The European experience in the North Sea: From theory to reality




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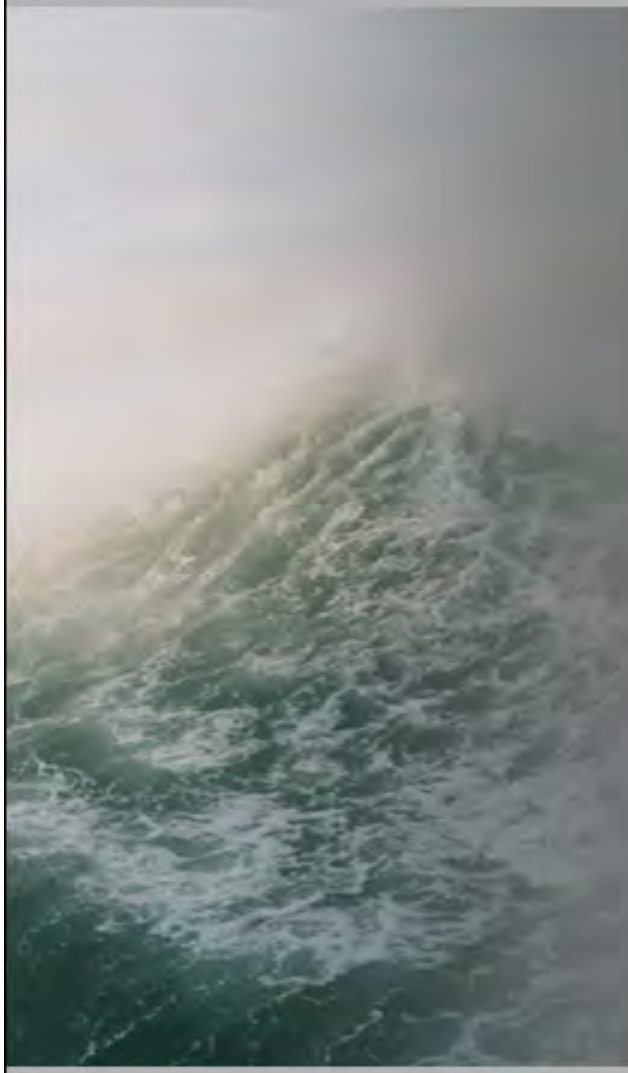
International Workshop on Bioextractive Technologies for Nutrient Remediation,
Dez. 3-4 '09, UCONN - Stamford, CT

AWI | imare Institut für Marine Ressourcen GmbH | Hochschule Bremerhaven

Research Fields Involved



Introduction

Current Situation Germany/EU

Site-Selection

Moving Offshore

Candidate Species

Saccharina latissima
(Laminaria saccharina)

Sugar Kelp

Mytilus edulis

Blue Mussel

Crassostrea gigas

Pacific Oyster

Ostrea edulis

European Oyster

Laminaria digitata, Solieria chordalis,
Palmaria palmata, Gracilaria vermiculophylla

On-Bottom Cultivation of Mussels


natural mussel bed


mussel cutter

Production depends on the availability of spat.

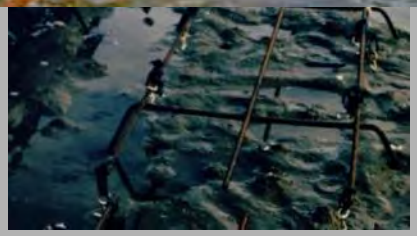
How is the spat fall in the next year?


mussel dredge


seabed after dredging

No expansion possible, due to stakeholder conflicts.

Poches-Culture of Oysters



Production depends on the availability of juveniles (Ireland).

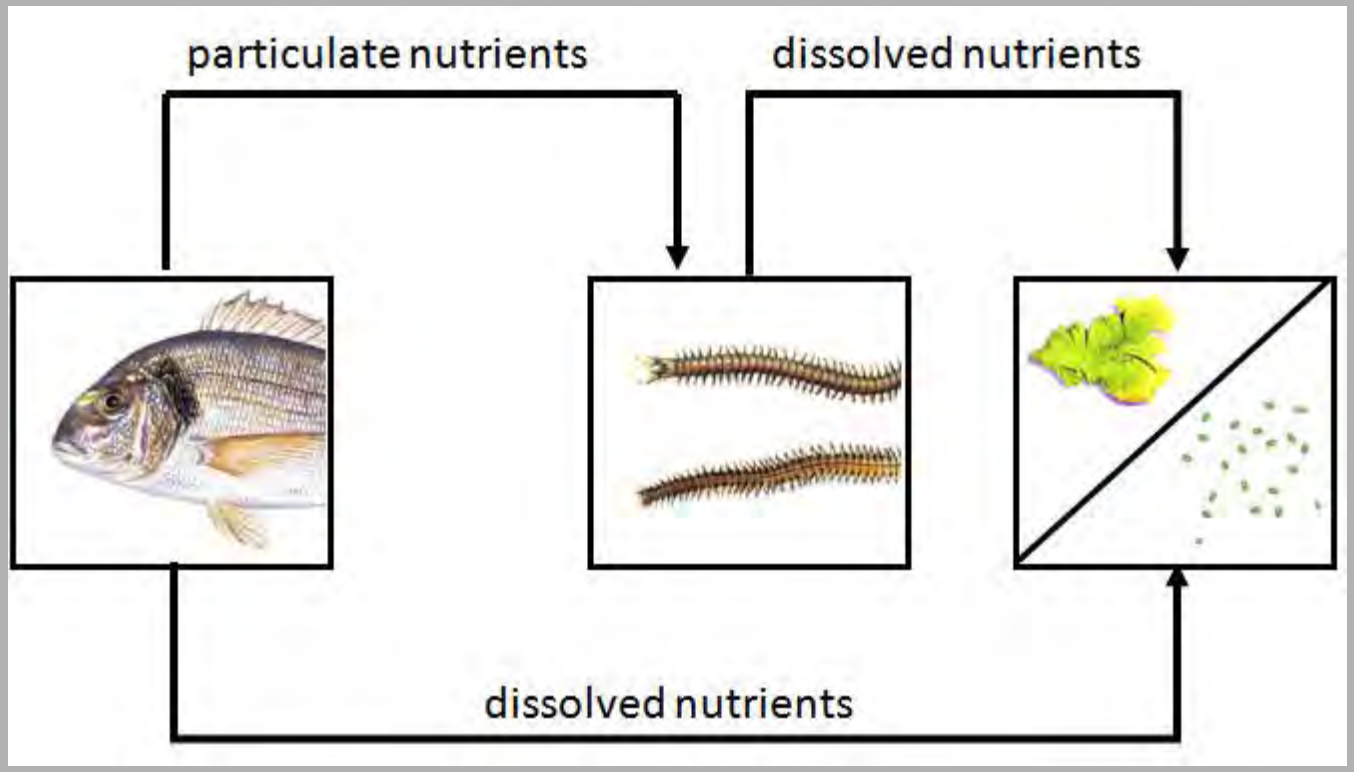
Transfer of species allows hitchhiking of other organisms.

Strom events and ice can damage the constructions.

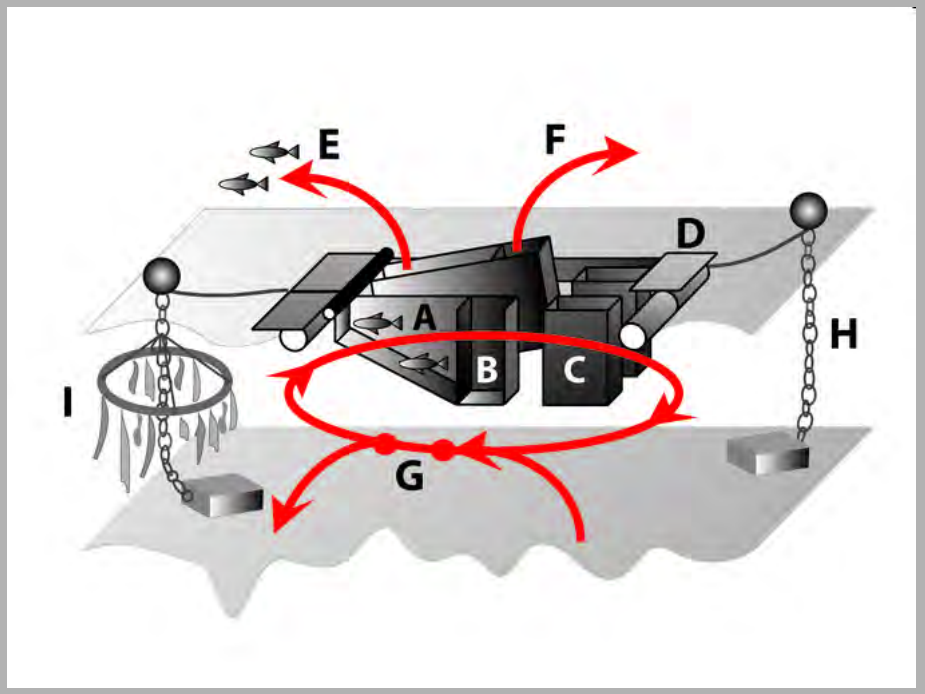
Regulations...

Other Aquaculture Species & Techniques

land based IMTA

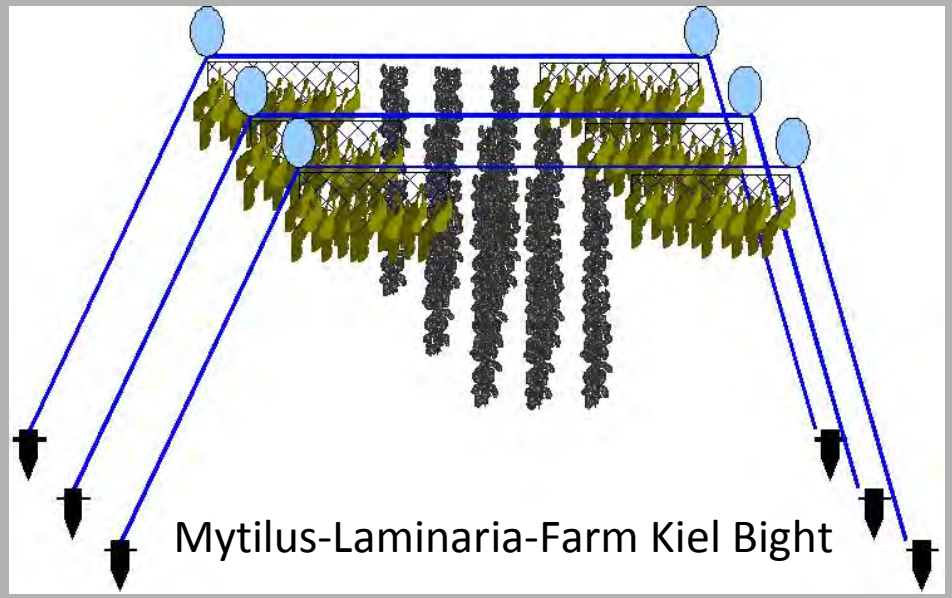


IMTA – in one System

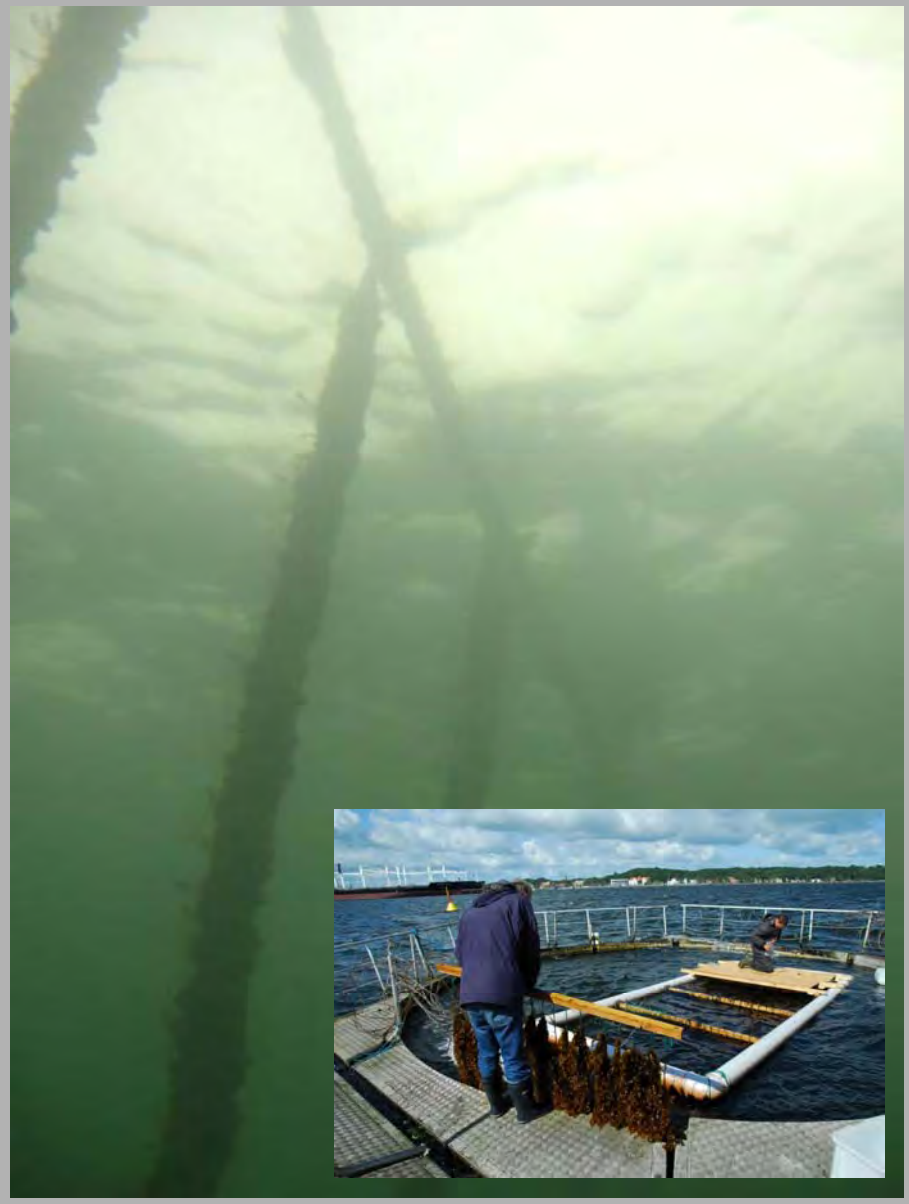


In-Pond-Raceways” (IPR) and “Recirculation-Aquaculture-Systems” (RAS) in one ecologically compatible, floating plant

IMTA – Kiel Bight



Mytilus-Laminaria-Farm Kiel Bight

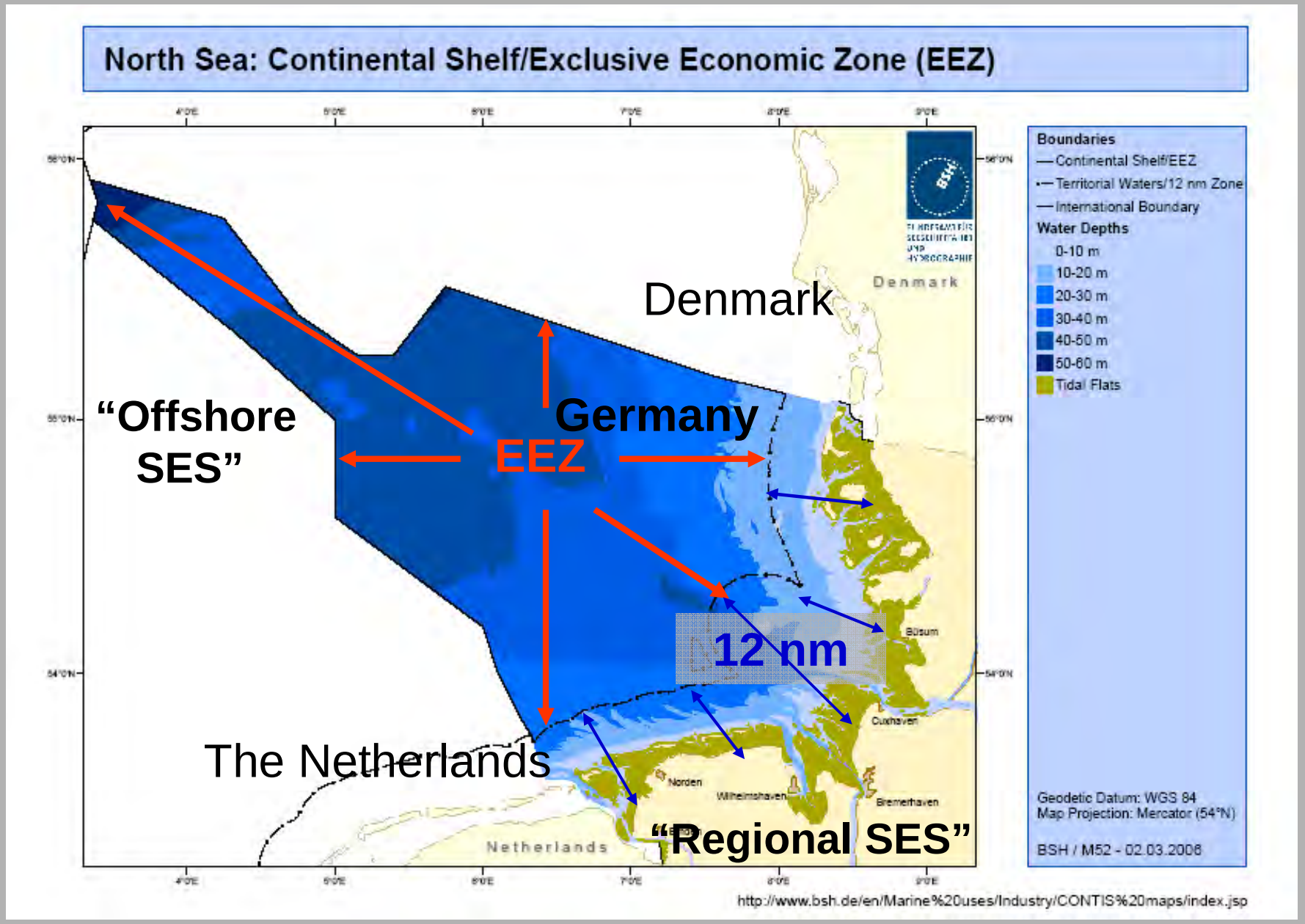


Problems & Limitations of Aquaculture in Germany

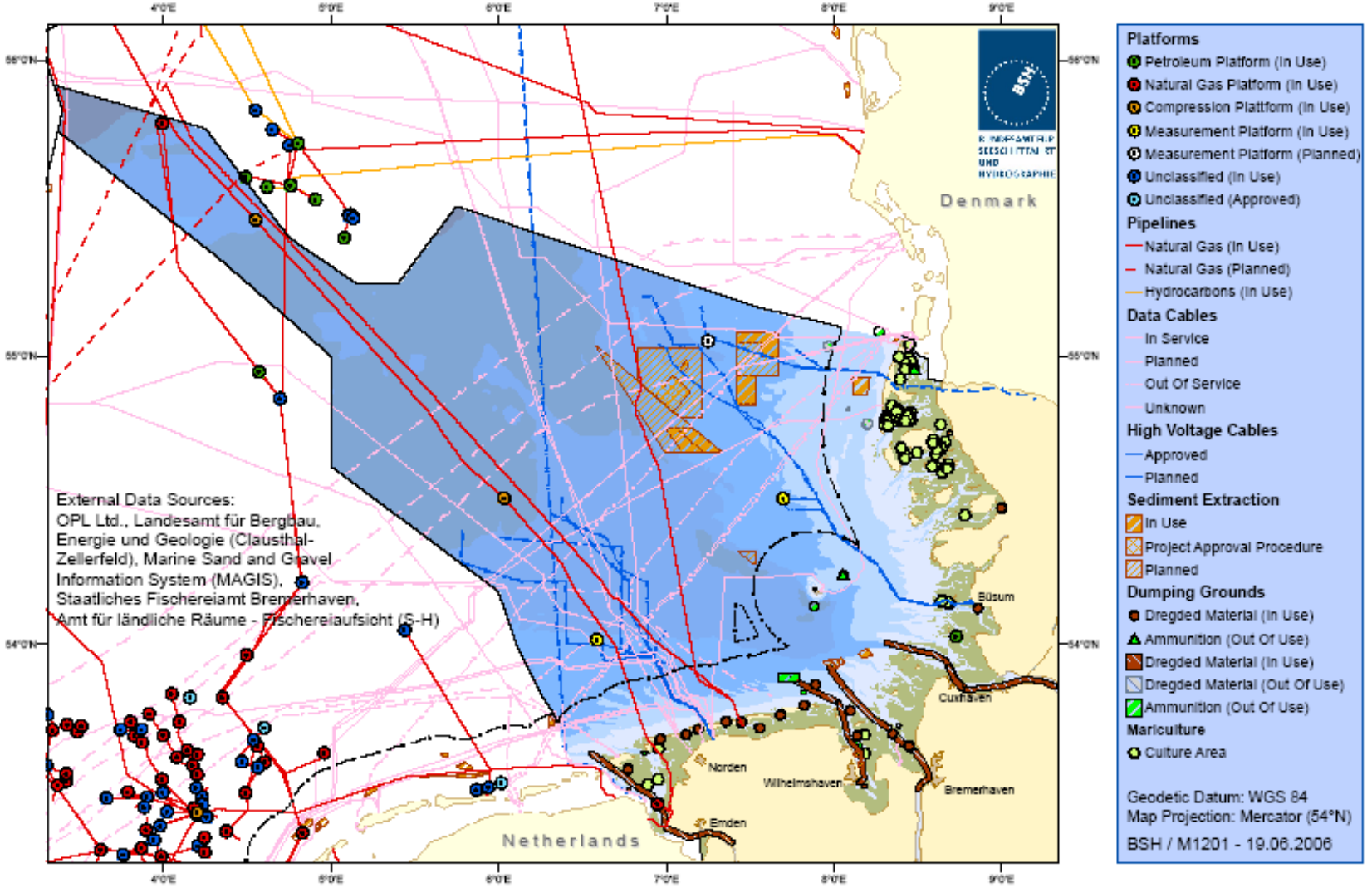
Is nearshore aquaculture in Germany stagnating?

- shallow sea (low depth)
- high sediment load (Wadden Sea)
- harsh conditions
  - high waves (- 8m)
  - strong currents (1.8 $m \cdot s^{-1}$)
  - wind speed
- high tidal level (4 m)
- conflicts
  - user and consumer
  - regulations
  - environment (impacts and quality)
  - health

Buck et al. (2004), *Ocean & Coastal Mgmt.*
Buck et al. (2003), *Kluwer Law International*


North Sea: Continental Shelf/Exclusive Economic Zone (EEZ)
Denmark
Germany
EEZ
"Offshore SES"
12 nm
The Netherlands
"Regional SES"
Netherlands
Boundaries
Continental Shelf/EEZ
Territorial Waters/12 nm Zone
International Boundary
Water Depths
0-10 m
10-20 m
20-30 m
30-40 m
40-50 m
50-60 m
Tidal Flats
Büsum
Cuxhaven
Norden
Wilhelmshaven
Bremerhaven
Geodetic Datum: WGS 84
Map Projection: Mercator (54°N)
BSH / M52 - 02.03.2006
http://www.bsh.de/en/Marine%20uses/Industry/CONTIS%20maps/index.jsp

North Sea: Platforms, Pipelines, Cables, Sediment Extraction, Mariculture



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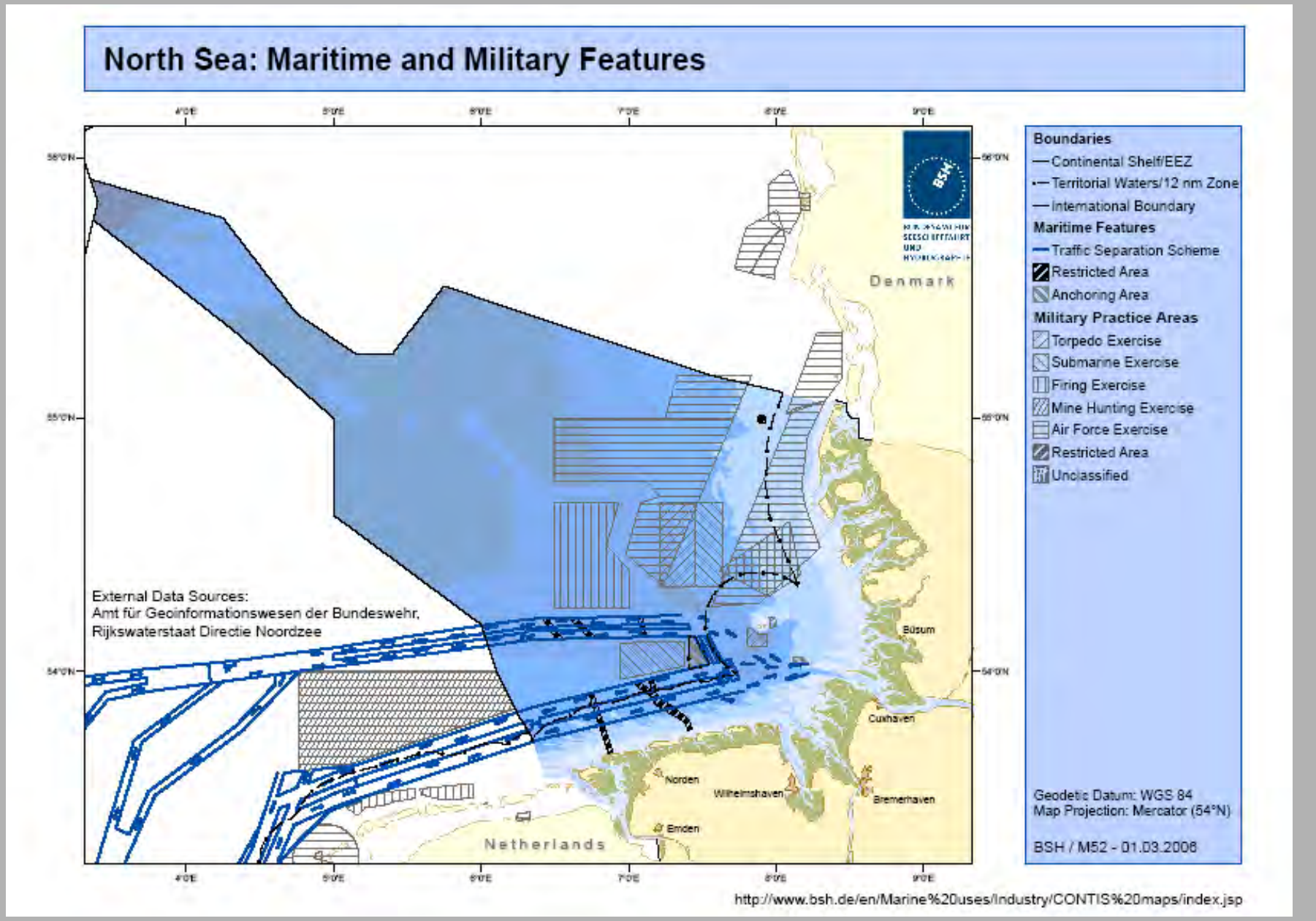
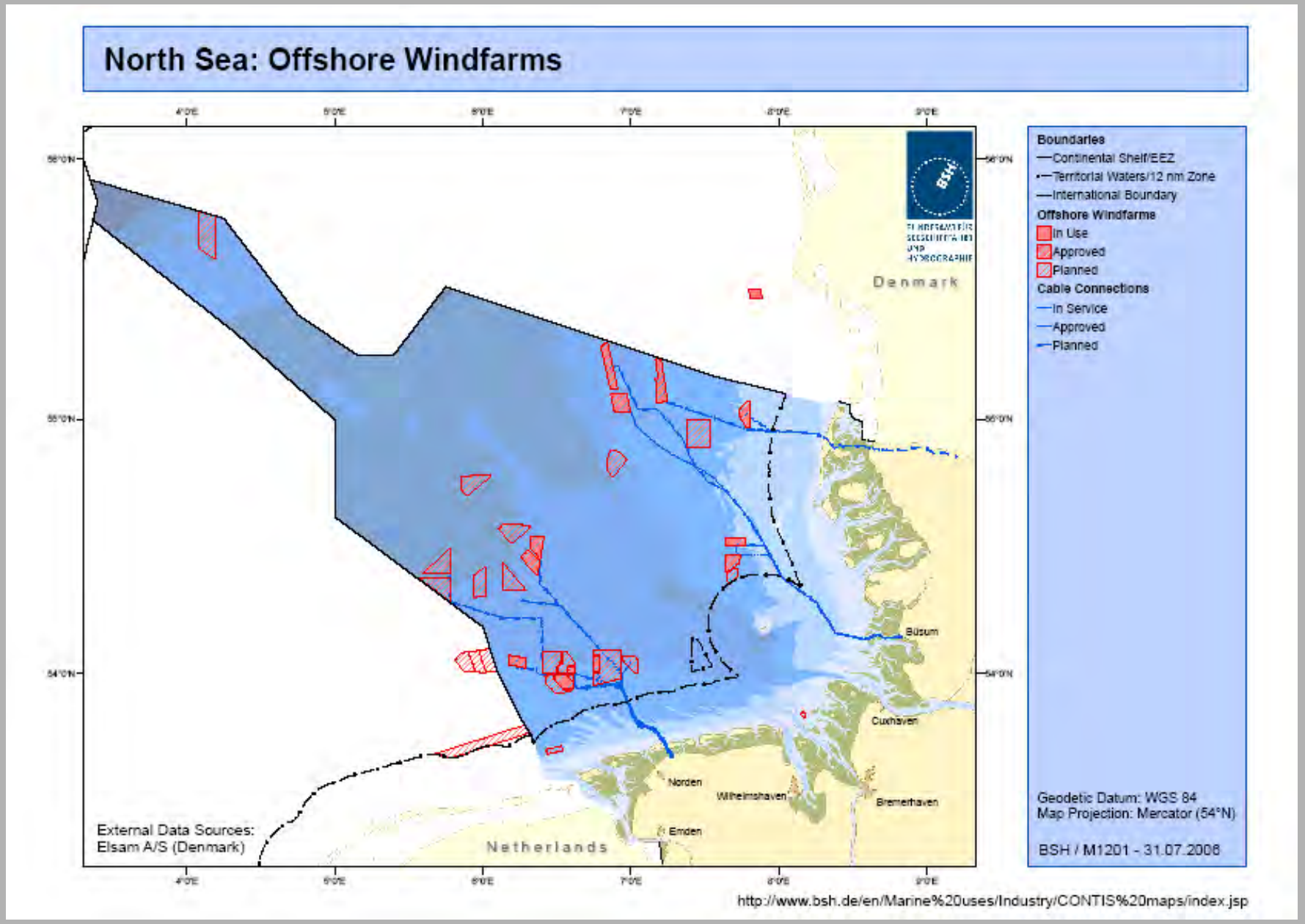
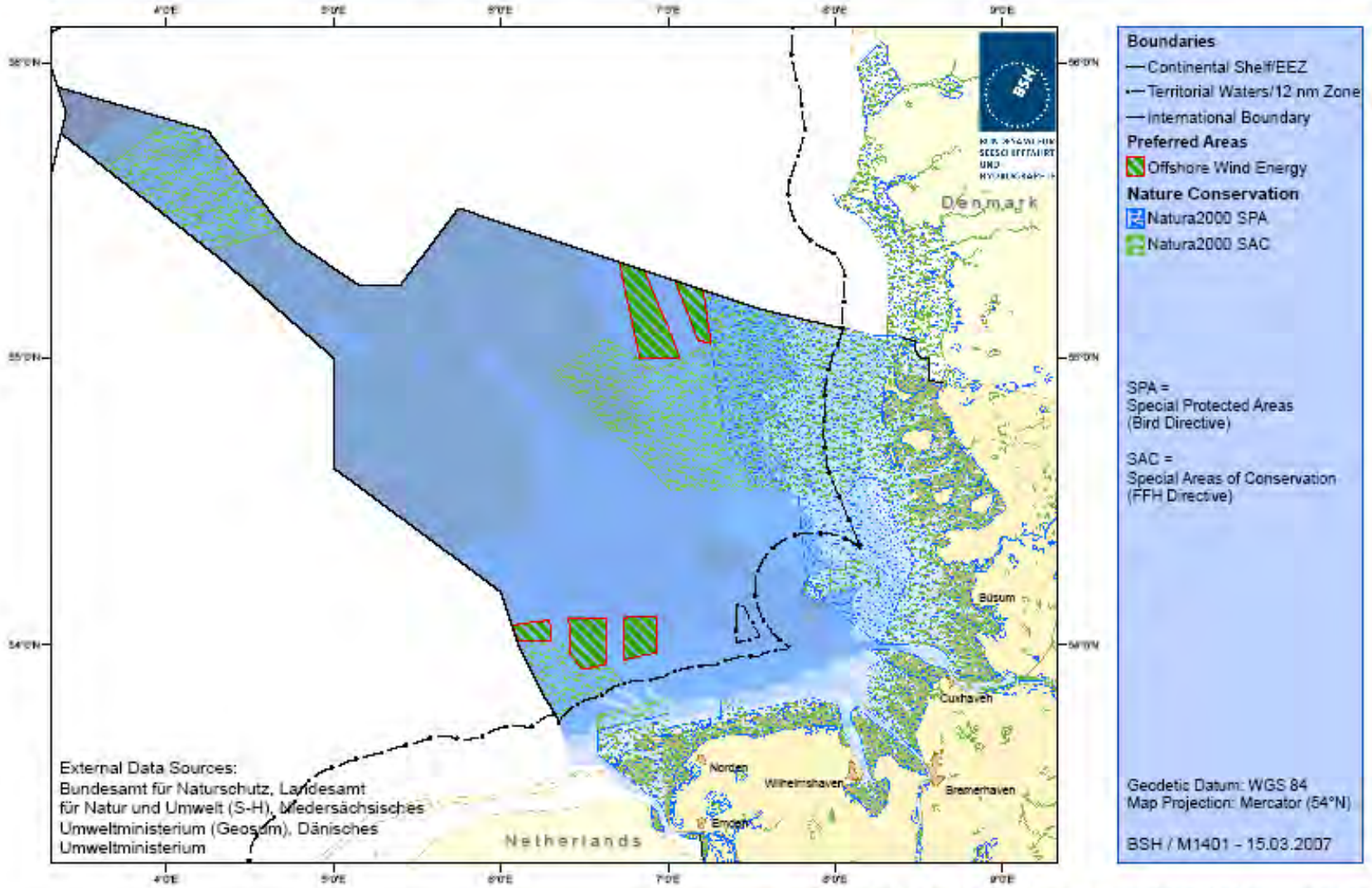

North Sea: Maritime and Military Features
4°0'E
5°0'E
6°0'E
7°0'E
8°0'E
9°0'E
56°0'N
55°0'N
54°0'N
Denmark
Netherlands
Büsum
Cuxhaven
Norden
Wilhelmshaven
Bremerhaven
Emden
External Data Sources:
Amt für Geoinformationswesen der Bundeswehr,
Rijkswaterstaat Directie Noordzee
Boundaries
Continental Shelf/EEZ
Territorial Waters/12 nm Zone
International Boundary
Maritime Features
Traffic Separation Scheme
Restricted Area
Anchoring Area
Military Practice Areas
Torpedo Exercise
Submarine Exercise
Firing Exercise
Mine Hunting Exercise
Air Force Exercise
Restricted Area
Unclassified
Geodetic Datum: WGS 84
Map Projection: Mercator (54°N)
BSH / M52 - 01.03.2006
http://www.bsh.de/en/Marine%20uses/Industry/CONTIS%20maps/index.jsp


North Sea: Offshore Windfarms
Denmark
Netherlands
Büsum
Cuxhaven
Norden
Wilhelmshaven
Bremerhaven
Emden
Boundaries
Continental Shelf/EEZ
Territorial Waters/12 nm Zone
International Boundary
Offshore Windfarms
In Use
Approved
Planned
Cable Connections
In Service
Approved
Planned
External Data Sources:
Elsam A/S (Denmark)
Geodetic Datum: WGS 84
Map Projection: Mercator (54°N)
BSH / M1201 - 31.07.2006
http://www.bsh.de/en/Marine%20uses/Industry/CONTIS%20maps/index.jsp

North Sea: Preferred Areas and Nature Conservation



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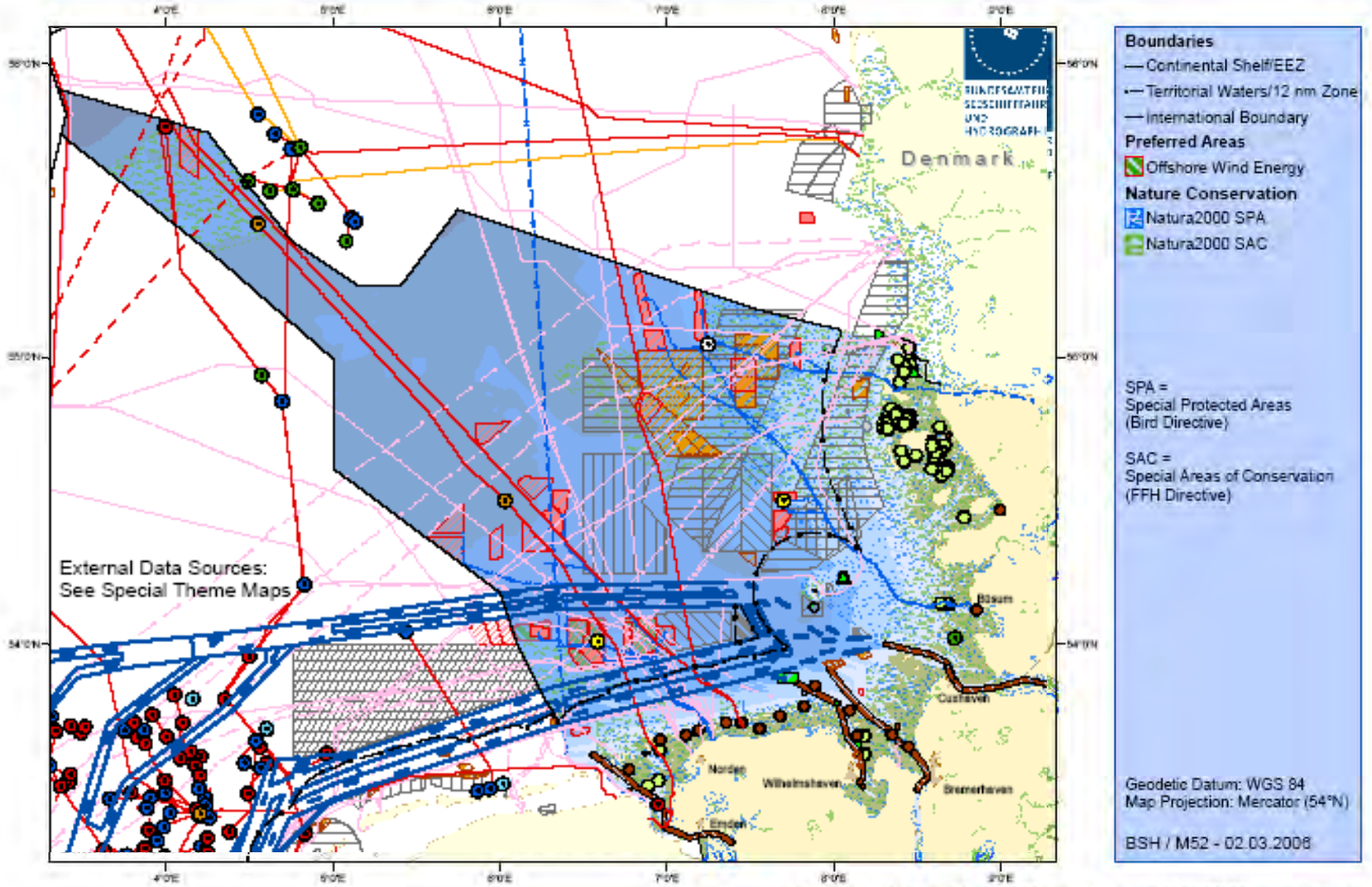
North Sea: Preferred Areas and Nature Conservation



http://www.bsh.de/en/Marine%20uses/Industry/CONTIS%20maps/index.jsp

1st Offshore Wind Farm Horns Rev

Alpha Ventus Wind Farm in Germany

Construction of the *Alpha Ventus* wind farm in the EEZ 60 km off the coast of Germany.

Bard Engineering GmbH (2009), www.bard-offshore.de

Alpha Ventus Wind Farm in Germany

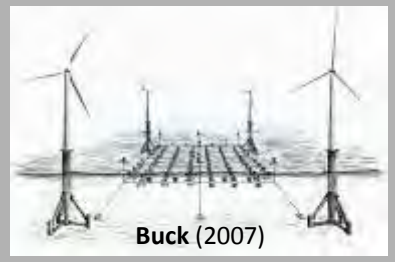
Tripod and *Tripile* grounding constructions.

Bard Engineering GmbH (2009), www.bard-offshore.de

Maximizing the Benefit

Multi-use ideas to maximize the benefit of an offshore area:

1. Ecology
   - Creating MPA‘s (nursery, sustainable fisheries…)
   - Set-up artificial reefs
2. Tourism
3. Additional energy resources
4. Offhore Aquaculture



Research Motivations

Why ...

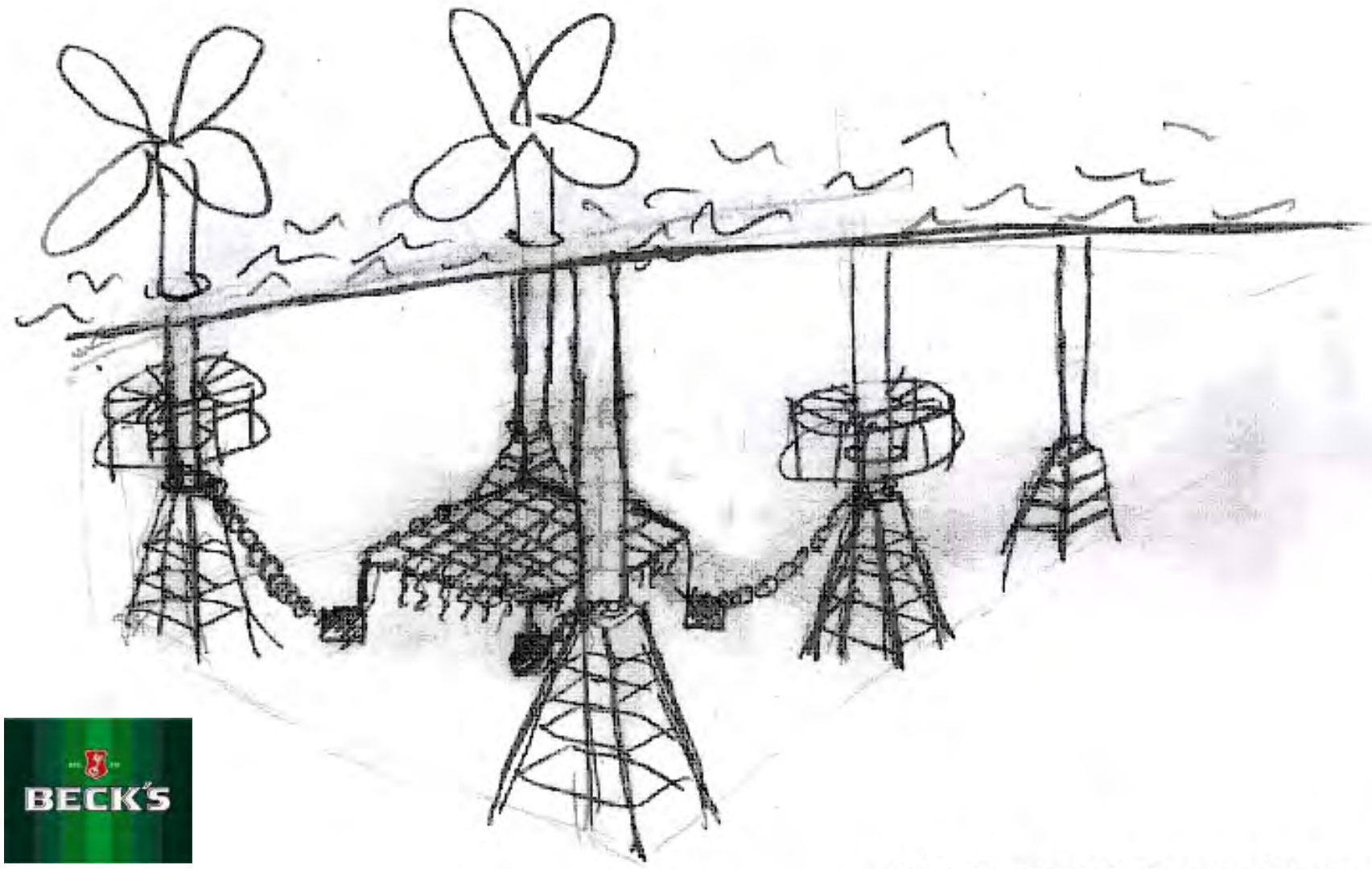
...Offshore Aquaculture?

1.increasing limitation of favourable coastal and nearshore sites
2.demise of ocean fisheries ***vs.*** rising demand on marine aquaculture products
3.little spatial regulations & better water quality

…Aquaculture in Offshore Wind Farms?

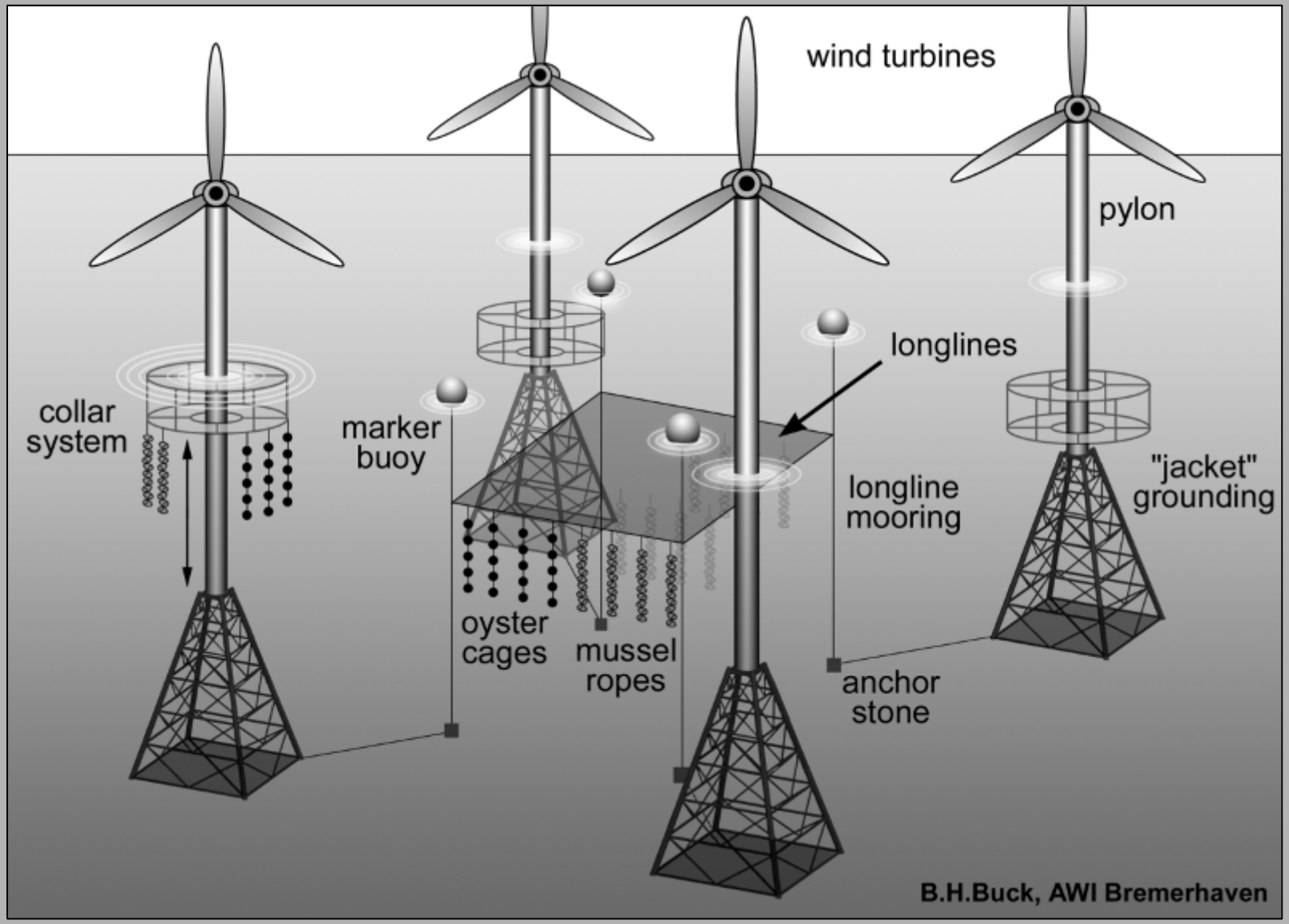
1.lack of legislation in EEZ → window of opportunity for concerted innovative multiple-use schemes
2.quest for spatial efficiency
3.maximizing return from a unit of sea
4.solid turbine foundations may provide support for mariculture devices

First Vision 2001



Beck‘s beer coaster

Multi-Use Concept



Buck et al. (2004), *Ocean & Coastal Mgmt.*

What is an Exposed Location?

Image: B. H. Buck (AWI)

Candidates

Species Selection

Resistance

Health Status and Fitness

Potential Uses of Laminarian Species

Basic Aspects of Site-Selection

Check basic criteria for kelp & mussel cultivation:

(site-selection process)

(1) Check water chemistry

(2) Check oceanographic and topographic data

- depth
- O_2, temperature , salinity and attenuation
- hydrodynamic conditions

(3) Check surrounding biota

=> Start with further investigations following the list

Parameters for site-selection-criteria

1. **candidate**
   - larval concentration
   - settlement/seeding success
   - growth rates
2. **health and fitness**
   - infestation of macro- and microparasites, bactaria
   - toxicity
   - lysosome stability, EM
   - RNA/DNA ratio
3. **water chemistry**
   - nutrients (nitrite, nitrate, ammonia, phosphate, etc.)
   - chlorophyll
   - C/N-ratio
4. **oceanographic parameters**
   - current velocities & waves/swell
   - depth
   - temperature & salinity
   - attenuation & fluorescence
   - O_2
5. **techniques**
   - submerged and floating devices
   - mooring system and connectedness
   - substrate development
   - harvest techniques
6. **ICZM**
7. **infrastructure**
8. **commercial feasibility**


Draft – Work in Progress

Community Guide to the Principles of Good Practice for the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas

with regard to Regulation 854/2004

Laminaria Cultivation

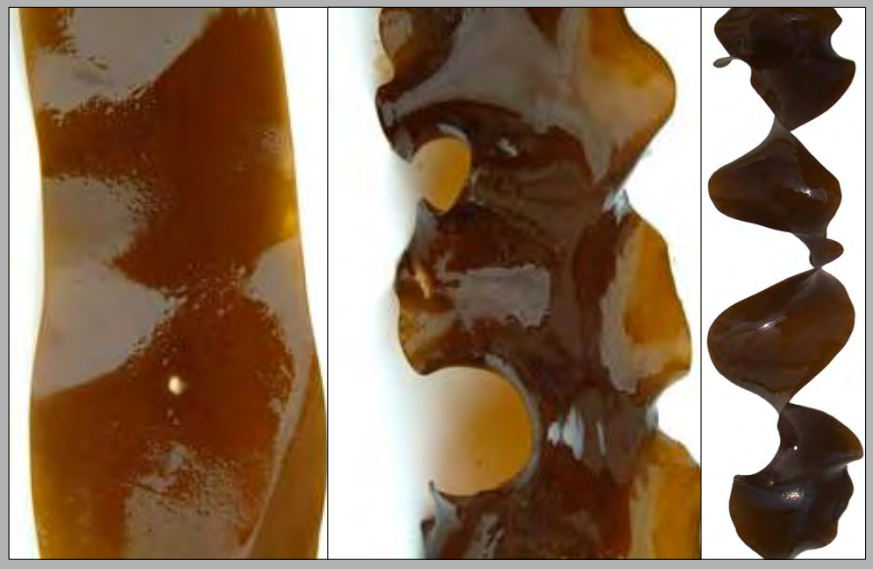
Biological Investigations:

- After seeding: young sporophytes should be transferred to sea at an early stage.

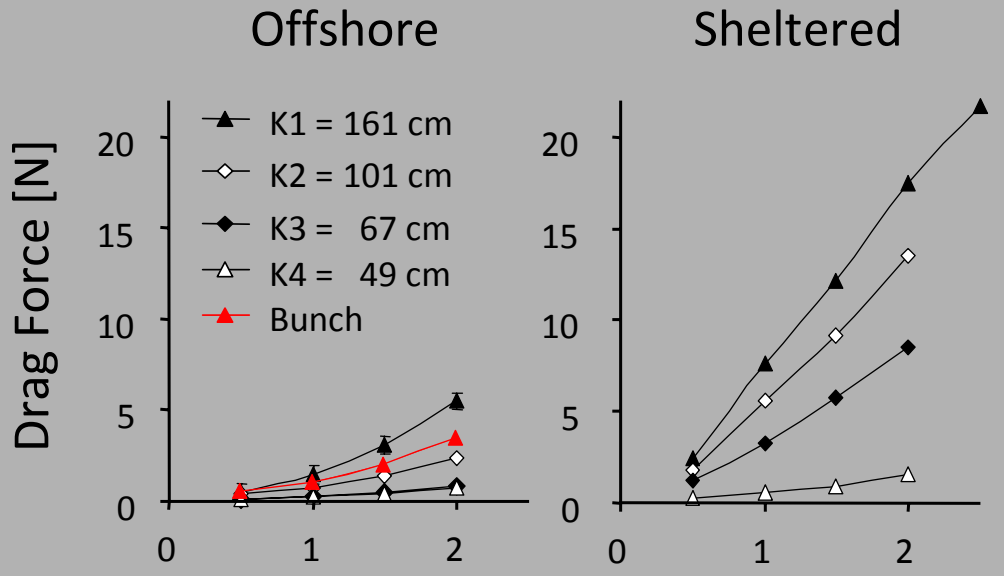
Biological Investigations:

=> Blades adapt and develop a streamlined morphology

=> Juveniles resist storm conditions (kauloids & phylloids)



offshore sheltered rotation



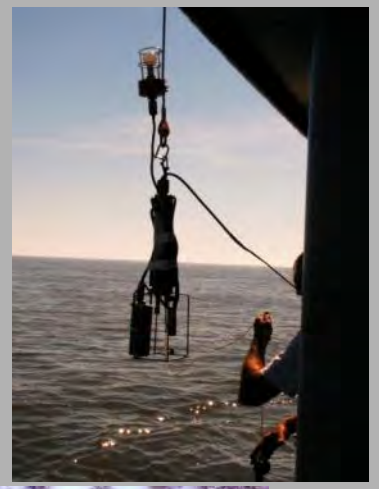
$$C_w = \frac{2 \cdot F_w}{\rho \cdot A \cdot v^2}$$

Buck & Buchholz (2005), *Aquaculture*

Health and Growth Performance

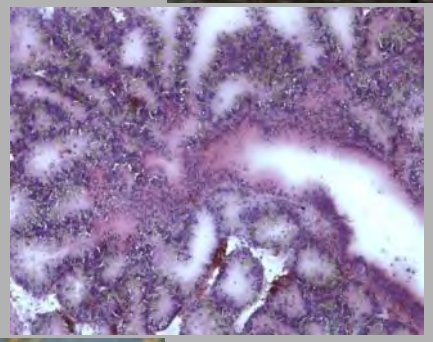
Extensive investigation of site characteristics

- Environmental conditions
- Concentration of pollutants
- Distribution of pollutants



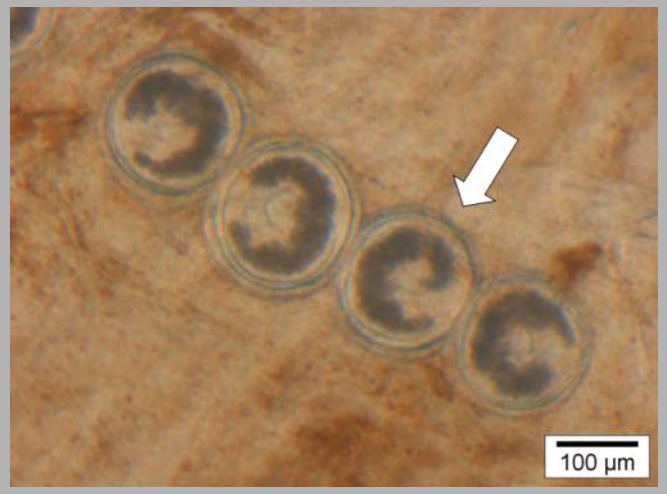
Health assessment

- Lysosomal membrane stability

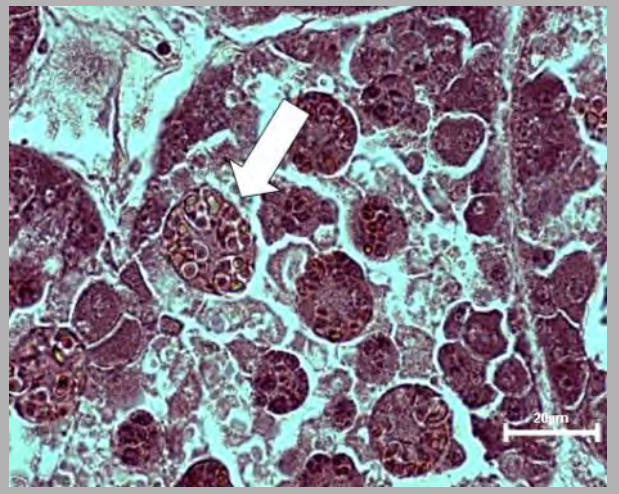


Settlement/growth rates

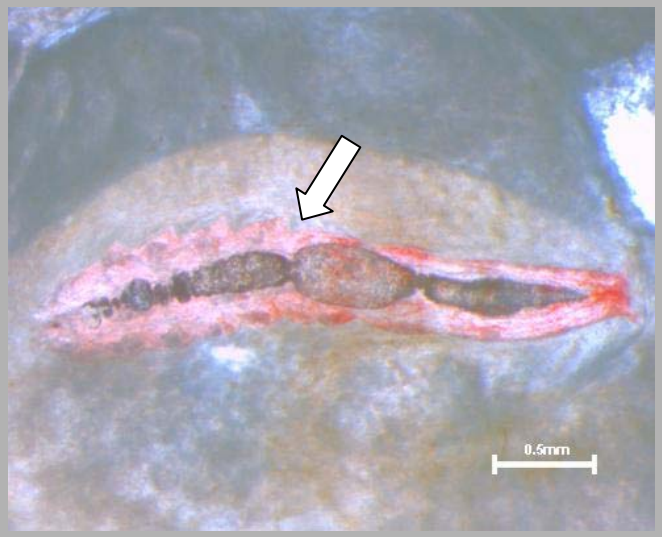
Consumption Suitability



Metacercaria of the trematode *Renicula roscovita*



Marteilia sp. from the digestive gland



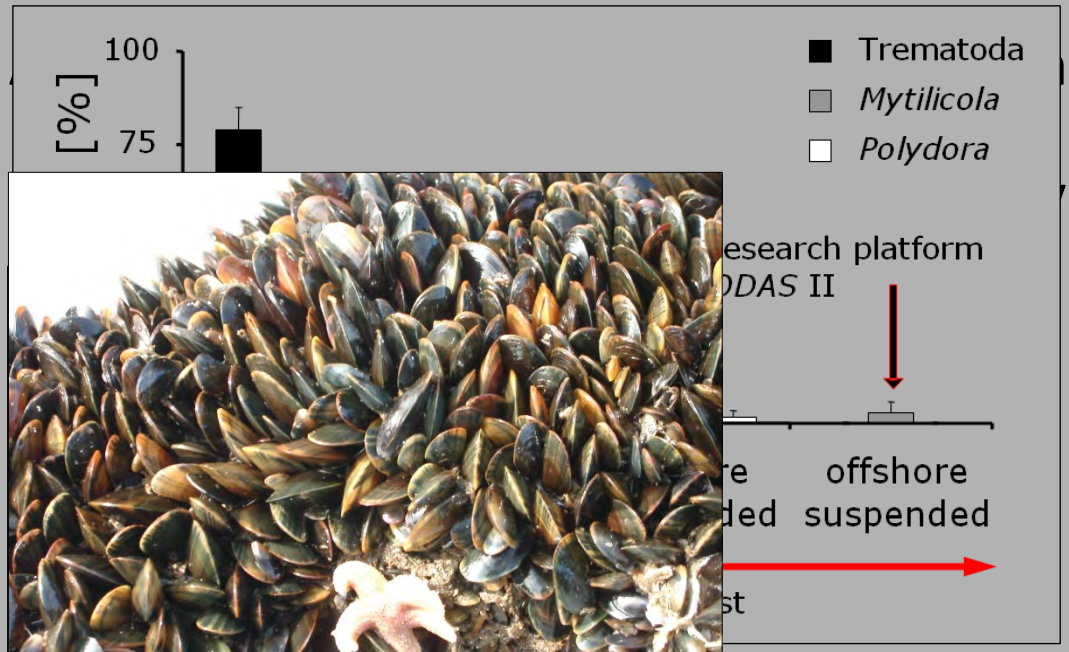
Adult copepode *Mytilicola intestinalis*

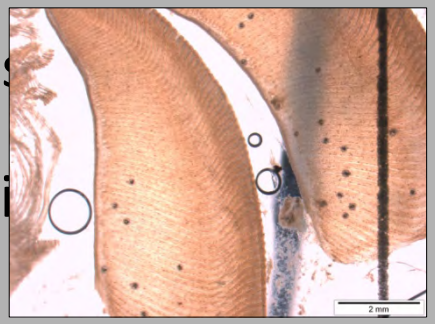
- Harmless to consumers
- High loads restrain growth (macro-) or condition (micro parasites) of mussels
- Trematods are known to hamper attachment
- Copepods are also an aesthetical problem

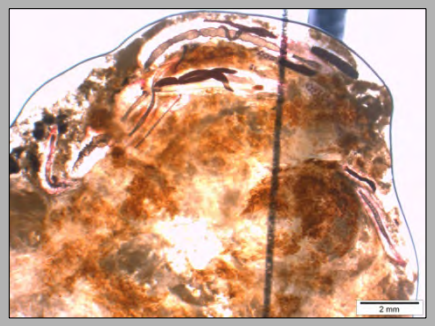
Biological Investigations

Biological Aspects (*Mytilus edulis*):

1. Mussels grow faster than inshore cultivated mussels.
2. Mussels have a better fitness and health status (CI).
3.
4.







Brenner et al. (2006), *Glo. Aqua. Adv.*

Buck et al. (2005), *Aquaculture*

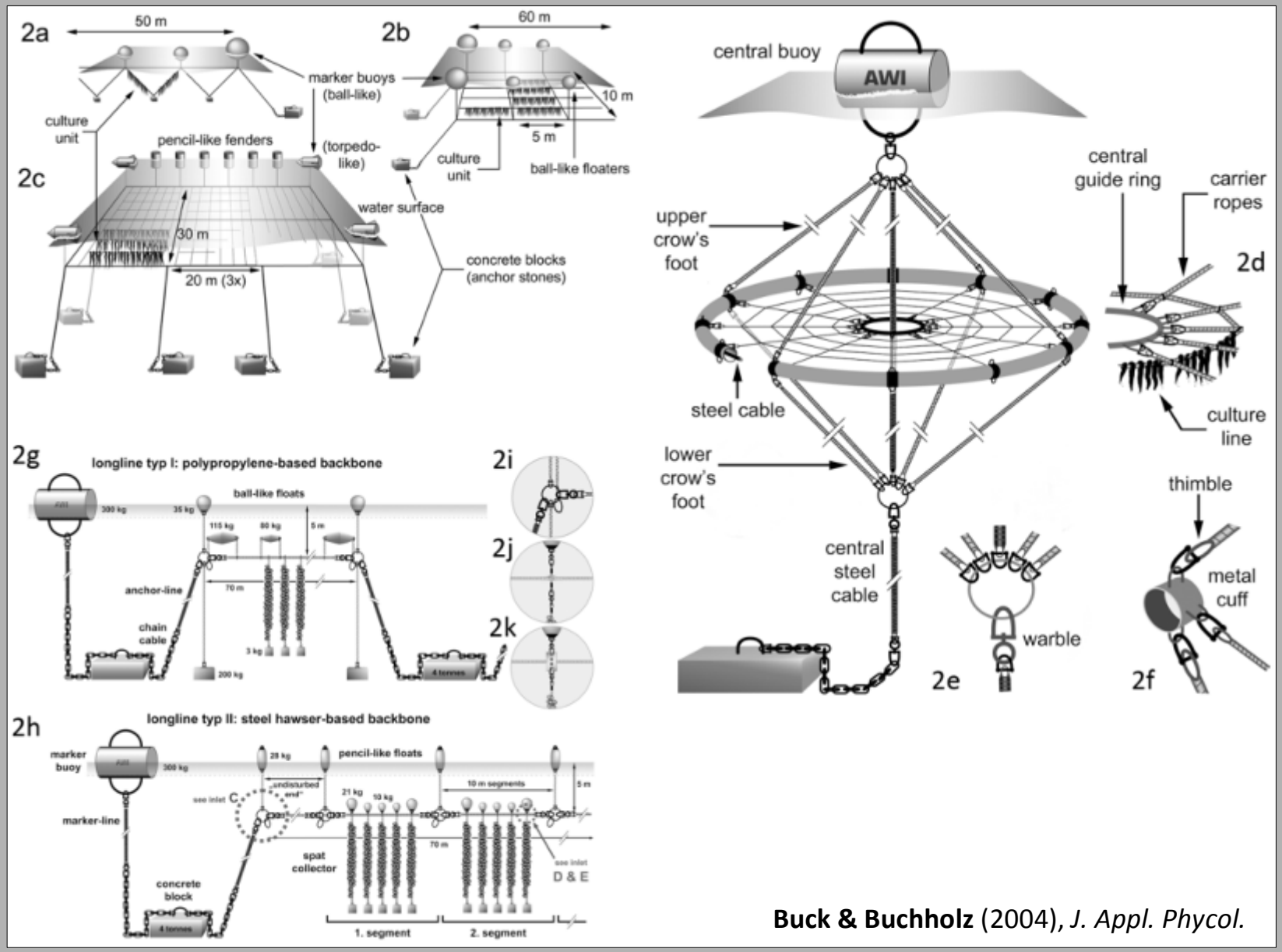
Techniques & System Design

Longline systems

Ring cultivation

Connection to turbines

Techniques & System Design



Buck & Buchholz (2004), *J. Appl. Phycol.*

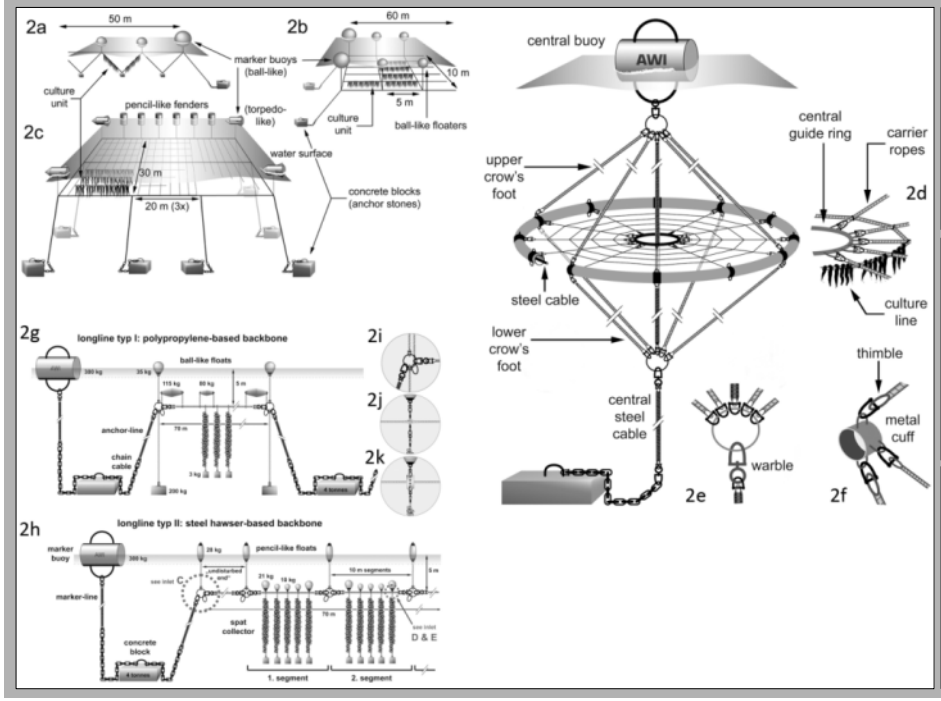
Technical Investigations and System Design:

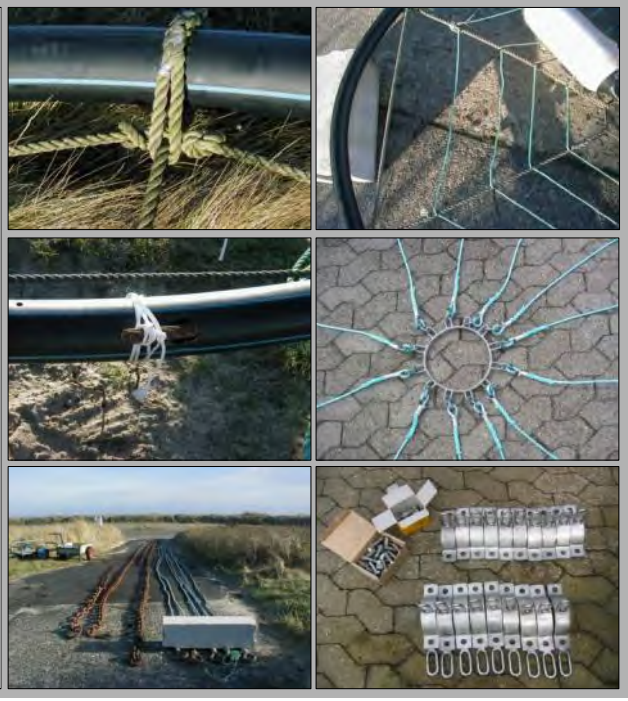
(3) Offshore devices for kelp culture

=> Ring-Systems can withstand harsh conditions

=> Type of fenders prevent loss and support buoyancy

=> Can be harvested easily





Buck & Buchholz (2004), *J. Appl. Phycol.*

Patent No DE 10 2004 010 652.5
(Buck & Buchholz, AWI)
Patent. No PCT/DE2005/000234
(Buck & Buchholz, AWI)

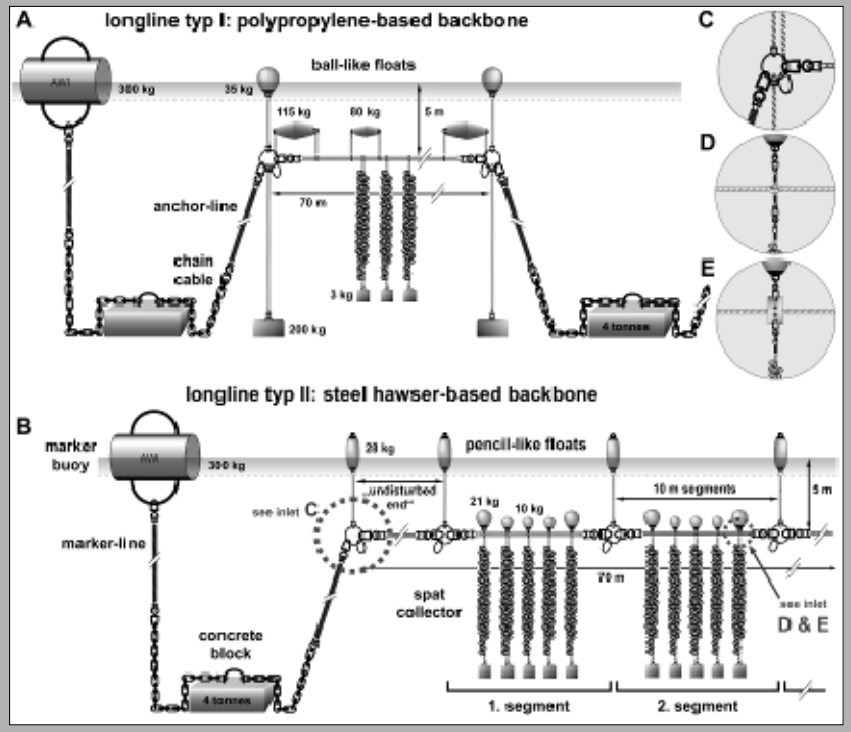
Technical Investigations and System Design:

Buck & Buchholz (2004), *J. Appl. Phycol.*

Results

Technical Aspects (*Mytilus edulis*):

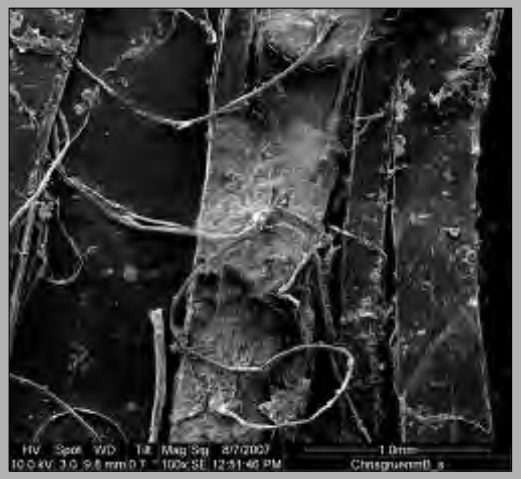
1. Systems have to be submerged up to 5 m below the surface.
2. Segmental modes will ease handling.



Buck (2007), *Helg. Marine Research*

Technical Aspects (*Mytilus edulis*):

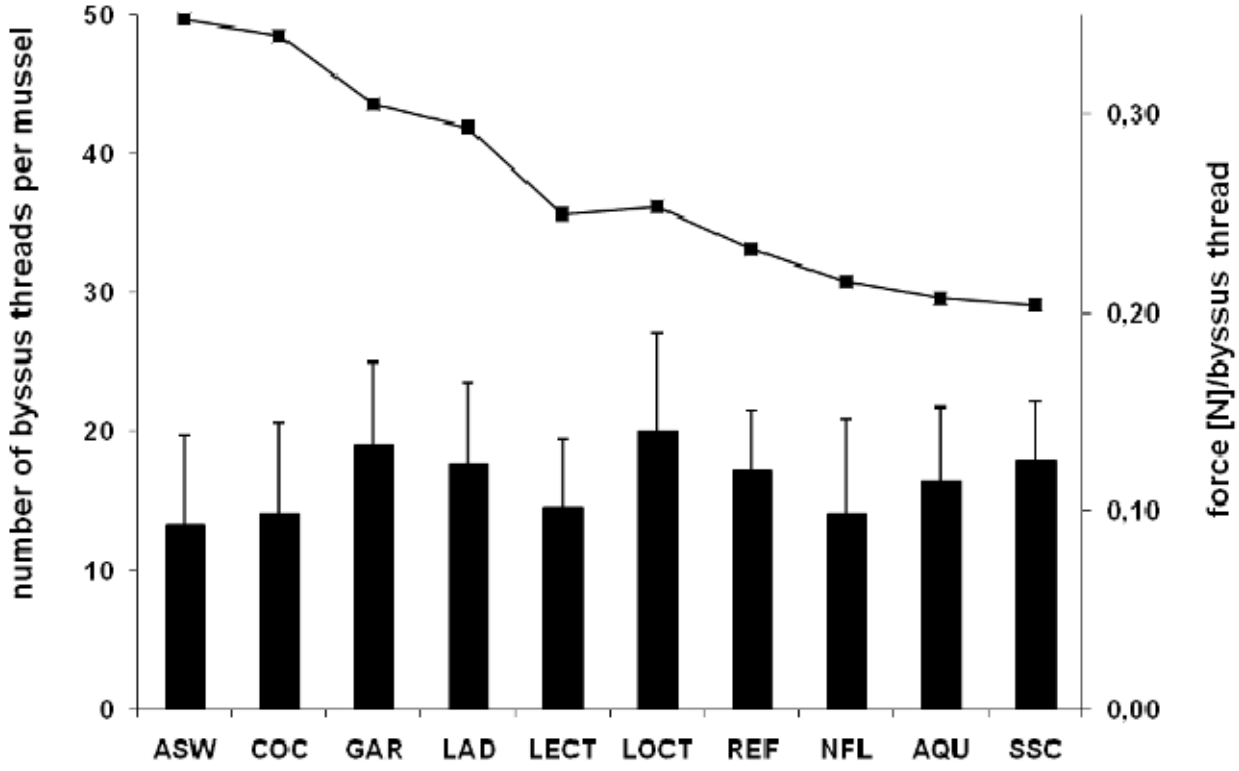
1. Systems have to be submerged up to 5 m below the surface.
2. Segmental modes will ease handling.
3. Type of fenders prevent mussel from loss / support buoyancy.
4. Type of surface and system design allow good settlement.



Pechura (2007), Thesis

Brenner & Buck (2009), submitted

Technical Requirements for Artificial Substrates

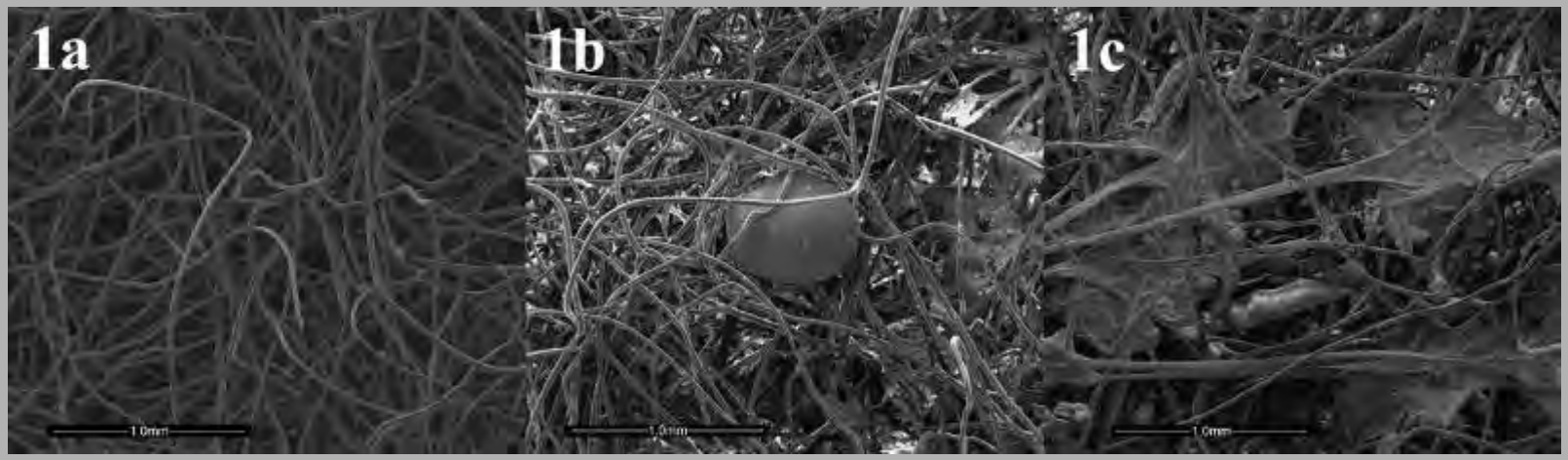


Brenner & Buck (2009) submitted

Technical Requirements for Artificial Substrates

AWI

Fleece substrate / AQU



new substrate **after 2 weeks of exposure** **after dislodgement**

Filamentous substrate / GAR

new substrate **after 2 weeks of exposure** **after dislodgement**

Brenner & Buck (2009) submitted

Technical Requirements for Artificial Substrates

NFL fleece

- Fleece like substrates are attractive to larvae
- No suitable foothold for growing mussels
- Loose most mussels during grow out

ASW filamentous

- Filamentous substrates less attractive to larvae
- Good foothold for grow out
- Mussel conglomerates interweave with appendices

- Suitable offshore substrates must combine different characteristics
- Fleece like part around the core rope
- Numerous and long appendices for interweaving
- Proportions of fleece and parts with appendices vary according to cultivation aim

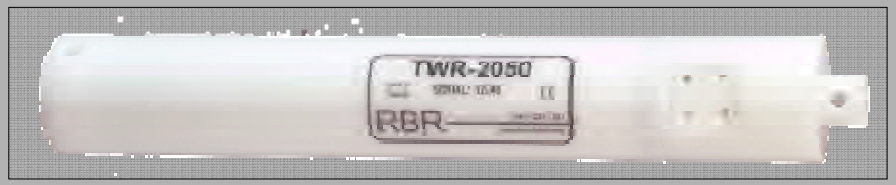
Brenner & Buck (2009) submitted

System Design for Grounding Constructions

Consideration of mechanical loads on grounding constructions of windmills by aquaculture devices

Longline →

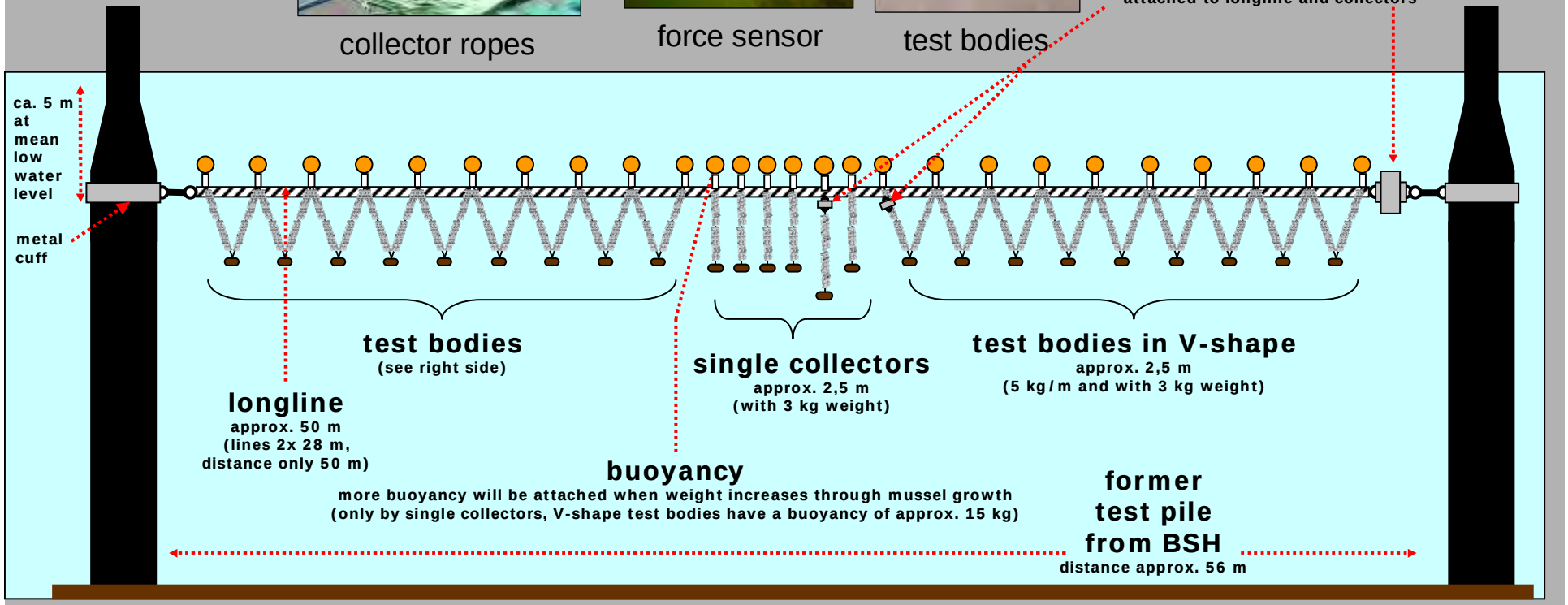
Longline at Offshore Test Location



collector ropes

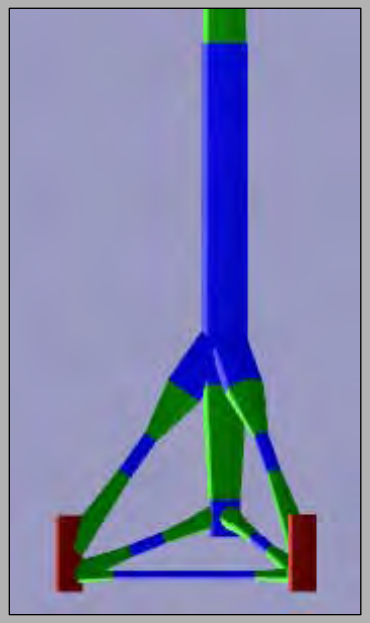
force sensor

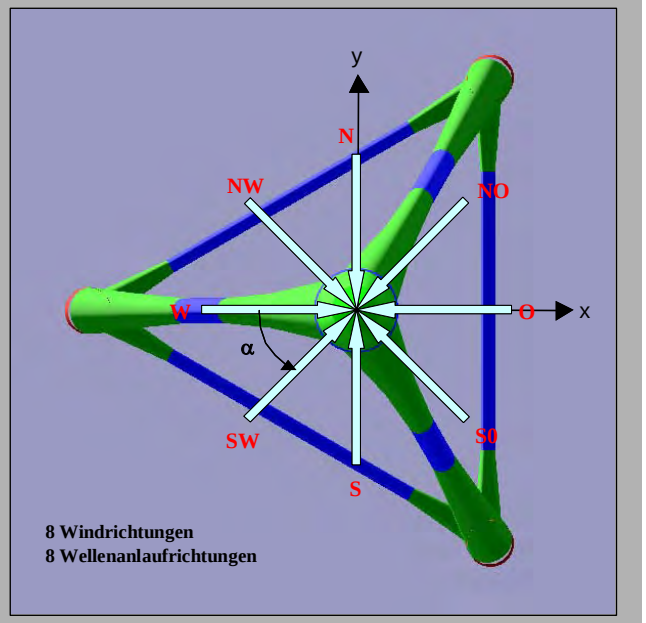
test bodies

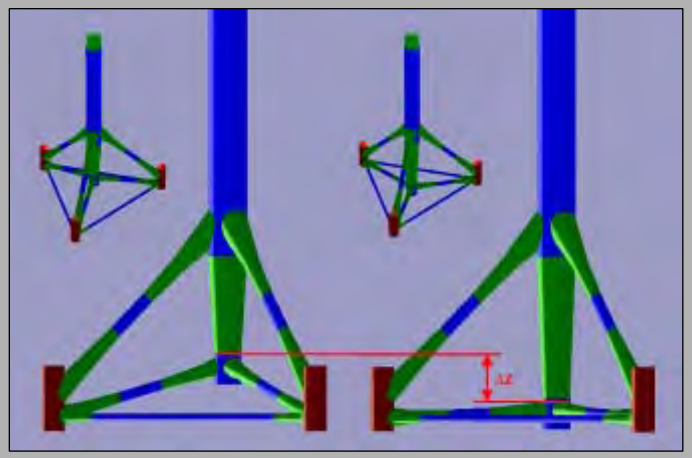


Buck et al. (2006), Ocean, Offshore, and Arctic Engineering

Loads on Grounding Structures



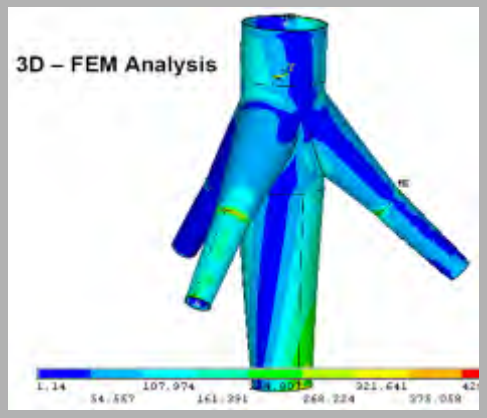


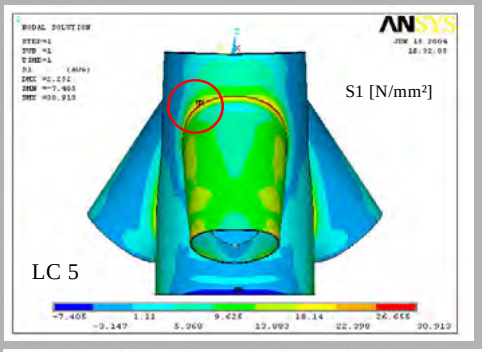


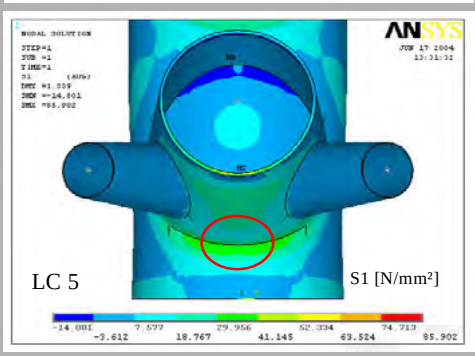
Development of static models
(for 3-5 MW turbine class)

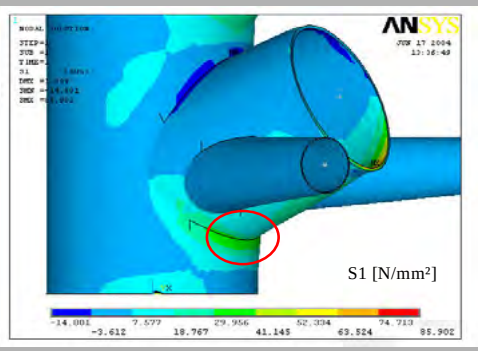
Buck et al. (2006), Ocean, Offshore, and Arctic Engineering

Loads on Grounding Structures





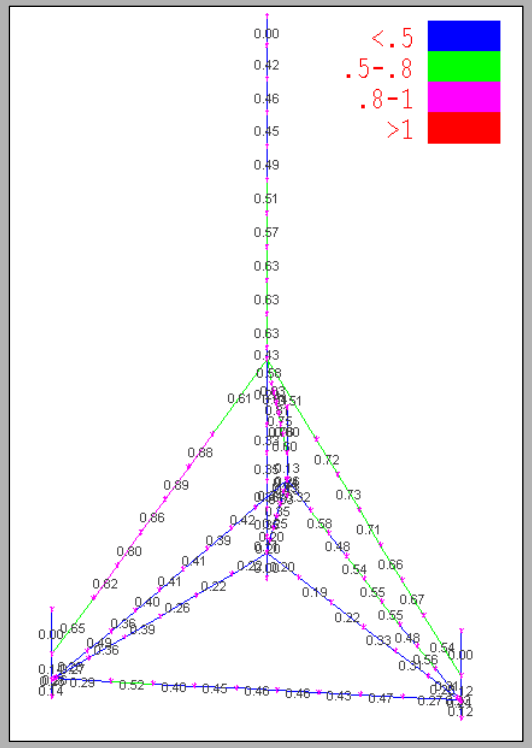


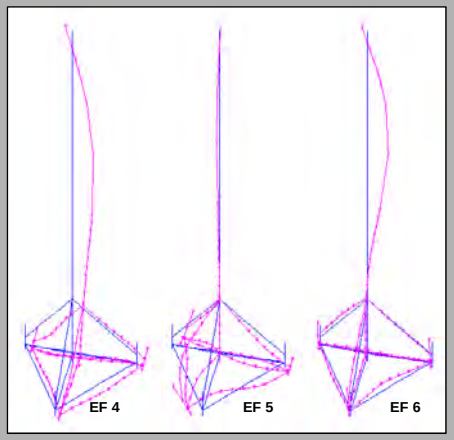


Discussion of alternative connection points of foundation structure

Buck et al. (2006), Ocean, Offshore, and Arctic Engineering

Loads on Grounding Structures

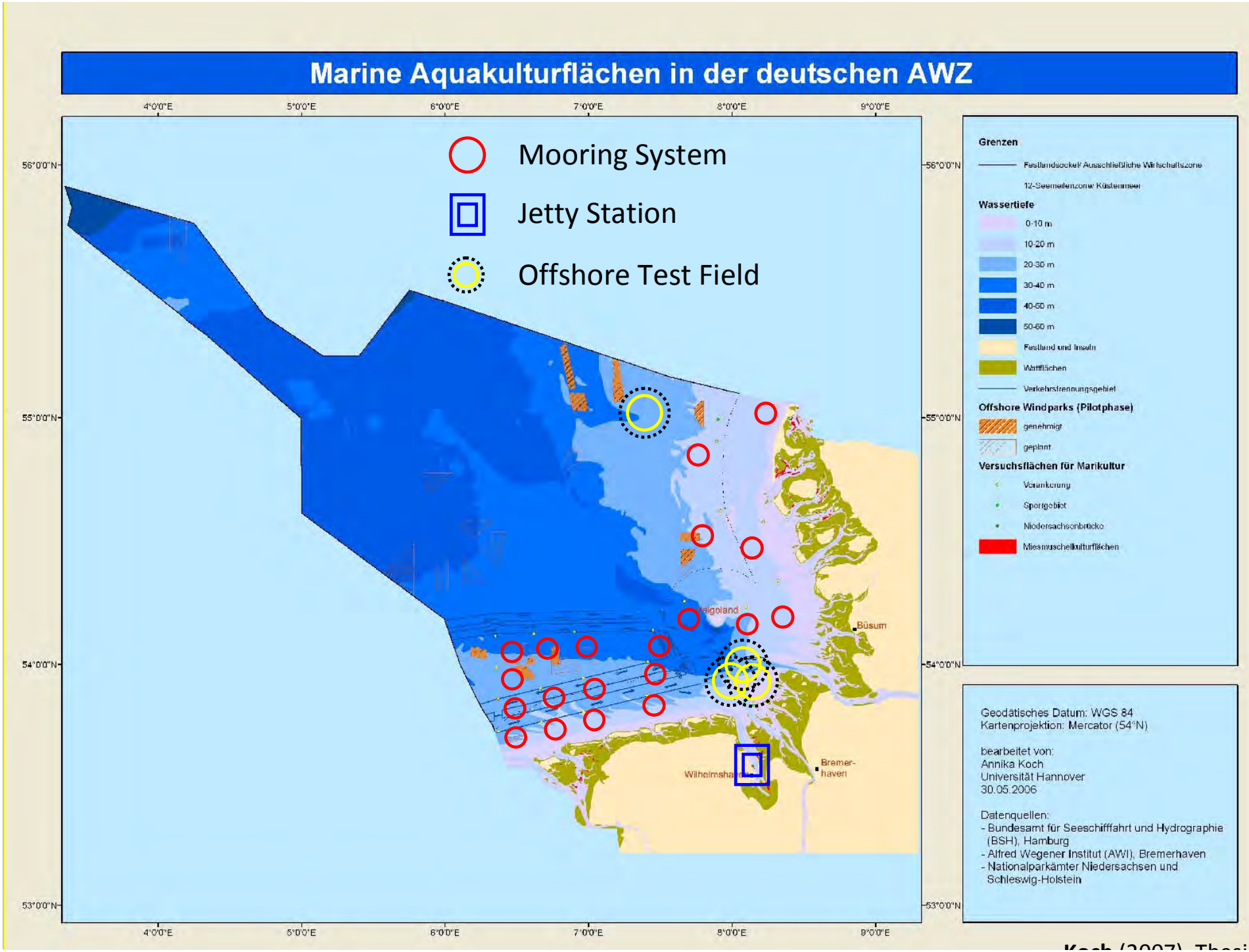




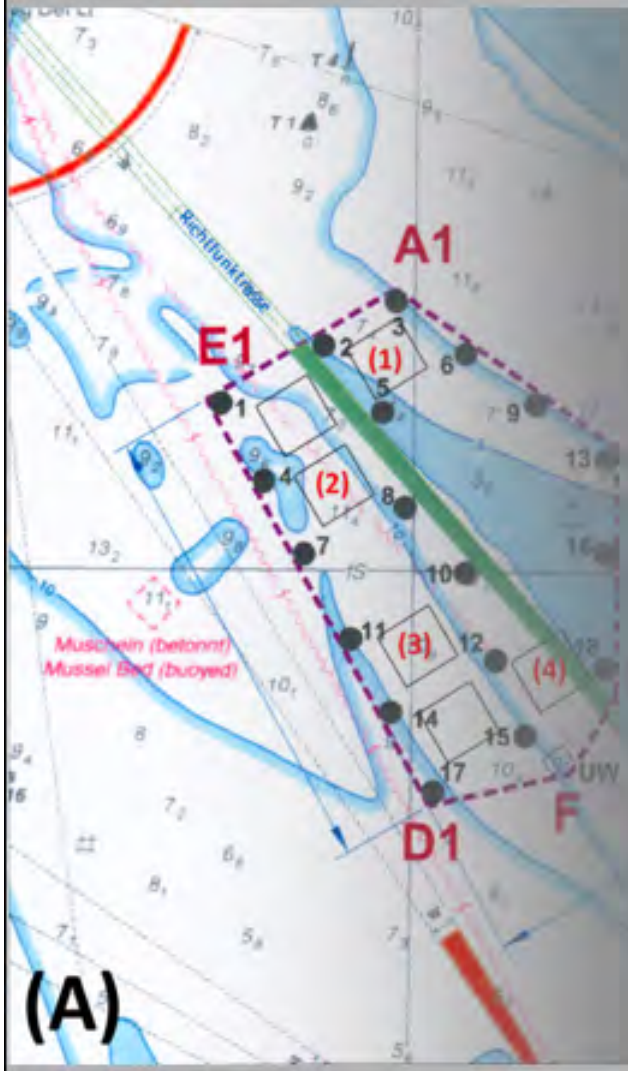
Generation of representative loads of wind energy installations

Buck et al. (2006), Ocean, Offshore, and Arctic Engineering

Research & Seasickness



Koch (2007), Thesis

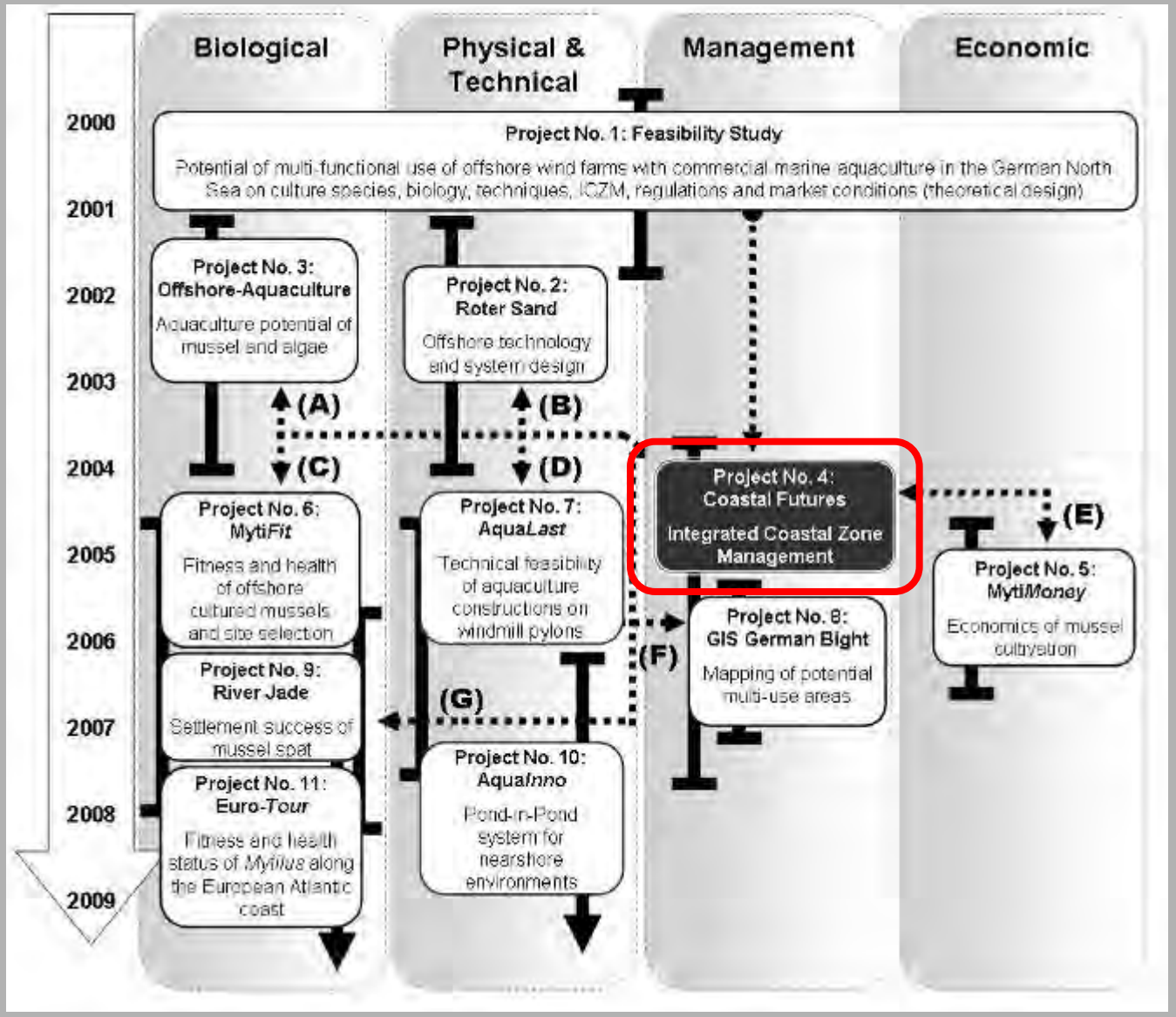


Management

Offshore Co-Management

Multiple-Use Scenario

Offshore AQ-Projects in the German Bight



Buck et al. (2008), Helg. Marine Research

Involved Parties

Involved Stakeholders

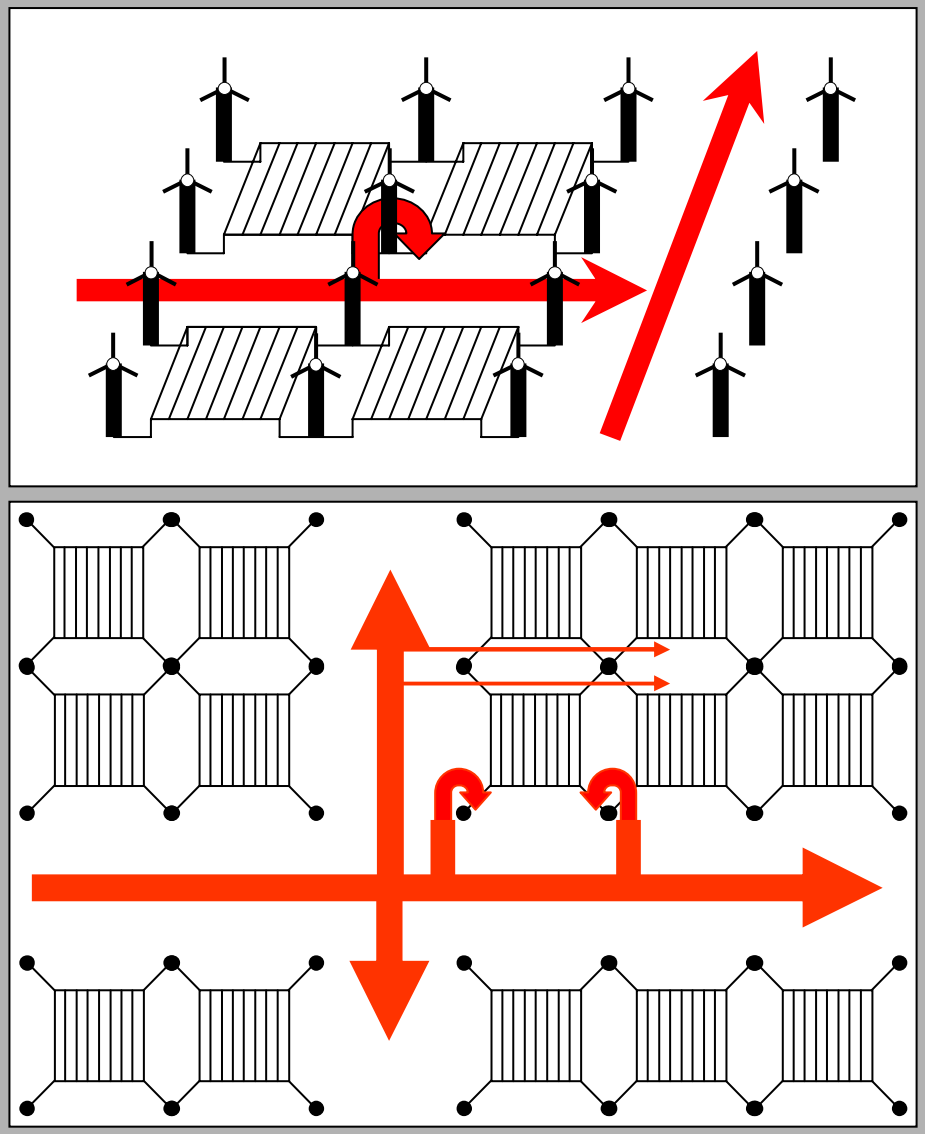
- Authorities:
  - 6 Water and Shipping Agencies
  - 2 Federal Water Ways Directorates
  - Federal Fisheries Agency
  - Federal Maritime and Hydrographic Agency
  - Food Quality Testing Laboratories
- 12 Mariculturists
- approx. 30 Fishermen
- 4 Offshore Wind Farm Planers & Operators (local player, int. player)
- 9 Research Institutes
- 10 Companies (Engineers, Economists, Food Production…)
- Senate of the City State of Bremen

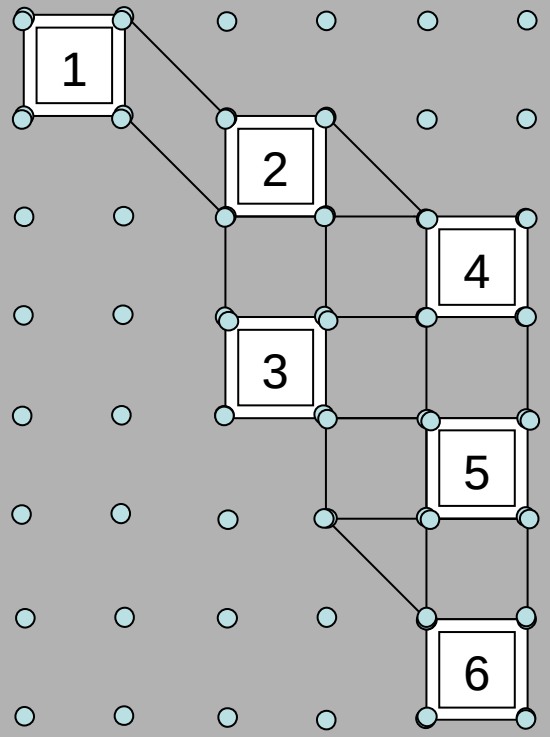
Fishery, oil companies, marine missions, shipping, wind farms, authorities, nature conservation, tourism, sand extraction, etc.

Krause et al. (2003), Rights & Duties

Buck et al. (2004), Ocean & Coastal Mgmt.

Waterway Management

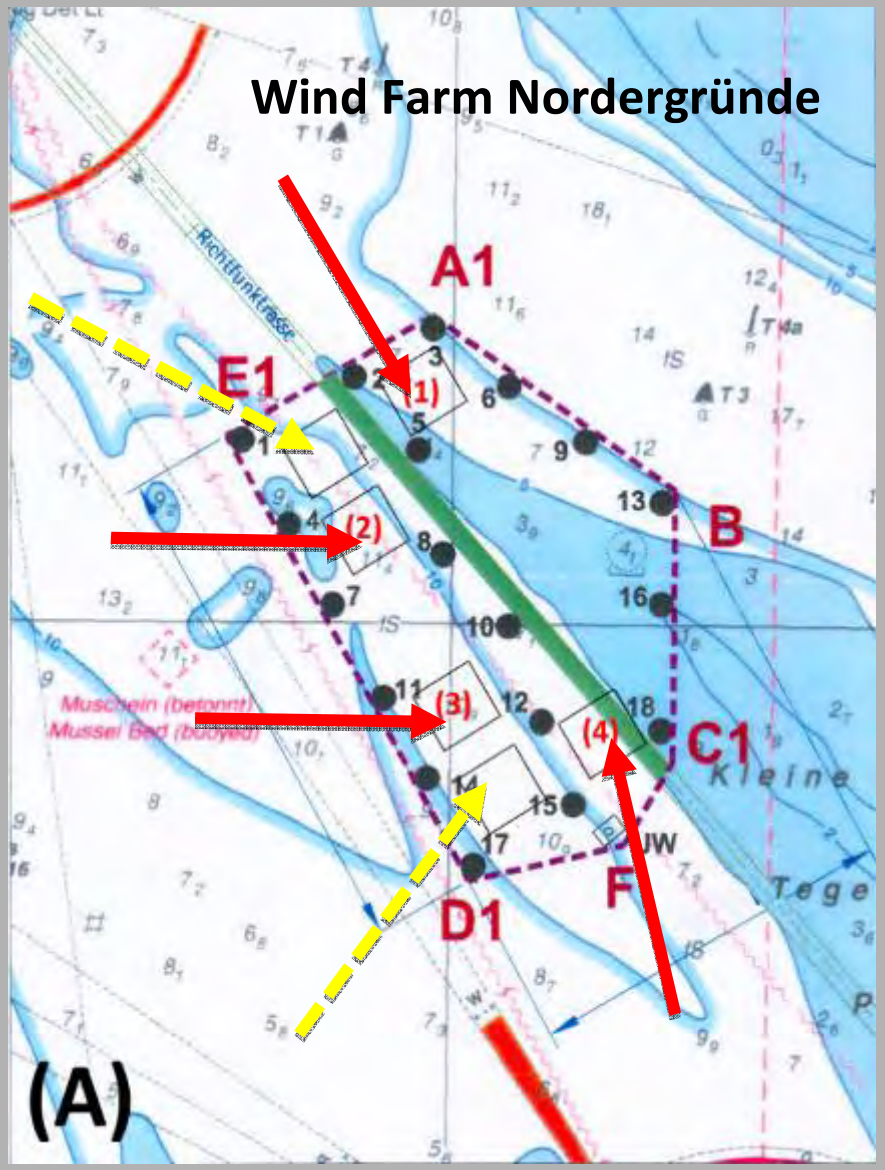


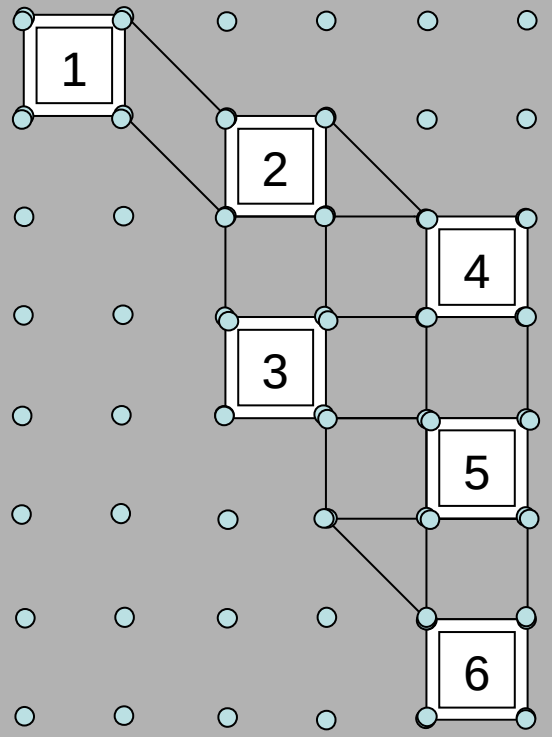


bird's-eye view of an offshore wind farm

Buck et al. (2009) Aquacult. Econ. & Mgmt., **Buck et al.** (2003), Law International, **Buck et al.** (2004), Ocean & Coastal Mgmt.

Waterway Management





bird's-eye view of an offshore wind farm

Buck et al. (2009) Aquacult. Econ. & Mgmt., **Buck et al.** (2003), Law International, **Buck et al.** (2004), Ocean & Coastal Mgmt.

Co-Management as a Solution

Vision

all-in-one device, suitable for every purpose

Co-Management as a Solution

Future

one boat: service, harvest and maintenance

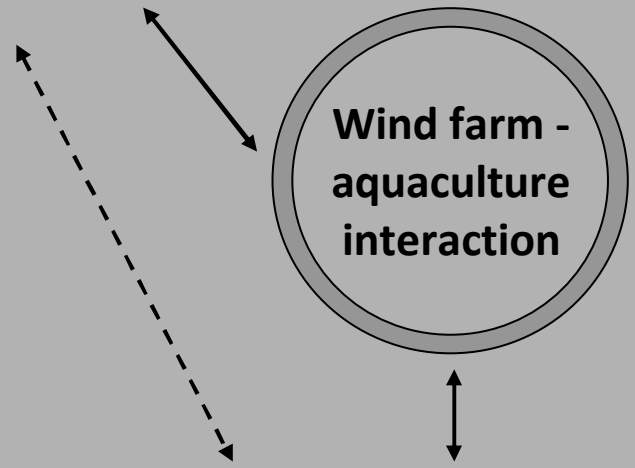
Involved Changes

Technology/Biology

- e.g. Interrelations of existing or new technologies

Infrastructure

- e.g. '*Free-Cable*' Areas
- Geared Platforms



Co-Evolution of Socio-Technical Regimes

Organization & Social

- Collective ocean use scheme
- Interrelations of knowledge, skills, routines, regulatory demands…

Management Constraints

Co-Management Scheme for Interrelated Operation & Maintenance Activities

	POTENTIALITIES	CONSTRAINTS
	STRENGTHS	**WEAKNESSES**
INTERNAL resources and capabilities	• Developing a collective cost-saving transportation scheme • Sharing of high-priced facilities • Rationalizing operating processes • Making use of available experience and knowledge → shortening of adaptive learning process for any offshore operations	• Little to no interest in joint planning process • Little willingness to engage into new fields of activity • Ambiguous assignment of rights and duties • Lack of motivating force
	OPPORTUNITIES	**THREATS**
EXTERNAL conditions	• Available working days coincide • Transportation and lifting devices are indispensable • Availability of a wide range of expertise (hard and soft skills) • Lack of legislation in EEZ favors implementation of innovative concepts	• Unfavorable accessibility of wind farm location inhibits joint O&M • Lack of legal and authority framework supporting co-management arrangements • No access rights within wind farm area for second party • Unsolvable problems of liability

SWOT-matrix

Michler-Cieluch et al. (2009)Ocesan & Coastal Mgmt.

Recommendations

- Indispensable
  - ✓ Assessment of Stakeholder Perception
  - ✓ Integration of “Local” Knowledge
- Offshore Co-management
  - ✓ Overcoming domains of uncertainty
  - ✓ Contributing to negotiate agreements
- Government’s Role
  - ✓ Political support
  - ✓ Institutional umbrella

Outlook

Offshore fish culture

Projects in other EU countries

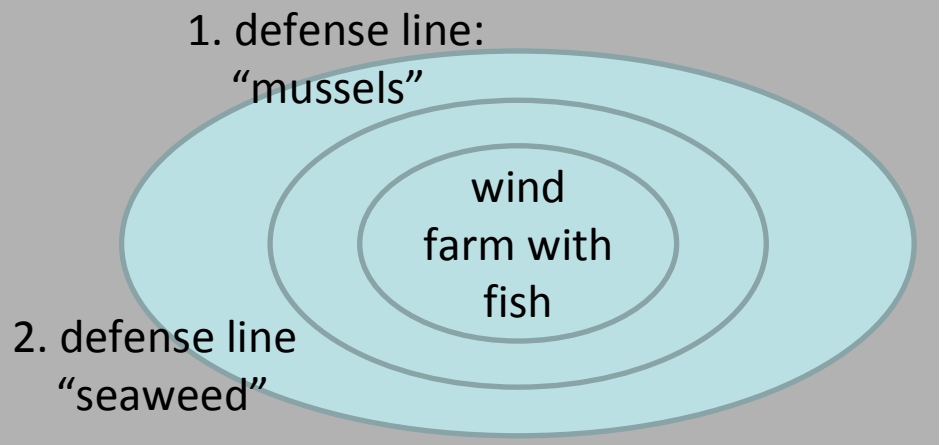
Perspectives

Expansion along the European Coast

Perspectives

Opportunities

1. employ opportunities
2. maintain ecosystem functions
3. sustainable resource use
4. Eco-innovations
   (ETAP - Environmental Technologies Action Plan)



Visions

1. Use (in a sustainable manner) the immense areas off the coastal sea
2. Constructions of both users (wind farm & AQ) should not develop independently.
3. Decentralisation, "backyard farming"


tkb
Technologiekontor Bremerhaven
WeserWind GmbH
Offshore Construction Georgsmarienhütte
AWI
Stiftung Alfred-Wegener-Institut
für Polar- und Meeresforschung
in der Helmholtz-Gemeinschaft
Fraunhofer
IFAM
Fraunhofer
TERRA mare
wsa bh
Hochschule Bremerhaven
imare
Institut für marine Ressourcen
CG
Unternehmensberatung
Bio Consult SH
BSH
BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE
WSA Tönning
Niedersächsisches Landesamt
für Verbraucherschutz
und Lebensmittelsicherheit
ISEB
Senator für
Bau, Umwelt
und Verkehr
z m t
bremen
INSTITUT FÜR MEERESKUNDE KIEL
HSVA
Bremerhavener Gesellschaft
für Investitionsförderung
und Stadtentwickung mbH
bis
IUB
International
University
Bremen
Bundesministerium
für Bildung
und Forschung
Niedersächsisches
Landesamt für
Ökologie
ENGEL NETZE
Fischereiausrüstung - Fishing Equipment
Diltmeyer's
Frucht-Plantagen
newmediamen
wunschmedia
EnergieKontor
MARISCOPE
Meerestechnik

Thank you

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