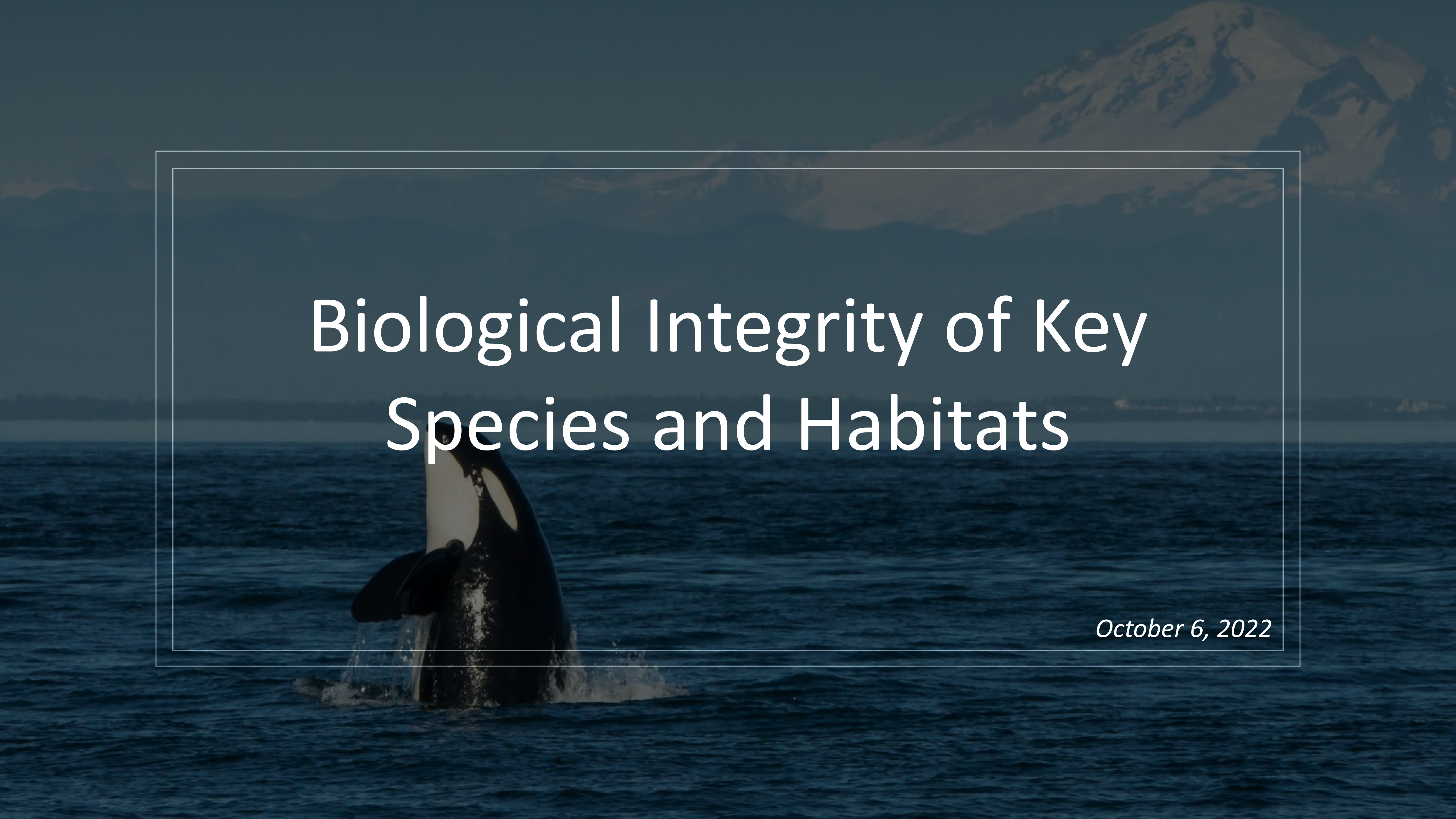


Biological Integrity of Key Species and Habitats

October 6, 2022

Biological Integrity of Key Species and Habitats

Agenda

8:00 AM	Intro
8:10 AM	What can be learned from managing oxygen problems in the Baltic Sea?
8:55 AM	Species and food web responses to low dissolved oxygen in the Salish Sea
9:25 AM	Break
9:30 AM	Q&A
9:45 AM	Biological impacts of low oxygen levels on Puget Sound species
10:00 AM	Discussion
10:25 AM	Wrap-up

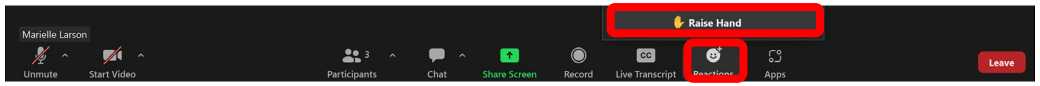
Navigating the Workshop

Welcome! While we wait, please:

- Update your name to include your pronouns and organization
- Message Marielle with any access needs
- Introduce yourself in the chat. We've muted participants and turned off your videos to minimize technical issues, so we encourage you to use the chat to say hello instead

Questions or Comments?

- Add them to the chat
- Raise your hand and we'll unmute you

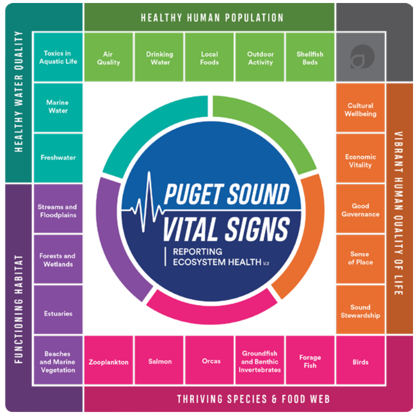


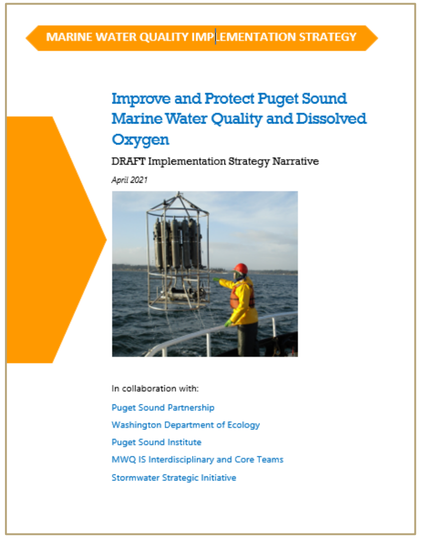
The slides, recording, and summary will be available on [Puget Sound Institute's website]


Land
Acknowledgement

University of Washington Puget Sound Institute's Role

Puget Sound Partnerships' Marine Water Quality Implementation Strategy




MARINE WATER QUALITY IMPLEMENTATION STRATEGY

Improve and Protect Puget Sound Marine Water Quality and Dissolved Oxygen

DRAFT Implementation Strategy Narrative

April 2021

In collaboration with:

Puget Sound Partnership

Washington Department of Ecology

Puget Sound Institute

MWQ IS Interdisciplinary and Core Teams

Stormwater Strategic Initiative

Technical Uncertainties

Research, Modeling, and Monitoring to Reduce Uncertainties

Nutrient Science Community in Puget Sound

PUGET SOUND INSTITUTE
UNIVERSITY of WASHINGTON | TACOMA

SALISH SEA MODELING CENTER
UNIVERSITY of WASHINGTON

Help address technical uncertainties and advance modeling tools to assist decision-making.

- Facilitate scientific workshops and regional collaboration
- Convene Model Evaluation Group
- Lead complementary model runs
- Expand access to models, outputs, tools, and scientific knowledge

Refine Research Actions

Targeted Technical Uncertainties

- Improve confidence in modeling of the Salish Sea and share findings
- Kickoff (7/26)
- Tools to Evaluate Water Quality (9/29)
- Biological integrity of key habitats and species (10/6)

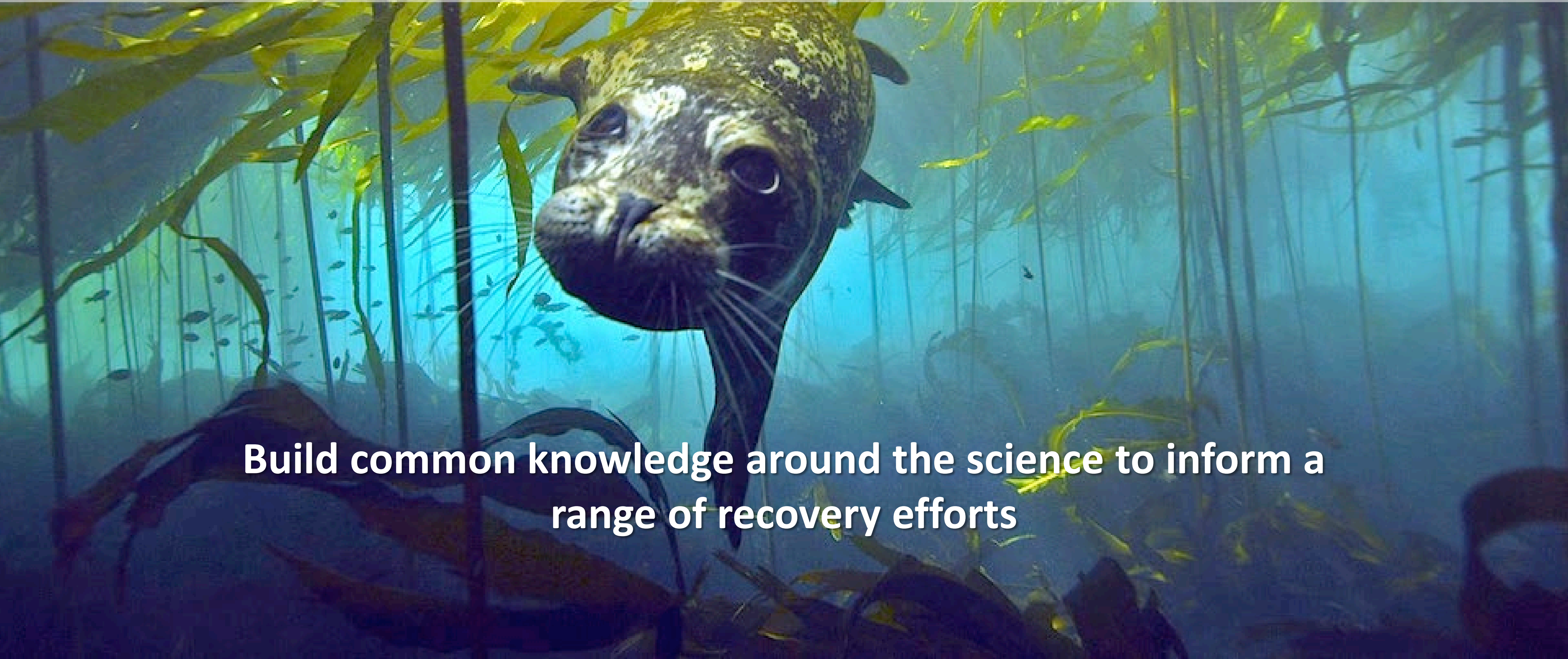
Upcoming Workshops

- **Sediment exchange** *(10/17)*
- **Phytoplankton and primary production** *(11/2)*
- **Change in interannual variability of rivers and ocean impact** *(week of 11/14)*
- **Improve watershed modeling to evaluate source reduction strategies to adaptively manage strategies** *(week of 12/12)*

Improved Confidence in Actions

Driving Scientific Question

How do we evaluate water quality with the tools that we have relative to the needs of key species, food webs, and habitats?



Build common knowledge around the science to inform a range of recovery efforts

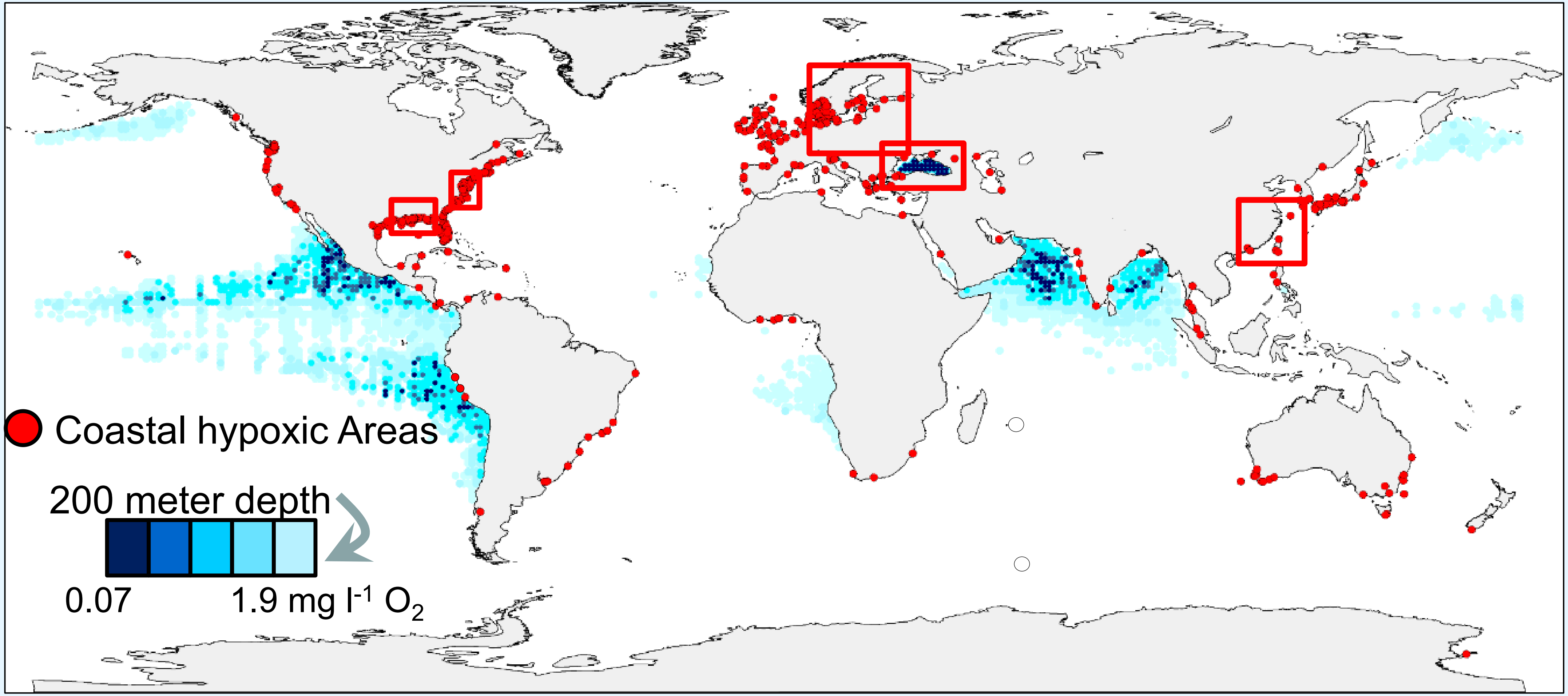
WHAT CAN BE LEARNED FROM MANAGING OXYGEN PROBLEMS IN THE BALTIC SEA?

Jacob Carstensen, Aarhus University

BONUS
SCIENCE FOR A BETTER FUTURE OF THE BALTIC SEA REGION
HYPER
HYPoxia mitigation for Baltic Sea Ecosystem Restoration
cocoa
Nutrient cocktails in the coastal zone of the Baltic Sea
Baltic Nest Institute

If you can’t breathe, nothing else matters

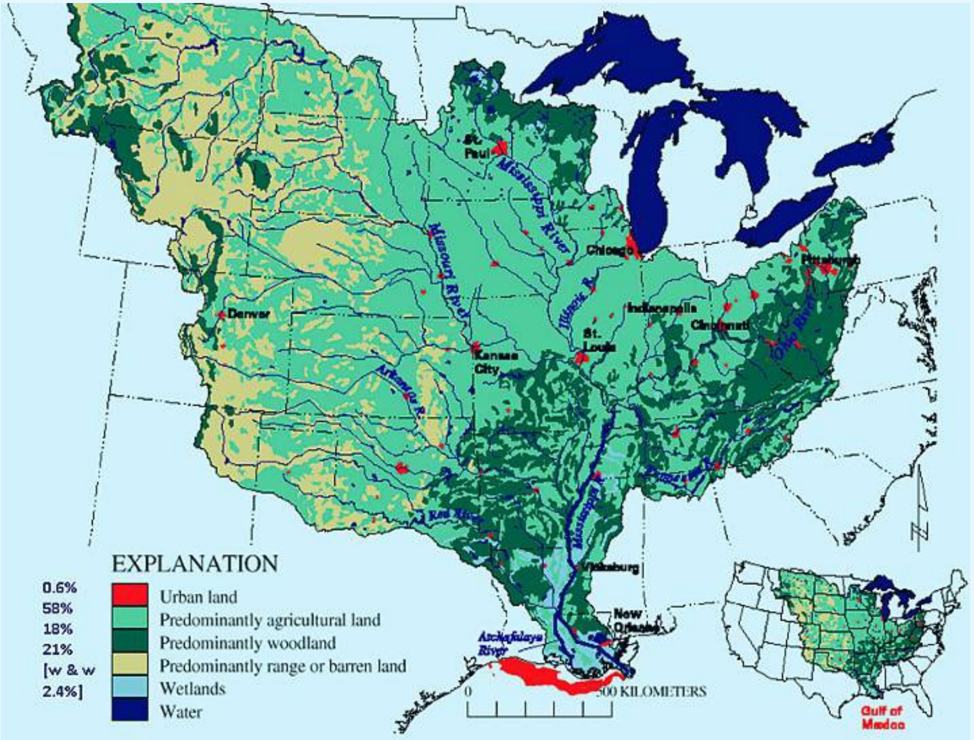
Hypoxia is a growing global problem

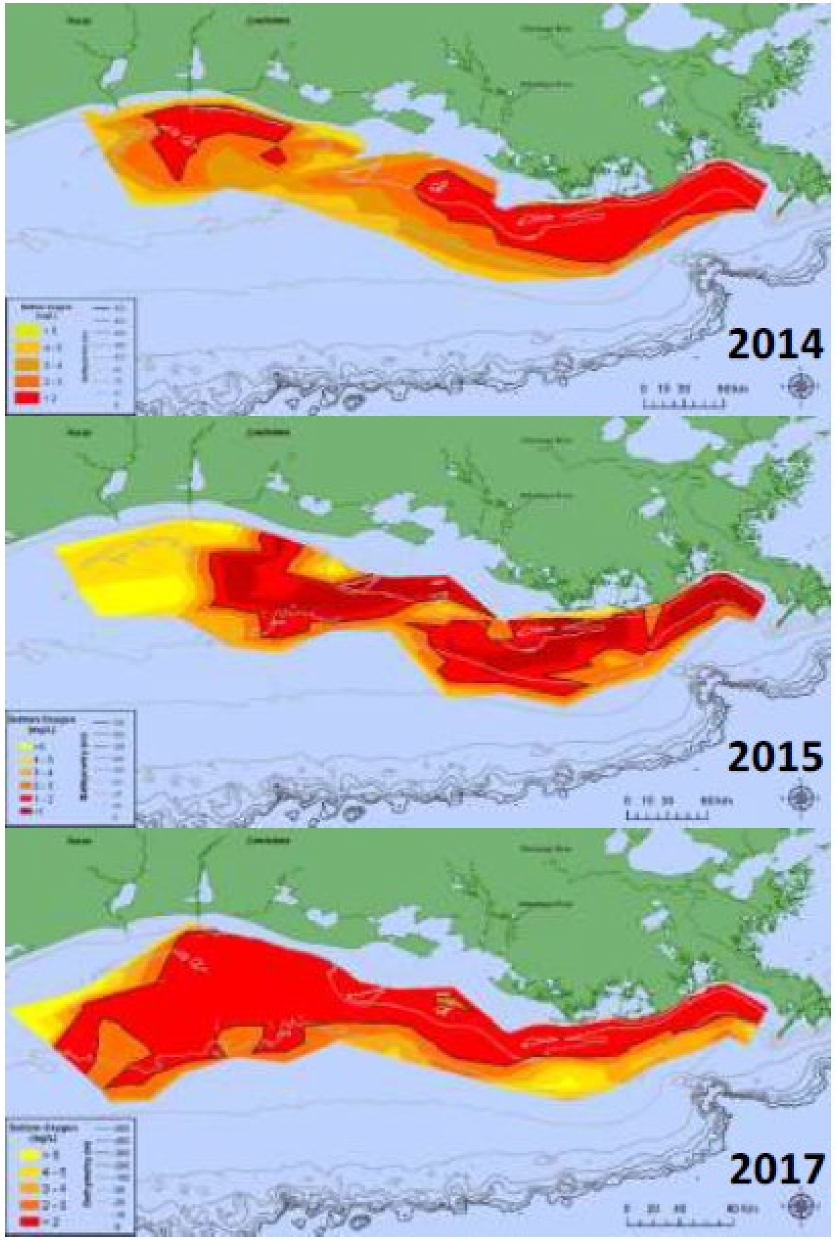


Breitburg et al., 2018, Science

Well-studied areas: Gulf of Mexico

- Receives excess nutrients from the Mississippi River watershed, stimulating production and creates stratified conditions along the coastal margin
- On average 14000 km² affected by hypoxia (<2 mg/L)
- June-August

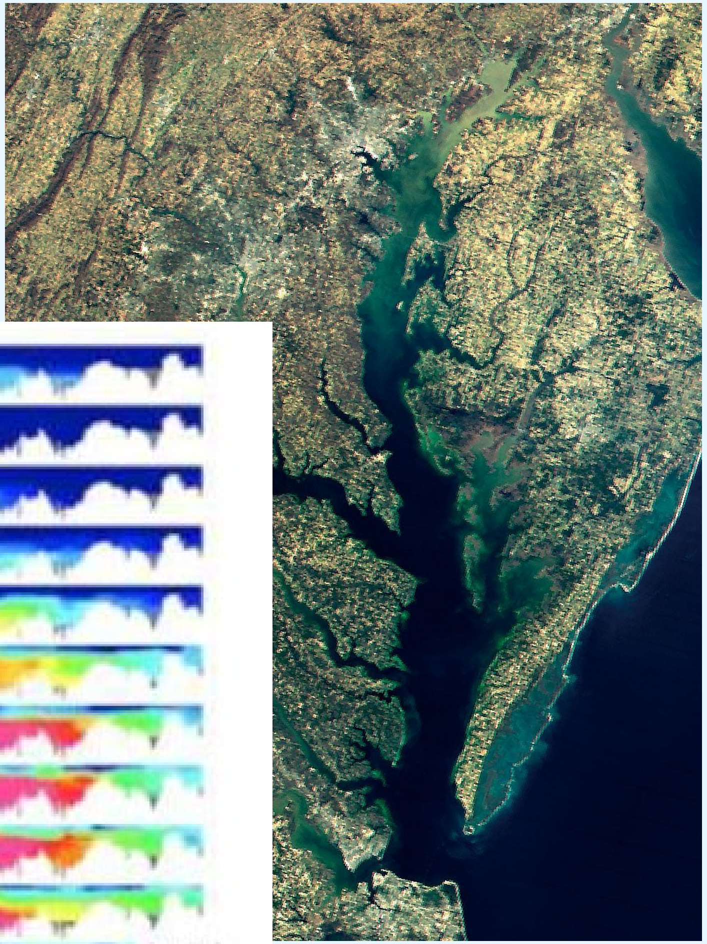


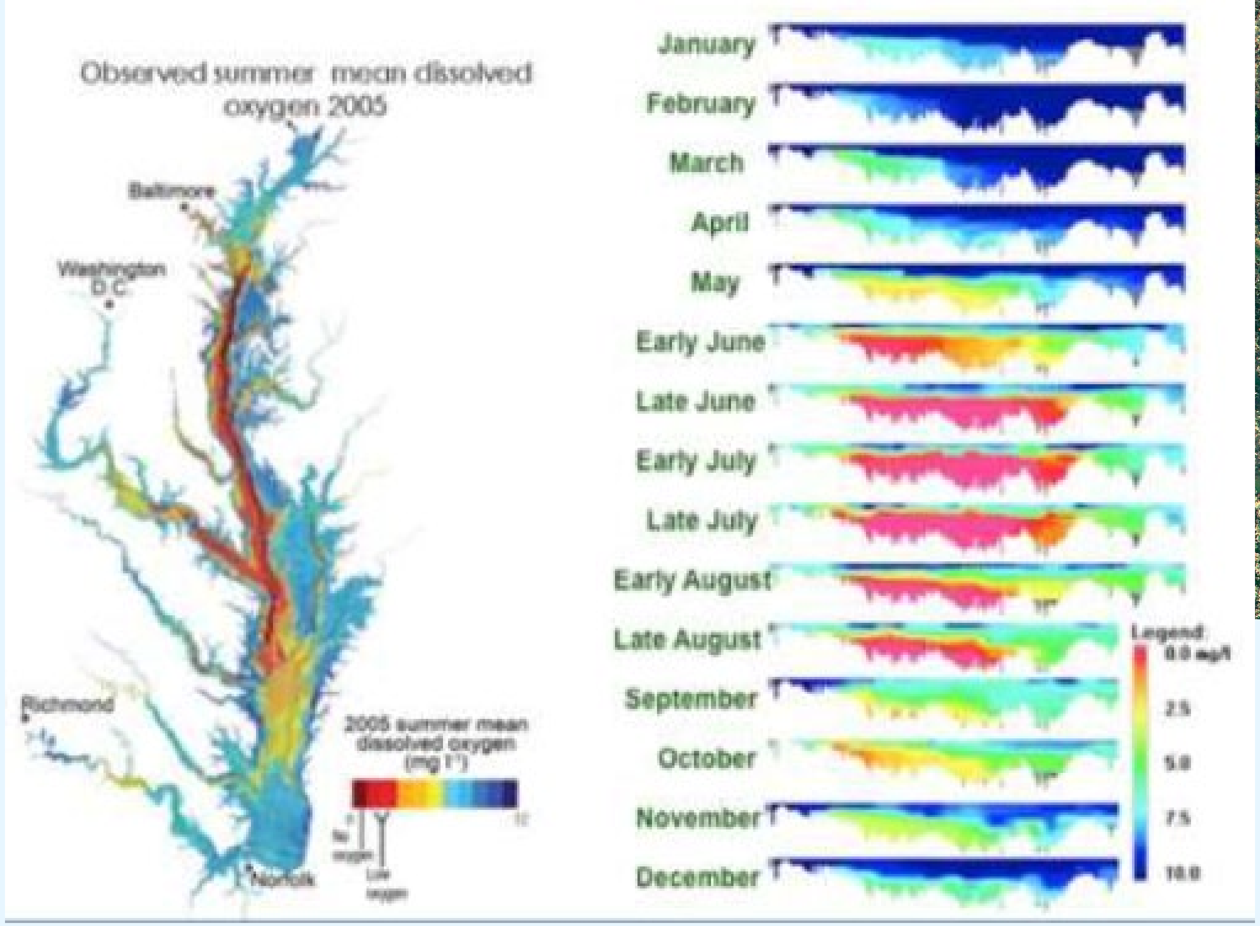


Pitcher et al. (2021) Prog.Oceanogr.

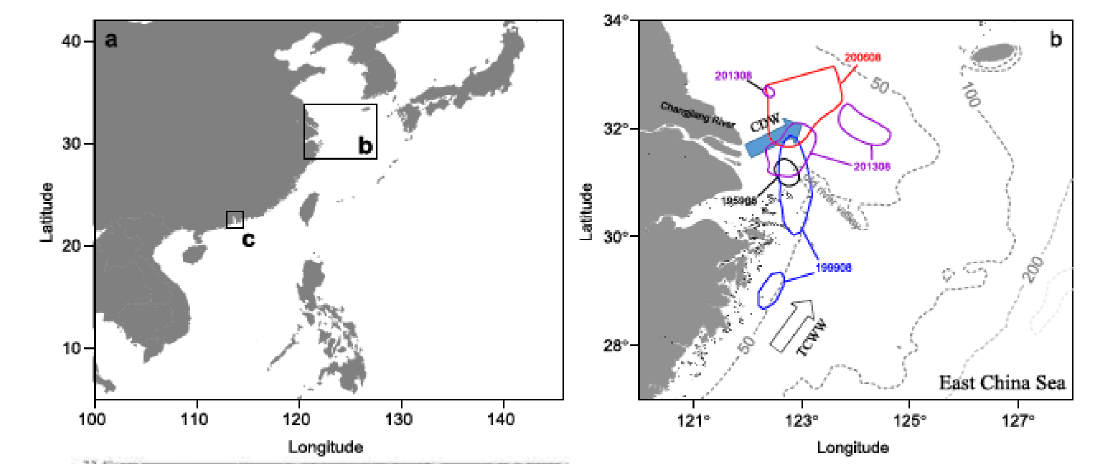
Well-studied areas: Chesapeake Bay

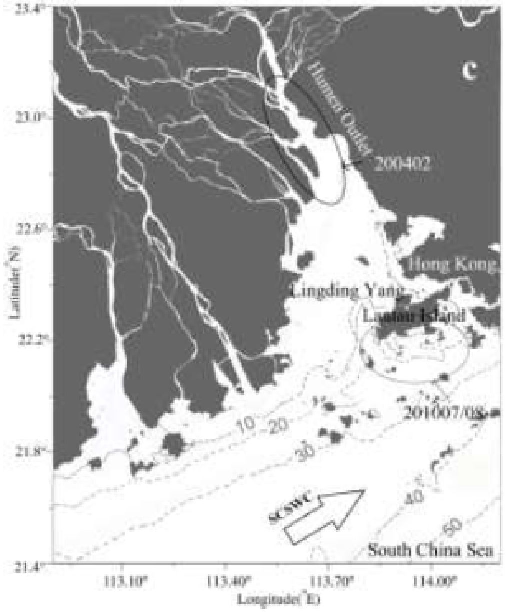
- **The largest estuary in the US**
- **Receives freshwater from several large rivers, although Susquehanna is the dominant (>80%)**
- **Seasonal hypoxia of about 10 km^3 (volume!)**

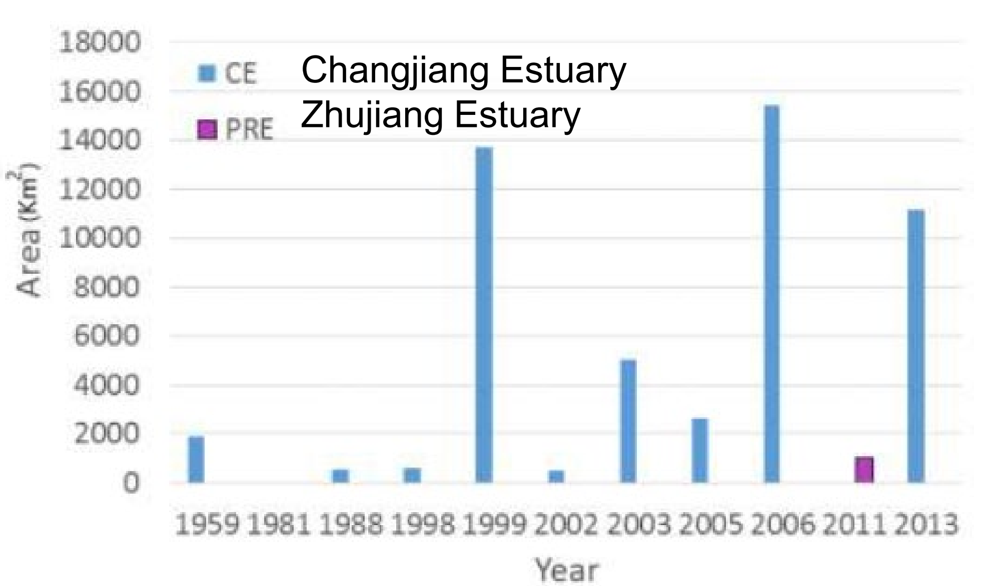




Well-studied areas: Changjiang and Zhujiang estuaries



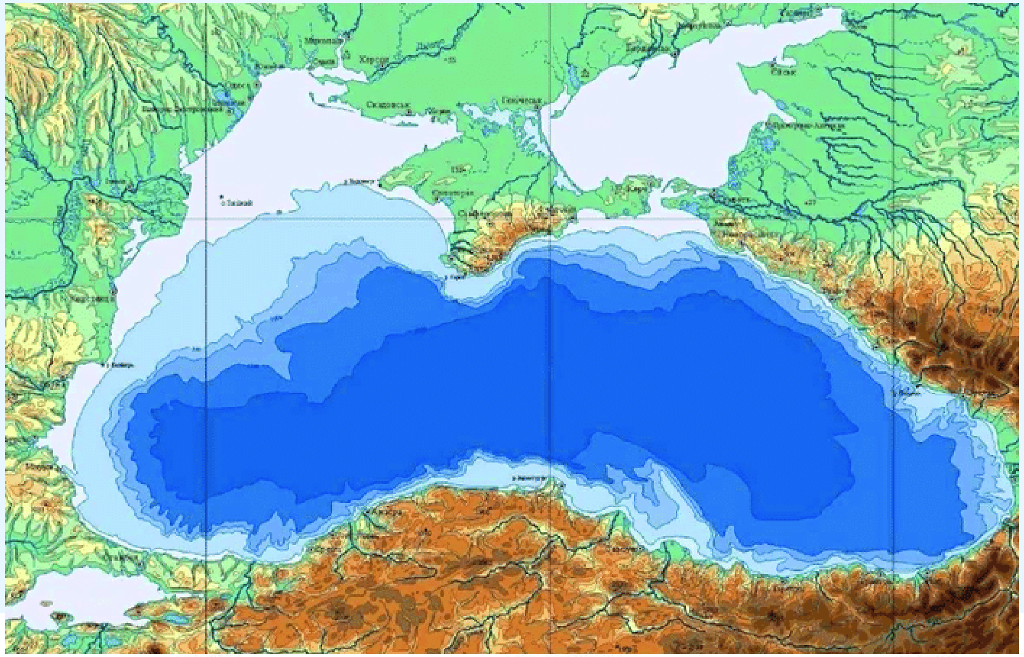




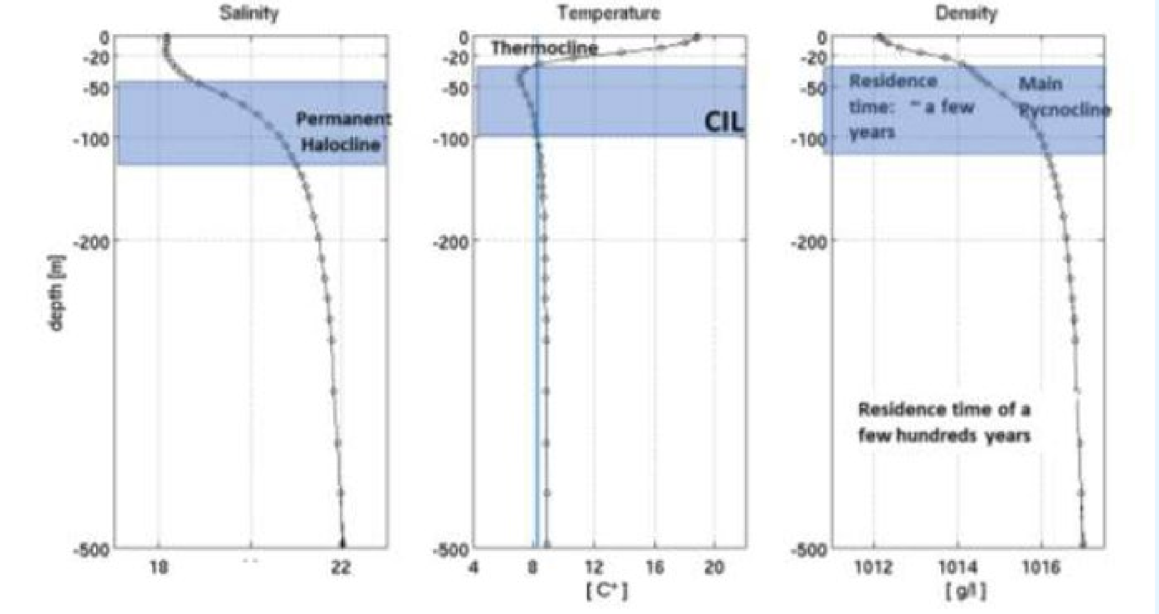
Pitcher et al. (2021)
Prog.Oceanogr.

- **Changjiang Estuary: Seasonal hypoxia- typically August for (around 10-15.000 km^2) at depths of 20-50 m**
- **Zhujiang Estuary: Seasonal hypoxia (~1000 km^2) in wet season (lower part) at depths of 10-30 m and dry season (upper part)**

Well-studied areas: Black Sea



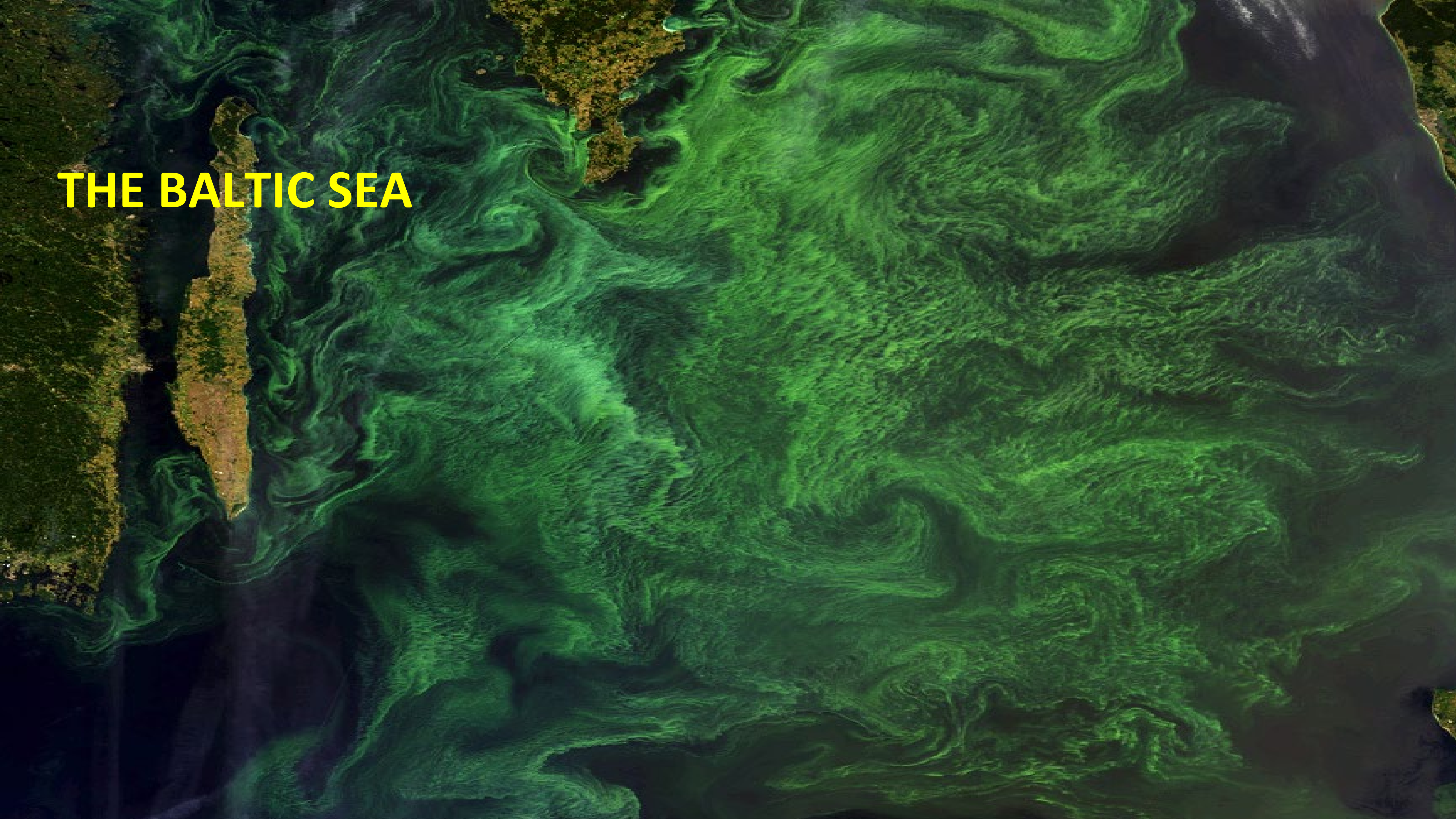
- Natural hypoxia due to the restricted ventilation of bottom waters
- Waters are sulfidic from about 100 m and below
- The Black Sea was a lake until ca. 8000 years ago
- The northwestern shelf has also experienced seasonal hypoxia



Pitcher et al. (2021)
Prog.Oceanogr.

Outline of talk

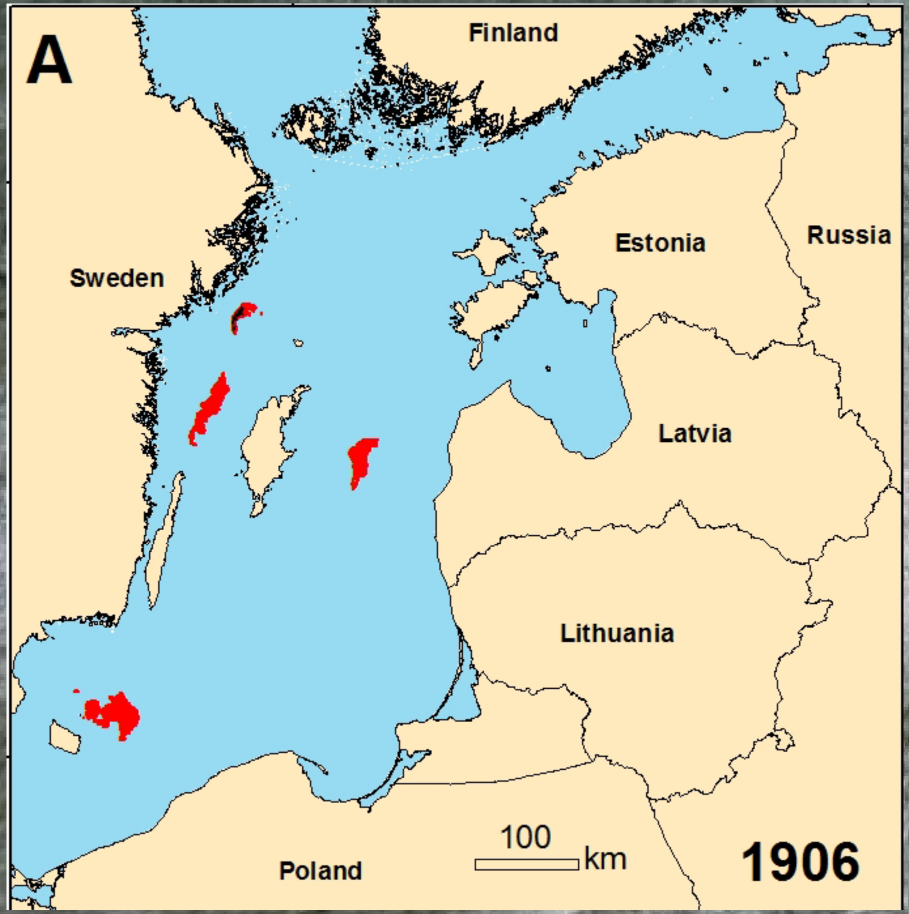
- **Different types of how hypoxia manifests itself in different Baltic systems and the mechanisms behind**
  - **Central open basin (perennial)**
  - **Entrance area/Danish Straits (seasonal)**
  - **Coastal areas (episodic)**
- **Future trajectories of hypoxia in response to management and climate change**
  - **Current policy frameworks**
  - **The multiple synergistic and negative effects of warming**
- **Consequences of hypoxia**
  - **Fauna**
  - **Biogeochemical cycles**

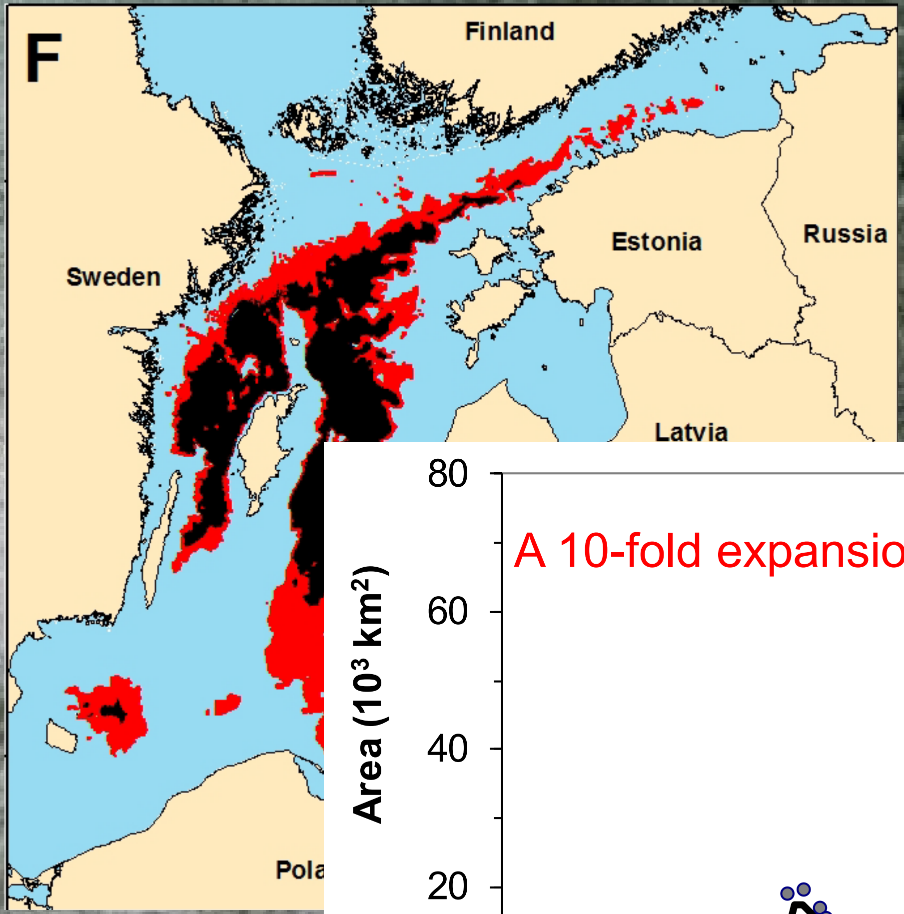

THE BALTIC SEA

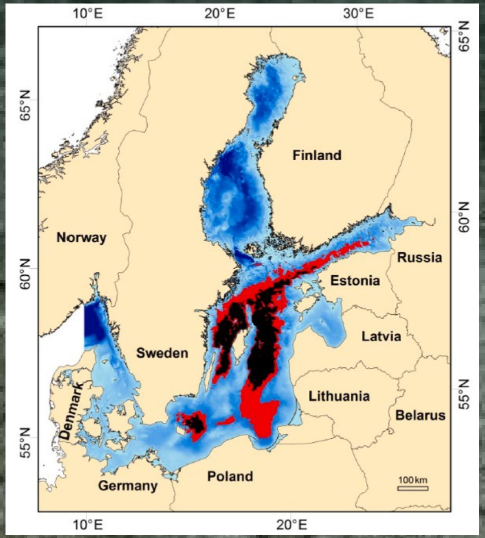
Below the surface – it's a different world

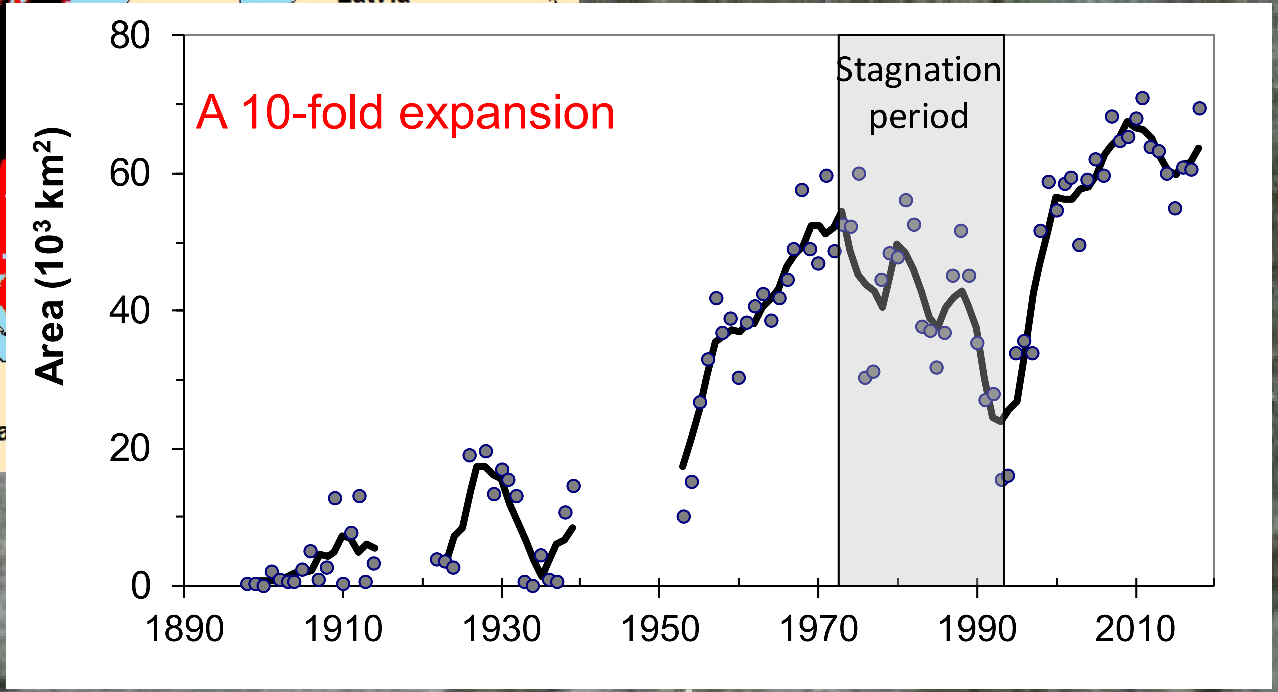
Photo: Nanna Rask

A century expansion of perennial hypoxia in the Baltic Sea



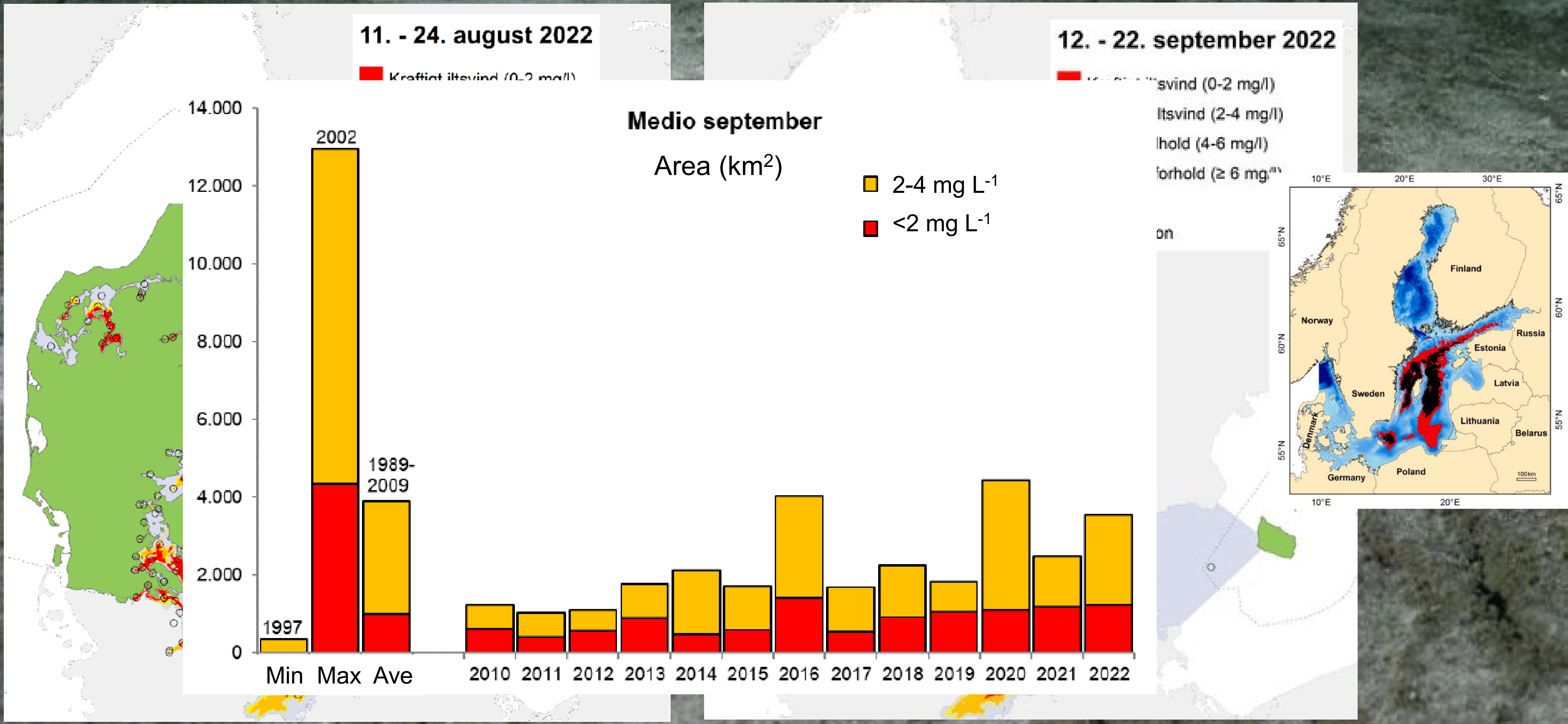




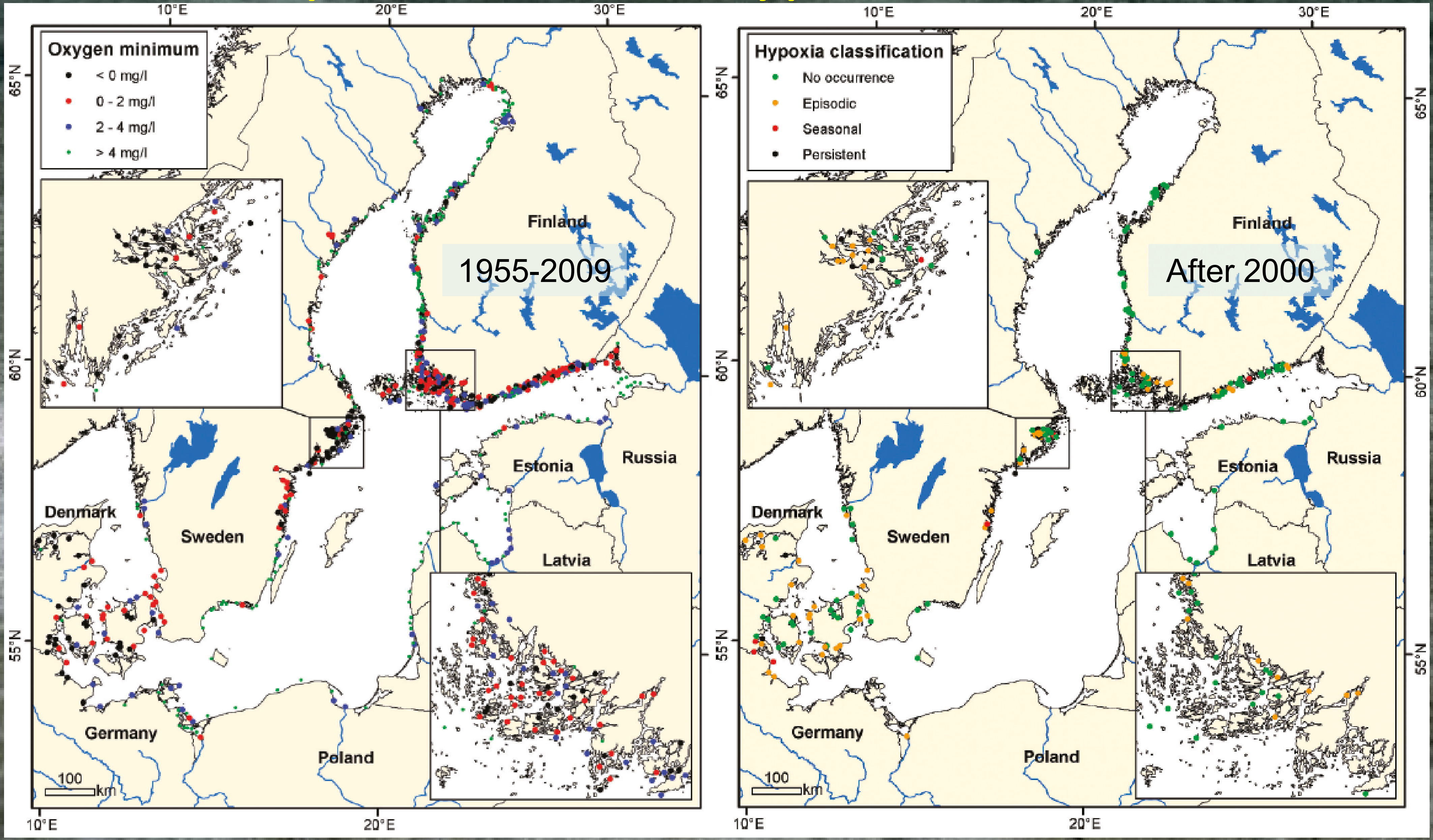


Updated from Carstensen et al. (2014) PNAS

Seasonal hypoxia in the western Baltic Sea



Widespread coastal hypoxia



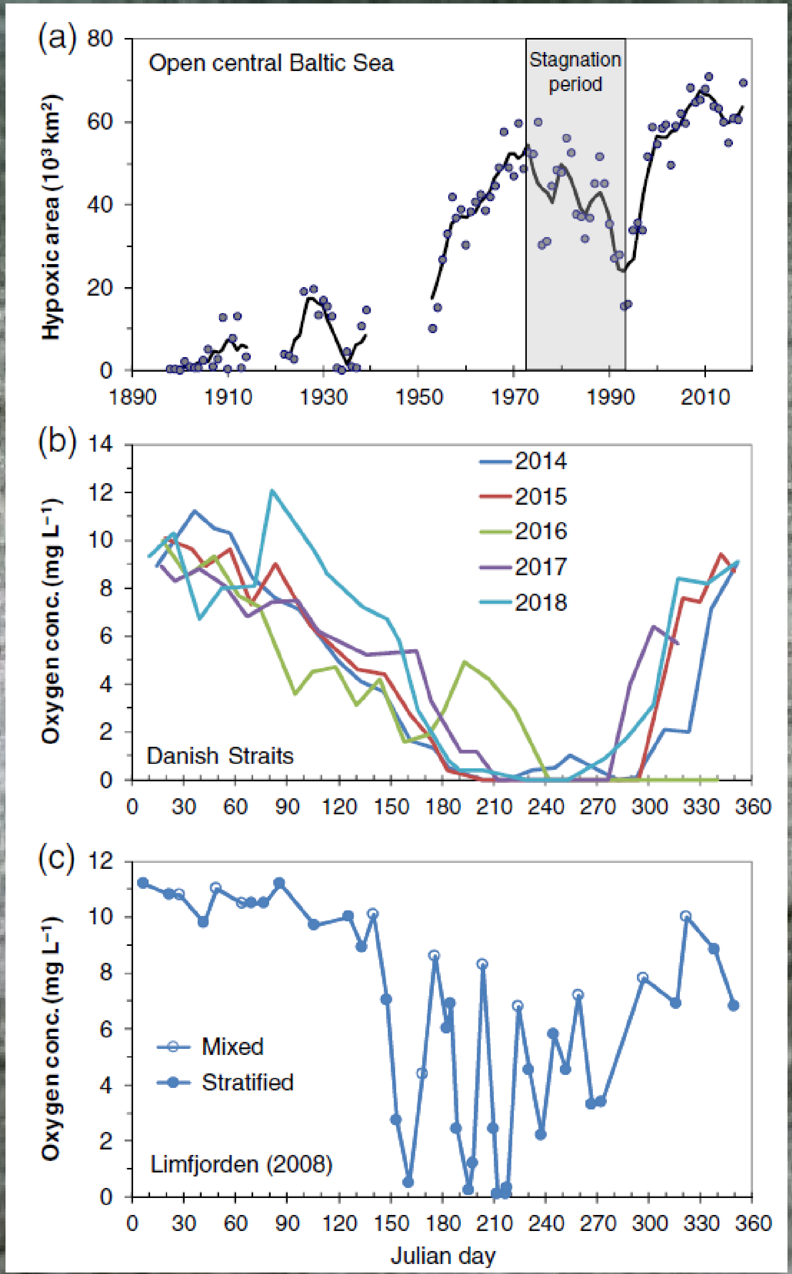
Source: Conley et al. (2011) ES&T

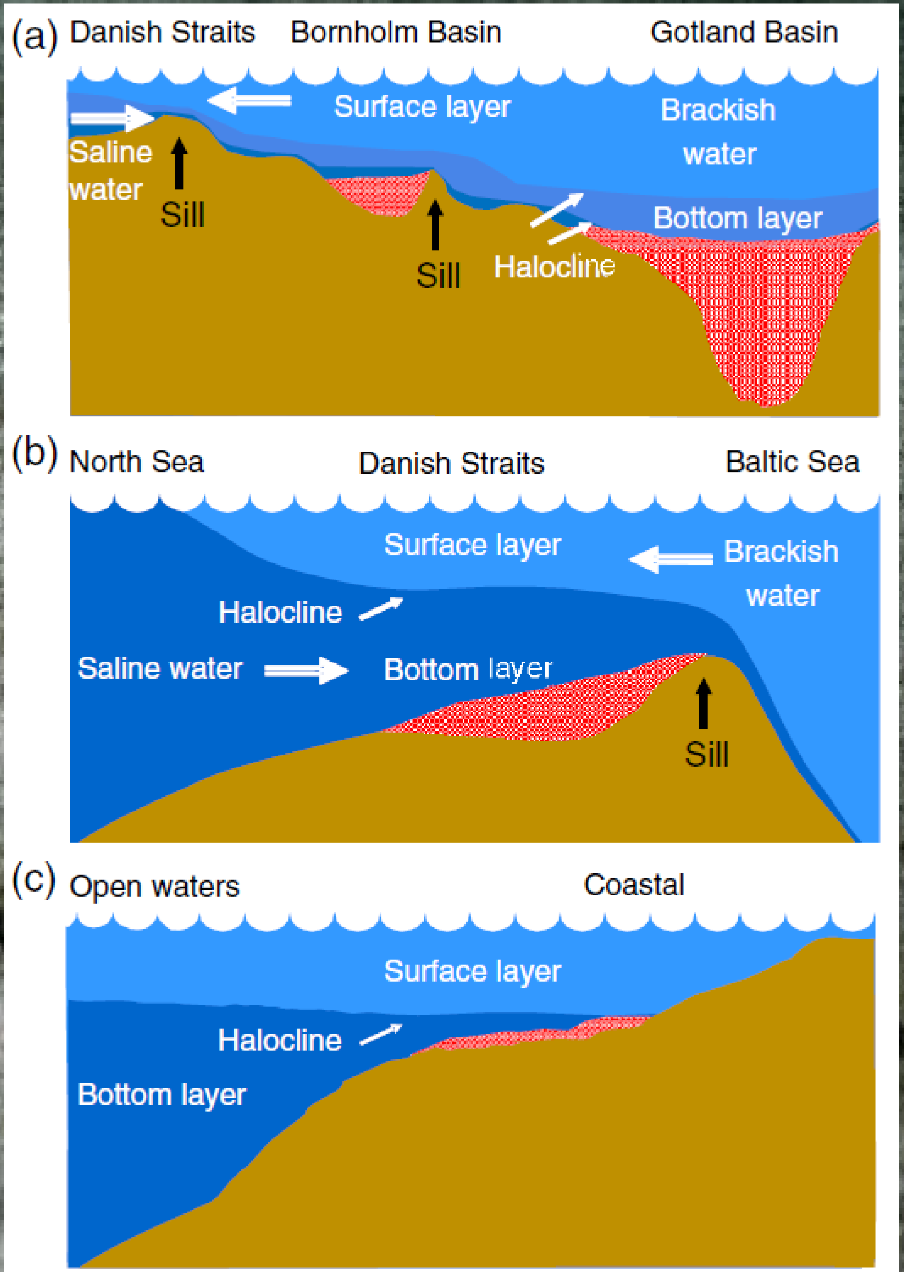
Baltic Sea hypoxia takes many shapes and sizes

Perennial hypoxia

Seasonal hypoxia

Episodic hypoxia





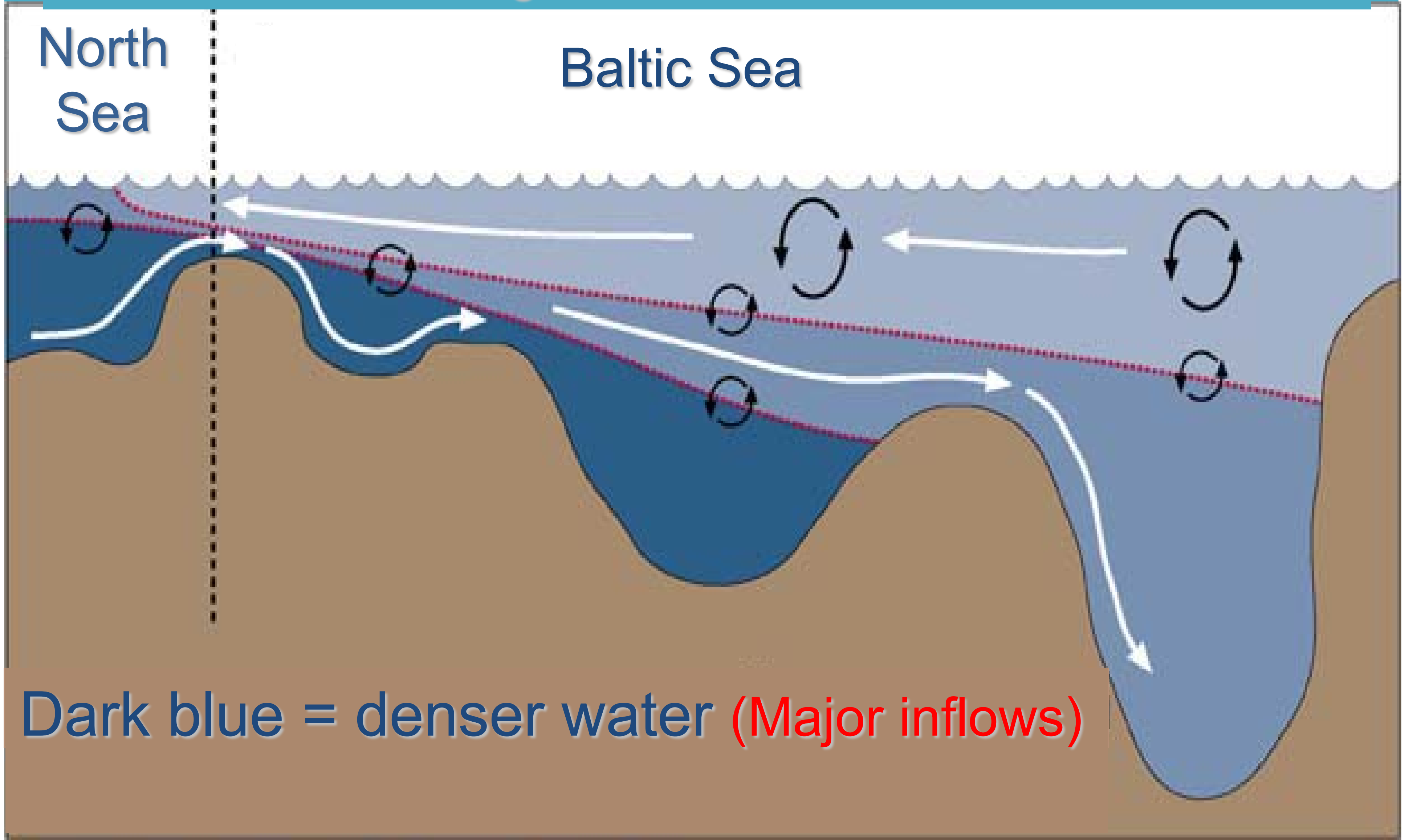
Carstensen & Conley (2019)
L&O Bulletin

WHY IS HYPOXIA SUCH A BIG PROBLEM IN THE BALTIC SEA?

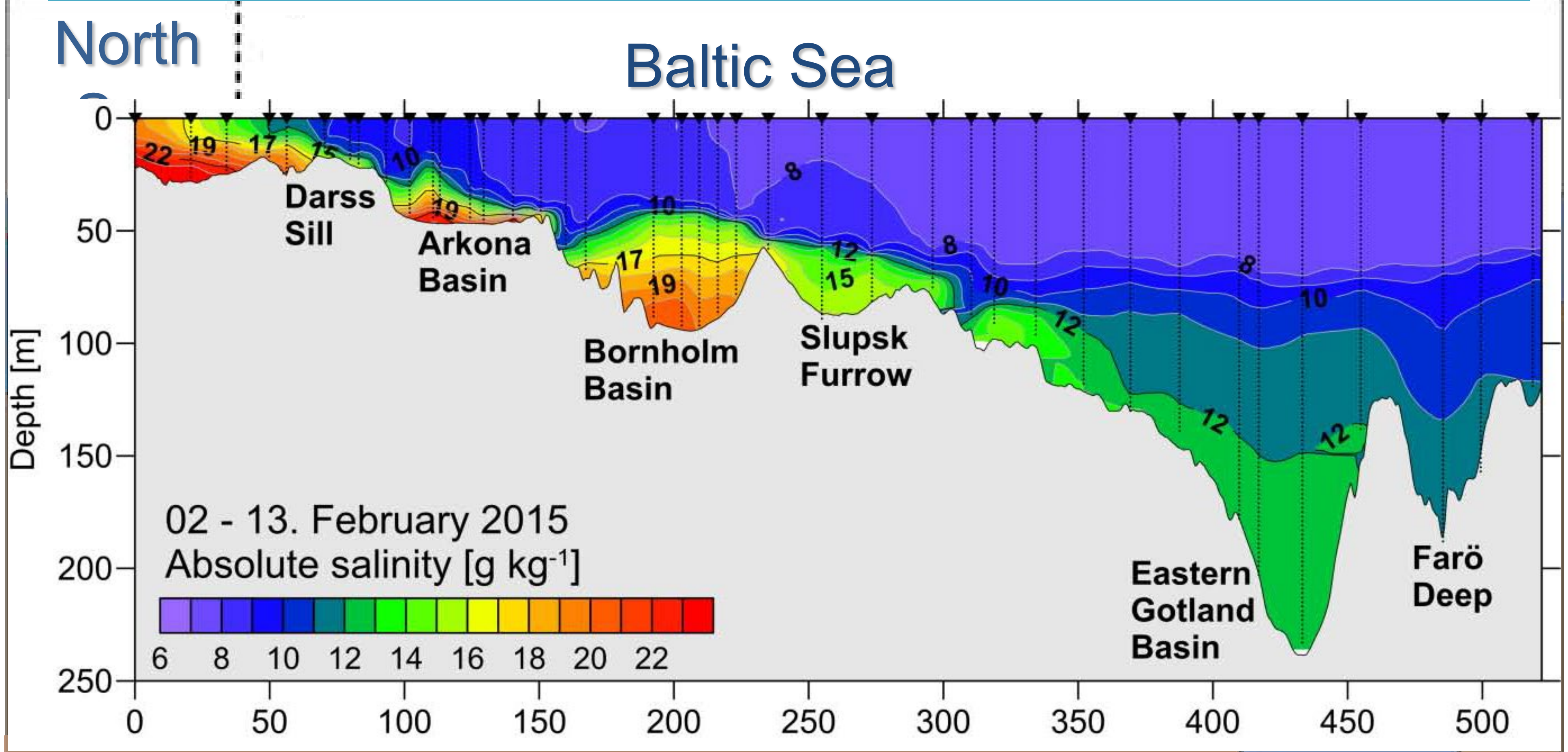
MECHANISMS GOVERNING THE OXYGEN SUPPLY

The Baltic Sea is naturally prone to hypoxia

The ventilation of the bottom waters is driven by events of saltwater intrusions of variable density and mixing across the halocline



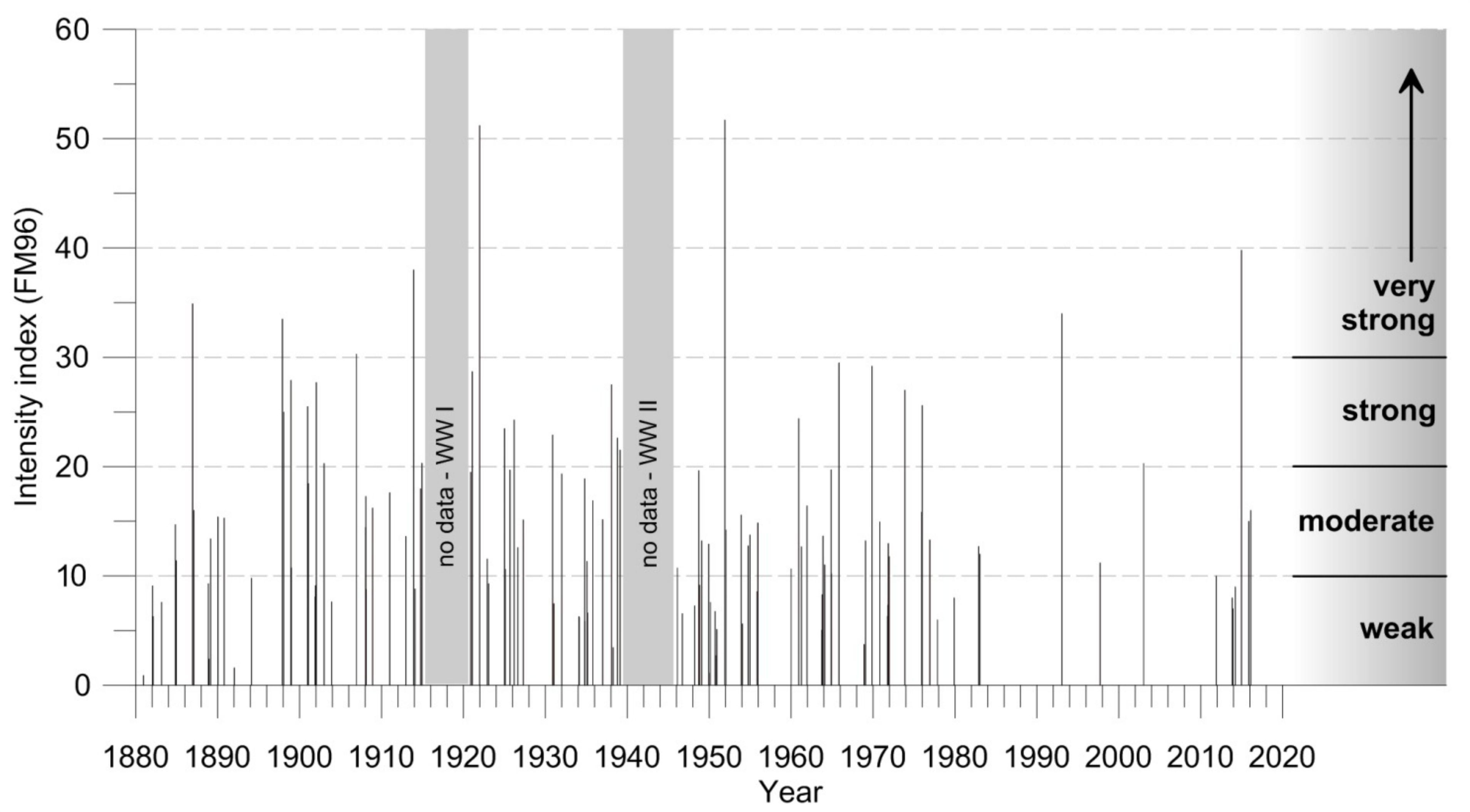
The ventilation of the bottom waters is driven by events of saltwater intrusions of variable density and mixing across the halocline



Dark blue = denser water (Major inflows)

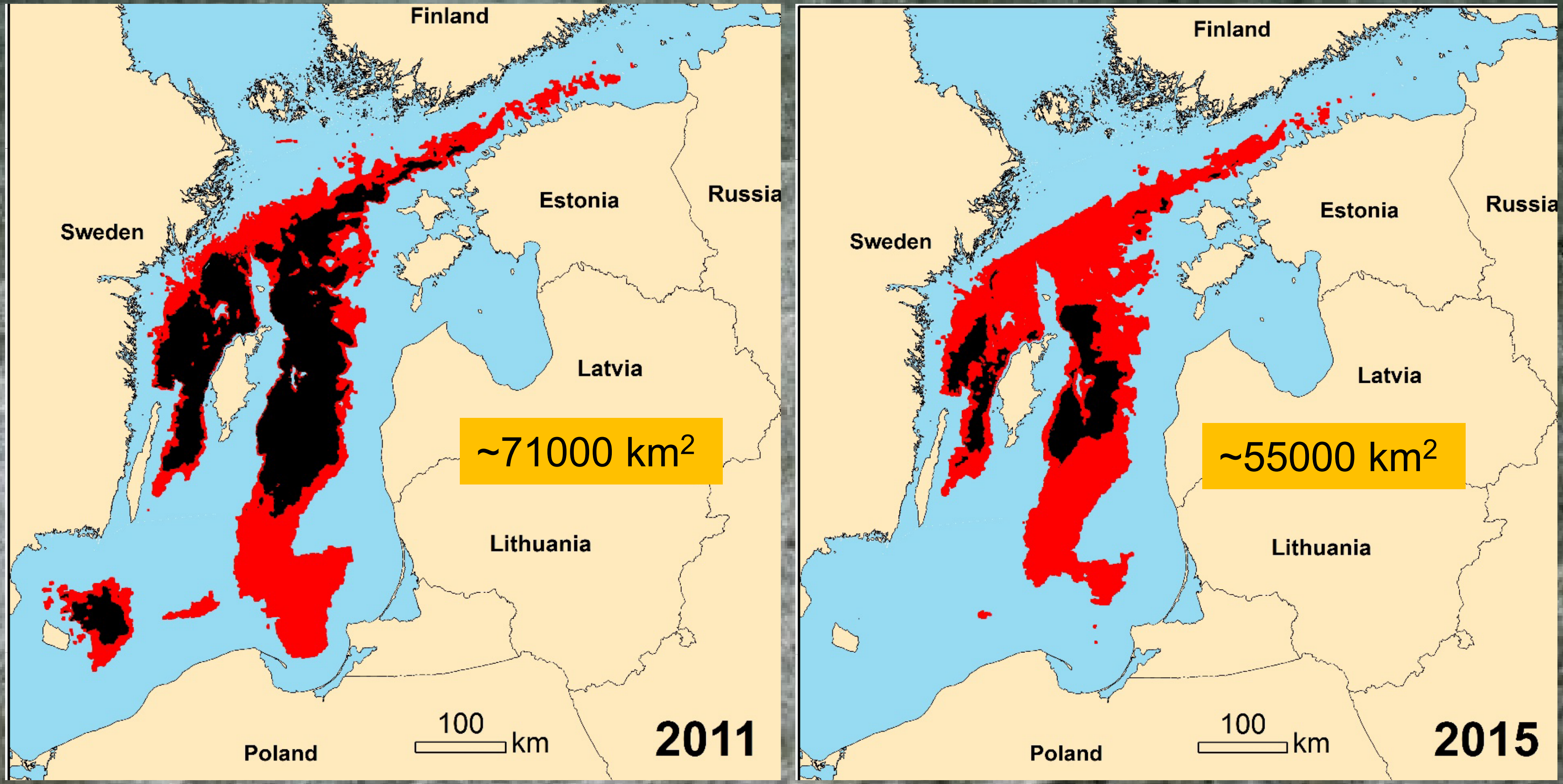
Source: Nausch et al. (2016) Meereswiss. Ber.

Saltwater intrusions happen at variable frequency and intensity



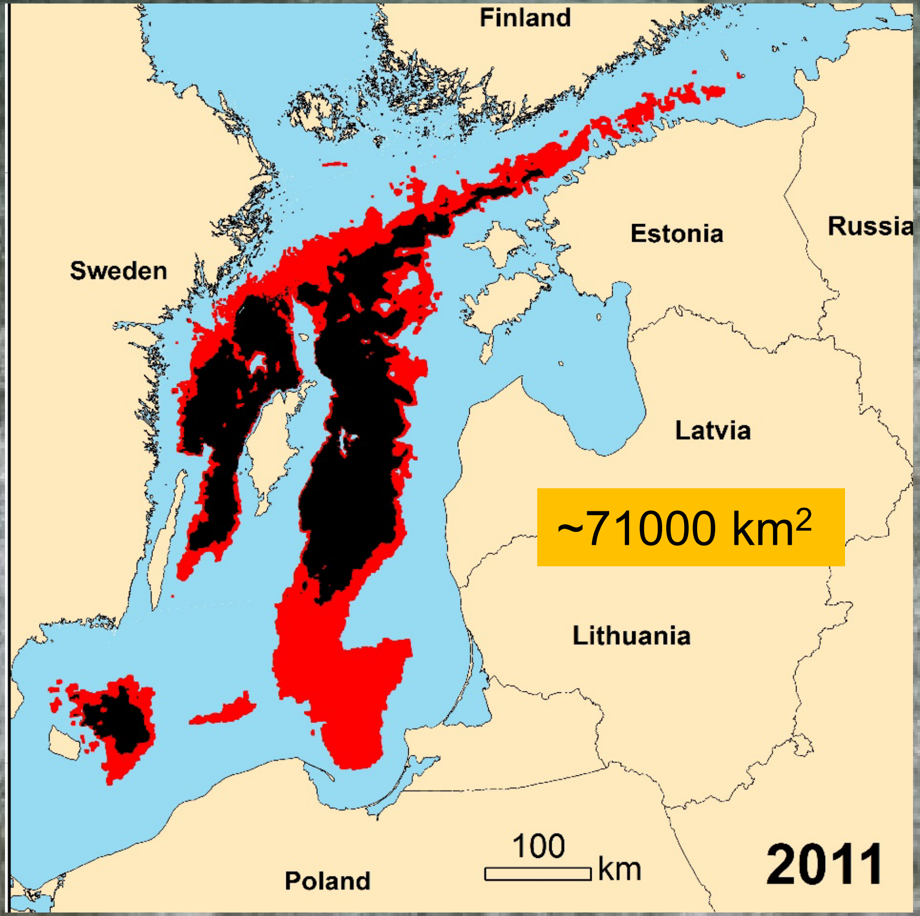
Source: Feistel et al. (2016) Meereswiss. Ber.

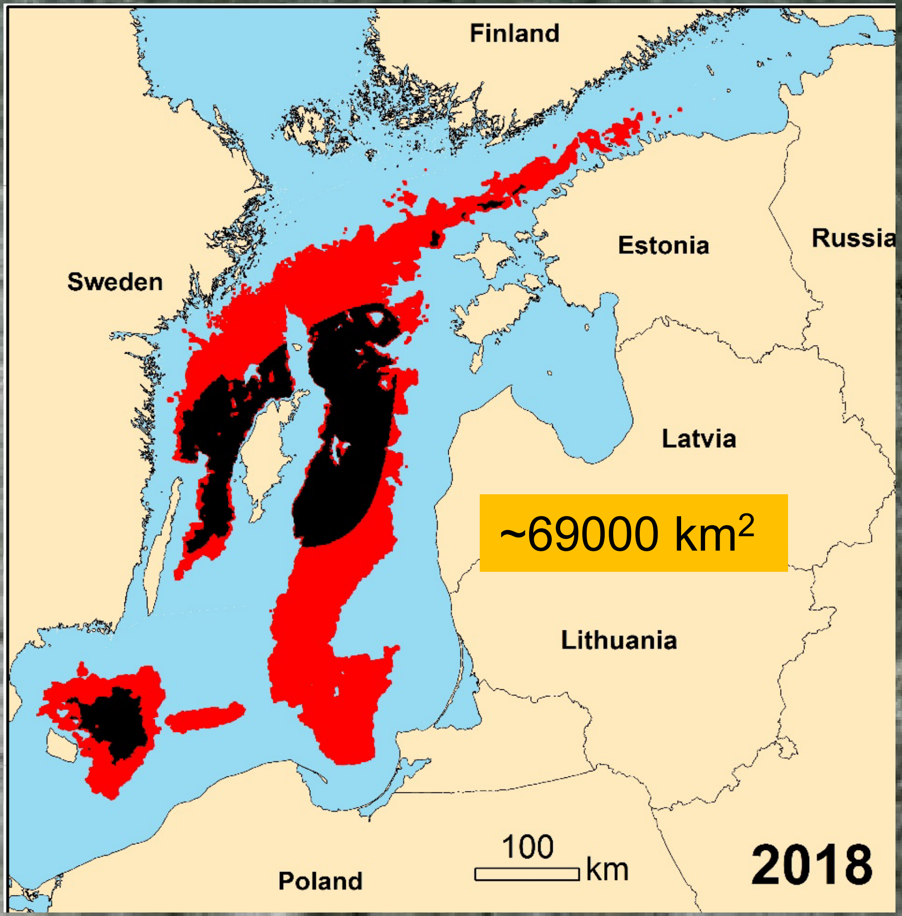
Recent expansion of perennial hypoxia in the Baltic Sea



Updated from Carstensen et al. (2014) PNAS

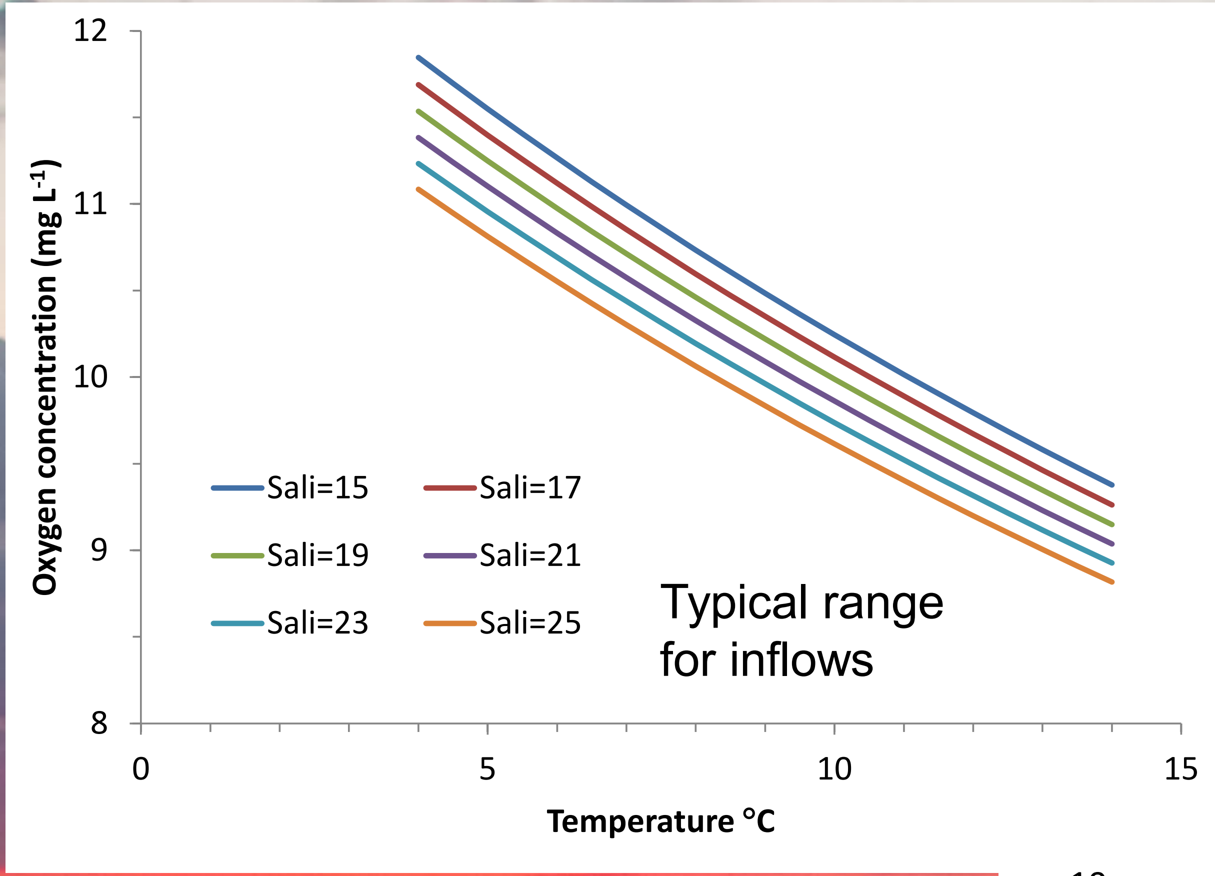
Recent expansion of perennial hypoxia in the Baltic Sea

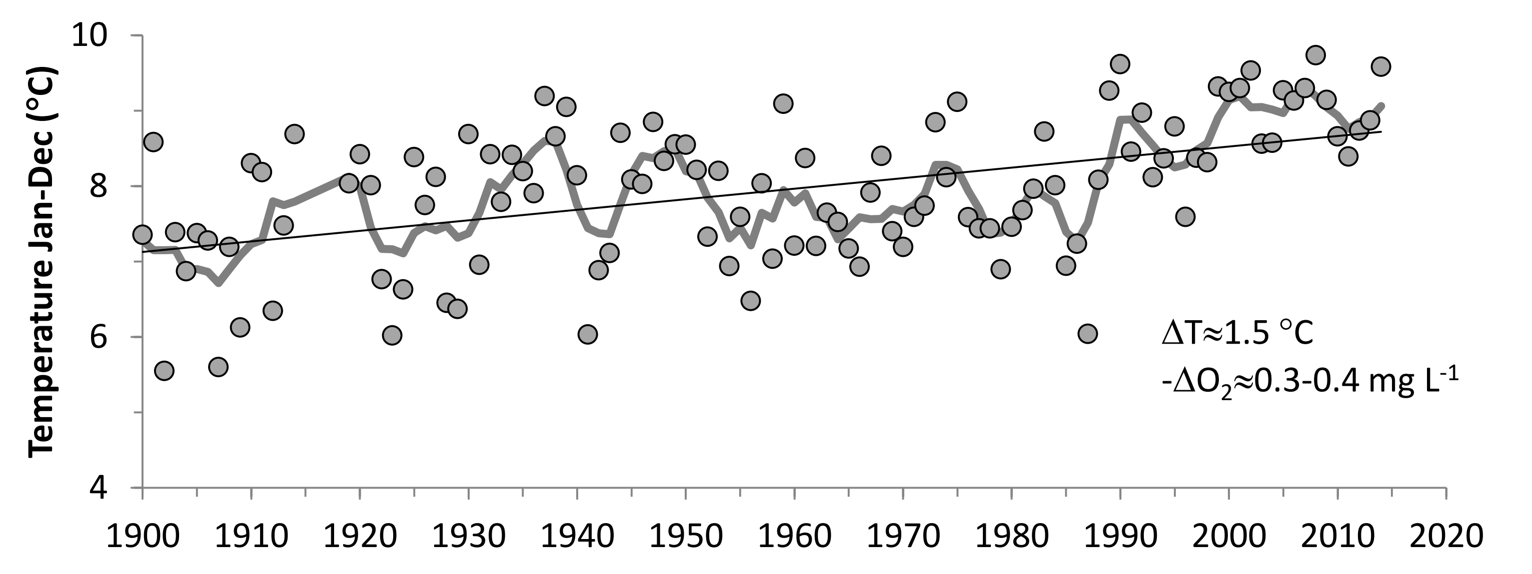




Updated from Carstensen et al. (2014) PNAS

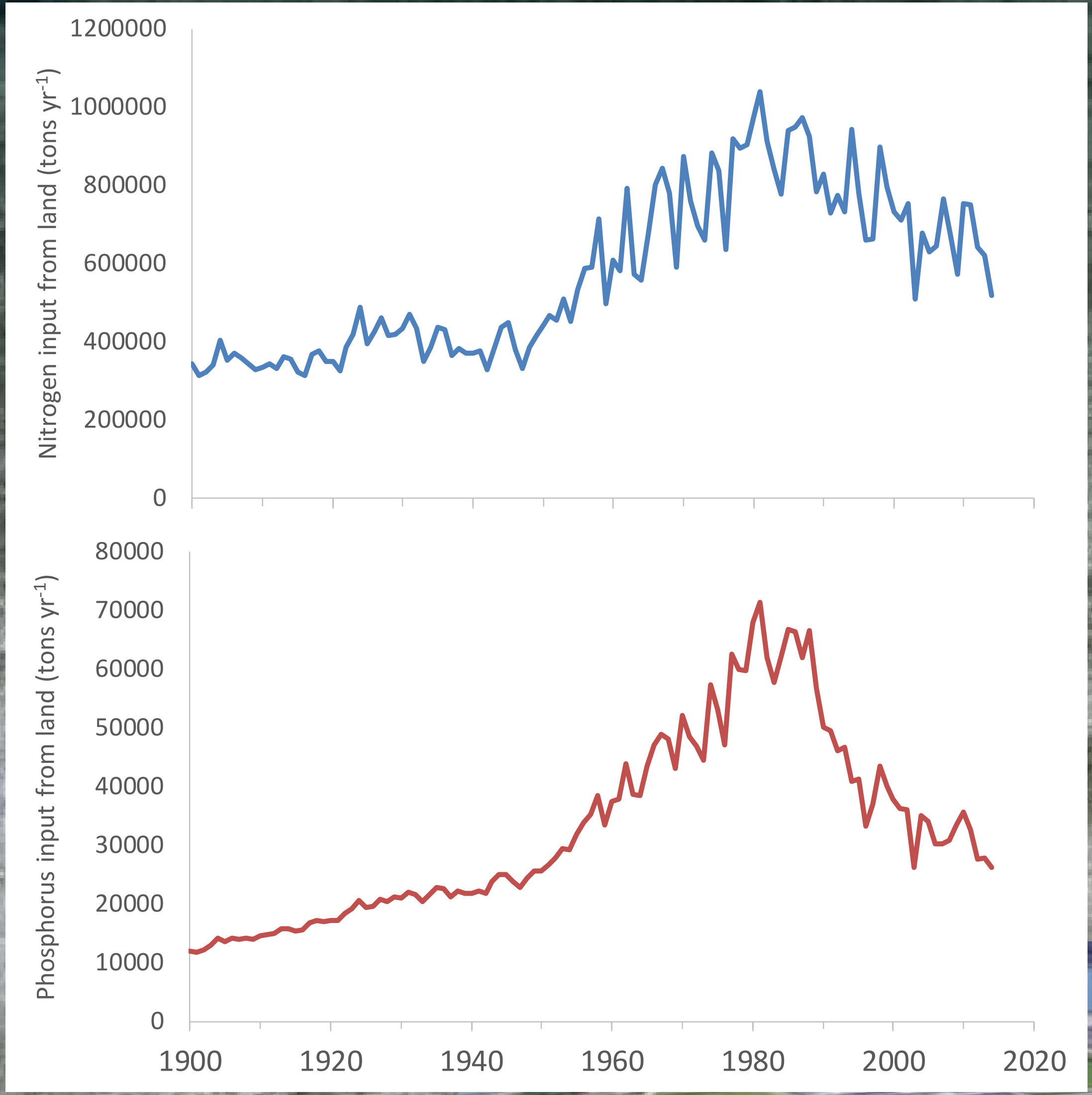
Oxygen supply decreases with temperature





MECHANISMS GOVERNING THE OXYGEN CONSUMPTION

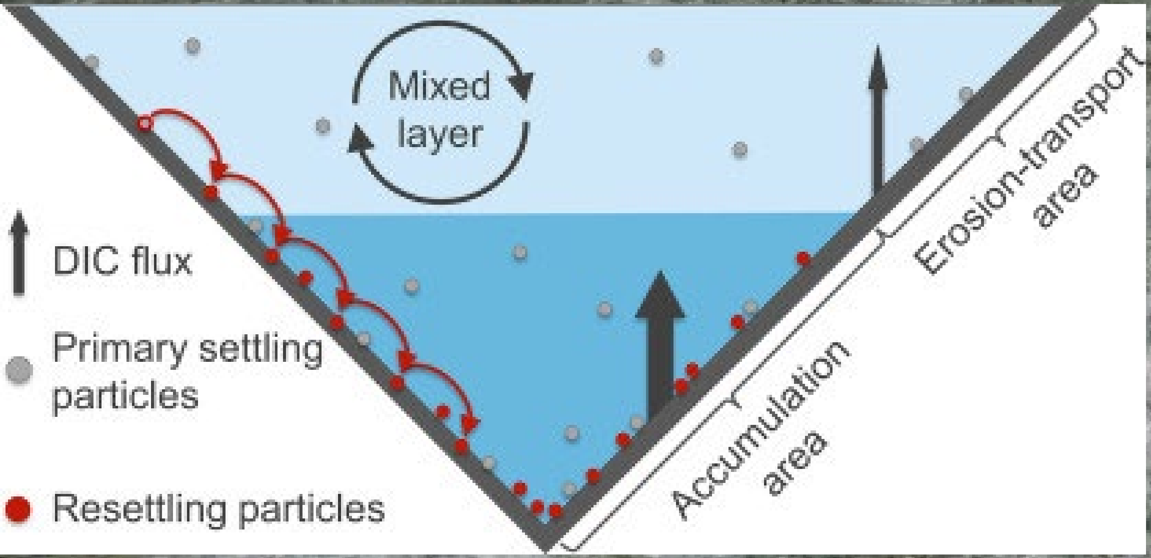
Nutrient enrichment of the Baltic Sea

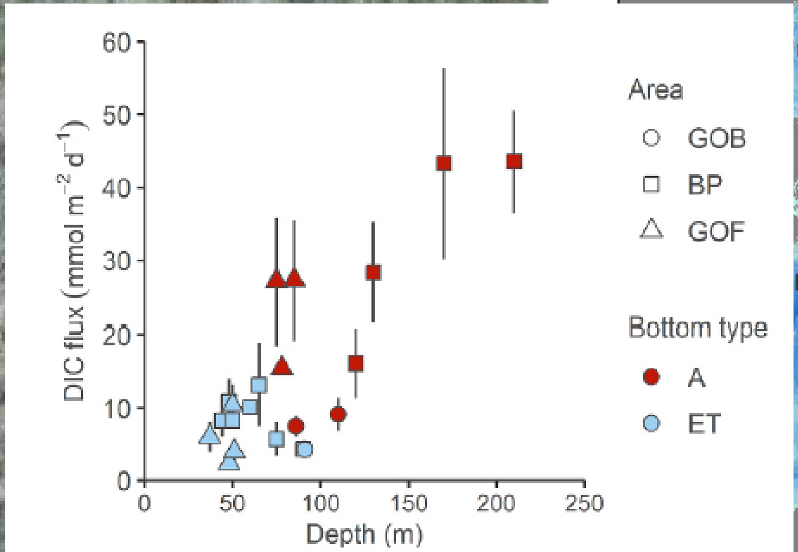


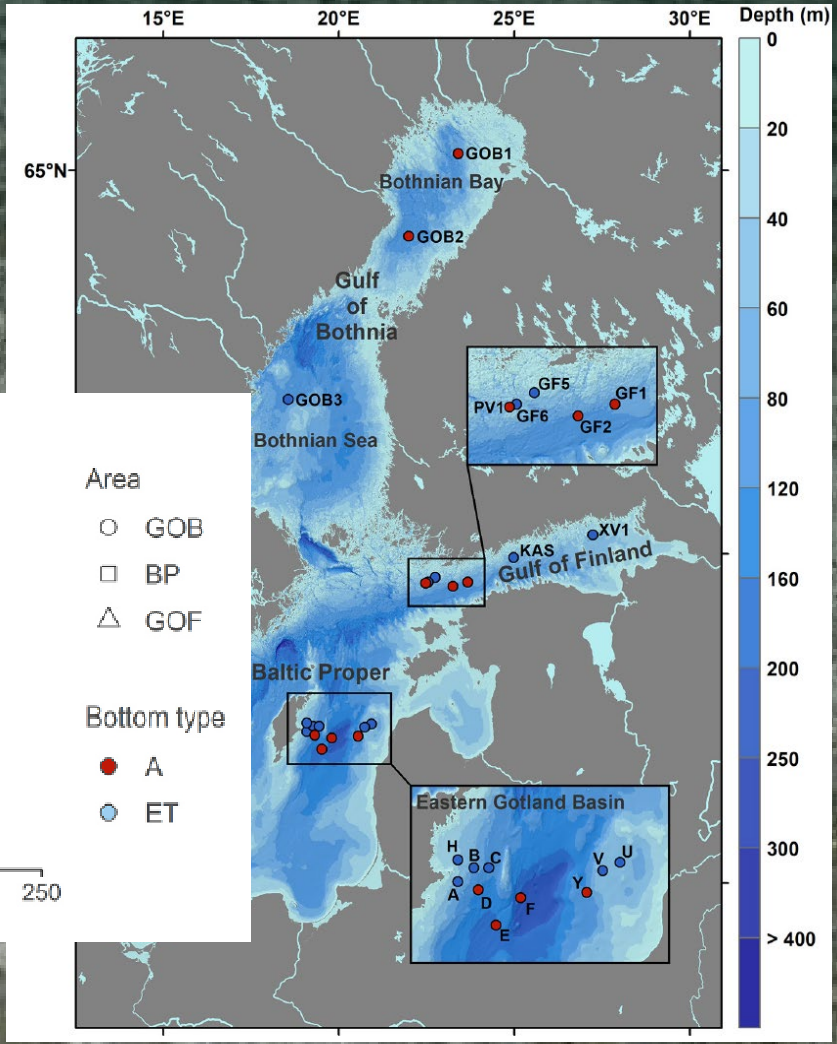
Updated from Gustafsson et al. (2012) Ambio

Source: Carstensen et al. (2014) PNAS

Particle shuttling contributes to oxygen demand in the deep basins



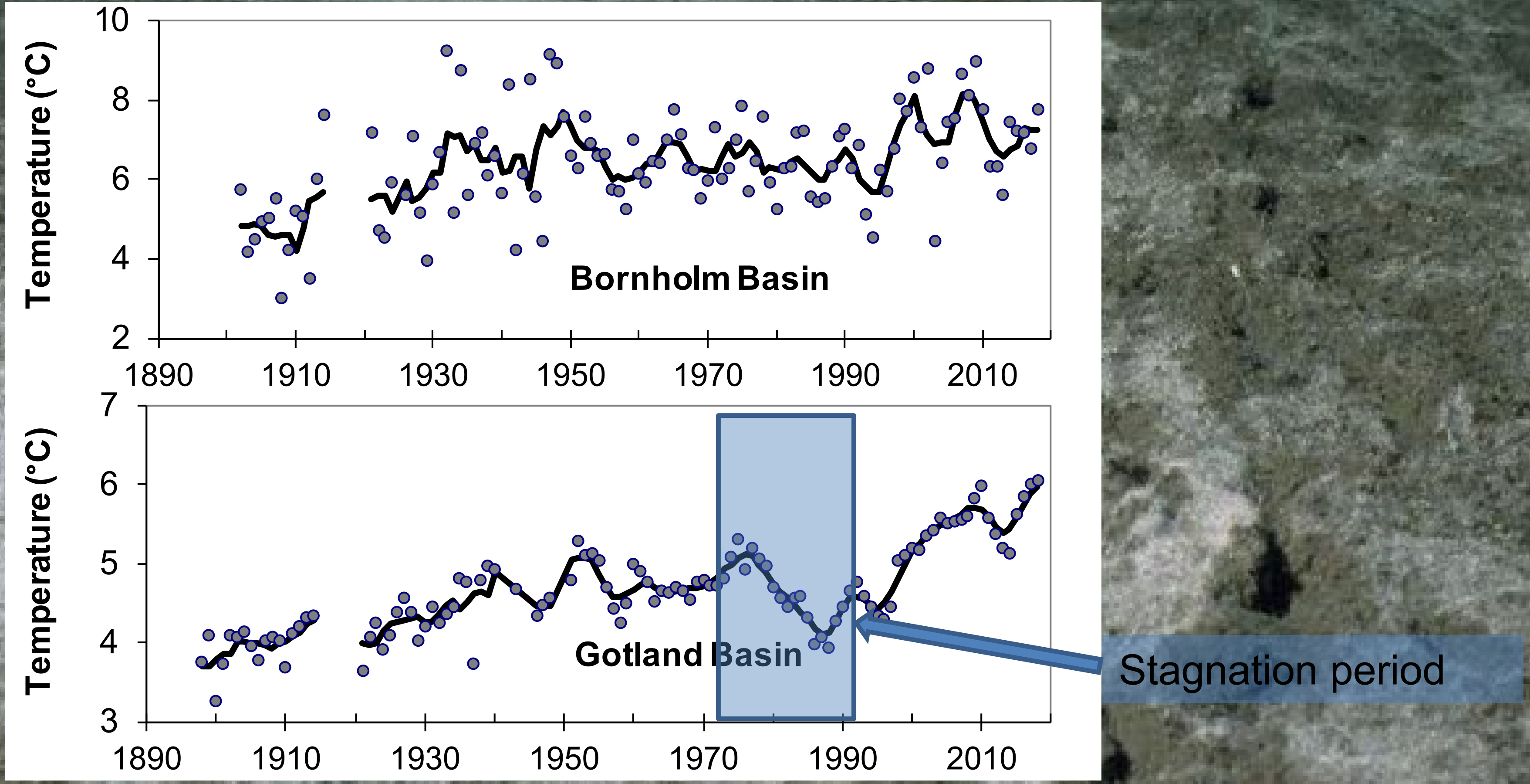




sediment age and increasing sedimentary inventories of POC and chlorophyll *a* with normalised water depth. Our calculations indicate that particle shuttling redistributes almost half of the deposited export production from ET areas to A areas in the Baltic Proper, and that substantial amounts of terrestrial organic material are transported

Source: Nielsson et al. (2021) MarChem

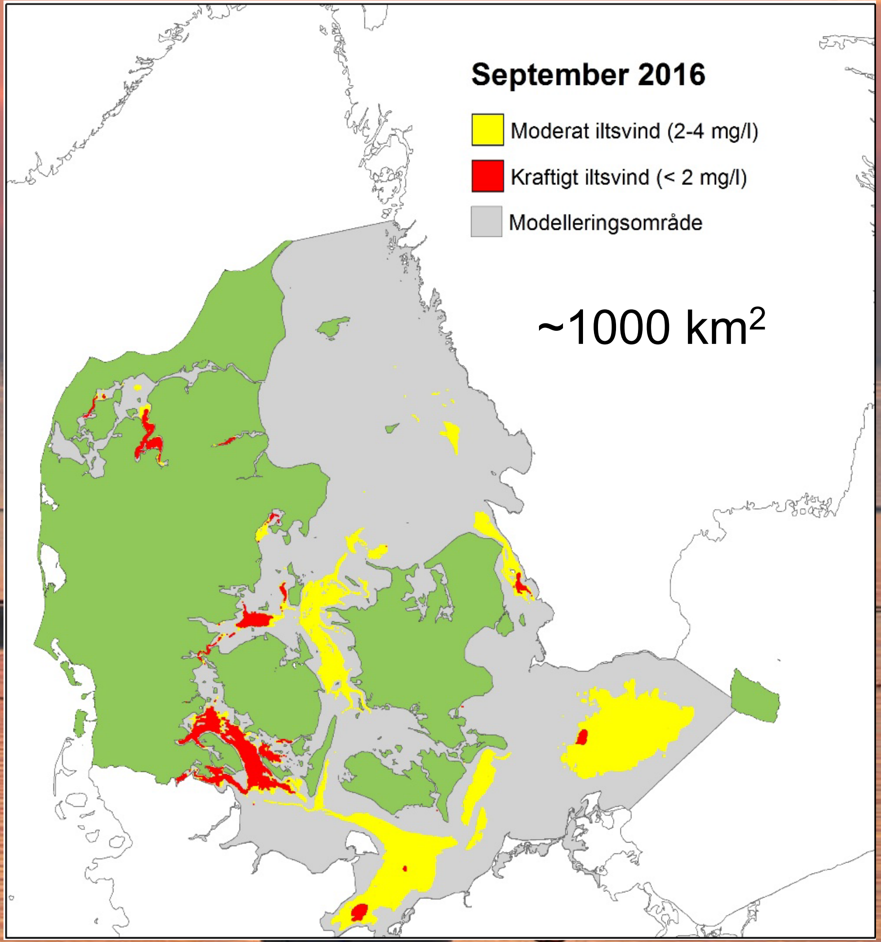
Temperature enhances respiration

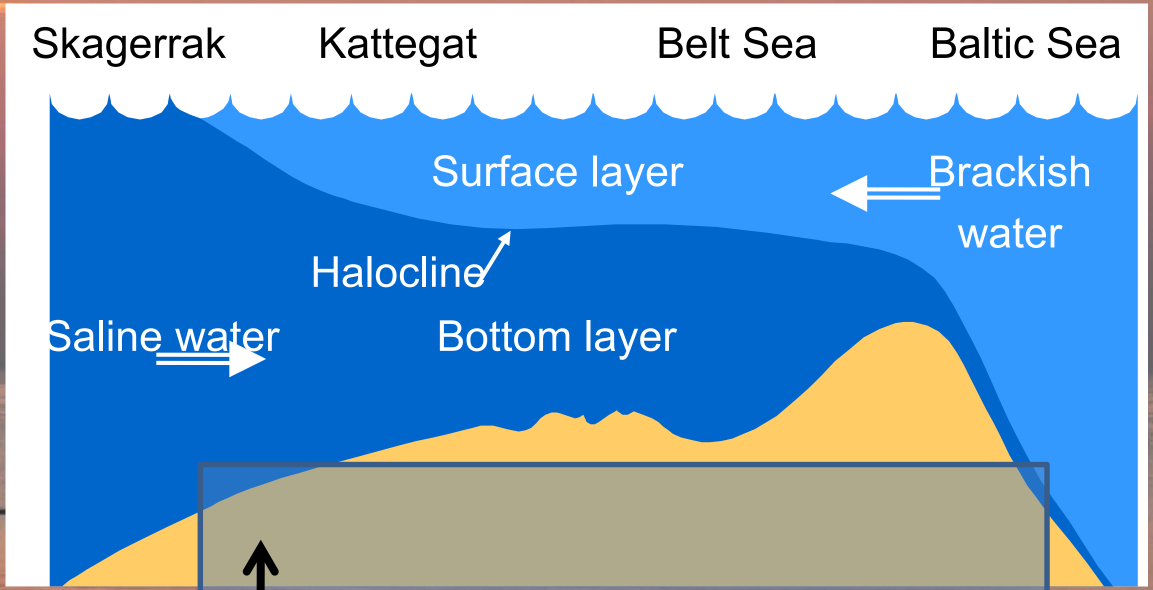


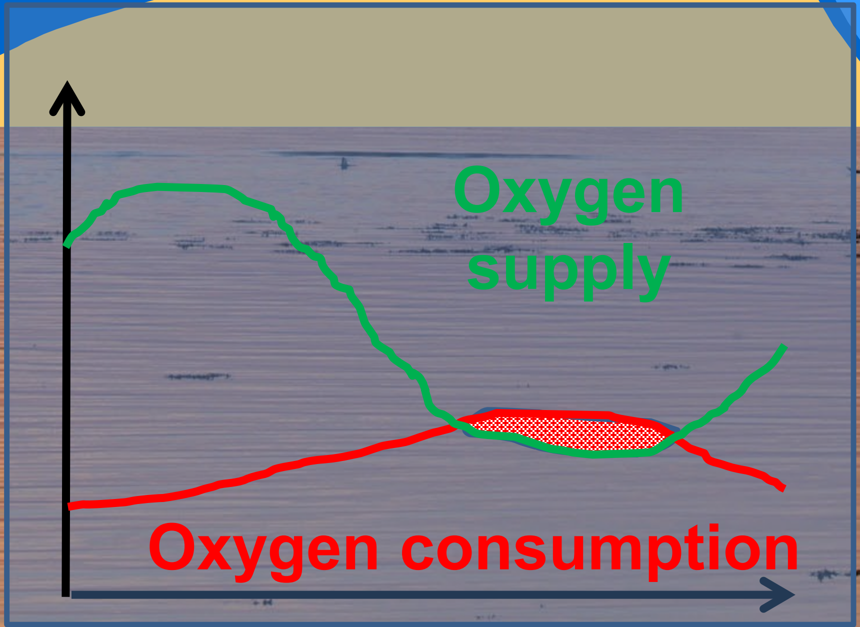
Updated from Carstensen et al. (2014) PNAS


SEASONAL HYPOXIA
IN THE WESTERN BALTIC SEA
1
20
40
60
70
81

Imbalance between oxygen supply and consumption on a seasonal scale

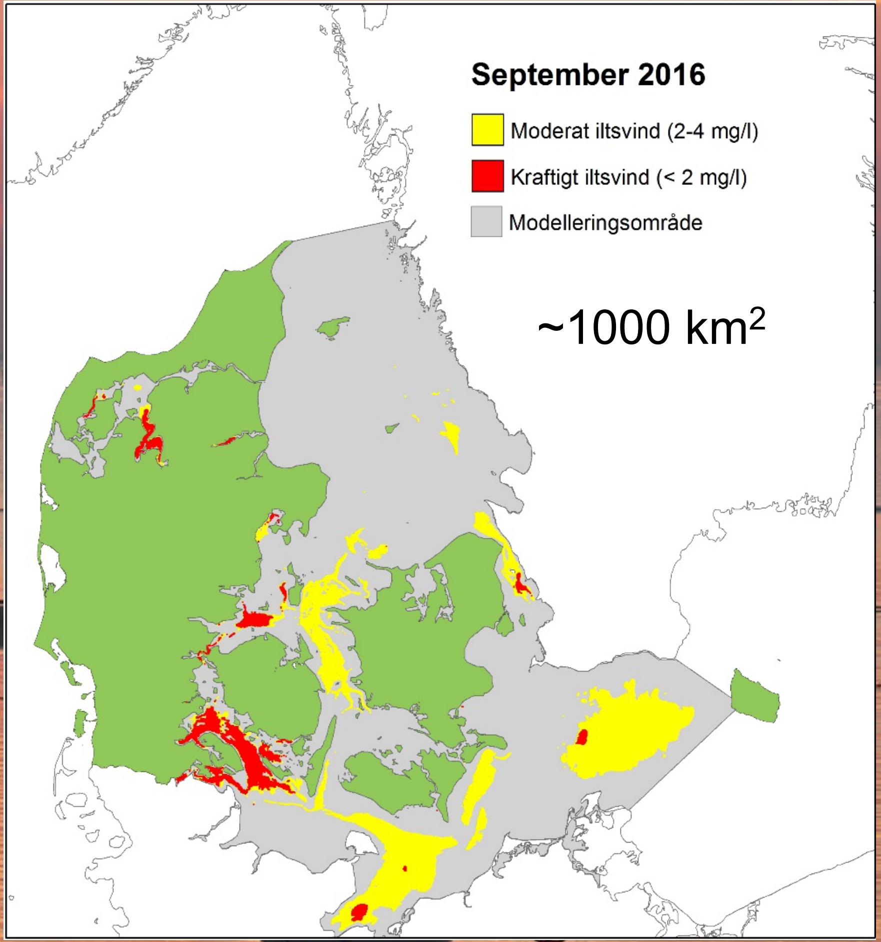


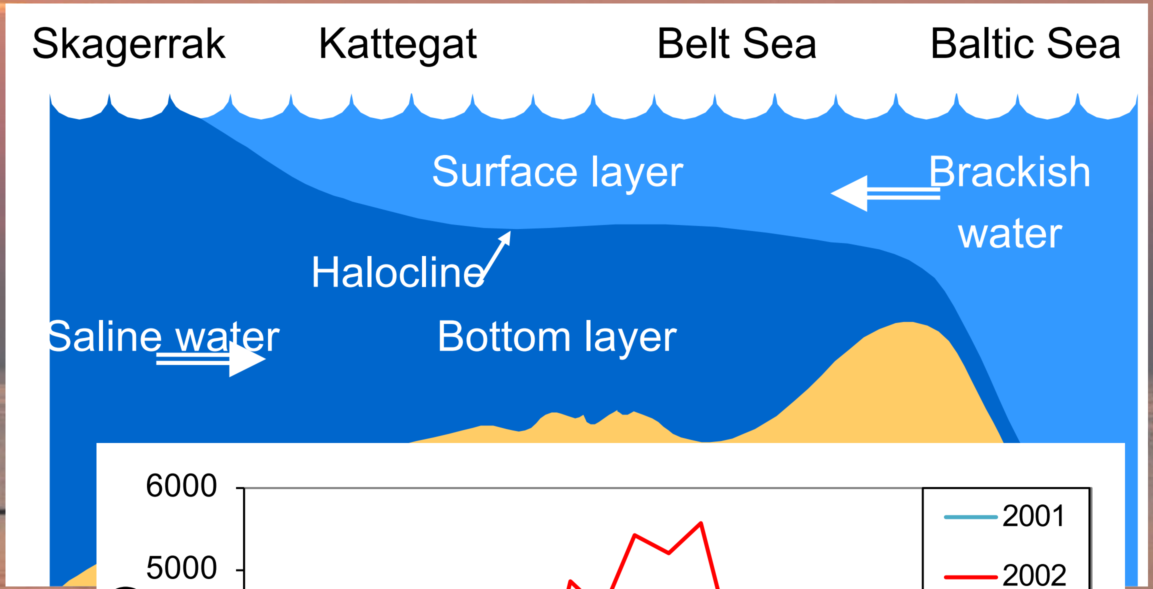


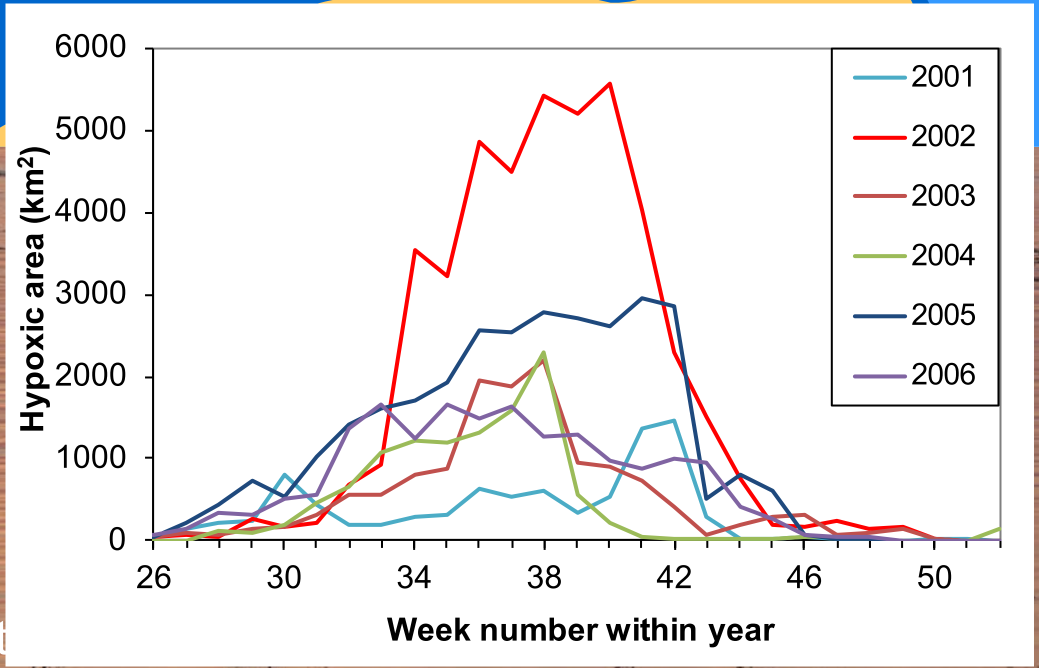


Source: Hansen et al. (2016) DCE report

Imbalance between oxygen supply and consumption on a seasonal scale



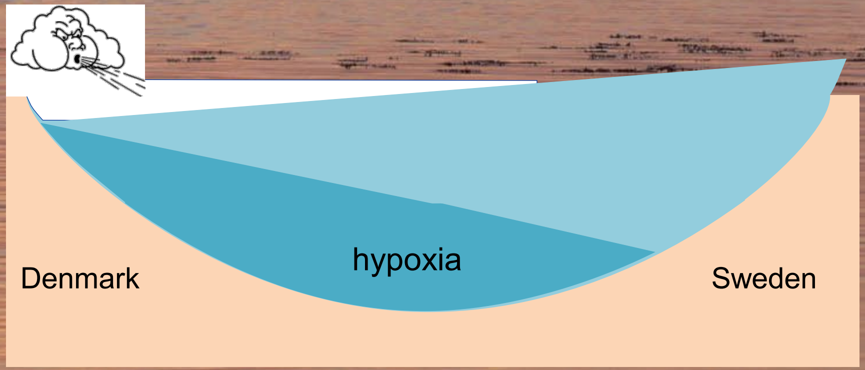




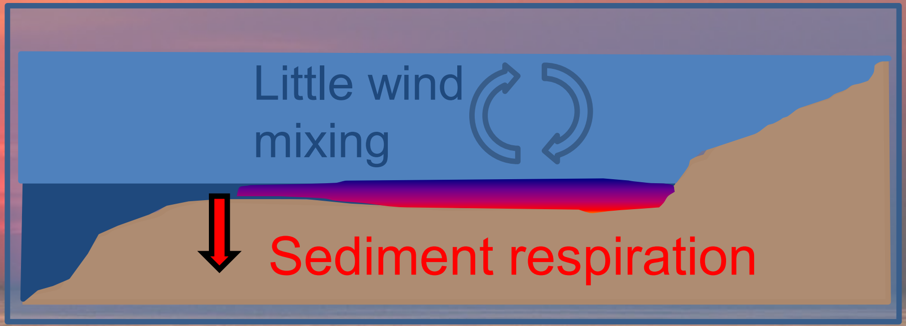
Source: Hansen et al. (2016) DCE report

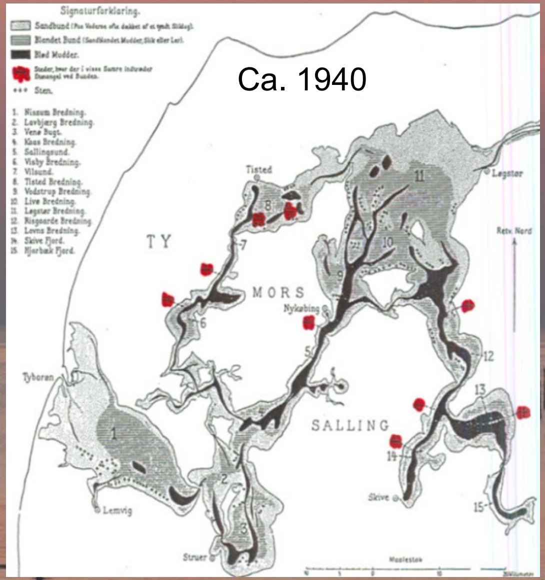
EPISODIC HYPOXIA

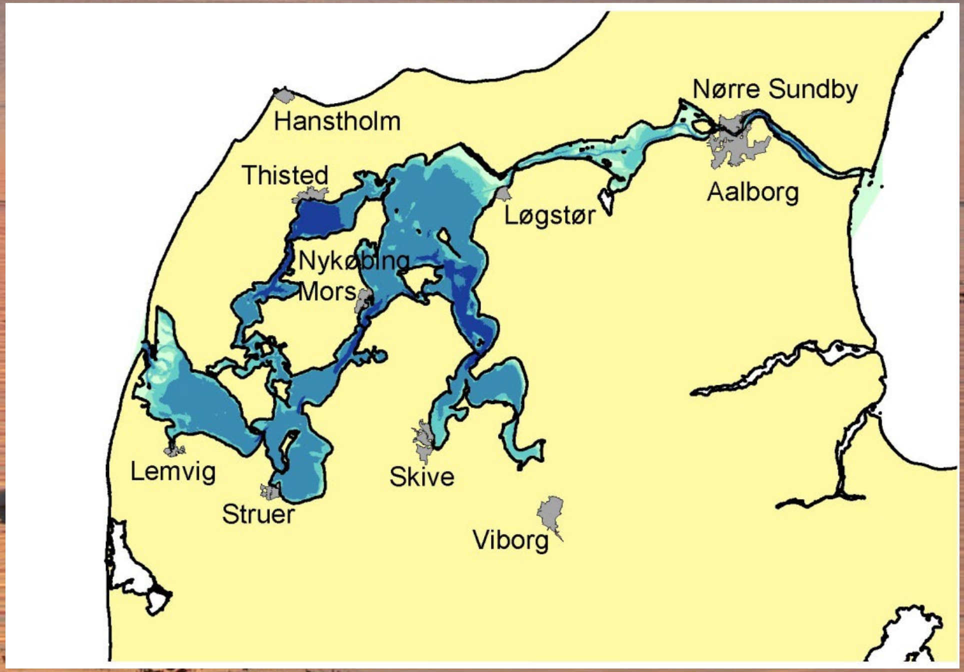
Imported hypoxia from deeper waters



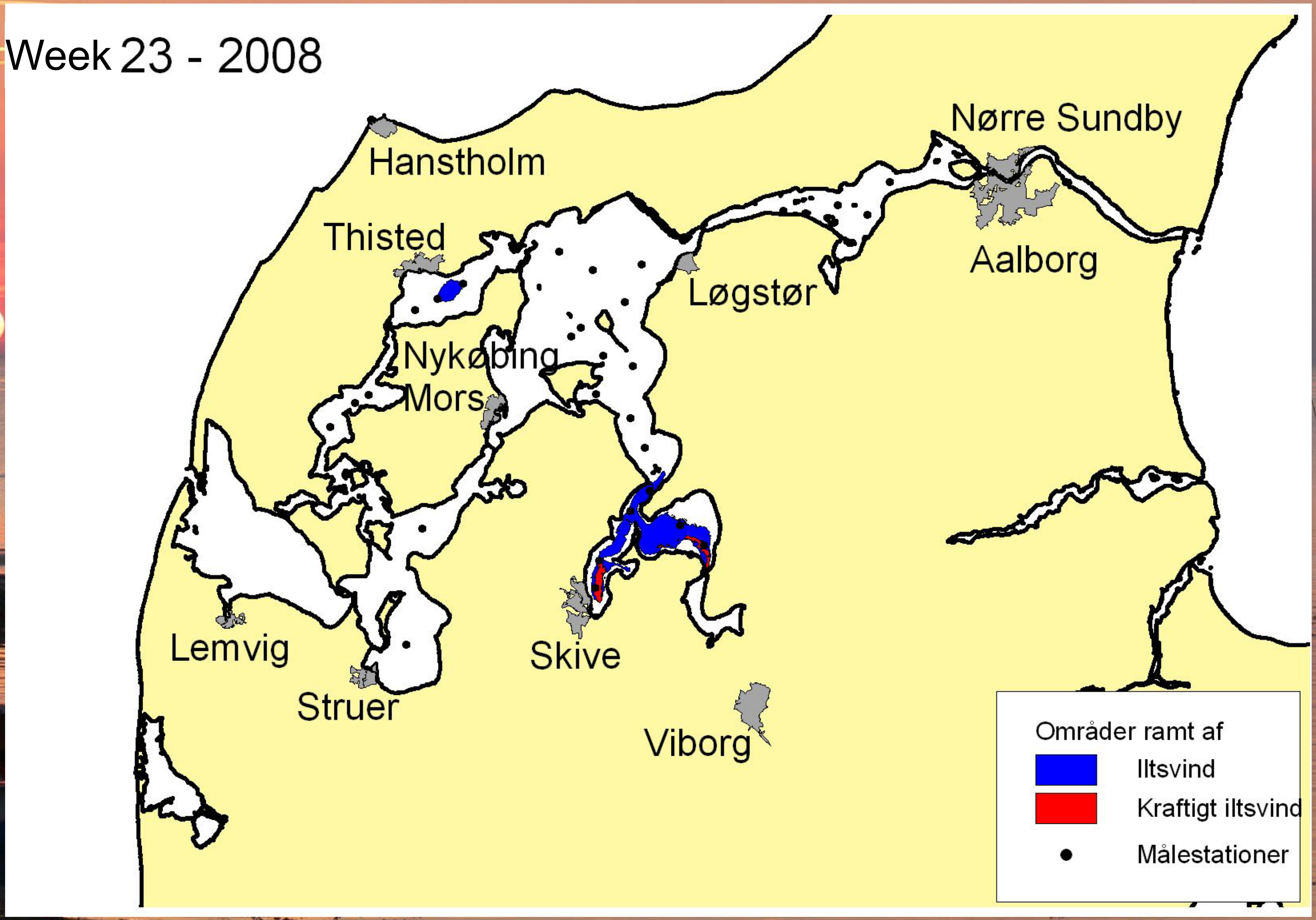
Low resilience from thin bottom layer and high oxygen demand



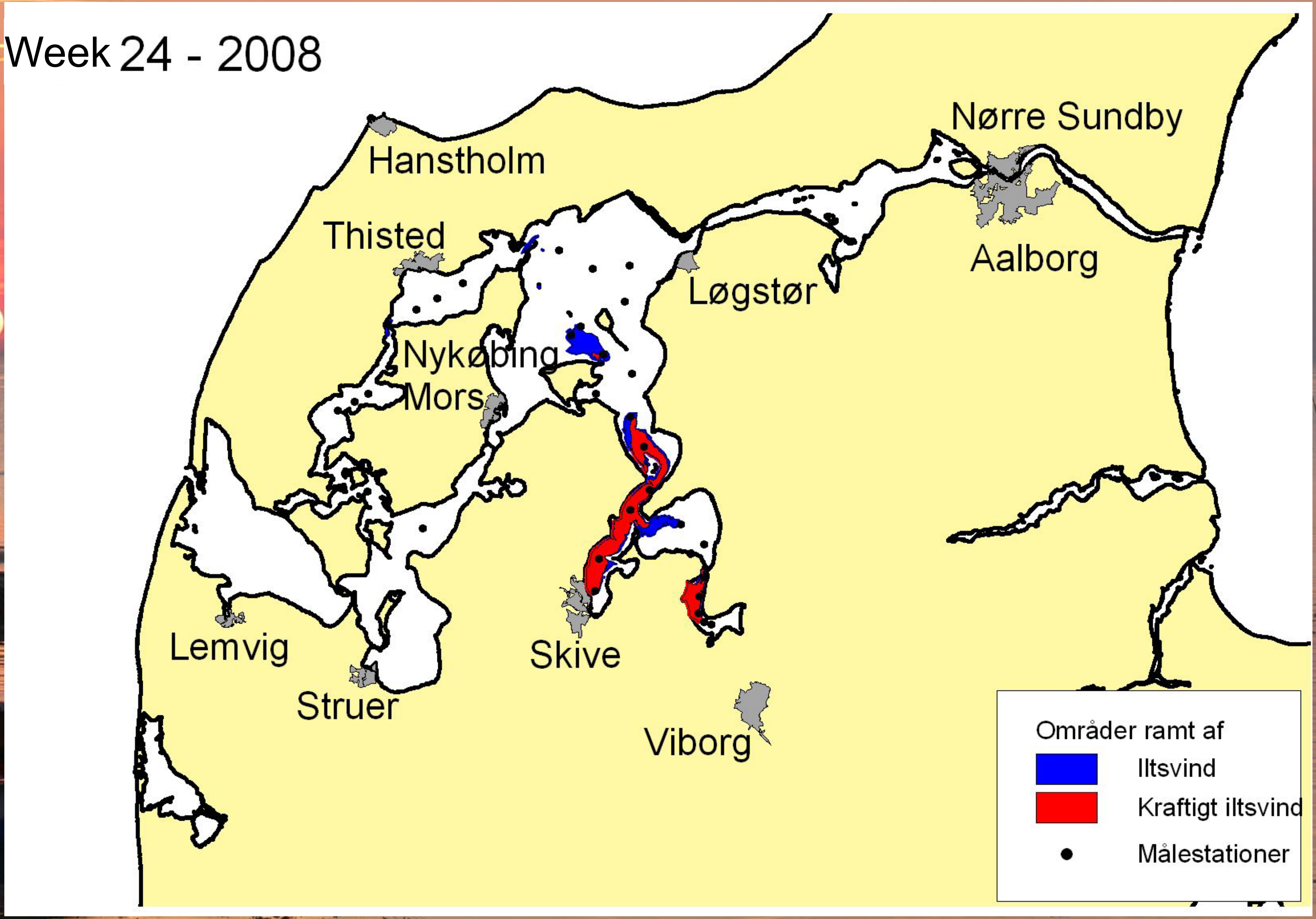




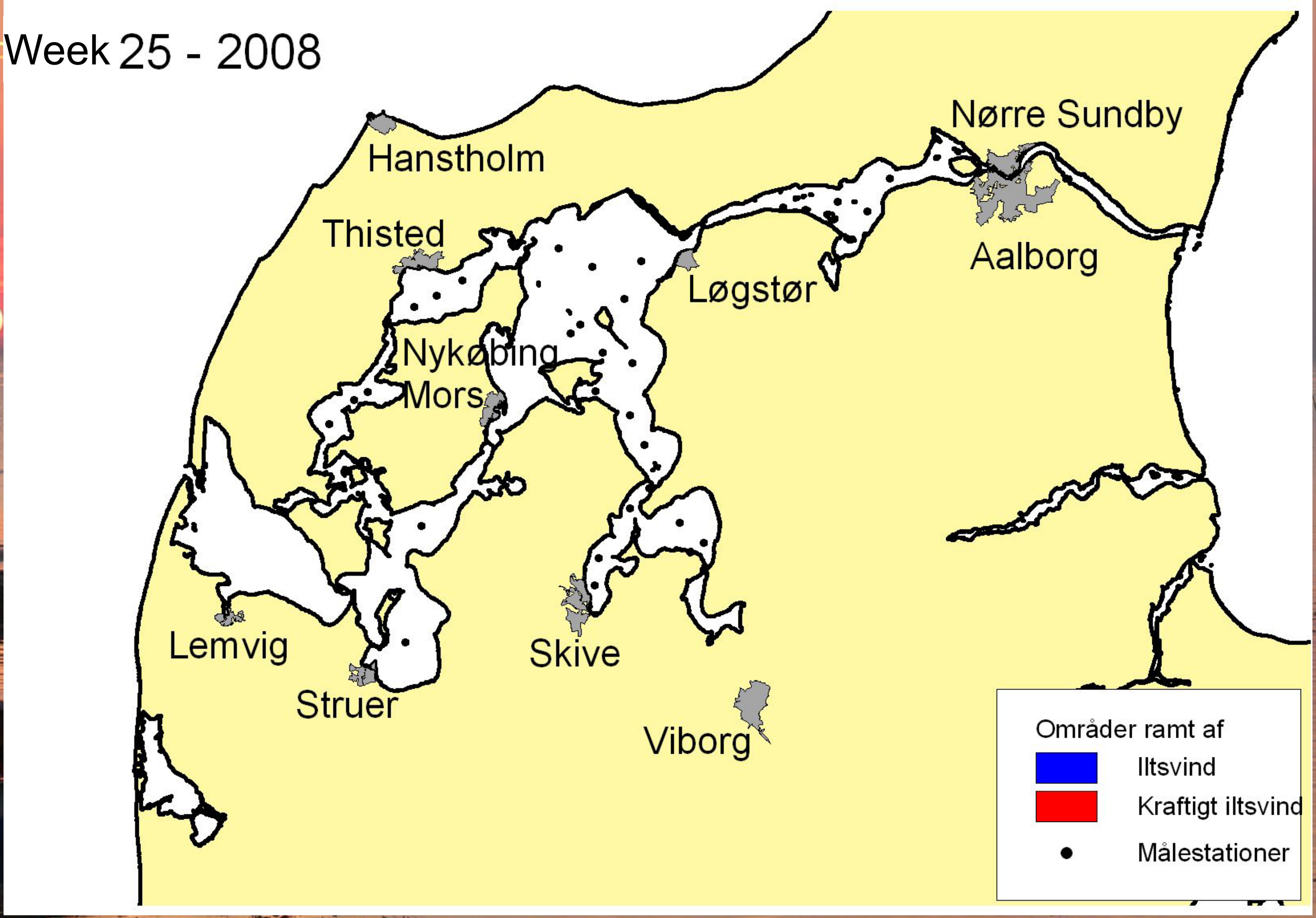
Hypoxia comes and goes



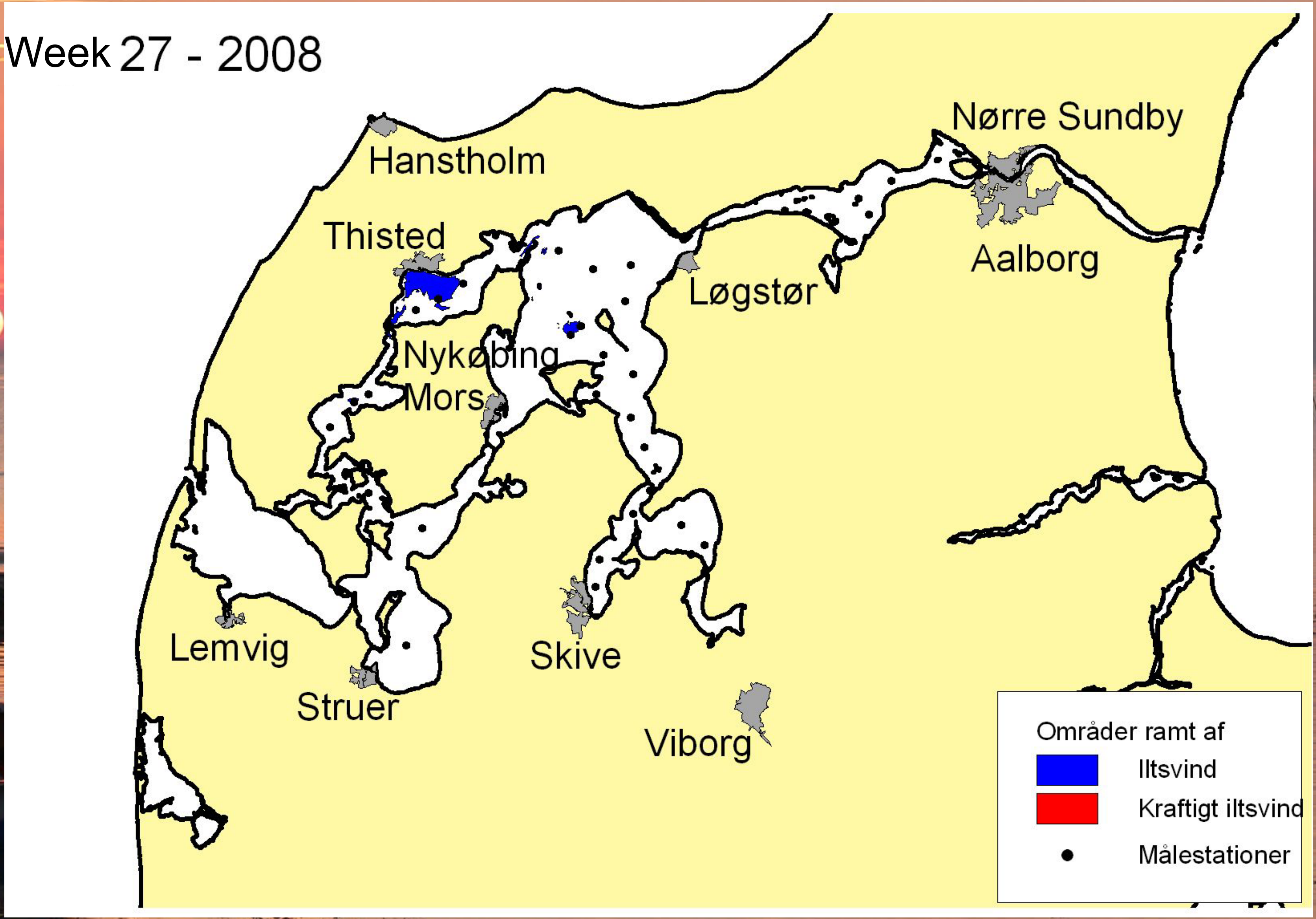
Hypoxia comes and goes



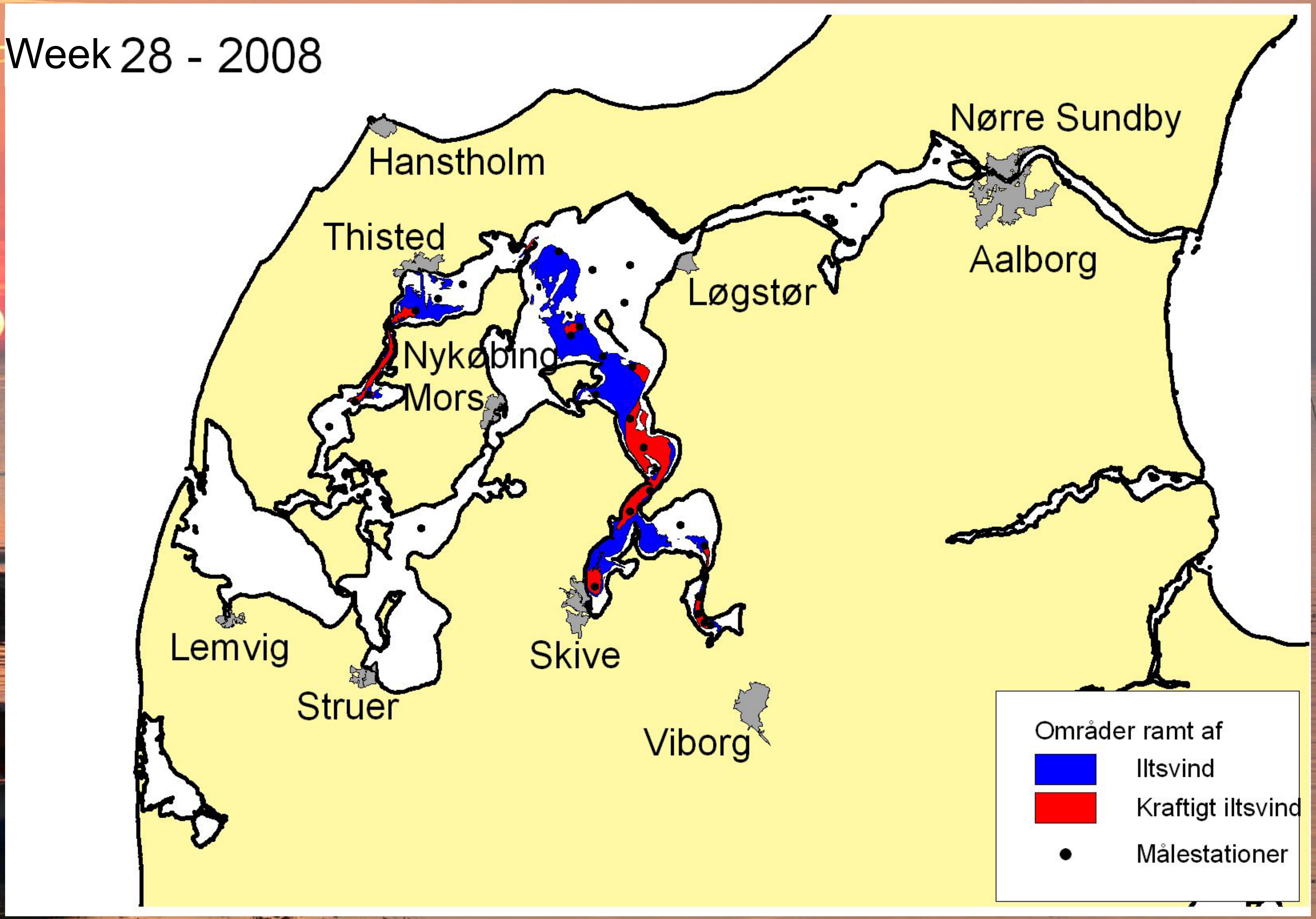
Hypoxia comes and goes



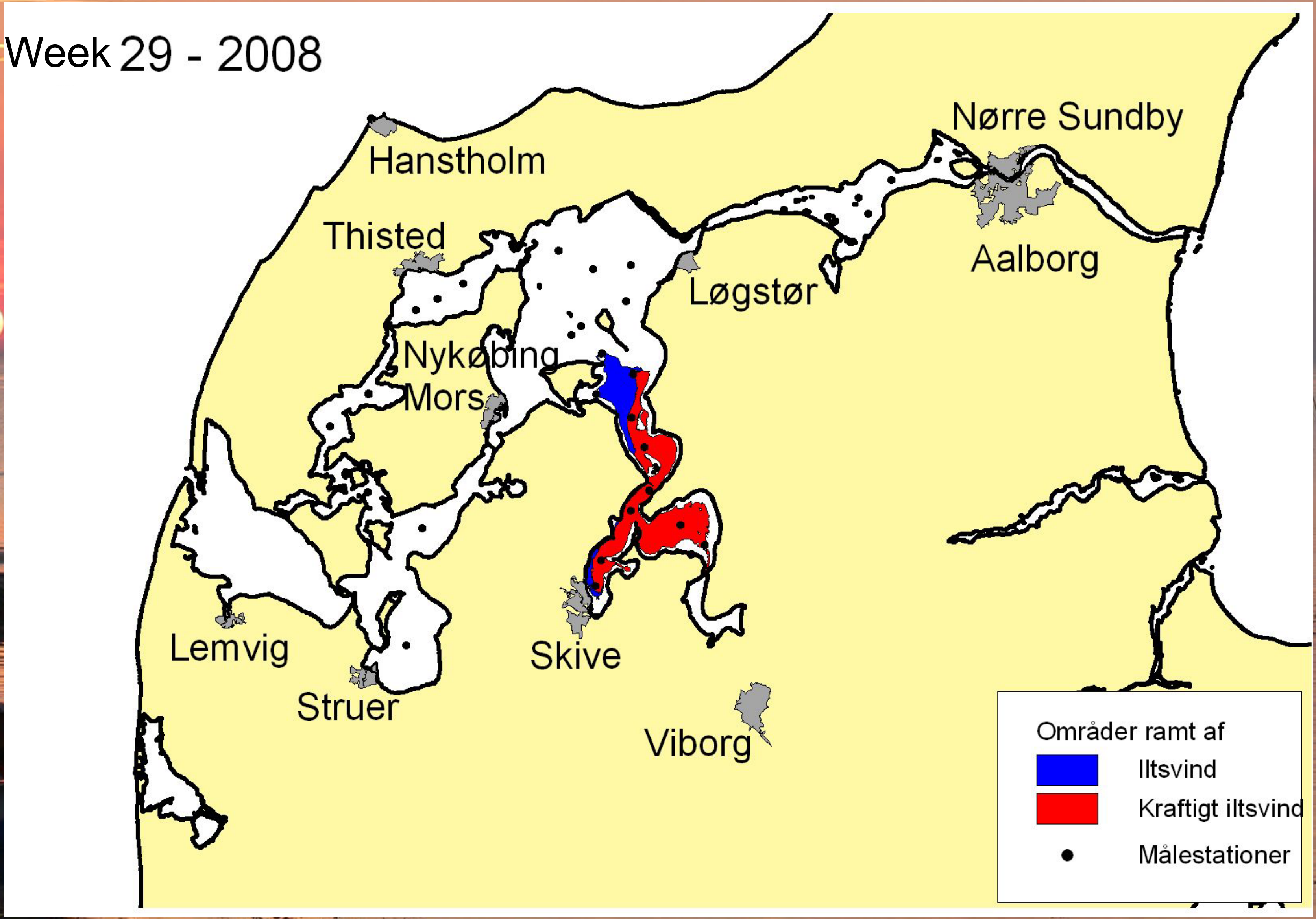
Hypoxia comes and goes



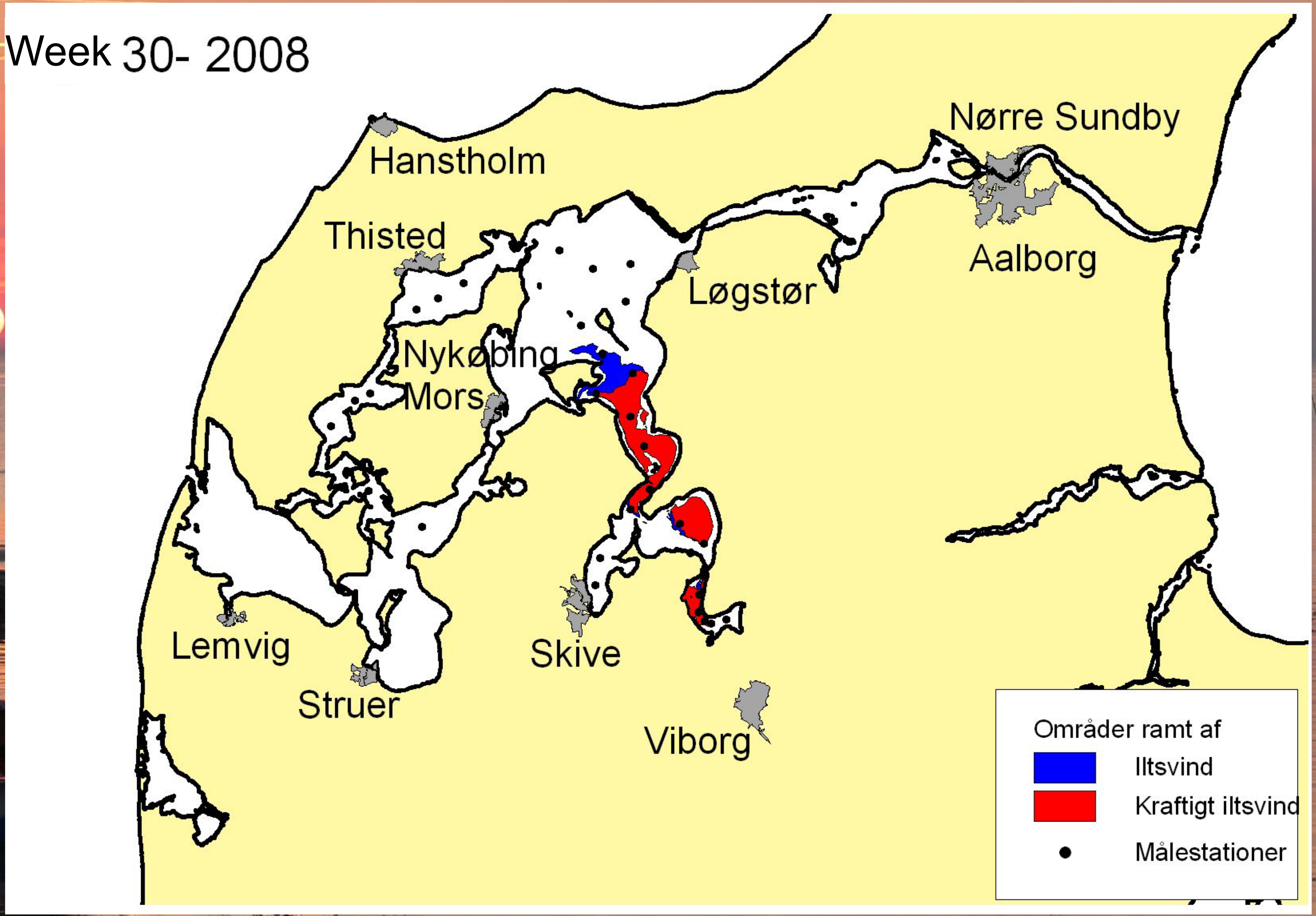
Hypoxia comes and goes



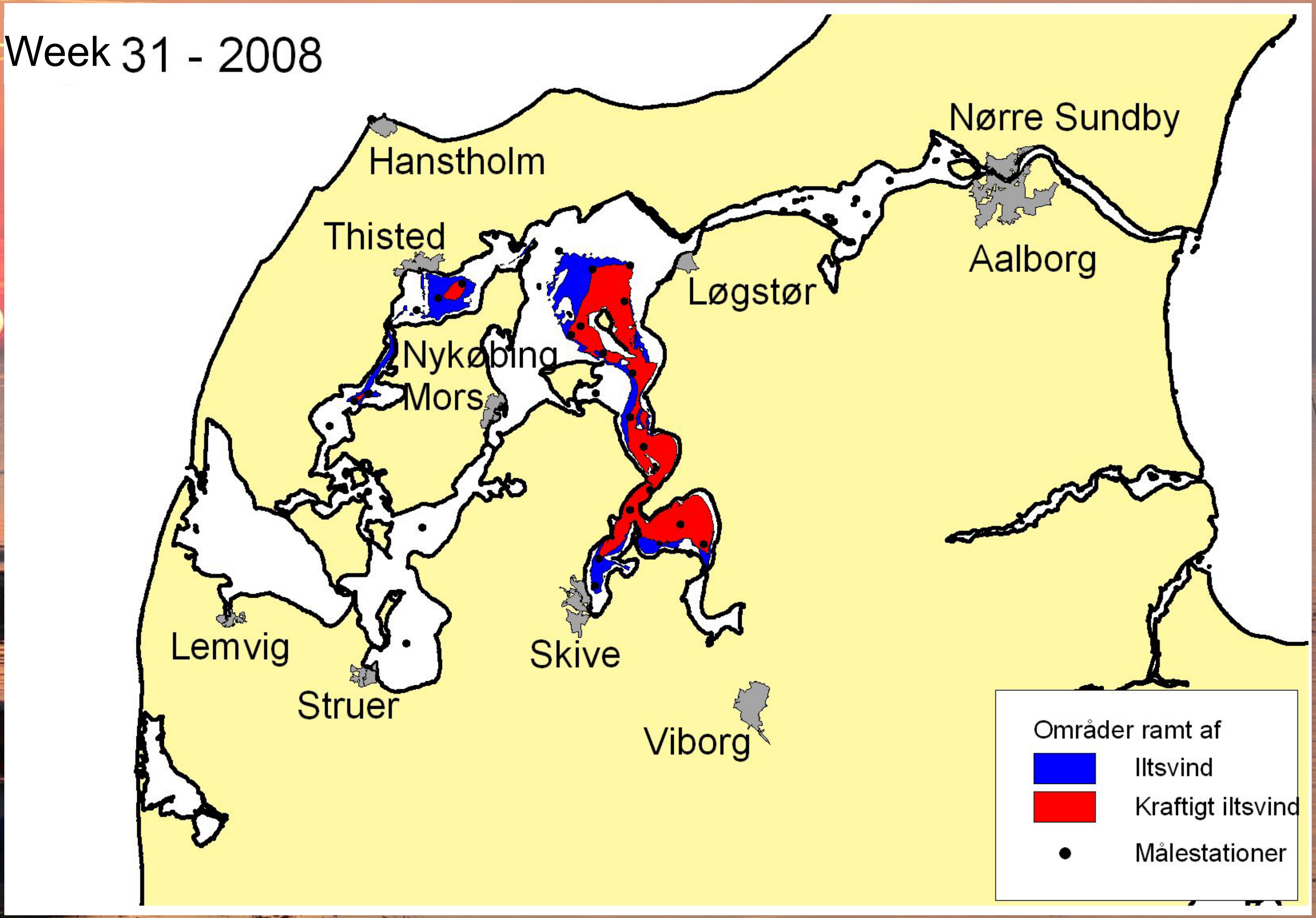
Hypoxia comes and goes



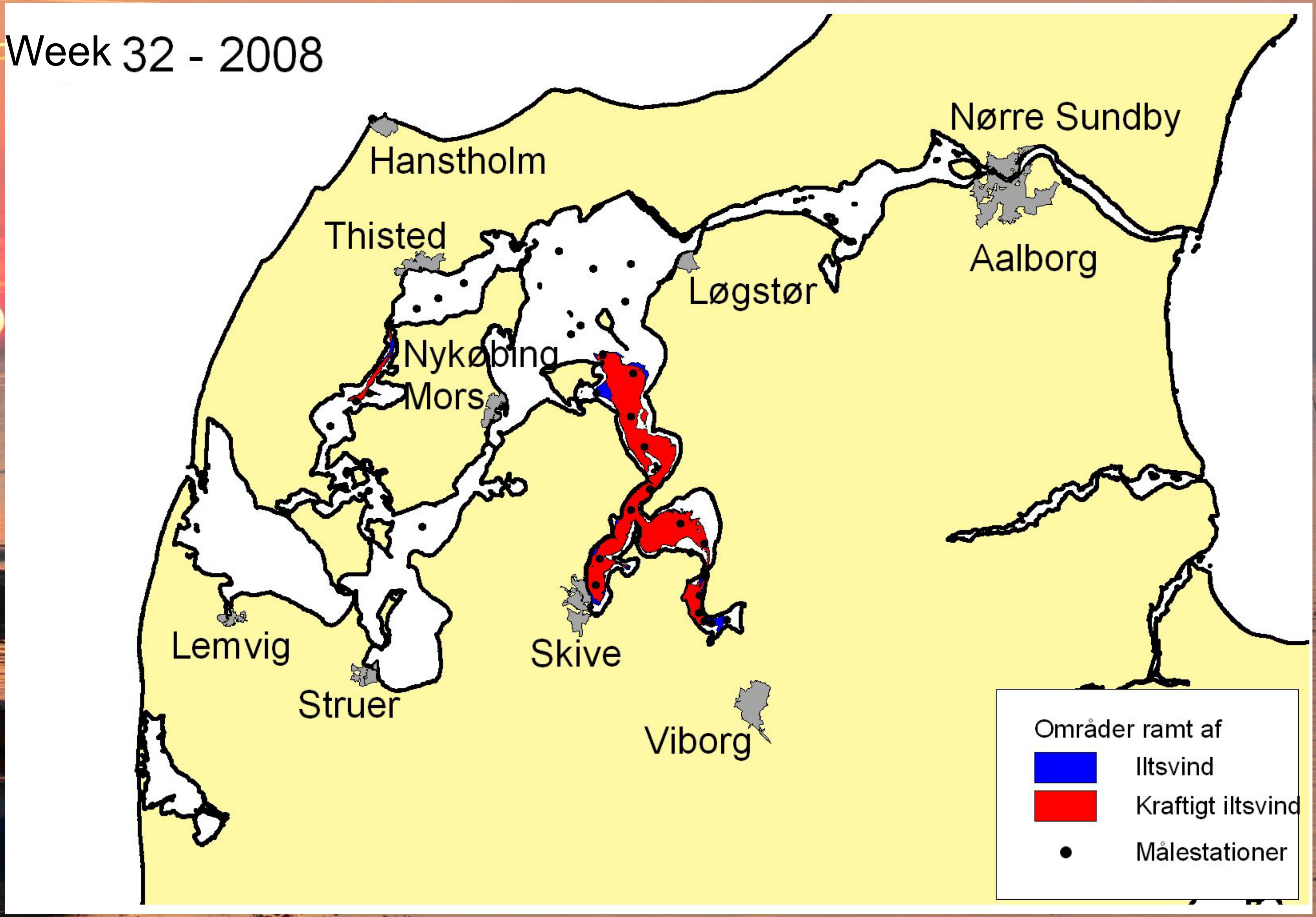
Hypoxia comes and goes



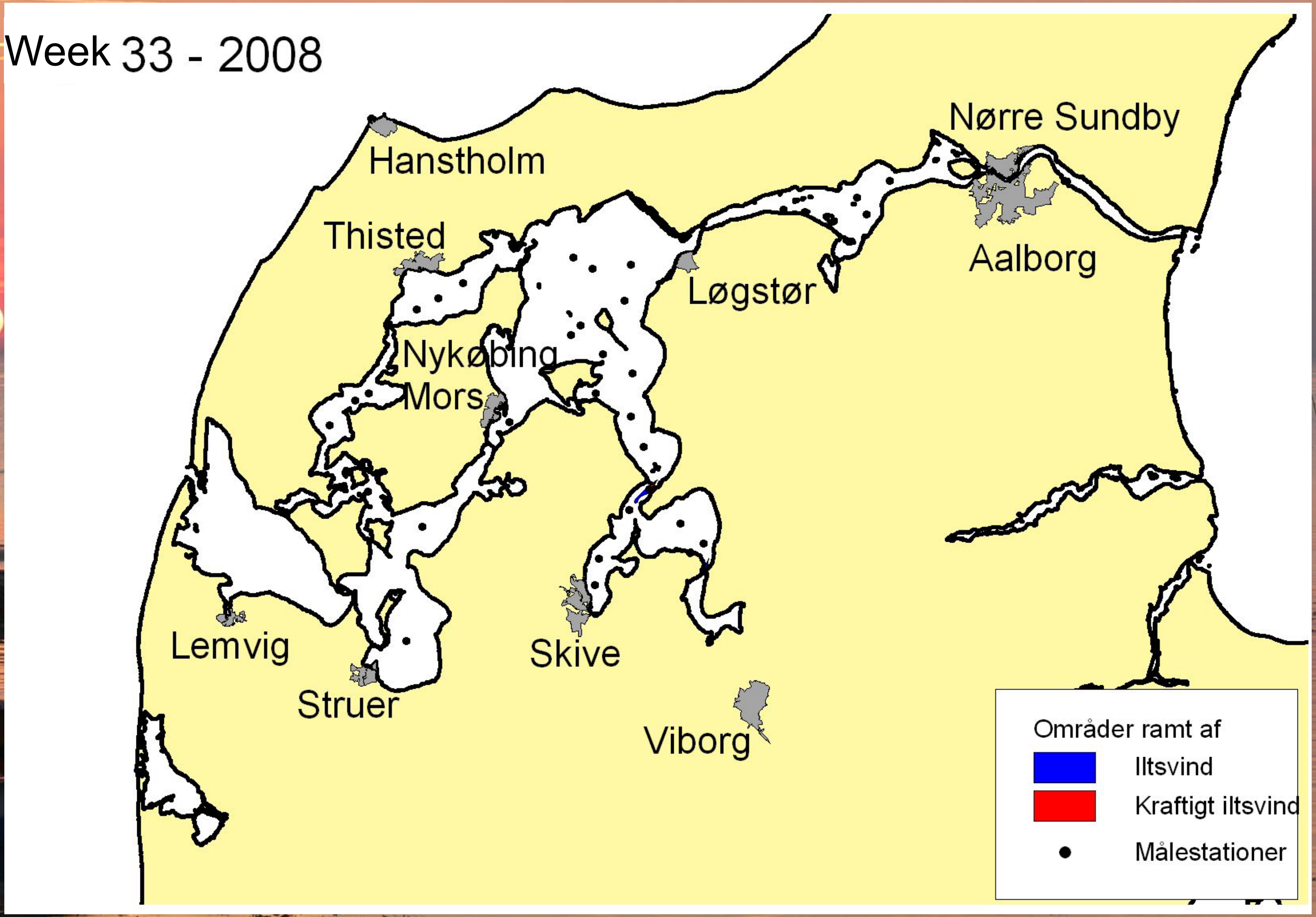
Hypoxia comes and goes



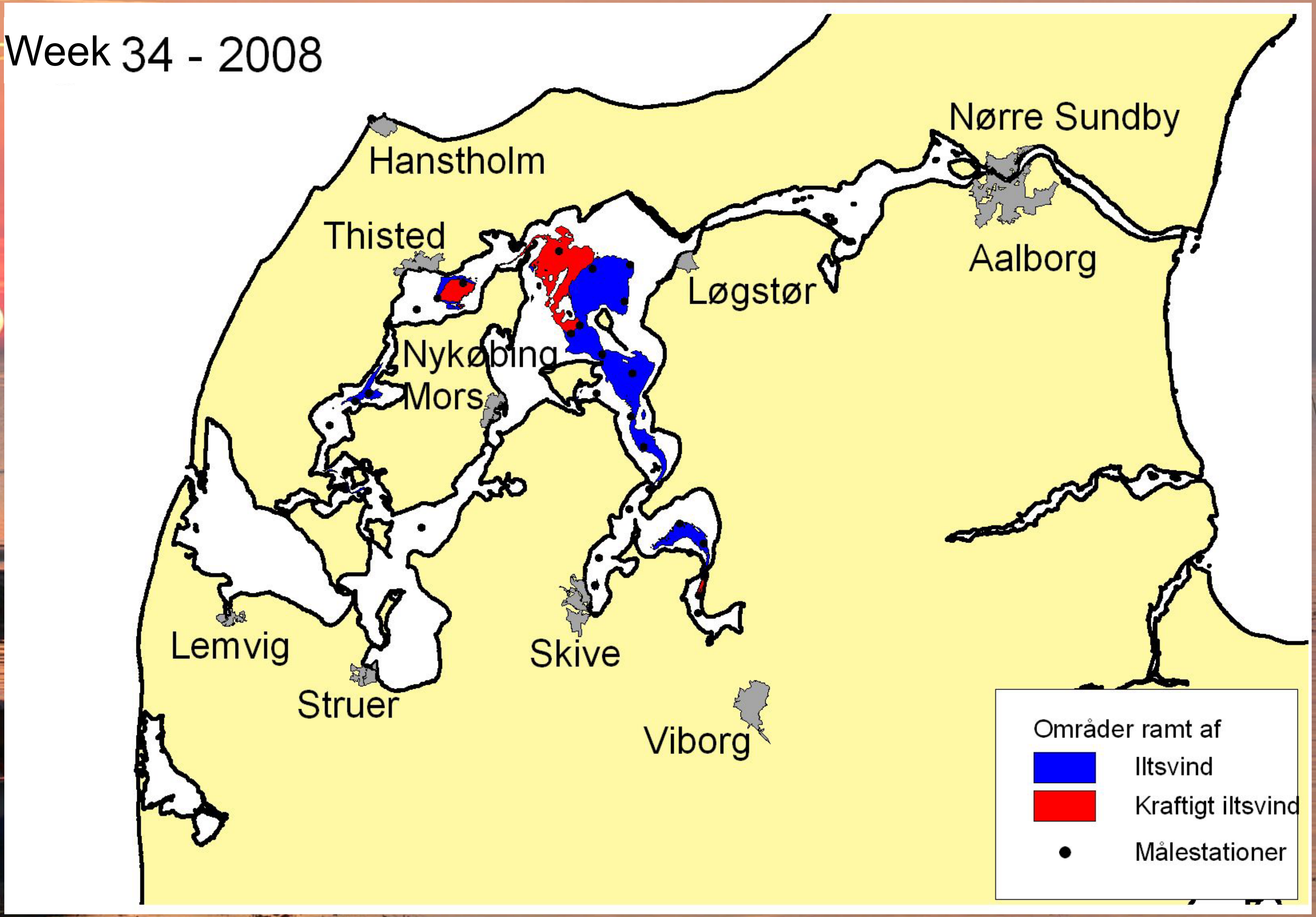
Hypoxia comes and goes



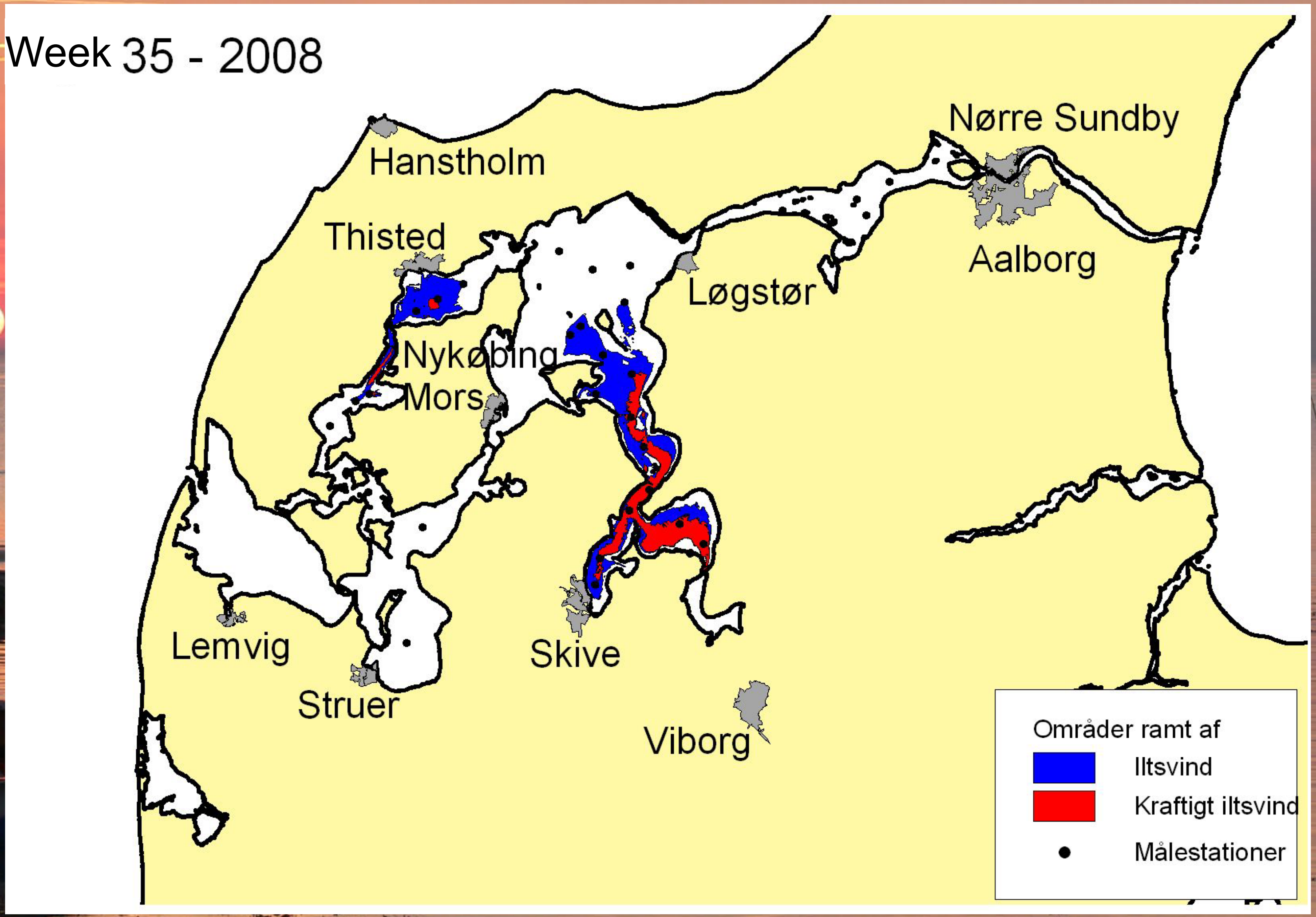
Hypoxia comes and goes



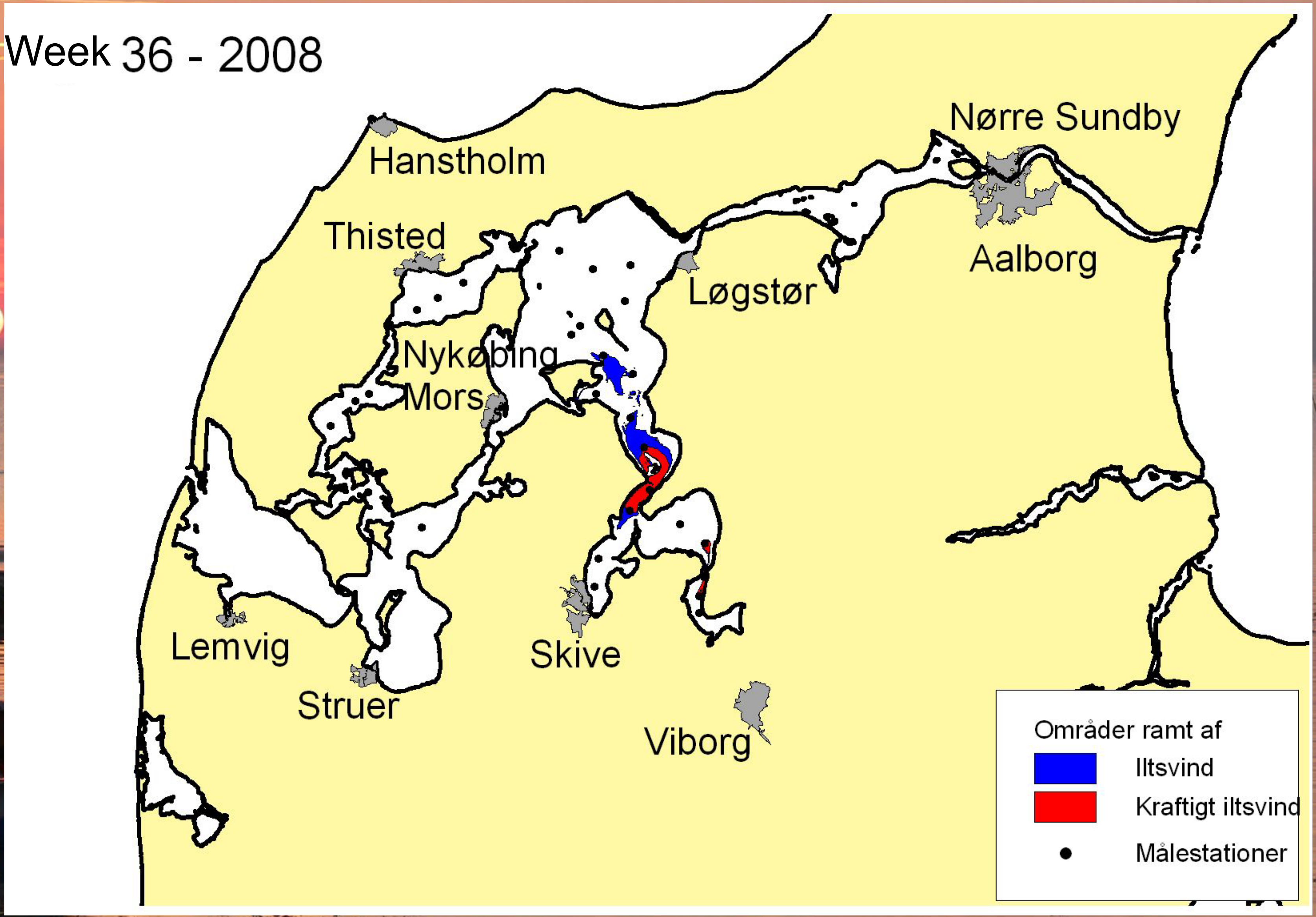
Hypoxia comes and goes



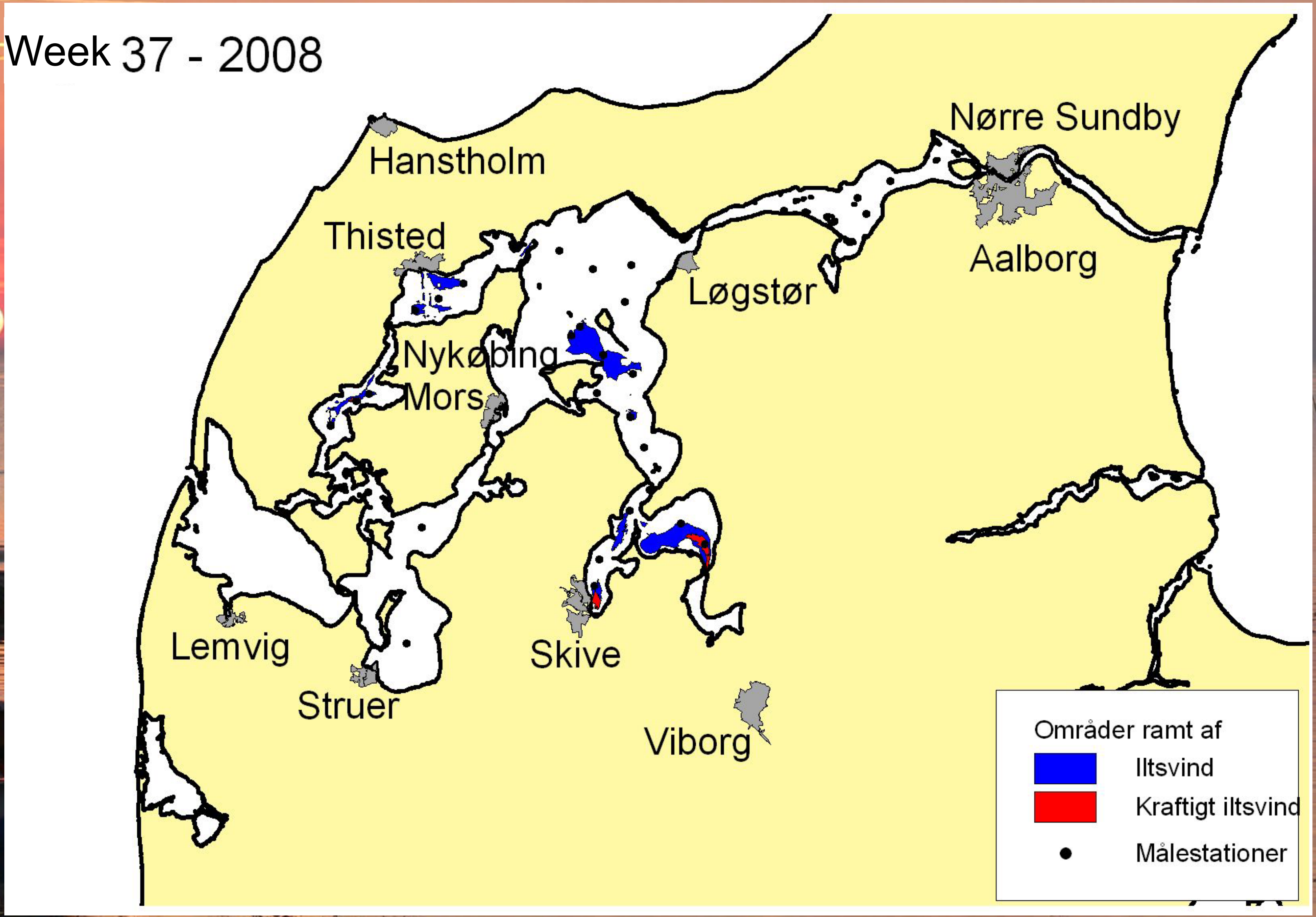
Hypoxia comes and goes



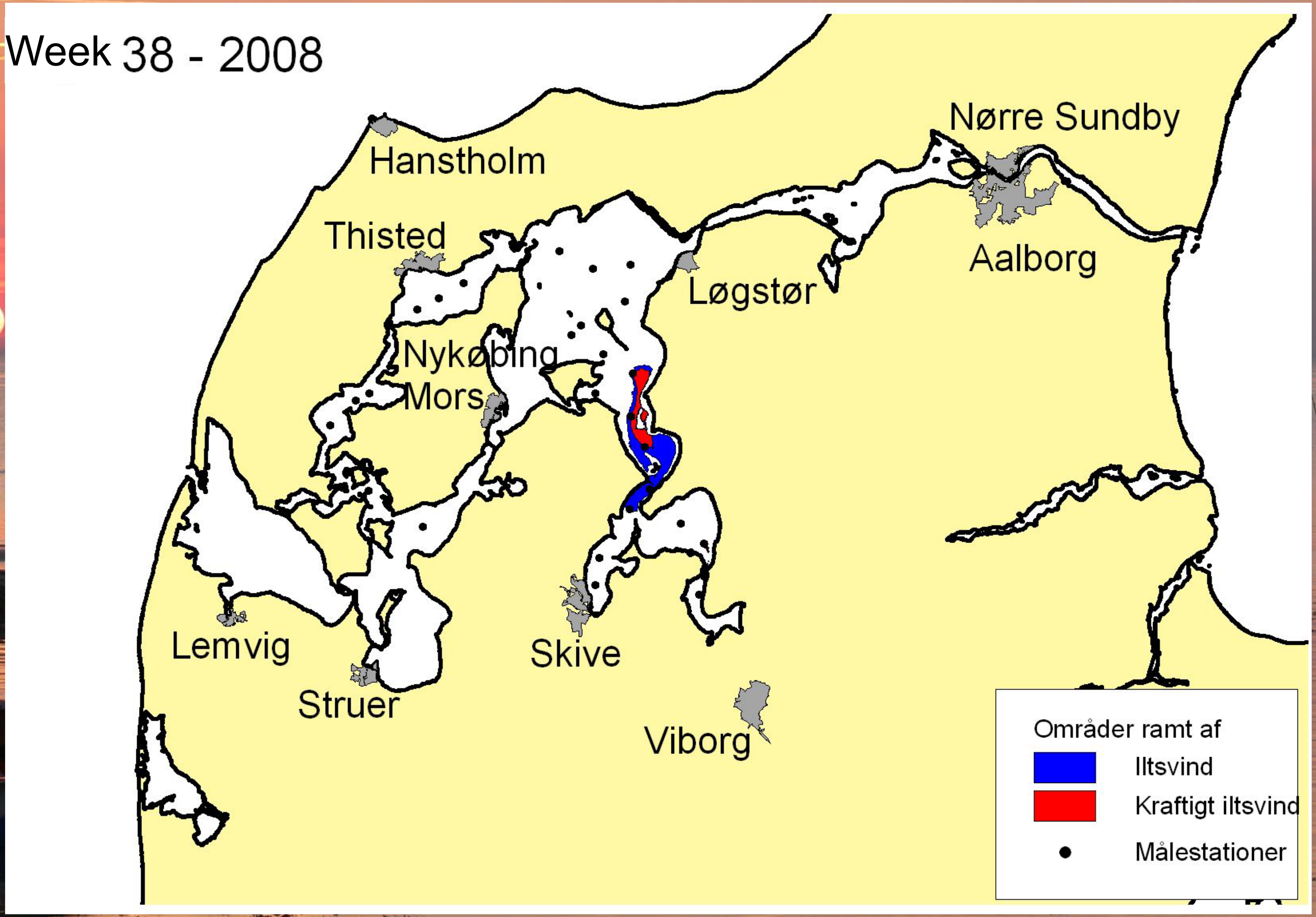
Hypoxia comes and goes



Hypoxia comes and goes



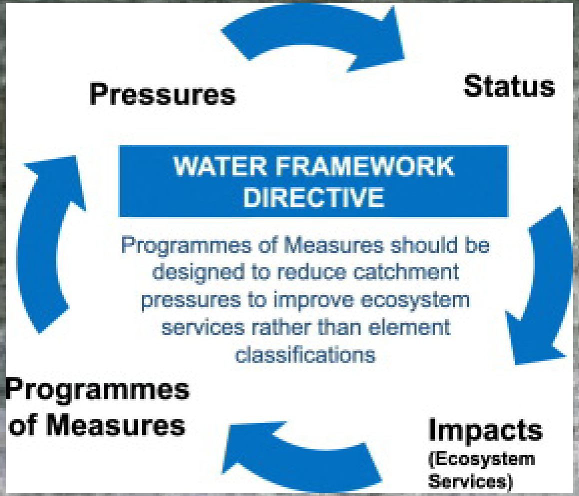
Hypoxia comes and goes



HYPOXIA IN THE FUTURE

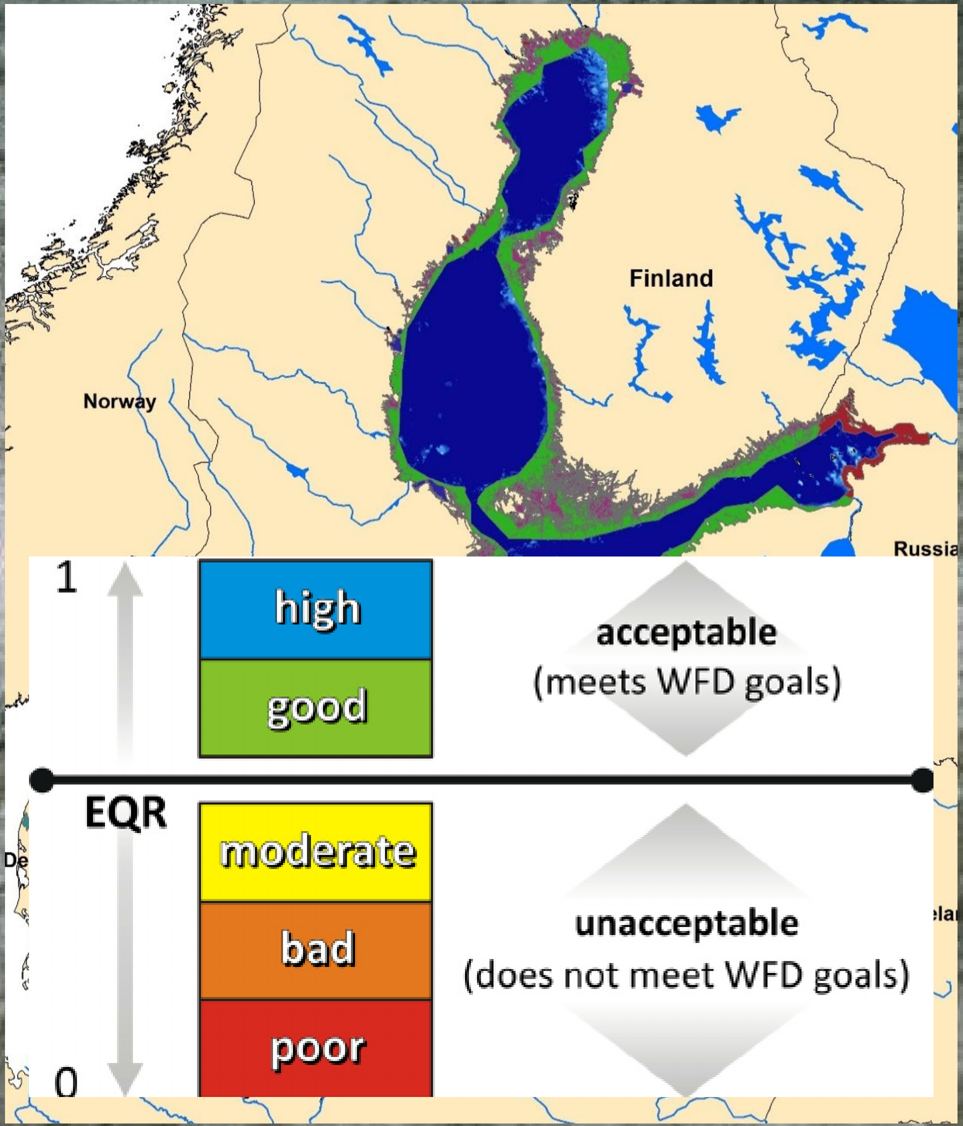
DIFFERENT POLICIES APPLY TO DIFFERENT PARTS OF THE BALTIC SEA

Coastal zone



National implementation by EU member states

Focus on ecological status, secondary supporting elements (incl. oxygen)



Offshore waters

HELCOM BSAP

EU Marine Strategy Framework Directive

BALTIC SEA ACTION PLAN (2021)

Eutrophication goal

"Baltic Sea unaffected by eutrophication"

Effects of climate change impacting eutrophication

Pressures addressed

Activities addressed

SDG targets addressed

- *2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.*
- *6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally*
- *6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate*
- *14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution*

Further information on connection to other treaties related to eutrophication can be found on page 26.

Cross-reference with other segments

- *Reaching the objectives for eutrophication is a necessity to meet the goal 'Baltic Sea ecosystem is healthy and resilient';*
- *Reaching the goal and objectives for sea-based activities is a requirement for reaching the goal for eutrophication.*

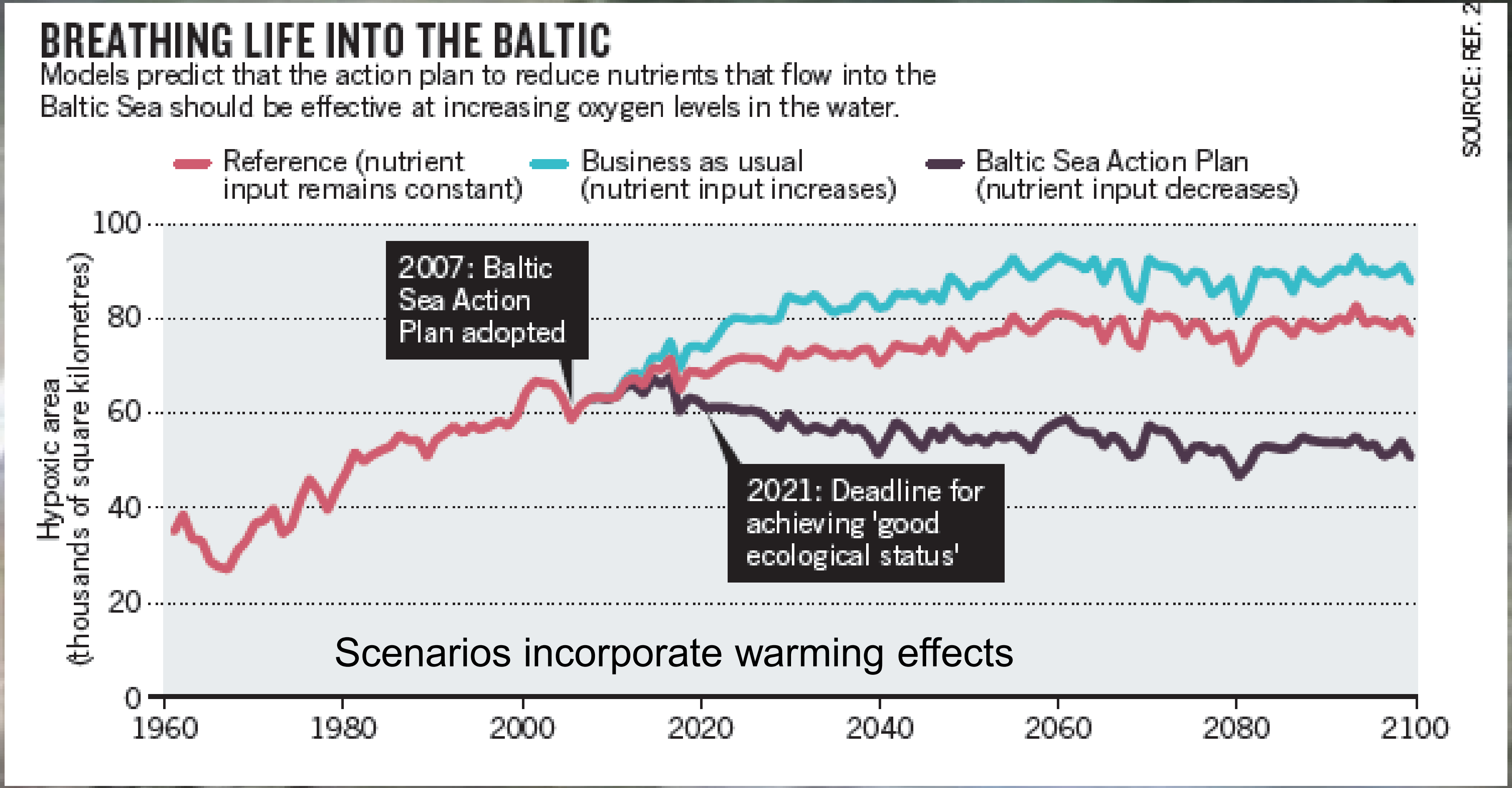
Table 2a. Net nutrient input ceilings (NIC) of nitrogen for the HELCOM countries, non-HELCOM countries in the Baltic Sea catchment area, other countries with airborne input, Baltic Sea shipping and North Sea shipping (in tonnes/year).

	Bothnian Bay	Bothnian Sea	Baltic Proper	Gulf of Finland	Gulf of Riga	Danish Straits	Kattegat
Germany	947	3,920	34,077	1,645	1,747	23,647	4,661
Denmark	280	1,148	9,025	421	462	28,067	28,538
Estonia	113	404	1,478	11,334	13,099	22	24
Finland	35,087	28,700	1,827	20,457	295	76	89
Lithuania	108	495	25,878	305	8,820	66	80
Latvia	73	330	6,457	246	43,074	31	34
Poland	668	3,125	151,997	1,407	1,596	1,480	1,443
Russia	839	1,993	10,317	61,503	3,296	238	245
Sweden	17,718	32,633	30,690	626	525	6,056	32,799
Other countries with airborne input	1,375	5,008	26,947	2,986	2,188	4,933	4,502
Belarus	-	-	13,456	-	12,820	-	-
Czech Republic	-	-	3,551	-	-	-	-
Ukraine	-	-	1,693	-	-	-	-
Baltic Sea shipping	284	1,141	5,180	675	345	651	701
North Sea shipping	131	475	2,427	196	150	729	884

https://helcom.fi/baltic-sea-action-plan/

Outlook for the Baltic Sea

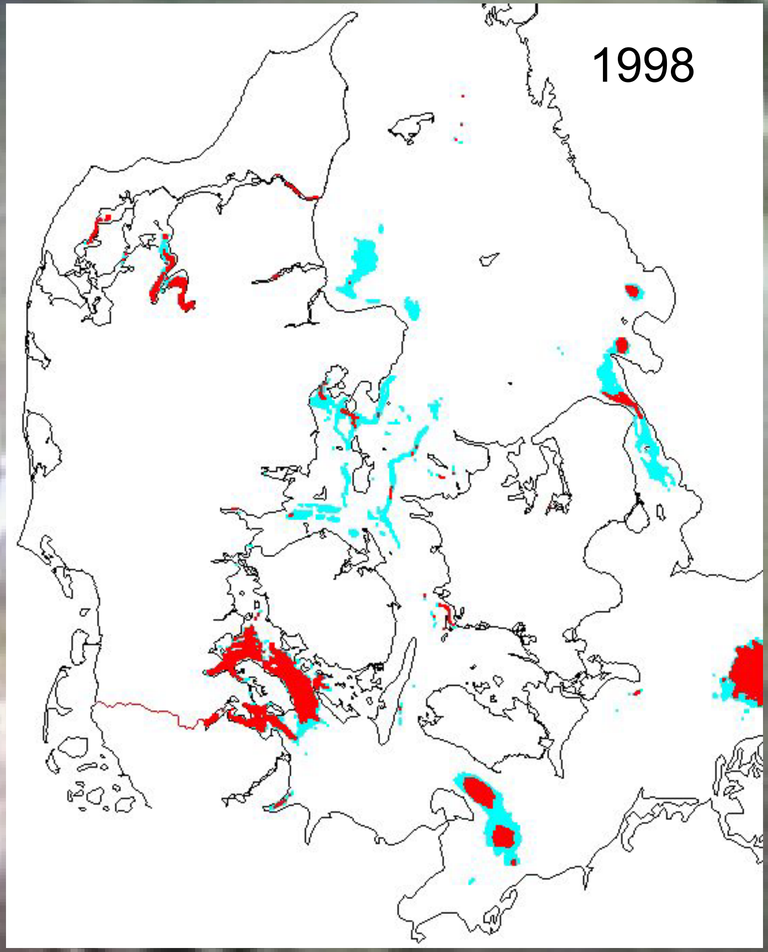
No quick recovery from hypoxia



Sources: Meier et al. (2011) GRL and Conley (2012) Nature

Outlook for the Danish Straits

A 4 °C temperature will double the hypoxic area

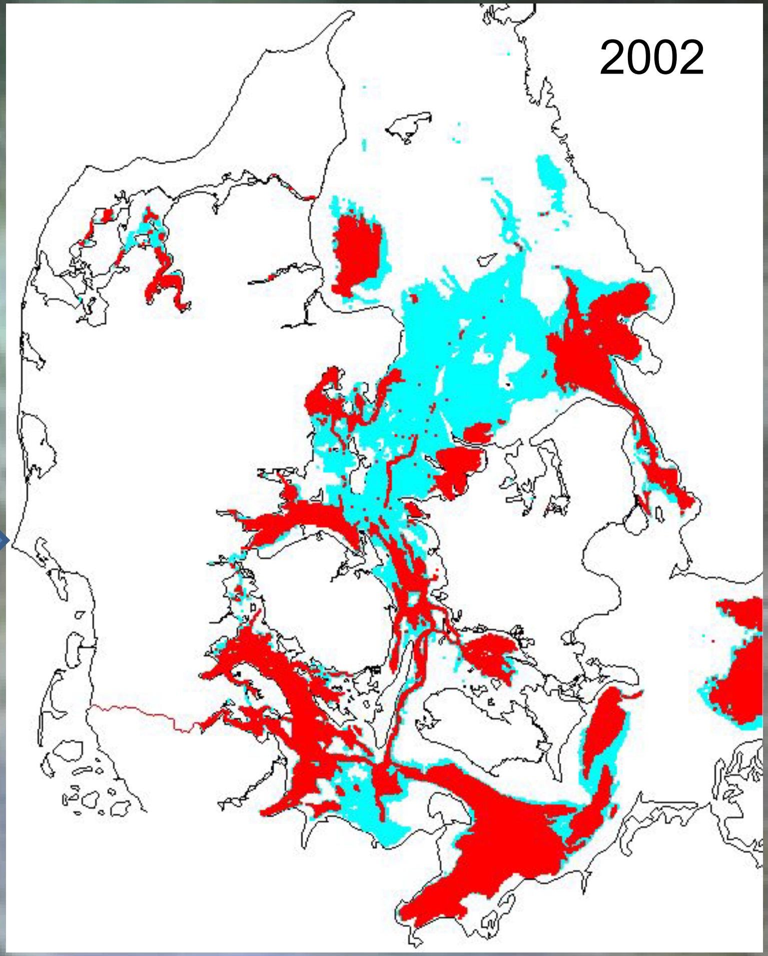


968 km^2

2269 km^2

8256 km^2

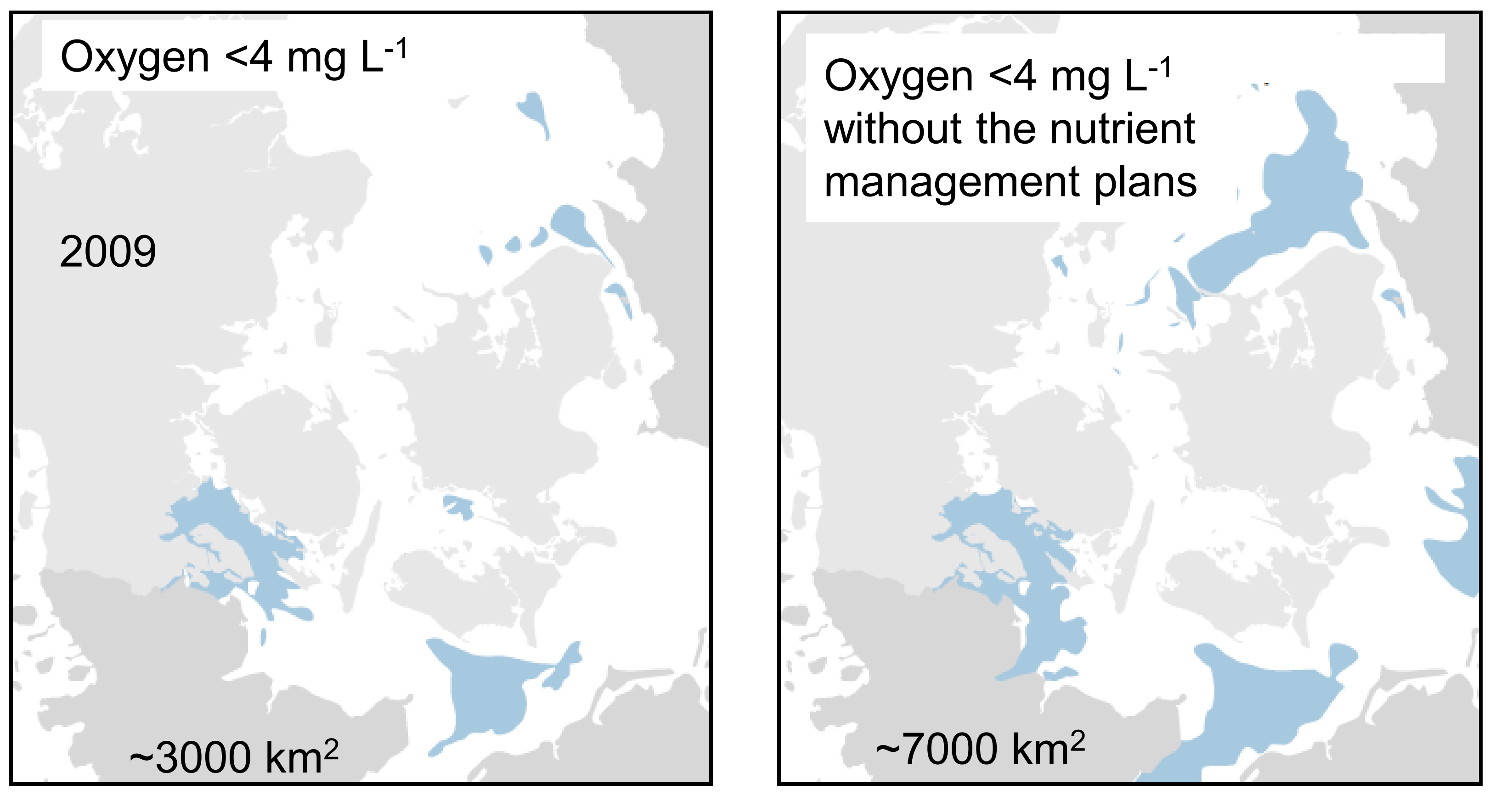
16720 km^2



Source: Conley et al. (2009) Hydrobiol

Effect of management

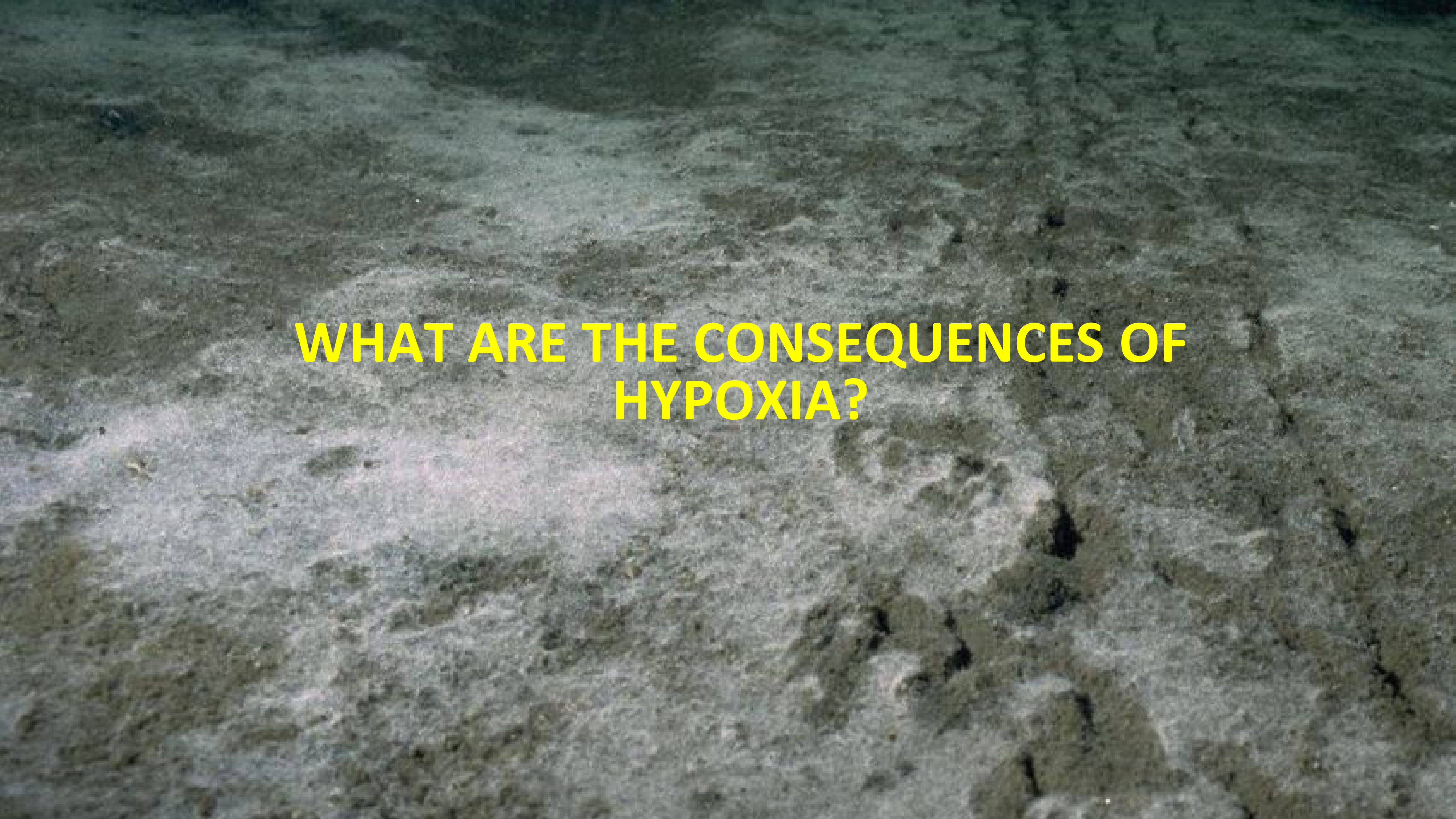
What if nutrient inputs had not been reduced?



Source: Andersen & Carstensen (2011) Politiken

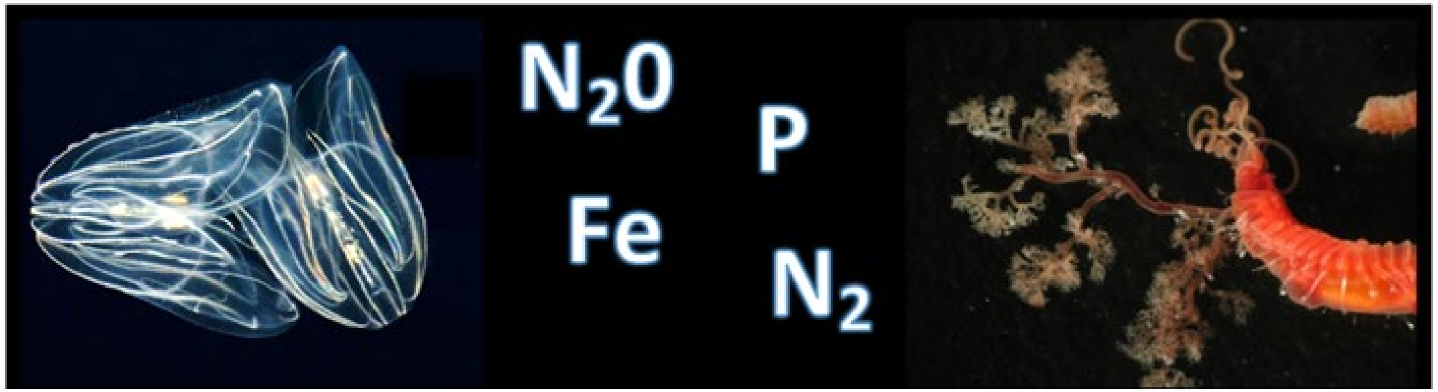
SUMMARY: DRIVERS OF HYPOXIA

- The Baltic Sea is naturally prone to hypoxia due to its restricted exchange with the oceans
- Modern hypoxia in the Baltic Sea is driven by increased nutrient input and is more intense and widespread than observed in the geological past
- Saltwater inflows modulate hypoxia in the Baltic Sea giving a short-term relief, but enhances stratification and hypoxia in the long term
- Seasonal hypoxia will become more frequent and hypoxia will expand in a warmer climate without nutrient reductions



WHAT ARE THE CONSEQUENCES OF HYPOXIA?

Oxygen affects everything



Biodiversity
Food webs

Biogeochemistry
Feedback to climate system
& further deoxygenation

Evolution/
Adaptation

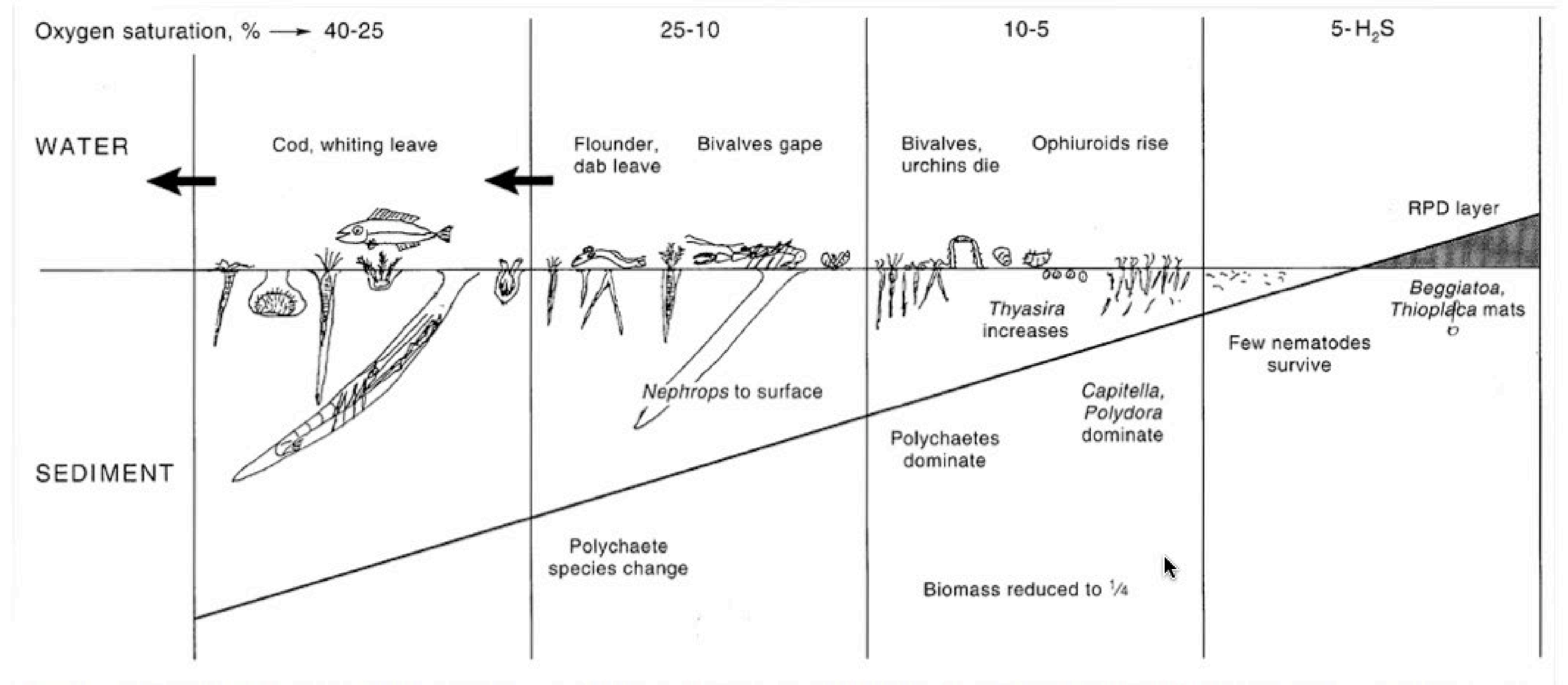
Habitat
degradation
Tropics – poles

Physiological –
Population level
effects

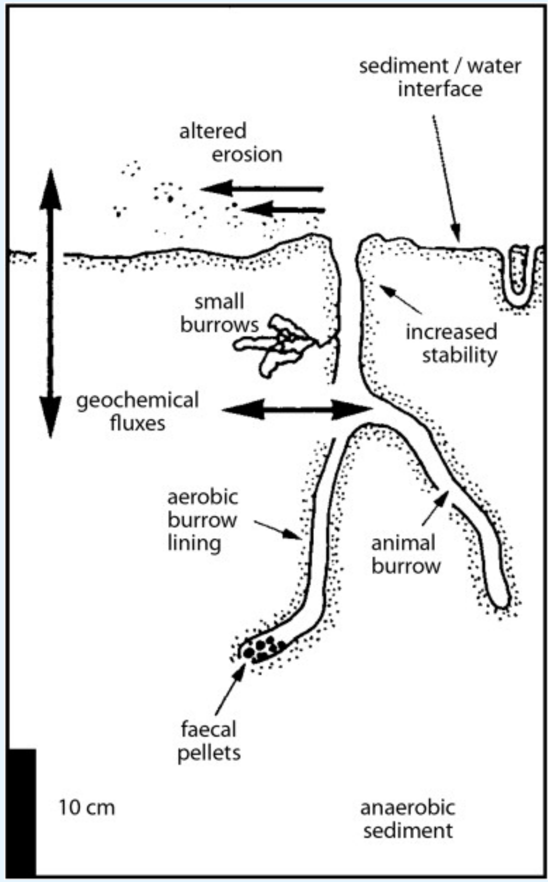
Fisheries
Economies
Human health

Image modified from Breitburg et a., 2018

Effect on benthic fauna and their bioengineering

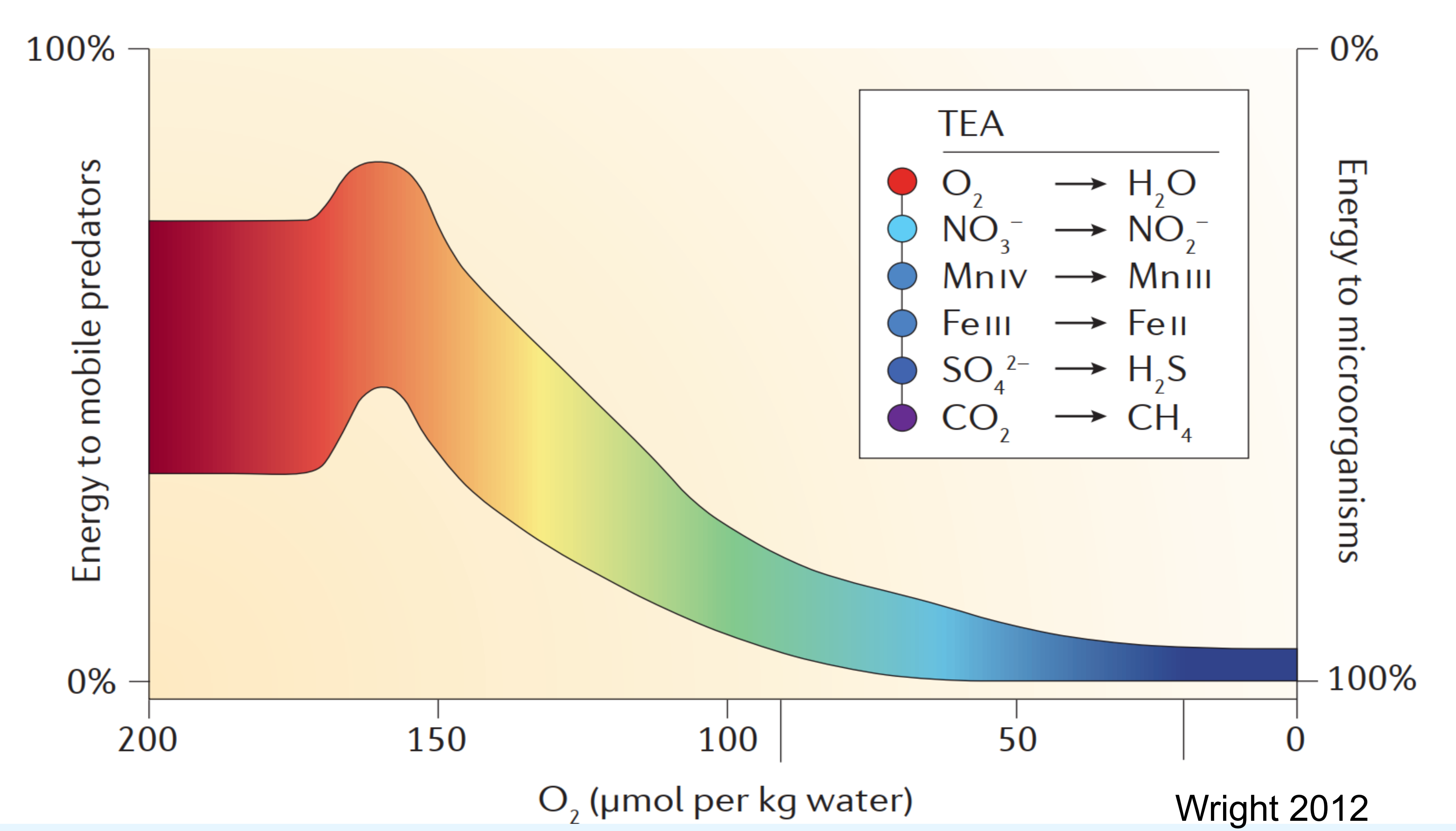


Pearson & Rosenberg (1978)



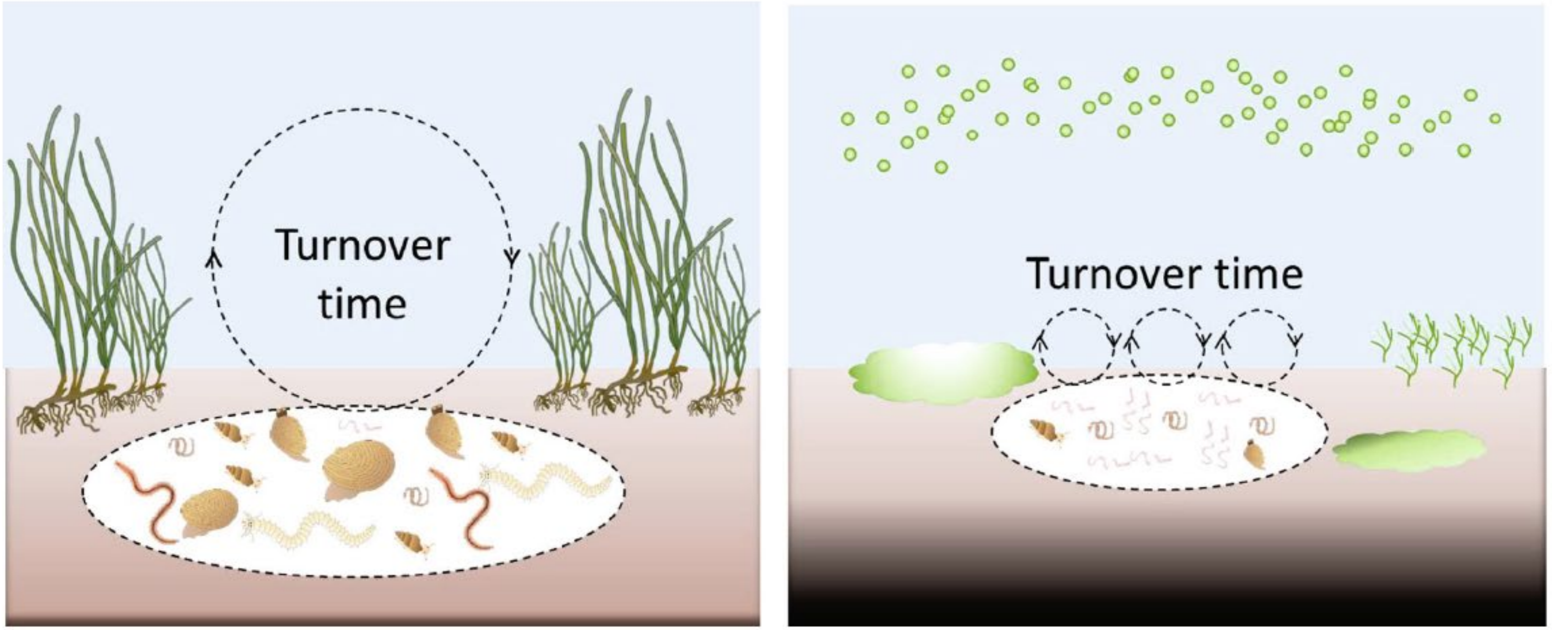
Meadows & Tait (1989)

Deoxygenation increases energy flow to microbes



Wright 2012

The entire benthic community changes



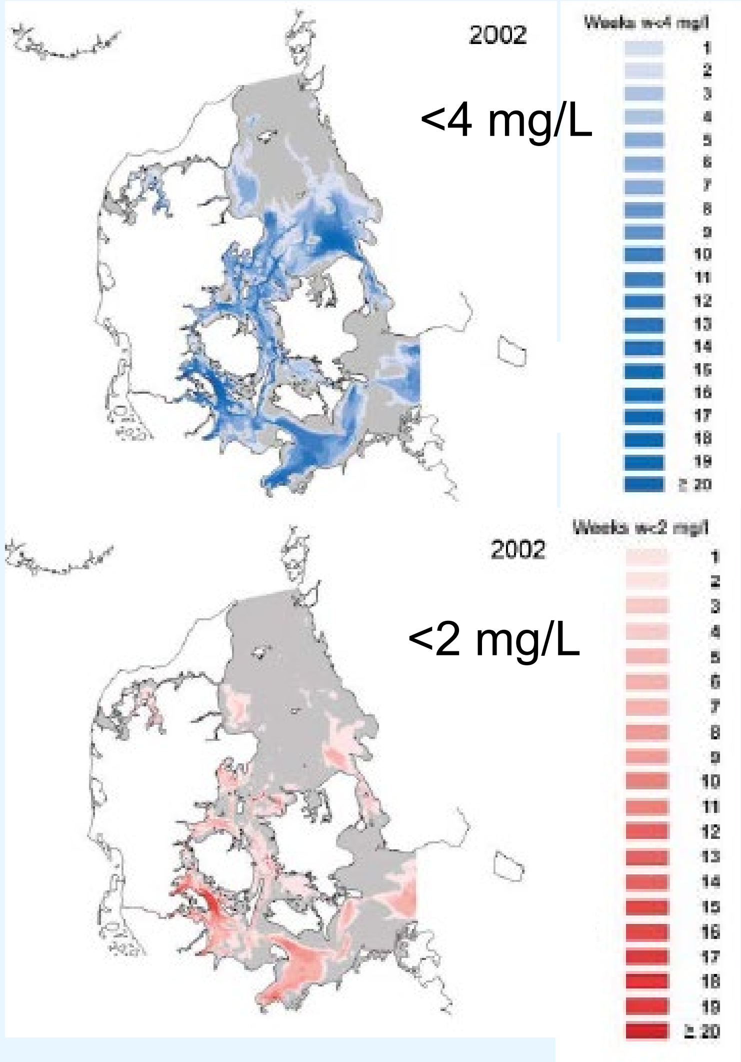
Biological Traits important for carbon and nutrient turnover and retention

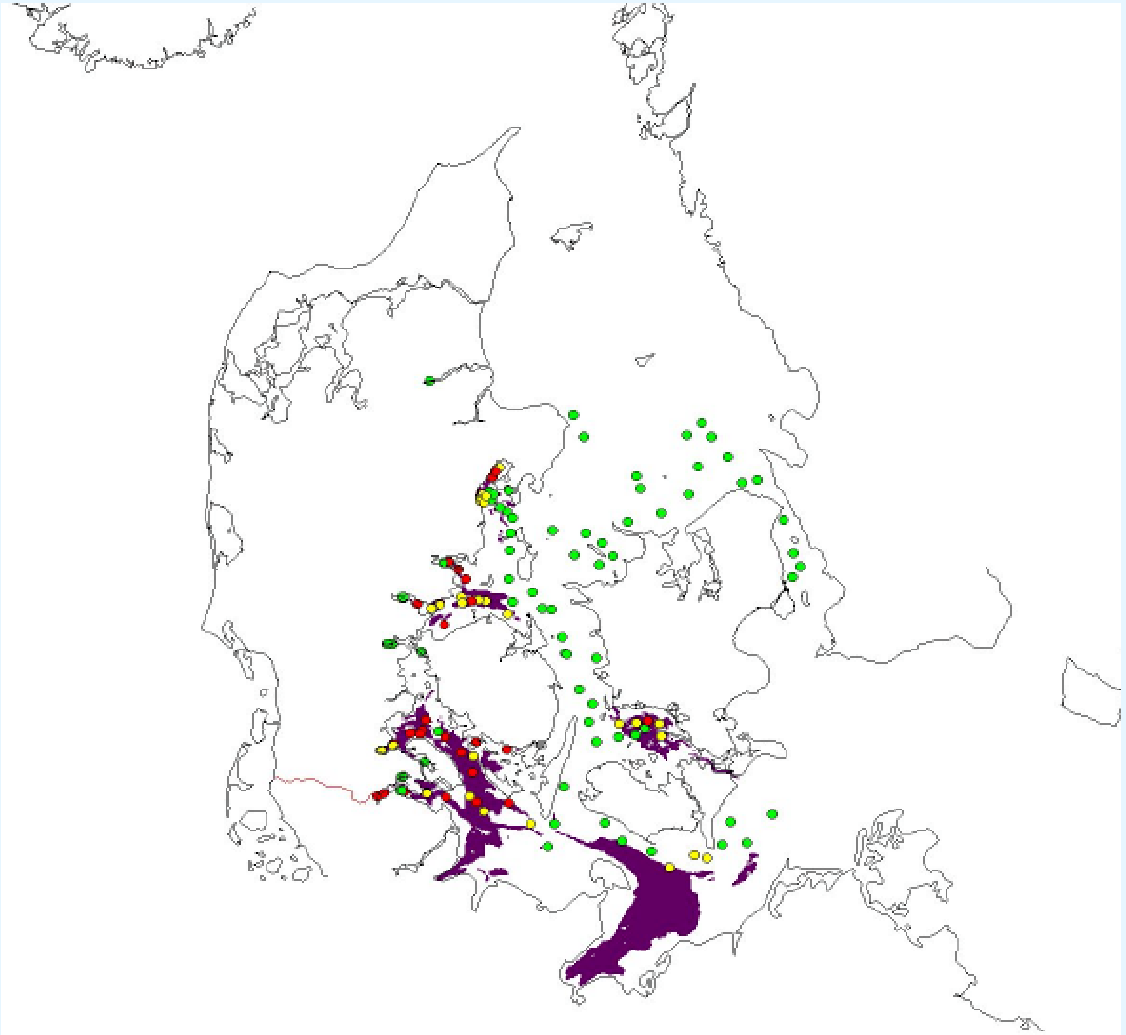
- large
- long-lived
- slow-growing
- perennials
- deep-dwelling bioturbators
- high energy and CNP content per individual

- small
- short-lived
- annuals
- fast-growing
- surface-modifiers
- low energy and CNP content per individual

Carstensen et al. (2020)
AMBIO

Assessing the loss of benthic fauna – catastrophic year



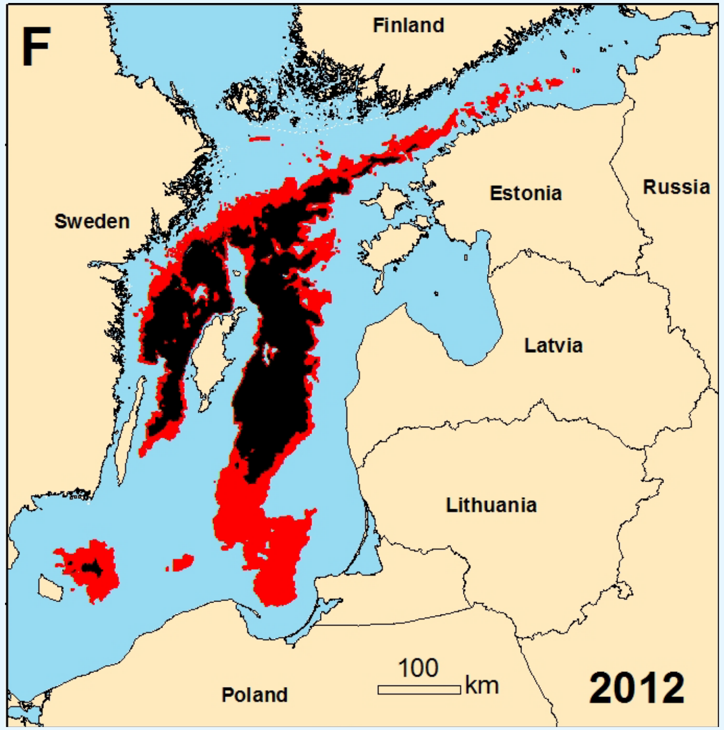


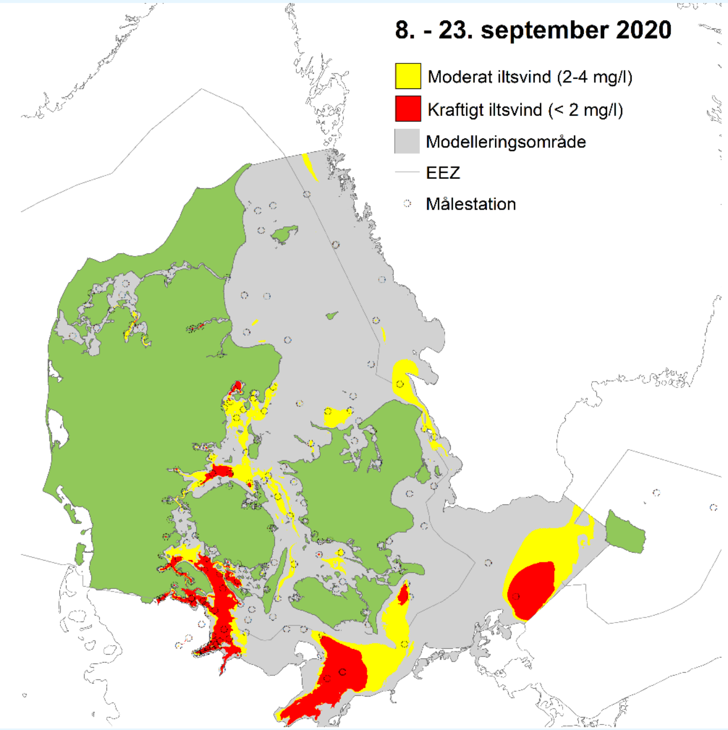
Estimated 300000 tons of benthic biomass was lost by comparing before and after situation

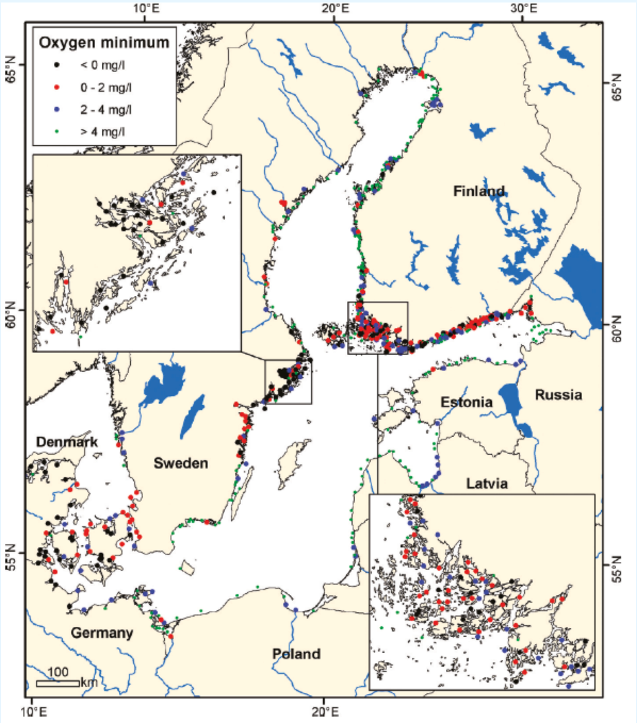
This corresponds roughly to the weight of the Danish population

Hansen et al. (2003)

Assessing the loss of benthic fauna – Baltic Sea





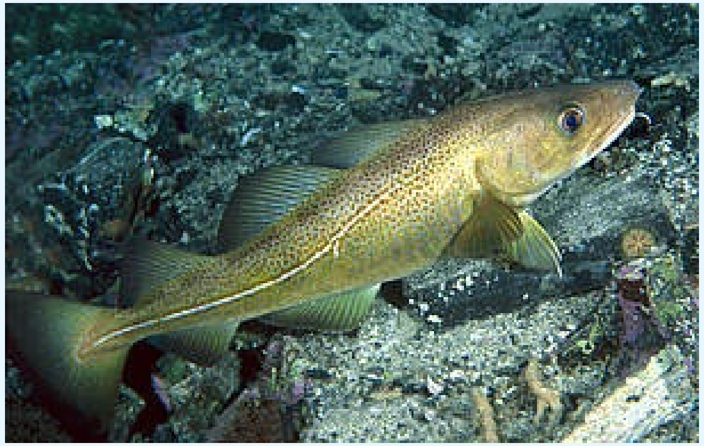


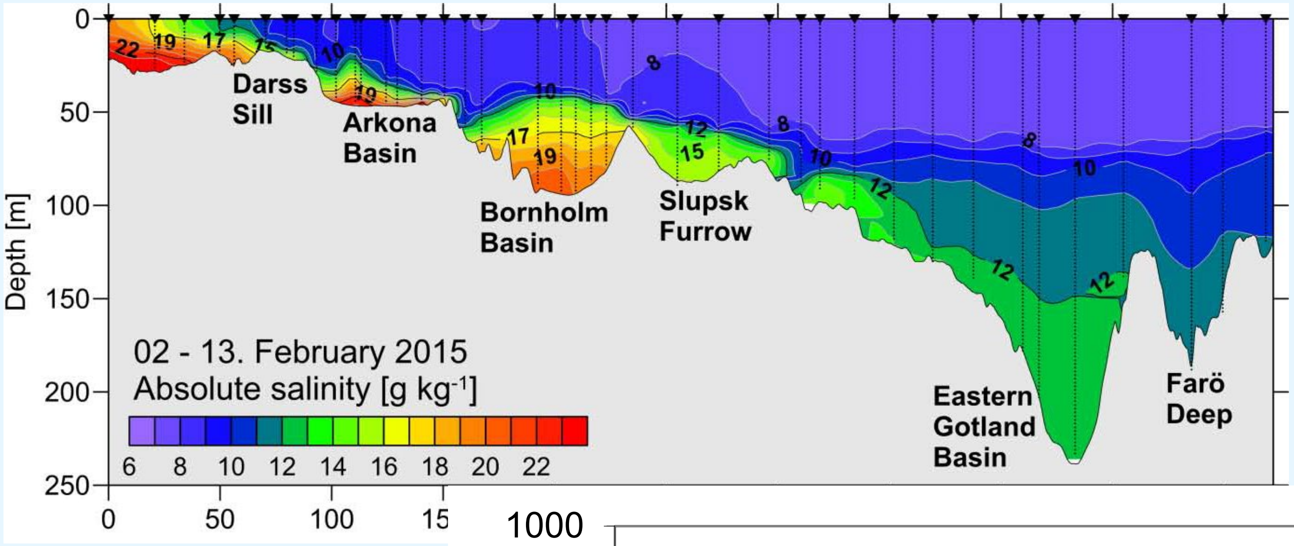
Estimated 3 mio. tons of benthic biomass is missing due to hypoxia

Karlson et al. (2002)

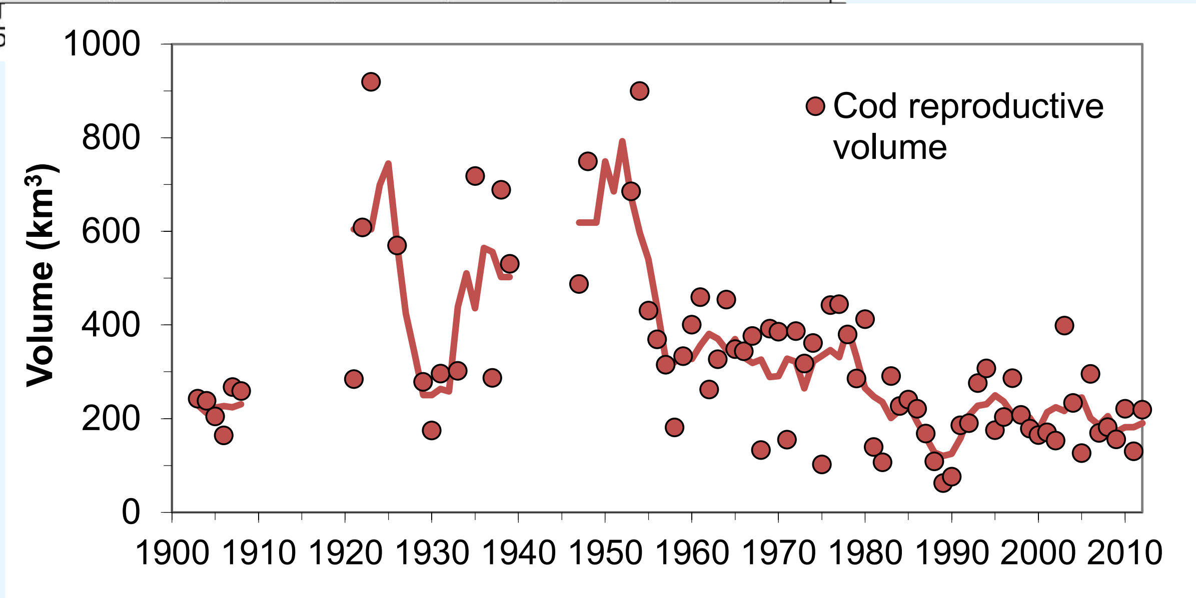
… and occasionally fish get caught in hypoxic waters

Cod reproductive volume in the Baltic Sea

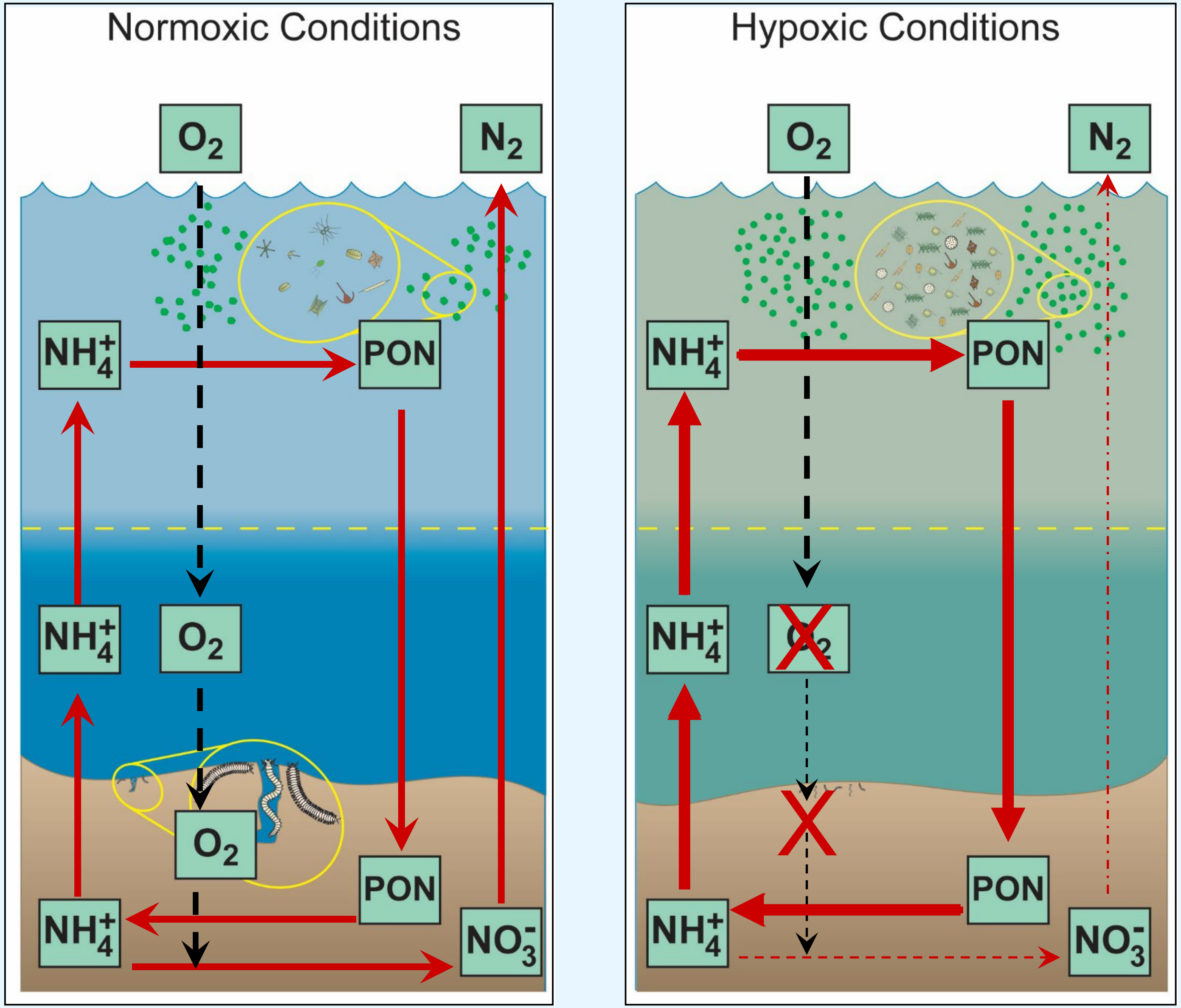




Hatching conditions:
S>11
O_2>2.8 mg/L

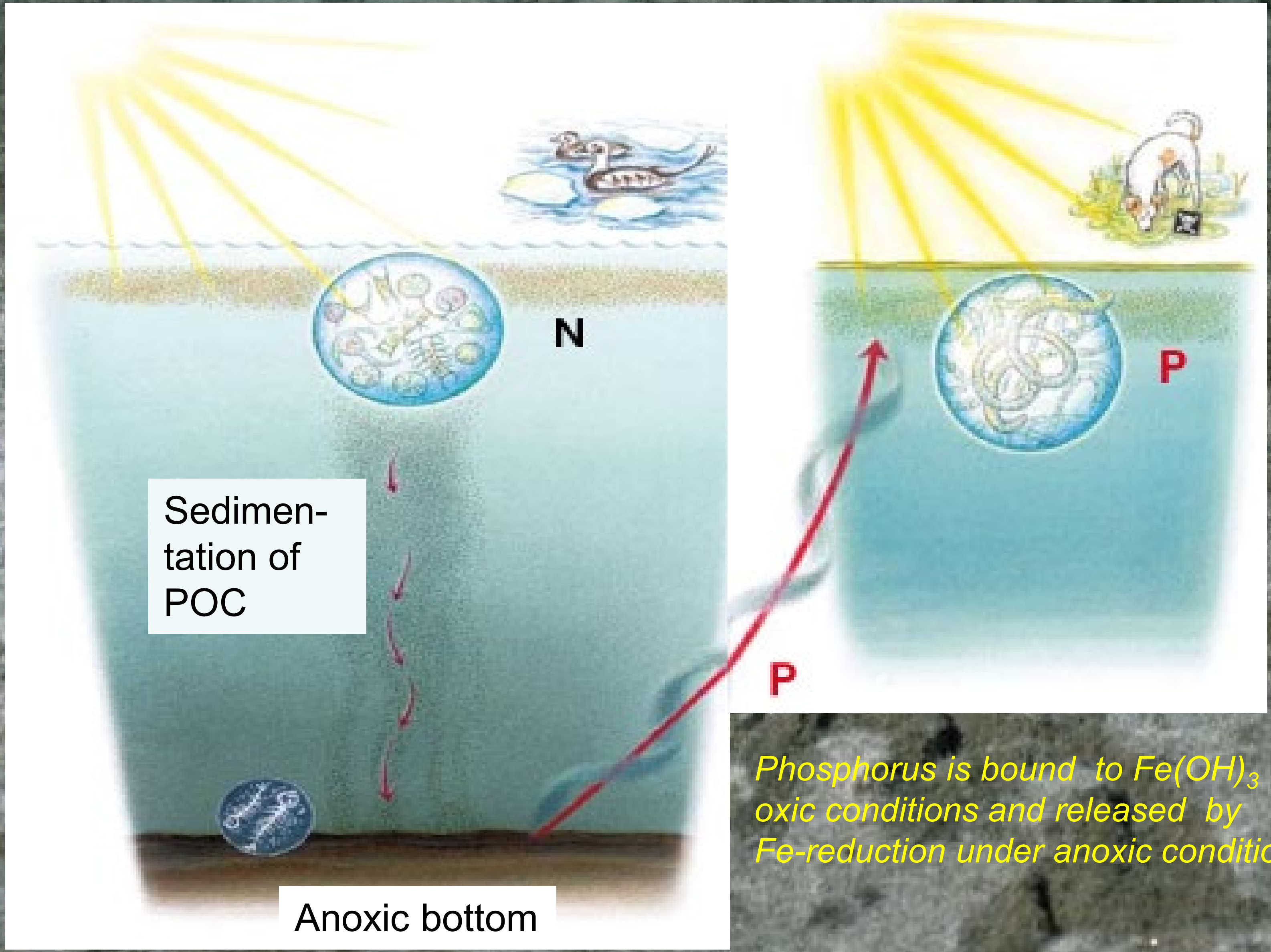


Hypoxia reduces sediment denitrification and creates N feedback



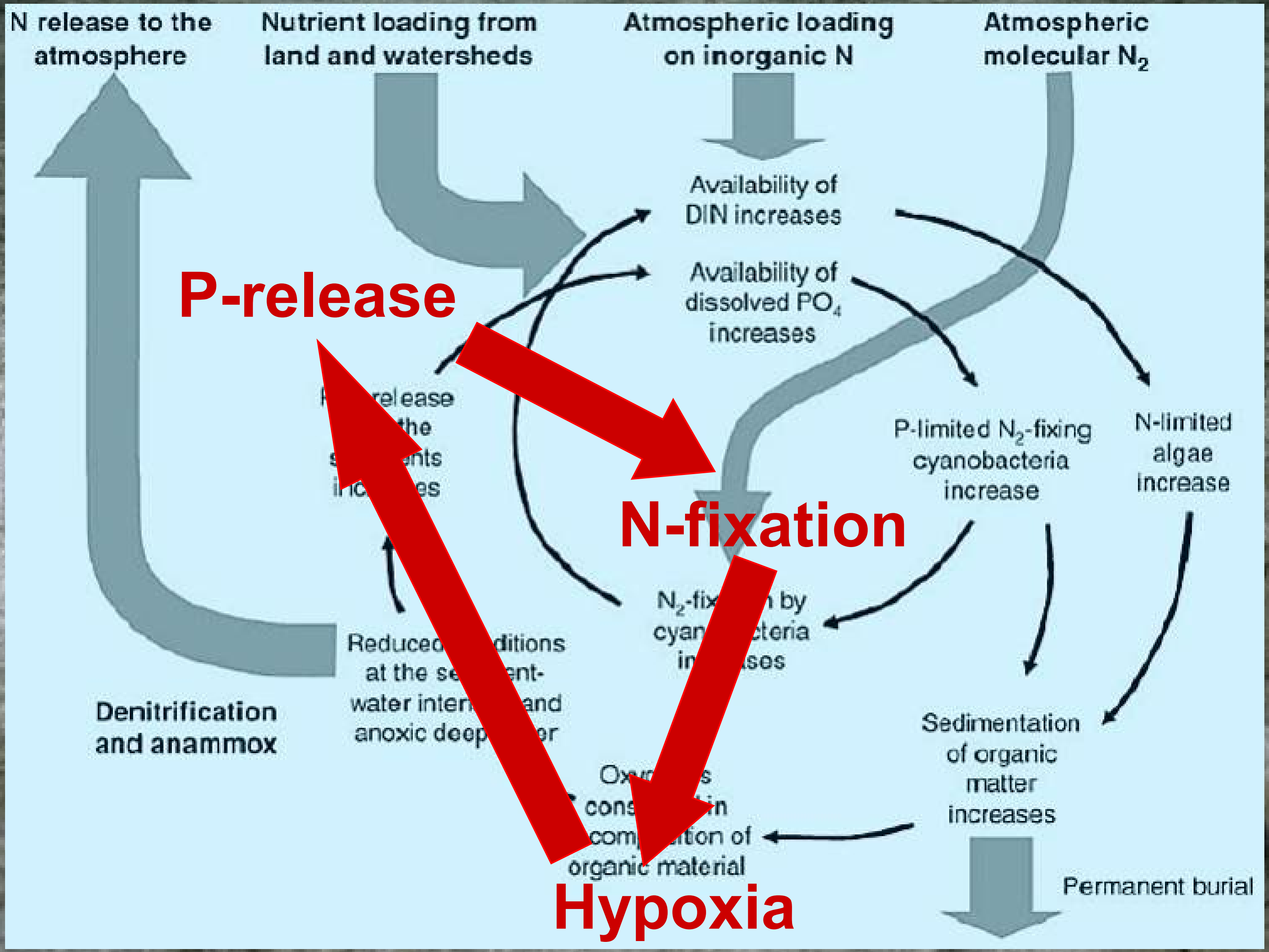
Source: Jeremy Testa

Hypoxia enhances P release from sediments



Phosphorus is bound to $Fe(OH)_3$ under oxic conditions and released by Fe-reduction under anoxic conditions

The "vicious" circle



Source: Vahtera et al. (2007) Ambio

SUMMARY: CONSEQUENCES OF HYPOXIA

- Hypoxia alters the biogeochemical cycling of nutrients (redox-dependent processes), enhancing recycling of N and P that sustain eutrophication
- Non-motile benthic species are naturally more tolerant to low oxygen concentrations
- … but also more susceptible to extended periods of hypoxia, which alters the composition by loosing perennial engineering species first
- Fish are affected through habitat losses (benthic and pelagic), making them more vulnerable to predation (including fishing)
- Warming enhances the effects of hypoxia and therefore nutrient reductions will be even more critical in the future

TAKE HOME MESSAGES FOR PUGET SOUND

- The terminal inlets are naturally prone to low oxygen conditions due to the relelatively shallow thickness of the bottom layer and reduced ventilation (seasonally) – similar to the mechanisms some areas of the Danish Straits
- The supply of oxygen is primarily governed by the physics, but the risk of oxygen demand outpacing oxygen supply increases with eutrophication (enhanced supply of OM to the bottom)
- Efforts to improve oxygen conditions can be counteracted by climate change, e.g. from oxygen-poorer waters entering PS, but this does not means that these efforts have been in wain

Species and Food Web Responses to low dissolved oxygen in the Salish Sea

Tim Essington

University of Washington

School of Aquatic and Fishery Sciences

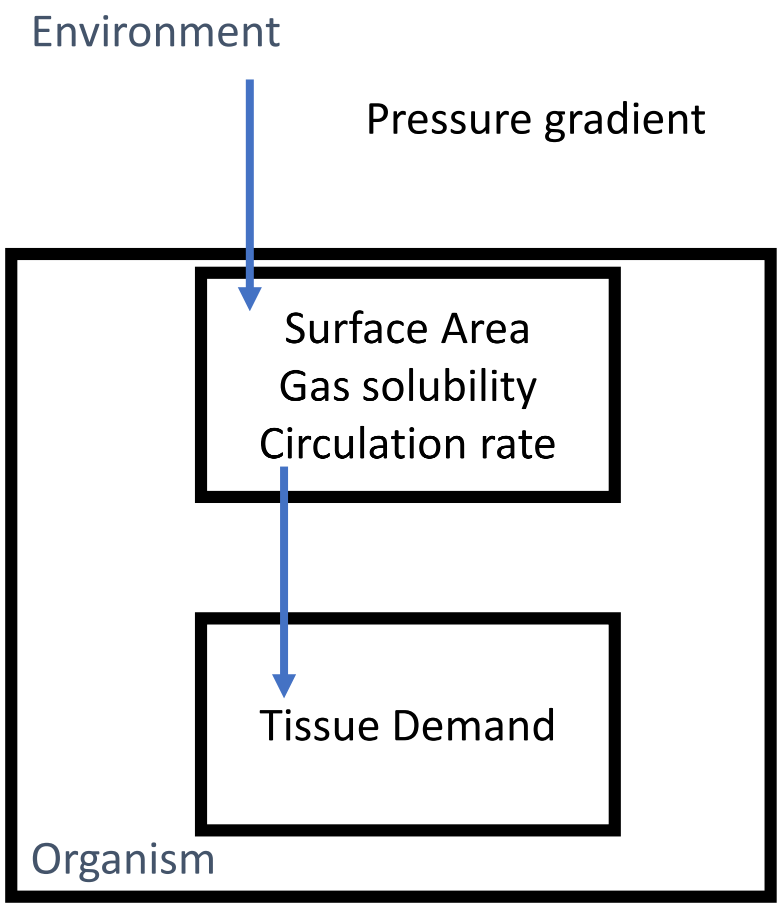
Collaborators

- Sean Anderson
- Lewis Barnett
- Anne Beaudreau
- Halle Berger
- Halley Froehlich
- John Horne
- Emma Hodgson
- Shannon Hennessey
- Phil Levin
- Lingbo Li
- Julie Keister
- P. Sean McDonald
- Pamela Moriarty
- Jan Newton
- Caroline Paulsen
- Sandy Parker-Stetter
- Samantha Sleidlecki
- Mei Sato
- Eric Ward

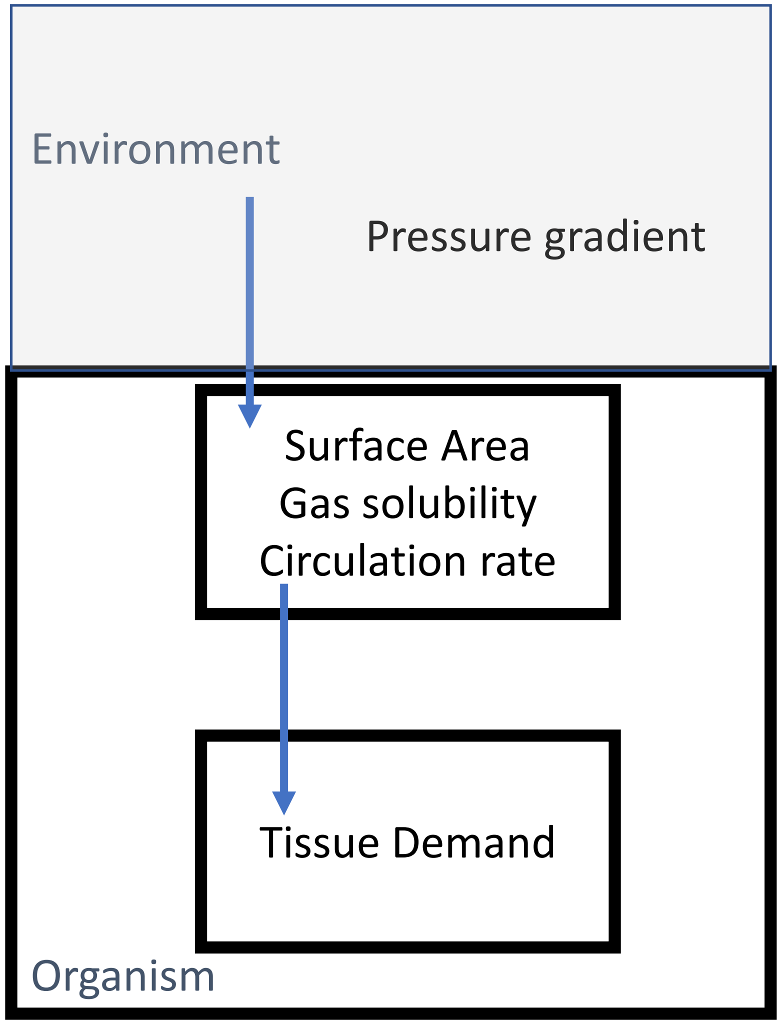
Main take home points

- Organisms have behavioral and physiological coping mechanisms that vary across taxa
- Indirect effects stemming from coping mechanisms are likely but hard to predict
- We have core biological knowledge to understand the types of organismal responses in a risk-based framework

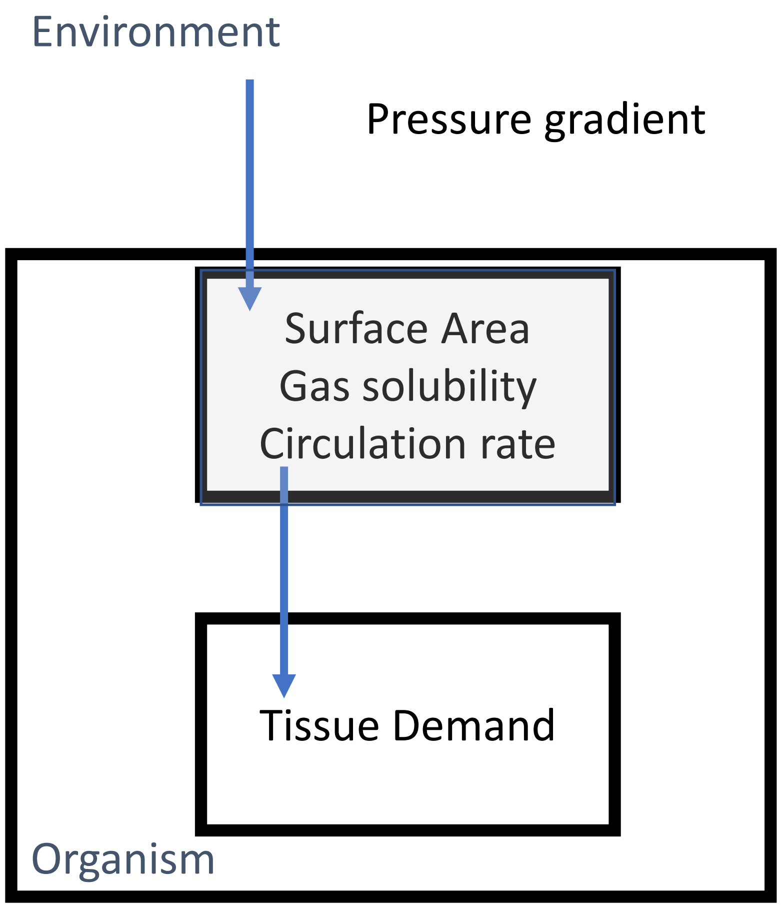
Gas physiology 101



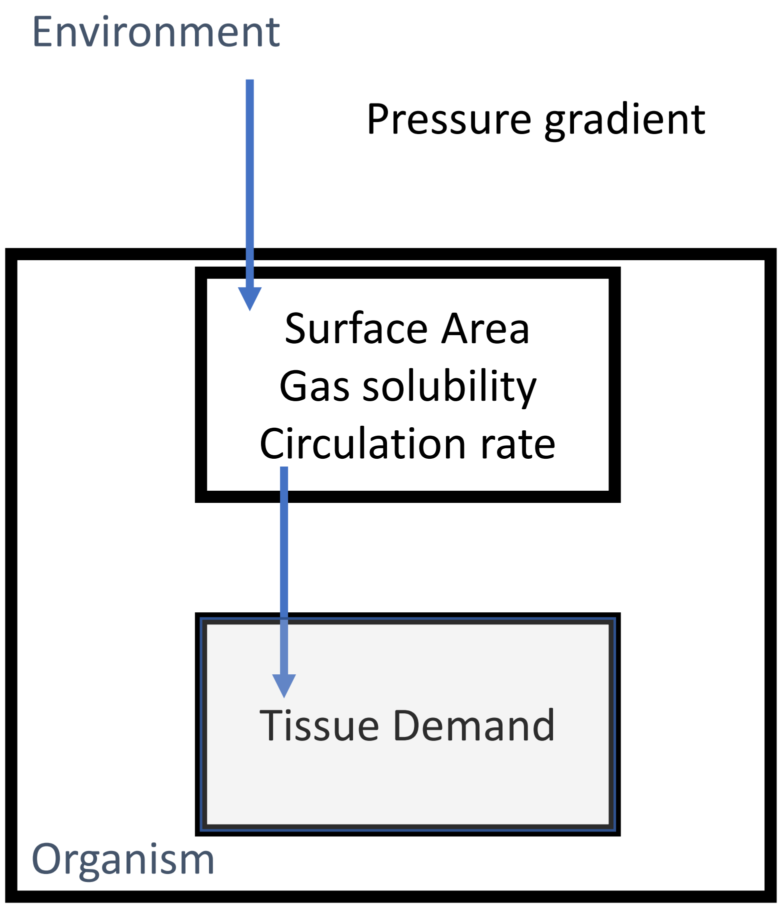
Coping with low dissolved oxygen?



Coping with low dissolved oxygen?

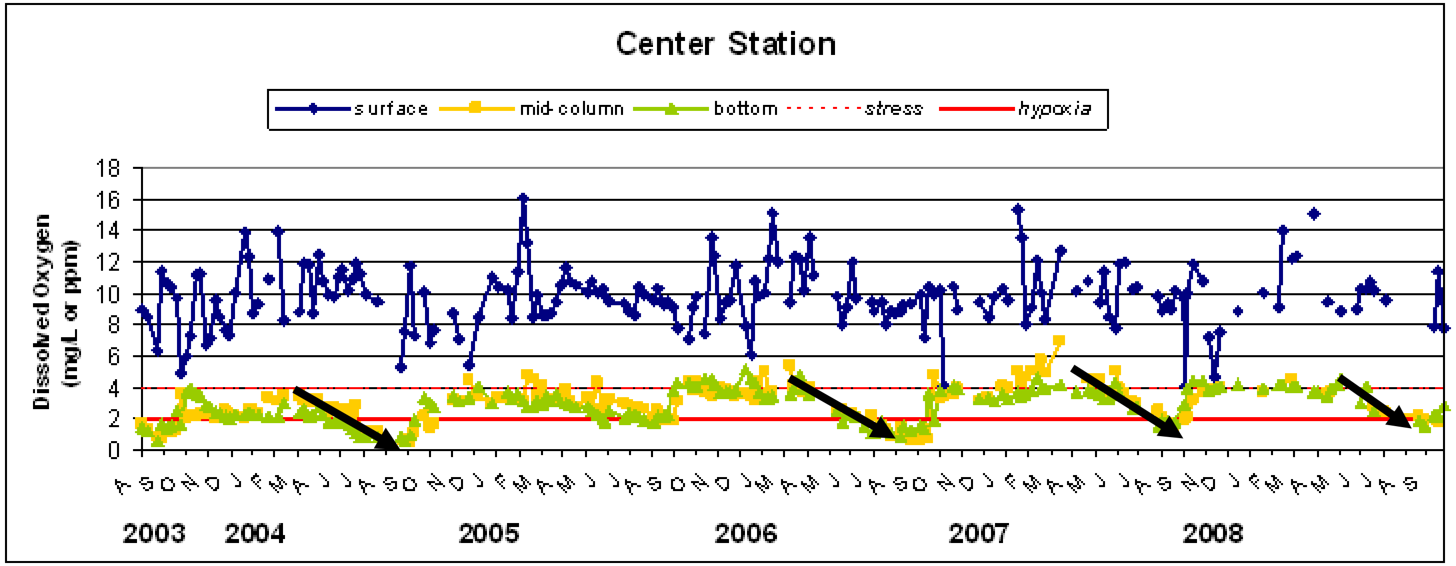


Coping with low dissolved oxygen?

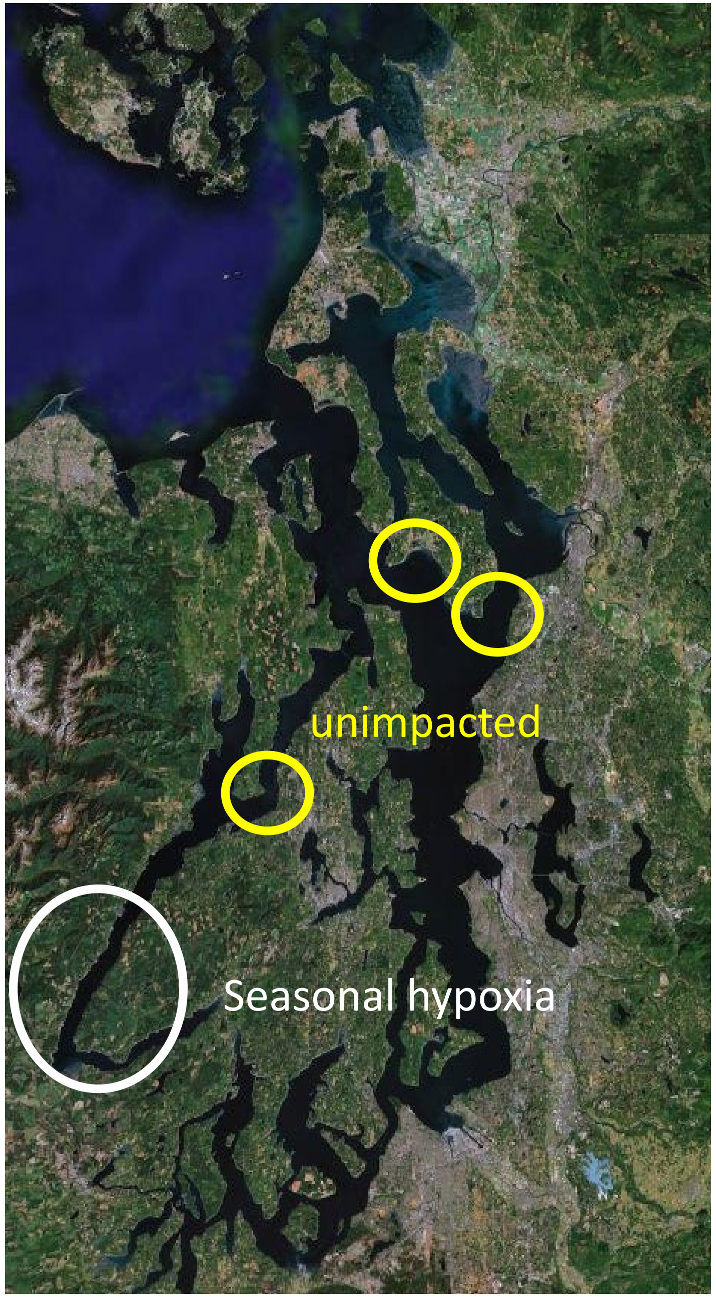


Responses to seasonal hypoxia: acute vs. chronic effects

Intensity of Seasonal Hypoxia: South Hood Canal



Data from HCDOP Citizens Monitoring Program

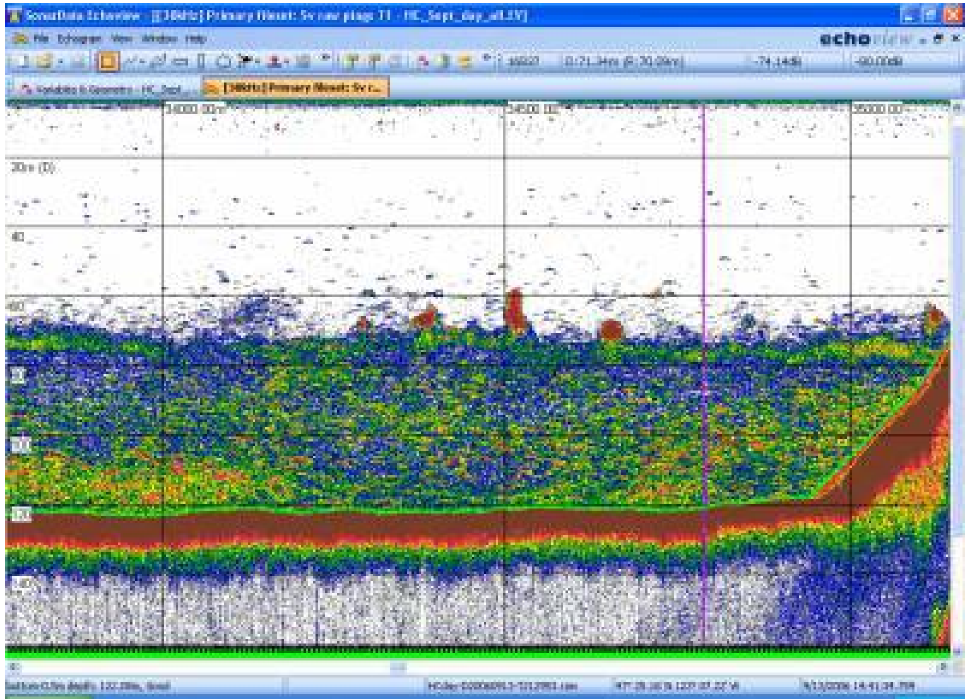


BACI – Type Design

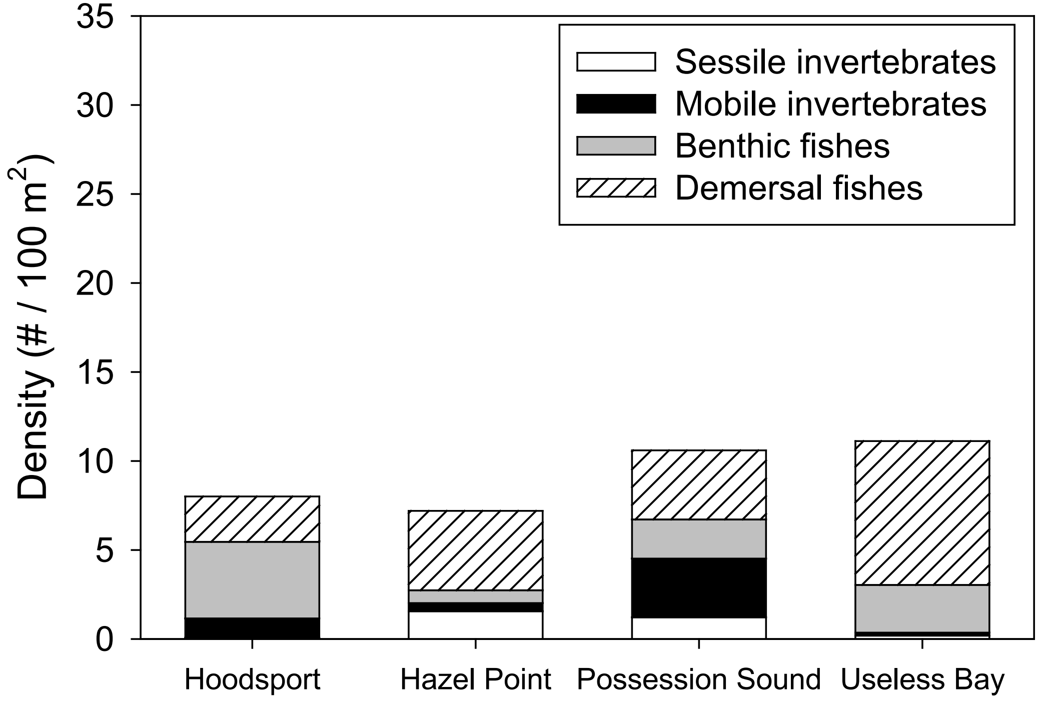
1 Impact site “Hoodsport”

3 Reference sites

Account for basin or other effects related to bathymetic profiles

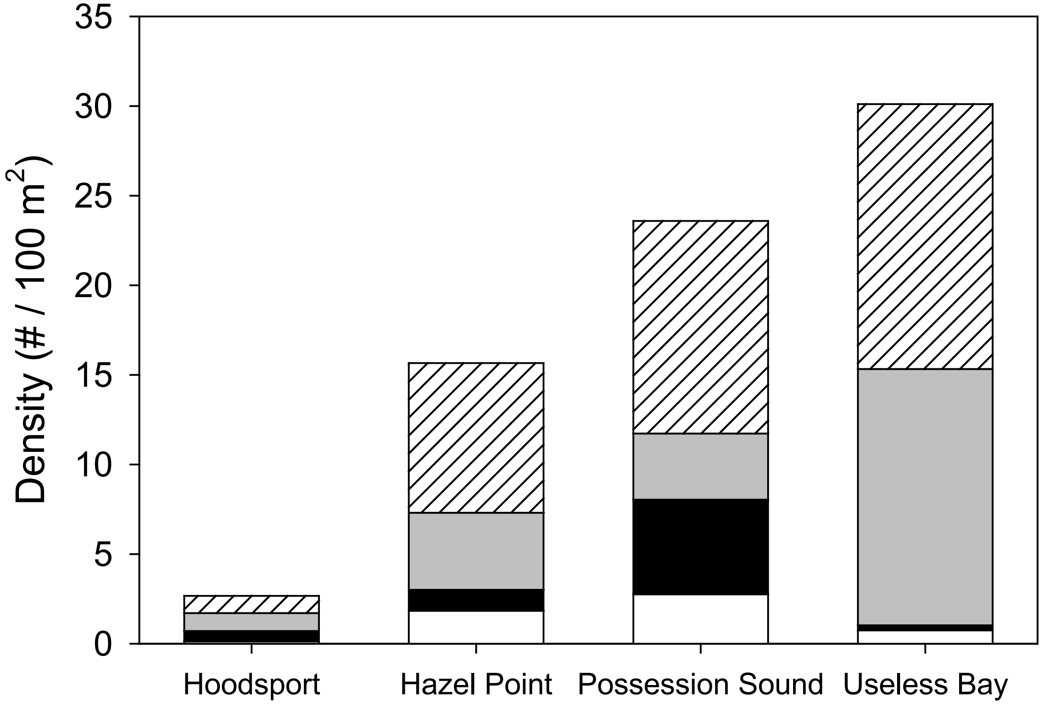


General Results



June

Oxygen high everywhere



September

Oxygen low at Hoodsport

Main Findings

Absent all of the Time

Absent during low dissolved oxygen events

What about nearshore habitats?

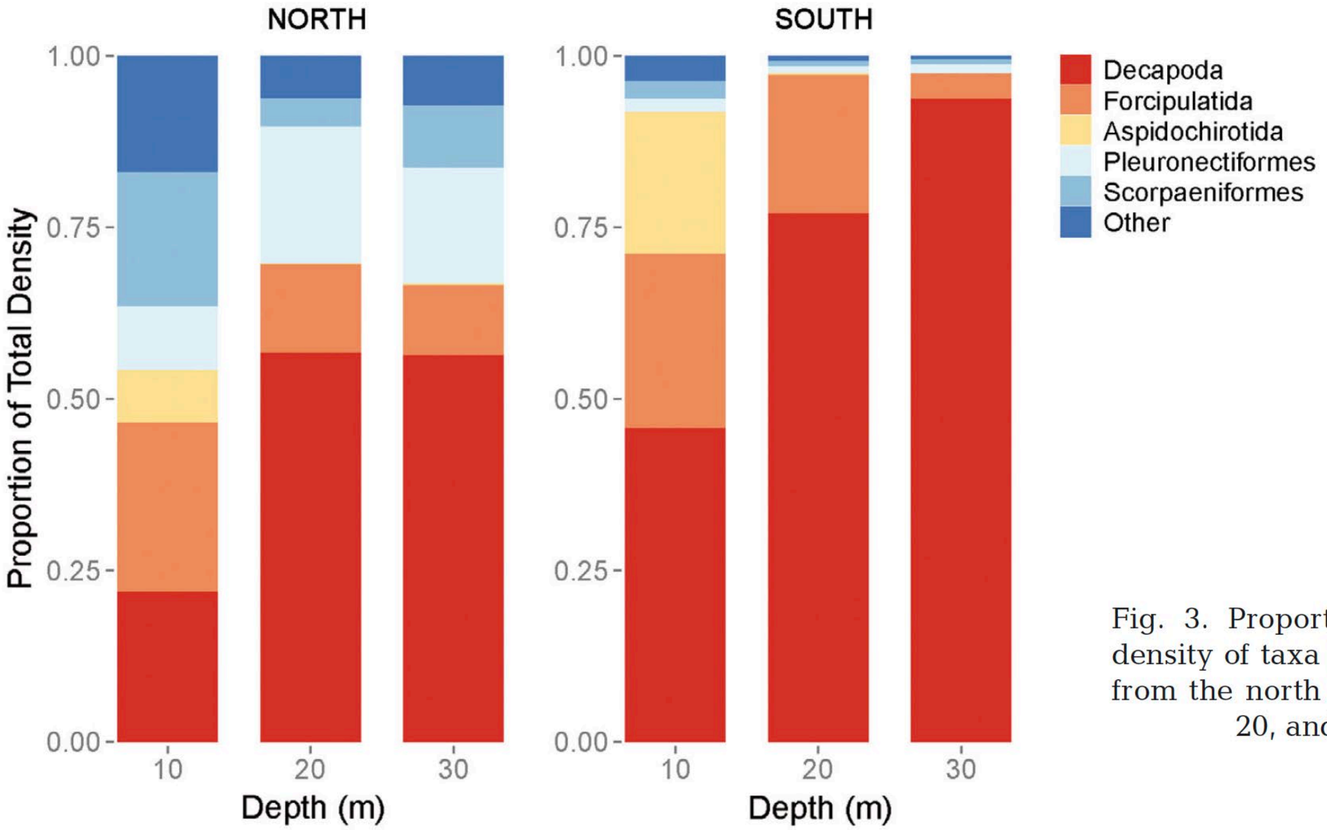
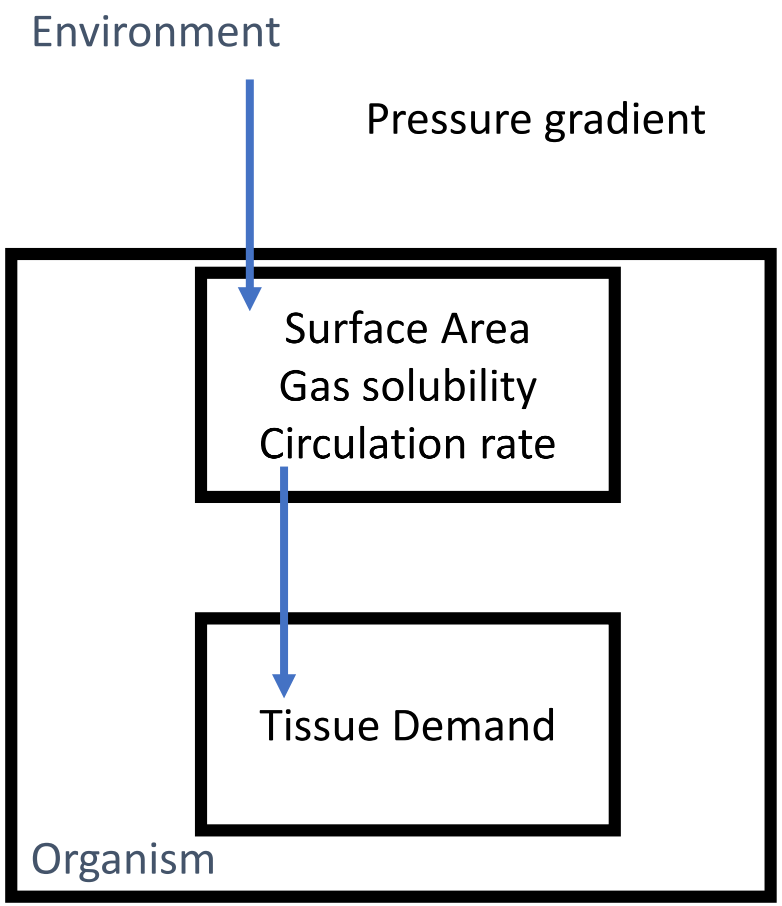


Fig. 3. Proportions of total relative density of taxa (at the level of Order) from the north and south sites at 10, 20, and 30 m depths

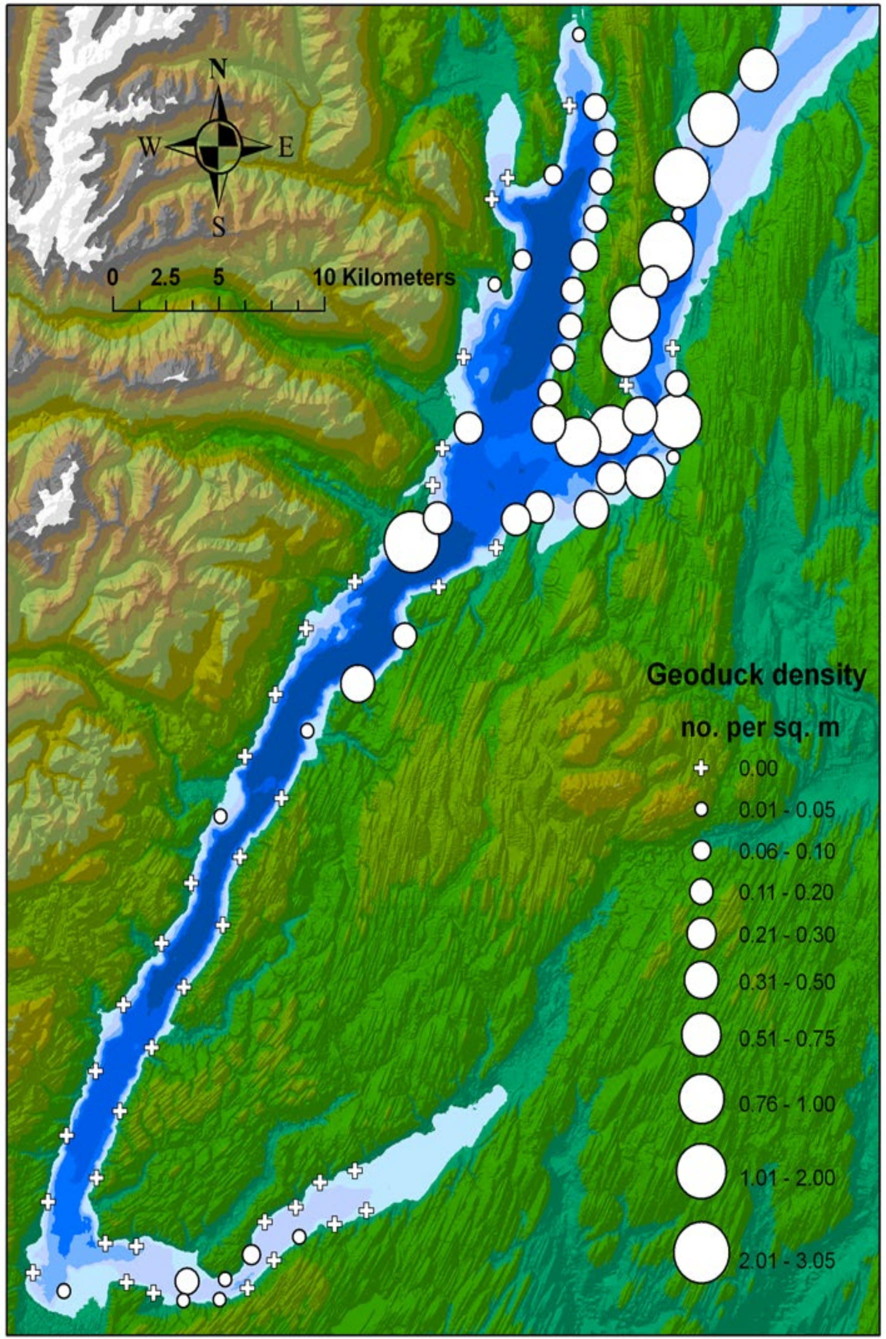
Gas physiology 101



An Aside on Geoducks

Geoducks are rare at all depths in southern region

Cannot be explained by substrate availability



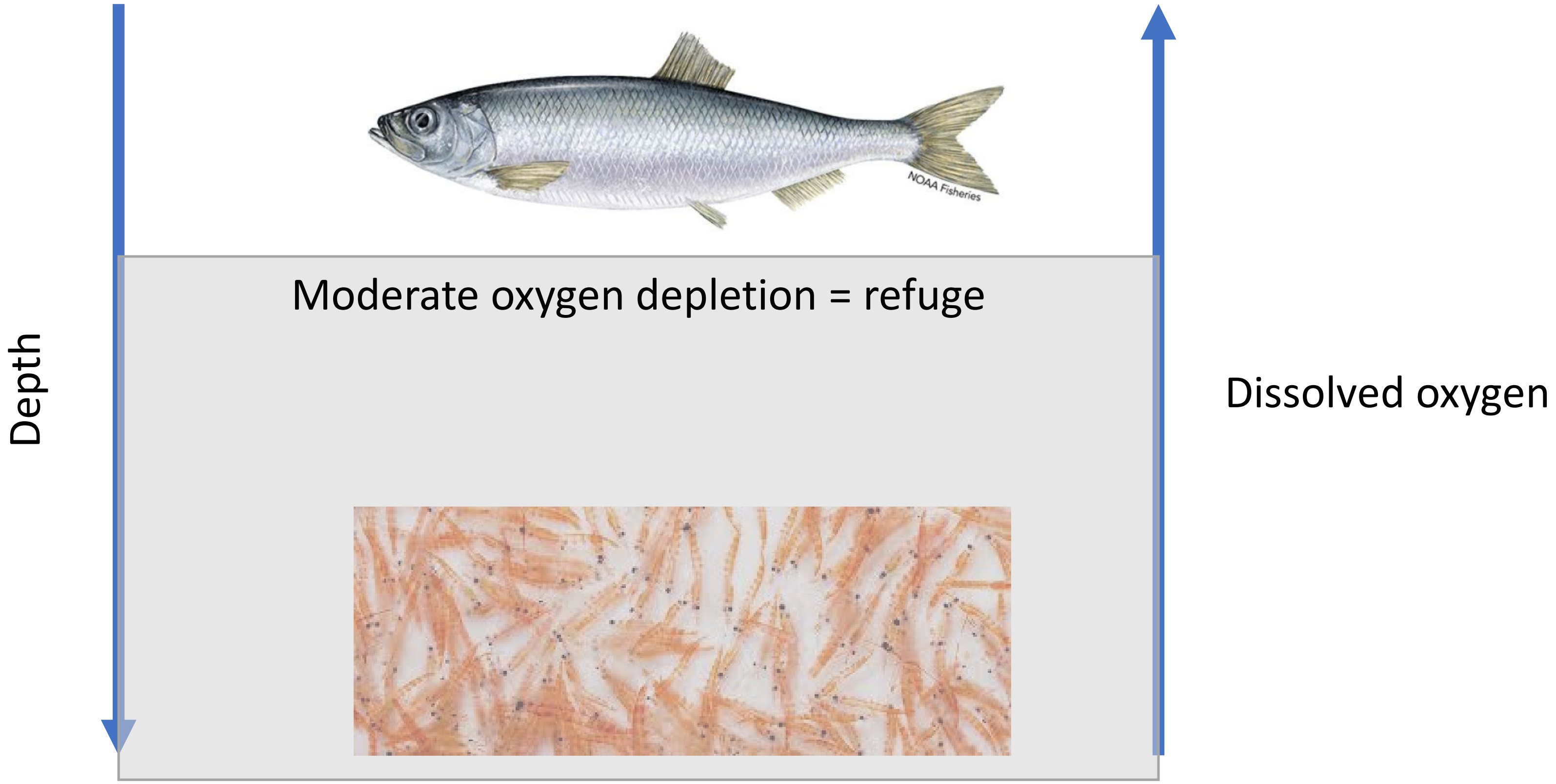
Unexpected Food Web Effects to low Dissolved Oxygen

Consequences of Distributional Shifts?

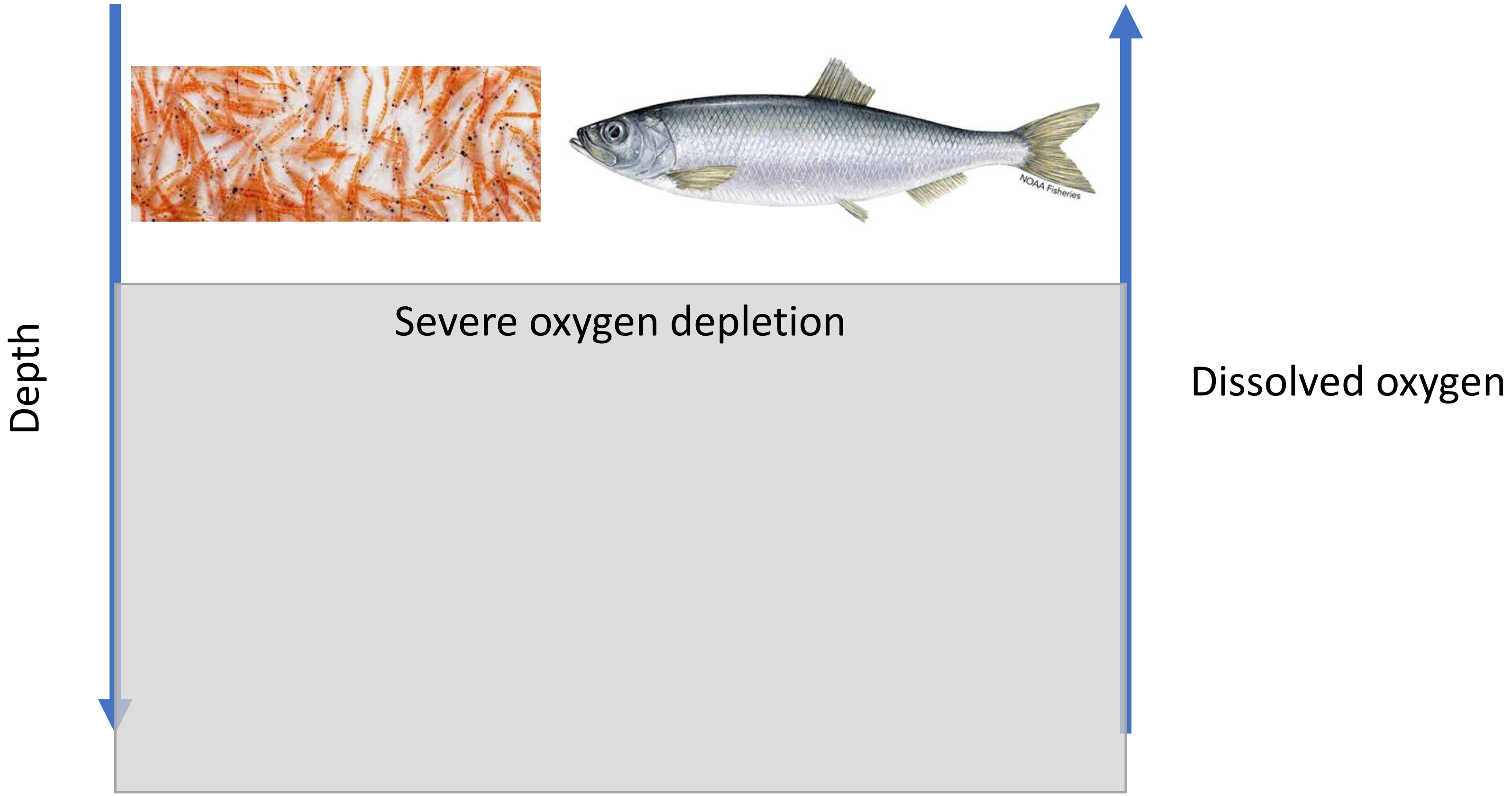
Moderate Tolerance

High tolerance

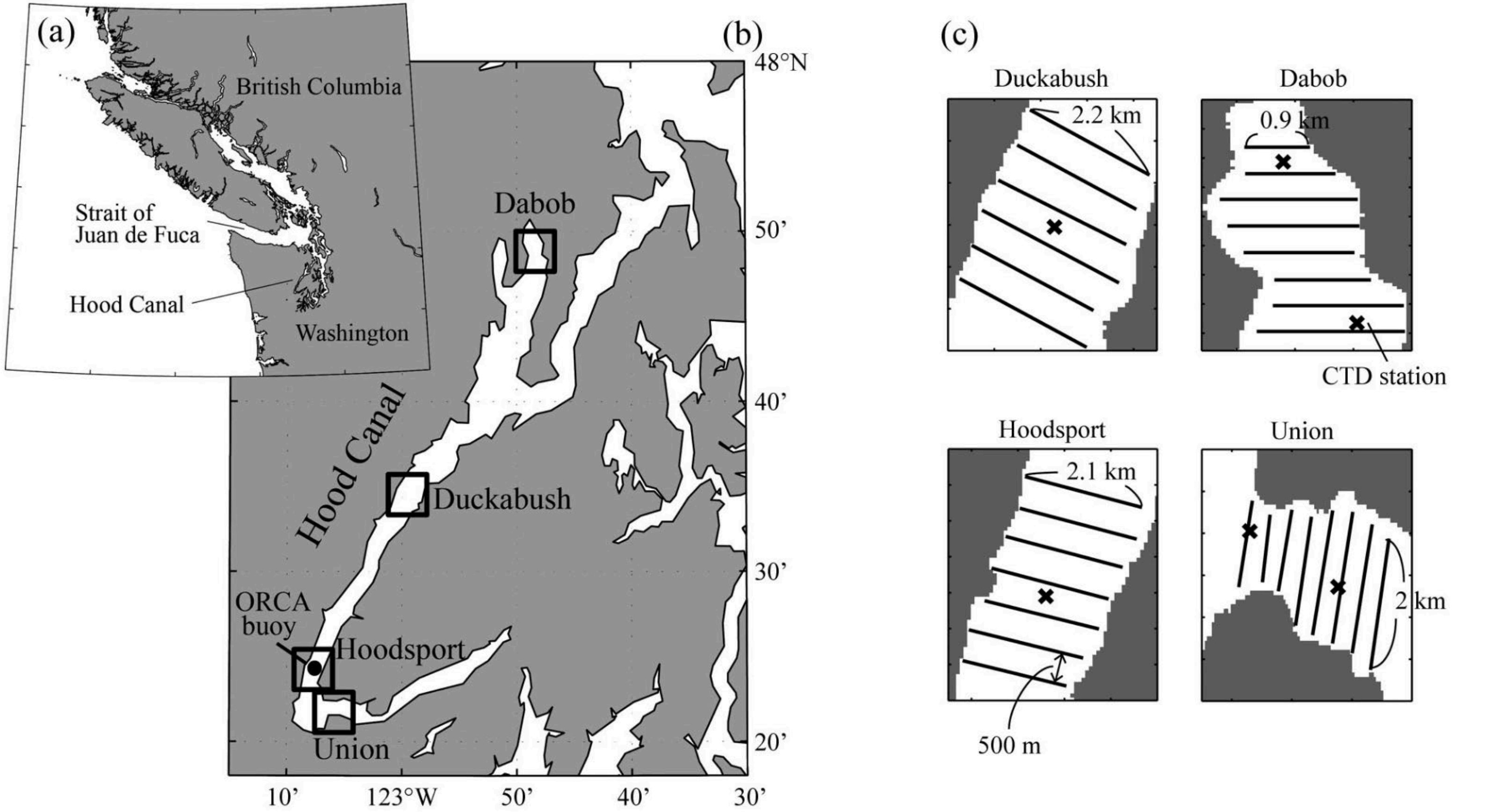
Consequences of Distributional Shifts?



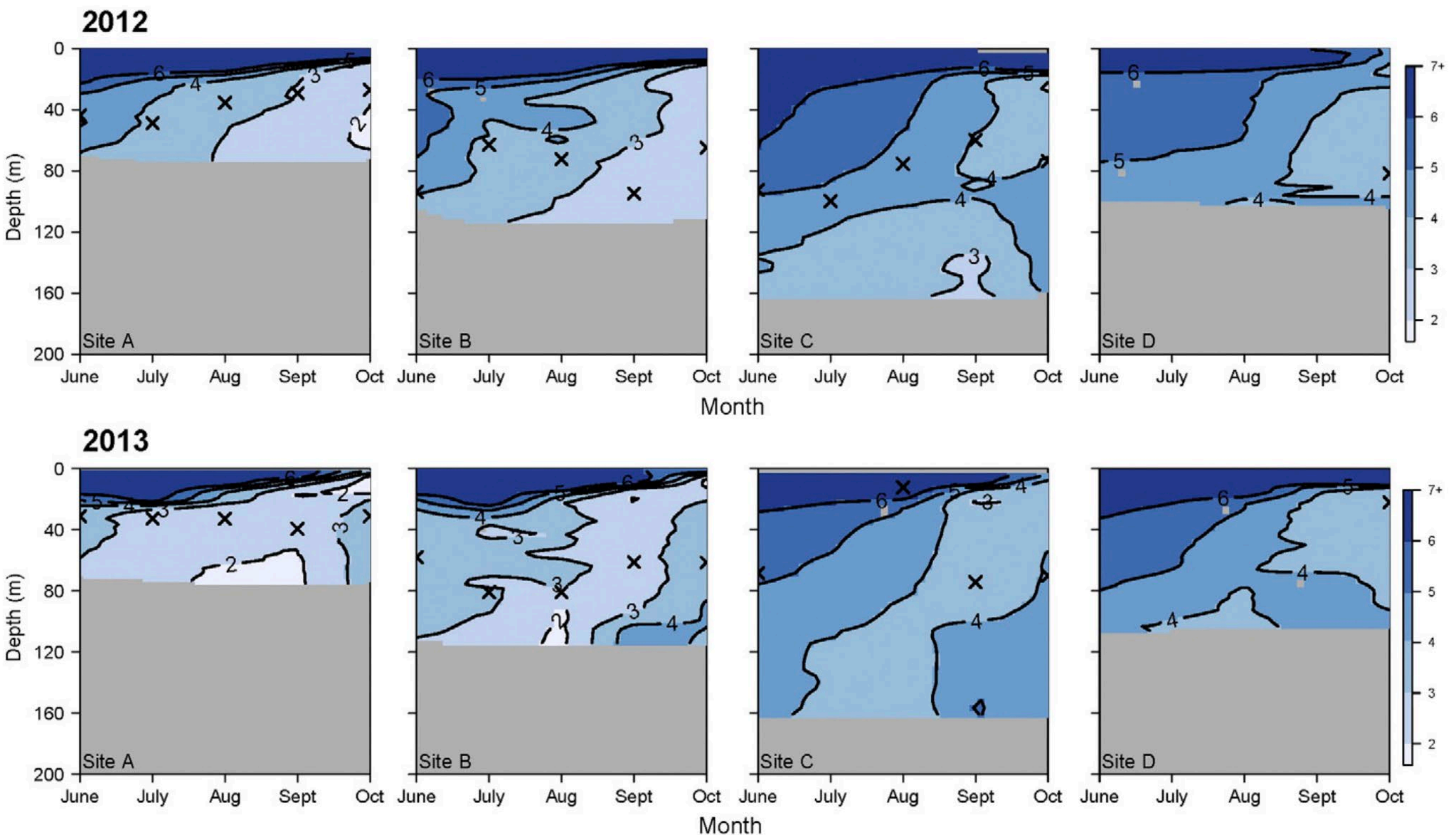
Consequences of Distributional Shifts?



Sampling Design

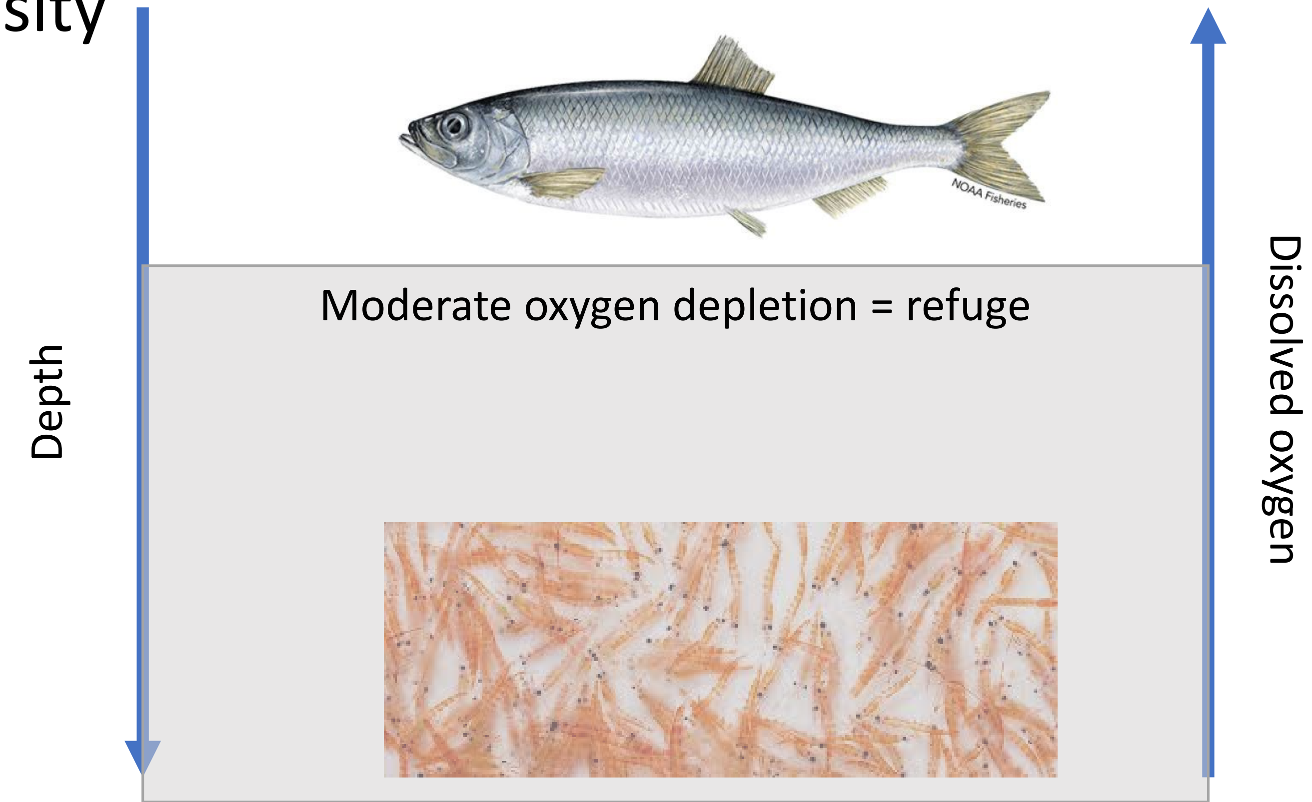


Seasonal dynamics of O_2 by Site



Expectations

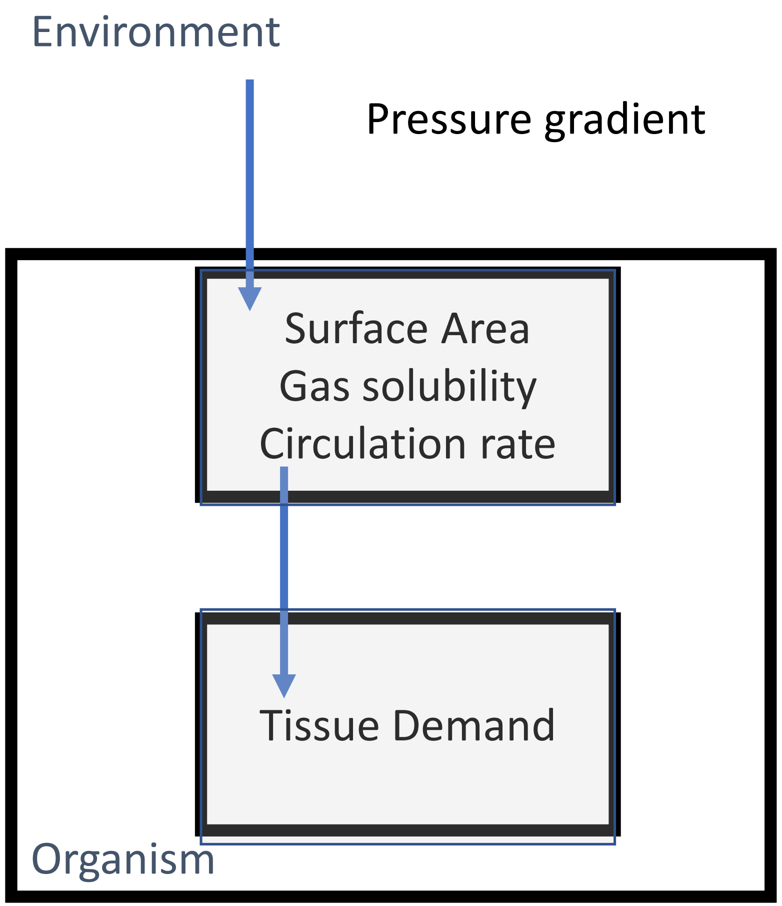
- Lower predator-prey overlap
- Reduced feeding rate on zooplankton
- Increased zooplankton density
- Reduced predator density



Reality

- Lower predator-prey overlap NOPE
- Reduced feeding rate on zooplankton A LITTLE
- Increased zooplankton density NOPE, the OPPOSITE
- Reduced predator density NOPE, THE OPPOSITE

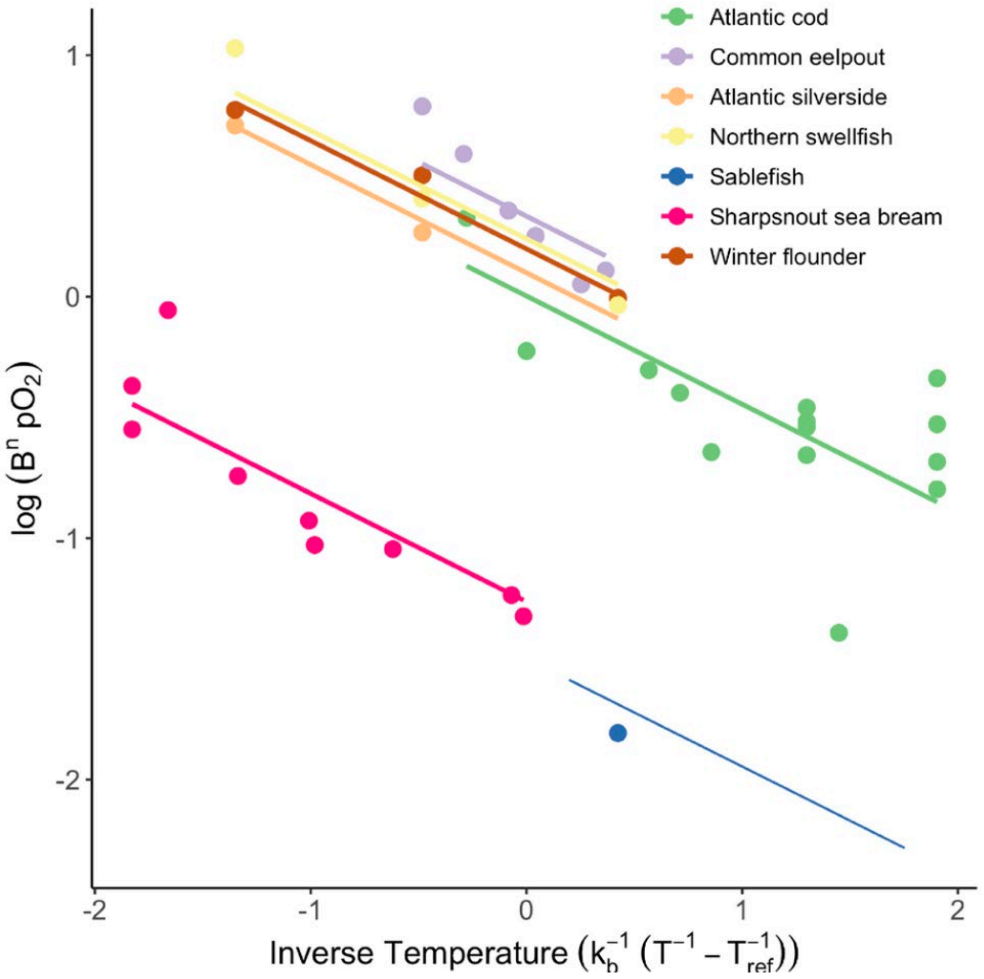
Herring were exposed to [O_2] that were lethal in lab studies, and expressed Hypoxia Inducible Factor



Estimating species tolerances and forecasting

Moving forward: predicting effects in a changing climate

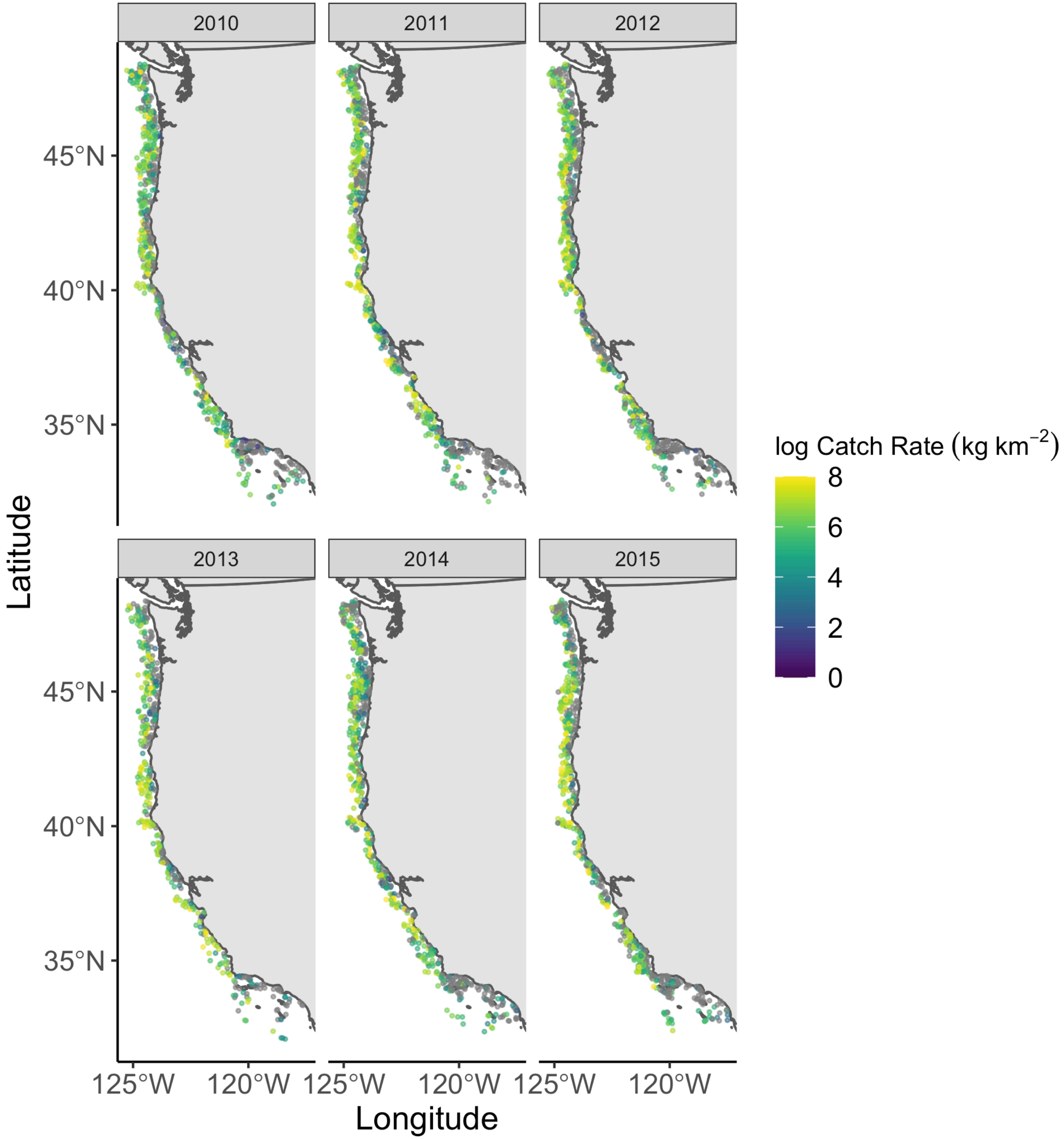
- Metabolic index: ratio of metabolic supply vs. demand
  - Incorporates joint effects of temperature and oxygen
- Estimating these in the lab



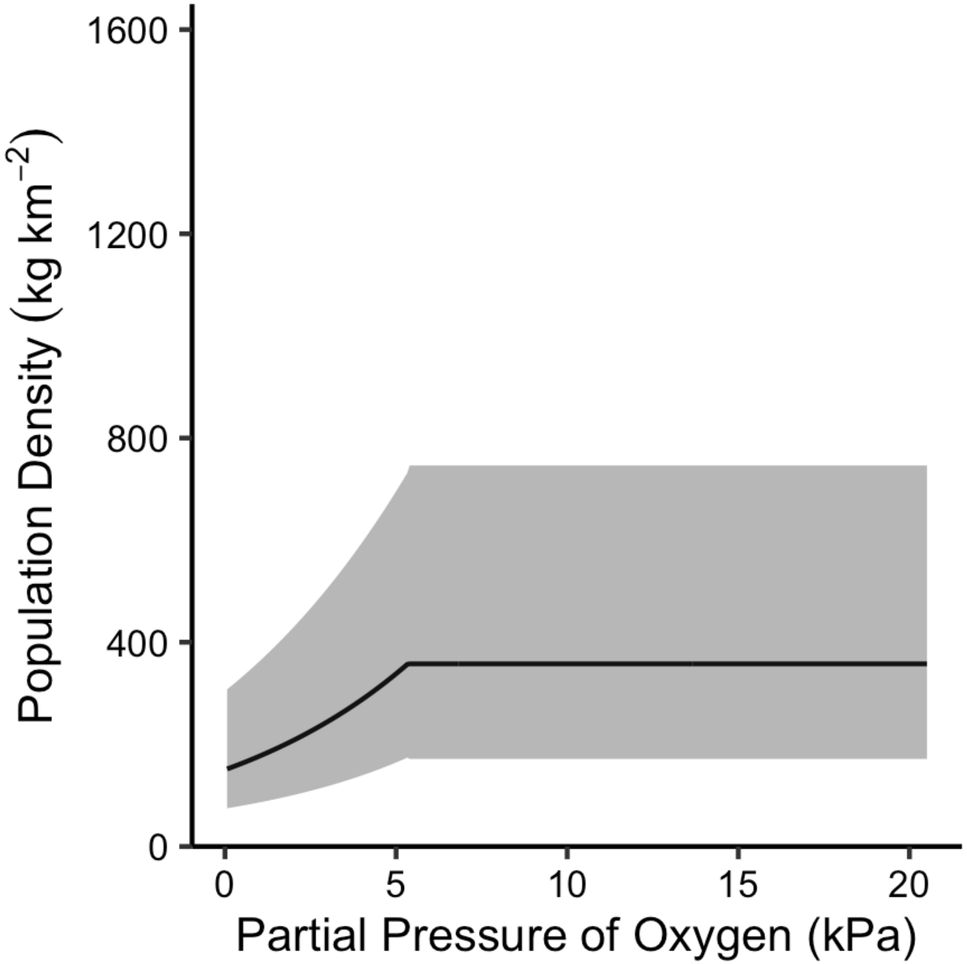
Sablefish Distributions in the California Current

Can we identify oxygen thresholds?

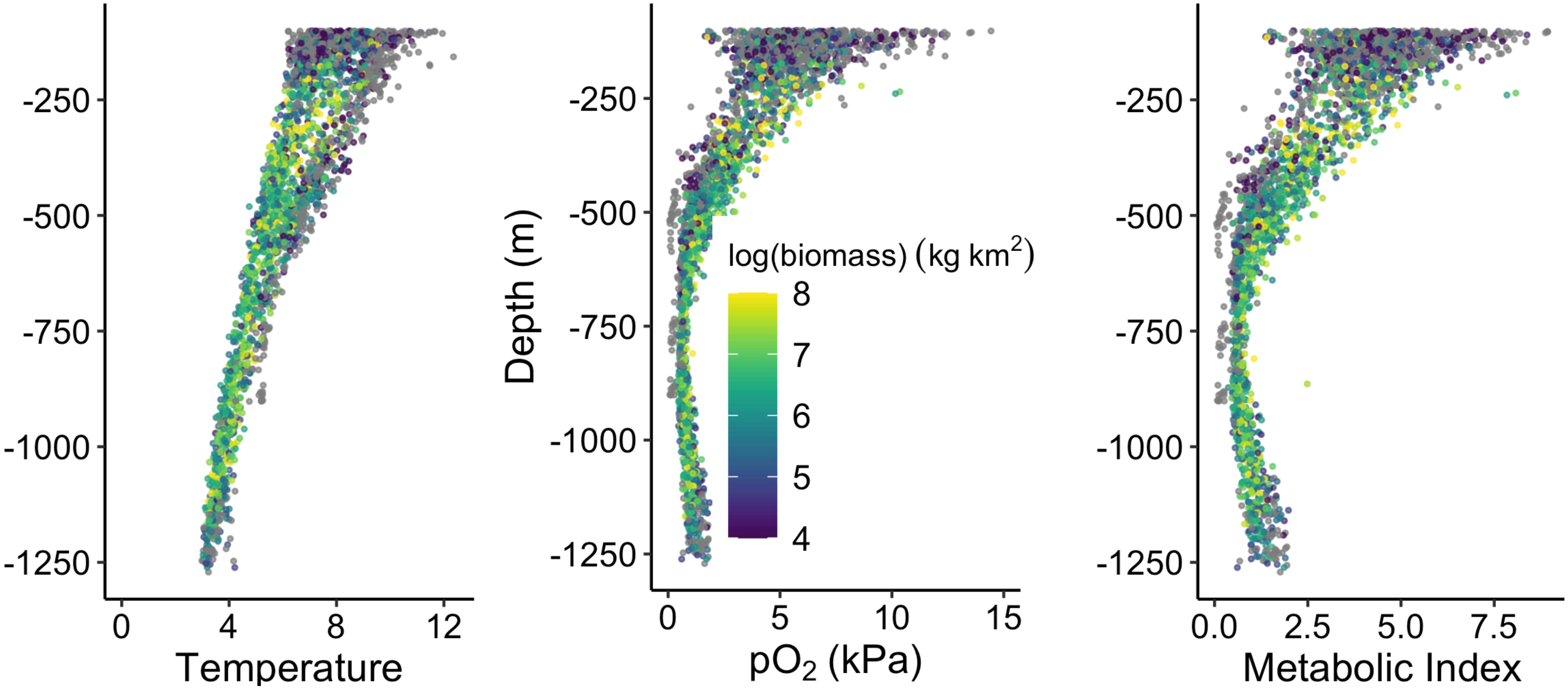
Does metabolic index improve predictions?



Yes! Threshold effects are estimated!



No! Metabolic Index gets confused ….



Ongoing Activities

- Can we predict oxygen sensitivities via metabolic index when lab experiments are lacking?
  - Hierarchical modeling approach
    - Nope
  - Species Distribution Approach
    - Working on it

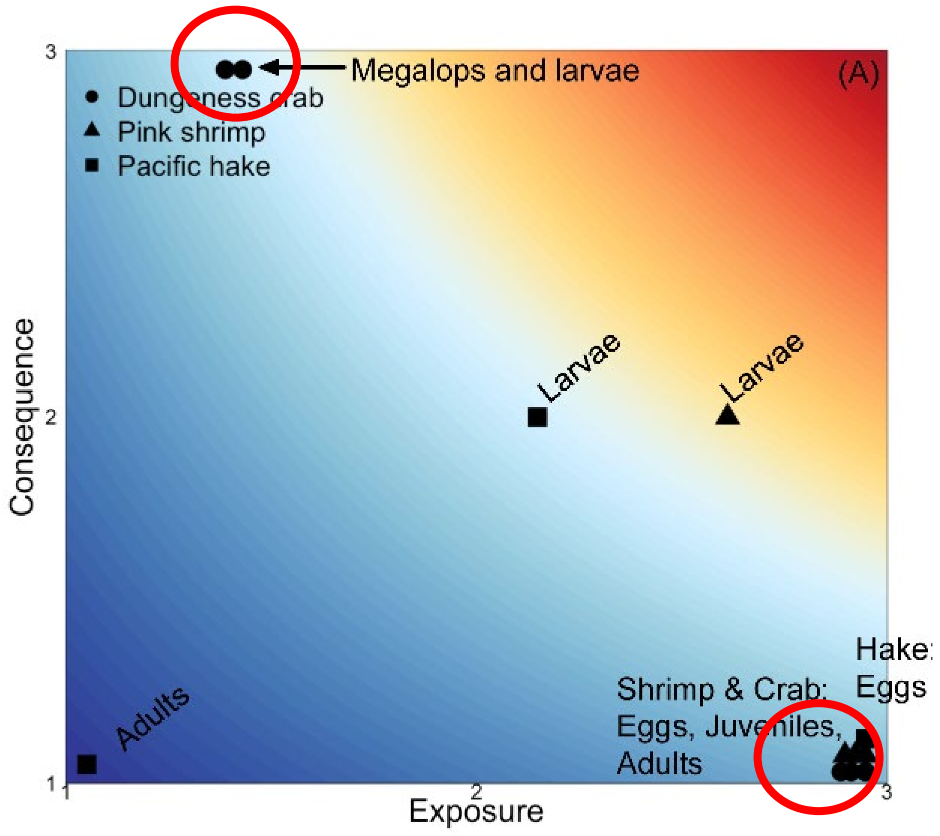
Moving forward in Puget Sound: A focus on Risk

Vulnerability Analysis

- Exposure – overlap between area of “bad” oxygen level (or metabolic index) and species (by life stage)

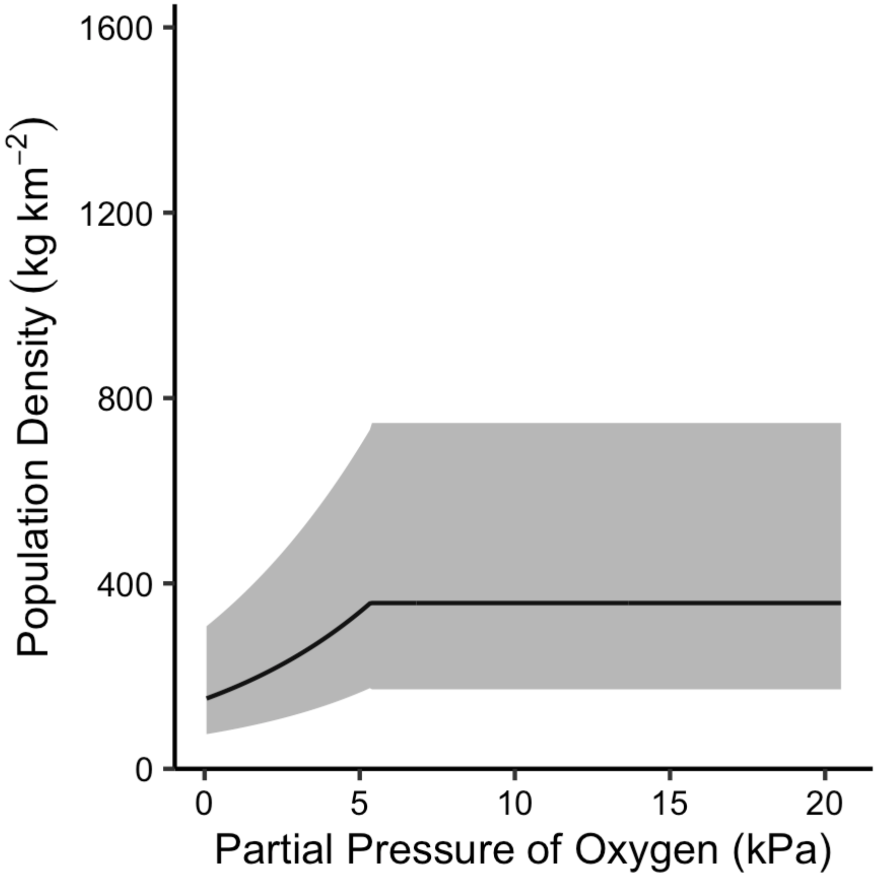
- Consequence at species level
  - Mortality
  - Development
  - Growth

Vulnerability Assessment: Dungeness Crab in the California Current



Pay attention to Dungeness Crab

Focus on Thresholds and Risk



Thank you to funders

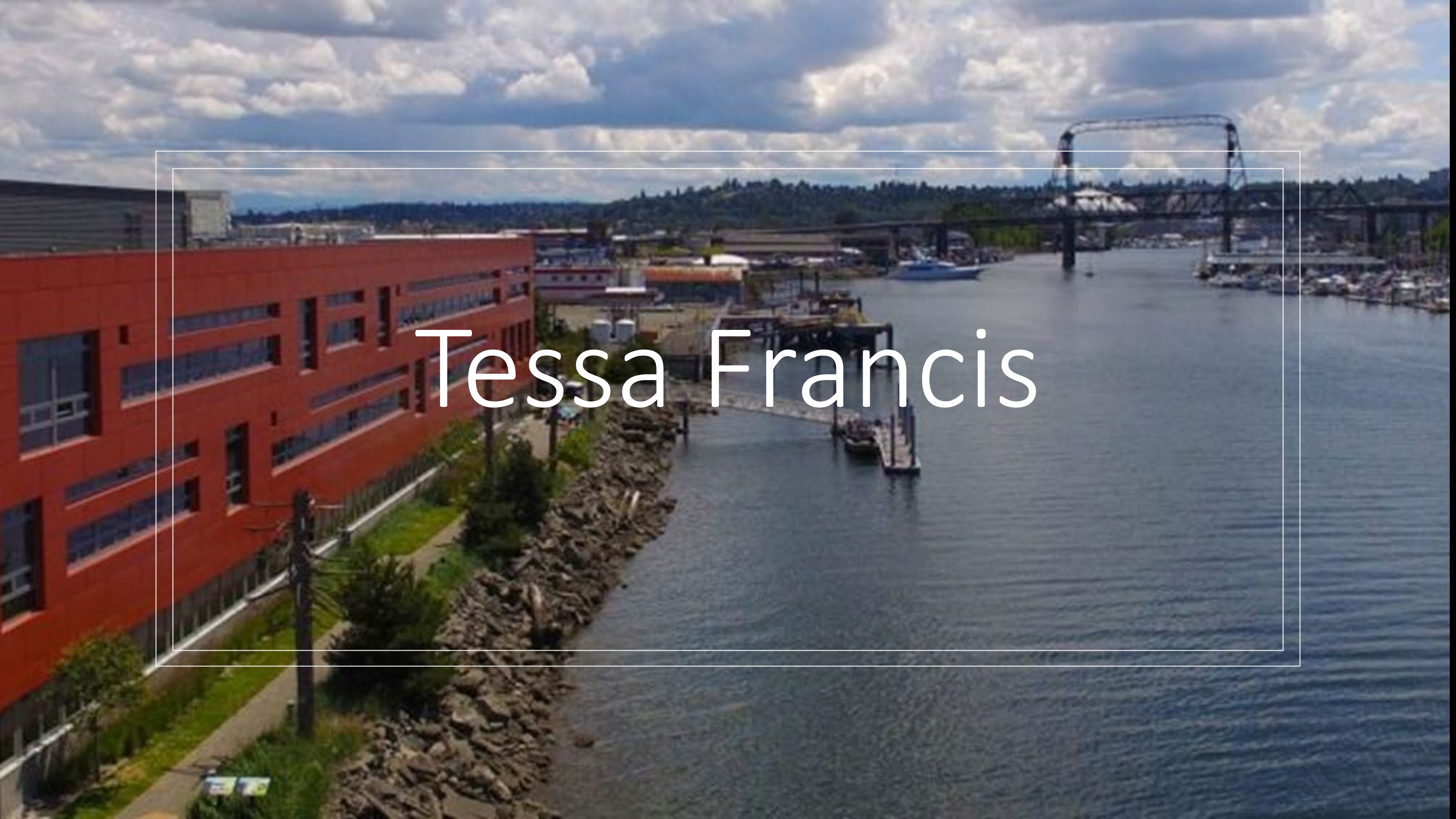
- National Science Foundation
- Washington Sea Grant
- Hood Canal Dissolved Oxygen Program
- NOAA Fisheries

Questions for the Region

Multiple-Stressors
+ Multiple Benefits

- How do we build on the current focus on dissolved oxygen and nutrients to include multiple stressors?
- How do we balance a species, key indicator, and ecosystem approach across different efforts?
- How do we incorporate ideas of adaptation and resilience in the face of climate change?


Questions?



Tessa Francis

Tessa Francis

UW Puget Sound Institute

Biological impacts of low oxygen levels on Puget Sound species

Biological impacts of low oxygen levels to Puget Sound species

Objective:

- Describe potential risk to Puget Sound species (mostly fish) of low oxygen levels in marine waters, using existing modeling output and literature sources.

A risk assessment framework

Risk = Exposure + Sensitivity

A risk assessment framework

Risk = Exposure + Sensitivity

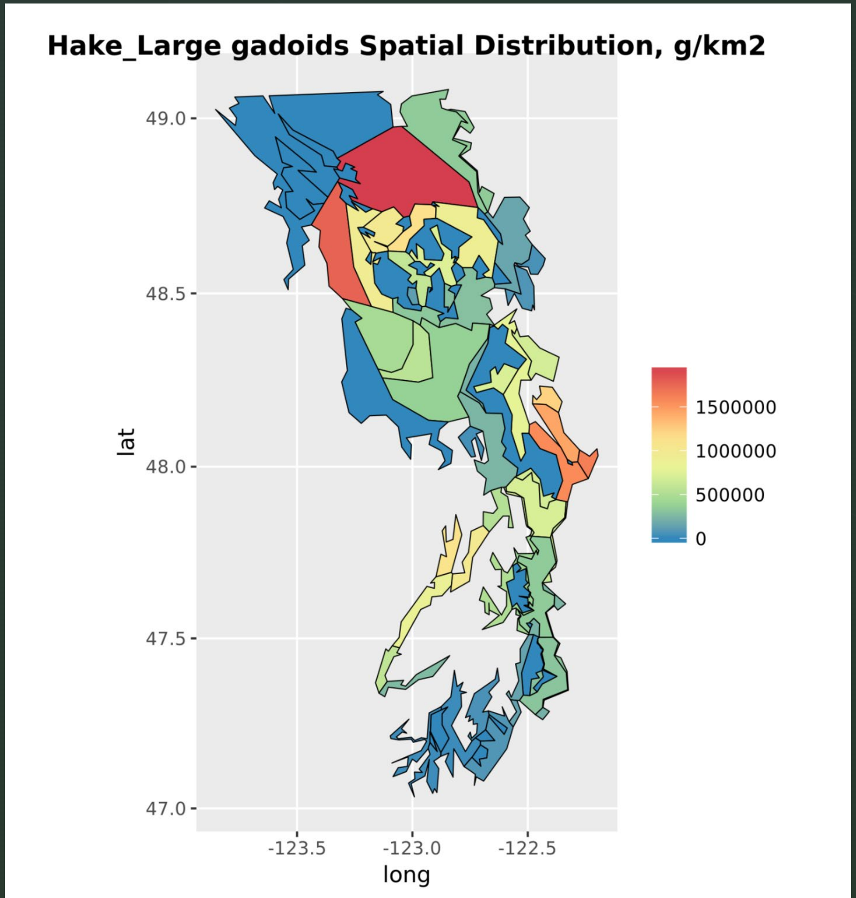
Species distribution

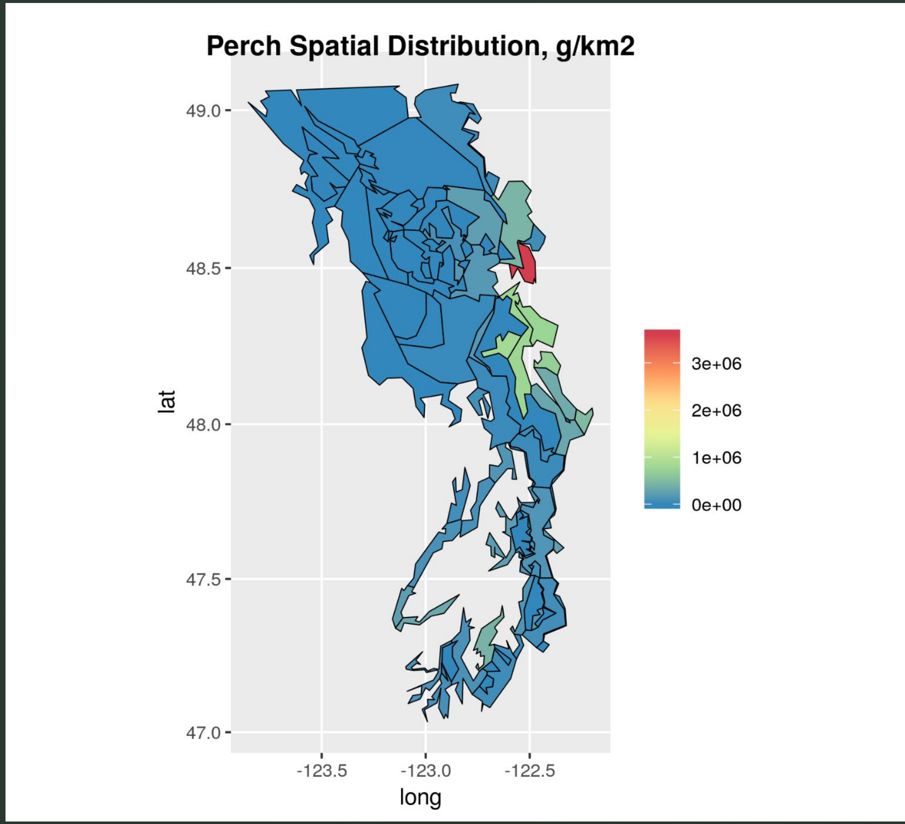
Oxygen patterns

Physiological effects

Exposure - I

- Species distribution
  Atlantis Ecosystem Model

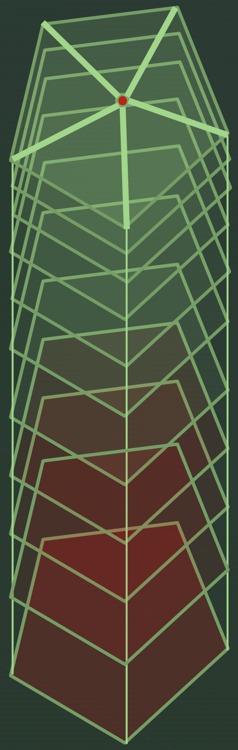




Courtesy of Hem Nalini Morzaria-Luna

Exposure - II

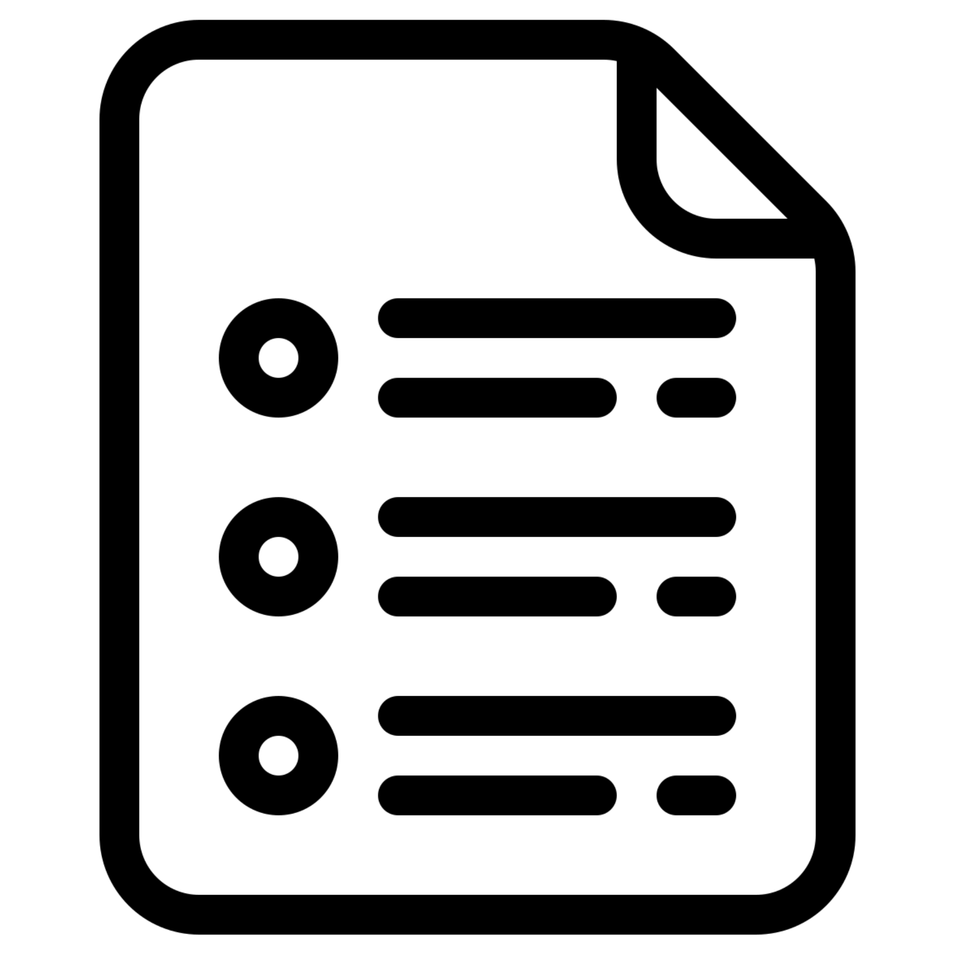
- Oxygen patterns
  Salish Sea Model



Ahmed et al. (2019)
2006 maximum dissolved oxygen depletions below the water quality standard due to all anthropogenic sources

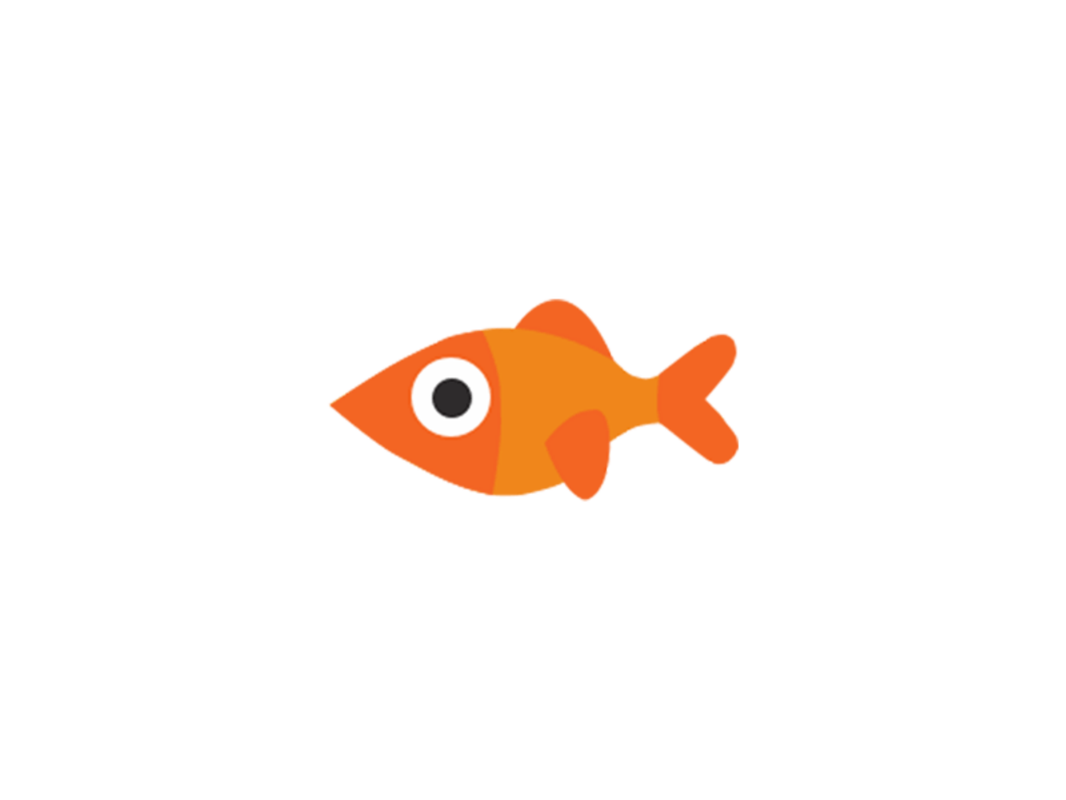
Sensitivity

- Literature review



Sensitivity

- Behavior
- Lethal vs sublethal effects
- Life stage




Contents lists available at SciVerse ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

ELSEVIER

Linking land- and sea-based activities to risk in coastal ecosystems

Jameal F. Samhouri *, Phillip S. Levin

Conservation Biology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 2725 Montlake Blvd. E, Seattle, WA 98112, USA

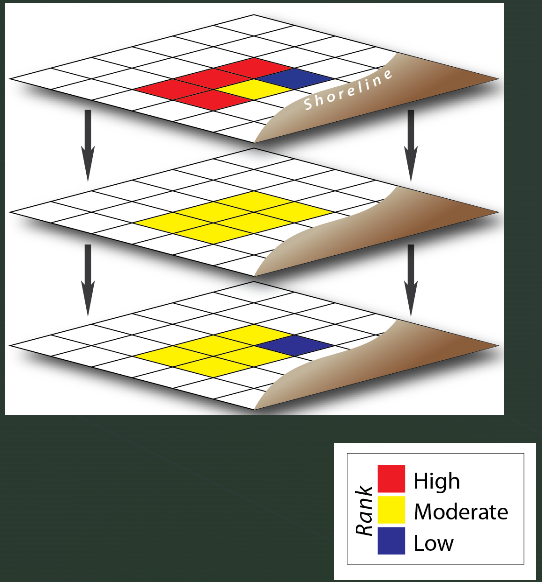
Exposure

<u>Qualitative criteria</u>

- Spatial overlap
- Temporal overlap
- Exploitation
- Etc.

Other criteria?

<u>Quantitative data</u>



Pressure

Species

Exposure

Contents lists available at SciVerse ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Linking land- and sea-based activities to risk in coastal ecosystems

Jameal F. Samhouri *, Phillip S. Levin

Conservation Biology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 2725 Montlake Blvd. E, Seattle, WA 98112, USA

Sensitivity

Qualitative criteria

- Severity of impact
  - Population
  - Individual
- Current status
- Intrinsic recovery factors
  - Replenishment rate
  - Connectivity

	1	2	3
Severity of impact (pop.)	<10% loss	10-50% loss	>50% loss

Other criteria?

Contents lists available at SciVerse ScienceDirect

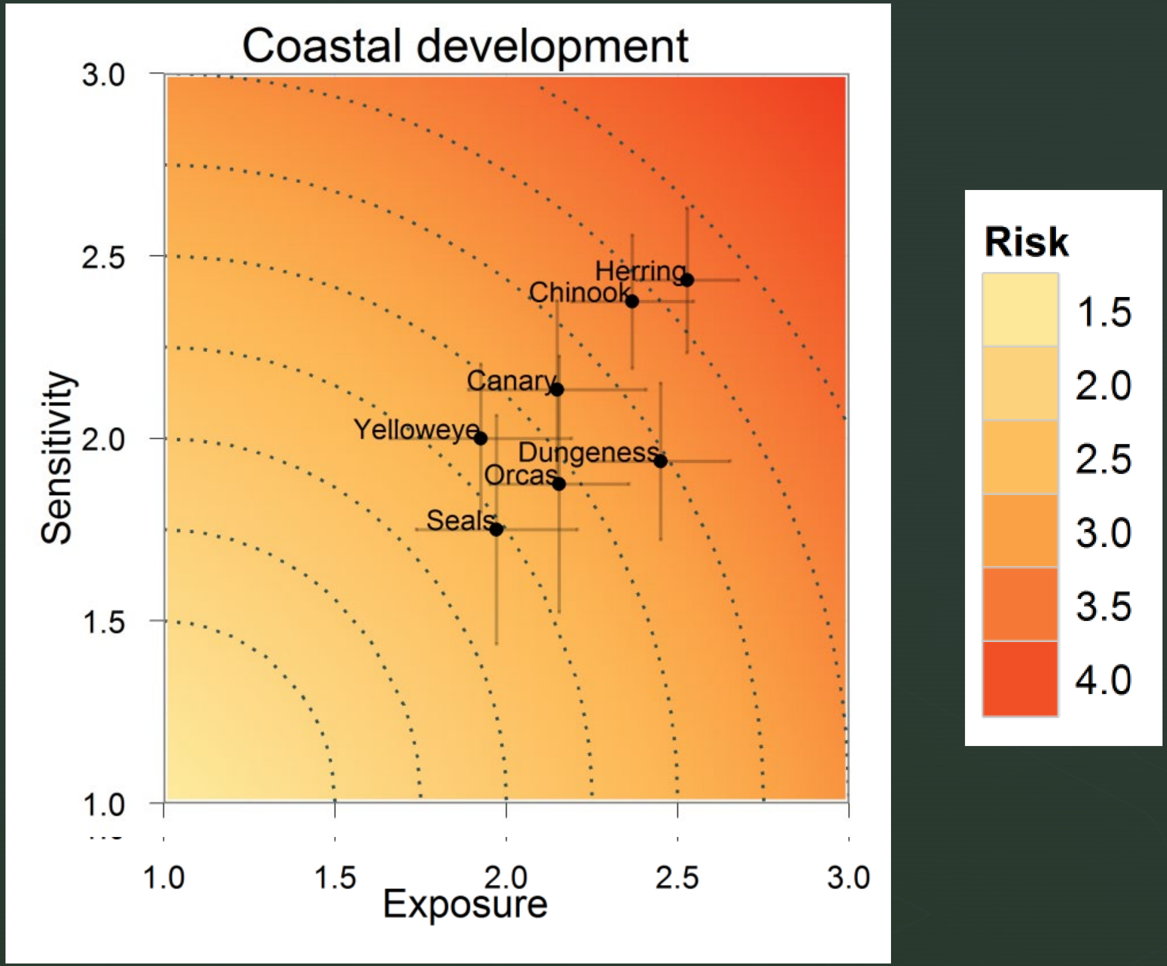
Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

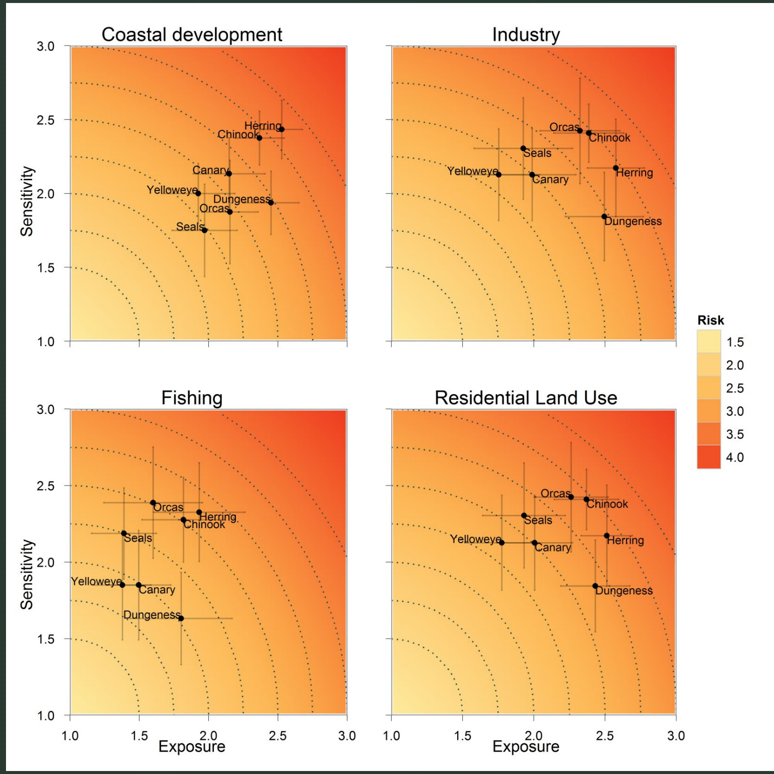
Linking land- and sea-based activities to risk in coastal ecosystems

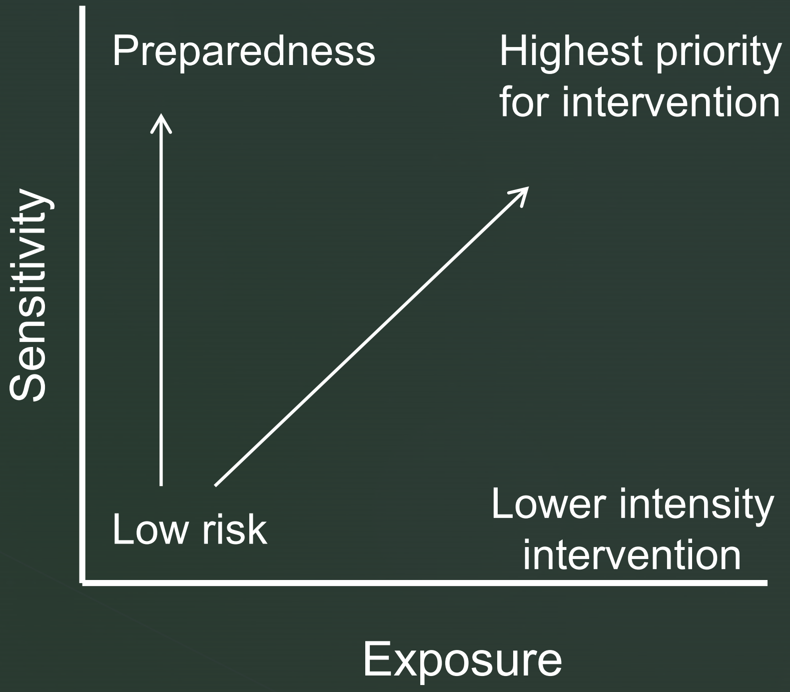
Jameal F. Samhouri *, Phillip S. Levin

Conservation Biology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 2725 Montlake Blvd. E, Seattle, WA 98112, USA



- Use an understanding of risk to prioritize action





- Take a multi-stressor approach

Thank you!

- tessa@uw.edu


Q&A

Wrap up

- We'll share the presentation materials, recording, and a summary of the discussion
- Subscribe for updates at http://eepurl.com/h5nxsr
- Share any people, programs, or studies we should connect with
- Continue the discussion
  - Email Stefano Mazzilli (mazzilli@uw.edu) and Marielle Larson (marlars@uw.edu) to connect directly
  - Join the upcoming workshops to dig in further

Upcoming Workshops

Sediment exchange *(10/17)*

Phytoplankton and primary production *(11/2)*

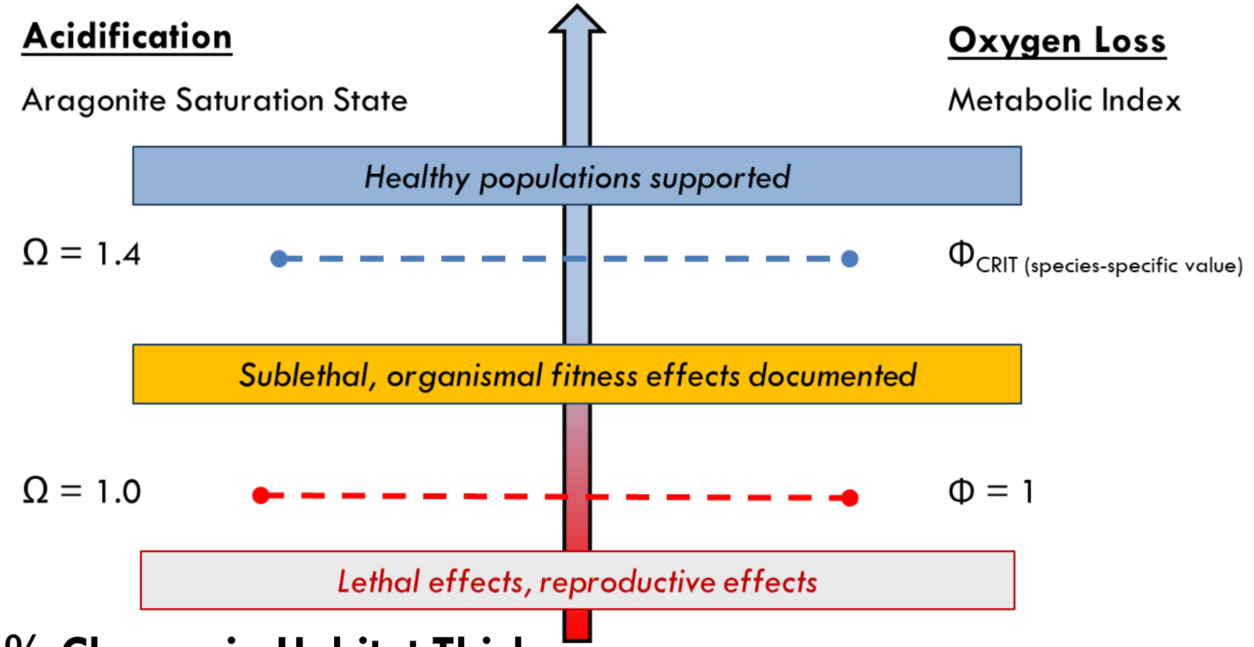
Change in interannual variability of rivers and ocean impact *(week of 11/14)*

Improve watershed modeling to evaluate source reduction strategies to adaptively manage strategies *(week of 12/12)*

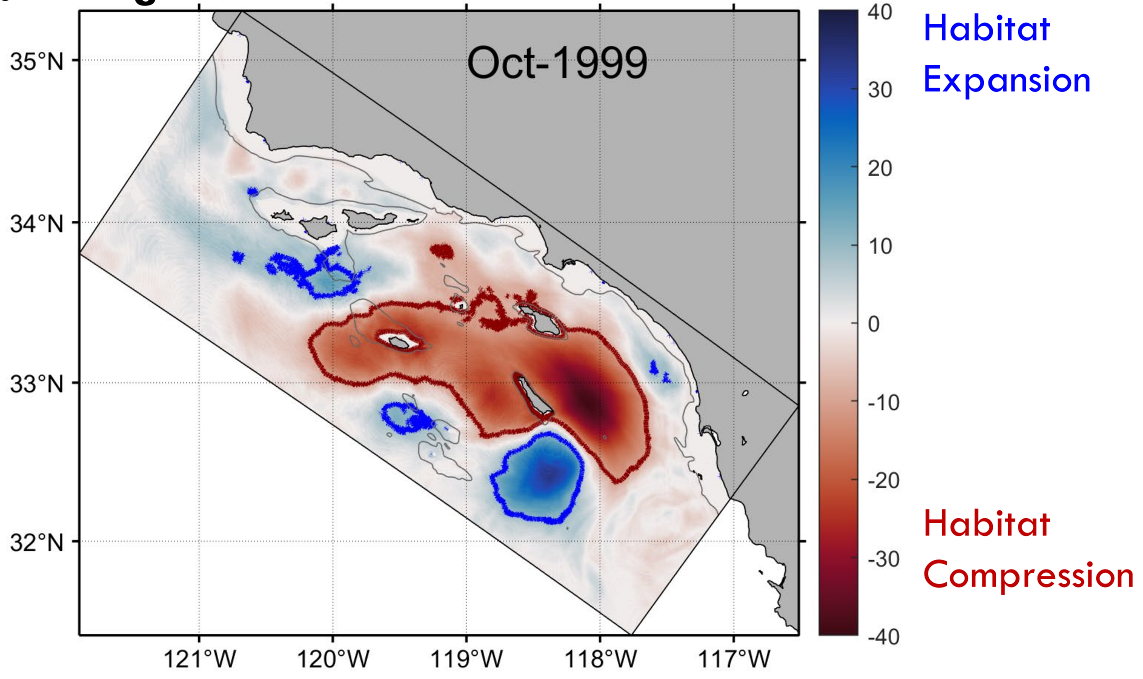

Appendix

Supporting Line of Evidence: Metabolic Index

Combines pO_2 with temperature-dependent biological responses to oxygen in order to define “aerobically available habitat”

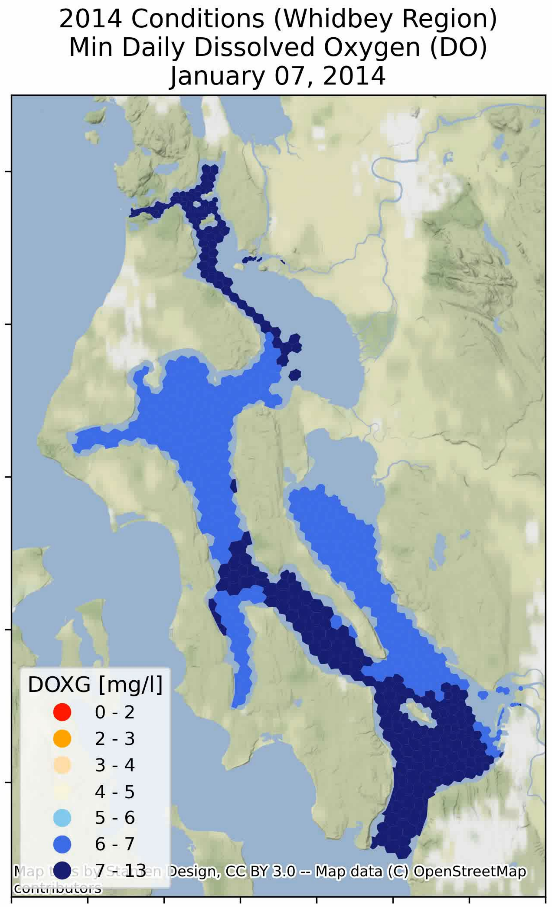


% Change in Habitat Thickness



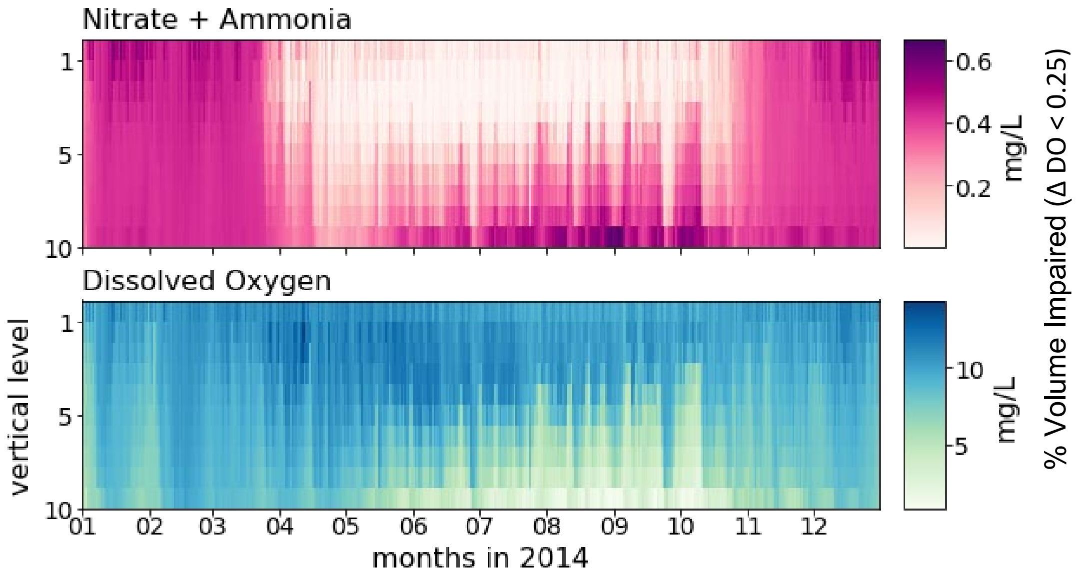
[Presentation by Martha Sutula at The Science of Puget Sound Water Quality workshop on July 26, 2022]

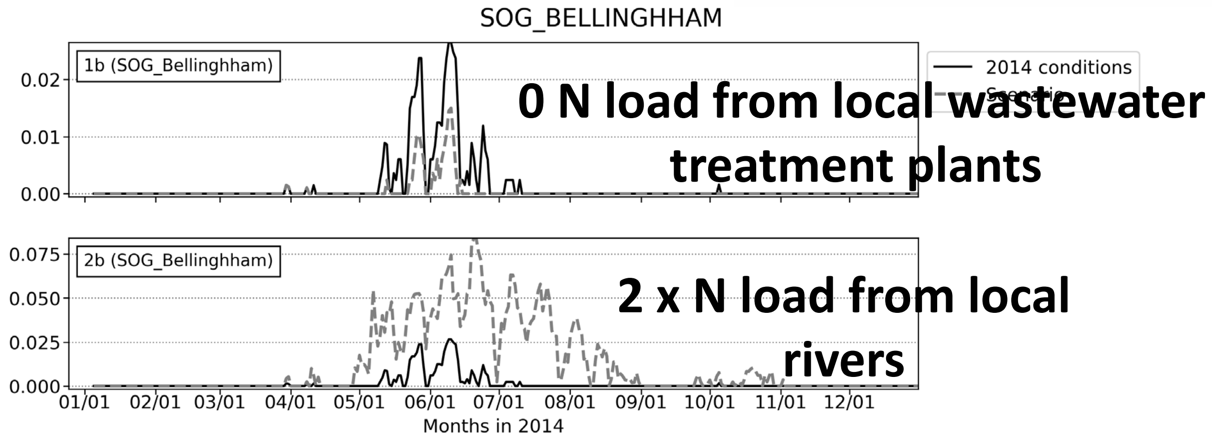
Modeling Capacity and Interpretation



Streamlined analyses to existing parameters (e.g., dissolved oxygen, temperature, net primary production rates, etc.):

- Across time, depth, and location, including:
  - — Annually, seasonally, or daily
  - — By basin and embayment
- From a range of perspectives (e.g., absolute values, non-compliance days, % volume days, etc.
- Under scenarios with different loading inputs at each wastewater treatment plant and river





Supporting Line of Evidence: DO Variability

Annually, seasonally or daily:

- Minimum dissolved oxygen
- Dissolved oxygen variability
- Rate of dissolved oxygen change
- Number of hypoxia exposures
- Hypoxia exposure duration (hours)
- Hypoxia return time (hours)

e.g., Low et al. (2021)