Feeding conditions for small pelagic fish in the southern Baltic Sea based on the long-term analyses of the zooplankton abundance and community structure changes in response to various environmental stressors.

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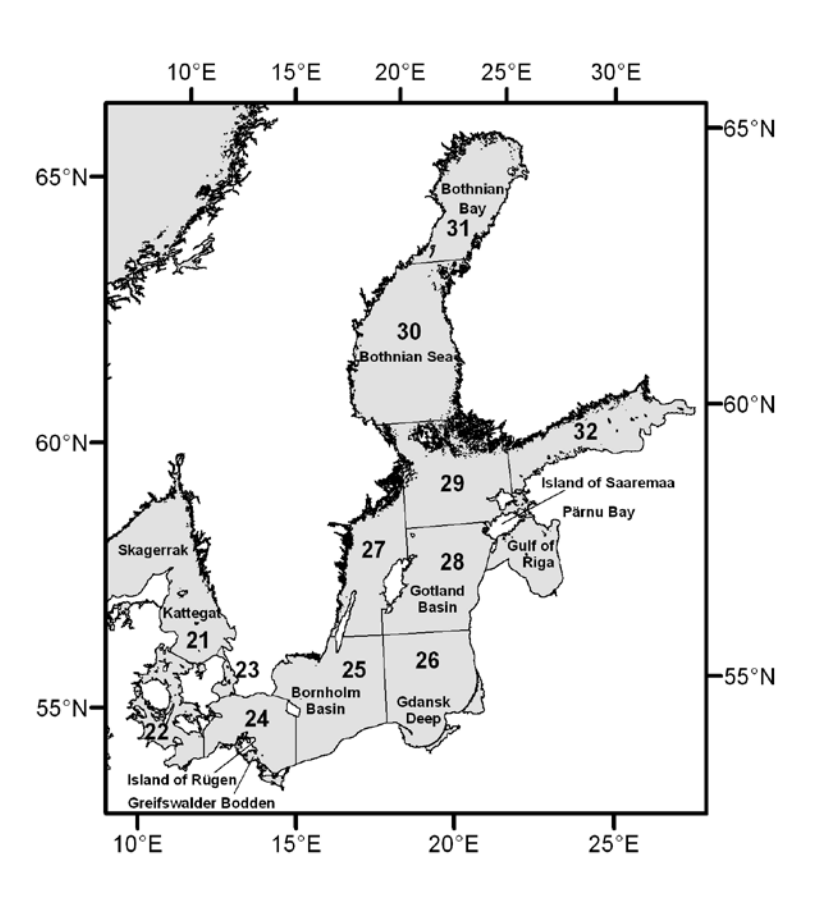
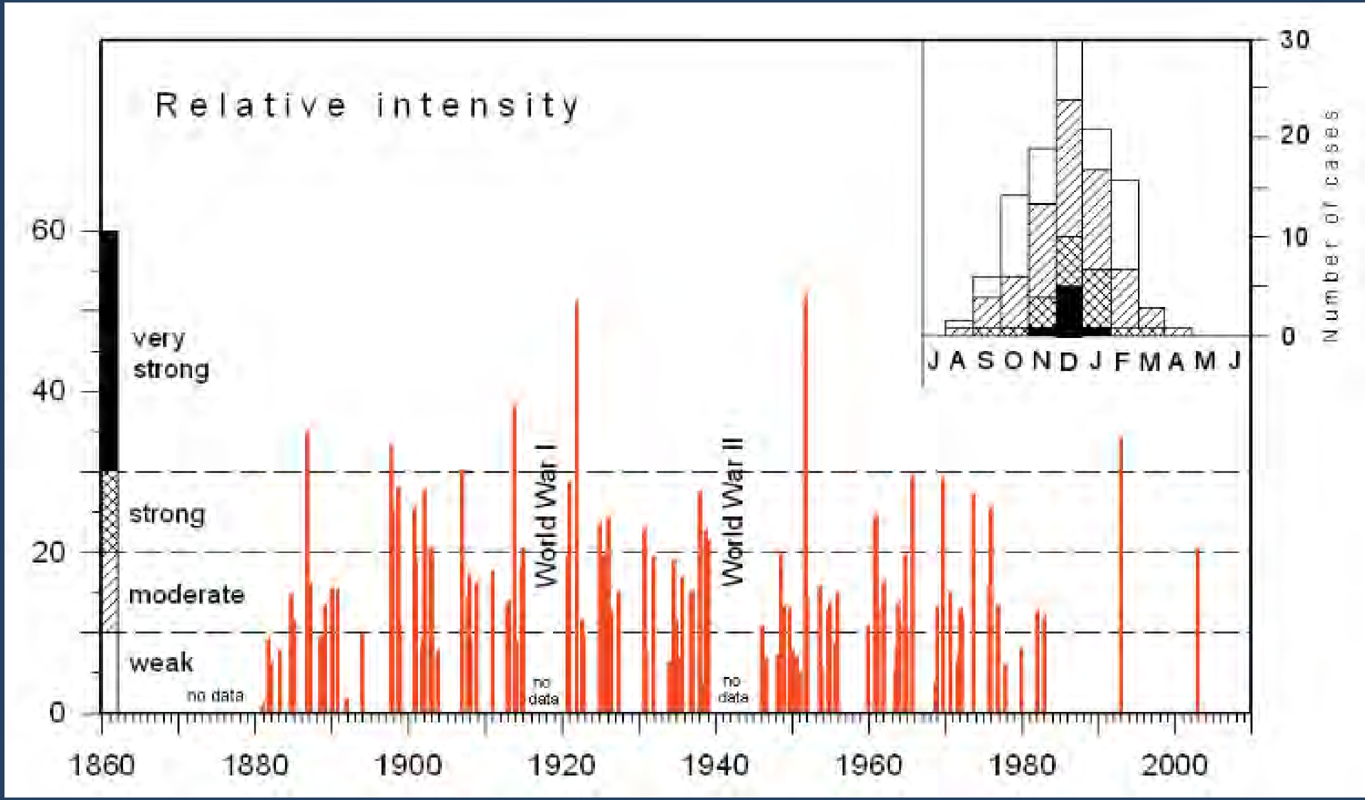
BONUS BIO-C3
SCIENCE FOR A BETTER FUTURE OF THE BALTIC SEA REGION

Baltic Sea – key facts:



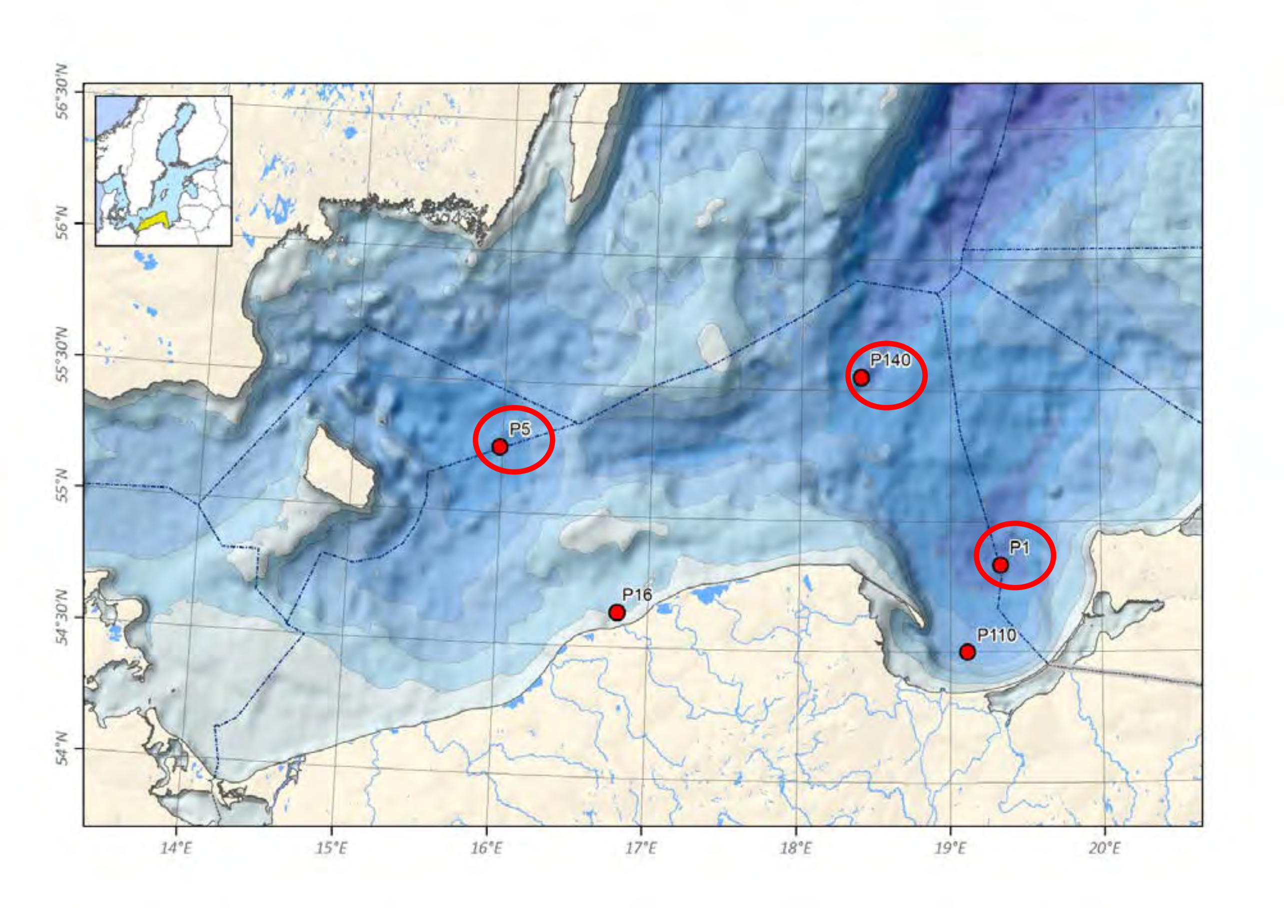
- Brackish inland sea with a limited water exchange
- Surface area is ~ 377,000 km²
- Average depth ~ 55 m
- The deepest area - 459 m
- Salinity gradient (down to 2 PSU in the Bothnian Bay)
- Vertical stratification
- Irregular inflows from North Sea

Major Baltic inflows and their seasonal distribution (upper right) shown in terms of their relative intensity (Matthäus and Franck, 1992; Fischer and Matthäus, 1996; supplemented and updated by BACC 2007).

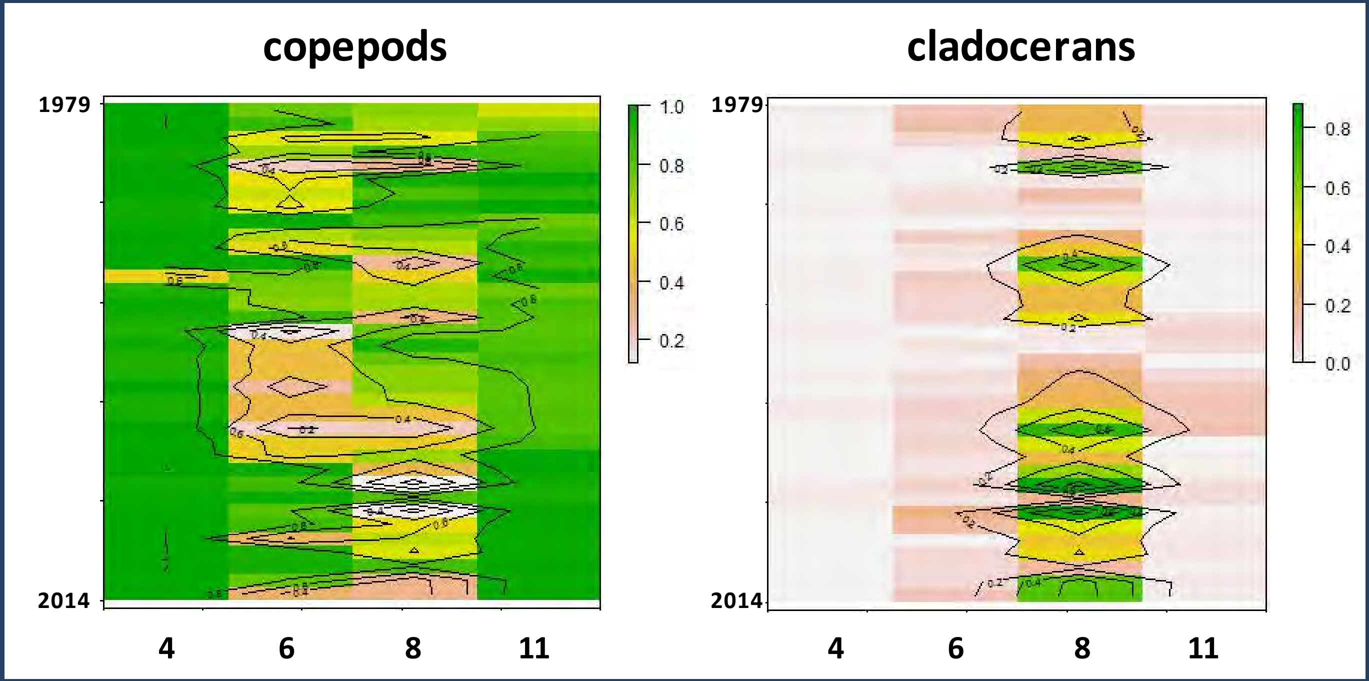


Zooplankton time-series

Presented data are the Polish contribution to the HELCOM COMBINE Programme. In most of the cases, samples were taken 5 times per year and the longest data series started in 1979.



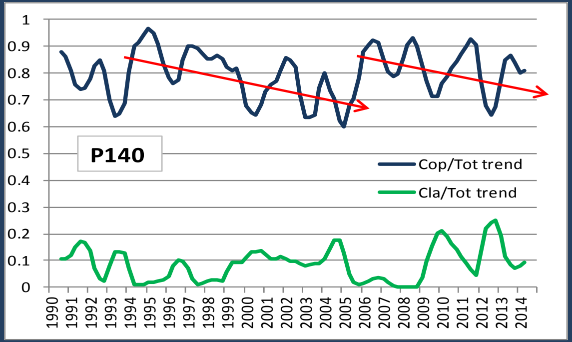
Seasonal dynamics in dominance of copepods and cladocerans in total zooplankton abundance

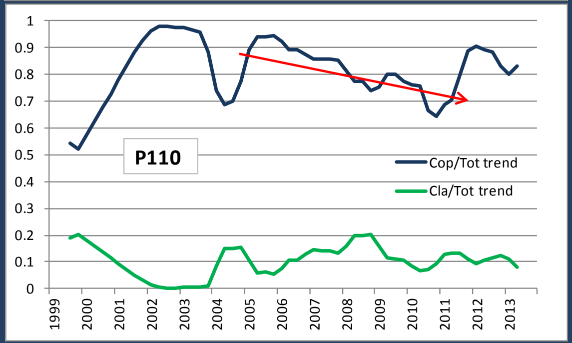


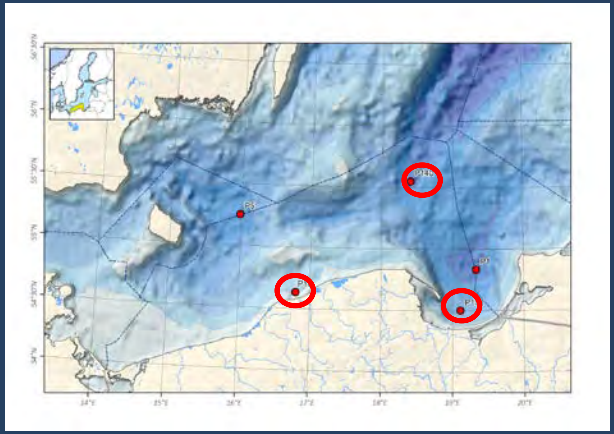
Percentage of copepods and cladocerans in total zooplankton abundance collected at P140 station (as an example).

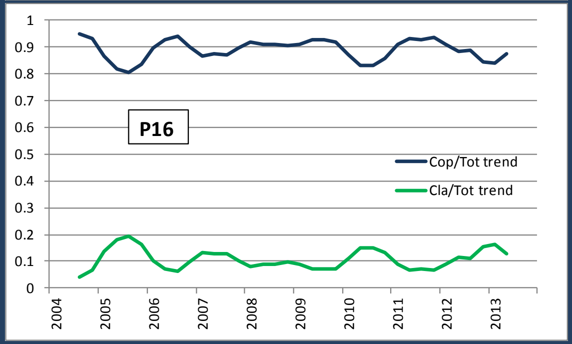
Percentage of copepods and cladocerans in total zooplankton abundance collected at three stations with decreasing distance to the coastline (from P140 in open waters to very coastal P16).

Red arrows denote a decrease of copepods dominance after the major inflow events in 1993 and 2003.



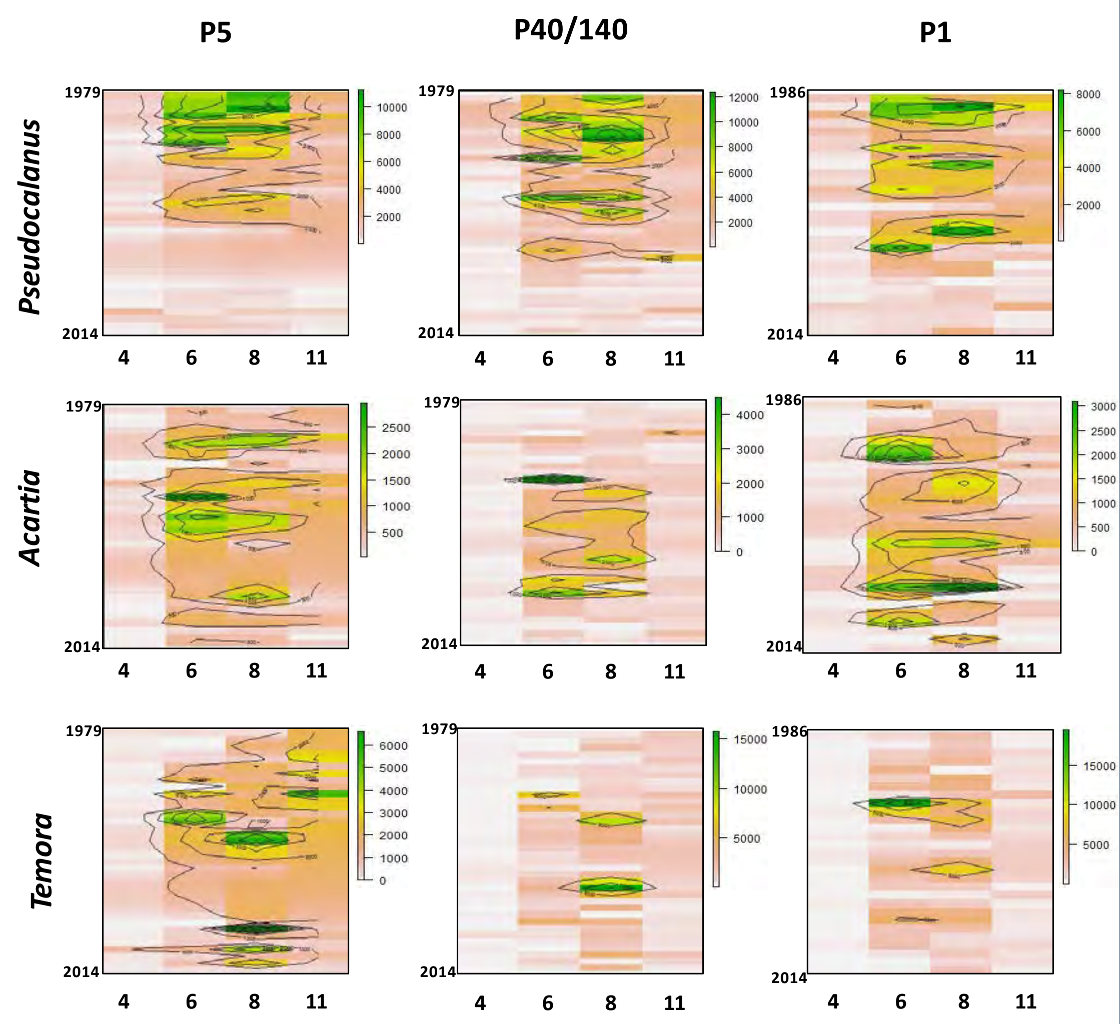






Long-term changes in abundance of *Pseudocalanus minutus*, *Acartia longiremis*, and *Temora longicornis*

Profound differences were observed between stations with much shorter period of *Acartia longiremis* high abundance at the station P140



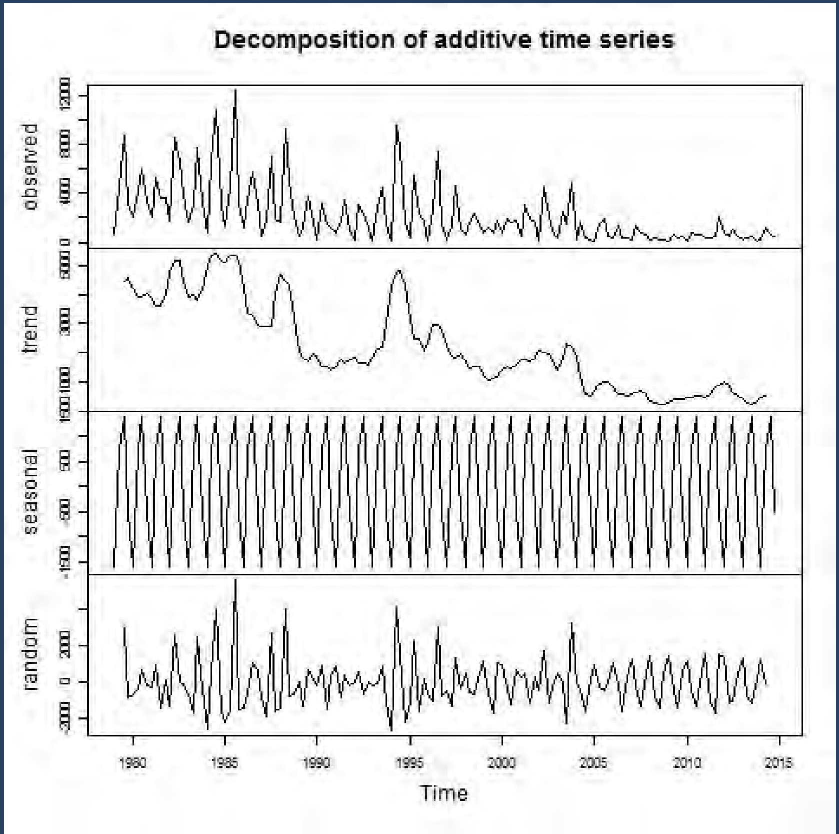
Zooplankton time-series decomposition

A classical seasonal decomposition by moving averages using additive model were performed.

Four ‘seasons’ (April, June, August and November) were selected.

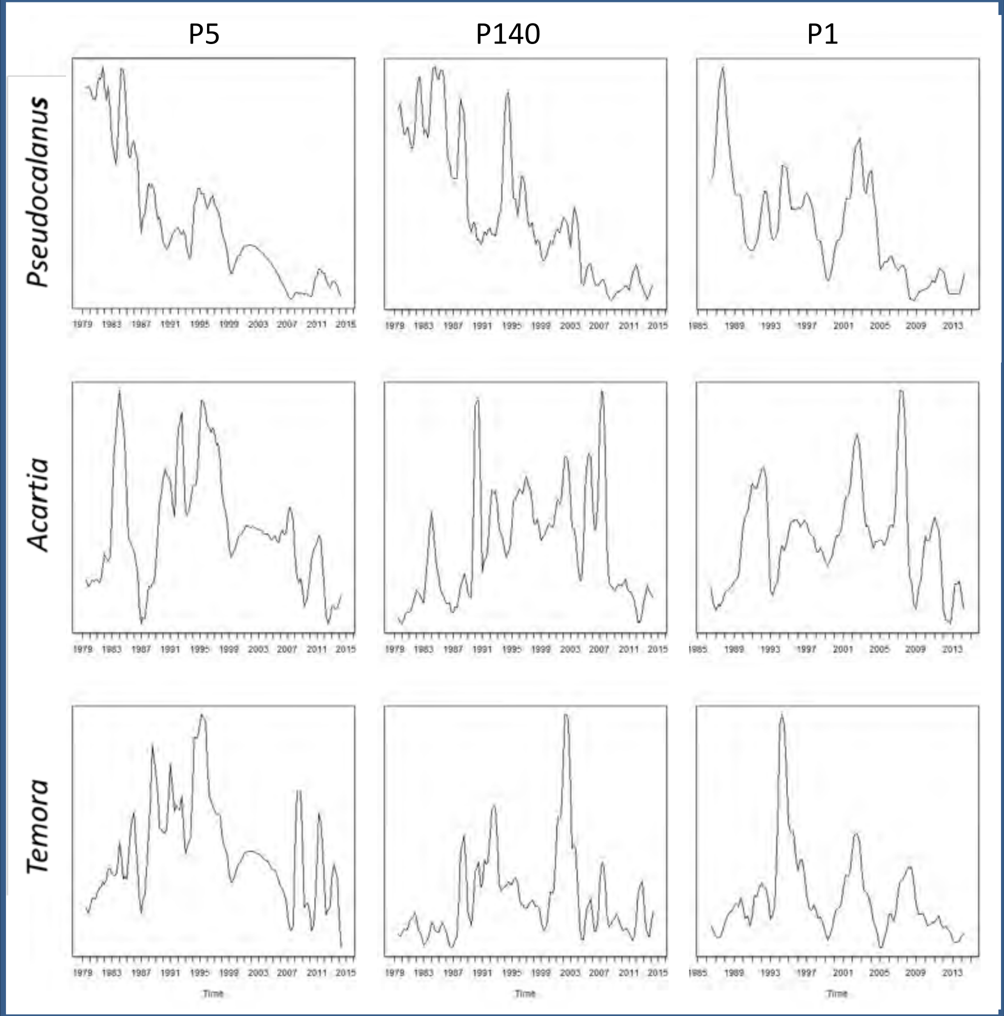
Missing data were replaced with values from the prior or following months (if the sampling date was less than 10 days apart).

For the remaining missing values the interpolation technique was used that estimates node values in a raster from a set of sample weighted points.

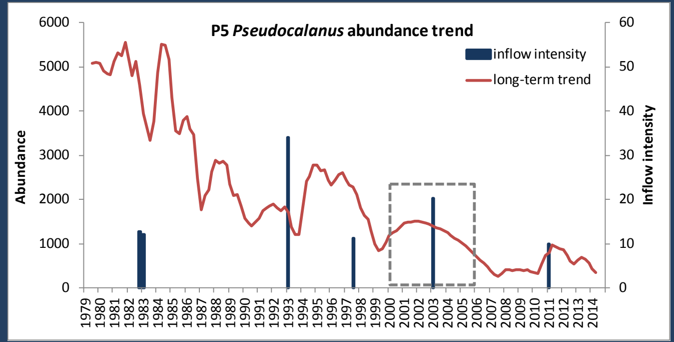


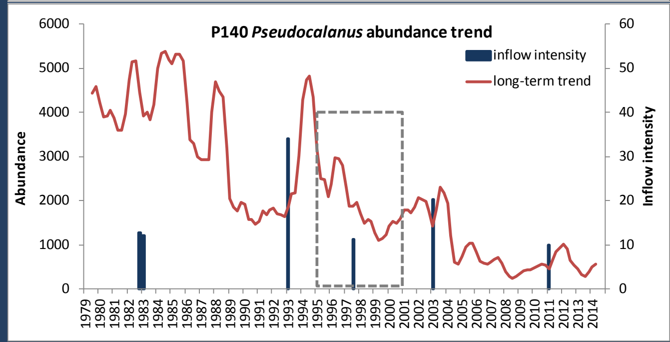
An example: the observed *Pseudocalanus* abundance at station P140 and the time series decomposition into three components: trend, seasonal, and random

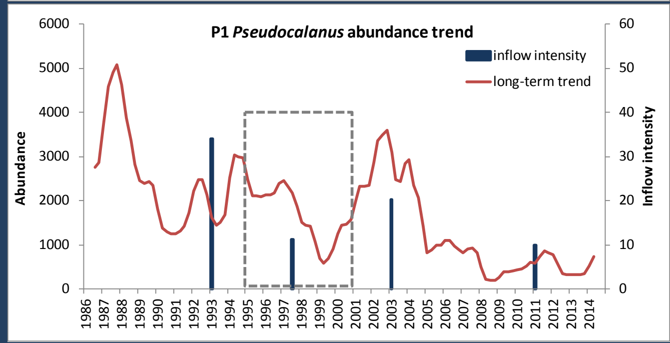
Long-term trend in abundance of *Pseudocalanus minutus*, *Acartia longiremis*, and *Temora longicornis* as derived from the decomposition analyses at three deep-water stations.



Pseudocalanus response to the saline inflows occurrence and intensity. Grey dotted rectangles indicate periods with significant share of interpolated data.







Changes in key copepod species biomass were tested against the environmental and climatic potential descriptors

Non-parametric approach was used: generalized additive modelling (GAM).

In this presentation we will discuss models calculated for three key species of copepods collected at the station P140 (southern slope of the Gotland Basin).

Data considered in our analyses:
Independent variables – biomass trend component of *Pseudocalanus*, *Acartia*, and *Temora*

Descriptors:

- hydrological parameters (oxygen concentration, temperature, salinity)
- chlorophyll *a* concentration as a proxy of phytoplankton biomass (Diatoms, Flagellates and others, and Cynobacteria)

all those data above were derived from SMHI RCO-Scobi model output (Meier et al., 2012)

- climatic indices (winter NAO and Baltic Sea Index (BSI, Lehmann et al., 2002))

The best model was selected based on Bayesian criterion (BIC)

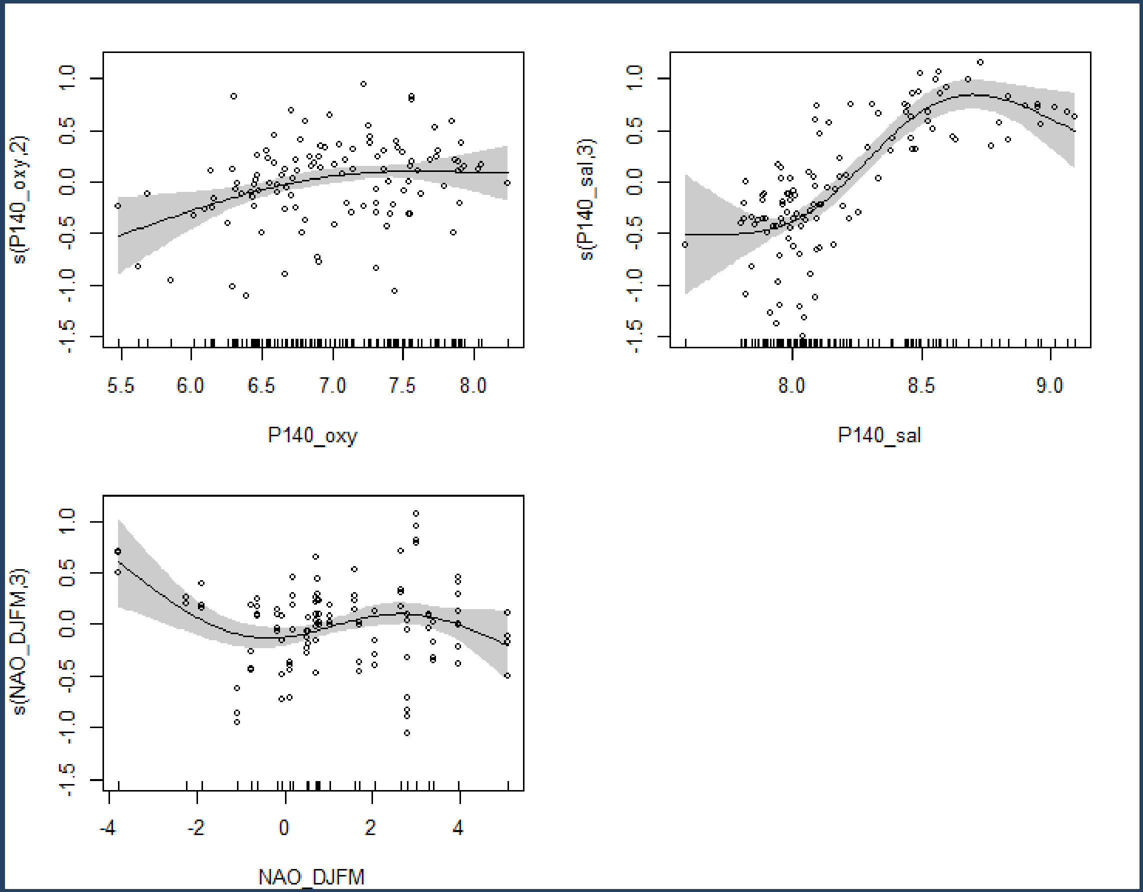
```
log(biomass + 1) ~ s(oxygen, k=3, fx=T) + s(salinity, k=4, fx=T) + s(NAO_DJFM, k=4, fx=T)
```

	edf	F	p-level
s(oxygen)	2	5.2	**
s(salinity)	3	52.9	***
s(NAO_DJFM)	3	4.0	**

'***' 0.001 '**' 0.01 '*' 0.05

Deviance explained = 61.4%

Pseudocalanus



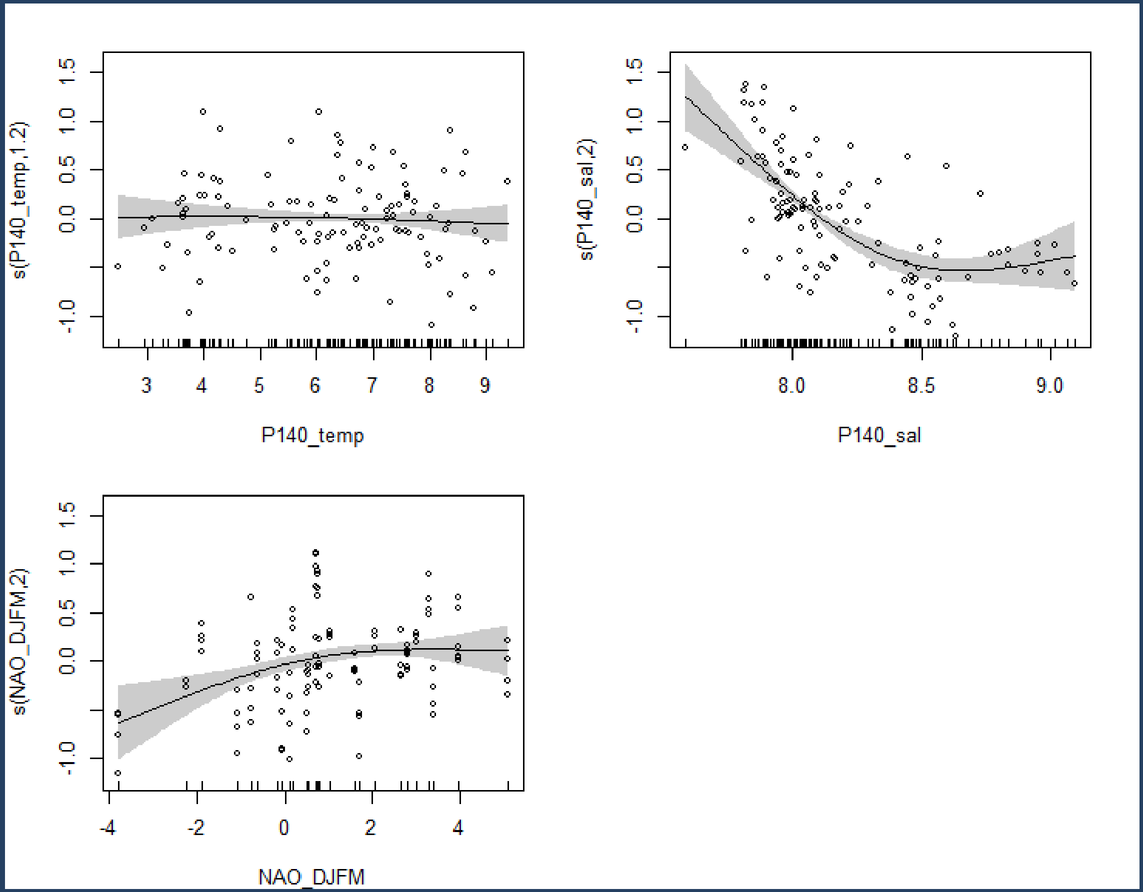
```
log(biomass + 1) ~ s(temperture) + s(salinity, k=3, fx=T) + s(NAO_DJFM, k=3, fx=T)
```

	edf	F	p-level
s(temperature)	1.2	0.09	NS
s(salinity)	2	40.4	***
s(NAO_DJFM)	2	6.5	**

'***' 0.001 '**' 0.01 '*' 0.05

Deviance explained = 44.3%

Temora



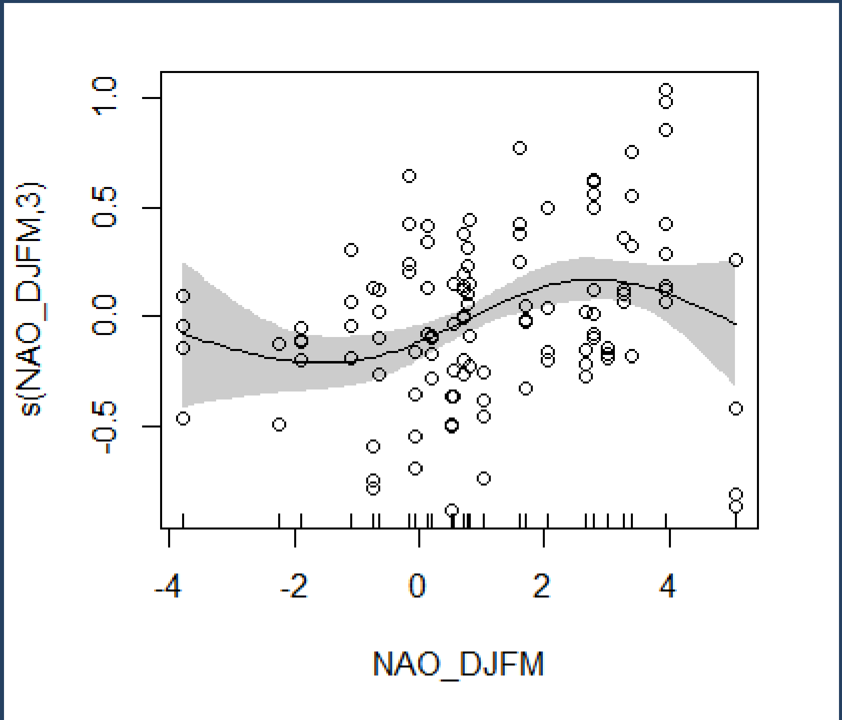
```
log(biomass + 1) ~ P140_sal + s(NAO_DJFM, k=4, fx=T)

              Estimate  t value p-level
(Intercept)   19.7919   22.4     ***
salinity      -1.6571   0.1      ***

               edf    F   p-level
s(NAO_DJFM)    3     4.5  **

'***' 0.001 '**' 0.01 '*' 0.05
Deviance explained = 71.3%
```

Acartia

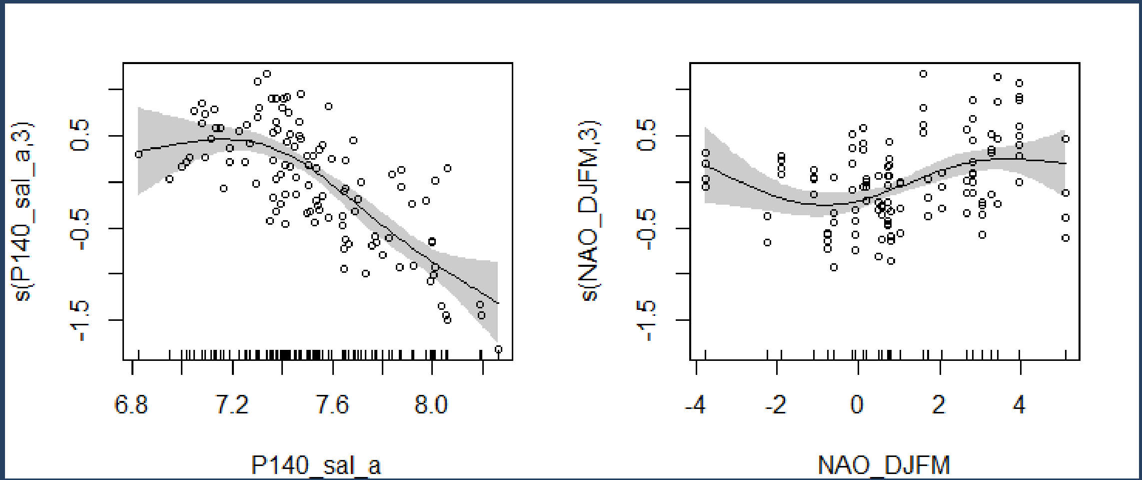


Acartia vs. hydrology from surface layer

```
log(biomass + 1) ~ +s(surface salinity, k=4, fx=T) + phytoplankton_2 + s(NAO_DJFM, k=4, fx=T)
                    Estimate  t value p-level
(Intercept)         5.7965    53.5    ***
phytoplankton_2     0.4481    0.1     ***

                    edf    F    p-level
s(surface salinity)   3  44.4   ***
s(NAO_DJFM)           3  6.4    ***

'***' 0.001 '**' 0.01 '*' 0.05
Deviance explained = 61.5%
```



Conclusions

Profound changes in zooplankton community were recorded at the deep-water stations which is mostly caused by a decrease in abundance of *Pseudocalanus* copepods responding to the salinity changes in-between of the inflows from the North Sea.

Similar changes were not observed in more shallow-water stations as *Pseudocalanus* is considerably less abundant there.

No clear long-term 'visual' patterns were detected for *Acartia* and *Temora* copepods.

Biomasses of all key copepod species were significantly correlated with hydrological parameters (especially with salinity) and winter NAO.

What does it mean for fish??? Unfortunately, identified drivers at the current stage are rather supporting *Acartia* and *Temora* than *Pseudocalanus*, which is not a good news for fish.

Acknowledgements:

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Presented data were collected within the National Monitoring Programme and permission to demonstrate them was granted by the Chief Inspector of Environmental Protection (http://www.gios.gov.pl/).

MANY THANKS!!!
to the Swedish Meteorological and Hydrological Institute (SMHI) for allowing us to use data derived from their *RCO-Scobi* model.

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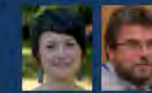
Zooplankton Mean Size and Total Stock (MSTS) indicator applied for testing the feeding conditions of small pelagic fish in the southern Baltic Sea



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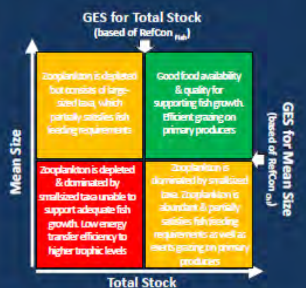
Indicator concept:

MSTS is a two-dimensional indicator representing a synthetic descriptor of zooplankton community structure. MSTS evaluates good environmental status (GES) using two GES boundaries, one for mean size and one for total standing stock (abundance or biomass) of zooplankton. This core indicator employs zooplankton mean size and total stock (MSTS) to evaluate pelagic food web structure, with particular focus on lower food web levels.

Green –> GES, Orange & Red –> subGES.

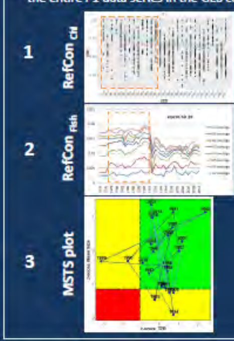


HELCOM 2013. Zooplankton Mean Size and Total Stock (MSTS). HELCOM core indicator report.

MSTS indicator appears to be very useful for testing of the temporal dynamics in the pelagic food web structure in the southern Baltic Sea. It considers the zooplankton mean size change as a consequence of an increase of small taxa biomass (along with an increasing eutrophication) and especially a decrease in abundance of larger copepods (due to the impact of hydrological conditions' change as well as predatory pressure of small pelagic fish). MSTS indicator provides estimates of the feeding conditions for sprat and herring in terms not only of food availability but its appropriate quality as well.

Station P1 example:

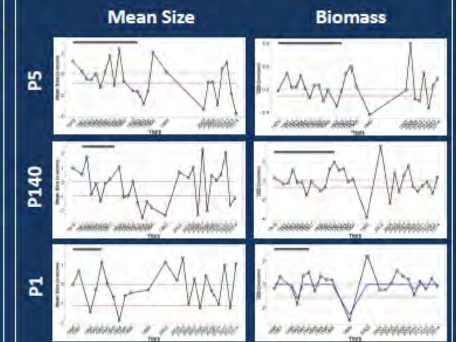
1. $RefCon_{Chl}$ derived from EQR data calculated from the RCO-Scobi model output (Meier et al., 2012).
2. $RefCon_{Fish}$ calculated based on sprat average biomass in age groups from the Stochastic Multi-Species model output (Lewy and Vinther, 2004) for ICES SD 26.
3. Resulting MSTS plot presenting allocation of the entire P1 data series in the GES context.



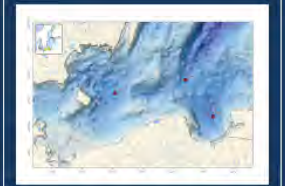
Results:

Long-term dynamics of Mean Size and Total Biomass z-scores calculated for all three stations representing changes in zooplankton community in the Bornholm, Gotland, and Gdansk basins.

Black horizontal bars are representing selected reference periods.



Samples:



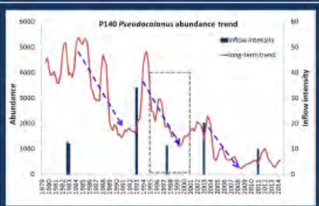
Presented data are the Polish contribution to the HELCOM COMBINE Programme. Samples were collected using the WP-2 net (100 µm). The MSTS indicator was tested for summer time conditions at three different sampling stations representing the Bornholm Basin (P5), southern slope of the Gotland Basin (P140), the Gdansk Basin (P1)

ACKNOWLEDGEMENTS:

This research has received funding from BONUS, the joint Baltic Sea research and development programme (Art 185), funded jointly from the European Union's Seventh Programme for research, technological development and demonstration and from the National Centre for Research and Development in Poland.

Summary:

- A decreasing trend in Mean Size was observed especially in open basins (i.e. at stations P5 and P140) up to the end of the last century. Later, no further decrease was noted with a considerable variation and still rather below long-term averages. This is very much in line with a long-term dynamics of Chlorophyll *a* concentrations in the southern Baltic Sea (see an example of $RefCon_{Chl}$ change at station P1, above)
- Total Biomass and Mean Size are significantly influenced by periodic changes of *Pseudocalacus* biomass in-between of the major inflows of saline waters from the North Sea.



Pseudocalanus response to the saline inflows occurrence and intensity. Grey, dashed rectangle indicates period with dominance of interpolated data.

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