KB Marine Low trophic Production Systems

7 februari 2020

M. Poelman, on behalf of KB team

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KB kernteam demands

- **Specifically for your project** we would like to see included in your work plan:
- Assure that you continue to develop the integrated program, as you started to do after the progress meeting in September, the actual multidisciplinair collaboration is an absolute condition for this project
- A clear communication plan with activities on how to share also the preliminary outcomes of the project.
- Allignment with the work of Martin Scholten on the ‘circular fishery’ vision (we can support you with that aspect)

The context of our work

Our contribution to circul climate smart food systems

Increase crop

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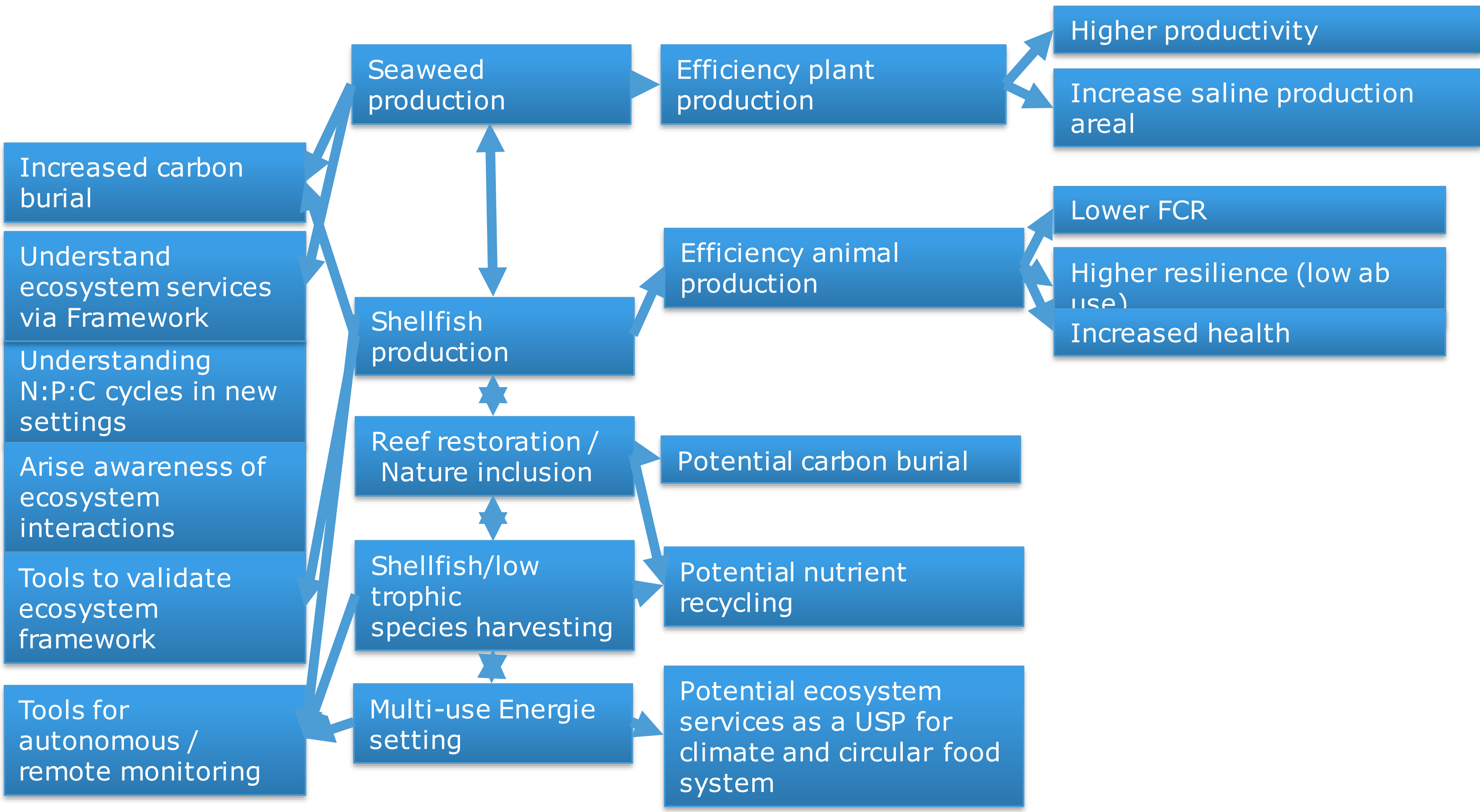

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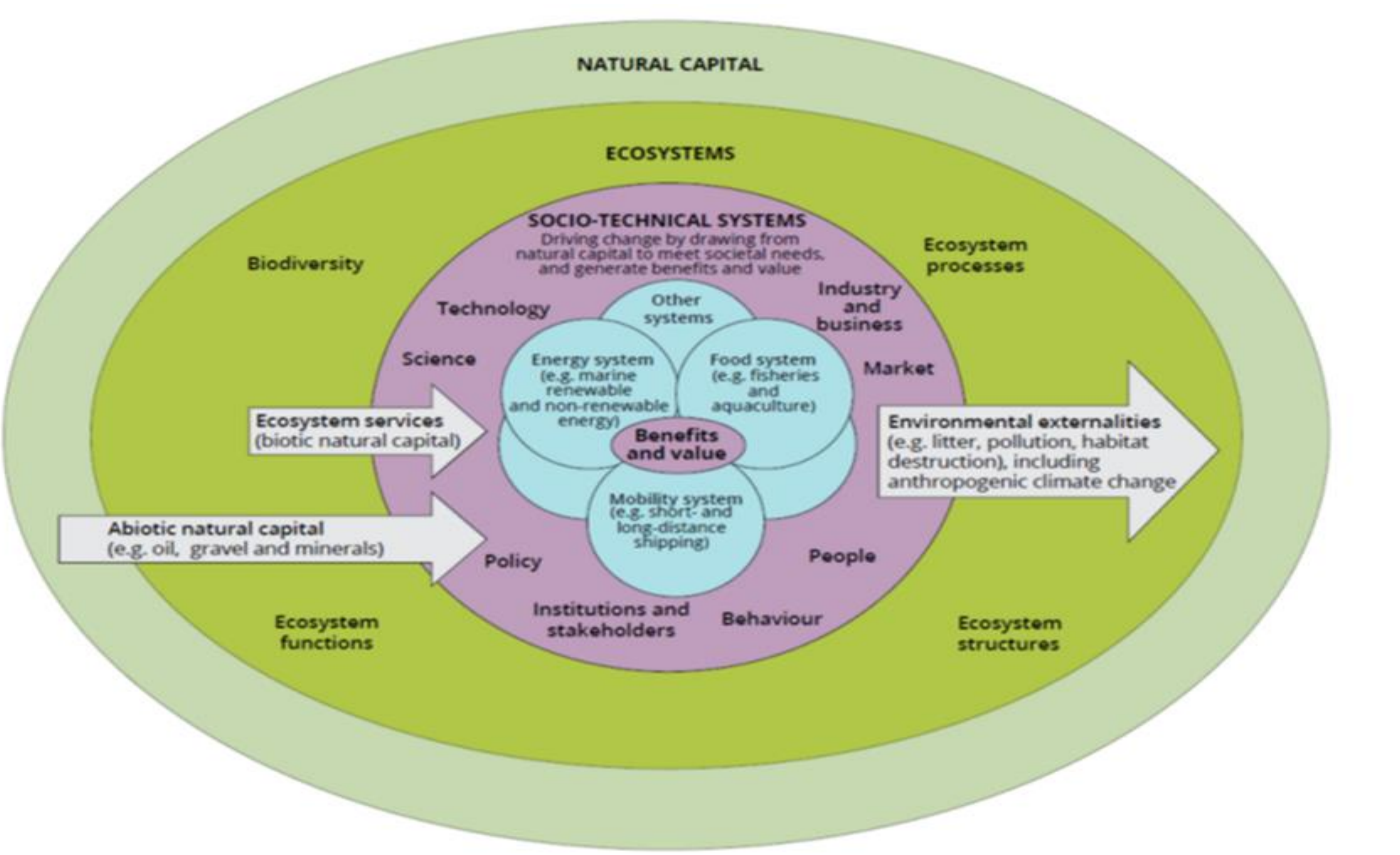
In the overall context of Sustainability!



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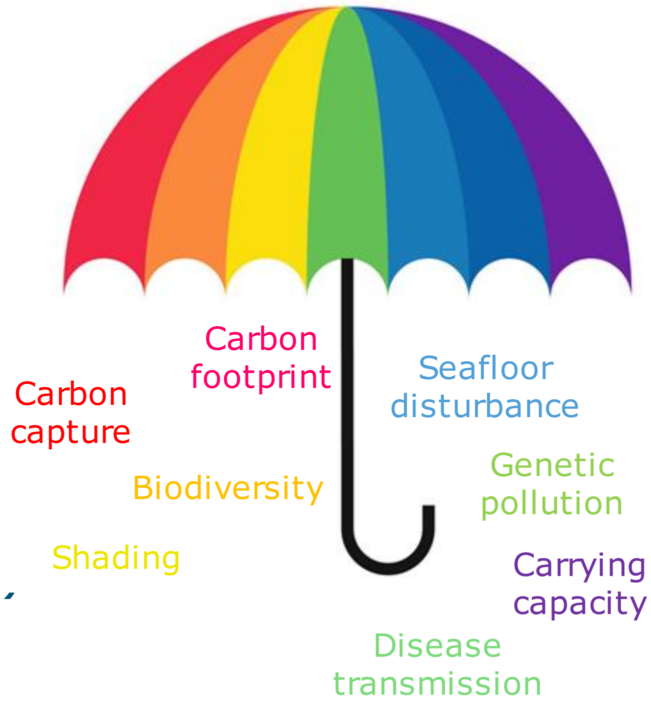
Ecosystem interactions seaweed cultivation

1.3 Framework development

Aim:

Develop an overarching framework, to monitor and evaluate interactions between seaweed cultivation and the surrounding ecosystem



Outline & quantify cumulative effects (negative impacts, supportive processes)

Long term scenario’s

Environmental impact assessment

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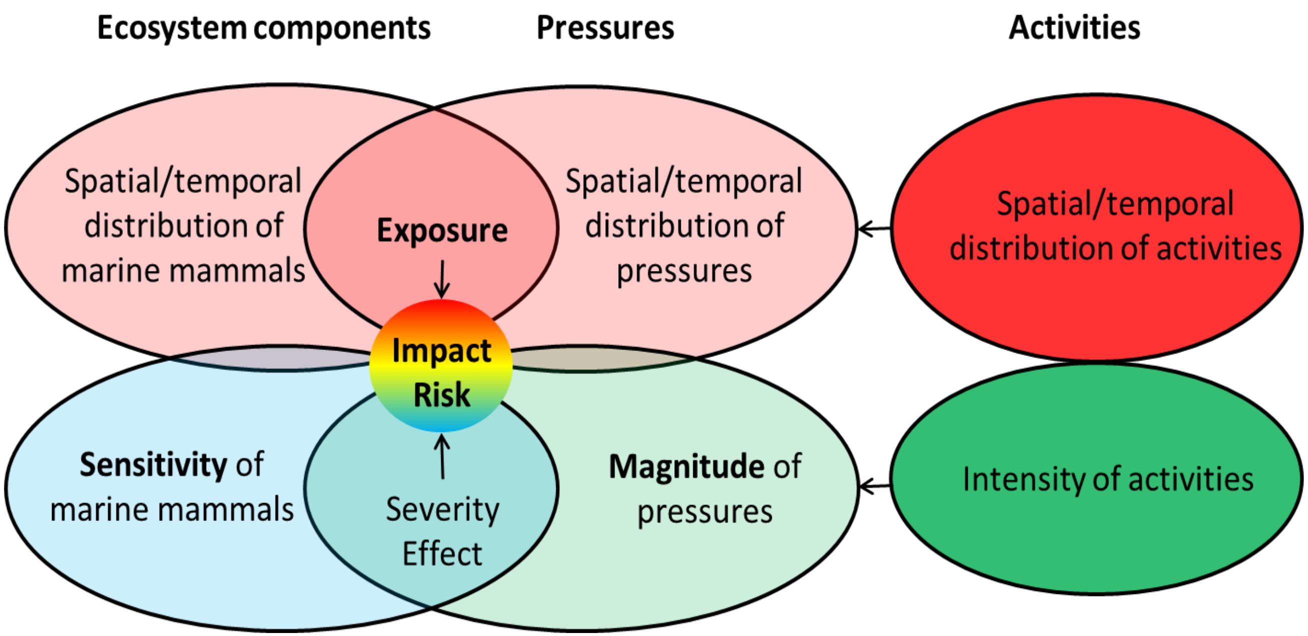
Ecosystem interactions seaweed cultivation

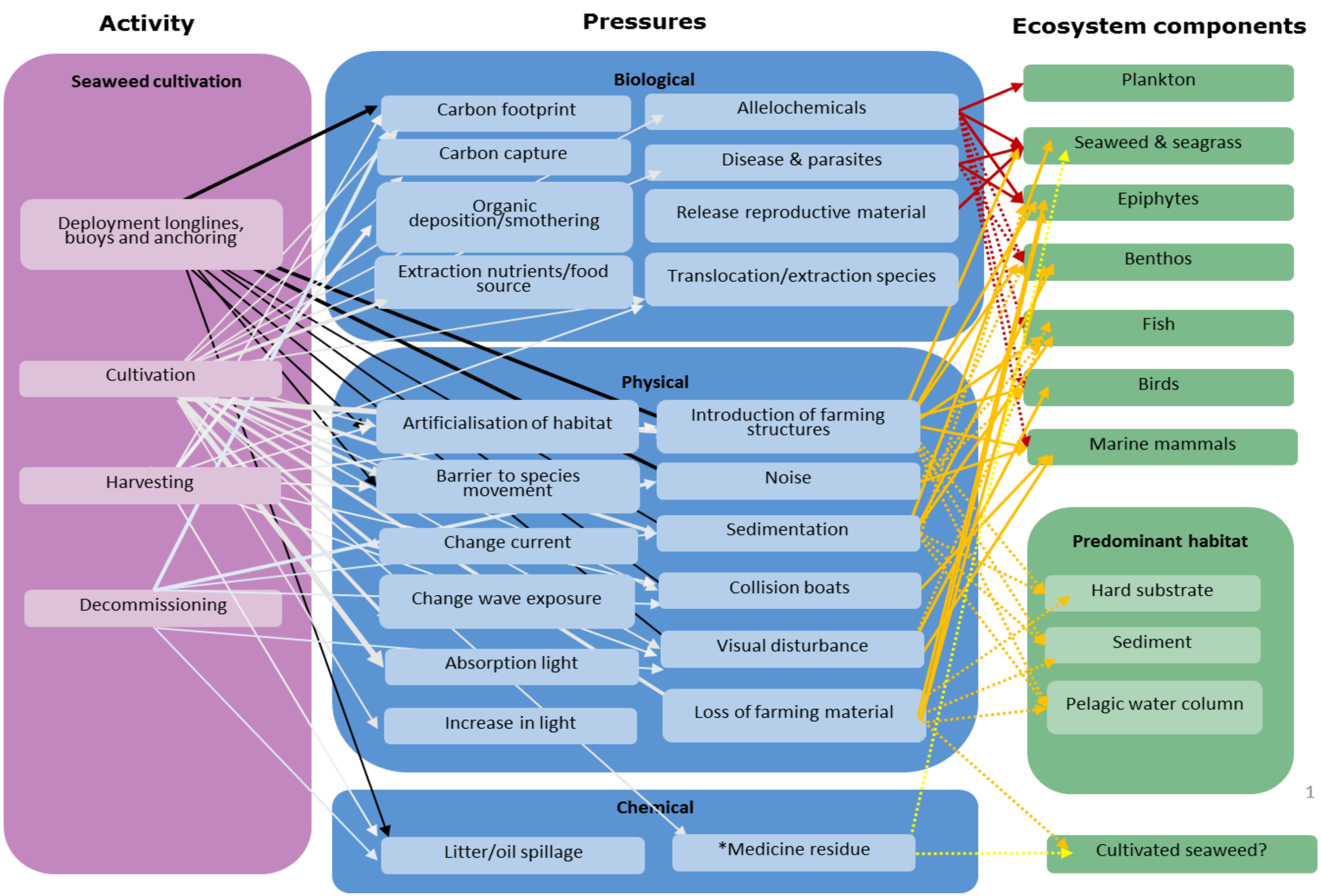
Approach:

- Link to existing frameworks (applied in North Sea):
  DPSIR (Driver>Pressure>State>Impact>Response)



Linkage based frameworks: oa Piet et al 2015

The framework



Including development of a Toolbox for measurement of Seaweed-Ecosystem interactions

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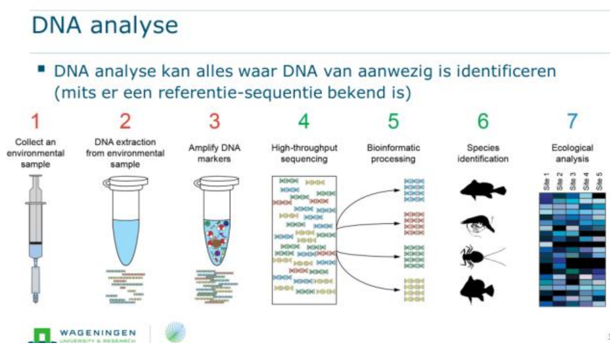
Autonomous and remote tools (seaweed)

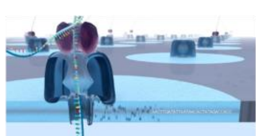


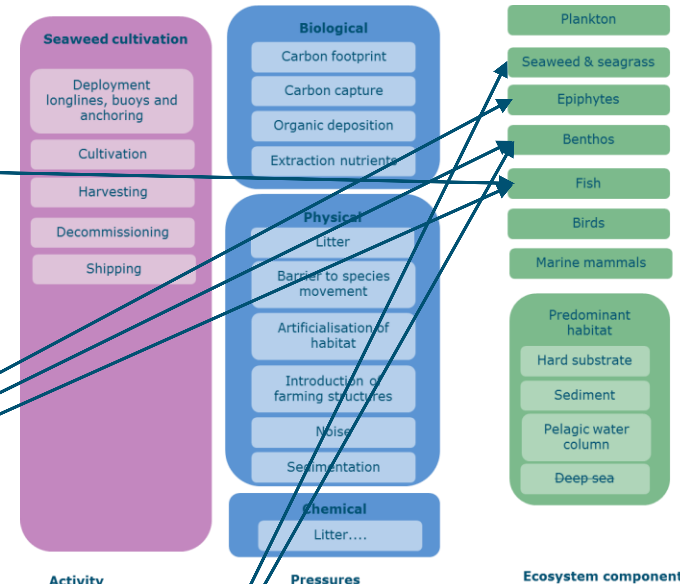
Nanopore DNA sequencing met de MinION

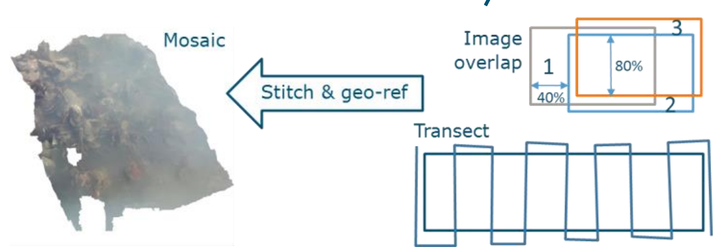
Kleine, handzame DNA sequencer, aanschaf: 900 €

Draagbaar, in te zetten in het veld

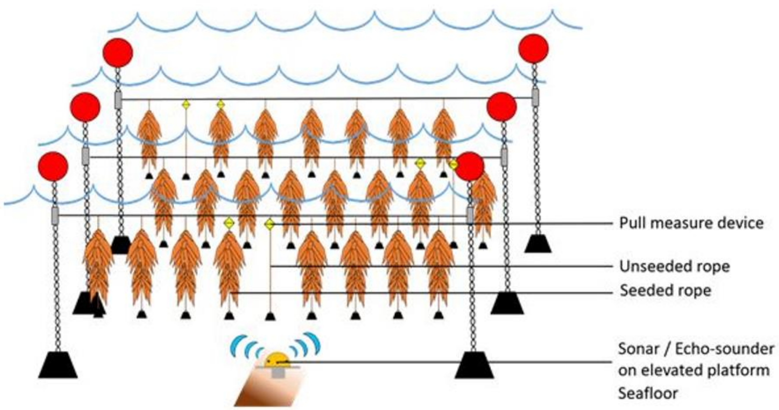
Van (water)monster naar soortenlijst in 4 a 5 uur

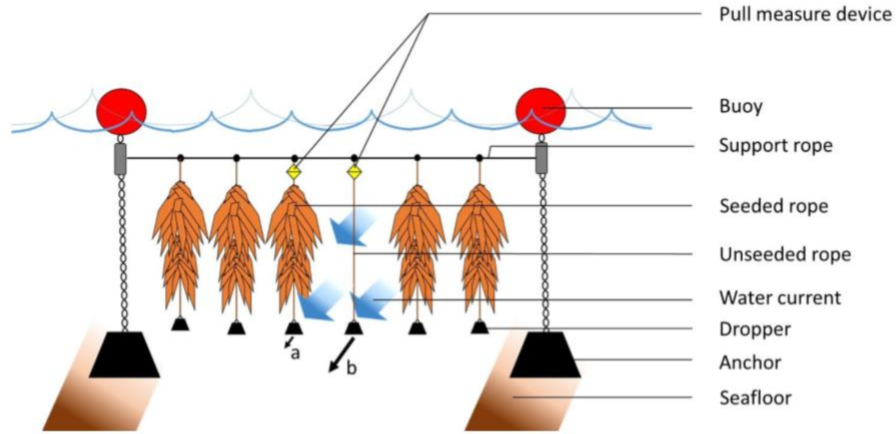






Remote monitoring of seaweed (pre-feasibility study)





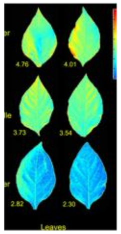
Measuring nitrogen content

- *Ulva* sp.: N content correlated to proteins, ash, starch and fiber

- *S. latissima*: No clear correlation
→ is it useful to monitor nitrogen content in kelps?

Method to measure nitrogen:

- Hyperspectral imagery
- Fluorescence



Underwater cameras

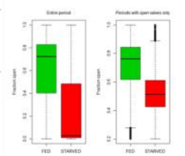
- Numerous models are available
- Data easily human interpretable
- Simultaneous biodiversity assessment

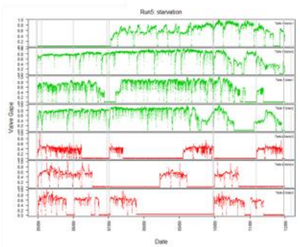
- Huge data files
- High energy demand
- Vulnerable to bio-fouling
- North sea is turbid

Autonomous and remote tools (shellfish)

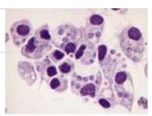
Valvometer

- Monitor shell gape in relation to environmental factors

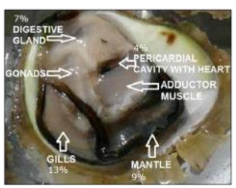




Bonamia-free oysters

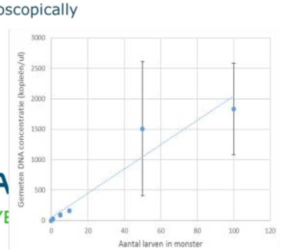


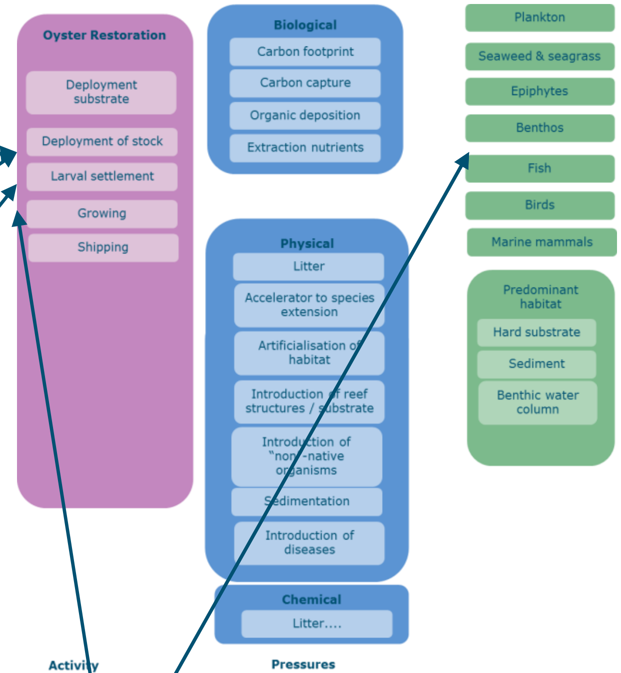
- Non destructive sampling: anaesthetise, cut piece of gill, keep dry until results of analysis available, separate into Bonamia postive and negative
- Is gill representative?



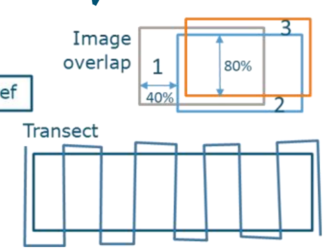
qPCR for larval detection (Arjen)

- Larval concentrations low in new oyster areas
- Difficult to detect microscopically





Stitch & geo-ref



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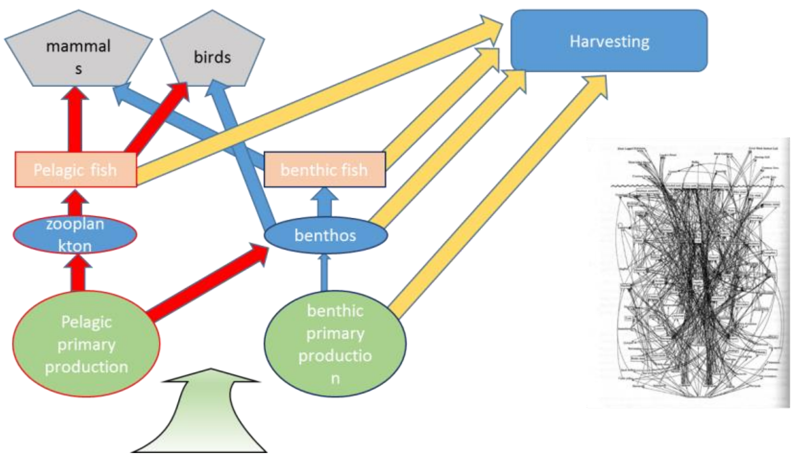
Nature inclusive concept and their influence (including CNP trade offs)

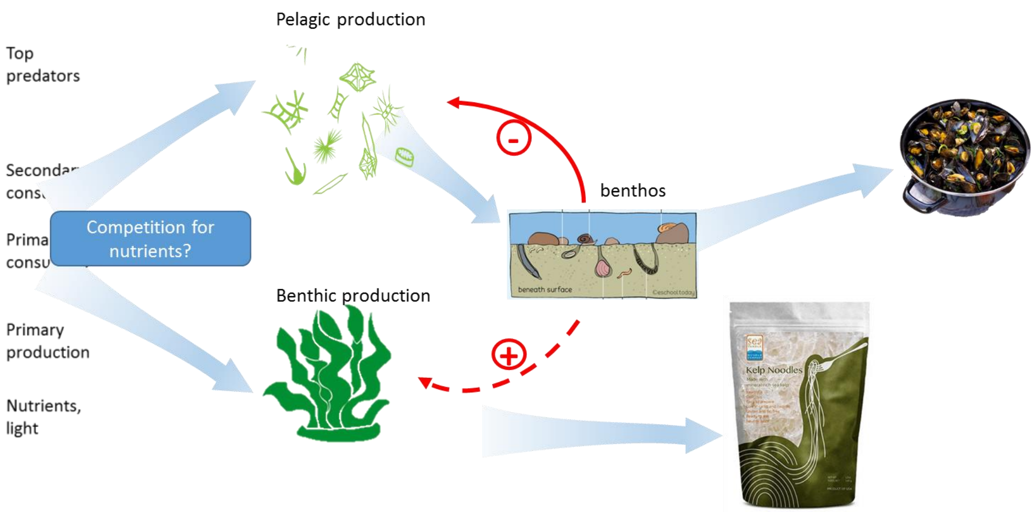
1) Memo: "Carrying capacity of seaweed culture limited to 400-500km2.

2) Modelling N:P extraction and the effects on the ecosystem components

Fluxes of energy...



and food web interactions

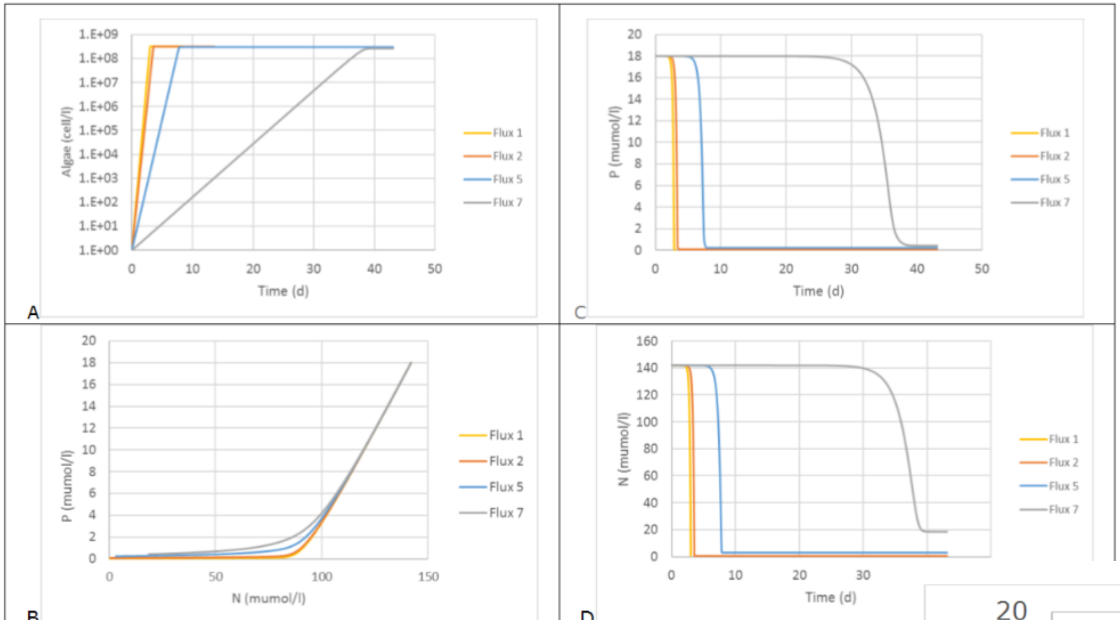


Case study: seaweed cultivation in the North Sea (Dutch)

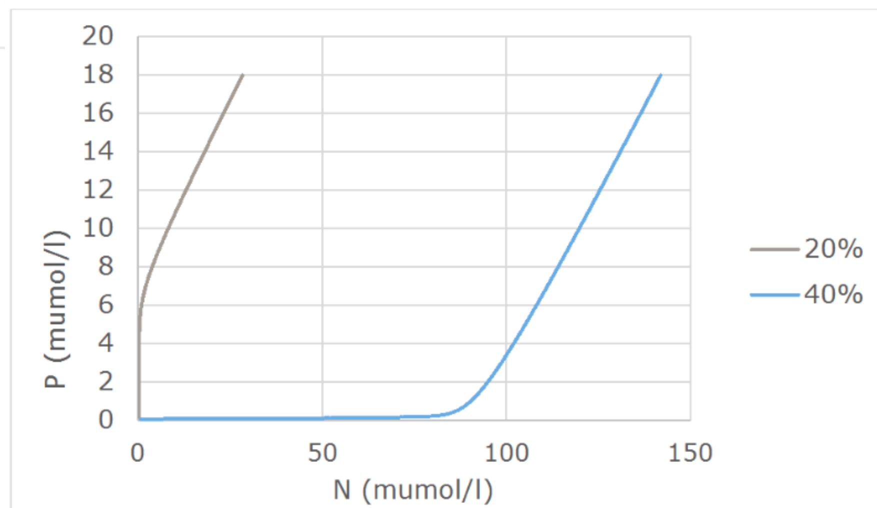
- Ambitions of Dutch Govt. & Noordzee Boerderij (2050):
  - 14,000km^2 co-use space for windfarm and seaweed production
- A realistic examination (*WMR memo BO-43-023.03-005*)
  -
  - Based on ecological capacity and usable space, it's estimated that ~2,900km^2 is feasible if all 'new' nutrients go to seaweed
  - Realistically, if 5% of nutrients go to seaweed, this yields only ~145km^2 space for seaweed farming in Dutch waters
- Theoretical co-culturing benefits: seaweed can reduce wave effects in wind farms, improve safety to vessels by restricting access to wind farms, and provide biodiversity benefits (e.g. habitat provision for fish species)

Model development

Testing parameterisation



Testing scenarios



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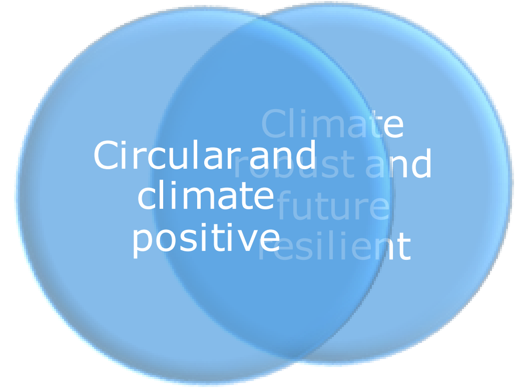
Wat zijn de voedselveiligheids-risico’s van zeewier?



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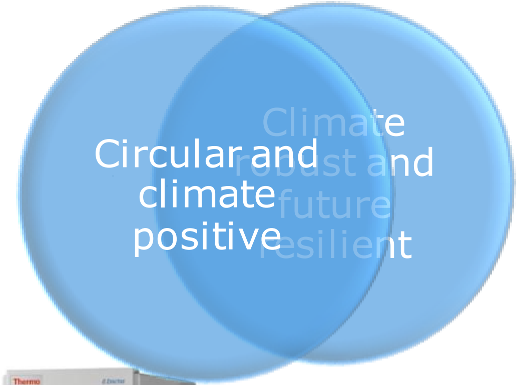
Stap 1: Brede screening voor voedselveiligheid



- Chemische analyse (e.g. LC-MS/MS)
  - Zoeken naar bekende stoffen

- Biologische tests (bioassays)
  - Zoeken naar biologische effecten
    - Waaronder effecten van (nog) onbekende stoffen
      - Hormoon verstorende stoffen
      - Zenuwgiffen
      - Dioxine-achtige stoffen

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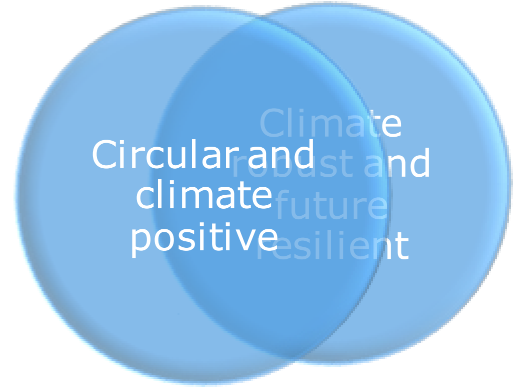
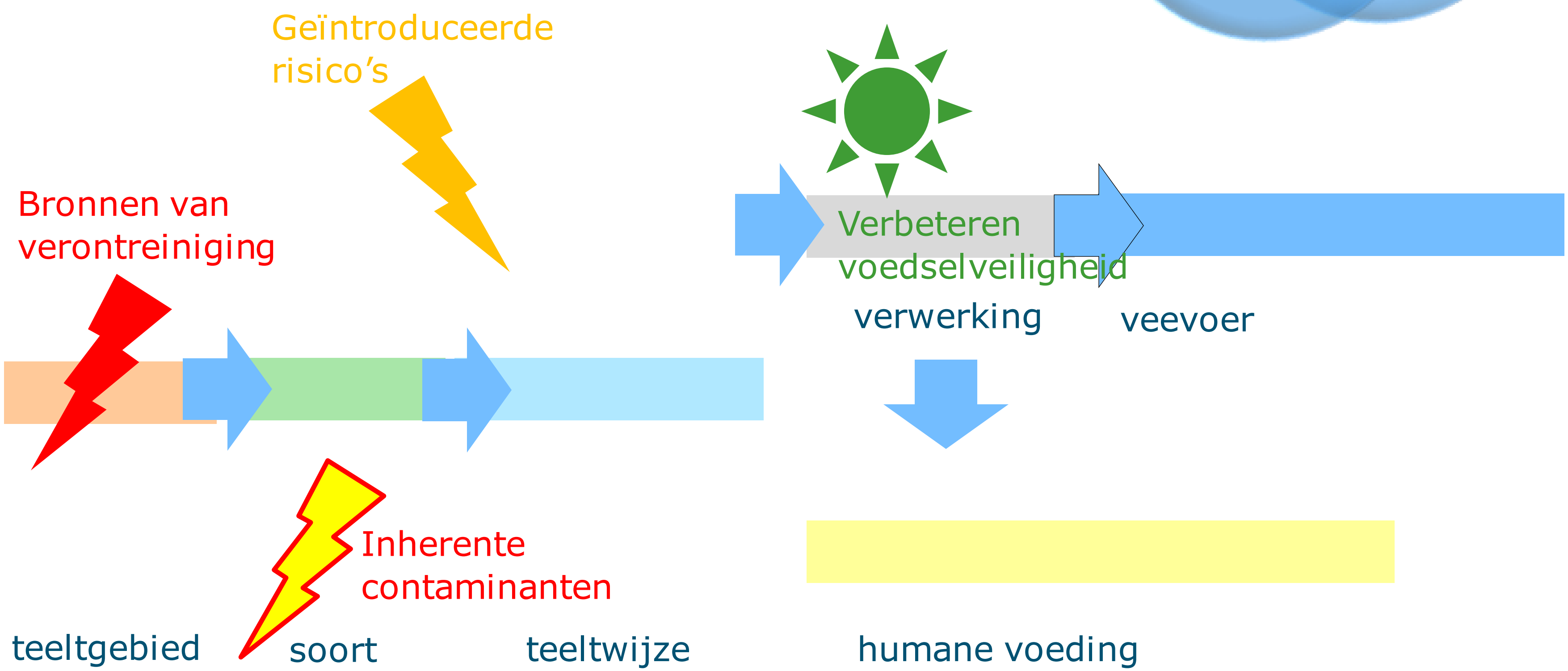
Stap 2: Safety by design



Data acquisitie voor zeewier in NL deels uitgevoerd



Calux (bioassay) voor dioxine-achtige stoffen worden een aantal positieve monsters gevonden welke niet worden bevestigd met de GC-MS methode (analytisch chemisch).

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New ways for terrestrial plant resilience

Seaweed materials

Extracts as biostimulants and/ or stress alleviators

D. Battac[illegible]yya et al. / Scientia Horticulturae 196 (2015) 39–48

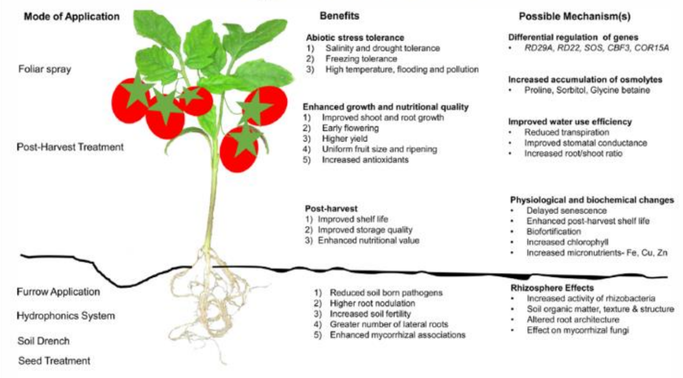

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Fig. 1. Schematic diagram depicting methods of application of seaweed extracts, and their effects on plant and mechanisms of action.

* Kennis over biochemische variatie in inhoudsstoffen van verschillende zeewierextracten

* Kennis over zeewiercomponenten die betrokken zijn bij verhogen van stress-resistentie van planten tegen droogte en zout

* Kennis over mogelijk mode of action in de plant, geïnduceerd door zeewierextract

Results plant experiments

- *Zeewierextract verhoogt de productie van broccoli (en sla) onder zowel optimale als suboptimale zoutomstandigheden.*
- *Metabolomics analyse van blad en wortel samples -> 300-400 individuele metabolieten in de samples met een verschillend effect van zowel de zoutstress als de zeewierextract behandeling.*
- *Het grootste deel van de metabolieten is nog niet geïdentificeerd, na identificatie kan het een eerste indicatie geven van mogelijke mechanismen die een rol spelen bij zowel zoutstress als het biostimulanten effect van het toedienen van een zeewierextract.*

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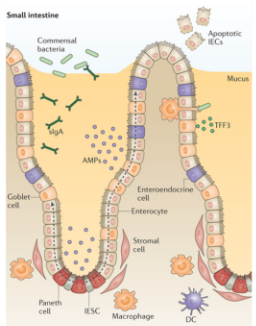
Adapting and improving animal production with sea sources

Circular and climate positive

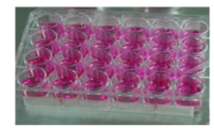
How to assess gut health in farm animals (*in vivo*)?

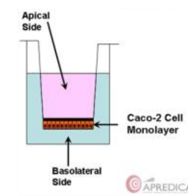
- Gut tissue
  - Gut morphology
  - Genes expression of gut enterocytes
  - Quantification of immune cells
- Gut microbiota (caeca, colon, ileum)
- Blood cytokines/chemokines
  - IFNα, IFNγ, IL-13, IL-1α, IL-1F5, IL-21, IP-10, MIG, MIP-1β, and TNFα
- Faeces inflammation proteins
  - MPO
  - IFAB
  - Calprotectin



In vitro models available for assessing gut health

- Use of cell lines (2-D)
- Use of organoids (3-D)
- Gut permeability tests
- Bacterial adhesion tests
- Mycotoxin preventing prop
- Immune modulation
- (Methane production)





Testing relationships between in vitro and/or in vivo parameters for gut health in running studies with piglets, broilers and laying hens fed with marine resources

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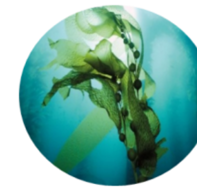
Seaweed and micro algae in weaned piglets

- Effect of micro and macro algae on performance and some health parameters
  - Negative control
  - Intact *Saccharina*
  - Intact Ascophyllum
  - *Ascophyllum* extract
  - Intact *Chlorella* (not processed)
  - Intact *Chlorella* (cell wall disrupted)
- Parameters: growth performance, inflammation proteins in manure
- Experiment in facility just finished

Planning 2019

- Digestibility study (July 2019)
  - Desalted protein extracts from *Ulva* and *Soleira* (+/- enzyme treated with a protease)
  - Nutrient digestibility, gut health parameters
- Doses-response study with *N. Limnetica* in laying hens (August 2019)
  - Impact on fatty acid profile in the eggs
  - Health parameters of the hen (to be defined)



Effect of graded levels of microalgae (*Chlorella vulgaris*) in the diet on performance and health status of broilers

Aim of the study

To measure the response in terms of performance and (gut) health in:

i. nutritionally challenged broilers, when fed increasing doses of *Chlorella vulgaris* (4 graded levels)

ii. unchallenged broilers, when fed increasing doses of *Chlorella vulgaris* (2 graded levels)

Experimental design

Diet

Animals groups in the experiment

1	6 (replicate)*10	broilers	diet 0.0 % micro algae+ rapeseed meal (25%)
2	6 (replicate)*10	broilers	diet 0.4 % micro algae+ rapeseed meal (25%)
3	6 (replicate)*10	broilers	diet 0.8 % micro algae+ rapeseed meal (25%)
4	6 (replicate)*10	broilers	diet 1.6 % micro algae+ rapeseed meal (25%)
5	6 (replicate)*10	broilers	diet 0.0 % micro algae + soybean meal
6	6 (replicate)*10	broilers	diet 0.8 % micro algae + soybean meal

Blood Haptoglobin, IL-13 & INF results

SBM: 14 d

Diet	Soybean meal based			
Algae level	**0%**	**0.8%**	**P-value**	**LSD**
Haptoglobin[1] (ng/ml)	0.345[a]	0.239[b]	0.023	0.0833
IL-13[1] (pg/ml)	1.60[a]	0.72[b]	0.005	0.441
INF[1,2] (pg/ml)	0.930	0.470	- - -	- - -

[1]) Log-transformation on original values. [2]) Most values below detection limit

- Reduced blood haptoglobin concentration, indicating less inflammation in these birds
- Reduced blood IL-13 concentration, indicating less allergic inflammation in these birds

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Mar. Drugs **2010**, *8*, 2038-2064; doi:10.3390/md8072038

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Marine D

ISSN 16

www.mdpi.com/journal/mar

Review

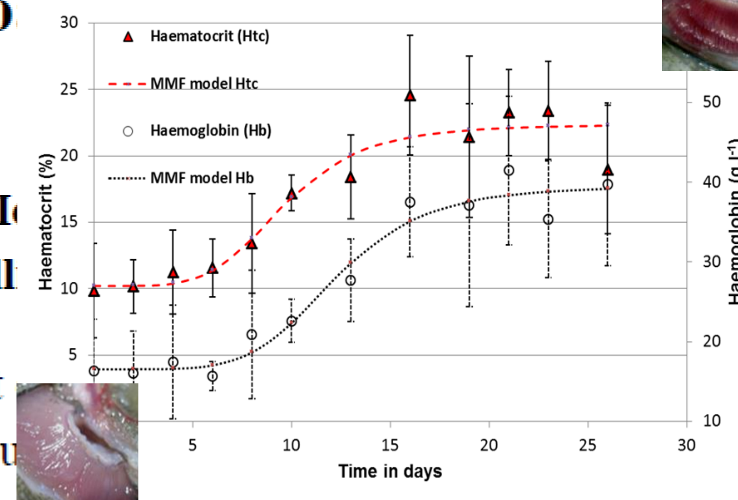
Prebiotics from Marine Macro… Health Applications

Laurie O'Sullivan [1], Brian Murphy [1], Peter M… Peadar G. Lawlor [2], Helen Hughes [1,*] and Gill…

[1] Eco-Innovation Research Centre, Department … Technology, Waterford, Ireland; E-Mails: losu… pmcloughlin@wit.ie (P.M.); pduggan@wit.ie (P.D.); ggardiner@wit.ie (G.E.G.)

[2] Teagasc, Pig Development Unit, Moorepark Research Centre, Fermoy, County Cork, Irelan… E-Mail: peadar.lawlor@teagasc.ie

* Author to whom correspondence should be addressed; E-Mail: hhughes@wit.ie;



To test the effect of low-trophic marine resources on anaemia status of sole

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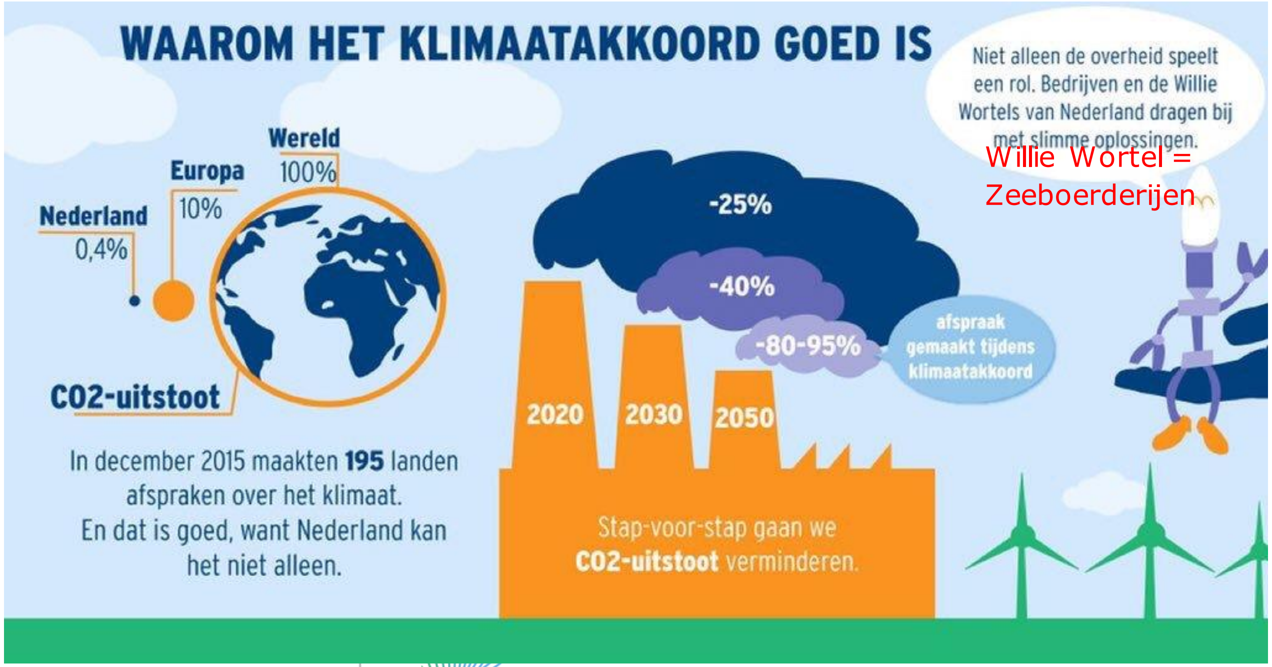
Societal relevance Blue Carbon

- Food production from land to sea
- Paris Agreement: emission reduction & verification
- Challenge: climate positive marine food production



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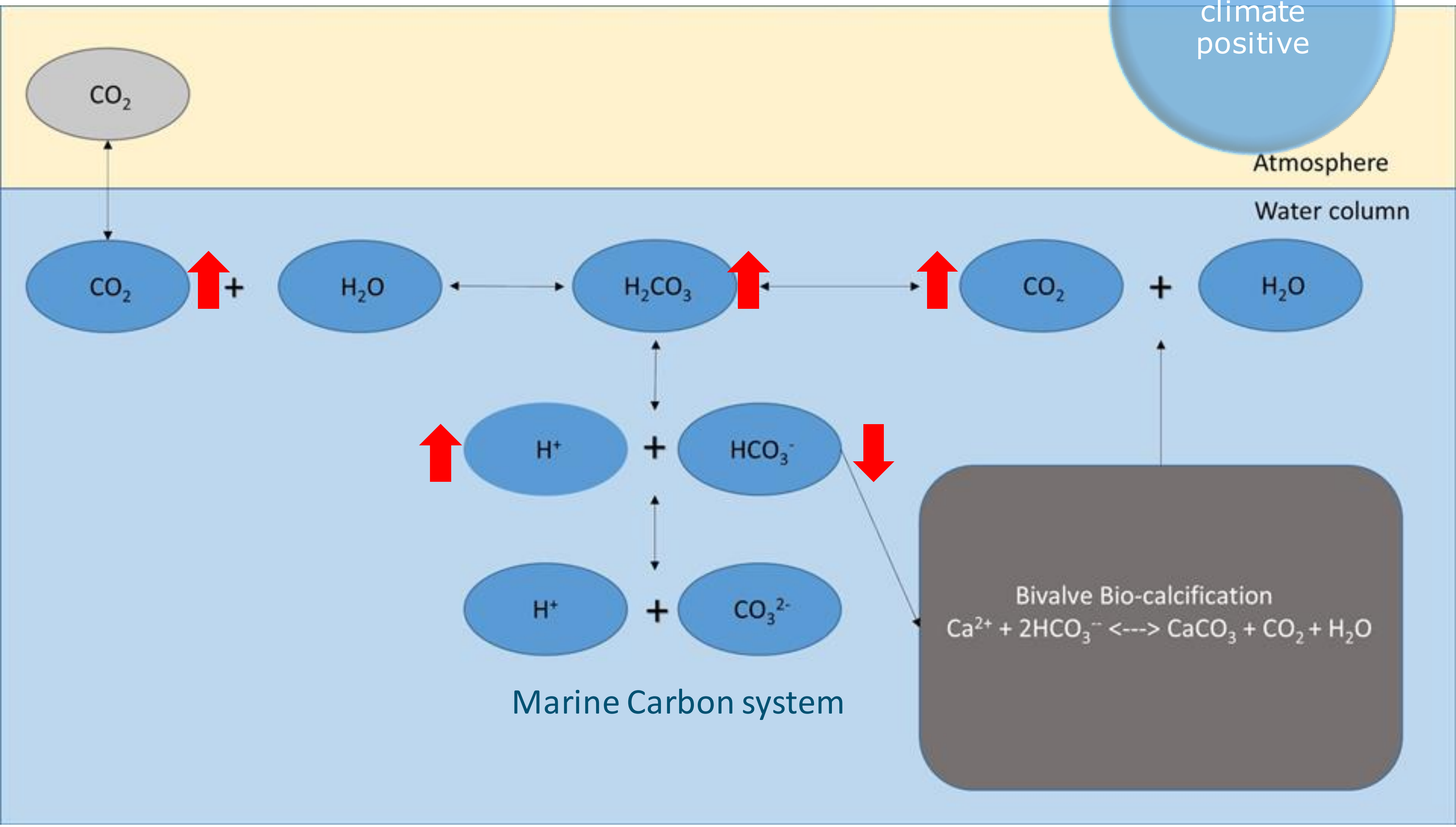
Carbon sequestration in production

Circular and climate positive



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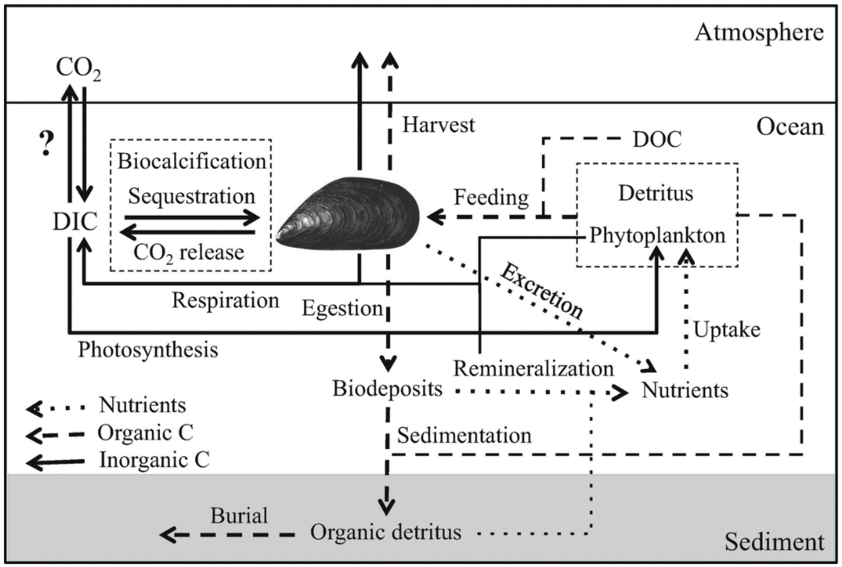
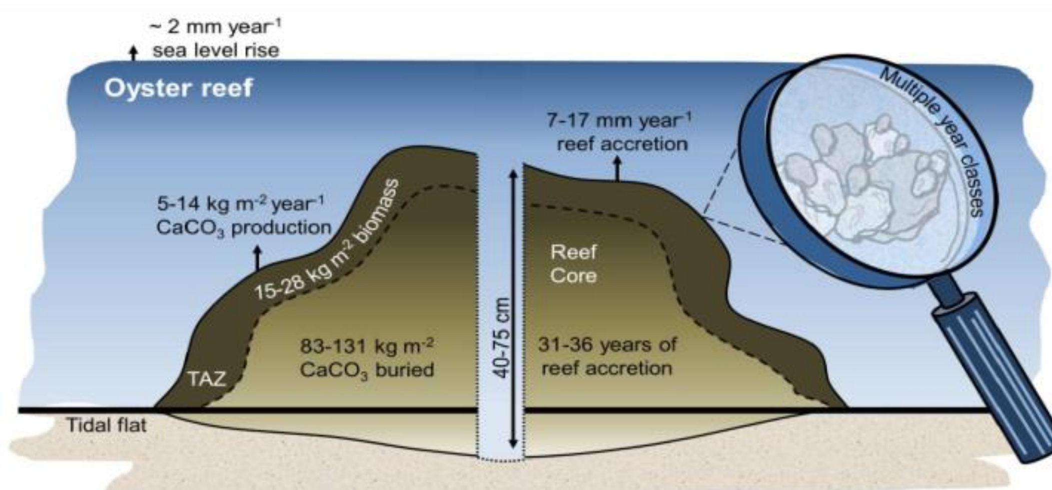
Carbon capture as a climate tool in shellfish, seaweed and energy production





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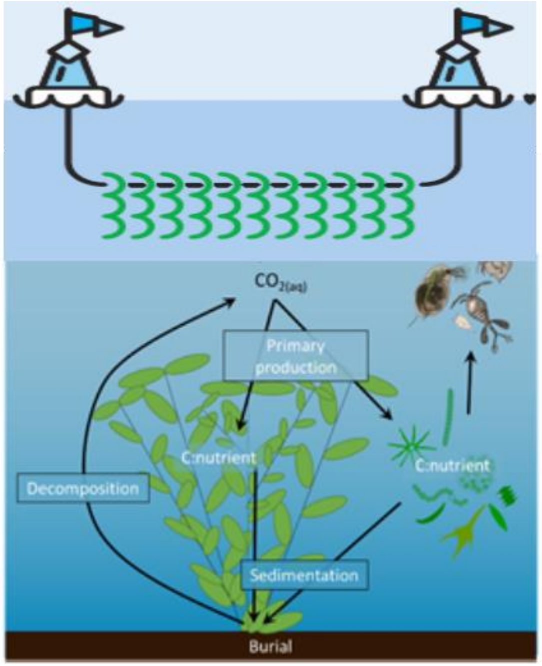
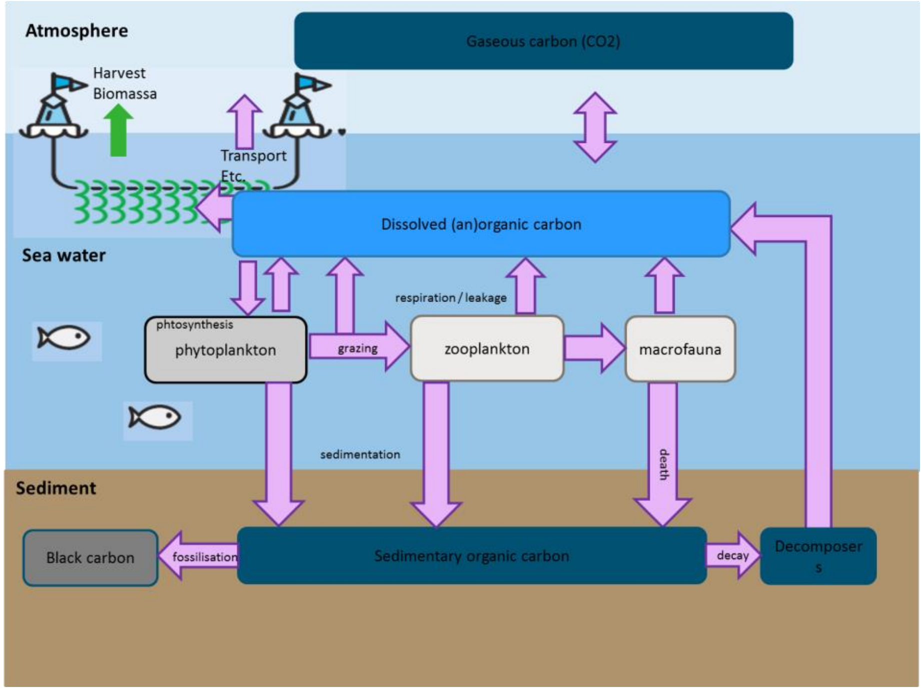
Feasibility study of **combined** monitoring systems for carbon budgeting





Criteria for the feasibility study

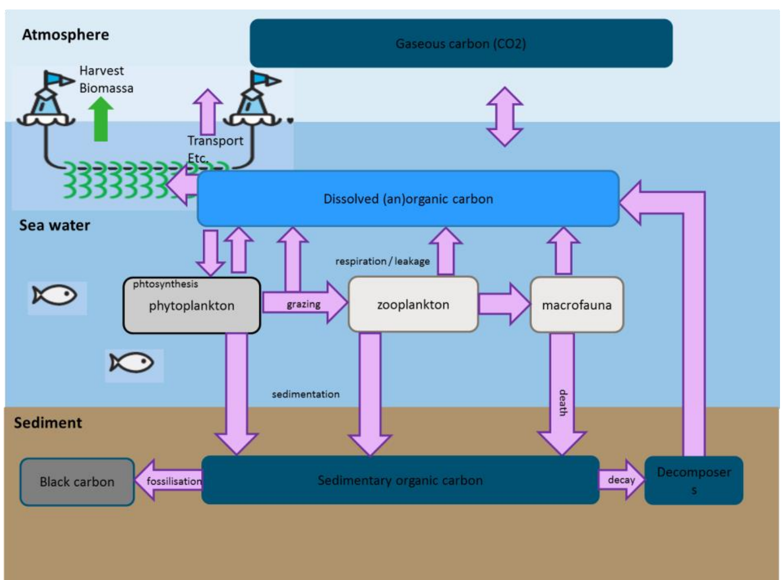
- Climate Policy needs ("rapportages")
- Manageable / user-friendly (model/report tool)
- Technical Applicability (including opportunities)
- Scientific logic (Do I measure the right thing)
- System approach
- Cost-effective
- Possibility to benchmark CO2 seq. for private partners (seafarmers, wind energy, etc.) [JEROEN]

E-DNA en plankton

Mogelijke proxies voor C-burial onder zeewier:

- Verhouding silicate phytoplankton versus overig
  (Bopp et al. 2005;Reinfelder 2010; Treguer & Pondaven 2000)
- Verhouding micro vs mesozooplankton
  (Beaugrand, 2010; PNAS)
- Diversiteit van mesozooplankton

Kortom: brede diversiteitscreening = metabarcoding approach, in combi met schatting van totale biomassa per groep



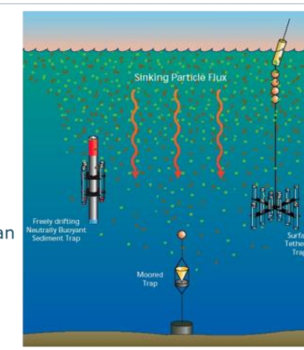
Sediment traps (Mandy Velthuis)

Voordelen:

- Gecombineerd toepasbaar op korte en langere periode
- Low-cost methode (inhangen, ophalen, drogen en wegen; evt koolstof bepalingen)

Nadelen:

- Geen contact met bodem:Onderschatting van decompositie?
- Te weinig inval bij minder productieve systemen?
- Langer inhangen: sedimentatie + decompositie
- Waterdiepte: uitdaging op Noordzee?



Correlatie Δsedimentatie en CO2 en CH4 flux Kosten et al., in prep.

Case study: seaweed cultivation in the North Sea

Seaweed species	**Kelp (*Saccharina latissima*)**	***Laminaria digitata***	***Chondrus crispus***
Space available	145 km^2	350 km^2	~250 km^2
Dry weight eqv.	145,000 mt	350,000 mt	250,000 mt
Carbon content	45,820 mt (eqv. 31.6%)[1]	105,000 mt (eqv. 30%)[2]	75,000 mt (eqv. 30%)[2]
Nitrogen content	4,785 mt (eqv. 3.3%)[1]	4,900 mt (eqv. 1.4%)[3]	5,000 mt (eqv. 2%)[3]
Traded price	N: US$30/kg, C: US$10-30/mt[2] N: US$11/kg, C: US$6-60/mt[4]		
Economic value	**€48.3m**	**€50m**	**€50.7m**

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Avenues to capitalise

Potential avenues for capitalisation for seaweed farmers on the North Sea

- Credits or offsets under carbon and nutrient trading programs
- Payments for services provided for localised ocean eutrophication mitigation (e.g. Pigouvian tax transfers from crop farms with fertiliser run-offs)
- Price premium achieved through eco-labelling of IMTA products or other circular nutrient recapturing systems

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ICES Journal of
Marine Science

ICES CIEM International Council for the Exploration of the Sea / Conseil International pour l'Exploration de la Mer

ICES Journal of Marine Science (2019), doi:10.1093/icesjms/fsz183

Contribution to the Themed Section: '*Marine aquaculture in the Anthropocene*'

Quo Vadimus

Towards sustainable European seaweed value chains: a triple P perspective

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Seaweeds are seen as important future feedstock for Europe, providing biomass for food, feed, and other applications. Seaweeds can contribute to a circular food system a protein transition and bio-based economy. Europe is a minor player in the world market dominated by the Asian producers and processors. According to the FAO, total production of aquatic plants (dominated by seaweed) was 30 million tonnes in 2016, with China (47.9%) and Indonesia (38, 7%) dominating production. This article discusses the challenges to seaweed production and use in Europe and formulates future directions for upscaling the European seaweed sector. From a People, Planet, Profit perspective, there is no need to focus on producing large volumes of seaweed per se. We need to focus on nature-inclusive production systems, producing the right amount of the right seaweeds, based on the carrying capacity of the European seas. The seaweed sector must avoid developing along the "old" economy's way of cost leadership but develop along the way of the "new" circular economy. Seaweeds should not be seen as a new product "added" to the market but become an integral part of the European food system, being used for human consumption, feed and improving production processes.

The seaweed sector must avoid developing along the "old" economy's way of cost leadership but develop along the way of the "new" circular economy. Seaweeds should not be seen as a new product "added" to the market but become an integral part of the European food system, being used for human consumption, feed and improving production processes.

The context of our work

Our contribution to circular climate smart food systems

Increase crop

nprove
esilience

Optimi

g-term

Close nutrient

s in

Understand processes

Understand effects

Understand processes

Understand effects

Understand processes

Understand effects

Understand

Close cycles

Categorise
Contextualise

bles

hic

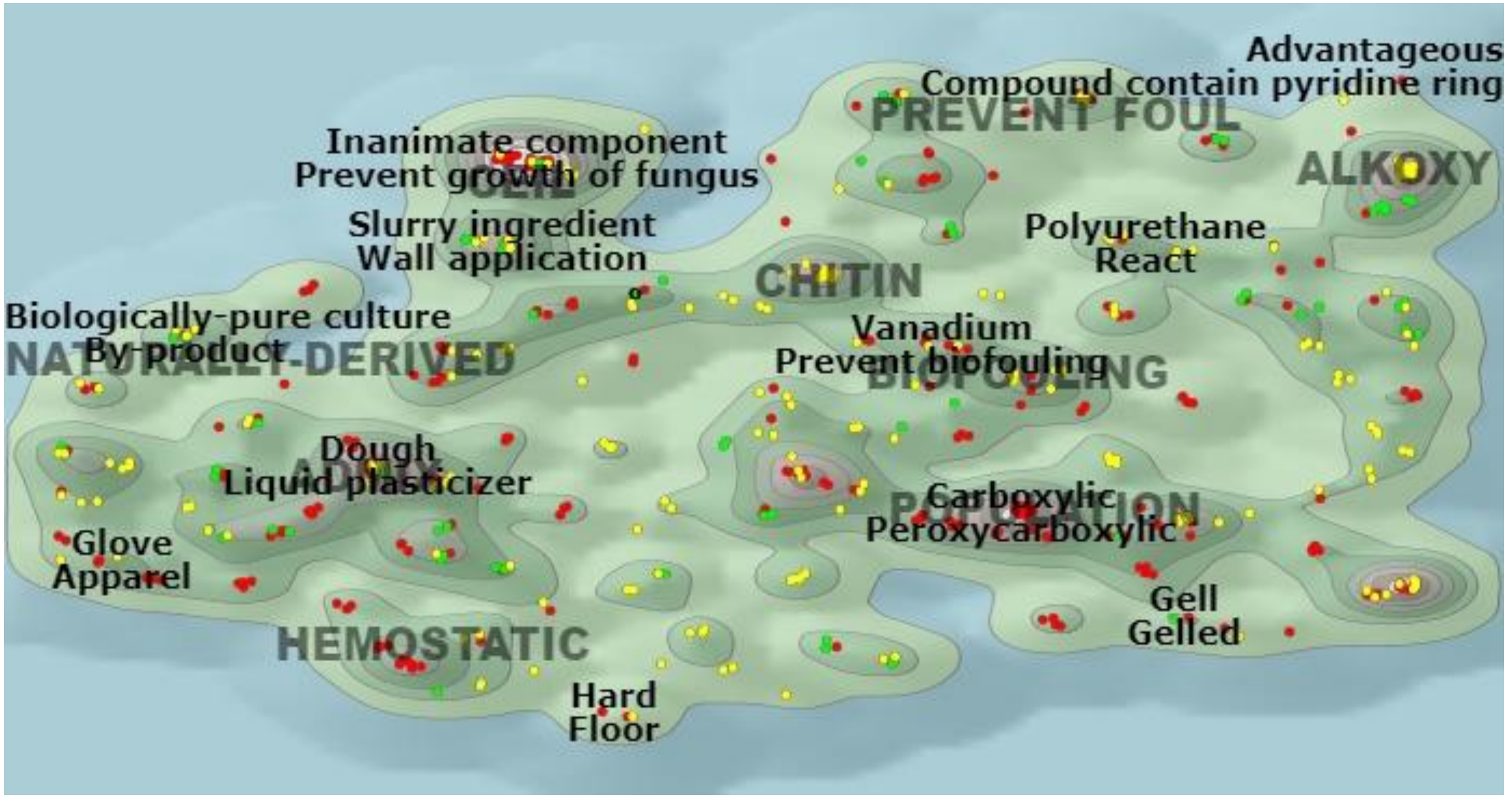
Synchronize produ
with natural capi
(development)

IP Heat mapping for applications status

Fig.
inte

- ALL=(("red algae" OR gelidium OR gracilaria OR pterocladia OR phyllophora OR ahnfeltia OR chondrus OR gigartina OR hypnea OR eucheuma OR iridea OR furcellaria) SAME (compound OR biocomponent OR protein OR proteins OR peptide OR peptides OR "amino acid" OR "amino acids" OR carbohydrate OR carbohydrates OR saccharide OR saccharides OR lipid OR lipids))

IP Heat mapping for applications status



- ALL=((crustacean* OR crab* OR crayfish* OR lobster* OR krill OR barnacle*) SAME (bioactivity OR bioactive OR bioactives OR biostimulant* OR antimicrobial))

Deliverables 2020

Aim	Deliverables 2020
Exploring an integrated framework for climate smart and circular inclusion of the sea in agricultural systems Scientific analysis to map the economic and sustainability effects of the development of seaweed chains and thereby provide input to the discussion about the desirable development of the seaweed sector.	Building blocks for a position paper on climate smart and circular inclusion of sea and agriculture systems. (prep. Integrated work for paper 2021) - Integration of data on production, products, applications end combining of gross climate and circular parameters. - Inventory of pros and cons, including data on carbon and nutrient, fixation, burial, harvest, application effects, processing outputs. - Detailling of MAGNET model - Optimised DIPSR Framework for aquaculture production
Blue Carbon in marine production systems: Feasibility of methods and applicability	Develop approaches for integral carbon fixation/burial assessment for Blue carbon - Model development (carrying capacity and externalities (seaweed/mussel) - Scenario's for carbon offset - Tool development carbon burial and exchange

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Deliverables 2020

Further development and in-situ application of measurement techniques for determining ecosystem services (focused on biomass, biodiversity, carbon fixation determination) The intended product of these developments is a first estimate of the feasibility of using these techniques and practical tests. The development agenda for new technologies is also being drawn up fitting the potential for quantification of ecosystem interactions framework	First development selected technique remote monitoring (to be selected in 2019) eDNA analysis implementation seaweed biodiversity Implementation and protocols ROV technology Identification oyster larvae mortality indicators Optimalisatie methode (qPCR) oesterlarven detectie. Quantification of ecosystem interactions Framework
Exploring avenues for capitalizing the value of ecosystem services for marine production	Position paper: Monitarise Ecosystem services Biodiversiteit, Carbon fixatie, Nutriënt extractie.

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Deliverables 2020

Knowledge about biochemical variation in ingredients of various seaweed extracts **Knowledge about seaweed components that are involved in increasing the stress resistance of plants against drought and salt** **Knowledge about possible fashion or action in the plant, induced by seaweed extract** **Optimization of the seaweed extract and the extraction method for the (set of) seaweed ingredients that act as a biostimulant** **Patent application on optimized extraction method of the subset of components that act as a biostimulant / stress alleviator**	**Screening effects of seaweed extracts on plant production.** **First insight in the mode of action.**
Define most promising low trophic marine resources, or extracts thereof, to improve efficiency, health, robustness and resilience of firstly poultry and fish. **Create extracts of, or process low trophic marine resources for optimal use in an in vitro and/or in vivo setting.** **Develop in vitro and/or in vivo tools to relatively quickly and accurately scan and monitor different marine resources on their effects on efficiency, health, robustness and resilience of firstly poultry and fish.**	**Report on: Identification which species, compounds or extracts from marine resources are most potential, including optional wildcards, aiming to reduce the carbon output of the target production animals (poultry and fish) and increase their robustness, resilience, efficiency and health**

Deliverables 2020

Overview of the main characteristics of seaweed/shellfish relevant for process and product development based on literature databases combined with e-science	Document
An assessment of the quality of the diverse data and their consistency with respect to different literature sources. The diverse methods that are used to quantify main components are reviewed. Data will focus on both fresh/raw seaweed and in purified biopolymer and the processing method of purification used	Ranking of main product and process characteristics on the basis of occurrence and impact on required functionality and quality.
A short list of seaweeds of interest will be prepared. For benchmarking purposes, a set of traditional biopolymers will also be included. Data will be made available in a compatible format to facilitate addition of data and literature references in the database.	Document having a shortlist of seaweeds/shellfish of interest

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Integrate our work

- Discussion on smart linkages
    - Match DIPSR with ecosystem services
    - What data is needed for overarching storyline
    - Carbon burial, fixation, exchange (who does what?)
    - Integrate Food Safety with DIPSR, characterisitcs or production (no specific task)?
- Use each others data

- ACT (Academic consultancy training) projects?

ACT Creating opportunities to connect nutrients from sea and land

- Nutrient balance of harvested nutrients versus agricultural nutrients and run off
- Create insights of use of extractive aquaculture to capture run off nutrients (based on current vision of 150km2 production of seaweed or shellfish)
- Create insights of the potential effects of new nitrogen measures, and circular agriculture for nutrient run off (to sea)

  - Insight in loss of production value by reduced nutrient availability

Biodiversity stimulation in seaweed and mussel culture

- In the light of biodiversity inclusion of seaweed (or shellfish) production on the North Sea should be combined with promotion of biodiversity, and natural effects.
- Compare the cycli for seaweed and mussel with natural (generic) biodiversity/ecosystem dynamics, analyze best fit solutions.
- What are potential routes to valorize biodiversity in a production setting
- How can aquaculture (water column) stimulate biodiversity on the bottom (benthic)
- Basic ideas and information is already available.

Marine Resources potential of new species to valorize in agriculture food systems

- Basic knowledge on the presence of stocks of different marine resource is available (eg. Shellfish, reefs, biogenic reefs)
- For optimal use the rapid turn-over of the ecosystem, insights in potential resources are needed.
- What stocks are available, of most promision (non human consumption), what are potential biomasses, protein, Carbohydraten, potential beneficial content (eg application in agriculture or aquaculture)

Aquaculture (extractive) biomass and quality remote sensing

- Some work has been done, we would like to test and expand these
- What options are available (remote, AI, in situ sensors) to monitor biomass development in extractive aquaculture
- What options are available (remote, AI, in situ sensors) to monitor biodiversity development in extractive aquaculture
- What are potential options for use of agricultural technologies (robots) for application at sea
- Ranking of potential options based on functionality
-

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