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Dynamics of aquaculture governance

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Abstract

Aquaculture is a growing industry with an annual growth rate that is far superior to the population growth rate. Most production occurs in lower- and middle-income countries, and therefore, they can improve the efficiency and modernize the production systems to increase exports to earn foreign exchange earnings for economic and social development. The institutional arrangements should be part of the mechanisms that ensure sustainable aquaculture growth, through the participation of all stakeholders. Sustainability is possible with good and dynamic governance through which the industry embraces the basic principles of governance, equity, accountability, efficiency, and predictability. Over the past decade, several countries made changes in governance and implemented regulations through their action plans to improve aquaculture productivity, and stakeholders profited from the changes made along the value chain. For the producers to benefit from the value-added products, they complied with the regulations imposed by the importing countries, international regulatory bodies, or their own consumers. Standards increased, and the implementation of certification resulted in changes in the industrial structure. These standards, which inflict regulatory cost on producers, stimulated an improvement in productivity and product quality. However, during the last decade, production growth

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declined from 5.8% from 2001 to 2010 to 4.5% from 2011 to 2018, resulting in the elusive realization of the potential of meeting the sustainable development targets. There is a need for a paradigm shift that encourages small-scale producers to engage in sustainable intensive aquaculture. The challenge is, therefore, to move toward production intensification and expansion, and the harmonization of national and international regulations to ensure the supply of safe and adequate fish to consumers, while maintaining a sustainable production system, and at the same time conserving the environment and maintaining social and economic stability. With good governance and political will, the social, economic, and environmental objectives for attaining the Sustainable Development Goals during the period 2020–2030 are possible if governments integrate sustainable aquaculture developments within an expanded aquatic and terrestrial food security policy framework using systems thinking and open innovation approaches.

KEYWORDS

accountability, dynamic governance, regulations, regulatory framework, sustainability

1 | INTRODUCTION

Aquaculture is the fastest-growing food-producing industry in the world with an annual growth rate of 9.58% from 1990 to 2018, attaining 114.5 million tonnes of live weight in 2018 at a total farm-gate sale value of \$263.6 billion (Food and Agricultural Organization [FAO], 2020a, 2020b, 2020c). Unfortunately, the growth rate slowed down from 5.8% in 2001 to 2010 to 4.5% during the period 2011–2018. The expansion of aquaculture has been stimulated by breakthroughs in production practices accompanied by technological innovations that have lowered production costs for most aquaculture species and the supply chain (Oluwemimo & Damilola, 2013). Accompanying these changes in the structure of the supply chain are a set of stringent public and private standards for control, and greater emphasis on the social responsibility of food traders. The rise in standards has influenced the industry structure, marketing activities, actor conduct, and governance along the supply and value chains and has created greater awareness by the public and private sectors for national aquaculture plans and a set of regulatory mechanisms that enforce good governance (Hammoudi et al., 2009). The question is, with the slowing down of the growth rate in production, even with enforced governance, will aquaculture enable the attainment of the Sustainable Development Goals (SDGs) set by the United Nations in 2015? We reviewed publications on aquaculture governance and investigate whether it contributed to the attainment of SDGs set by the United Nations for the period 2010–2020.

Countries and production regions have shown various growth rates since 2010. African aquaculture development is growing rapidly with a contribution of 2.2 million tons representing 2.7% of World Aquaculture (Adeleke et al., 2020; Halwart, 2020). The region recorded a twenty-fold production increase from 110,200 to 2,196,000 tons from 1995 to 2018, at an annual compounded growth rate of 15.6% (FAO, 2016; Halwart, 2020). Production is dominated by small-scale aquaculture, concentrating on various tilapia species, the African catfish, and seaweed (Adeleke et al., 2020).

Aquaculture production in the Americas was 3.1 million tons, or 3.8% of the world's total in 2018. The region experienced a 300% growth rate from the 1950s, allowing it to surpass aquaculture production in Europe and become the second largest global aquaculture-producing region, behind Asia. Finfish production was responsible for 2.19 million tonnes while crustaceans contributed 961 thousand tonnes, and mollusks 640 thousand tons (FAO, 2020a, 2020b, 2020c). Asian countries dominated world-farmed aquatic animals, with an 89% share in the last two decades or so, with China contributing 71% of the production. Aquaculture contribution exceeded more than 50% of all fish produced in four Asian countries in 2018 (i.e., China 76.5%, India 57%, Vietnam 55.3%, and Bangladesh 56.2%). The share of aquaculture in Asian fish production (excluding China) reached 42.0% in 2018, up from 19.3% in 2000 (FAO, 2020a, 2020b, 2020c). Indonesia, India, Bangladesh, and Myanmar have experienced increases in aquatic production and their rank, as major producing countries, while the Philippines, Republic of Korea, Japan, and Thailand have experienced shortfalls in production and have dropped in rank (FAO, 2020a, 2020b, 2020c). Europe, plus Cyprus, produced 3082.6 thousand tonnes of fish from aquaculture in 2018 or 3.7% of the world's total production in 2018. Norway is the largest producer in Europe and was responsible for 44% of the total European farmed fish production (FAO, 2020a, 2020b, 2020c). SOFIA (2022) showed decay in the global aquaculture growth rate from 4.4% in 2010 to 2020 to 3.3% from 2010 to 2018 to 2.6% from 2018 to 2019. The question is then with such a decadence in aquaculture growth rate, can aquatic fish production, with improvement in governance, influence the attainment of the SDGs?

While important progress in aquaculture governance has been achieved over the past decade, many policy issues are still unresolved. Some countries have started to develop their policies in a participatory and transparent manner through Strategic Aquaculture Development Plans (SADP), considering stakeholders involvement. The Policy Framework and Reform Strategy (PFRS) for Fisheries and Aquaculture adopted by all Member States of the African Union (AU) Africa aims to create an enabling environment that will lead to the transformation of Africa's aquaculture into a sustainable market-oriented private-sector-led commercial agricultural activity (AUC-NEPAD, 2014). The United States has recently involved in stakeholder engagement in aquaculture (Lester et al., 2018). For example, the United States Department of Agriculture (USDA) Working Group on Aquaculture sought to provide the domestic aquaculture industry an opportunity to communicate on how USDA can best serve this farming community (Biga et al., 2020). While many attempts at governance have promoted aquaculture in countries like Colombia, Peru, and Paraguay, weaknesses remain, and thus impede further aquaculture development. In Latin America and Caribbean (LAC), aquaculture has low political and institutional profile, resulting in lack of strong policies and limited allocation of funds to the sector (FAO, 2021c). Statutory and regulatory frameworks for aquaculture development have been established in major aquaculture-producing countries in Asia, with relevant policies, laws, regulations, and standards being formed and institutional mechanisms developed for implementation and enforcement (FAO, 2021a). The major Asian exporting countries like China, India, Vietnam, and Thailand usually follow government decrees and adhere to specifications outlined by industry leaders. When the government fails to play a leadership role in producing countries, private sector actors like businesses and civil society groups accept to promote good practices and long-term learning for sustainable production. In Europe, the Common Fisheries of the European Union (EU) (OJ, 2013) and the Policy Framework Reform Strategy for Fisheries and Aquaculture have resulted in the emergence of the 2013 Strategic Guidelines on Aquaculture (European Commission, 2013). Governance, which is a set of policy frameworks designed by stakeholders in the aquaculture industry, is the driving force behind progress in the industry and can influence the attainment of the SDGs. Despite the diverse governance-related actions undertaken by the various countries and regions, it is not evident that aquaculture governance influenced the attainment of the SDGs from 2010 to 2020. Partelow et al. (2022) indicated that aquaculture governance at the country level assessment is not optimal and requires more studies. In this article, we investigate the effects of governance on the attainment of the SDGs set by the United Nations in 2015.

1.1 | Objective

The United Nations set 17 SDGs in 2015 that can be related to aquaculture development goals and the closest of these include: achievement of poverty elimination (SDG1); end hunger through the attainment of food security

(SDG2); good health and community well-being (SDG3); gender equality (SDG5); decent work, economic growth, and trade (SDG8) and; conserve the use of the oceans, seas, and marine resources for sustainable development (SDG 14) (Said & Chuenpagdee, 2019; Stead, 2019). These selected goals are broad and are not all directly related to aquaculture growth and development but may indirectly influence the SDGs. Hence, in this article, we conduct a diagnostic analysis to evaluate the effects of governance on the attainment of these selected SDGs.

1.2 | Specific objectives

1. Perform a comparative analysis of the components of aquaculture governance undertaken by the various countries and regions from 2010 to 2020.
2. Compare the effects of governance on the SDGs from 2010 to 2020 and 2000 to 2009 and propose a way forward.

1.3 | Aim of paper

The incorporation of the SDGs within the policy frameworks and programs of all countries will increase the awareness of all governments and stakeholders and empower them to promote the strengthening of aquaculture governance mechanisms ensuring fair and transparent involvement and consultation in decision-making of different interest groups concerned with aquaculture development that will foster the sustainable attainment of the SDGs. The perceived effects of governance on aquaculture growth and development may enhance aquaculture sustainability and influence the attainment of the SDGs.

The article continues with a conceptual framework that shows a likely pathway from governance to the attainment of the SDGs; a definition and discussions of aquaculture governance; methods, results, and discussions.

1.4 | Conceptual framework

Governance can be described as the implementation of a policy framework, or informal arrangements, that include the involvement of stakeholders, local associations, interest groups, and private actors in decision-making to attain a common purpose, such as the delivery of public goods and services or projects (Kooiman, 1999). Fundamentally, it is about power, relationships, and accountability: who has influence, who decides, and how decision makers are held accountable. The term governance is characterized by the involvement of representatives of the public, private, voluntary, and community sectors in the process of policy decision (Rhodes, 1997). It is, therefore, evident that governance involves the interactions among structures, processes, and traditions that determine how power is exercised, and how citizens or other stakeholders have their say in decision-making. Government, on the other hand, consists of representatives who govern or rule the state—elected people—whereas governance denotes the framework or procedures followed by the government. Clearly, it is the administration and organizational structure for the operation and functioning of a body or institution or industry with inclusive participation of members in the attainment of a set of goals or objectives. Governance is not government and should not be used synonymously. The concept may usefully be applied in different contexts—global, national, and local; societal, institutional, and industrial as in the case of the aquaculture sector (Plumptre & Graham, 1999). Hence, in this article, it is quickly applied to aquaculture and its influence on the attainment of the SDGs.

The SDGs outline the development programs of countries. There are 17 SDGs, with 169 targets and 232 related indicators that monitor progress in social, economic, and environmental development (Griffin et al., 2019). The SDGs express the shared commitment made by the global community to fight poverty. The SDGs are an interlinked set of

objectives that call for cross-sectoral planning and implementation. The future advancement of aquaculture development toward the SDGs depends on local, national, and global actors, operating through alliances to increase aquaculture production that generates sustainable benefits to stakeholders while preserving the environment and social stability. The desire of all stakeholders is the accessibility of supportive, dedicated legislation with a lead agency to coordinate regulations that ensure public well-being and yet not overly constraining to permit them to cope with environmental and social challenges and approach the stipulated SDG (Mustafa et al., 2018). The choices to be made involve decisions related to environmental quality, foreign direct investment (FDI), domestic capital mobilization, national economic strategies, and new globalized mechanisms supporting aquaculture production at a reasonable cost and FDI in the production of traded goods and services with participation of all stakeholders in the governance of the aquaculture industry.

1.5 | Aquaculture governance

Aquaculture governance is the set of practices by which a jurisdiction manages its resources. Hence, governance of aquaculture enables improved relationships between government and the private sector and can be defined as a set of policy decisions and processes made to reflect social expectations through the management or leadership of the government (by extension, research, and other agencies), the will of “the people” as they rule themselves. At the extreme, it is argued that “governance without government” is becoming the dominant pattern of management for advanced industrial democracies (Rhodes, 1997).

The practices of aquaculture governance refer to the norms, institutions, and processes that determine how power and responsibilities over “natural resources/fisheries” are exercised; its stakeholders participate in making and implementing decisions affecting the sector; government personnel are accountable to the aquaculture community and other stakeholders, and the respect of the rule of law is applied and enforced (FAO, 2017a; Hishamunada, 2014). The aim of aquaculture governance is to ensure sustainability of the sector, balancing environmental, economic, social, and technical imperatives. There are four key principles that guide good governance in the aquaculture sector (Hishamunada, 2014; Varadi & Bekefi, 2015):

- i. Effectiveness and efficiency—doing the right things well.
- ii. Equity—must consider the interests of different groups of the current generation (gender and youth) and safeguarding future generations.
- iii. Accountability—refers to the degree to which officials are answerable to the public for their actions.
- iv. Predictability of rule of law—the application of laws and regulations is fair and consistent and the decision process is transparent, open, and clear.

Aquaculture governance is achieved when those key principles are adhered to and appropriate instruments are implemented, such as a transparent aquaculture administrative structure—a clear legal and regulatory framework that includes licensing-effective civil participation in decision-making; adequate aquaculture statistics and research in support of policy and planning (FAO, 2017b). Aquaculture productivity and long-term growth are probably dependent on governance. Aquaculture governance, therefore, includes a set of regulations that guarantees enforceable property rights and the expansion of commercial aquaculture. Regulation enforcement will provide the incentive to investors to allocate time and resources in aquaculture (Hishamunda, 2014).

The application of aquaculture governance to SDGs framework provides a flexible guide to a diagnostic and qualitative means of observing the effects of governance on aquaculture growth and sustainability. Aquaculture sustainability suggests that aquaculture governance is becoming even more important over time in directing aquaculture growth. This is because all factors of sustainability—(economic, environmental, legal, social, and technical)—will encounter opportunities and development challenges. Figure 1 shows the pathways of governance and its proposed

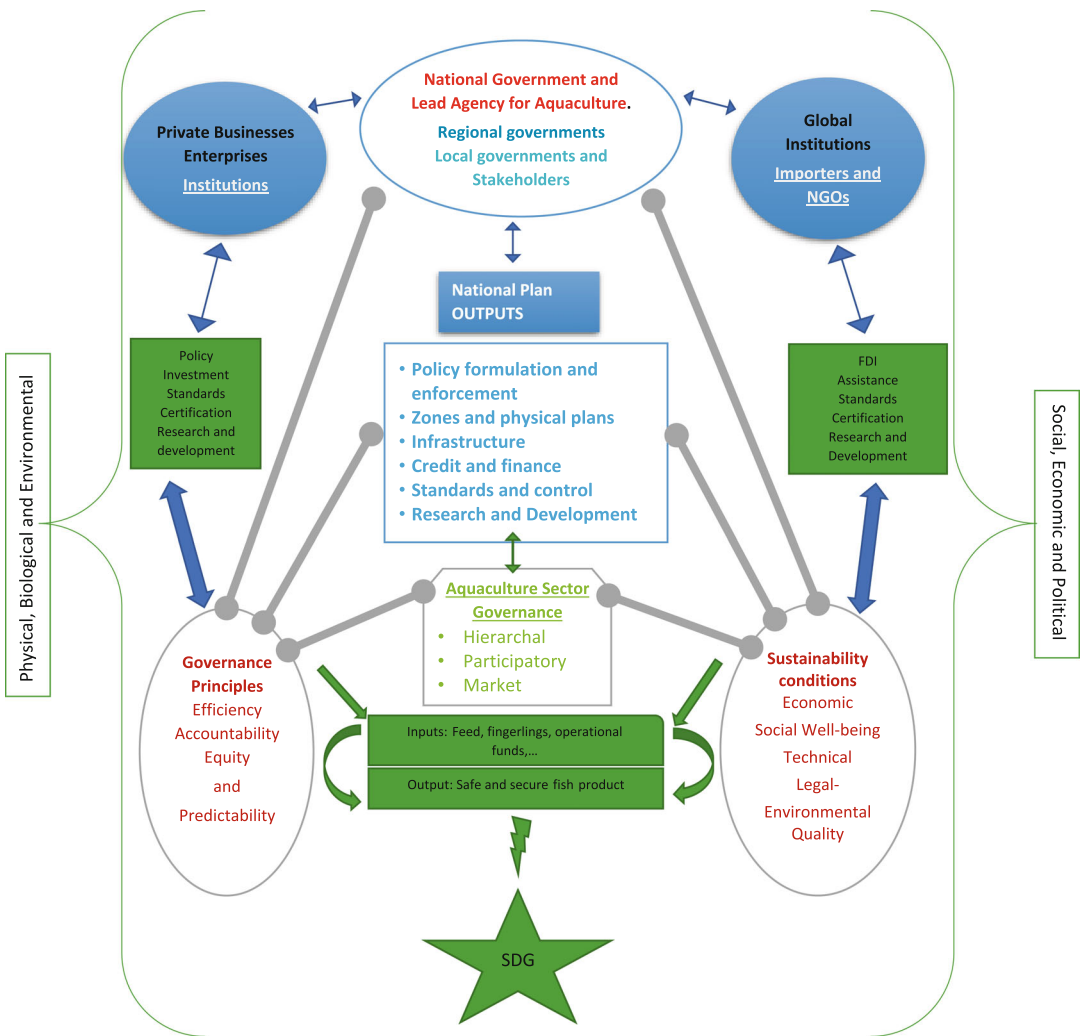


FIGURE 1 Model of pathways from aquaculture governance to the probable attainment of Sustainable Development Goals. FDI, foreign direct investment; SDG, Sustainable Development Goal.

effects on aquaculture output and the possibility of attainment of the SDGs. The governance process is usually elaborated as a set of constructs in the national government plans by some legal authority, congress, government department or agencies, the organizational and institutional plans of the private sector, and the international organizational plans. All plans or policies are conceived with the contribution of stakeholders and the community and guided by the principles of governance (effectiveness or efficiency, accountability, equity, and predictability) and the conditions of sustainability (economic, social well-being, technical, legal, and environmental quality) existing in the aquaculture sector. A combination of efficient allocation of inputs in a production process and the existing environmental conditions, with a national plan with clear and achievable objectives within a coordinated international platform, assists each aquaculture-producing country to attain high levels of outputs and the objectives outlined in its national plan and help the countries to approach the attainment of the SDGs. The squiggly line from output to SDGs indicates that the achievement of the SDGs is only probable given the wide-ranging physical, biological, environment, social, economic, and political complexities and external pressures exerted, as indicated on the right and left sides of the figure, that influence the goal attainment. Some (particularly African) countries include aquaculture in their goals of poverty

eradication, food security, income generation, and gender mainstreaming within their national plans. On the other hand, there are countries with modest aquaculture output, but include in their plans policies for growth and development of the sector. Such policies are an implicit acknowledgment of the sector's potential (Murekezi et al., 2020).

Aquaculture as a food-producing sector offers ample opportunities to alleviate poverty, hunger, and malnutrition, and generates economic growth and societal well-being. Efficient allocation of resources in the production process ensures better use of natural resources (FAO, 2017c). The necessity to increase aquaculture production has been triggered by the growing demand per capita for fish parallel to the increase in global population. However, the development of a sustainable aquaculture industry is particularly challenged by the limited availability of natural resources (clean water) as well as the impact of the industry on the environment (Costa-Pierce et al., 2012; Verdegem, 2013) and overregulation that can retard the progress of aquaculture contribution to the SDGs (Engle & van Senten, 2022; Engle & Stone, 2013; Sharm El-Sheikh 2015; Stead, 2019). Marine aquaculture expansion as well as species of aquatic products are considered as the solution to the reduction of fish deficit at global markets. The production of alternative species such as seaweeds and sea cucumbers has shown great promise to raise productivity and aquaculture production (Felaco et al., 2020; Namukose et al., 2016). Seaweed aquaculture globally produced 31.8 million tons in 2018, comprising 51.3% of global mariculture production, with a market value of more than 11.3 billion USD (FAO, 2020a, 2020b, 2020c). Almost all the production (99.9%) is derived from Asia, with China and Indonesia accounting for about half and a third of global seaweed production, respectively.

Meeting the SDGs has become an integral element of global policy, especially through the Sustainable Development Strategy Vision 2030, which outlines programs, formulates policies, and measurable indicators for sustainable development (Hambrey, 2017; Nasr-Allah et al., 2020). Recently, the science of organizational law has adopted the alleged “new governance,” including the use of policy framework that involves the conference of public responsibilities to the private sector. Many present-day legal scholars have classified this legal framework as an essential part of governance, which allows stakeholders to participate in all aspects of decision-making (Bingham, 2009).

1.6 | Legal and regulatory frameworks

The governance dimension of sustainability and resilience includes laws and regulations at federal, national, state/provincial, and local levels. Aquaculture production at local and coastal areas often have complex and overlapping jurisdictional and regulatory authorities (Engle & Stone, 2013), in which local authority by diverse entities is often more prominent (Knapp & Rubino, 2016; van Senten et al., 2020). In most countries, a legal framework designates a ministry or department as overseeing the aquaculture sector (Hishamunda et al., 2014). In Africa, most of the countries do not have a stand-alone Ministry for Fisheries and Aquaculture, except for Ghana where there is a Ministry of Fisheries and Aquaculture Development. In most cases, aquaculture is domiciled in a Ministry that is responsible for either agriculture, livestock, or forestry. Even when aquaculture output is relatively small and under a Ministry of Agriculture, as in Zambia, the lead agency is often a department of fisheries (DOF), so that it can be regulated separately from other forms of established agriculture like crops and livestock (Chuenpagdee et al., 2008). Often, aquaculture is one of the departments or directorates within the organizational structure. However, many African countries in collaboration with FAO have developed comprehensive aquaculture plans during the last decade. The PFRS for Fisheries and Aquaculture is adopted by all.

The United States does not have a single framework or set of laws and legislation that govern aquaculture. The USDA as part of the sub-committee on agriculture (SCA) and the joint sub-committee on Aquaculture (JSA) serves as the lead federal agency directing freshwater aquaculture (Love et al., 2017). The types of policies and supporting mechanisms vary widely from state to state, as does their receptivity. Some states, like Hawaii, Florida, Maine, and Mississippi actively promote aquaculture development. Others have developed state policies or even plans but established few programs to assist the industry. The Department of Commerce through the National Oceanic and Atmospheric Administration (NOAA) is responsible for marine aquaculture and the Department of Health and

Human Services through the Food and Drug Administration (FDA) work with stakeholders on drugs and food safety compliance (National Science and Technology Council Subcommittee [NSTCS], 2022; Engle & van Senten, 2022).

The Canadian federal government through its lead agency, the DOF and Oceans, has responsibility for marine coasts. However, in the two salmon farming provinces in the Atlantic, this responsibility has been delegated to the provinces, but not in the Pacific where the province of British Columbia administers the Crown lands adjacent to farms, and the federal government regulates aquaculture operations (Mowi, 2019).

Aquaculture maintains a relatively low institutional hierarchy in Latin America. There are only two countries that have a Ministry of Fisheries and Aquaculture (Nicaragua and Venezuela). Most of the countries have the aquaculture organizational structure as part of the Ministry of Agriculture or similar; where terrestrial agricultural activities tend to have much more production volume, number of dependent families, and political weight; therefore, financial and human resources are comparatively much lower than those allocated to the aquaculture sector. In Chile, aquaculture is under the Ministry of Economics (Appendix A). Using Ecuador as an example, there are no targeted regulations for the aquaculture sector. Instead of having evidence-based policies that are fit-for-purpose, the rules governing aquaculture had been adapted from the fisheries sector (Howell, 2020). This means that many countries cannot give the aquaculture industry the institutional expertise or support it needs to thrive and this may be a problem existing in many other developing nations.

Among the world's largest aquaculture producers, China's Bureau of Fisheries, India's Aquaculture Authority, and Thailand's DOF are the lead agencies for aquaculture, and all fall under their respective Ministries of Agriculture. In Vietnam, the Ministry of Agriculture and Rural Development (MARD) is the main body for aquaculture decisions, with supporting ministries and regional governments for the regulation and enforcement of aquaculture laws (Nguyen & Jolly, 2020b). FAO has collaborated with the Network of Aquaculture Centers in Asia-Pacific (NACA) through the convening of a regional consultation on strengthening the governance of aquaculture in Asia-Pacific to ensure sustainable development.

The European Commission is made up of 27 commissioners (one from each member state) and is based in Brussels. Each member state nominates a commissioner, but the nominated candidates must be approved by the European Parliament. The Commission provides a common vision for EU countries, the aquaculture sector, and other stakeholders to develop the sector in a way that contributes directly to the European Green Deal and the Farm to Fork Strategy. The Commission has an Aquaculture Advisory Council that consists of sector representatives and stakeholders (Abate et al., 2018). It provides EU countries and EU institutions with recommendations on sustainable aquaculture. The Commission has adopted a Common Fisheries Policy which is the mechanism and set of rules through which European fishing fleets and fish stocks are managed (Bostock et al., 2016). It began in 1970 and was most recently reformed in 2014. EU countries review their national strategic plans to promote aquaculture to take into consideration that vision.

2 | MATERIALS AND METHODS

The first part of the study was an intense literature review of government documents, scientific papers, World Bank, FAO, and other related industry papers on aquaculture governance in Africa, the Americas, Asia, and Europe to provide background information on aquaculture governance and development in the selected regions and major producing countries in each region. The review process depended on Google Scholar searches and other printed documents. The review documents were selected based on whether the research or development activities occurred during the periods 2000–2010 or 2010–2020. We used the existing World Bank Governance Indicators purport to measure state aspects of state capacity (government effectiveness, regulatory quality, and stability and absence of violence, control of corruption; Fukuyama, 2013). These aggregate indicators combined the views of many enterprises, citizens, and expert survey respondents in industrial and developing countries. They are based on over 30 individual data sources produced by a variety of survey institutes, think tanks, non-governmental organizations, international organizations, and private sector firms: <https://info.worldbank.org/governance/wgi/>.

We identified the SDGs that are central to the literature and summarized the identified interactions between governance and SDG targets. Finally, we discussed the implications for the governance of sustainable development and the attainment of the SDGs. We examined the role of the public and private sectors in directing the sustainable development impacts of the economic activities that they undertake or invest. We evaluated economic activities' that influenced the attainment of the SDGs (Van Zanten & van Tulder, 2021).

UN documents were consulted for the SDGs proposed for 2010–2020. Although aquaculture's role in contributing to the SDGs has not always been clearly identified or communicated, almost all the SDGs are relevant (Zhang et al., 2022). All 17 goals were tabulated and six were maintained: achievement of poverty elimination (SDG1); end hunger through the attainment of food security (SDG2); good health and community well-being (SDG3); gender equality (SDG5); decent work, economic growth, and trade (SDG8) and; conserve the use of the oceans, seas, and marine resources for sustainable development (SDG 14) (Said & Chuenpagdee, 2019; Stead, 2019). www.un.org/sustainabledevelopment/sustainable-development-goals/ closely related to aquaculture development were selected (Mustafa et al., 2018).

We developed a conceptual model to show the relationship between governance principles, inputs, outputs, and the attainment of the SDGs, under environmental, physical, or biological, social, economic, and political conditions. The model shows how changes in governance are likely to influence changes in efficient resource allocation, output improvement, and the possible contribution and probable attainment of SDGs.

Secondary data were collected from official publications of the Ministries of Agriculture, agencies responsible for aquaculture development and planning, the World Bank, and FAO to provide descriptive statistics of production, inputs, governance, and administrative structures and their levels of governance. An analytical approach was adopted in the review of the literature to extract information related to governance and improvements in the SDGs during the periods 2010 and 2010–2020. From these data, we performed qualitative analysis to determine how governance and public and private sector interventions influenced the attainment of SDGs, given the biological, physical, environment, economic, sociological, and political constraints. Since the measurement of governance is bent more toward political actions and the SDGs are so broad and there are numerous industries and other factors contributing to targeted SDGs, it is impossible to associate governance directly and solely to the attainment of the SDGs, but its contribution to these goals. Hence, there are no quantitative correlations presented, but rather anecdotal documentation of scientific evidence of improvements in governance and/or the attainment of the SDGS during the period 2010–2020.

3 | RESULTS

3.1 | Changes in governance since 2010

3.1.1 | Administrative changes

Modern aquaculture is expanding rapidly in many countries and needs constant adaptive alteration in its administration. Aquaculture's importance in national programs increased significantly between 2011 and 2018. In 2007, only a few countries surveyed recognized aquaculture as an economic sector and of those 87% reported having some form of legal framework in place to regulate the development of responsible aquaculture (FAO, 2020a, 2020b, 2020c). However, of the 98% reporting the presence of aquaculture activities in their countries, only about 40% of these had legislative and institutional frameworks in place. Thus, the growth of aquaculture activities appears to have outpaced the development of legislation and legal frameworks for aquaculture governance. In 2018, the figure had risen to just over half, still indicating a need for some countries to adopt a legislative framework to better manage and benefit from aquacultural economic activity (FAO, 2020a, 2020b, 2020c).

Africa includes a total of 55 national states, of which 54 are members of the AU, Morocco is not a part of the AU (Makinda & Okumu, 2007). Within the AU, the continent is subdivided into eight officially recognized Regional Economic Communities (RECs). A PFRS for fisheries and aquaculture in Africa was adopted by African ministers in May 2014 providing the basis for improved fisheries governance, with particular reference to improving governance and institutional arrangements, developing sustainable small-scale fisheries, promoting responsible and equitable fish trade and marketing, and developing coordinated mechanisms among RECs, Regional Fisheries Bodies and Large Marine Ecosystem based commissions. The fisheries issues are also referred to in the AU 2050 Africa's Integrated Maritime Strategy (AIMS), which was adopted at the AU Summit in January 2014. This PFRS is being promoted by African Union-Inter-African Bureau for Animal Resources (AU-IBAR), in collaboration with FAO, the new partnership for Africa's Development (NEPAD) and African national institutions (Ababouch & Fipi, 2015).

The PFRS for Fisheries and Aquaculture in Africa emphasizes the urgent need to strengthen the knowledge base of the sector and increase the capacity of key stakeholders to develop and implement a strategic perspective on its future. At the regional level, the Southern African Development Community (SADC) Protocol on Fisheries (2001) calls for state parties to collaborate in the management and development of fisheries and aquaculture resources (Union Africa, 2014). Further to this, SADC developed a SADC Regional Aquaculture Strategy and Action Plan. This clearly shows that there is enthusiasm at the political level to boost aquaculture production in the region (Moyo & Rapatsa, 2021).

The U.S. Federal aquaculture governance has been vague and confusing because of the dispersal of regulations and oversight among several Federal Departments and agencies as well as varied departments at the state level. The dispersion of responsibilities among the numerous departments and agencies leads to ambiguity, and duplication of regulations that have constrained aquaculture development and expansion. The National Aquaculture Act of 1980 established the Interagency Working Group on Aquaculture (IWG-A), which reports to the National Science and Technology Council (NSTC) and the Office of Science and Technology Policy (OSTP) in the Executive Office of the President. The NSTC is the principal means by which the executive branch coordinates science and technology policy across the diverse entities that make up the Federal research and development enterprise. The IWG-A provides leadership and facilitates the coordination of federal programs associated with aquaculture. This is done through The Aquaculture Act set in motion the first National Aquaculture Development Plan (published in 1983), which established the USDA as the lead federal agency to coordinate and disseminate aquaculture information in 1980. The Joint Sub-Committee on Agriculture (JSA) coordinates federal activities carried out by agencies operating under the National Science and Technology Council in the Office of the Science Advisor to the President (NSTCS, 2022).

In January 2019, with the approval of the State Council of China, the Ministry of Agriculture and Rural Affairs of China (MARAC) and other nine ministries jointly issued "Several Opinions on Accelerating the Green Development of Aquaculture" (shortened to "Opinions"; Ministry of Agriculture and Rural Affairs of the People's Republic of China [MARAC, 2019]). Socioeconomic assessments have been conducted by many Asian countries. The Republic of Korea and Japan have also conducted similar routine assessments (Jayanthi et al., 2018). Japan has a special department for resource assessment for its fishery sector's sustainable development. The Fisheries Infrastructure and Aquaculture Policy Division under the Ministry of Oceans and Fisheries direct aquaculture policy formulation in the Republic of South Korea. The Republic of Korea and Japan have also conducted planning and routine assessments of their aquaculture sectors (Jayanthi et al., 2018). Cambodia drafted their revised Fisheries Law that covers the practices for the discharge of waste and water quality control (Miao & Yuan, 2019). Bangladesh set up workshops to improve communication between administrators and stakeholders on aquaculture development (Bremer et al., 2016). India's Green Certification Guidelines gave the assurance of the value chain system that can further improve its freshwater ornamental fish (Miao & Yuan, 2019). Section 51 of the 2015 Fisheries Act of Thailand makes aquaculture in rivers, as public water bodies with capture fisheries, illegal unless specific exception or permission is granted by the province (DOF, 2015). Before this Act, cage culture in rivers had de facto support from the DOF and other relevant bodies, and access went primarily to people who lived near the riverbanks (Lebel et al., 2014). In 2013, MARD of Vietnam developed a comprehensive plan for long-term development of its fisheries and aquaculture that synchronizes all

legal, economic, social, and environmental aspects of innovation, aquaculture in various spaces of water; processing and commercial consumption in the domestic and international markets; mechanical ship building and fishing logistics service.

The European Commission has recognized the essential role of aquaculture in the food system and the importance of boosting the sustainable development of EU aquaculture. In 2013, the Commission published their “Strategic Guidelines for the sustainable development of EU aquaculture” (Varadi & Bekefi, 2015). The aquaculture sector must also engage in environmental protection while it intensifies productivity and its environmental performance. Recently, the EU launched the European Green Deal (European Commission, 2019), the roadmap for making EU's economy environmentally sustainable. As part of this agenda, a new Circular Economy Action Plan (European Commission, 2020) has been recently published which aims to involve economic actors, consumers, citizens, and civil society organizations in the dynamization of the regulatory framework. Besides, maintaining or promoting the competitiveness, productivity, and durability of the EU aquaculture sector, the plan promotes policies and regulations regarding marine and coastal management, environmental protection, waste, or animal health, among others, and at different institutional levels (Alexander et al., 2015).

3.1.2 | Changes in governance programs and industry

There have been many advancements in the economic environmental, social, and technical dimensions of aquaculture governance over the last 10 years. African countries have encouraged private-public sector partnerships and engaged in sustainable aquaculture strategies to diversify aquaculture production. Producers have switched from pond culture to cage culture. Large transnational aquaculture companies have been successful and have increased international aquatic trade and consumption. Today, lakes Victoria (Kenya, Tanzania, and Uganda), Kariba (Zambia and Zimbabwe), Kivu (Rwanda and Democratic Republic of the Congo), Muhazi (Rwanda), and Volta (Ghana) host 91% of the total inland cage aquaculture (Musinguzi et al., 2019). Private sector investments led to aquaculture expansion across sub-Saharan Africa's (SSAs) inland water, from nine cages in 2006 to more than 20,000 in 2019 (Ragasa et al., 2022). Countries have engaged in alternate aquatic enterprises such as the production of seaweeds in Kenya to sea cucumbers in Zanzibar. To create an enabling environment for aquaculture in South Africa the government adopted the National Aquaculture Framework in 2013 (Adeleke et al., 2020). The policy framework is supported by the National Aquaculture Strategy and Action Plan. Specific goals were set, and aquaculture production was supposed to double by 2020. While important progress in aquaculture governance has been achieved over the past 10 years because of programs and projects stemming from those sectoral plans that have propelled aquaculture in countries like Kenya, Ghana, and Zambia, the environmental effects have not been assessed.

Previously policy formulation and enforcement in many regions lacked total community participation and hence aquaculture policies are not people oriented and fail to incorporate the communities' voice in policy development (Barton & Fløysand, 2010). Some countries have decided to rectify the problem and started to develop their policies in a participatory and transparent manner through SADP, considering the stakeholders involved. In February 2019, the US Sub-Committee on Aquaculture (SCA) established a Regulatory Efficiency Task Force charged with developing a new plan for interagency science and technology coordination to improve regulatory efficiency, research and technology development, and economic growth. The USDA Working Group on Aquaculture sought to provide the domestic aquaculture industry an opportunity to communicate on how USDA can best serve this farming community. USDA, FDA, and NOAA are now encouraging community participation in development of their five-year plans (Fisheries NOAA, 2014). The overarching vision of the master plans for aquaculture economic development is to create a robust, resilient, and environmentally sustainable domestic aquaculture sector. The plans have encouraged a flow of investments by private sector to engage in ocean aquaculture expansion and allied services since 2011. The number of large companies grew with time. From 2011 to 2015 there were only four companies established, but

from 2016 to 2018 the number of large-scale companies established was six. Presently there are about 1928 small-scale venture aquaculture companies (USD 350,000) conducting business in the US.

The United States is proactive in its design or rules and regulations of food safety, and therefore, has some of the most comprehensive environmental, seafood safety, and regulatory programs in the world (Engle et al., 2020; Engle & Stone, 2013; Engle & van Senten, 2022). The U.S. NOAA has set specific goals for marine aquaculture (coastal and offshore), and NOAA as well as other government agencies, including the USDA, are investing in growing the US marine aquaculture sector while supporting the production of freshwater aquaculture which is in the domain of the USDA. North Carolina recently started a NOAA-partnered shellfish initiative, passed new legislation to enable shellfish aquaculture, and commissioned a state-wide study that projects the potential to grow the farm-gate value of shellfish aquaculture from USD 2.5 million to USD 33 million by 2030 (North Carolina Shellfish Mariculture Advisory Committee, 2019). Similarly, in Maine, significant public investments in marine aquaculture have spurred parallel private investments and an increase in new aquaculture operators over the past 5 years (Stoll et al., 2020).

Currently, USDA primarily supports aquaculture production research through extramural programs administered by the National Institute of Food and Agriculture (NIFA) and intramural projects in Agriculture Research Service. USDA and NOAA shared a focus on funding institutions in coastal and Great Lakes states, while USDA also funded institutions in land-locked states (e.g., Arkansas, Idaho, Iowa, Kentucky, Missouri, South Dakota, and West Virginia). NIFA funds aquaculture research projects through a combination of competitive grants, either formula grants or capacity building grants. Over the past 5 years, NIFA has funded more than 220 competitive research projects, including more than USD 90 million invested in 57 Small Business Innovation Research ventures and 64 projects through Regional Aquaculture Centres. Much of NIFA's funding was focused on coastal and Great Lakes states as expected (Love et al., 2017). States with more aquaculture production and more research centers conducting aquaculture research received more grants than states with fewer farms and research centers, except for New Hampshire or Rhode Island (Love et al., 2017).

A further governance complication is the allocation of responsibilities in a federal system. Canada is a relatively small producer of farmed Atlantic salmon with less than 10% of global output, but it is Canada's most valuable aquaculture species, cultivated in both the Atlantic and Pacific. The Canadian federal government through its lead agency, the DOF and Oceans, has responsibility for marine coasts (Mowi, 2019). Interactive governance recognizes that societal problems and opportunities can be characterized by their diversity, complexity, dynamics, and scale, and that governance responses must therefore come not only from the state, but also from the market and civil society (Cai et al., 2012). In Canada, the rights of indigenous groups over traditionally used territories are increasingly recognized in court verdicts, forcing senior governments to consult with indigenous communities about economic decisions in marine and terrestrial spaces (Newman, 2009; Young et al., 2019). Some aquaculture companies have partnered directly with indigenous communities through agreements on enhanced environment monitoring and employment opportunities (Young et al., 2019; Young & Liston, 2010).

Asian countries have applied a governance framework to make changes along the value chain at the farm and market level, technical upgrading production facilities, effective adoption of farming and marketing practices to establish enhanced management standards to improve efficiency and reduced negative environmental and social impacts (Krause et al., 2015; Ponte et al., 2014). Value chains have undergone rapid technological change in all segments as they have modernized (Nguyen, Cheng, et al., 2020). The literature describes successful technical implementation of different standards, but also includes critical reflections on the weak inclusion of smallholder producers (Belton et al., 2011; Bush et al., 2013; Hatanaka & Konefal, 2013; Vandergeest, 2007). This has been due both to spontaneous experimentation and invention by value chain actors, and induced innovation in response to greater competition as a function of shrinking margins. Evidence for such innovation includes the growing use of pelleted feeds, and strategies such as deepening ponds, stocking fingerlings at larger sizes, and integration with poultry (Belton et al., 2018). Structural changes have occurred throughout the chain as farms and related firms have proliferated and become more specialized (as individual enterprises) and diversified (in aggregate). Occasionally, they have

become more concentrated (such as in the case of farmed Atlantic salmon or Indian pangasius) in certain nodes, or vertically integrated across them. There are many structural changes in the Vietnamese value chain to improve product quality and to maintain or increase market share (Nguyen & Jolly, 2020a). MARD in 2013 developed a comprehensive plan for long-term development of Vietnam's fisheries and aquaculture that synchronizes all legal, economic, social, and environmental aspects of innovation, aquaculture in various spaces of water; processing and commercial consumption in the domestic and international markets; mechanical ship building and fishing logistics service. The Master Plan also includes strategic programs of fisheries and aquaculture development based on the real conditions, competing factors, and natural characteristics in major centers of Vietnam (Hong et al., 2017).

The Republic of Korea has conducted a progressive management pathway to improve aquaculture biosecurity (Bondad-Reantaso et al., 2018). Japan has a special department for resource assessment which has conducted a socioeconomic assessment of Japanese aquaculture (Jayanthi et al., 2018). Cambodia drafted its revised Fisheries Law that covers the practices for the discharge of waste and water quality control (Miao & Yuan, 2019). On the practice of governance and value chain development, Bangladesh set up workshops to improve communication between administrators and stakeholders on aquaculture development. The responses suggest that there is great potential for mobilizing a rich store of knowledge for bottom-up construction of standards (Bremer et al., 2016). India's Green Certification Guidelines gave the assurance of the value chain system that can further improve its freshwater ornamental fish (Miao & Yuan, 2019). The Master Plan prepared by MARD also includes strategic programs of fisheries and aquaculture development based on the real conditions, competing factors, and natural characteristics in major centers of Vietnam (Hong et al., 2017).

The European Commission concluded in 2013 that aquaculture production in the EU was stagnating and aimed to address the challenges (Varadi & Bekefi, 2015). EU engaged in regulatory intervention and spatial planning to create a balance between aquaculture producers and environmental protectors as aquaculture has had a significant economic impact on rural communities in certain regions of the Union, where there are few alternative sources of employment and industrial development (Long, 2016). In April 2009, The European Commission issued a communication on "Building a sustainable future for aquaculture, designed to provide a new impetus for the Strategy for the Sustainable Development of European Aquaculture" which recognized the anticipated growth rate for aquaculture of 4% per year. This proved highly unrealistic and in overall volume terms, the sector has stagnated since the turn of the century. In contrast to the increasing aquaculture production of mussels worldwide, production in the EU has shown a decreasing trend over the last two decades (Avedelas et al., 2021). In Norway, applicants must have permits for land and water access before they can get an aquaculture license (Hishamunda et al., 2014). Another major obstacle to progress is that of ownership of the aquaculture resource which is vested in either a natural person or corporate entity, normally the holder of the aquaculture license or other installation or business approval. Aquaculture may thus be distinguished from other marine resources such as commercial sea fisheries, which are a common property natural resource over which the State exercises, in the first instance, public property rights (Puszkarski & Śniadach, 2022). EU policy is generally supportive of sustainable aquaculture development for reasons of food security and economic development.

3.1.3 | Technological advancement

Aquaculture governance in some countries has focused largely on the technical upgrading of production to foster improved or "better" management standards designed to improve efficiency and reduce negative environmental and social impacts (Anh et al., 2011; Krause et al., 2015). The literature describes successful technical implementation of different standards, but also includes critical reflections on the weak inclusion of smallholder producers, enclosure, and the limitations of governing "off-farm" common resources sustainably and ethically (Belton et al., 2011; Bush et al., 2013; Hatanaka & Konefal, 2013; Vandergeest, 2007). Studies have revealed innovations that resulted in productivity increases that enhanced aquaculture competitiveness (Asche et al., 2008; Kumar & Engle, 2016).

Dynamic processes of continuous innovation and technological change are omnipresent in most aquaculture value chains, reflecting the attempt to increase accountability and transparency in governance. This is apparent in Yi et al. (2015) study of Indonesian shrimp, Kassam and Dorward (2017) studies of Zambia and Ghana, Kaminski et al. (2018) and Asche et al. (2018) study of Norwegian salmon. The government of Kenya, for example, introduced a large-scale aquaculture subsidy program under the Economic Stimulus Programme (ESP) implemented from 2009 to 2012 (Ole-Moiyoi, 2017). The ESP focused on pond construction, fish feeds and fingerlings supply, post-harvest management, and human resource capacity building of fish farmers and associated institutions (Obiero et al., 2019). The main aquaculture technologies ranked highly in this study which was related to feed and seed production. The genetically improved Abbassa Nile tilapia strain saw Egypt become Africa's leading tilapia producer—and the third highest globally—while reducing environmental impacts (Henriksson et al., 2017; Ragasa et al., 2022). The Akosombo strain of tilapia through selective breeding in Ghana has contributed to the booming of tilapia industry in that country. Some important science and technology developments in aquaculture have contributed to increased productivity (Satia, 2017). Aquaculture research in Zambia is mandated to design and facilitate the adoption of science and aquaculture technologies to enhance productivity (Maulu et al., 2019). Disease resistance and feed efficiency traits are being incorporated into fish breeding (Barría et al., 2021), with huge potential for SSA. In Zambia, aquaculture researchers have focused on trying to adapt the science and technologies developed elsewhere to local conditions (Mudenda, 2009). In Egypt, new production systems and feed quality were improved and existing technologies are also hopeful in the demonstration of offshore aquaculture technical feasibility since the impact of technological progress is most apparent where there has also been substantial industrial consolidation (Bostock, 2011; Garlock et al., 2020). Research on substitute, locally existing, and lower cost ingredients for aquafeeds are being utilized and are increasing feed use efficiency and resulting in incredible benefits to farmers (Ssepuuya et al., 2017).

In the past decade, technological advances in production and breeding systems, feeds and nutrition technology, vaccines, species and strain selection, reproductive control, mechanical aeration, and water exchange and non-technological innovations, market, and certification standards, among others, have enabled the growth of the US aquaculture sector (Joffre et al., 2017; Kumar & Engle, 2016). Recent studies indicate that investments in new production systems, management practices, and new products result in substantial benefits to producers and consumers. Split ponds are modified versions of the partitioned-aquaculture system (Tucker et al., 2014) where existing earthen ponds are divided into a fish-containment basin (15%–25% of pond area) and a waste treatment zone (75%–85% of pond area). Greater fish yields achieved from these two systems generated cost efficiencies by spreading fixed costs over larger volumes of fish production (Kumar et al., 2018, 2020). In all other aquaculture product categories, sales increased between 2013 and 2018. Mollusks sales in 2018 were USD 441.8 million, up 34% from 2013 (Shamshak et al., 2019). Crustacean sales totaled USD 100.4 million, up 18%. Sport fish sales increased by 65% between 2013 and 2018. In each product type, a couple of species account for most sales. Catfish sales, valued at USD 366.8 million in 2018, accounted for 51% of all food fish sales. Trout accounted for 16%.

The introduction of new and genetically improved farmed tilapia (GIFT) in Southeast Asia resulted in enhanced productivity, ranging from 18% to 58% in China and Bangladesh (Tran et al., 2021), with each generation yielding 7%–10% gains in productivity (Ragasa et al., 2022). On the recommendation of its Fisheries and Aquaculture Department, Cambodia established a new Fish Health and Disease Management Office at the Department of Aquaculture Development in 2018 to strengthen its capacity for disease diagnosis. India is in the process of drafting a new bill for not only aquaculture products' quality control but also for aquatic animal disease prevention and spreading (Miao & Yuan, 2019). China has not only improved aquaculture technology (including fish feeding method) (Zhou & Niu, 2020), aeration (Huang et al., 2020), and seed (Liu et al., 2018) but also developed aquatic products' traceability system to improve product quality, clarified standards for food safety, and improved routine food safety inspection for aquatic products (Han et al., 2018). Aquaculture development in Vietnam is based on strong educational institutions in terms of human resource development and technology dissemination. There have been close interactions among education, research, technological innovation and diffusion, and aquaculture development (Tri et al., 2022).

Aquaculture production technologies have undergone significant changes in Europe. There has been an increased use of Recirculating Aquaculture Systems (RAS) for the production of large smolts and in some cases for growing fish up to 1.0 kg in fresh water before transferring them to sea cages. The most promising development has been the continuing increase in the production of Atlantic salmon (by 43% for the period 2009–2014), mainly in the Kingdom of Norway but with significant contributions from the Faroe Islands, the United Kingdom of Great Britain and Northern Ireland and the Russian Federation. The production of European seabass and gilthead seabream in cages in the Mediterranean Sea has increased (Clarke & Bostock, 2017).

3.2 | Achievement of poverty elimination (SDG1)

The way governance influences aquaculture production and distribution to support the achievement of the SDGs is interrogated. The political, economic, social, technological, legal, and environmental factors framework is being applied to prioritize activity, with the aim of achieving the SDGs. The process is circuitous and involves the stakeholder's willingness and ability to use aquaculture development to improve their welfare. The approach identifies the observed outcomes (in this case SDG1) as the result of policy implementation and practice, highlighting a need to introduce arrangements that focus on technical inputs—property rights in aquaculture (Sutinen, 2008). The evidence for change is in the form of benefits to producers, efficiency, and environmental outcomes. However, the evidence of the effectiveness of these measures in terms of addressing poverty may be weak (Béné et al., 2009, 2016).

Aquaculture can contribute directly to poverty alleviation by increasing the output, which generates income from the use of aquaculture inputs and provides services and outputs to the industry, and domestic and international consumers. Aquaculture production has experienced increases from 41.1 to 78 million m.t. during the period 2000–2010, an 8.97% increase from 78 to 122.6 million m.t. a 5.72% increase from 2010 to 2020 (Figure 2). Indirectly, aquaculture contributes to the livelihoods of the rural poor by providing the following benefits: increased availability of low-cost fish in local markets; multiplier benefits, or employment; benefits from common property resources, particularly the landless, through cage culture and enhanced fisheries in otherwise underutilized resources; and increased farm sustainability through construction of ponds that also serve as on-farm reservoirs (Edwards, 2013). The indirect poverty impacts of aquaculture tend to be larger than the direct impacts (Belton et al., 2012; Kassam & Dorward, 2017). At the macro level, all states emphasized increased production in their annual plans. Aquaculture production increased by 5.8% from 2000 to 2018. The SSA countries showed the highest growth rate of 11.2% and next in line are the Northern African Arab countries with 9.0%. The Asian Pacific countries increased by 5.6%, North America by 0.68%, and Europe by 2.59%. However, despite not being in Asia, four of the top producing countries experienced growth rates, while Asian countries experienced declining growth rates from 2009 (Bartley, 2022).

Output levels depend on the governance strategy each region adopted in the effort to direct production. In Table 1 the emphasis varies, but with some repetition in each region. The relationship between governance scores for the period shows no real pattern with levels of growth in production. Countries with high governance scores have low and decreasing production growth rates. The information in the table shows that each region had a different emphasis on the policies embraced during 2010–2020. The North American region had the highest governance score but the lowest growth rates. For example, African countries emphasized, food production, nutrition, employment, investment, and trade in their national plans whereas the US and Canada prioritized environmental impact, human and animal health, regulatory frameworks, sustainability, partnerships, marketing, and investment as key factors influencing production decisions. SSA countries experienced increases in freshwater aquaculture because of low initial production, a demonstrated effort to expand aquaculture in the region and switch from pond culture to cage culture on the major lakes. Asian countries highlighted food, nutrition, exports, foreign, environmental regulation, and employment as their major planning concerns. European countries emphasized environmental stewardship, pollution, nutrition, and employment reduction. Hence the level of output and the degree to which the regions are approaching levels of poverty reduction may not assist in achieving the stated goals. The growth rates from 2010 to

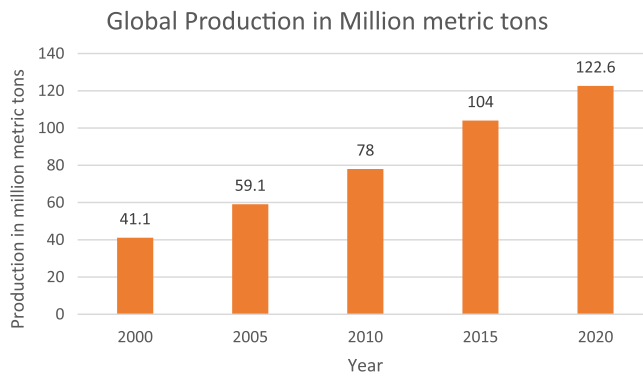


FIGURE 2 Global production of fish in million metric tons, 2000–2020.

TABLE 1 Regions Governance strategy, average governance score and growth rates, 2000–2020.

Regions	Governance strategies adopted	Governance score	% change in production 2000–2009	% change in production 2010–2020
SSA	Poverty reduction; employment; food security; sustainable development; private–public partnerships	29.65	26.11	4.52
NENA	Poverty reduction; employment; food security; sustainable development	36.87	11.36	7.22
North America	Environmental sustainability; regulatory framework; food safety and health concerns; capital investment and technology concern	86.97	1.93	0.59
Asia-Pacific	Food security; exports; foreign exchange earnings; food safety; standards; public–private partnership	55.42	–0.91	4.72
Europe	Environmental sustainability; regulatory framework; pollution; health concerns; pollution reduction	70.48	2.52	2.80
LAC	Exports; foreign exchange earnings; food security; rural development; pollution reduction	55.76	11.97	6.59

2020 were less than that of 2000–2009 across all regions, but for Asia-Pacific region. The value of output has been declining in regions with heavy emphasis on environmental impact and regulatory frameworks.

Commercial aquaculture can create employment linkages that are greater than those associated with crop farming (Belton et al., 2015, 2017), and these employment linkages can be poverty and income inequality reducing (Irz et al., 2007). However, since the major producing regions like Asia and Latin America have small-scale commercial fish farms, they may create larger multiplier effects than small non-commercial or large commercial farms (Belton et al., 2012; Kassam & Dorward, 2017). Aquaculture contributes to livelihoods as well as revenue in several countries alone and fish would still be insufficient to attain the SDGs. They also suggest that the economic multipliers generated by small- to medium-sized farmers in Ghana had more indirect benefits on poverty reduction than large commercial cage farms or low-input subsistence ponds (Bush, Beltonb, et al., 2019; Bush, Oosterveer, et al., 2019). Without considering the secondary fisheries sector and other value chain stakeholders, the FAO (2016) estimates that, as of 2014, there are about 57 million people engaged in the fisheries and aquaculture sector with aquaculture accounting for about 33% of this population and Asia alone has 96% of world fish farmers. Employment income in some locales is adequate to lead households out of poverty, but that all depends on the species selected, the levels of technology, and the quantities produced (Nguyen et al., 2016). Abdullah et al. (2017), on the other hand,

suggested that aquaculture caused inequity in income distribution since higher income households in Bangladesh benefitted more in terms of absolute and relative income from the shrimp sector than the lower income households because of land ownership or access to land.

The value of aquaculture products has risen from \$53.7 billion in 2000 to \$263 billion in 2018. The value of production reflects the diversity of species and the price received (Bartley, 2020). Many countries have identified aquaculture as one enterprise for increasing fish production, fostering economic development, and reducing poverty through increased food production, income, and employment. About 20.53 million people across the globe, but about 96% of those jobs are on the Asian continent. The number of jobs created in SSA is low although the rates of employment are high, and the population growth rates are the highest. America and Europe depend on technology to operate their farms because of labor costs and their production is technology based and requires a highly educated workforce (FAO, 2020b). The exploitation of aquatic resources for aquaculture will continue in SSA, given the necessity to survive and maintain livelihoods among people who are employed. However, since not all the benefits of economic growth from each aquaculture system are likely to accrue to the poor, small-scale pond aquaculture was estimated to have more potential to indirectly affect poverty at a medium level, as compared with weaker small medium enterprise (SME) cage aquaculture, with large-scale cage aquaculture generating the weakest impacts (Kassam, 2013).

Kassam (2013) suggests that aquaculture does not appear to have direct poverty impacts on poor households, but it does have the potential to directly benefit poor fish farming households if their resource constraints can be overcome and they are able to use and benefit from BMPs. The potential for aquaculture growth is much lower for pond aquaculture than cage culture. Much growth in the sector has emanated from the establishment of large-scale cage culture farms that have given rise to a cluster of SMEs. The noted drivers behind this increase are higher urban demand for fish and macroeconomic policy (Bartley, 2020; Kassam, 2014). It is a valuable source of income and employment, particularly in developing nations, where seaweed aquaculture often provides additional income to artisanal fisher households (Rebours et al., 2014; Robledo et al., 2013).

A large proportion of the world's poor depend on fish culture for their animal source of protein. Few isolated case studies evoke the possibility that income and employment created by aquaculture can benefit low-income households participating in specific, often rural aquaculture activities in SSA and Asia (Arthur et al., 2013; Nguyen et al., 2016). However, the overwhelming evidence from the literature indicates that it is usually the better-off farmers and households who tend not just to benefit the most from aquaculture development but are also able to take up the new technology and connect to the extension services where they are available (Arthur et al., 2013). The reasons for this include not only income, and access to credit and information but also structural issues such as ownership or land rental and water resources, which are still a considerable constraint for the poorest households in SSA (Abdullah et al., 2017; Arthur et al., 2013). Overall, it seems that peri-urban fish farmers are more likely to generate higher incomes and net returns and longer-term financial viability, than similar producers in more remote rural areas because of access to both inputs such as feed and fingerlings, and higher value markets (Arthur et al., 2013).

Researchers have stated that by 2012, 98% of aquaculture farming businesses provided income and employment for many communities around the world (Sheriff et al., 2008) and offered potential for increased positive social and economic impacts upstream and downstream (Little et al., 2013). An early formal estimate of the economic contribution of US aquaculture was US \$5.6 billion to Gross Domestic Product and 181,000 jobs. Farms that support recreational fisheries have high multipliers (US \$36 of angler expenditures for every dollar spent on the fish stocked; Diesenroth et al., 2012). Aquaculture was found to support more than 500 economic sectors (Engle, 2022). The economic sectors identified ranged from grain farms that supply fish feed ingredients, to automotive repair and maintenance, and transportation. In addition to direct, on-farm employment opportunities, aquaculture farms stimulate development of new upstream and downstream businesses that multiply the number of jobs in rural economies that often suffer from high unemployment (Kaliba et al., 2004; Kaliba & Engle, 2004). Yet still aquaculture contributes significantly to certain locales and stimulates the economy in certain poverty-stricken areas. For example, the catfish industry is in the southeastern United States, with ideal climatic conditions, natural resources, and labor for

expansion, but in areas plagued by poverty, and poor economic and social indicators of development (Kaliba & Engle, 2006). Ninety-four percent of all US catfish is raised on farms in Alabama (14.9%), Arkansas (15.47%), Louisiana (18.0%), and Mississippi (19.07%) with poverty levels ranging from 14.9% to 19.07% and all are in the top 10 poverty rankings in the US.

Asia has, by far, the greatest number of fish farmers, and this number has been increasing over the years (Suzuki, 2021). The effects of aquaculture on-farm employment generation are cumulatively quite low; the entire Vietnamese *Pangasius* industry generating probably less than 20,000 paid farm jobs. Multiple employment opportunities are created elsewhere in the value chains of highly commercial forms of aquaculture, especially where farms have been established in dense geographical clusters (Belton, 2013). Fish farms in Myanmar generate demand for almost four times more person days of labor (unpaid family labor, plus hired casual labor and hired long-term labor) per acre/year than crop farms (94 days vs. 24 days, respectively, on average) (Filipski et al., 2018). Among fish grow-out farms, those under 10 acres generate by far the greatest relative demand for labor (152 days/acre/year). Large fish farms generate an average demand for labor of 32 days per acre/year. Differences in labor demand from large and small farms likely reflect economies of scale for certain types of labor (e.g., the number of person hours required to guard a 20-acre pond may differ little from the number required to guard a 5-acre pond). The low demand for labor in agriculture relative to aquaculture reflects the highly seasonal nature of the former. However, *Pangasius* farms of 0.5 ha or more in both Bangladesh and Vietnam typically also employ hired workers; in part since households that are wealthy enough to participate in this form of aquaculture can also afford to educate their children to a level where higher status forms of off-farm employment become available. It should also be noted that absentee ownership is common on larger farms (Belton, 2013).

Aquaculture plays a significant economic and social role in certain rural European communities. The majority of the EU aquaculture sector are micro-enterprises with fewer than 10 employees. In 2012 these comprised 90% of all aquaculture enterprises in the EU (Member Organization) (by number of enterprises, rather than by production output). These micro-enterprises tend to be family owned and use extensive production methods and systems (STECF, 2014). Overall employment in the aquaculture sector is largely insignificant; however, it impacts rural economies where there are few other employment opportunities (Clarke & Bostock, 2015).

Aquaculture production, employment, and income increased in all regions, and therefore, food fish supply. The question is, can this increase in production result in the attainment of poverty reduction? While there may be a reduction in poverty in some locales like in the Mekong Delta where small-scale shrimp farmers benefit from shrimp income, but such opportunity is not prevalent throughout low-income areas (Nguyen et al., 2016). The number of jobs created at the farm level is still small in most regions with high levels of poverty, since most small-scale producers employ mainly family labor. However, with shrimp and other high-valued species production intensification of small-scale aquaculture, more technically qualified individuals can gain employment at different nodes of the marketing chain (Nguyen, Cheng, et al., 2020; Nguyen, Nguyen, et al., 2020), and in this case the impact on poverty reduction can be improved.

3.3 | End hunger through the attainment of food security (SDG2)

Governance has brought changes in efficient resource allocation along the value chain. Recently aquaculture contributions to global food security have been recognized (Belton & Thilsted, 2014; Béné et al., 2016; Běň et al., 2015; De Silva, 2016; Kawarazuka & Bene, 2010; Youn et al., 2014). This recognition is also linked to the fact that fish demand and consumption have increased over the years and the growing realization that aquaculture is becoming an important food production sector, benefiting millions and contributing significantly to global food security (Béné et al., 2016; Samples, 2014; Subasinghe et al., 2012; Tacon & Metian, 2015; Troell et al., 2014). The increase in

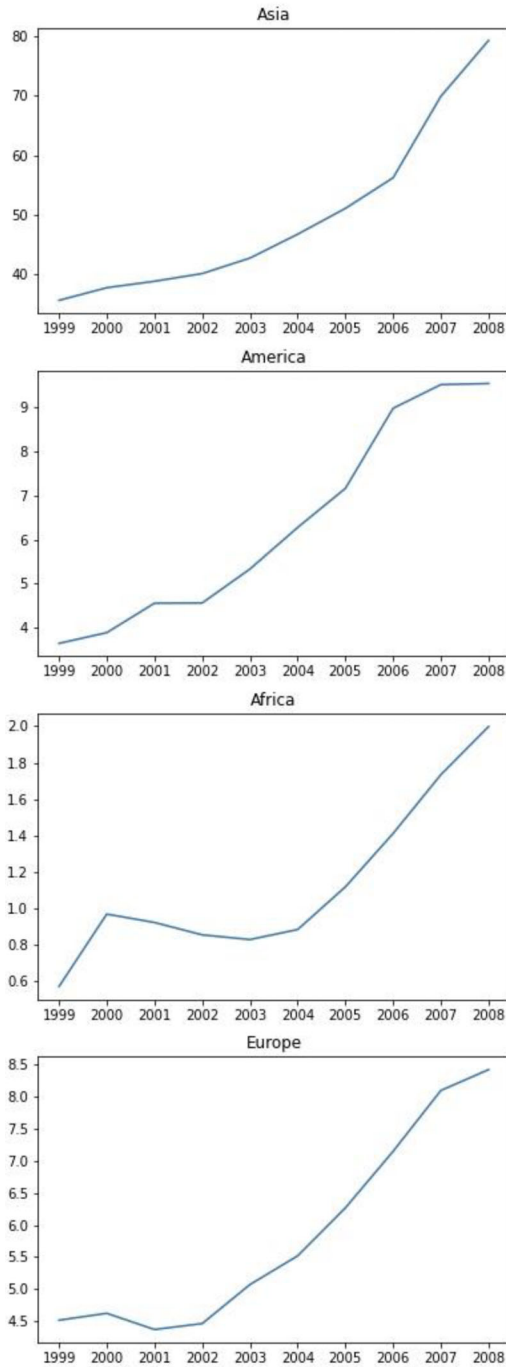
aquaculture production is expected to be sustained via increased production from the Americas, Asia, and Africa with the expansion of intermediate systems, marine aquaculture, aquatic plant production, and small-scale pond and cage aquaculture, which will be aided by sound nutrition (Hasan, 2001; Bartley, 2020). Most cultivated seaweeds are currently used for human consumption (90% of production), directly or as additives, the latter being predominantly hydrocolloids including agar, alginates, and carrageenans, used as viscosity-modifying agents in the food and pharmaceutical industries (Mazarrasa et al., 2013).

All continents had upward trends in total output (Figure 2). The growth rate from 2000 to 2010 was 8.97% and from 2010 to 2020 was 5.72% which means that production is increasing at a decreasing rate. The value of production from 1999 to 2008 increased but slower from 2009 to 2018 (Figure 3a,b). The growth rates are seen in Figure 4a,b and show that all continents had growth rates from 1999 to 2008, but declining growth rates from 2009 to 2018. This is particularly visible for Africa, Americas, and Europe that displayed negative growth rates between 2014 and 2015. China maintains its dominance in production, but with a decrease in growth rates, with growth rates in South America and Africa exceeding Asia during the past two decades (with a lower production base), and with rapid expansion in South and Southeast Asia compared with East Asia (Adeleke et al., 2020; Garlock et al., 2020; Naylor et al., 2021; Tacon, 2020). The largest aquaculture producers outside Asia—each accounting for 1%–2% of the global production—include Norway and Chile, which mainly produce Atlantic salmon (*Salmo salar*). Aquaculture in the Western Hemisphere has largely developed around single- or dual-species and single-production systems (e.g., Atlantic salmon in cages, Nile tilapia (*Oreochromis niloticus*) and channel catfish [*Ictalurus punctatus*] in ponds; Naylor et al., 2021).

Some maritime nations, are starting to show signs of adopting a wider systems approach to aquaculture, embracing the blue growth agenda (Burgess et al., 2018; Eikeseta et al., 2018) by considering broader socio-political, as well as ecological linkages to show the relationship between governance and the achievement of the SDGs. Countries such as the Seychelles (and more recently Grenada) are also adopting the contested Blue Economy concept (Techera, 2018) and innovative financial stewardship schemes, such as the Blue Bonds to generate financial support (US \$20 million from the World Bank) to improve marine food security and end hunger. (www.nl4worldbank.org/2018/10/31/seychelles-launched-bluebonds-what-are-blue-bonds-faqs/). The Seychelles' government has decided to focus on developing the marine aquaculture sector with particular focus on finfish. The project will start with four species: brown-marbled grouper *Epinephelus fuscoguttatus* (Forsskål 1775), red emperor snapper *Lutjanus sebae* (Cuvier 1816), mangrove snapper *Lutjanus argentimaculatus* (Forsskål 1775) and the snub-nosed pompano *Trachinotus blochii* (Lacépède 1801) (Stead, 2019).

Large production increases have been noted in freshwater in Sub-Saharan Africa, and brackish water in Asia. Freshwater increases have been low in Europe and North America. Many countries see marine culture as the future of the aquaculture industry. In 2018 the Chilean venture Ocean Arks Tech obtained a patent for a self-propelled fish farm—basically a 170-m vessel that can produce 3900 tonnes of commercial fish species such as salmon, tuna, and amberjack. In 2017, a Norwegian company SalMar began operating Ocean Farm 1, which it called the world's first offshore fish farm. Many of the countries practicing marine aquaculture have established some regulatory and environmental oversight but have yet to develop comprehensive and complete frameworks for the emerging sector development (Davies et al., 2019). However, in North America and Europe, the industry is overregulated and hence production is low. Also, there is a decline in freshwater culture in North America, but a small increase in Europe. The recent growth rates in North America and SSA are not adequate to meet current demands for fish, even with stable per capita consumption from 2010 to 2020 (Figure 5). During 1961–2017, the average annual growth rate of total fish consumption was 3.1%, outpacing the annual population growth rate (1.6%), and per capita fish consumption rose from 9.0 kg (live weight equivalent) in 1961 to 20.3 kg in 2017 (FAO, 2020a). The World Bank (2013) estimated that globally the fish consumption per person would increase from 16.8 kg in 2006 to 18.2 kg in 2030. It was estimated that even at the current rate of fish consumption the world would require an additional 30–40 million tonnes by 2030 to account for the expected population increase. The global fish consumption is already 20.2 kg as seen in Figure 5.

(a) Production 1999 to 2008



(b) Production 2009 to 2018

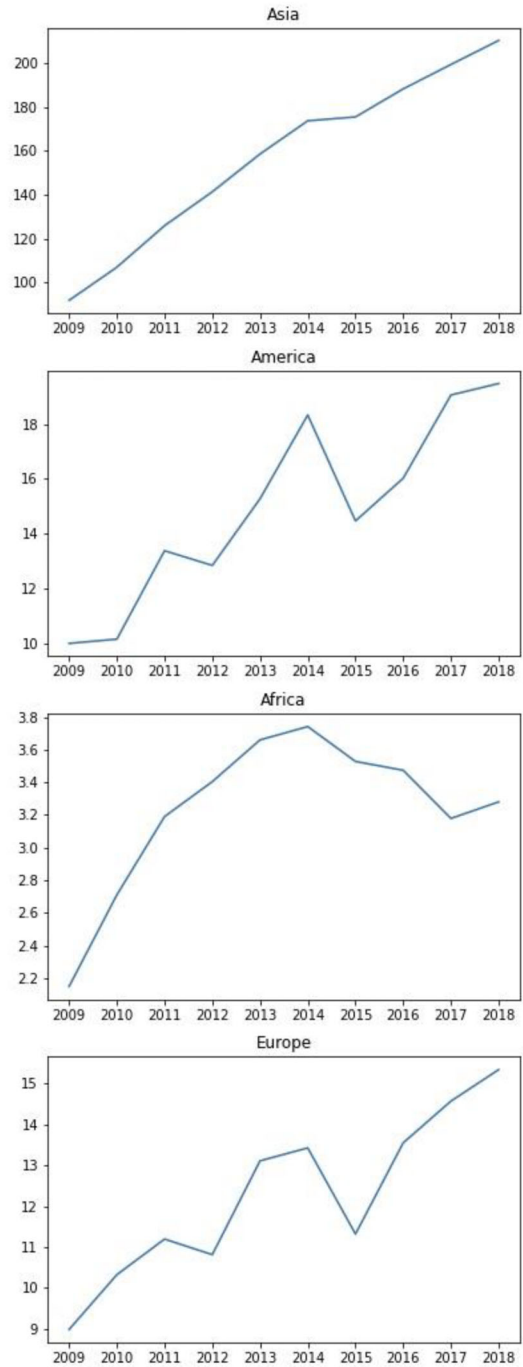


FIGURE 3 Aquaculture production by continent in US billion dollars, 1999–2008 and 2009–2018. (a) Production 1999–2008; (b) Production 2009–2018.

Despite the negative production growth rates and the increased rates of per capita consumption, individual countries and continents experienced increased growth and contribution of some species to food security. Aquaculture is viewed as an important resource in the attainment of global food security in developing countries (Beveridge

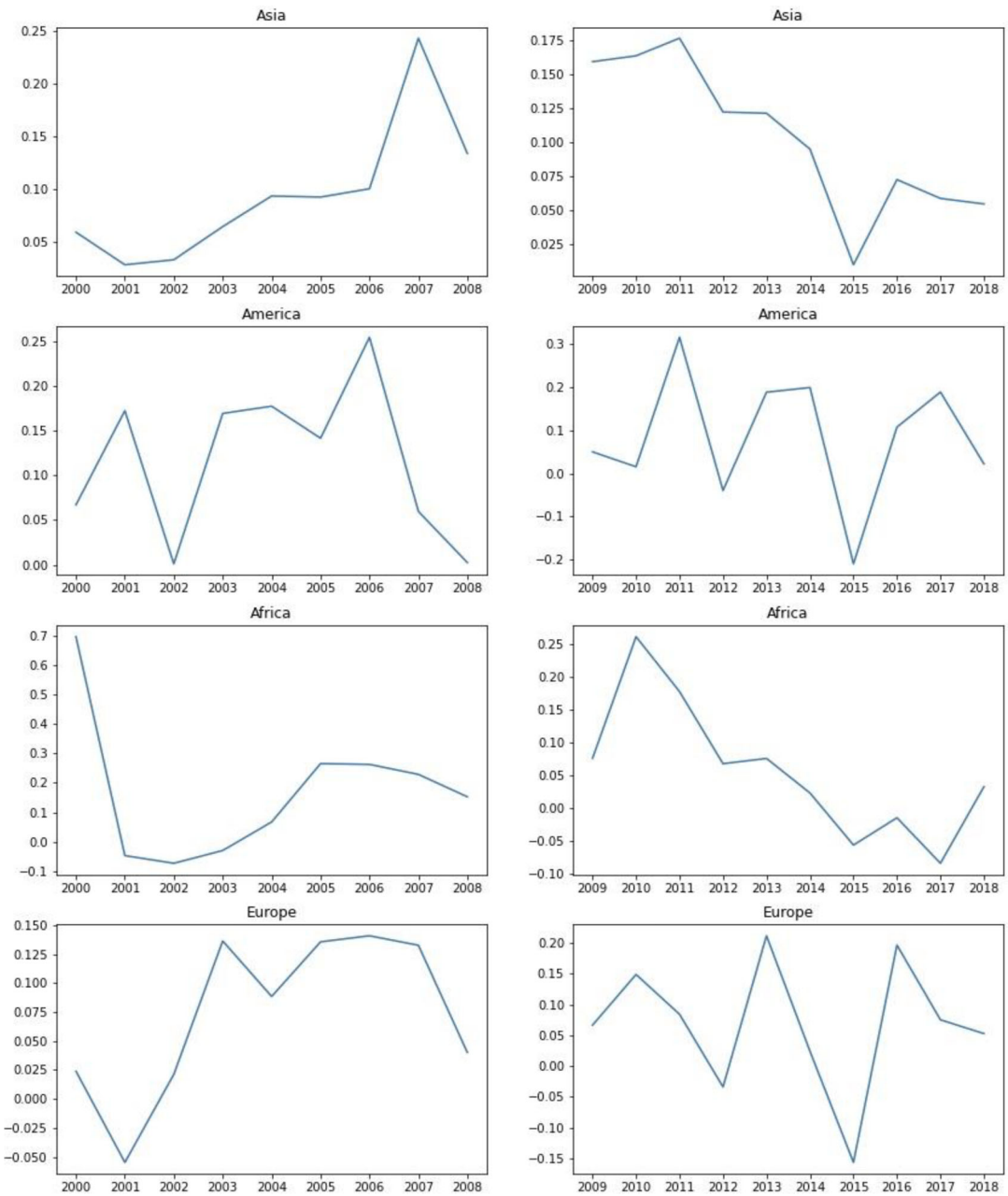


FIGURE 4 Aquaculture production growth rates (%) by continent 1999–2008 and 2009–2018. (a) Growth rate 1999–2008; (b) Growth rates 2009–2018.

et al., 2013; Outeiro & Villasante, 2013; Villasante et al., 2015). The aquaculture success of tilapia cage culture in terms of increased production brought hope to several African countries about the possible effects of aquaculture on food security. Lake Volta, Ghana, cage aquaculture represents about 90% of total national tilapia production and is expected to remain within environmentally sustainable limits even if expanded three times over current levels (Ragasa et al., 2018). Cage culture of tilapia on Lake Kariba encouraged by policies reflecting adaptive governance that encouraged FDI prompted private sector's interest in aquaculture production (Kaminski et al., 2018). *O. niloticus*,

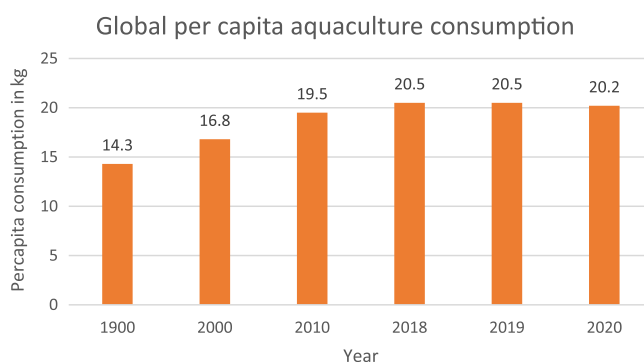


FIGURE 5 Global per capita (in kilo grams) consumption of fish from 1900 to 2020.

Linnaeus, 1758 is the main tilapia species cultured in Zambia along with *Oreochromis andersonii*, Castenau, 1861. The ADB is currently financing implementation of Zambia Aquaculture Enterprise Development Project and has invested US \$29 million in the project (Genschick et al., 2017). This is a five-year project which started in 2017. Zambia's success is largely viewed from the perspective of increased tilapia aquaculture production. Zimbabwe also experienced major success in cage culture. The most widely cultured tilapia species in Zimbabwe are *O. niloticus* and *Oreochromis mossambicus*, Peters, 1852.

The African aquaculture industry is still small but its contribution to global production is promising, given Africa's vast potential for supplying products for food security (Adeleke, 2021; Halwart, 2020) and contribute to rural economies of these countries. The aquaculture industry in Egypt, for instance, contributes 77% of the total national fisheries production and employs more than 580,000 workers (El-Sayed et al., 2015; FAO, 2016; Shaalan et al., 2018). The contribution of Egypt, Nigeria, Uganda, Ghana, and South Africa to food security is adequate to entice investments in these countries (Cai et al., 2017; FAO, 2018). Out of the top 10 aquaculture producers in Africa, Egypt, Nigeria, Uganda, and Ghana contribute about 93% of total regional production output. African production growth is projected to be only 4.5% compared to the world average of 23.6%, increasing SSA reliance on imports and vulnerable to shocks in global markets. Per capita supply in Africa is predicted to fall from a current 6.8 kg per person per year to 5.6 kg in 2030. The prospect of such a decline affects food security (Philpot et al., 2015). The hope is that small-scale aquaculture can provide subsistence or income to foster food security attainment among fishery-dependent communities (Kaiser & Stead, 2002).

Four of the top 10 aquaculture-producing countries, China producing 36.7 million tonnes, Vietnam 2.8 million, Bangladesh 1.5 million, and Thailand 1 million tonnes (2011 figures; FAO, 2013) supplied more than half of total seafood exports from Asia in 2009, and 20% of world exports. They play a predominant role in production and trade: In 2009, 40% of globally traded shrimp and prawns originated from these four countries, with Thailand as the largest exporter; China dominated the international market for tilapia, supplying 87% of world exports; and Vietnam dominated the international pangasius market, with a 98% share (FAO, 2013; Ponte et al., 2014).

In 2019, aquaculture accounted for 54.31% of the total fisheries output in Vietnam (8.27 million m.t.); in which cultured fish accounted for 69.86% and cultured shrimp for 20.04% of aquaculture production (4.49 million m.t.). Among geo-ecological zones of aquaculture, the Mekong River delta has the highest potential for development because of its favorable conditions (Ha et al., 2018). The changes in the aquaculture policy framework (changes in aquaculture administrative process, in increased research output, private sector involvement, and the regulatory mechanism) are partially responsible for production enhancement (FAO, 2020a, 2020b, 2020c; Ponte et al., 2014). In Thailand, the DOF provides substantial technical support. Participation in aquaculture field schools in Odisha, India, resulted in higher fish production, investment, and household expenditure (De Kumar et al., 2016).

China has made huge achievements in the offshore cage culture area, which not only include 100,000 tons of offshore cage culture platform, semi-submersible truss floating structure aquaculture ship, and deep-sea intelligent

fishing platform (Deng, 2020; Shi et al., 2020), but also the world's first fully automatic deep sea semi-submersible “intelligent fishing platform.” However, if aquaculture were to continue its significant contribution to global food security it is imperative that the sector in China, which contributes approximately 60% in volume and 45% in value to the sector globally, be sustained despite the various critiques levied on production practices and sustainability (Cao et al., 2015; Chiu et al., 2013; Herbeck et al., 2013; Zeng et al., 2013; Zhou et al., 2016). Efforts are being made to improve practices during aquaculture production and reduce environmental damage.

The EU represents the largest fish market in the world. However, just 10% of the EU's consumed seafood came from EU aquaculture with 25% sourced from EU fisheries and the remaining 65% imported from the rest of the world (European Commission, 2014). The underlying basis for this is maximizing the quality and health benefits of farmed products, while improving resource efficiency and minimizing impacts (Bostock et al., 2016). The incentive for national governments with limited resources to implement such measures is however somewhat dependent on the perceived wider benefits of expansion. In the context of wider EU policy objectives such as the prioritization of extensive marine spatial planning, the full economic benefits of facilitating an expansion in aquaculture must be assessed. In addition to its potential to contribute to growth, the aquaculture industry can also support rural development and sustain local communities (Grealis et al., 2017) while providing employment in typically more rural coastal areas.

The lack of space for expansion and new sites, limited freshwater availability, and concerns over pollution have forced the EU countries to adopt RAS and ocean expansion as adaptive governance strategies to increase aquaculture production. The development of RAS has shown massive growth in many European countries despite the number of constraints (Badiola et al., 2012). Marine aquaculture has expanded in the last decade and provided significant quantities of fish. In 2017, aquaculture production in the EU reached a 10-year high of 1.37 million tonnes with a value of EUR 5.06 billion. Compared with 10 years ago, its value almost doubled, while its volume increased 11%, growing to 136,760 tonnes. The increasing value of aquaculture over the past decade is because of increased production of high-value species (such as salmon, seabass, and bluefin tuna), combined with the strong policy initiatives adopted by various countries (Zamlynskyi et al., 2022).

Production growth rate has declined during this decade compared to the past decade, despite an increase in total production. Population growth is on the rise and per capita fish consumption remains stable. There have been changes in governance by many countries as demonstrated by the implementation of five-year plans and the willingness of leaders to participate in discussion fora (Table A1). Will production increases reduce hunger and increase food security? The answer is yes but not necessarily to zero.

3.4 | Ensure healthy lives and promote community well-being (SDG 3)

Aquaculture production significantly increased in tonnage and value over the last decades. It is seen as a potential solution to replace the declining wild fishery stocks, therefore, addressing food safety and human well-being (Costello et al., 2020; FAO, 2018; FAO, 2020a, 2020b, 2020c; Hambrey, 2017; Stentiford et al., 2020). Fish produced through aquaculture improves human diet which could reduce malnutrition and increase life expectancy (Herrero et al., 2021). The improvement of a healthy diet is not only increasing product constituency but also its cleanliness and presentation. Improvement in aquatic food handling has been emphasized in policy framework in all aquaculture importing and exporting countries.

The rise in certification bodies not only affects production systems and post-harvest handling of foods, but also the industry structure, marketing activities, actor conduct along the supply and value chains (Hammoudi et al., 2009), and corporate competitiveness repositioning (Giraud-Héraud et al., 2012). Despite the increased number of voluntary labeling and certification bodies, the level of producer compliance remains low (Naylor, 2021). The Aquaculture Stewardship Council (ASC) and the Global Aquaculture Alliance Best Aquaculture Practice (GAA-BAP) standards—account for 3% of global aquaculture production. Improved production and logistical efficiencies that occur with

commoditization and modernization have resulted in farmed fish becoming accessible to greater numbers of low-income consumers in over 140 countries (Belton et al., 2018; Kassam & Dorward, 2017; Saguin, 2018). There are currently more than thirty (30) aquaculture standards available, ranging from certification schemes to recommendation lists, representing a diverse set of requirements related to food safety, quality, traceability, and environmental and social impact (Parkes et al., 2010; Samerwong et al., 2018).

In 2012, 77% of FAO Member State reported having largely complete and enabling effective food-safety and quality-assurance systems for fish and fisheries products implemented nationally. Progress in this field has advanced steadily since 2001, when only 58% of members reported having an effective food safety management system in place. An indication of this progress can be observed in the priority that countries assign to post-harvest practices, with a decrease of 6.9% between 2011 and 2018. Responses in 2018 reflected an increasing inclination to improve bycatch utilization and increase traceability. Moreover, more than three-quarters of members reported that processors were able to trace the origin of the fisheries products they purchase, and this too can be observed in the 6.1% increase in priority that countries give to trade.

Aquaculture is a very important source of food and nutrition security for many Africans, especially women, as well as a source of protein, essential fatty acids, and micro-nutrients. Fish is an easily digestible form of animal protein that compliments the traditional, high carbohydrate diets that are characteristic of many African countries (Oxfam, 2011). However, food safety related to health issues remains a problem. Governments and industry still face major challenges in producing safe aquaculture products for delivery to markets in developed countries. Environmental and farm conditions in SSA potentially expose aquaculture products to a variety of food hazards. These hazards include chemical contaminants, foodborne pathogenic bacteria, and trematode infestations. Although most aquaculture enterprises in SSA are small, commercial aquaculture in SSA continues to expand. Quality control and risk management is gradually gaining ground in African countries (Bagumire et al., 2009).

The FDA under the Department of Health and Human Services is assigned the responsibility to oversee the safety of US food supply. The FDA operates a mandatory food safety compliance program for all domestic and imported fish and fishery products under the provisions of the Federal Food, Drug, and Cosmetic Act, and pertinent regulations. FDA partners with other Federal, State, and local agencies in a cooperative effort to manage food safety risks and provide consistent standards and regulations for seafood products in various industry sectors (NSTCS, 2022). The United States has adopted the most stringent aquaculture regulations in the world to the point of overregulation.

In Canada, for example, there is a national code of conduct for responsible aquaculture developed by the Canadian Aquaculture Industry Alliance. This code is based on the hazard analysis and critical control point (HACCP) system indicating standards for fish health, environmental quality, and product traceability.

China's HACCP certification was approved by the Global Food Safety Initiative (GFSI) in 2015 and 2019, becoming the first Asian country as well as nonprivatization country that recognized the GFSI (Sun et al., 2020). In Vietnam, 100% of the pangasius processing companies have adopted HACCP, a mandatory international regulation for the global food industry. Thailand has its Good Aquaculture Practice guidelines for the responsible husbandry of shrimp. It also has a sophisticated code. Attempts have been made in post-harvest handling to improve product image and to reduce product rejection by importing countries. Improved production and logistical efficiencies that occur with commoditization and modernization have resulted in farmed fish becoming accessible to greater numbers of low-income consumers in over 140 countries (see Belton et al., 2018; Kassam & Dorward, 2017; Saguin, 2018). There are currently more than 30 aquaculture standards available, ranging from certification schemes to recommendation lists, and representing a diverse set of requirements related to food safety, quality, traceability, environmental, and social impact (Parkes et al., 2010; Samerwong et al., 2018). Many countries are adopting best management practices (BMPs) and other standards in all aspects of their aquaculture farming practices.

Vietnam has adopted the Viet Nam Good Aquaculture practices (VietGAP) which is an amalgamation of almost all standard international practices and Vietnam's farming practices. A comparison between VietGAP and non-GAP applied farms showed that farmers in the GAP system performed well on seven control points related to quality

management, especially regarding reservoir construction, water monitoring, and chemical use. Of the farms, 49% reported disease, and the ratio of safety rejections was low. The farmers in non-GAP farms appeared to have weak practices in quality control with high usage of antibiotics, leading to 64% of farmers reporting disease and 20% of tested shipments being rejected (Quyen et al., 2020).

The United Kingdom has “Quality Assurance” schemes in which members must meet standards of quality and environmental management that are internationally recognized, such as ISO 14001. At the regional level, an example of self-regulation is the Federation of European Aquaculture Production association. It has a code of conduct that has nine themes that cover environmental issues, consumer issues, husbandry, socioeconomic issues, and the public image of the industry. In Norway, most hatcheries and nurseries that produce fry or smolt already use semi-closed systems, while all new ones must use recirculation aquaculture systems, drastically reducing water demand and pollution (Sandvold, 2016).

The upsurge in awareness created by the increased information diffusion of quality assurance and standards has influenced the attainment of improved human and animal health and well-being. Certified production is related to major export species. About 57% of salmon and trout, 17% of shrimp and prawns, 17% of pangasius, and 11% of tilapia are certified because of countries' desire to participate in aquaculture trade, with higher levels of compliance noted for vertically integrated production systems. (Ponte et al., 2014; Trifković, 2014). With the growing importance of domestic markets, particularly in Asia, the inclusion of large and smallholder producers for compliance improvement is essential since 90% of aquaculture output is not directed toward export markets (Brugère et al., 2019). However, there is still more work to be done with standard compliance and the distribution of a healthy diet to individuals living in rural areas and depressed urban locales.

3.5 | Equity (SDG5)

Attempts to encourage participation in new enterprises may fail unless the local communities have strong governance structures and are empowered to maintain collective ownership of their coastal resources. These communities, especially those occupied by large numbers of limited-resource fish farmers, once vested are less likely to lose access to larger interests associated with large-scale intensive aquaculture (Eriksson et al., 2012). Large-scale producers are more prone to engage in partnership or some sort of contract farming with small-scale or limited-resource farmers. The potential loss of fishing grounds because of new investments as in the case of sea cucumber farming in Zanzibar, Tanzania, with the creation of grow-out areas designated to take zones in favor of farms within lagoon habitats, may trigger competition for space and user conflicts (Charisiadou et al., 2022).

Existing evidence, however, indicates gender imbalances exist in fishing communities and along the value chain. Women do not have equal access to equal pay, capital, or voice in governance as men in aquaculture-dependent communities or along the value chain. The specifics were found to vary by context and to be shaped in relation to factors such as class, needs, and social and religious norms (Kruijssen et al., 2018). Transformative changes can be brought about by several means, including planned interventions by institutions. Coles and Mitchell (2011) present an empirical study conducted in the Barotse Floodplain, Zambia which utilizes participatory action research to test improved post-harvest fish processing technologies together with a comparative assessment of two approaches to address gender barriers. The authors report that the use of a transformative approach has led to greater gains compared to using an approach that accommodates existing gender norms and power relations. The authors underscore the importance of using a gender transformative approach together with technical innovations, in this case, post-harvest loss-reducing technologies, for programs to achieve gender equality and women's empowerment (Gopal et al., 2020). An emerging body of research on gender, technology, innovation, and adaptive capacity demonstrates the ways in which innovation, adaptive capacity, and technology adoption are deeply gendered processes (see Cohen et al., 2016; Ravera, Martin-Lopez, 2016).

In many developing nations, women take care of seaweed farms while men work as fishermen. According to the FAO data, the global seaweed output (both aquaculture and wild) has increased from 118,000 tons to 358,200 tons

from 2000 to 2019, a 5.7% growth rate per year. (FAO, 2021a, 2021b, 2021c). The role of women as seaweed farmers, who are organized in communities in Africa and Indonesia, has empowered them in their communities, and raised their status by contributing to the household economy. Men's and women's practices and capacities are, however, constrained by local institutional factors, although generally the number of women involved in aquaculture has been increasing. The percentage of women employed in aquaculture is about 19% which is higher than the number of women (12%) in fisheries. For example, women seaweed gatherers in the small fishing community of Coliumo in southern Chile formed an all-women union to obtain Territorial Use Rights for Fisheries under fisheries management arrangements introduced in 1997. They experienced both cooperation and conflicts arising from their union (Gallardo-Fernandez & Saunders, 2018). In Japan, women's fisheries groups within the local Fisheries Cooperative Associations (FCAs) began in the mid-1950s and have undergone a long evolution. They changed from focusing on social issues to environmental protection and the promotion of fishery products and are now engaged in entrepreneurial activities that can revitalize their aging communities and may pave the way for full membership of the FCAs (Soejima & Frangoudes, 2019).

Women in Vietnam, like in most developing economies, have lower access to capital and technologies than men (FAO, 2011), and this decreases their participation in levels of the value chain as decision makers and confines them to lower profit nodes (Coles & Mitchell, 2011). Studies in Asia have shown that greater equity can be achieved if women and youth have access to credit and financial assistance. If women and youth have investment capital, they are likely to have greater voice in decision-making and able to participate in the governance along the aquaculture value chain (Kruijssen et al., 2018). Women in Mexico's second largest wholesale fish market, the Mercado del Mar in Guadalajara, mobilize family networking, develop their managerial skills, and manage to thrive in a productive urban economy that supports the rise of powerful women (Pedroza-Gutiérrez, 2019).

Equity between the north and south has been changing because of north/south dialogue. The south has been claiming a lack of access to certain technologies, especially in terms of genetic resources. The CBD and its implementing agreement, the 2010 Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from Their Utilization to the Convention on Biological Diversity (Nagoya Protocol) set up a framework for: access to genetic resources and traditional knowledge (including prior informed consent and mutually agreed terms); benefit sharing (contractual agreements including monetary and non-monetary benefits); and monitoring and compliance. Both information and knowledge about genetic resources are gaining attention because the physical materials can be used with that information and knowledge without necessarily engaging the access benefit sharing provisions (Lawson & Rourke, 2020).

Other agreements may also shape the way a country approaches traditional knowledge, such as the United Nations Declaration on the Rights of Indigenous Peoples, that recognizes the right to maintain, control, and protect traditional knowledge (and cultural expressions) and the manifestations of their sciences, technologies, and cultures including human and genetic resources (article 31). Human and labor rights issues in fisheries and aquaculture value chains are increasingly discussed at the international levels (FAO-ILO, 2013; FAO, 2016; Kittinger et al., 2017). There seemed to be intangible results from access to benefit sharing of genetic resources, but there is a lack of research information on the benefits of the selected African countries.

All political leaders have included gender equality in their national plans. There is a push for equal job opportunities and education. The trend toward the sharing of genetic resources is on the rise. Production increases have been achieved through the sharing of genetic resources. However, there is still a major gap in shared benefits which can only be erased with adequate governance and a sustainable effort at ensuring equity programs at all levels.

3.6 | Economic growth and trade (SDG8)

Fish and fish products are one of the most traded commodities in the world. In 2018, about 66 million tonnes or 37% of total fisheries products were traded internationally (FAO, 2022a). The growing demand for seafood

stimulated the rapid development of trade. From 1976 to 2018, the value of global fish-related exports increased at an annual rate of 8% in nominal terms; by 2018, export revenues were more than 20 times the 1976 figure of USD 7.8 billion (FAO, 2020a). International fish trade remains limited, however, to a relatively small number of species and countries: salmon, shrimp, catfish, representing approximately one third of internationally traded seafood by value, but only 8% of global seafood production (FAO 2020a, 2020b, 2020c). Analytical studies show that governance as measured by the global, quality of institutions was negatively related to aquaculture growth rates (Abate et al., 2016; Nadarajah & Flaaten, 2017). Regulatory measures adopted by institutions in developed countries to guide aquaculture trade and growth are most often command and control instruments that limit aquaculture production even with the technologies, skilled manpower, and financial support to adopt BMPs. Strict environmental regulation has been suggested as a major reason for low aquaculture growth rates in the United States of America and European countries (Engle & Stone, 2013; Knapp & Rubino, 2016; Naylor et al., 2021; Nielsen et al., 2016). On the other hand, other management styles such as co-management, innovative management or collective action governance have resulted in increased production and benefits distribution. For example, the collective action management style for sturgeon production in Vietnam has stimulated industry growth (Nguyen & Jolly, 2020a, 2020b).

The level of international trade varies by region, with North African and Sub-Saharan countries consuming most of the fishery's products while South American and certain Asian countries depend heavily on trade (Bartley, 2020). Live, fresh, and frozen fish are responsible for 67% of total fisheries supplies today compared with 58% in 2000. Exporting countries concentrate on the freshness of the products as consumers in high-value markets demand guarantees on sustainable and certified fresh seafood (FAO, 2020a, 2020b, 2020c). Aquaculture trade policies emphasizing quality improvement also serve as a tool that can generate direct and indirect benefits to communities. Governance exercised by the public and private sectors must design and enforce health and safety procedures and good aquaculture management practices to meet national and international consumer demands to encourage industry growth.

In its development stages aquaculture used to be self-managed but the government was involved directly in policy formulation, training, infrastructure development, inputs, and products production (FAO, 2004–2020). The current policy considers aquaculture as an industry in which production at all levels of the value chain is driven by the private sector, while the government creates enabling environments (Anetekhai, 2010). Government policies in developing countries have increased in importance with exports as consumers demand a safe and reasonably priced product. Many Sub-Saharan countries have included in their plans the export marketing of aquaculture products, but the only African countries engaged in large enough quantities of fish to maintain a regular market flow are Egypt, South Africa, and South Uganda. The current policy for the development of aquaculture and fisheries industries in those countries emphasize quality and standards plus return on investments.

The Nigerian government is saddled with the responsibility of providing a conducive business environment, while the entire aquaculture value chain development is driven by the private sector initiatives (FDF, 2012). The DOF Resources (DFR) of Uganda is mandated to promote, guide, and support public and private sector partners involved in fisheries and aquaculture activities in sustainable development as well as responsible for setting and enforcing regulations and standards for practices on fisheries and aquaculture (MAAIF, 2012). The DFR also provides services such as technical back-up associated with fisheries and capacity building for local governments; information provided for all stakeholder groups; creation of funding strategies for sector development; ensure sustainable resource utilization through good fisheries policy and equitable legal basis for sustainable fisheries and aquaculture management (FAO, 2004–2020).

The importance of fish farming in enabling rural communities in addressing food insecurity, malnutrition, unemployment, hunger, and economic growth in Africa, especially countries like Ghana, cannot be underestimated. Tilapia farming has shown great promise in improving the livelihoods and protein needs of rural households and consumers, and at the same time creating economic opportunities in Ghana despite the challenges (Asiedu et al., 2017). These studies imply that there is value in assessing the potential for small- to medium-sized commercial enterprises and their role in aquaculture development and growth (Kaminski et al., 2020).

Association of aquaculture producers located in many African countries play key roles such as information transfer, knowledge exchange, and facilitation of aquaculture-related activities (Satia, 2017). The formation of clusters of fish farmers has efficiently contributed to support services delivery, economies of scale, reduction of transaction costs, and competitiveness (Satia, 2017). These key aquaculture producers experienced remarkable growth in the past decade because of several factors such as capacity building in critical subject areas, embracing good governance, research and development, access to credit facilities, and mainly because of the promotion of private-sector-led aquaculture development (Satia, 2017). Private-sector-led initiatives gave rise to investments in sound management, emerging production systems, the formulation and utilization of aquafeeds, and the emergence of dynamic and robust producer associations and service providers (Adeleke et al., 2020; Satia, 2011).

The aquaculture industry in the United States not only generates jobs and economic opportunities across the country but also contributes to the increase and diversification of fish and sea food production (NOAA Fisheries, 2020). Aquaculture production accounted for 22% of US fish and seafood production in 2017 (National Marine Fisheries Service, 2020), though that percentage is expected to grow. A 2013 World Bank report projected that US and Canadian aquaculture production will increase by 40% between 2010 and 2030, while suggesting capture fisheries production in the region will decrease by 0.1% during the same period (Botta et al., 2021; World Bank, 2013). Between 2008 and 2018, exports increased by a total of 30%, while imports increased by 55%. The US is the 17th-largest aquaculture producer and a net importer of fish (Garlock et al., 2020). Though the US is a net importer of fish, she contributes significantly to the blue revolution globally by providing capital, technologies, and input factors to the industry elsewhere (Chu et al., 2010; Kumar et al., 2021) and by being a major importer of farmed seafood, creating a market for export-oriented producers in other countries (Anderson et al., 2019; Garlock et al., 2020). Four of the five most consumed seafood species (shrimp, salmon, tilapia, and pangasius/catfish) are primarily imported and from aquaculture, with tuna as the only top five species primarily supplied from wild fisheries (Love et al., 2021; Shamshak et al., 2019). Thus, the US contributes by alleviating poverty in the developing world.

The catfish industry is responsible for more than 90% of all freshwater finfish produced in the US. Hegde et al. (2022) using an INPLAN model found that the catfish industry's direct output from the catfish industry (USD 1.10 billion) generated a total economic contribution of USD 1.91 billion. The industry directly employed 4298 people and created an additional 4868 jobs in Alabama, Arkansas, and Mississippi for a total employment effect of 9166 jobs. Catfish industry spending created an indirect economic effect of USD 552 million in other secondary sectors that supplied production inputs and services. The induced economic effect generated from household spending amounted to USD 254 million. Some of the key sectors influenced by the catfish industry were grain farming, banking, and financial institutions, truck transportation services, electricity generation, equipment, and machinery manufacturing (Hegde et al., 2021).

Chile and Canada are major fish exporters of the Americas. Figure 6 below shows the growth in aquaculture exports of Chile and Canada. Chile is the largest producer and exporter of aquaculture products in South America, with an export-driven aquaculture industry (Poblete et al., 2019). Aquaculture exports from Chile are composed mainly of three high-value species (Atlantic salmon, Rainbow trout, and Chilean blue mussel). These three species accounted for over 90% of the volume and value of Chilean exports by 2014. About 90.0% of the imported aquaculture products are produced by limited-resource farmers in developing economies. Chilean salmon mainly destined for markets in high-income developed nations, such as the United States, Japan, and the European Union (EUMOFA, 2017). Further, as noted by Ceballos et al. (2018), salmon aquaculture in Chile also creates employment that has a significant impact on poverty reduction in remote regions of Chile. Canada exported more than 65% of its aquaculture production to over 22 countries around the world (more than 90,000 tonnes valued at more than US \$818.4 million; CAIA, 2014; Chopin, 2015; Fisheries and Oceans Canada [DFO], 2014). Figure 6 shows that Canada's exports have followed the same trajectory as Chile, a notable increase in exports since 2016. The primary farmed seafood export markets include the United States (more than 88,000 tonnes valued at more than US \$784.3 million), Japan (US \$15.4 million), Taiwan (US \$4.9 million), Singapore (US \$ 2.04 million), China (US \$1.63 million), and Hong Kong (US \$0.68 million; DFO, 2014). Canada is the main seafood supplier to the United States. Other suppliers include China, Thailand,

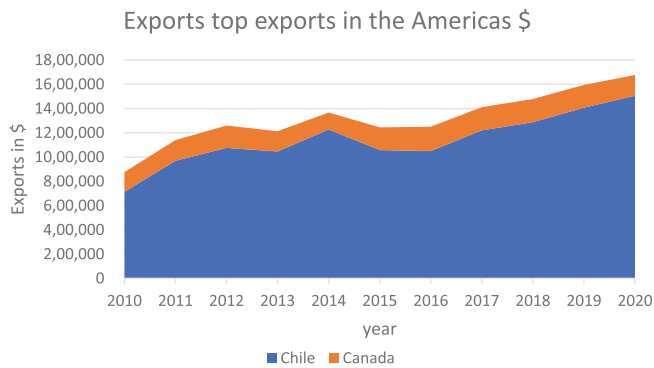


FIGURE 6 Aquaculture exports from Chile and Canada.

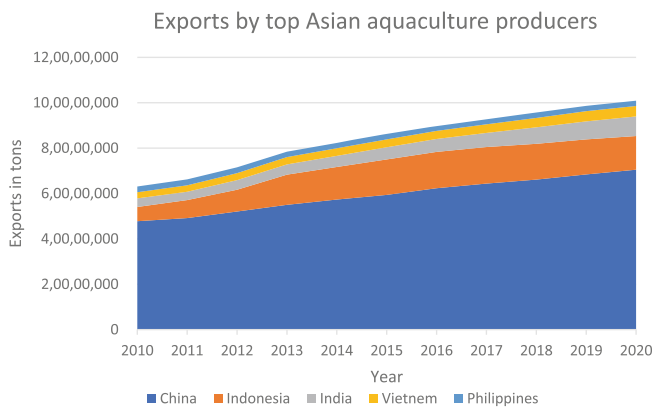


FIGURE 7 Aquaculture exports from China, Indonesia, India, Vietnam, and Philippines.

Indonesia, Chile, and Vietnam (Agriculture and Agri-Food Canada, 2010). Approximately 50% of these imports come from aquaculture (National Oceanic and Atmospheric Administration, 2013, 2014).

Aquaculture contributes to Asian economic growth through the provision of nutrition, income, foreign exchange earnings, and jobs (Suzuki, 2021). Figure 7 shows the growth in selected Asian countries exports from 2010 to 2020. From 2010 to 2013 exports increased at a rapid rate and from 2013 to 2020 exports increased but at a reduced rate. Although Asian fish farmers are the largest producers of aquatic products, most aquaculture in Asia serves domestic markets and makes significant contributions to local food security (Belton et al., 2016; Little et al., 2018). Countries like Vietnam, India, and Indonesia, however, grow some species for export to increase foreign exchange earnings (Little et al., 2018). Aquaculture exports have been driven by increasing demand in higher value export markets in Europe, North America, and Japan and, more recently, emergent markets. In addition, regional trade within Asia has grown considerably, as has trade between Asia and Africa (Zhang et al., 2015). Asian countries adopted a between a supply chain and cost-efficient response to satisfy consumers' demand for a high-quality product in order to increase sales (Nguyen et al., 2023). Regulatory frameworks including certification, the application of standards, and BMPs have enabled Asian countries to increase exports (Jespersen, 2014). Aquaculture exports have stimulated economic growth in most rural areas of Asia.

Over 80% of capture fisheries and 95% of aquaculture production in Indonesia are consumed domestically (Belton et al., 2017). Indonesia was recognized as the world's third largest aquaculture producer after China and India (FAO, 2015). However, Indonesia only occupied the top 10 positions as fishery products exporter in the world.

This condition was caused by the low export value of Indonesian fishery products in the international market. The export volume of fishery products from 2011 to 2015 showed a decrease of 3.41% per year, from 1159.35 thousand tons to 974.55 thousand tons. The decreased export volume was because of lower shrimp exports (23%) and fish (6%) to the primary destination markets such as the US, Japan, and the EU (Statistics Indonesia, 2015). The country has adopted promotional strategies, including certification and standards to increase export sales. The value of Indonesian fishery export showed a growth of 2.29% per year.

China is a major seafood-producing country. China was the world's top aquaculture producer (47.56) million or (57.93%) of 82.1 million tons, contributing 61.5% to the world production in 2018 (FAO, 2018; Miao et al., 2021), and has undergone tremendous expansion of aquaculture. In 2018, China ranked first globally in total seafood export value (USD 21.55 billion) and third in total import value (USD 11.92 billion) based on UN Comtrade Database. China's improved overall position in global trade is attributable to the "reform and opening up," beginning in the late 1970s. China has adopted supply chain response strategies such as: Farm and processor registration, and food inspection (CIQ), certification and labeling, plus private and hybrid standards certification by numerous bodies to increase international sales (Jespersen, 2014).

China's governance policy included decentralization of production and expansion. Demands for high-quality raw material, food safety, competitive price, and sustainability were parts of China's export promotion strategies. Aquaculture has expanded rapidly at different coastal regions of China and was responsible for large-scale loss and fragmentation of wetland habitats through land reclamation and conversion along the coast of the South China Sea (Peng et al., 2013; Spalding et al., 2014). Although China is the biggest exporter of aquatic products (USD 21.55 billion) and the third largest importer (USD 11.92 billion) of aquatic products, increasing aquaculture costs, falling market demand, and rising international trade barriers pose great challenges to the sustainable development of trade in China's aquatic products, especially after the financial crisis of (Tan et al., 2020). China is focused on increasing production and expanding exports of aquaculture products.

The Vietnamese aquaculture sector contributed about 65%–70% of seafood export values yearly. In 2020, the seafood export value of Vietnam reached 8.5 billion USD. The country's aquaculture was highly developed during the last three decades, particularly of striped catfish and marine shrimp farming, and driven by many factors such as state development policies, international collaboration, technological adaptation, and so forth (VASEP, 2018). The country applied domestic regulatory framework plus proactive and reactive strategies to increase exports (Nguyen et al., 2017). The policies include processor registration, food and farm inspection by the National Agro-Forestry-Fisheries Quality Assurance (NAFIQAD); promotion of BMPs and VietGAP standards (Jespersen et al., 2014). However, the sector is still facing challenges of sustainable development on disease control, environmental pollution, certification, small-scale household exclusion, and so forth (Tri et al., 2022).

India is the second largest producer of aquaculture products globally and accounts for nearly 6% of the global fish production (Kasozi et al., 2017). India's aquaculture development has focused on national programs and policy driven by private sector initiatives and enterprises. Shrimp is the most important seafood export commodity from India and the largest shrimp exporter to the US (Singh et al., 2022). It contributes 66% in value and 39% in quantity in total seafood exports from India (Sarada et al., 2006; Singh et al., 2022). India with an export volume of 43.85 million tonnes registering a 14.5% growth over 2015 was among the top five shrimp exporters in the international market in 2016 (Singh et al., 2022). The shrimp culture industry in India in the last two decades contributed to foreign exchange earnings, which are directed to rural economic development.

Thailand's aquacultural sector has rapidly developed during the last few decades and has been accompanied with tangible socioeconomic development (Sampantamit et al., 2020). Recent statistics that were collected by the DOF estimate that Thailand's aquaculture production in 2016 exceeded more than 0.9 million tons, of which 0.5 million tons (57%) were from coastal aquaculture and 0.4 million tons (43%) were from freshwater aquaculture (DOF, 2018). Although Thailand's reputation as a provider of high-quality production and volume, availability, consistency, and certified sustainability, and its exports are primarily destined for retail chains and the high-end foodservice industry in the EU, (Jespersen et al., 2014) she is proactive in increasing promotion to maintain market share. Private industry is

extremely powerful in Thai farmed shrimp production and the largest companies carefully manage production and processing, even from the research stage.

Bangladesh has ranked third in the world in inland fish production, fifth in aquaculture production and is now exporting large quantities of products (Shamsuzzaman et al., 2020). Fisheries and aquaculture are the second-largest export industry and the most critical contributors in export earning in Bangladesh (Shamsuzzaman et al., 2017). Bangladesh having characterized of having a weak regulatory framework can be characterized as facing challenges of heavy product scrutiny by importers. Bangladesh adopted domestic regulations plus private and hybrid standards and certification including Farm and processor registration and food inspection (UNIDO/DoF); and export subsidies for increasing export sales (Jespersen, 2014).

Aquaculture production levels suggest that the role of smallholder farmers is crucial to future fish supplies and increasing food and nutrition security for consumers (Herrero et al., 2017; Waite et al., 2014). The concept of a “quiet revolution” in Myanmar (Belton et al., 2018) and Bangladesh (Hernandez et al., 2018) has recently gained ground suggesting that a growing increase in small- to medium-sized enterprises in aquaculture is playing an important role in economic growth and domestic fish supply. A study that modeled the impact of aquaculture in Myanmar revealed that small commercial fish farms generate larger spillovers by way of retail and labor in the rural economy than larger commercial farms (Filipski & Belton, 2018).

The EU is dependent on imported seafood, with more than half of its seafood consumed from imported sources (Eufuma, 2015). The EU-28 is the most valuable seafood market in the world but faced with limitations in increasing its own indigenous farmed and wild-capture supplies. Area-based management has been used to great effect in the UK and Norwegian salmon sectors for which such collective action has been a key part of managing sea lice problems (Berrill, 2013). Significant sector consolidation and strong regulatory capacity appear to have been key preconditions for fostering the necessary partnerships between the private sector, government, and other resource users, however. In Norway, aquaculture farms were found to benefit primarily local communities (Krause et al., 2015; Peel & Llyod, 2008). The figure shows the two largest fish exporters in Europe, Norway, and France.

Growth in trade has been experienced. More countries are increasing the production of species directed at international markets. However, there are efforts to stimulate domestic consumption of aquaculture products. Hence policies to increase trade and economic growth are influencing the attainment of SDG8.

3.7 | Conserve and sustainably use the oceans, seas, and marine resources for sustainable development (SDG 14)

The attainment of SDG14 and its various components require processes that address sustainable development and conservation of ocean resources. This involves decent governance applications and combined efforts of government departments, policy makers, civil society, the private sector, and the community (Virto, 2018). National and regional governments have agreed to act for the full implementation of the SDG14 realizing that public policies and the effective use of resources are critical to meet the challenges and conflicts of ocean management (Wright et al., 2017).

The development of coastal zone management strategies to achieve the objectives of SDG14 start with the identification of initiatives to increase the sustainable exploitation of ocean resources. This is in relation to reducing dependence on wild-caught fisheries and relying more on aquaculture. Approaches are diverse, including top-down management involving government-controlled marine protected areas (MPAs) (Bergseth et al., 2018) for conserving biodiversity to informal governance systems, such as co-management involving collaboration between local communities and state governments, and the distribution of territorial user rights for fisheries and aquaculture. Despite initiatives attempted at the implementation of integrated coastal zone management (ICZM) since 2010, when ICZM was a top priority for countries, the progress has been slow. According to an FAO questionnaire on the adoption of ICZM, those responding dropped from 43.6% to 28.9% in 2011, and today remains at 27.4%. Fewer than one third of responding participants had in place complete and enabling policy, legal and institutional frameworks for ICZM,

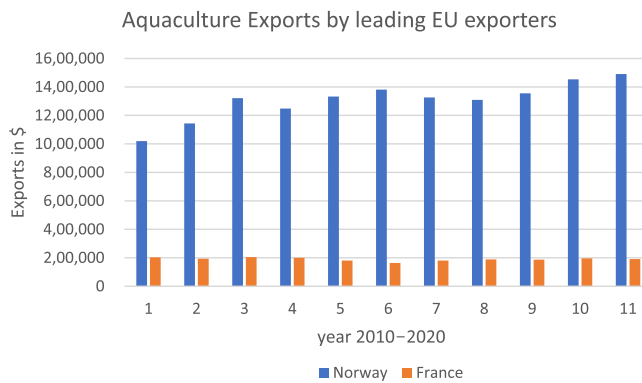


FIGURE 8 Aquaculture exports from Norway and France, 2010–2020. EU, European Union.

TABLE 2 Area of mangroves annual change, by region and subregion, 2000 and 2010 and 2010 and 2020.

Region/subregion	Annual change (1000 ha/year)	
	2000–2010	2010–2200
Eastern and Southern Africa	−1.9	2.2
Northern Africa	0.1	10.1
Western and Central Africa	−5.1	4.5
Total Africa	−6.9	−2.3
East Asia	0.3	0.7
South and Southeast Asia	−39.6	−38.3
Western and Central Asia	0.0	0.7
Total Asia	−30.3	−38.2
Total Europe	0	0
Caribbean	−1.6	11.7
Central America	0.1	−1.8
North America	2.3	0.5
Total North and Central America	0.8	10.5
Total South America	−7.4	14.8
Oceania	16.4	−5.9
World	−36.3	−21.3

and about half have partially developed frameworks awaiting adoption. The successes of coastal zone management have been mixed. Some countries have put in place MPAs for marine resource conservation and management of biodiversity. As seen in Figure 8 the number of MPAs as expressed as a ratio of percent protected areas has increased from 2000 to 2020. There has been a decline in area of mangroves from 1900 to 2020 of −1.48%, although the decline is at a reduced rate (Table 2) (FAO, 2020a, 2020b, 2020c).

The creation of zones facilitates the integration of aquaculture activities into broader areas of ocean management. Zonation contributes to improved coordination among the public and private agencies involved in aquaculture licensing and monitoring processes and facilitates collective action and joint management and governance by stakeholders. The zoning process is normally led by national or local governments with important stakeholder participation and supported by pertinent regulations (Aguilar-Manjarrez et al., 2017). In the absence of ICZM and governance

conflict arise from resource use. Conflict management in resource use is facilitated by policy frameworks that foster cooperation between domestic and international users of the ocean resources. In, Africa, the Americas, Asia, and Europe, for example, marine cage culture has created conflicts with other users of waterways. The growing emphasis on ICZM has the potential to reconcile such conflicts over aquaculture sites (Hishamunda et al., 2014).

Some successes of marine aquaculture industry include collaboration with the marine biotechnology sector such as vaccine-producing companies, fish-feed development firms, marine management operations and fish breeding units in the development of useful products for the promotion of human and animal health (Ninawe & Sahul, 2017). Karlsen et al. (2011) explained that in Norway, collaboration between universities and vaccine-producing marine biotechnology companies has radically reduced the incidence of disease in fish farming. Similarly, in New Zealand, effective linkages between fisheries companies and chemical companies led to the extraction of bioactive compounds from marine organisms for commercial use, a good example of which is Lyprinol, an anti-inflammatory extracted from the New Zealand Green-Lipped Mussel (*Perna canaliculus*) (Ahmad et al., 2018; Sankaran, 2007). The establishment of MPAs, reduction of illegal, unreported, and unregulated (IUU) fishing, plus the reduction of ocean pollutants are indicators of success and positive approaches to the achievement of SDG14. In the National Plan of Action of Thailand, policies have been documented to Prevent, Deter, and Eliminate IUU Fishing 2015–2019 (IOTC 2015; Pauly & Zeller, 2016; Sampantamit et al., 2020), which will also reduce fishing effort and decrease harvest will benefit the development of fisheries in a long term.

The AU acknowledges the ocean as an important asset for economic growth. In its AIMS 2050, it identifies long-term opportunities for wealth creation and sustainable utilization for Africa's maritime domain (Wright et al., 2017). The AU has executed the marine and coastal component of its Action Plan on the Environment Initiative to support the Nairobi and Abidjan Conventions (Wright et al., 2017). Included in the maritime strategy are plans to eliminate IUU fishing, establishment of MPAs, and coastal protection (Figure 9).

In the case of Kenya, the 2010 reform of government administration strengthened the county government's role on issues of aquaculture at the expense of the national government's state department in charge of fisheries and aquaculture. There is lack of/inadequate support to aquaculture by some of the devolved county governments to keep the sector on the growth path. Devolution has visibly resulted in decline in the assessment of national aquaculture data. The performance of the sector cannot be accurately determined, and hence policy recommendations to guide the sector do not inspire confidence that would attract investment in the sector.

The Seychelles has adopted Blue Bonds to generate financial support including US \$20 million from the World Bank to preserve its natural capital, by expanding its offshore MPAs and fish production. The country leaders now view finfish aquaculture as an environmentally responsible form of aquatic farming and a strategic solution to mitigating food insecurity and an alternative or supplementary source of protein to terrestrial animal varieties, or marine wild-capture fisheries (Kaiser & Stead, 2002; Stead, 2019).

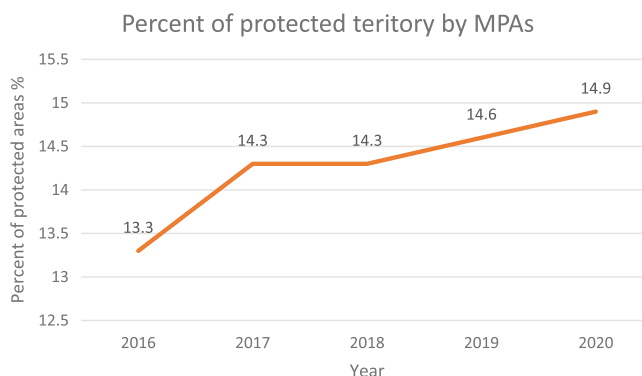


FIGURE 9 Percent of protected territory by marine protected areas.

The World Bank PROBLUE (Blue Economy program) which aims to ensure the protection and sustainable use of marine and coastal resources, is a good example of donor policies that can be used to enable African countries to address ocean health problems. The World Bank active “Blue Economy” portfolio is around \$3.7 billion, with a further \$1.5 billion in the pipeline. Projects range from implementing large regional fisheries programs in Africa and the Pacific to artisanal fisheries. These projects tackle all sources of marine pollution and support coastal development around the world, with emphasis on addressing erosion and the other effects of climate change on marine and coastal resources (World Bank, 2018). The World Bank also launched the West African Coastal Areas Management Program to help meet the challenges of climate change events and preserve the coastline. The program finances interventions such as the construction of protective measures, mangrove restoration, and waste treatment to combat pollution (World Bank, 2019b).

In the United States, management of water resources is shared by the federal, state, and local governments. The federal government governs the nation's freshwater through laws and regulations. The National Coastal Zone Management Program works with coastal states and territories to address pressing coastal issues, including climate change, ocean planning, and planning for energy facilities and development. The program is a voluntary partnership between the federal government and US coastal and Great Lakes states and territories authorized by the Coastal Zone Management Act (CZMA) of 1972 to address national coastal issues. The program is administered by NOAA. The state and local governments regulate allocation of water (Christian-Smith et al., 2012). Some of the primary federal laws include: Flood protection, and aquatic ecosystems protection and restoration; and the “Clean Water Act” in 1972, which oversees water pollution (Christian-Smith et al., 2012; USACE, 2012). More than 40 federal agencies are involved in managing the US water resources. Besides the Federal regulations that apply to all states, state-based water rights also govern the use of water resources. In addition, some states now have implemented permit systems and allowed some forms of water marketing, especially the water-scarce states that need to manage their groundwater use to meet the changing water demands of growing urban population.

The CZMA of 1972 also provides many opportunities for public access to coastal zones. It has created 470 new access sites, enhanced 730 sites, educated 37,000 people, trained 650 coastal decision makers, and invested \$26 million dollars between 2008 and 2011 into providing public access; these numbers are not insignificant (Garten, 2016). The CZMA's effectiveness in controlling non-point source (NPS) pollution has been limited. NPS pollution such as runoff, precipitation, atmospheric deposition, drainage, seepage, or hydrologic modification cannot be sourced to a particular polluter.

South American countries participation in coastal zone management is evident in the ratification of international and regional conventions (UNEP, 2003). There is a participatory approach involving excessive government presence in ICZM in LAC countries compared to representatives of society and employers (Muñoz et al., 2020). There is a significant number of regional agreements and a vast body of laws, rules, and regulations to ensure systematic and coordinated actions for protecting the environment and promoting sustainable development (Bertucci et al., 1996; Solano, 1997). Most South American governments have developed and implemented comprehensive environmental legal frameworks (Delgado et al., 2007; Mateus et al., 2008). Marine space is increasingly present in ICZM products and has appeared in marine spatial projects in countries like Mexico, Chile, Peru, Colombia, Ecuador, etc. (Muñoz et al., 2020).

Asian countries have developed sectoral regional policies and institutional arrangements on the conservation and sustainable use of biological diversity (including marine biodiversity) and fisheries. Through the ASEAN Centre for Biodiversity and the ASEAN Working Group on Coastal and Marine Environment, Member States coordinate their actions regionally, as well as with other regional and international bodies. However, policies to expand aquaculture exports have resulted in increased productivity and area expansion of production. The total area of coastal aquaculture ponds has expanded 2.6 times in the past 25 years, endangering coastal ecosystems and posing a real challenge to the attainment of SDG14. Vietnam has the largest area of aquaculture in 2015 and the highest annual increasing rate, accounting for 40.28% and 298.5 km²/year, followed by Indonesia (31.50% and 156.8 km²/year), Thailand (10.79% and 64.8 km²/year), Myanmar (8.76% and 61.1 km²/year) (Luo et al., 2022). While development of

aquaculture increased trade and family income, it has also led to mangrove destruction and coastal water pollution (eutrophication). The reduction of mangrove areas is the worst among regions with a loss of 393,000 ha from 2000 to 2010 and 382,000 ha from 2010 to 2010 (Table 2). Coastal zone management creates policy challenges, which may be solved locally through support for alternative livelihoods (Bernier et al., 2016).

To manage conflicts between rice and rice–shrimp or shrimp systems in Bac Lieu Province in the Mekong Delta, provincial authorities designated a buffer zone in which rice is grown in the wet season, and shrimp reared in the dry season (Dung et al., 2009). As returns from shrimp were much higher, farmers responded by extending the period with saline water, at the end making it impossible to grow rice. Lack of coastal zone management plans contributes to these conflicts, but even existing plans may not be enforceable.

Expansion or maintenance of irrigation in coastal areas of Bangladesh may be limited by competition or conflicts over water management with traditional brackish water shrimp aquaculture (Bell et al., 2015). Azad et al. (2009) argue that coastal zoning, including return of illegally farmed public lands in Bangladesh, is a way to deal with expansion of freshwater and brackish water shrimp. Thus, Burbridge et al. (2001) argue that “to achieve sustainability, mariculture must be included in strategic development plans for coastal lands and waters. Mariculture should also be granted rights of access to coastal lands and waters equal to those rights enjoyed by other forms of human development.” Increasing attention to environmental responsibility of aquaculture underscores the urgent need to understand the environmental footprints of different production systems to better manage them to promote more sustainable aquaculture (Cao et al., 2013).

Ministry of Environment, Forest and Climate change of India established a Society of Integrated Coastal Management (SICOM) for vibrant, marine, and resilient coastal and marine environment with the objective to support implementation of ICZM activities in India (Telave & Chandankar, 2021). The SICOM has established and operationalized a world-class Institute- National Centre for Sustainable Coastal Management (NCSCM) at Anna University, Chennai, which aids in the better protection, conservation, rehabilitation, management, and policy design of the coast. They have also completed mapping of the entire coast under project Phase 1 (ICZM project Phase 1 report 2018) and Phase 2 is designated to the conservation of coastal and marine ecological resources, coastal pollution management and related infrastructure upgrade, and capacity building and implementation of ICZM Plans (ICZM project Phase II report, 2018).

In 2011, the State Council of China (the executive branch of the central government) set the goals of China's water resources management. The aims are to develop a system that optimizes distribution and efficiency of the nation's water resources, ensures the health of river and lakes, mitigates the impacts of floods, droughts, and other natural disasters, and values the advancement of water science and governance by prioritizing municipal water supply, implementing comprehensive water resources management, maintaining people–water harmony, ensuring governmental leadership, and promoting reforms and innovations (He, 2012; MWR, 2017).

The UK and overseas governments, combined with current opinions in participatory governance, secure a balance between food production and supply. The EU has developed a comprehensive ocean policy covering a spectrum of issues including maritime affairs, ocean uses, conservation, and research. In recent years, existing regional governance structures and mechanisms have been increasingly recognized and complemented primarily through the Integrated Maritime Policy. ICZM emphasizes the benefits associated with effectively involving people in the marine management decision-making cycle. MPA supporters heralded MSP to overcome the policy vacuum associated with earlier forms of ICZM albeit the latter placed a greater emphasis on implementing good governance processes using a principle-based approach (Stead, 2005) to underpin effective engagement. With growing awareness of implications for gaps in social science data constraining governments in achieving the SDG 14 targets by 2030, policy makers are advised to better integrate socioeconomic scientific evidence with marine environmental data to improve relevance to local contexts.

The increase in the number of MPAs, the engagement of the community in the management of ocean resources through co-management, the attempts to reduce unwanted regulations preventing uncontrolled and illegal harvesting of certain species and reduction of the rate of coastal mangrove disappearance are all performance

indicators that ensure sustainable coastal management and the approaching of SDG 14. Continuous discourse of environmental management will assist in the attainment of the goal of ocean resource management.

4 | THE WAY FORWARD: SUGGESTIONS FOR IMPROVEMENTS IN GOVERNANCE

The future of aquaculture development depends on local, national, and global actors, operating through alliances to increase fish production that generate benefits to stakeholders while preserving the environment and social stability. The desire of all stakeholders is supportable and balanced fish production under a governance of sustainability. This requires improvements in good governance the establishment of a communication platform and legal international frameworks for safeguarding equity, accountability, transparency, and predictability.

The successful contribution of government to the process of governance requires more than funding or financial stimulation of the production and marketing process. It requires trustworthy communication, leadership, and constant interaction with all stakeholders. Decentralized governance approaches, including co-management and community-based management, are important to monitor the product along the value chain to meet the social and environmental objectives, institutional designs, and levels of community, state, and private sector participation (Evans et al., 2011). Similarly, coastal zone governance requires a holistic and integrative approach (Chuenpagdee et al., 2008). Though the role of the state remains prominent, greater private sector involvement is also necessary, especially in the formation of MPAs and the development of “rights-based approaches” to offshore aquaculture (Allison et al., 2011). However, government must provide a framework for successful governance.

The United States and Africa are the two continents with vast potentials for increasing production, poverty reduction, and improvement in rural economies yet they have made only limited advances toward the SDGs. Hence, comprehensiveness of US aquaculture governance could provide an example to other nations on how to set a policy framework and institutions for coordinating research and extension for the increase in aquaculture productivity and attain the selected SDGs (1, 2, 3, 5, 8, and 14). However, the US system of governance is riddled with numerous legislations that hinder aquaculture governance and development of the industry (Abate et al., 2016; Engle & Stone, 2013; Engle & van Senten, 2022). The legislative process is cumbersome, costly, and limits the advancement of projects that are necessary to attain the selected SDGs. Though all countries and regions should improve their regulatory and enforcement capacities they should also avoid being overburdened by regulatory processes. The African continent needs to facilitate the access to clean water, increase credit availability, and the improvement in regulatory reforms.

A systems analysis for prioritization of aquaculture research areas to support responsible aquaculture development to achieve the SDGs needs attention so that the science required for advising food security policy is integrated, adequately funded, and generates relevant information to the local context where implementation is planned (Stead, 2018). Many government departments responsible for aquaculture and fisheries are separated, and research and planning are done in isolation. These sectors should work and plan together as part of a highly interconnected system. Hence, it is important to conduct research and development, using systems thinking and open innovation in an environment of futuristic aquaculture policy making (Stead, 2018), where big data and digital technology can improve evidence-based decisions through improved participatory governance (Stead, 2005; Turner et al., 2017), to generate results that can enable meaningful aquaculture contribution to the achievement of the selected SDGs.

Countries with limited land and ocean resources for inland and offshore aquaculture must seek ways to innovate and expand their aquaculture. The expansion of offshore aquaculture to produce finfish, mollusks, seaweeds, and other species serves as an indicator of the future role of mariculture in supplementing the increasing gap between aquaculture and wild-caught fish. Mariculture is expanding without adequate policies to regulate its growth. There have been piecemeal regulations by more developed economies but there is still a need for comprehensive national and global frameworks for the governance of this emerging sector. An illustration is salmon farming where there are

environmental and social challenges to traditional netpen culture in sheltered waters. Given its contribution to incomes, exports, and employment, governments have been proactive with public–private research partnerships. As the technological leader in salmon farming, the government of Norway levies a small tax on exports for research, which is supplemented by industry. Therefore, it is appropriate to suggest that the time is opportune for the development of general and specific policy frameworks for the exploitation of this ocean resource.

Fisheries and aquaculture contribute little to agriculture GDP in African countries but have the potential of making an important contribution to food security and protein supply particularly to rural communities. Though aquaculture contributed to 17% of total fish production in Africa (Obiero et al., 2019), the industry exhibited dynamic growth during the period 1999–2008 but growth slowed down during the period 2010–2018. Policies to promote sustainable aquaculture growth, and reduce post-harvest losses, within the context of good governance, which embraces the improvement in land tenure and ownership, coupled with private–public investments in open ocean aquaculture can improve benefits to stakeholders and help the countries move closer in attaining the SDGs.

FDI can be promoted so that all stakeholders participate in the governance structure without alienation from even the smallest producer. Small-scale producers may not have to give up their rights of ownership, but some type of coalition between large enterprises and small-scale producers, either through vertical integration or specialization to encourage individual entrepreneurship, can be embraced. Nguyen and Jolly (2020b) showed how large cooperative entities can combine with small-scale shrimp producers in production intensification and quadruple yields and income. These processes require technological modernization. Murekezi et al. (2018) have suggested public–private partnerships and contract farming in aquaculture as ways of integrating women and youth in aquaculture and increasing standards. The use of electronic marketing capabilities including Phones, Pads, and other electronic mobile devices can assist in information dissemination and rapid communication. Successful operation of these devices requires reorganization and regionalization of the whole process aided by research and extension efforts for diffusion and adoption of the evolving technologies. Operational management will become more transparent, along the value chain, but there must be greater accountability, planning, and solid decision-making guided by lead firms and guidelines from government legal framework.

The enforcement of good governance may result in challenges and simultaneously present opportunities for cross-national learning and the development and adoption of best practices. Information transfer can be interactive and can assist in the solution of problems usually encountered by the most resource-poor farmers and local communities resulting in south–north dialogue. This is particularly salient in the domains of disease and pathogen management in species such as shrimp produced by limited-resource farmers, but are high-income earners, or disease of salmon culture practiced by higher income farmers in more developing economies. Hence, easy communication of ideas can advance the monitoring and reporting of disease and pathogen prevalence in all countries, but the requirements in terms of testing intervals, public disclosure of information, and thresholds for mitigation and remedial action vary substantially. Added transferred knowledge may reduce farmers' risk of losses of traded products.

An important point within the global market is the growing importance of international agreements that involve food (and fish) safety aspects. Aquaculture contributes primarily to domestic consumption but, at an international level, important trade has developed for several aquaculture products. About 40% of all fish produced are traded internationally, which means that there is a search for common criteria that facilitate or permit clear and transparent rules for compliance. It is hoped that in the future there will be a common electronic platform for communication of procedures and rules of governance, certification needs, standards, and regulation that facilitate product and information flow through the supply chain.

If the continuous development of aquaculture is impossible using current material and the technical base of farm ponds, a new approach is needed. It could include the automation of management system of fish farming enterprises considering advanced digital technologies such as the Industrial Internet, large data banks, and a unified system of data storage and processing. The implementation of all these technologies in a single automation system can ensure the competitiveness of domestic enterprises compared to foreign fish producers thus making fish farms attractive for investment. It is proposed to consider the create robotic aquaculture control systems, the basis of which will

include automated floating feeders ensuring optimal feeding of fish. All these measures will help to achieve the main goal of the strategy for the development of aquaculture and the simplification of governance throughout the marketing chain.

With increased research and development and information diffused by modern technical forms of communication innovation there will be increasing penetration of new technologies into fish and seafood trade. These technologies will speed up information flows up and down the supply and value chains that will become difficult to sustain without dynamic governance. The beneficiaries of this injection of new technologies will be consumers and producers as more quality products flow through the system. Accountability will increase as the system becomes more transparent and prediction will be facilitated with greater equity, transparency, and access to new knowledge.

This is explicit in the PFRS for Fisheries and Aquaculture in Africa which is Africa's blueprint to support the transformation of Africa's fisheries and aquaculture which was endorsed by member states after recognizing the challenges being faced in the aquaculture sub-sector. The CAADP was also specially formulated to stimulate the necessary reforms in the agriculture sector and sustainable development (Menezes et al., 2018). For aquaculture, the PFRS aims to create an enabling environment that will lead to the transformation of Africa's aquaculture into a sustainable market-oriented private-sector-led commercial agricultural activity.

5 | CONCLUSIONS

Institutions and legal frameworks provide support for aquaculture with the adoption of principles of governance: effectiveness and efficiency, equity, accountability, and predictability that will enable the countries practicing aquaculture to attain the SDGs. Dynamic governance is not sufficient for aquaculture sustainability but is necessary. Participation of stakeholders is also a requirement. Aquaculture is an important driver of local economies, so its institutional arrangements should be part of the mechanisms of territorial development and governance and be included in territorial planning programs. It is essential to establish mechanisms for the inclusion and participation of all aquaculture stakeholders (producers of different scales, representatives of fish and shrimp feed, industry, universities, support institutions, government, etc.) for the discussion of problems and sectoral strategic planning as is currently adopted by USDA, FDA, and NOAA in the development of their five-year plans. The rapid and profitable expansion of salmon farming is due in part to governance. In Norway, it provided the institutional and licensing framework to avoid social disruption and has spearheaded innovation into mitigating environmental damage. Other countries have followed its example. The next 10 years should see the sustainability of the industry enhanced with new technologies, often promoted by governments.

Government support to the industry could be in the form of encouraging the participation of the private sector and Non-governmental Organization (NGOs). Governance should therefore include strategies to create a balance between increased production and environmental conservation. A reduction in the overregulation in countries with vast potential for marine expansion in the United States and under regulation in Africa can be useful in expanding regulation and enabling the attainment of the SDGs. Government policies should therefore engage in export promotion and assist in the development of marketing strategies; branding/certification of products; traceability; regulatory frameworks for trade (e.g., tariff rates); the availability and timeliness of market information available to producers/exporters; processing, preservation, and transport technologies; and institutional development of marketing organizations. There are long-term benefits if the aquaculture industry becomes more sustainable, but trade is a risky activity influenced by international economic pressures; hence government intervention is sometimes necessary, especially when requested by stakeholders, to ensure vulnerable interest groups share in the trade benefits.

SSA has enormous potential for aquaculture production. It is the continent with the greatest probable gap in the achievement of the SDGs, yet production and consumption of aquaculture products are low in comparison to other regions. There is need for coherent strategies for aquaculture development in the continent, and with good governance that embodies equity, transparency and accountability, the continent could increase aquaculture production

that will contribute to achieving the United Nations SDGs (NEPAD, 2016). Fast growth of aquaculture without proper planning and management has raised increasing concern over its sustainability. Aquaculture will have to continue to grow to meet the increasing demand for fish. But growth would not be sustainable if the planning and management are not improved significantly. There is a need for local, national, and international planning and management to cater for environmental, social, economic, health and animal welfare concerns. These form the core of BMP as regards aquaculture.

Technology transfer is important in the aquaculture sector and can be enhanced at the international level through policies that support international cooperation (FAO, 2014a). Government technical support for aquaculture varies widely among countries (Ponte et al., 2014). The government of China has provided tax relief to farmers to expand fish aquaculture. sustainable fisheries management, governance, and failure to protect Indonesia from future biodiversity loss (Zulbainarni et al., 2020). Norway has issued special licenses for salmon farming companies wishing to develop technological alternatives to marine cages. All these technologies can be transferred successfully when accompanied by some financial planning and management.

In some of the European countries, with developed aquaculture programs, the production growth rates have been on a decline. Even with the establishment of national aquaculture plans and recent surges in production growth rates African aquaculture has experienced a decline in growth rates during the last decade. Countries wanting to attain the SDGs should not only have national aquaculture plans with well-articulated objectives in place but should also set targets with the mechanisms for achieving those. This indicates that not only should there be good and dynamic governance, but countries must work toward the attainment of the SDGs. It also signifies underachievement of these goals if production expansion and intensification are unsustainable in all countries.

The global aquaculture value chains have been increasingly influenced by “extra-chain” actors such as standard setting and certification bodies, mainly NGOs or importing government institutions, and the standards and regulations that they impose on producers and processors. Because these international standards and regulations are intended to reflect the expectations of consumers that are remote in both geographical and cultural senses, they can be disconnected from the realities that prevail at the local level, neglecting or marginalizing local schemes, practices, and knowledge dedicated to governing the use and management of natural aquatic resources. Transparent and predictable trade regimes should promote equivalence and recognition of local schemes, practices, and knowledge for market access based on internationally negotiated codes, guidelines, and standards such as the Code of Conduct for Responsible Fisheries and its supporting instruments. To increase or maintain market share aquaculture producers must comply with regulations required by the importing countries, or international regulatory bodies. The conformity to standards imposed by outside bodies generates a compliance cost because of the changes that must be made. The compliance costs associated with improvement in standards and certification schemes can inflict a burden on producers to which the importers may not be sensitive or aware. This asymmetry in information flows may result in conflicts that can only be solved through a platform of open dialogue.

The tendency is, therefore, to move toward the harmonization of national regulations, meaning that such regulations could assure an equivalent level of food protection to consumers while maintaining a sustainable production system and at the same time conserving the environment and the social order. This increases the importance of internationally accepted guidelines, recommendations, and standards, such as those of the Codex Alimentarius. The provisions related to food trade of the General Agreement on Tariffs and Trade compound this tendency, and all these aspects are interlinked. However, with good governance, the social, economic, and environmental objectives can be attained, and the SDG targets are approachable in the next decade.

Many countries face huge fiscal difficulties, especially those from rural areas in developing economies. However, it is necessary to guarantee support for developing activities that quickly provide work, income, and food to the people in the post-pandemic world. Aquaculture has already demonstrated that it can be one of those activities that respond quickly and effectively to these challenges. The biggest opportunity for positive change in the post-pandemic world is for our global food system to become more local, sustainable, and equitable, and for standards that guarantee export flexibility. While so much of our collective attention and investor capital have been focused

on providing consumer convenience foods, the pandemic has irreversibly shifted the conversation to building community resilience and export safe foods. Governments are now actively working with stakeholders across the entire fish (agricultural) supply chain to promote and invest in innovation related to indoor farming, precision aquaculture, food safety and preservation, waste reduction, and alternative proteins.

Continued sustainable development of aquaculture is needed to meet future demands for fish. Aquaculture production can substitute and complement wild-capture production but will rely on effective development and environmental management in countries in need. At present, aquaculture and imports make a minimal contribution to the overall fish production in regions facing the greatest cumulative impacts and population growth rates (e.g., countries including Mauritania, Namibia, Angola, and Somalia). Faster adoption of existing knowledge and technology in aquaculture could help but recognizing environmental and logistical limits on the scope to develop freshwater aquaculture in some of these countries. One major concern about the development of aquaculture has been the use of wild stocks to feed farmed fish. The proportion of directly consumed capture fisheries production, including small forage fish increased from the mid-1990s to 86% in 2012, while the absolute production of fish meal and oil, in part used for aquaculture and animal feed, has fallen with an increased reliance on crops (Blanchard et al., 2017).

DISCLAIMER

The views expressed in this publication are those of the author(s) and do not necessarily reflect the views or policies of the Food and Agriculture Organization of the United Nations.

DATA AVAILABILITY STATEMENT

No data as review

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APPENDIX A

TABLE A1 Selected countries, legal bodies, national plans, governance, production rank, and changes in production and value 1999–2008 and 2009–2018.

Country	Legal body responsible for aquaculture	Year of first policy plan	Description of policy plan	Governance rank	Production in USD				% change in production value USD		
				2019	1999	2008	2009	2018	1999–2008	2009–2018	
Africa						570,233	2,001,149	2,149,079	3,279,668	14.95	4.80
Egypt	General Authority for Fisheries Resources (GAFRG) 1983 ^a	1985	Production plan	27.88	447,146	1,251,119	1,356,149	1,469,470	12.09	0.89	
Nigeria	State Department of Fisheries	2011	National plan	12.98	46,401	409,770	430,828	839,821	26.61	7.69	
Asia						35,687,784	79,669,049	91,875,207	210,190,381	9.32	9.62
Bangladesh	Ministry of Fisheries and Livestock	1998 & 2006	National Fisheries Policy and National Fisheries Strategy	16.35	977,235	1,766,182	2,351,316	5,894,683	6.78	10.74	
Cambodia	Ministry of Agriculture Forestry and Fisheries	2006–2010	National Strategic Plan	9.2	-	70,470	91,548	612,730	-	23.49	
China	Ministry of Agriculture	After the reform	Development Strategy	43.27	20,003,401	106,765,973	113,827,454	144,999,209	23.49	2.72	
India	Ministry of Fisheries, Animal Husbandry and Dairying	1975–84	Aquaculture Development Plan	47.64	2,509,328	6,075,531	5,492,697	13,178,432	10.32	9.36	
Indonesia	Ministry of Maritime Affairs and Fisheries	1975–1984	National Plan for Aquaculture	37.98	2,187,545	2,814,094	4,893,790	11,981,365	2.94	10.45	
Japan	Ministry of Agriculture, Forestry and Fisheries	2002	Basic Plan in Fisheries	88.90	3,365,566	3,343,456	3,632,458	3,929,219	−0.11	0.75	
Myanmar	Department of Fisheries	2000–2003	Three year Expanded Plan	28.85	805,218	817,218	912,454	1,749,584	0.54	7.49	
Philippines	Bureau of Fisheries and Aquatic Resources	2006–2007	Development Plan	31.25	678,716	1,576,141	1,485,706	1,887,247	9.80	2.69	

(Continues)

TABLE A1 (Continued)

Country	Legal body responsible for aquaculture	Year of first policy plan	Description of policy plan	Governance rank	Production in USD				% change in production value USD	
				2019	1999	2008	2009	2018	1999–2008	2009–2018
South Korea	Ministry of Maritime Affairs and Fisheries	1997 and 2003	Aquaculture plan	76.92	586,288	1,287,039	1,360,587	2,321,683	9.11	6.13
Thailand	Ministry of Agriculture and Cooperatives	1961	Fisheries Development Plan	39.42	2,092,228	2,345,592	2,622,728	2,701,065	1.27	0.33
Vietnam	Ministry of Agriculture and Rural Development	1960–1980	Development Plan for Fisheries and Aquaculture	34.13	37,028	4,606,180	4,803,237	14,460,784	22.56	13.01
Europe					4,513,236	8,506,238	8,985,814	15,337,814	9.29	6.11
France	Ministry of Agriculture, Fisheries and Forestry Resources	1852 onwards	Various degrees regulating aquaculture	88.94	487,919	1,017,518	958,637	847,187	8.50	−0.12
Turkey	Ministry of Food Agriculture and Livestock; three Directorates	2007	Joint Decree	44.71	306,408	649,372	615,738	1,125,221	8.69	6.92
Norway	Directorate of Fisheries	2005	Aquaculture Regulation Act	97.12	1,339,487	3,138,994	3,590,060	8,342,301	9.91	9.80
Spain	Ministry of Agriculture, Fisheries and Marine Aquaculture	1942	Laws for Aquaculture	73.56	299,957	556,594	519,334	596,027	7.10	1.54
UK	Ministry of Agriculture, Fisheries and Food	1938	Legislation Relevant to Aquaculture	93.75	478,531	967,103	780,730	1,344,170	8.12	6.22
Americas					3,643,861	9,545,474	10,025,011	19,470,726	11.02	7.64
Brazil	Ministry of Fishing and Aquaculture	2003	National Plan	42.31	216,699	850,617	1,012,255	1,345,833	16.39	3.21
Canada	Federal Authority Department of Fisheries and Oceans Canada	2009 to 2010	National strategic plan	93.27	355,365	720,747	702,841	1,091,347	8.16	5.01

TABLE A1 (Continued)

Country	Legal body responsible for aquaculture	Year of first policy plan	Description of policy plan	Governance rank	Production in USD					% change in production value USD	
				2019	1999	2008	2009	2018	1999-2008	2009-2018	
Chile	Undersecretariat for Fisheries and Aquaculture	2005	National Plan	83.17	908,200	4,502,789	4,668,055	10,446,268	19.44	9.35	
Ecuador	Ministry of Agriculture, Livestock Aquaculture and Fisheries	2002	Fisheries Law	34.62	601,517	767,901	1,012,516	2,799,442	2.75	11.95	
Mexico	National Commission on Aquaculture and Fisheries	1992	Actual Law	22.60	192,016	565,705	477,500	847,419	12.71	6.58	
US	United States Department of Agriculture	1980	National Aquaculture Act	84.62	833,456	983,583	958,882	1,226,902	1.86	2.77	

^ahttp://www.fao.org/fishery/legalframework/nalo_egypt/en.