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Mapping existing and emerging LTS aquaculture in the Atlantic Region

Sub-task in activity 6.1 of Work Package 6 – Environmental Monitoring, Risk Assessment and Sustainability in AquaVitae

Åsa Strand, Anton Rydstedt, Erik Lindblom

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Executive summary

AquaVitae (AV) is a research and innovation project, funded by the EU's Horizon 2020 program. The overall objective is to introduce new low trophic species (LTS), products and processes to marine aquaculture value chains across the Atlantic, with a net positive impact on sustainability.

This report aims to provide a common framework for the AV sustainability and risk assessments, by mapping existing and emerging LTS aquaculture. To be included, the LTS-system must exist at commercial or near-commercial scale or has been proven as a biologically feasible activity in research or pilot-scale activities in the Atlantic Region. These LTS-systems together form AV's so-called assessment domain (AD). Each LTS-system is defined by a unique combination of different domain elements, i.e., geographical sector (Europe, North America, Brazil, or South Africa & Namibia), organism group (brown macroalgae, red/green macroalgae, bivalves, abalone, or echinoderms), production system (land-based ponds and tanks, surface systems or bottom culture systems), production mode (mono- or polyculture), value chain step (seed production or grow-out) and production location (near- or offshore). Data was provided by industry experts from the targeted geographical sectors and supplemented by literature review.

The diversity of LTS-systems was found to be higher in North America and Europe than in Brazil and South Africa & Namibia. Bivalves (mussels and oysters) were found to be the most diverse organism group in terms of valid domain elements, with monoculture production recorded in all culture systems and in all geographical areas. Polyculture of bivalves (often including macroalgae) was recorded in surface systems in all geographical sectors except in Africa. Red/green macroalgae were also found to be cultured in all geographical areas, in both surface systems and land-based ponds and tanks. Echinoderms (sea cucumbers and sea urchins) were recorded in all geographical sectors but Brazil, primarily in monoculture land-based ponds and tanks, while brown macroalgae (e.g., kelp) was only recorded for the northern Atlantic (North America and Europe) and abalone only in eastern Atlantic (Europe and South Africa & Namibia). Most recorded LTS-systems were nearshore activities. Offshore activities were only recorded in Europe and North America, as suspended systems for bivalves, brown and red/green macroalgae.

All in all, 72 unique LTS-systems were recorded. These were compared with data from the Food and Agriculture Organization of the United Nations (FAO) database of Fisheries & Aquaculture from the year 2010 to 2019. The FAO data clearly underlined bivalves as the commercially most important LTS organism group in the Atlantic Region. Furthermore, the FAO data corresponded well to the AD for bivalves, brown macroalgae and abalone, but less so for red/green macroalgae and echinoderms. This is particularly evident for North America, where the FAO data did not show production of any of these organism groups while the AD recognized all of them. This indicates that the AD results allowed identification of emerging aquaculture activities at a scale not registered in the FAO database, and the methodology can thus be a useful tool to predict developing aquaculture sectors. This may facilitate early interventions to support the transition from research to commercialization as well as enable early actions to streamline governance and regulations to facilitate expansion of emerging sectors.

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Abbreviations

AV	AquaVitae
AD	Assessment domain
CSF	Challenge-structuring framework
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
ICES	International Council for the Exploration of the Sea.
IMTA	Integrated multi-trophic aquaculture
LTS	Low-trophic species
RAS	Recirculating aquaculture systems
SDG	United Nations sustainable development goals
VC	Value chain
WGOAA	ICES Working Group of Open Ocean Aquaculture
WP	Work package

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1. Introduction

1.1. Synopsis of AquaVitae

AquaVitae (AV) is a research and innovation project, funded by the EU's Horizon 2020 program. The project consortium consists of 35 partners, from 16 different countries spread across four continents. In addition to Europe, partners are situated in countries bordering the Atlantic Ocean, including Brazil, South Africa, Namibia, as well as North America. The overall objective of AV is to introduce new low trophic species (LTS), products and processes to marine aquaculture value chains (VCs) across the Atlantic, in a sustainable way. AV focuses on the VCs for macroalgae production, integrated multi-trophic aquaculture (IMTA) and production of new echinoderm species as well as of underutilized shellfish species and low trophic finfish species. In addition to research in specific VCs, a significant part of the research activities in AV, directed through several work packages (WPs), focuses on aspects of high relevance to the different domains in the sustainability matrix (social, economic, and environmental). WP6, by which this report was developed, is one of AV's four cross-cutting scientific WPs. Its main objective is to develop recommendations on how to increase LTS aquaculture production with a net positive impact on sustainability in and around the Atlantic Ocean.

1.2. Scope and motivation

To achieve AV's objective to sustainably increase LTS aquaculture production, opportunities must be exploited, and threats mitigated. To facilitate this, a Challenge-Structuring Framework (CSF) for sustainability and risk assessment was established by WP6. This framework consists of a **description of the desired state** for LTS aquaculture in the Atlantic Region, **prioritized sustainable development goals (SDGs)** and a set of **sustainability indicators** deconstructed into four domains of sustainability, as seen in Figure 1.

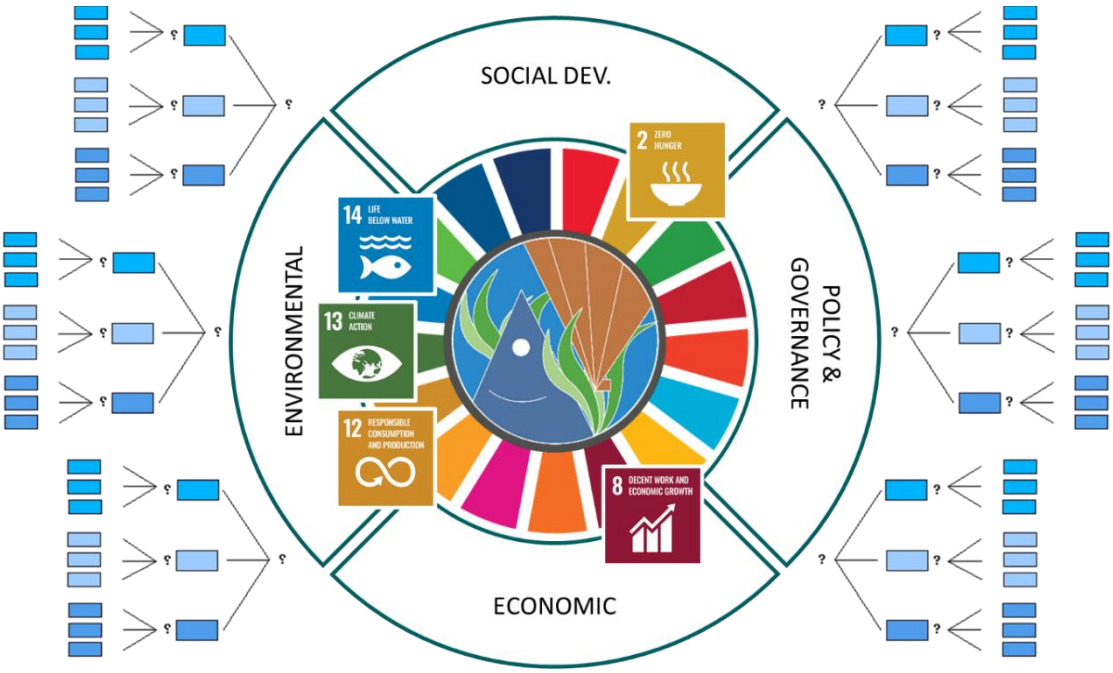

Figure 1. A conceptual illustration of the challenge-structuring framework (CSF) for sustainability and risk assessment of low-trophic species (LTS) aquaculture in the Atlantic Region.

To fully integrate the activities and ambitions of the AV project into the developed framework and to support identification of what systems to target in the forthcoming sustainability and risk assessments, both existing and emerging LTS aquaculture activities were mapped and described in an assessment domain (AD). The AD was constructed from a set of characteristics (main aspects/categories, e.g., organism group or production system), each consisting of several pre-determined elements (sub-categories, e.g., bivalves, brown macroalgae or surface systems, bottom culture systems) describing the activities, with each unique combination of characteristics (i.e., of one element per characteristic) resulting in the description of one type of LTS-system. The total of all possible LTS-systems constitutes the domain, providing the boundaries and resolution for the work to come.

In this report, the results from the mapping of existing and emerging LTS aquaculture activities around the Atlantic is reported and summarised. The results are related to FAO production statistics and analysed in terms of recommendations for the WP6 activities. In more general terms, the report may also act as a baseline to explore regional differences in LTS aquaculture diversity as well as diversification of LTS activities over time in the region.

2. Methods

2.1. Outline

The AD is defined by a set of characteristics, selected by the AV environmental sustainability core team in WP6 to delimit AV's scope. Each characteristic consists of several pre-determined elements, giving the boundaries and resolution of LTS systems around the Atlantic, in the form of a multi-dimensional matrix (Figure 2). Each node, or combination of characteristics, represents one possible LTS-system. Note that "LTS system" does not strictly refer to a production system, but a unique combination of characteristic elements, where the production system is but one element. The general criteria for including a LTS system in the AD was that the LTS system must exist at commercial or near-commercial scale, or that the activity had been proven as a biologically feasible activity in research or pilot-scale activities in the Atlantic Region. These criteria were selected to enable identification also of emerging activities not yet visible in FAO aquaculture production statistics.

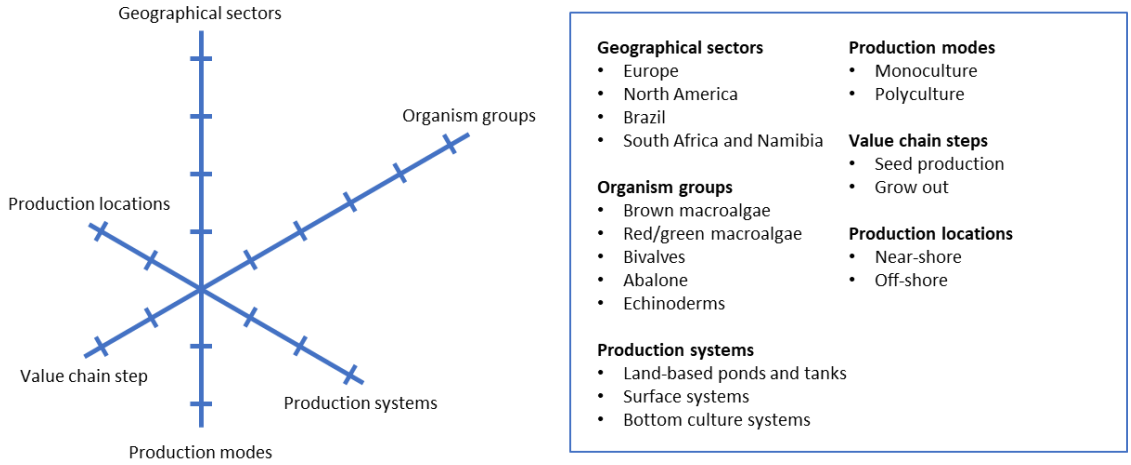

Figure 2. The total domain theoretically consists of 480 LTS-systems, each a unique combination of the six characteristics' different elements.

2.2. Progress of domain definitions

The AD was developed in two major steps. First, it was structured through identification of the domain's characteristics and elements. Second, existing LTS-systems were scoped. Step 1 was initiated during a break-out meeting at the AV kick-off meeting in Tromsø, Norway, in June 2019. The domain was evaluated on a few internal test users and then modified according to received feedback. In line with the iterative principles applied, several revisions were made to the original domain's structure during the second half of 2019. Noteworthy changes were:

1. The inclusion of the organism group echinoderms (initially excluded).
2. Revision of geographical boundaries.
3. Addition of production location (nearshore/offshore).
4. The merging of two production system types (land-based tank and pond systems with static or batch-wise water exchange/land-based recirculating and flow-through systems).

The domain characteristic **geographical sector** was initially based on the temperate and tropical zones in the Atlantic Ocean combined with geographical location (i.e., North, South, East, West). Based on the AV partner list (and subsequent good knowledge base of existing LTS aquaculture activities) the following areas were included in the domain: Northeast temperate/Europe, Northwest temperate/North America, West tropical/Brazil, and Southeast temperate/South Africa & Namibia. The elements were later updated to FAO's major fishing areas (Figure 3) to facilitate alignment to statistical databases. (Note that these delimitations do not align completely with geographical/political definitions of the related continents.)

- Europe = Area 27 Atlantic, Northeast
- North America = Area 21 Atlantic, Northwest
- Brazil = Area 41 Atlantic, Southeast
- South Africa & Namibia = Area 47 Atlantic Southeast

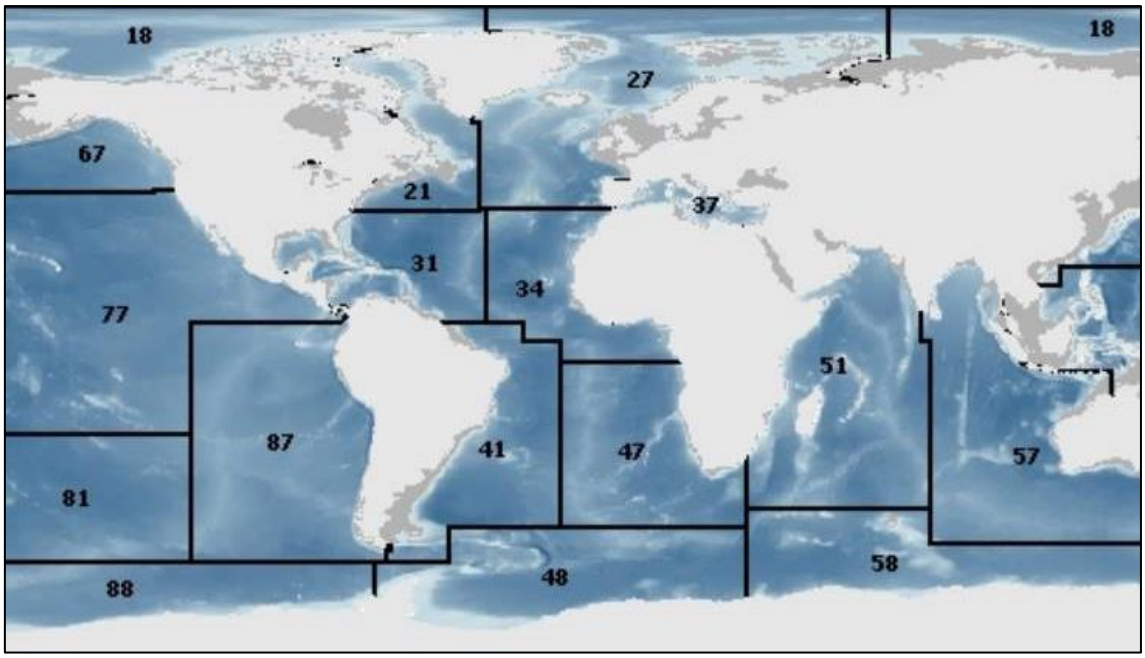

Figure 3. FAOs major fishing areas.

The domain characteristic **organism group** was characterized using the organism value chains (VC) proposed in AquaVitae as a basis. This resulted in the elements brown macroalgae, red/green macroalgae, bivalves (limited to mussels and oysters), abalone and echinoderms (sea cucumbers and sea urchins). Finfish was excluded due to the existence of several other EU projects (e.g., Diversify[1], ClimeFish[2] and others) that already cover sustainability and risk assessments related to fish aquaculture.

Production system refers to the technique or method of production of the aquaculture species. This category initially included five different elements (land-based ponds and tanks with static or batch-wise water exchange, Land-based recirculating and flow-through systems, Suspended systems, Bottom culture systems and Surface-based floating cage systems). The differentiation between the first two elements was initially based on the exchange rate of water in the systems. This level of detail was too difficult to maintain throughout the scoping process and the two elements were therefore merged into the element "land-based ponds and tanks". Moreover, the element "surface based floating cages" was only valid for oysters and was evaluated to be too specific in relation to the other element categories and was therefore merged with the element "Suspended systems" that was then renamed to surface systems. The systems' definitions are partly based on the FAO definitions[3] and were finalized as:

- Land-based ponds and tanks are artificial holding units of varying sizes constructed above or below ground and capable of holding and interchanging water at varying rates, depending on construction and design. The category includes both open and closed systems with respect to water and nutrient exchange with the surrounding environment, ranging from fully interconnected systems such as flow-through systems or systems with partial water exchange in ponds, raceways, or tanks, to semi-closed or fully closed recirculating aquaculture systems (RAS) where the use of mechanical and biological filtration allow up to 100% water reuse. As apparent by the category name, only land-based systems are considered, hence sea-based, semi-closed systems for fish culture are not included in the definition as fish was not an included element in the category "organism group".
- Surface systems are traditional longline systems, rafts, or other systems where lines, nets or cages are hanging freely in the water column and are supported by structures providing buoyancy. The element also includes surface-based structures using net or mesh (plastic or metal). Systems for fish culture (net-cages or semi-closed systems) are not included in the definition as fish was not an included element in the category "organism group".
- Bottom culture systems include both on-bottom and off-bottom culture techniques. On-bottom culture is also referred to as "sea-ranching" and refer to relaying of the culture organism directly on the seabed for grow-out either during the full grow-out period or part of the grow-out period. Off-bottom culture structures include plastic mesh bags (e.g., for oysters), plastic, wooden or metal cages, racks or other structures either placed directly on the bottom or supported by structures that are standing on/attached in/on the bottom (e.g., poles, racks etc.).

[1] https://www.diversifyfish.eu/
[2] https://climefish.eu/
[3] Coordinating Working Party on Fishery Statistics (CWP). http://www.fao.org/cwp-on-fishery-statistics/handbook/aquaculture-statistics/en/

Production was also divided into the characteristic **production mode** defined as monoculture (i.e., culture of one single species) or polyculture (i.e., culture of several species in one system). Polyculture may include species from different trophic levels or ecological niches, as in Integrated multitrophic aquaculture (IMTA), or species from the same trophic level and ecological niches. In the definition of polyculture, only intentional co-culture was considered, i.e., unintended settling of fouling organisms on sea-based seed collectors or culture structures was not considered polyculture.

For **value chain step**, two production steps were included as elements: seed production and grow-out. Seed production includes both wild seed collection, hatchery processes and nursery production, while grow-out was defined as the production of the species from placement in a grow-out system to harvest.

Originally, only nearshore LTS aquaculture activities were included as an element for the characteristic **production location** in the domain. However, due to the status as an emerging sector, offshore was included as a supplementary element in the domain. There are no general definitions of “nearshore” and “offshore” that may help delimit the two regions. Such a definition is currently under development in the International Council for the Exploration of the Sea (ICES) working group (Working Group of Open Ocean Aquaculture - WGOAA). The current division is therefore to be considered subjective with “offshore” representing cases of aquaculture considered to be located in high energy and exposed conditions by the data provider. The category “nearshore” includes activities located on land as well as all sea-based activities not considered to be “offshore”.

Step 2, the scoping of LTS systems, was mainly carried out during autumn 2019, after the refinement of the domain characteristics and elements, i.e., integration of new elements (organism groups and production location), modification of element definitions (geographical areas) and exclusion of elements (VC steps). Additional changes to the AD after initiation of data collection (reduction in number of elements in the production systems category) only resulted in aggregation of data from the data collection matrix and could therefore be done during the data collection and analysis process. The domain was disseminated to identified key expertise primarily CS leaders and other participants within the AV consortium who were asked to provide data based on their expertise related to specific organism groups or geographical areas. External experts were addressed when needed. All respondents had the possibility to mark domain elements as valid (1), unsure/conflicted (disagreement between two or more experts regarding the validity/existence of a specific case, 2), or invalid (0), and to comment on what was referred to in the response or provide references. The input was followed up by literature searches and direct contact with respondents for data validation. After data collection, the AD data was checked for consistency and quality and challenged inputs (labelled 2) were validated through literature and expert contacts.

3. Results

3.1. Geographical sectors, locations, and value chain steps

The final selection of domain characteristics and elements resulted in a total of 480 possible combinations (i.e., unique LTS systems), of which 72 existing or emerging LTS systems were identified as valid cases for the AD (see also section 2.1). The distribution of these valid cases differed between **geographical sectors** with the highest number in Europe, followed by North America, South Africa & Namibia (denoted as Africa in the text below) and Brazil (Table 1). It is

noteworthy that the diversity in LTS systems was found to be substantially higher in North America and Europe compared to in South Africa & Namibia, and Brazil.

Table 1. Number of valid cases in the AD depending on the area. Each case represents a unique combination of geographical sector, production location, value chain step, production system, production mode and organism group

FAO-fishing area	Valid cases (number)
Area 21 (North America)	20
Area 27 (Europe)	28
Area 47 (South Africa & Namibia)	13
Area 41 (Brazil)	11

The first domain characteristic to be explored was **location** (offshore/nearshore). Nearshore activities were more diverse compared to offshore activities, covering all organism groups and geographical sectors. Offshore activities, on the other hand, were only present in the Europe and North America. Suspended systems were (not surprisingly) the only type of production system used in offshore locations, and only brown macroalgae, red/green macroalgae and bivalves were represented in these systems (not echinoderms or abalone). Bivalves (mussels) were also the only organism group for which sea-based seed production in offshore environments was utilized. The systems included both monoculture and polyculture.

The next domain characteristic to be explored was the **value chain step** (VC-step). Except for sea-based seed collection of mussels, offshore systems were only used for grow-out. Nearshore systems were used for both seed production and nursery/grow-out. Seed production was identified as being primarily monoculture, except for in special cases such as abalone, where abalone was cultured with macroalgae or diatoms during the hatchery phase in Europe and Africa. However, there were also monocultures of abalone.

The two major **production systems** for seed production were land-based ponds and tanks (all organism groups), and for bivalves also surface systems in all areas (collection of wild mussel and oyster seed through natural settlement on artificial substrates), and bottom culture systems in Europe and Brazil (primarily bottom-based structures for wild oyster seed collection).

Due to the low diversity of systems in offshore areas, as presented above, the following comprehensive analysis was done on nearshore activities only.

3.2. Grow-out in nearshore activities

The general analysis revealed that the complexity in valid domain elements were primarily driven by **geographical sector, organism group** and **production systems** for the grow-out VC step for nearshore activities. Therefore, all valid cases in nearshore areas and during the grow-out VC step were selected for further analysis. In the analysis, the existence of valid cases in terms of culture system was compared between different geographical regions for each organism group separately. The results are presented below and are visualized in Figure 4.

- **Abalone**: Abalone culture was only identified on the east coast of the Atlantic Ocean, i.e., in Europe (3 valid cases) and in Africa (3 valid cases), in the form of monoculture in bottom culture systems and in land-based ponds and tanks. A few cases of polyculture (IMTA) were also recorded, e.g., in bottom culture systems in Europe (abalone with macroalgae cultured as food for the abalones) and in land-based ponds and tanks in Europe and Africa (abalones cultured with macroalgae and abalones cultured with sea cucumbers in a research setting).

- **Bivalves**: Bivalves (mussels and oysters) were found to be the most diverse organism group, with 14 valid cases out of 24 possible in the AD. Bivalves were cultured in all geographical regions, but only in surface systems in Africa, where bottom culture systems have been used previously but are no longer in use. Both surface and bottom culture systems were used in north America, and in Europe and Brazil, all three system types were used. Pond culture of oysters is practiced, often in polyculture systems, in northern Brazil, and in Europe pond systems are sometimes used for conditioning the oysters before harvest and release to the market. Whether conditioning for increased market quality should be included in the grow-out phase can be debated but was nevertheless included in this analysis. Monoculture of bivalves was recorded in all culture systems and in all geographical areas. Polyculture of bivalves (often including macroalgae) was recorded in surface systems in all geographical regions except for in Africa. Other examples of polyculture included the previously mentioned culture of oysters and other organisms in ponds in Brazil and oysters in bottom culture systems together with other bivalve species in North America. The number of valid cases in North America, Europe, Africa, and Brazil were 4, 4, 1, 5 for the different geographical areas respectively.

- **Brown macroalgae**: Culture of brown macroalgae (e.g., kelp) was only recorded for the northern Atlantic, i.e., North America (2 valid cases) and Europe (3 valid cases). In both regions, both mono- and polyculture were recorded in surface systems (primarily longline systems, combination of mussels and kelp or fish and kelp). In Europe, bladderwrack (*Fucus sp.*) was also cultured in land-based ponds and tanks in Europe.

- **Echinoderms**: Echinoderms (sea cucumbers and sea urchins) were found to be cultured in all areas except for in Brazil and primarily in monoculture in land-based ponds and tanks. In Africa, sea cucumbers were also co-cultured with abalone in a research setting (as mentioned previously), and in North America (Canada) surface systems were used for sea urchins with culture primarily focused on “live storage”/conditioning during the roe enhancement processes. In many cases the activities were identified as emerging activities (i.e., research and/or pilot-scale activities). The number of valid cases in North America, Europe, Africa, and Brazil were 2, 1, 2 and 0 for the different geographical areas respectively.

- **Red/green macroalgae**: Red/green macroalgae were found to be cultured in all geographical areas in both surface systems and in land-based ponds and tanks. In North America there was only monoculture, but in the other geographical regions cases of polyculture were recorded. In Europe, different red and green algae (*Ulva, Codium, Porphyra, chondrus crispus*) were co-cultured in land-based ponds and tanks. In both Africa and Brazil, polyculture was recorded in two of the culture systems. In Africa in the form of co-culture of Abalone and *Ulva* (as previously mentioned in land-based ponds and tanks), but also in the form of co-culture of mussels and *Gracilaria* in surface systems. In Brazil, shrimp are co-cultured with *Ulva* at experimental scale in land-based ponds and tanks at several locations, and *Kappaphycus* is co-cultured with mussels in surface systems, also at experimental scale. The number of valid cases North America, Europe, Africa, and Brazil were 2, 3, 3 and 3 for the different geographical areas respectively.

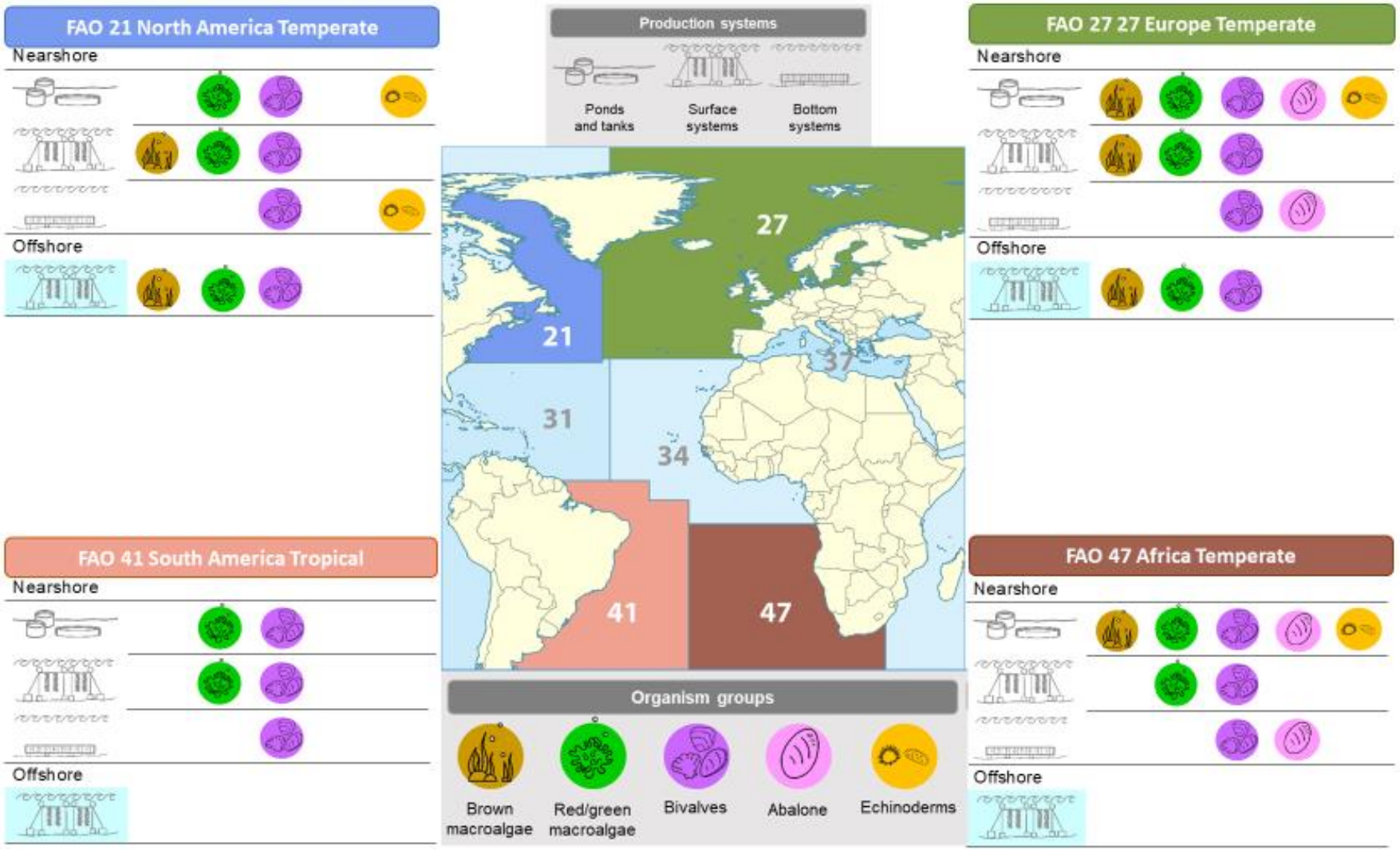

Figure 4. Illustration of existing and emerging LTS aquaculture in the Atlantic Region. Background map is based on "FAO Major Fishing Areas", by NordNordWest under CC BY 3.0. Figure developed jointly by CETMAR and IVL.

3.3. FAO aquaculture statistics

Statistics of commercial aquaculture production is available at FAO[4]. For quality control and as a comparison to the results in the AD, aquaculture production data (fresh wet weight, tonnes) from the FAO database of Fisheries & Aquaculture from the year 2010 to 2019 was collated based on the following search criteria;

- Oceanic area: Atlantic, northern and southern, and east and west Atlantic.
- Sixteen countries with coastlines around the Atlantic Ocean were selected, including South Africa & Namibia (area 47), Brazil (area 41), United State of America and Canada (area 21) and eleven countries in Europe (area 27).
- Organisms included were the international standard statistical classification of aquatic animals and plants (ISSCAAP) groups brown, green and red seaweeds, all sea-urchins and other echinoderms, mussels, and oysters. Abalone was selected as family *Haliotidae*.
- Years 2010-2019
- Marine areas

The FAO data corresponded well to the AD for the organism groups abalone, bivalves and brown macroalgae in terms of representation in geographical areas. For echinoderms, however, the FAO data indicated production only in Europe, while the AD also highlighted production in North America and Africa. In addition, the FAO data reported commercial production of red/green macroalgae in Europe, Africa and in Brazil, while records of such activities were also noted for North America in the AD. This illustrates the emergence of new activities in accordance with expert comments received during the development of the AD. The data also highlights the importance of bivalves in commercial culture around the Atlantic.

Table 2. Regional sums of country specific average yearly production quantity of LTS for 2010–2019 (live wet weight, tonnes) according to the FAO database of Fisheries & Aquaculture. Blue cells indicate which combinations of organism group and geographical sectors are identified as valid in the AD.

Organism group	Europe (Area 27)	North America (Area 21)	Africa (Area 47)	Brazil (Area 41)	Sum
Abalone (tonnes)	8		1,333		1,341
Bivalves (tonnes)	444,163	32,398	2,330	19,095	497,986
Brown macroalgae (tonnes)	861	45			906
Echinoderm (tonnes)	1				1
Red/green macroalgae (tonnes)	21		2,325	730	3,076

[4] Global aquaculture production Quantity (1950 - 2019). https://www.fao.org/fishery/statistics-query/en/aquaculture/aquaculture_quantity

4. Discussion and conclusions

The primary objective of the AD was to support the work in WP6 in the AV project with a framework and boundaries for the forthcoming sustainability and risk assessment analysis aimed at supporting a sustainable expansion of LTS aquaculture around the Atlantic. Given the systemic approach explained above, yet with the realistic understanding that these may not be *all* the LTS-systems in this vast geographical region, the iterative process of the AD development resulted in a fair representation of existing systems in the region. In addition, we have created a typology to classify the cultures of LTS and a rough overview of the status of LTS farming surrounding the Atlantic Ocean.

Currently, bivalves are the most important organism group of low trophic species produced in the Atlantic Ocean and the group is well represented in all geographical areas across the Atlantic. Consequently, this group should be included in the forthcoming analysis in WP6 as the scale of the current production infers a high probability of access to high quality data, as impacts based on the scale of the production may be impactful and as there is an expressed interest from both policy bodies and industry to further expand the production of this organism group. Since some organism groups, such red/green macroalgae and echinoderms were identified as emerging activities, it is important to evaluate the sustainability and risks of production of these organism groups before the production increase. This, however, may be challenging due to data availability constraints. Moreover, as different organism groups are not equally represented or important in all geographical areas, cases for analysis should be selected carefully to enable relevant comparisons between regions and/or organism groups.

Although the purpose of the AD was to facilitate the work related to sustainability and risk assessments for LTS around the Atlantic in the AV project, some general conclusions can be drawn from the results:

- The culture of bivalves is the most diverse (i.e., has the highest number of valid cases for all organism groups). This is not surprising considering the dominance in production, both in quantities and in number of species observed in the FAO data for this organism group. The diversity of species and the wide geographical spread of the organism group will require species specific and local adaptations of culture systems, as the culture activities must be adapted to the local context.
- The diversity in LTS-systems identified in the AD was highest in Europe, which was also the geographical region with the highest production of the corresponding organism groups in the FAO data. Although lower than in Europe, the diversity in north America was also higher compared to in Brazil and Africa. This may be a consequence of the recent efforts to explore the possibilities to expand also LTS aquaculture into offshore areas and into multi-use areas, as well as increased incentives to promote brown seaweed culture in Europe and North America.
- Africa and Brazil have similar diversity in terms of total number of valid cases in the AD, 13 and 11 respectively (see Table 1). However, Africa appear to utilize a wider species variety (4 organism groups compared to 2 organism groups according to the AD for Brazil). At the same time, FAO data report roughly four times higher production in Brazil than in Africa, indicating a strong focus on a selected few species. The recent challenges related to pathogen outbreaks experienced by e.g., the European and Australian oyster industry reflects the importance of diversification of the aquaculture industry to increase resilience and adaptation potential to emerging threats.

Moreover, the comparison between the AD results and FAO production statistics confirmed the analysis of emerging organism groups in aquaculture around the Atlantic area. Over the past years, significant effort has been directed towards development and expansion of culture of seaweeds and diversification of aquaculture species production. This was reflected in the AD by records of red and green macroalgae production in different geographical regions, yet this information was not reflected in the FAO data. Similarly, echinoderms seem to be an organism group in advancement, at least in the research community. This indicates that the methodology used to develop the AD can be a useful tool to predict developing sectors in aquaculture, which may facilitate early interventions to support the transition from research to commercialisation as well as enable early actions to streamline governance and regulations to facilitate expansion of emerging sectors. The data presented in this report may also allow monitoring of diversification of LTS aquaculture around the Atlantic by offering a baseline for the state-of-the-art in LTS culture in 2019.

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