



Upscaling aquaculture operations in offshore environments - challenges and possibilities in Europe



Bela H. Buck et al.

SUBMARINER Conference - Gdańsk, Poland

Offshore Aquaculture in North Europe

→ The Multi-Use Approach

© B. H. Buck – AWI All presented data can be obtained from ISI-Journals		Renewables					Marine Resources & Environment					Monitoring, Surveillance & Communication					Presentation & Training		Others		Maritime Traffic								
		(1) Wind Energy	(2) Wave Energy	(3) Current Energy	(4) Tide Energy	(5) Solar Energy	(6) Marine Aquaculture	(7) Fishing (all kinds: see No. 1)	(8) Ecosystem Protection (all kinds: see No. 2)	(9) Desalination	(10) Oil-, Gas- & Petroleum Platforms	(11) Sediment Extraction	(12) Water Parameters (all kinds: see No. 3)	(13) Flora & Fauna Parameters	(14) Security (all kinds: No. 4)	(15) Weather Forecast & Tsunami Watch	(16) Research (all kinds: No. 5)	(17) Navigation (e.g. Radar)	(18) Communication Technology (all kinds: No. 6)	(19) Tourism (all kinds: No. 7)	(20) Sport Events and Leisure	(21) Education	(22) Advertisement	(23) Pipelines & Cables	(24) Dumping Zones	(25) Shipping (all kinds: No. 8)	(26) Shipping Anchoring Areas	(27) Terminals (Offshore Harbours)	(28) Marine Missions (all kinds: No. 9)
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		Marine Missions (all kinds: No. 9) (28)																											
		serial use compatibility																											

concurrent use compatibility

serial use compatibility

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

multifunctional use

secondary use

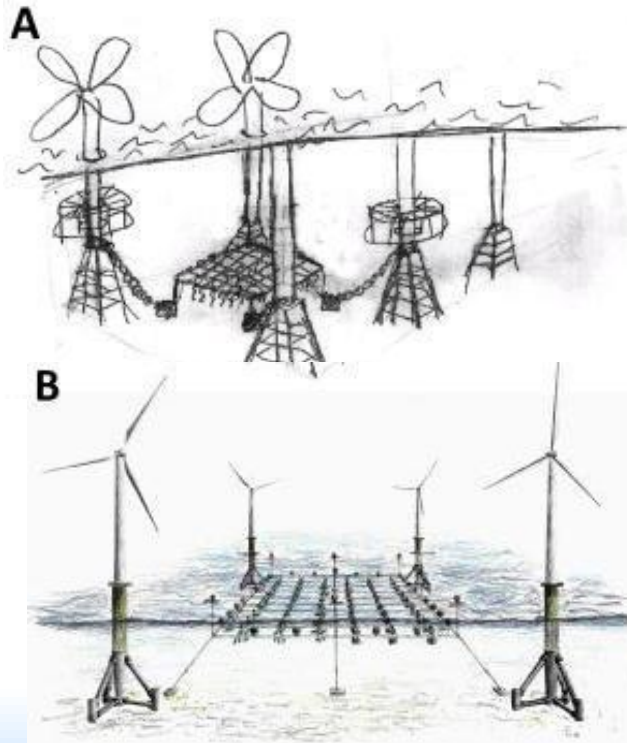
additional use

co-use



Leatherman et al.

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. Offshore Aquaculture

5. Bio-Remediation / Bio-Extraction

6. Use of fouling organisms



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



5 MW class turbines:

65 MWh·day⁻¹·windmill⁻¹

8,000 €·day⁻¹·windmill⁻¹

70% of companies SME



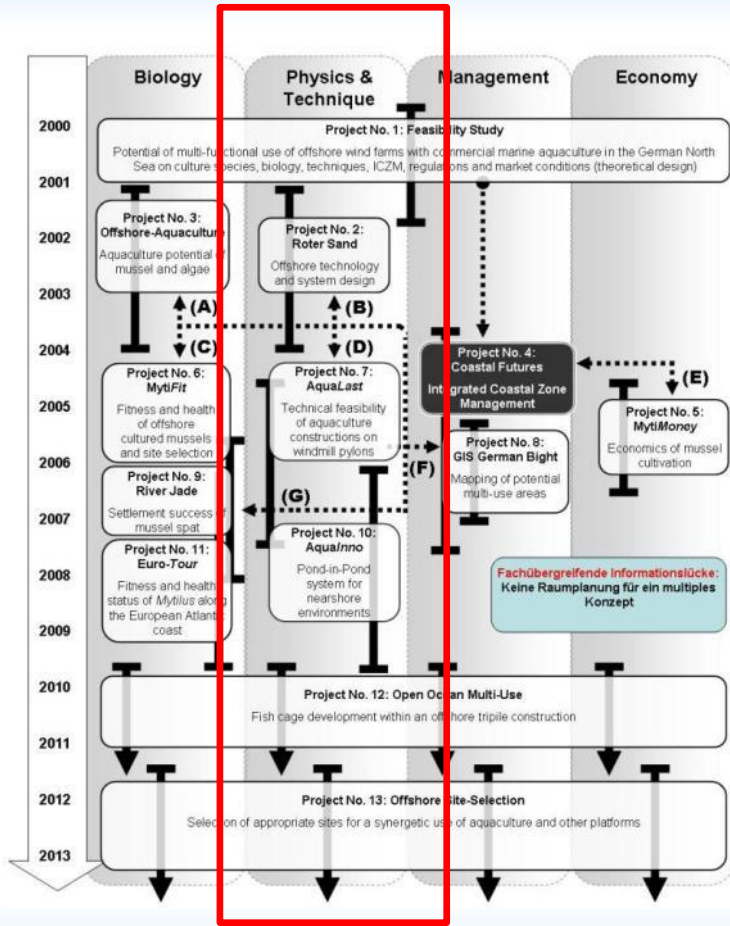
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5 MW class turbines:

65 MWh·day⁻¹·windmill⁻¹

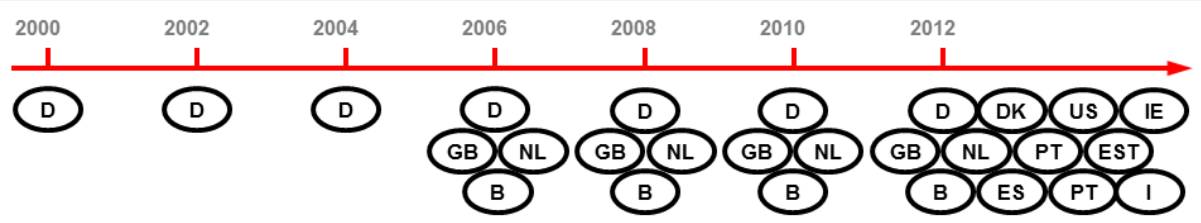
8,000 €·day⁻¹·windmill⁻¹

70% of companies SME



Marine Facilities Ordinance

OSS-Project forces wind farm operators to investigate in co-uses concepts





Main biological results:

- grow faster
- no parasites
- adapt to and withstand conditions
- resist detachment
- settlement is lower

Main biological results:

- low diversification
- only a few resist exposed conditions
- need an IMTA concept
- problems to submerge all fish



Technical Realisation

→ Co-Use in High Energy Environments



longline, cage
or other
constructions



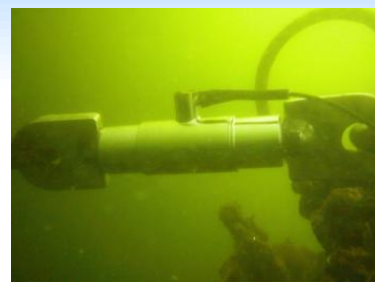
Consideration of
mechanical
loads on
grounding
constructions of
windmills by
aquaculture
devices



test bodies



collector ropes

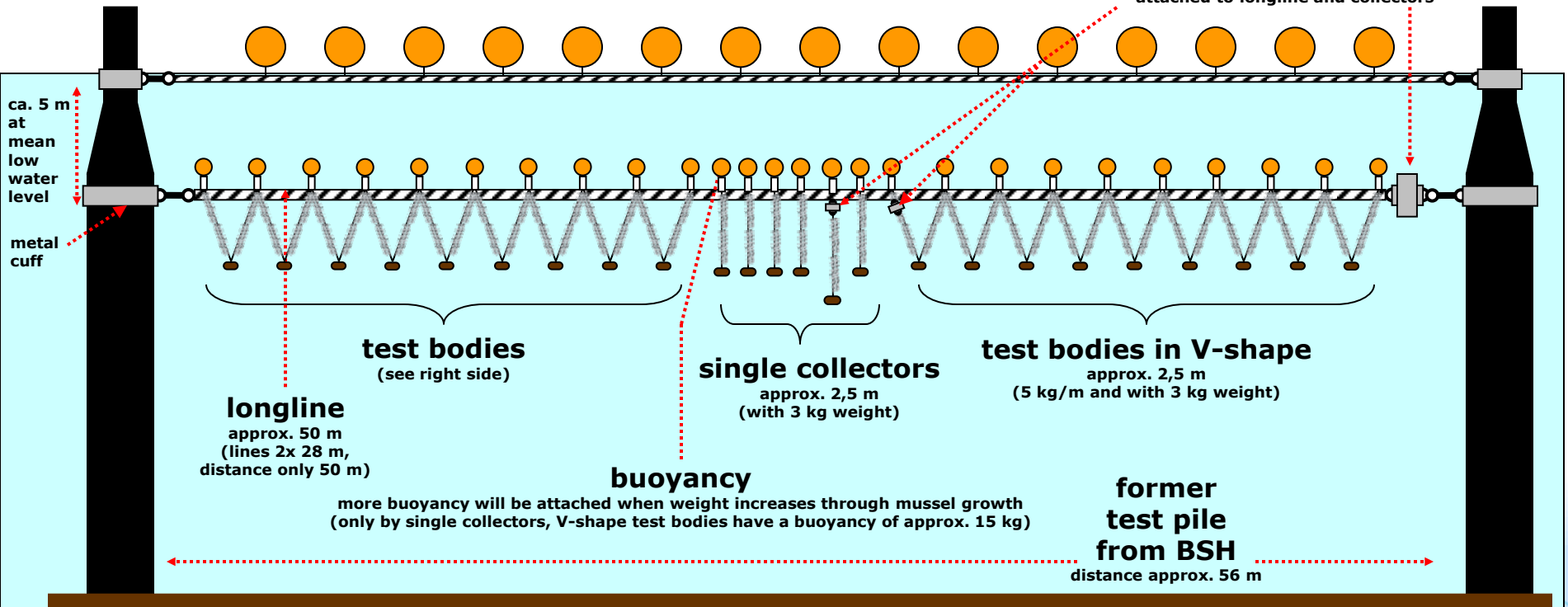


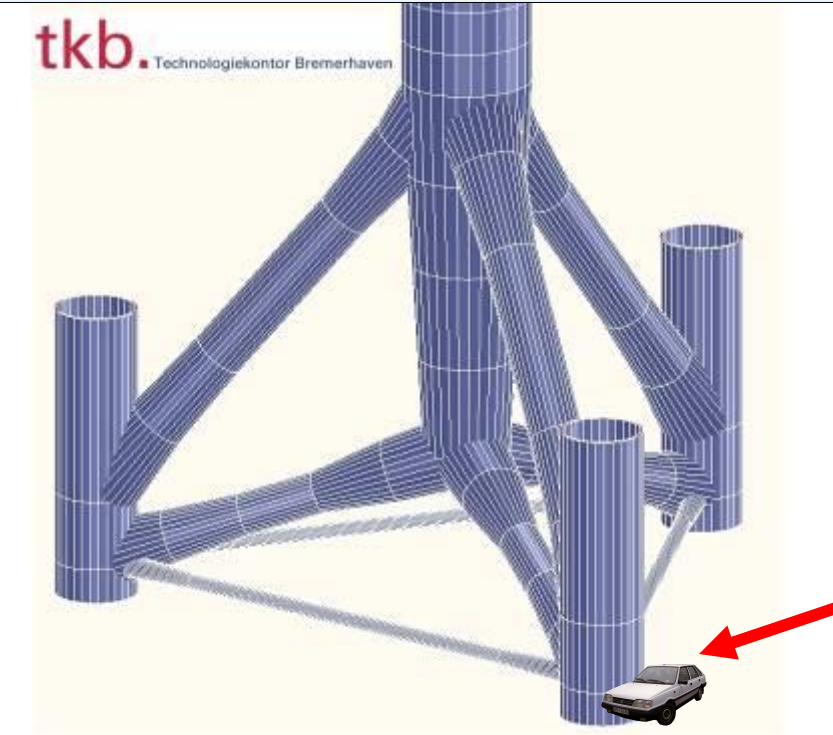
force sensor

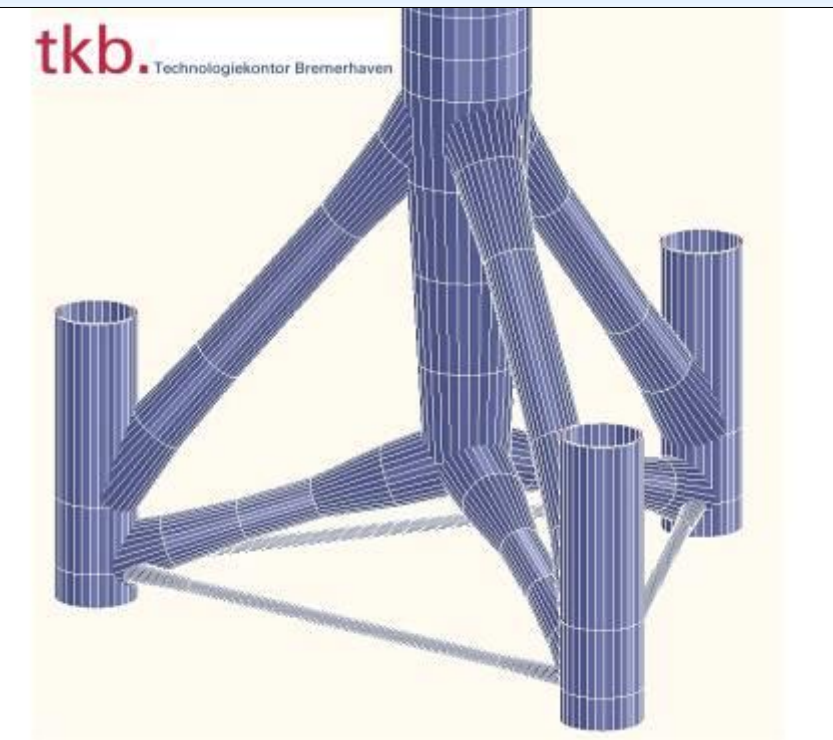


force sensors

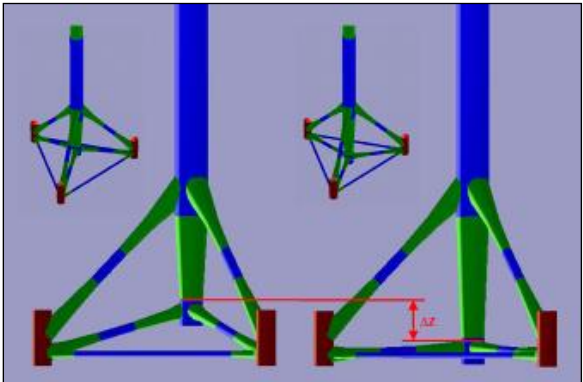
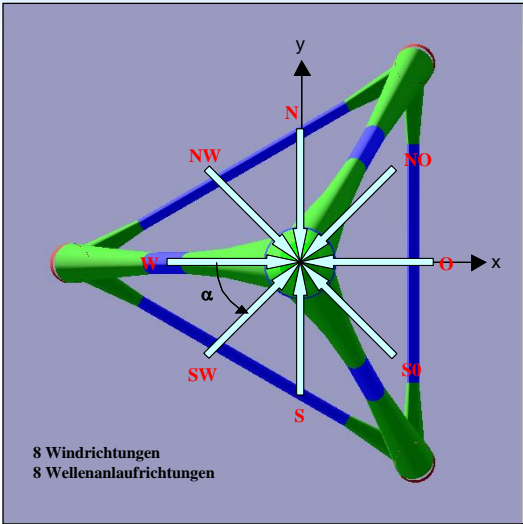
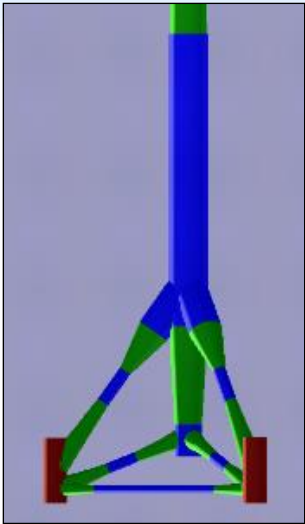
attached to longline and collectors

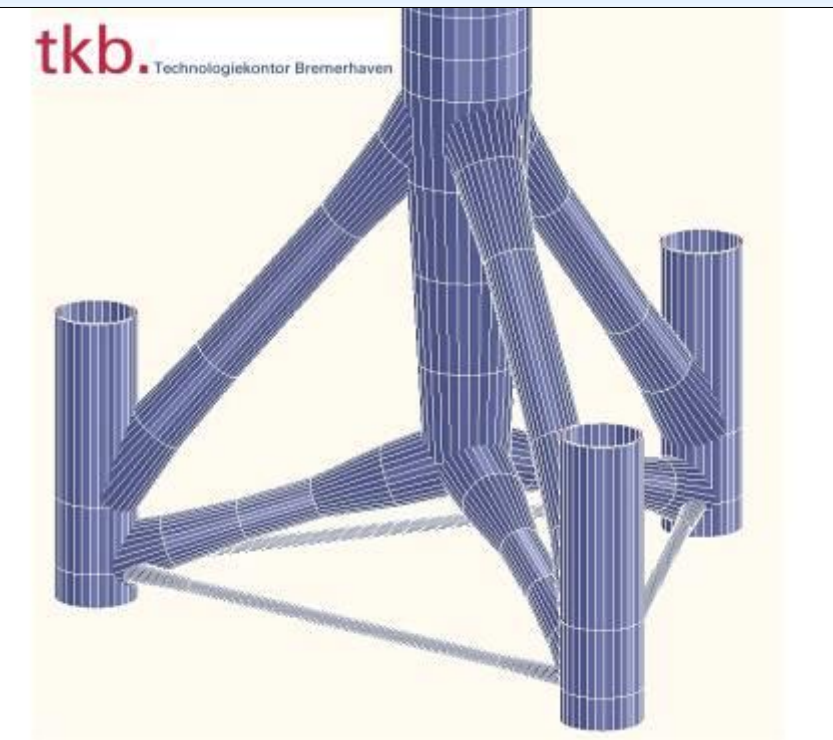




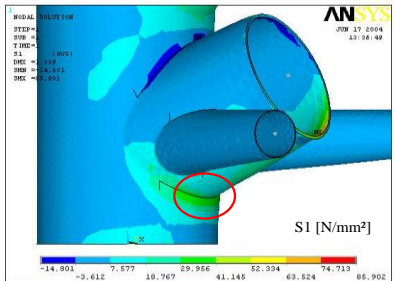
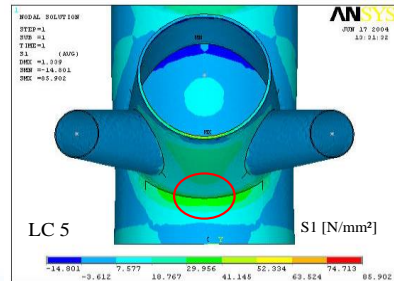
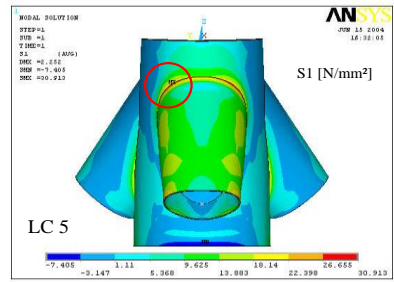
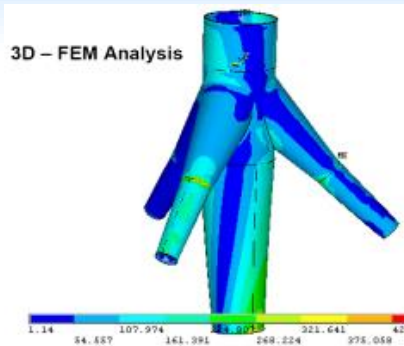


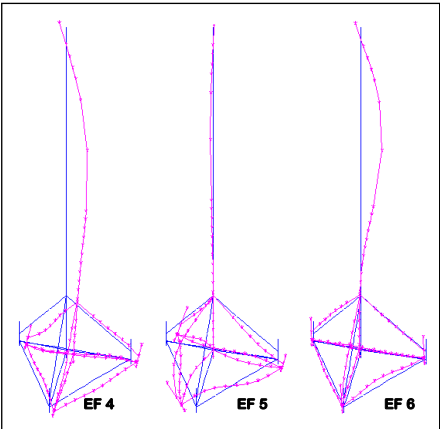
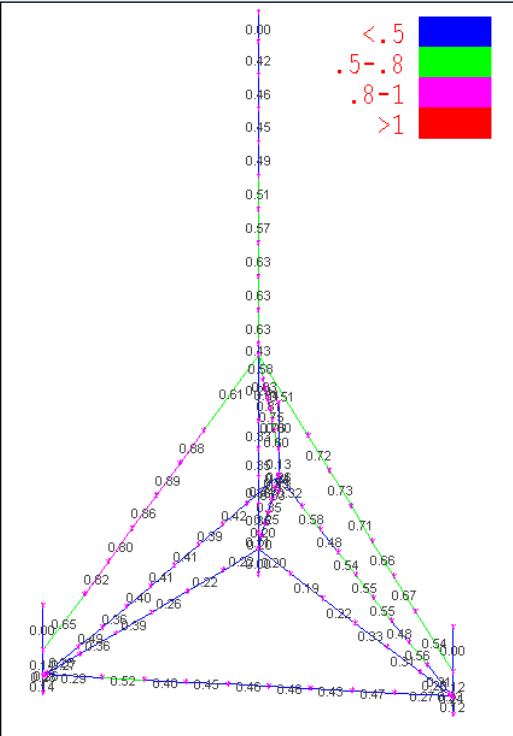
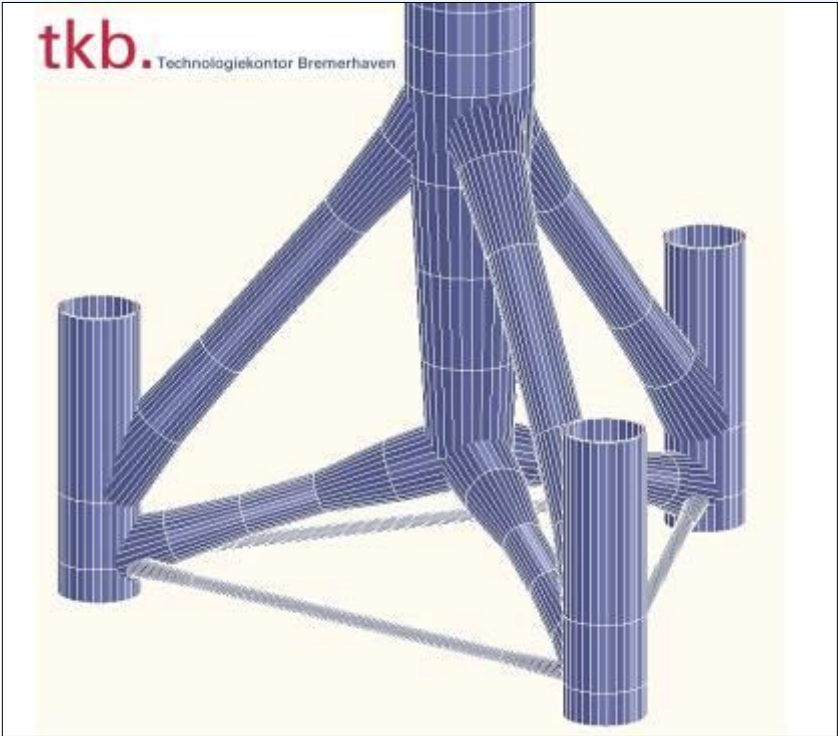
Development of static models
(for 3-5 MW turbine class)





Discussion of alternative
connection points of foundation
structure





Generation of representative
loads of wind energy
installations

A longline type I: polypropylene-based backbone

AWI 300 kg 35 kg ball-like floats 115 kg 80 kg 5 m 70 m anchor-line chain cable 3 kg 200 kg 4 tonnes

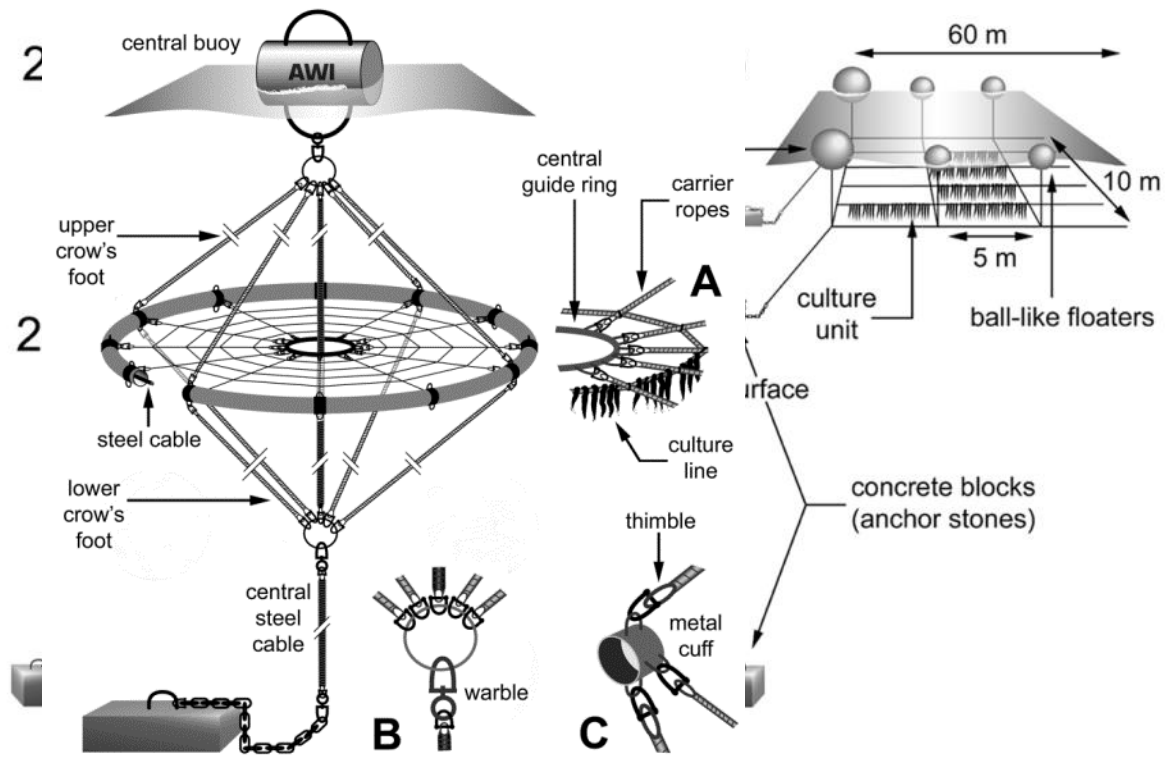
B longline type II: steel hawser-based backbone

marker buoy marker-line AWI 300 kg 28 kg pencil-like floats 21 kg 10 kg 10 m segments 5 m 70 m spat collector 1. segment 2. segment concrete block 4 tonnes

C **D** **E**

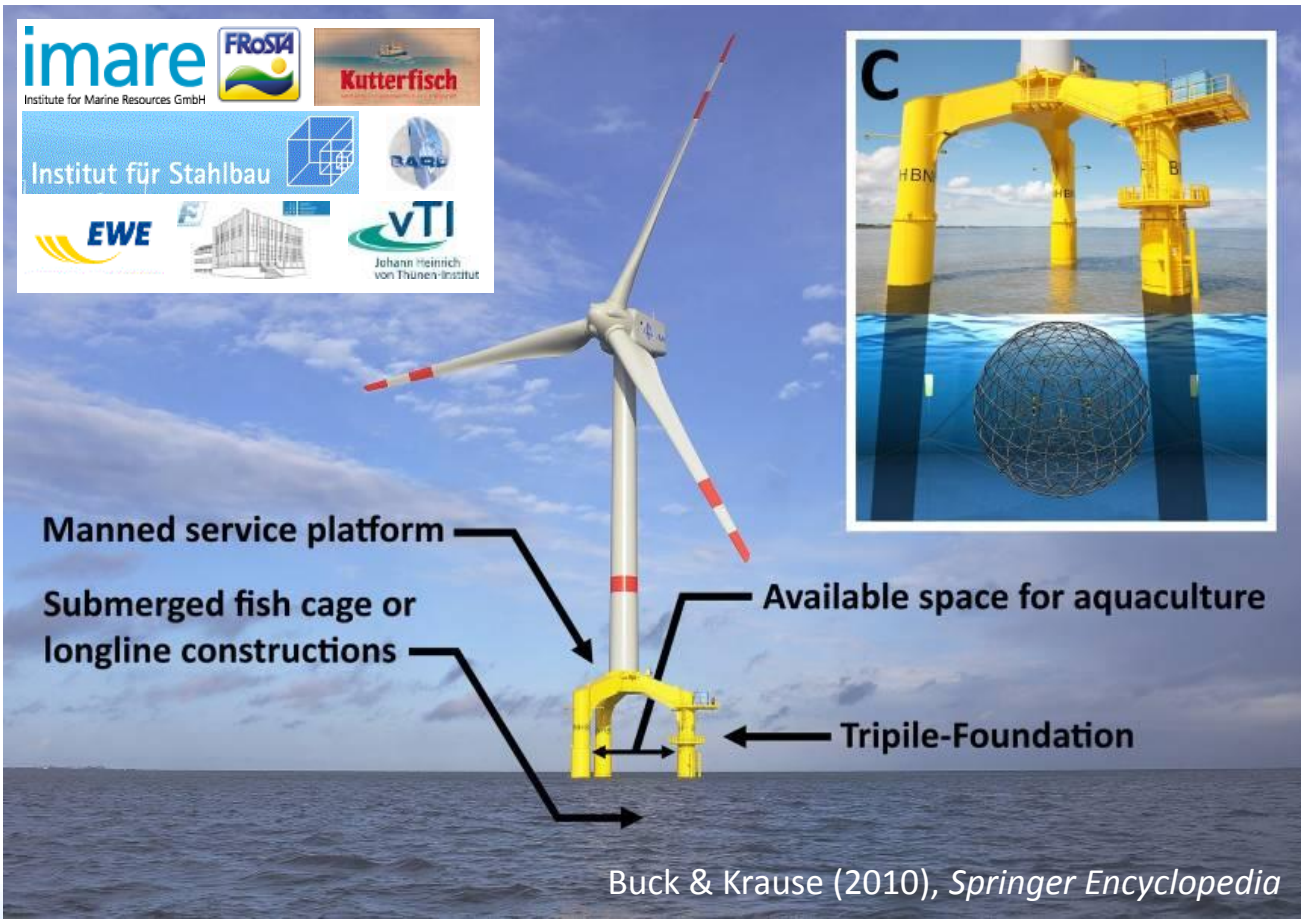
Buck et al. (2010), Aquac. Econom. Management

Seaweed cultivation



- longlines
- ladder
- grid

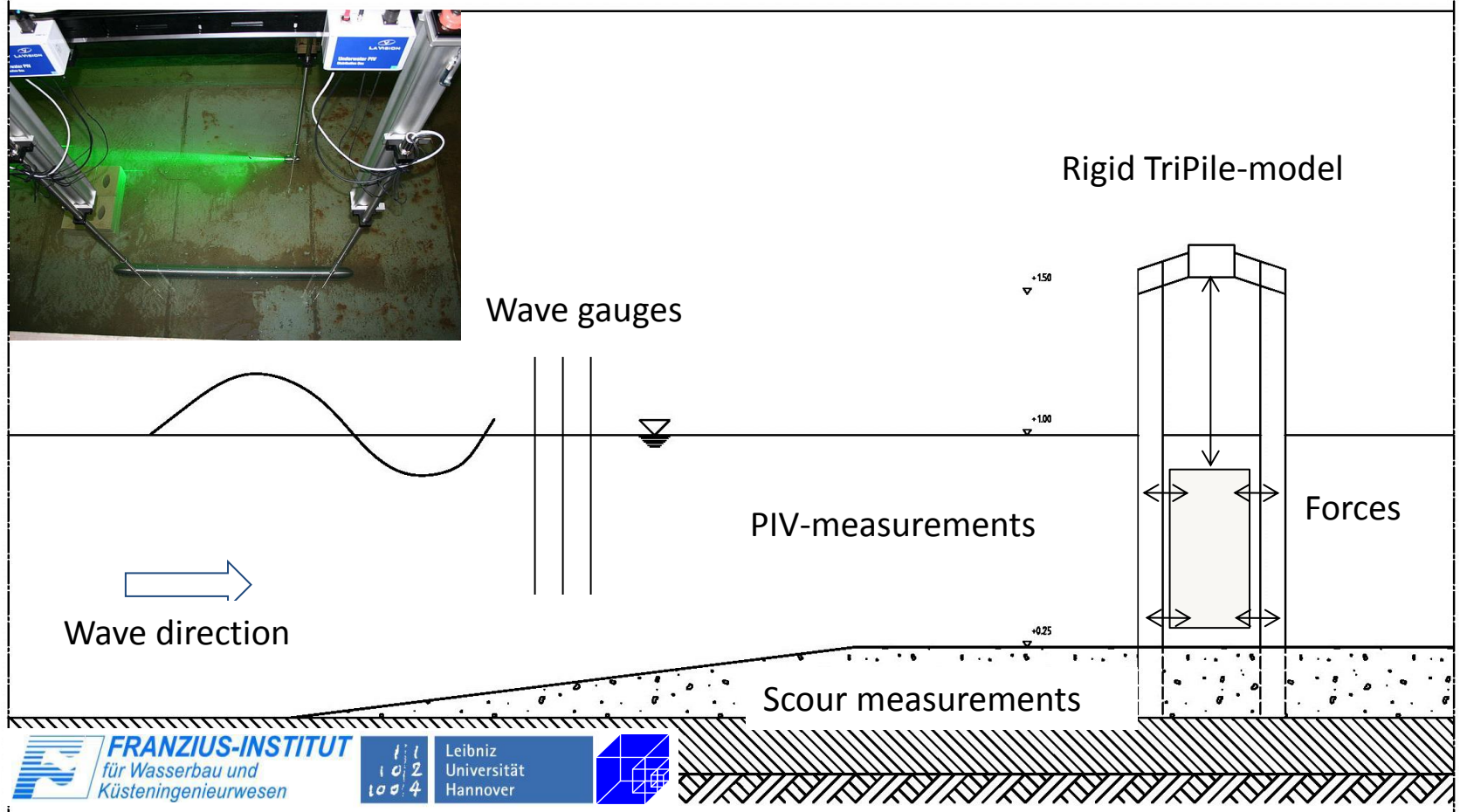




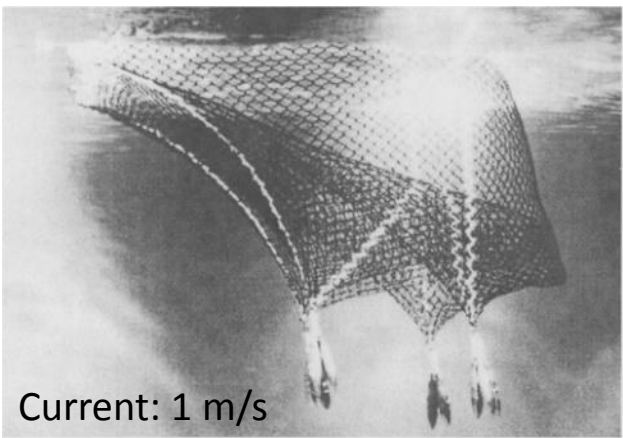


Experimental facility and probes

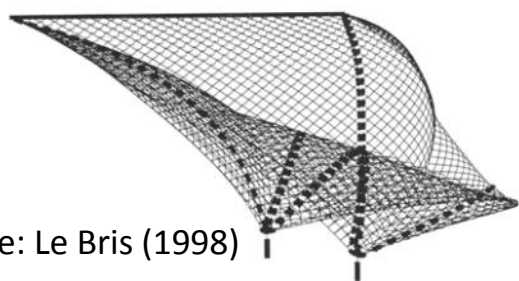
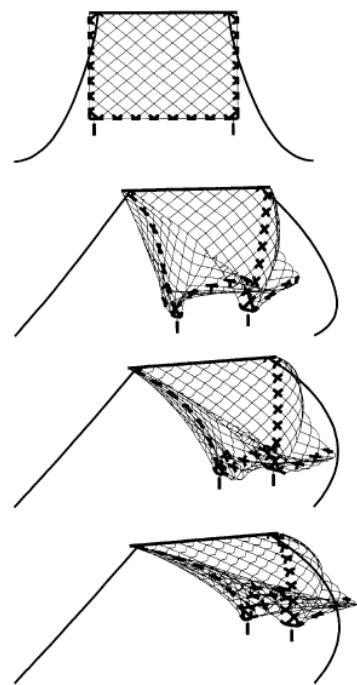
Stereo Particle Image Velocimetry (PIV): Flow field near structure



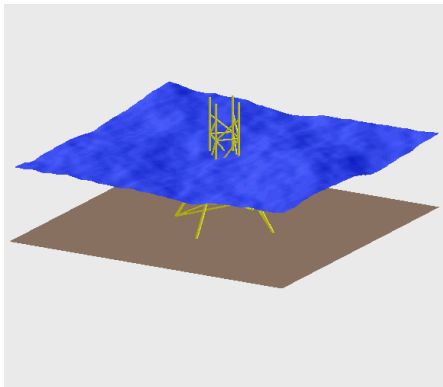
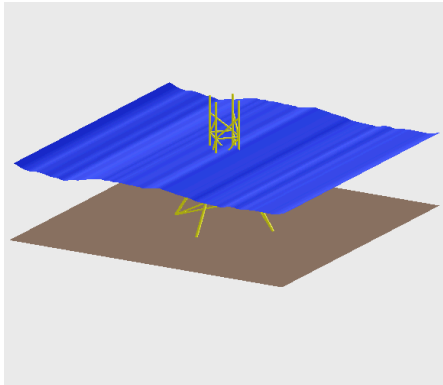
Include net loading in beam model



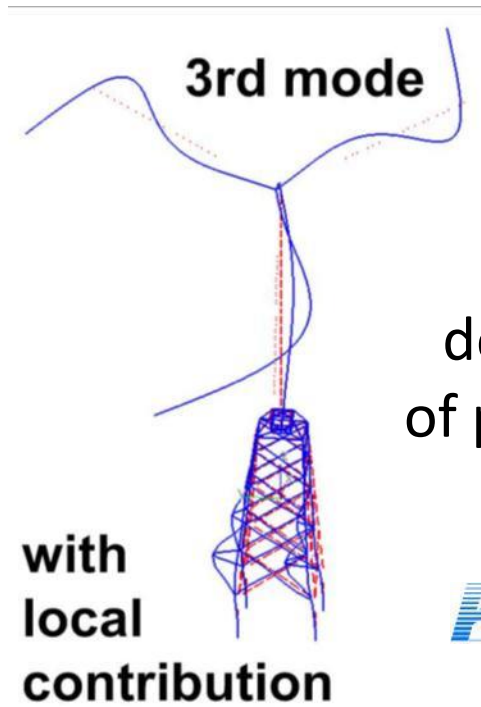
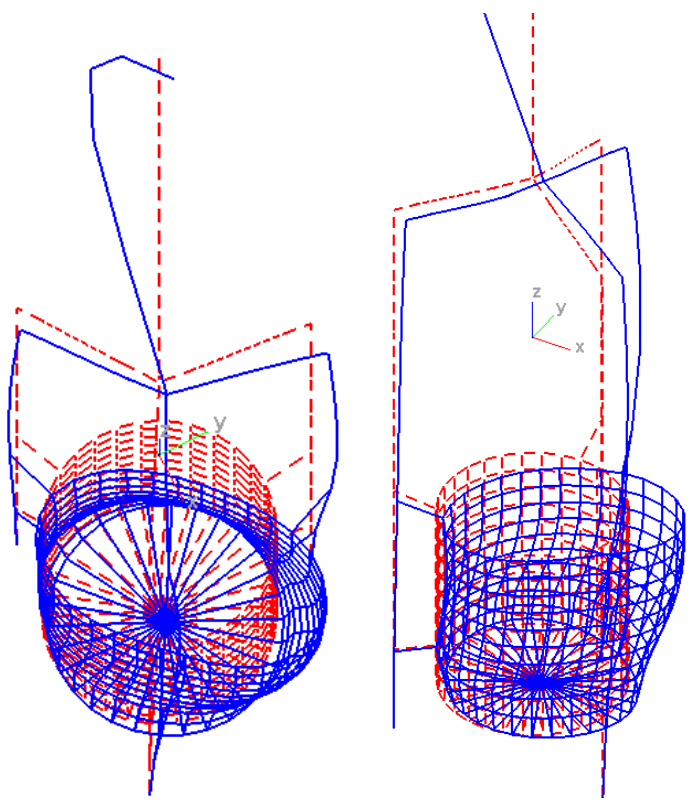
Tripile + cage + net?
Experiments and numerical
simulations



Source: Le Bris (1998)



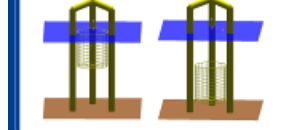
Influence on support structure dynamics




depends on stiffness
of pile-cage connection!


Lastfallbelegung/Havarie – Extremwellen – Fatigelasten


Befüllzustand temporär Betriebszustand



ForWind  Open Ocean Multi User (OOUMU)

Anschlusskonstruktion



ForWind  Open Ocean Multi User (OOUMU)

Details zu den Messungen

- PV-Messfühler im Halbbereich der Strahler



ForWind  Open Ocean Multi User (OOUMU)

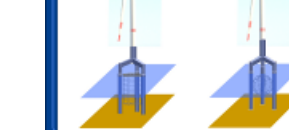
Details zu den Messungen


- Positionen der Beschleunigungs-



ForWind  Open Ocean Multi User (OOUMU)

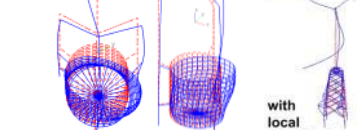
Parametrisierte Modelle und Lastfallbelegungen



ForWind  Open Ocean Multi User (OOUMU)

3rd mod

with local contribution



Untersuchungen im Wellenkanal – Messkonzept

- Messgrößen / Variablen
- Bild aus dem Geschwindigkeitssensor
- Spannungssensoren im Material
- Kraftmessdrücken an Verbindungsknoten
- Oberflächenverformung auf der Strahler
- Geschwindigkeitsmessungen an verschiedenen Positionen
- Überwachung der relativen Verformung
- Wellenprofil
- Energiefluss der Wellenfronten
- Abstandsmessung mit Ultraschall-Sensoren (3000)



ForWind  Open Ocean Multi User (OOUMU)

Verankerung / Verankerung



ForWind  Open Ocean Multi User (OOUMU)

Voruntersuchungen Seiloberflächen

- Abstand aller Seiloberflächen
- Länge: 20 m
- Breite: 1 m
- Tiefe: 1 m



ForWind  Open Ocean Multi User (OOUMU)


Details zu den Messungen


- PV-Messfühler im Halbbereich der Strahler



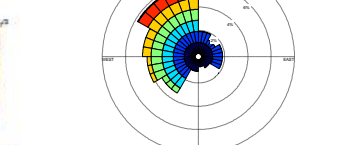
ForWind  Open Ocean Multi User (OOUMU)

Basiszustand Endzustand Heber/Senken



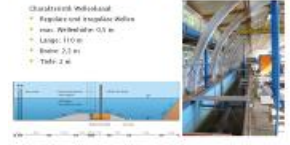
ForWind  Open Ocean Multi User (OOUMU)

Directional Wave Scatter Location Map



Untersuchungen im Wellenkanal

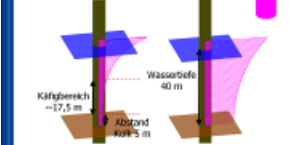
- Charakteristisches Wellenprofil
- Regelmäßige und irreguläre Wellen
- max. Wellenlänge: 0,5 m
- Länge: 10 m
- Breite: 2,5 m
- Tiefe: 2 m




ForWind  Open Ocean Multi User (OOUMU)

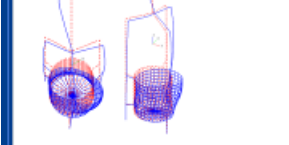
Wellenlasten Extremwellen – Fatigue


- Vergleich der Wellenlastverläufe



ForWind  Open Ocean Multi User (OOUMU)

Gekoppelte Tragstruktur – Käfigeigenfrequenzen



ForWind  Open Ocean Multi User (OOUMU)

Diskussion Käfigdesign und Anschlusskonstruktion

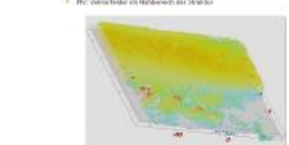
- Haltpunkte
- Aussteifungsstrahlungen
- Auftriebskörper
- Stollenlagen bei Abtriebsflächen
- Luftverdrängung 10 Jahre
- Anschlussdetails
- Maritimer Bewuchs
- Kritische Flachbewegungen?
- $V = 3.100 \text{ m}^3$
- Transportkosten?





ForWind  Open Ocean Multi User (OOUMU)

Details zu den Messungen

- PV-Messfühler im Halbbereich der Strahler

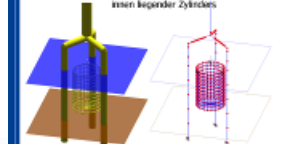



ForWind  Open Ocean Multi User (OOUMU)



Teilleistung 1

- Variante 2 + 3: Parametrisiertes numerisches Modell des innen liegenden Zylinders



ForWind  Open Ocean Multi User (OOUMU)

Teilleistung 1

- Variante 3: Schirmen-Boden zwischen mehreren Anlagen



ForWind  Open Ocean Multi User (OOUMU)

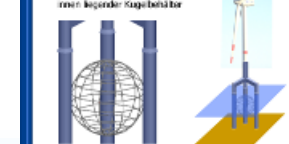
Abiotische Umweltfaktoren




ForWind  Open Ocean Multi User (OOUMU)

Teilleistung 1

- Variante 1: innen liegender Kugelbehälter




ForWind  Open Ocean Multi User (OOUMU)

Teilleistung 1

- Variante 2: innen liegender Zylinder



ForWind  Open Ocean Multi User (OOUMU)



Sustainable Production of Food

→ The IMTA-concept

Bioextraction

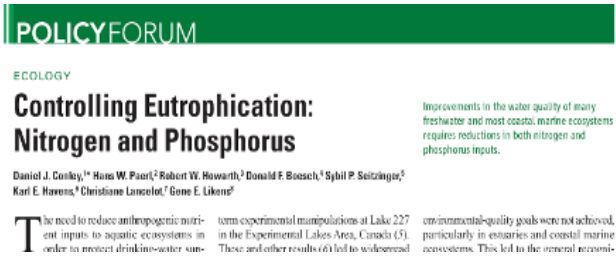
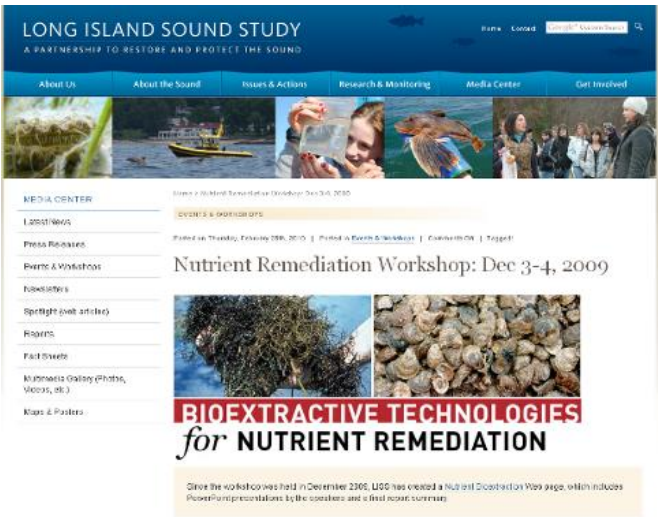
“An environmental management strategy by which nutrients are removed from an aquatic ecosystem through the harvest of enhanced biological production, including the aquaculture of suspension-feeding shellfish or algae”

Ecological Engineering

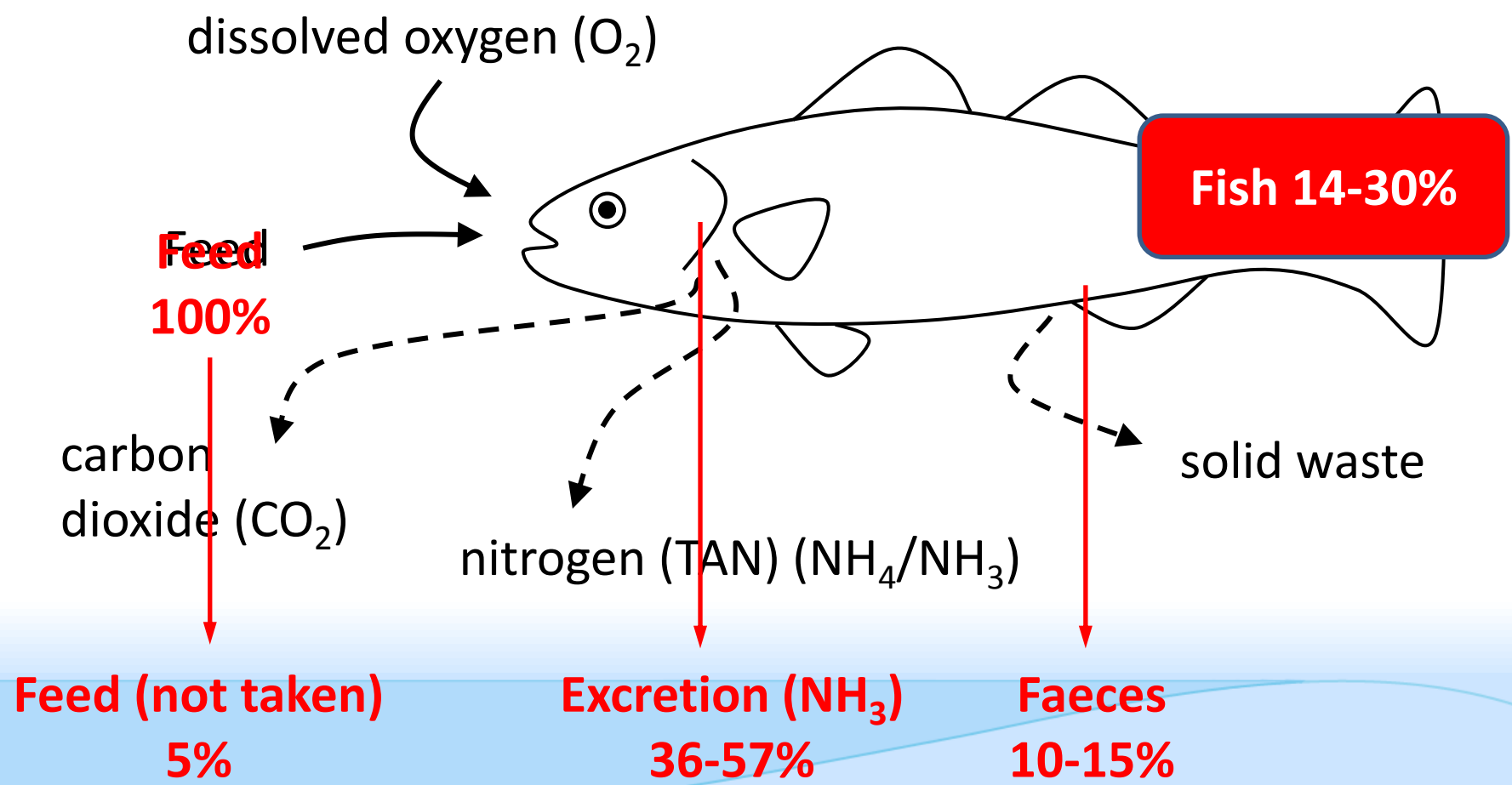
“Ecological Engineering is an emerging field that uses ecological processes within natural or constructed systems to achieve environmental goals”

Balanced Ecosystem Approach

“Fed aquaculture of finfish or shrimp with extractive organic aquaculture of shellfish and extractive inorganic aquaculture of seaweed (IMTA)”



FLOWS OF MATTER (N)



MODEL FOR NITROGEN BUDGETS WITHIN IMTA-SITE

Basic Data Fish (fed AQ)

- standing stock and stocking density
- growth performance / FCR
- feed components
- biology and diet

Basic Data (extractive AQ)

- dissolved inorganic extraction (macroalgae)
- particulate organic extraction (polychaetes, bivalves)
- biology

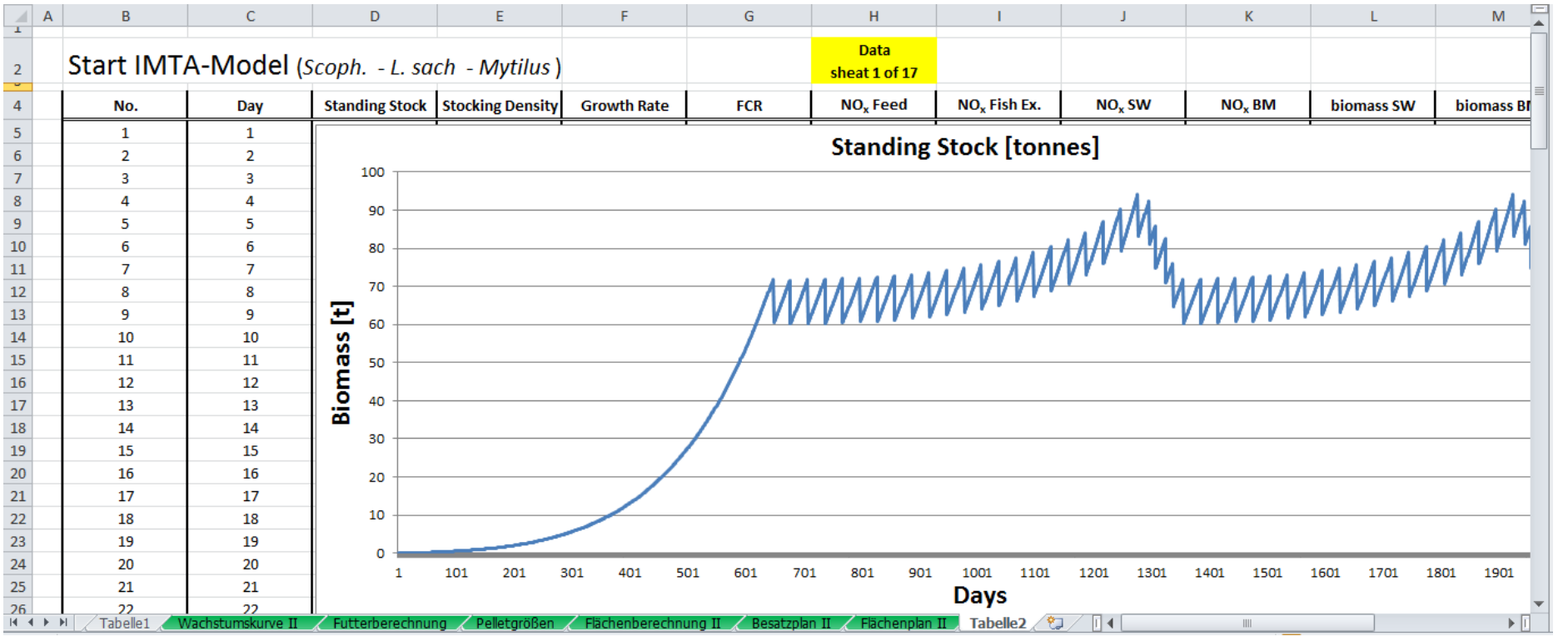
Basic Data (environment)

- local current regime
- carrying capacity

Basic Data Origin

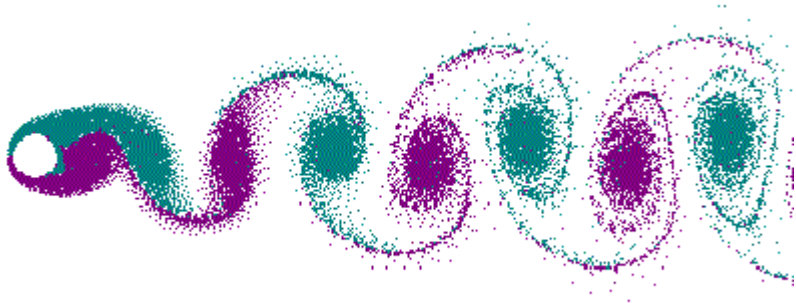
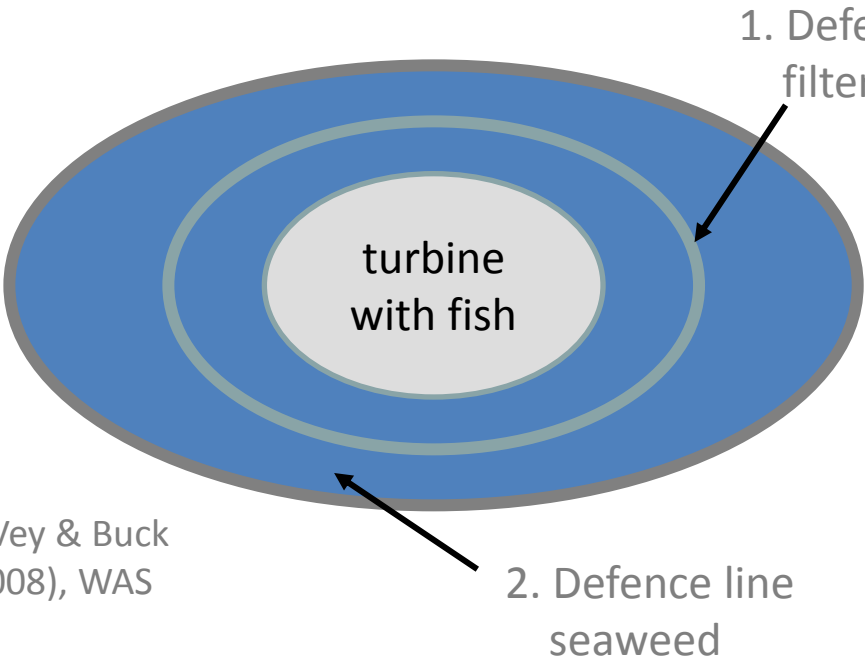
- data bases (ASFA, Scirrus, Web of Science, etc.)
- peer-reviewed publications as well as “grey” lit.
- own research

MODEL FOR NITROGEN BUDGETS WITHIN IMTA-SITE



IMTA

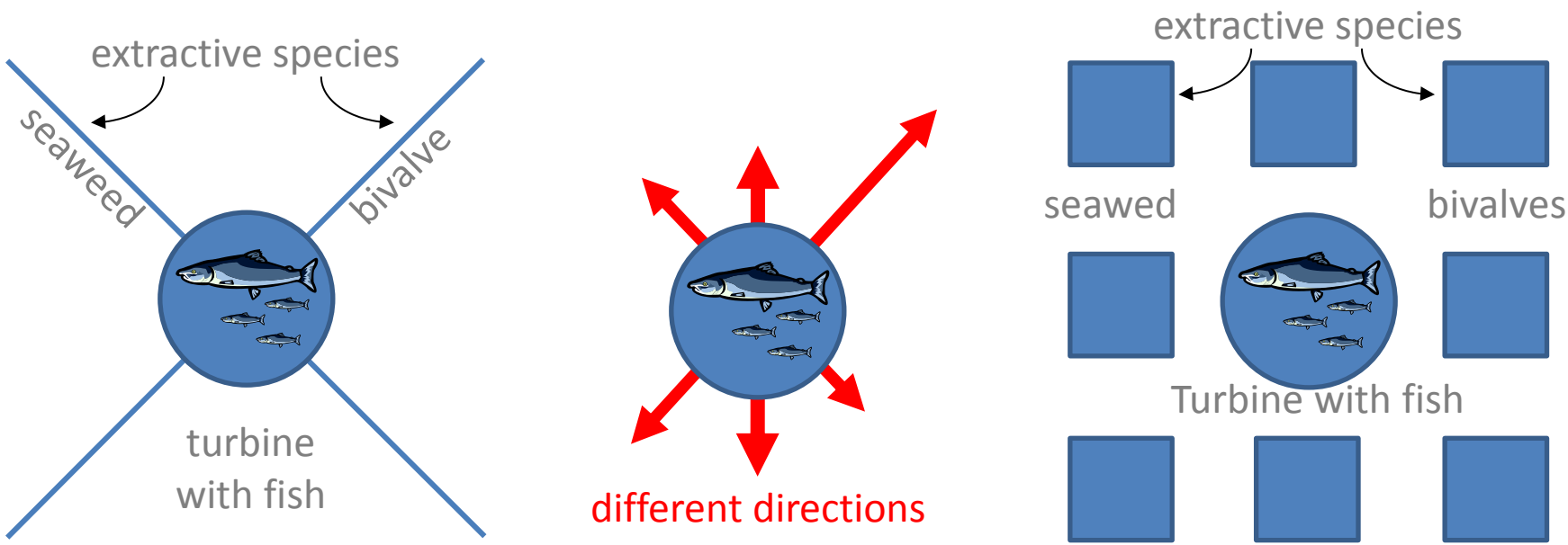
(Integrated multi-trophic aquaculture)



McVey & Buck
(2008), WAS

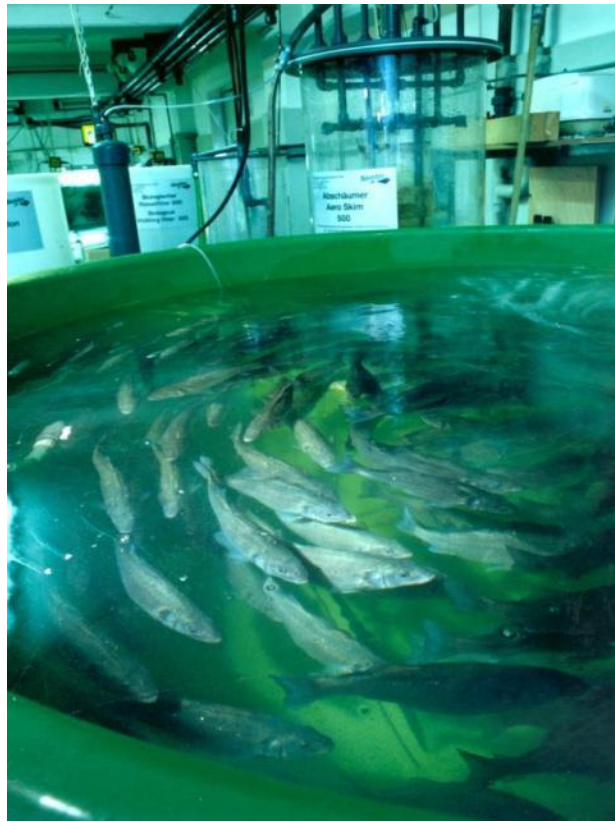
IMTA

(Integrated multi-trophic aquaculture)



Combination with other Infrastructure

→ RAS ↔ OOA



Open Ocean
Aquaculture
(OOA)

Land-Based
Recirc.-System
(RAS)





small

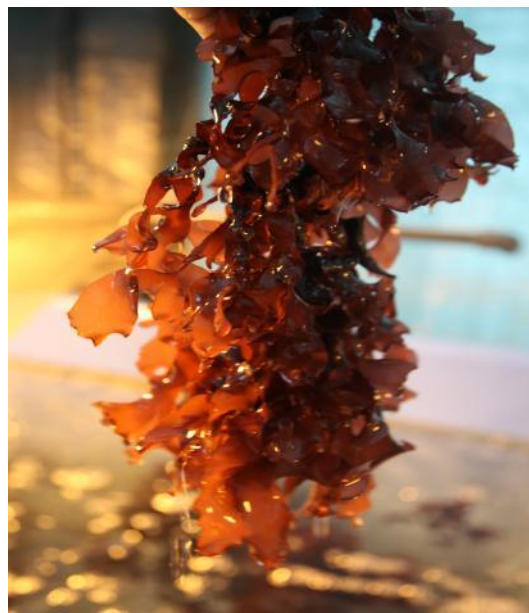


Marked size





Integrated
Multi-Trophic
Multi-Loop
Aquaculture



Scophthalmus maximus



*Nereis
diversicolor*

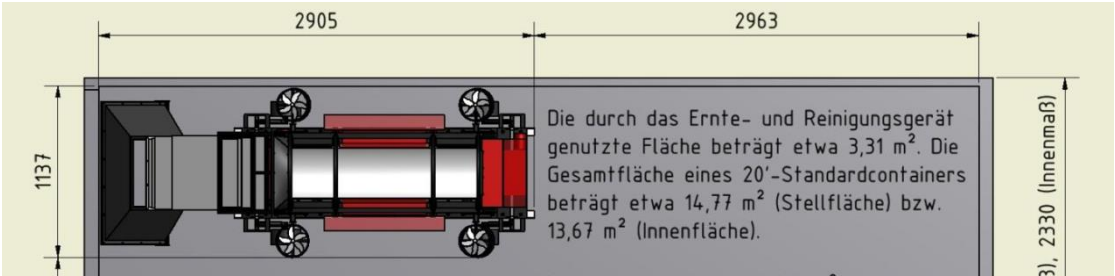
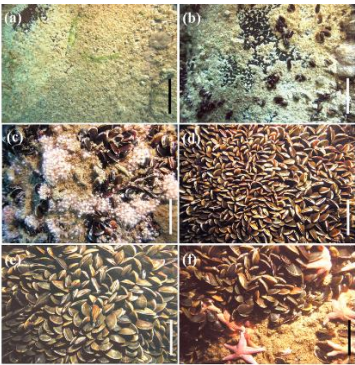


Mytilus edulis



Palmaria palmata

imare GmbH






Future Production of Food from the Oceans:

- Follow guidelines defined by the FAO
- Foster cooperation with experts within the EU
- Develop innovative technologies to allow co-use concepts
- Set-up an inter. offshore test facility




Aquaculture Forum
BREMERHAVEN



Bremerhaven Declaration
on the Future of
Global Open Ocean Aquaculture

1

Part I
Preamble and Recommendations



Workshop I
March 26 – 27, 2012
OPEN OCEAN AQUACULTURE DEVELOPMENT
From visions to reality: the future of offshore farming

www.aquaculture-forum.com

Aquaculture Forum
BREMERHAVEN



Bremerhaven Declaration
on the Future of
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1

Part II
Recommendations on subject areas and justifications



Workshop I
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www.aquaculture-forum.com

Bremerhaven Declaration

on the Future of Global
Open Ocean Aquaculture

Key Issues:

1. Upscaling aquaculture requires a move offshore.
2. IMTA concepts should form the basis for new enterprises to fulfill criteria of sustainability and environmental friendly techniques => acceptance
3. Multi-use will have a better acceptance for both stakeholders and would save costs/have economic benefits
 - quick procedure
 - combined EIA
 - shared vessels/personal
 - training
 - additional biomass

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