TOWARDS AN ECOSYSTEM-BASED STOCK MANAGEMENT OF KRILL IN THE GULF OF ST. LAWRENCE, CANADA

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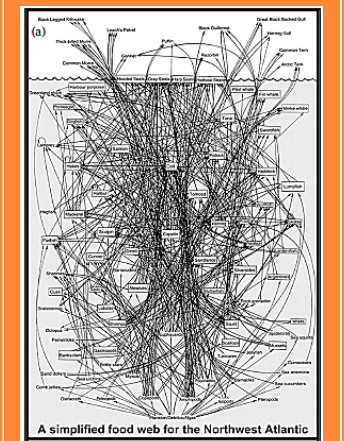
Students: Jory Cabrol, Angélique Ollier, Marie Guilpin, Déborah Benkort, Blandine de Maillard

ICES/PICES:
6th Zooplankton Symposium, Bergen, 9-13 Mai 2016

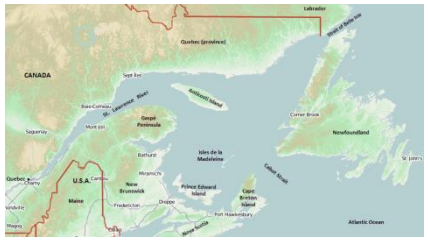
Sustainable Exploitation – Krill Fisheries



- Avoid fishing down the food web effects
- Maintain ecosystem integrity
- Need to understand key processes controlling population dynamics

- Exploratory fishery
- Estuary and the Gulf of St. Lawrence (EGSL) in mid 1990's
  - Closed under the Precautionary Approach (Canadian Oceans Act)

Krill in the EGSL

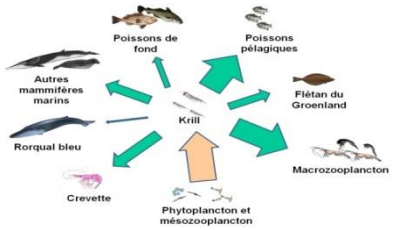


What we know:

- Arctic krill: *Thysanoessa raschii , T. inermis* – cold adapted
- Northern krill: *Meganyctiphanes norvegica* – warm adapted
- Form large and dense aggregations
- Large inter-annual variations in standing stock biomass
- Pivotal role in the food web

Simmard et al. 1986, Simard & Lavoie 1999, Lavoie et al. 2000, Simard et al. 2003, Cotté & Simard 2005, Sourisseau et al. 2006, 2008, Simard & Sourisseau 2009, Simard 2009, Plourde et al. 2011, Doniol-Valcroze et al. 2012, Savenkoff 2013, Maps et al. 2014 Plourde et al. 2014, McQuinn et al. 2014, Gavrilchuk et al. 2014

Krill in the EGSL



What we do not know:

- Natural variability in quality and quantity of krill
- Ecological resilience of species-specific krill stocks to environmental forcing

We need prior to any new exploitation:

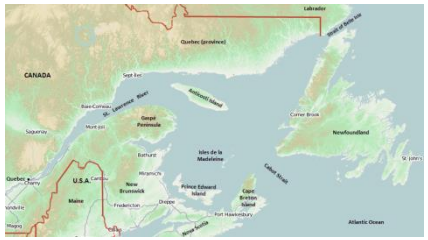
- Concise and holistic research approach on key processes involved in production and consumption of krill
- Development of an ecosystem-based krill stock assessment, in view of a precautionary approach of a potential krill fishery

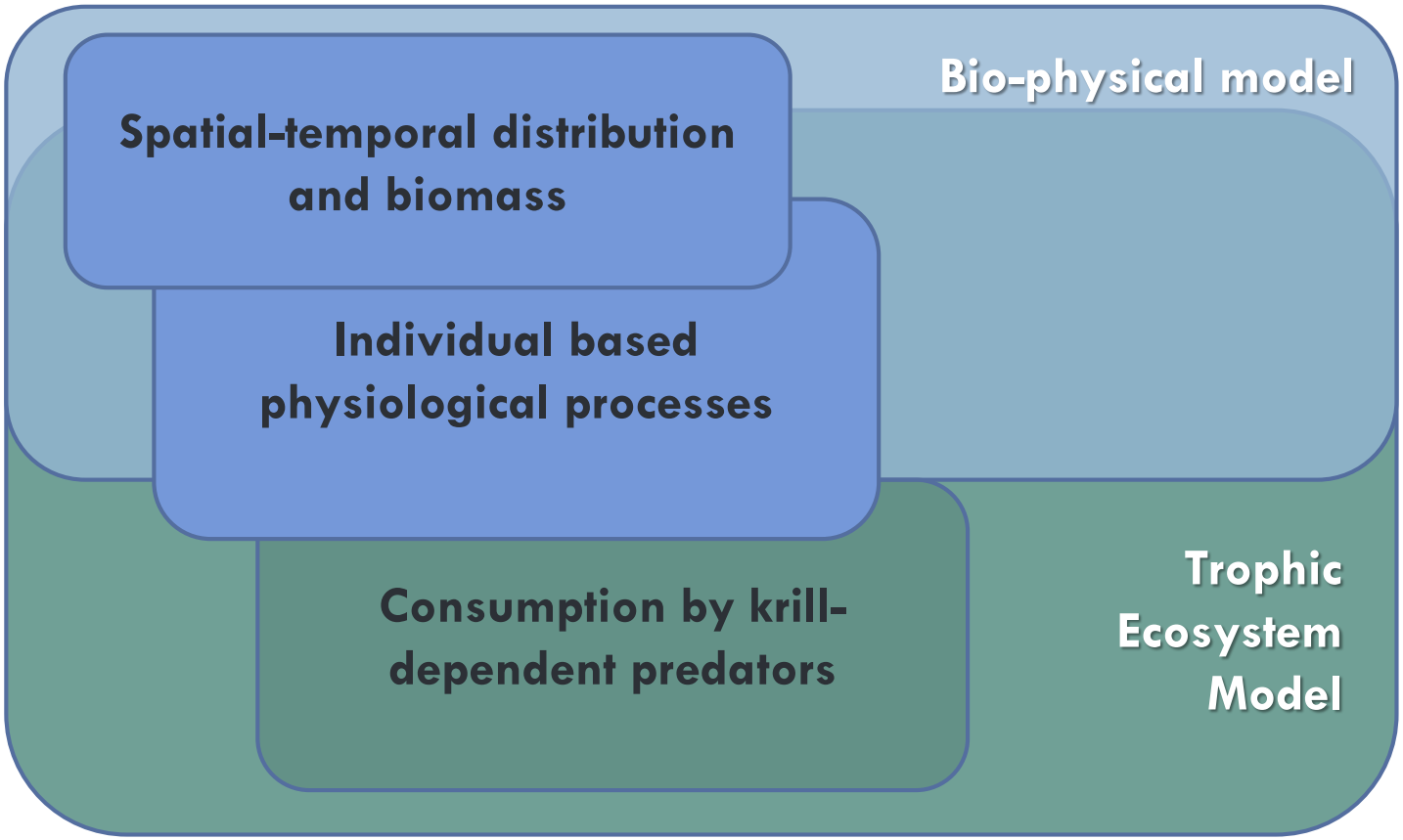
Project (2013-2017)

Production and Consumption of Krill in the Gulf of St. Lawrence: Toward an Ecosystem-Based Stock Assessment

- Universities:
  - Institut des Sciences de la Mer – University of Quebec at Rimouski
  - Laval University
- Partners:
  - DFO - Science
  - Neptune Bioresources and Technologies
  - Parc Marin Saguenay-Saint-Laurent
- Users:
  - Fisheries and Oceans Canada
  - Parc Canada
  - Potential transforming industries

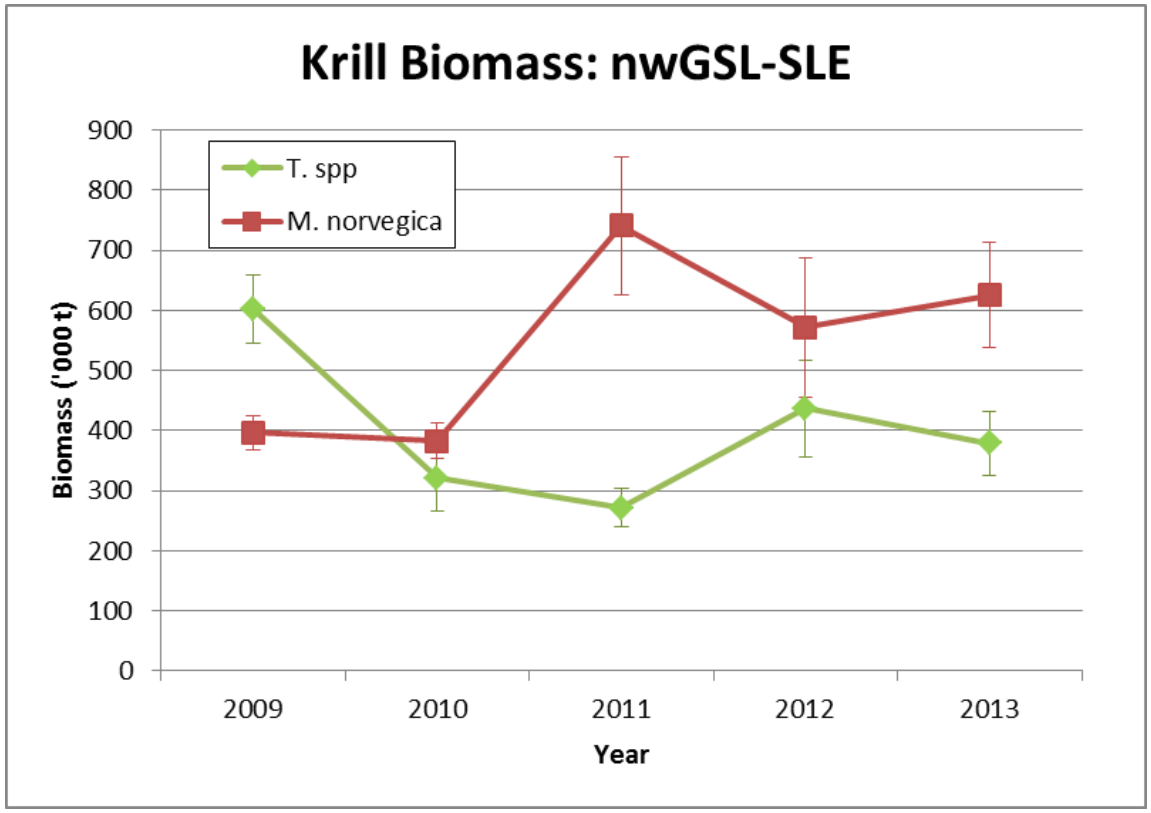
Ecosystem approach



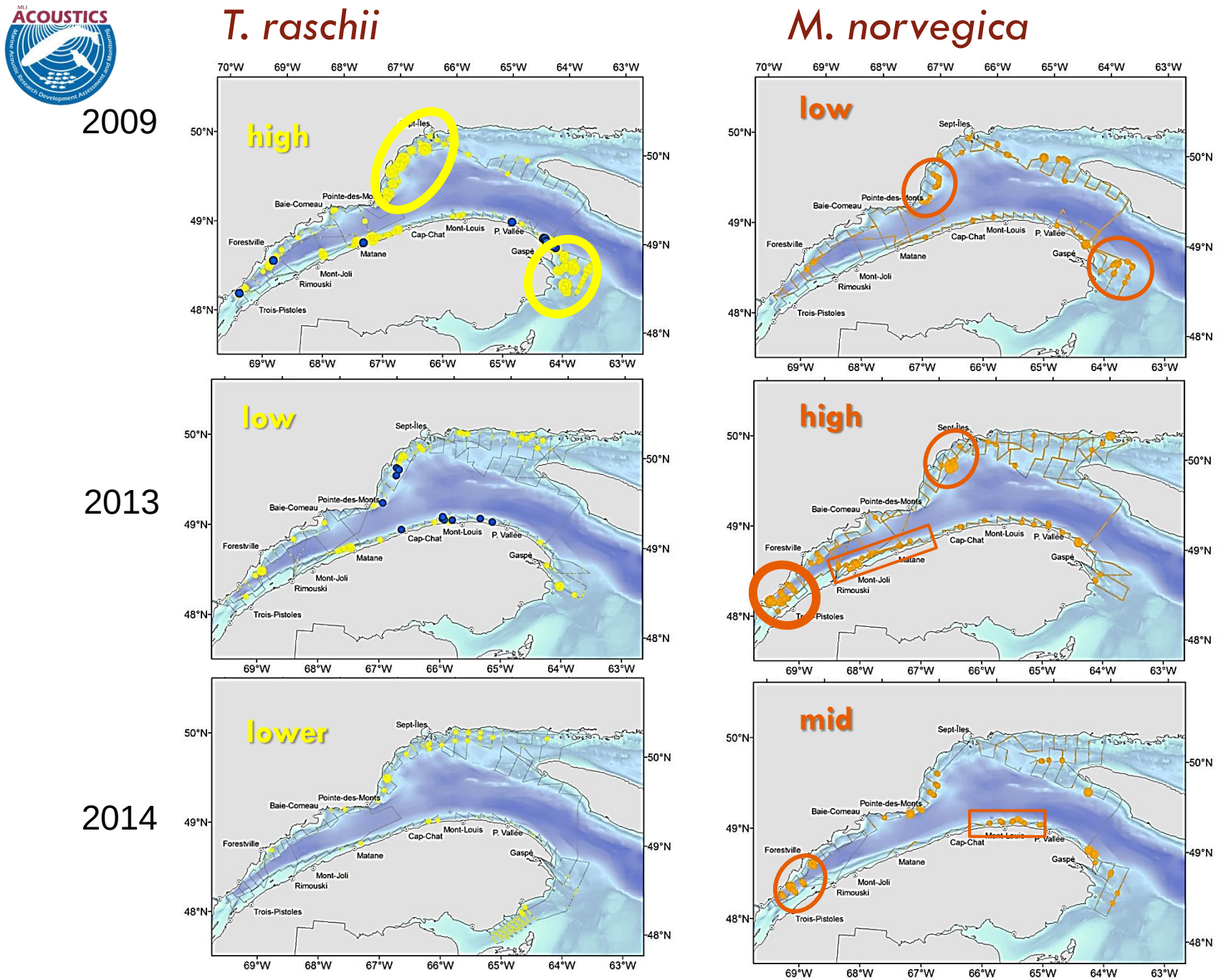


Preliminary Krill Biomass estimates

Acoustic surveys: Biomass estimates



McQuinn, unpublished



McQuinn, unpublished

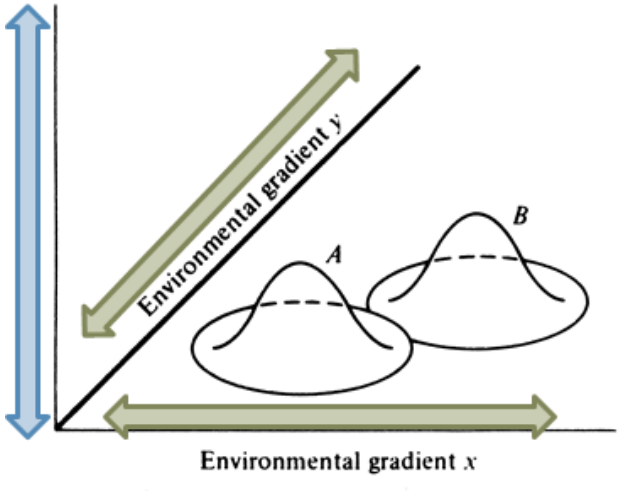
Key physiological processes

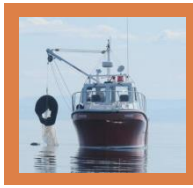
Functional response

Environmental control

Traits

- Growth and reproductive potential
- Feeding
- Biochemical composition/condition
- Metabolic capacity





Field sampling : seasons, years

Laboratory experiments

Serve parameterisation of biophysical and trophic ecosystem models

Growth and Reproduction

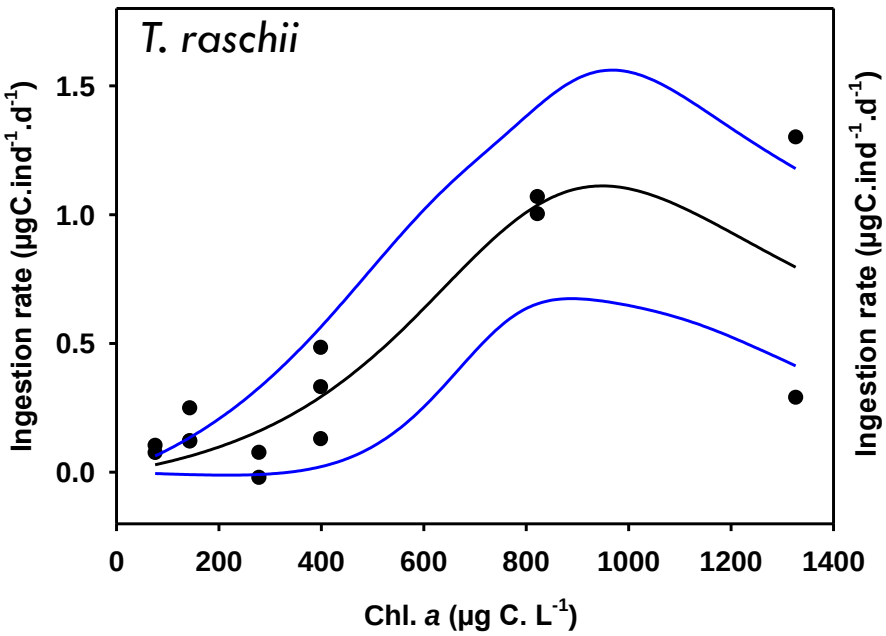
- Spatial and temporal observations
  - 4 Years: 2010, 2011, 2014, 2015
    - Instantaneous growth rate method
    - Egg production rate

- To develop functional response to environmental factors such as T°C and food availability (Chl a / zooplankton)

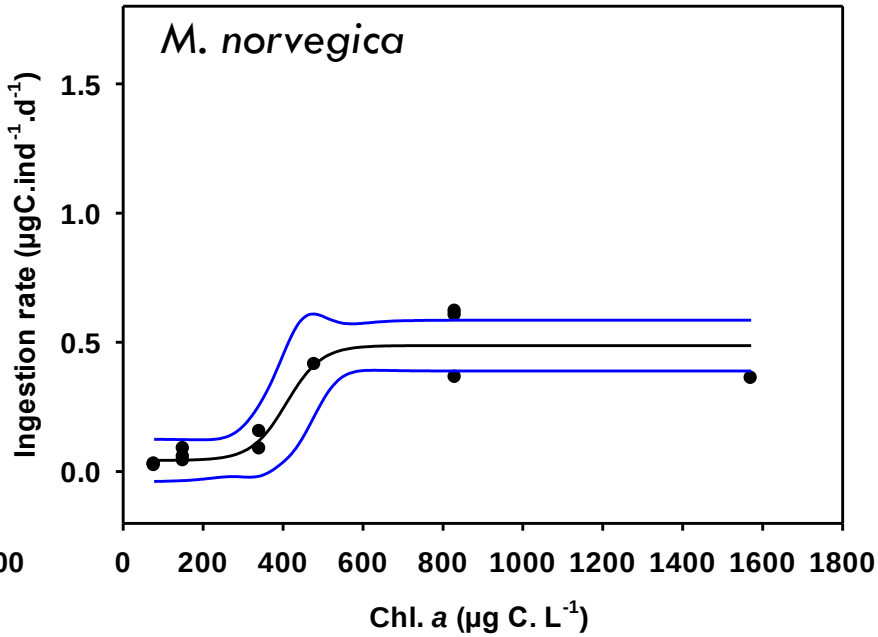
Feeding

- Ingestion rate as a function of phytoplankton density

T. raschii
Holling IV: f =a*x/(b+c*x+x²)
adj R² = 0.66



M. norvegica
Holling III: f = y0+a/(1+exp(-(x-x0)/b))
R² = 0.85



- To come: ingestion rates as a function of zooplankton density

Anaïs Fabre, Jory Cabrol

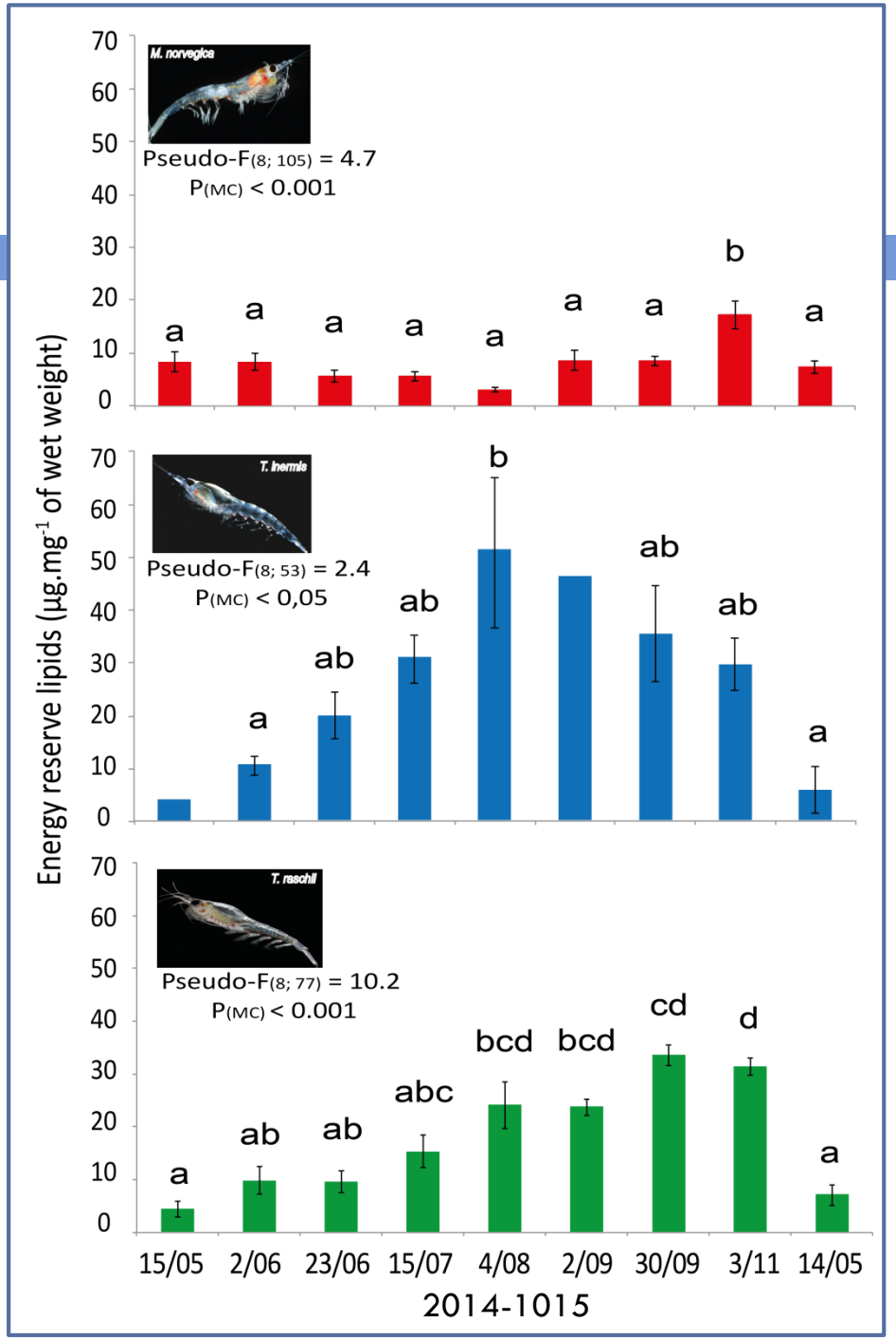
Condition

- Temporal variation in lipid reserves

- Interested?

  Go see Jory Cabrol

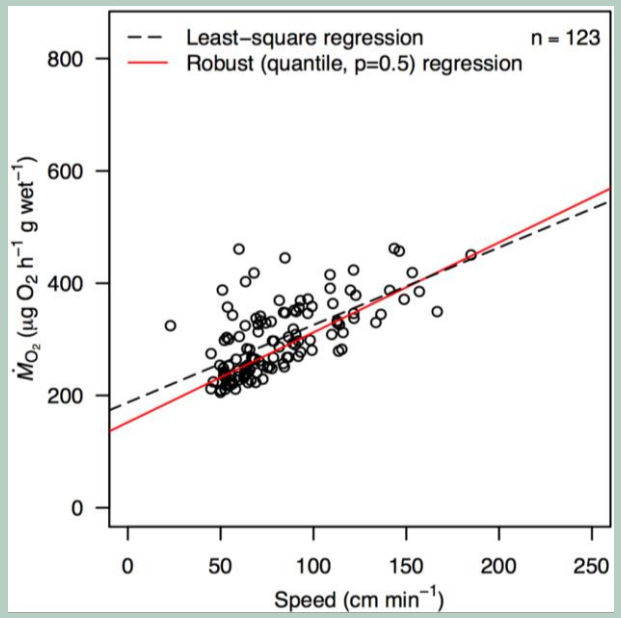
  Presentation on Thursday



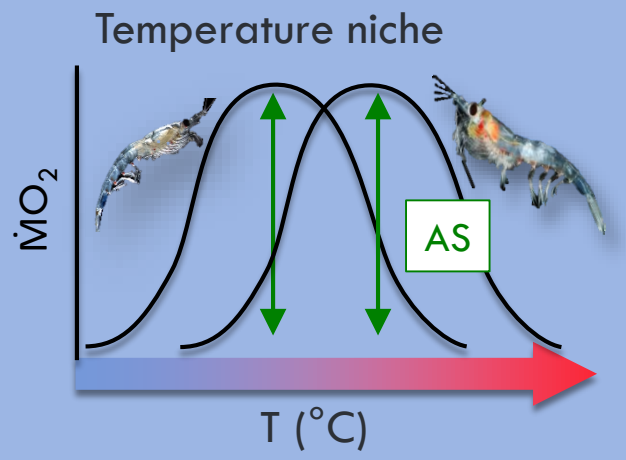
Metabolic capacity

Newly designed respirometers , adapted to each krill species

Oxygen consumption rates during free swimming activity,
using intermittent-flow respirometry

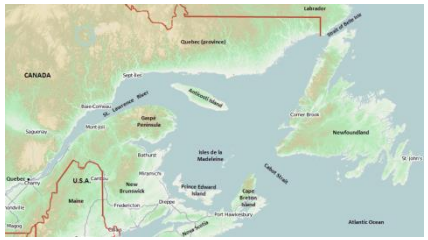


6 different temperatures 0-15°C
2 species: *T. raschii, M. norvegica*



Angélique Olliers' poster "The influence of temperature on the oxygen consumption of the Northern krill"

Biophysical Models



Based on mechanistic functions (ecophysiological key processes)

IBMs

Species specific population dynamic models

Coupling to a physical model

To model spatio-temporal population dynamics

Hotspots for growth, reproduction and aggregations

Environmental forcing

+

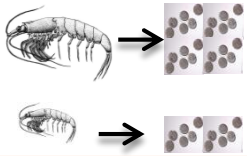
Physiological IBM

Development moult

Growth =
ingestion – metabolism

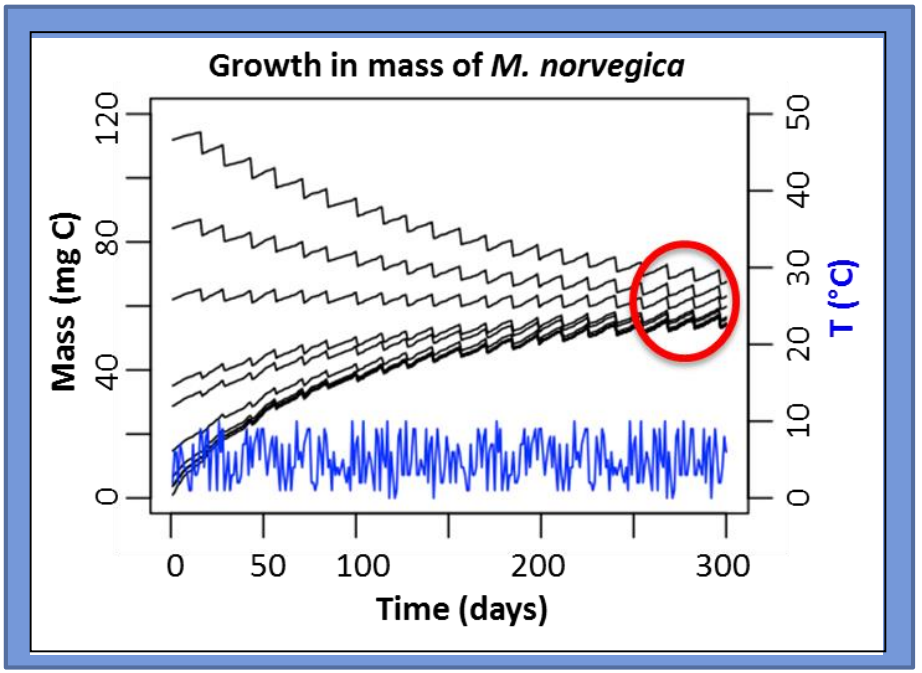
Reproduction

Allometric relationship relative to female length



Mortality

If mass ↓ 70 % initial mass = death

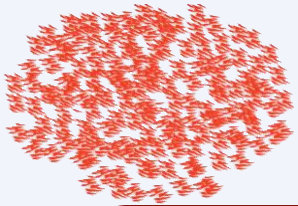


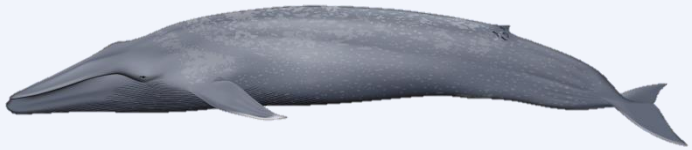
Déborah Benkort

Consumption of krill

Bio-energetic model of foraging baleen whales

- Assess energy requirements to put on adequate fat reserves
- Inter-annual availability of prey patches of adequate quality





Gross Energy Intake

Krill patch quality
Prey energy content
Prey density

Energy Expenditure

Foraging effort
Dive depth

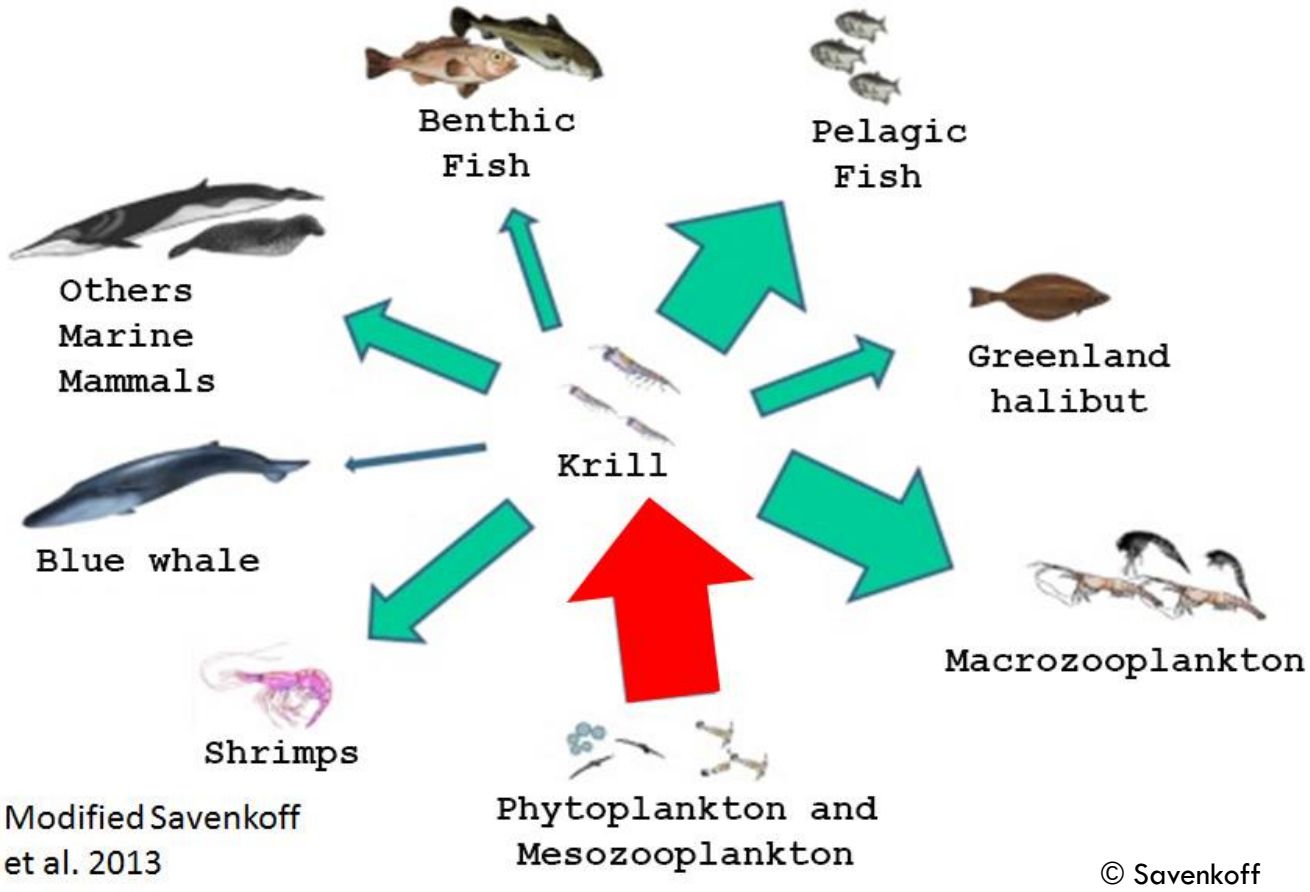
Foraging efficiency & Energy surplus

x 11 on blue whales

139 hours of data
6501 dives
2689 feeding events

M. Guilpin et al.

Serve parameterisation of trophic ecosystem model



Trophic ecosystem model

- Krill stock biomass in the framework of a mass-balanced food web model
- Quantify and qualify role as forage species for a large array of dependent predator species relative to krill production

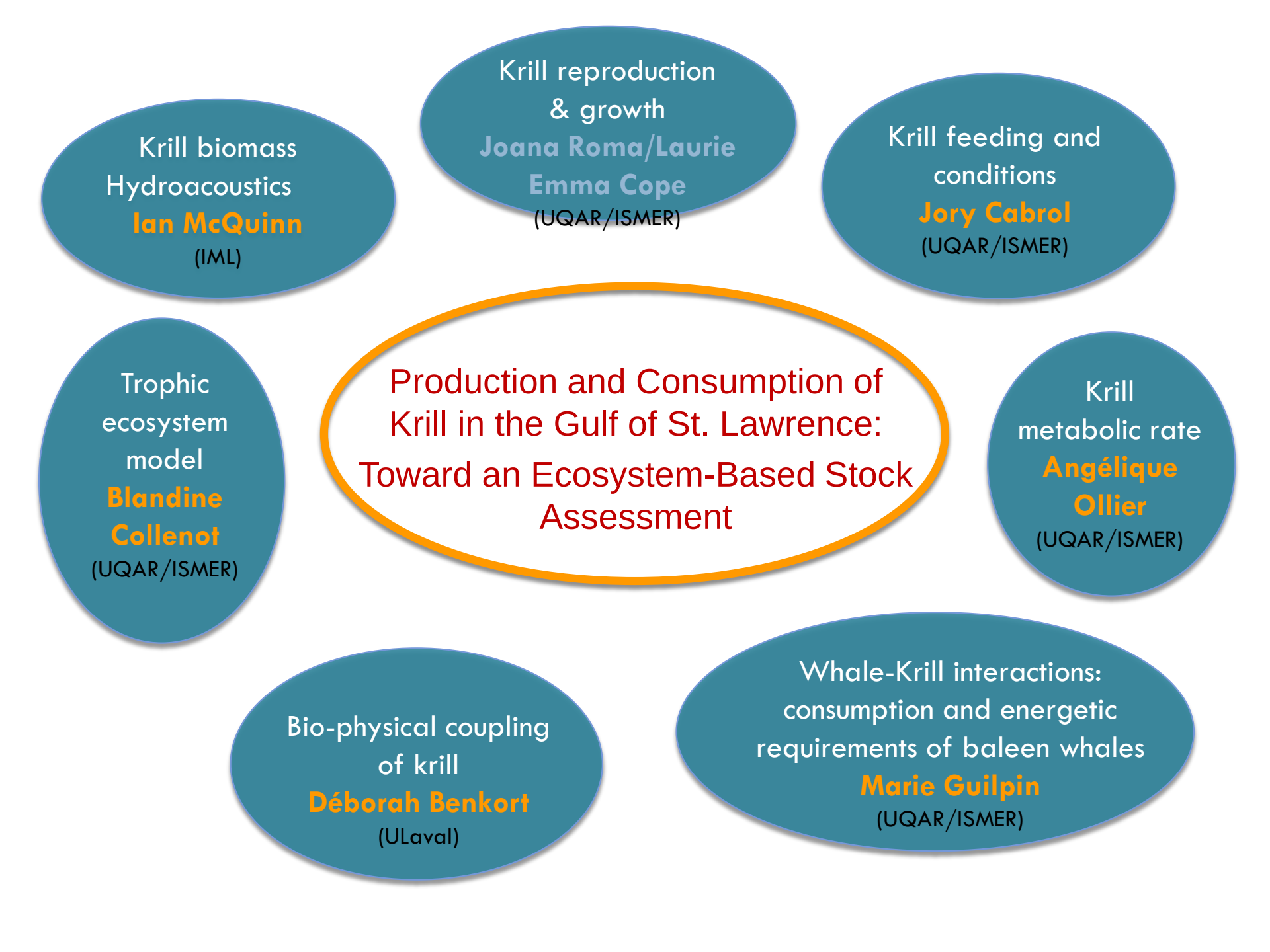
The project will benefit

- Oceanographic Sciences in the EGSL
- Natural resources management
- Recovery strategy of the blue whale
- Ecotourism
- Fisheries
- Transformation industries

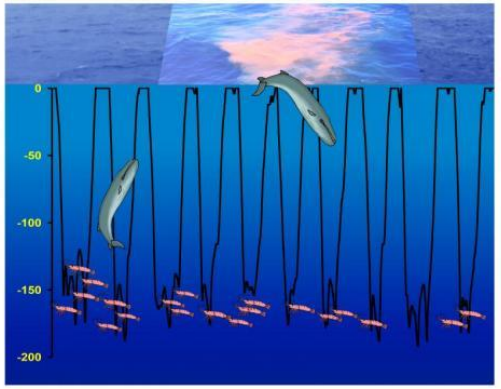
Acknowledgement

- Students: Jory Cabrol, Angélique Ollier, Blandine de Maillard, Déborah Benkort, Anne-Marie Trudel, Mathilde St. Pierre, Magali Combes, Danaë Lemieux-Uresandi

- Technicians: Pierre Joly, Jean-François St. Pierre, Liliane St. Amande, Catherine Bayzak, Luc Beaudin and Jean-Philip Lapierre


Krill reproduction & growth
Joana Roma/Laurie Emma Cope
(UQAR/ISMER)
Krill biomass Hydroacoustics
Ian McQuinn
(IML)
Krill feeding and conditions
Jory Cabrol
(UQAR/ISMER)
Production and Consumption of Krill in the Gulf of St. Lawrence:
Toward an Ecosystem-Based Stock Assessment
Trophic ecosystem model
Blandine Collenot
(UQAR/ISMER)
Krill metabolic rate
Angélique Ollier
(UQAR/ISMER)
Bio-physical coupling of krill
Déborah Benkort
(ULaval)
Whale-Krill interactions: consumption and energetic requirements of baleen whales
Marie Guilpin
(UQAR/ISMER)

Consumption of krill



Krill patch quality

- Depth
- Local density
- Krill biomass
- Krill quality

Foraging activity

- Foraging efficiency
- Diel and seasonal foraging activity by archival tags

- Assess energy requirements to put on adequate fat reserves
- Inter-annual availability of prey patches of adequate quality

Serve parameterisation of trophic ecosystem model

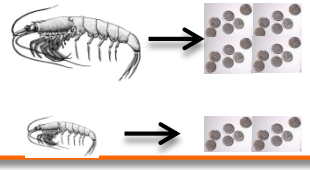
Environmental forcing

+

Physiological model

Reproduction

Allometric relationship relative to female length



Mortality

If mass ↓ > 70 % initial mass = death

Data of others themes of Krill's project

Growth = ingestion – metabolism

Holling type III

$$I = A * \frac{food^2 * V}{1 + Th * V * food^2}$$

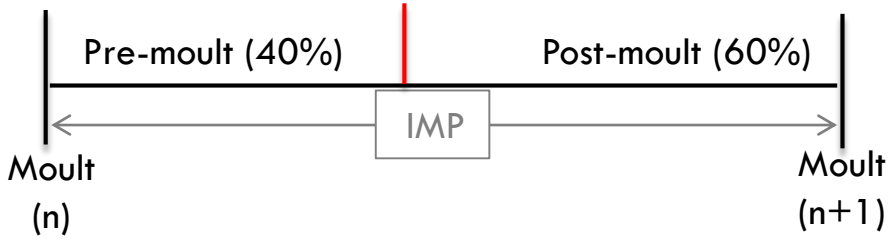
Respiration

$$R = R0 * M^{3/4} * \exp\left[\frac{-Ei(T-T0)}{(kTT0)}\right]$$

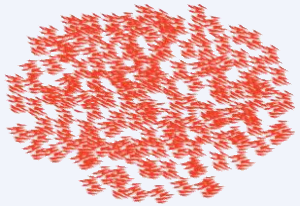
Development and moult

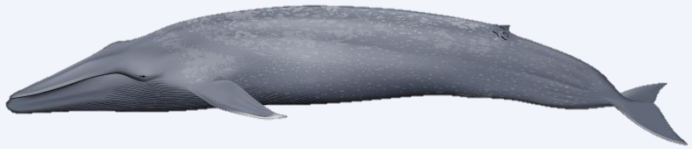
Intermoult period (IMP) = 20.62 - 1.16*temperature

When 40 % of IMP reached
Moult way is decided



Bio-energetic model of foraging baleen whales





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Gross Energy Intake
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Impact of change in prey availability, accessibility, prey type and biomass

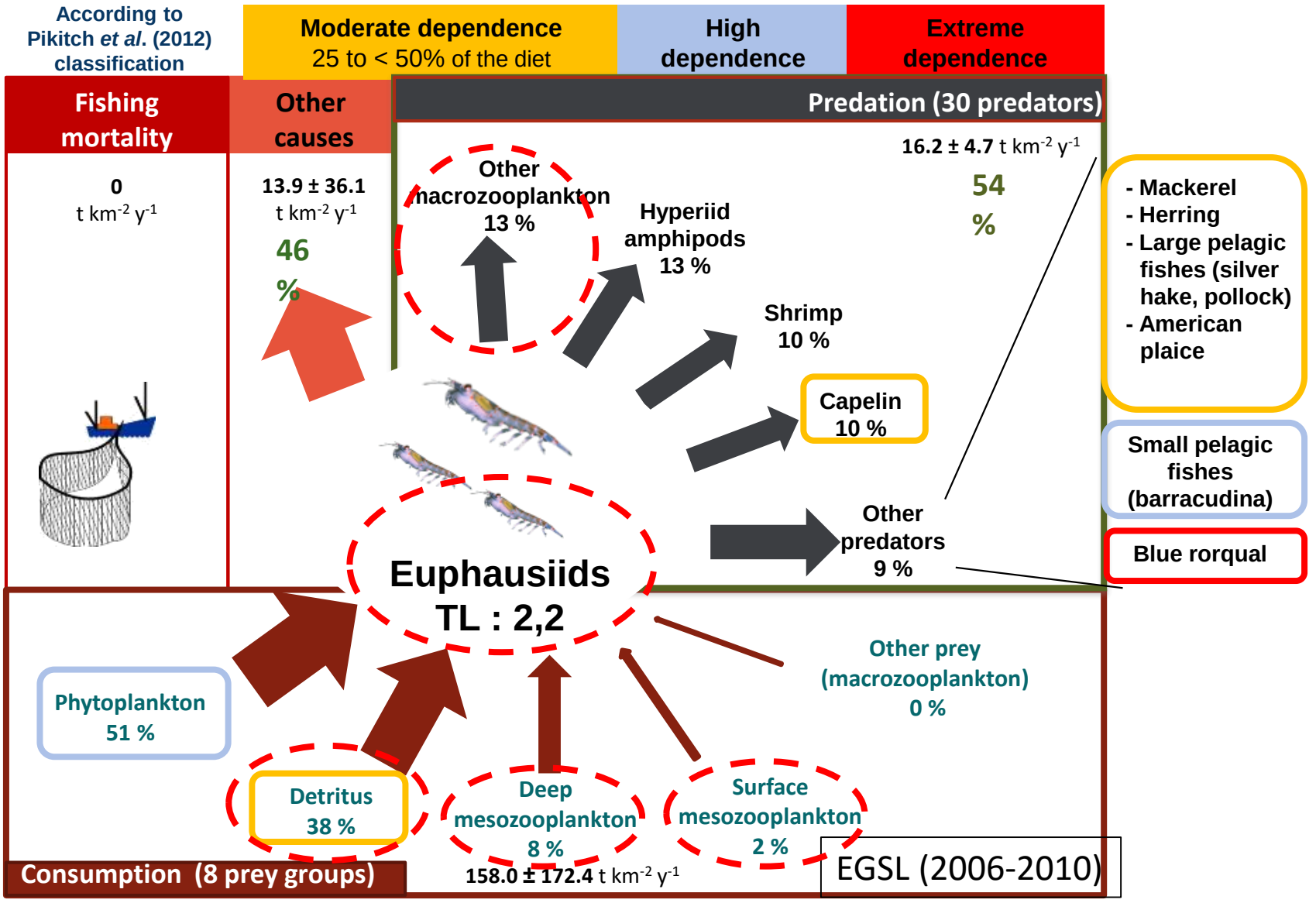
Krill consumption & energy required

Prey density threshold for beneficial exploitation

Impact of affecting foraging effort

M. Guilpin et al.

Group improvements groups



(Savenkoff *et al.* , 2013)