Ecology of krill in Icelandic waters

Teresa Silva
What are krill?

Video used with permission from Steinunn H. Ólafsdóttir (MFRI)
Introduction

Life-Cycle

Larval krill: plankton, i.e., drift with the currents
Adult krill: micro-nektonic life-forms, i.e., small animals capable of individual motion against (weak) currents.
Distribution of common krill species
Meganyciphanes norvegica
Adults 22-45 mm

Thysanoessa inermis
Adults 25-32 mm

T. longicaudata
Adults 10-16 mm

T. raschii
Adults 20-30 mm

Illustrations by T. Silva
Introduction
Why are krill important?

- 3rd largest component within the Icelandic EEZ based (Astthorsson et al., 2007)
Introduction

Why are krill important?

Phytoplankton

Small zooplankton

Invertebrates

Video © Steinunn H. Ólafsdóttir (MFRI)

Seabirds

Marine mammals

Fishes

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Introduction

Research problem

Lack of studies

- Paulsen 1909
- Stephensen, 1938
  - Basic overview krill species
- Einarsson 1945
  - Extensive study of krill around Iceland and nearby areas
- Astthorsson 1990
  - Seasonal study of krill in a fjord northwest of Iceland
- Astthorsson & Gislason 1997
  - Seasonal study of Krill north of Iceland
- Saunders et al 2007
  - Regional variation of krill in the Irminger Sea
- Silva et al 2014, 2016, 2017
  - Extensive study of krill around Iceland and nearby areas
Introduction

Water Masses

Southwest: Atlantic water
North: a mixture of Atlantic-Arctic water
East: Arctic water

- NAC, North Atlantic Current;
- IC, Irminger Current;
- NIIC, North Icelandic Irminger current
- EGC, East Greenland Current;
- EIC, East Iceland Current.
Objective

The aim of the project is to evaluate the ecological role of krill in Icelandic waters.

• Studying the distribution, population structure and long-term changes of krill around Iceland in relation with environmental parameters.
Methodology

• Continuous Plankton Recorder
• Plankton net: WP2 net
• Macrozooplankton trawl
Methodology

- Zooplankton samples were analysed automatically with ZoolImage. (Paper II)

Estimate bloom timing [OPB]:
The week when the annual median of Chl a concentration increases 5 % (Siegel et al 2002, Science)
Long-term changes of euphausiids in shelf and oceanic habitats southwest, south and southeast of Iceland

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### Paper I: Long-term changes

**Aim**

- To describe the long-term and seasonal changes of krill in Icelandic waters and adjacent sea areas.
- To evaluate how environmental variables and the onset of the phytoplankton spring bloom and biomass affect the multidecadal variability of krill.
**Paper I: Long-term changes**

**Results**
Seasonal variability of **total krill abundance** in the CPR Surveys from 1958 to 2007.
Paper I- long-term changes

Highlights

Temporal and spatial variability in total numbers of krill
- with a decline of krill abundance in most CPR areas in the North Atlantic.
- Irminger sea shows high values of krill numbers in the North Atlantic.

*Single variable-based GAMs*
- Phytoplankton biomass was the main environmental factor regulating krill presence and high numbers.

Why do we observed a decrease in krill population?
↓ strength temporal synchrony between the development of young krill and the phytoplankton

*Multiple variable-based GAMs*
- Phytoplankton biomass and development were the strongest predictors of euphausiid abundance in the west.
- Temperature appears to be most important in the east.
ORIGINAL ARTICLE

Abundance and distribution of early life stages of krill around Iceland during spring

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\textbf{ABSTRACT}

Abundance, distribution and development of early life stages of krill (eggs, nauplii, calyptopodes and furciliae) around Iceland were studied during the latter half of May 2013. Multivariate analyses were used to examine the relationships between water mass characteristics and phytoplankton spring bloom dynamics and distribution of krill. The results show that krill eggs, nauplii and calyptopodes were most abundant over the shelf edges off the southwest and east coasts, while furciliae were most abundant on the shelf off the southwest coast. \textit{Meganyctiphanes norvegica} and \textit{Thysanoessa longicaudata} larvae were found mainly in the southwest, while \textit{T. inermis} larvae were found in highest numbers on the east coast. Redundancy analysis showed that phytoplankton biomass, temperature and bottom depth explained 41\% of the distribution pattern of early ontogenetic krill stages. In areas where krill eggs and larvae were most abundant (off the southwest coast), the phytoplankton spring bloom was in an advanced state, and the phytoplankton biomass and temperature were particularly high.
Paper II: Distribution eggs and larvae

**Aim**

- Describe the abundance, distribution and development of early life stages of krill (eggs, nauplii, calyptopes and furciliae) in relation to environmental variables and phytoplankton spring bloom dynamics around Iceland.

- Main hydrographic domains:
  - southwest - Atlantic water
  - north - a mixture of Atlantic-Arctic water
  - east - Arctic water
**Paper II: results**

**Eggs**

**Nauplius**

**Calyptopis**

**Furcilia Juveniles**

**Abundance Ind m$^3$**

[Graphs and images showing distribution and abundance of different life stages of mesopelagic copepods across different latitudes.]
Paper II: Distribution of eggs and larvae

**Highlights**

- *M. norvegica* and *T. longicaudata* larvae were found mainly in the southwest,
- while *T. inermis* larvae were found in highest numbers on the east coast.

Redundancy analysis showed that chl $\alpha$, temperature and bottom depth explained 41% of the distribution pattern of early ontogenetic krill stages ($p<0.01$, Monte Carlo permutation tests).
RESEARCH ARTICLE

Distribution, maturity and population structure of Meganystiphanes norvegica and Thysanoessa inermis around Iceland in spring

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Abstract

This study aims to explain the distribution, maturity and population structure of Meganystiphanes norvegica and Thysanoessa inermis in springtime in relation to main hydrographic regions around Iceland: Atlantic in the southwest, Atlantic-Arctic mixture in the north and Arctic in the east. Krill were collected 14–29 May 2013 using a macrozooplankton trawl. Biomass of both species combined was significantly higher in the southwest than in north and east. M. norvegica clearly dominated in Atlantic waters, whereas T. inermis was more evenly distributed around the island, while the highest values were also observed in the southwest for this species. Simple linear regressions showed that the abundance of M. norvegica was positively related to temperature, salinity and phytoplankton concentration, while the abundance of T. inermis was negatively related to bathymetry. Multiple linear regression analyses did not add to this information of a positive relationship between abundance and temperature for M. norvegica, while T. inermis was shown to be negatively related to both temperature and bathymetry. During the latter half of May, the main spawning of both species was confined to the regions off the southwest coast. Sex ratio (males/ females) of M. norvegica was higher in the southwest than in the north and east, whereas T. inermis showed a similar sex ratio all around the island. In all regions, M. norvegica appears to have a lifespan of 2 years while T. inermis is 1 year in the southwest and possibly 2 years in north and east.
Paper III: Distribution of adults

Aim

- Describe the distribution, maturity and population structure of *M. norvegica* and *T. inermis* around Iceland in relation to the main hydrographic domains:
  - southwest - Atlantic water
  - north - a mixture of Atlantic-Arctic water
  - east - Arctic water
Paper III: Distribution of Adults

M. norvegica

T. inermis
Paper III: Distribution of Adults

Highlights

- *M. norvegica* were predominant in the warm water in the southwest and *T. inermis* in the colder waters North and East.
- The main spawning of both species took place off the southwest coast.
- *M. norvegica* appears to have a life span of 2-years, in all regions.
- *T. inermis* of 1-year in the southwest and possibly 2-years in north and east.

Linear analysis

- Abundance of *M. norvegica* was positively related to temperature.
- Whereas *T. inermis* was negatively related to temperature and bathymetry.
Significance of findings

• Climate change – increase temperature (Paper I)
  • Decline on krill -> Lower synchrony with the young krill and phytoplankton spring bloom

• Phytoplankton biomass and dynamics play an important part
  • in the distribution and abundance of krill (Paper I, II, III)
  • Spawning (Paper II, III)

• Overlap between distribution of eggs and adults species. (Paper I, II, III)
• Atlantic water importance in the distribution of krill around Iceland
Further work

- Further understanding of the phytoplankton bloom development effects on krill
- Trophic studies
- Transfer efficiency of mass and energy in the ecosystem with emphasis on krill
- Seasonal monitoring program for krill
Acknowledge

Many thanks

• Astthor Gislason
• Gudrun Marteinsdottir
• Olafur S. Astthorsson
• Sólrún Sigurgeirsdóttir
• Mette Adgested
• Colleagues at the MFRI and at HI
• Crew of R.V. Bjarni Sæmundsson
• Crew of R.V. Meteor
• ....

Funding

Euro-Basin
MFRI
Emskip grant
UI’s Teaching assistance fund
Arctic Studies Fund
UI’s Research Fund – Travel Grant
Krill species commonly found in the North Atlantic

- **Thysanoessa longicaudata**
  - Adults 10-16 mm

- **Meganyctiphanes norvegica**
  - Adults 22-45 mm
  - Adults 25-32 mm

- **T. inermis**
  - Adults 20-30 mm

- **T. raschii**
  - Adults 10-16 mm
  - Adults 22-45 mm
  - Adults 25-32 mm