presentation

1. **Conceptual framework on variability in recruitment**
2. **Diet and prey selectivity during the larval stage of fish**
3. **Relationships linking prey availability to vital rates and recruitment**
4. **Species-specific variability in the potential timing of a 'Critical Period' for recruitment**
5. **Concluding remarks**



Critical Period Hypothesis

(Hjort 1914)

"the numerical value of a year-class is determined at a very early stage, and continues in approximately the same relation to that of other year-classes throughout the life of the individuals"

- Hjort 1914

Key assumptions behind Hjort's Critical Period:

1. **<u>Prey availability</u>: Determined by the difference in timing between larval fish emergence and the seasonal peak in secondary production**

2. **<u>Prey suitability</u>: Determined by the capacity of potential prey to provide a net energy intake sufficient to fuel fast growth**

Larval Stage and Recruitment

Several trophic hypotheses based on growth were inspired from Hjort's seminal publication (Cushing 1972, Lasker 1978, Cury & Roy 1989, Anderson 1988). Top-down mechanisms in addition to concept of bottom-up control.

Three complementary mechanisms predict increased survival probability in fast-growing individuals:

1. **Bigger is better (e.g. Miller *et al*. 1988) : Larger individuals at a given age are less vulnerable to planktonic predators**
2. **Stage duration (e.g. Chambers & Leggett 1987) : Fast-growing larvae reach juvenile stage at younger age, reducing total cumulative mortality during larval period, when mortality rate is maximal**
3. **Growth-selective predation (Takasuka *et al*. 2003, 2007) : Fast-growing individuals are less vulnerable to predators at a given size**

Larval Stage and Recruitment

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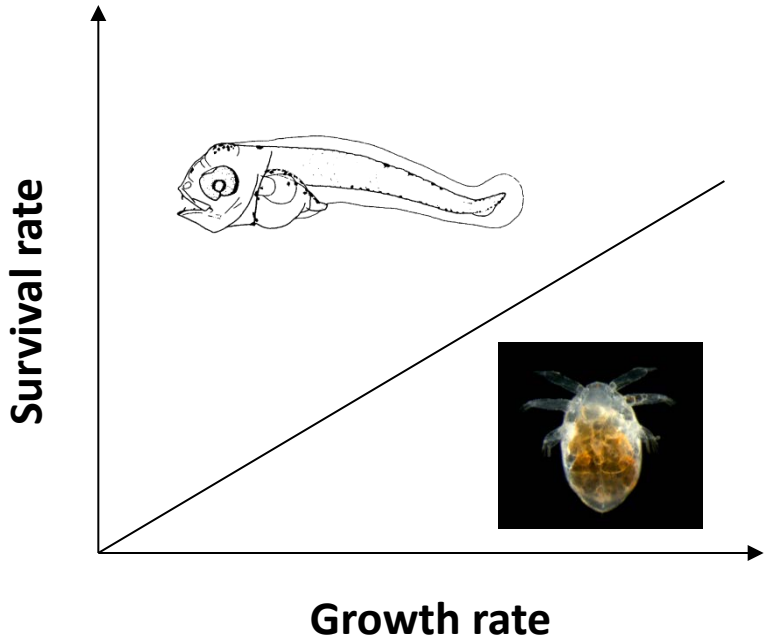


Growth-Survival Paradigm:

Fast-growing larvae are generally predicted to achieve higher survival relative to their slow-growing conspecifics

Prey availability is a primary driver of variability in growth

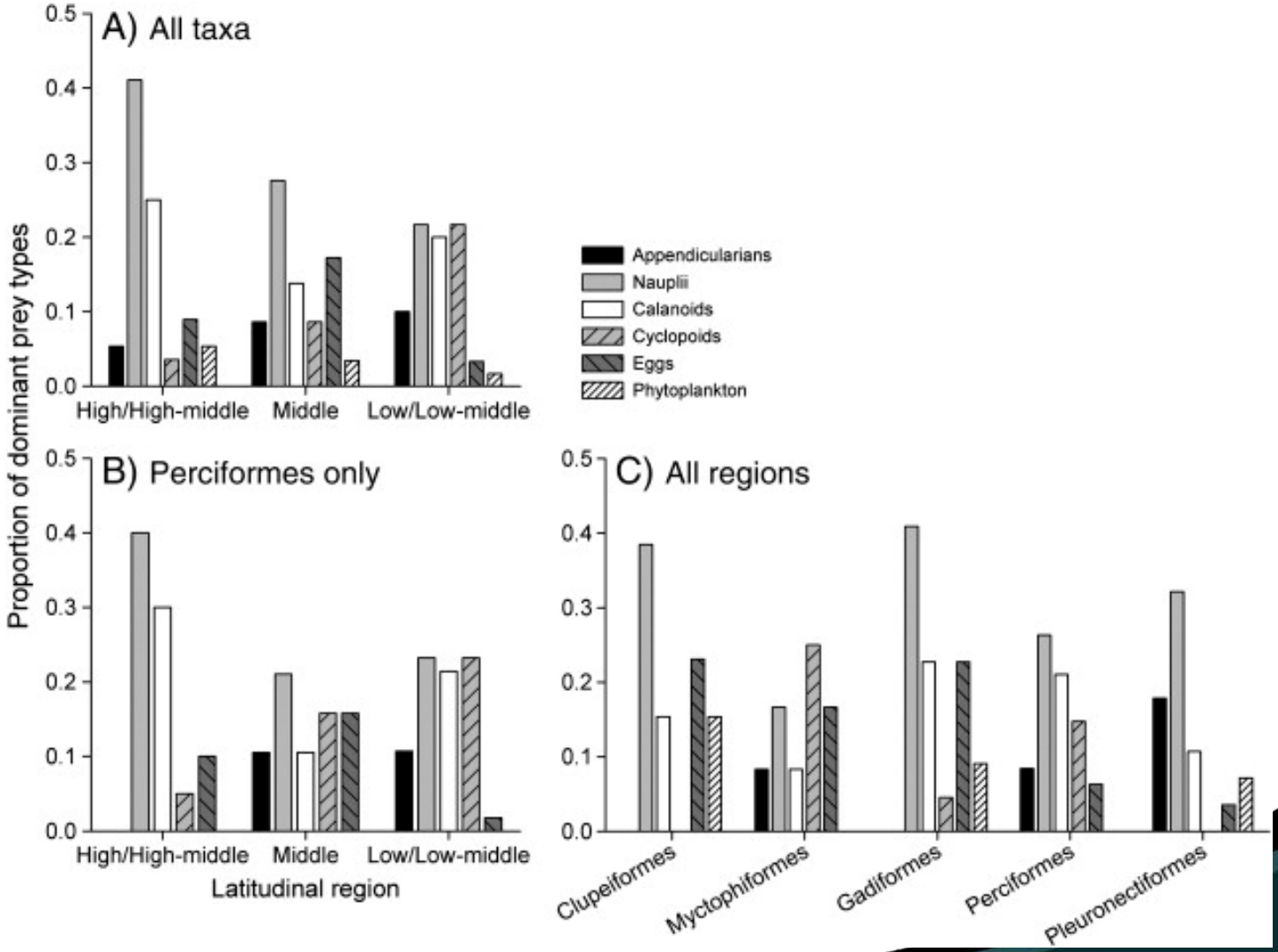
Atlantic mackerel
Claude Nozères, DFO

2. Larval diet composition and prey selectivity

A summary of work on SPFs in Canadian waters

Diet composition of fish larvae

Llopiz (2013) reviewed 129 studies that examined larval fish diet composition:

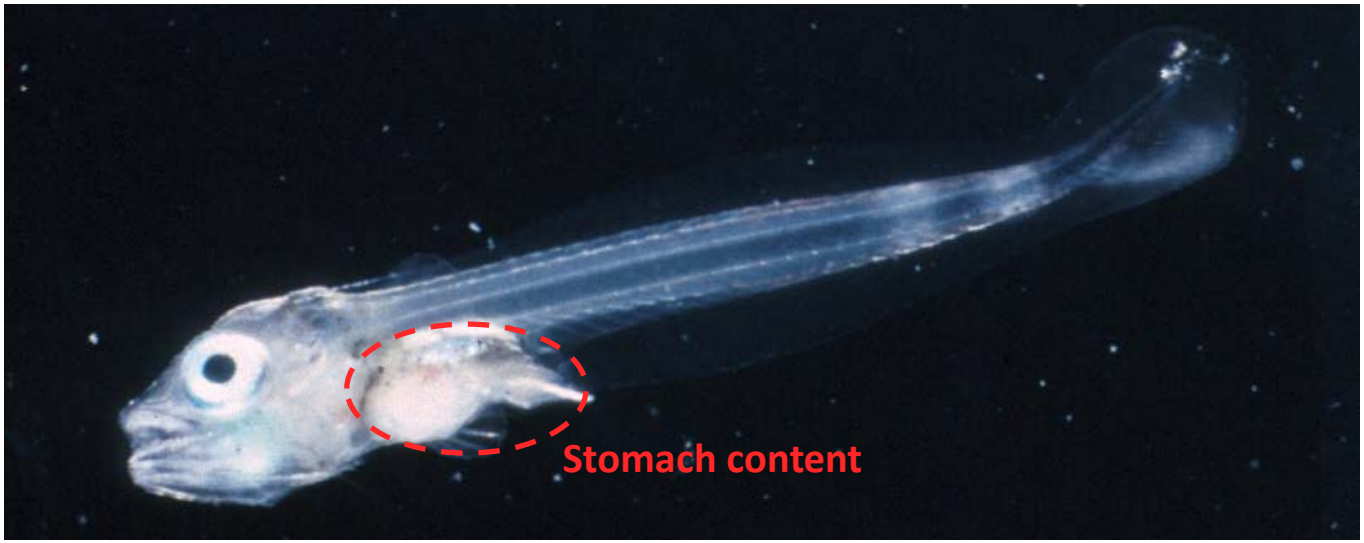


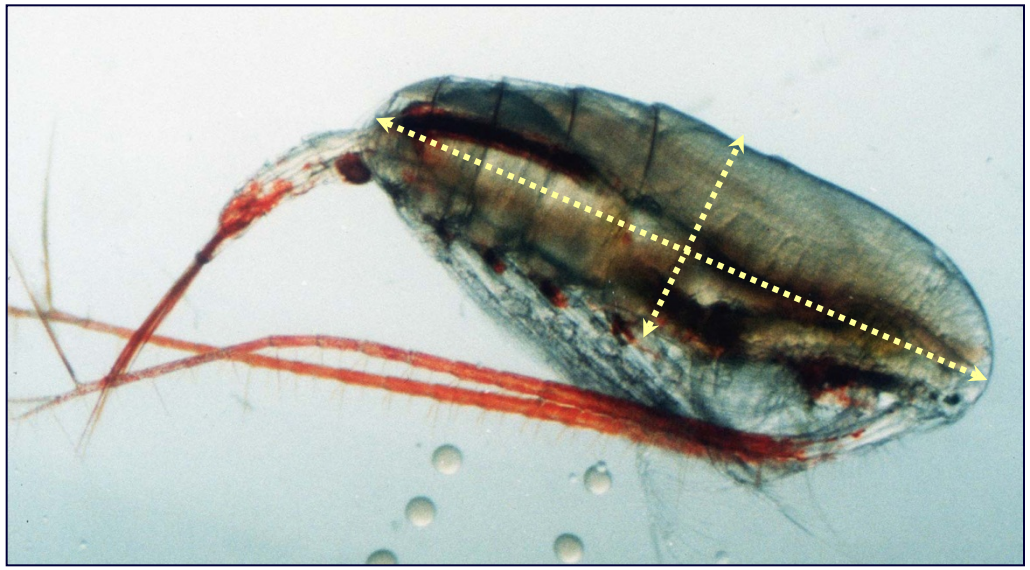
Prey selectivity in fish larvae

Robert et al. (2014a) ICES JMS 71

- **All of 18 studies that have assessed prey selectivity to the species level have concluded that fish larvae strongly select for a restricted number of potential prey taxa**
- **The vast majority of statistically significant relationships found between larval vital rates and prey availability were based on detailed knowledge of diet and prey preference**
- **The difficulty of revealing links between larval trophic ecology and vital rates is due to the challenge of identifying and sampling quantitatively the prey field of first-feeding larvae, primarily composed of copepod nauplii**

Visual assessment of larval diet composition

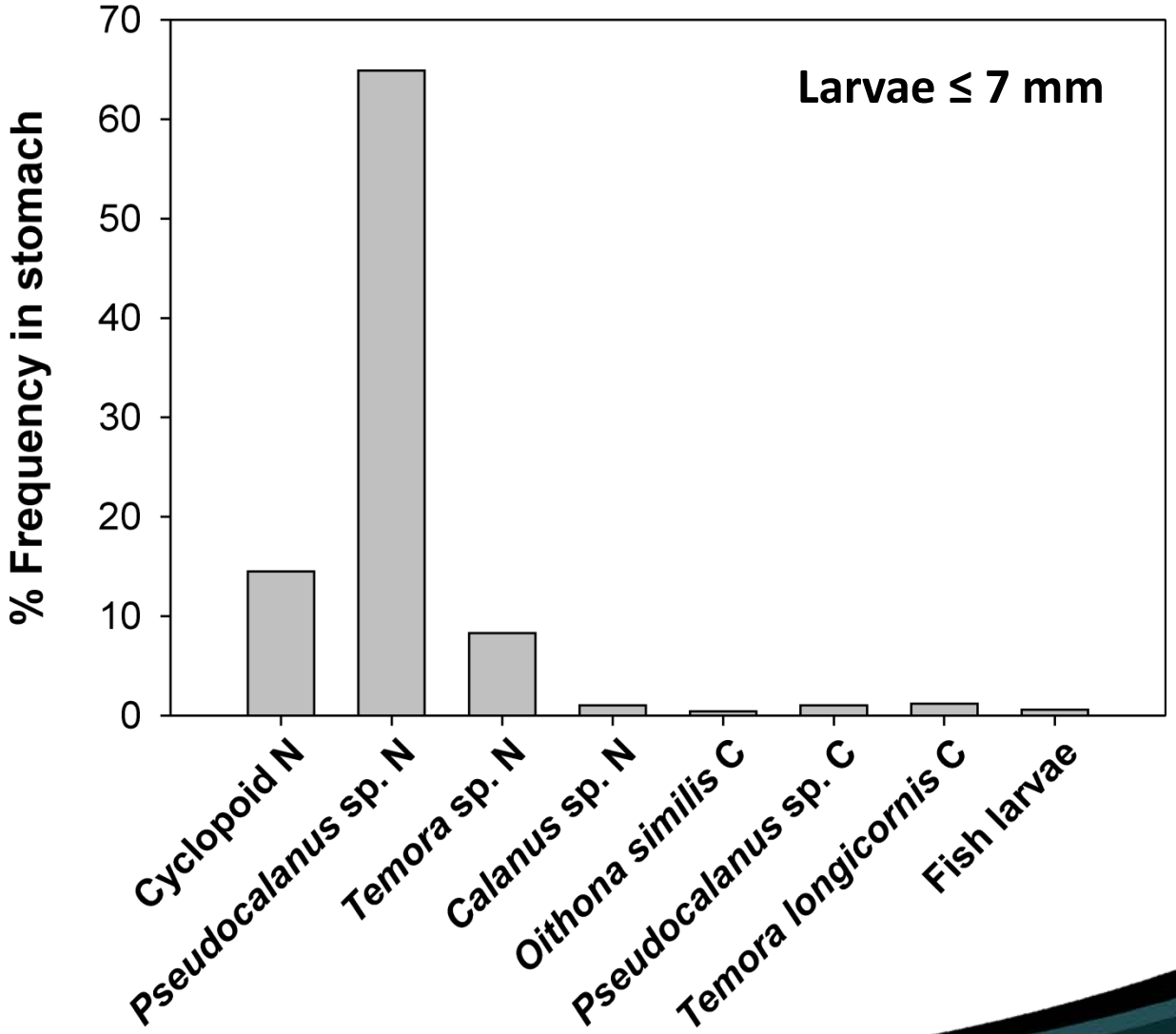




- **Length**
- **Width**
- **ID to species and development stage**

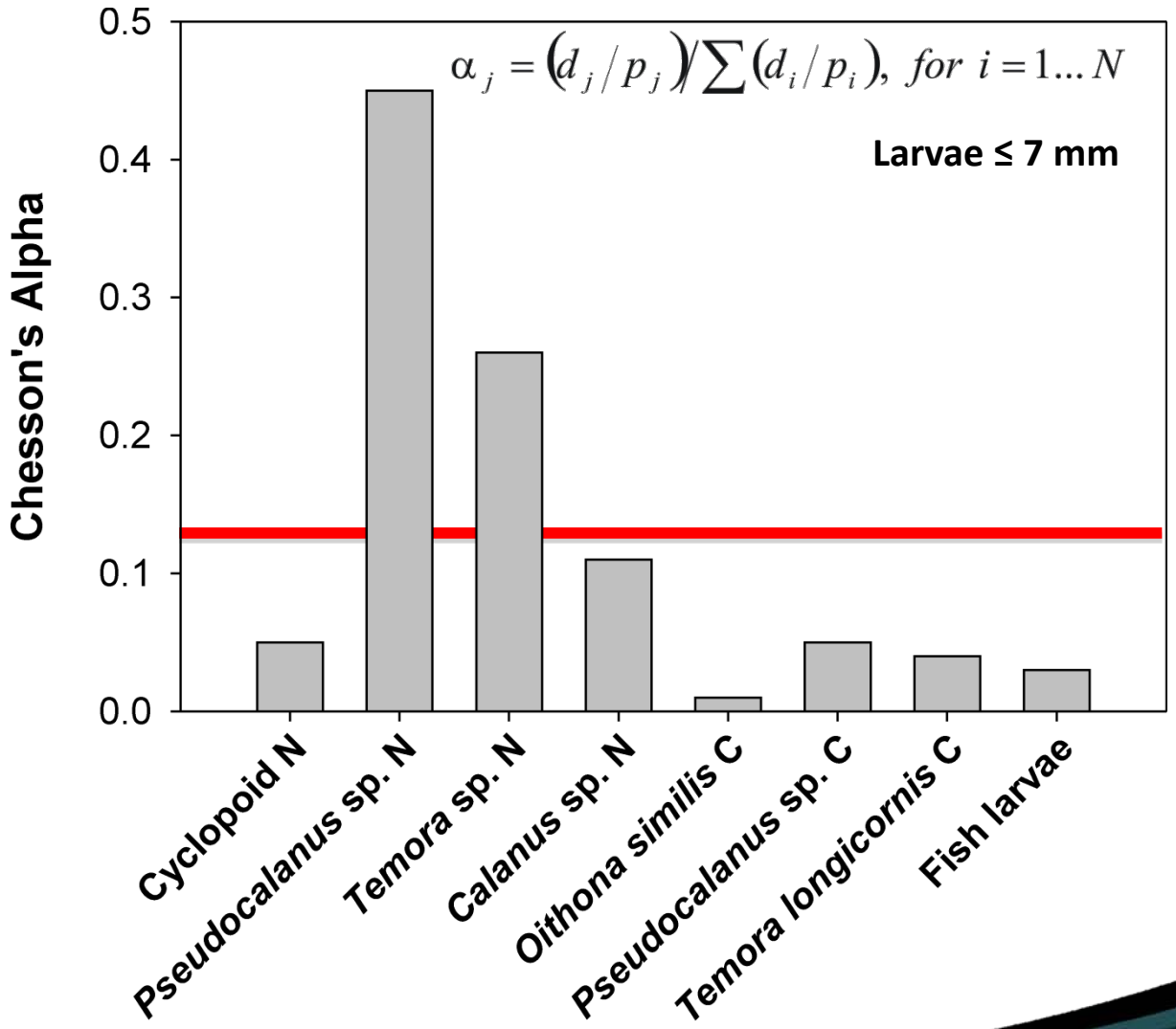
Diet composition of early larvae

Robert *et al.* 2008. *J Plankton Res* 30 – Atlantic mackerel

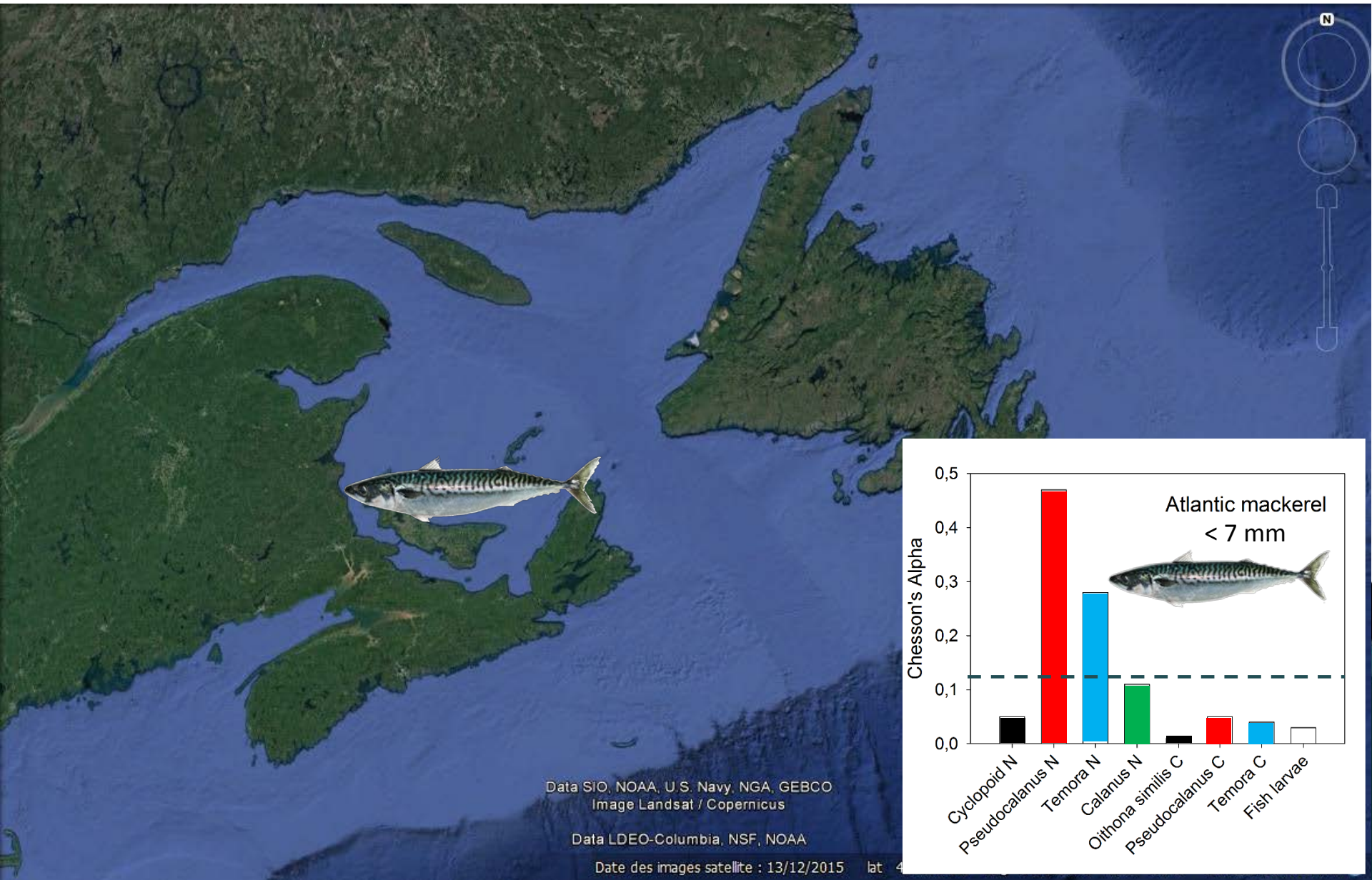


Prey selectivity

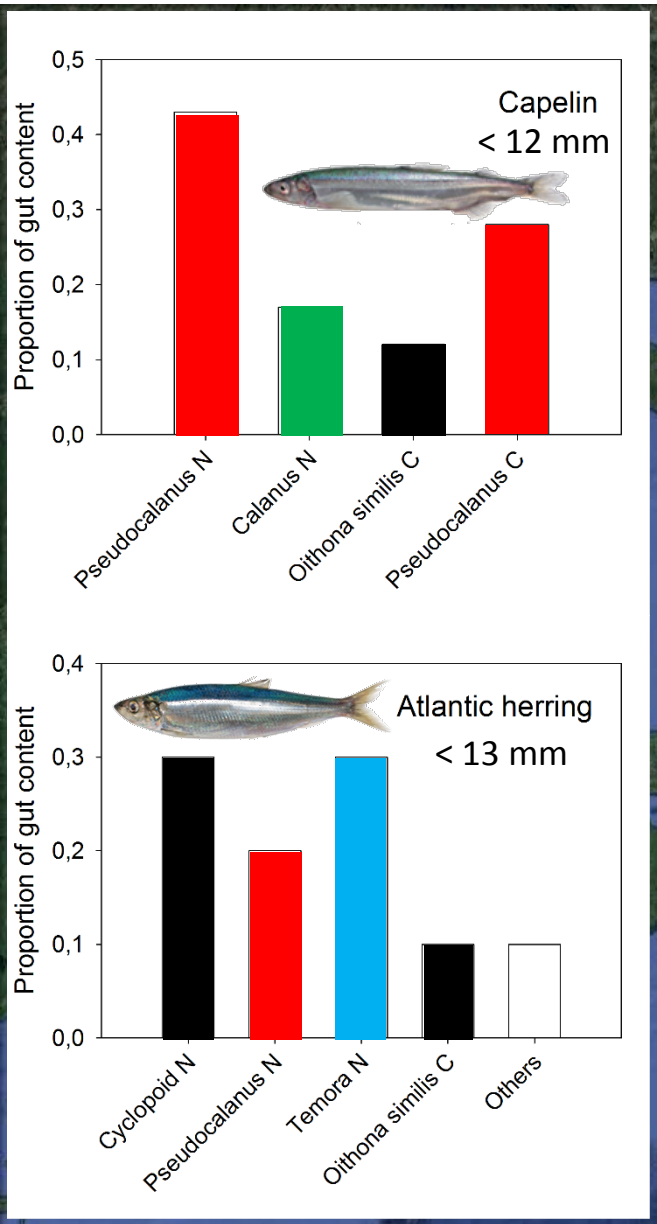
Robert *et al.* 2008. *J Plankton Res* 30 – Atlantic mackerel

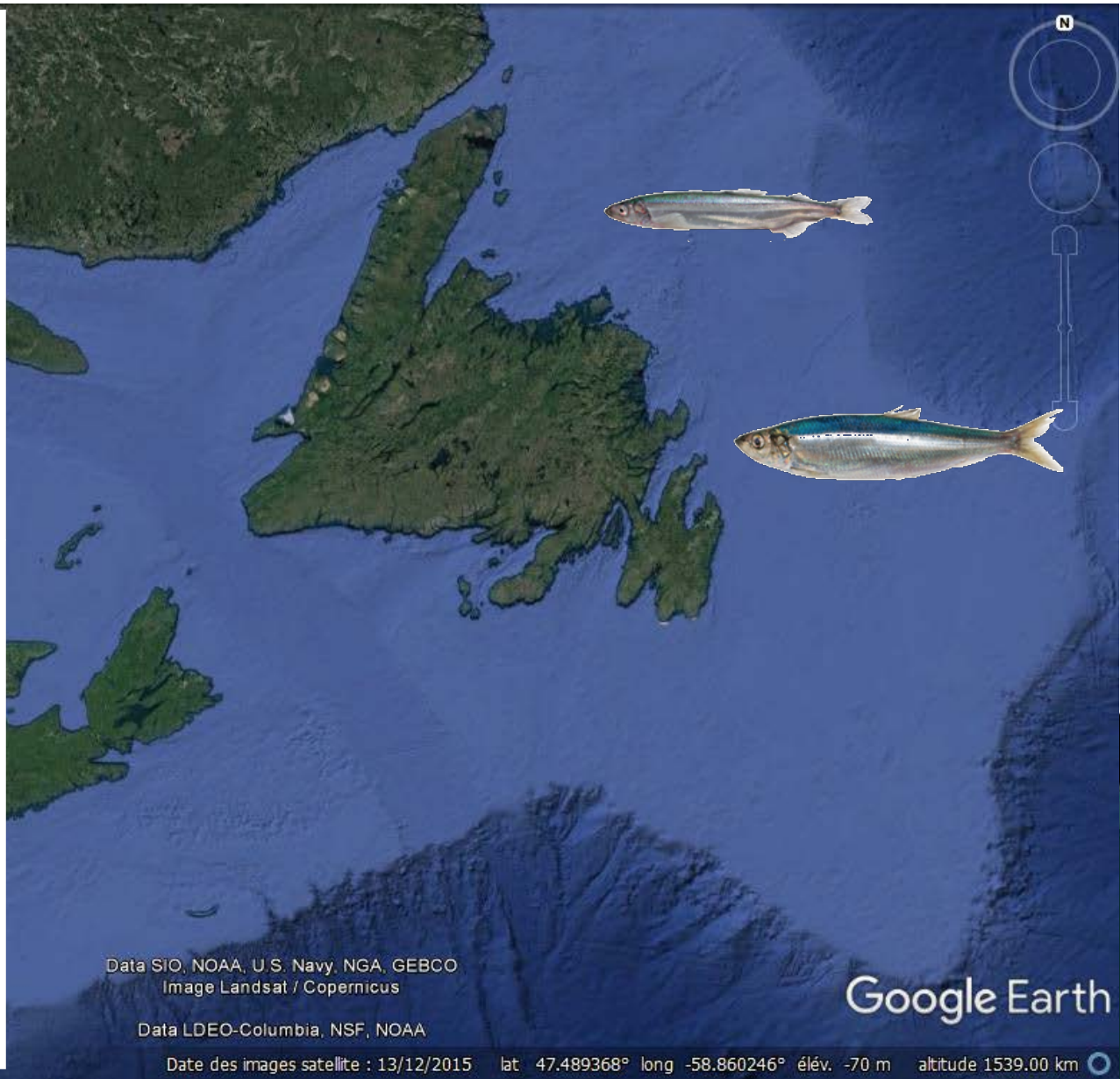


Southern Gulf of St. Lawrence

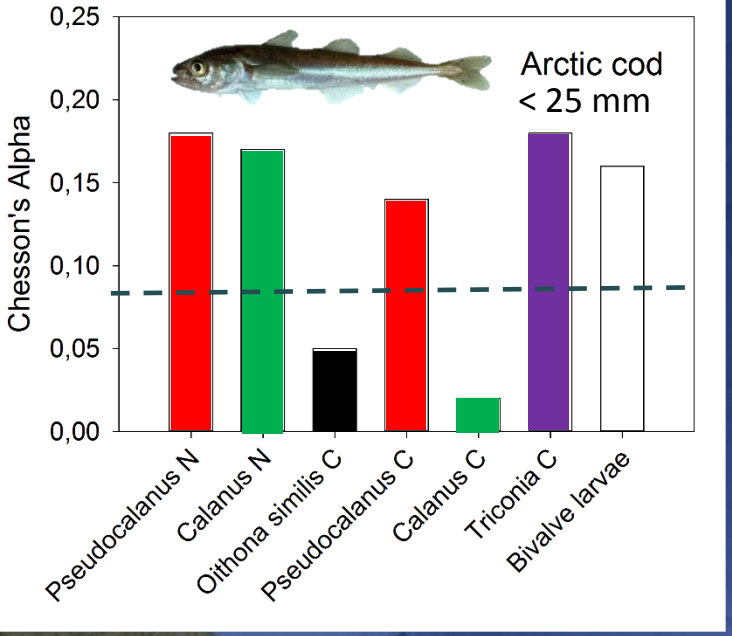


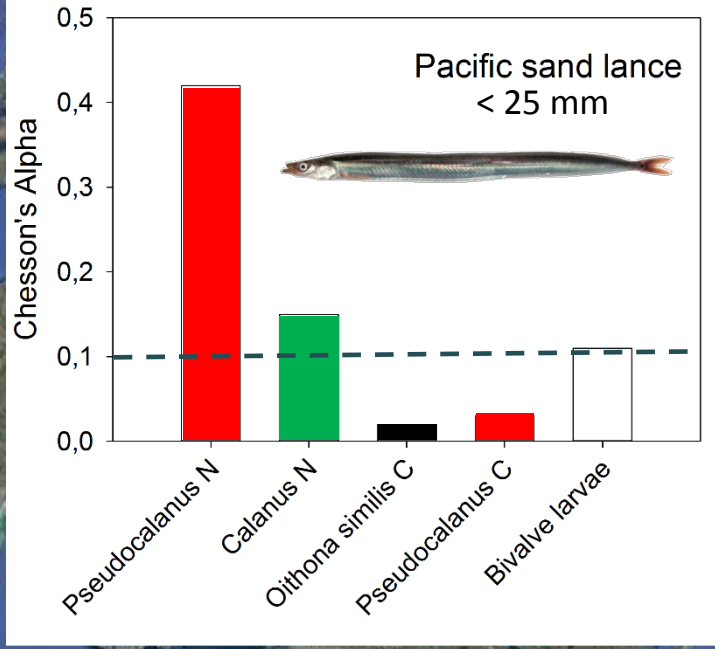
Newfoundland East Coast

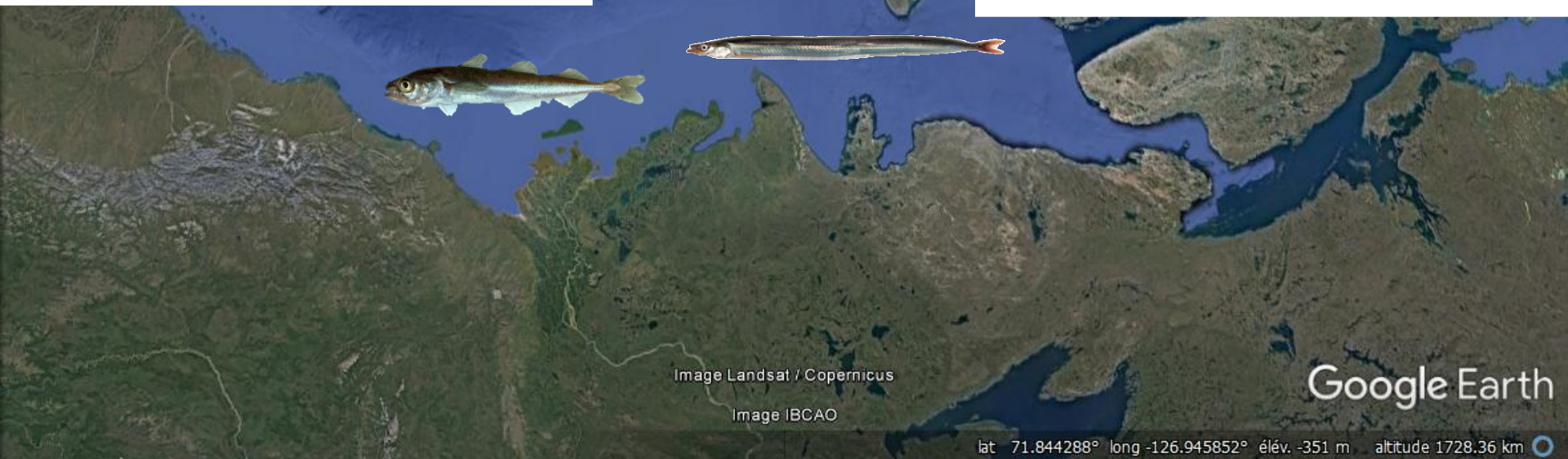




Southeastern Beaufort Sea







Synthesis of prey selectivity info

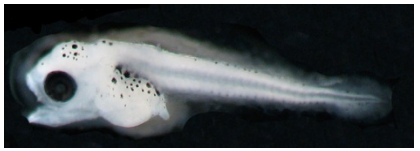
- **Diet of small pelagic fish is composed of a low number zooplankton taxa relative to availability in the plankton**
- **Indicative of strong prey selectivity from the first-feeding stage**
- **It is necessary to first identify preferred prey for a given species/population before assessing relationships between variability in the phenology or production of zooplankton, and year-class strength**

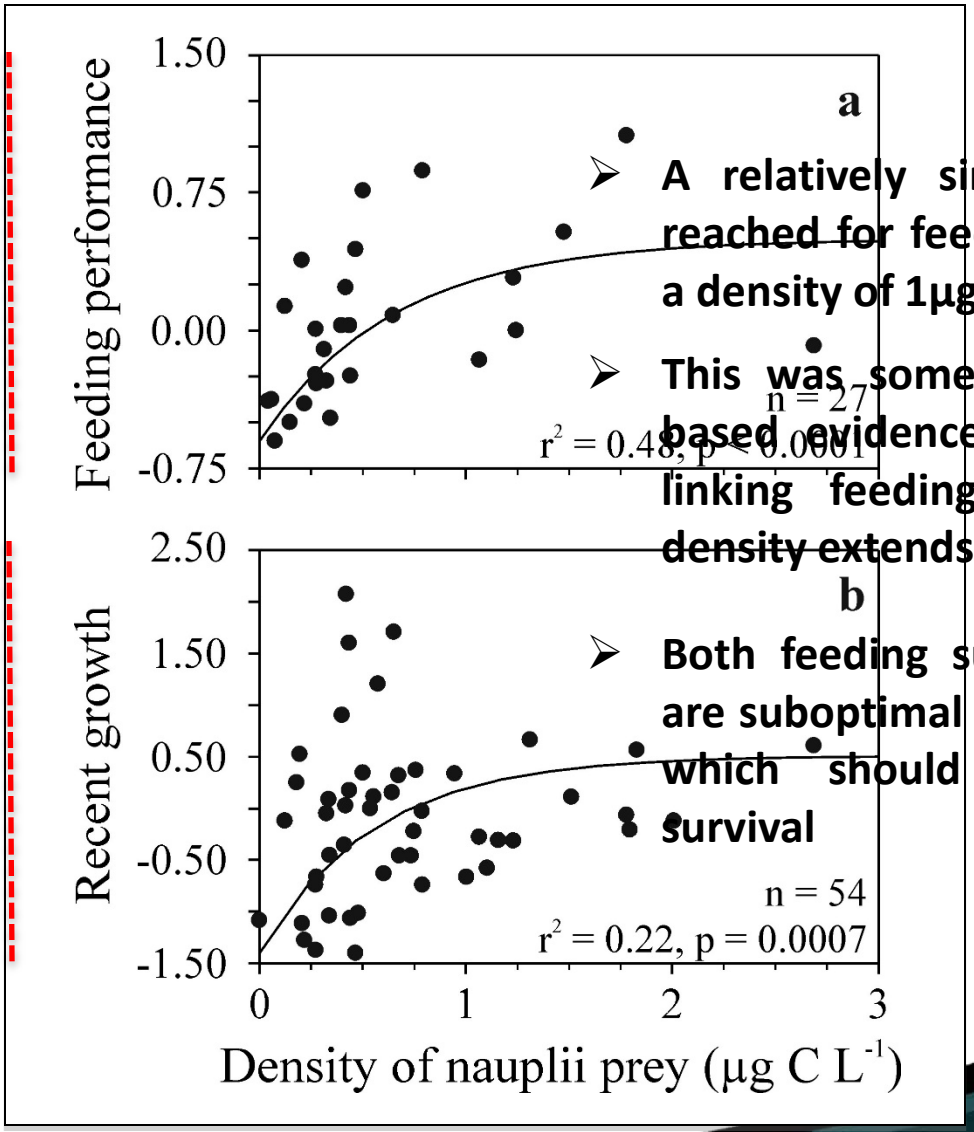

Claude Nozères, DFO

3. Links between prey availability, vital rates and recruitment

GSL Atlantic mackerel as a model

Effect of prey availability on feeding success and growth



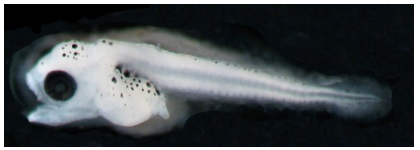


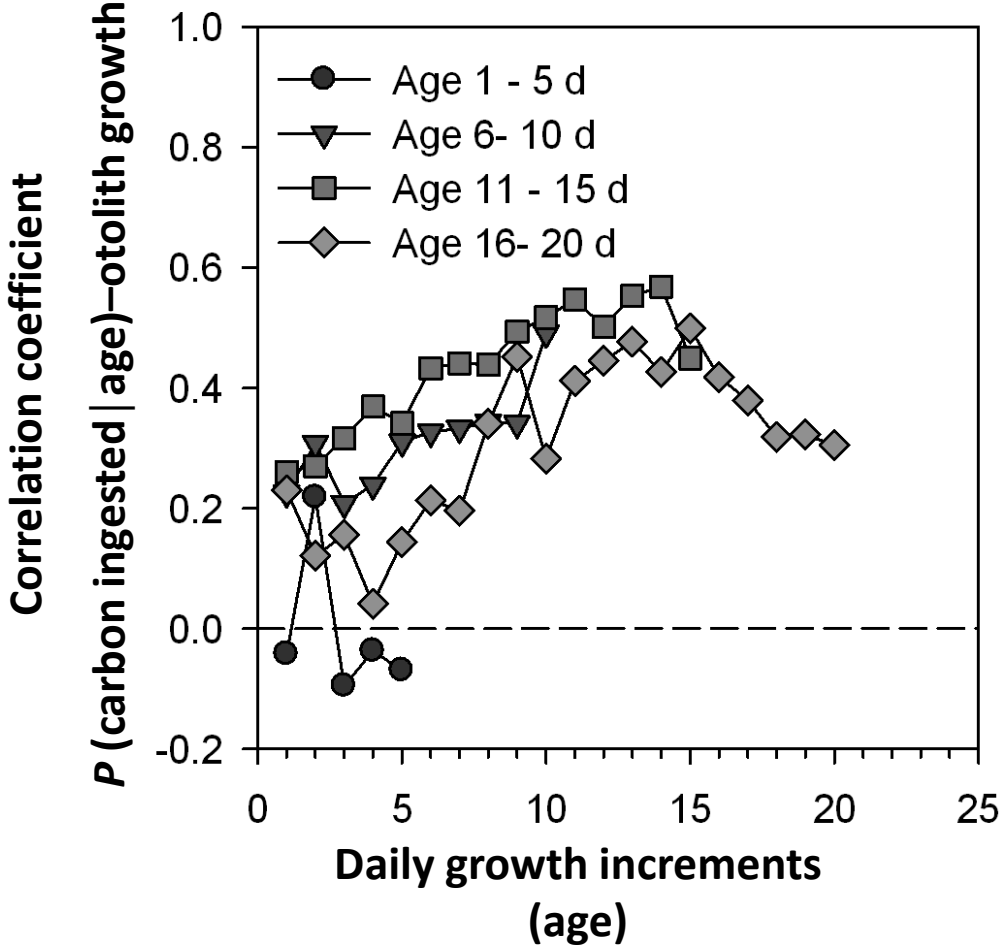
- **A relatively similar plateau was reached for feeding and growth at a density of 1µgC L^{-1}**
- **This was some of the first field-based evidence that the relation linking feeding success to prey density extends to growth**
- **Both feeding success and growth are suboptimal below this treshold, which should in turn impact survival**

Robert *et al.* 2009. *MEPS* 377

Link between growth and gut content

Robert *et al*. 2014b. ICES JMS 71





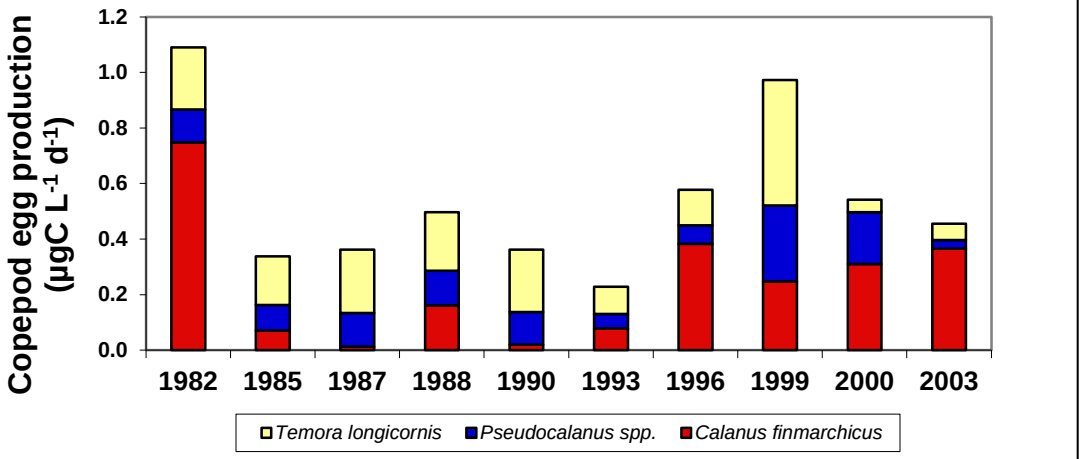
Non-parametric local density estimators used to describe the change in variability in larval state (i.e. length, growth, gut content) with age (Pepin et al. 1999)

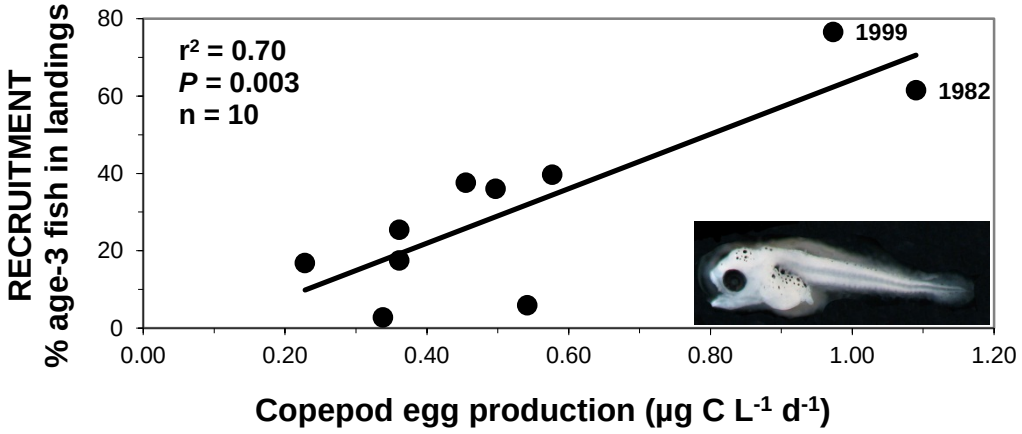
No assumption about the age dependency of the variance

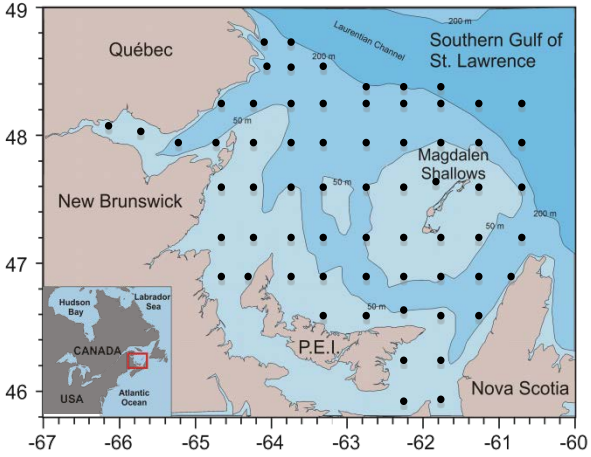
The state (i.e. gut content, otolith growth) of each individual can be described in age-dependent percentile scores (0 to 1)

Prey availability and recruitment

Castonguay *et al.* 2008. *Can J Fish Aquat Sci* 65







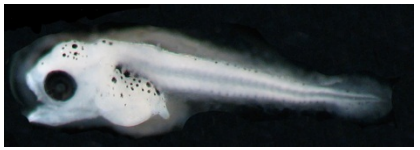
- **Strong link between preferred prey production during first-feeding stage and year-class strength**
- **Relationships between vital rates and prey availability could be revealed due to detailed knowledge of diet and prey selectivity**

4. Specific variability in the potential timing of a Critical Period

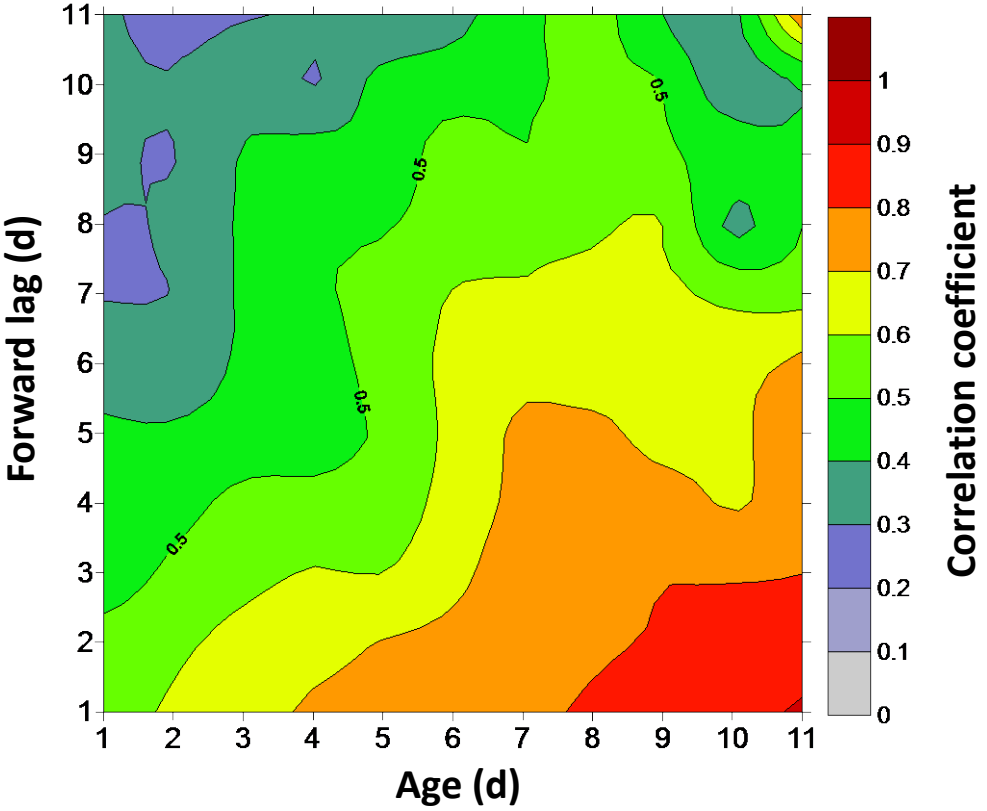
Arctic cod and Atlantic mackerel as 2 extremes

Age-dependent growth autocorrelation

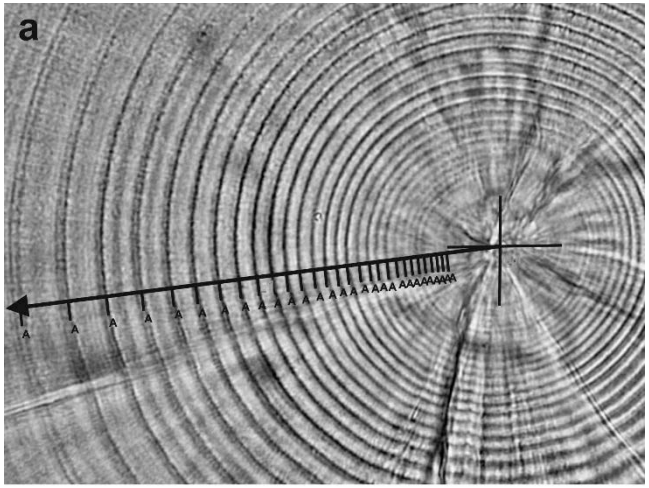
Robert et al. 2014b. *ICES JMS 71*



Atlantic mackerel



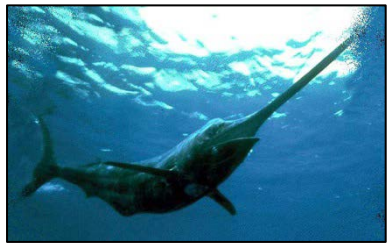
Individual growth trajectory



Multi-species analysis of the link between feeding and growth

Pepin, Robert et al. 2015. *ICES JMS*

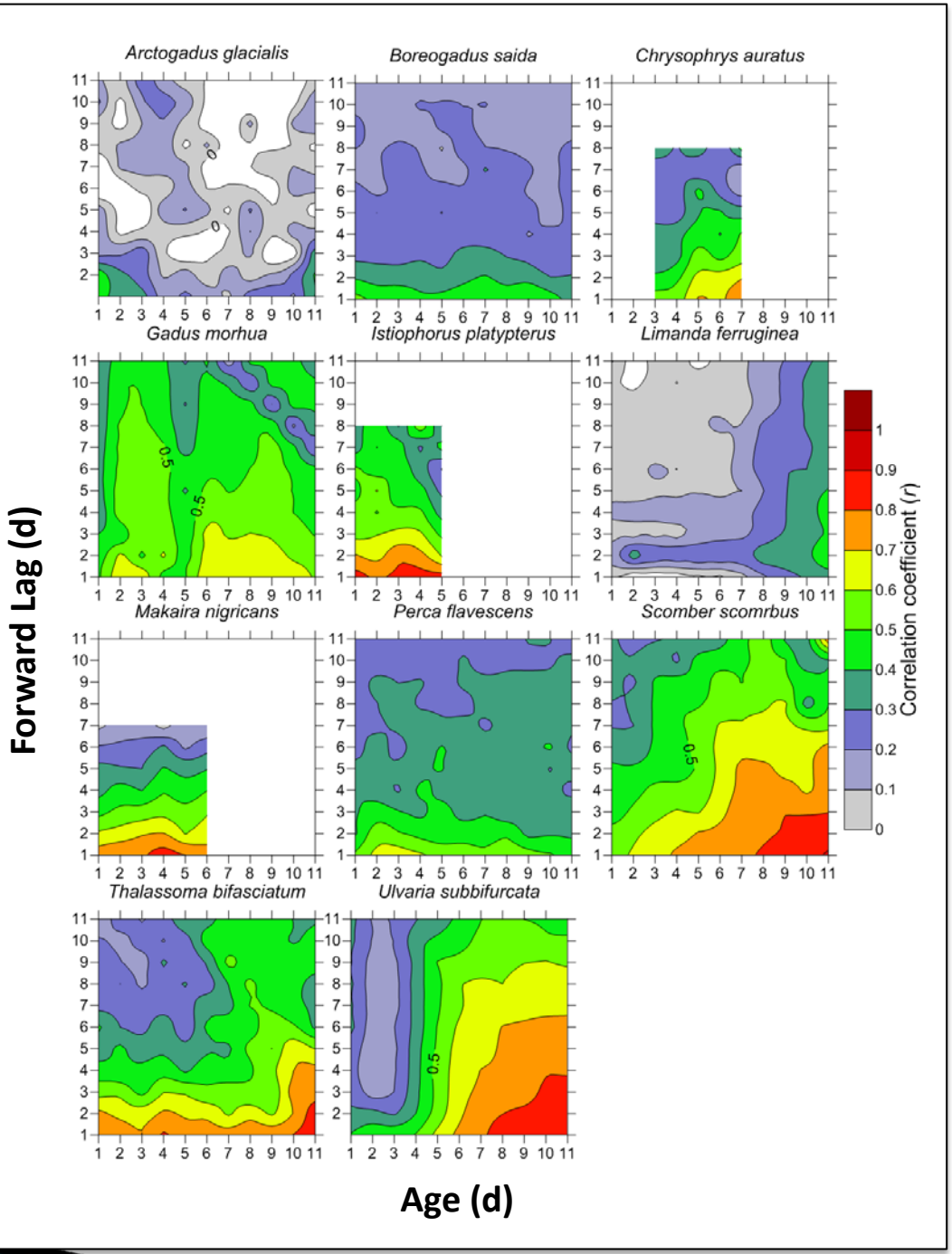



Arctogadus glacialis **(ice cod)**
Boreogadus saida **(Arctic cod)**
Chrysophrys auratus **(pink snapper)**
Gadus morhua **(Atlantic cod)**
Istiophorus platypterus **(sailfish)**
Limanda ferruginea **(yellowtail flounder)**
Makaira nigricans **(blue marlin)**
Perca flavescens **(yellow perch)**
Scomber scombrus **(Atlantic mackerel)**
Thalassoma bifasciatum **(bluehead wrasse)**
Ulvaria subbifurcata **(radiated shanny)**





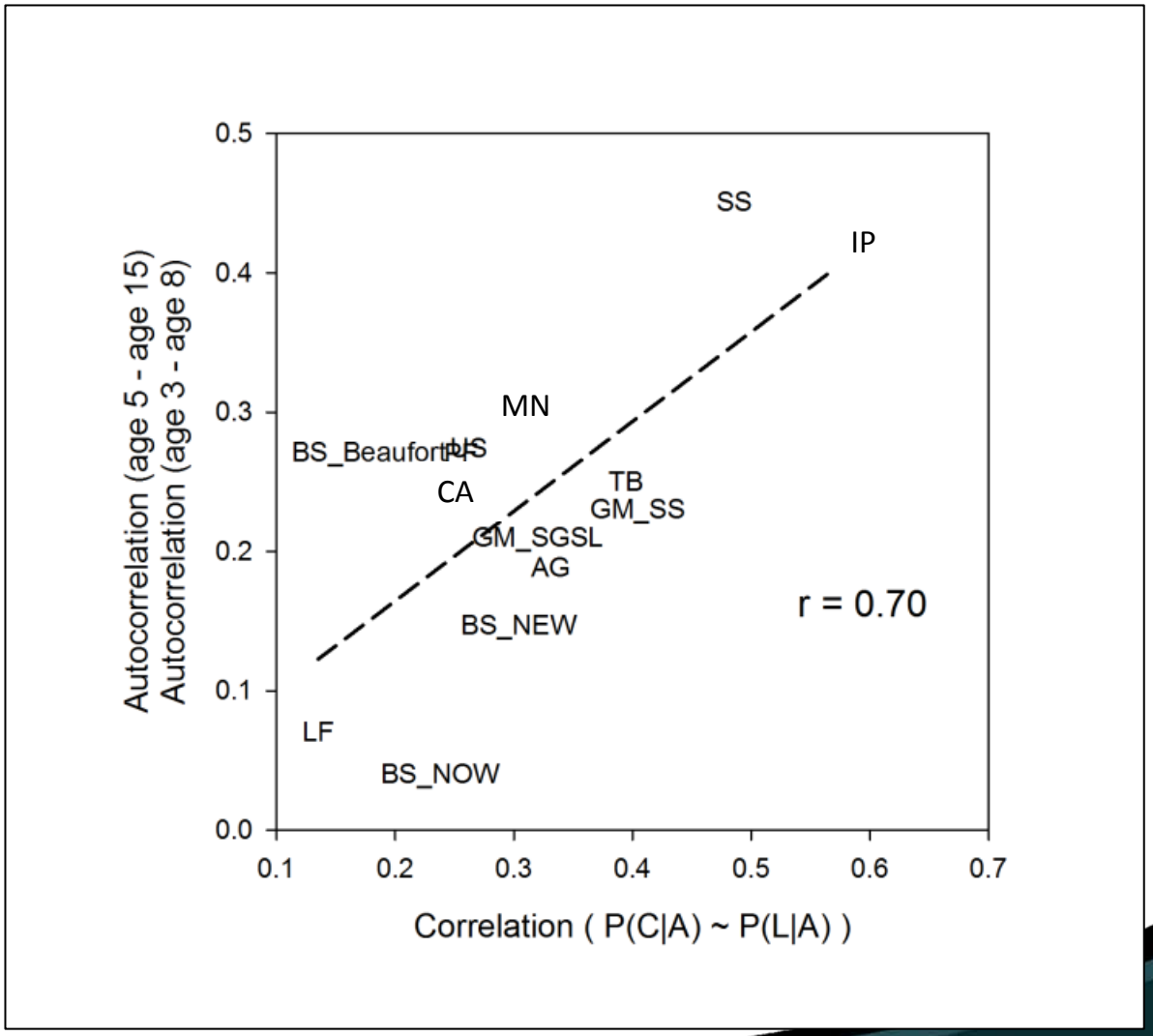



Age-dependent patterns in growth autocorrelation

Arctic cod and some other species demonstrated no evidence that growth autocorrelation became stronger with age

In contrast, Atlantic mackerel was among species showing evidence that the persistence of high or low growth rates became stronger with age, indicative of an increasing differentiation of individuals within a cohort over time

Growth serial correlation Vs. Feeding-Growth correlation



In Summary

- **Much like juveniles and adults, larval stages of small pelagic fish exhibit strong prey selectivity, which is apparent from the first-feeding stage when considering prey field and gut content at the species level**
- **Consideration of preferred prey taxa may allow to reveal links between variability in zooplankton prey supply and variability in vital rates and recruitment (e.g. Atlantic mackerel)**
- **Growth autocorrelation analysis suggests that there exists massive variability among taxa in the timing of the importance of feeding and growth in driving mortality**

Concluding remarks

- **Species displaying high serial correlation early in life such as mackerel exhibit a strong potential for recruitment regulation through a 'Critical Period' at first feeding**
- **Slow-growing species such as Arctic cod are more resilient to variable environmental conditions during the early larval stage and year-class strength could be modulated later in life**
- **This highlights the importance of accounting for species-specific differences in early life dynamics when assessing links between environment, vital rates and recruitment**
- **Interspecific variability is not considered in the current paradigm linking larval growth and recruitment**

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