THE UNTAPPED

POTENTIALS OF THE SEAS

TO CONTRIBUTE TO THE CIRCULAR BIOECONOMY

AARHUS
UNIVERSITY
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NEW FUTURE PROTEIN RESOURCES

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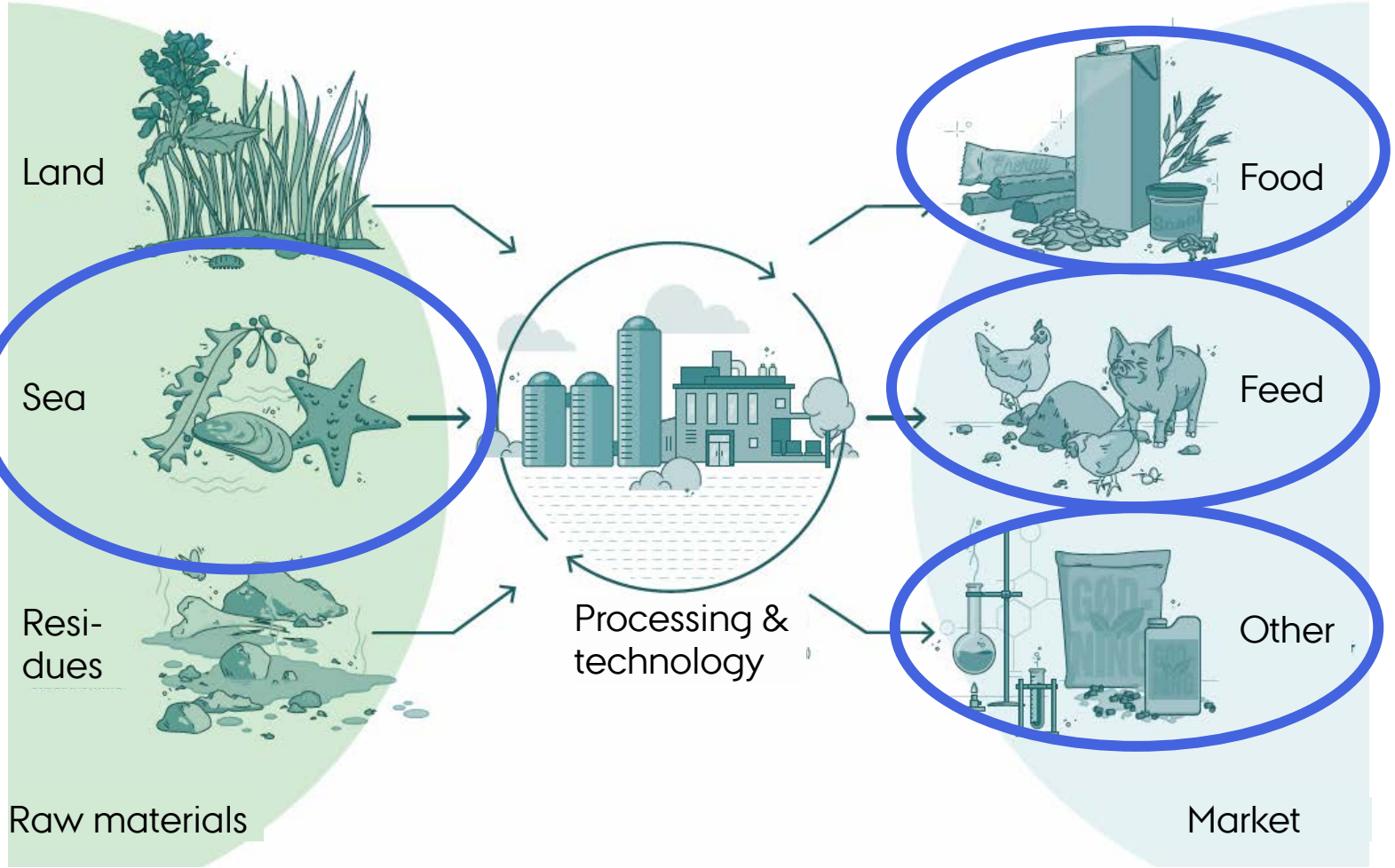
The Ocean covers 71% of the globe, and when pressures on landbased resources increase, it is natural to turn to the ocean in the pursue of new protein resources

Proteins for the Future

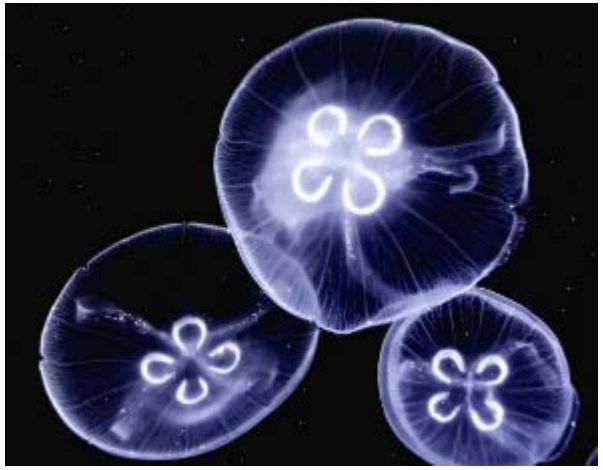
The Danish National Bioeconomy Panel, 2018



FUTURE AND THE BLUE BIOMASS

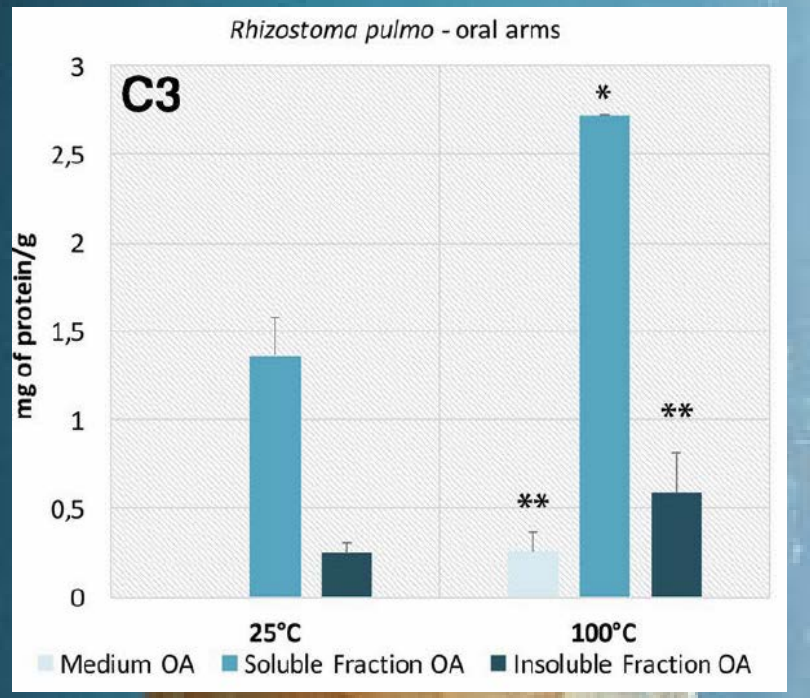
Danish Protein Innovation – 5 year:
15.000 tons marine protein

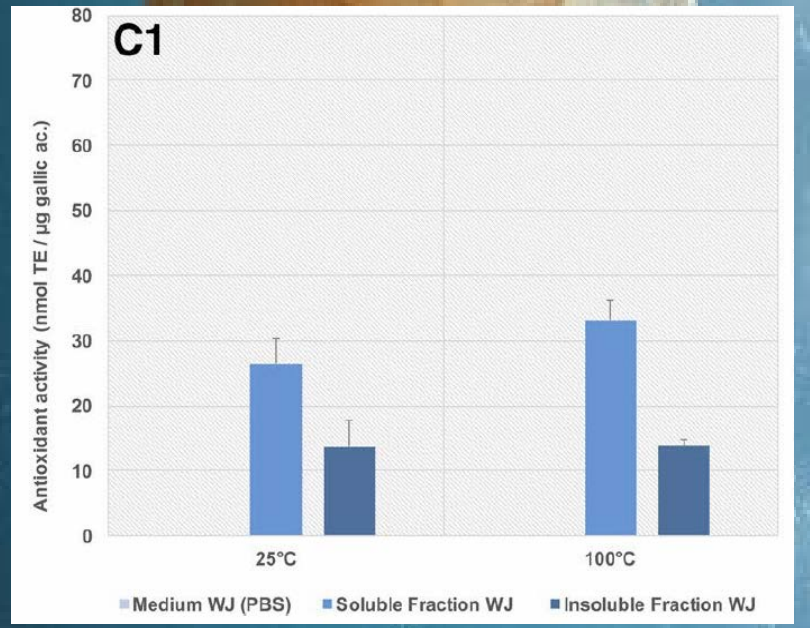
- **Un-utilised resources**
  - Jellyfish
  - Starfish
  - ....
- **Under-utilised resources**
  - Mussels
  - Seaweed




JELLYFISH - PEST TO PROTEIN

- Proteins for food
  - *Rhizostoma pulmo* – barrel jelly (lungegople)
  - Heat treatment promising as first proces step
  - Stabilises protein
  - Increase antioxidant activity
- Mucus with functional properties - to be integrated in filters – adsorbes microplastic
- Go Jelly – H2020 – 2018-2021





Leone et al, 2019

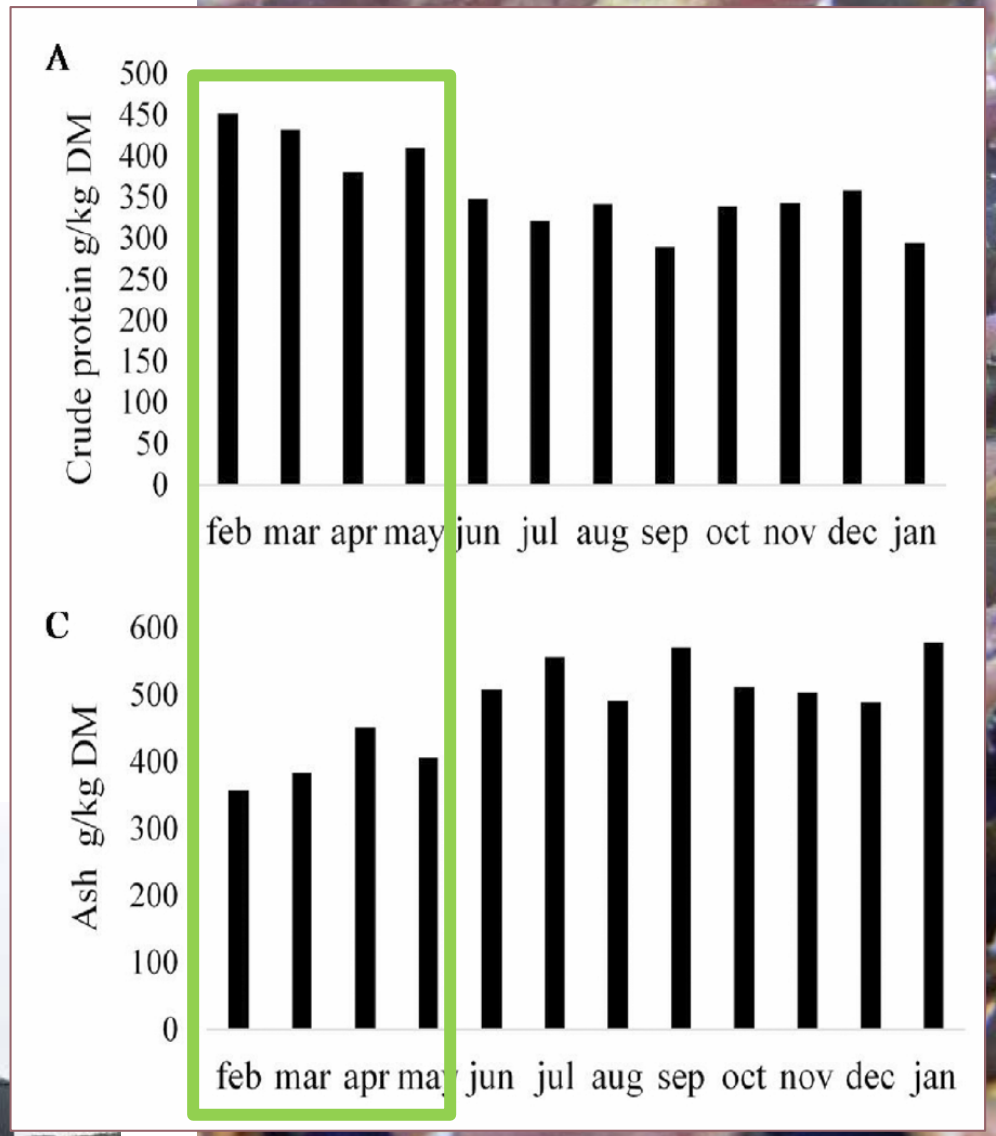
STARFISH – PEST TO PROTEIN

- Limfjorden – 50,000 ton blue mussels year^{-1}
- Starfish clearing the same amount annually
- 45-55% protein
- Organic feed for pigs (5%) and hens (8%) substitute for fish meal
- **Challenges**
  - Impact on seabed
    → Special designed seine/dragnet
  - EU feed legislation (2017)
    → change (2017) allow use in pig feed

Sørensen & Nørgaard 2016.
Afrose et al, 2016

STARFISH PROTEIN INDUSTRY

- First starfish meal factory in the world (2019)
- Up to 10,000 ton starfish year^{-1}
- Process: Drying → Milling
- 45-55% protein
- 1 ton starfish → 300 kg protein powder
- Seasonality – season feb-may
- Open for alternative (marine) feedstock for the remaining season



van der Heide et al, 2018

BLUE MUSSELS

Food

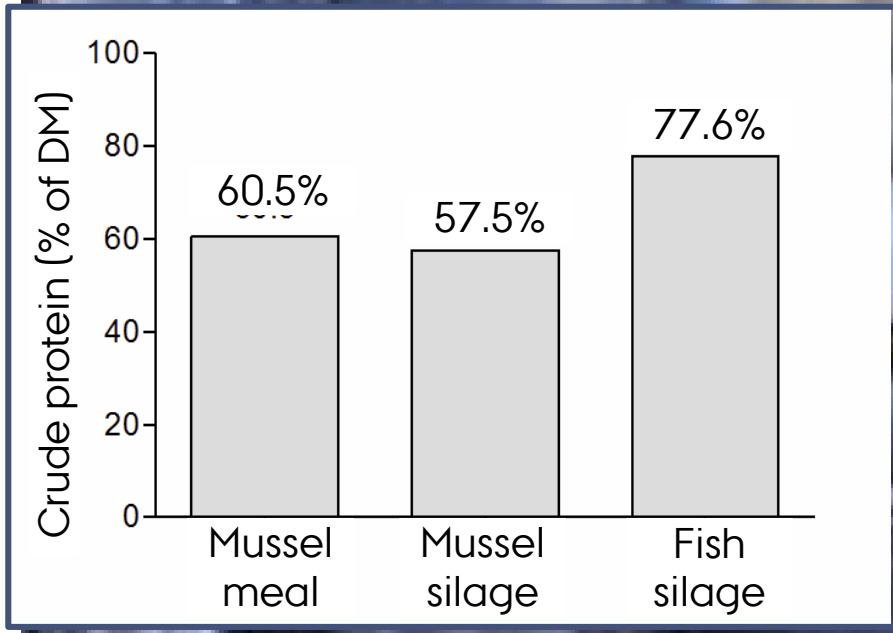
Production methods

- Natural resources – fishing ~ 40.000 ton year^{-1}
- Cultivated on line systems ~ 4.000 ton (2019)

- 95% of cultivated production for human consumption is organic
- Mainly export
- Large potential for expanding DK market
- Consumer perceptance

MUSSEL PROTEIN FOR FEED

- Mussel cultivation as instrument for nutrient extraction in eutrophic areas
- Area efficient → up to 900 kg N ha^{-1}
- Optimal nutrient extraction → large quantities → less handling → shorter growth period → too small for food purposes
- **Mussel meal → valid alternative to fish meal**
- Rich in essential amino acids
- Pigs - Digestibility: mussel meal = fish meal
- Laying hens – 4-12% mussel meal – good egg production + positive effect on yolk colour



Petersen et al 2016. Afrose et al 2016. Nørgaard et al 2015

MUSSEL PROTEIN INDUSTRY

- Scaling up – large net units
- Blå Biomasse → 6,000-8,000 ton $year^{-1}$
- Limfjorden DK
- Modelling of Danish waters for suitable sites + maximal nutrient extraction

- **Challenges**
  - Separation of meat and shells
  - Predation from eider ducks

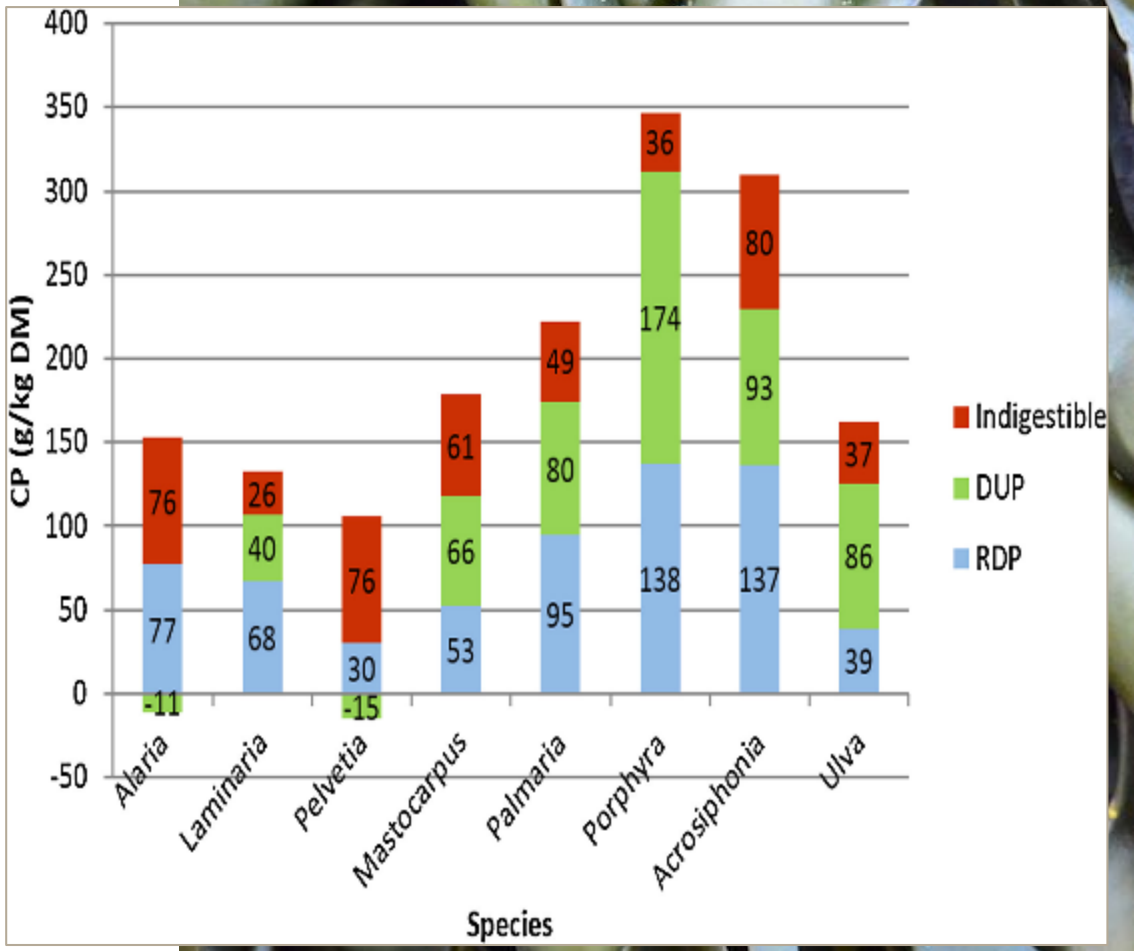
SEAWEED

Seaweed aquaculture

- Huge diversity – red/green/brown
- Global production of 30 mio tons year^{-1}
- (96.5% = aquaculture)
- Europe ~ 150,000 ton year^{-1}
- DK < 10 ton year^{-1}
- Food & food ingredients

Seaweed protein

- 1-50% of DM
- Species – season - site
- Amino acid content: red>green>brown



FAO 2018. Gaillard et al 2018. Tayyab et al 2016. Holdt & Kraan 2011

SEAWEED PROTEIN – BIO-REFINERIES

Existing production chain:

1. Protein extraction
2. Extraction of carrageenan

- Protein = additional product
- Improved quality of carrageenan
  - gel strength
  - colour
- Testing in pilot-scale at CP Kelco
- DTU Food

Potential production chain:

1. Ethanol production via fermentation
2. Protein increased residue = Feed protein

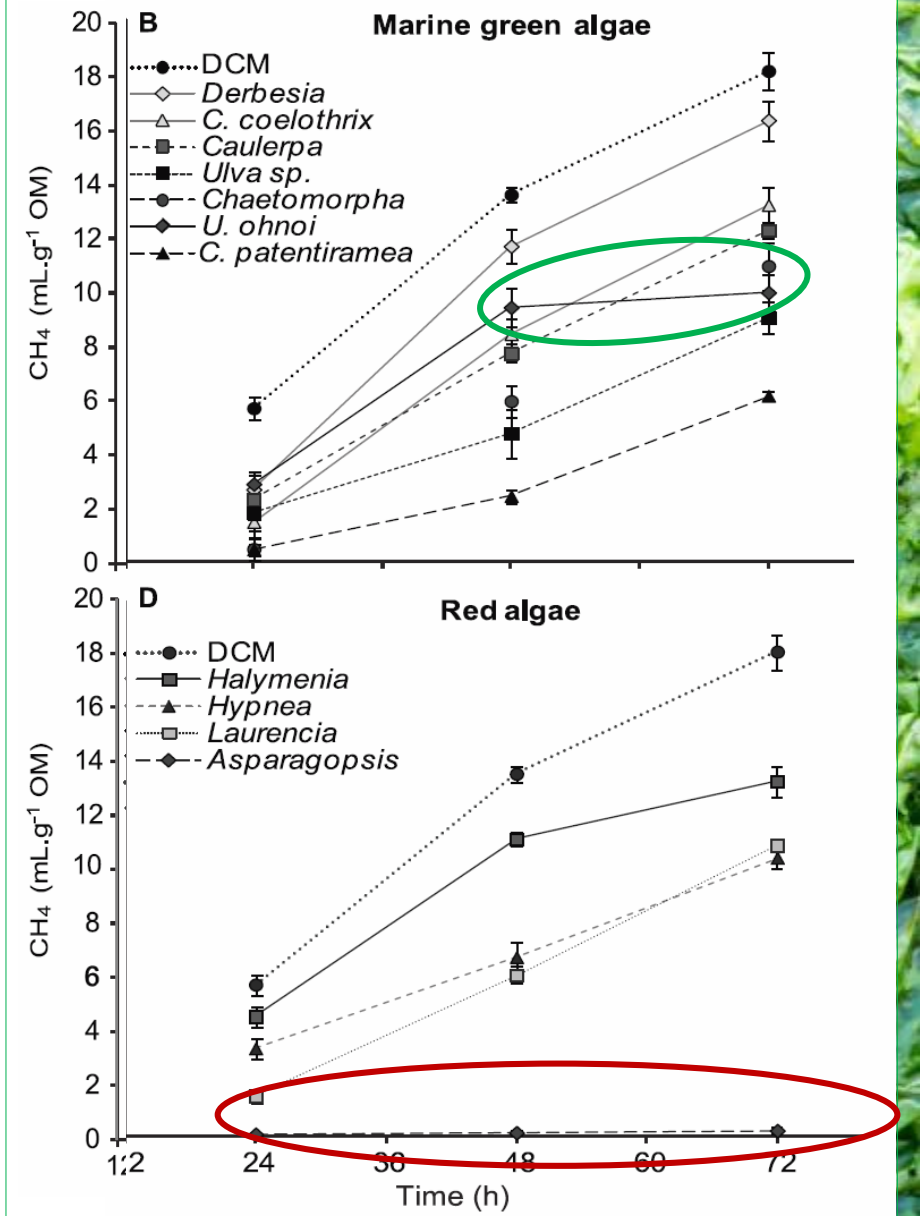
- Two products

SEAWEED → PROTEIN AGENDA

Reduction of methane emission from cattle

- Rumen methane = 39% of livestock GHG
- Red algae – *Asparagopsis taxiforme*
- Bromoform inhibits methanogens in rumen
- By up to 99% with 2% inclusion
- **Climate change mitigation**
- **More sustainable production of beef and dairy**

- Danish/temperate perspective
- *Asparagopsis* = not endemic species = no go
- Temperate species with large potential

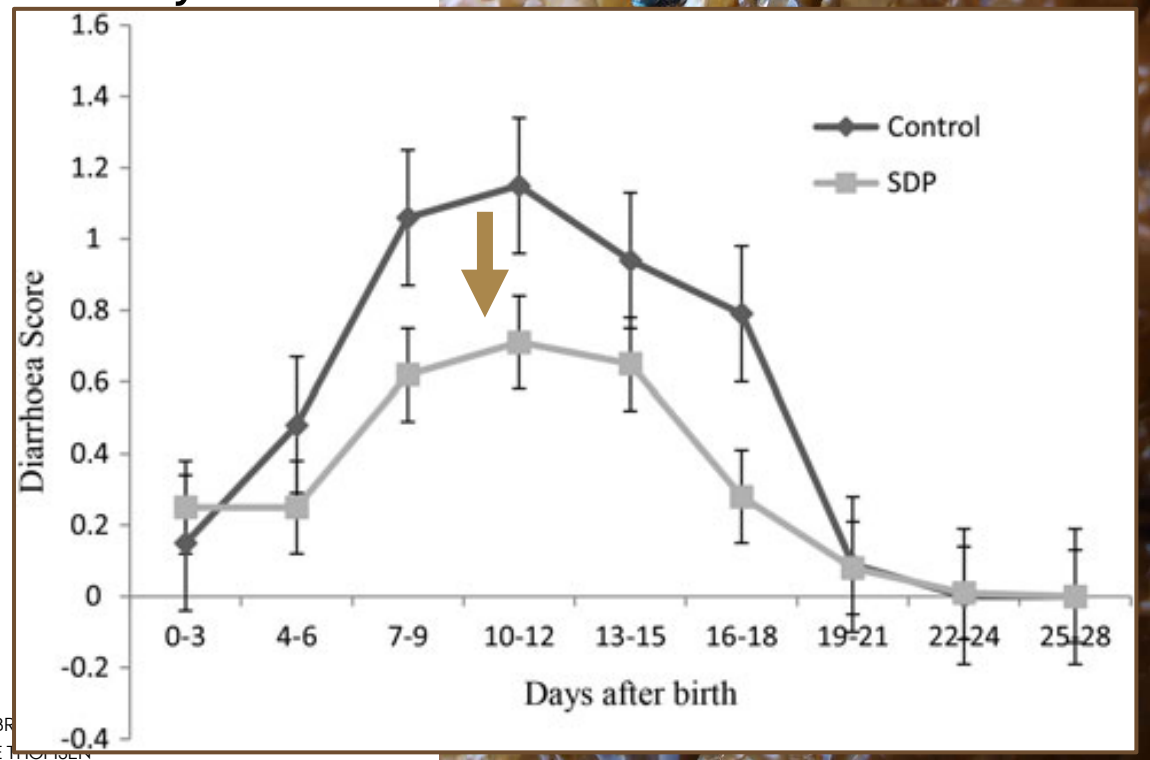


Machado et al 2014, 2016, 2018

SEAWEED → PROTEIN AGENDA

- Sulphated polysaccharides improve gut health
- Potentially reducing need for antibiotics in animal production
- More sustainable production of meat and dairy products

- **Challenges**
  - Efficient production technology
  - Mechanisation/selective breeding
  - High ash content
  - Arsenic/iodine high in brown algae



O'Doherty et al 2015

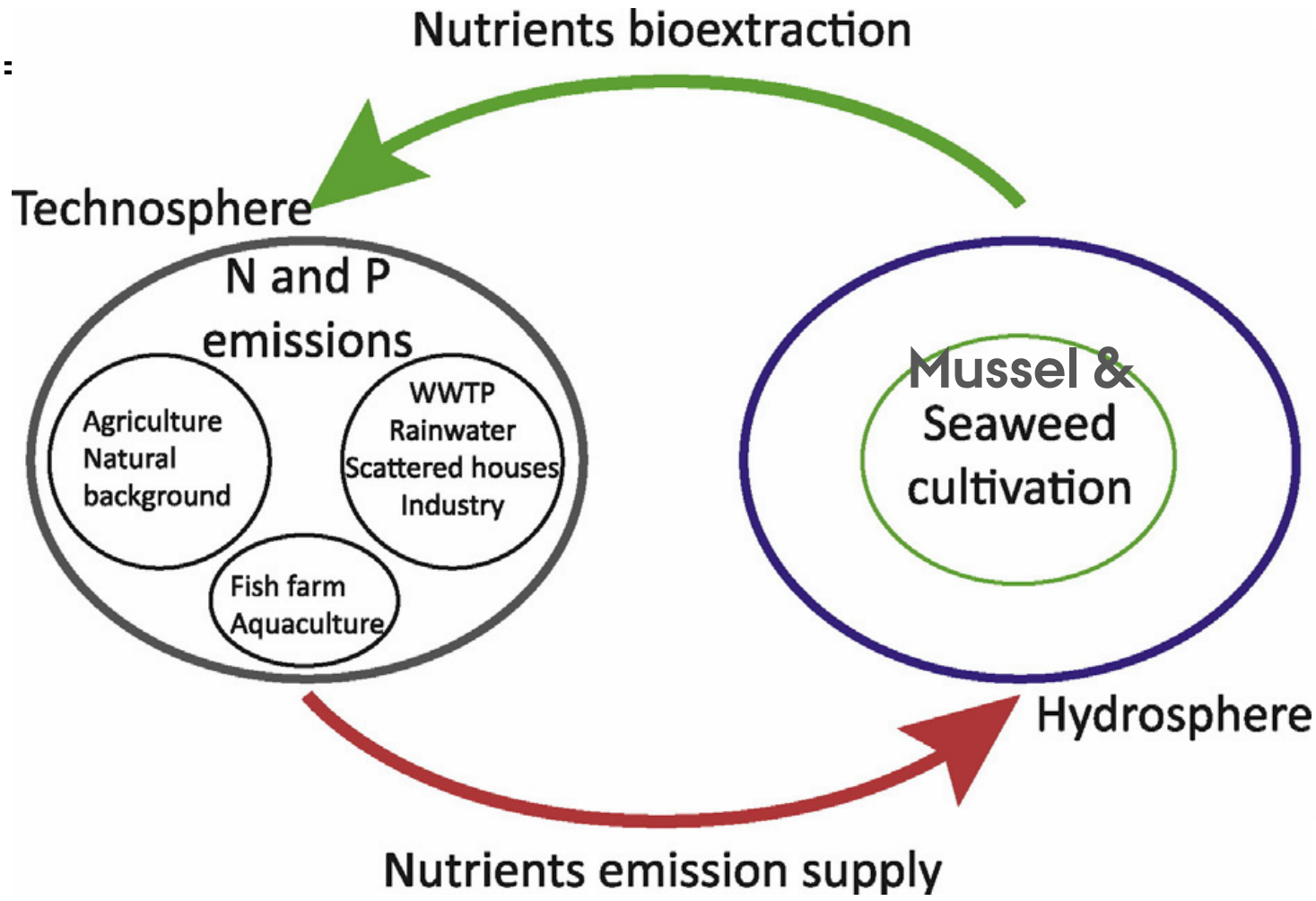
CIRCULAR BIOECONOMY

Seaweed + mussel **cultivation** =

Ecological engineering

= Intervention option to

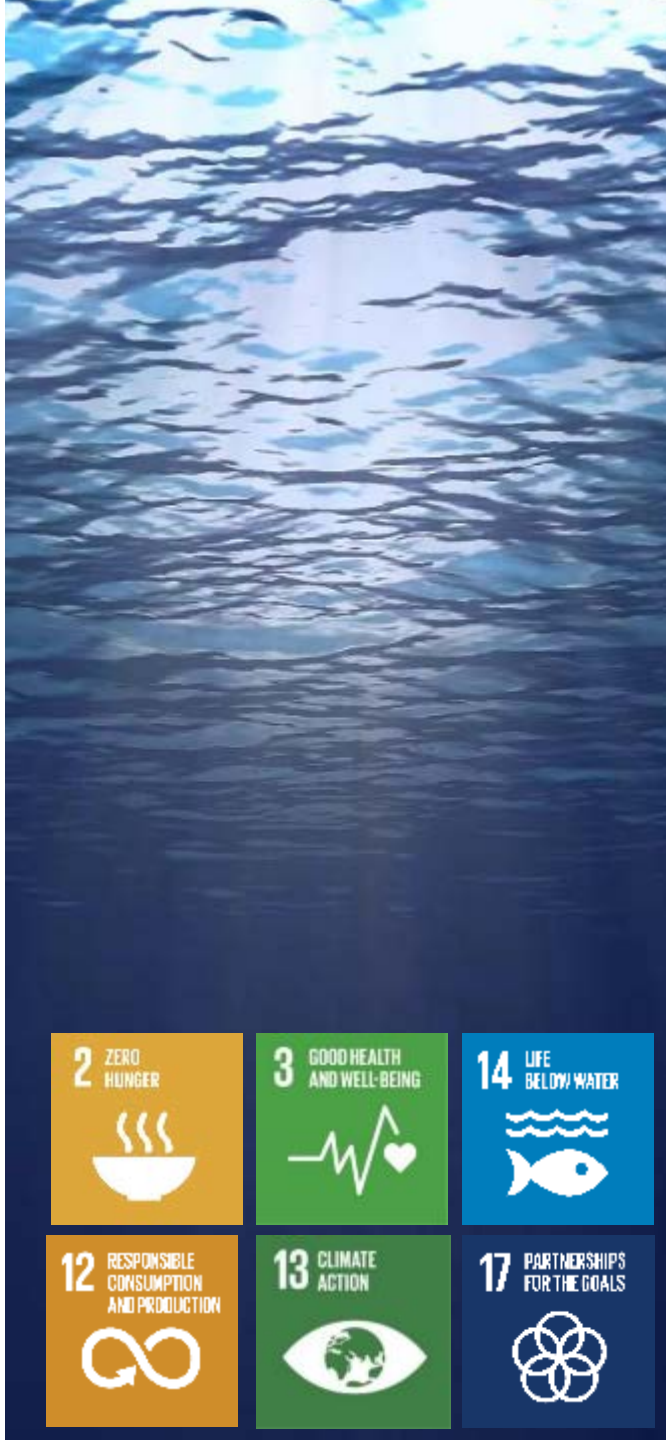
- **Accelerate ecosystem recovery** from coastal eutrophication (EU Waterframe Directive)
- **Turn linear ressource flow into circular flow** enabling recirculation of lost nutrients in economic system on land (EU Blue Growth Strategy)



Duarte & Krause-Jensen 2018. Seghetta et al, 2016

SUMMARY

- Blue bioeconomy is emerging
- Possible to meet DPI target of 15.000 ton in 2024
- Few industries are at advanced Technological Readiness Level
- Novel raw materials feed into the protein industry
- Legislation and standardisations may need adjustments
- Consumer perception is an issue
- Sustainable cultivation of extractive crops offer valuable ecosystem services i.e. nutrient extraction & climate mitigation contributing to positive carbon foot-prints and (potentially) improved economy



THANKS FOR YOUR ATTENTION!

AlgeCenter Danmark

CBIO
AARHUS UNIVERSITY CENTRE FOR CIRCULAR BIOECONOMY

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ECOSYSTEM SERVICES

Benefit that human obtain from an ecosystem (MEA, 2005)

Seaweed + mussel **cultivation** +

Eco-industrial system =

Engineered ecosystem services mimicking the natural system

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25 JUNE 2019

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