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AquaVitae

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New species, processes and products contributing to increased production and improved sustainability in emerging low trophic, and existing low and high trophic aquaculture value chains in the Atlantic

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Deliverable D2.2

Report on first developmental phase in case studies WP2

11/03/2021

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Executive Summary

This deliverable (D2.2) summarises the work that has taken place as part of the H2020 AquaVitae Project by the case studies (CS) that contribute to innovation and research. These CS's introduces new low trophic species (LTS), products and processes to the grow-out phase (i.e. post-hatchery to harvest) of aquaculture production. The CS's that will contribute to the tasks of WP2 include:

- New macro-algae species (CS1);
- Offshore macro-algae culture (CS2);
- Land based integrated multitrophic aquaculture (IMTA; CS3);
- Sea based IMTA (CS4);
- Biofloc IMTA (CS5);
- Sea urchin roe enhancement (CS6);
- Native oyster production (CS8);
- Offshore production of blue mussel (CS9);
- Freshwater finfish in Brazil (CS10);
- By-products from LTS aquaculture (CS12); and
- Algae into LTS aquafeeds (CS13)

The outcome of the work carried out in the CSs' linked to WP2 will contribute to the development of various aquaculture value chains (VC), including: macroalgae culture (VC1); IMTA (VC2); echinoderm culture (VC3); shellfish culture (VC4); and finfish culture (VC5). The focus of the innovation and research here is on developing aquaculture grow-out technology with a circular reuse of products and a reduction in the industry's environmental impact.

All detailed planning, scientific, technical and innovation information for each CS which advanced the completion of WP2 tasks are presented in Annex 3 of Deliverable D1.1 (CS specific work plans) and in Annex 3 of D1.2 (Detailed Case Study Reports (M1-M12)). Annex 3 of D1.2 specifically contains an abstract/summary for each CS. The Case Study Reports (M1-M12) detail the methods used and results obtained. Where applicable the results are discussed. In a final section the progress, deviations, problems/solutions and planned future outlooks for next 12 months are provided.

Forty-eight project outcomes are presented as part of this WP, in the form of reports, processes and products. These are produced by 11 of the 13 CS that make up AquaVitae (AV). A description of the main outcomes (that includes the requirement specification of each), the completeness of these tasks, and their exploitation potential have been identified and presented. This was largely made possible through the creation of a reporting system developed jointly by WP1, 2 and 3 (Appendix 1), and the production of a database that made this, and other task details, readily available (Appendix 2).

The percentage completeness of the tasks that report to WP2 ranged from 0 (for tasks that were not scheduled to start in the first 12-months) to 95% complete (for tasks that were started ahead of schedule). Most CS tasks are on track with average completeness of 24% across all tasks that report to WP2, which is largely in-line with the progress that might be expected since we are a quarter of the way throughout this 48-month project.

The main users of this deliverable will be the leaders of WP1-3, WP5-7 scientists, WP9 participants and the CS leaders. The next phase will see the CS task leader carrying out research and development through the second 24-month loop of the developmental cycle. They will focus on further developing the details of the requirement specifications of each project outcome and we will develop the exploitation plan for all outcomes that have been identified with this potential.

1. Introduction

i. Synopsis AquaVitae

AquaVitae is the name of this research and innovation project. It is funded by the EU's Horizon 2020 programme. The project started in June 2019 and is scheduled to be finished within 48 months. The consortium includes a total of 35 members. They come from 16 countries that, in addition to those from Europe, all border the Atlantic Ocean, with Brazil, South Africa and Namibia in the south, as well as North America. Its overall aim is to introduce new low trophic species, products and processes to marine aquaculture value chains across the Atlantic.

ii. Scope and motivation of D2.2

The contribution that Work Package 2 (WP2) is making to the overall aim of AquaVitae (AV) is focused on post-hatchery production of low trophic species (LTS) in aquaculture through to the point where they are harvested. The research and innovation reported here will feed from WP1 (hatchery production) and deliver to WP3 (post-harvest technology development) (Figure 1). Together, these work packages contribute to AV's overall goal to introduce new low trophic species (LTS), products and processes into various aquaculture value chains across the Atlantic, with an emphasis on circular reuse of products and reduced environmental impact. This report will demonstrate the synergies that have been developed with WP1, 2 and 3, that make it possible for WP2 to contribute to AV's overall aim. As such, the focus of D2.2 will be to:

(a) identify and highlight the main outcomes of all the AV case studies (CS) that will contribute to the tasks of WP2, with particular emphasis on their requirement specifications (i.e. aspects of the work that will contribute to the innovative qualities of the project outcomes) and exploitation potential (i.e. the contribution they will ultimately make to the aquaculture industry and society);

(b) to demonstrate and comment on the progress of these CS's;

(c) to show how WP1, 2 and 3 have worked together to develop an efficient reporting system that will feed into the AV project and make the innovative outcomes of the project (and in this instance, particularly those of WP2) easily accessible to the other work packages (i.e. WP4 to WP10) that make up the AV project.

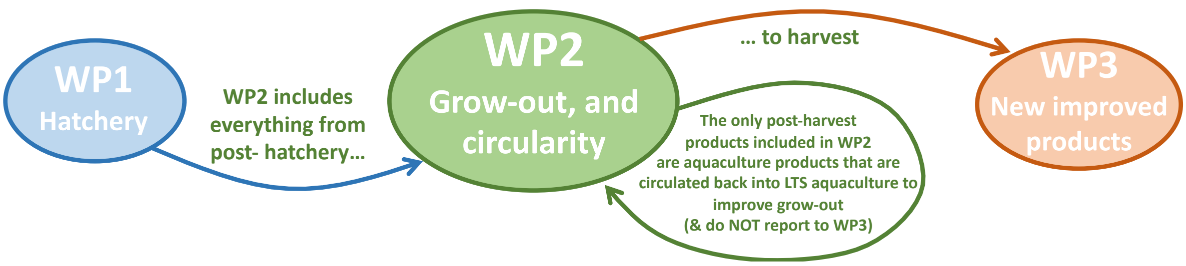

Figure 1: Work Package 2 (WP2) will report on research and innovation aimed at aquaculture grow out (including product that is circulated back into the production of low trophic species). WP2 will feed from work developed for hatchery production (WP1) and deliver reports, process and products that will contribute to the development of post-harvest product development (WP3).

The research and innovation that will be reported in D2.2 will be drawn from the CS's that will contribute to WP2's responsibility towards: scoping, planning and eliciting stakeholder feedback for CS linked to WP2, innovation and exploitation, the use of by-products from LTS aquaculture, and the use of macro-algae in the feeds of other LTS. This post-hatchery to harvest research and innovation will focus on improved performance and efficiency of aquaculture production and value adding through sustainable, circular processes that aim to work towards zero waste and reduced environmental impact in aquaculture production.

2. Report on first development phase for post hatchery/seedling to harvest processes and production in CSs, including requirement specification

i. Methodology

The approach and method adopted in WP2 is the same as that presented in D1.2 and D3.2:

Following the spiral model of innovation methodology (Figure 1, D1.1) CS leaders have completed their first 12-month innovation loop and reached a first prototype stage. All the scientific, technical and innovative progress that has been completed in each CS and that reports to WP2 has been detailed in Annex 3 of D1.2 (i.e. Detailed Case Study Reports, M1-M12).

It should be noted that the meaning of a "prototype" here translates to any sort of output from a CS, and it may be a new or improved product (including new species and technical hardware), process or a report.

To gather the necessary information for this deliverable, three tools were used: firstly, the completed Case Study reports that used the "CS Report Template" (Appendix 1, D1.2) that was completed by CS leaders at month-6 and month-12, and will be updated at 6-monthly intervals for the duration of the project; secondly, a new Excel tool developed by the leaders of WP1-3 to make the entire dataset of the progress made by all 13 CS more manageable and available – the "AquaVitae WP 1 - 3 database" (Appendix 2, D1.2); and thirdly, a technical case study report for the work from M1-M12 that was completed by all CS leader (Appendix 3, D1.2).

. In order to clearly match the work and outputs of all case studies with the best fitting WP (WP1-3), the terminology used within AV and the database was refined and explained in D1.2.

To generate the tables summarizing the outputs of the first development phase, a number of filters were set in the database. This allowed extraction of the information specific to WP2. The product specifications were requested by email from all partners and added to the tables.

ii. A synopsis of the progress to date

Currently 11 of the 13 AquaVitae CSs have reported a total of 48 project outcomes that contribute to the tasks of WP2. These innovative outcomes will take the form of 17 reports, 22 process and 9 products (Tables 1 to 7). To reduce a duplication in reporting due to an overlap with work that involves grow-out technology development that results in the production of clearly defined post-harvest product (i.e. an overlap in WP2 and WP3), we have decided not to report on this work in both WP2 and WP3, but to report such work as a post-harvest product in WP3 only. As such, only one outcome that report to WP2 will also report to WP3 (post-harvest product) (Table 5). Similarly, there are six outcomes that will report to both WP1 and WP2 (Tables 1, 4 and 7); i.e. where CS tasks result in outcomes that bridge both hatchery technology development and grow-out, and will thus contribute to the progress reported here and in WP1 (hatchery development).

The innovative contribution of each of CS has been summarised using the main exploitable outcomes of the CS task, together with its percentage completeness, a summary of the outcome's requirement specification and its percentage completeness (Tables 1 to 7). These tables also include outcome "identifier" numbers, and these will link each outcome to the other task details, such as progress at different stages of the project, problems and solutions that the researchers have identified, its current technology readiness level (TRL), a description of the contribution that the work will make towards taking it beyond state of the art, and various other project details (Appendix 2).

iii. Progress of case studies at the end of the first development loop of the project

At month-10 when the CS reports were delivered to WP leaders, percent completes ranges from zero to 95%, with mean TRL levels between 3 and 4 (Tables 1 to 8), Those that are at 0% complete were largely not scheduled to start this work in the first 12 months of the project; whereas some of the CS started their work early and are very much ahead of schedule. Most CS tasks are on track with average completeness across all tasks that report to WP2 at 24% complete, which corresponds with the expected progress at month-12 of this 48-month project. A more detailed account of this progress, supported by scientific, technical and innovative information/data produced in each CS has been detailed in Annex 3 of Deliverable D1.2 (Case Study Reports for M1-M12); and this corresponds to the work plans of these case studies (see Annex 3, D1.1).

There have been inevitable delays in progress as a result of the Covid-19 pandemic; and these are being lodged with the AV management group. This will be an ongoing process as the impacts become clearer.

The first five months of the project included the preparation of the methodology for scoping the 13 case studies, with a focus on the needs and expectations of the stakeholders. The leaders of WP1, 2 and 3 worked closely to complete this task since all three WP's share many of the stakeholders. As such, numerous CS contribute to the completion of a single task, with the results of a single task reporting to more than one CS. The scope of each WP was clearly defined to identify the differences in outputs that appeared to fall under both WP2 and WP3.

A common structure was developed to facilitate efficient reporting of the progress of all CS for WP1, WP2 and WP3 (Appendix 1, D1.1). In order to better understand the needs and expectations of industry stakeholders, a survey was developed. The results from the survey varied, but overall, there is alignment of what the project will deliver and what the stakeholders are looking for. Although the survey was well designed for industry stakeholders, stakeholders with other interests, for example policy makers or non-governments organisations were not catered for. It was also noted that more background/contextual information should be given to new industry stakeholders prior to completing the survey. The anonymity and outcome of the survey was of concern to the stakeholders as some of the stakeholders are competitors. Numerous ways to improve the stakeholder survey have been suggested and reported in Deliverable D2.1.

Over the past 12 months of the project, meetings and workshops have been held between industry partners and stakeholders, with future workshops in development. Site visits with industry partners have also taken place. Literature reviews have been compiled, some with the help of MSc and PhD students that have been recruited to assist and contribute to a number of sub-tasks within different case studies. The methodologies and planning of a number of case studies are either under way or have been finalised and work implemented.

The majority of the CS tasks that report to WP2 contribute towards making aquaculture industry more innovative through developing more sustainable methods of production and the development of circular processes to work towards achieving zero waste in aquaculture production (Table 1 to 7). For example, tasks in CS3 (land-based IMTA) have taken local wild sea cucumbers from the South African coast to be used in experiments where these organisms are used to remove solid waste from land-based abalone rearing facilities. This innovative research is taking place under industry conditions so the result remain applicable and easily transferable to the end user. Most of the CS tasks that report to WP2 (CS1 to 13) see a similar approach where researchers are working very closely with their industry partners to develop alternative and more innovative technologies for aquaculture production.

There are cross cutting CS's (e.g. CS12 and CS13; Tables 7 and 8) that focus on the potential of using by-products from LTS to improve the blue-bioeconomy and circularity of aquaculture value chains. Much of the outcome of this work involves grow-out technology development (and will be reported in WP2), but most of this work will result in clear post-harvest products so its bulk will be reported later in WP3. Similarly, the work that aims to utilize macroalgae to improve and optimize feeding strategies for low trophic species is reported in WP2. Numerous CS will contribute to this innovation (i.e. CS2, CS3 and CS4; Tables 2-4) whereas it will be brought together primarily in a cross cutting CS13 that focuses on the inclusion of LTS in aquafeeds (Table 8). Again, the detailed progress of the work that was completed between M1-M12 in these CS has been presented in Annex 3 of D1.2.

Table 1: All outputs related to WP2 from CS1 (New macro-algae species) and their requirement specifications (with: CS = corresponding Case Study Number; Ident. = specific identifier; Pot. Product (Y/N/tbc) = potential for becoming a future sellable product (Yes, No, to be confirmed); Complete = level of completeness with regard to what is expected by the end of the project; current technology readiness level (TRL); WP task = the WP task to which each output reports, according to description of action).

CS	Ident.	Output type	Detail	Requirement Specifications	Pot. Product (Y/N/tbc)	Com-plete	Current TRL	WP task
1	1.2.1	Process	A new method for cultivation of Codium tomentosum in substrates in earthen pounds.	Cultivation of C. tomentosum in substrates will improve the deployment and harvest of biomass, and will allow upscale its production in underutilized, low cost, earthen pounds. This will be done in an organic certified land-based IMTA.	tbc	0%	3	T2.2
	1.4.1	Process	A new method for cultivation of Ulva sp. in substrates in earthen pounds	Cultivation of Ulva rigida in substrates will improve the deployment and harvest of biomass, and will allow upscale its production in underutilized, low cost, earthen pounds. This will be done in an organic certified land-based IMTA.	tbc	0%	4	T1.2, T2.2

Table 2: All outputs related to WP2 from CS2 (Offshore macro-algae culture) and their requirement specifications (with: CS = corresponding Case Study Number; Ident. = specific identifier; Pot. Product (Y/N/tbc) = potential for becoming a future sellable product (Yes, No, to be confirmed); Complete = level of completeness with regard to what is expected by the end of the project; current technology readiness level (TRL); WP task = the WP task to which each output reports, according to description of action).

CS	Ident.	Output type	Detail	Requirement Specifications	Pot. Product (Y/N/tbc)	Com-plete	Current TRL	WP task
2	2.1.1	Report	Site selection map for offshore macro-algae cultivation in the Faroe Islands	GIS map.	N	95%	9	T2.2
	2.1.2	Report	Report describing selected parameters and suitable offshore macroalgal cultivation sites in the Faroe Islands	Report can be used to indicate suitable offshore macroalgal cultivation sites in the Faroe Islands, based on established criteria for depth, current speed, wave height, and distance to pollution sources, marine traffic and recreational areas.	N	95%	3	T2.2
	2.2.1	Process	Incorporating used fish farm equipment in macroalgal cultivation	Conduct a benefit analysis of new vs. old (re-use) equipment. Indicate standards for strength and annual durability of the re-used equipment.	N	67%	6	T2.2
	2.3.1	Process	A new mechanical harvesting method for growth lines seeded with S. latissima at MACRs	Improve logistics to ensure low-cost handling and high-quality storage stable macroalgal biomass.	Y	75%	7	T2.2
	2.4.2	Product	Ocean cultivated kelp included in an abalone diet	Cost effective feed with reduced environmental footprint. Feed will adhere to industry standards with regard to risk management and ingredient traceability.	Y	20%	4	T2.4
	2.5.1	Process	Optimised cultivation system, harvesting and landing logistics	Design of cultivation rig based on the principles of the MacroAlgal Cultivation Rig	tbc	0%	1	T2.2
	2.6.1	Report	Site selection map for offshore macro-algae cultivation in the Atlantic Ocean	GIS map.	N	0%	1	T2.2
	2.6.2	Report	Report describing selected parameters and suitable offshore macroalgal cultivation sites in the Atlantic Ocean	Find suitable sites for large scale production (>500 ha) in open ocean environments in the Atlantic Ocean.	N	0%	1	T2.2
	2.7.1	Report	Feasibility study/knowledge transfer plan for an industrial partner outside of Europe	Road map for how to implement seaweed cultivation offshore outside of Europe. Make technology transfer agreements or other type of commercial communication.	Y	0%	1	T2.2

Table 3: All outputs related to WP2 from CS3 (Land based IMTA) and their requirement specifications (with: CS = corresponding Case Study Number; Ident. = specific identifier; Pot. Product (Y/N/tbc) = potential for becoming a future sellable product (Yes, No, to be confirmed); Complete = level of completeness with regard to what is expected by the end of the project; current technology readiness level (TRL); WP task = the WP task to which each output reports, according to description of action).

CS	Ident.	Output type	Detail	Requirement Specifications	Pot. Product (Y/N/tbc)	Com-plete	Current TRL	WP task
3	3.4.1	Process	Abalone/sea cucumber IMTA production.	This deliverable will produce a protocol, supported by evidence (data), for land based IMTA production of a new species that will include a description of how to integrated the new species into an existing aquaculture production system used to farm a different organism.	N	30%	3/4	T2.2
	3.6.1	Process	Abalone IMTA production/nutrition and systems.	Here we will describe the production of abalone (i.e. growth and feed conversion) on an abalone farm, where they are produced using various feeding strategies (e.g. fed formulated feed and fresh land based IMTA algae, versus the same land based IMTA algae incorporated into a pellet, versus non-IMTA algae incorporated into the formulated pellet) and the data will be used to motivate the most efficient production process for industry.	N	30%	3/4	T2.2, T2.4
	3.7.1	Product	Pelletised abalone feed containing land-based IMTA grown seaweed.	Produce compound feed integrating IMTA produced macroalgae to demonstrate the effects of IMTA production on nutritional aspects and benefits for circular processes.	Y	10%	3	T2.2, T2.4
	3.7.2	Report	Life cycle analysis of land based IMTA.	The deliverable will include a life cycle analysis (LCA) carried out under industry conditions where land based IMTA will be compared with conventional aquaculture, and a “cradle-to-grave” analysis will be carried out on both, using data (i.e., C, N, P flow) collected over the same period in the same environment. This will be among the first real, evidence-based analysis that quantifies the benefit (or not) of IMTA in terms of energy flow and cost savings under commercial conditions on a land based abalone farm.	N	10%	3	T2.2, T2.4

Table 4: All outputs related to WP2 from CS4 (Sea based IMTA) and their requirement specifications (with: CS = corresponding Case Study Number; Ident. = specific identifier; Pot. Product (Y/N/tbc) = potential for becoming a future sellable product (Yes, No, to be confirmed); Complete = level of completeness with regard to what is expected by the end of the project; current technology readiness level (TRL); WP task = the WP task to which each output reports, according to description of action).

CS	Ident.	Output type	Detail	Requirement Specifications	Pot. Product (Y/N/tbc)	Com-plete	Current TRL	WP task
4	4.1.1	Process	Method to make algae biosecure when introduced to an abalone feed.	First method to make IMTA (and other sources) of algae biosecure when fed to abalone, where the nutritional value of the feed is not compromised. Process will adhere to industry standards with regard to risk management and ingredient traceability.	Y	15%	4	T2.2, T2.4
	4.2.1	Process	Coproduction of algae with mussels	More efficient use of existing infrastructure aimed at job creation and reduced environmental footprint. Adhere to environmental legislation/monitoring and black economic empowerment legislation in South Africa.	tbc	80%	5	T2.2, T2.4
	4.3.1	Report	Data supporting use of abalone diet with alternative LTS dietary ingredient, that originates from sea based IMTA.	Cost effective feed with reduced environmental footprint. Feed will adhere to industry standards with regard to risk management and ingredient traceability.	Y	8%	4	T2.2, T2.4
	4.4.1	Process	New prototype and protocol for co-cultivation of lobsters and oysters, for increased food production and restocking purposes.	Process will contribute to reduce environmental footprint of aquaculture production methods and will make production more cost-effective; contribute to developing new industry standards.	tbc	25%	4	T2.2
	4.4.2	Process	Adaptation of the culture system for Swedish environmental conditions, with stratified waters and large fluctuations in temperature, salinity and plankton availability.	Process will contribute to reduce environmental footprint of aquaculture production methods and will make production more cost-effective; contribute to developing new industry standards.	tbc	25%	4	T2.2

Table 4: continued…

CS	Ident.	Output type	Detail	Requirement Specifications	Pot. Product (Y/N/tbc)	Com-plete	Current TRL	WP task
	4.4.3	Process	Evaluation of low tech and relatively inexpensive method for on growth of lobster juveniles in sea-based systems that request minimized rearing and no additional food supply.	Process will contribute to reduce environmental footprint of aquaculture production methods and will make production more cost-effective; contribute to developing new industry standards.	tbc	25%	4	T2.2
	4.5.1	Report	Production site evaluation.	The first 3D hydrodynamic model for the region Vágar, Faroe Islands.	N	25%	3	T1.5, T2.2
	4.5.2	Process	Development of mussel seeding lines for wild settlement and optimal growth.	The mussel spat availability in Faroese waters will be clarified and settlement on two types of seeding lines investigated.	tbc	25%	3	T1.5, T2.2
	4.5.3	Report	Evaluating the IMTA potential with salmon/blue mussel coculture.	The potential waste assimilation by blue mussel around a commercial scale fish farm will be modelled taking into account the spatial constraints. This will add to the knowledge already established around the subject of fish mussel co-culture.	N	25%	3	T1.5, T2.2
	4.5.4	Report	Evaluation of the influence of salmon/blue mussel/seaweed coculture on fjord ecology	Evaluation of the influence of IMTA on the fjord ecology, when the lower trophic species are not feeding directly on the waste from the higher species.	N	25%	3	T1.5, T2.2
	4.6.2	Product	Saccharina latissima obtained in abalone IMTA co-culture.	Process will contribute to reduce environmental footprint of aquaculture production methods and will make production more cost-effective; contribute to developing new industry standards.	Y	40%	5	T2.2, T2.4

Table 5: All outputs related to WP2 from CS5 (Biofloc IMTA) and CS6 (Sea urchin roe enhancement) and their requirement specifications (with: CS = corresponding Case Study Number; Ident. = specific identifier; Pot. Product (Y/N/tbc) = potential for becoming a future sellable product (Yes, No, to be confirmed); Complete = level of completeness with regard to what is expected by the end of the project; current technology readiness level (TRL); WP task = the WP task to which each output reports, according to description of action).

CS	Ident.	Output type	Detail	Requirement Specifications	Pot. Product (Y/N/tbc)	Com-plete	Current TRL	WP task
5	5.1.1	Process	Optimized grow out system (optimized aeration system).	Optimizing biofloc aeration system for shrimp production in biofloc, improving the nitrification improving shrimp production for farmers.	tbc	40%	5	T2.2
	5.2.1	Process	New IMTA system design (shrimp, mullet and Ulva production in biofloc system).	Optimizing rearing system in biofloc by diversification of the species, improving the efficiency in nutrient use.	tbc	35%	5	T2.2
	5.3.1	Process	New IMTA production system for shrimp farmers.	Optimizing rearing system in ponds by diversification of the species (IMTA), improving the efficiency in nutrient use inside the system and profitability.	tbc	25%	5	T2.2
6	6.1.1	Process	Protocols for sea urchin roe enhancement - technology transfer	A description of the protocols for the live holding of sea urchins in land-based systems for roe enhancement. This will include, feeding and density related information and sampling methodology for measuring the efficacy of roe enhancement. The protocols will be aimed at a non-scientific audience.	N	12%	4	T2.2
	6.1.2	Process	Land based holding system for sea urchin roe enhancement.	The output will be split into two types: (1) Commercial prototype (commercially sensitive) of a land-based raceway system with an integrated tipper self-cleaning system. Testing this system will be part of the project output (Norway); (2) Tech Transfer: Land-based holding system design parameters (e.g. raceway and inlet water designs) to enable industry to run sea urchin roe enhancement trials (Spain).	Y	12%	4	T2.2, T3.2

Table 6: All outputs related to WP2 from CS8 (Native oyster production) and CS9 (Offshore production of blue mussel) and their requirement specifications (with: CS = corresponding Case Study Number; Ident. = specific identifier; Pot. Product (Y/N/tbc) = potential for becoming a future sellable product (Yes, No, to be confirmed); Complete = level of completeness with regard to what is expected by the end of the project; current technology readiness level (TRL); WP task = the WP task to which each output reports, according to description of action).

CS	Ident.	Output type	Detail	Requirement Specifications	Pot. Product (Y/N/tbc)	Com-plete	Current TRL	WP task
8	8.3.1	Report	Recommendations of oyster grow-out systems for Scandinavia and Brazil including adaptation of existing techniques and newly developed systems.	In areas with emerging industries, traditional culture systems developed for existing culture species are often used also for new species, resulting in sub-optimal culture conditions and processes. Tech-transfer and adjustment of already existing culture techniques is therefore needed.	N	20%	5	T2.2
	8.3.2	Report	New culture system for oysters	In areas with emerging industries, traditional culture systems developed for existing culture species are often used also for new species, resulting in sub-optimal culture conditions and processes. Development of new systems adapted to local conditions is therefore needed.	Y	20%	3	T2.2
	8.3.3	Report	A new protocol for heat treatment of fouling on oysters will be developed	Fouling of calcifying worms may reduce product value significantly. This type of fouling is more difficult to manage compared to soft bodied fouling organisms and barnacles, and protocols must be developed to allow efficient treatment of fouling.	tbc	0%	3	T2.2
9	9.3.1	Process	Adapted mussel cultivation systems	Initiating the work to modifying existing systems to be submerged .	tbc	10%	2	T2.2
	9.4.1	Process	Protocol for heat treatment of calcifying worms on blue mussels during the production cycle.	Developing a protocol for on-site fouling treatment of calcifying worms on blue mussels and by providing an industry scale demonstration facility for knowledge transfer to the aquaculture industry.	tbc	0%	3	T2.2

Table 7: All outputs related to WP2 from CS10 (Freshwater finfish in Brazil) and CS12 (cross cutting by products from LTS aquaculture) and their requirement specifications (with: CS = corresponding Case Study Number; Ident. = specific identifier; Pot. Product (Y/N/tbc) = potential for becoming a future sellable product (Yes, No, to be confirmed); Complete = level of completeness with regard to what is expected by the end of the project; current technology readiness level (TRL); WP task = the WP task to which each output reports, according to description of action).

CS	Ident.	Output type	Detail	Requirement Specifications	Pot. Product (Y/N/tbc)	Com-plete	Current TRL	WP task
10	10.1.1	Process	Optimized protocol for captive reproduction of pairs of Arapaima gigas in earth ponds.	Protocol designed to increase spawning rates of A. gigas using synthetic hormonal inducers for pairs in earth ponds.	tbc	10%	3	T1.2, T2.2
	10.2.2	Report	Evaluation of triploid tambaqui reared in farms in the Amazon region.	Description of the growth performance of triploid tambaqui when reared at the Amazon farming conditions, in comparison with the diploid form.	N	5%	3	T2.2
	10.2.3	Report	Evaluation of triploid tambaqui reared in farms in other climate zones in Brazil.	Description of the growth performance of triploid tambaqui when reared at the Savanas farming conditions, in comparison with the diploid form.	N	5%	3	T2.2
	10.3.1	Report	Predictive models to identify the type, number and length variation of intermuscular bones in tambaqui, Colossoma macropomum.	A method to estimate the intermuscular bone variations to be include in a future tambaqui breeding program.	N	10%	2	T2.2
12	12.1.1	Report	Incorporation of shellfish aquaculture to the international carbon trading scheme.	Performs tailored estimates of the CO2 sequestration potential of shellfish aquaculture and proposes the triad highest added value, lowest carbon footprint and longest carbon sequestration to identify the best applications for shellfish CaCO3 for each case study.	tbc	50%	2	T2.3
	12.2.1	Process	Protocol for the alkalinisation of the coastal waters of Galicia.	Environmental engineering application of CaCO3 from shellfish aquaculture consisting on adding crusted shells to carbonate ion oversaturated adjacent shelf waters where it can be immobilized for decades. It will be applied to the coastal waters of Galicia, main producer of shellfish in Europe using shell from the mussel industry. Application of this protocol will require authorisation from the Galician government.	N	5%	2	T2.3

Table 8: All outputs related to WP2 from (cross cutting LTS into aquafeeds) and their requirement specifications (with: CS = corresponding Case Study Number; Ident. = specific identifier; Pot. Product (Y/N/tbc) = potential for becoming a future sellable product (Yes, No, to be confirmed); Complete = level of completeness with regard to what is expected by the end of the project; current technology readiness level (TRL); WP task = the WP task to which each output reports, according to description of action).

CS	Ident.	Output type	Detail	Requirement Specifications	Pot. Product (Y/N/tbc)	Com-plete	Current TRL	WP task
13	13.1.1	Product	Diet formulation for European abalone macroalgae-based.	The formulation that will include macroalgae needs to be nutritional balanced (protein, amino acids, lipid, fatty acids, vitamin and minerals) for European abalone juveniles to meet the known requirements for optimal growth.	Y	21%	4	T2.4
	13.1.2	Product	Diet formulation for European abalone macroalgae- and vegetable-based.	The formulation that will include macroalgae and vegetable needs to be nutritional balanced (protein, amino acids, lipid, fatty acids, vitamin and minerals) for European abalone juveniles to meet the known requirements for optimal growth.	Y	21%	4	T2.4
	13.1.3	Product	Diet formulation for African abalone harvested kelp-based.	The formulation that will include kelp needs to be nutritional balanced (protein, amino acids, lipid, fatty acids, vitamin and minerals) for African abalone juveniles to meet the known requirements for optimal growth.	Y	21%	4	T2.4
	13.1.4	Product	Diet formulation for African abalone IMTA macro-algae-based.	The formulation that will include macroalgae needs to be nutritional balanced (protein, amino acids, lipid, fatty acids, vitamin and minerals) for African abalone juveniles to meet the known requirements for optimal growth.	Y	21%	4	T2.4
	13.1.5	Product	Diet for European abalone macroalgae-based.	The diet will have a pellet quality (e.g. density, durability, hardness, water stability), size, and shape suitable for the species and stage.	Y	21%	4	T2.4
	13.1.6	Product	Diet for European abalone macroalgae- and vegetable-based.	The diet will have a pellet quality (e.g. density, durability, hardness, water stability), size, and shape suitable for the species and stage.	Y	21%	4	T2.4

3. Conclusion

Work Packages 1, 2 and 3 have developed a common system to increase reporting efficiency for CS leaders (from 35 institutions across four continents) that produce outcomes that contribute to more than one of these research and innovation work packages. This reporting system was also designed to make the large volume of research (13 case studies, each with numerous tasks) easily available to the project team (particularly the WP leaders of WP4 to WP8 who will require these data to develop their own deliverables) and so that it can be drawn on in a way that makes it accessible and useable. As such, the development of "AquaVitae WP 1 - 3 database" (Appendix 2, D1.2) is an achievement in the first 12-months of AquaVitae that will form a foundation upon which the project can grow.

From the reports that were generated by the CS leaders and recorded in the database, it has become apparent that WP2 will produce a total of 48 main project outcomes, in the form of reports, processes and products. The first 12 months was also used to identify which of these reports, process and products have exploitation potential, and the requirement specifications of each have been identified.

The next two years will see the CS leaders subjecting the outcomes that have been identified in the first loop of the developmental phase, to further research and development through a second loop of research in the developmental cycle. This will incorporate feedback from the evaluation WPs 5, 6 and 7. This period will focus on refining and further developing the details of the requirement specifications of each project outcome, so as to clearly develop their exploitation potential.

Overall, the CS tasks that contribute to the development of WP2 of AquaVitae have reported good progress (Annex 3, D1.2) that remains in line with that expected in the proposed work plans (Annex 3, D1.1), and it remains on-track and in-line with that expected at month-12 of the project.