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Deliverable D8.3

Recommendations for LTS aquaculture policy framework

31/05/2022

Executive summary

Low-trophic aquaculture (LTA), which primarily includes cultivation of molluscs, echinoderms, shrimp and macroalgae, as well as plankton-feeding fish, represents an opportunity for efficient and sustainable food production. However, some of the major challenges for the realisation of this opportunity are that the complex regulatory frameworks designed for managing the production of a few commercial aquaculture species, usually finfish and bivalve molluscs, are not necessarily well suited to novel LTA products and processes, and could lack real-world flexibility to accommodate sustainable aquaculture diversification.

Such challenges have been highlighted in previous AquaVitae work, with the existing governance context and regulatory barriers analysed in-depth in Deliverables 8.1 and 8.2 (AquaVitae D8.1 and D8.2). The former, on current policy frameworks for aquaculture in Europe, Brazil and South Africa (D8.1), reviews existing legislation in eight countries in the Atlantic, provides the status and identifies gaps in regulations relevant for LTA. The latter, on industry perceptions of current policy frameworks for LTA (D8.2), provides insights on what stakeholders perceive to either constrain or promote LTA. The goal of the present Deliverable (AquaVitae D8.3) is to synthesise previous findings and complement this work by providing recommendations for policy frameworks for LTA in Europe, Brazil and South Africa and take a strategic approach to policy-making in this fast evolving food blue economy sector.

While results from D8.1 and D8.2 highlighted the need to address specific regulations and aspects of regulatory frameworks, a more strategic approach considers improving adaptive capacity of the aquaculture policies, allowing flexibility to incorporate emerging opportunities related to new production forms, including LTA. Research on adaptive governance promotes the idea that governance systems can be designed in a way that facilitates adaptation to emerging changes. Laws, for example, can have built-in mechanisms that help realise stakeholders' inherent adaptation capacity. The main characteristics of adaptive processes include flexibility and openness to revision, iterative decision-making, experimentation possibilities and constant integration of new knowledge (DeCaro et al., 2017). Adaptiveness also promotes formal and informal self-organisation and participation of stakeholders (Cosens et al., 2017). Characteristics of adaptive governance translate to design principles of legal frameworks and institutions, which describe specific features that make laws and institutions adaptive. These design principles can be used as criteria to evaluate adaptive capacity, to help identify problematic areas and prioritise areas for improvement.

Accordingly, this Deliverable (AquaVitae D8.3) analyses aquaculture policy frameworks across the Atlantic from the perspective of adaptive governance, using fifteen legal design principles (adaptiveness criteria) synthesised from the literature. A quantitative scale was used for assessment, to facilitate visualisation and interpretation of the results. The countries and regions included in the analysis are Spain (Galicia), Germany (Schleswig-Holstein), Scotland, Norway, Brazil and South Africa. For each, the legislation and regulations that are most relevant for LTA management were assessed. The results were aggregated by region, document, and by adaptiveness criterion (Figure 1,2).

We studied the extent to which aquaculture policy documents contain features linked to adaptiveness, but stopped short of seeking evidence that regulatory adaptiveness improves the adoption of LTA. The aggregated results of the study provide a general picture of aquaculture policy adaptiveness in relation to LTA, highlighting the scope for improvement of the adaptiveness of regulations in different countries and regions of the Atlantic. Our analysis suggests that most of the reviewed aquaculture legislation lacks properties of iterative governance process, where planning for revisions, learning and

incorporation of new knowledge were the weakest points. This creates legal uncertainty for practicing LTA and other innovative aquaculture concepts. Many of the documents relevant for LTA regulation do not provide sufficient opportunities and/or requirements for delegation and stakeholder participation, which limits possibilities for stakeholders to influence regulatory frameworks locally. Although some of the adaptiveness criteria, such as simplification of administrative procedures and funding provision were satisfied in many cases, these improvements are often fragmented and lack a systematic approach.

In light of these novel findings, results from D8.1 and D8.2, and current state of the art, we propose the following general recommendations for aquaculture policy development in the Atlantic:

1. **Improve adaptive capacity** of regional and national aquaculture laws and regulations, to promote LTA development.
2. Prioritise the creation of **iterative regulation processes**, considering learning and the incorporation of new knowledge.
3. Include provisions for the **regular evaluation and revision of central policies and regulations,** in order to best address emerging risks and opportunities.
4. Include provisions for **delegation to local and sectoral authorities and stakeholder groups,** facilitating self-organisation.
5. Address **stakeholder participation** in the aquaculture laws and regulations.
6. Address aquaculture **diversification** in legislation, in countries or regions with developed and highly specialised aquaculture.
7. Further **simplify and streamline** regulatory procedures in aquaculture and LTA in particular.
8. In cases where specific LTA regulations are lacking, **widen the scope of existing regulations** so that core definitions and areas of application include low-trophic species.
9. **Allocate diverse tangible support**, in the form of **funding and/or access to infrastructure**, to support stakeholders and promote adaptation activities.

The implementation of these recommendations alone may not be sufficient to significantly support the future development of LTA, and adaptive properties of institutions (e.g., social norms), processes and communities is a necessary condition for making use of adaptive regulations. Importantly, aquaculture regulations, including those related to LTA, are not independent from the national legislation systems which set the limits for adaptiveness and improvement for laws and processes. Regional adaptiveness strategies should consider these local institutional and legal constraints. A detailed regional analysis is recommended to work out tailored recommendations for each region, and which are fit for the potential novel species and systems most relevant to each context. Experts, policy makers and stakeholders in these countries play the key role in this work. Thus, this Deliverable is a valuable key input for further work in in AquaVitae WP8 and WP9. In particular, it is expected that the aggregated results will be used as a starting point for discussion of regional aquaculture policies during a planned meeting with stakeholders and policy makers within AquaVitae Policy Forum. This report also contributes to the overview of good practices for policy development for LTA (AquaVitae D8.5).

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Abbreviations

EEZ	Exclusive Economic Zone
ESGA	Estratexia Galega da Acuicultura (Galician Aquaculture Strategy)
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
IMTA	Integrated Multi-Trophic Aquaculture
LTA	Low-Trophic Aquaculture
LTS	Low-Trophic Species
MELUND	Ministerium für Energiewende, Landwirtschaft, Umwelt, Natur und Digitalisierung (Ministry of Energy, Agriculture, the Environment, Nature and Digitalisation), Schleswig-Holstein
NASTAQ	National Strategy for Aquaculture Development (Germany)
OECD	The Organisation for Economic Co-operation and Development
SES	Socio-Ecological Systems
WFD	Water Framework Directive

1. Introduction

1.1 Low-trophic aquaculture (LTA)

Aquaculture is an important contributor to global food production with 82,1 million tonnes of aquatic animals and 31,5 million tonnes aquatic plants produced in 2018 (FAO, 2020). Aquaculture products are utilised directly and indirectly for human consumption through various value chains.

In terms of edible weight, globally finfish species account for 89 % of aquaculture production output (Edwards et al., 2019). However, sustainable increase of food supply by finfish fed aquaculture is constrained by its reliance on wild-caught fish as aquaculture feed ingredients. Even with a steadily improving feed ratio, increased use of alternative protein sources, and improved wild-caught fish-for-feed utilisation, the growing demand for seafood may drive the production beyond sustainable limits by 2050 (Froehlich et al., 2018).

In addition to its role in direct human consumption and as ingredients in food, aquaculture products and by-products are processed further for animal feed (Morais et al., 2020; Øverland et al., 2019), bait and fertilisers (Stevens et al., 2018; Yan & Chen, 2015), thus entering the food system as inputs in multiple agriculture value chains. The demand for ingredients from aquaculture for such purposes is likely to increase (OECD/FAO, 2020).

One path towards a sustainable expansion of the production of marine species for human consumption directly and indirectly concerns the cultivation of plant- and plankton-feeding species and autotrophic organisms in non-fed aquaculture systems. The calls for shifting aquaculture towards lower trophic levels have been supported internationally (European Commission et al., 2017).

In this study, we use the term low-trophic aquaculture (LTA) to refer to the cultivation of marine species such as molluscs, echinoderms, crustaceans and small pelagic fish, that are primarily plankton-feeders (Smith et al., 2011) and marine macroalgae (seaweed). Apart from their value as input in food production, these species provide a range of ecosystem services including carbon storage, water purification and habitat for commercially valuable fish species (Barrett et al., 2022; Suplicy, 2020; van der Schatte Olivier et al., 2020). Due to their ability to utilise aquatic nutrients, they have been produced together with finfish in integrated multi-trophic aquaculture systems (IMTA), increasing the total productivity of aquaculture systems (Handå et al., 2013). The efficient use of resources by low-trophic organisms results in increased economic efficiency and reduced food waste (Neori & Nobre, 2012). In case of IMTA, economic potential is also related to product diversification, optimising production cycles and price premiums on more sustainable products (Knowler et al., 2020). Some of the low-trophic species, such as sea urchins and sea cucumbers are high-value niche products and are considered promising candidates for aquaculture, especially within IMTA (Grosso et al., 2021).

Several low-trophic marine organisms are already produced on a large scale. Production of seaweed (cultivated and wild-collected) has increased from 10,6 million tonnes in 2000 to 32,4 million tonnes in 2018, of which farmed seaweed constitutes over 97% of total output (FAO, 2020). Most of the seaweed production is concentrated in China (18,5 million tonnes) and Indonesia (9,3 million tonnes). The growth in seaweed production in the recent decade was driven mostly by their utilisation for carrageenan extraction, which apart from numerous industrial applications is used as thickening and stabilising agent in foods. Some macroalgae species, such as wakame (*Undaria pinnatifida*) and nori

(*Porphyra spp*.) are cultivated mostly for human consumption, with production totalling 4,3 million tonnes live weight in 2018 (FAO, 2020).

Cultivation of molluscs (mostly bivalves) accounts for 17,5 million tonnes in 2018 (FAO, 2020). Shrimp aquaculture has been increasing around the world, with leading producers located in Asia and Latin America, including Mexico and Brazil (Boyd & Jescovitch, 2020; Valenti et al., 2021). Other low-trophic species, such as echinoderms and gastropods are produced on a limited scale. However, due to the high demand, sea cucumber aquaculture has been expanding significantly in Asia (Gianasi et al., 2021), while abalone has been produced on land in South Africa since 1990-s (Robertson-Andersson et al., 2007).

In Europe, LTA is mainly represented by mollusc farming, where France is the major producer of oysters, Spain is the main producer of mussels and Italy is the leading producer of clams (Gutiérrez et al., 2020). However, production has been declining since 1990-s due to technological, economic and ecological challenges (Avdelas et al., 2021). Seaweed aquaculture in Europe is in early stage of development. Unlike Asian countries, most of seaweed biomass in Europe is harvested from wild stocks. Norway has the highest number of macroalgae producers (13) among European countries (Araújo et al., 2021).

1.2 Challenges for LTA development

Expanding low-trophic species production is not without challenges. Conceptually, advocates of LTA have been challenged by the fact that the term of "trophic levels" is being blurred as innovation in feed composition (i.e. increasing proportions of vegetable matter) leads to lowering the *effective* trophic level of aquaculture production (Cottrell et al., 2021). In this respect, a relative term, "lower-trophic" is more appropriate. Further, environmental, and economic sustainability gains of expanding lower-trophic aquaculture are not obvious, as this activity also generates waste and requires space and energy that have alternative use.

Several obstacles also exist on the practical level. The growth in LTA is constrained by current state of knowledge on the biology of many low-trophic aquatic organisms. Consumer preferences for traditional types of seafood limit the market for LTA products (Belton et al., 2020). Moreover, environmental and economic benefits of LTA are likely to be site-specific (Barrett et al., 2022). Social acceptance of aquaculture in general, as noted by producers in AquaVitae D8.2 workshops, can represent another problem for LTA development (Cavallo et al., 2021), where the negative attitudes are partly attributed to potential environmental externalities.

Regulatory challenges related to the quality and structure of governance are suggested to play an important role in aquaculture development. Gentry et al. (2019) highlight the need for integrated governance that encourages dialog between stakeholders and feedback to policy makers, which could be particularly relevant as aquaculture diversifies and new production methods develops from exploratory to large-scale commercial ventures. Dialogue should be supported on the administrative level by establishing and streamlining procedures and providing necessary investments. The stringency of environmental regulations has been noted by Abate et al. (2016) to correlate with lower growth rates of aquaculture industry in developed countries, highlighting the challenge of striking a suitable dynamic balance between protectionism and economic development across contexts, but also one which could accommodate over time the required sustainable development pathway for the aquaculture industry.

Regarding the regulatory frameworks related to LTA specifically, studies from different countries and AquaVitae D8.1 find some common barriers. Marine spatial planning has been one of the fields not easily adapted to the LTA and IMTA context (Stenton-Dozey et al., 2021). Elements of food safety rules, environmental policies, aquaculture licensing, taxation and subsidising has been identified as problematic for farming of aquatic plants in EU (Lähteenmäki-Uutela et al., 2021). Similar challenges were found in the Norwegian seaweed aquaculture (Stévant et al., 2017). High regulatory costs were estimated for molluscs farming in the US (van Senten et al., 2020), primarily associated with permit application procedures.

An analysis of aquaculture regulations in eight areas of the Atlantic Ocean was conducted as part of AquaVitae WP8 (AquaVitae Deliverable D8.1), covering Scotland, Norway, Germany, Sweden, Spain (Galicia), Portugal, South Africa and Brazil, as well as EU in general. The objective of the report was to give an overview and identify the barriers in the aquaculture regulations in these countries in relation to the LTA and IMTA development. The legal analyses addressed several domains: access to natural resources and space through licensing; marine spatial planning; the rules of aquaculture operation; environmental, food security and animal welfare. The study found that despite much progress made recently, the legislation in many areas still represents significant obstacles for LTA development. Cumbersome and time-consuming licensing procedures, unclear rules and the difficulty in assessing policy compliance was identified as common barriers. Moreover, legislation on new aquaculture forms, such as IMTA, has generally not yet been developed, which poses a considerable legal uncertainty for producers in this sector. Some of the difficulties of licensing and policy in the studied countries can be usefully understood in the context of *polycentric governance*.

The concept of polycentric governance (Ostrom, 2010; McGinnis, 2011) distinguishes decision making at different hierarchical levels of government, and additionally identifies overlapping or adjacent jurisdictions amongst different public agencies, which is relevant when we come to compare findings across countries that differ in their governance structure. The three main levels are operational (at which individual licensing decisions are made), collective-choice (where society decides e.g., through elected governments, on the laws and policies that regulate operational decisions), and constitutional (which provides the rules and broad policy directions that influence collective-choice decisions).

The stakeholders' perspective on the legal frameworks for LTA and IMTA development was presented in another study (AquaVitae Deliverable D8.2), the results of which mostly supported the findings of the legal analysis. In particular, time consuming and complicated application process were identified as an impediment to the development of LTA in all studied cases and regions. Food safety procedures and financial support were also named as problematic areas. Specific recommendations provided by stakeholders targeted these respective areas, such as, for instance, to establish streamlined procedures in the licensing process.

The present work (AquaVitae Deliverable D8.3) draws on the previous research in AquaVitae and has a purpose of providing recommendations regarding the improvements in aquaculture regulations to facilitate LTA development. Previous literature including the cited reports, identified specific weaknesses in regulations and suggested improvements in selected areas of legislation. This study takes a complementary approach to the problem and evaluates aquaculture policies from the perspective of their adaptive capacity. Our approach is in line with the findings of Osmundsen et al. (2017), who conclude that adaptiveness is a key quality of the regulatory framework that allows to adequately respond to the "wicked" nature of aquaculture sector. Improving overall adaptiveness of aquaculture regulations is a more strategic way of facilitating LTA development. Moreover, adaptive legislation allows accommodation of other emerging opportunities and risks in the aquaculture sector.

1.3 Objectives, methodological approach and scope

This work aims to provide an overview of the adaptive capacity of aquaculture-relevant regulations in the context of facilitating LTA development, with the objective to inform on common strengths and weaknesses in policy frameworks and improve the understanding of the aspects of adaptiveness that need to be addressed when developing fit-for-purpose frameworks for LTA. General recommendations for improvements of the adaptiveness of aquaculture governance are provided, in particular in relation to LTA.

We limited the scope of the analysis to the legal part of aquaculture governance. We evaluated regulations most relevant for LTA management in six countries and regions: Scotland, Norway, Spain (Galicia), Germany (Schleswig-Holstein), South Africa and Brazil. We applied criteria for analysis of legal adaptiveness (legal design principles) synthesised from the literature. The legal design principles were translated to adaptiveness criteria that specifically apply to facilitating new aquaculture forms, particularly LTA. The analysis was therefore contextualised in terms of types of uncertainty that must be met through adaptative approaches. The analysis was chiefly qualitative, but a quantitative scale was used for evaluation of policy frameworks. The aggregated quantitative results facilitate illustration and further qualitative inquiry.

The remainder of the report proceeds as follows. Section 2 discusses adaptive governance frameworks in the context of LTA, summarising the legal design principles proposed in the literature. The adaptiveness criteria formulated according to the objective of the study, description of evaluation procedure and its limitations are presented in Section 3. *Results and Discussion* are presented in Section 4, followed by *Conclusions and Recommendations* in Section 5.

2. Theoretical framework

2.1 Adaptive governance: conceptual framework and operationalisation

The adaptive governance concept has emerged in late 1990s as a strand in the theoretical research on managing uncertainty and complexity of socio-ecological systems (SES), where resilience is a central issue (Chaffin et al., 2014). Resilience is understood as the capacity of SES to adapt and respond to stressors, both of natural and human origin, while maintaining its structure and functions (Folke, 2006). Negative changes, such as climate change, are the key factors justifying the need for flexibility and adaptiveness of governance on different levels (Biber & Eagle, 2015). However, adaptive capacity and resilience theoretically also encompass the ability of SES to respond to positive changes and exploit emerging opportunities in the best possible way. As put by Cosens and Gunderson (2018), adaptive governance facilitates response to “change and surprise” in general. In this respect, LTA represents an opportunity for a sustainable and efficient food production, which requires adaptation of legal and institutional elements of governance in order to realise its potential.

Adaptive governance scholarship promotes the idea that governance systems in theory, can be designed to facilitate adaptation to emerging changes. Laws, for example, can have built-in mechanisms to support stakeholders’ inherent adaptation capacity (DeCaro et al., 2017). By evaluating

government systems through the adaptive capacity lens, one can get a better understanding about strengths and weaknesses of institutions and can suggest areas of improvements to facilitate adaptation (McDonald & McCormack, 2021).

There is no single and static definition of adaptive governance and adaptive management. The distinction between adaptive governance and adaptive management is vague, and the two terms are often used interchangeably. However, adaptive governance usually refers to a broader social context and acknowledges multiple levels of governance (Greenhill et al., 2020). Adaptive governance is different from the concept of transformative governance, as it does not seek a complete change of the governance essence (Chaffin et al., 2016).

The main characteristics of adaptive processes include flexibility and openness to revision, iterative decision-making, experimentation and constant integration of new knowledge (DeCaro et al., 2017). Adaptiveness also promotes formal and informal self-organisation and participation of stakeholders (Cosens & Gunderson, 2018).

Characteristics of adaptive governance translate to the design principles of legal frameworks and institutions. Social scientists suggest different answers on how exactly adaptive laws and institutions should look like (DeCaro et al., 2017). When it comes to legal frameworks, it is suggested that they should empower stakeholders, anticipate and plan for changes (Novellie et al., 2016), contain built-in revision and learning mechanisms (Soininen & Platjouw, 2018), and include monitoring and evaluation requirements (Frohlich et al., 2018). It further requires that laws and regulations explicitly facilitate tangible support (i.e., in the form of funding and/or access to infrastructure) for implementation of activities that underly adaptiveness (Gupta et al., 2010). DeCaro et al. (2017) summarise institutional design principles rooted in Ostrom's institutional analysis (Ostrom, 2014). Formal institutions' adaptive capacity depends, among others, on the efficiency of mechanisms for conflict management, participatory decision-making, monitoring and enforcement. As to informal institutions, adaptiveness is defined by the role of practices, customs and social norms in the management of SES (Frohlich et al., 2018).

Adaptive capacity of governance is operationalised through an interplay of legal frameworks and other formal and informal institutions (e.g., authorities, stakeholders and their values, practices, unwritten customs, norms, distribution of power etc.). While on the one hand, there are limits to the flexibility of laws (i.e., as too much flexibility can undermine the core values of legal systems), on the other hand, recent studies suggest that rigid laws may prevent empowerment and self-organisation of stakeholders (Greenhill et al., 2020). According to Frohlich et al. (2018), the core values of law are related to creating order and stability (stationarity), predictability (certainty), and avoiding revisiting earlier decisions (finality). Thus, institutions and processes need to be adaptive to compensate for the inherent rigidity of legislation.

Although general principles and criteria of adaptiveness apply to the analysis of adaptive governance on a case-level, such analysis needs to be scoped within the types of risks and opportunities we seek a response to. For instance, some adaptiveness studies are contextualised in terms of climate change risk and resilience, whilst others contribute to a discussion about economic uncertainty (e.g., of small-scale fisheries). The context defined by the type of risks or opportunities (as in the case of LTA) defines the scope and angle of the study, as well as the applied interpretation of adaptive capacity principles and criteria. As suggested by Soininen and Platjouw (2018, p. 25) "the regulation of adaptive management is discussed in substantive and procedural terms, on different levels of abstraction, and in very different social ecological contexts. Stating the social ecological problems that adaptive management seeks to address is paramount for establishing what is required from the law."

2.2 Review of adaptive capacity criteria relevant to the analysis of legislation

The adaptive governance literature suggests a range of different approaches to how legal frameworks should be designed to facilitate adaptiveness to environmental and societal changes. Legal design principles outlined by DeCaro et al. (2017) highlight iterative decision-making, empowerment of stakeholders and tangible support as the main categories of provisions that increase adaptiveness of laws and regulations. Gupta et al. (2010) operate within an "adaptive capacity wheel" framework, which includes six categories of adaptiveness criteria: variety, learning capacity, room for autonomous change, leadership, resources, and fair governance. Soininen and Platjouw (2018) suggest another approach to grouping criteria of adaptiveness, emphasizing substance, procedure, instrument choice and enforcement as the main categories. There is however a considerable overlap in the interpretations of legal design criteria and therefore for an analysis of adaptiveness, a thematic classification may be useful. In Table 1, we suggest a list of adaptive capacity criteria that synthesises the approaches proposed in the literature. We group the criteria in six categories related to: the iterative process of decision-making, flexibility, learning and experimentation, stakeholder participation, time-efficiency and tangible support.

The criteria related to the **iterative process** reflect the need for recognising uncertainties and planning accordingly. In this respect, allowing laws or policy strategies to be revised and changed in light of new knowledge is a key factor of adaptiveness. **Flexibility** criteria are those emphasising the need for clear goals and formulation of regulatory requirements in terms of broader standards and thresholds, rather than specified solutions. **Learning and experimentation** criteria support the evaluation of adaptive capacity of policy instruments, in terms of their ability to encourage constant improvement of knowledge about SES. New knowledge in adaptive laws enters the iterative process and may initiate change and adaptation. The **role of stakeholders** in adaptive governance is also emphasised by most authors in the field. On the one hand, environmental stakeholders, industry, and other affected or interested stakeholder groups need to be empowered to initiate and carry out activities required for adaptation. Here, public participation is also necessary to ensure an open and balanced decision-making process. On the other hand, stakeholders need to have formal responsibility to participate in management actions. Access to information for all stakeholders is another key factor for effective participation. **Time-efficiency** of procedures is an important factor of adaptiveness. Streamlining and optimising requirements for bureaucratic processes can be included explicitly in the regulations and legal framework in general. Finally, all the activities aimed to increase adaptive capacity of governance should be supported by necessary **infrastructure and funding.**

Table 1. Adaptive capacity criteria relevant to the analysis of policy frameworks, according to references and grouped by category, notably: iterative process of decision-making, flexibility, learning and experimentation, stakeholder participation, time-efficiency and tangible support.

Criteria related to iterative process and changes in legal frameworks	Reference
Institutions (including legal frameworks) need to articulate the possibility of expected and unexpected environmental impacts by suggesting proactive strategies and instruments.	(Gupta et al., 2010)
Laws and regulations should allow incremental revision over long periods of time.	(DeCaro et al., 2017)
Laws should have formal sunsets ("expiry date") on existing legal provisions and create planned windows of opportunity for making adjustment of most significant provisions.	(DeCaro et al., 2017)

Legal frameworks need to have in-built review mechanisms or sunset clauses for regulatory objectives.	(Frohlich et al., 2018)
Adaptive laws may include monitoring and evaluation requirements.	(Frohlich et al., 2018)
Laws designed for adaptive management should provide feedback-loop processes, with opportunities for evaluation and adjustments of relevant provisions in light of new available knowledge.	(Frohlich et al., 2018)
A stable governance structure (such as law) can contribute to accommodate change if it provides for its own formal amendment.	(Craig et al., 2017)
In-built mechanisms such as sunset clauses and regular review requirements can contribute to the law's adaptive capacity by identifying negative consequences early and avoiding path-dependency.	(McDonald & McCormack, 2021)
Adaptive capacity and resilience of regulations require establishing an iterative management process that facilitates learning.	(Soininen & Platjouw, 2018)
Regulatory processes should facilitate constant improving of routines (single-loop learning) and allow for changing assumptions (double loop learning).	(Gupta et al., 2010)
Laws should explicitly consider doubts and uncertainties.	(Gupta et al., 2010)
Criteria related to flexibility	
Laws should have clear goals within which adaptivity is justified.	(Soininen & Platjouw, 2018)
Legal systems affected by uncertainties need to emphasize standards and general principles (e.g., proportional water allocation principles), instead of specific rules (e.g., fixed water allocation rules).	(DeCaro et al., 2017)
Laws should formulate process-oriented requirements instead of narrow and prescriptive rules.	(Frohlich et al., 2018)
The definition of goals in regulatory frameworks should be clear, specific, and measurable.	(Frohlich et al., 2018)
Laws should contain less concrete and more nuanced substantive standards. Agencies should not be obliged to use preservationist or historical baselines for purposes of goal setting.	(Biber & Eagle, 2015)
Applying adaptive management to aquaculture will require a clear definition of objectives and measures for their assessment. Adaptive management needs to emphasize standards, reference points, as well as contingency plans developed with stakeholders' participation.	(Anderman-Hahn, 2005)
Regulations should recognise the variety of ideological frameworks and possible policy strategies to encourage stakeholders to generate tailor-made solutions.	(Gupta et al., 2010)
Criteria related to learning and experimentation	
Laws should establish clear provisions to promote learning, facilitate experimentation and reduce uncertainties.	(Frohlich et al., 2018)
Legal support for innovation may require planning for "exit strategies," that is, allowing projects to be terminated promptly in case of failure or negative impacts on the environment and society.	(McDonald & McCormack, 2021)

Iterative processes should be supported by constant monitoring of the changes in SES.	(Soininen & Platjouw, 2018)
Criteria related to stakeholder participation	
Laws should permit delegation of activities to appropriate agencies on different levels.	(DeCaro et al., 2017)
Adaptiveness requires enhanced public participation processes and coordination between levels of governance.	(Frohlich et al., 2018)
Participation requirements may create unnecessary bureaucratic processes. To avoid these, public participation should be targeted on specific points of the management process.	(Frohlich et al., 2018)
Laws should ensure participation of affected groups at appropriate geographical scales.	(McDonald & McCormack, 2021)
Adaptative laws must provide transparent and explicit processes for managing trade-offs across sectors, scales, and affected stakeholder groups.	(McDonald & McCormack, 2021)
Laws should formally recognise the authority and responsibility of stakeholders to make decisions, carry out plans, and otherwise self-govern.	(DeCaro et al., 2017)
Access to information for all institutions and stakeholders can influence the possibilities for autonomous change.	(Gupta et al., 2010)
Time-efficiency criteria	
Requirements for judicial review can make adaptive management implementation more difficult.	(Frohlich et al., 2018)
Laws should give agencies the power to act quickly by curtailing or streamlining ordinary procedural mechanisms, such as environmental assessment, stakeholder participation, and judicial review.	(Biber & Eagle, 2015)
Criteria related to tangible support	
Enforceable mandates are needed to ensure necessary budgetary provisions to activities such as monitoring.	(Frohlich et al., 2018)
Proper financial and technical support should be provided to the management actors.	(DeCaro et al., 2017)
Legal mechanisms can be designed to allocate funding for monitoring.	(Frohlich et al., 2018)
Economic instruments and access to information and justice are crucial complements to the policy mix, in addition to direct regulation.	(Soininen & Platjouw, 2018)

3. Materials and methods

3.1 Data collection

Based on the review of the literature on adaptive governance (Section 2 and Table 1), we synthesised the literature relevant to adaptive capacity into 15 criteria formulated for the analysis of policy frameworks in the contexts of LTA. Each general criterion has been specified within this context to measure adaptiveness of laws and regulations in terms of facilitating LTA (Table 2). Our selection and

adaptation of general criteria to the problem of LTA is one of many possible. As in other qualitative studies, alternative formulations of concepts could be produced and would have led to different results. To be clear, we assessed the extent to which regulations and policies allowed, enabled or constrained LTA and IMTA, not the extent to which existing adaptive governance has benefitted LTA or IMTA.

The countries Included in the review cover different geographical regions, governance structures and levels of aquaculture development. Not all of the countries included in the previous AquaVitae studies are subject to the current analysis, and our subset includes Scotland, Norway, Spain (Galicia), Germany (Schleswig-Holstein), South Africa and Brazil.

With the aim to analyse adaptive capacity of the legal documents most relevant to LTA development, as a general principle guiding our choice of documents for each region, we used the overarching question: "If LTA development is to be facilitated in the country (or region), which laws and regulations should be changed first?". Clearly, due to the differences in legal organisation of aquaculture governance in the studied regions, the list of documents most relevant to LTA differs across context, which limits the possibility for direct comparison. The number of documents also varies in each case, since often the countries/regions with more developed aquaculture sector will have a broader legislation. However, we attempted to standardise the material to the extent possible by introducing the following specific principles for document selection:

- The list should include up to 8 policy documents;
- The general principle is to include documents most relevant for the regulation of LTA;
- Where relevant and possible, the list should include the following:
    a) Documents regulating aquaculture in general (e.g., Aquaculture Act, Fisheries Law) and LTA in particular;
    b) Aquaculture development strategy in general and LTA development strategy;
    c) Documents outlining the licensing procedure for aquaculture in general and LTA in particular;
    d) Documents outlining technical requirements regarding farm operation in general and LTA farms;
    e) Area/coastal zone planning regulations;
    f) Water management regulations;
    g) Environmental impact assessment laws;
    h) Veterinary rules and food safety regulations;
- Where several documents are available for one topic, we choose the most relevant one (containing critical provisions regarding LTA);
- Documents in the list can be national (for the whole country) or regional (for example Galicia, Spain). The latter will imply that the analysis of adaptiveness is done for a particular region.

Application of these principles was inevitably subjective, and this is one of the main limitations in this study. Analysis of individual documents was possible for European countries: Spain (Galicia), Germany (Schleswig-Holstein), Scotland and Norway. Only one document was evaluated for South Africa, and for Brazil, the evaluation was done for aquaculture regulations in general. In total, 22 documents were analysed, in addition to one general country analysis (see Annex 1 for the list of references). Below we explain in more detail how the documents were chosen in each case.

Spain (Galicia): Spain has a decentralised governance system with Central Government and Autonomous Regional Governments, which independently apply their own regulations. Galicia is one of the main European regions depending on the fisheries and aquaculture sector. It has a long tradition

in both fisheries and aquaculture industries, especially production of mussels. Aquaculture in Galicia is regulated in the Law 11/2008 on fishing in Galicia. Although not mentioned in its title, it contains some very important articles regulating aquaculture. Considering the huge number of norms regulating aquaculture in Galicia, the regional government has considered promoting a new Aquaculture Act. In the absence of Aquaculture Act so far, two decrees are regulating aquaculture activities: Decree 406/1996 on maritime aquaculture and Decree 274/2003 regulating licensing of land-based aquaculture. As the region has a developed shellfish aquaculture sector (mostly bivalve aquaculture), specific regulations related to shellfish are relevant for the analysis. Here, the Decree 153/2019 on conservation, exploitation of shellfish resources and algae is particularly important. This Decree regulates shellfish harvest, a specific, traditional and economically important activity in Galicia that is considered as a form of extensive aquaculture. Galician Aquaculture Strategy ESGA (2014) is also considered relevant for the analysis.

Germany (Schleswig-Holstein): In Germany there is no single legal document regulating aquaculture in general or to authorise aquaculture operations, including LTA. As in any EU member state, an aquaculture development strategy exists in form of the recently updated NASTAQ, i.e., the National Strategic Plan for Aquaculture in Germany 2021 – 2030. Besides representing the national strategy for aquaculture development, the NASTAQ also outlines in part the licensing procedure for aquaculture. Three scenarios for aquaculture development exist in Germany: land-based production, production in the coastal area of the Baltic Sea or in the exclusive economic zone (EEZ) of the German North Sea - all fundamentally different when looking at the authorisation process. The German Baltic Sea coast offers some potential for marine aquaculture but as of 2021 there was no societal consensus in Germany as to whether marine aquaculture in open systems (in the Baltic Sea) should be developed at all, due to the environmental concerns. As low-trophic species have the potential to decrease environmental pressures and offer ecosystem services, their cultivation could benefit the Baltic, thus this area remains the most likely place for LTA development in Germany. The federal state that is most advanced in promoting aquaculture is Schleswig-Holstein. In accordance with the strategic orientation of the EU's Common Fisheries Policy, Schleswig-Holstein's state government promotes the development of ecosystem-compatible aquaculture. As one measure Schleswig-Holstein's Ministry of Energy Transition, Agriculture, Environment and Nature and Digitalisation (MELUND) released a licensing guide for investors called "Development of and financial support for sustainable aquaculture in Schleswig-Holstein (coastal waters of the Baltic Sea)". This guide deals with permit and authorisation procedures for the establishment of aquaculture facilities in the coastal waters of the Baltic Sea in Schleswig-Holstein. As such, it outlines the complete permit and approval procedure citing the relevant paragraphs of all relevant regulatory documents, directives and acts. This document and NASTAQ are included in the analysis.

Scotland: The Scottish Parliament has the power to introduce new laws on *devolved matters* such as environment, fisheries, land use planning, amongst others; whilst some other matters, such as trade and industry or foreign policy, constitute *reserved matters*, remaining the responsibility of the UK parliament; with the policy instruments relevant to aquaculture existing therefore at different constitutional levels. Since the application of the above selection criteria to the Scottish context would deliver upwards of 16 documents, this list was down-selected to a total of 8 documents that contain some of the most critical provisions for LTA regulation; this invariably means that some gaps remain in terms of how criteria are represented across the final document selection. The Aquaculture and Fisheries (Scotland) Act 2013 was included as it regulates aquatic pollution. It is reviewed in consideration of how LTA is covered within the Act, with part 4 including most specific provisions to shellfish. The Aquatic Animal Health (Scotland) Regulations 2009 regulates fish health and biosecurity issues. The Water Environment and Water Services (Scotland) Act 2003 was considered relevant as it

implements The Water Framework Directive (WFD). The Marine (Scotland) Act 2010 provides the rules for marine licence inshore, while Marine and Coastal Access Act 2009 regulates marine offshore licencing. Scotland's National Marine Plan (2015) provides the legal framework for inshore and offshore planning. Two strategy documents are included in the analysis: (i) A Fresh Start: The renewed Strategic Framework for Scottish Aquaculture 2009, as the previous government strategy, and (ii) Aquaculture Growth to 2030, adopted in 2016 and is an industry strategy.

Norway: Compared with the other countries, Norway has a less complex governance context, where laws are made centrally and administered locally. Recent policy documents on marine and ocean activities seem to reflect an increased interest in low-trophic species, however, salmon farming continues to dominate production, as well as legislation. Aquaculture legislation in Norway is in general quite comprehensive. The Aquaculture Act of 2005 sets the premises for all aquaculture activities. The County Authorities, who grant site licences pursuant to the Aquaculture Act, coordinate the application process and function as a one-stop-shop. However, granting a site licence requires approval from several sector authorities that act according to sectorial regulations. Of these, the most relevant for LTA are the Act on Food Production and Food Safety (LOV-2003-12-94-124), the Animal Welfare Act (LOV-2021-06-18- 134) and Regulation on operating aquaculture farms (FOR-2008-06-17-822). Regulation of aquaculture of other species than salmon, trout and rainbow trout (FOR-2004-12-22-1799) is directly relevant for our analysis. The most recent aquaculture strategy (2021) is also included according to the selection principles.

Brazil and South Africa: Aquaculture in Brazil and South Africa are special cases in our analysis. For Brazil, which has a complex and multi-level legislation (federal and regional) it made more sense to analyse the adaptiveness of aquaculture regulations as a whole, rather than individual policy instruments. In South Africa, we only analysed the National Aquaculture Policy Framework, because the Aquaculture Bill is still not approved and other legislation is scattered, making it difficult to form a consistent sample for analysis.

Assessment of each document is based on the principles adapted from (Gupta et al., 2010) and presented in Table 3. Explanation of the score choice in each case was provided[3] (the data are available at: https://zenodo.org/deposit/6490935).

Table 2. Adaptive capacity criteria for the analysis of legislation, regulations and strategies in the Atlantic, relevant in the context of LTA development.

Criterion of adaptiveness		Explanation of the criterion in the LTA context
Iterative process		
1	Recognises uncertainties	To what extent the document recognises uncertainty, risk and opportunities (such as LTA) in the aquaculture sector?
2	Plans/rules for assessment and revisions of the document itself	To what extent the document allows its own revision/reassessment that could include LTA?
3	Allows new knowledge to be included to improve management practices (feedback-loops)	To what extent the document supports incorporation of new knowledge about aquaculture, such as those related to LTA?
4	Allows incremental revisions	To what extent the document allows incremental revisions that can be relevant for LTA?

[3] Data are prepared and made accessible according to AquaVitae Data Management Plan.

5	Allows major changes (assumptions and principles)	To what extent the document allows change of principles and assumptions related to LTA (e.g., definition of aquaculture)?
Flexibility		
6	General guidelines instead of specific requirements	To what extent critical provisions of the document (definitions, technical descriptions) apply to low-trophic species such as macroalgae and molluscs?
7	Provides clear goals and how they are to be achieved	To what extent LTA development is consistent with the goals as they are formulated in the document?
Learning and experimentation		
8	Allows experimentation	To what extent the document allows testing new aquaculture methods such as LTA? (e.g., special licenses, projects and possibility for quick termination of the project in case of negative effects)
9	Establishes requirements for monitoring and improving knowledge about SES	To what extent the document requires from responsible authorities to monitor risks and opportunities in aquaculture such as LTA?
Stakeholder participation		
10	Plurality of goals, interests and perspectives	To what extent the document recognises a variety of stakeholders including LTA-producers?
11	Participation requirements	To what extent participation requirements promote incorporation of LTA stakeholders in the regulation practices described in the document?
12	Delegation	To what extent the document allows local or sectorial authorities to implement changes needed for aquaculture development, such as LTA?
13	Access to information	To what extent the document facilitates access to information for all stakeholders, included LTA-stakeholders?
Time-efficiency		
14	Streamline procedures	To what extent the document establishes streamlined procedures relevant to LTA?
Tangible support		
15	Material resources	To what extent the document considers material support to activities improving adaptive capacity? (According to at least one of the above listed criteria).

Table 3. Definition of the scores for assessment.

Score	Activities and practices described in the adaptive capacity criterion are:
2	Explicitly required/established
1	Mentioned/recognised but are not explicitly required/established
0	Not mentioned, but without consequences for implementation of such activities (criterion not relevant in the context)
-1	Not mentioned, and it makes implementation difficult or there are provisions that create obstacles for implementation
-2	Explicitly forbidden/excluded/made practically impossible

3.2 Data analysis

The assessment of the documents was performed according to the definitions and guidelines in Tables 2 and 3. Each document was reviewed by one researcher. We calculated the mean for region, document and each criterion. Due to differences in the data collection method, we treated Brazil and South Africa mostly as special cases. We applied qualitative analysis with elements of quantitative assessment, with the data collection and assessment procedure not allowing for statistical analysis and interpretation. Scores that were assigned subjectively, were used to facilitate visualisation of the results for further qualitative exploration.

To assess adaptive capacity of aquaculture policy frameworks in relation to LTA development, we set out to answer the following questions:

1. What is the mean of adaptiveness scores for all documents?
2. Which types of documents (e.g., strategies, licensing rules) have higher and lower scores in general and in different regions?
3. Which regions have relatively high and low adaptive capacity of regulations?
4. Which criteria have higher and lower scores in general and in different regions?

4. Results and Discussion

Figure 1 summarises the mean adaptiveness scores for each document and per region analysed, whilst Figure 2 illustrates the mean scores for each adaptiveness criteria and the variation on the region level.

The **mean adaptiveness score** of the 6 studied regions is 0,7 of a maximum 2,0 on the scale used for the analysis. Of course, this does not provide a perfect measure for the adaptive capacity of regulations in the Atlantic since the 6 regions are not representative and the assessment procedure does not meet the requirements of statistical analysis. However, this is an indication of a relatively low adaptiveness in the sample and potential room for improvement. To understand where improvements can be made, we need to explore the variation in the data and consider the local context, as well as the limitations to the data collection and analysis in each case.

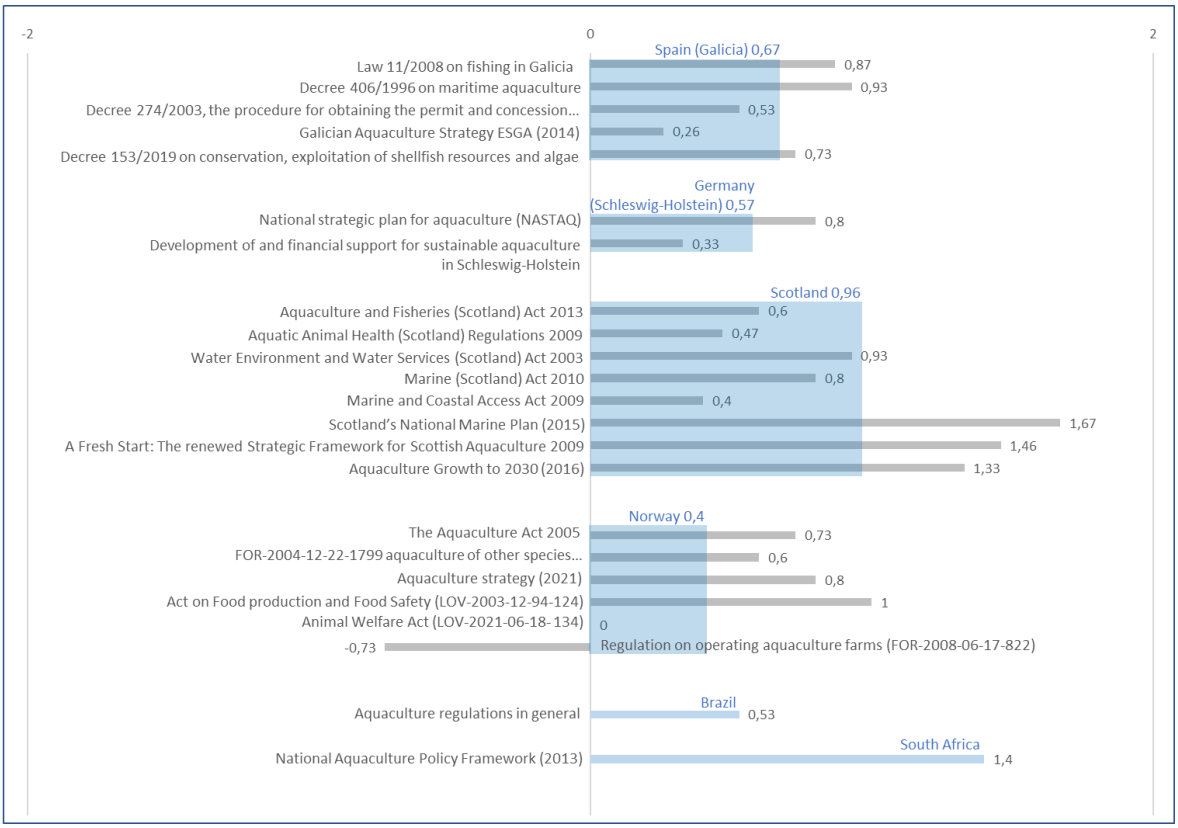

Figure 1. The mean adaptiveness scores for each document and region. The grey bars represent the mean for the document calculated as the average score of 15 adaptiveness criteria. The blue bars represent the mean for the region calculated as the average score of all regional documents. Assessment for Brazil does not specify documents. For South Africa only one document was assessed.

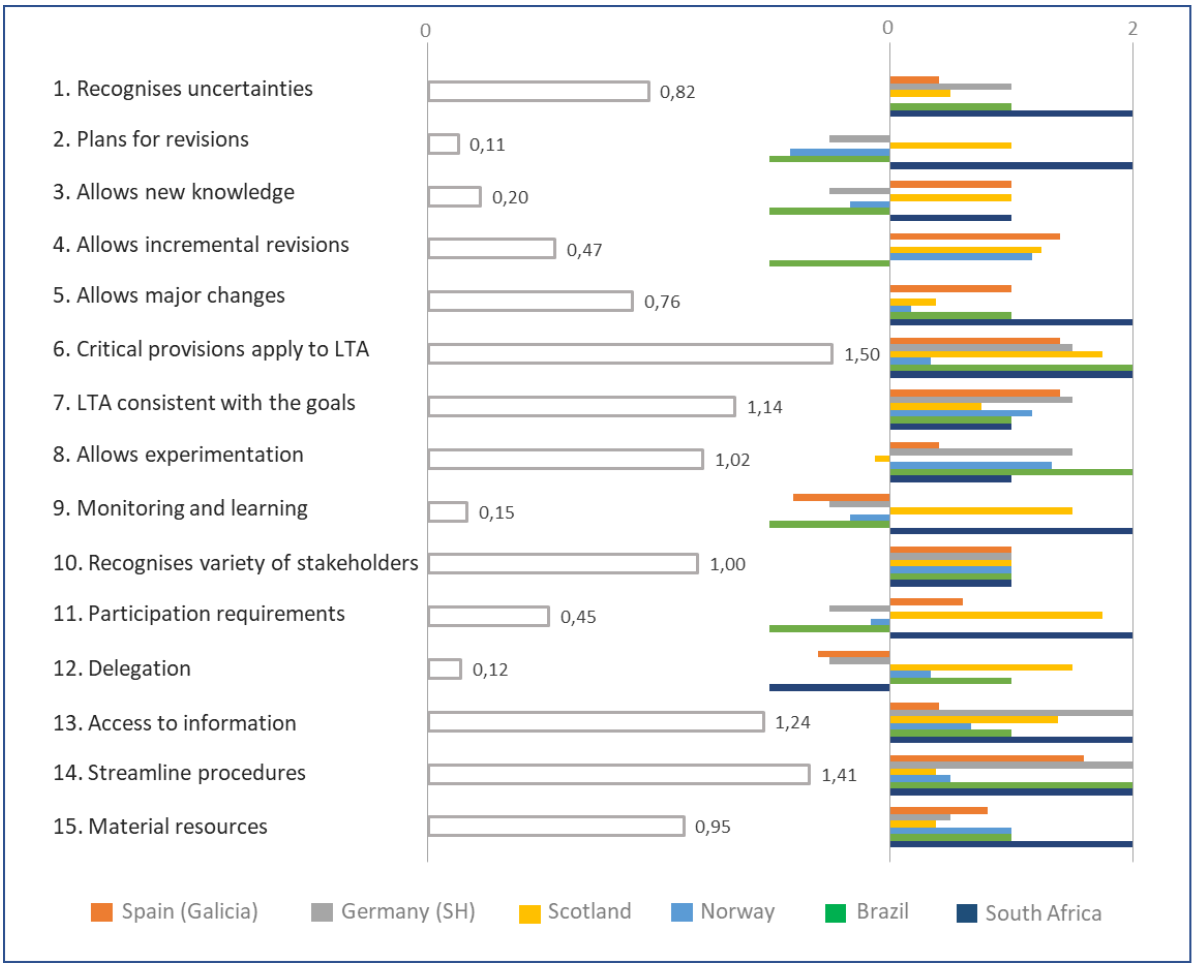

Figure 2. The mean scores for each adaptiveness criteria and the variation on the region level. The left column lists 15 adaptiveness criteria (Table 2), short descriptions are used. The bars in the middle show the mean scores of the criterion for all documents and regions. The coloured bars in the right column represent the means of regional scores for each criterion. Absent bars mean that the average score is zero.

As seen from Figure 1, there is a considerable variation between **countries and regions** included in the analysis. Scotland scores highest for the assessed documents, among the four European countries, while Norway has the lowest score, even lower than Germany where aquaculture is not a large economic sector. For South Africa, only one document was analysed, and it is the strategy for aquaculture development. Strategical documents are usually highly adaptive, as they intend to cover many aspects of aquaculture development on a very general level. This explains the highest score for South Africa, which we treat as a special case, but also some of the results in Scotland, for which two strategies were analysed, as well as a national marine plan. Brazilian legislation, which is also a special case here, has a relatively low adaptiveness score.

While the mean score for each country is a convenient measure for comparison, it is important to explore the variation within each regional score. The Norwegian case is the only one in the sample with a negative adaptiveness score for one of the analysed documents, which explains its lowest mean. The Regulation for operating aquaculture farms (FOR-2008-06-17-822) was evaluated at -0,73, while the Animal Welfare Act (LOV-2021-06-18-134) at 0, the second-lowest score among all analysed documents. The former document has been developed to regulate mostly salmon farming which can explain the lack of flexibility with regard to other species. The most adaptive document in the Norwegian sample is the Food Production and Food Safety Act (LOV-2003-12-94-124).

In Spain (Galicia) the Galician Aquaculture Strategy ESGA (2014) has the lowest adaptiveness score, in terms of possibilities for LTA development. This is unusual and might be related to the potential to improve existing aquaculture forms rather than exploring new ones. In other countries (e.g., South Africa, Germany, Scotland, Norway) the national strategical documents analysed scored as relatively adaptive. Interestingly, in the German case, the regional strategy was much more rigid than the national one.

In Scotland, there are at least 3 strategical documents relevant to LTA (i.e., Scotland's National Marine Plan; A Fresh Start: The renewed Strategic Framework for Scottish Aquaculture 2009; Aquaculture Growth to 2030). All three are highly adaptive, which contributes to the high overall adaptiveness of Scottish regulations. Regulation of access to coastal areas and Aquatic Animal Health regulations are less adaptive, which is expected considering their technical level.

In terms of **document types**, we notice the pattern where adaptiveness decreases as the scope of regulations narrows. Technical regulations (e.g., Regulation for operating aquaculture farms in Norway), licencing procedures (e.g., Decree 274/2003 in Galicia) and area regulations (e.g., Marine and Coastal Access Act 2009) are less adaptive as they are focused on specific governance issues. Policy instruments covering a wide range of issues are generally more adaptive (e.g., Law 11/2008 on fishing in Galicia, Water Environment and Water Services (Scotland) Act 2003). Aquaculture strategies were found highly adaptive in almost all cases, except for Spain (Galicia).

Analysis of the **mean scores for each adaptiveness criterion** (Figure 2) reveals a clear pattern of strengths and weaknesses of aquaculture policies in terms of their adaptiveness. In most of the studied countries and regions, the scope of documents covers low trophic species, thus criterion #6 scored the highest. This means that critical definitions and areas of application are compatible with LTA. A notable exception is Norway, where this score is low, mostly to the account of specialisation on salmon. A related aspect of adaptiveness described by criterion #7 (i.e., consistency of LTA development with the set goals) is also represented in the legislation in all regions, with some variation within positive values.

The second-highest score is associated with criterion #14, which relates to the presence of streamlined procedures within the analysed policies. This criterion concerns communication with authorities, e.g., licensing, monitoring and reporting rules. Spanish (Galician), German (Schleswig-Holstein), Brazilian and South African policy frameworks contribute to the high score, but it is important to note that the latter two regions are special cases.

The criterion related to the possibilities for experimentation (#8) is among the highest, however with considerable differences between regions. Here, Scottish regulations are relatively strict while German and Norwegian are more flexible, allowing for experimentation. In all studied countries and regions, the access to information (#13) and material resources (#15) were among the strongest aspects of adaptive capacity. Although scores varied, there were all positive.

The lowest mean score was found for criterion #2 (i.e., planning for revisions), as few documents include such provisions. Scottish legislation scored best on this criterion among the four European countries, while German and Norwegian documents had negative scores indicating restrictions related to revision possibility. Interestingly, the scores related to major changes (#5) were on average higher than scores related to minor changes (#4), however, there is a large variation in the country and regional scores that makes generalisation and interpretation of this result difficult. Delegation (#12) was amongst the most problematic criteria, with negative scores assigned to Spanish (Galician), German (Schleswig-Holstein) and Brazilian samples. Monitoring, learning and incorporation of new knowledge within legislation (criteria #3 and #9) were clearly major weak points of adaptiveness, with Norwegian and German samples having negative scores on both criteria. Participation requirements

(#11) were not sufficient in many of the documents analysed and the relative score is low, indicating the need for improvement in specific pieces of legislation. In all regions, the legislation seemed to recognise the variety of stakeholders, with the mean equal 1.

Although the method used for data collection and analysis has limitations, the results provide a general pattern of adaptiveness, especially when it comes to common strengths and weaknesses in LTA-related legislation.

5. Conclusions and recommendations for policy making

This work studied the extent to which aquaculture policy documents contains features linked to adaptiveness but did not address the more difficult task of seeking evidence that regulatory adaptiveness improves the adoption of LTA and IMTA. The aggregated results provide a general picture of aquaculture policy adaptiveness in relation to LTA.

Adaptive capacity of national and regional legislation varies. Norwegian, Brazilian and German aquaculture policies demonstrated lower adaptiveness in terms of LTA development, which may indicate a higher need for change in these countries. In terms of recommendations for policy, the analysis of 15 adaptiveness criteria is more useful than the country comparison. Our analysis suggests that one of the weak points, that should be addressed first, concerns the iterative process of regulation, specifically the possibility to learn, incorporate new knowledge, and revise the key documents related to aquaculture including LTA. Delegation and stakeholder participation are also among the aspects that need to be addressed in order to facilitate LTA development.

The present study provides new knowledge about the potential for policies development to facilitate LTA and other emerging opportunities in aquaculture sector (as well as risks). By using adaptive governance framework, we shift focus from specific sectors and areas of regulations to a more general level of governance. This method yields a new contribution to policy analysis in the AquaVitae project, as the aspects of iterative process, learning, delegation and stakeholder participation in developing and practicing aquaculture policies were not in the focus of previous reports or addressed only cursorily.

As concluded by D8.1, most countries have included in the spirit of their laws the flexibility to cope with innovation and technological developments, opening the door to the diversification of species and culture system. This is confirmed by our analysis, where we specify and evaluate different aspects of adaptiveness. A discussion of the regulatory barriers from the perspective of adaptive governance constitutes a useful input for further work in this field. Our findings also complement the scarce academic literature on adaptive governance of the aquaculture sector. Previous studies on adaptiveness of aquaculture policies contextualised the discussion of solutions as the accommodation of risks, such as climate change (Craig, 2019) and organic pollution (Soininen et al., 2019). The present work emphasizes the need to adapt to innovations that bring opportunities for sustainable food production, and we demonstrate that the same adaptiveness criteria apply.

In addition, the present analysis complemented and put in the perspective of adaptiveness some of the findings of D8.1 and D8.2 and related literature on governance of food production. The report on current policy frameworks in aquaculture (D8.1) points to the fact that in countries or regions where aquaculture is a mature economic sector (Scotland, Galicia and Norway), the existing enabling provisions for finfish and shellfish aquaculture are not necessarily so well suited for macroalgae or

IMTA. This conclusion is partly supported by the present report. Indeed, Norway had the lowest adaptiveness in terms of possibilities for developing LTA under the current legislation. However, Scottish and Galician policies demonstrated a relatively good regulatory adaptiveness when measured by the 15 criteria. This may suggest that not only the scale of aquaculture sector, but also the specialisation on few species (as with prevalence of salmon aquaculture in Norway) may affect adaptiveness, though the limited scope of the study and its qualitative character does not allow to verify this hypothesis. However, it has been shown that with presence of dominant food systems (e.g., monoculture in crops production) the elements such as technology, infrastructure, routines, values and regulations co-evolve in a path-dependent manner and form a stable, locked-in structure (Morel et al., 2020). Such systems are then less adaptive than diversified ones.

Cumbersome and time-consuming licensing procedures were shown to persist despite the many initiatives intended to address them (e.g., administrative simplification) according to D8.1. Stakeholder workshops (D8.2) also identified this issue as an impediment to the development of LTS aquaculture in all cases and regions. In our analysis, streamlining procedures (criterion #14) was among the criteria with the highest score, which suggests that this issue is being considered by policy makers. However, the simplification of procedures is not necessarily systematic and may concern specific aspects of regulations on different levels (e.g., emphasis can be given to simplification of the licencing process for sea-based pen aquaculture, as covered within NASTAQ in Germany, but not to other technologies). There is also a difference between encouraging or planning for simplification of procedures (e.g., the Law 11/2008 on fishing in Galicia), to the actual establishment of streamlined processes, through regulations and in a legally binding way (as in Decree 153/2019 on conservation, exploitation of shellfish resources and algae in Galicia). Criterion definition does not cover this diversity of meanings; thus, its high score means only that some steps are being taken in the analysed documents with the effect to streamline the related administrative procedures. According to the feedback from stakeholders (D8.2), further administrative simplification is required. Such call for simplification and streamlining of administrative procedures is also common in the recent literature on aquaculture governance (Gentry et al., 2019).

The lack of clear rules and regulations was identified as an obstacle for LTA producers in the previous reports; this need for legal certainty and clarity in the commercialization of new aquaculture forms, such as cultivation of macroalgae and IMTA, also emphasised in the recent literature (Kleitou et al., 2018; Stévant et al., 2017). In terms of the variety of species and aquaculture forms covered by policy instruments, we note that many regulations cover LTA to some extent, however, specific regulations may be less explicit about the scope or even exclude low-trophic species (as in the animal Welfare act in Norway LOV-2021-06-18-134). LTA may also be addressed partly. For example, Aquaculture and Fisheries (Scotland) Act 2013 specifically mentions shellfish, while Galician legislation (Decree 159/2019) regulates harvest of shellfish and algae, a specific activity which is a different from aquaculture production. This contextual variation is not reflected in the adaptiveness criteria used in the analysis. Depending on the context, improving adaptiveness of policy frameworks in terms of LTA coverage will imply either introducing dedicated provisions for LTA or widening the scope of key regulation to include more alternative aquaculture forms. We refer here to the criterion #6, which emphasizes the need for providing general guidelines instead of prescribed final solutions.

The need for a broader stakeholder participation in aquaculture governance has been emphasized in the analysis of Brazilian regulations and EU policies (D8.1). Results of stakeholder workshops (D8.2) also suggest that there is scope to improve the communication between LTA producers and public authorities. The principle of stakeholder participation has been embedded in the EU aquaculture policy framework, however implementation within national policies may not always be efficient or

consistently applied. Outside the EU, a similar problem exists. For example, the review of Brazilian aquaculture policies and the South African aquaculture strategy reveals that formal institutions for stakeholder involvement are promoted, but their actual influence remains low. The present work suggests that stakeholder participation is a problem in the legislation in most reviewed documents related to LTA regulation, however it should be addressed in relation to different elements of adaptiveness, such as learning and revision of legislation, in addition the consultation role in decision-making. According to the adaptive governance framework, stakeholders should have formal opportunities, but also binding responsibilities, to participate in these activities (DeCaro et al., 2017).

The importance of financial support for R&D, innovation and start-up was highlighted in nearly all cases in the stakeholder workshops (D8.2). Participants of these workshops argued that LTA has not developed yet to a mature and competitive industry segment, and its further development would strongly depend on adequate financial support. Similar concerns have been reported in the literature, on prospects for algae cultivation (Cai et al., 2021), shellfish aquaculture (Avdelas et al., 2021), and aquaculture in general (Guillen et al., 2019). We find that in many regulatory documents some sort of financial support for activities increasing adaptiveness to LTA is included, however, this does not necessarily concern support to LTA producers. In some cases, payment or deposits are required from aquaculture producers to finance activities, such as monitoring of environmental impact (e.g., Aquaculture Act 2005, Norway), or funding is referred to as to be distributed to host communities (e.g., Aquaculture Growth to 2030, Scotland). We suggest that tangible support in the form of funding and infrastructure, needs to be delivered in practice at different levels, so as to facilitate all aspects of adaptiveness, including knowledge improvement, revision work, improvement of administrative procedures and stakeholder participation.

In synthesising the novel findings from this work, jointly with the findings from AquaVitae D8.1 and D8.2, we propose the following recommendations for aquaculture policy development:

1. **Improve adaptive capacity** of regional and national aquaculture laws and regulations, to promote LTA development.
2. Prioritise the creation of **iterative regulation processes**, considering learning and the incorporation of new knowledge.
3. Include provisions for the **regular evaluation and revision of central policies and regulations,** in order to best address emerging risks and opportunities.
4. Include provisions for **delegation to local and sectoral authorities and stakeholder groups,** facilitating self-organisation.
5. Address **stakeholder participation** in the aquaculture laws and regulations.
6. Address aquaculture **diversification** in legislation, in countries or regions with developed and highly specialised aquaculture.
7. Further **simplify and streamline** regulatory procedures in aquaculture and LTA in particular.
8. In cases where specific LTA regulations are lacking, **widen the scope of existing regulations** so that core definitions and areas of application include LTS.
9. **Allocate diverse tangible support**, in the form of **funding and/or access to infrastructure**, to support stakeholders and promote adaptation activities.

Implementation of these recommendations alone may be insufficient for a significant positive improvement towards LTA development, as the adaptiveness of institutions (social norms and rules), processes and communities is a necessary condition for practicing adaptive regulations. Equally important is the fact that aquaculture regulations (i.e., including those related to LTA) are not independent from the wider national legislation systems, which set the limits for the improvement of adaptiveness for particular laws, and therefore a systemic action with the view on policy coherence is

needed to embed such adaptiveness in broader governance frameworks. Governance levels (regional and national), principles of practicing the law, sectorial division, enforcement and compliance are among the key aspects of the national legal systems. Previous deliverables on aquaculture policy frameworks (D8.1 and D8.2), have partly addressed these constraints, as well as institutional aspects of aquaculture regulations such as role and attitudes of stakeholders, role of information, administrative set-up, history of aquaculture development, the role of informal rules and customs, and others. Regional adaptiveness strategies should consider these local institutional and legal factors. A detailed regional analysis is needed to develop tailored recommendations for each region; with experts, policy makers and stakeholders in these regions playing a key role in this work.

Finally, public authorities should consider how adaptiveness can be built into each level of the governance hierarchy. Institutions for local (Operational level) adaptiveness need careful design in order to avoid capture by interest groups. In most countries considered, the Collective-choice level encompasses a variety of public organisations and often overlapping national and regional levels of decision-making. AquaVitae will be carrying out further work to find examples of 'what works' at this level for successful LTA and IMTA. The Constitutional level of governance is explicit in the constitutions of the federal states of Brazil and Germany, exists in a less organised fashion in Spain and the UK, and is effectively also present in the treaty organisation that is the EU. The latter, as evidenced in the EU environmental and planning directives, can shape goals, whilst allowing collective-choice decision-making to determine the means.

Annex 1. Policy documents included in the analysis

Country (region)	Document	Reference
Spain (Galicia)	Law 11/2008 on fishing in Galicia	*Ley 11/2008, de 3 de diciembre, de pesca de Galicia.* Official State Gazette reference: BOE-A-2009-805. Available at: https://www.boe.es/eli/es-ga/l/2008/12/03/11
	Decree 406/1996 maritime aquaculture	*DECRETO 406/1996, do 7 de novembro, polo que se aproba o Regulamento de viveiros de cultivos mariños nas augas de Galicia.* Galician official Bulletin DOG nr 228. Available at: https://www.xunta.gal/dog/Publicados/1996/19961121/AnuncioBB56_gl.html
	Decree 274/2003, the procedure for obtaining the permit and concession of activities for aquaculture in land area	*DECRETO 274/2003, de 4 de junio, por el que se regula el procedimiento de obtención del permiso y concesión de actividad para los establecimientos de acuicultura y auxiliares de acuicultura en la zona terrestre.* Galician official Bulletin DOG nr 110. Available at: https://www.xunta.gal/dog/Publicados/2003/20030609/AnuncioF5A6_es.html)
	Galician Aquaculture Strategy ESGA (2014)	*Estratexia Galega de Acuicultura (ESGA).* Available at: http://www.intecmar.gal/esga/
	Decree 153/2019 on conservation, exploitation of shellfish resources and algae	*DECRETO 153/2019, do 21 de novembro, polo que se regula o réxime de conservación e explotación dos recursos marisqueiros e das algas.* Galician official Bulletin DOG nr 223. Available at: https://www.xunta.gal/dog/Publicados/2019/20191209/AnuncioG0427-281119-0002_gl.html
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	Development of and financial support for sustainable aquaculture in Schleswig-Holstein	*Entwicklung und Förderung einer nachhaltigen Aquakultur in Schleswig-Holstein (Küstengewässer Ostsee).* Available at: https://www.schleswig-holstein.de/
Scotland	Aquaculture and Fisheries (Scotland) Act 2013	Available at:

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	Aquatic Animal Health (Scotland) Regulations 2009	Available at: https://www.legislation.gov.uk/ssi/2009/85/contents
	Water Environment and Water Services (Scotland) Act 2003	Available at: https://www.legislation.gov.uk/asp/2003/3/contents
	Marine (Scotland) Act 2010	Available at: https://www.legislation.gov.uk/asp/2010/5/contents
	Marine and Coastal Access Act 2009	Available at: https://www.legislation.gov.uk/ukpga/2009/23/contents
	Scotland's National Marine Plan	Available at: https://www.gov.scot/publications/scotlands-national-marine-plan/
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