Progress report KB Circular & Climate Neutral

Projectnumber/ theme number: KB34 / 2C-4, 34 Circular and climate neutral society;

Title: Marine lower trophic food systems

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Objective of the project and annual work (as in the workplan/proposal):

The multidisciplinary research program: "Marine lower trophic food systems", contributes to the development of a food system based on low trophic marine species. The transformation to application and optimized use of low trophic production of marine resources offers opportunities for efficient use of nutrients, achieving climate objectives, and the development of new product perspectives, applications and processes. Yet there is still a lack of integrated knowledge to develop and implement these food production systems in a sustainable, circular way and to learn from the lessons learned in our agricultural past. It is therefore necessary to support developments towards low-tropic production systems.

It is necessary to support these developments towards low trophic production systems and provide a scientific basis for the proof -of-concept, the license - to-produce , the beneficial effects of these food systems and insight into the socio-ecological context. (figure 1).

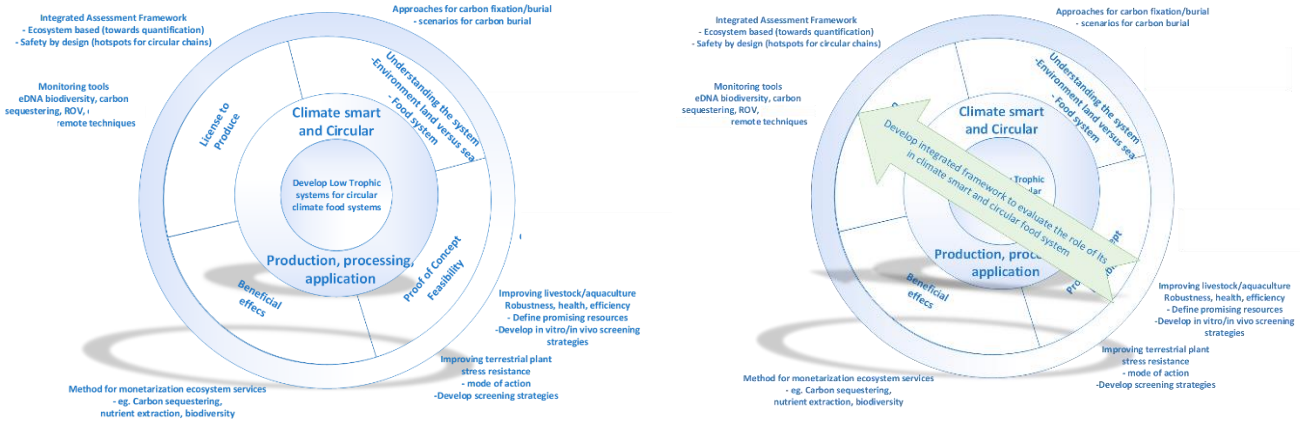

Figure 1. a) Overview of the KB circular low trophic food production systems project, including focus in the outer shell, b) Integrated approach for a a framework to evaluate the role of low trophic systems in climate smart and circular food production systems.

This program contributes to the scientific basis for a transition to a circular ocean view. This is needed to make sustainable use of the sea possible (for efficient nutrient use). Primarily in the context of a growing wind power ambitions at sea, with the requirements of the development of social, environmental and economic accepted multiple use of space (food and energy). With a primary focus on insights into a healthy marine and circular ecosystem (circulation of carbon and nutrients in the system), and in a social and economic context.

Strategic choices for climate goals are explored by analyzing, applying and developing the potential of "Blue Carbon" and eco-system services. Translating this into the benefits of marine resources in

smart climate production systems, both at sea and on the land. Various frameworks are being developed and integrated for this. This is supported by the development of suitable tools to assess the ecosystem effects and impact. For example in vitro and in vivo tools to quickly evaluate and or identify the functional components in marine resources.

Progress until December 1st 2021 based upon the deliverables in the workplan:

Planned deliverables (online line per deliverable)	**Actual deliverable**	**Remarks ; e.g. reason delay, reason change**
1. Contribution Circular@WUR 2. Progress powerpoint 2021	**Deliverable 1.** All contributions are prepared. A science session was prepared and a workshop organized. This work will be reinitiated for April 2022. **Deliverable 2.** Not yet included.	Will be done to support the preparation of the Kick off 2022. (January 2022)
3. Draft paper on climate smart and circular inclusion of sea and agriculture systems. (WMR, WEcR, WEnR) Inclusion; - 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.	**Deliverable 3a** Draft paper "How to measure the marine lower trophic species contribution to the Sustainable Development Goals" **Deliverable 3b** Report "Development of a framework and toolbox for measuring and evaluating ecosystem interactions of seaweed aquaculture" **Deliverable 3c** Draft Report "Capturing Complex Ecosystem Services Evaluation with Rubrics" Deliverables 3c and 3d were not described in the table earlier: In 2020, a DPSIR (Driver-Pressure-State-Impact-Response) analysis is performed for seaweed. This framework provides an inventory of ecosystem impacts based on the production steps for seaweed, which serves as a bench mark for impact analysis. This tool is further exploited towards, BO and MONS programs. The framework will be further developed and published to provide scientific evidence. In 2021 the aim of the work will put special emphasis on the inclusion of ecosystem service components. The framework results in scientific based insights in the most critical processes of impact, which will be further implemented in governmental programs. Also, the framework results in key indicators, which need to be addressed and measured in the field, which creates a basis for the agenda setting of the development of physical methodologies.	Currently in prep SDG story Redesign in 2022 Application in 2022
- Student Thesis report	**Deliverable 3d** Thesis report Exploration of low-trophic aquaculture's potential contribution to nature- development and restoration in offshore windfarms through assessing the change in ecosystem service supply.	

	Deliverable 3e ACT report "From Pest to Product: Using Green shore Crabs from the Wadden Sea for food and nonfood products" **Deliverable 3f** ACT report "Routes for the Utilization of Shellfish in the Future Food System"	
Development selected technique remote monitoring; Protocols or report: 4. eDNA implementation biodiversity 5. Implementation and protocols ROV technology 6. Implementation development sonar biomass detection (shellfish rope culture / seaweed) 7. Monitoring set up support project -	**Deliverable 4.** Procedures demonstrated and implemented for "Shellfish species identification: a DNA approach". Further implementation adopted by KB WOT. Protocols delivered. **Deliverable 5. None:** Deliverable 5 should have been focused on Ecosystem service inclusion of DPSIR as reported in Deliverable 3 (c and d). Budget for ROV (10keuro) not allocated due to new ROV strategy WMR, which does not match the ambitions and timelines of food production. **Deliverable 6a** Report**: "**Sonar Seaweed Monitoring" **Deliverable 6b** Presentation: "Sonar Seaweed Monitoring: Prototype seaweed monitoring " **Deliverable 7.** Not performed due to the absence of scientific suitable "commercial" production sites for seaweed. Budget allocated to WLR and WPR.	ROV development has not been done in this project. The reason is that different trials did not match the ambitions and timelines of food production. A shared monitoring program has not been performed. WMR Budget (a total of 40keuro) has been allocated to WLR, WPR, and WFBR.
8. Updated Report on carbon/nutrient effects on phyto-/zooplankton (2020): Mesocosm study winter seaweed eDNA development and analysis	**Deliverable 8a**. Factsheet: "Hoe monitoren we de koolstofdynamiek op zee, in relatie tot zeewierproductie?" **Deliverable 8b** Blue carbon dynamiek op de zeewierboerderij Mogelijkheden van DNA metabarcoding als methode voor het meten van de effecten van zeewierkweek op de planktondynamiek in zeewater	Experimental work in mesocosms to be included in report/paper (Work done and analysed)

Including Updated eDNA sampling and analysis protocols (July 2021) Progress report (in general ppt) on second experiment (November 2021) 9. Position paper Blue Carbon in low trophic production systems 10. Report on Comparative assessment biodiversity	**Deliverable 9**. Paper submitted "Is seaweed the climate solution? A framework to disentangle climate mitigation pathways" **Deliverable 10.** Memo: " Impact of increasing offshore mussel cultures on the North Sea: urgent call for future research"	
Set up a plant biostimulant bioassay for (fractions of) seaweed extracts 11. Opinion paper on seaweed as a biostimulant for crops under abiotic stress 12. Submission of a scientific opinion paper on the use of seaweed extracts as biostimulant to boost abiotic stress resistance of (protein) crops	**Deliverable 11 and 12:** Opinion/review paper "The power of seaweeds as plant biostimulants to boost crop production under abiotic stress" It needs to be modified as requested by the editor and then re-submitted (2022) https://www.authorea.com/doi/full/10.22541/au.163256665.52941026/v1 NB. Set up a plant biostimulant assay for (fractions) of biostimulant extracts. This is already running, and has been validated, for three consecutive years. Tested three different fractions of a commercial seaweed extract, prepared by WFBR, that previously showed to have biostimulant effect on plants under salt stress in a plant experiment. None of the fractions, nor the commercial extract as control, showed any positive biostimulant effect this year. We tested three different 'WUR' extracts of Ascophyllum nodosum, extracted by WFR on plants under salt stress. Unfortunately, these three A. nodosum extracts showed also no positive biostimulant effect. All extracts used in plant experiments in this year, prepared by WFBR, are being analysed on metabolite profile. Next to that, all previously used (and some already previously analysed) biostimulant extracts are also being analysed biochemically. This hopefully will shed light on the failure of the different extracts to show a biostimulant effect in the plant experiments this year. Biochemical data will be linked to the quantitative data of WFBR on a few specific compounds present in seaweed extracts and fractions that they use to standardise their extraction method	

13. Report standardized extractions 14. Report Evaluation of new seaweed products from micro- and macro-economic perspective.	**Deliverable 13**. Report "Seaweed extract standardization" **Deliverable 14.** Memo "The macro-economic effects of increasing seaweed production in North Sea"	
15. Report including the set-up and results of the 2020-2021 performed in-vitro and in vivo trials, annexed by Workplan 2022 16. Report on patent search applications in selected case areas	**Deliverable 15.** Confidential report: "The ability of two novel bivalve species and raw, blanched and cooked mussel to alleviate anaemia in common sole (Solea solea L.)" **Deliverable 16**. Report: "Research trend detection tool"	
17. Report on food safety by design in low trophic species production (focus seaweed) Hotspot identification of marine products circular application safety risks, and potential mitigation measures..	**Deliverable 17.** None yet.	No report for 2021 has been delivered by WFSR (lead) yet. Reason not known by project manager.

Financial exhaustion %:
We assume 100% budget exhaustion by end of December 2021

Project Highlights:

The team (Kals as a coordinator) managed to develop a PPS proposal " Low heterotrophic resources for new revenue models in the shellfish industry". The partners consist (names not reported) of shellfish companies, and large players in the field. This is the first project, which was supported both financially (international) as from a future oriented perspective. The project was not granted, the team interprets the reasoning of not granting conventional and not with a focus on the next stage of the protein transition. This illustrates both the potential of the research as well as the difficulties to valorize the investment (conservative marine sector), therefore focus on novel protein sources is required.

The efforts on biomass monitoring for future quality improvement, automated and remote offshore production have been valorized. In the course of the project automated imaging by WFBR has been incorporated in the project (budget switch). The steps for the next years is to develop a partnership or market oriented projects.

A range of papers has been developed among the institutes.

Several spin offs are in preparation or in development. A WUR wide circularity project (small but functional) has broad together shared knowledge. Insights on circularity are however still compartmentised, where a broad integration is yet to be developed.

DNA technologies are implemented and developed in different stages. The DNA protocols to identify shellfish species are further developed in KB WOT for further validation on bivalve application.

A wide range of carbon related insights are developed, on potential effects of cultures on the ecosystem, on monitoring of carbon flues (with zooplankton as proxi) and on the application of carbon trading has been implemented. Also the insights indicate that transitions to a circular marine resource inclusive food system still requires extra steps. The main development for storage of blue carbon in the food system is needed to allow storage in the long chain. Due to the complexity of the solutions (a paper has been submitted on this topic), the team will also focus on new insights for Phosphorus cycle in the next year.

A TKI Project: "Mariene bouwstenen: Circulaire benutting van schelpen in betonproductie" (WFBR, WMR, TNO, Betonsector, Schelpdiersector) has been developed and is currently developed. This was inspired by the KB investments.

Additional remarks:

Really building forward on a full integration of the experiments is inhibited by the lack of live discussion opportunities. This inhibits inspirational sessions, and collective energy development to take progress. The work on integration towards a framework or integrated insights is therefore progressing to less extent then hoped. The full integration to an indicator based comparison framework has been set, and quite some investment has taken place. However, in the course of this trial data availability, and complexity, and knowledge gaps inhibit this to contextualize. The team went back a couple of steps and approaches low trophic food systems from an SDG perspective (how do SDGs fit to marine low trophic production).