The Baltic Sea
Environmental assessment using indicators

Sarah Piehl

Leibniz Institute for Baltic Sea Research, Warnemünde, Germany

Overview

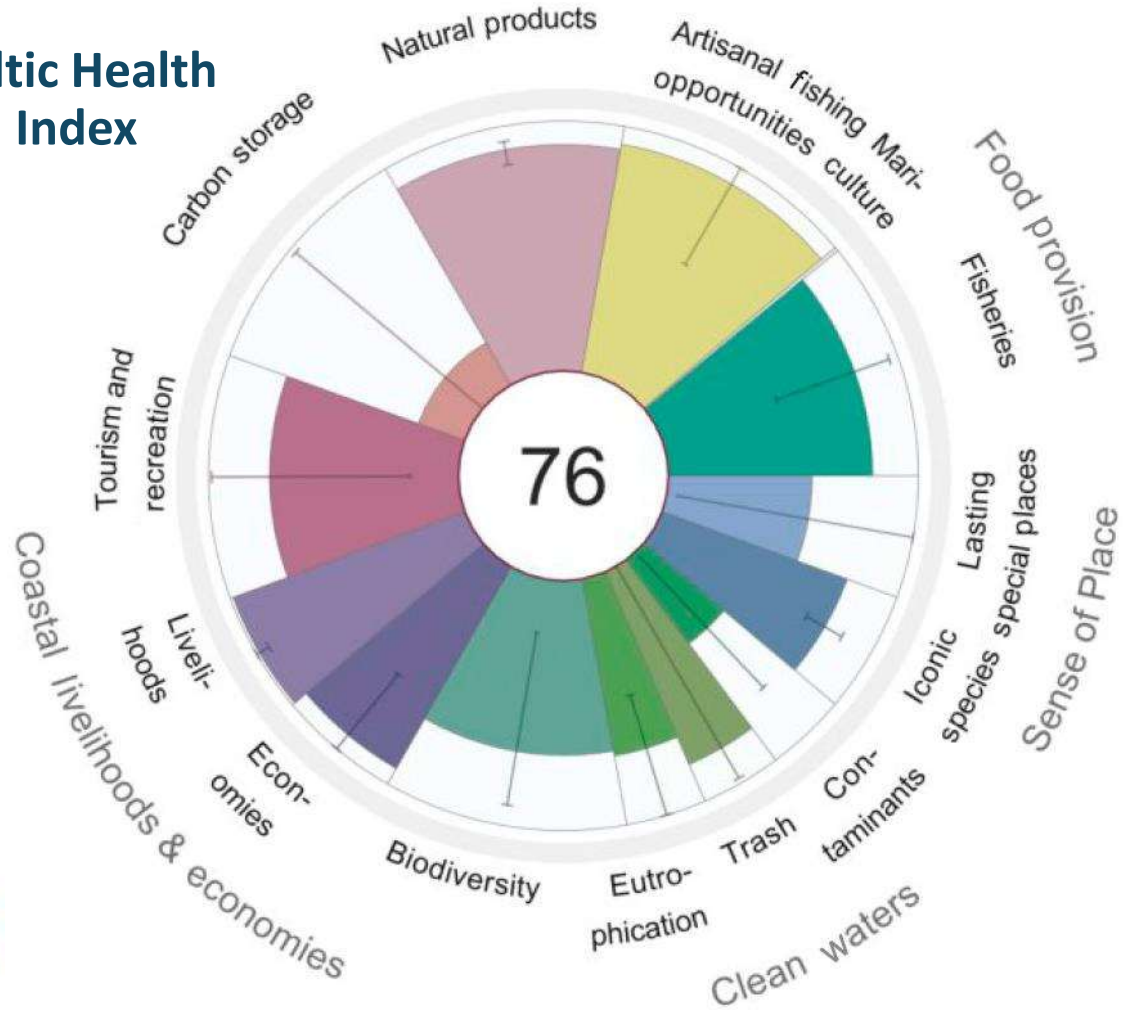
1. Indicators - Introduction
2. The Baltic Sea - Status assessment
3. The Baltic Sea - Eutrophication assessment
4. The Baltic Sea - Eutrophication indicators
5. The Baltic Sea - Oxygen indicators
6. Indicators - Summary and outlook

1. Indicators - Introduction

Indicators…

- …are any measurable metric or indices
- …respond to pressures acting on a system
- … can be used to evaluate a status and to monitor trends

Baltic Health Index



Blenckner et al. (2021) British Ecological Society Vol.3

Indicators are tools that facilitate a simplified view of complex systems

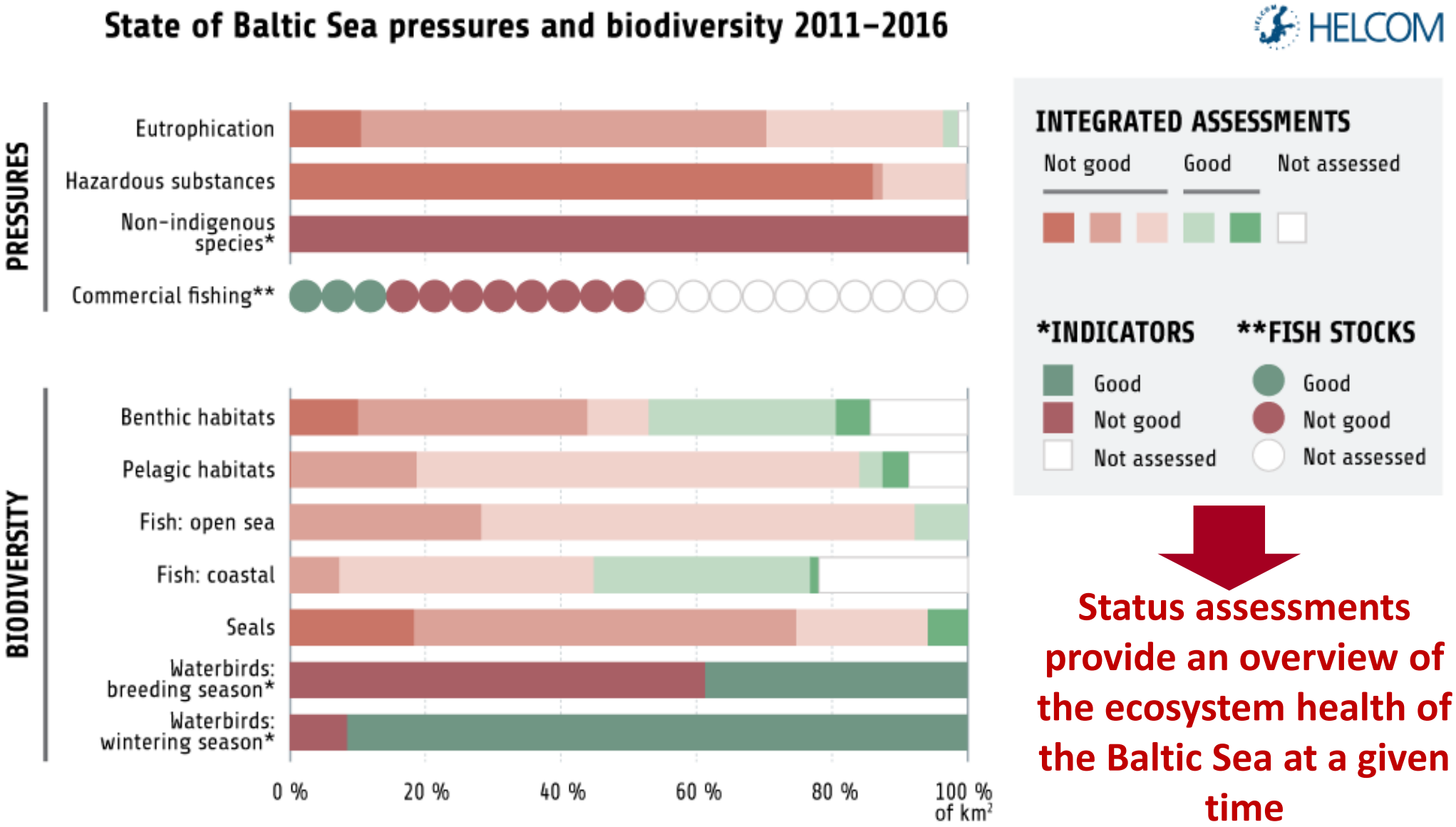
1. Indicators - Introduction

- **Indicator**
  = a measureable metric that provides key information about a status and/or a trend

- **Goal**
  = description of a future status which you want to achieve

- **Where are you?**
- **How far are you from where you want to be?**
- **Which way are you going?**

2. The Baltic Sea - Status assessment



Status assessments provide an overview of the ecosystem health of the Baltic Sea at a given time

HELCOM (2018) Balt. Sea. Env. Proc. No. 155

2. The Baltic Sea - Status assessment

What are the causes of environmental degradation?

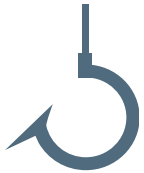
Baltic Sea pressures used in the status assessment:

Underwater sound

Seabed loss and disturbance

Hazardous substances

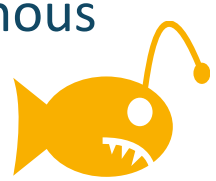
Eutrophication



Species removal by fishing and hunting

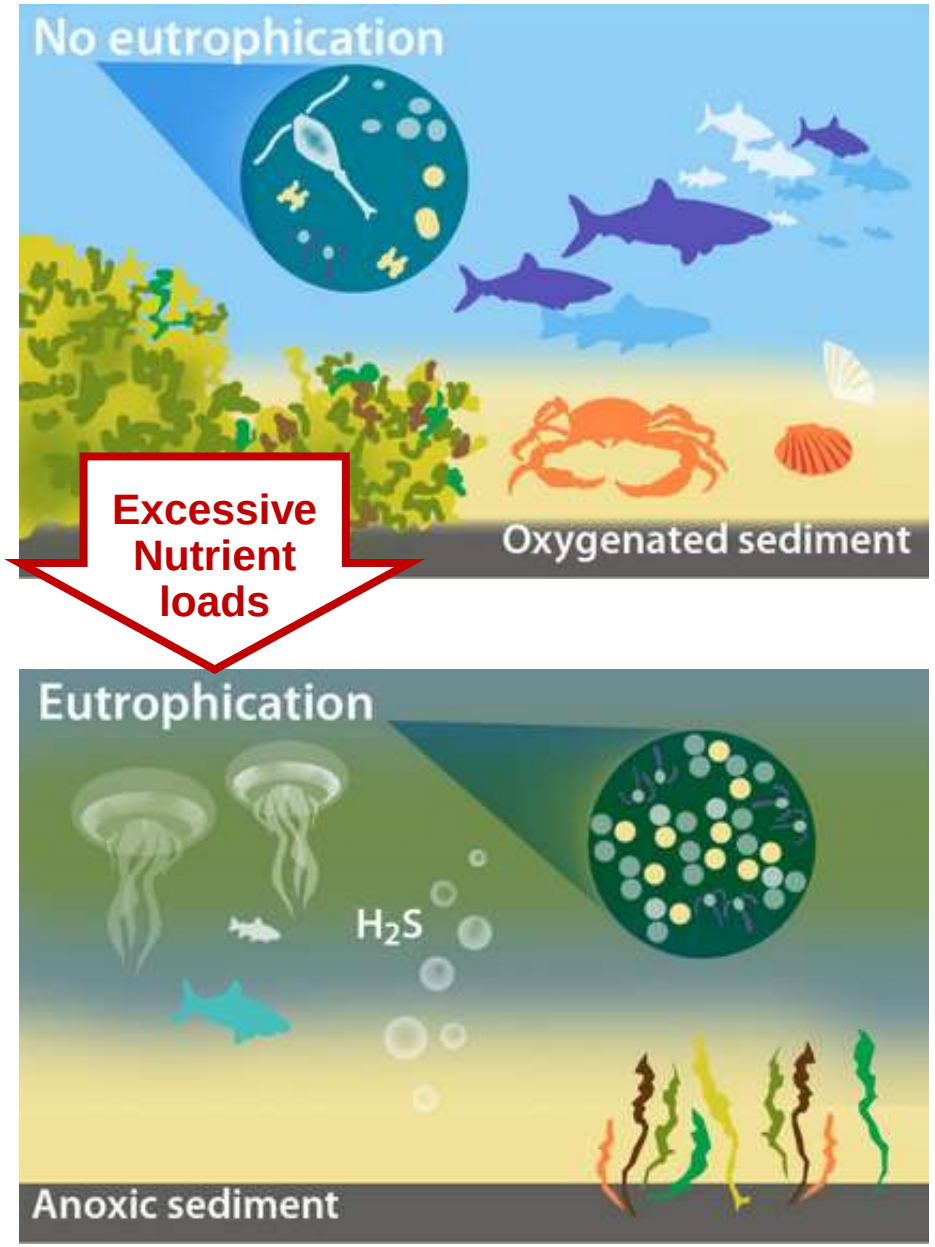
Marine litter

Non-indigenous species



HELCOM

3. The Baltic Sea - Eutrophication



Eutrophication symptoms in the Baltic Sea

Nutrient levels:

- Increased concentrations of nitrogen and phosphorus
- Changes in nutrient ratios

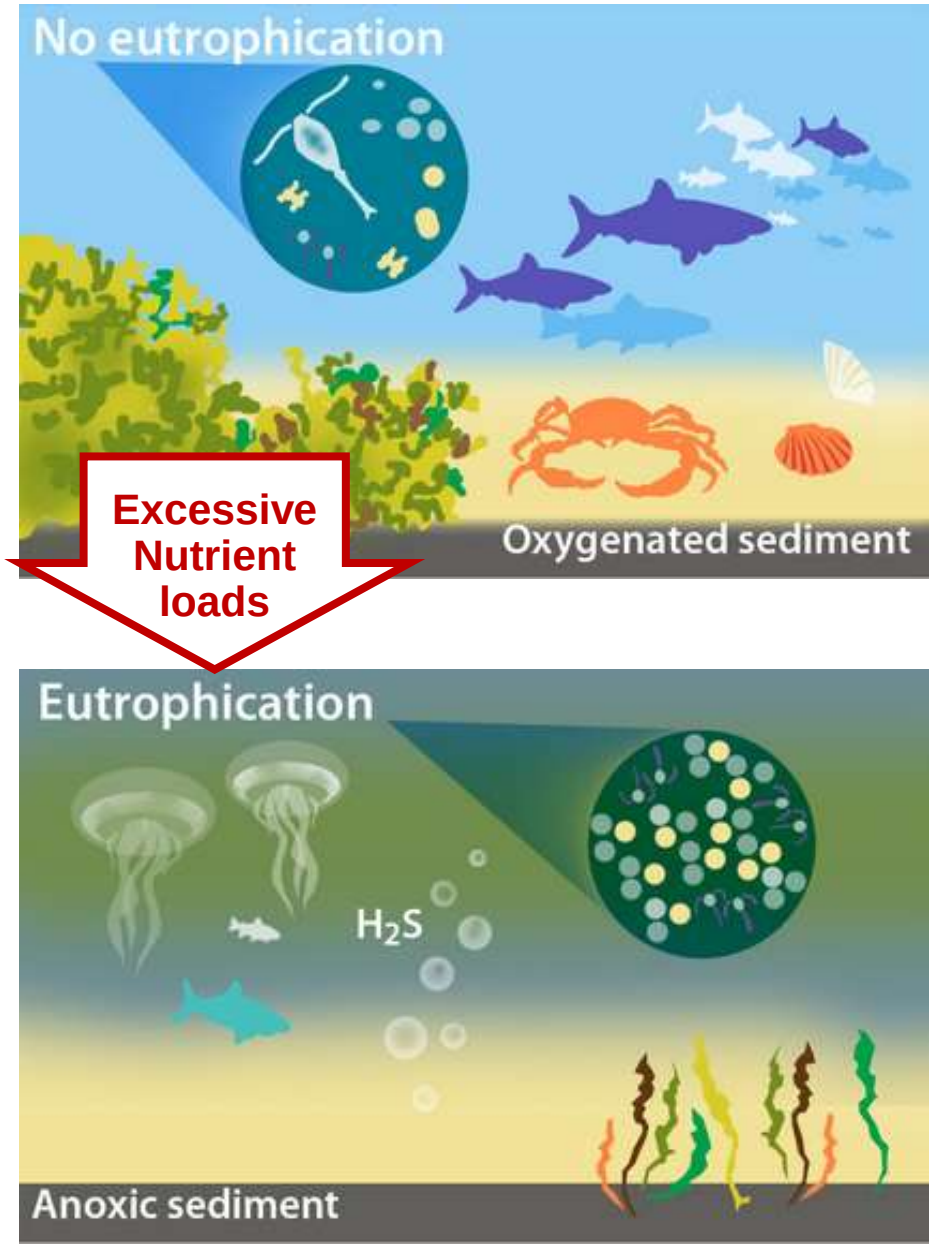
Direct effects:

- Enhanced primary production
- Changed phytoplankton community structures
- Enhanced cyanobacteria growth
- Growth of short-lived macroalgae
- Increased sedimentation of organic material and reduced water clarity

G. Schernewski

https://oap.ospar.org/

3. The Baltic Sea - Eutrophication



Eutrophication symptoms in the Baltic Sea

Indirect effects:

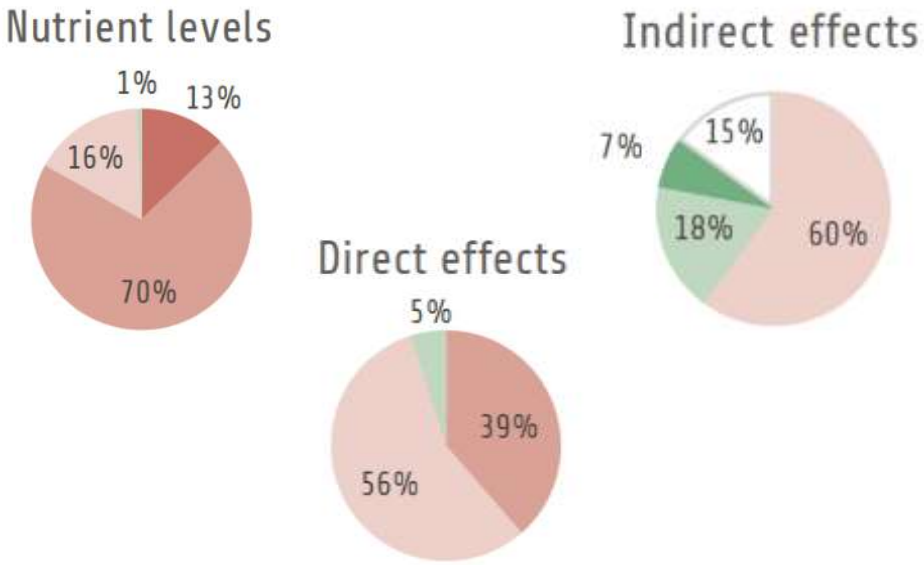
- Reduced bottom water oxygen concentrations
- Kills of benthic fauna
- Altered species composition and food web interactions

https://oap.ospar.org/

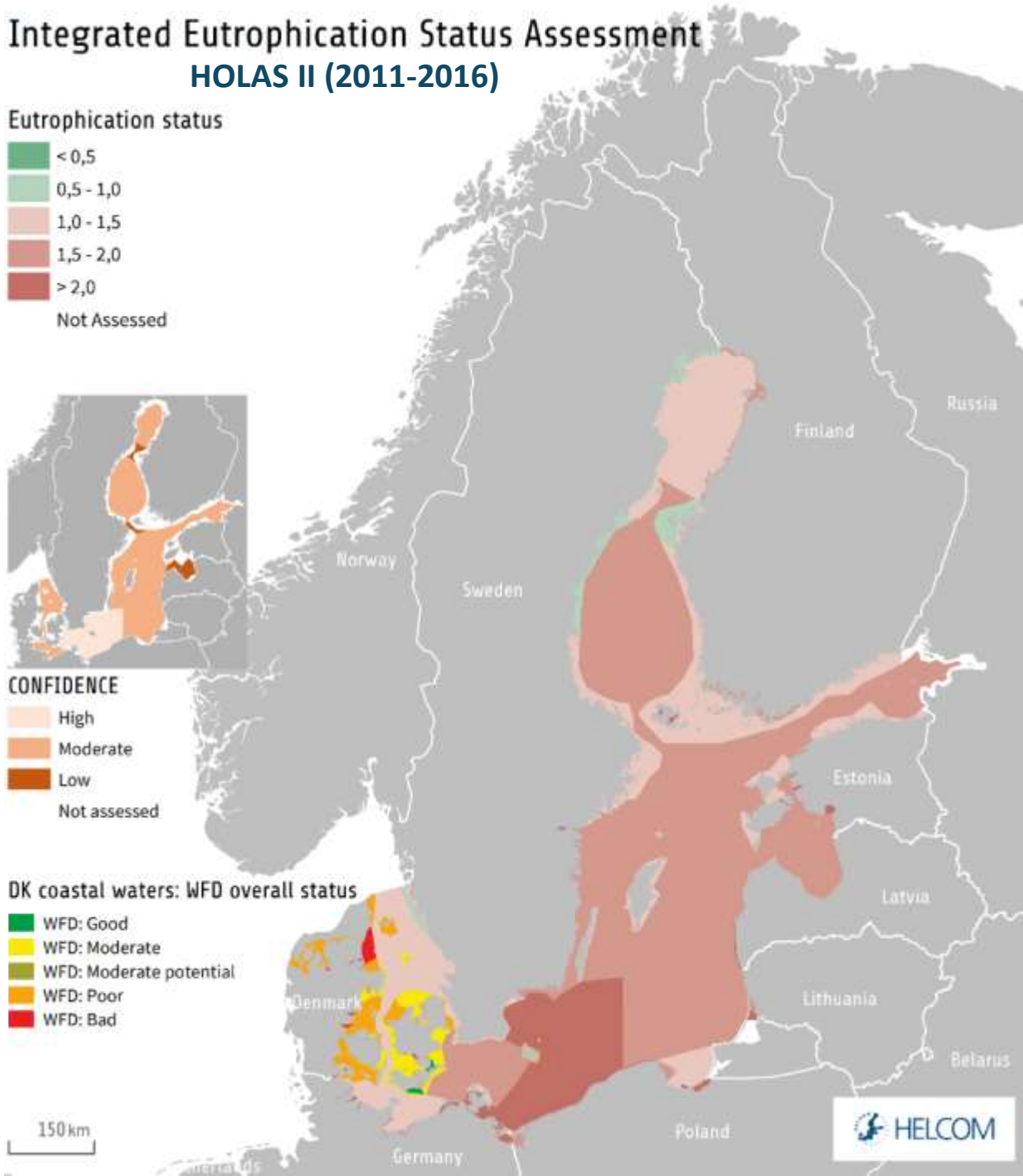
G. Schernewski

3. The Baltic Sea
- Eutrophication assessment

- ~97 % affected by eutrophication



Eutrophication status is assessed using indicators that reflect its symptoms

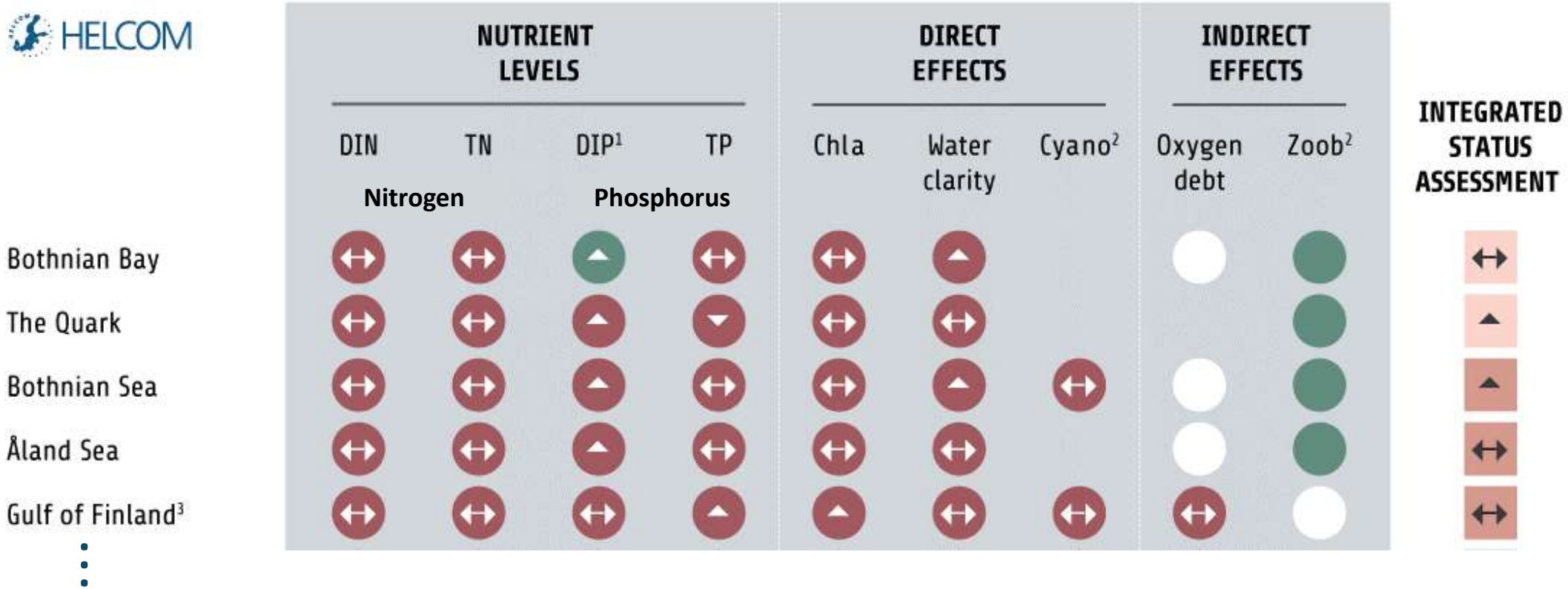


HELCOM (2018) Balt. Sea. Env. Proc. No. 156

G. Schernewski

4. The Baltic Sea - Eutrophication indicators

Eutrophication indicator results (2011-2016):



Indicators are selected based on several criteria including ecological and policy relevance, measurability, and linkage to anthropogenic pressures

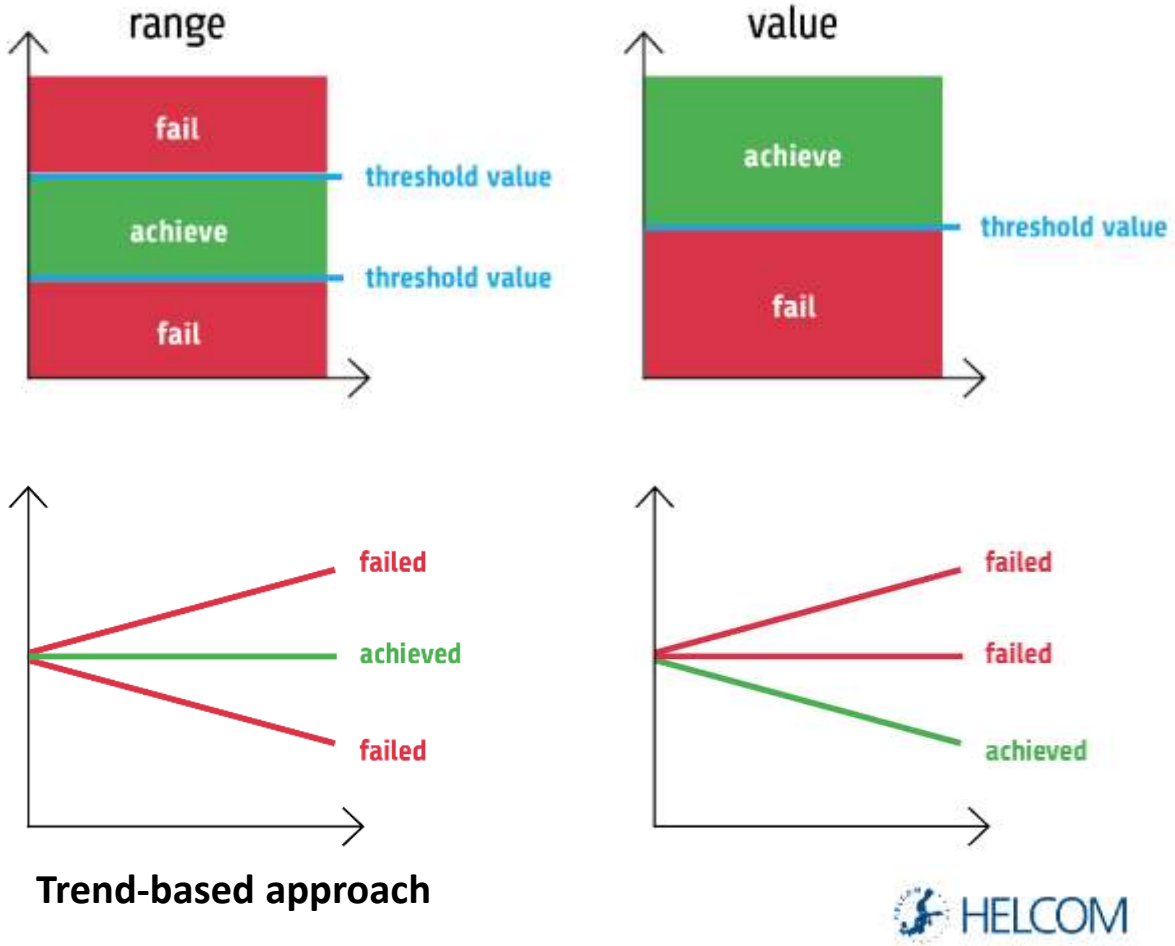
G. Schernewski

HELCOM (2018) Balt. Sea. Env. Proc. No. 156

4. The Baltic Sea - Eutrophication indicators

By evaluating the **observed status** of an indicator **against** a **threshold value!**

- Maximum, minimum, range of values or data trends
- Thresholds can vary within a single indicator to account for regional variation
  → harmonized threshold value setting approach
- Outcome of indicator evaluation expressed in terms of achieving or failing the threshold



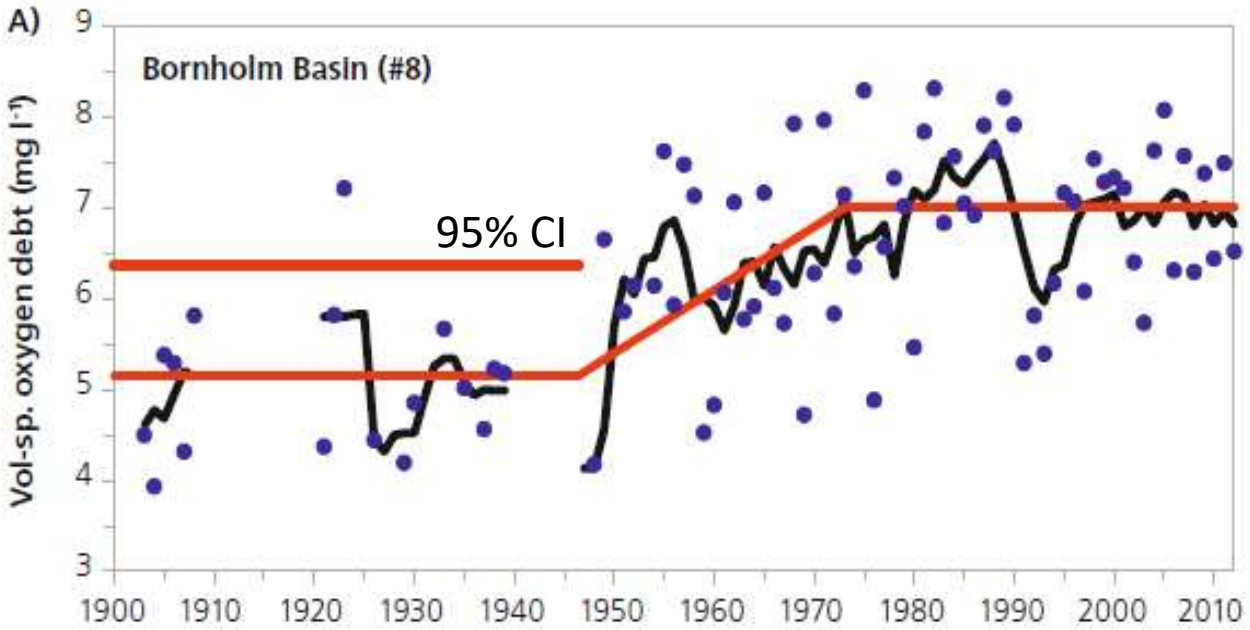
How to obtain threshold values?

G. Schernewski

4. The Baltic Sea - Eutrophication indicators

Threshold setting approaches

- **Existing undisturbed sites** for reference conditions
- **Change point analysis** if sufficient **observational data** before 1950 is available
  Threshold = identified change points
- **Hindcast modeling**



Threshold setting is a critical step as assessments are based on whether the threshold is met or not met

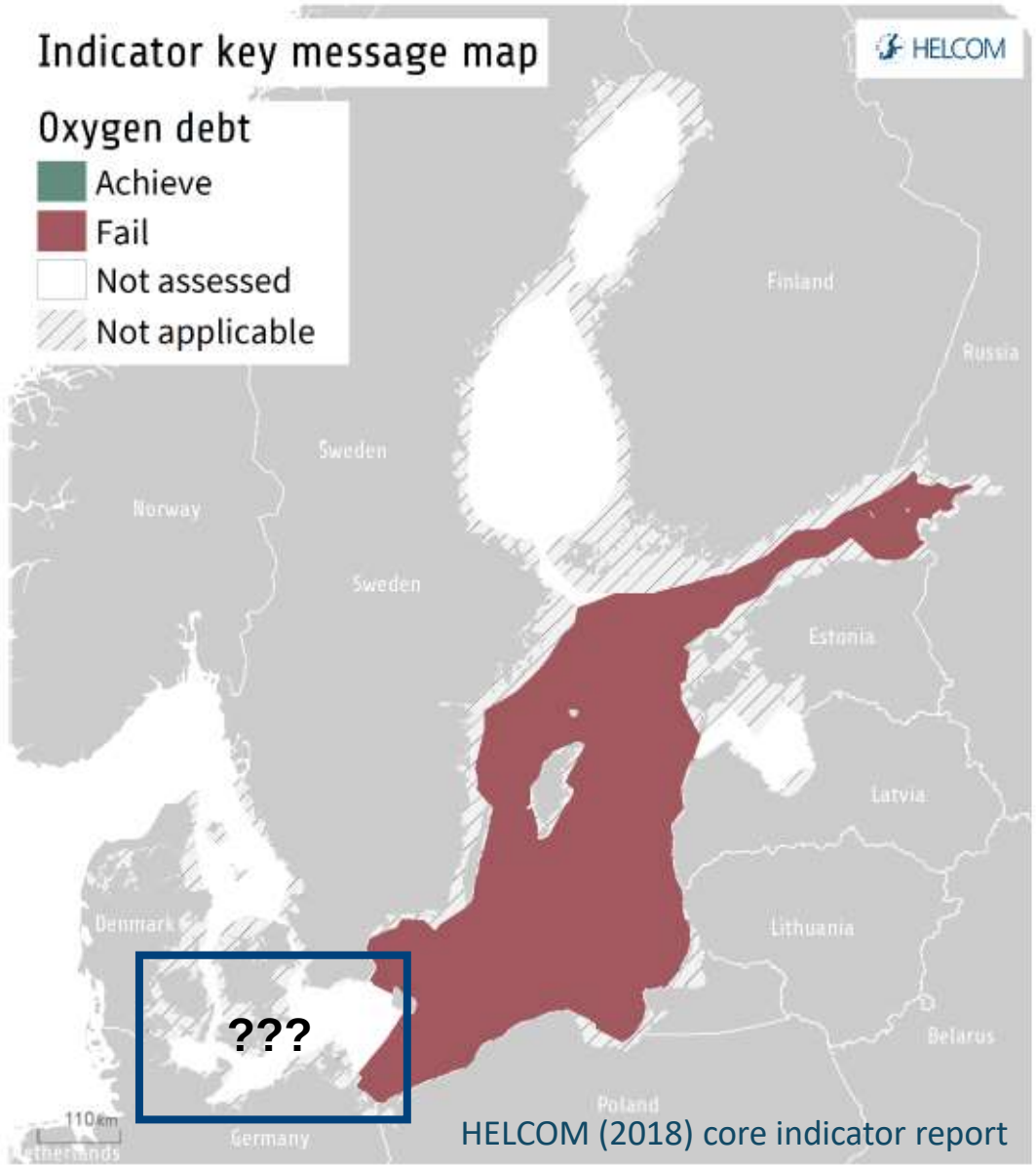
G. Schernewski

HELCOM (2013) Balt. Sea. Env. Proc. No. 133

5. The Baltic Sea - Oxygen indicators

Oxygen dept indicator

- **Permanent hypoxia (<2 mg/l)** in the deep open & central parts
- Applied for basins with a permanent halocline
- No HELCOM-wide application



HELCOM (2018) core indicator report

Shallow-water oxygen indicator

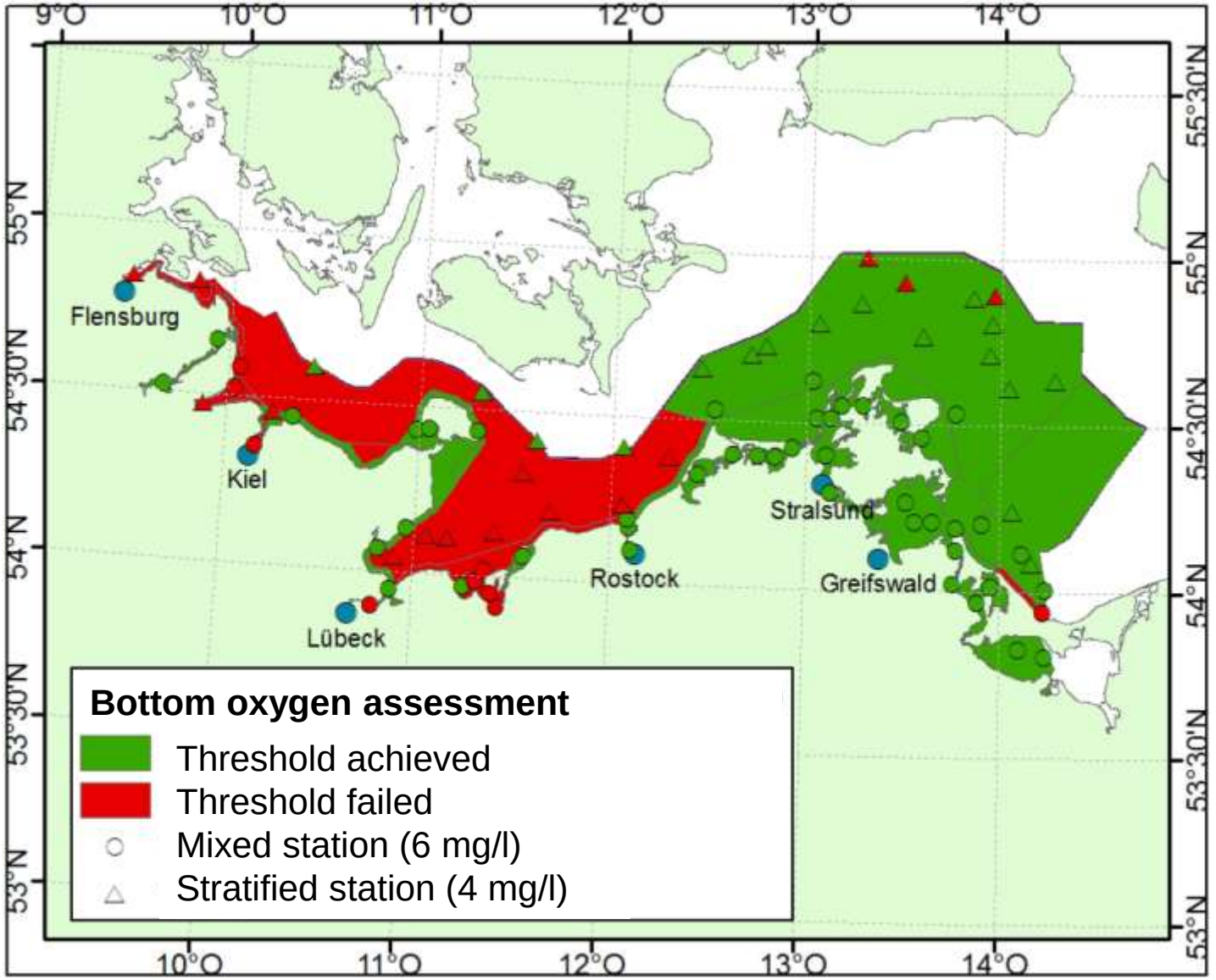
- **Seasonal oxygen depletion**
- Various national concepts & thresholds **(<2 to <6 mg/l)**
- No HELCOM-wide coordinated indicator

5. The Baltic Sea - Oxygen indicators

German approach

- Two thresholds (4 mg/l and 6 mg/l)
- Near-bottom oxygen measurements
- 5 annual measurements per station
- First temporal then spatial data aggregation

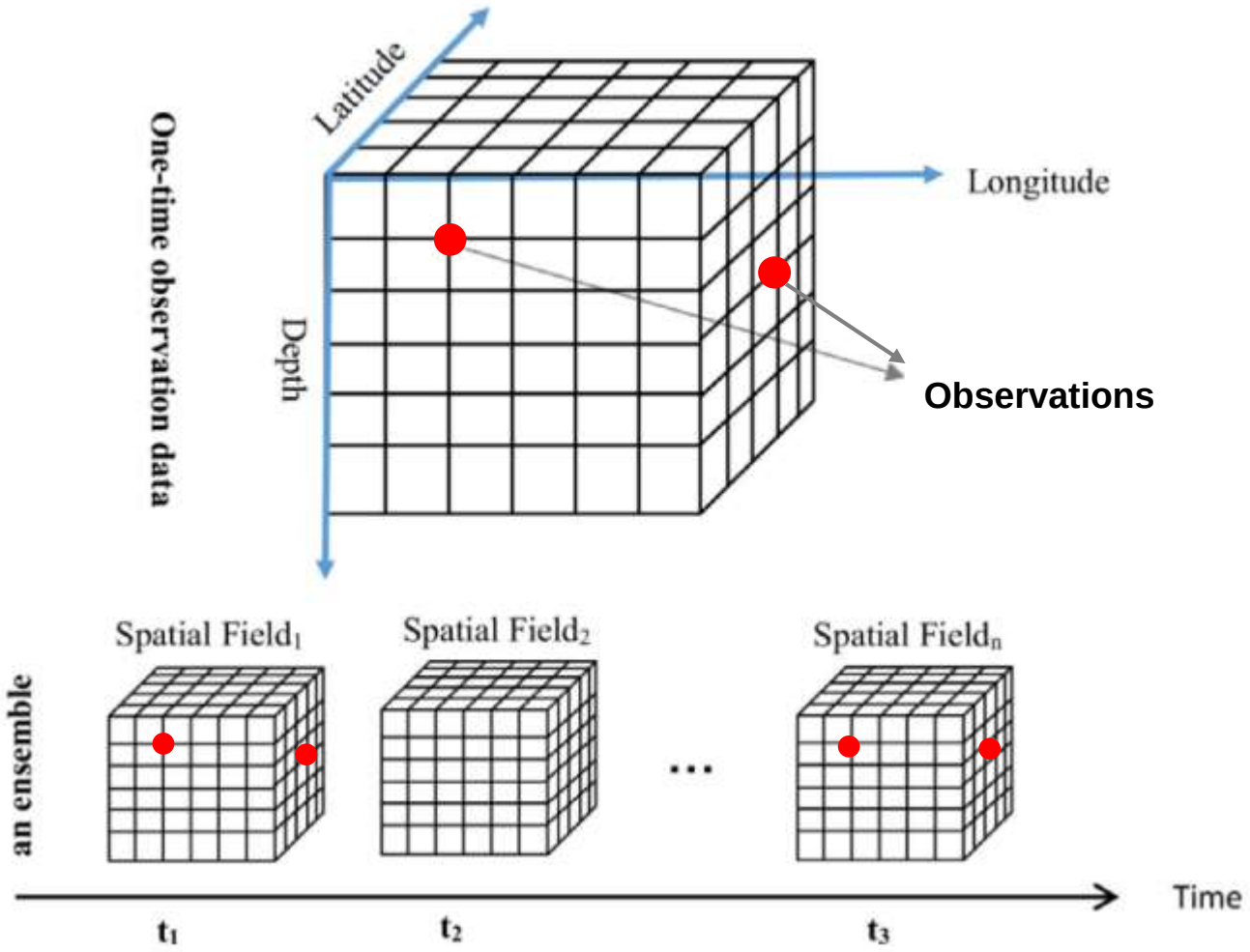
Sufficient monitoring data is needed for a reliable assessment



Adapted from BLANO (2018) nationale Indikatorblätter

5. The Baltic Sea - Oxygen indicators

How to fill gaps in monitoring data?



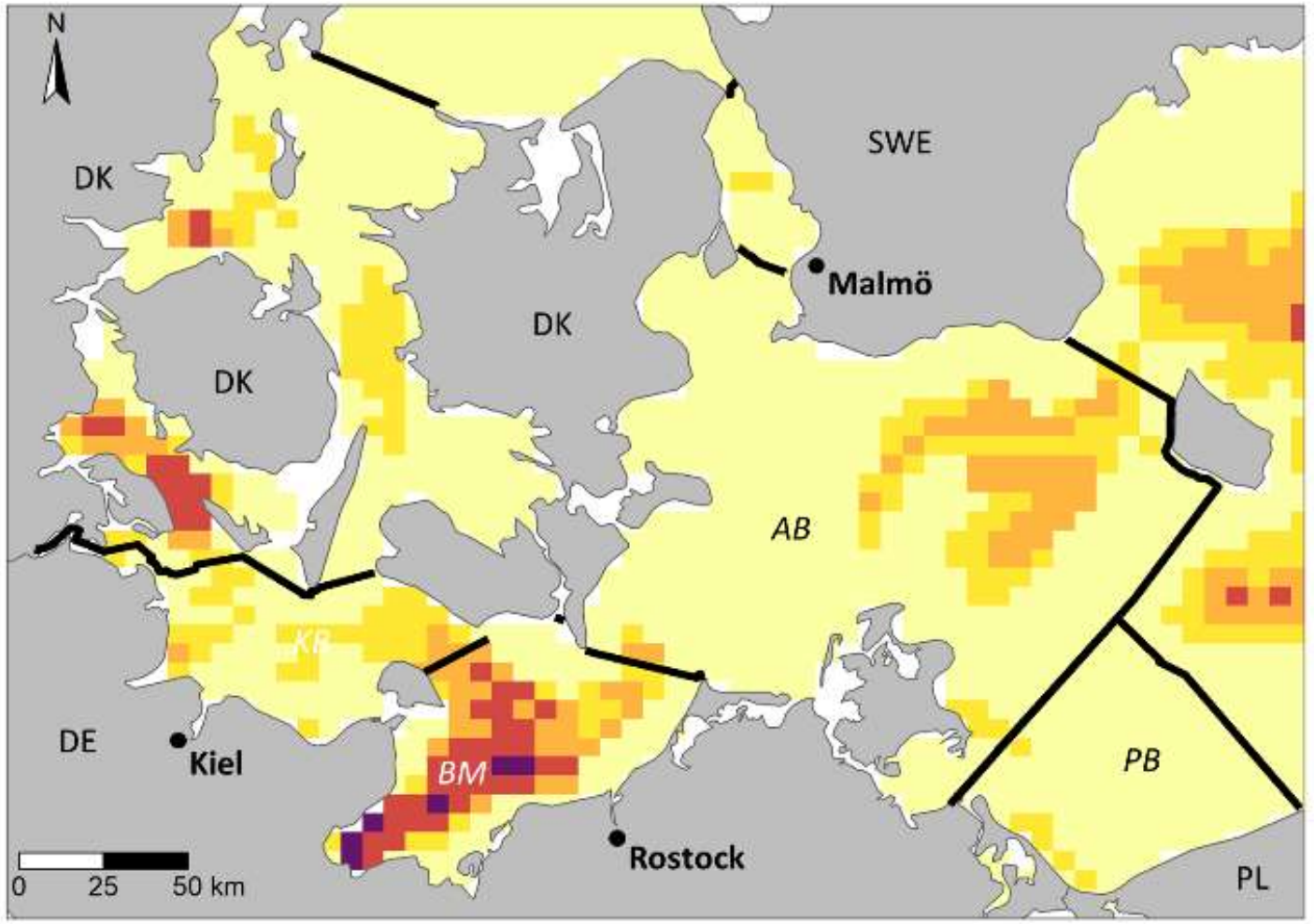
- Models to extrapolate single point measurements into the area and to provide high resolution information
- But: a model is a simplified description of reality
- **Integration of observed and modeled data to increase accuracy of oxygen indicators**

Adapted from Xie et al. (2019) Visual Informatics Vol.3

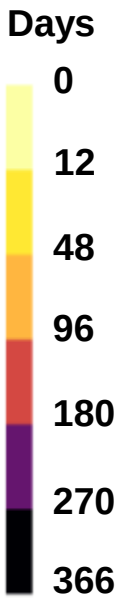
G. Schernewski

5. The Baltic Sea - Oxygen indicators

- Average yearly occurrences of hypoxia (oxygen <2 mg/l) in the bottom water layer in the southwestern Baltic Sea



Average modeled days with oxygen concentrations <2 mg/l; bottom water layer (2.5 m); 2011-2016

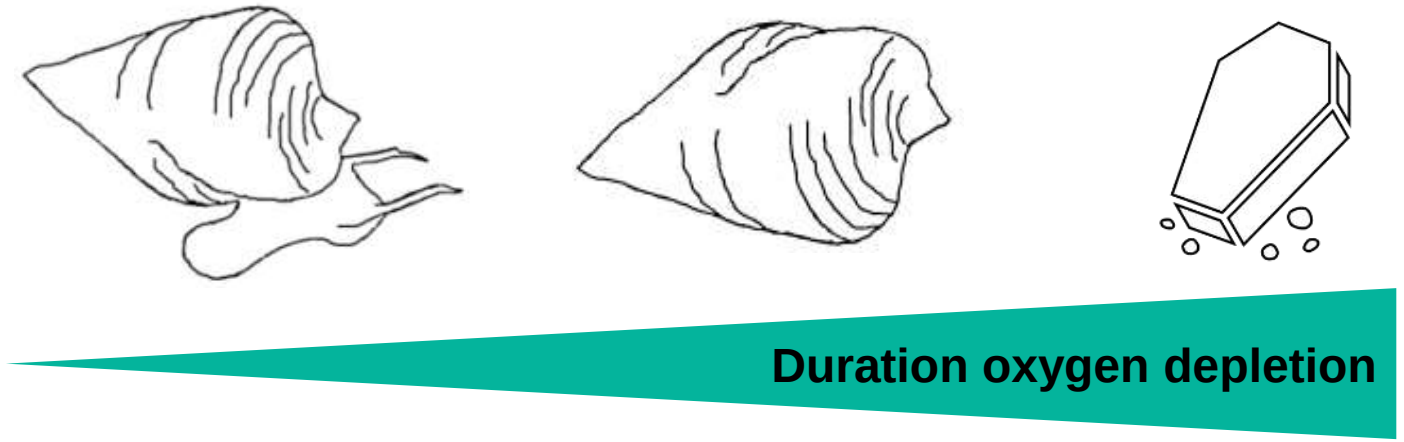


But what is relevant for benthic organisms?

G. Schernewski

5. The Baltic Sea - Oxygen indicators

- Organisms in the Baltic Sea are adapted to oxygen depletion
- Different species exhibit different tolerances to critical thresholds, duration, and repetition rates of oxygen depletion
- Measuring the duration and repetition rates of oxygen depletion is important for the **development of a biologically meaningful indicator**



G. Schernewski

5. The Baltic Sea - Oxygen indicators

Seasonal oxygen depletion

Weaknesses

- National concepts for seasonal oxygen depletion utilize different thresholds and assessment approaches
- Lack of information on spatial extent and/or temporal duration of oxygen depletion situations
- High spatiotemporal variability

Strengths

- Additional application in shallow areas
- In combination with model data high resolution spatiotemporal data
- High ecological and policy relevance
- Stronger link to pressure

A combined approach with modeled and observed data enables the use of seasonal oxygen depletion as a powerful eutrophication indicator

G. Schernewski

6. Indicators – Summary and outlook

Environmental indicators…

- …are **measurable metrics** that **respond to a pressure acting on an ecosystem** and that are used to **monitor** the **status and trends** of an ecosystem
- **…link anthropogenic pressures to policy measures** for achieving a good status

Indicator threshold setting is a crucial step as achieving the goal of a good status is based on whether meeting or not meeting the threshold

The validity of an indicator is only **as good as** the underlying **monitoring data**

Current research:

- **Linking water quality** parameters with **biological parameters**
- Incooperating **climate change effects** into thresholds and assessments

A **combination of measurements, models and remote sensing methods** will enable comprehensive environmental monitoring in the future

Thank you for your attention

Supported by the project UBA-Eutro

Dr. Sarah Piehl

sarah.piehl@io-warnemunde.de
Leibniz Institute for Baltic Sea Research, Warnemünde, Germany

LEIBNIZ INSTITUTE FOR BALTIC SEA RESEARCH WARNEMÜNDE

References

https://stateofthebalticsea.helcom.fi/
https://helcom.fi/about-us/

HELCOM (2018) State of the Baltic Sea – Second HELCOM holistic assessment 2011-2016. Baltic Sea Environment Proceedings 155. Available at: https://helcom.fi/baltic-sea-trends/holistic-assessments/state-of-the-baltic-sea-2018/reports-and-materials/

HELCOM (2018) HELCOM Thematic assessment of eutrophication 2011-2016. Baltic Sea Environment Proceedings No. 156. Available at: https://helcom.fi/baltic-sea-trends/holistic-assessments/state-of-the-baltic-sea-2018/reports-and-materials/

HELCOM (2018) HELCOM core indicator report – Oxygen debt. Available at: https://helcom.fi/baltic-sea604/trends/indicators/

HELCOM (2021b) Baltic Sea Action Plan – 2021 update. Adopted on 20 October 2021 in Lübeck, Germany by the HELCOM Ministerial Meeting. Available at: https://helcom.fi/baltic-613 sea-action-plan/

BLANO (2018) Zustand der deutschen Ostseegewässer 2018. Aktualisierung der Anfangsbewertung nach § 45c, der Beschreibung des guten Zustands der Meeresgewässer nach § 45d und der Festlegung von Zielen nach § 45e des Wasserhaushaltsgesetzes zur Umsetzung der Meeresstrategie-Rahmenrichtlinie. Anlage 1: Ergänzende nationale Indikatorblätter. Available at: https://www.meeresschutz.info/berichte-art-810.html?file=files/meeresschutz/berichte/%0bart8910/zyklus18/Zustandsbericht_Ostsee_2018.pdf

Turnhout E, Hisschemöller M, Eijsackers H (2007) Ecological indicators: Between the two fires of science and policy. Ecol Indic 7:215–228. https://doi.org/10.1016/j.ecolind.2005.12.003

Xie C, Li M, Wang H, Dong J (2019) Visual Informatics A survey on visual analysis of ocean data ☆. Vis Informatics 3:113–128. https://doi.org/10.1016/j.visinf.2019.08.001

Czúcz B, Keith H, Maes J, et al (2021) Selection criteria for ecosystem condition indicators. Ecol Indic 133:108376. https://doi.org/10.1016/j.ecolind.2021.108376

Niemeijer D, de Groot RS (2008) A conceptual framework for selecting environmental indicator sets. Ecol Indic 8:14–25. https://doi.org/10.1016/j.ecolind.2006.11.012