Wolfgang Kunther* – DTU Sustain: Materials and Durability

Use of concrete in artificial reefs *and NID infrastructure*

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Reef types and materials

- Origin of reefs
  - Geogenic: cliffs, rocks, sandbanks
  - Biogenic: mussel banks, coral reefs
  - Artificial: man-made

Themes:

Reviews and theory

Fisheries ecology and management

General ecology

Design and monitoring

Habitat protection and mitigation

Sport diving

Waste disposal

Coastal protection and development

Types of material used for artificial reef construction

Material	Number of citations
Concrete	79
Rock, stone, boulders, gravel, etc.	29
FADs	17
Offshore platforms	16
Tyres	15
Stabilised ash waste, harbour mud	14
Plastic, PVC, etc.	12
Vessels, barges, shipwrecks	11
Wood, trees, etc.	11
Breakwaters, coastal structures	12
Steel, metal	10
Rope, netting	9
Automobiles, train cars	6
Unspecified mix of materials	6
Review of wide range of materials	13
Other materials	18
Unspecified	31
Total	309

Artificial reefs: a review of their design, application, management and performance

Ocean & Coastal Management 44 (2001) 241–259

Where do we find concrete?

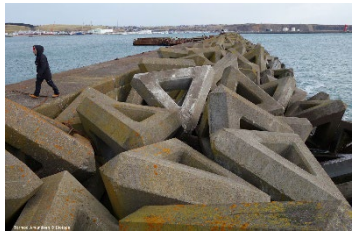
- Low price
- High availability
- Formability
- High durability

Urbanisation

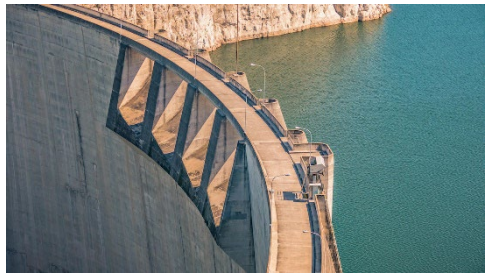
Houses

Waste and sewage

Transportation infrastructure



Energy



Digitalisation and communication

Disclaimer: **Who am I?**

- Civil Engineer, Material Scientist
- Cement chemistry and concrete durability
- No "*commercial*" intent
- Passion for water sports

- Why not design infrastructure with **positive impact on habitats**?

Chosen boundary conditions for "our" reefs:

- Permanently submerged
- No reinforcement steel
  - Extra CO_2
  - Corrosion risk

Disclaimer:
I am not a biologist!

- Interdisciplinary research
  - Key environmental parameters
  - Succession or biofouling
  - Reproductive cycles and seasons
- Biodiversity, biomass, and ecosystems ….
- Climate change – shifting baselines?

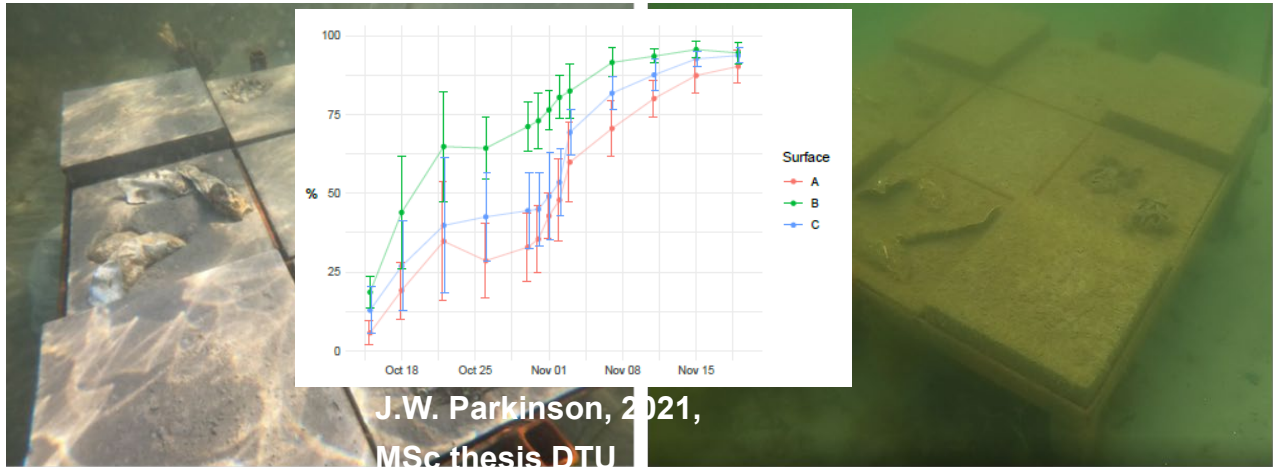
Succession (or biofouling)

Minutes – weeks biofilm:

Particles of organized matter

Primary colonizers (microbial)

Secondary colonizers



Weeks - months:

Biofilm +

Community of macroscopic Individuals

algae and invertebrates

Additional months:

Biofilm +

Community of macroscopic Individuals

Early adopters / invasive?

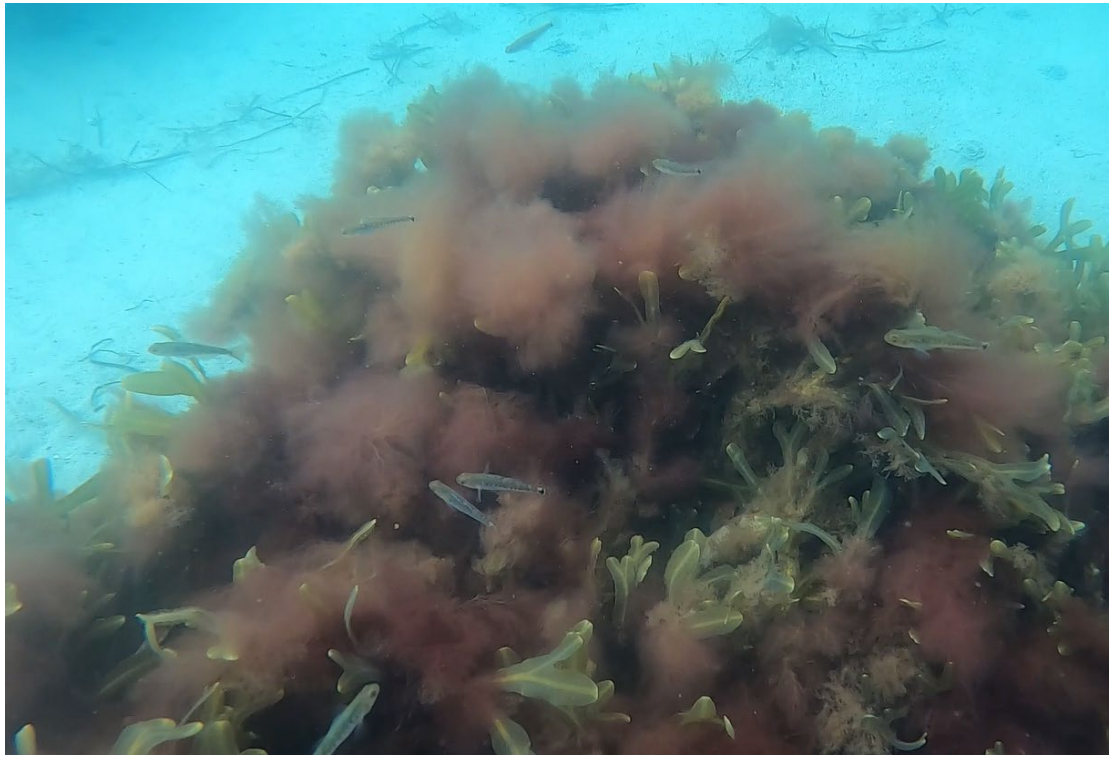
years:

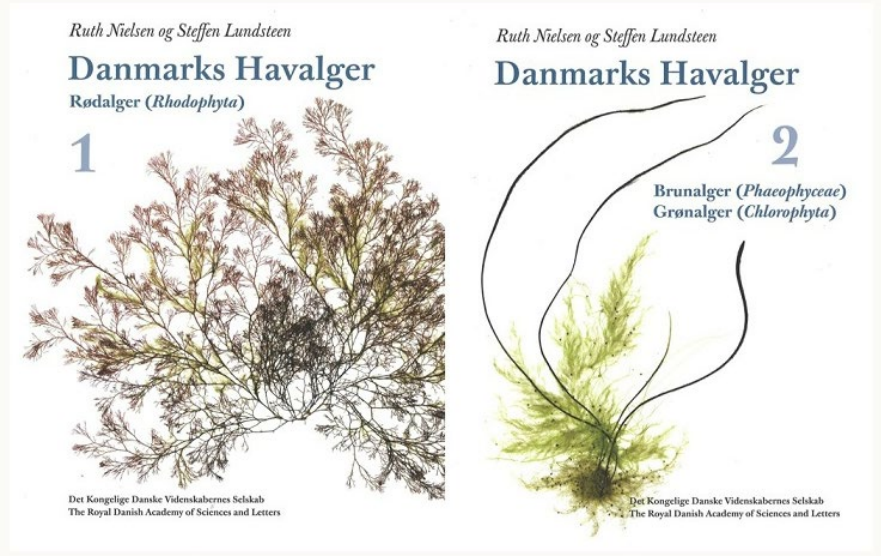
Biofilm +

Community of macroscopic Individuals

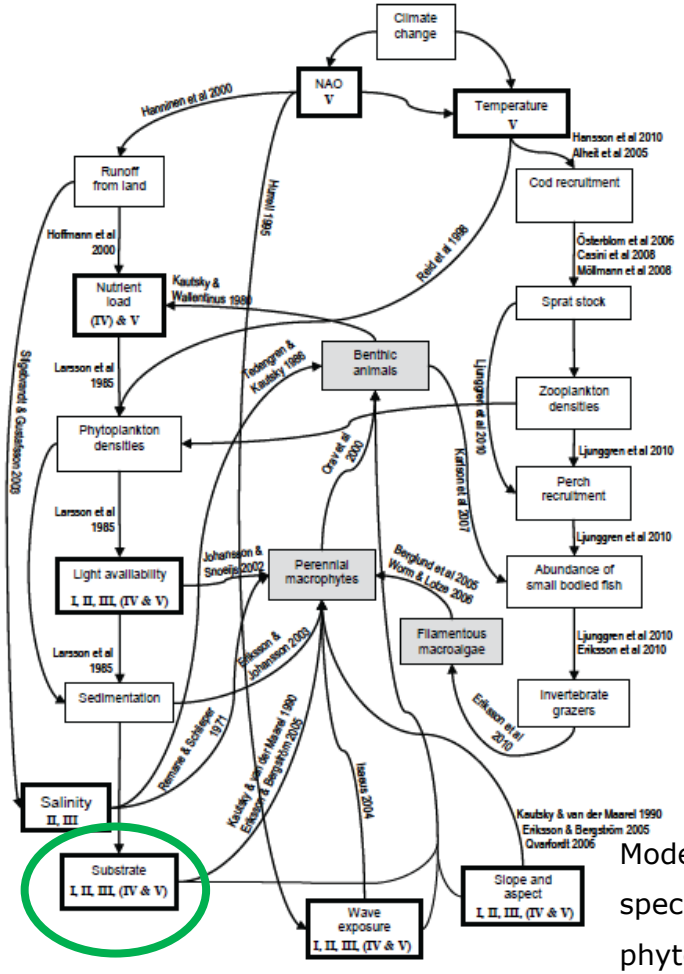
Seasonal changes etc.

After two growth periods:





Biological and material factors?



Modelling spatial and temporal species distribution in the Baltic Sea phytobenthic zone, 2011, A.N. Sandman, Stockholm University

Contents lists available at ScienceDirect

Ecological Engineering

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

Getting into the groove: Opportunities to enhance the ecological value of hard coastal infrastructure using fine-scale surface textures

Martin A. Coombes [a,*], Emanuela Claudia La Marca [b], Larissa A. Naylor [c], Richard C. Thompson [d]

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[b] Department of Earth and Sea Sciences, University of Palermo, Italy
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Contents lists available at ScienceDirect

Ecological Engineering

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

Material type weakly affects algal colonisation but not macrofaunal community in an artificial intertidal habitat

Rania S. Hartanto [a], Lynette H.L. Loke [a,1], Eliza C. Heery [a,2], Amanda R. Hsiung [a,3], Marcus W. X. Goh [a], Y. Shona Pek [b], William R. Birch [b], Peter A. Todd [a,*]

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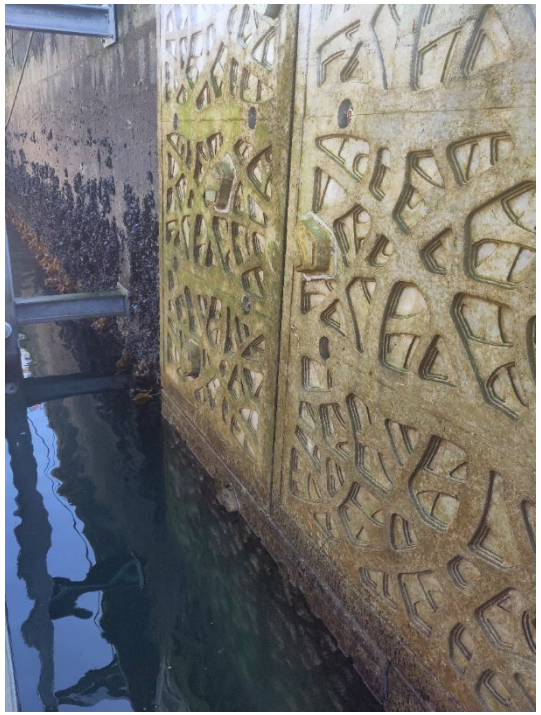
[b] Institute of Materials Research & Engineering, 2 Fusionopolis Way, Innovis 138634, Singapore

Hard substrates for bio-colonization in industrial harbours…

- Size
- Structure
- Texture
- Chemistry
  - pH
  - other



LIVING PORTS PROJECT

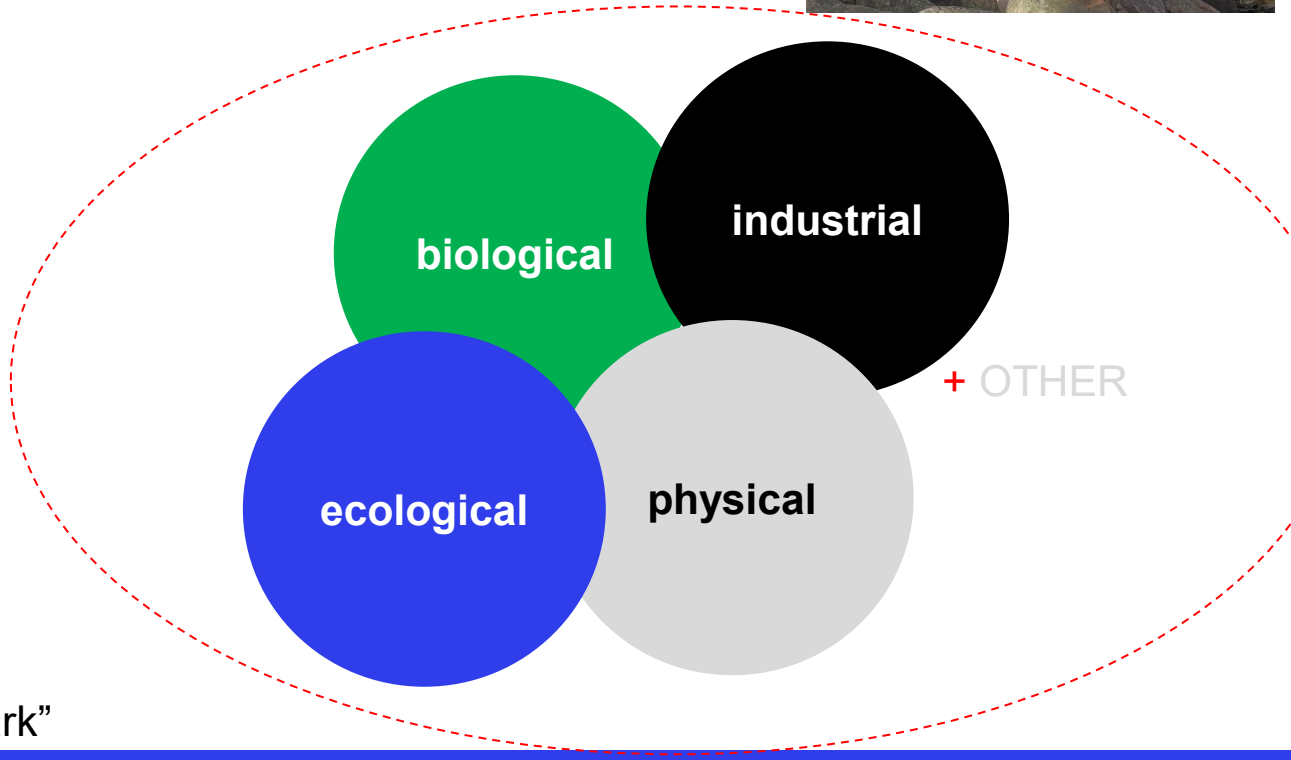
European Union's Horizon 2020 research and innovation program under grant agreement No GA 970972

Funded by the European Union

Select the best concrete for habitat creation in Køge Bay:

- Mechanical properties
- Biological factors *(biodiversity, types of species, biomass …)*
- Environmental factors *(salt content, nutrients, shelter, predation…)*
- CO_2 footprint and other environmental impacts
- *Toxicity and leaching?*
- *Hydrodynamics?*
- *Sediment transport?*

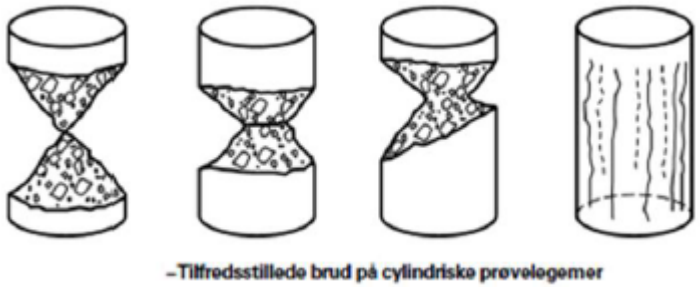
Literature study & analysis



Funding: VELUX FONDEN for the project “Køge Bugt Marine Park”

Physical properties

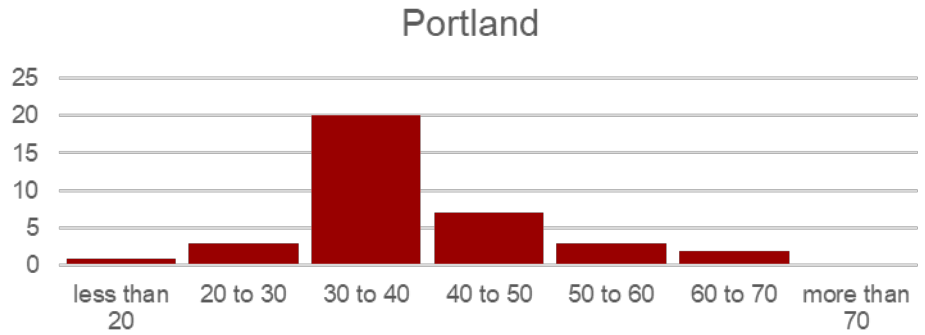
- Compressive strength
- *Other mechanical properties*
- *Cement type*
- *Porosity*
- *Density*
- *Curing times*

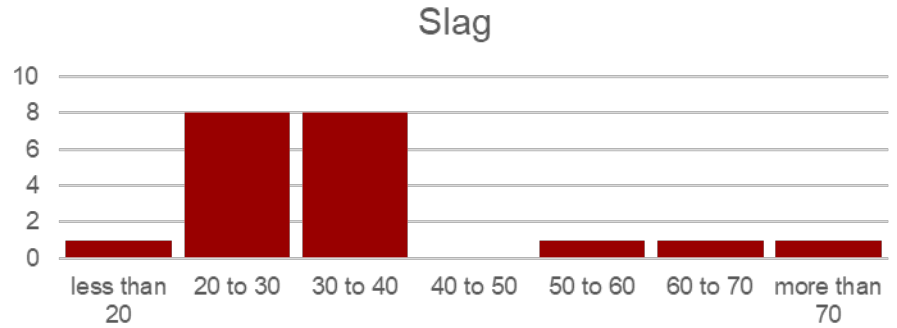


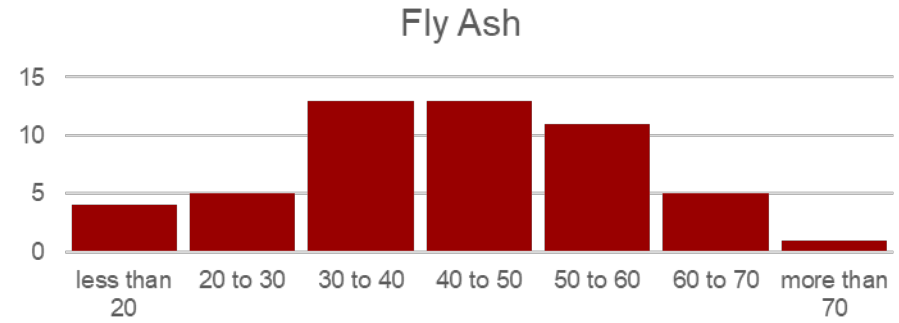
–Tilfredsstillede brud på cylindriske prøvelegemer

DS/EN 12390-3+AC:2012

Compressive strength (28 days)



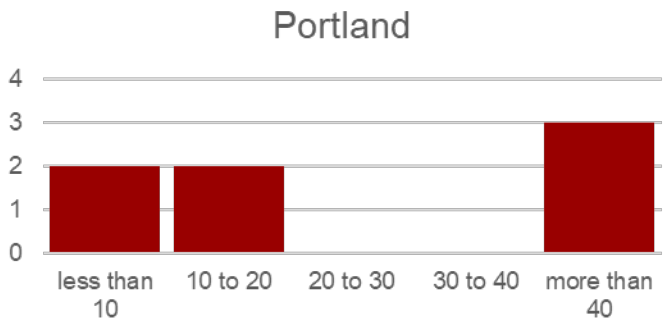


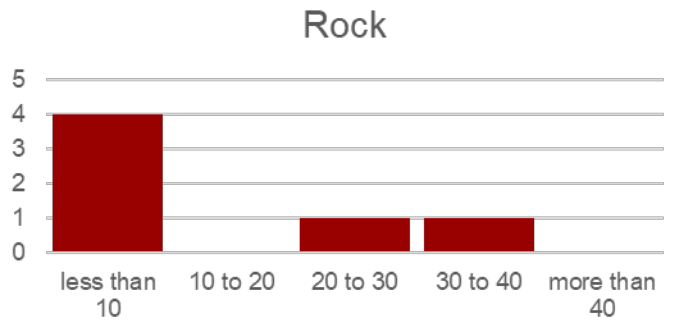


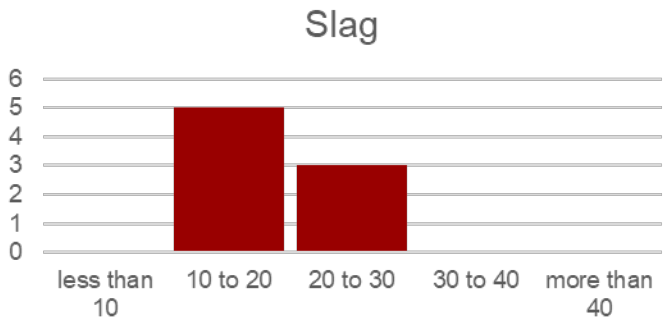
Biology

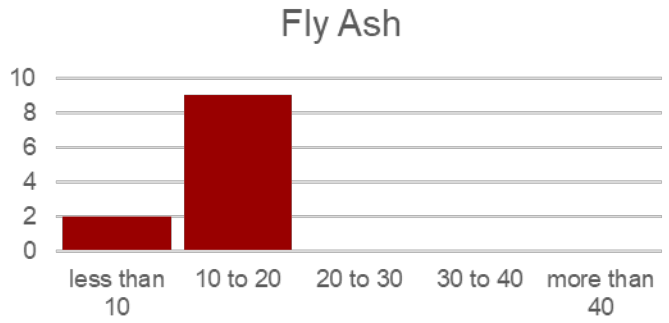
- coverage
- # of species/taxa
- Biomass
- Light adsorption …
- *Time of*
  - *Deployment*
  - *Measurement*
  - *Of "stable" habitat*
- *Period of exposure*
- *Drift in baselines*

Species diversity by cement type (last reported date)

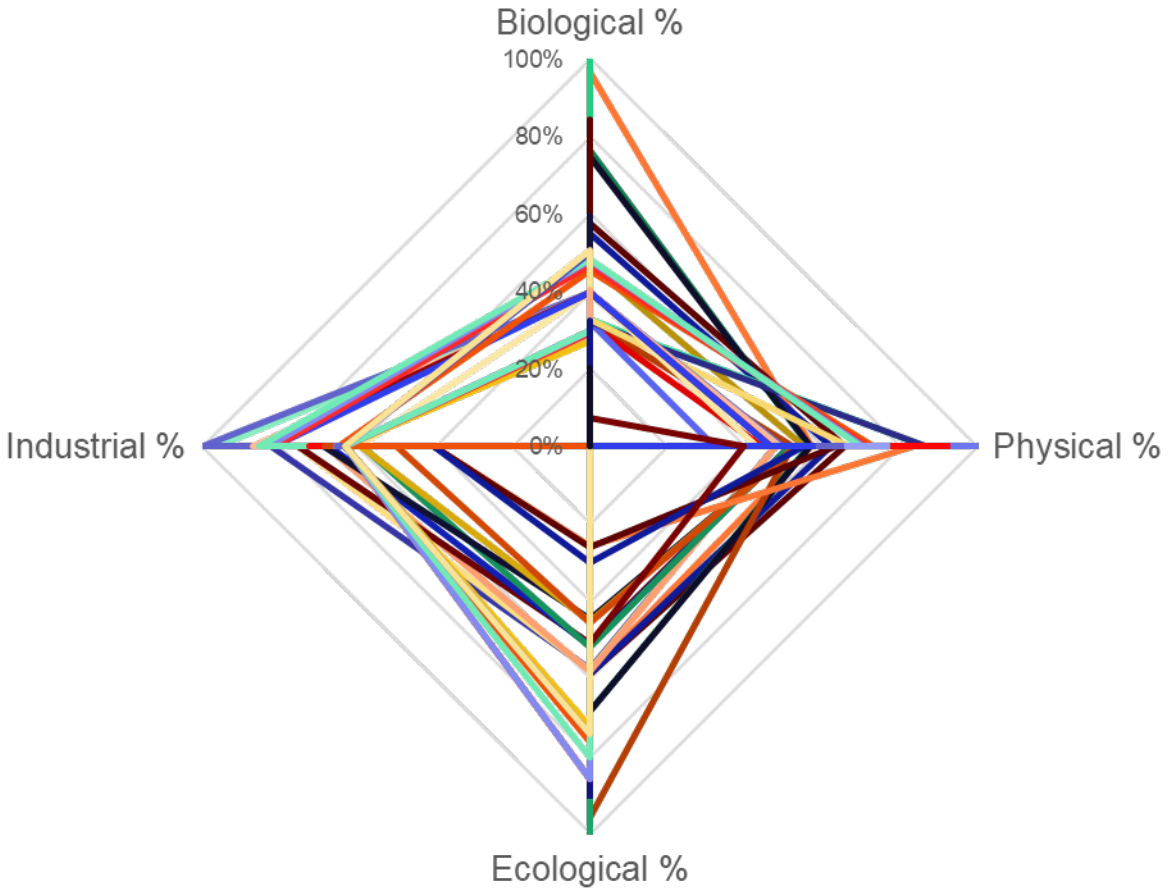


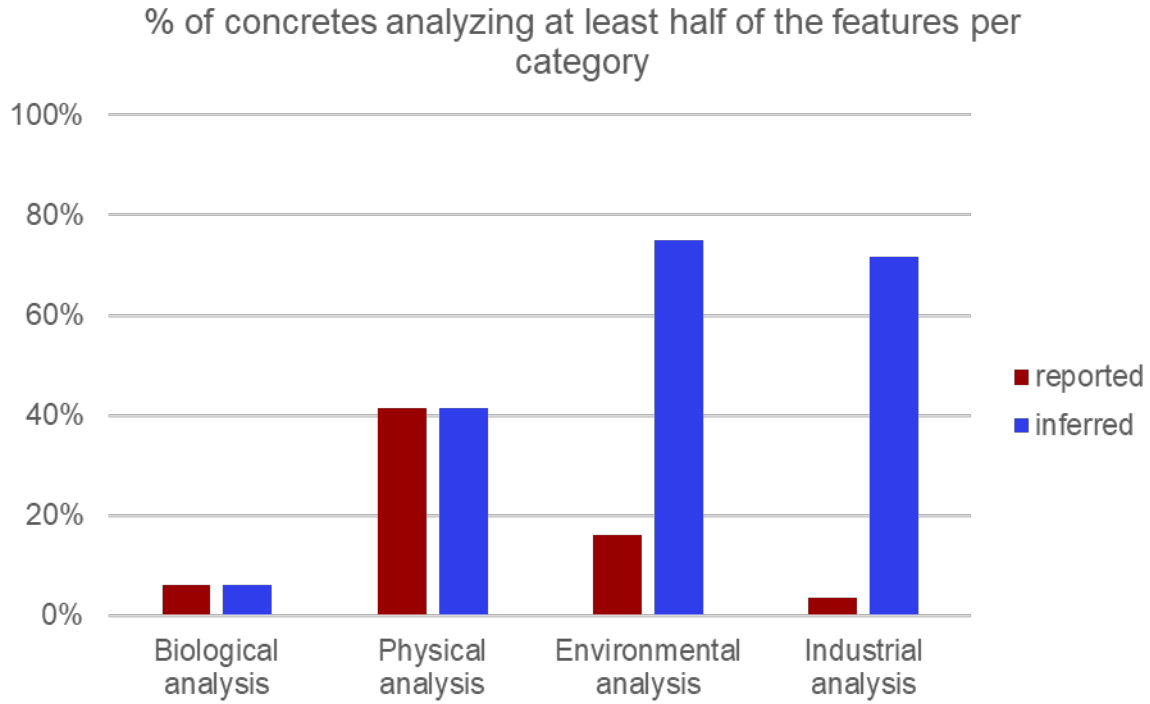






Integrated data?
And estimates…





Example

Biological:

The performance of the concrete/reef in terms of biocompatibility and attractiveness to the marine species. (# taxa, coverage, …)

Physical:

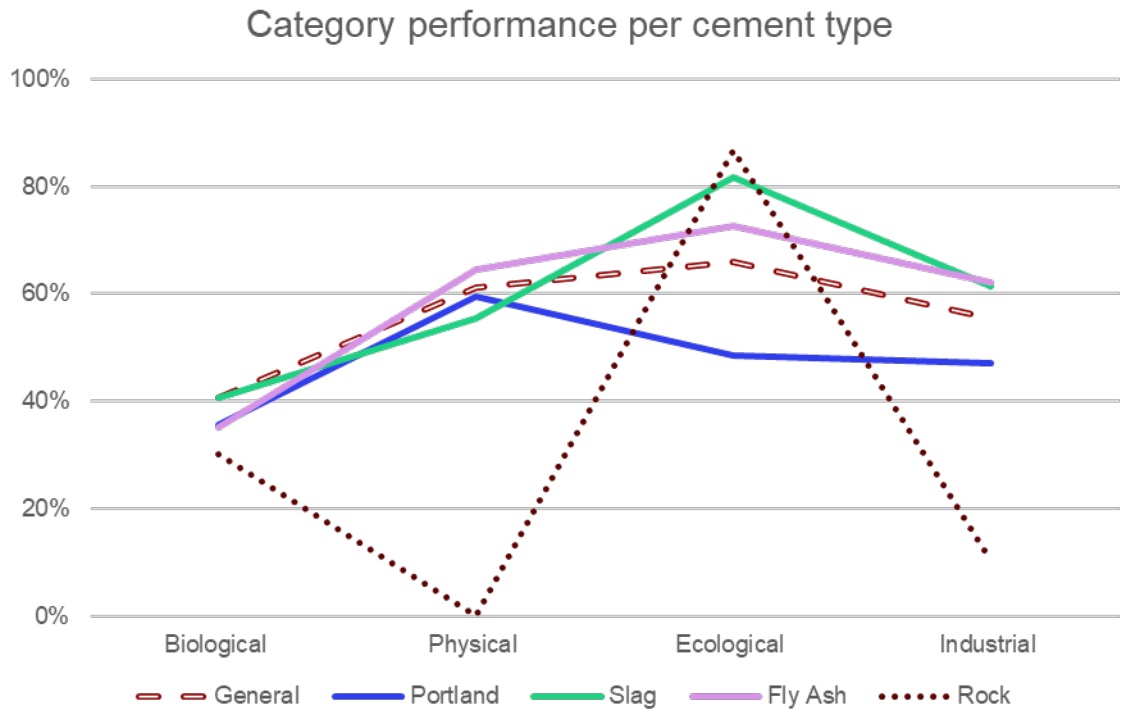
Mechanical properties and durability of the concrete/reef. (Compressive strength, chloride resistance)

Ecological:

Assessment of the environmental impact of the concrete both when produced and when implemented in the surrounding environments – "Global more hidden impacts" (pH, CO_2)

Industrial:

The efficiency of the concrete production lines, both economically and in resources. "Tangible impacts/cost to manufacturer" (cost, water consumption, energy consumption)



> 250 concrete types

Reef data for use infrastructures in DK?

- **Most beneficial concretes from published, peer reviewed articles:**
  - Slag-based concrete
  - Biogenic aggregates
  - And lower strength

Best integration in habitats **after literature analysis**

Tabel DK NA-F.1 – Krævede grænseværdier for betonsammensætning og betonegenskaber for normal og tung beton

	Ingen risiko for korrosion eller fugtpåvirkning	Risiko for korrosion forårsaget af karbonatisering				Risiko for korrosion forårsaget af chlorider fra andet end havvand			Risiko for korrosion forårsaget af chlorider fra havvand			Risiko for frost/tøpåvirkning				Risiko for kemisk påvirkning		
Eksponeringsklasse	X0	XC1	XC2	XC3	XC4	XD1	XD2	XD3	XS1	XS2	XS3	XF1	XF2	XF3	XF4	XA1	XA2	XA3
Maksimum vand/cement-forhold [c)]	---	---	0,55	0,55	0,55	0,45	0,40	0,40	0,45	0,45	0,40	0,55	0,45	0,45	0,40	0,55	0,45	0,40
Minimum klasse for trykstyrke [a)]	C12/15	C12/15	C30/37	C30/37	C30/37	C35/45	C40/50	C40/50	C35/45	C35/45	C40/50	C30/37	C35/45	C35/45	C40/50	C30/37	C35/45	C40/50
Dokumenteret egnede cementtyper CEM [b) h) k)]	I II/A-V II/B-V II/A-L II/A-LL II/A-M (Q,L) II/A-M (Q,LL) II/B-M (Q,L) II/B-M (Q,LL)	I II/A-V II/B-V II/A-L II/A-LL II/A-M (Q,L) II/A-M (Q,LL) II/B-M (Q,L) II/B-M (Q,LL)	I II/A-V II/B-V II/A-L II/A-LL II/A-M (Q,L) II/A-M (Q,LL) II/B-M (Q,L) II/B-M (Q,LL)	I II/A-V II/B-V II/A-L II/A-LL II/A-M (Q,L) II/A-M (Q,LL) II/B-M(Q,L) II/B-M (Q,LL)	I II/A-V II/B-V II/A-L II/A-LL II/A-M (Q,L) II/A-M (Q,LL) II/B-M (Q,L) II/B-M (Q,LL)	I II/A-V II/A-L II/A-LL II/A-M (Q,L) II/A-M (Q,LL) II/B-M (Q,L) II/B-M (Q,LL)	I II/A-V II/A-L[i)] II/A-LL[i)] II/A-M (Q,L)[i)] II/A-M (Q,LL)[i)] II/B-M (Q,L)[i)] II/B-M (Q,LL)[i)]	I II/A-V II/A-L II/A-LL II/A-M (Q,L) II/A-M (Q,LL) II/B-M (Q,L) II/B-M (Q,LL)	I II/A-V II/A-L II/A-LL II/A-M (Q,L) II/A-M (Q,LL) II/B-M (Q,L) II/B-M (Q,LL)	I II/A-V	I II/A-V	I II/A-V II/B-V II/A-L II/A-LL II/A-M (Q,L) II/A-M (Q,LL) II/B-M (Q,L) II/B-M (Q,LL)	I II/A-V II/A-L II/A-LL II/A-M (Q,L) II/A-M (Q,LL) II/B-M(Q,L) II/B-M (Q,LL)	I II/A-V II/A-L II/A-LL II/A-M (Q,L) II/A-M (Q,LL) II/B-M (Q,L) II/B-M (Q,LL)	I II/A-V II/A-L II/A-LL II/A-M (Q,L) II/A-M (Q,LL) II/B-M (Q,L) II/B-M (Q,LL)	I II/A-V II/B-V II/A-L II/A-LL II/A-M (Q,L) II/A-M (Q,LL) II/B-M (Q,L) II/B-M (Q,LL)	I II/A-V II/A-L II/A-LL II/A-M (Q,L) II/A-M (Q,LL) II/B-M (Q,L) II/B-M (Q,LL)	I II/A-V
Minimum styrkeklasse for cement	32,5	32,5	42,5	42,5	42,5	42,5	42,5	42,5	42,5	42,5	42,5	42,5	42,5	42,5	42,5	42,5	42,5	42,5

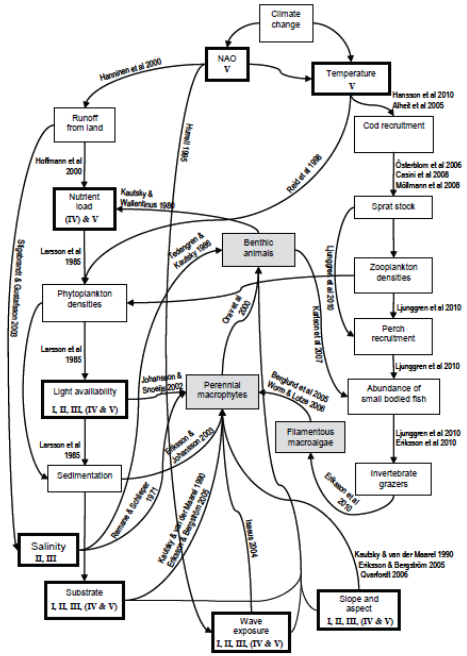
DS/EN206 DK NA:2020

Take home messages

- **Multidisciplinary work and data:**
  - Many angles and interests across **all topics we touched**
  - we need **integrated** data: r**eporting requirements**

- From an **engineering view**:
  - **active** approaches on **how to facilitate habitats** would be desirable

- Adaptation to **NID infrastructures**:
  - Missing Danish experience with "*exotic*" cement and aggregate types in **standards** (in comparison to neighbouring countries)



Questions?

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