Increasing surface temperature causes changes in plankton communities of the Baltic Sea

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Motivation

- ~40 years of environmental monitoring in the Baltic Sea enables analysis of long-term trends
- Recent analyses mostly focused on single ecosystem components, or on the more southern basins
- Whole-ecosystem analysis can reveal resource-based bottom-up effects, climate change effects and cascading food web effects, which act simultaneously

Photo: Seija Hällfors
Study area

- Five northern Baltic Sea sub-basins
- NBP and GF connected without a sill, ÅS and GoB separated by a sill
- O$_2$ deficiency, internal nutrient loading in the GF and NBP
The goals of our analysis were to reveal:

1. How the physical environment and nutrient status has changed during the last 35 years
2. How these changes are reflected in the food web structure
3. How strong is top-down control vs. bottom-up limitation
## Long term monitoring data used

<table>
<thead>
<tr>
<th>Parameter</th>
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<tbody>
<tr>
<td><strong>Surface water temperature, salinity</strong></td>
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<tr>
<td><strong>Deep water temperature, salinity</strong></td>
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<tr>
<td><strong>Stratification index, E</strong></td>
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<td><strong>Deep water oxygen</strong></td>
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<tr>
<td><strong>Dissolved inorganic nutrients (DIN, PO(_4), SiO(_4))</strong></td>
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<tr>
<td><strong>Total nutrients (TotN, TotP)</strong></td>
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<tr>
<td><strong>Secchi depth</strong></td>
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<tr>
<td><strong>Chlorophyll (a)</strong></td>
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<tr>
<td><strong>Phytoplankton biomass</strong></td>
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<tr>
<td><strong>Zooplankton abundance</strong></td>
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<tr>
<td><strong>Mysis abundance</strong></td>
</tr>
<tr>
<td><strong>Benthic fauna (abundance)</strong></td>
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<tr>
<td><strong>Fish</strong></td>
</tr>
</tbody>
</table>
Statistics

- **Mann-Kendall test** (non-parametric): Monotonic trends
- **Redundancy analysis (RDA)**: Relationships between plankton community composition and environmental variables
- **Generalised additive models (GAM)**: Long-term trends in the environmental and biological variables
Significant trends in hydrography

**Northern Baltic Proper**
- Temperature (°C)
- Salinity

**Gulf of Finland**
- Temperature (°C)

**Åland Sea**
- Temperature (°C)
Significant trends in hydrography

Bothnian Sea

Bothnian Bay
Phytoplankton community change in the Northern Baltic Sea

1979-1983 (TotBM 261 µg L\(^{-1}\))
- Cyanobacteria
- Cryptophytes
- Chrysophytes

1979-1983 (TotBM 261 µg L\(^{-1}\))
- diatoms 7%
- chlorophytes 1%
- chrysophytes 2%
- cryptophytes 27%
- cyanobacteria 35%
- dinoflagellates 16%
- euglenophytes 3%
- prasinophytes 9%
- prymnesiophytes 0%

2004-2008 (TotBM 466 µg L\(^{-1}\))
- Prymnesiophytes
- Chrysophytes
- Cryptophytes
- Cyanobacteria

2004-2008 (TotBM 466 µg L\(^{-1}\))
- diatoms 2%
- chlorophytes 0%
- chrysophytes 15%
- cryptophytes 3%
- cyanobacteria 47%
- dinoflagellates 16%
- euglenophytes 0%
- prasinophytes 7%
- prymnesiophytes 10%
Negative zooplankton trends

Northern Baltic Proper  
- *Evadne* spp. (ind m$^{-3}$)
- *Podon* spp. (ind m$^{-3}$) △

Gulf of Finland  
- Total zpl abundance (ind m$^{-3}$)
- *Eubosmina* spp. (ind m$^{-3}$)
- *Acartia* spp. (ind m$^{-3}$)

Åland Sea  
- *Podon* spp. (ind m$^{-3}$)
- *Eurytemora* spp. (ind m$^{-3}$)
Positive zooplankton trends

Northern Baltic Proper

Keratella spp. (ind m$^{-3}$)

Synchaeta spp. (ind m$^{-3}$)

Åland Sea

Keratella spp. (ind m$^{-3}$)

Eubosmina spp. (ind m$^{-3}$)
Bothnian Sea

Significant trends in
- Zooplankton
- Benthos
- Herring
Bothnian Sea, abundance of nektobenthic mysid shrimps
Zooplankton community change in the Northern Baltic Sea

1979-1983 (Tot abundance 62 763 ind m$^{-3}$)

2004-2008 (Tot abundance 63 186 ind m$^{-3}$)

Tendency towards smaller organisms (smaller species or younger individuals) in the community
Relationships between plankton and environment - RDA

Northern Baltic Proper

Gulf of Finland

Åland Sea

*Temperature

*Salinity

**DIN**

**SiO**

**DIP**
Relationships between environmental and biological factors (RDA)

Bothnian Sea

Response: PPL

Response: ZPL

Bothnian Bay
Summary: Changes in the Northern Baltic Sea

Since 1979

- “High-quality” phytoplankton food (Cryptophyceae) ↓
- “Low-quality” phytoplankton food (Cyano+Prymnesiophyceae) ↑
- Small zpl (rotifers) ↑
- Large zpl (copepods, cladocerans) ↓

→ Shift in the food web structure towards more microbial, less energy-efficient food webs consisting of lower-food-quality and smaller sized organisms

→ Less energy available for grazing zooplankton and fish
Environmental changes in the Gulf of Bothnia, the northernmost basins of the BS

- Increasing water temperature, decreasing salinity, partly due to increasing river inflow → on-going climate change
- Decreased deep-water oxygen, probably caused by inflow of hypoxic deep water, increased amount of settling material, enhanced microbial decomposition and strengthened stratification
- The change in PPL and benthic communities may be a response to an increasingly DOM-based food web
- Surface salinity and stratification play major roles in explaining ZPL community variability
- Baltic herring SSB increased several-fold with a simultaneous decline of weight-at-age: increasing food limitation
Thank you Anders Brutemark, Vivi Fleming-Lehtinen, Jonna Engström-Öst, Silvia Pulina, Mika Raateoja, Jari Raitaniemi, Laura Uusitalo

Thank you for your attention!