



Predicting the unpredictable - a macroecological approach towards future ecosystem scenarios

Thomas Brey, AWI

T.Brey 2012

HELMHOLTZ
GEMEINSCHAFT

Natasha Del Cid 2011

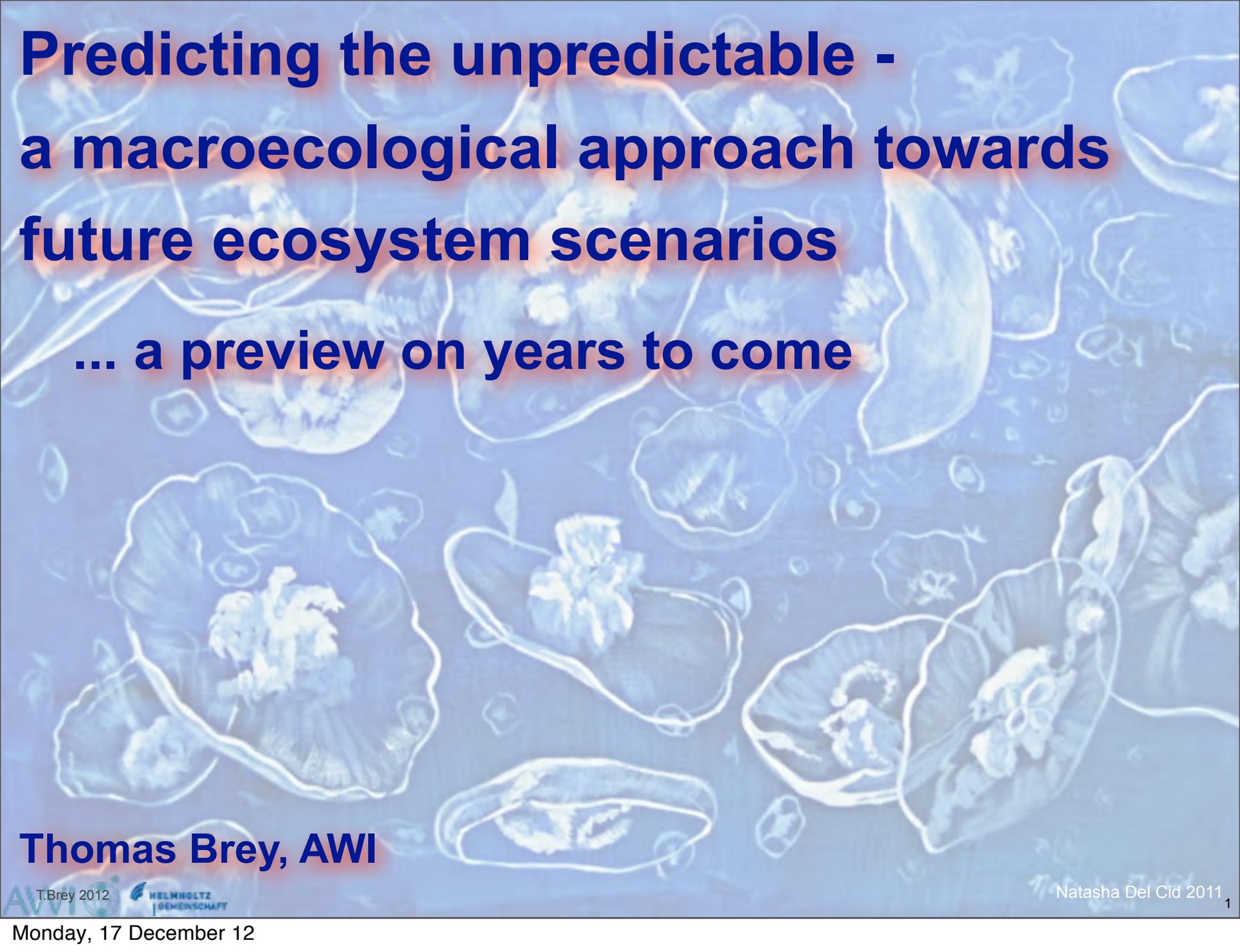
1

Monday, 17 December 12

Predicting the unpredictable - a macroecological approach towards future ecosystem scenarios

Macroecology = study of relationships between organisms and their environment at large spatial scales to characterise and explain statistical patterns of abundance, distribution and diversity (Brown 1989)

Thomas Brey, AWI



**Predicting the unpredictable -
a macroecological approach towards
future ecosystem scenarios
... a preview on years to come**

Thomas Brey, AWI

T.Brey 2012



Natasha Del Cid 2011

Predicting the unpredictable - a macroecological approach towards future ecosystem scenarios

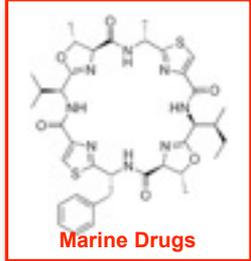
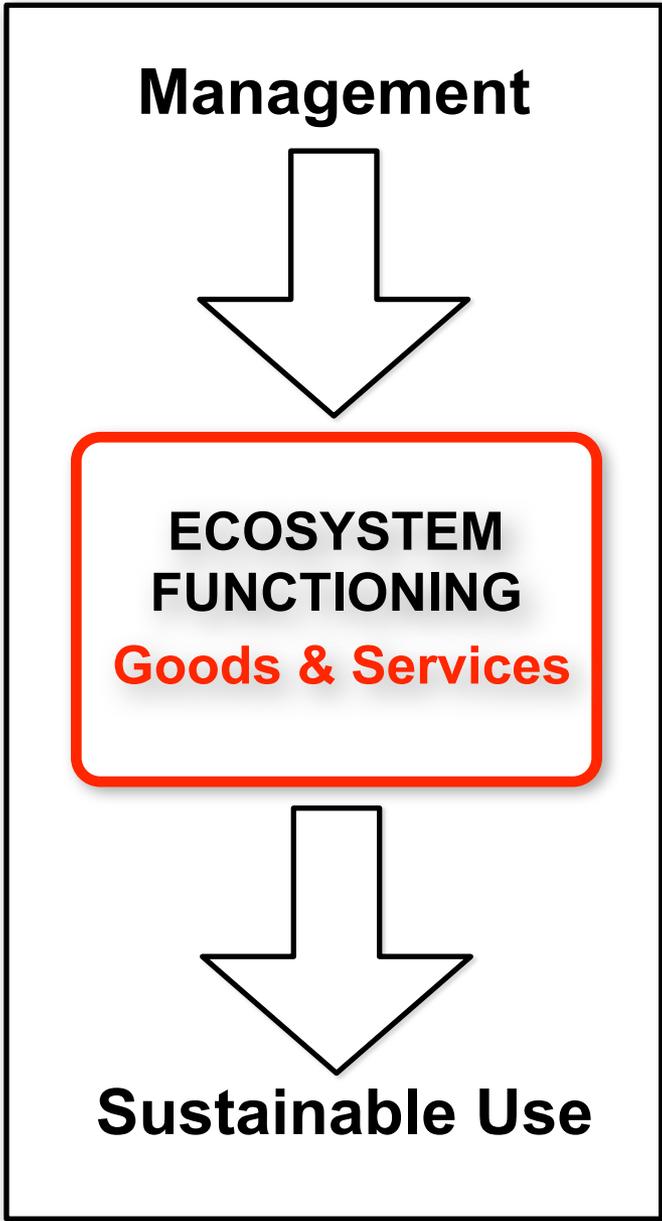
... a preview on years to come

... with focus on the
benthic compartment

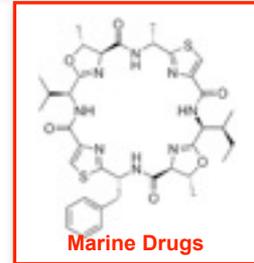
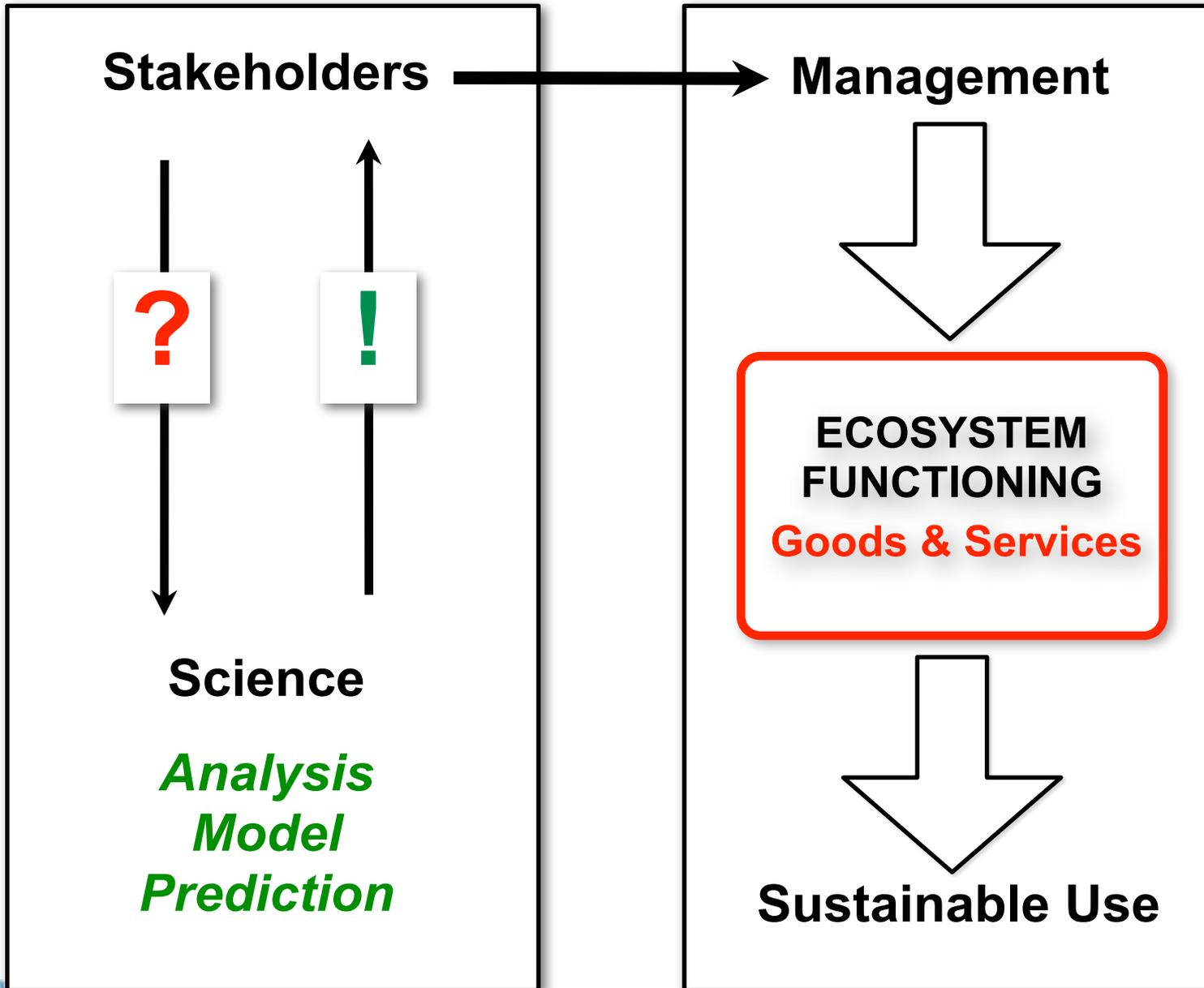


Thomas Brey, AWI

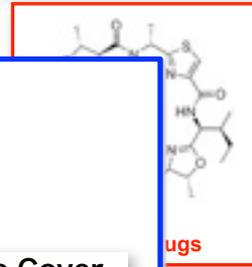
What are we expected to deliver ?



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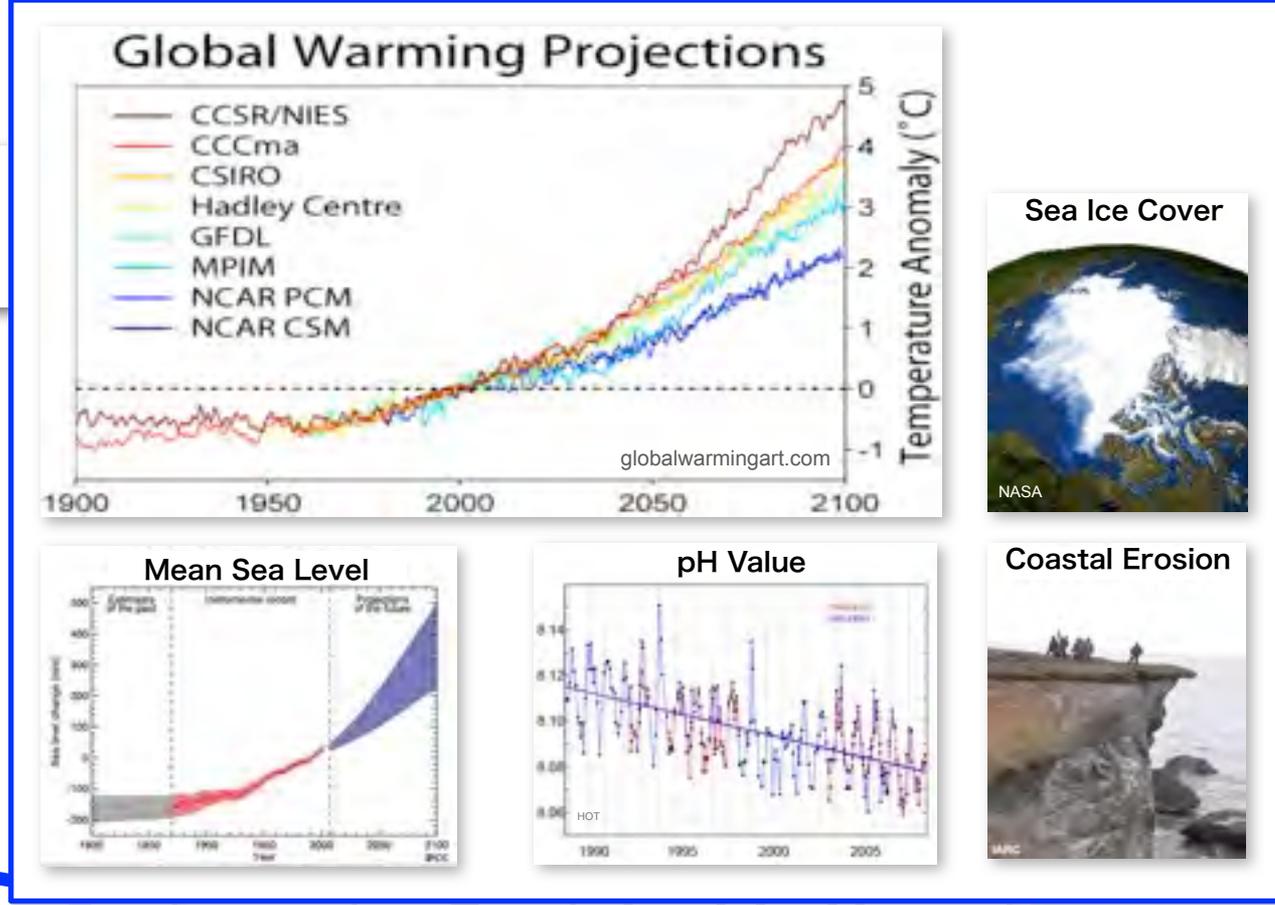
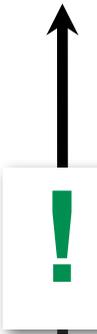


What are we expected to deliver ?



Stakeholders

Management



Science

Analysis
Model
Prediction

Sustainable Use

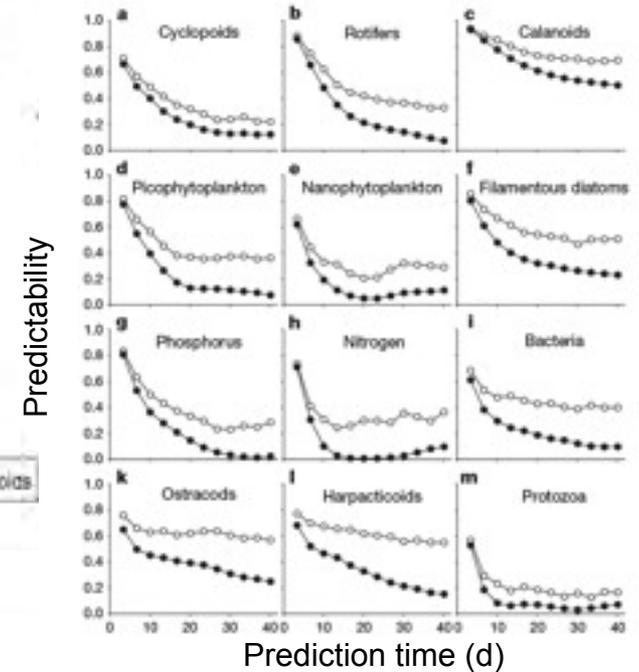
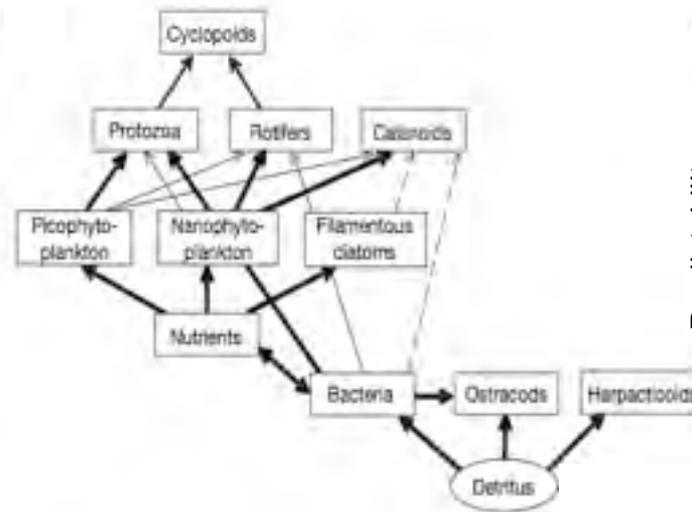
Why is ecosystem modeling so difficult ?

Why is ecosystem modeling so difficult ?

- *Non-deterministic ecological processes*

Benincá et al. 2008 Nature 451

Chaos in a long-term experiment with a plankton community



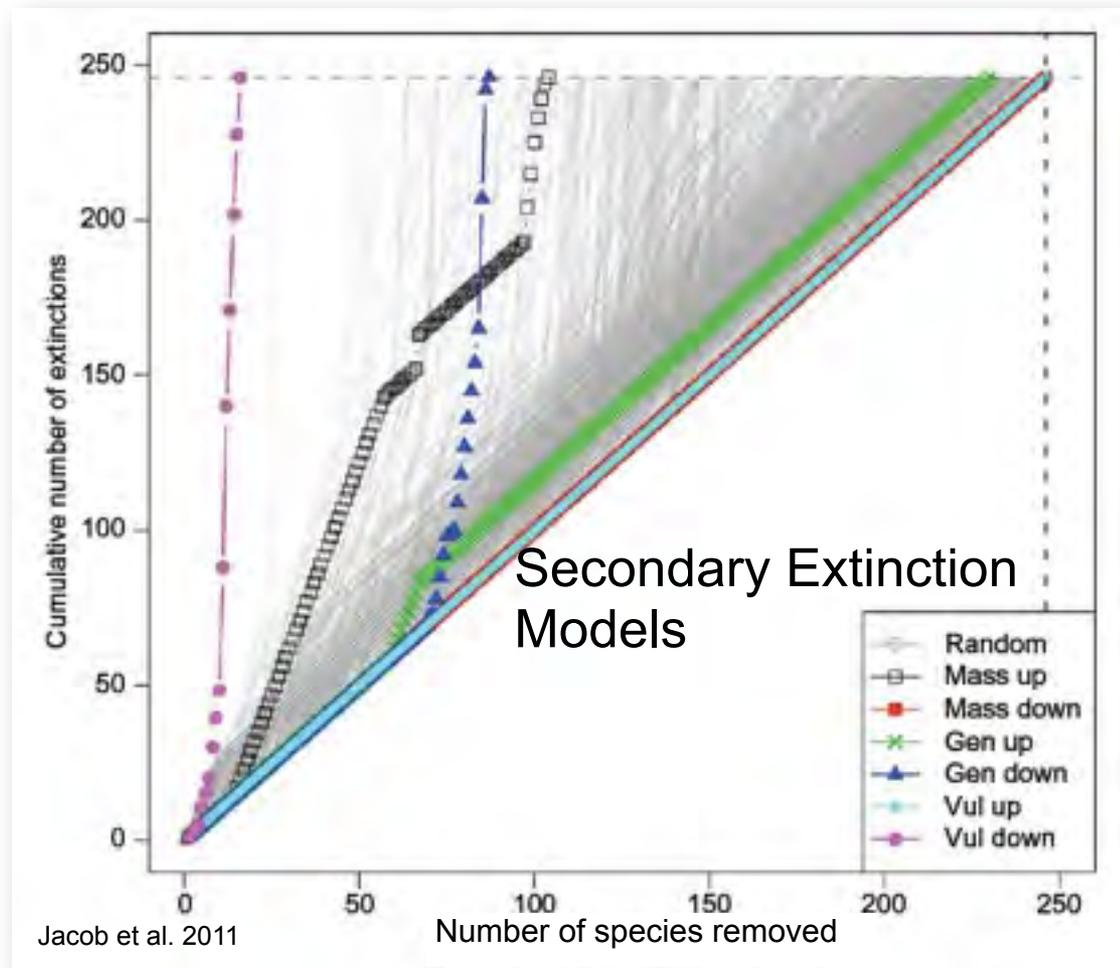
Why is ecosystem modeling so difficult ?

- *Non-deterministic ecological processes*
- *The players: genetic, taxonomic, functional diversity ?*



Why is ecosystem modeling so difficult ?

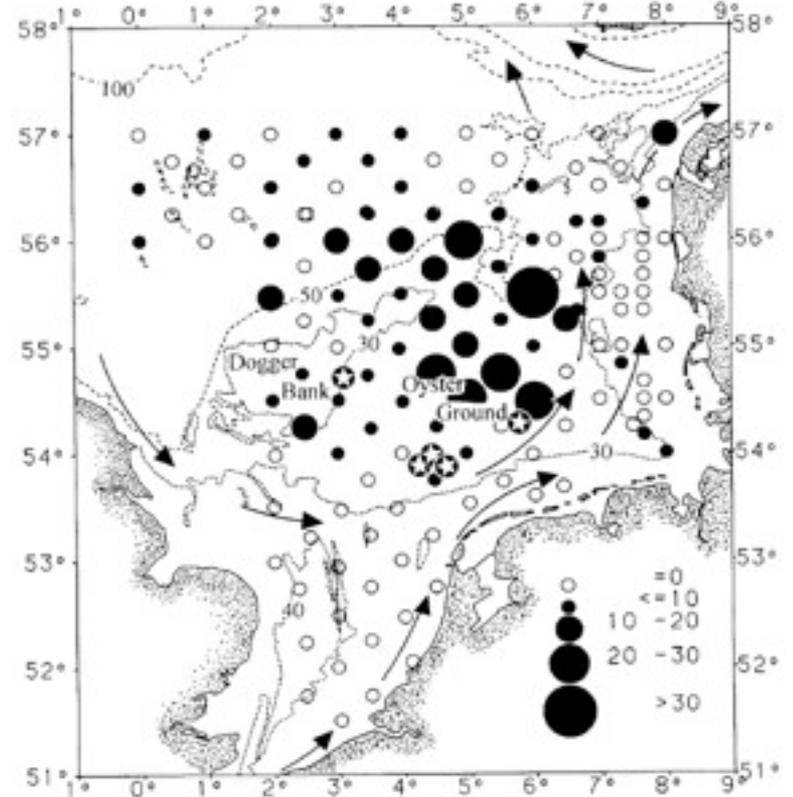
- *Non-deterministic ecological processes*
- *The players: genetic, taxonomic, functional diversity ?*
- *The rules: “1st Principles” in ecophysiology & ecology ?*



Why is ecosystem modeling so difficult ?

- *Non-deterministic ecological processes*
- *The players: genetic, taxonomic, functional diversity ?*
- *The rules: “1st Principles” in ecophysiology & ecology ?*
- *Spatial heterogeneity of state & change*

Arctica islandica
in the southern North Sea



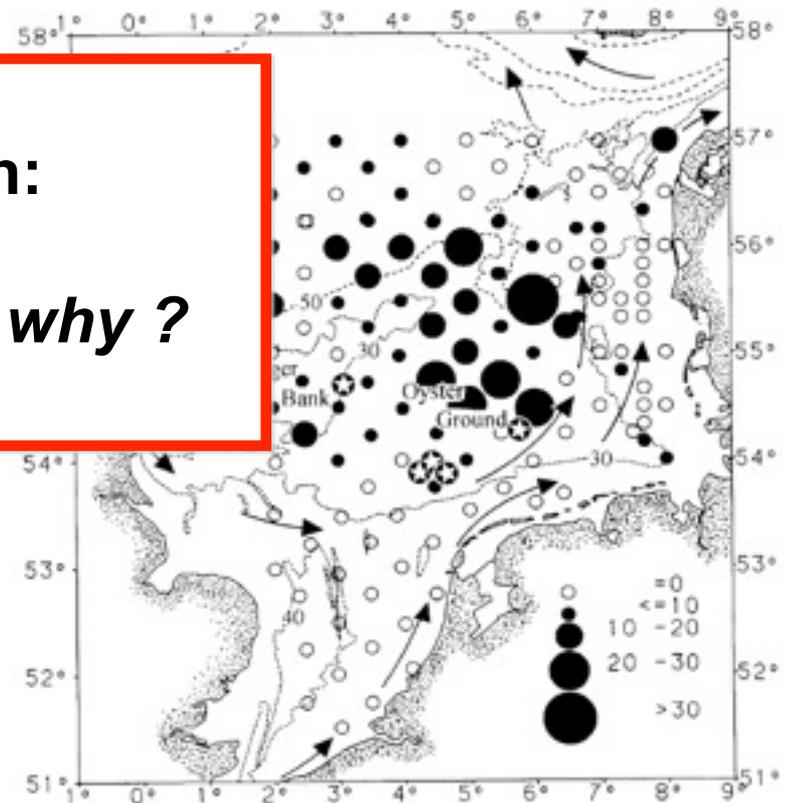
Witbaard et al. 1994

Why is ecosystem modeling so difficult ?

- *Non-deterministic ecological processes*
- *The players: genetic, taxonomic, functional diversity ?*
- *The rules: "1st Principles" in ecophysiology & ecology ?*
- ***Spatial heterogeneity of state & change***

Spatially explicit approach:

Who is doing what, where and why ?

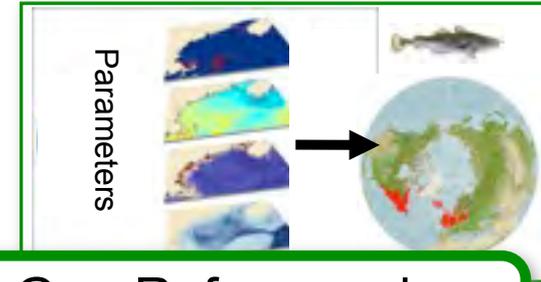


Witbaard et al. 1994

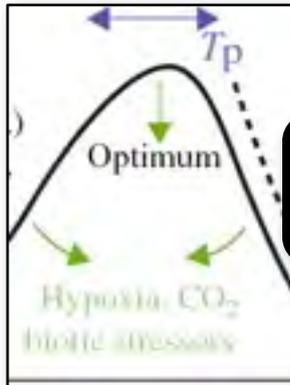
Is the whole > the sum of its parts ?



Dynamic
Habitat Models



Geo-Referenced
Ecological Niche Models



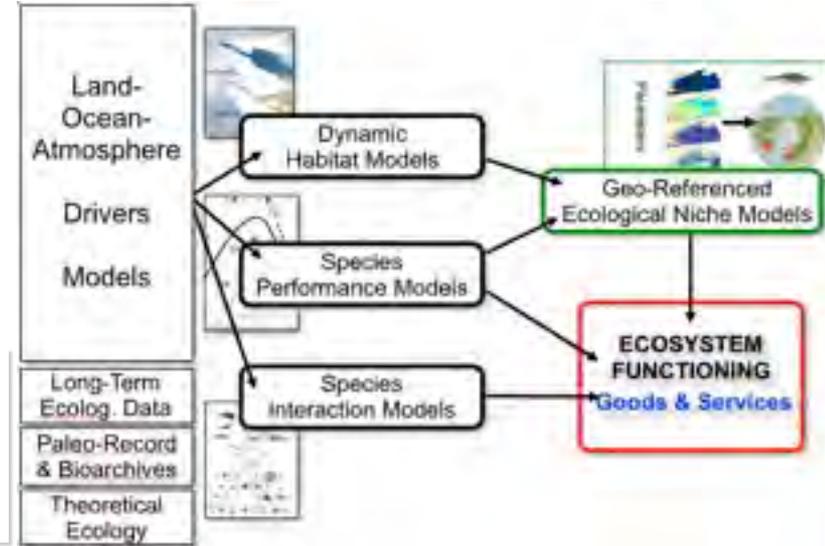
Species
Performance Models

Species
Interaction Models



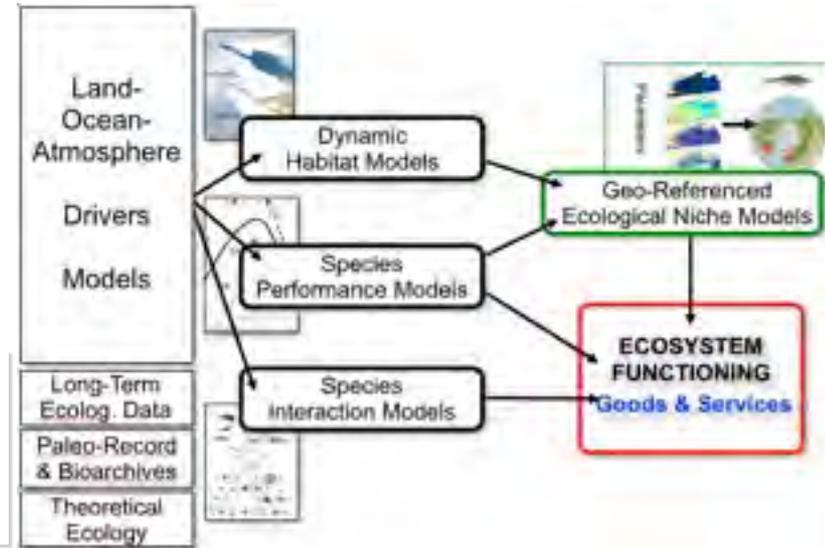
**ECOSYSTEM
FUNCTIONING**
Goods & Services

Is the whole > the sum of its parts ?



Implicit chapter headings...

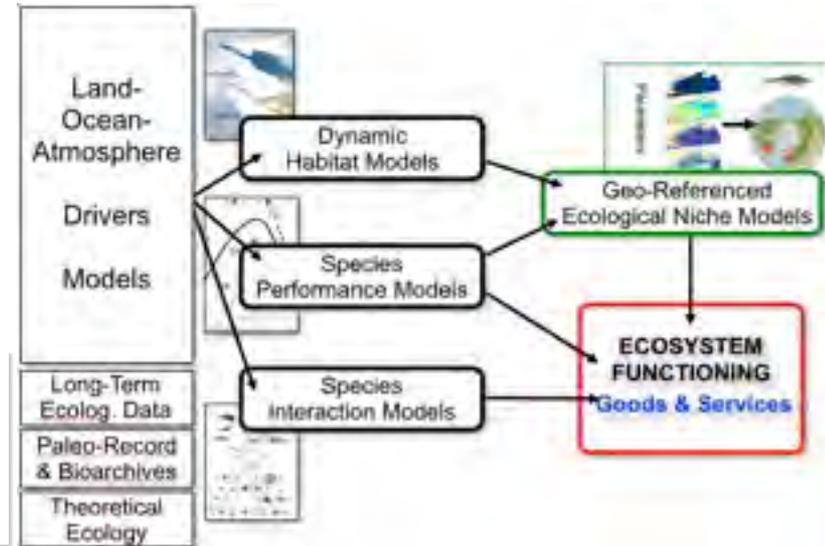
Is the whole > the sum of its parts ?



Implicit chapter headings...

- **Geostatistics + niche models = game changer**

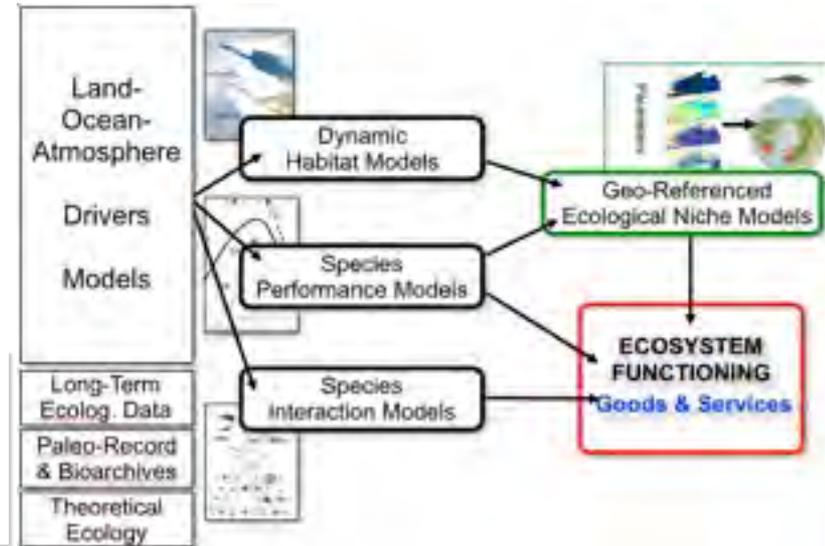
Is the whole > the sum of its parts ?



Implicit chapter headings...

- **Geostatistics + niche models = game changer**
- **Measuring performance of benthic biota**

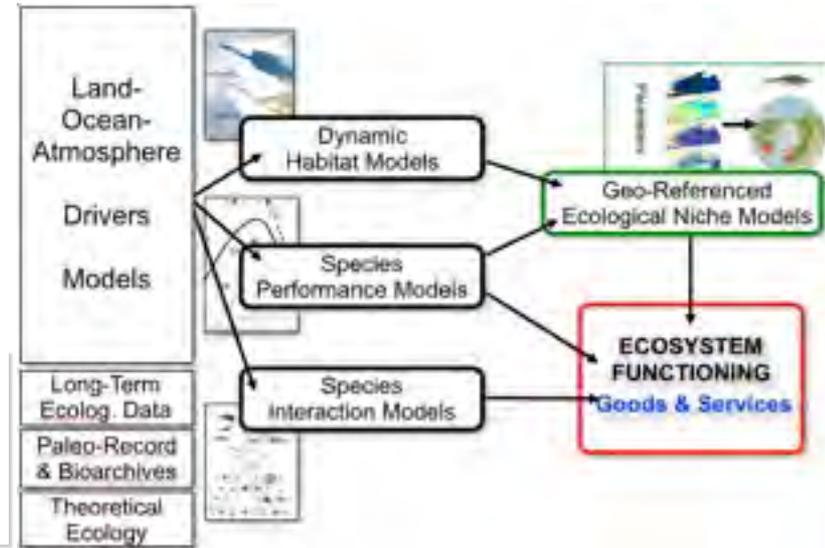
Is the whole > the sum of its parts ?



Implicit chapter headings...

- **Geostatistics + niche models = game changer**
- **Measuring performance of benthic biota**
- **Linking the biosphere to its drivers**

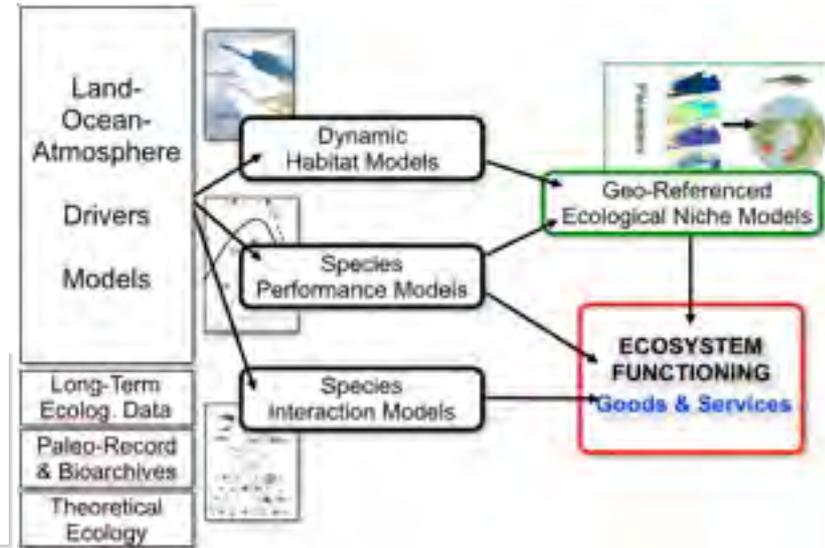
Is the whole > the sum of its parts ?



Implicit chapter headings...

- **Geostatistics + niche models = game changer**
- **Measuring performance of benthic biota**
- **Linking the biosphere to its drivers**
- **A holistic view from the service side**

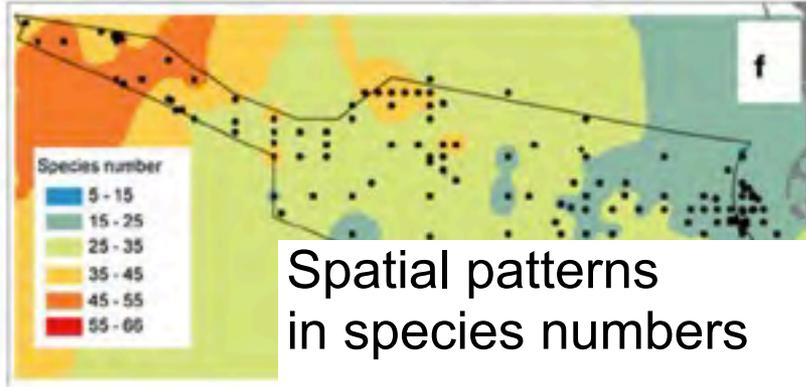
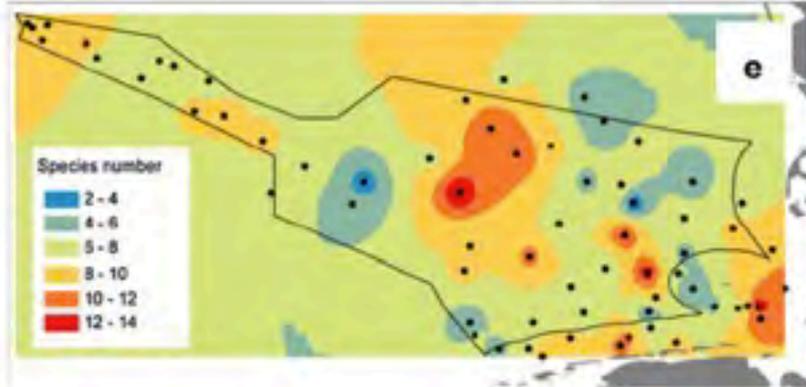
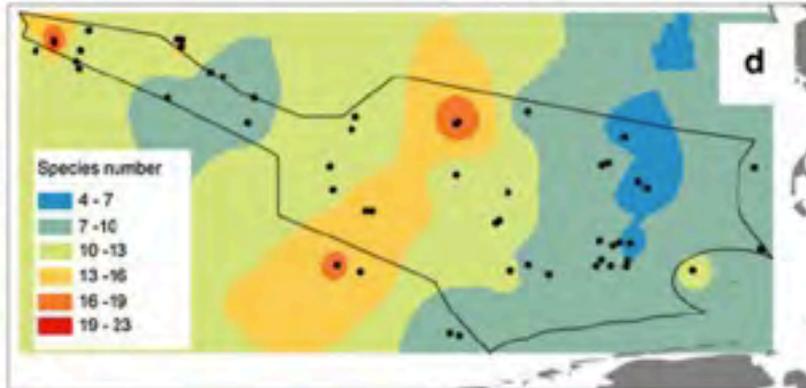
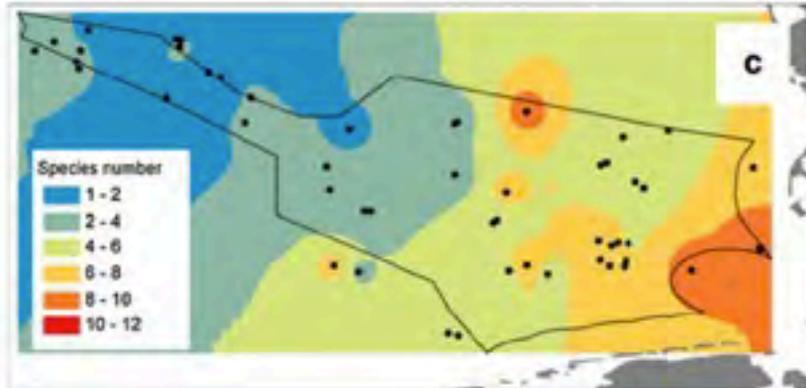
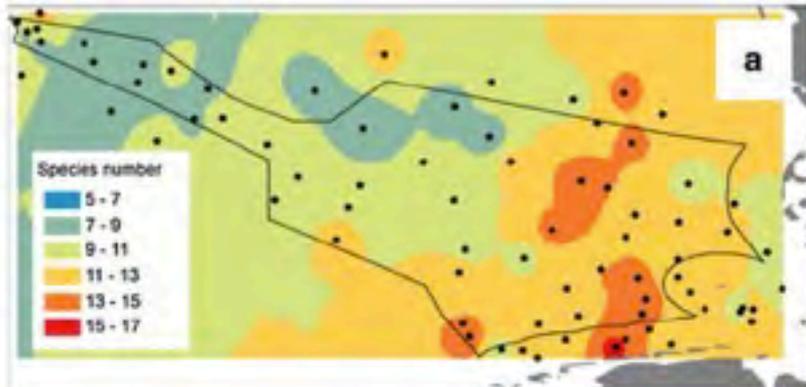
Is the whole > the sum of its parts ?



Implicit chapter headings...

- **Geostatistics + niche models = game changer**
- **Measuring performance of benthic biota**
- **Linking the biosphere to its drivers**
- **A holistic view from the service side**
- **Our regional focus**

Geostatistics - Spatial pattern analysis



Spatial patterns
in species numbers

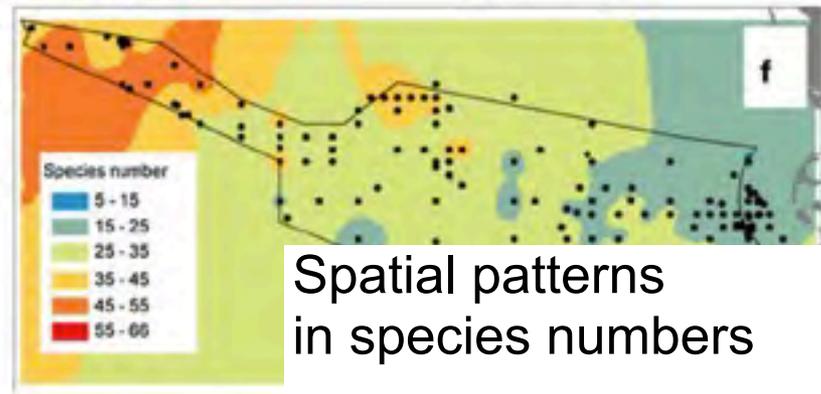
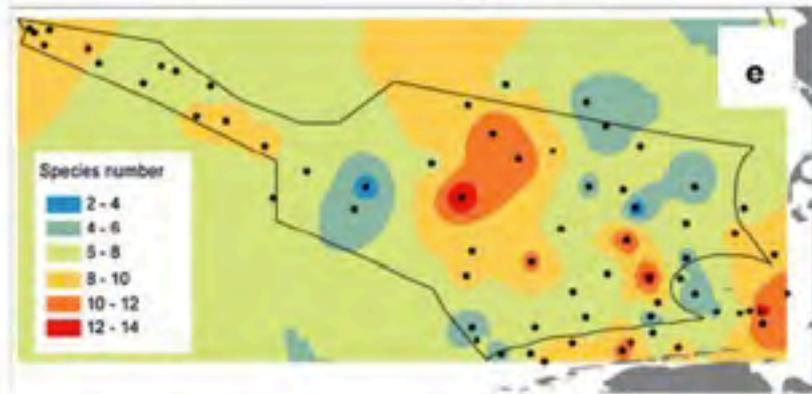
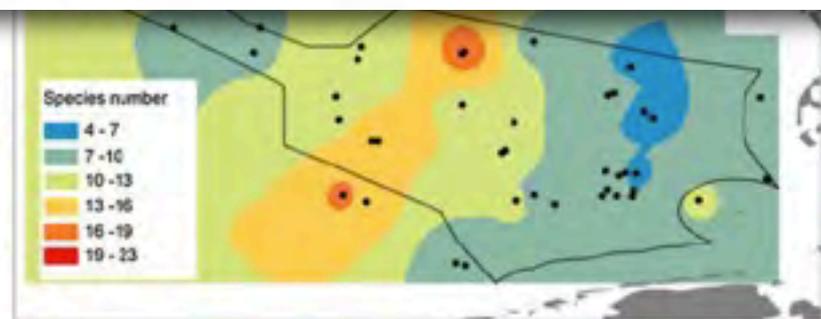
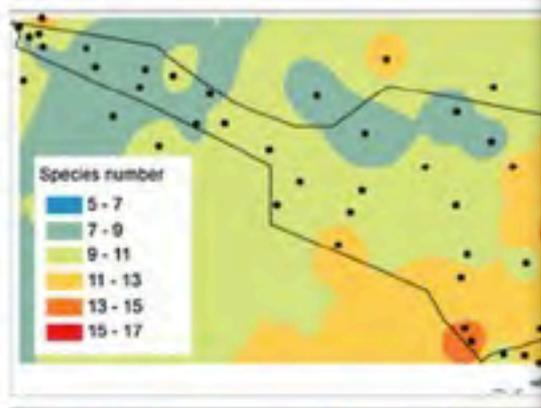
Geostatistics - Spatial pattern analysis

Helgol Mar Res
DOI 10.1007/s10152-012-0334-z

ORIGINAL ARTICLE

Benthos and demersal fish habitats in the German Exclusive Economic Zone (EEZ) of the North Sea

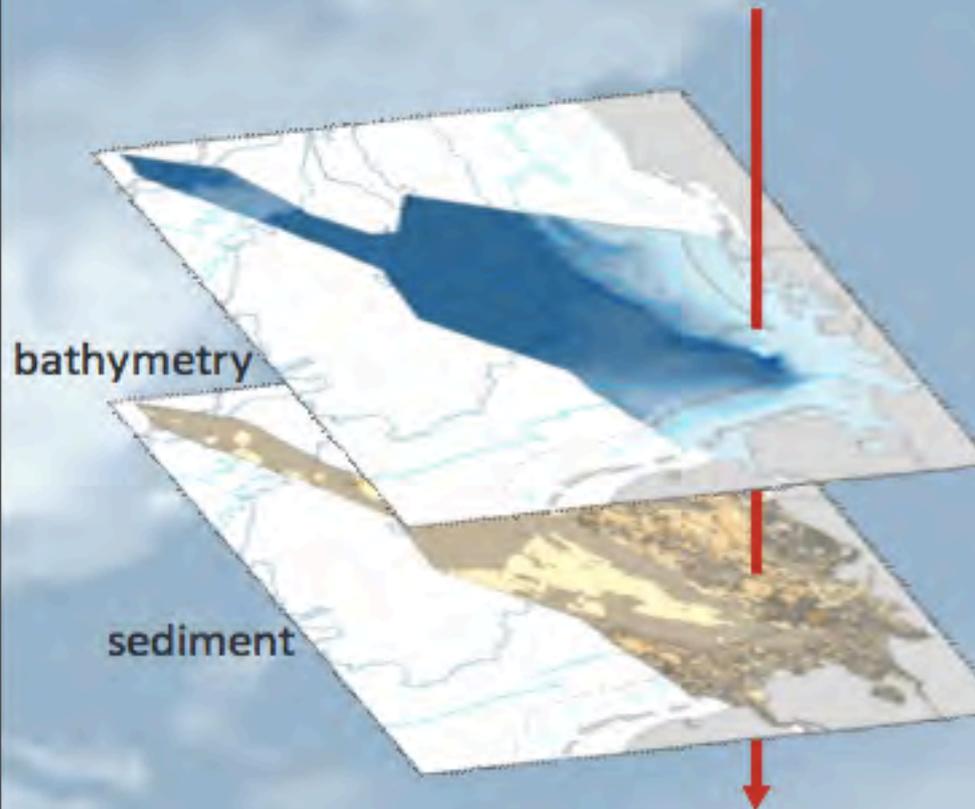
Hermann Neumann · Henning Reiss · Siegfried Ehrlich ·
Anne Sell · Kay Panten · Matthias Kloppmann ·
Ingo Wilhelms · Ingrid Kröncke



Spatial patterns in species numbers

Benthic habitat modeling

Habitat information



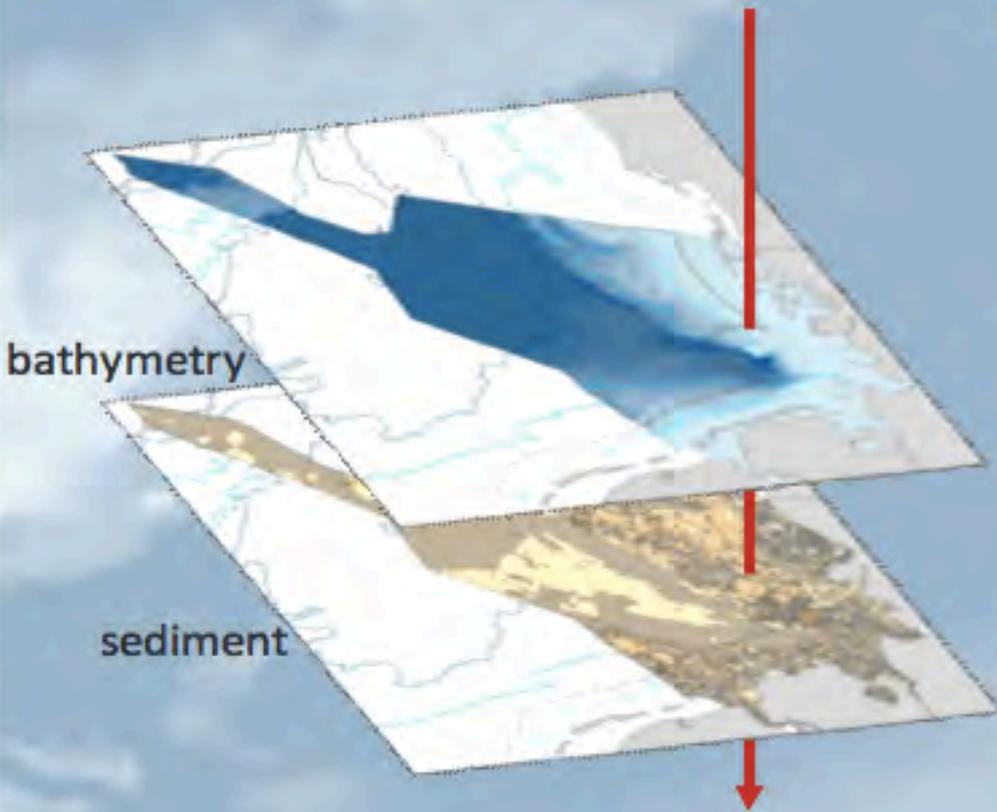
Depth & sediment type for each (grid) cell of the raster map

Benthic habitat modeling &

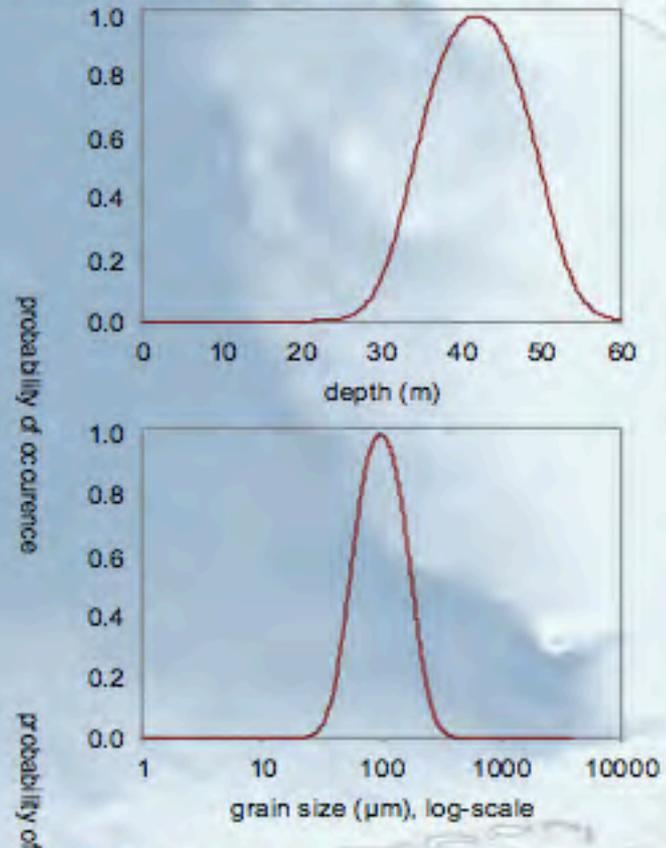
Species preferences

Habitat information

Species information



Binominal logistic regression model

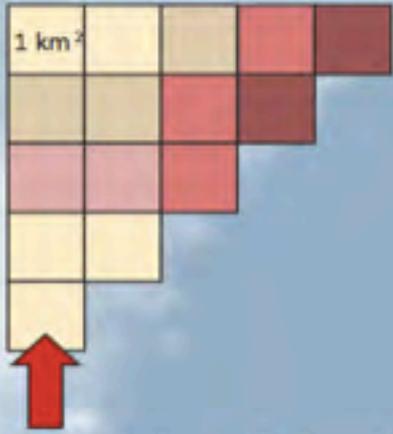


Depth & sediment type for each (grid) cell of the raster map

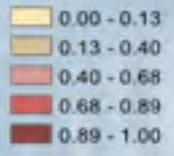
Probability of species occurrence in the depth & sediment continua

Dynamic habitat models

Spatial probability model of species occurrence



Probability of species occurrence in raster cell



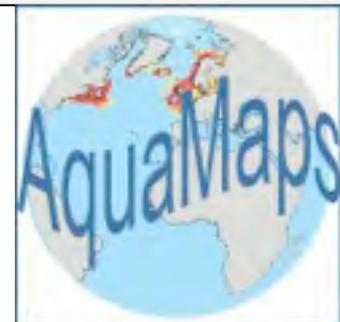
(Dannheim 2011, unpubl)

German Bight

Dynamic habitat models

Spatial probability model of species occurrence

Pleuronectes platessa



Mapping parameters for *Pleuronectes platessa* (European plaice)

Area restrictions:

FAO Areas: 21, 27, 34 Pelagic: False

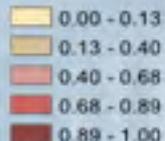
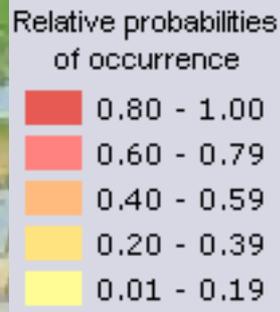
Bounding Box (NSWE): 72 36 -47 45

Environmental envelope:

	Min	Pref Min (10th)	Pref Max (90th)	Max
Depth (m)	0	10	50	200
Water temp. (°C) (surface)	-1.77	8.8	13.4	18
Salinity (psu) (surface)	6.25	28.7	35.37	36
Primary Production	0	559	1742	2669
Sea Ice Concentration (% cover)	-0.981077375	0	0.03	0.81
Distance to Land (km)	0	4	166	594



Probab
occur



Dynamic habitat models

Spatial probability model of species occurrence

-> Validation ! Suitable habitat <-> Realized niche



Probab
occur

Area restrictions:

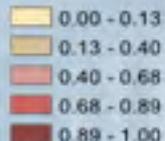
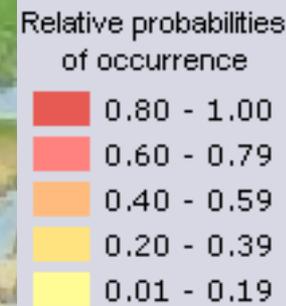
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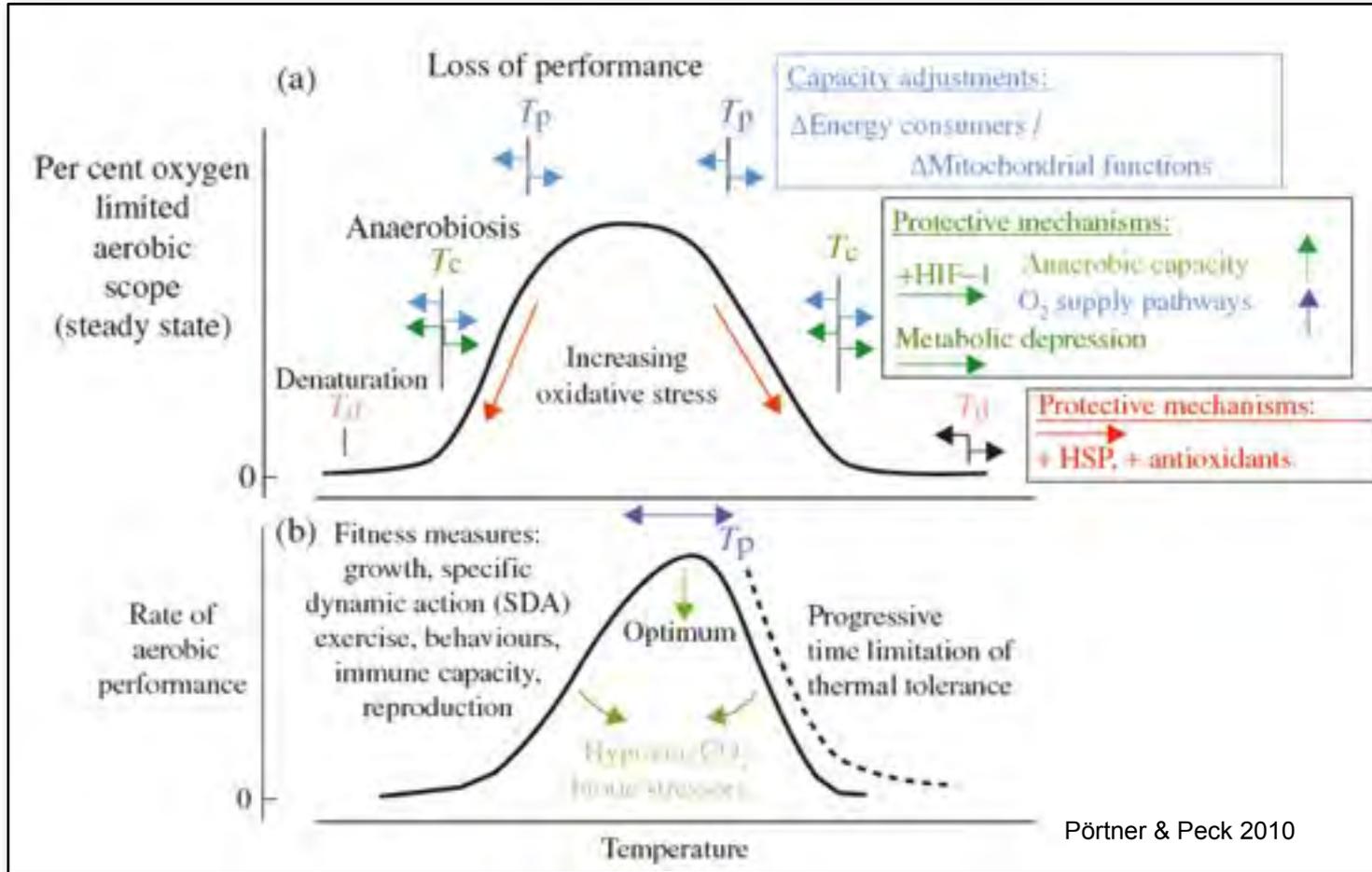
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platessa



Ecophysiological niche modeling

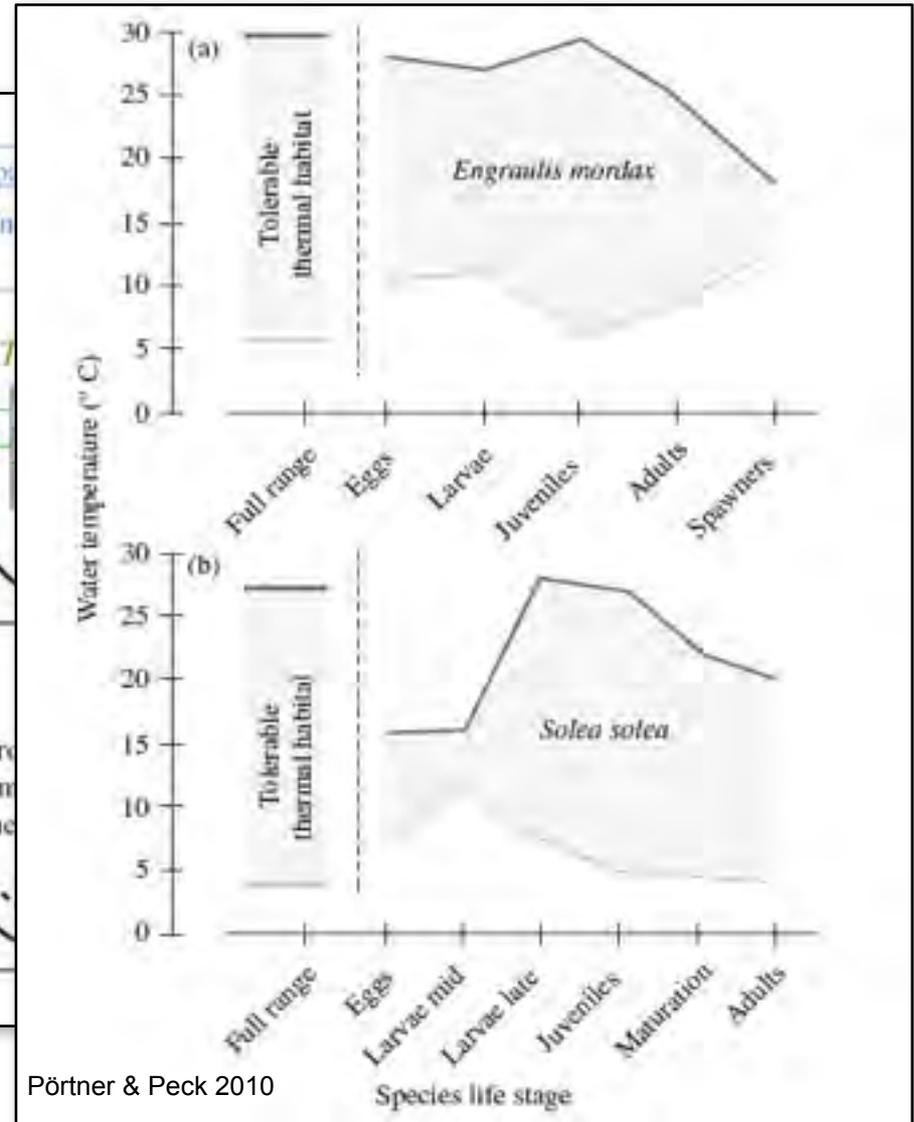
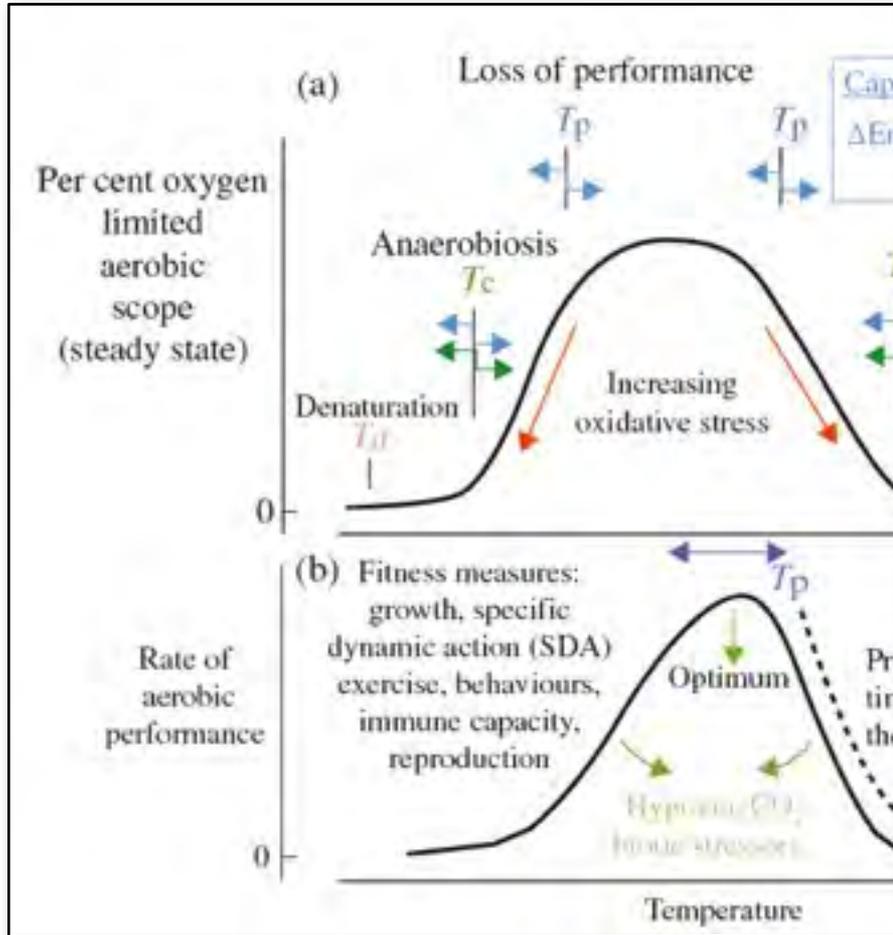
Thermal tolerance model



Ecophysiological niche modeling

Species thermal niche model

Thermal tolerance model



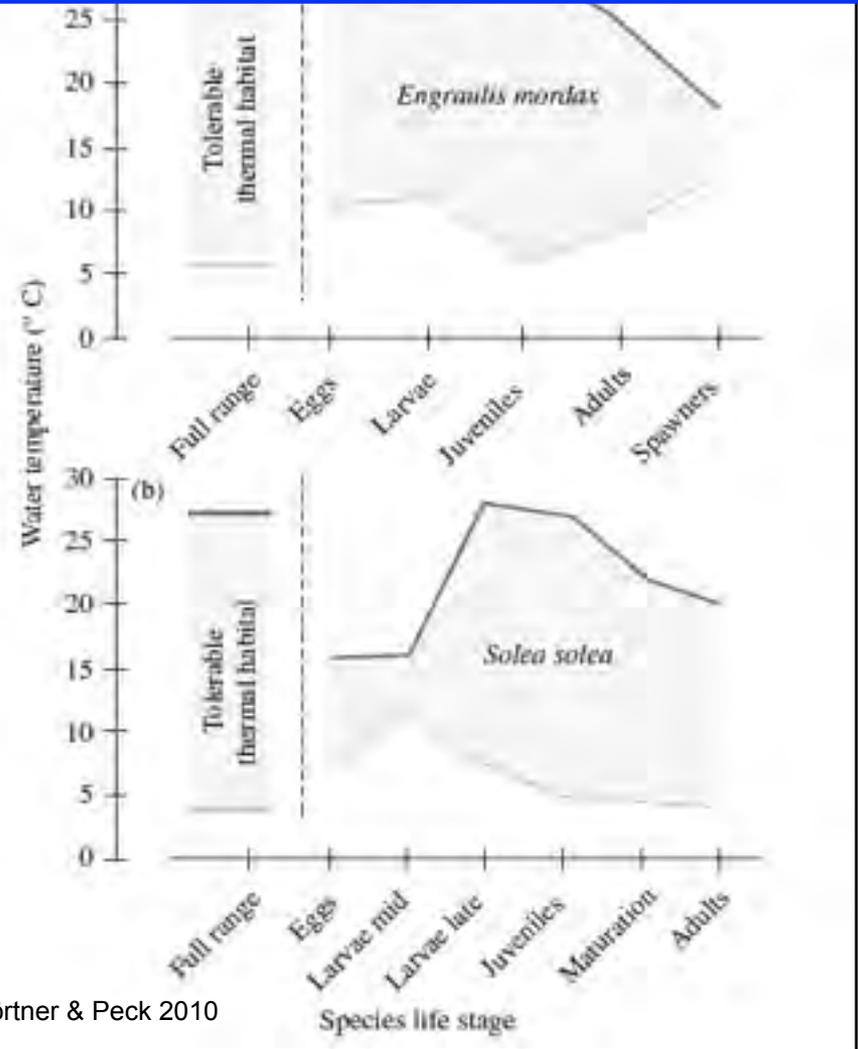
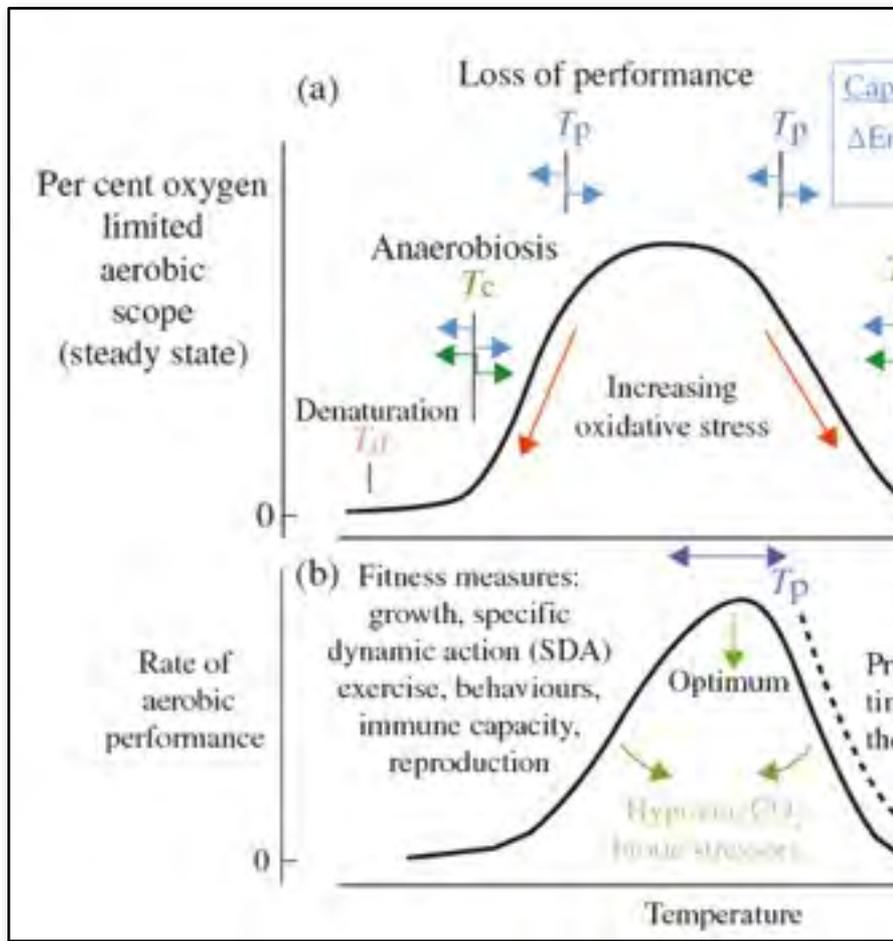
Pörtner & Peck 2010

Ecophysiological niche modeling

Species thermal niche model

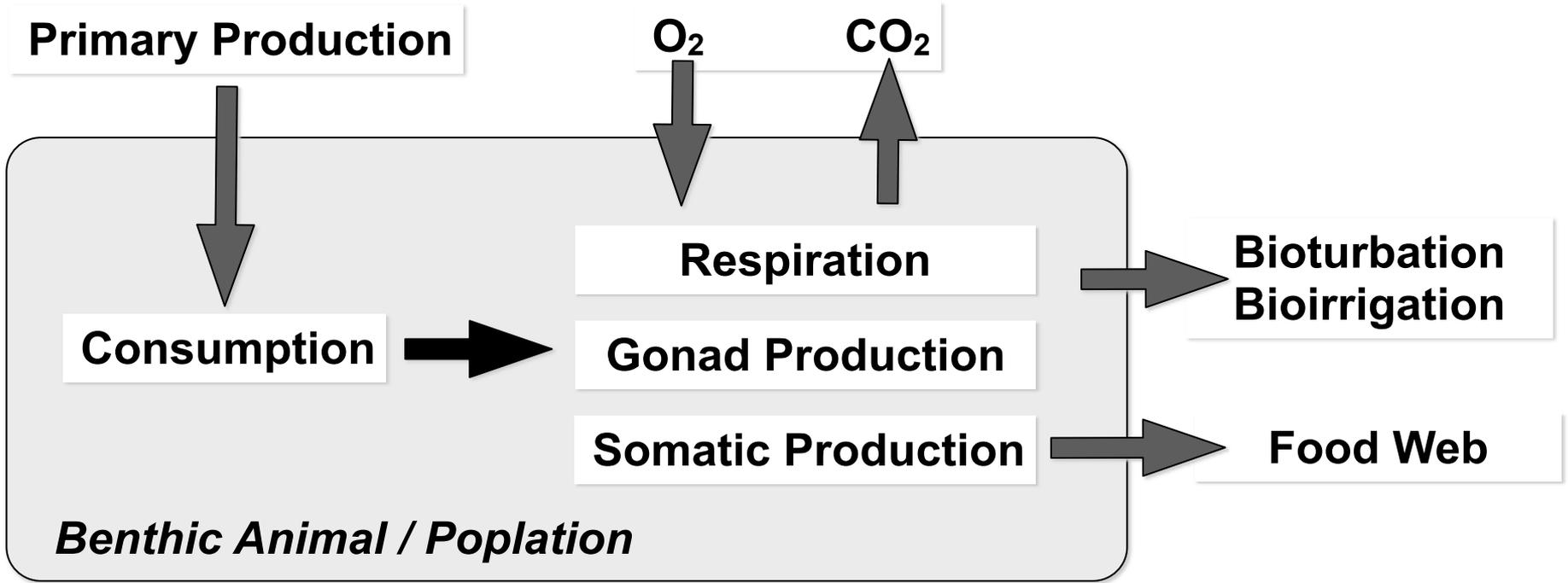
Thermal

-> Validation ! Functional niche <-> Realized niche



Pörtner & Peck 2010

Performance modeling -> Services



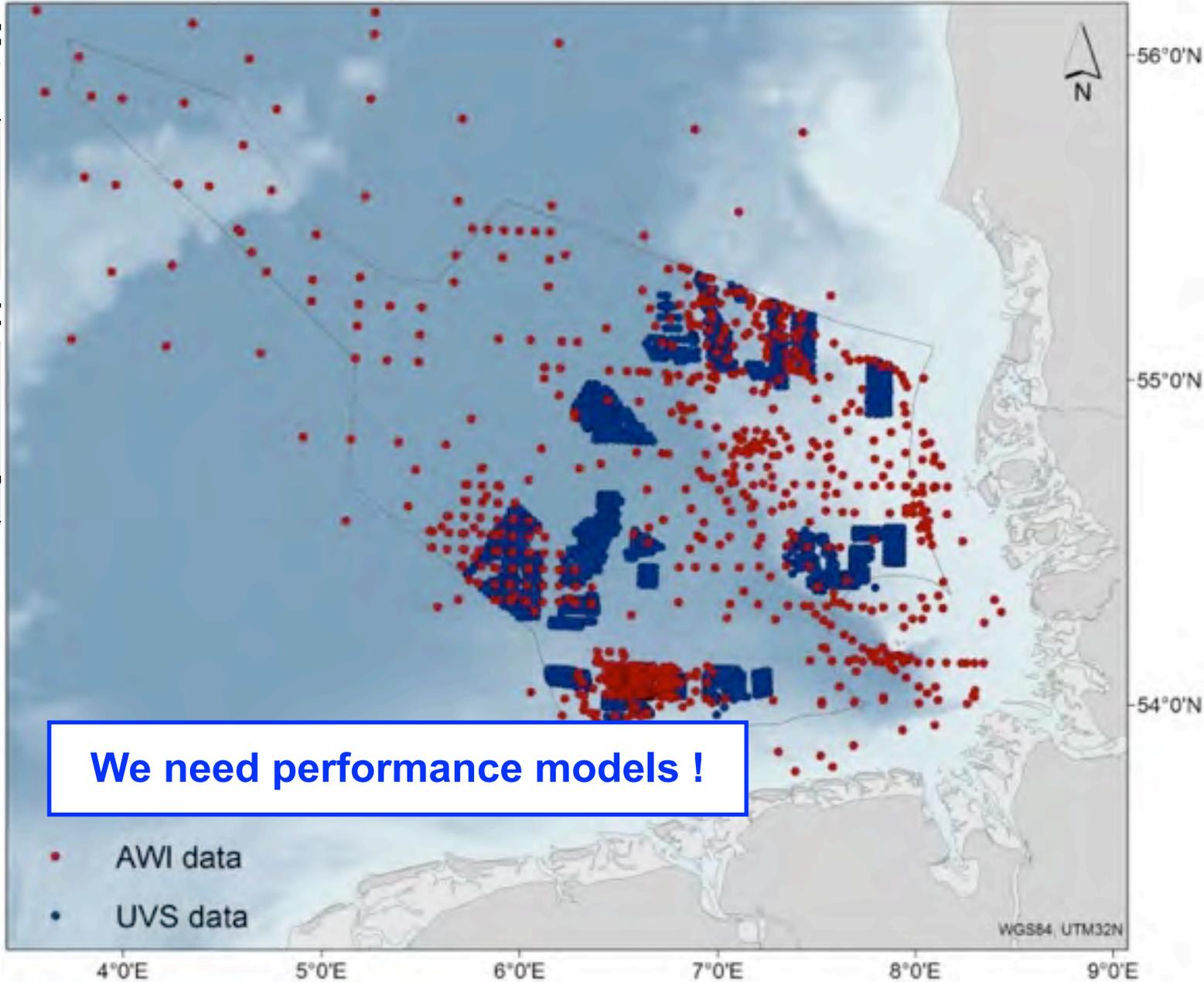
Performance modeling -> Services

Primary Proc

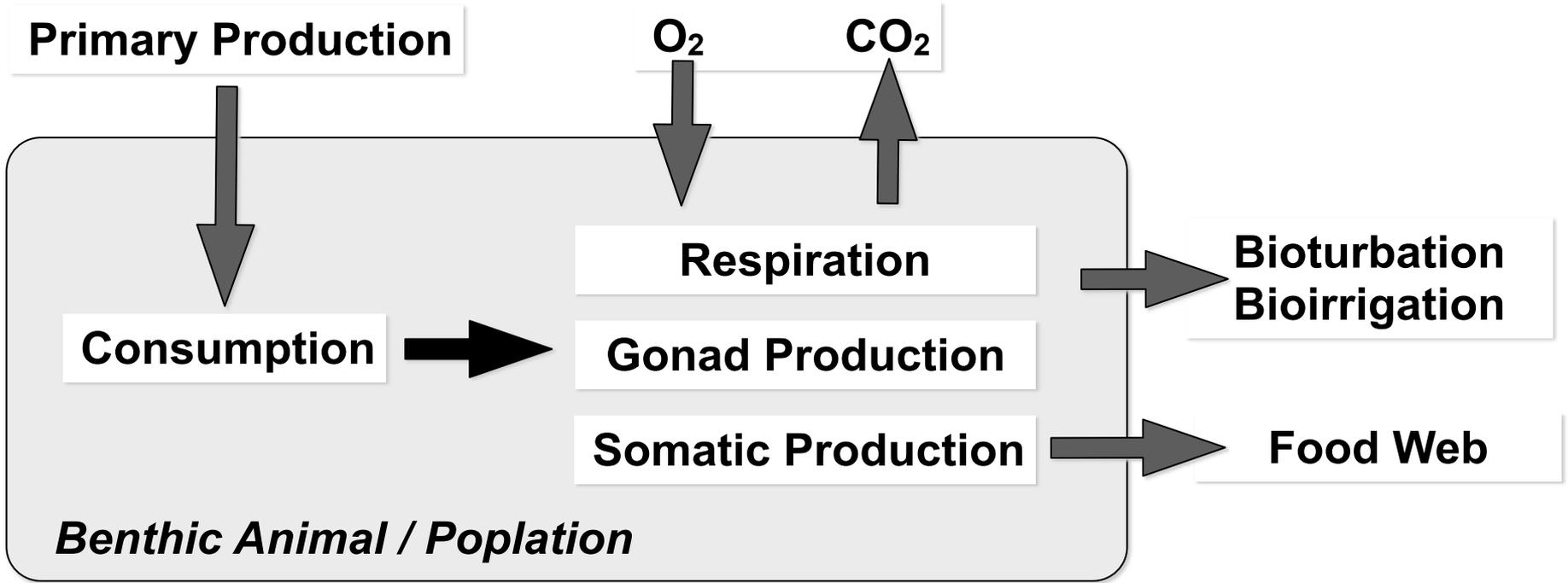


Consump

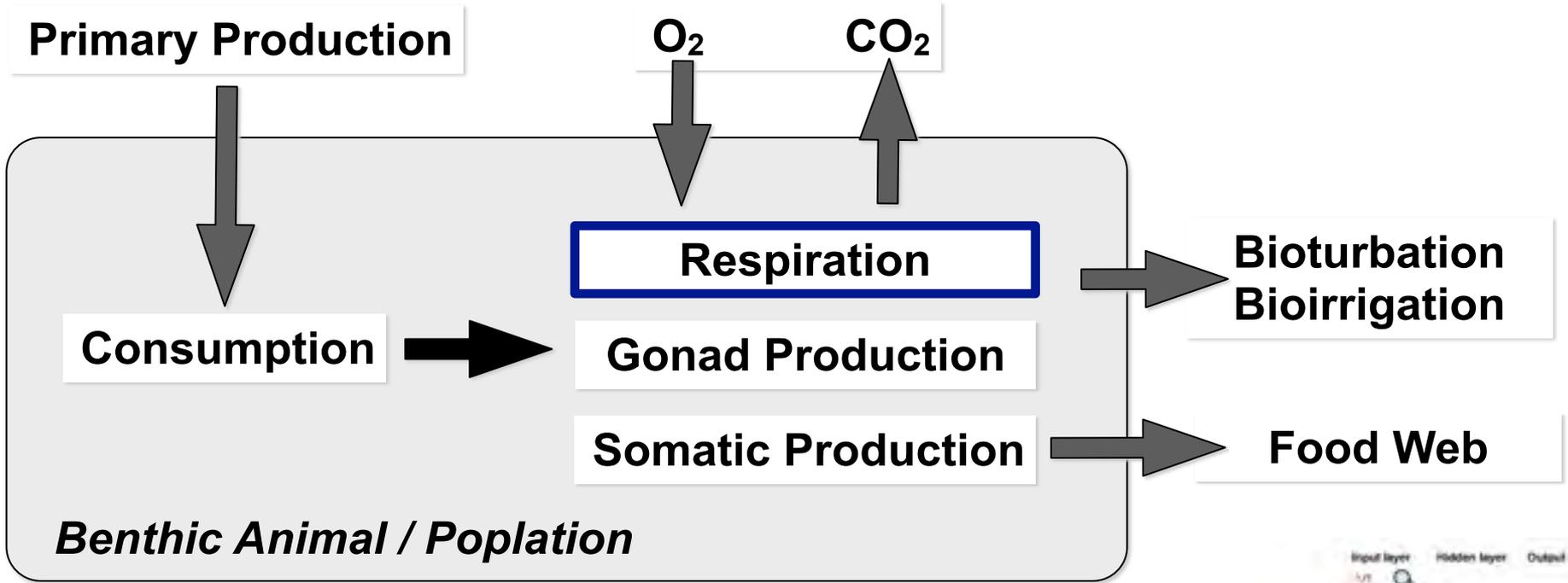
Benthic A



Performance modeling -> Services



Performance modeling -> Services



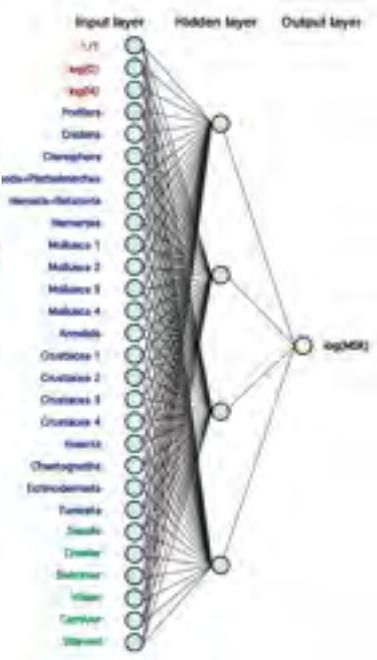
Respiration model

Methods in Ecology and Evolution

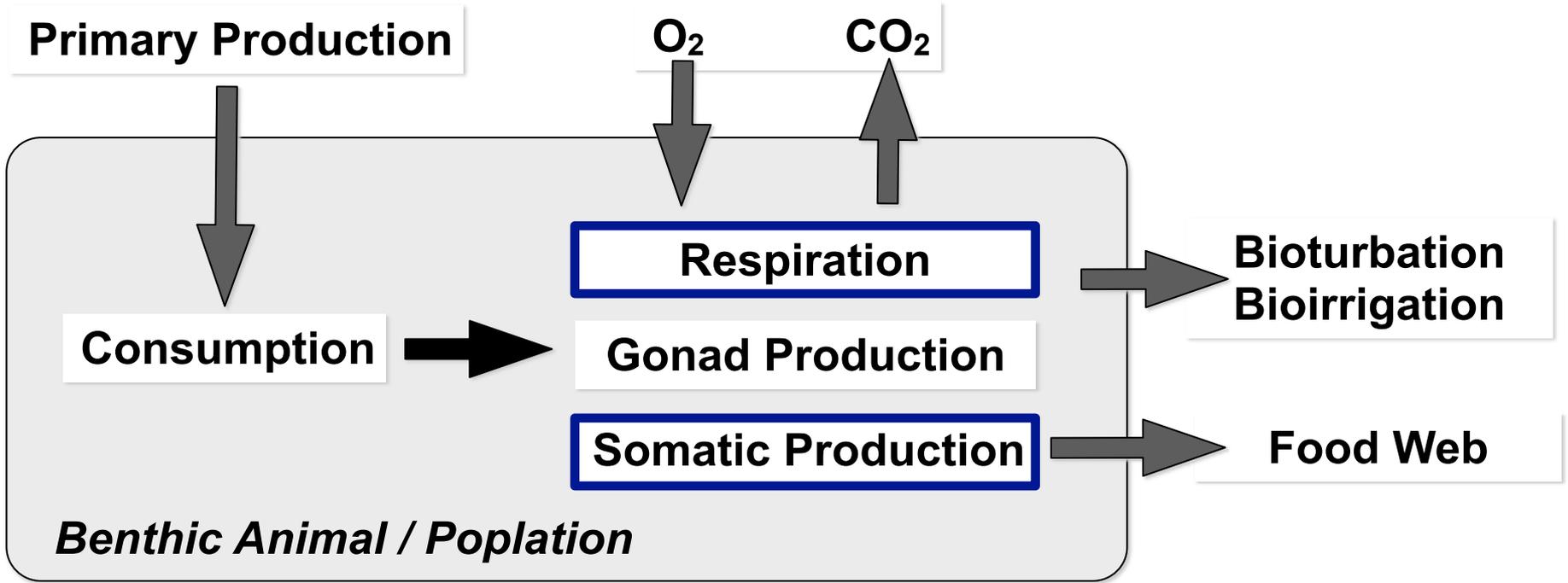
Methods in Ecology & Evolution 2010, 1, 92–101

doi: 10.1111/j.2041-210X.2009.00008.x

An empirical model for estimating aquatic invertebrate respiration



Performance modeling -> Services

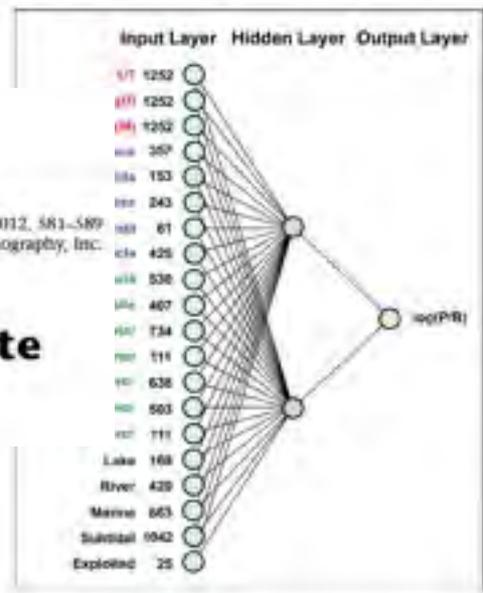


Production model

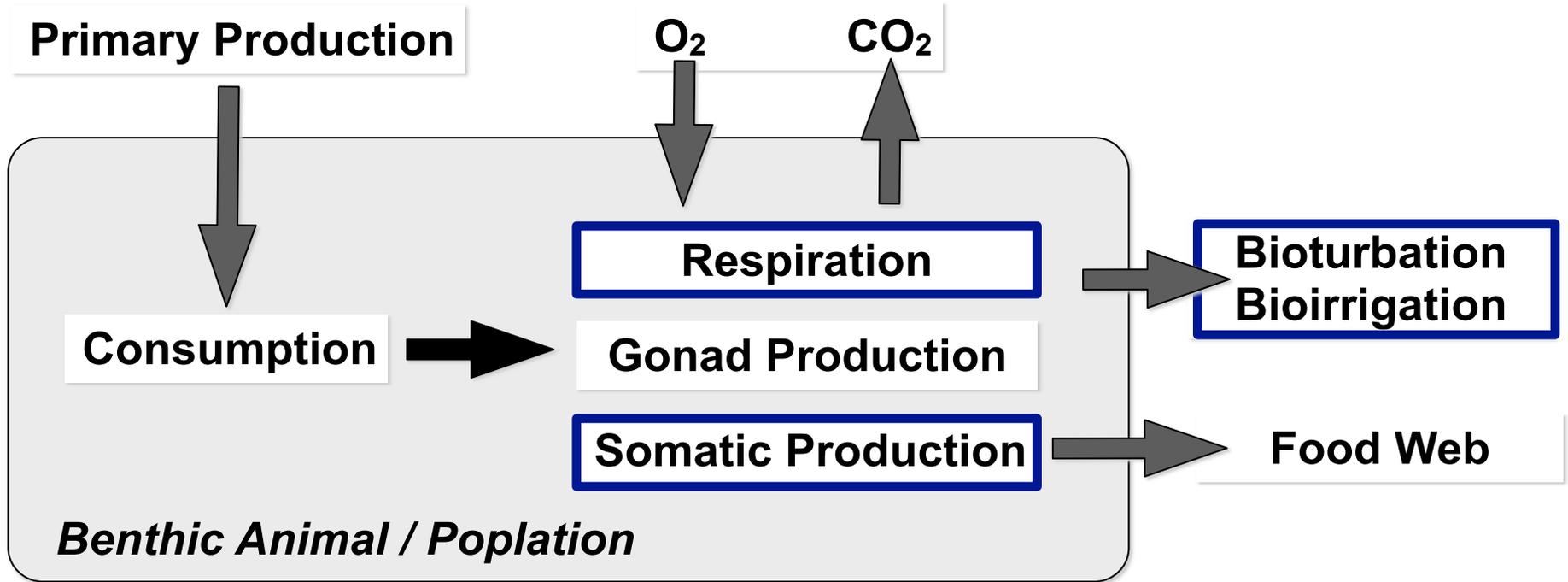
LIMNOLOGY
and
OCEANOGRAPHY: METHODS

Limnol. Oceanogr.: Methods 10, 2012, 581-589
© 2012, by the American Society of Limnology and Oceanography, Inc.

A multi-parameter artificial neural network model to estimate macrobenthic invertebrate productivity and production



Performance modeling -> Services



Bioturbation model

Role of macrofauna functional traits and density in biogeochemical fluxes and bioturbation

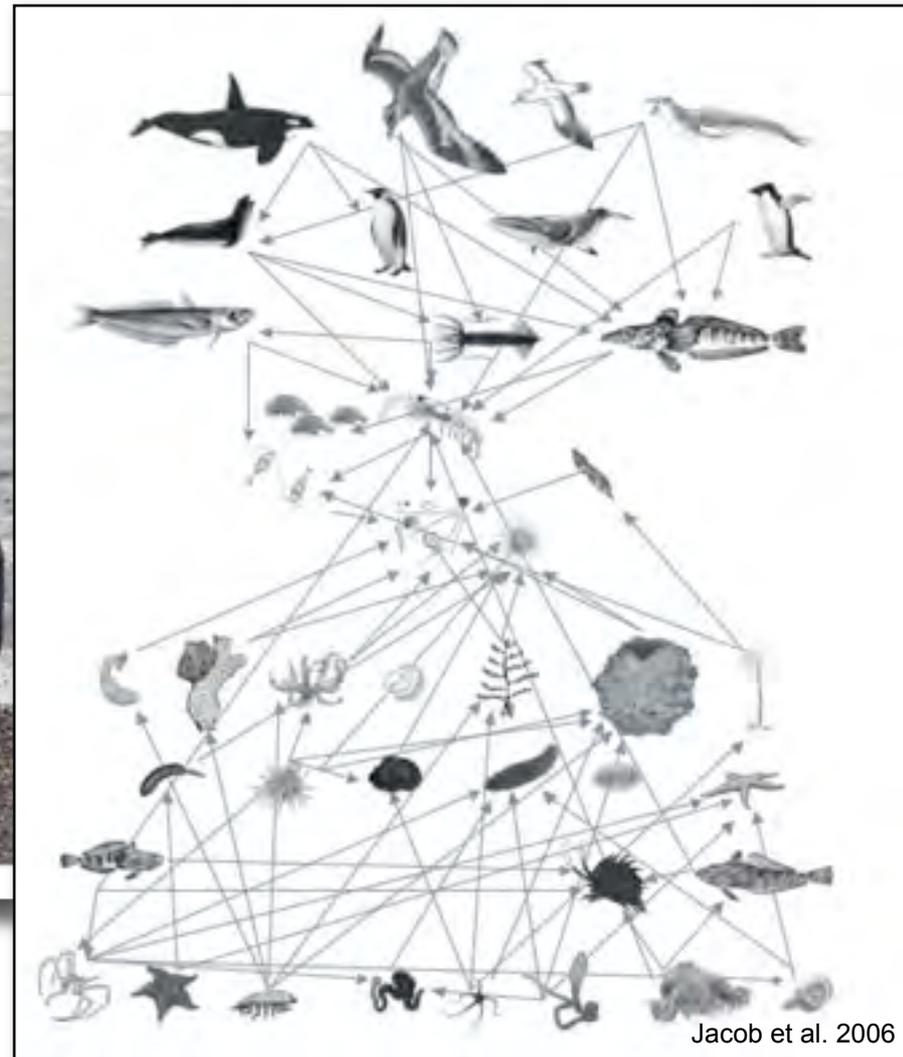
Ulrike Braeckman^{1,*}, Pieter Provoost², Britta Gribsholt³, Dirk Van Gansbeke¹,
Jack J. Middelburg², Karline Soetaert², Magda Vincx¹, Jan Vanaverbeke¹

Species interaction modeling



Species interaction modeling

Food web model



Species interaction modeling

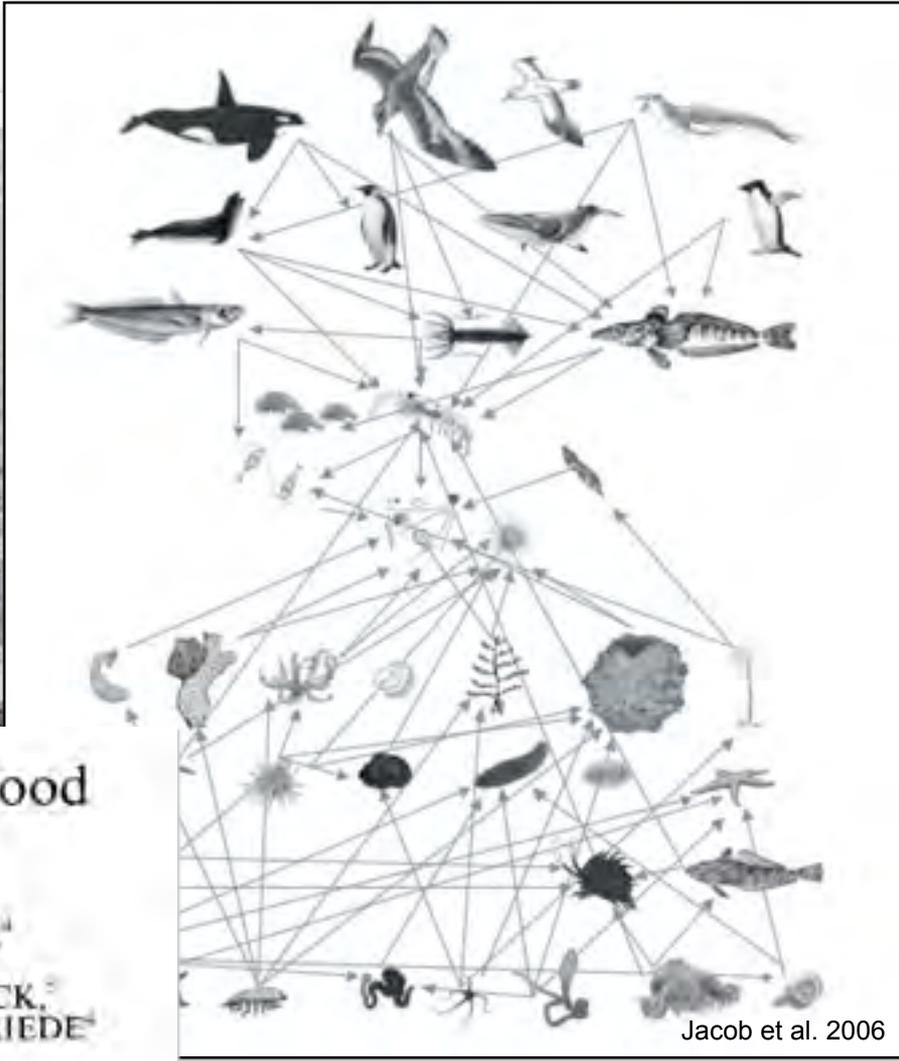
Food web model



The Role of Body Size in Complex Food Webs: A Cold Case

UTE JACOB,^{1,*} AARON THIERRY,^{2,3} ULRICH BROSE,⁴
WOLF E. ARNTZ,⁵ SOFIA BERG,⁶ THOMAS BREY,⁷
INGO FETZER,⁸ TOMAS JONSSON,⁹ KATJA MINTENBECK,⁷
CHRISTIAN MÖLLMANN,¹ OWEN L. PETCHEY,¹⁰ JENS O. RIEDE,¹¹
AND JENNIFER A. DUNNE^{9,10,11}

Adv. Ecological Res. 45; 2011



Jacob et al. 2006

Environmental drivers & system response

Environmental drivers & system response

Land-
Ocean-
Atmosphere

Drivers

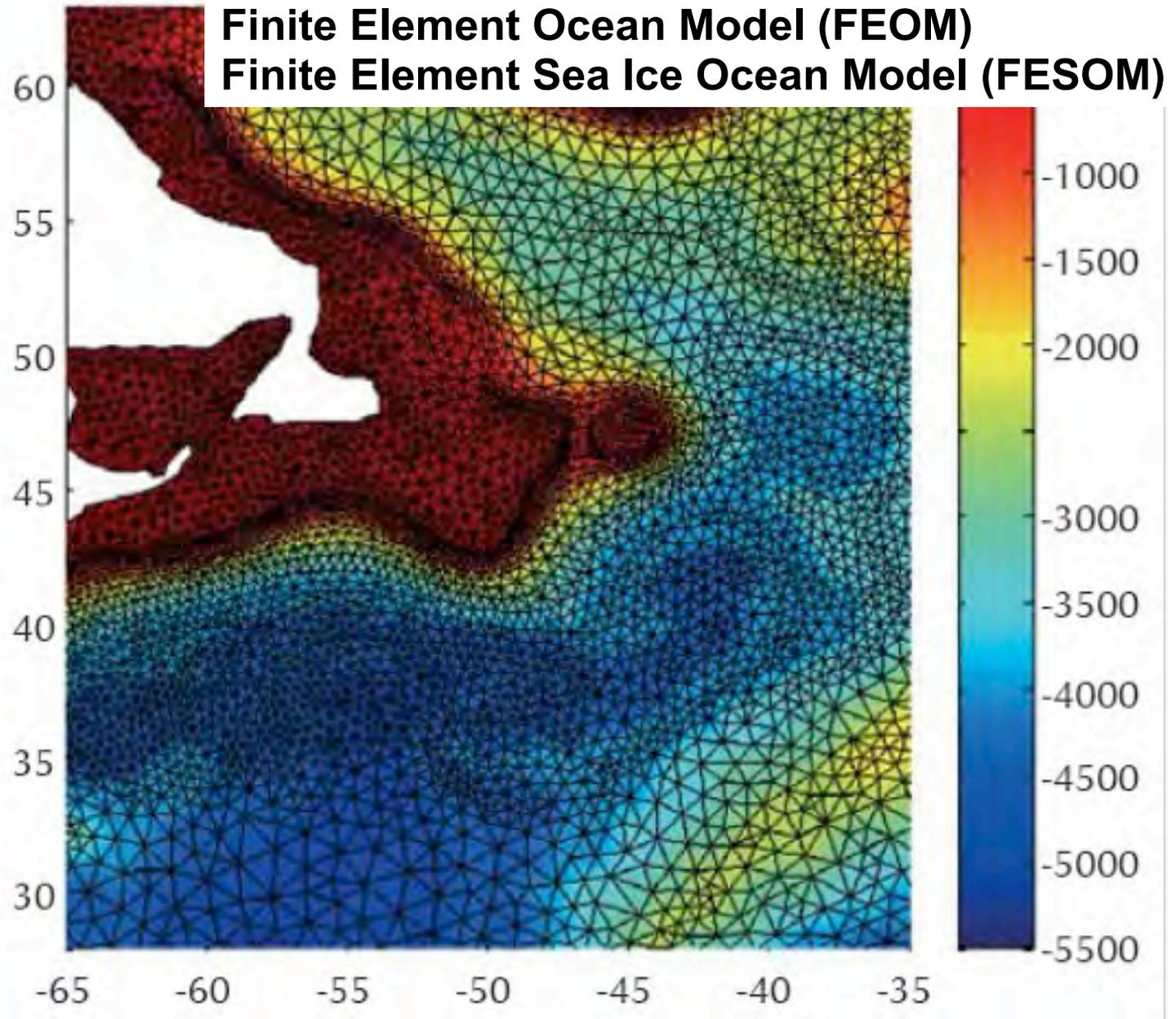
Models

Environmental drivers & system response

Land-
Ocean-
Atmosphere

Drivers

Models

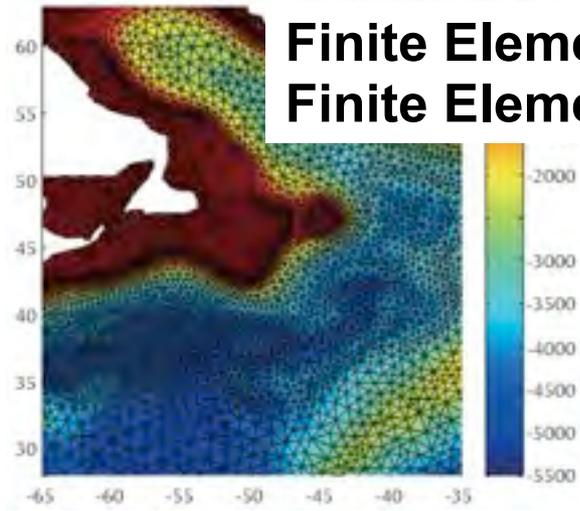


Environmental drivers & system response

Land-
Ocean-
Atmosphere

Drivers

Models



Long-Term
Ecolog. Data

Paleo-Record
& Bioarchives

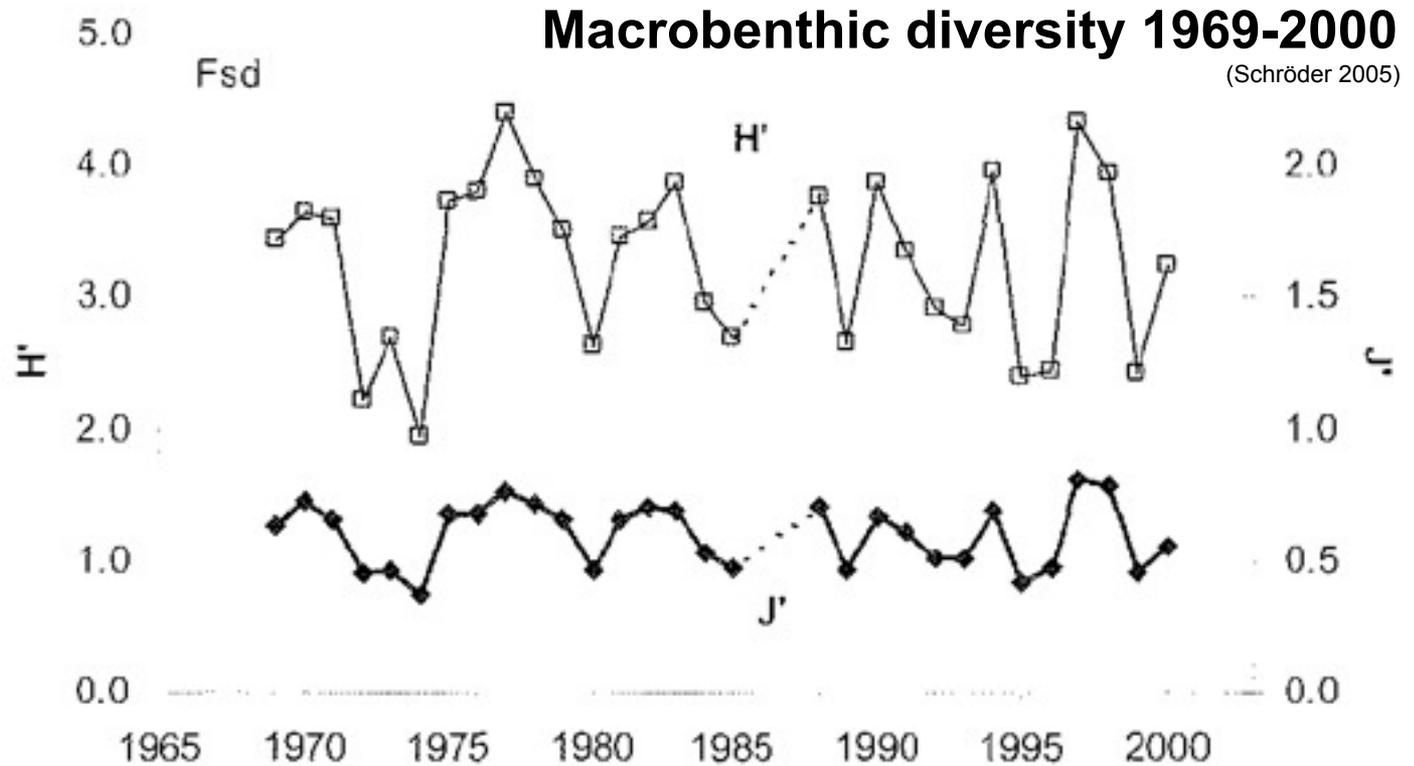
Theoretical
Ecology

Environmental drivers & system response

Land-
Ocean-
Atmosphere

Drivers

Models



Long-Term
Ecolog. Data

Paleo-Record
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Theoretical
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Environmental drivers & system response

Land-
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Atmosphere

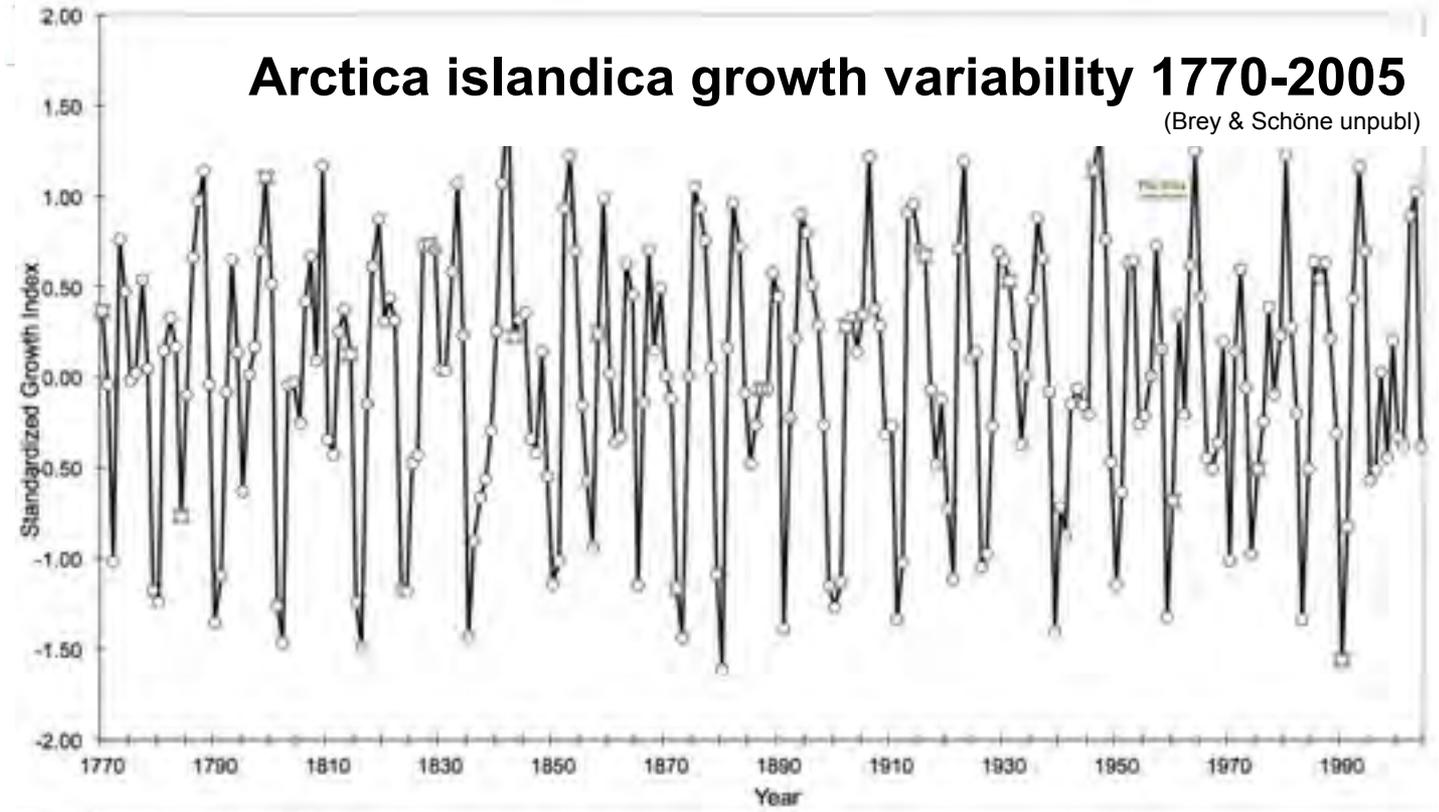
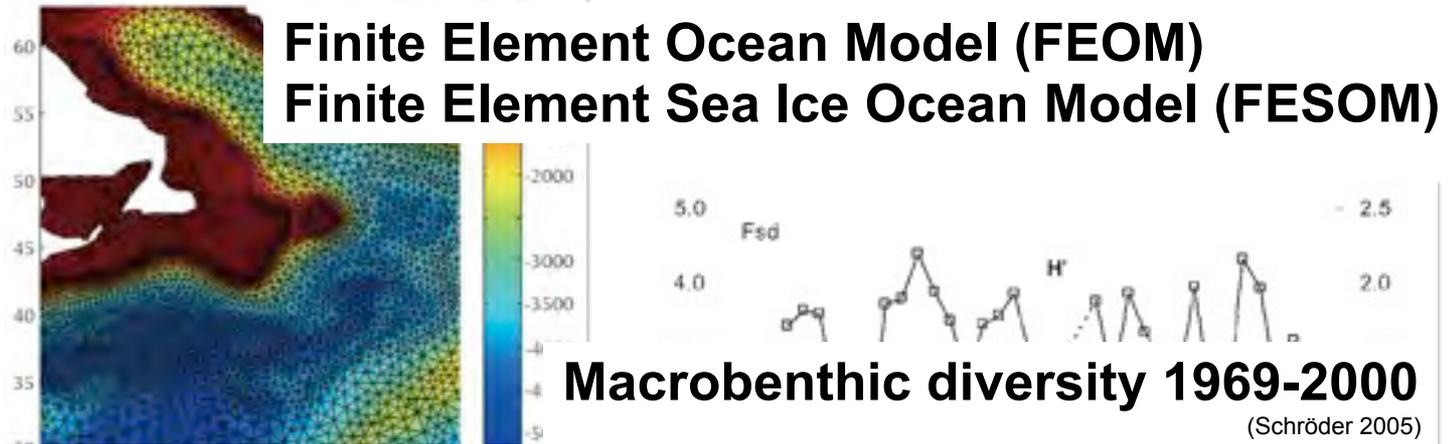
Drivers

Models

Long-Term
Ecolog. Data

Paleo-Record
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Theoretical
Ecology

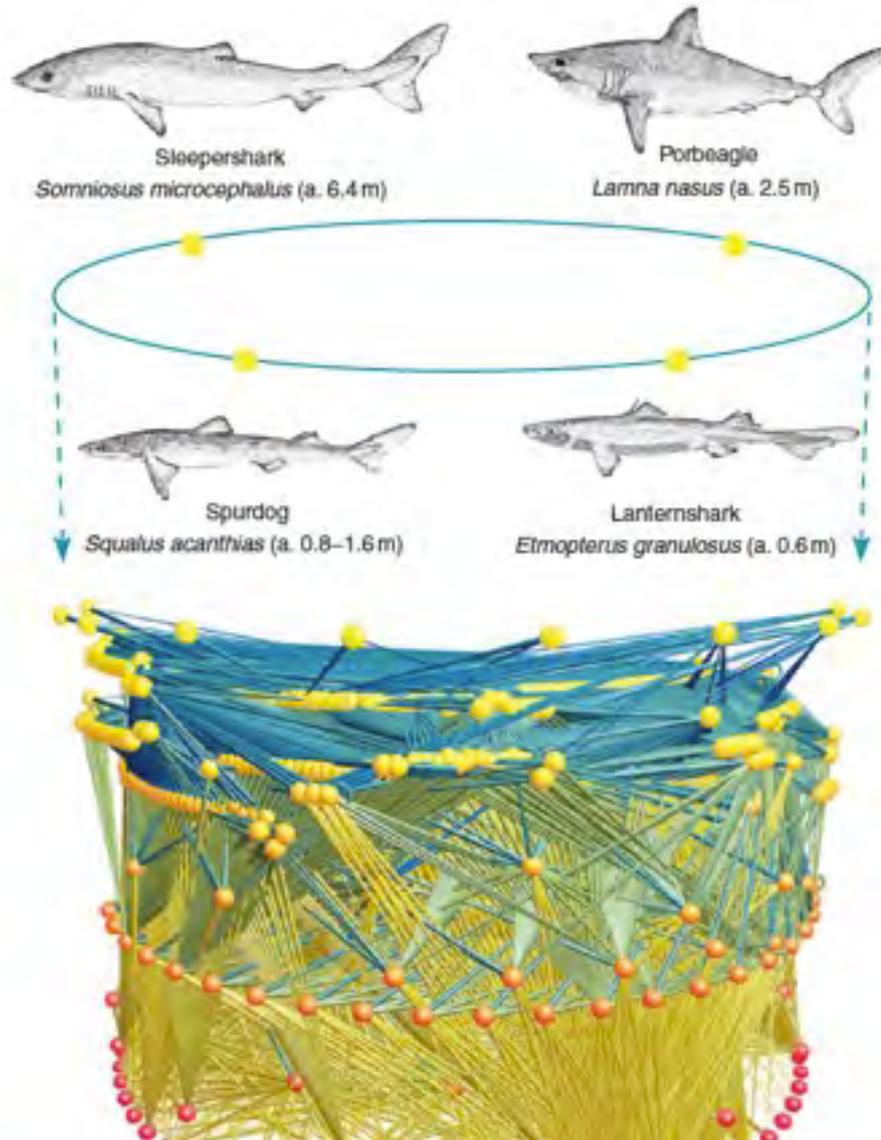


Environmental drivers & system response

Land-
Ocean-
Atmosphere

Drivers

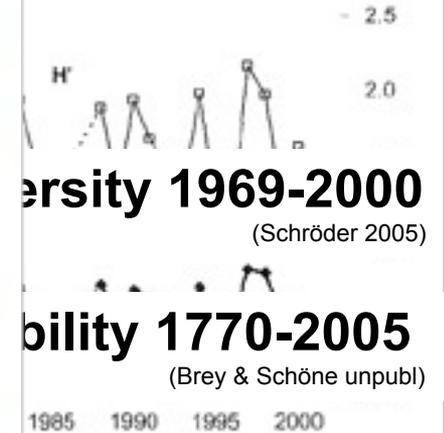
Models



A Post-Invasion Weddell Sea Food Web

(Woodward et al. 2010)

(FEOM)
Model (FESOM)



Long-Term
Ecolog. Data

Paleo-Record
& Bioarchives

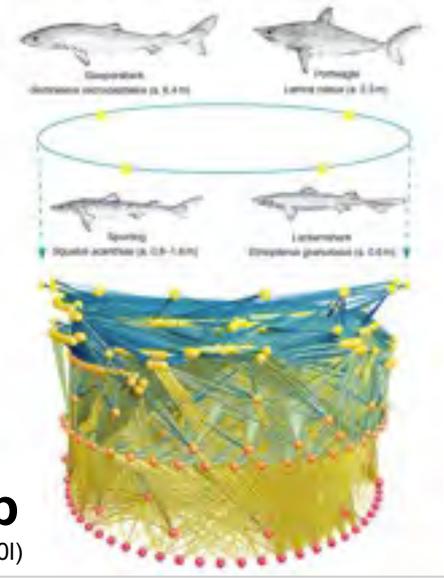
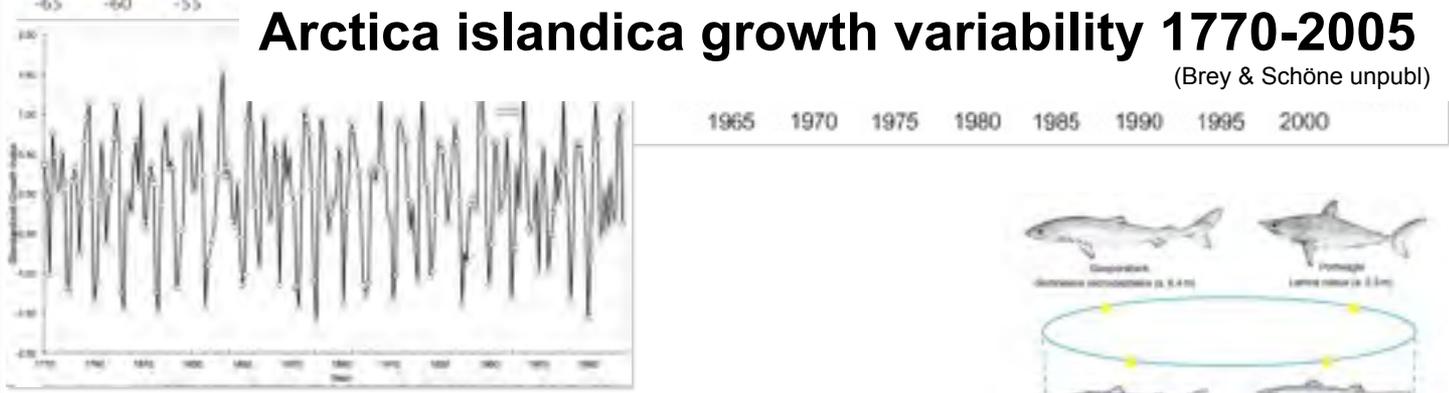
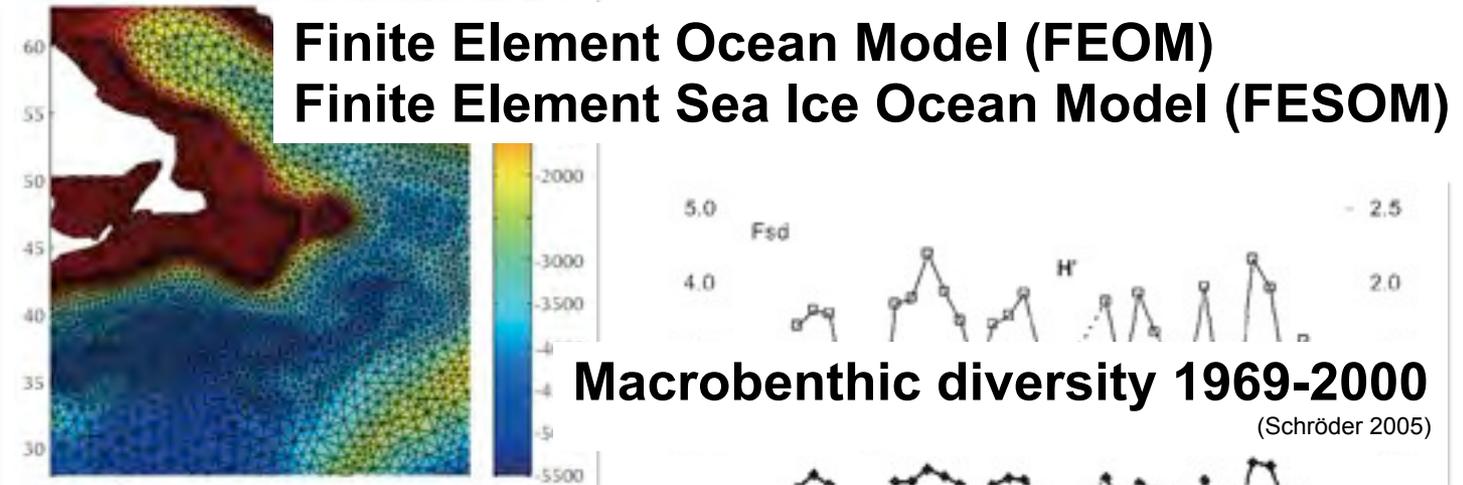
Theoretical
Ecology

Environmental drivers & system response

Land-
Ocean-
Atmosphere

Drivers

Models



A Post-Invasion Weddell Sea Food Web

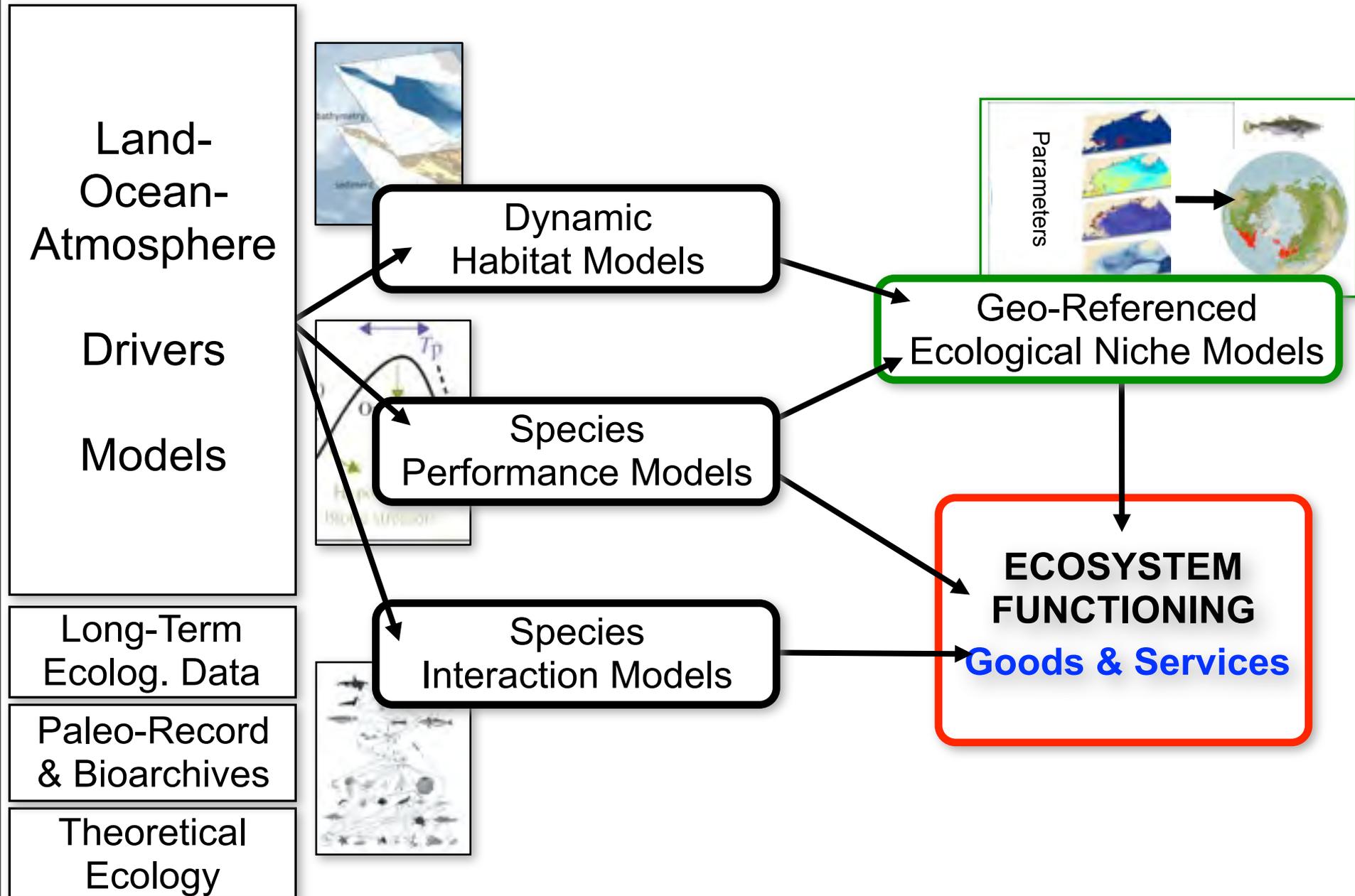
(Woodward et al. 2010)

Long-Term
Ecolog. Data

Paleo-Record
& Bioarchives

Theoretical
Ecology

Macroecological-/physiological Scenario Generator



Macroecological-/physiological Scenario Generator

Land-
Ocean-
Atmospher



Drivers

Models

- *Actual system state*
- *Cause & effect relationships*
- *Future scenarios*
- *Hypothesis testing*



Referenced
Ecological Models

Long-Term
Ecolog. Data

Paleo-Records
& Bioarchives

Theoretical
Ecology



STEM
MONITORING
Services

The sediment-water interface challenge

Ecosystem Goods & Services

- Nutrient Remineralization
-> Primary Production
- Carbon Metabolization
-> Higher Trophic Levels
- Processing & Neutralization
of Anthropogenic Substances

The sediment-water interface challenge



Ecosystem Goods & Services

- Nutrient Remineralization
-> Primary Production
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The sediment-water interface challenge

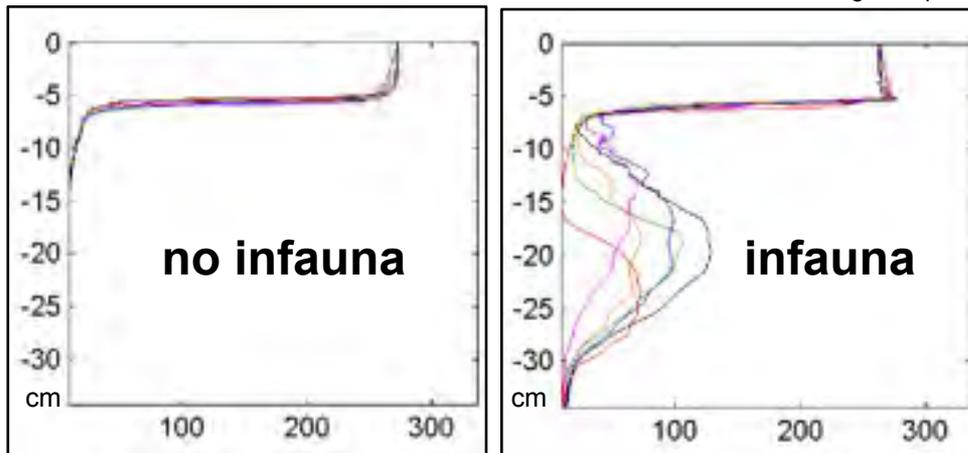


Ecosystem Goods & Services

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of Anthropogenic Substances

Sediment Oxygen Profile

D. Sevilgen unpubl.



The sediment-water interface challenge

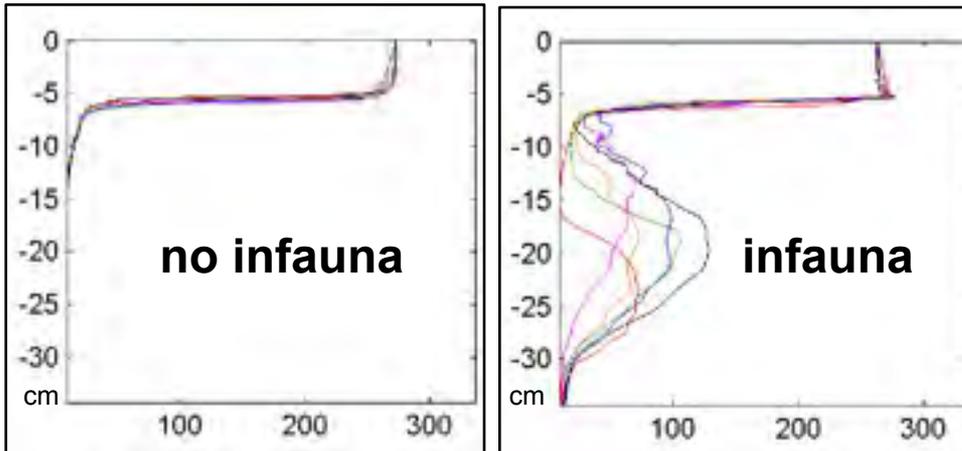


Benthic macrofauna impact on biogeochemical processes



Sediment Oxygen Profile

D. Sevilgen unpubl.

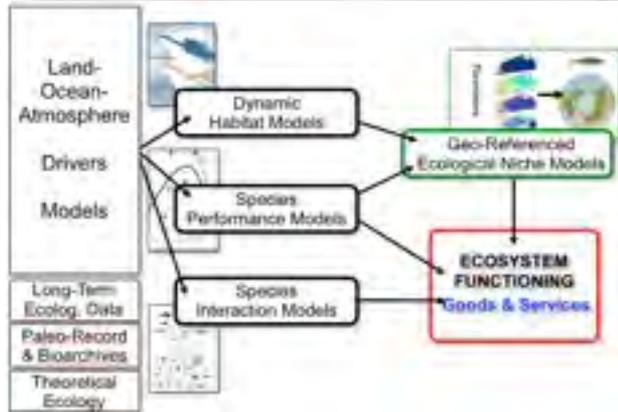


Ecosystem Goods & Services

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The Shelf Sea Benthic Biogeochemical Reactor

Macrobenthic Community

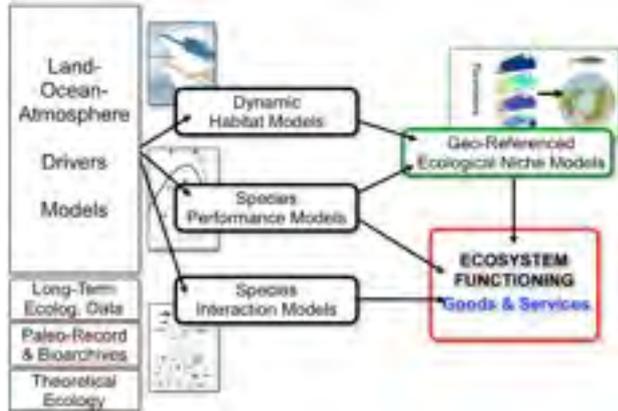


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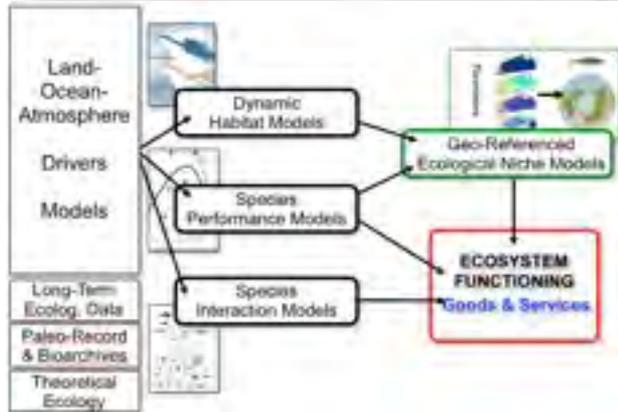


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The Shelf Sea Benthic Biogeochemical Reactor

Macrobenthic Community



POM Turnover & Metabolism
Sediment Bioirrigation
Bioturbation

Biogeochemical Cycling

POM & DOM Dynamics

System Metabolism



Ecosystem Goods & Services

- Nutrient Remineralization
-> Primary Production
- Carbon Metabolization
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The Shelf Sea Benthic Biogeochemical Reactor

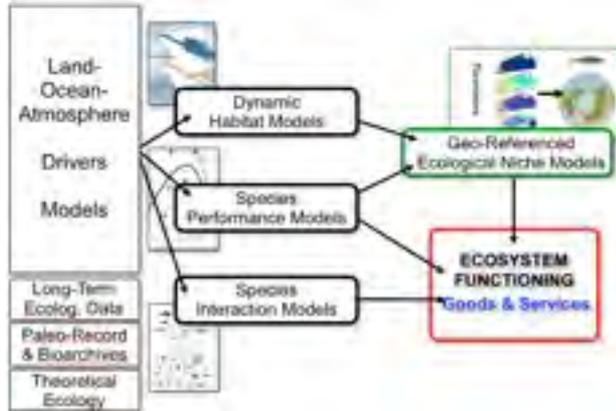
Anthropogenic Impact



Fisheries
Windfarms



Macrobenthic Community



POM Turnover & Metabolism
Sediment Bioirrigation
Bioturbation

Biogeochemical Cycling

POM & DOM Dynamics

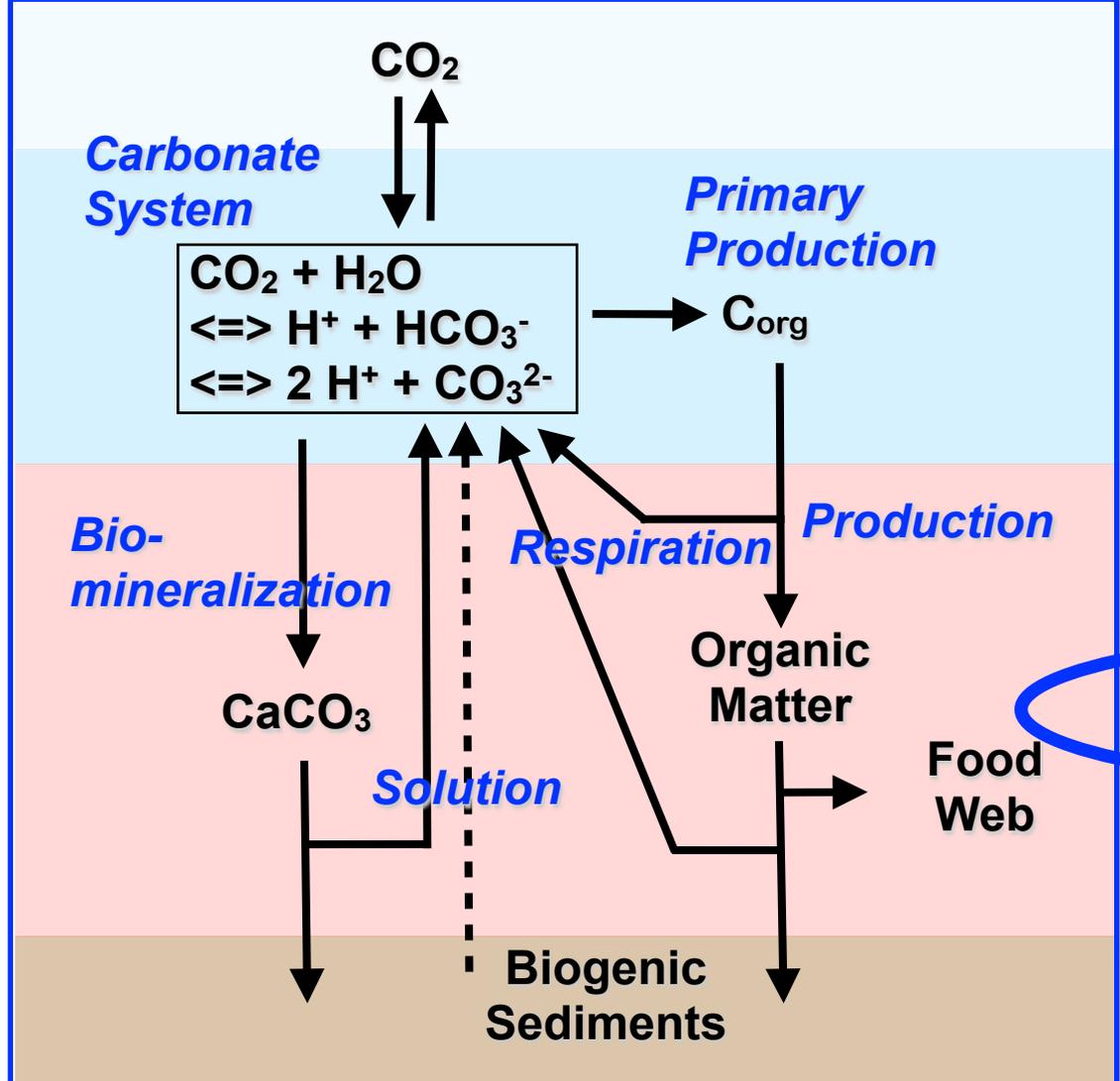
System Metabolism



Ecosystem Goods & Services

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The Shelf Sea Benthic Biogeochemical Reactor



Ecosystem Goods & Services

Nutrient Remineralization
 -> Primary Production

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Processing & Neutralization
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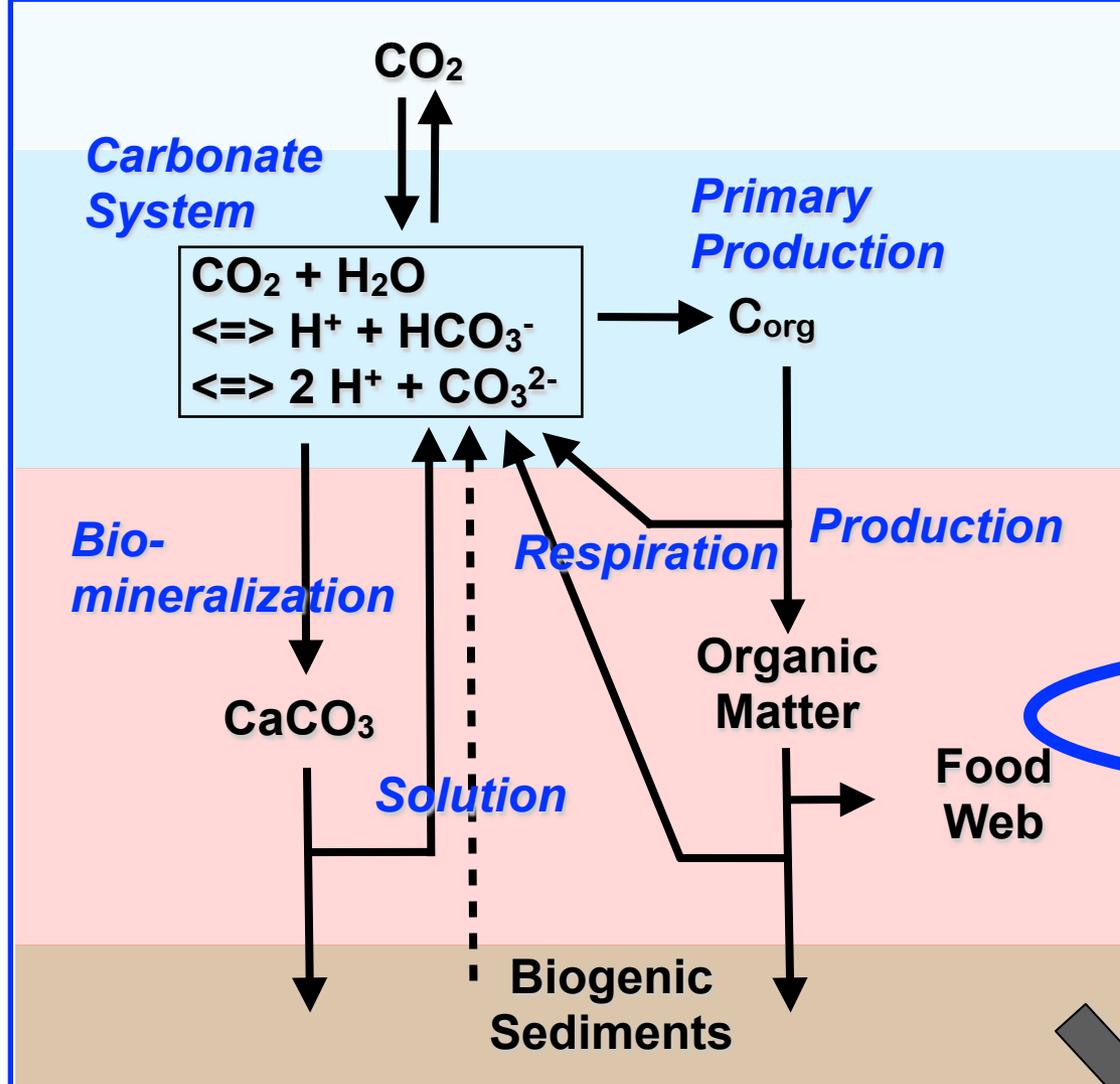
Biogeochemical Cycling

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The Shelf Sea Benthic Biogeochemical Reactor



Ecosystem Goods & Services

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Biogeochemical Cycling

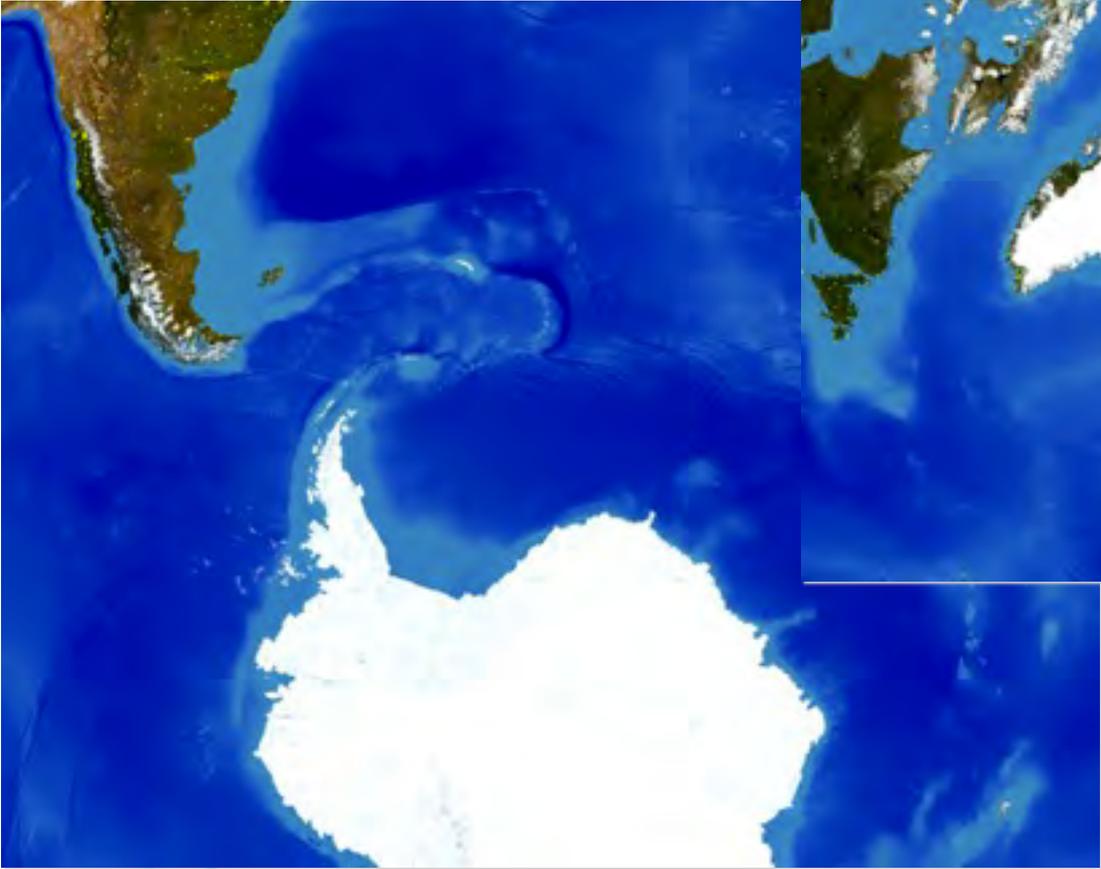
POM & DOM Dynamics

System Metabolism

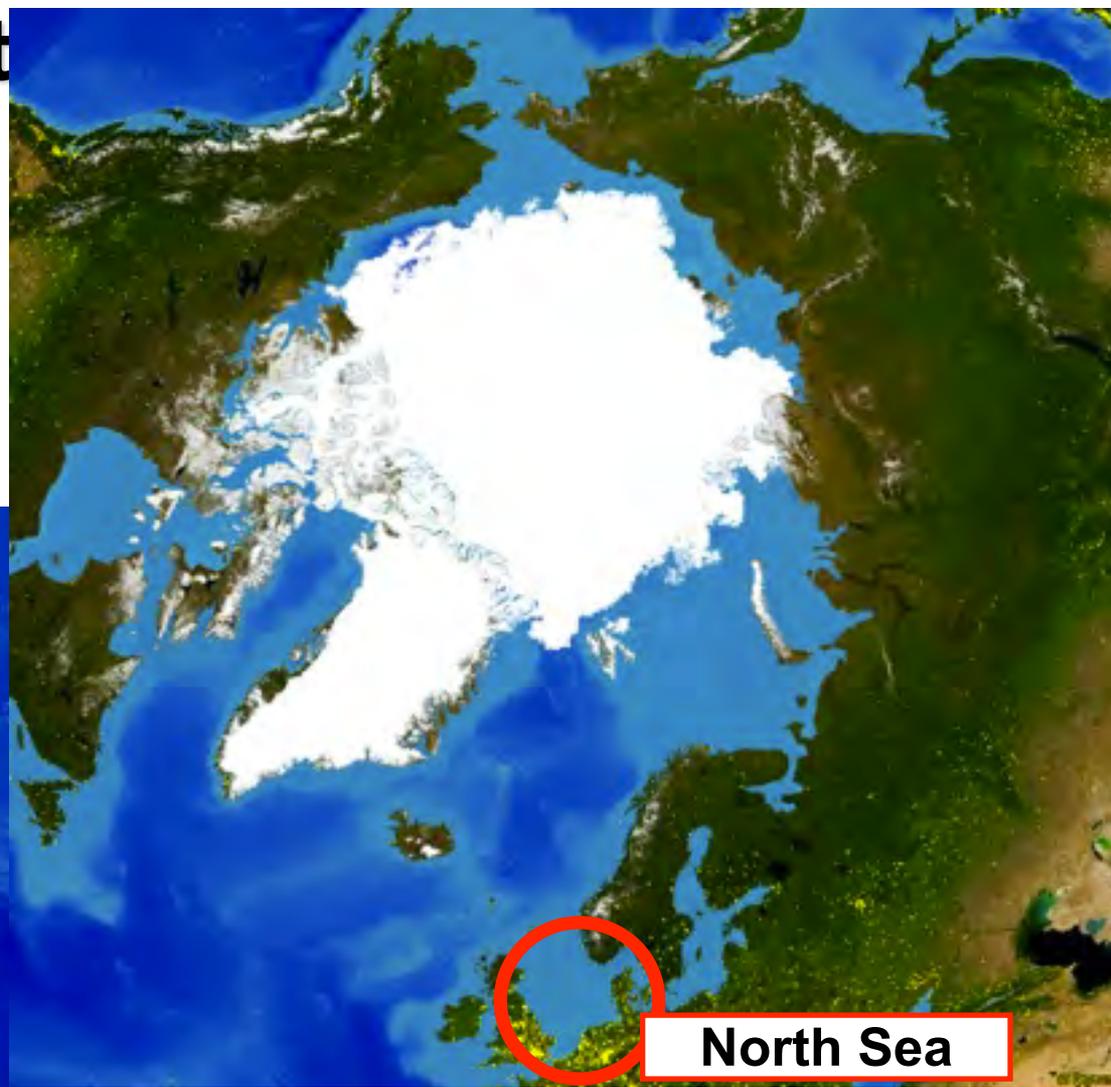


Regional / Global Biogeochemical Models

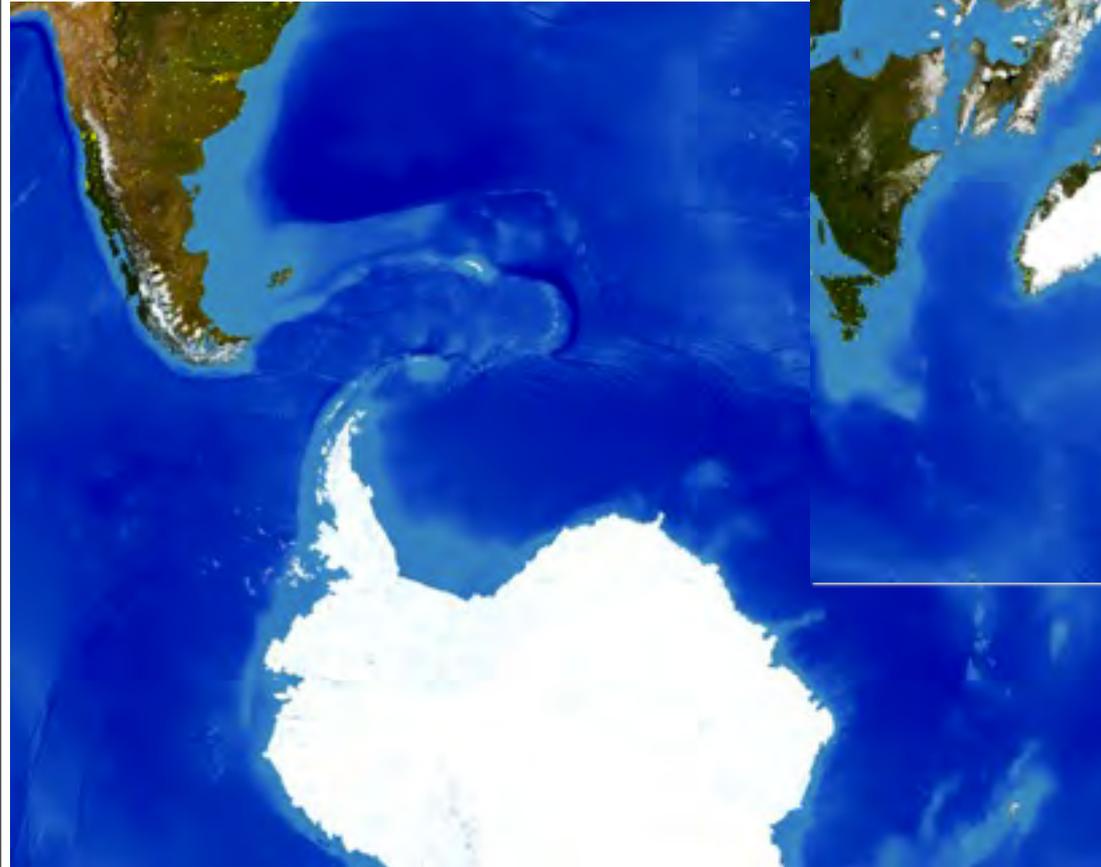
Regions of interest



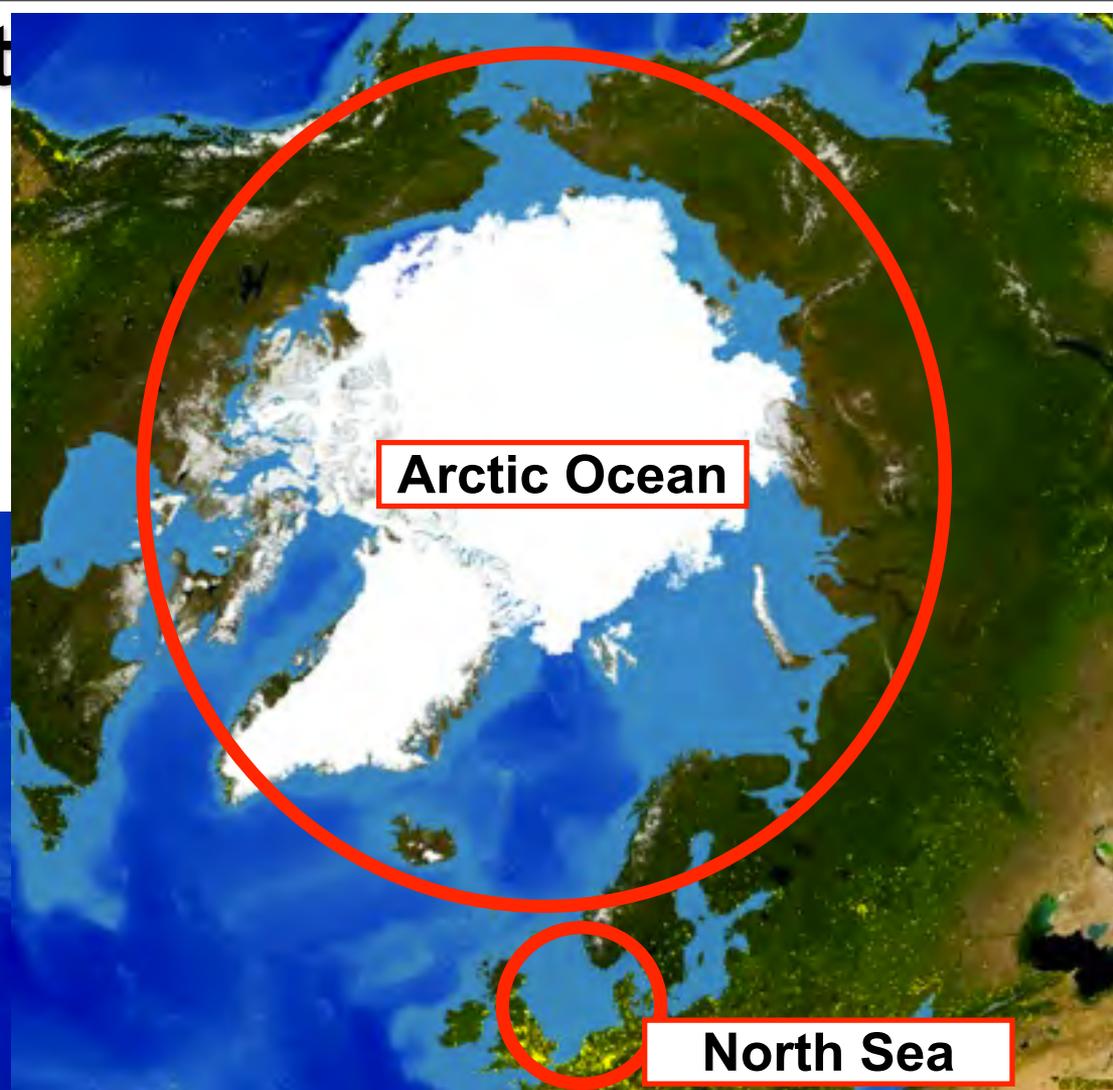
Regions of interest



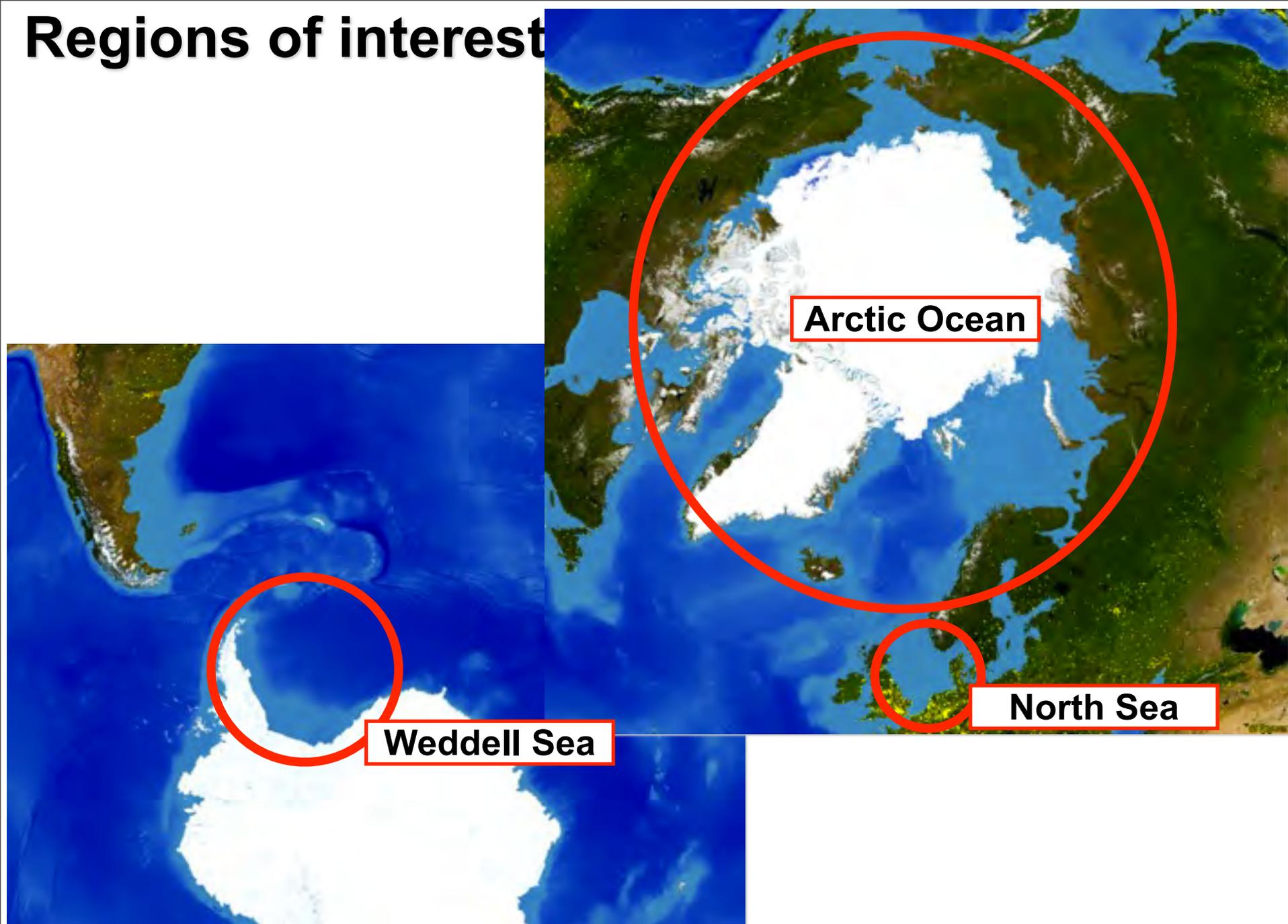
North Sea



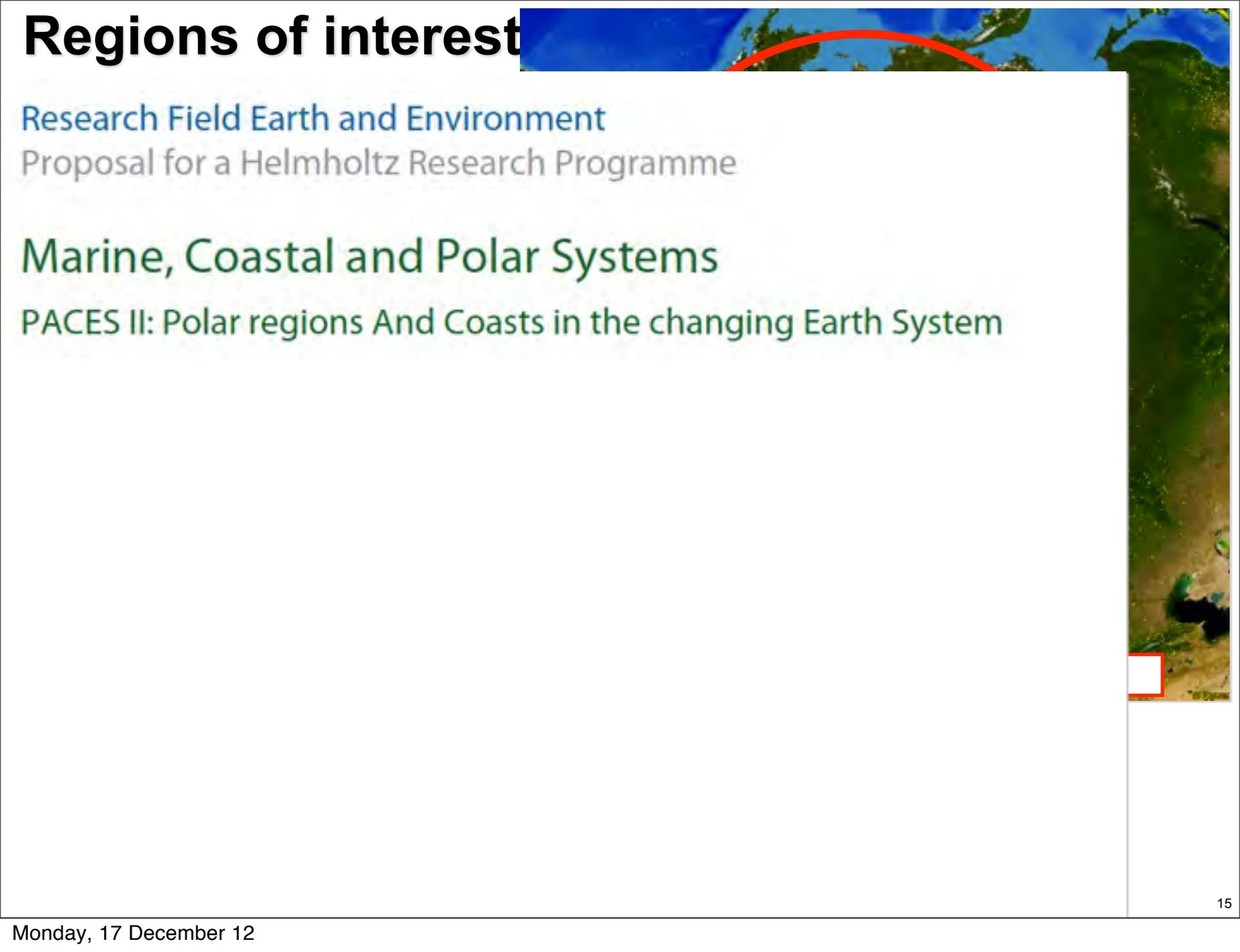
Regions of interest



Regions of interest



Regions of interest

A satellite image of Earth is visible in the background. A red arc is drawn across the top of the image, and a red box is drawn on the right side, highlighting a specific region of interest.

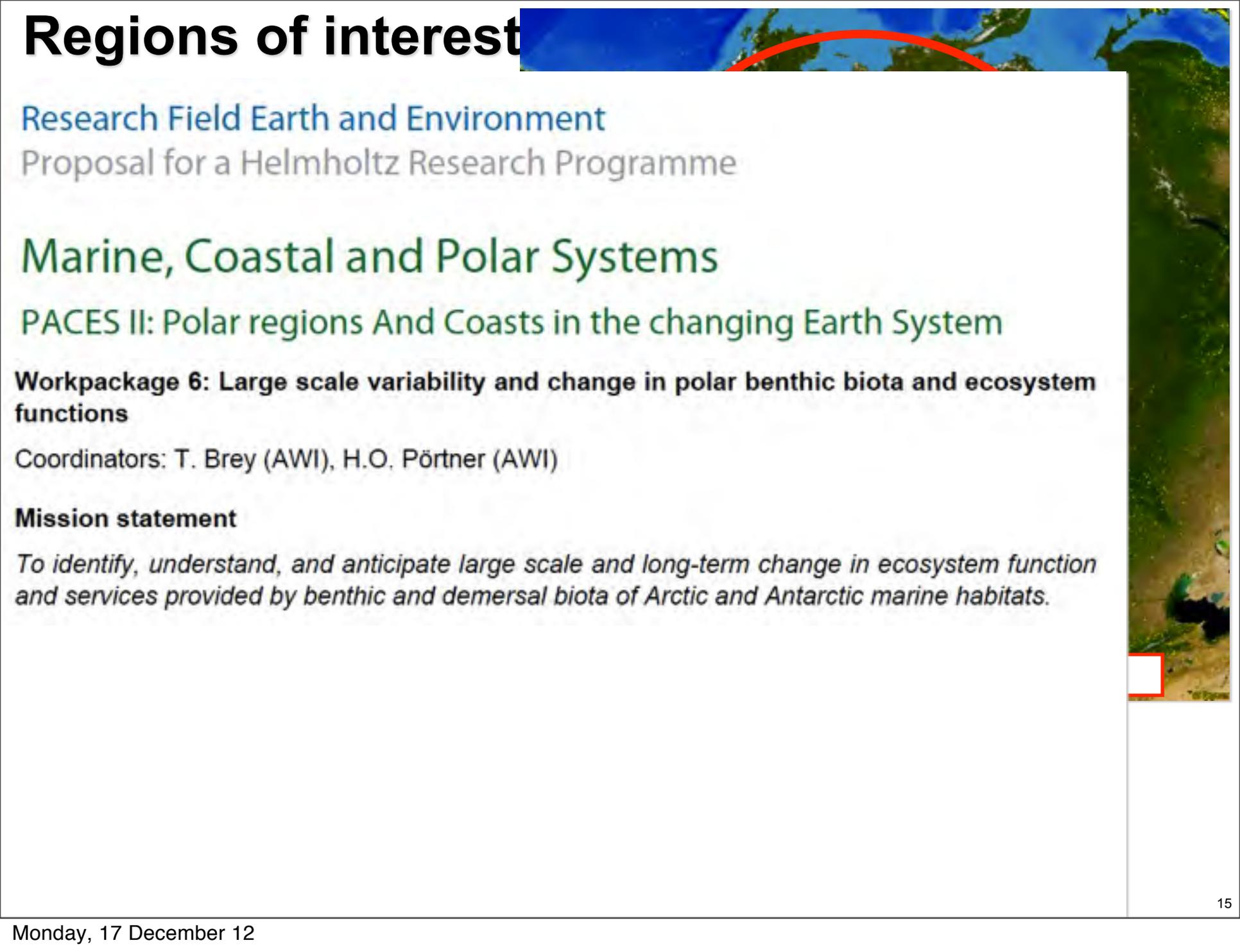
Research Field Earth and Environment

Proposal for a Helmholtz Research Programme

Marine, Coastal and Polar Systems

PACES II: Polar regions And Coasts in the changing Earth System

Regions of interest



Research Field Earth and Environment

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PACES II: Polar regions And Coasts in the changing Earth System

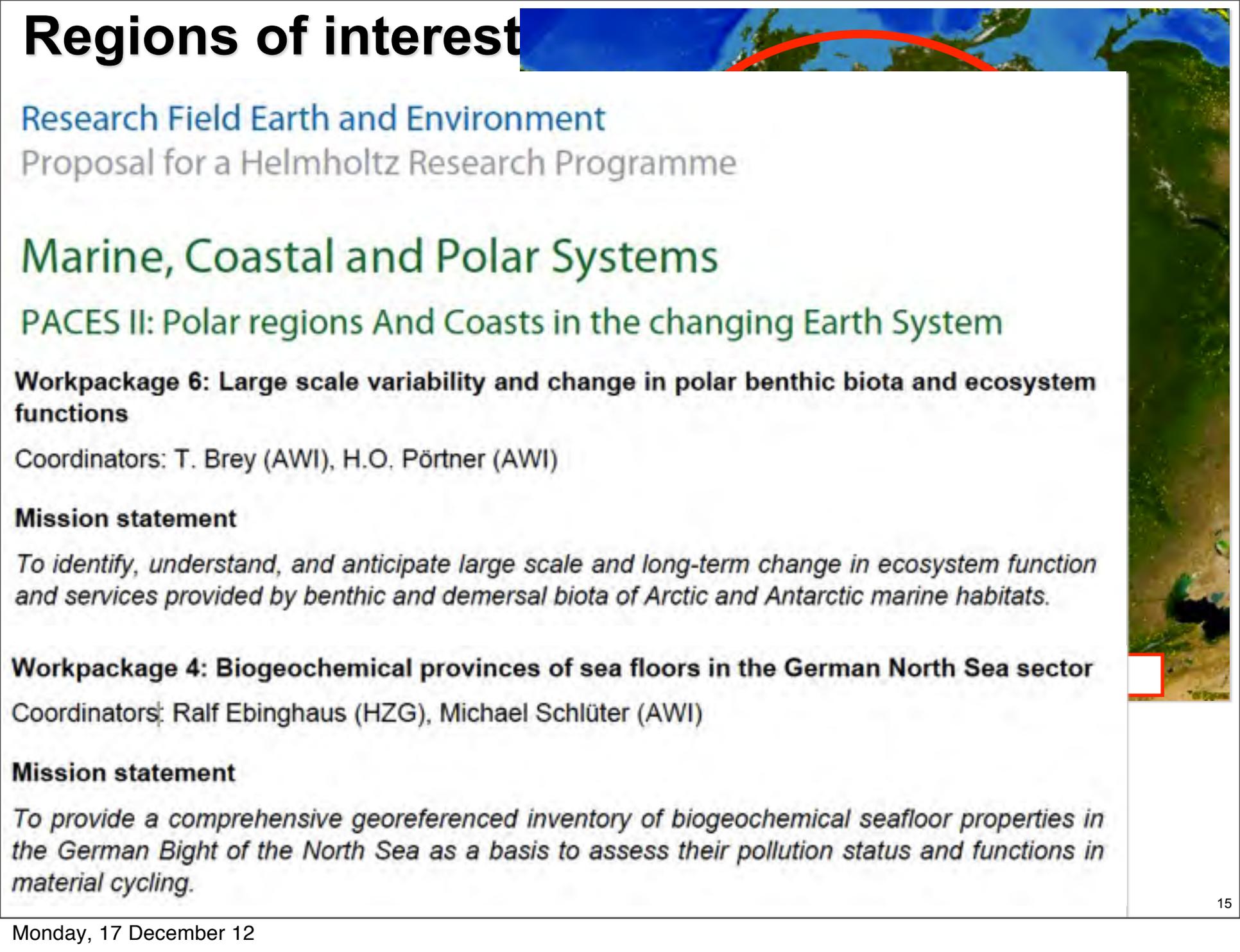
Workpackage 6: Large scale variability and change in polar benthic biota and ecosystem functions

Coordinators: T. Brey (AWI), H.O. Pörtner (AWI)

Mission statement

To identify, understand, and anticipate large scale and long-term change in ecosystem function and services provided by benthic and demersal biota of Arctic and Antarctic marine habitats.

Regions of interest



Research Field Earth and Environment

Proposal for a Helmholtz Research Programme

Marine, Coastal and Polar Systems

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Workpackage 4: Biogeochemical provinces of sea floors in the German North Sea sector

Coordinators: Ralf Ebinghaus (HZG), Michael Schlüter (AWI)

Mission statement

To provide a comprehensive georeferenced inventory of biogeochemical seafloor properties in the German Bight of the North Sea as a basis to assess their pollution status and functions in material cycling.

Antarctic Weddell Sea



Antarctic Weddell Sea



Bundesministerium für
Ernährung, Landwirtschaft
und Verbraucherschutz

Pressemitteilung Nr. 318 vom 29.10.12 Deutschland plant Meeresschutzgebiete in der Antarktis

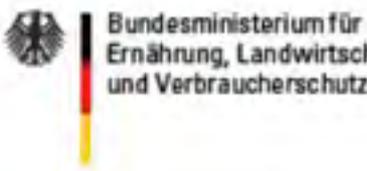
Aigner: "Einzigartige Ökosysteme müssen wirksam geschützt werden"

Die Bundesrepublik Deutschland wird für die "Internationale Kommission zum Schutz lebender Ressourcen in der Antarktis" (CCAMLR: Commission for the Conservation of Antarctic Living Resources) die Vorbereitungen zur Errichtung von Meeresschutzgebieten im Weddellmeer übernehmen.



Weddell Sea

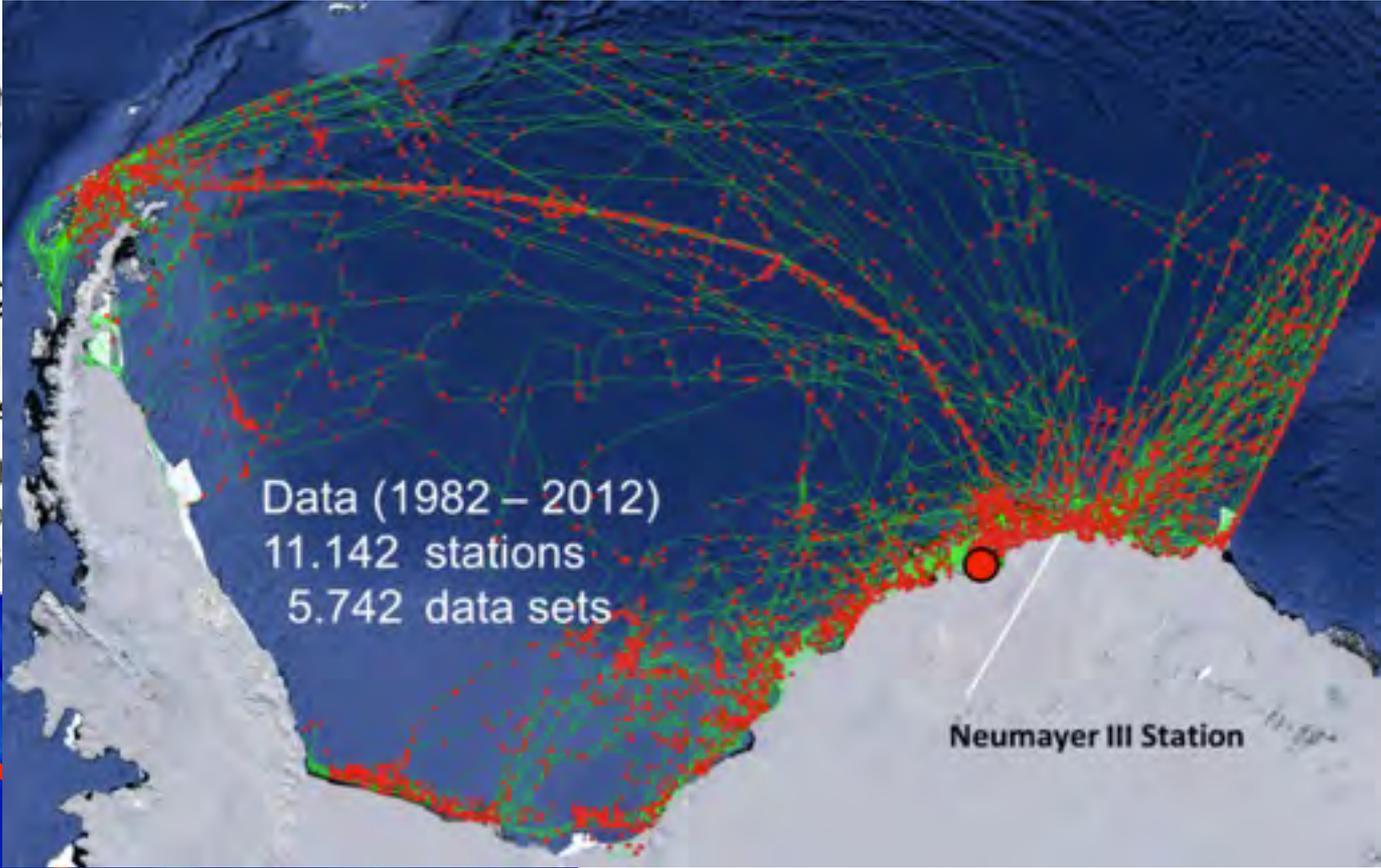
Antarctic Weddell Sea



Pressemitteilung Meeresschutzge

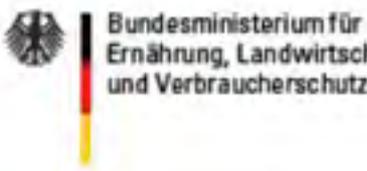
Aigner: "Einzigartige Ökos

Die Bundesrepublik Deutsch
der Antarktis" (CCAMLR: Co
zur Errichtung von Meeress



Weddell Sea

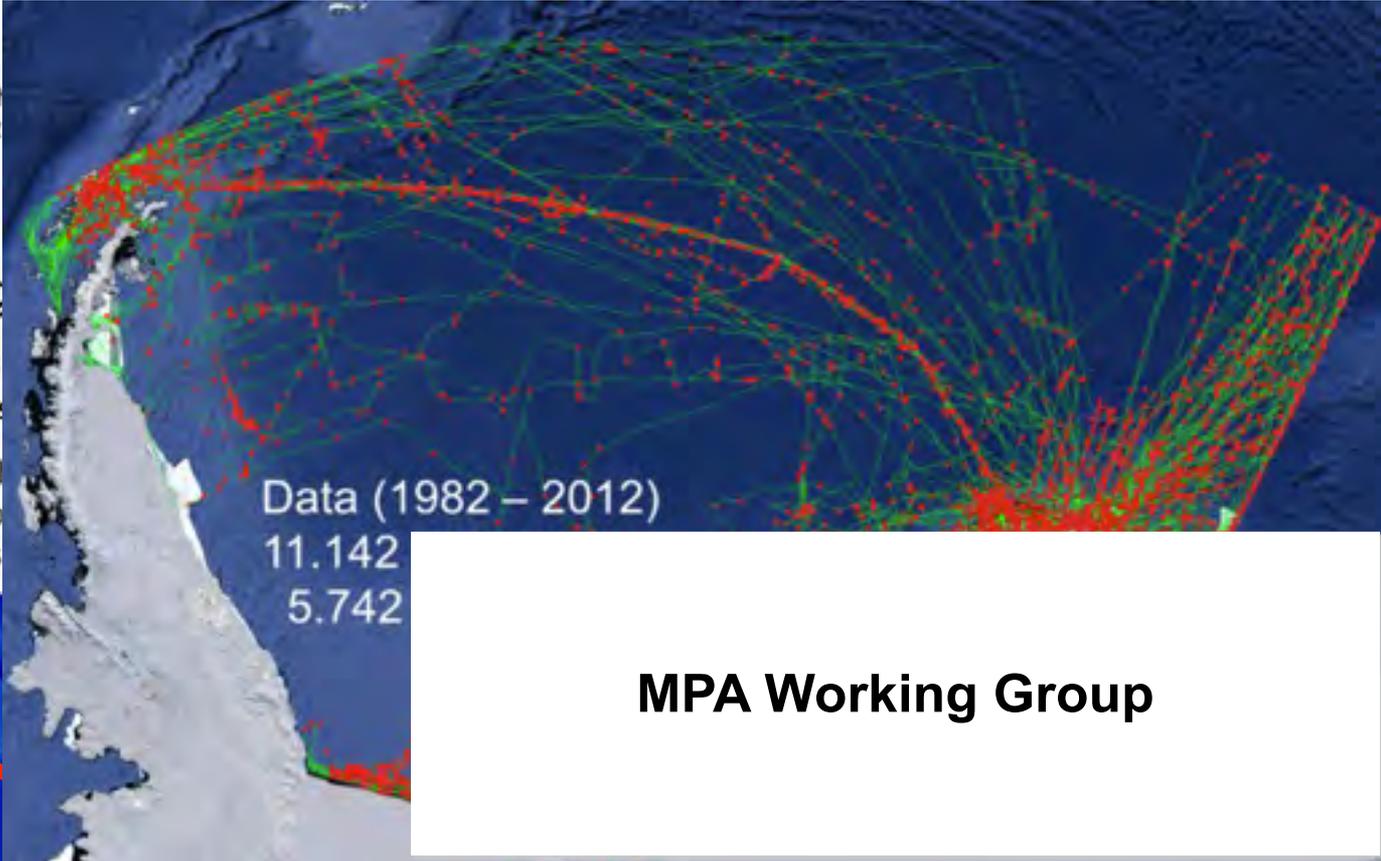
Antarctic Weddell Sea



Pressemitteilung Meeresschutzge

Aigner: "Einzigartige Ökos

Die Bundesrepublik Deutsch
der Antarktis" (CCAMLR: Co
zur Errichtung von Meeress

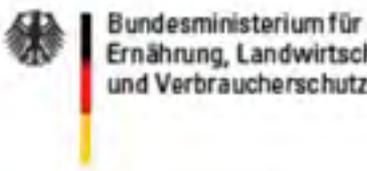


MPA Working Group



Weddell Sea

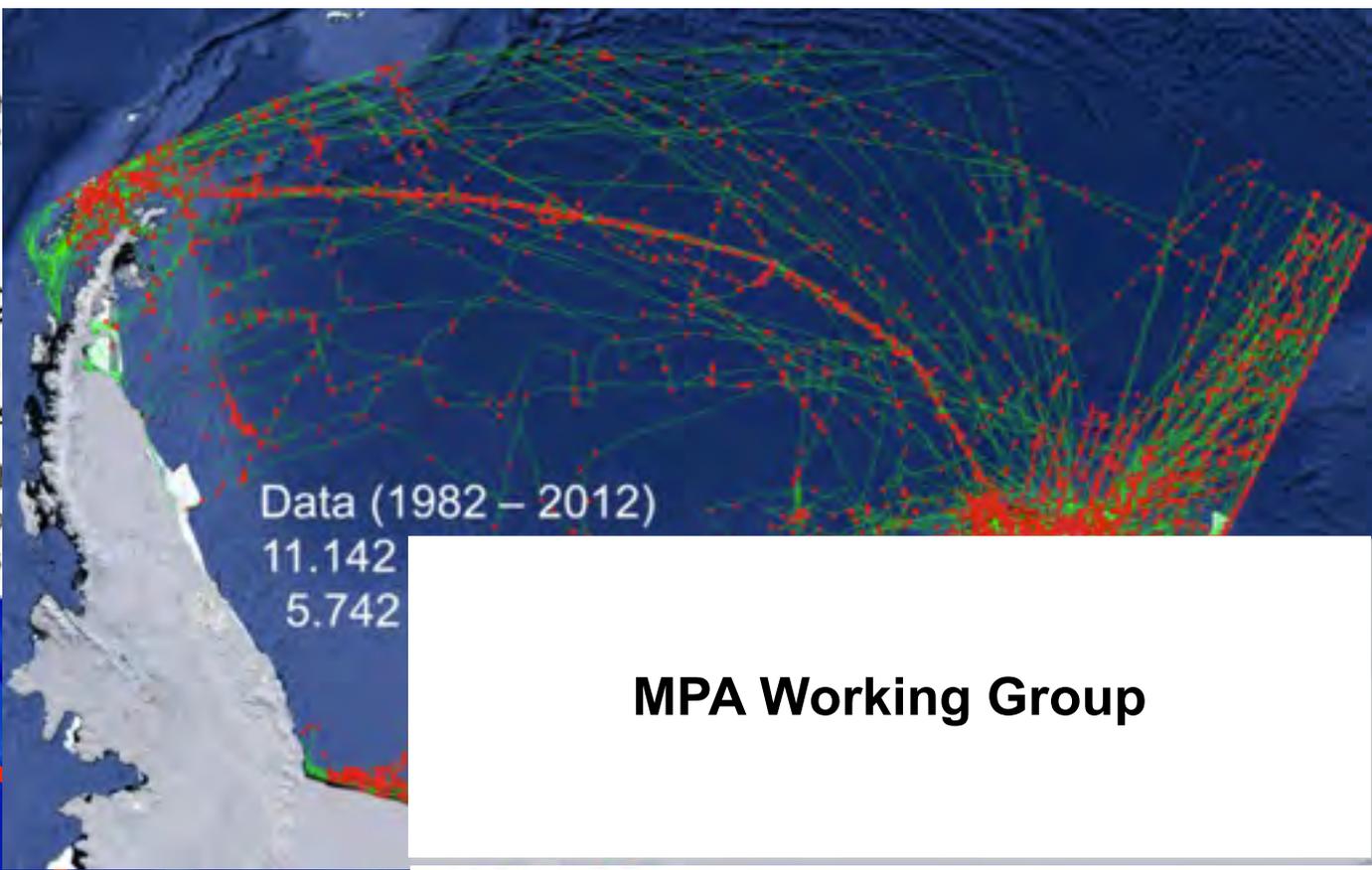
Antarctic Weddell Sea



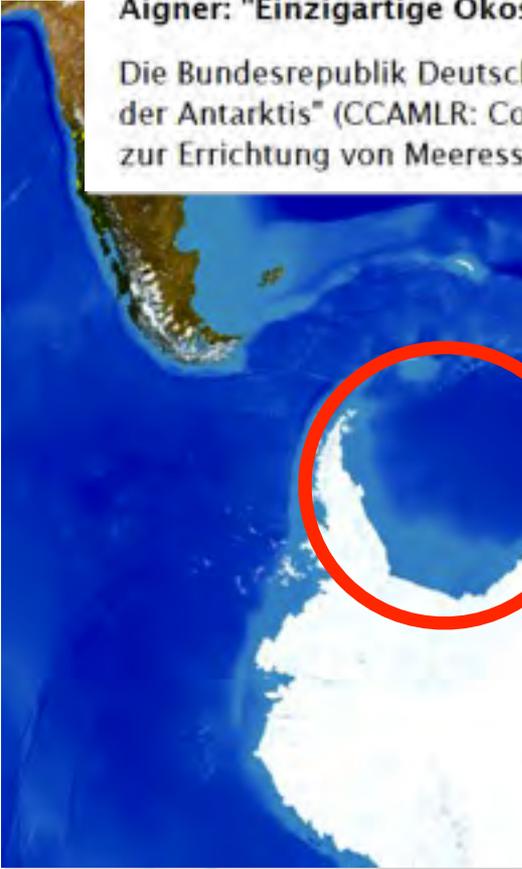
Pressemitteilung Meeresschutzge

Aigner: "Einzigartige Ökos

Die Bundesrepublik Deutsch
der Antarktis" (CCAMLR: Co
zur Errichtung von Meeress



Data (1982 - 2012)
11.142
5.742



Weddell Sea

MPA Working Group

DFG Project

Identification of biogeochemical provinces in the Southern Ocean: spatial modeling of biological, geochemical and sedimentological data

Dr. Kerstin Jerosch

Arctic Ocean



Arctic Ocean

Vision:

**pan-Arctic approach:
1st step: geo-referenced benthic data
bank**



Arctic Ocean

Vision:

**pan-Arctic approach:
1st step: geo-referenced benthic data
bank**



Arctic Ocean

Mar Biodiv (2011) 41:51–70
DOI 10.1007/s12526-010-0059-7

SENCKENBERG

ARCTIC OCEAN DIVERSITY SYNTHESIS

Towards a pan-Arctic inventory of the species diversity of the macro- and megabenthic fauna of the Arctic shelf seas

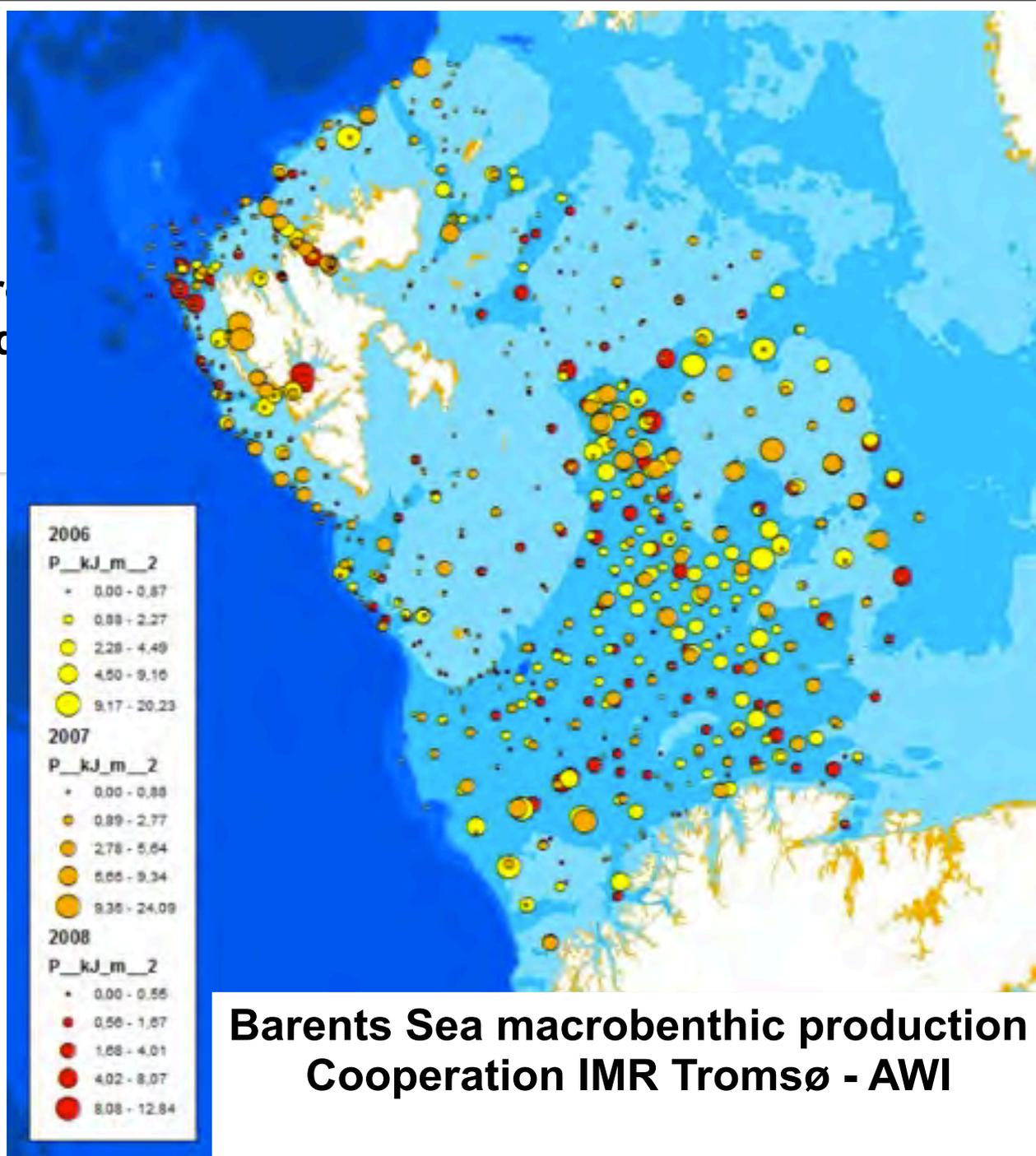
Dieter Piepenburg • Philippe Archambault • William G. Ambrose Jr. •
Arny L. Blanchard • Bodil A. Bluhm • Michael L. Carroll • Kathleen E. Conlan •
Mathieu Cusson • Howard M. Feder • Jacqueline M. Grebmeier • Stephen C. Jewett •
Mélanie Lévesque • Victor V. Petryashev • Mikael K. Sejr • Boris I. Sirenko •
Maria Włodarska-Kowalczyk

Arctic Ocean

Vision:

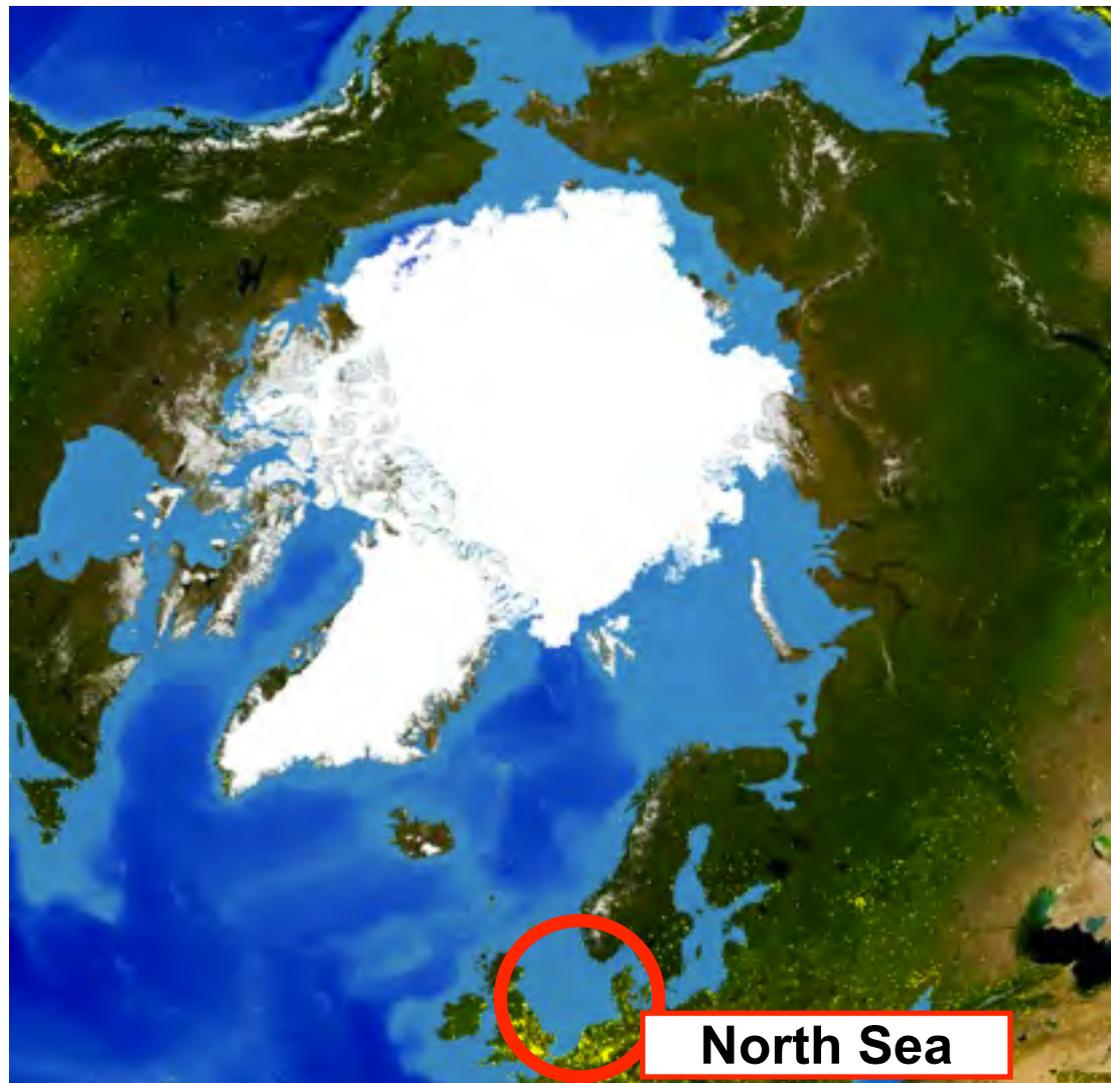
pan-Arctic approach

1st step: geo-referenced
data bank

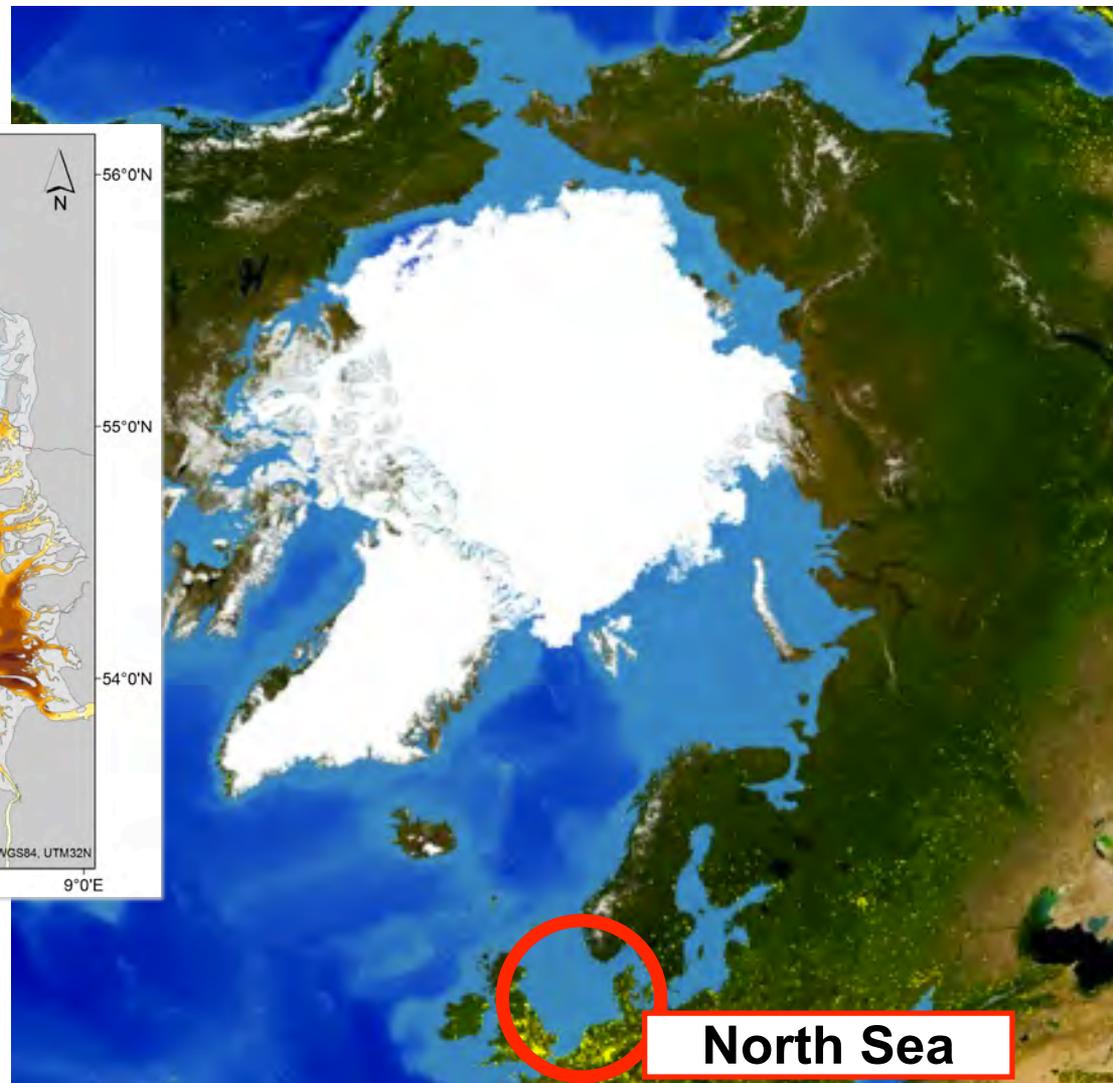
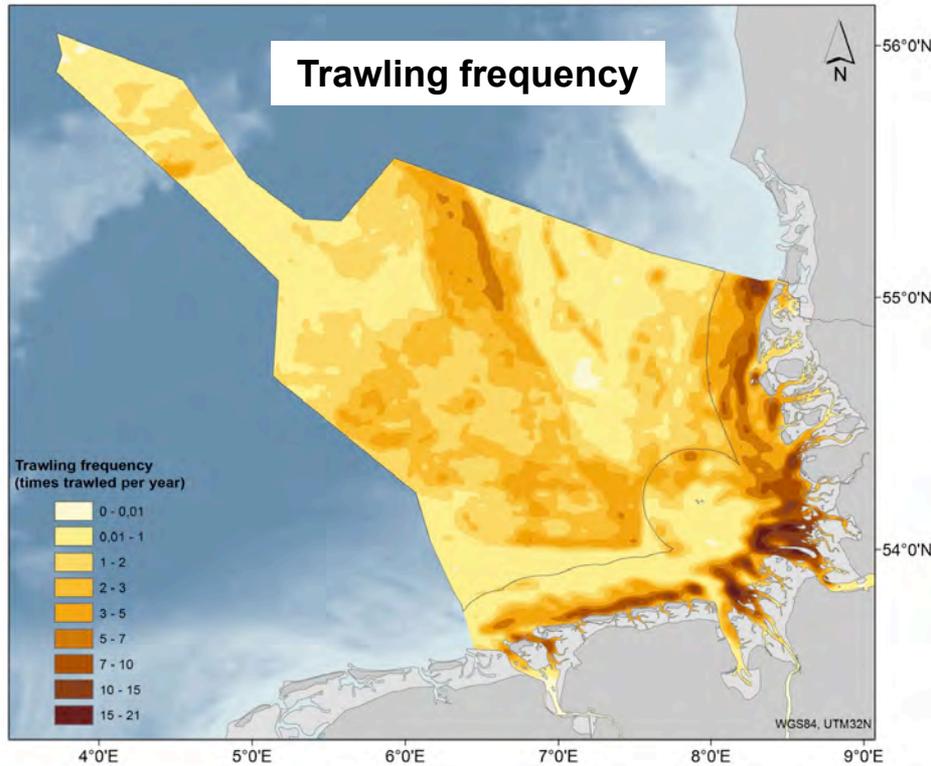


**Barents Sea macrobenthic production
Cooperation IMR Tromsø - AWI**

North Sea

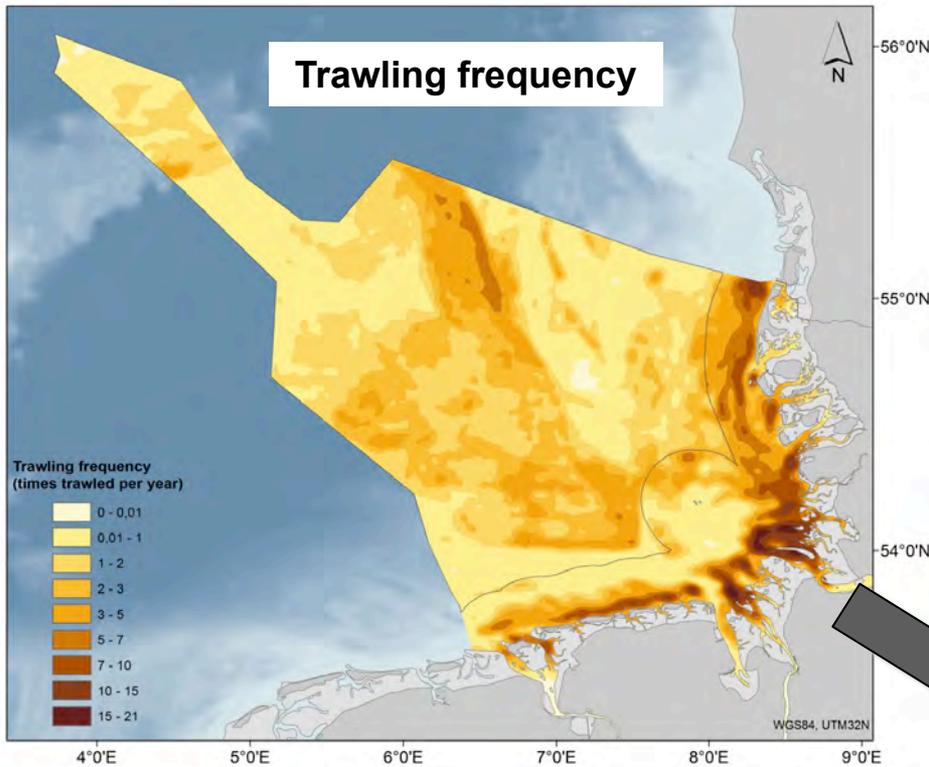


North Sea

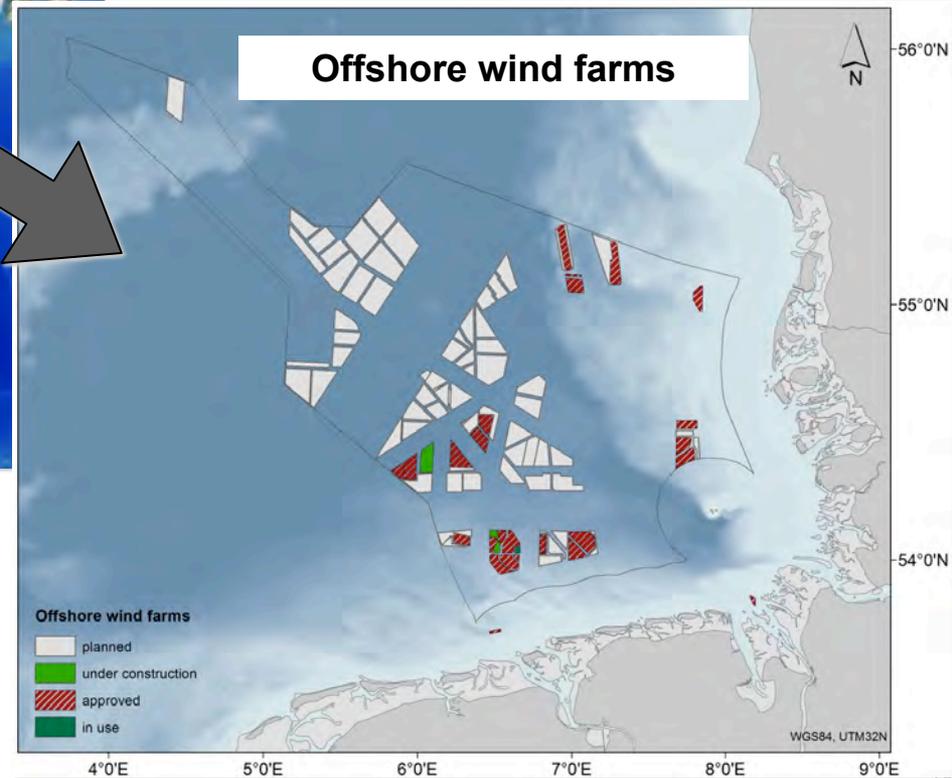


North Sea

Trawling frequency

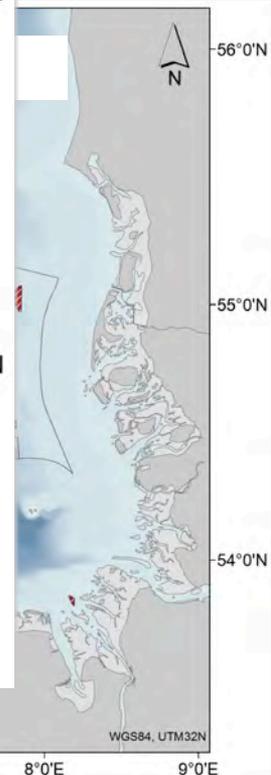
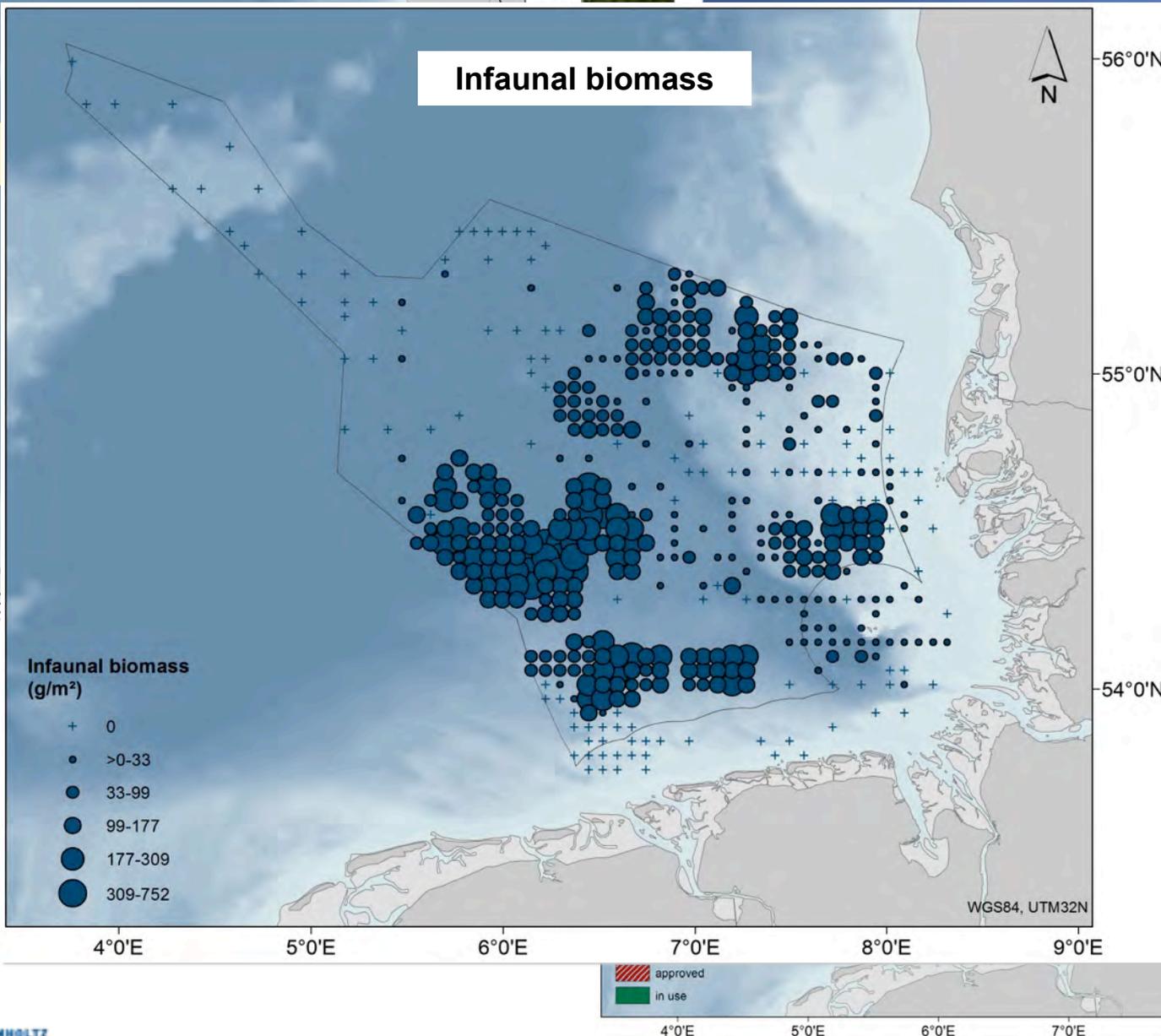
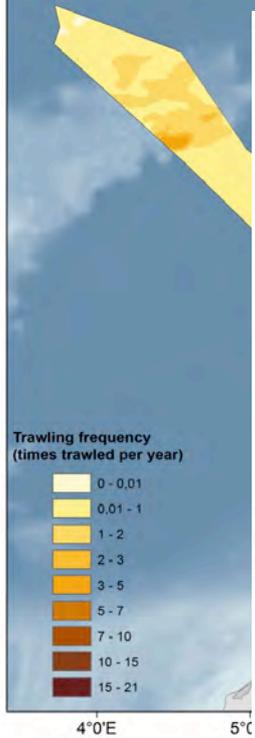


Offshore wind farms



North Sea

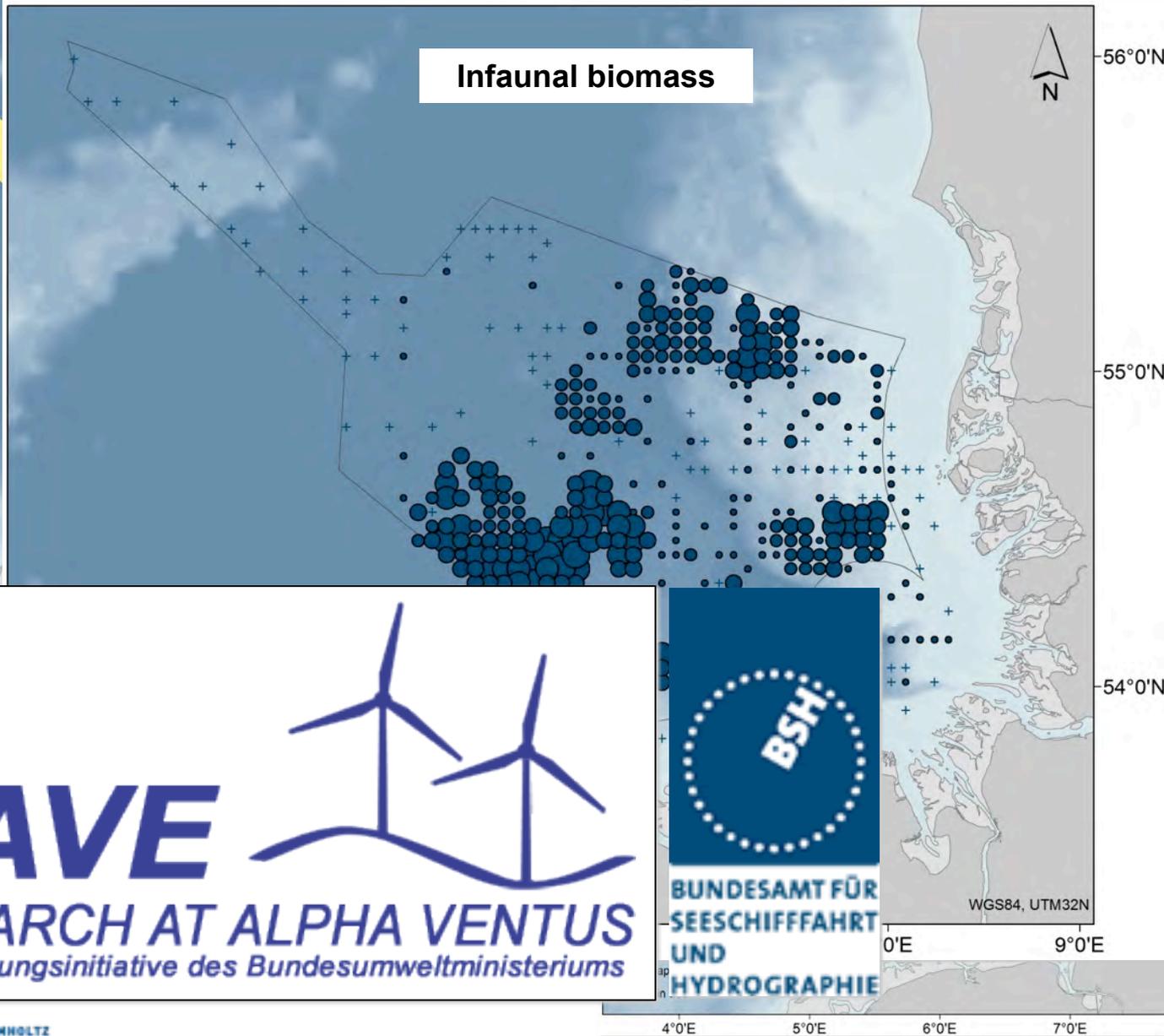
Infaunal biomass



North Sea

Infaunal biomass

Trawling frequency
(times trawled per year)



RAVE

RESEARCH AT ALPHA VENTUS
Eine Forschungsinitiative des Bundesumweltministeriums



BUNDESAMT FÜR
SEESCHIFFFAHRT
UND
HYDROGRAPHIE





- The End -