



AQUACULTURE'S VITAL ROLE IN ADVANCING THE SUSTAINABLE DEVELOPMENT GOALS: A COMPREHENSIVE OVERVIEW

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Abstract

Aquaculture presents a unique opportunity for advancing the sustainable development agenda in the Mediterranean region, addressing a range of critical 21st century challenges. This paper discusses the transversality of aquaculture across economic, environmental, and social themes and its potential to tackle issues such as climate change, and gender equity, with a specific focus on SDGs 1, 2, 5, 10, 13, and 14, within the complex context of the Mediterranean region. It explores the potential of aquaculture to contribute to various aspects of sustainable development, including food security, environmental sustainability, and economic growth, while considering the challenges and controversies associated with the aquaculture industry.

This paper uses the SDGs framework to analyze how aquaculture can be a key leverage to bridge the development gap between different regions and it makes three general contributions. First, it provides the definition of aquaculture and it distinguishes it from sustainable aquaculture. Secondly, it highlights some of the impacts of the aquaculture sector on the environment which include nutrient pollution, chemical usage, and the risk of biological pollution. Moreover, issues regarding human health, working conditions, and the livelihood of coastal communities are also included. Finally, it shows different perspectives on aquaculture contributions to the SDGs. In this context, the paper sheds light on the potential of aquaculture, as a transversal thematic sector, can address a wide spectrum of development issues, and how it can be a catalyst for sustainable development in the Mediterranean area, transcending its role as a source of alternative food protein. In regard to this, some initiatives developed within the Mediterranean scale are also mentioned.

Aquaculture's Vital Role in Advancing the Sustainable Development Goals: A Comprehensive Overview

In its 2020 report¹ The Sustainable Development Solution Network stressed that the Mediterranean area was falling far from achieving its sustainable development target. The report breaks down the 17 SDGs into six thematic approaches that cover the whole range of challenges related to their achievement. Those pillars include:

- 1) Policies for education, gender & inequality
- 2) Policies for health, wellbeing & demography
- 3) Policies for energy, decarbonization & sustainable industry
- 4) Policies for sustainable food, land, water & sea
- 5) Policies for sustainable cities & communities
- 6) Policies for digital revolution for sustainable development

Each pillar encompasses challenges related to specific SDGs, as well as a list of KPIs to report on it. As a consequence, SDGs achievement implies setting policies to develop sectors and practices fitting into one of those pillars to have additional impact on related challenges. Yet, some sectors covering a broad range of issues have cross-pillar impacts, hence resulting in an exponential effect on SDGs achievement.

In such a scattered and diverse area as the Mediterranean basin from a development viewpoint, countries come up with development plans with as scattered and diverse strategies. Yet, some economic sectors get consistently mentioned. Aquaculture is one of them. Most countries being aware of the need to regulate activities in such a confined basin, the United Nations Environment Program - Mediterranean Action Plan (UNEP-MAP), which gathers officials of the entire area, mandated Plan Bleu to develop a Roadmap for the development of a Mediterranean aquaculture sector². Aquaculture is a vertical sector, not only contributing to seafood production & related food issues, but also has a substantial impact on environmental, social & economic issues. Yet, it is also very controversial, and nothing indicates related impacts are actually beneficial for SDGs achievement.

However, adopting a sustainable aquaculture system in the whole area might be a solution to favor sustainability on various levels & thematics. This paper will cover the potential of aquaculture related to some SDGs, with a focus on SDGs 1, 2, 5, 10 13 and 14.

Aquaculture is defined as the controlled process of cultivating aquatic organisms such as fish, crustaceans, mollusks and aquatic plants. It involves cultivating freshwater and saltwater populations under controlled or semi-natural conditions, and can be distinguished

¹ Riccaboni, A., Sachs, J., Cresti, S., Gigliotti, M., Pulselli, R.M. (2020): "Sustainable Development in the Mediterranean. Report 2020. Transformations to achieve the Sustainable Development Goals." Siena: Sustainable Development Solutions Network Mediterranean (SDSN Mediterranean), p.6.

² Plan-bleu: Environnement et développement en Méditerranée (2021): "Aquaculture in the Mediterranean - Plan-Bleu : Environnement et Développement En Méditerranée", available at: <https://planbleu.org/en/page-theme/aquaculture/>

with commercial fishing, which is the harvesting of wild fish. Aquaculture is the fastest growing form of food production across the globe and there is a growing interest in utilizing aquaculture for conservation purposes including species recovery, habitat restoration and offsetting the impacts of capture of vulnerable species³. As aquaculture is developing and expanding, it has an increasing effect on the environment and the society. In developing regions where small-scale freshwater aquaculture is common, issues such as landscape change, water quality, deforestation, and loss of wetlands have been identified as key problems. In wealthier countries, controversy has emerged over impacts on wild stocks and species, degradation of habitat, rural futures and economic restructuring, and legal and moral rights to aquatic spaces and resources. These challenges and disagreements vary substantially across different localities and regions, but they also share common themes⁴.

Concerning the environment, effects of aquaculture include nutrient pollution that come from the production process where uneaten feed and metabolic waste like phosphorus and nitrogen find their way to water sources leading to proliferation of primary producers that may trigger micro- and macroalgal blooms that may be toxic⁵ and then contribute to changes in the composition of seaweed communities in the coastal lines. Numerous chemicals are also being used in aquaculture production to prevent and treat disease outbreaks. These chemicals range from medicines such as antiparasites, antibiotics to disinfectants. They enter the surrounding marine environments and may be toxic to non-target organisms in proximity of the farming sites because they are not highly selective. Parasiticides, which are used to control ectoparasite infections are an environmental risk since they contaminate water columns as well as the seabed⁶.

Another issue concerning aquaculture-based negative effects on the environment is the risk of biological pollution. Biological pollution can be caused by the farming of exotic species, which also act as vectors for new parasites and disease, which may also pose a threat to wild populations. After shipping, aquaculture is the second largest sector causing the introduction of exotic species worldwide and likely to increase because of the spread of farms into more pristine areas⁷. Growing local concerns are related to the consequences of fish escapes, including predation on wild juvenile salmon, sea lice infection transfers to wild stocks, genetic introgression of farmed fish into wild populations, unsustainable production of fishmeal and fish oil and competition effects with native species⁸. Marine plastic waste is also an increasing problem, and although the share originating from aquaculture is small, the

³ Mizuta, D. D., Froehlich, H. E. & Wilson, J. R. (2023): "The changing role and definitions of aquaculture for environmental purposes" *Reviews in Aquaculture*, pp.15, 130;141.

⁴ Young, N. *et al.* (2019): "Limitations to growth: Social-ecological challenges to aquaculture development in five wealthy nations" *Marine Policy*, pp. 104, 216;224.

⁵ Wang, B., Xin, M., Wei, Q. & Xie, L. (2018) "A historical overview of coastal eutrophication in the China Seas" *Marine Pollution Bulletin*, pp.136, 394;400.

⁶ Carballeira Braña, C. B., Cerbule, K., Senff, P. & Stolz, I. K. (2021): "Towards Environmental Sustainability in Marine Finfish Aquaculture" *Front. Mar. Sci.* 8, 666662, p. 6.

⁷*ibidem*

⁸ Cavallo, M., Raux, P., Massa, F., Fezzardi, D. & Pérez Agúndez, J. A. (2022): "Why not? Decrypting social attitudes toward European aquaculture: An updated policy perspective for an old problem" *Integr. Envir. Assess & Manag* *ieam*. 4663

sector has not taken control of this pollution problem, which is unfortunate given the prospective expansion of the aquaculture sector⁹.

Concerns over the impact of aquaculture on human health are related to consumption of farmed species (food safety), to farmers working conditions, and to local coastal users. Perceptions of food safety are linked to intensive finfish farming, mostly salmon, which includes the use of chemicals, antibiotics, antiparasitic, hormones, and genetically modified organisms (GMOs; that can potentially be transferred to consumers). Inadequate aquacultural development and irresponsible practices can also threaten the structure and functioning of the surrounding ecosystems, leading to opposition by local users.

Nevertheless aquaculture plays a vital role in food security to millions of people worldwide and these negative impacts should be addressed to facilitate growth in the sector. Consequently, sustainable aquaculture practices should be enforced. Sustainable aquaculture is defined as the cultivation of fish species for commercial purposes by means that have a benign, if not positive, net impact on the environment, contribute to local community development, and generate an economic profit. Sustainable aquaculture is backed by eco-certification schemes such as aquaculture stewardship council (ASC) which communicate to consumers that the food products are obtained in a sustainable way.

Over the past century, aquaculture production has grown rapidly in many parts of the world particularly in East Asia, although Southern and Eastern Mediterranean countries have also seen a significant development, collectively increasing production in the region by 160% over the last decade. Despite the slight predominance of capture fisheries as the main production source, aquaculture is highly significant for several Mediterranean countries and plays a rising role in fish supply. In fact, while marine fish production in the region increased by 15% compared to 2010; this was entirely due to aquaculture (+71%) as capture fisheries dropped by 8%. Mediterranean marine aquaculture is majorly dominated by finfish, comprising 83% of the total production, followed by molluscs (16%). The sector is also heavily concentrated in the region, with Egypt producing 31% of the total quantity in 2019, followed by Turkey (29%), Greece (14%) and Italy (12%)¹⁰.

Replicating global trends, aquaculture at the Mediterranean scale is not the most sustainable sector, especially from an environmental viewpoint. However, there is a growing acknowledgment in the area of the importance of a coordinated and inclusive management of marine ecosystems at basin scale, embodied by joint initiatives as the Barcelona convention, to sustain food security and economic growth since some major sectors rely on water quality, including fishing, aquaculture, tourism etc. Hence, while poor practices in the sector are still undertaken around the basin, the industry is adopting new farming practices and technologies limiting the impact on surrounding ecosystems¹¹. As a consequence of those changes, some Mediterranean countries are counting on sustainable aquaculture as a way to tackle a broad range of sustainability issues through the development spectrum.

⁹ Iheanacho, S., Ogbu, M., Bhuyan, M. S. & Ogunji, J. (2023): "Microplastic pollution: An emerging contaminant in aquaculture, *Aquaculture and Fisheries*" 8, p. 603–616

¹⁰ Carvalho, N., Guillen, J. (2021): "Aquaculture in the Mediterranean" IEMED Mediterranean Yearbook

¹¹ Sourd P. et. al. (2021.): "Precision sea bass: New technologies at Mediterranean Seafarms - Responsible Seafood Advocate"

Using the SDGs framework, the goal of this analysis will be to highlight the potential of aquaculture to address sustainable development issues beyond the only production of an alternative food protein. As a transversal thematic, aquaculture covers a wide scope of development issues, and could be one of the key leverages to close the gap between the north & the south.

SDG 1: No poverty & SDG 8: Socio-Economic Development

Aquaculture worldwide is a \$287 Bn industry, providing primary jobs for more than 20 Mn people. In addition, considering the trend the sector is taking in the area, under the influence of the EU Green Deal, or of nationally determined plans to develop the sector, like the Egypt Strategic Objective and Development Plan for Aquaculture and Fisheries sectors, it is very likely that the sector will substantially grow within the next few years. Governments and regional unions in the area understood the potential of the sector to address several development issues through consolidated efforts.

Poverty being one of those issues. Indeed, while almost countries in the area have an extreme poverty rate below 3%, hence aligned with SDG 1 goals, Egypt is still not meeting the target¹². Looking a bit ahead of the current extreme poverty concept, there are still 50 Mn people at risk of extreme poverty in the area, including 28 Mn Europeans¹³. This data itself highlights the failure of economic models in the area to secure steady livelihoods for around 12% of the population, and consequently underlines the gap separating us from true sustainable development. Further digging into poverty data, it appears very clear that the biggest share of people living either in poverty are concentrated in rural areas. For instance, the ratio for Egypt¹⁴, the country with the most important extreme poverty rate in nominal value in the area, is 92% of poverty concentration in rural areas. It actually aligns with worldwide rates as defined per the IFAD, which estimated that 83.5% of extreme poverty was rural.¹⁵

After having done this statement, one must wonder how could aquaculture of all sectors reverse the poverty trend? Especially considering that incomes proposed in the aquaculture industry worldwide are usually below market incomes, the risk of adopting aquaculture at scale in the area could actually be to speed poverty risk exposure more than anything else.

Aquaculture worldwide is a \$287 Bn industry, providing jobs to more than 23 Mn people¹⁶. It is a work intensive industry, not only for fish farming activities, representing 16 Mn workers, but alongside a broader value chain encompassing indirect processing and recycling

¹² World Bank Group (2020): "Reversals of future; Chapter II - Poverty and shared prosperity" p. 81-121

¹³ SDSN Mediterranean (2020): Sustainable Development in the Mediterranean, Report 2020 "Transformations to achieve the Sustainable Development Goals"

¹⁴ World Data Lab; World Poverty Clock

¹⁵ Suttie, D. (2019): "Overview: Rural poverty in developing countries: Issues, policies and challenges" In: IFAD

¹⁶ FAO (2022): "The State of World Fisheries and Aquaculture 2022, Towards Blue Transformation" Rome, FAO.

activities, in a number estimated at 6 Mn people. Considering the trend the sector is taking in the area, under the influence of the EU Green Deal, or of nationally determined plans to develop the sector, like the Egypt Strategic Objective and Development Plan for Aquaculture and Fisheries sectors, the sector is seen as a strategic leverage to achieve sustainable development targets. Especially, through the commitment for sustainable wildstocks management in the area, the European Union, with some Southern partners from time, intends to align its sustainable development agenda with market demand. In this context, aquaculture will appear as an alternative source of animal protein, spurring the Northern Mediterranean demand, hence production and prices. In addition, the growing population in Southern Med will also require alternative sources of animal protein¹⁷. This trend of increased need for alternative sources of animal protein is especially true for some countries which took pledges on carbon emissions reduction through NDCs (Nationally Determined Contributions) including Morocco, Tunisia or Lebanon. As a consequence of those political, environmental and demographic considerations, it is very likely that the aquaculture market will reach a critical size in the next decades.

Beyond those macroeconomic trends, which reflect extensive job and livelihood opportunities provided through the soar of the sector within the next decade, aquaculture is also substantially a more sustainable livelihood solution for small-scale fisheries-relying coastal communities. Indeed, it represents a way out of the poverty trap a substantial share of the Southern and Eastern Mediterranean population is at risk of due to decreasing yields in fisheries in the area. This phenomenon lies in the tragedy of commons, which states that common goods are by definition doomed to overexploitation since individuals want to maximize their own utility instead of ensuring a sustainable commonly shared management plan. The same happens in fisheries all over the world, including in the Mediterranean area where 86 % of wild stocks as per the estimates of the Scientific, Technical and Economic Committee for Fisheries of the European Commission¹⁸. This trend is not based on greed from fishermen across the area, but really highlights the tragedy of commons since those overfishing behaviors are due to decreasing fishing yields, themselves based on depletion of the stock caused by overfishing. Hence, it is a vicious circle which leads small-scale fisheries-relying communities right to high poverty if no livelihood alternative is found soon. Then aquaculture appears as a more sustainable solution, from an environmental, economic and social viewpoint, since it overcomes the tragedy of commons, hence providing steadier long-term livelihoods substitutes to coastal communities.

Finally, while challenging, especially from the access to finance viewpoint, the development of small-scale aquaculture in the region, especially under regenerative forms like seaweed or conch farming, fits labor market related issues in remote coastal areas with high poverty rates. Indeed, this type of aquaculture, as opposed to intensive systems, requires fewer skills and knowledge. As a consequence, those systems are easily replicable and adaptable to remote areas where education is not always accessible. Moreover, there is an opportunity

¹⁷Ali, E., W. Cramer, J. Carnicer, E. Georgopoulou, N.J.M. Hilmi, G. Le Cozannet, and P. Lionello (2022): "Cross-Chapter Paper 4: Mediterranean Region. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change" p.2243

¹⁸ IFREMER (2022): "2022 report: Overfishing is on the decline, but fish populations aren't yet 100% sustainably managed"

to build on centuries-long traditions of fishing and seafood management through the development of a subsidiary sector. While capturing and farming are two very different activities, the underlying is relatively identical, which justifies hopes that this millenary expertise could serve the transition towards a more sustainable sector, would it from a financial, environmental or social viewpoint.

As a consequence, aquaculture appears as an opportunity to reduce poverty in the Mediterranean area, whether from a macroeconomic trend viewpoint, or regarding the economic viability of aquaculture models themselves. Yet, while the SDSN Youth Mediterranean appreciates aquaculture has the potential to hack sustainable development in the area, we are also aware of the risks it could represent for millions of Mediterraneans from an economic and social viewpoint.

Indeed, the first red flag relates to working conditions in the sector. Over the past decades, aquaculture has been subjected to many scandals of modern slavery, especially in shrimp farming in South-East Asia. The International Labor Organization recognized in 2021 that working conditions and below-average incomes represented a substantial risk for small-scale aquaculture relying populations worldwide¹⁹. It is especially true in the informal economy in South-East Asian, African and South-American facilities whose products are consumed locally, or at least outside of OECD countries where sustainability considerations are growing in fish consumption. While those risks are absolutely void in the EU, since such facilities wouldn't even stand a chance to open, and/or to be BAP or ASC certified, the risk remains substantial in some countries of the area where there is not such thing as a labor code and local consumers are not concerned by sustainability issues. Unfortunately, those countries are the ones that need a new economic model the most to break out from endemic poverty. Egypt might be the best example. The demographic trend the country knows might lead it to be the 11th most populated country in 2050, with an overall 205 Mn inhabitants. Yet, as already mentioned, the country still has more than 3% of its population living under the extreme poverty rate, which implies it dramatically needs new economic opportunities and alternative animal protein solutions to answer both those challenges. Yet, without a serious commitment of the government, a potential development of aquaculture would result in the soar of aquaculture facilities undertaking poor working conditions practices and paying low incomes to populations with no livelihood alternatives. It is very likely that the change won't come from the consumer market in developing countries, so the public powers need to take over the sector's development to benefit from its potential benefits regarding the achievement of SDGs.

SDG 2: Zero Hunger

According to the 2020 SDSN Mediterranean Report, food security is one the top sustainable development challenges the Mediterranean area will face in the next few years. Indeed, in 2019 and 2020, indicators showed a degradation or stagnation in the achievement of SDG number 2 in most of the countries of the area, with obviously some countries displaying extremely worrying performances in the matter, including Lebanon, Egypt, Syria or Libya.

¹⁹ ILO (2021): "The future of work in aquaculture in the context of the rural economy" p. 1-40

Even in Northern or Eastern Mediterranean countries like Greece or Albania, food security indexes were stagnating.²⁰

And yet, it was in 2020. Taking into account the macro-economic context of the past two years, compounding the Covid 19 crisis and the war in Ukraine, the situation has worsened and jeopardizes food security in the Mediterranean area in ways unseen in a long time²¹. Indeed, for the past three years, volatility in commodity supplies resulted in a soar of commodity markets prices, especially for oil, cereals and wheat. This trend resulted in important inflation rates striking the global economy, especially on staple products like food. While Southern Mediterranean countries handled inflation in different ways, sometimes better than Northern countries, food CPI inflation rates remain worrying in 2022. For instance, Morocco records a 8.9% CPI inflation rate from January 2022 to January 2023²², partly sustained by a 16.4% food CPI inflation rate. Yet, Morocco has one of the lowest inflation rates in the MENA area, which suggests that the situation is by far worse in other countries with fewer data availability. The IMF in June 2022, estimated a global CPI inflation rate of 17% in North Africa²³. This trend in generalized prices increase in the area is extremely worrying for two main reasons:

- First, it is the result of disrupted supply chains which implies staple products, hence food scarcity in the area.
- In addition, while food prices increase are still sustainable in developing countries where consumption baskets are diluted between different categories of products, resulting in a more important price elasticity for staple products, it is extremely dangerous in Southern Mediterranean countries where food products represent a major share of this basket, hence resulting in a limited price elasticity, consequently jeopardizing food purchase power.²⁴

Beyond this macroeconomic context, food security in the area is also at risk due to climate change, extensively jeopardizing water supplies, hence the agricultural sector in the area, using 75% of groundwater resources. Indeed, climate change particularly strikes hard around the basin, which is already framed as dry by the National Geographic²⁵ and has been classified “highly vulnerable to climate change” by the IPCC²⁶. Over the last century, temperatures soared significantly in the Mediterranean basin, resulting in an increase of 1.54 degree celsius in comparison to the average of 1860 to 1890, representing a +0.4 degree difference in comparison to global average change²⁷. It tends to sustain, since the area experiences a warming trend 20% faster than the rest of the world. Many models suggest

²⁰ *ibidem*, n.1

²¹ Rauschendorfer, J. Krivonos, E. (2022): “Implications of the war in Ukraine for agrifood trade and food security in the Southern and Eastern Mediterranean: Egypt, Jordan” FAO

²² Eljehtimi, A. (2023): “Morocco's inflation jumps 8.9% in January as food prices soar” Reuters

²³ “IMF Data Mapper ®”

²⁴ Azour, J. et. al. (2022): “Middle East and North Africa's Commodity Importers Hit by Higher Prices”

²⁵National Geographic “Köppen Climate Classification System) IMF

²⁶ *ibidem*, n.17, p. 2235

²⁷ Cramer et al. (2018): “Climate change and interconnected risks to sustainable development in the Mediterranean” Nature Climate Change volume 8, p. 972–980

that this trend will pursue and, most probably, accelerate in the future, which could lead to a low-bound pessimistic scenario with average on-land temperatures increasing by up to 5.6 degree celsius by the end of the century²⁸. Consequently, a decrease in precipitation and groundwater availability, combined to an increase in frequency and duration of drought, is expected due to climatic drivers, exacerbating water scarcity. Yet, this trend results in a decrease in yields in agriculture, which will spur the development of intensive irrigation systems, hence self-sustaining the desertification process.

Hence, both the macroeconomic and environmental contexts represent major threats to food supplies in the area. Building on this statement, more sustainable food value chains are to be built to ensure food security in the area, following the guideline of the FAO which defines them as *“the full range of farms and firms and their successive coordinated value-adding activities that produce particular raw agricultural materials and transform them into particular food products that are sold to final consumers and disposed of after use, in a manner that is profitable throughout, has broad-based benefits for society, and does not permanently deplete natural resources”*. In a nutshell, the sustainable design of those chains should account for a broad range of diverse and complexly entangled criteria, including food independence, energy consumption, environmental footprint, nutrition intake, profitability...

In this context, aquaculture is a great match. While the sector might not be totally sustainable yet as presented earlier, new aquaculture practices are being adopted and it is moving in the right direction, especially in the Northern and Western Mediterranean basin. Building on the definition of the FAO and related key criteria to address, we are confident that aquaculture could support food security in the area and the achievement of SDG 2.

Firstly, because it could be a supply of animal protein source in a resource scarcity context. Indeed, while meat farming is exposed to the same macroeconomic and environmental risks as exposed earlier, and wild fish stocks face an unprecedented depletion, especially in the Mediterranean area which displays one of the most important overfishing rate in the world, aquaculture overcomes the resource constraint to potentially supply steady animal protein flows, *ceteris paribus*. Indeed, with more than 90% of farmed fishes produced consumed locally in the global South²⁹, the aquaculture sector is non-arguably a domestic market, relatively independent from the global macroeconomic context. It tends to be strengthened by two trending phenomena. The first one being the development of alternative feed solutions to fish meal and fish oil, the latest being mostly based on imports from South-America and China. Those alternatives solutions, mostly based on insect, plant and fish waste, already represented a US\$5.24 Bn market in 2021, and is expected to display a 10.9% CAGR up to 2030 where it should top

²⁸ *ibidem*

²⁹ Belton, B. (2017): “Not just for the wealthy: Rethinking farmed fish consumption in the Global South” Global Food Security, p.16

US\$131 Bn³⁰. These solutions will improve the resilience of supply chains, substituting the dependency towards feed supply from China and Peru to locally or regionally produced feed sources.

The second phenomena supporting the development of domestic aquaculture markets in emerging countries is the increase in demand, resulting from livelihood improvement. This trend supports the scaling of production levels, hence allowing producers to benefit from economies of scale and decreasing prices, providing a more affordable food protein source to local markets. As a consequence, aquaculture appears as an opportunity to decrease exposure to the global macroeconomic volatility which is jeopardizing food security in the area.

Beyond aquaculture supply chains sustainability regarding trade considerations, the sector also overcomes resource scarcity. While aquaculture systems are exposed to climate events, especially to increase in temperatures shifting fish living conditions, which are super sensitive, the sector is more resilient to climate change than the agricultural sector, especially in the area³¹. Not only do aquaculture systems overcome environmental constraints through their resilience to climate events, but they also support a steady animal protein supply in a wild fish stocks reduction context. Indeed, with a 64% overfishing rate, the Mediterranean area is the most overfished spot in the world, according to the FAO & the Food Security Center.³²

Building on this sustainability profile of aquaculture value chains compared to more conventional animal protein supply chains in the area, the aquaculture sector appears as the best match to feed an everly growing and young population. Especially considering the nutrition intake of fish in a context of both undernourishment and growing obesity rates in the South of the area³³. Depending on categories, fish are stacked in essential proteins, omega-3 fatty acids or calcium etc, resulting in a broad range of health benefits including reduced heart disease risks, improved breastfeeding conditions, memory and bone construction.

Regarding its ability to overcome macroeconomic contexts and environmental constraints, as well as regarding the intrinsic health benefits of fish products, the aquaculture sector results in a sustainable alternative to current sensitive food supply chains in the area, especially considering its ability to provide a steady resilient healthy diet to a young growing population.

³⁰ PRNewsWire (2022): "Sustainable Feed & Nutrition for Aquaculture Market worth \$ 13.1 Billion by 2030 - Exclusive Report by InsightAce Analytic"

³¹ NOAA Fisheries (2022): "Fact Sheet: Climate Resilience and Aquaculture"

³² Food Security Center (2019): "Mediterranean Sea is getting empty"

³³ *ibidem*, n. 1

SDG 5: Gender (Vulnerable groups) Equity & SDG 10: Reduced Inequalities

The fifth and tenth Sustainable Development Goals go hand-in-hand. Goal 5 is gender equality, and goal 10 is reduced inequality. While these goals have two different outcomes, the process of reaching these goals is similar – including more diverse groups of people in the economy, as well as empowering companies to give them more opportunities.

Gender equity, as defined by the International Labor Organization (ILO), refers to “fairness of treatment for women and men, according to their respective needs.” Gender equality, on the other hand, is defined by the ILO as the “enjoyment of equal rights, opportunities and treatment by men and women and by boys and girls in all spheres of life”.

Women in developing countries, not only Mediterranean areas face substantive challenges to engaging in and benefiting equitably from agriculture sectors. There are a combination of factors, including limited access to and control over assets and resources, constraining gender norms, time and labor burdens of unpaid work, and barriers to sustaining entrepreneurship. The result is women having fewer opportunities and receiving smaller returns from fisheries and aquaculture than men—including lower income.

These challenges are significant for more than reasons of social justice. Growing evidence signals that gender equality will play a key role in these sectors’ important contributions to achieving the Sustainable Development Goals on poverty reduction and food and nutrition security. In particular, gender equality in fisheries and aquaculture can bring many potential benefits including higher fish productivity and household incomes, as well as positive nutritional outcomes.

In small-scale fisheries and aquaculture, the circumstances, involvement, constraints, barriers, options, and benefits are often different for women and men. Recognizing this, WorldFish³⁴ research commits and contributes to gender equality (SDG 5), including through innovative gender transformative approaches. At the same time, WorldFish includes a focus on gender equity, to ensure that research and development interventions are inclusive, equitable in process and outcome, and meet the specific needs of different women and men.

Women have a vital role in fisheries and aquaculture - as fishers, fish farmers, processors and traders. In fact, in developing countries, women do up to 90 percent of secondary fisheries activities (e.g. processing)³⁵. Addressing these gender inequalities and their underlying factors will not only positively affect the livelihoods of women, it will also benefit the families, communities, and sectors that depend on them by working on SDG 10. Gender equality is central to realizing the potential of fisheries and aquaculture to increase fish production, and to improve livelihoods and enhance nutrition security, especially for the most nutritionally vulnerable.

The invisibility of women in fisheries is a persistent issue in the Mediterranean basin. This is directly related to the lack of systematic collection of sex-disaggregated data on the

³⁴Underwood C.R. Leddy A.M. and Morgan M. (2014): “Gender-equity or gender-equality scales and indices for potential use in aquatic agricultural systems” CGIAR Research Program on Aquatic Agricultural System, Program Report: AAS-2014-37. p.8-21

³⁵ Carvalho, N., Guillen, J. (2021): “Aquaculture in the Mediterranean” IEMED Mediterranean Yearbook

participation and the positions occupied by men and women in the sub-sectors, especially in catching but also in aquaculture and processing. The catching sub-sector is heavily dominated by men. Formally employed women represent only a small share of the workforce (between 1 and 6%, depending on the EU Member State). This is also the sub-sector with the highest number of women who work in assisting roles without a specific legal status or remuneration. This is particularly the case in small-scale, family-run businesses where fishers' wives, daughters, mothers, assist with operations of the family business on a full-time or ad-hoc basis. They are predominantly found in land-based activities such as administering permits, licenses, registrations, contracts, etc., as well as in accounting and marketing activities. In some EU Member States, women are often employed in other sectors on a full-time or part-time basis and still support their family's fishing business. In Italy, stakeholders estimated that there were 500 to 800 women who played assisting roles without a specific legal status or remuneration, in Greece over 90 "invisible" female workers in the catching sub-sector, and 550 to 650 in Malta³⁶.

Gender equality begins with visibility. Too often women are under-represented in official statistics for fisheries and aquaculture and that means their contribution to the sector is not always fully acknowledged or appreciated. It also means women have less access to social protection programmes and decision making processes that affect their lives and livelihoods. Women make up only 23% of Europe's total aquaculture workforce. Moreover, female employees in the EU's seafood sectors tend to occupy what are considered low-valued positions.

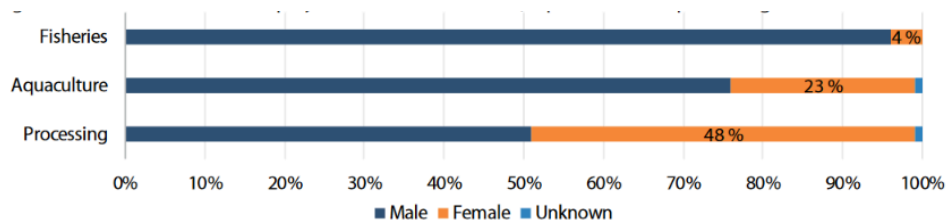
There is a need for the formation of a fisheries and aquaculture gender mainstreaming strategy in the Mediterranean: objectives, programme and budget. Most respondents stated a lack of adequate financial and human resources dedicated to ensuring gender-responsiveness of projects which is considered as one critical barrier. While there is considerable recognition of the potential of gender mainstreaming, it seems to rank low in prioritization.

Inequality is a real, palpable issue in every corner of our world. Aquaculture can be a part of the solution by lifting up marginalized voices. Farmed seafood can contribute to reducing global inequality through providing economic opportunities for women and disadvantaged people, as well as access to fresh, safe, nutritious food. Aquaculture aligns and intersects with reducing inequality. When people don't have jobs or income, nutritious food can be hard to come by. Aquaculture not only creates nutritious food locally, but also employs impoverished people in the process. The industry, most notably when involved in rural communities, can contribute to these goals by generating jobs and healthful food.³⁷

Figure I - Gender aspect in employment rates in EU aquaculture sector

³⁶ *Ibidem*

³⁷ CGIAR (2020): "SDG 10 - Reduced Inequalities"



Source: STEF 19-03, STED 19-15, STEF 20-12

SDG 13: Climate Change

Changes in climate, such as rising temperatures, changing precipitation patterns, and increased frequency of some extreme events are evident on water resources, while others are still emerging and directly affecting aquaculture. Although aquaculture activities, such as power input, transport, and feed production are considered the main pathways of the sector's contribution to GHGs, the sector's contribution is rather relatively small despite being significant when compared to other food production sectors. Recently, climate change effects on aquaculture sustainability have gained considerable interest owing to the sector's significant contribution to global food security, nutrition, and livelihoods meaning it is directly related to SDGs. Despite some aspects of uncertainty, several projections show that the entire aquaculture value chain is vulnerable to the effects of climate change.³⁸

Some of the implications for aquatic systems include: hydrological cycle & rainfall patterns, water change and oxygen content, ice coverage and sea level, ocean circulation and acidification and consequently the primary production.

Although climate change is a global food production risk, the associated risks on aquaculture are expected to differ across geographical or climatic zones, national economy, water environment, production systems, the scale of production, and cultured species of the aquaculture producers. For example, predicted higher effects on producers in developing nations and poorer economies compared with those in developed ones. Small-scale farmers will be more affected by climate change risks due to increased production costs in farm management and lack of support systems to recover from the effects compared to large-scale producers³⁹. Furthermore, it is important to note that climate change effects will not only affect aquaculture production systems, but also the entire value chain.

However, on the other hand, aquaculture is acting as a climate change mitigation tool, i.e. providing climate benefits. Seaweed is one of those tools. For instance, numerous studies are showing how seaweed aquaculture can sequester carbon under certain circumstances, when seaweed fragments break free of farms and are sequestered in deep sea habitats, or as a donor to near shore blue carbon habitats. Intercropping seaweeds with some types of mollusks could also reduce the emissions created during the farming of shellfish. Even more encouraging are new developments in usage of seaweed in end products that have

³⁸ Maulu, S. Hasimuna, O. et al. (2021): "Climate Change Effects on Aquaculture Production; Sustainability Implications, Mitigations and Adaptations" p.2-11

³⁹ Barange, M., Bahri, T., Beveridge, M. C. M., Cochrane, A. L., Funge-Smith, S., and Paulain, F. (2018): "Impacts of Climate Change on Fisheries and Aquaculture, Synthesis of Current Knowledge, Adaptation and Mitigation Options" Rome: FAO. chapter 20

climate-positive linkages, such feed supplements that reduce methane emissions when fed to cows, bio-plastics, and bio-char.⁴⁰ Researchers are also demonstrating the ability of seaweed aquaculture to mitigate the local effects of ocean acidification, one of the most significant impacts of climate change on ocean and coastal ecosystems. As seaweeds photosynthesize, they turn dissolved carbon dioxide (CO₂) in surrounding water into growth and oxygen.

The Mediterranean Sea is among the most vulnerable semi-enclosed seas to climate change. Multiple oceanic changes occur besides warming that can generate numerous ecological, social and economic risks, challenging fisheries management at various spatial scales – from local to international. Mediterranean aquatic systems that sustain fisheries and aquaculture are undergoing significant changes as a result of global warming and projections indicate that these changes will be accentuated in the future.

Surface warming, increasing heatwaves and a decrease in precipitation are very likely over the Mediterranean, with changes in circulation, sea level rise and winter weather regionally likely. The most frequently reported evidence of climate change impacts of relevance for Mediterranean fisheries are the observed and very likely progressive decrease in precipitation, water warming and salinity increase from surface to the deep water masses, increased intensity and frequency of heat extreme events (heatwaves) and changes in stratification.⁴¹

Fisheries in the Mediterranean sea are multi-specific and multi-fleet, with small pelagic species the most important in terms of landings and small-scale fisheries the dominant fleet. Current high rates of overfishing will affect their capacity to cope with climate change impacts. Changes in primary production and runoff will likely have a negative impact on the optimum habitats for small pelagic fish in the Mediterranean. Fisheries vulnerability to climate change is likely to be higher in southern countries given the higher exposure to warming and the arrival of non-indigenous species, as well as their overall lower socio-economic adaptive capacity.

SDG 14: Life Below Water

SDG 14 is about conserving and sustainably using the oceans, seas and marine resources. The current state of marine ecosystems in the area summarizes how far Mediterranean countries are to achieve true sustainable development. Indeed, while the area has a strong marine identity, shaped over centuries of trade, conflict, resources use, including fishing, tourism, energy etc; the current state of the Mediterranean sea jeopardizes the entire integrity of the area.

As a point of reference, marine ecosystems are major units of ecological function in the marine environment. Ecosystems are communities of organisms and their physical, chemical, and geological environment – distinct assemblages of species coevolved with a

⁴⁰ The Nature Conservancy (2022): "Aquaculture Critical for Feeding the World in a Changing Climate"

⁴¹ Adloff, F., Somot, S., Sevault, F., Jordà, G., Aznar, R., Déqué, M., Herrmann, M. et al. (2015): "Mediterranean Sea response to climate change in an ensemble of twenty first century scenarios" *Climate Dynamics*, 45: p. 2775–2802

particular environment over long periods of evolutionary history. It includes biotic (living) and abiotic (non-living) components. They do provide ecosystem services, which are the broad benefits provided by nature to society, including provision, regulation, support and cultural dimensions. Marine ecosystems provide a wide range of ecosystem services including provisioning services through the supply of seafood or energy; regulation services through coastal protection or carbon sequestration...

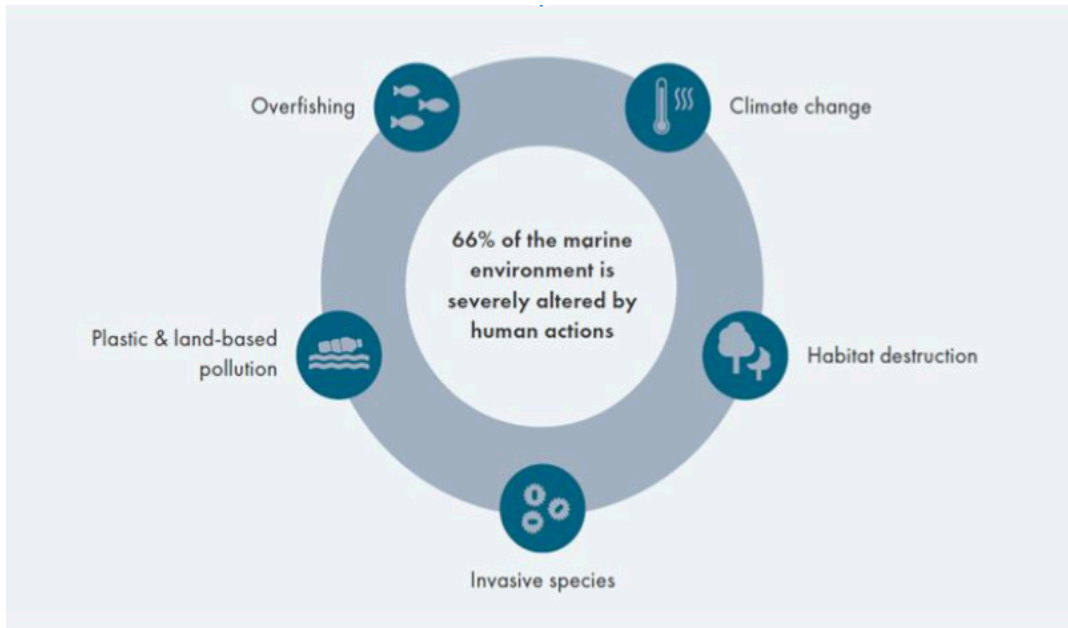
Figure II: Marine Ecosystem Services presentation



Source: "Ecosystem Services | Mapping Ocean Wealth"

The Ocean Impact Navigator, a coalition of stakeholders in the Blue Economy field including NGOs, startups, incubators and investors, framed ocean-born risks as follows:

Figure III: Pressures on marine ecosystems



Source: The Ocean Impact Navigator

As already mentioned, the Mediterranean is the most overfished sea in the world with a +60% overfishing rate. In 2018, the overall fishing mortality for all resources combined was estimated at nearly 2.5 times higher than sustainable reference points. It was especially true for commercially important stocks including hake or turbot.⁴² Not only does this trend jeopardize food security and livelihoods in most vulnerable areas, but it also constitutes a major threat to the ocean's biological equilibrium as a whole. Indeed, ecosystems being a compound of complexly entangled environmental parameters, the alteration of one of them results in a shift in the entire ecosystem, hence jeopardizing its equilibrium and ability to provide ecosystem services. One of the top negative impacts of overfishing on marine ecosystems is the shift it implies alongside the food chain, which exponentially flows down into many other biotic and abiotic related impacts.

In addition, the Illegal, Unregulated and Unreported (IUU) fishing spectrum also includes illegal fishing practices, beyond stock specific considerations. Habitat destructive fishing techniques, especially bottom trawling which consists in dragging seabeds with large nets, are still being undertaken in the area, especially in Fisheries Restricted Areas (FRAs), as suggested by the Global Fishing Watch. Indeed, while three areas were declared FRA in the Sicily Strait in 2017 to support the recovery of hake stocks, the NGO identified bottom-trawlers activity jeopardizing nursery grounds and hake stock recovery⁴³. Even though the General Fisheries Commission for the Mediterranean is making progress in unifying actions towards IUU.⁴⁴ These types of events can discard years of improvement in the fisheries management collaboration between states of the area.

As presented in the below graph from the SOED 2020 report, the Mediterranean sea is under a wide range of pollution pressures, jeopardizing water quality in the area. The most important pollution forms are obviously plastic littering, microplastic and watershed pollution. Through this phenomenon, the marine biodiversity of the area is at risk. Indeed, with more than 64 million floating microplastic particles per km² in the Mediterranean sea, fish health is jeopardized through oxidative stress, tissue damage and immune-related gene expression. This phenomenon, combined with overfishing and destruction of marine habitats, represents a threat to the ability of fish stocks to sustain overtime.

But presenting aquaculture as the turnkey solution to marine pollution would be very hypocritical. The sector has also been part of the problem, whether at Mediterranean or world scale for a long time⁴⁵. While it might not be as harmful as littering and resulting microplastic pollution, it can still be extremely polluting. Or at least one way to do it is harmful. Indeed, extensive aquaculture, or open or semi-open systems, represents a threat

⁴²*ibidem*, n.5

⁴³ Álvarez, H., Vulperhorst, V., Blanco, J., Fournier, N., Marin, P., Perry, A.L. and Coelho, V. (2021): "Transparency and compliance weaknesses in GFCM Fisheries Restricted Areas, How continuous IUU fishing inside the Strait of Sicily FRAs undermines fisheries sustainability and the credibility of the GFCM". Oceana, Madrid, p.6.

⁴⁴ FAO (2021): "Mediterranean and Black Sea countries unite to fight IUU fishing" General Fisheries Commission for the Mediterranean (GFCM)

⁴⁵ Tičina, V., Katavić, I., & Grubišić, L. (2020). Marine Aquaculture Impacts on Marine Biota in Oligotrophic Environments of the Mediterranean Sea – A Review. *Frontiers in Marine Science*, 7, 217. <https://doi.org/10.3389/fmars.2020.00217>

to marine biodiversity in certain conditions. The main issue related to aquaculture pollution is the problem of effluents, composed of solid and liquid organic and chemical wastes resulting from the growth process. They include non-digested feed, feces, antibiotics... Beyond that, the issue of invasive species or animal welfare should be considered, but they do not relate to pollution.

As a consequence, and based on the outstanding aquaculture potential displayed through this paper, the Mediterranean area should address the sustainability of aquaculture techniques problematic to take advantage of all the benefits it offers. Fortunately, the sector has been shifting fast, pushed by different elements including economic loss, civil society pressure and investors' awareness.

New practices are being adopted and they could definitely change the whole aquaculture game in the area. Effluents have been a main issue for farmers due to the fact they result in sedimentation, which has different impacts ranging from disease development to eutrophication, increasing mortality rates and jeopardizing fish survival. Consequently, different solutions were adopted, following the ERC sequence (Avoid, Reduce, Compensate). Avoiding effluents in aquaculture is obviously the first step. The best solution to avoid fish waste is to develop organic feed solutions with improved digestibility properties to reduce feces, hence deposits favoring sedimentation. Improved digestibility is reflected in the Fish Conversion Rate (FCR), an indicator measuring the quantity of feed required in kg to produce one kg of fish. New feed solutions have been spreading globally, featuring alternative feed sources like insects, algae and fish wastes with biotechnology expertise to isolate and match biological properties that will produce a feed balancing growth requirements and digestibility, both resulting in an improved FCR at farm level. This market, which was worth US\$5.24 Bn in 2021, is expected to display a 10.9% CAGR up to 2030 where it should top US\$131 Bn)⁴⁶. Europe is currently the biggest market, with stakeholders around the basin including Innovafeed, Ynsect and nextProtein in France, Ittinsect in Italy, Bioflytech and AlgaEnergy in Spain, Algatechnologies in Israel... Not only does it show an opportunity to shift the industry momentum through a sustained supply, but it also displays that the sector is already shifting gears since some of those companies have been established in the space for several years, with a track-record in revenue collection in the area.

Further down the ERC sequence, the aquaculture sector is also witnessing the development of technology based solutions to improve management at farm level. Those new solutions, displaying water monitoring hardware and related software, provide information on parameters like water quality, temperature, stock density, fish activity etc, supporting informed farm management decisions, including inputs, especially feed and antibiotics, management. While farmers use those devices mostly for economic reasons, the end-result is to reduce inputs in ponds, hence effluents.

Finally, the ERC sequence also includes a compensation component, which has also been explored in aquaculture through the past few years. Indeed, beyond their provision services, some culture types are recognized for their ability to deliver additional ecosystem services. Regarding their biological properties, seaweed and conch offer a wide range of benefits,

⁴⁶ PRNewsWire (2022): "Sustainable Feed & Nutrition for Aquaculture Market worth \$ 13.1 Billion by 2030 - Exclusive Report by InsightAce Analytic

among which water quality improvement through filtration. Algae farming has been developing extensively in the area over the past decades. Not only is marine pollution addressed through standalone seaweed farming facilities, but also through multi trophic aquaculture. Indeed, some actors in the area already mitigate for their own environmental impact resulting from fish-based aquaculture through a multitrophic approach drawing on some species' filtration capacities.⁴⁷

Pursuing current aquaculture practices in the area, especially in the Eastern Mediterranean, could represent additional threats to already fragile marine ecosystems. However, building on the current momentum in the industry through new feed solutions, aquatech and culture types, not only does the aquaculture sector have a way to address stock depletion and habitat destruction related to the fishing sector, but it can also address marine pollution at farm level and beyond.

⁴⁷Correia, D., Escarcega, B., Barreto, F., Mata, J., Del Rio, O., Viana, M., & Nishioka, A. (2019): "Growth performance and body composition of hybrid red tilapia (*Oreochromis mossambicus* O. aureus) fed with different protein levels raised in saltwater" *Latin American Journal of Aquatic Research*, 47(5), 853–859. <https://doi.org/10.3856/vol47-issue5-fulltext-15>

Conclusion

Regarding its transversality across economic, environmental and social thematic, aquaculture constitutes a leverage to substantially move forward the sustainable development agenda of the area (cf Annex I). Its capacity to address a diversity of major challenges of the 21st century, including food security, climate change or gender equity, makes it one of the top-trending sectors to look at in the Mediterranean. Yet, is there really such a thing as a Mediterranean area sustainable development agenda?

While this paper mentioned some initiatives developed at the Mediterranean scale, including Barcelona Convention for marine resources matters, the basin is divided into geographic areas with different economic, environmental or and issues, and consequently different SDG targets. For instance, while some countries experiencing a skyrocket growth of the sector, including Turkey⁴⁸ and Egypt, are more focused on SDGs 1, 2 or 8, EU countries are restricted by different national and EU level regulation layers⁴⁹ aiming for the achievement of SDG 14. Even if most European countries are more than happy to be supplied fresh Eastern Mediterranean sea bass or trout for the moment, the differences of position on some sensitive issues such as environmental impact, sanitary management or working conditions, might present barriers to the development of a Mediterranean aquaculture sector. While a country like Egypt is constrained to feed a booming population in a context of natural resources scarcity, it obviously does not have the same streamlined and consistent level of commitment towards long-termist considerations as sustainability of practices, which are on the contrary the top concern of EU countries.

In such an interconnected area as the Mediterranean basin, countries moving at a different pace towards different purposes will for sure represent major challenges in the coming years. As a consequence, unlocking the potential of aquaculture to create sustainable development synergies around the basin will require to include all stakeholders in the area in a multi-pronged coordinated sector development plan.

As a tool to achieve SDGs, aquaculture can bring new economic development to Mediterranean coastal communities and strengthen food security at local and global levels. Aquaculture can be the path forward to increase global food production and trade opportunities in changing times and a changing climate.

⁴⁸ OECD. (2022): "OECD Review of Fisheries 2022" OECD. <https://doi.org/10.1787/9c3ad238-en>

⁴⁹ European Commission (2023): "Aquaculture Policy, Ocean and Fisheries"

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Annex

Annex I: The ASC label and SDGs

ASC has a strong and demonstrable contribution to the following SDGs:



The ASC programme also aligns strongly with targets related to:



Globally, ASC addresses targets within all 17 SDGs