Exploring the microzooplankton-ichthyoplankton link:

A combined field and modeling study of Atlantic herring (*Clupea harengus*) in the Irish Sea

Franziska Bils[1], Marta Moyano[1], Marc Hufnagl[1], Nicole Aberle[2], Santiago Alvarez-Fernandez[3] & Myron Peck[1]

[1]University of Hamburg, Institute for Hydrobiology and Fisheries Science
[2]Norwegian University of Science and Technology, Trondhjem Biological Station
[3]Alfred Wegener Institute, Kurpromenade, 27498 Helgoland, Germany

March 6 – 11 2017, Victoria, Canada

Protozooplankton – ichthyoplankton link

+

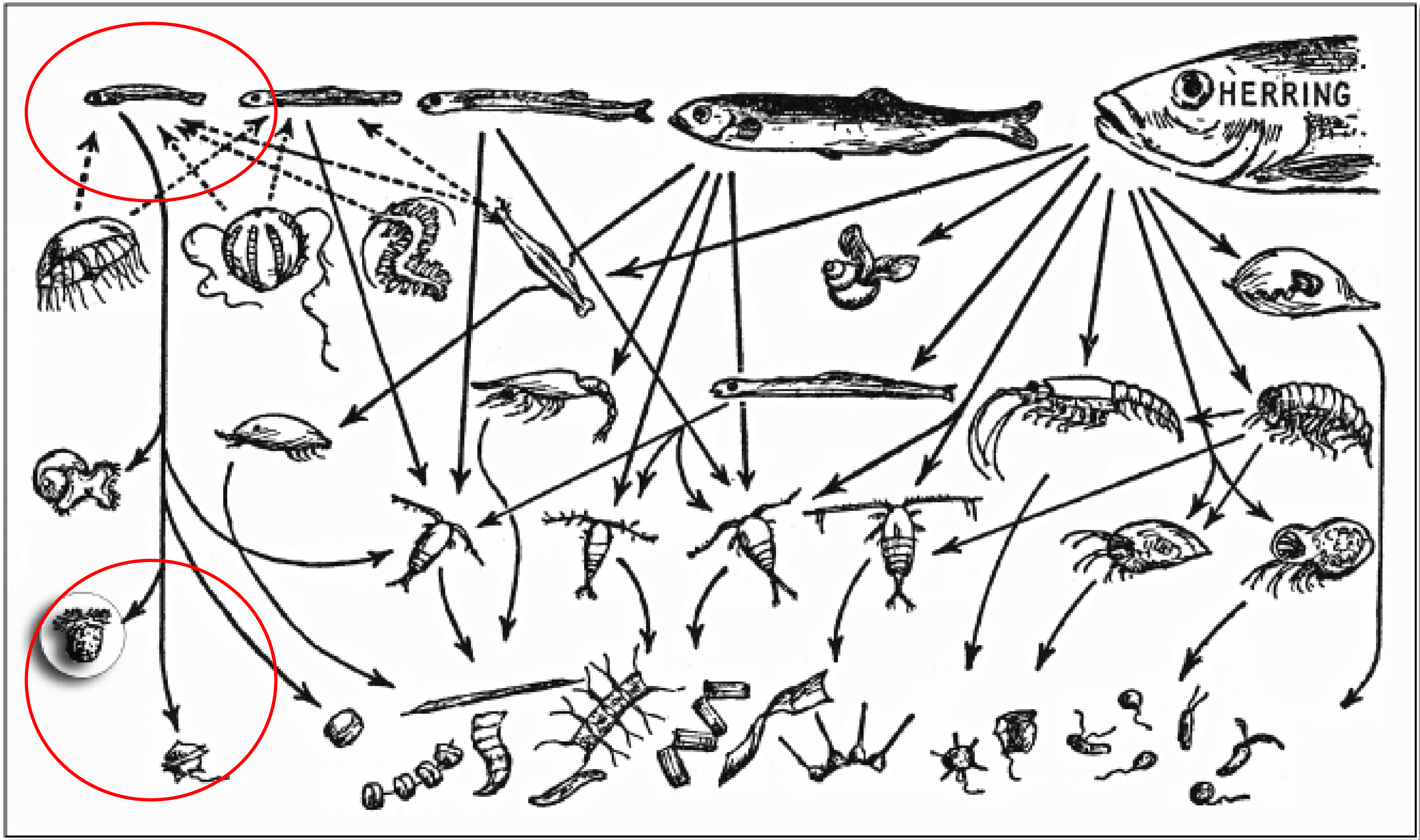
PZP = Unicellular hetero- and mixotrophic plankton

- Enhance first feeding (Overton et al., 2010; Illing et al., 2016)
- Preferred prey for first feeding (Hunt von Herbing et al., 2001)
- Improve survival (Nagano et al., 2001)
- Observations in gut content & stable isotopes (Fukami et al. ,1999; Figueiredo et al. , 2005; Pepin & Dower, 2007; Denis et al., 2016)

Why is there so little knowledge?

Rapid digestion → difficult gut content analysis
Preservation in Formalin → many protists dissolve
Few data on PZP abundance and composition

Microzooplankton – ichthyoplankton link



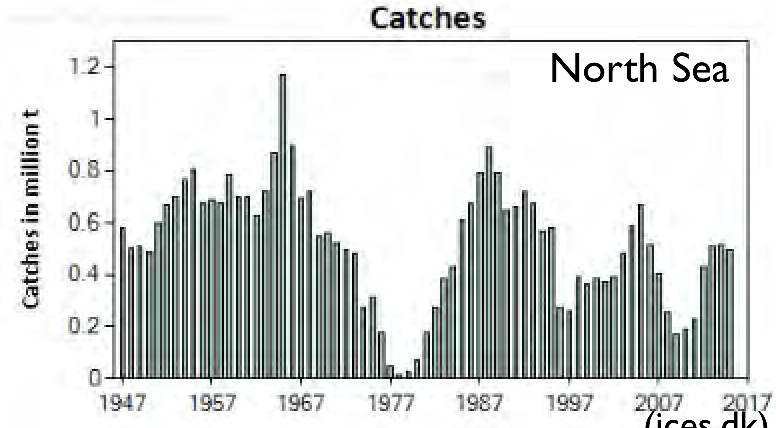
(Hardy, 1924, modified by Dolan et al. ,2013)

Atlantic herring as model species

1. Commercialy important species

2. Well studied species
   - Knowledge about larval physiology, feeding, prey preferences and behaviour (e.g. Illing, 2016; Spittler, 1990; Blaxter, 1965)

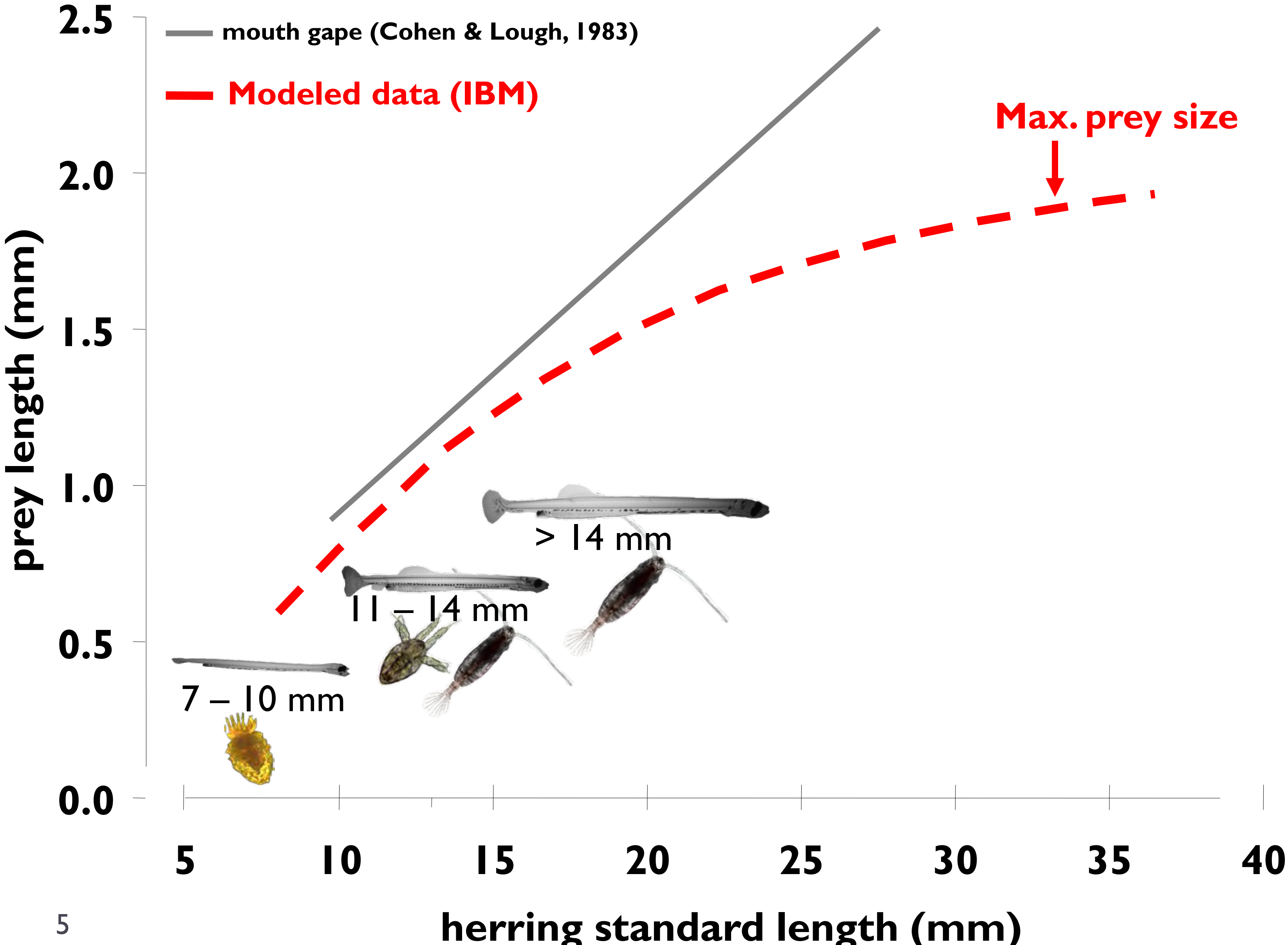
3. Autumn- and winter spawning stock
   - Small prey may be of higher importance during times of low productivity (Alvarez-Fernandez , 2015; Payne, 2013)



(ices.dk)

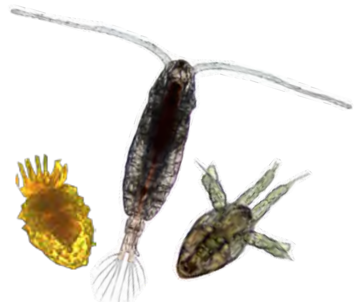
(eea.europa.eu)

Larval foraging



(modified after Hufnagl & Peck, 2011)

Irish Sea – Autumn spawning herring



Field data

Model

What is the potential small sized *in-situ* prey field (20-300µm) herring larvae experience and how does it influence larval abundance and growth?

Combination of field sampling and modeling.

Irish Sea – November 2012 & 2013

ICES CIEM

ICES coordinated herring larvae survey (NINEL) coordinated by AFBI, Belfast

Gulf VII (280µm)

Abundance, distribution & length

Biochemistry: RNA:DNA

Micro – and small mesozooplankton (MZP)

PUP-net (52 µm)

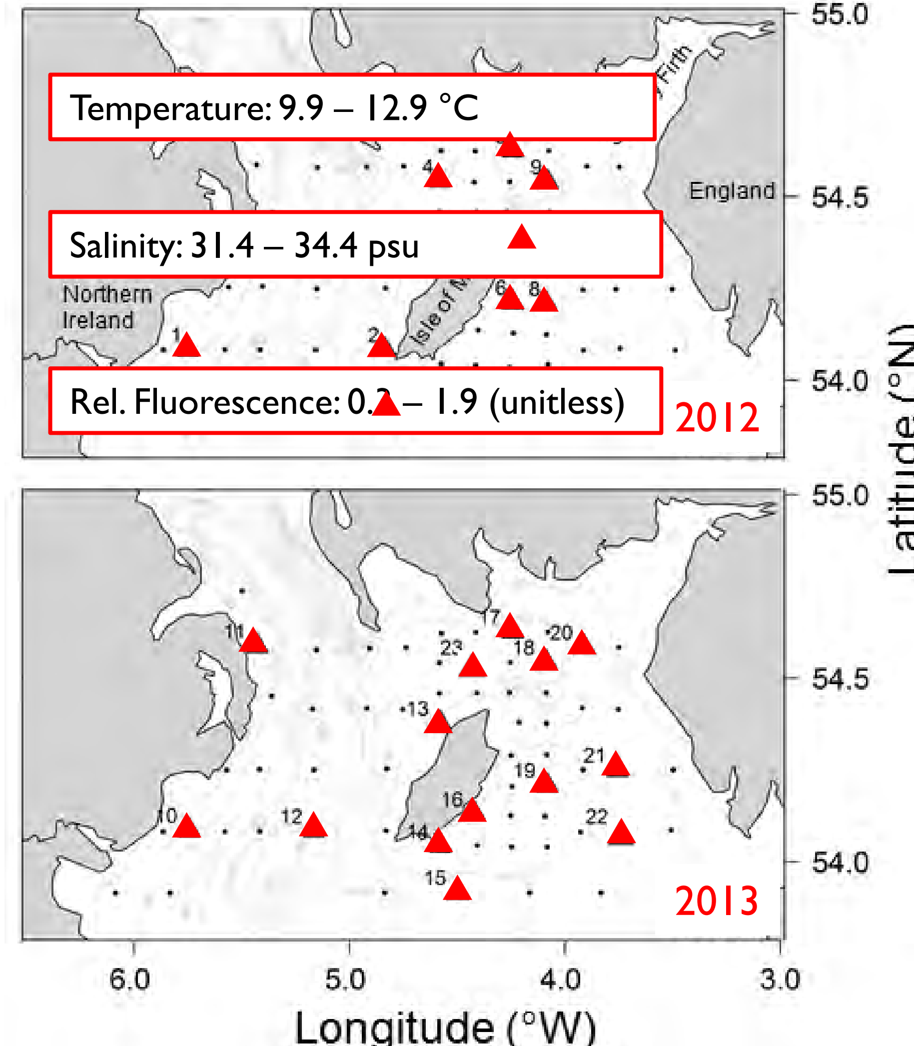
(52 – 300µm)

Protozooplankton (PZP)

Biomass, distribution & composition

CTD-rosette

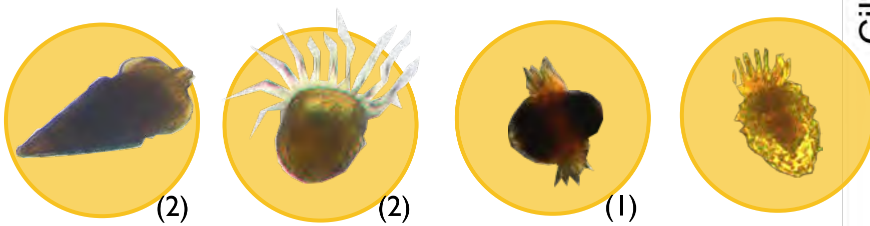
(12 – 200µm)



(Bils et al., 2016)

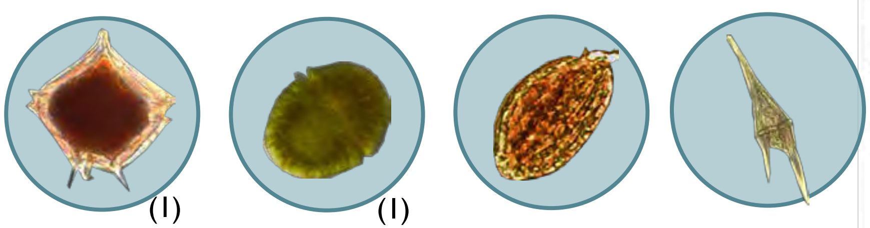
PZP composition

- Mainly ciliates and dinoflagellates
- 13 ciliate taxa

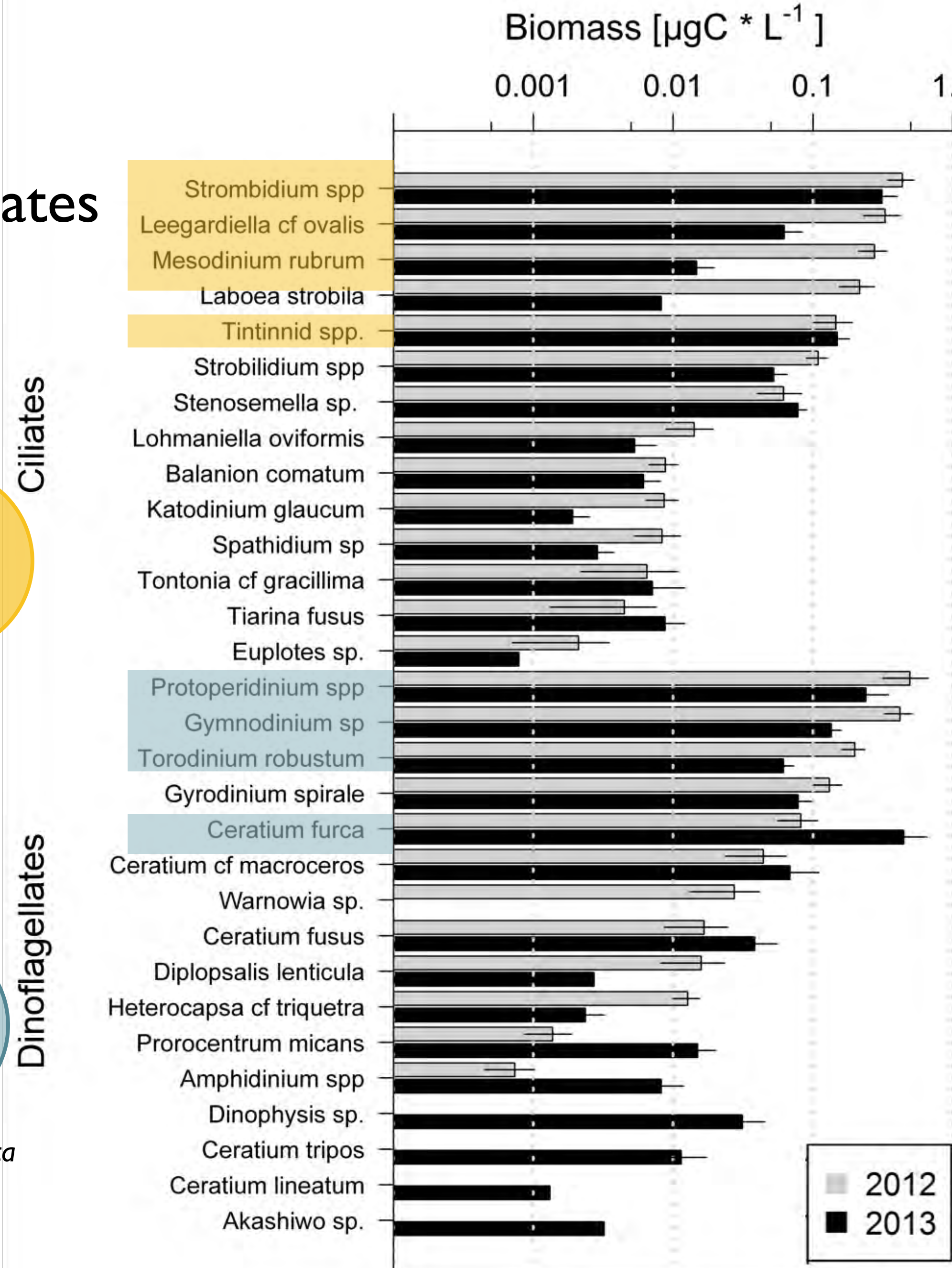


Strombidium spp · *Leegardiella ovalis* · *Mesodinium rubrum* · *Tintinnida*

- 16 dinoflagellate taxa



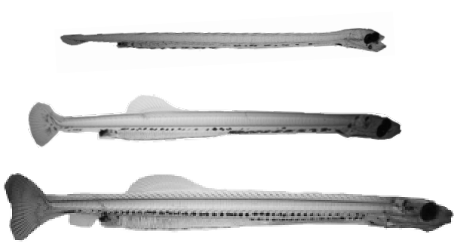
Protoperidinium spp · *Gymnodinium spp* · *Torodinium robustum* · *Ceratium furca*

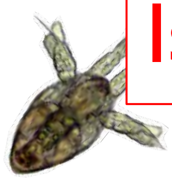


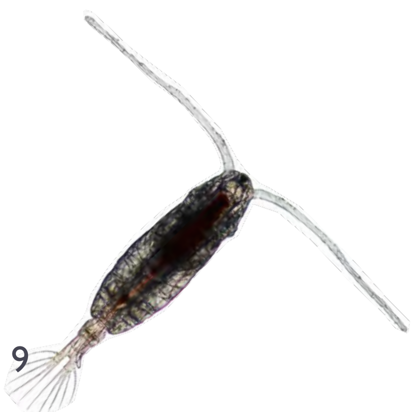
(Bils et al., 2016)

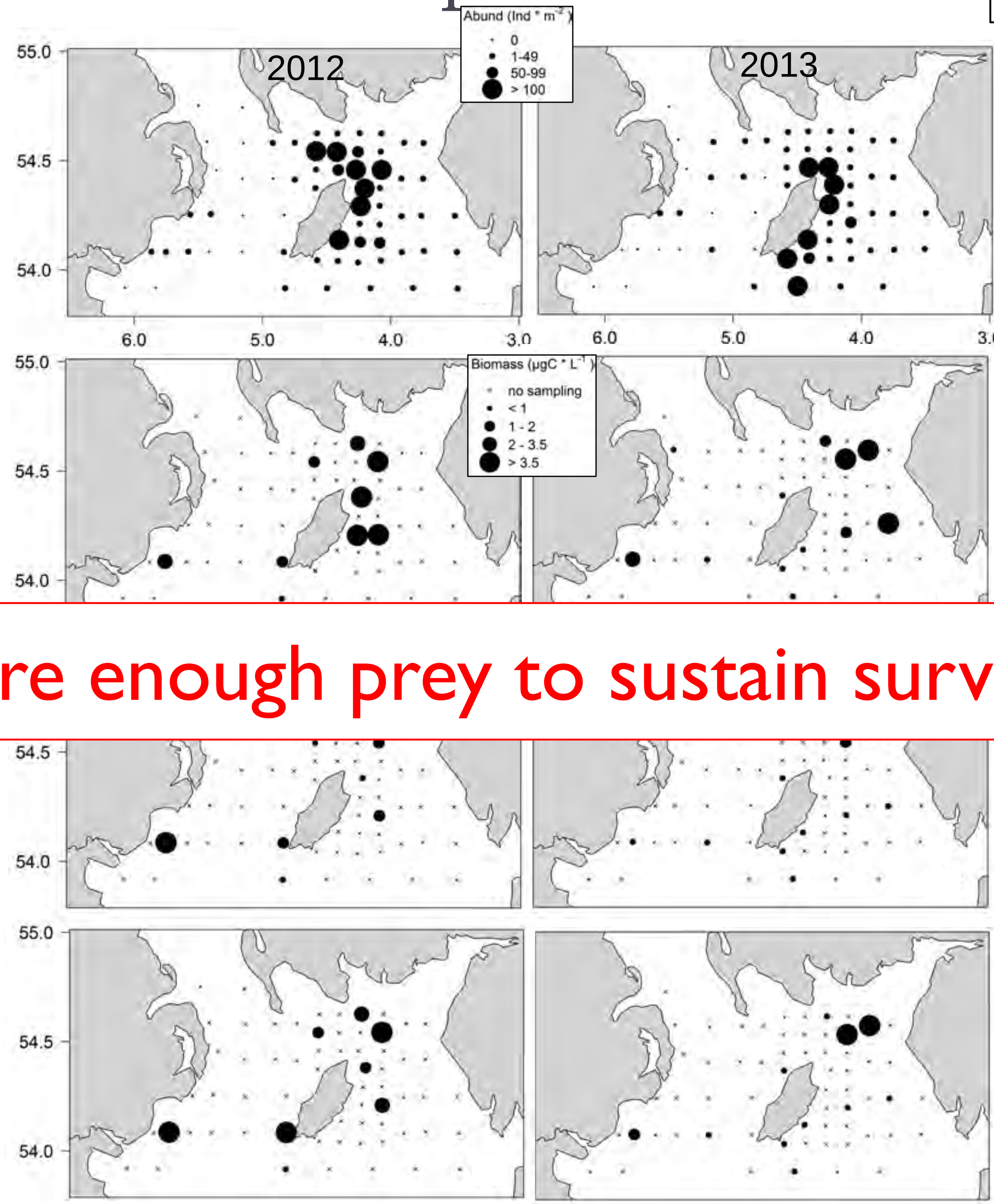
Distribution of larvae & plankton

GLMM









Is there enough prey to sustain survival?

(Bils et al., 2016)

Sufficient food supply for herring larvae?

Field vs. Model

Copepods 200-300µm

Nauplii 100-200 µm

PZP < 100 µm

Biochemically derived RNA:DNA

observed

Individual based foraging and growth model (IBM)

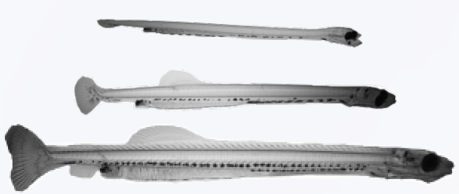
$$\text{Growth} = \text{Consumption} \cdot \beta \cdot (1 - \text{SDA}) - (R_R \cdot k)$$

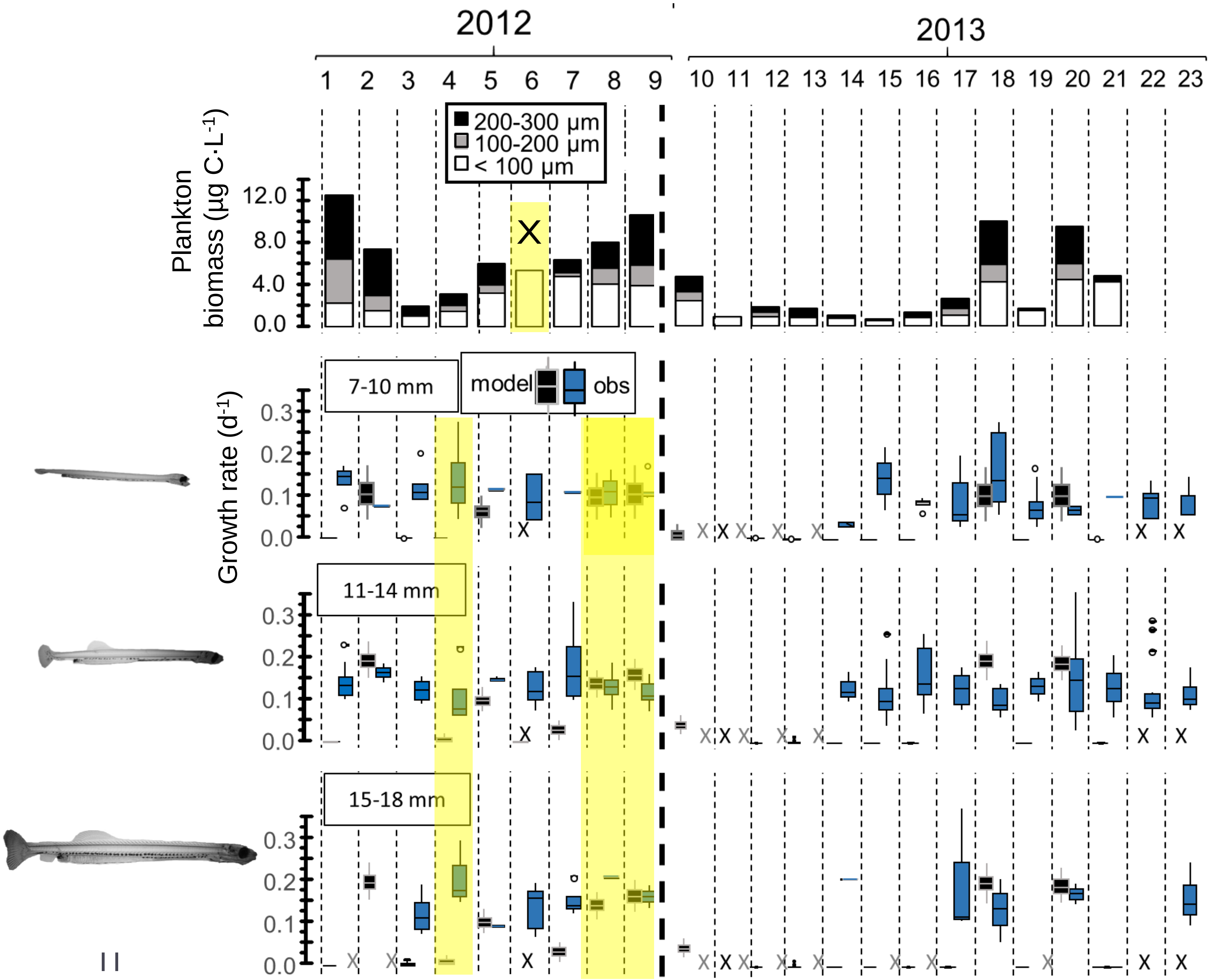
Energy gain (Consumption) · Assimilation ($\beta \cdot (1-\text{SDA})$) · Metabolism ($R_R \cdot k$)

Hufnagl & Peck (2011), Hufnagl et al. (2015)

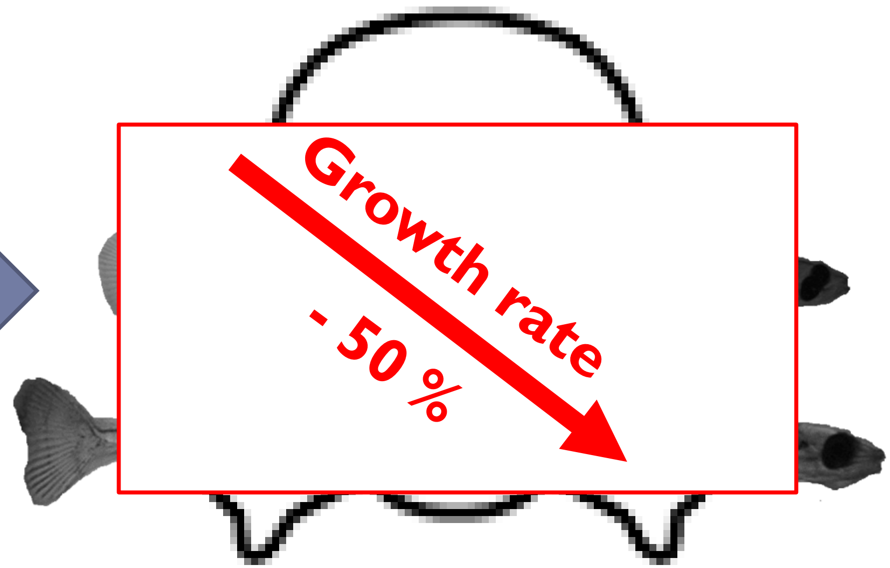
modeled

Growth rate




2012
2013
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
200-300 µm
100-200 µm
< 100 µm
Plankton biomass (µg C·L-1)
12.0
8.0
4.0
0.0
7-10 mm
model
obs
Growth rate (d-1)
0.3
0.2
0.1
0.0
11-14 mm
15-18 mm

al., 2016)



Model suggests: PZP is important for larval growth!

Conclusion

1. Small plankton is important for herring larvae and likely other larvae under low productivity conditions
2. IBM‘s need to include PZP
3. We lack data on autumn- and winter PZP community

→ Potential for augmenting routine surveys for fish stock assesment

→ Simultaneous sampling of different trophic levels

Future tasks:

What are the food preferences of larvae?

What is the nutritional quality of potential prey organisms?

Acknowledgements

- Steven Beggs (AFBI, Belfast)
- The crew from RV Corystes
- Johanna Thoms
- ICES and UHH for travel funds

JPR Advance Access published October 20, 2016

Journal of Plankton Research

plankt.oxfordjournals.org

J. Plankton Res. (2016) 00(00): 1–17. doi:10.1093/plankt/fbw074

Exploring the microzooplankton–ichthyoplankton link: a combined field and modeling study of Atlantic herring (*Clupea harengus*) in the Irish Sea

FRANZISKA BILS[1*], MARTA MOYANO[1], NICOLE ABERLE[2], MARC HUFNAGL[1], SANTIAGO ALVAREZ-FERNANDEZ[3] AND MYRON A. PECK[1]

[1]INSTITUTE FOR HYDROBIOLOGY AND FISHERIES SCIENCE, UNIVERSITY OF HAMBURG, OLBERSWEG 24, 22767 HAMBURG, GERMANY, [2]NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY, TRONDHJEM BIOLOGICAL STATION, DEPARTMENT OF BIOLOGY, 7491 TRONDHEIM, NORWAY AND [3]ALFRED WEGENER INSTITUTE, KURPROMENADE, 27498 HELGOLAND, GERMANY

*CORRESPONDING AUTHOR: franziska.bils@uni-hamburg.de

Received April 18, 2016; accepted September 7, 2016

Corresponding Editor: John Dolan

The microzooplankton–ichthyoplankton link remains poorly resolved in field studies due to a lack of simultaneous sampling of these predators and potential prey. This study compared the abundance, distribution and growth of larval Atlantic herring (*Clupea harengus*) and the abundance, biomass and composition of micro- and small mesozooplankton throughout the Irish Sea in November 2012 and 2013. In contrast to warmer months, microzooplankton biomass was highest in eastern areas, in the vicinity of the main spawning grounds of herring. Although the protozoan composition differed somewhat between years, dinoflagellates (e.g. *Gymnodinium* spp., *Protoperidinium* spp., *Ceratium furca*) dominated in abundance and/or biomass, similar to other temperate shelf seas in autumn/winter. Spatial differences in the protozoan community were strongly related to hydrographic characteristics (temperature, salinity). Significant relationships between the abundance of larval herring and dinoflagellates (positive) and copepodites (negative) suggested that complex grazing dynamics existed among lower trophic levels. When different, *in situ* size fractions of zooplankton were used as prey in a larval herring individual-based model, simulations that omitted protozooplankton under-predicted observed (biochemically-based) growth of 8–18 mm larvae. This study suggests that small planktonic organisms (20–300 µm) should be routinely surveyed to better understand factors affecting larval fish feeding, growth and survival.

KEYWORDS: autumn-spawning herring; protozooplankton community; microzooplankton–ichthyoplankton link; individual-based model

available online at www.plankt.oxfordjournals.org

References

- (1) nordicmicroalgae.org
- (2) by E. Sherr
- Alvarez-Fernandez, S., Licandro, P., van Damme, C. J. G. and Hufnagl, M. (2015) Effect of zooplankton on fish larval abundance and distribution: a long-term study on North Sea herring (*Clupea harengus*). *ICES J. Mar. Sci.*, **72**, 2569–2577.
- Blaxter, J. H. S. (1965). The feeding of herring larvae and their ecology in relation to feeding. *Calif. Coop. Oceanic Fish. Invest. Rep.,* **10**: 79–88.
- Denis, J., Vallet, C., Courcot, L., Lefebvre, V., Caboche, J., Antajan, E., Marchal, P., *et al.* (2016) Feeding strategy of Downs herring larvae (*Clupea harengus* L.) in the English Channel and North Sea. *Journal of Sea Research*, **115**: 33–46.
- Figueiredo de, G. M., Nash, R. D. M. and Montagnes, D. J. S. (2005) The role of the generally unrecognised microprey source as food for larval fish in the Irish Sea. *Mar. Biol.*, **148**, 395–404.
- Fukami, K., Watanabe, A., Fujita, S., Yamaoka, K. and Nishijima, T. (1999) Predation on naked protozoan microzooplankton by fish larvae. *Mar. Ecol. Prog. Ser.*, **185**, 285–291.
- Hufnagl, M. and Peck, M. A. (2011) Physiological individual-based modelling of larval Atlantic herring (*Clupea harengus*) foraging and growth: insights on climate-driven life-history scheduling. *ICES J. Mar. Sci.*, **68**, 1170–1188.
- Hufnagl, M., Peck, M. A., Nash, R. D. M. and Dickey-Collas, M. (2015) Unravelling the Gordian knot! Key processes impacting overwintering larval survival and growth: A North Sea herring case study. *Prog. Oceanogr.*, **138**, 486-503.
- Hunt von Herbing, I. and Gallager, S. M. (2000) Foraging behavior in early Atlantic cod larvae (*Gadus morhua*) feeding on a protozoan (*Balanion* sp.) and a copepod nauplius (*Pseudodiaptomus* sp.). *Mar. Biol.*, **136**, 591–602.
- Illing, B., Moyano, M., Niemax, J. and Peck, M. A. (2015) Direct Effects of Microalgae and Protists on Herring (*Clupea harengus*) Yolk Sac Larvae. *PloS one*, **10**: e0129344
- Illing, B., Moyano, M., Berg, J., Hufnagl, M. and Peck, M. A. (2016) Behavioral and physiological responses to prey match-mismatch in larval herring. *Estuarine, Coastal Shelf Sci.* (in press). doi: 10.1016/j.ecss.2016.01.003
- Nagano, N., Iwatsuki, Y., Kamiyama, T. and Nakata, H. (2000) Effects of marine ciliates on survivability of the first-feeding larval surgeonfish, *Paracanthurus hepatus*: laboratory rearing experiments. *Hydrobiologia*, **432**, 149–157.
- Overton, J., Meyer, S., Støttrup, J. and Peck, M. (2010) Role of heterotrophic protists in first feeding by cod (*Gadus morhua*) larvae. *Mar. Ecol. Prog. Ser.*, **410**, 197–204.
- Payne, M., Stine, D., Worsøe Clausen, L., Munk, P., Mosegaard, H. and Nash, R. (2013) Recruitment decline in North Sea herring is accompanied by reduced larval growth rates. *Mar. Ecol. Prog. Ser.*, **489**, 197–211.
- Spittler, P., Brenning, U. and Arlt, G. (1990) Protozoans—the first food of larval herring (*Clupea harengus* L.)? *Int. Rev. Gesamten Hydrobiol. Hydrogr.*, **75**, 597–603.