STUDY

Requested by the PECH Committee

European Parliament

Workshop on the European Green Deal – Challenges and opportunities for EU fisheries and aquaculture

Part III: Food security aspects

Fisheries

Policy Department for Structural and Cohesion Policies
Directorate-General for Internal Policies
PE 752.437 - October 2023

EN

RESEARCH FOR PECH COMMITTEE

Workshop on the European Green Deal – Challenges and opportunities for EU fisheries and aquaculture

Part III: Food security aspects

Abstract

This study is the third in a series of three research papers, prepared for a PECH Committee Workshop. It explores how initiatives within the European Green Deal may impact food security in fisheries and aquaculture. The Farm to Fork Strategy's aim of sustainable food production indicates prioritising low-trophic species like bivalves and algae. 'Fit for 55' requires greater fuel efficiency and a transition to clean energy by the fishing fleet. A net positive long-term impact on food security is expected from sustainable production. As two thirds of the EU's seafood consumption is imported, such ambitions should be extended to non-EU country producers.

This document was requested by the European Parliament's Committee on Fisheries.

AUTHORS

Poseidon: Rod CAPPELL and Tim HUNTINGTON

Research administrator: Marcus BREUER
Project, publication and communication assistance: Ginka TSONEVA, Kinga OSTAŃSKA, Stéphanie DUPONT, Anton KÜCH (Trainee)
Policy Department for Structural and Cohesion Policies, European Parliament

LINGUISTIC VERSIONS

Original: EN

ABOUT THE PUBLISHER

To contact the Policy Department or to subscribe to updates on our work for the PECH Committee please write to: Poldep-cohesion@ep.europa.eu

Manuscript completed in September 2023

This document is available on the internet in summary with option to download the full text at: https://bit.ly/48QNfzF

This document is available on the internet at:
http://www.europarl.europa.eu/thinktank/en/document.html?reference=IPOL_STU(2023)752437

Further information on research for PECH by the Policy Department is available at:
https://research4committees.blog/pech/
Follow us on Twitter: @PolicyPECH

Please use the following reference to cite this study:
Cappell, R., & T. Huntington (2023), Research for PECH Committee – Workshop on the European Green Deal – Challenges and opportunities for EU fisheries and aquaculture – Part III: Food security aspects, European Parliament, Policy Department for Structural and Cohesion Policies, Brussels
Please use the following reference for in-text citations:
Cappell & Huntington (2023)

DISCLAIMER

CONTENTS

LIST OF ABBREVIATIONS

AAC	Aquaculture Advisory Council
AAM	Aquaculture Assistance Mechanism
AECID	Agencia Española de Cooperación Internacional para el Desarrollo *Spanish Agency for International Development Cooperation*
BSFLM	black soldier fly pre-pupae meal
CAP	Common Agricultural Policy
CFP	Common Fisheries Policy
CMO	common market organisation
DAI	Development Alternative Incorporated
EAA	ecosystem approach to aquaculture
EATiP	European Aquaculture Technology and Innovation Platform
EDG	European Green Deal
EEZ	Exclusive Economic Zone
EMFAF	European Maritime Fisheries and Aquaculture Fund (2021-2027)
ETP	Energy Transition Partnership
EUMOFA	European Union Market Observatory for Fisheries and Aquaculture
GDP	gross domestic product
FAO	Food and Agriculture Organization of the United Nations
GHG	greenhouse gas
FAP	fishery and aquaculture product
GWP	global warming potential
IMTA	integrated multi-trophic aquaculture
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IUU	Illegal, Unreported and Unregulated Fishing
LCA	life cycle analysis
LWE	life weight equivalent
MNAP	Multi-annual National Strategic Plans for Aquaculture
MPA	marine protected area
MSP	maritime spatial planning
PEF	product environmental footprint
OMC	Open Method of Coordination
RAS	recirculating aquaculture systems
RFMO	Regional Fishery Management Organisation
SFPA	Sustainable Fisheries Partnership Agreement
SRIA	Strategic Research and Innovation Agenda'
STECF	Scientific, Technical and Economic Committee for Fisheries

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Overview of the main EGD policy initiatives as regards food security

The **European Green Deal** (EGD) is the EU's overarching environmental strategy to address climate change and environmental degradation. It consists of several policy initiatives that have the potential to impact EU food security, including from fisheries and aquaculture.

A **lack of action on climate** change has direct, severe consequences for fisheries and aquaculture with a decrease in global catches predicted, particularly impacting populations that already face food insecurity. This also impacts aquaculture as 2/3 of production is dependent on food from wild fisheries, while ocean acidification and rising temperature increase risks of disease.

Farm to Fork, the EU's food production strategy, has the most direct implications for food security. Blue Farming promotes the expansion of shellfish and algae production in the EU.

Other EDG policy initiatives such as the **Fit for 55 package** and the **EU Biodiversity Strategy for 2030** are expected to impact the significant EU fisheries and aquaculture production that is fuel intensive and damaging to benthic habitats.

EU dependence on seafood imports

In 2020, the **EU produced 5 million tonnes** of fisheries (3.9 million tonnes) and aquaculture (1.1 million tonnes) products, which represents 2% of global production. It is the seventh largest global seafood producer (seventh for capture fisheries and 11th for aquaculture). However, not all EU fleet landings are into the EU and not all production is for direct human consumption. The 2020 production of fisheries and aquaculture products for human consumption totals just over 4 million tonnes. In 2020, people living in the **EU consumed more than twice as much** as they produced. Three quarters came from wild capture fisheries and a quarter from aquaculture.

Growth in EU seafood consumption is supplied by an increase in **extra-EU imports** (whitefish, tuna, salmon and shrimp), which are often then subject to intra-EU exchanges. More of the lower-value species like herring and mackerel are exported.

China and other **Asian countries** remain important **reprocessing centres** for seafood destined for the EU, but this has declined following the COVID-19 pandemic with increasing) logistics and labour costs. **EU companies are developing shorter supply chains** with more added value processing closer to landing and aquaculture production centres.

The characteristics of **sustainable fisheries** models are well-understood (effective, adaptive management informed by sound science), **but must be applied more broadly** to all EU production and to its imports.

The EU's **Sustainable Fishery Partnership Agreements** (SFPAs) with non-EU countries contribute significantly to EU production. Rather than seeking to avoid negative impacts on the food security of non-EU countries, SFPAs have the potential to make a positive contribution.

EU aquaculture production

In 2020, EU aquaculture **production** was **1.1 million tonnes**, a decline on the previous year's total mainly due to the UK's exit from the EU as well as COVID-19 disruption. 2020 also saw the **EU import 2.1 million tonnes** of aquaculture products and export **0.3 million tonnes**, resulting in apparent **consumption of 2.9 million tonnes** (EUMOFA, 2022). Almost half of EU aquaculture production volume consists of bivalves and other molluscs and aquatic invertebrates, mainly thanks to the production of mussel in Spain and oyster in France.

The European Commission recently adopted new "***Strategic guidelines*** *for a more sustainable and competitive EU aquaculture for the period 2021 to 2030*". These Strategic guidelines align with the development objectives set out in the European Green Deal. The potential of EU aquaculture to support and diversify seafood production is also highlighted by the Farm to Fork Strategy. The Strategic guidelines have **several approaches**, including the following:

- building resilience and competitiveness;
- participating in the green transition;
- ensuring social acceptance and consumer information; and
- increasing knowledge and innovation.

Best practices for resilient, green and innovative sustainable aquaculture include the increased use of the following elements:

- **low or multi-trophic aquaculture** to reduce the global warming potential (GWP) and potentially sequester carbon,
- develop **innovative techniques to diversify aquaculture,** including more controllable production systems and the use of circular feed materials, and
- formally embracing the **ecosystem approach to aquaculture (EAA)**.

The EU Farm to Fork Strategy: best practices and lesson learned

The Farm2Fork (F2F) Strategy is more focused on land-based production systems but does recognise the need for an accelerated shift to **sustainable fish and seafood** production. The CFP, Open Method of Coordination (for aquaculture) and EMFAF funding will be key resources.

The F2F Strategy has a great deal of synergy in current thinking in both **mitigating and adapting to climate change** in fisheries and aquaculture, and the overall progression towards carbon zero. Given the impact of high energy prices on profitability, this is a commercial as well as an environmental necessity.

A focus on **low-trophic aquaculture** is key and this needs to be supported by market development and consumer behavioural change. Higher trophic level aquaculture (e.g., most finfish farming) needs to undergo change to reduce its energy use across the life cycle (especially in aquafeed production and distribution). Better **animal welfare** and a greater move to **organic farming** will support this process.

Policy recommendations

Food security is fundamentally compromised if the supply of that food is not from **sustainable production**. This principle should **apply to all fisheries and aquaculture** products, irrespective of source, i.e., EU fisheries production (EU stocks, shared stocks – with Norway, the UK, etc. – and those targeted by EU fleets under SFPAs), aquaculture and imports. Based on the analysis and the knowledge collated in this study, the following policy recommendations are presented:

(1) **Improving food security from sustainable EU fisheries production**:

a) Sustainable **stocks** targeted by EU fleets through:

- effective **management** and enforcement, based on **sound science** that is funded sufficiently;
- bringing the **Control** Regulation up to date and tackling **IUU** fishing everywhere;
- **SFPAs** that make a positive contribution to food security in non-EU countries;
- recognising the **social and cultural importance** of fishing to value future generations of fishers.

b) Reducing the **emissions** from fishing vessels through:

- lowering energy use via **fuel efficiency** measures (funding gear and vessel modifications, removing regulatory barriers, incentivising moves to lower impact gears);
- switching to **clean** fuels (that can be used with existing engines) and **renewable** energy sources (such as batteries and hydrogen) by supporting R&D, **knowledge transfer** from other sectors and **infrastructure** requirements).

c) Addressing the **environmental** impacts of fisheries production:

- reducing benthic impact on sensitive habitats with **effective marine protected areas (MPAs)**;
- reducing **bycatch** of unwanted catch (juveniles and vulnerable species).

(2) **Improving food security from EU aquaculture production**:

- DG MARE and others (e.g., DG ENV and the Aquaculture Advisory Council, AAC) conduct a formal review of the **ecosystem approach to aquaculture** and how EU policy and member state guidance might be updated to reflect lessons learned;
- developing bivalves and other edible **low-trophic species in deeper water**, more **offshore** locations and at a larger scale; the **use of maritime spatial planning (MSP)** in allocating space to such aquaculture;
- encouraging **consumers** to increase the contribution of these lower-trophic alternatives as part of a **balanced diet** through a range of approaches; product development and consumer information provision;
- encouraging the **provision of ecosystem services** from aquaculture can be used at bay or sea basin levels, e.g., **carbon** sequestration or **nutrient** assimilation, both though private sector as well as public-private partnerships for larger-scale projects;
- innovative thinking in terms of pen design, stock containment and associated permitting to add controllability to **open water pen farming**, this should be supported by a more forward-thinking approaches in MSP that encourage planners to allocate specific areas to

aquaculture without compromising their environmental integrity or conflicting with other sea usage;

- using **audits** of energy and other ecological resources **across aquaculture value chains** as a guide for management decisions;
- reviewing and improving **certification standards** and industry management codes and guidance documents to ensure that they reflect ecologically efficient approaches to farm management and value chains, and thus encourage the sector to **contribute to climate change mitigation**.

(3) **Improving food security of imported seafood:**

- Supporting international producers in sustainable seafood production by **improving regional fisheries management**, supporting marine resource **management in non-EU countries** and **knowledge-sharing** on sustainable aquaculture production;
- ensuring a **level playing field** for EU producers, encouraging improved performance and maintaining competitiveness by ensuring imported seafood meets defined environmental standards;
- revised **marketing standards** to cover more imports and include environmental criteria;
- improved **traceability systems** to minimise seafood fraud;
- clear consumer **labelling** and awareness-raising.

(4) **Improving food security in the seafood supply chain:**

- Improving the **efficiency** of supply chains with shorter supply chains; better **cold chains** and increased value added at point of **landing**;
- product **innovation** to create attractive, convenient products from low-carbon sources and by-products;
- promoting consumption of **low-carbon seafood** choices (small pelagics and low-trophic culture: bivalves and algae) with **improved information** on product nutrition and environmental impact.

1. OVERVIEW OF THE MAIN EGD POLICY INITIATIVES AS REGARDS FOOD SECURITY

KEY FINDINGS

- The **European Green Deal** (EGD) is the EU's overarching environmental strategy to address climate change and environmental degradation. It consists of several policy initiatives that have the potential to impact EU food security, including from fisheries and aquaculture.
- Not acting on climate change has severe **consequences for fisheries and aquaculture**. The predicted decrease in global catches is much greater with higher emissions scenarios, particularly impacting populations that already face food insecurity.
- A **decrease in global catch** also **impacts aquaculture** as 2/3 of production is currently dependent on food from wild fisheries, while ocean acidification and rising temperature create more problems, including increased risk of disease.
- **Farm to Fork**, the EU's food production strategy, has the most direct implications for food security. Blue Farming promotes the expansion of shellfish and algae production in the EU.
- Other EDG policy initiatives such as the **'Fit for 55' package** and the **EU Biodiversity Strategy for 2030** are expected to impact the significant EU fisheries and aquaculture production that is fuel intensive and damaging to benthic habitats.

1.1. European Green Deal

This report explores the challenges and opportunities for fisheries and aquaculture in implementing the European Green Deal, the EU's overarching environmental strategy to tackle climate change and environmental degradation resulting from human activity. However, it is also worth noting the severe consequences for fisheries and aquaculture of not taking action.

The Intergovernmental Panel on Climate Change (IPCC) reports that **climate change** will result in a redistribution of stocks and a **loss of fisheries catch potential**[1]. This will affect many populations in low-latitude regions, such as in the Pacific Islands and West Africa that are already facing food insecurity challenges (IPCC, 2019). Overall, the combined impacts of climate change on coral reefs and fish stocks are expected to affect small-scale coastal fisheries the most, with catches decreasing by up to 20% by 2050, and by up to 50% by 2100, under the high emission scenario.

Aquaculture will also be affected, as two thirds of the food for farmed fish originates from wild catches, while ocean acidification and increasing temperatures also threaten marine aquaculture directly, leading to heterogeneous patterns of gains and losses, but an overall greater probability of declines worldwide (Froehlich et al., 2018; Huntington, 2022).

[1] Models predict a decrease in catch potential in the low-emission scenario of up to 6.4% by the end of the century, while the expected loss in the high-emission scenario would be up to almost a quarter, with even a decrease of more than 50% in some regions by 2100. Tropical oceans will be most negatively impacted, with a three-fold or greater decrease in catch potential compared with the global average, in particular in the western central Pacific Ocean, eastern central Atlantic Ocean and the western Indian Ocean.

Perhaps the most comprehensive synthesis of current knowledge, adaptation and mitigation options of climate change on fisheries and aquaculture is from FAO (Barange et al., 2018). This notes both the impacts from short-term climate change impacts causing large-scale loss of production from extreme events such as floods, increased risks of diseases, parasites and harmful algal blooms. Long-term impacts can include reduced precipitation leading to increasing competition for freshwater. An increase in fishing productivity, on the other hand, would be limited to the Poles, in particular the Arctic Ocean, and some other locations (IPCC, 2019).

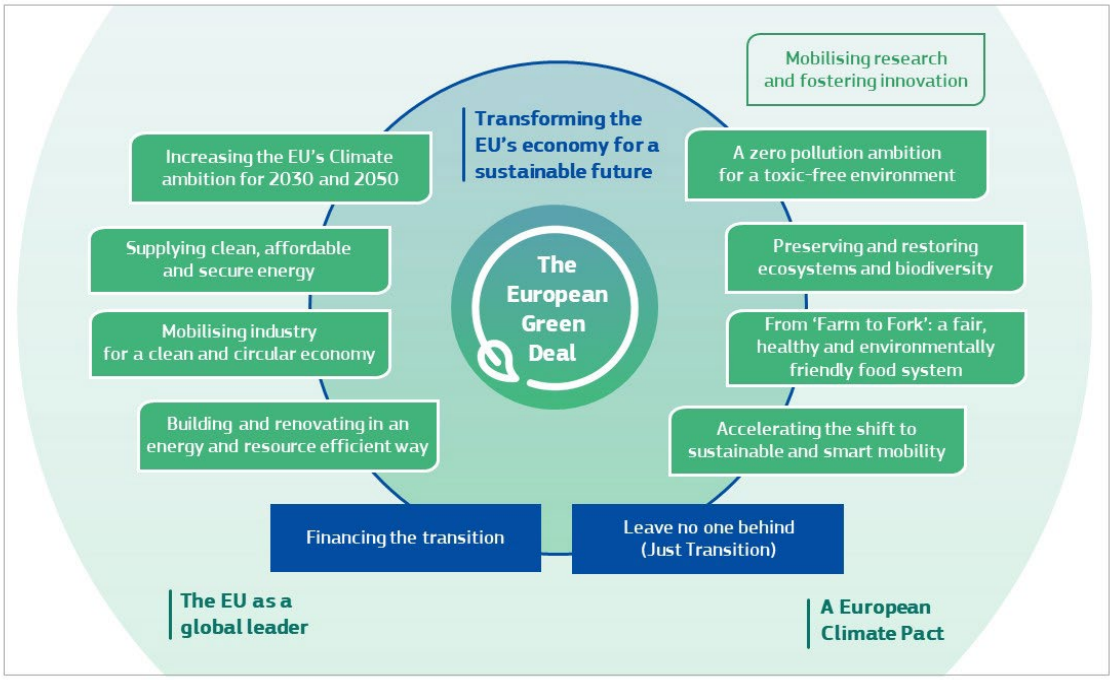
The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Global Assessment on biodiversity and ecosystem services (2019)[2] reports that "*in marine ecosystems, direct exploitation of organisms (mainly fishing) has had the largest relative impact, followed by land-/ sea-use change [...] including coastal development for infrastructure and aquaculture*". The report suggests that sustaining and conserving fisheries and marine species and ecosystems can be achieved through a coordinated mix of interventions on land, in freshwater and in the oceans (IPBES, 2019).

The EGD is the EU's coordinated framework of interventions, setting out how it intends to address the many challenges facing the planet, including climate change and biodiversity loss. In December 2022, the Commission President also cited the EGD in confirming the EU's support for the Kunming-Montreal Biodiversity Agreement, which sets binding targets for 2030 and 2050[3].

The EGD aims to **transform the EU** into a fair and prosperous **society**, with a modern, resource-efficient and competitive **economy** where there are no net emissions of greenhouse gases in 2050 and where economic **growth** is decoupled from **resource use**. It also aims to protect, conserve and enhance the EU's **natural capital**, and protect the health and well-being of citizens from **environment-related risks** and impacts (European Commission, 2019). The multiple elements of the EGD are set out in **Figure 1**.

[2] https://www.ipbes.net/sites/default/files/inline/files/ipbes_global_assessment_report_summary_for_policymakers.pdf
[3] https://ec.europa.eu/commission/presscorner/detail/en/statement_22_7827

Figure 1: Elements of the European Green Deal



Source: European Commission, 2019

The implications of the EGD policy initiatives for food security are summarised in **Table 1** overleaf. Farm to Fork, the EU's food production strategy, has the most direct implications for food security, but other policy initiatives may also be expected to have implications for food security in the fisheries and aquaculture sectors, as indicated by the shading in the table (darker green = greater implications).

These policies are discussed in more detail below, along with recent communications from the Commission on how the fisheries and aquaculture sector can align with EU Green Deal policies.

Table 1: Linkages between EGD policy initiatives and food security in fisheries and aquaculture

	EGD policy	Implications for seafood security
1	**EU's climate ambition for 2030 and 2050** Numerous initiatives as set out in 'Fit for 55', to deliver at least 55% cut in carbon emissions by 2030.	These objectives are in line with COM(2023) 100 on energy transition in fisheries and aquaculture and will be informed by ongoing research on energy transition in the sector. This will explore the impact of innovations on the carbon footprint of seafood production. Without decarbonisation, the need to reduce emissions has the potential to reduce EU fisheries and aquaculture production.
2	**Supplying clean affordable and secure energy** Decarbonising the energy system with renewable energy; further development of offshore wind.	Offshore wind developments can displace commercial fishing vessels from traditional fishing grounds. New areas may be less productive or further from home ports, resulting in increased costs and trade-offs. The expansion of the renewables sector has also heightened the demand for fishing vessels to provide guard or survey duties. The growth in new maritime industries like renewable energy can exacerbate the labour shortages in the fisheries sector.
3	**Mobilising industry for a clean and circular economy** Decarbonisation of industries and increasing recycling and circularity through an EU industrial strategy. Further development of the 2018 Plastics Strategy. Access to sustainable raw materials (especially for clean technologies, digital, space and defence).	The move towards decarbonisation is described above under point 1 and 'Fit for 55'. Fishing and Aquaculture gear containing plastic is included in the Single Use Plastics Directive requiring Extended Producer Responsibility schemes for gear by the end of 2024. There is not intended to be an impact upon food production, but some producers cite such demands as an additional pressure on business viability.
4	**Buildings are energy and resource efficient.** A 'renovation wave' of public and private buildings.	No direct implications were identified for fisheries and aquaculture.
5	**Zero pollution for a toxic-free environment** Zero pollution action plan for air, soil and water. Restore natural functions of ground and surface water. Protect citizens and the environment from hazardous chemicals.	Overall, this could be viewed as having positive implications for EU seafood production as long as imports are required to meet the same standards. One potential implication is in finfish culture where chemicals and pharmaceuticals are used. If less polluting alternatives have a lower efficacy, increased mortality or reduced growth rates could impact yield.
6	**Preserving and restoring ecosystems and biodiversity**	Mixed implications of increased MPA coverage for EU seafood production: Positive: resource spill over effects for fisheries and tackling IUU fishing.

	EGD policy	Implications for seafood security
	Set out in an EU Biodiversity Strategy for 2030. Increasing the coverage of Marine Protected Areas (MPAs). Zero tolerance approach to Illegal, Unreported and Unregulated (IUU) fishing.	Negative: reduced production levels if fishing vessels are excluded from areas with productive fishing grounds and the space available to aquaculture is constrained or consenting are affected. Resulting in more imports.
7	**From 'Farm to Fork': a fair, healthy and environmentally friendly food system.** European food should become the global standard for sustainability with a significant proportion of EU CAP and CFP funding to contribute to this goal. Develop the potential of sustainable seafood as a source of low-carbon food.	This has the most direct implications for EU seafood security. Positive implications for seafood as live cycle analysis (LCA) studies show many seafood species (representing the bulk of production by weight) to be relatively low-carbon foods, particularly in relation to other animal proteins. Blue Farming within the new Strategic guidelines for aquaculture (COM(2021) 236) actively promote the expansion of shellfish and algae production in the EU. Implications for some imports if the same production standards for EU production are required via marketing standards, which may make it difficult to supply the EU market.
8	**Accelerating shift to sustainable, smart mobility** Contribution to climate neutrality by road, rail, aviation and water transport. Shifting road freight onto rail, waterways and support short-sea shipping.	For the movement of goods, this initiative encourages the decarbonisation and shortening of supply chains (e.g., doing more at the point of landing), which reduces carbon emissions. If a move away from reprocessing products in Asia this may be positive for the EU import/export balance. Avoiding air freight may also show a shift towards frozen over fresh or live seafood. Increased processing at point of landing is positive for employment in coastal communities, making local production more robust.

Source: Author's own elaboration

1.2. Farm to Fork Strategy

The **Farm to Fork Strategy** has the most direct implications for EU seafood in relation to food security, as it seeks to address the challenges of **sustainable food systems**. It recognises the inextricable links between healthy people, healthy societies and a healthy planet. The Farm to Fork Strategy sets out both **regulatory and non-regulatory initiatives**, with the common agricultural and fisheries policies as key tools to support a just transition to a sustainable food system that should[4]:

- have a neutral or positive **environmental** impact;
- help to mitigate **climate change** and adapt to its impacts;
- reverse the loss of **biodiversity**;
- ensure **food security**, **nutrition** and **public health**, making sure that everyone has access to sufficient, safe, nutritious, sustainable food;
- preserve the **affordability of food** while generating fairer **economic returns**, fostering **the competitiveness** of the EU supply sector and promoting **fair trade**.

Figure 2: Elements of the Farm to Fork Strategy

Source: https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en

[4] https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en

The Farm to Fork Strategy is more focused on land-based production systems, but does recognise the need for an accelerated shift to sustainable fish and seafood production. The **Annex** presents a review of how ensuring sustainable food production and the other elements of the Farm to Fork Strategy can be applied to the fisheries and aquaculture sectors.

The varied impacts of the COVID-19 pandemic have underlined the importance of a robust and resilient food system that functions in all circumstances and is capable of ensuring access to a sufficient supply of affordable food for citizens (Nielsen et al., 2023). It has also made us acutely aware of the interrelations between our health, ecosystems, supply chains, consumption patterns and planetary boundaries (Carpenter et al., 2023; Love et al., 2021). The increasing recurrence of droughts, floods, forest fires and new pests are a constant reminder that our food system is under threat and must become more sustainable and resilient (European Commission, 2020).

The EU's goals are to reduce the environmental and **climate footprint** of the EU food system and strengthen its resilience, **ensure food security** in the face of climate change and biodiversity loss and **lead a global transition** towards competitive sustainability from Farm to Fork and tapping into new opportunities.

The Farm2Fork Strategy has a great deal of synergy in current thinking in both mitigating and adapting to climate change in fisheries and aquaculture, and the overall progression towards carbon zero. Given the impact of high energy prices on profitability, this is a commercial as well as an environmental necessity.

For aquaculture, a focus on low-trophic aquaculture is key and needs to be supported by associated market development and consumer behavioural change. Higher trophic level aquaculture (e.g., most finfish farming) needs to undergo change to reduce its energy use across the life cycle (e.g., esp. in aquafeed production and distribution). Better animal welfare and a greater move to organic farming will support this process.

For fisheries, sustainable food production relates to the sustainable harvesting of the wild resource without damaging the marine environment. Food supply from fisheries must tackle many other F2F elements: food security, processing, trade, fraud and waste and consumption are highly relevant to wild fisheries production.

1.3. Fit for 55 package

The 'Fit for 55' package includes a set of proposals to update EU regulation to achieve at least a **55% cut in net greenhouse gas emissions by 2030**[5]**.** Binding annual greenhouse gas emissions targets for EU Member States, increase the reduction target for 2030 **from 29% to 40%**, compared with 2005. As a result, Member States are looking to many sectors to contribute to emission reduction, including fisheries and aquaculture. Fit for 55 also includes a revised Energy Taxation Directive, which will make cleaner fuels more attractive in all transport modes and close loopholes for polluting fuels (COM(2021) 550)[6]. The Commission's 2021 proposal puts forward minimum rates of taxation that **encourage a switch to more sustainable fuels**. It also encourages more efficient and less polluting aircraft and vessels in the EU's aviation and waterborne sectors. In practice, the new rules lay down a **minimum excise duty rate** on the relevant fuels used for intra-EU passenger flights, as well as intra-EU ferry, **fishing** and freight vessels.[7]

[5] https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/
[6] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0550
[7] https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3662

A special report on **Ocean-based solutions** to climate change summarises the potentially positive contribution that the stimulation of sustainability in fisheries and aquaculture production can make through reducing emissions in fisheries, replacing feed in aquaculture, and by increasing the share of ocean-based protein in human diets, as it is far less carbon-intensive than land-based proteins (Hoegh-Guldberg et al., 2019; Willett et al., 2019).

Energy is one of the major cost items in the EU fisheries and aquaculture sector. At present, most **fishing vessels rely on marine diesel** for their operations, although smaller vessels may use petrol. In total, the EU fleet consumed over 1.9 billion litres of marine diesel in 2020 to catch and land 4.05 million tonnes of fish valued at EUR 6.3 billion at the first sale. This fuel consumption led to direct emissions of approximately **5.2 million tonnes of CO_2**. Since 2009, the EU fishing fleet has reduced its fuel consumption per kg of landed fish by over 15%, but these reductions have stagnated in recent years[8] and now stand at around 0.5 litres of fuel per kg of landings (STECF, 2022).

The hike in energy prices resulted in marine diesel prices more than doubling in 2022 compared to average prices in 2021. This in turn led to **surging operational costs for the fishing fleet**, with energy costs increasing from 13% of revenues in 2020 to an estimated 35% in 2022[9] (COM(2023) 100)[10]. In 2022, a part of the EU fishing fleet was unable to cover operational costs at current fuel prices, forcing some fishers to dock their vessel or rely on support measures to keep operating. The performance of the EU fishing fleet moderately (in 2021) and heavily (in 2022) deteriorated, specially driven by the increase in fuel prices (STECF, 2022). This situation has developed despite the continued subsidies provided to the EU fleet, including duty-free fuel. The 2022 WTO Agreement on Fisheries Subsidies is supported by the EU, but this does not include marine fuel subsidies as they are not specific to fisheries[11].

For aquaculture, the share of costs for **energy consumption differs widely** depending on both the type of species farmed and the production technique used. For example, energy costs in EU mussel aquaculture range from 3% of total costs in operations using mussel rafts, to 14% of total costs in operations using mussel longlines. In EU rainbow trout aquaculture, which represents over half of EU freshwater farming production, costs range from an almost negligible percentage in operations using trout cages, to 8% of total costs in raceways and trout tanks (STECF, 2020).

The Commission, in partnership with all stakeholders, aims to step up collective efforts on the energy transition with a more comprehensive and coordinated approach (COM(2023) 100). EU fisheries are encouraged to continue the positive trend, as observed for the period 2009-2019, towards **reducing fuel intensity** by reducing the fossil-fuel consumption per kg of landed product for at least an additional 15% for the period 2019-2030. EU aquaculture is also encouraged to reduce fossil-fuel consumption and non-renewable sources of energy (COM(2023) 100).

Broadly, two mutually reinforcing strands of actions can be pursued to reduce the energy intensity and carbon footprint of fisheries and aquaculture: a. **lower the energy needs** per kilogram of landed or farmed fish and, b. **switch to clean and renewable energy sources**.

Technologies to reduce energy consumption in the fisheries sector are already available: modifications to the vessel (e.g., fitting engines that are more efficient, nozzles and larger propellers); fishing gear

[8] Data collected under the EU Data Collection Framework indicates that EU fisheries reduced their fuel intensity (i.e. fuel consumption per tonne of landings) by more than 15% between 2009 and 2014, but this trend has stagnated since then.

[9] In a number of segments of the EU fleet, particularly those using energy-intensive fishing methods, fuel costs represented more than half of the value of landings in 2022.

[10] COM(2023) 100 On the Energy Transition of the EU Fisheries and Aquaculture sector.

[11] The WTO Agreement on Fisheries Subsidies is further explained in this briefing note: https://ec.europa.eu/commission/presscorner/detail/en/statement_22_7827

(lighter and more efficient gear) and fishing patterns (optimising quota use across the fleet) could be pursued to reduce the energy intensity of fisheries. Waterborne zero-emission fuel and powertrain technologies are commercially available and a limited number already in use in the fishing sector[12]. These fuels and energy sources include electricity, ammonia, renewable hydrogen, sustainable biogas, synthetic fuels, and sustainable biofuels[13] (including drop-in fuels such as algae biofuels, that can used in existing engines) and other innovative renewable and low-carbon energy sources.

Fishing and aquaculture are in most settings a relatively small market for alternative technology providers[14]. These sectors may not themselves drive innovation in some technologies, but they do have specific operational needs. There is a need to learn from innovations in other sectors and effective cooperation is needed to link seafood producers and supply chain operators with those researchers, technology providers and operators in other sectors to ensure synergies and knowledge-sharing.

However, there are barriers to the uptake of technologies and strategies by the fisheries and aquaculture sector. Limited knowledge transfer on the technologies, financial barriers to innovation uptake, and lack of trust towards innovation in current fisheries and aquaculture practices (Bastardie et al., 2022 a). Overhauling and upgrading engines is the most significant single modification suggested by operators to improve fuel efficiency. Engines are a major capital investment, but the fitting and associated connections are also a **significant cost of engine replacement**. In practice, operators are faced with the choice of sourcing a different engine (with the additional costs and difficulty of replacing pipes and electrics) or buying a new/refurbished engine of the same model (to minimise fitting costs, less likely to result in major reductions in fuel use which is proving more challenging as older engine models become hard to find). Skippers with experience in several engine manufacturers recognised there is a trade-off between operational efficiency and maintenance costs, with some suggesting that some of the more fuel-efficient engines need more frequent and costly overhauls (Cappell et al., 2022).

Small-scale fishing vessels and aquaculture-service vessels could be electrified and supported by solar panels or other renewable or low-carbon main or auxiliary power sources[15]. Where possible, existing engines can be modified, while in some segments the acquisition of new low-carbon-emission (hybrid) engines and vessels could be the solution. However, many in the EU catching sector are faced with a quandary: the lack of profitability in current operations caused by high fuel use limits the ability to invest in new technologies that would reduce that fuel use.

There are also **regulatory factors** that hinder fuel efficiency. For example, regulations based on vessel length has resulted in vessels that are less hydrodynamic vessels as operators seek to maximise capacity within a particular length category. Conservation measures can also result in a trade-off with fuel efficiency: increased selectivity to avoid bycatch of marketable species means a higher carbon footprint per kg landed.

Regulatory and management measures should be reviewed to identify where fuel efficiency can be incentivised, and **barriers removed**. This should be part of the work Energy Transition Partnership (ETP) knowledge-sharing platform that is to be established by the Commission.

[12] Examples of hybrid and full-electric fishing vessels are provided in this article: https://www.globalseafood.org/advocate/net-zero-heroes-hybrid-and-electric-commercial-fishing-vessels-set-out-to-cut-the-industrys-carbon-emissions/.

[13] While preventing the adverse effects of pressure from biofuel demand on global food security due to indirect land use change and competition between crops produced for food and biofuels, in line with the framework laid down under Directive (EU) 2018/2001.

[14] The Global Maritime Forum's global mapping of zero-emission pilots and demonstration projects does not list any related to fishing and aquaculture: https://www.globalseafood.org/advocate/net-zero-heroes-hybrid-and-electric-commercial-fishing-vessels-set-out-to-cut-the-industrys-carbon-emissions/ .

[15] E.g. for hauling, navigation, fish-finding equipment, the galley, and cabin power.

Substantial funding is required to support the sector in improving fuel efficiency in the first instance and ultimately to decarbonise the sector. Structural funding should also extend to **support the infrastructure** required to enable fishing fleets to take up alternative fuels. The recent communication on Energy Transition in Fisheries and Aquaculture claims that the EMFAF can already support investments for this energy transition (COM(2023) 100). The eligibility conditions (including fleet capacity imbalance) should be reviewed to ensure they do not prevent investments by the fleet segments that are most in need of fuel efficiency improvements. Other potential measures to encourage energy efficient fisheries include:

- **Preferential quota allocation** towards more fuel-efficient gears and vessels.
- International harmonisation of **fuel taxes**.
- **Fuel-monitoring** tools on board vessels.

1.4. EU Biodiversity Strategy for 2030

At the current pace of climate change impacts, fish stocks have little time to adapt; the result is geographical shifts and **loss of ocean biodiversity**. In May 2020, the Commission published its communication on a new EU Biodiversity Strategy, another important element of the Green Deal. The proposed strategy includes the objective of **designating at least 30% of EU seas** as protected areas, of which **at least a third under stricter protection**. This represents an ambitious target for EU waters as compared to the current situation (Scholaert, F. 2021). The strategy contains specific commitments and actions to be delivered by 2030:

- **Establishing a larger EU-wide network of protected areas on land and at sea**: at least 30% and 1/3 of this under stricter protection.
- **Launching an EU nature restoration plan**: to restore degraded systems, particularly those that can capture and store carbon [such as seagrass, saltmarsh and biogenic reefs].
- **Introducing measures to enable the necessary transformative change**: for improved implementation, monitoring, financing and decision-making.
- **Introducing measures to tackle the global biodiversity challenge**: supporting the **global biodiversity framework**.

The EU can reduce a significant share of pressure [on the marine environment] by creating new MPAs and effectively managing existing ones as well as by making fishing practices more sustainable, including using low-impact fishing gears. Effectively managed protected areas minimise incidental catches of sensitive species, protect fish spawning and nursery areas and juveniles, and reduce impacts on sensitive habitats, in particular the seabed (COM(2023) 102) [16].

Technical gear measures intended to reduce bycatch of sensitive species and benthic impact should not in most instances significantly impact EU fisheries production. Improving the selectivity of gear to reduce juvenile bycatch can help to optimise catches and stock productivity. The spill-over effects of Marine Protected Areas (MPAs) are also positive for EU fisheries production. Spill-over is shown to support increased catch per unit effort (CPUE) for a range of gear types and target species in waters surrounding areas closed from fishing (EASME, 2018).

The expansion of the EU's MPA network could impact fishing productivity if vessels are displaced from important fishing grounds. Combined with displacement caused by offshore developments such as

[16] COM(2023) 102. EU Action Plan: Protecting and restoring marine ecosystems for sustainable and resilient fisheries.

offshore wind, fishing operations may become less efficient (a trade-off in attempts to reduce fuel use per kg landed) and result in more effort on the grounds that remain open.

A move to low-impact fishing gears (driven by lower fuel use as well as reduced benthic impact) also has the potential to impact production levels as many gear switches (e.g., demersal trawl to longline and gillnet) will result in lower catch levels. This can be partly compensated by higher prices being paid for improved catch quality (e.g., line-caught hake compared to trawl caught) and premiums for this lower environmental impact, if communicated to consumers.

At present many European MPAs are often little more than 'paper parks'[17] that provide limited protection to species and habitats. More than 500 Natura 2000 MPAs designated for seabed habitat protection permitted 'high-risk' fishing: fishing with gears that are known to damage those very habitats. Such fishing was so pervasive that only 14% of the total area designated for habitat protection lay within MPAs that were not exposed to high-risk gears (Perry et al, 2020).

Overall, the EU Biodiversity Strategy for 2030 will support more sustainable fisheries, which should counter the disruption caused by increased restrictions on fishing if a science-based approach is taken to managing fishing and its impacts within and beyond Europe's expanded MPA network.

[17] Relano & Pauly (2023) have developed a 'paper parks index' comparing their levels of protection. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52011DC0244 .

2. EU DEPENDENCE ON SEAFOOD IMPORTS

KEY FINDINGS

- The EU produced 5 million tonnes of fisheries and aquaculture products in 2020 (2% of global production), with just over 4 million tonnes available for human consumption in the EU. It is the **seventh largest global seafood producer** (seventh for capture fisheries and 11th for aquaculture). But people living in the EU consume twice as much as the EU produces. Three quarters came from wild capture fisheries and a quarter from aquaculture.
- Growth in the **EU seafood consumption** is supplied by an increase in **extra-EU imports** (whitefish, tuna, salmon and shrimp), which are often then subject to intra-EU exchanges. More of the lower value species like herring and mackerel are exported.
- **China and other Asian** countries remain important **re-processing centres for seafood destined for the EU**, but this has declined following the COVID-19 pandemic with increasing logistics and labour costs. EU companies are developing shorter supply chains: more added-value processing closer to landing and aquaculture production centres.
- The characteristics of **sustainable fisheries models** are well-understood (effective, adaptive management informed by sound science), but must be applied more broadly to all EU production and to its imports.
- The EU's **SFPAs with non-EU countries** contribute significantly to EU production. Rather than seeking to avoid negative impacts on the food security of non-EU countries, SFPAs have the potential to make a positive contribution.

2.1. Position of EU fisheries and aquaculture in the single market

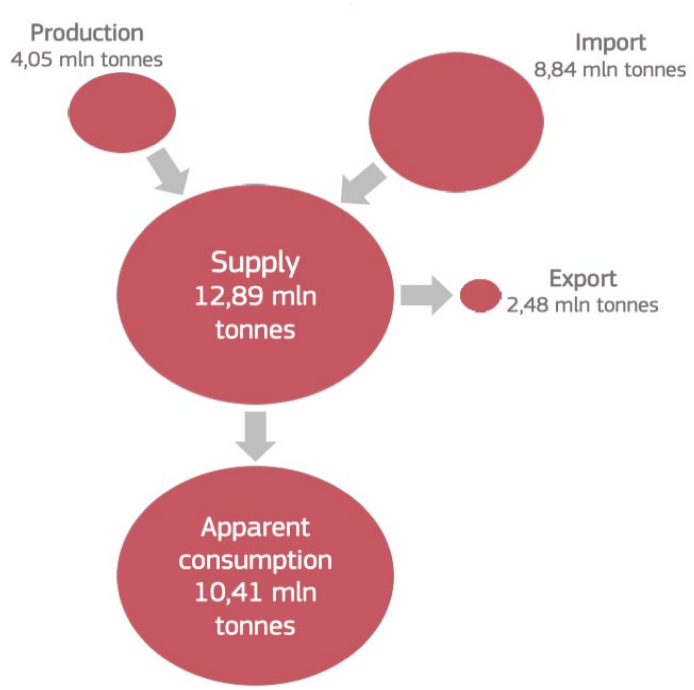
On average, every person in the EU consumes 24 kg of seafood per year, but this is highly variable across the Member States with Portugal highest at nearly 60 kg per year. Three quarters of the fish consumed comes from wild capture fisheries and a quarter from aquaculture.

An aspect of EU food security is the level of self-sufficiency, which can be expressed as the ratio between domestic production (catches plus aquaculture) and domestic consumption (EUMOFA, 2022). The level of EU demand for seafood compared to its production results in an EU supply balance, as shown in **Figure 3, Figure 4** and **Figure 5**. The EU's seafood self-sufficiency rate remains well below 50% (**Figure 4**). People living in the European Union consumed roughly twice as much as they produced (European Commission, 2022a). This rate has declined since 2018 and in 2020 was estimated at 38.9%, which reflects both a downward trend of EU production and, even more, the increase of imports (EUMOFA, 2022).

Even though pelagic fishes show the highest self-sufficiency at 63% (**Figure 5**), this is more unbalanced than it appears as consumption of large pelagics like tuna is mainly from imports, while more of the lower-value small pelagics (herring and mackerel) are exported out of the EU. EU consumption of salmon and shrimp is also driven by imports from non-EU countries.

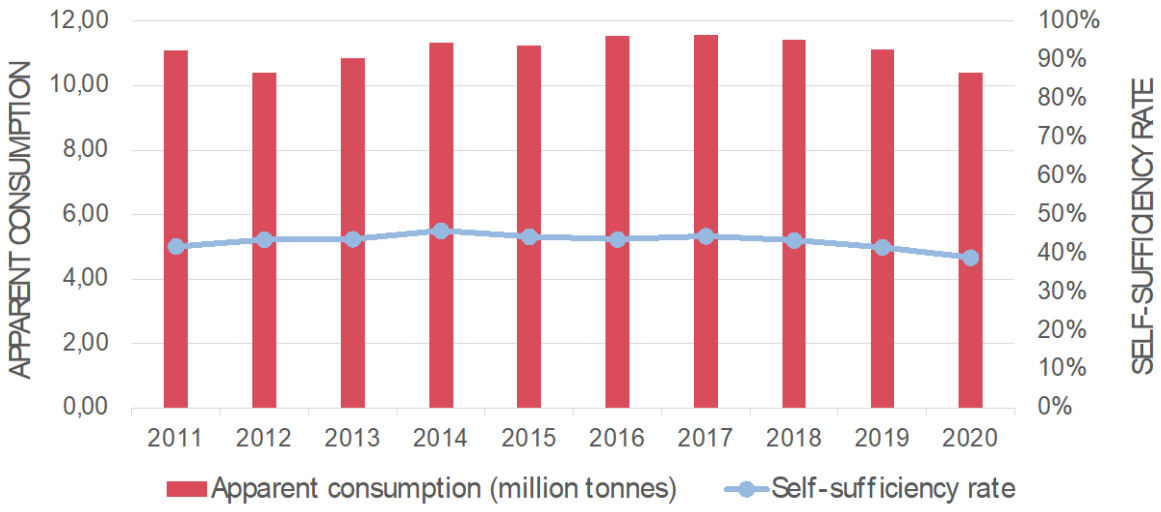
It should also be noted that some EU production, mainly of small pelagics, does not directly contribute to EU consumption as it is used for fishmeal and fish oil, some of which is destined for aquaculture. Of the EU's nearly 5 million tonnes of total fisheries and aquaculture production (**Table 2**), the amount directly available for EU consumption is just over 4 million tonnes (**Figure** 3).

Figure 3: Fishery and aquaculture products EU supply balance by million tonnes LWE, 2020



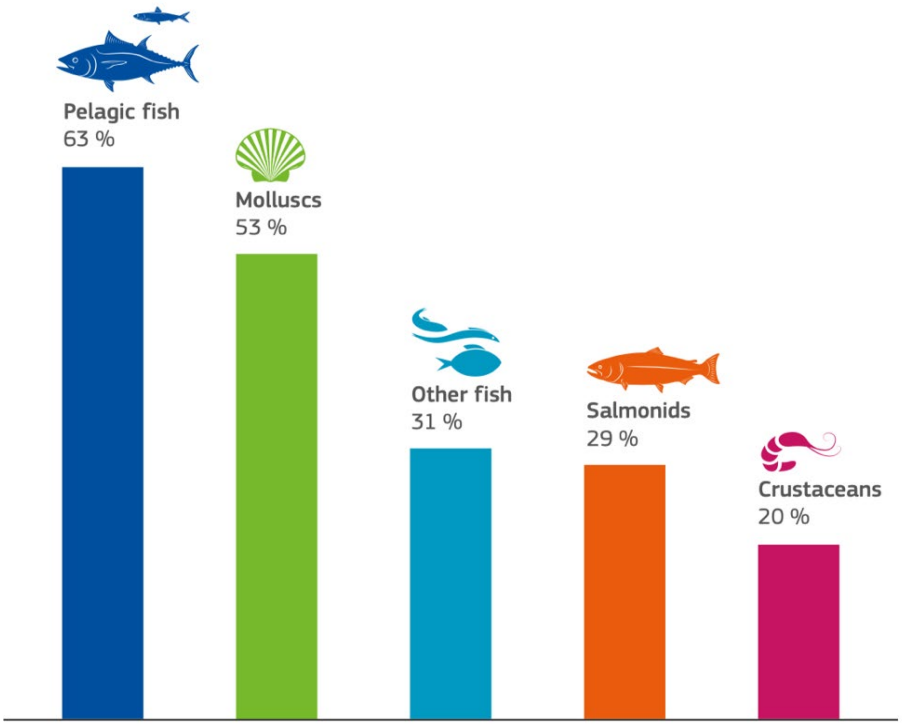
Source: EUMOFA, 2022

Figure 4: Trend in EU apparent consumption and self-sufficiency rate, 2011-2020



Source: EUMOFA, 2022

Figure 5: The EU's self-sufficiency rate by commodity group, 2019



Source: European Commission, 2022a

National dietary recommendations for fish consumption were only satisfied by net seafood supplies in 13 out of 31 European countries; those countries with large coastal access or traditional fish-eating cultures. If trade (i.e., imports and exports) ceased and countries retain their capture production, then 10 of 31 countries would satisfy dietary recommendations: Iceland, Faroe Islands, Norway, Lithuania, Latvia, Netherlands, Ireland, Denmark, Croatia and Estonia (Lofstedt et al., 2021). Based on current production levels, encouraging healthier European diets through the recommended fish consumption levels would result in a greater reliance on imports.

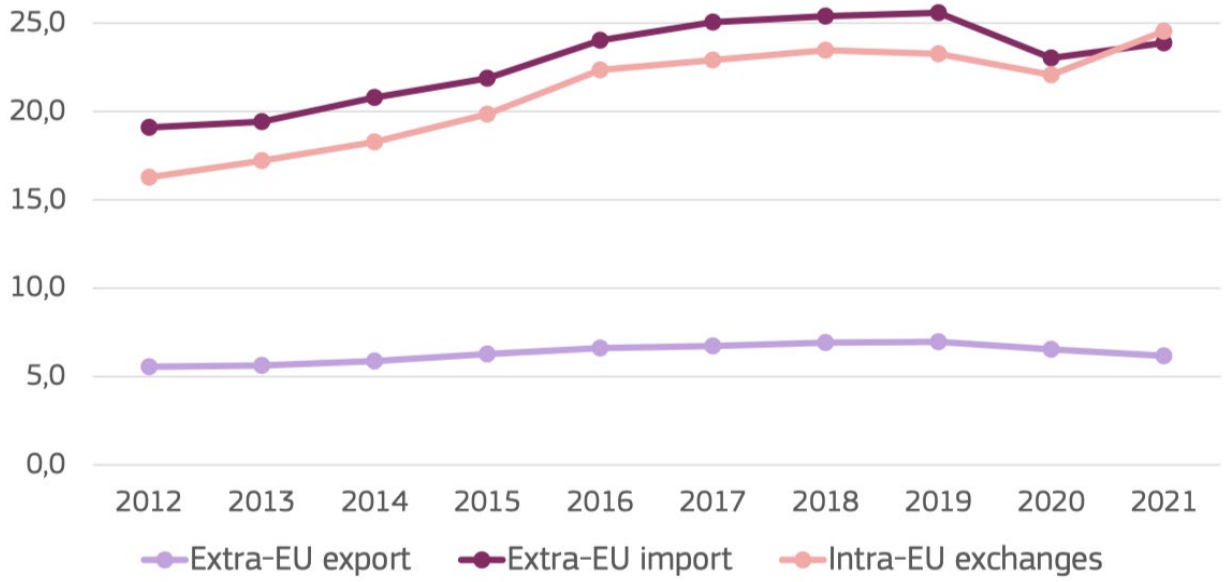
During the 2012–2021 decade, the total value of EU trade flows of fishery and aquaculture products (FAP) increased at a compound annual growth rate of 3%. This included imports and exports between the EU and the rest of the world, as well as exchanges between EU Member States. EU trade (i.e., imports and exports) has increased over the past few years, reaching EUR 31.2 billion in 2020. Norway, the United Kingdom, China, Morocco and Ecuador are the EU's main suppliers, while the United Kingdom, the United States, China, Norway and Switzerland are the EU's main customers (European Commission, 2022 a). In 2021, the combined value of EU imports of agri-food, plus fishery and aquaculture products totalled EUR 155.97 billion [18]. Of this, fish accounted for 14% and meat for 2%. The EU is a net importer of FAP, while it is a net exporter of meat (EUMOFA, 2022).

As **Figure 6** shows, the growth in trade is driven by an increase in extra-EU imports, which are often subject to intra-EU exchanges. For example, intra-EU 'exports' of salmon from Sweden primarily originate from Norway, and most whitefish 'exports' by the Netherlands are re-exports either directly after import or following processing. There are genuine intra-EU exports of certain species such as yellowfin and skipjack tuna from Spain, but here again, most production comes from Spain's distant

[18] This total amount includes extra-EU imports of the items referring to fishery and aquaculture products monitored by EUMOFA (list by CN-8 code available at the link http://www.eumofa.eu/documents/20178/24415/Metadata+2+-+DM+-+Annex+4+Corr+_CN8-CG-MCS+%282002+-+2014%29.pdf/ae431f8e-9246-4c3a-a1432b740a860291, and extra-EU imports of agri-food products, source: DG AGRI.

water fleet operating in waters outside the EU (see section 2.2.2 on SFPAs below). Exports out of the EU are at a much lower level compared to imports into the EU, but they have nevertheless grown 11% over the past decade.

Figure 6: EU trade flows of fishery and aquaculture products by value (EUR billion), 2012-21



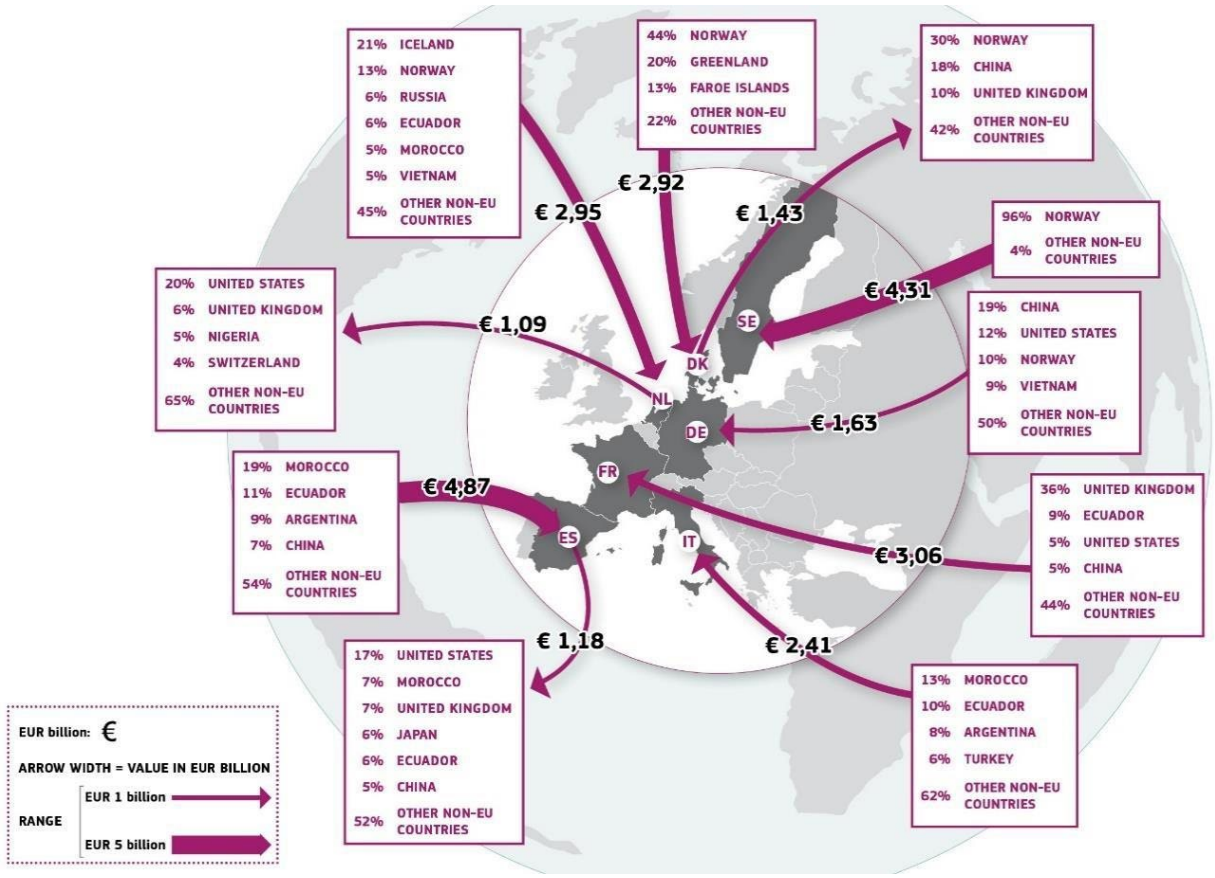
Source: EUMOFA, 2022

Figure 7 below shows the main countries involved in extra-EU trade with imports of Norwegian salmon; whitefish (cod, haddock, saithe) and cold-water prawns from northern countries (Iceland, Greenland, Norway); the cultured catfish, pangasius (a cheap substitute species for processed whitefish) from Vietnam; skipjack tuna and warm water prawns from Ecuador; sardine and fishmeal from Morocco. Norway accounted for 26% of extra-EU imports, followed by several other countries each representing 5-6% of imports (Morocco, UK, Ecuador, China, and Iceland).

China remains an important processing centre for FAP, particularly frozen fish fillets (e.g., Alaskan pollock), but this has declined recently as continuing COVID-19 restrictions and high logistics costs have driven EU companies to seek shorter supply chains with more added value processing closer to landing centres rather than exporting to China for processing and then re-importing.

In 2020, exports to non-EU countries increased to EUR 6.96 billion. Denmark, the Netherlands and Spain are the leading exporting Member States.

Figure 7: Most relevant extra-EU trade flows by MS by value (in EUR billion), 2021



Source: EUMOFA, 2022

Trade between Member States is very significant, totalling EUR 23.25 billion in 2020, a similar value to non-EU imports (EUR 24.2 billion). This level of trade equates to around 14% of all agri-food imports to the EU (DG Agri, 2023). The main exporters of seafood to other Member States are the Netherlands, Sweden, Spain and Denmark. The main importers are Germany, France, Italy and Spain.

The EU-27 produced 5 million tonnes of seafood in 2020, which was 2% of global production. It was the seventh largest global producer of fisheries and aquaculture products (EUMOFA, 2022). **Table 2** shows that it ranked seventh in global capture fisheries production with 3.9 million tonnes and 11th in global aquaculture production with 1.1 million tonnes.

A comparison of global fish consumption against regional fish supplies to determine which areas meet demand by production and/or imports using population and catch data for 64 Large Marine Ecosystems (LME's) found that two thirds of LME's reported landings were not sufficient to meet local consumption (Quaas et al., 2016).

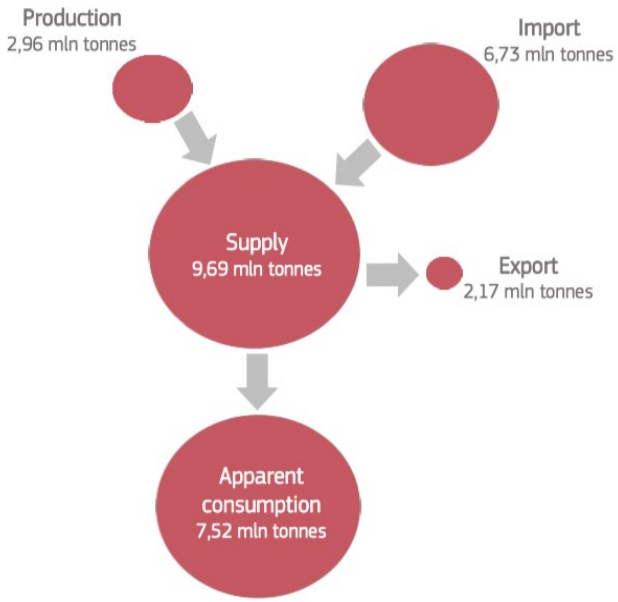
Table 2: Top 15 world fisheries and aquaculture producers (thousands of tonnes), 2020

	Catches	Aquaculture	Total production	% of total	% evolution of total production 2020 / 2019
China	13.446	70.483	83.929	39%	+2%
Indonesia	6.989	14.845	21.834	10%	-7%
India	5.523	8.641	14.164	7%	+7%
Vietnam	3.422	4.615	8.037	4%	+2%
Peru	5.675	144	5.819	3%	+16%
Russian Federation	5.081	291	5.372	3%	+3%
EU-27	3.869	1.088	4.957	2%	-7%
United States	4.253	449	4.702	2%	-11%
Bangladesh	1.920	2.584	4.503	2%	+3%
Philippines	1.912	2.323	4.235	2%	-4%
Japan	3.215	996	4.211	2%	+1%
Norway	2.604	1.490	4.094	2%	+4%
Republic of Korea	1.375	2.328	3.703	2%	-2%
Chile	2.183	1.505	3.688	2%	-3%
Myanmar	1.854	1.145	2.999	1%	-1%
Others	27.940	9.645	37.584	18%	-1%
Total	91.260	122.573	213.832	100%	+0,1%

Source: EUMOFA, 2022
Note: Catches total includes landings outside the EU and for non-food use, e.g. for fishmeal

2.1.1. EU capture fisheries production

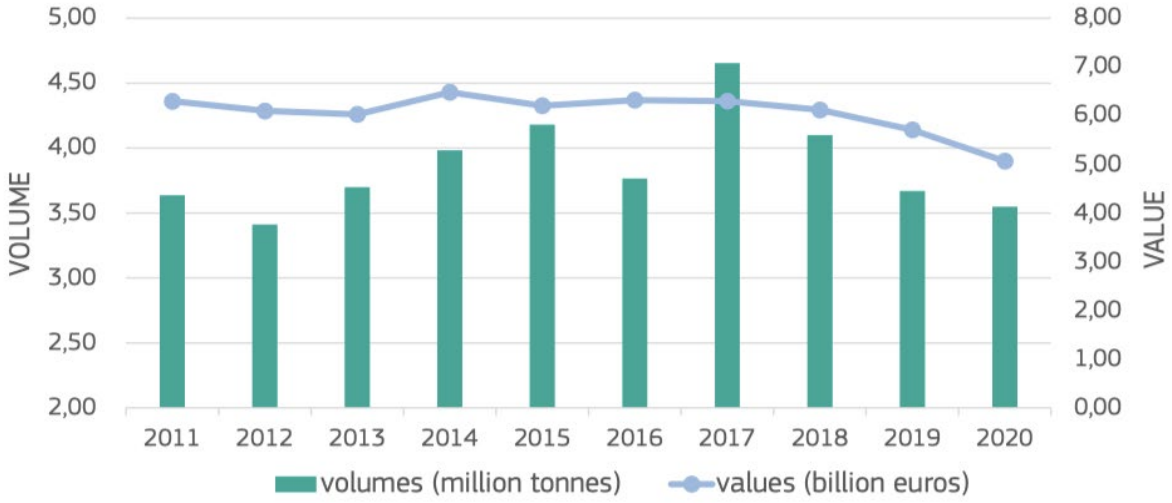
Figure 8: Fishery products EU supply balance by volume (million tonnes), 2020



Source: EUMOFA, 2022

Landings into the EU totalled 3.55 million tonnes of capture fisheries production in 2020 (2.96 million tonnes for food use)[19]. This is the lowest recorded in the last decade, in part due to COVID-19 pandemic disruption and quota reductions (EUMOFA, 2022). EU landed volumes have fluctuated more than value, but recent years have seen a decline in both (**Figure** 9).

Figure 9: Total landings into the EU by volumes and values, 2011-2020



Source: EUMOFA, 2022

73% of the EU catch came from the Northeast Atlantic: 9% from the Mediterranean, 2.1% from inland waters and 0.4% from the Black Sea, i.e., the Exclusive Economic Zones (EEZs) of Member States and adjacent seas (European Commission, 2022 a).

Around 15% of EU capture fisheries production comes from areas targeted by the EU's Distant Water Fleet (DWF). Some of this comes from EU vessels operating on the high seas beyond national jurisdiction, but most comes via resource access public fishing agreements with non-EU countries in the form of SFPAs. These are considered in more detail in section 2.2.2.

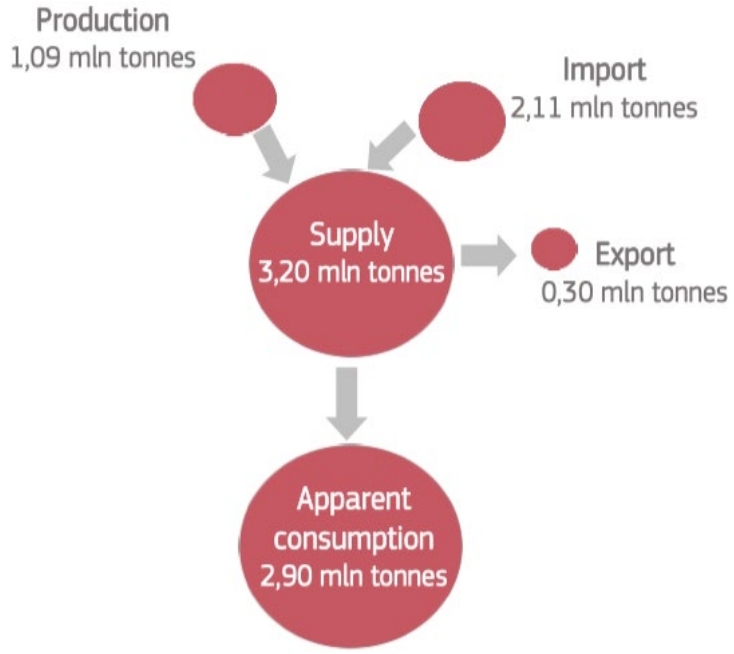
EU fisheries production relates to landings made by fishing vessels that are registered in an EU member state. There is also significant investment by EU interests in joint ventures producing seafood in non-EU countries from fishing and aquaculture operations. These may be exported to the EU and so contribute to EU seafood supplies. These private enterprises may even prioritise supply to the EU as it is a high-value market, but they are free to sell into any market and this may be determined by other factors such as trade agreements and tariff levels.

Small pelagic species (e.g., mackerel, herring, sardine, sprat, blue whiting) account for 42% of fisheries production by volume. Most mackerel, herring and sardine are processed in high volumes (mainly frozen or tinned) for EU or export markets in Asia and Africa. For some of these species (sprat, blue whiting) much of the production goes to fish meal for agriculture or aquaculture feed. In terms of food security, this exemplifies an interesting dichotomy in the EU market, which is a relatively high-value market: the EU is 63% self-sufficient in small pelagics, the largest commodity group by volume, but large amounts of these species are exported out of the EU as they are less favoured by relatively affluent European consumers.

[19] Note: total landings into the EU differs to total EU production as the EU fleet lands some of its catch outside the EU and non-EU vessels land into the EU.

2.1.2. EU aquaculture production

Figure 10: Aquaculture products EU supply balance by volume (million tonnes), 2020



Source: EUMOFA, 2022

Aquaculture is a significant activity in many EU Member States, producing around 1.09 million tonnes in volume and more than EUR 5 billion in value. Mediterranean mussels make up around 36% of the total volume farmed in the EU, while Atlantic salmon and rainbow trout together represent another 30% of the main commercial species. The main aquaculture-producing Member States in terms of volume are Spain, France, Italy and Greece (European Commission, 2022a).

2.2. Measures to contribute to food supply and security

2.2.1. Characteristics of sustainable fisheries models

Sustainable fisheries enhance food security as they best ensure the continued supply of seafood. It is essential that the EU implements policies that delivers sustainable exploitation levels for fisheries in EU waters and globally as the EU will remain dependent on imported seafood.

FAO reports mixed progress towards Sustainable Development Goal (SDG) 14: 'Life Below Water', with the indicator on sustainable fish stocks being 'far from target' with a 'deteriorating' trend (**Figure 11**). Andriamahefazafy et al. (2022) assessed progress towards four SDG14 and concluded that achieving this target "*appears to be the most challenging as reflected by the very low number of countries that have achieved the targets and a high number of countries in no/low progress*".

Ignorance is not a valid excuse as we know the characteristics of sustainable fisheries models: effective management of fisheries exploitation levels based on sound science. In volume terms biologically sustainable stocks account for 82.5% of 2019 landings of assessed stocks (FAO, 2022). This is because the world's largest commercial stocks receive the necessary management and scientific attention to better ensure good governance.

Although about 50% of the global marine catch is subjected to quantitative stock assessments, the other 50%, mostly targeted by small-scale and inland fisheries, is largely not being effectively monitored and their status is mostly unknown. Moreover, the unassessed stocks of the world largely come from developing regions with low management intensity and, based upon the relationship seen in the assessed stocks between management intensity and stock status, it is expected for these regions to have poorer stock status (FAO, 2020).

Worldwide, assessed fish stocks have a greater relative abundance than unassessed stocks. While biomass had been reduced to just below the most productive levels in previous decades, biomass for the average [assessed] stock is now greater than sustainable levels and is increasing (Melnychuk et al., 2020). This shows that fisheries management, informed by scientific assessments, does enable the recovery of fish stocks.

EU Member States have the resources to assess a relatively higher proportion of their fish stocks compared to other regions of the globe, but this does not translate into greater EU food security from fisheries production as the largest volume fisheries are small pelagic species that are mainly exported out of the EU.

The transboundary nature of many fisheries resources and the scale of many marine ecosystems make it appropriate to operate at a regional level, but some regions have shown more progress compared to others. As **Figure 11** shows, the proportion of unsustainable [assessed] stocks in the Mediterranean and Black Sea region is far greater than for the Northeast Atlantic region. The most recent CFP monitoring report by the Scientific, Technical and Economic Committee for Fisheries (STECF) confirms that for the Northeast Atlantic (among the stocks which are fully assessed), the proportion of overexploited stocks has decreased from around 74% (2003-2008) to 26% in 2021. The proportion of stocks outside safe biological limits follows a similar decreasing trend, from 81% in 2003 to 38% in 2021. However, results for the Mediterranean and Black Sea (where fewer stocks are assessed) a large majority of those stocks remain overexploited (in 2021, 41 out of 57 stocks (72%) were overfished) (STECF, 2023).

Sustainable fisheries require **adaptive management** that relies on **sound science**, and **effective enforcement**, meaningful partnerships, and robust public participation.[20] It has long been recognised that a collaborative approach is required to deliver sound science for the Atlantic, which spans numerous coastal states and international waters. The International Council for the Exploration of the Seas (ICES) delivers the collaboration on sound science and the European Union must ensure that **decision-making follows scientific advice** through its internal and international negotiations.

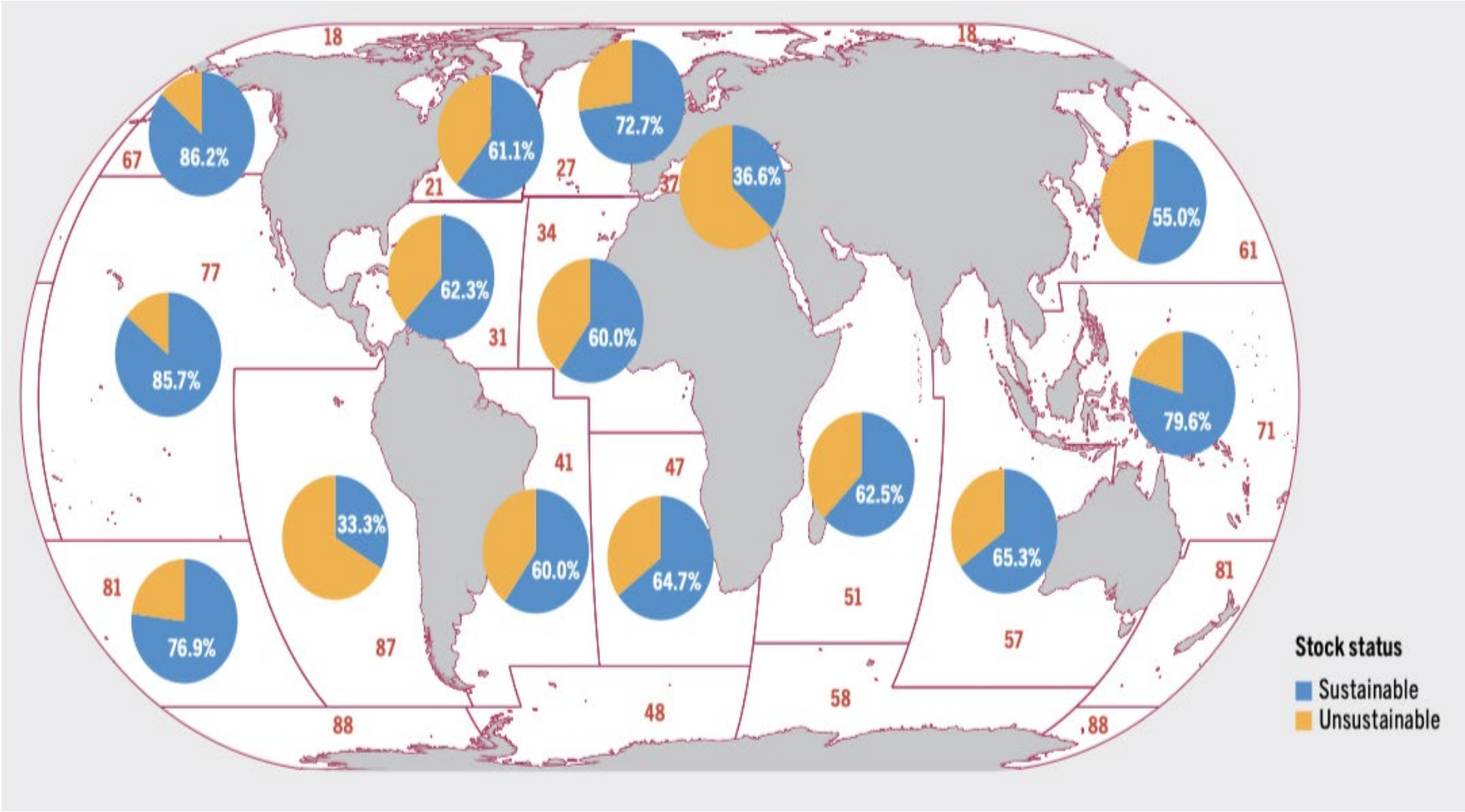
Another principle is to take a **long-term perspective** through the development of Long-Term Management Plans (LTMPs). These are beneficial as they seek to achieve and then maintain sustainable levels of exploitation over a given timeframe. They also smooth management responses by limiting annual changes in TACs to reduce short-term financial shocks to fisheries operators. In 2013, the latest CFP re-defined long-term plans as Multi-Annual Plans (MAPs), which include the CFP objective of ensuring stocks are above Maximum Sustainable Yield (MSY). Having a MAP in place reduces (without fully removing) the potential for political interference in setting annual fishing opportunities. This gives more stability and certainty, which is of economic benefit to operators (Cappell & Nimmo, 2020).

Decades of comprehensive, long-term management for NE Atlantic stocks using quotas and technical gear measures as well as reducing overall capacity in European fleets has had a positive impact. By contrast, the Med and Black Seas' more complex fisheries, mix of EU and non-EU coastal states, and predominance of small-scale fleets present multiple management challenges. Encouragingly, an

[20] NOAA Fisheries, *Status of Stocks*.

improving situation is becoming evident for Med and Black Sea stocks, albeit from a poor position. FAO reports that '*while most stocks remain in overexploitation, the number of* ***stocks in overexploitation has decreased****, as has the overall exploitation ratio for the whole Mediterranean and Black Sea region. This dynamic is reflected in marked improvements for several demersal species in terms of fishing mortality and, in some cases, of biomass too. Notable examples are provided by European hake and Black Sea turbot, as well as red mullet and common sole, most likely* ***demonstrating the effectiveness of national and regional management measures****, including overall effort reduction and the protection of coastal areas from trawlers. Conversely, sardine and blue and red shrimp have shown opposite trends: the reasons may lie in the overall lack of coverage and management measures for the former and the extremely high prices fetched by the latter, which sustain the incentive to overexploit it* (FAO, 2020).

Figure 11: Percentage of biologically sustainable and unsustainable fishery stocks by FAO major fishing area, 2019



Source: FAO, 2022

Although Atlantic fishing nations have committed to basing management on sound science, this remains open to interpretation; for example, to what extent should economic and social factors be included within the "science"? Moreover, there is still room for political influence within many of these management processes; for example, setting Total Allowable Catches (TACs) in the EU remains a process involving the EU Council of Ministers.

For stocks that extend outside EU waters, bilateral agreements on the relative share of fishing opportunities are sought between the EU and independent coastal states such as Norway and now the UK. For widely distributed stocks, Coastal States Agreements (CSA) have been established to determine the share of TACs between fishing nations. This is not a straightforward process and can become highly politicised, as exemplified by Northeast Atlantic mackerel, which recently expanded its range north-westwards, creating 'new' coastal states seeking a share of the TAC. With no agreement reached between fishing nations, total catch has far exceeded scientific advice in recent years. This shows how difficult it can be for science to keep pace with a changing marine environment and provide timely advice. Management authorities must collectively apply that scientific advice, while the industry needs to engage with, and support, the scientific basis for those management decisions.

IUU fishing contributes to unsustainable fisheries and adversely impacts legitimate operators. IUU vessel operators ignore conservation measures and other regulations. Their catch goes unreported, which undermines scientific assessment and management. A comprehensive enforcement regime is required to tackle IUU fishing within EU waters and this stems from an effective control regulation. In 2018, the Commission made a proposal to reform the current Control Regulation (Regulation (EC) 1224/2009) as it recognised that it does not align with the revised CFP and does not take account of developments in monitoring and data, but this is still to be agreed. In particular, the main shortcoming identified in the Control Regulation by the REFIT evaluation is the absence of measures empowering Member States to effectively control the Landing Obligation[21].

A 2022 European Court of Auditors Special Report concluded that the control systems in place to combat illegal fishing are partially effective; although they mitigate the risk, their effectiveness is reduced by the uneven application of checks and sanctions by Member States (ECA, 2022). In May 2023, the European Parliament and the Council of Ministers announced they had reached agreement on the Commission's 2018 proposals[22] and the deal on new EU fisheries control rules was approved by the PECH Committee in the following month[23].

The EU's IUU Regulation (Regulation (EC) 1005/2008), requiring fish imported into the EU to be accompanied by catch certificates, and identifying countries exporting to the EU without effective control systems, helped those countries to improve their efforts to tackle IUU fishing. Combating IUU fishing has seen progress, with increased regulation and the implementation of the Port State Measures Agreement (PSMA). Nevertheless, there is still a lot of work to do to effectively address IUU fishing. In March 2023, the EU joined the **IUU Fishing Action Alliance**. "*The EU fully supports the main objectives of the Alliance through the IUU Regulation: internally with Member States by means of the EU Catch Certification Scheme and externally via IUU dialogues with non-EU countries, actions on international ocean governance, maritime safety and labour conditions*"[24].

[21] SWD 280 (2018) and accompanying document. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018SC0280&from=EN .

[22] https://oceans-and-fisheries.ec.europa.eu/news/sustainable-fisheries-agreement-revision-fisheries-control-system-2023-05-31_en .

[23] https://www.europarl.europa.eu/news/en/press-room/20230626IPR00821/pech-committee-approves-deal-on-new-eu-fishing-control-rules .

[24] https://oceans-and-fisheries.ec.europa.eu/fisheries/rules/illegal-fishing_en .

The **overcapacity** that exists in global fishing fleets also needs to be addressed and this overcapacity is exacerbated by **fleet subsidies**. The percentage of capacity-enhancing subsidies increased from 57% in 2009 to 63% in 2018. Over 80% of fisheries subsidies go to the large-scale fleet, but even in small-scale fisheries capacity-enhancing subsidies have increased from 41% in 2009 to 59% in 2018 (Schuhbauer et al., 2020).

Skerritt et al. (2023) found that Asia, Europe, and North America, are net subsidy sources; they provide more harmful subsidies to their fishing fleets than their respective ecosystems are impacted by; while Africa, South, Central America and Caribbean, and Oceania are net subsidy-sinks. They suggest that this discrepancy between the source of harmful subsidies and the nations that are ultimately impacted is unsustainable and unjust. Prohibiting all harmful subsidies to distant water fishing and fishing in the high seas – with narrow exceptions for Small Island Developing States – should be prioritised to support the advancement of sustainable and equitable fisheries worldwide (Skerritt et al., 2023).

After many years of debate, the WTO Agreement on Fisheries Subsidies was finalised, representing a landmark development that will help to end the harmful subsidies that still drive unsustainable exploitation of fishery resources. Debate continues around what is a 'harmful subsidy', as to an extent any subsidy provided to private sector operators can distort the market.

While EU funds no longer support vessel modernisation or other increases in fishing capacity, EU Member States continue to provide fuel subsidies via beneficial taxation, which may be considered harmful as it encourages the continuation of activity that would not be viable without it, particularly with the large recent increases in fuel prices. Asia, Europe and Africa provide approximately 18%, 13% and 13% of the landed value from their fishing fleets back in the form of harmful fisheries subsidies, respectively (Skerritt & Sumaila, 2021).

The implications for EU fisheries production of removing subsidies can be significant as vessels with heavy fuel use (bottom trawlers) account for around 32% of EU fisheries production[25]. The recent fuel price increases, even with current fuel subsidies, saw vessel operators choosing to not go fishing. A significant part of the EU fisheries fleet was not able to cover their operational costs in 2022, leading many vessels to stay in port (COM(2023) 100).

The EU bottom trawl fleet has become unprofitable as it faces higher fuel costs, displacement from grounds and the need to increase selectivity. In current and future operating conditions, the dependence of EU fisheries production on bottom trawlers may make it difficult to achieve sustainable EU fisheries production in economic and social terms as well as environmental terms. The European Bottom Fisheries Alliance states this sector accounts for 7 000 vessels and 20 000 fishers[26]. This ultimately presents a risk to EU food security as reduced fishing activity and a move to lower impact gears would reduce EU catch and increase dependence on imports.

To maintain EU fisheries production, changes to fuel taxation and the overall energy transition by the EU fishing fleet should be carefully managed on a phased basis to ensure fleet viability can be maintained. Norway is one of the leading players in the decarbonisation of maritime vessels, with government support available through its Enova fund for research and development in maritime industries. Industry has asked for this to be followed by incentivised implementation, as it did with its fund to cut NOx emissions.

[25] According to analysis in a Seas at Risk report https://seas-at-risk.org/wp-content/uploads/2022/09/SAR_Report_V9.pdf.

[26] https://bottomfishingalliance.eu/#:~:text=We%20are%20the%20European%20Bottom,gears%20as%20a%20sustainable_%20activity.

The above management principles and benefits resulting from effective governance are recognised in the recent Communication on Fisheries and Ocean Pact (COM(2023) 103[27] and accompanying (SWD(2023) 103).[28] This document also crucially recognises the social pillar sustainability: if the fishing and aquaculture sectors are not attractive to the younger generation, there will not be enough EU fishers and fish farmer to maintain the EU's seafood production. This situation will also result in higher imports. The upcoming 'Fishers for the Future' project should identify how the attractiveness of the sector can be improved.

The overarching objective of the external dimension of the CFP is to promote high standards in terms of fisheries management at the international and regional levels. Applying EU marketing standards to imports is also demanded by EU producers to ensure a level playing field. EU operators continuing good practice outside of EU waters and the requirement for high standards in non-EU production are both important elements for the EU's seafood security as the EU should not support unsustainable practices outside the EU via seafood imports. Allowing unsustainable seafood imports undermines global efforts to tackle climate change and other environmental challenges, as well as undermining the competitiveness of EU operators who are required to meet higher standards.

Fisheries are dynamic and we know the marine environment is changing due to climate change and biodiversity loss, making it all the more important for fisheries management to be adaptive. Bastardie et al. (2022) propose **10 lessons** on the **resilience of the CFP** towards **climate change** and **fuel efficiency**:

Lesson 1: **Healthy and well-managed stocks** are highly resilient to short-term stress, but not long-term climate change.

Lesson 2: A **well-informed fisheries management** makes EU stocks more resilient.

Lesson 3: Including **environmental considerations** makes EU stocks more resilient.

Lesson 4: Stocks are not isolated but part of an **ecosystem** that **must also be resilient**.

Lesson 5: EU fisheries´ **economic resilience** depends on **current profitability**.

Lesson 6: There are likely **collateral effects of stock developments** on **fuel reduction targets** (or other ecosystem components).

Lesson 7: Many **economic aspects** could **come into play** in changing fuel use, including **fuel use intensity** and **fuel-catch efficiency**.

Lesson 8: A large panel of **technologies to reduce fuel use** in fisheries already exist.

Lesson 9: The actual uptake of technological innovations is still low because of some **impediments and regulatory barriers**.

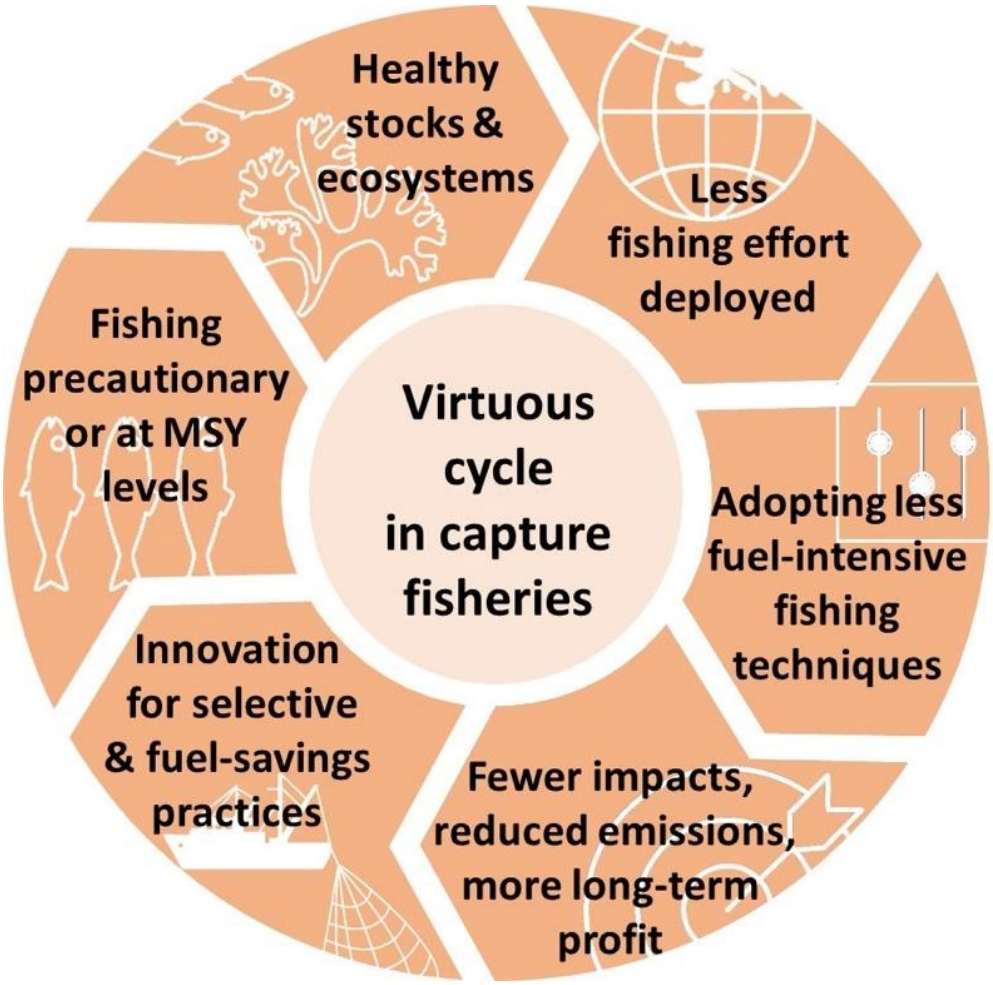
Lesson 10: The governance of fisheries should support the **adaptive, and flexible management** to face environmental conditions.

Applying these lessons should result in a virtuous cycle in capture fisheries (**Figure 12**). This is environmentally-focused, but if fisheries are not environmentally sustainable, they will not have the potential to be economically or socially sustainable.

[27] COM(2023) 103. The common fisheries policy today and tomorrow: a Fisheries and Oceans Pact towards sustainable, science-based, innovative and inclusive fisheries management.

[28] SWD(2023) 103 Common Fisheries Policy - State of play. Accompanying COM(2023 103 final on 'The common fisheries policy today and tomorrow: a Fisheries and Oceans Pact towards sustainable, science-based, innovative and inclusive fisheries management.

Figure 12: A virtuous cycle in capture fisheries



Source: Bastardie et al., 2022

Several of the above lessons relate to the need for effective governance. This can be enhanced through a co-management approach[29], which is the subject of a European Parliament resolution of 9 May 2023 (A9- 0119/2023) that advocates the inclusion of co-management in future revisions of the CFP. In Article 33 the resolution "*reiterates that fisheries co-management already exists and has been successful in many of the known cases; notes that these are based on different legal frameworks, both at local level, such as in Galicia, Catalonia and Andalusia in Spain, and at state level, such as in Portugal, Italy, France, Sweden, Croatia and the Netherlands; stresses that the lack of experience and good examples at European level prevents this system from being applied in other regions and countries.*" (European Parliament, 2022a).

2.2.2. Sustainable Fisheries Partnership Agreements

The EU negotiates SFPAs with non-EU countries to enable EU fleet access to tuna and a range of other fishery resources in their waters (**Figure 13**). The EU is required to ensure those agreements neither threaten the small-scale fisheries sector in non-EU countries nor undermine local food security.

[29] 'Co-management' is defined by the FAO as "*a partnership arrangement in which the community of local resource users (fishers) and government, with support and assistance as needed from other stakeholders (boat owners, fish traders, fish processors, boat builders, business people, etc.) and external agents (non-governmental organisation, academic and research institutions), share the responsibility and authority for the management of the fishery*".

At the end of 2022, there were 13 SFPAs with active implementing Protocols (nine tuna and four mixed agreements), and seven SFPAs without (the 'dormant agreements') (European Commission, 2021 b). The SFPA protocols establish two types of payments to non-EU countries: a. direct funding for **EU fleet access** to 'surplus' fishing opportunities and b. fisheries **sector development support**, which is intended to be decoupled from access payments. EU commitments to partner non-EU countries between 2015 and 2020 represented an annual average of EUR 159 million in total, including EUR 126 million paid from the EU public budget (EUR 98 million as a contribution for access and EUR 28 million as a contribution for sectoral support). 81% of this went to West African countries (European Commission, 2021b).

EU catch obtained in the waters of partner non-EU countries was close to **300 000 tonnes per year** between 2015 and 2020, of which 49% by weight were small pelagic species, 39% highly migratory species such as tuna, 10% various other fish species (mostly hake) and 2% crustacean species. The average annual first sale value of these catches was EUR 410 million, dominated by the tuna catches.

Total EU catch within the framework of SFPAs represented **9% of the average total EU catch**, contributing 21% of EU catches of tuna and other large pelagic species. Most catches obtained by EU vessels within the framework of SFPAs are consumed in the EU market. They meet **3% of the needs of the EU market** for fisheries products, with the contribution being 6% for highly migratory species and 7% for small pelagic species.

Figure 13: Sustainable Fishery Partnership Agreements between the EU and non-EU countries

Source: European Commission, 2022 a

Less than 10% of the EU fleet's catch from non-EU country waters under these agreements contributes to food security in those countries, mostly through sales of by-catches by EU tuna vessels and landings of in-kind contributions for access in Mauritania and Guinea-Bissau for certain categories of EU trawlers (European Commission, 2021b).

An evaluation of the SFPAs found them to be consistent with the CFP's objectives, were broadly effective at enhancing the capacities of non-EU countries to control fishing activities and that they made a positive contribution to the global fight against IUU fishing (European Commission, 2021b).

Overall, the SFPAs are a significant contributor to the EU's food supply and partner countries derived substantial economic benefits, but do not make a significant contribution to food security in those countries as most of the landings are exported. Whether SFPAs negatively impact on food security depends on the extent to which those resources would be caught by domestic fleets and made available to local markets.

As much of the tuna is destined for export EU markets, only the 'faux thon' bycatch is made available locally and this may be expected to be the case irrespective of who catches it. However, this may not be the case for the mixed multi-species fishery agreements with Morocco, Mauritania and Guinea-Bissau[30].

Article 4 (33) of the CFP Regulation[31] defines the surplus of allowable catch as "*that part of the allowable catch which a coastal State does not harvest, resulting in an overall exploitation rate for individual stocks that remains below levels at which stocks are capable of restoring themselves and maintaining populations of harvested species above desired levels based on the best available scientific advice*". The surplus of a stock may be defined as its annual potential catch at sustainable levels minus the potential catch of the national fleet, according to its capacity to harvest the total catch.

A scientific study found that the determination of the surplus is complex[32]. For straddling stocks such as stocks of small pelagic species or black hake assumed to extend between Morocco and Guinea-Bissau, the determination of a surplus in the waters of a coastal State requires, to start with, identification of a regional surplus and a distribution key of the surplus between the different coastal States involved (García-Isarch et al., 2016).

Small pelagic species are an important resource in West African waters. Over time, the EU catch of sardinellas in West Africa decreased significantly, from 150 000 tonnes in 2010, to less than 10 000 tonnes in 2018. However, catches of sardinellas by national and chartered foreign fleets considerably increased in the waters of Mauritania, completely offsetting the effects of catch reductions by the EU and other foreign industrial fleets on the exploitation status of the sardinella stocks. Catch increases in Mauritania have been driven by the fish meal factories' demand for raw material, with negative impacts on food security in West Africa (DAI, 2015). A negative impact on food security results from the demand for fish meal, including from aquaculture production, rather than the SFPAs.

The impact of foreign activities in West African waters on the region's food security is increasingly concerning. Not only is a greater proportion of catch being taken by foreign vessels, making it less available to local populations, this catch is often destined for the foreign-owned fishmeal factories that have become established throughout the region. There is a considerable negative impact on food security in Senegal because the country is strongly dependent on fish consumption; it is projected to have a gap of fish demand of about 150 000 tonnes every year during the 2020s. Increasing fishmeal production that may depend on edible fish will worsen the already critical situation of fish availability and affordability (FAO, 2022).

[30] Greenland exports nearly all its fisheries production, which is the great majority of national exports and so not an issue of food security.

[31] Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy; see last consolidated version of 1/1/202.

[32] The surplus concept is not applicable to tuna and tuna-like species which are highly migratory and mainly found in areas beyond national jurisdictions. The determination of the tuna and tuna-like resources available for access in the framework of tuna SFPAs should consider scientific assessments and management adopted by relevant tuna RFMOs.

The SFPAs between the EU and non-EU countries could help to address the risk that foreign fishing activities pose to food security. In Mauritania, the Protocol starting in 2012 introduced a requirement for small pelagic trawlers to donate an in-kind contribution equivalent to 2% of their catch. The resulting quantities of fish added to the quantities obtained from a similar provision imposed to other foreign small pelagic trawlers and was distributed by a public entity to the poorest layers of the population at subsidised prices. Between 2018 and 2020, the in-kind contribution of EU pelagic trawlers was close to 2 000 tonnes per year on average, and the total quantity distributed to the local population close to 11 000 tonnes, including contributions from other fleets. An evaluation of the distribution programme organised by the government underlined its positive contribution to food security and nutrition [through the distribution of these in-kind contributions to poor communities] and suggested improvements to increase its benefits for the local population (AECID, 2016).

The Protocol concluded in 2019 with Guinea-Bissau also foresaw an in-kind contribution to be landed in the country (i.e., 2.5 tonnes per quarter and per vessel for finfish/cephalopods vessels and 1.25 tonnes per quarter and per vessel for shrimp trawlers) which could potentially result in supply of about 200 tonnes of fisheries products annually.

SFPAs already contain checks to try and avoid negative impacts on food security for the local population in the non-EU country. If designed with the right provisions within the protocols, such as is seen with Mauritania, SFPAs could directly support food security in those non-EU countries.

3. EU AQUACULTURE PRODUCTION

KEY FINDINGS

- EU aquaculture contributes around **1.1 million tonnes of seafood**, half of which are low-trophic species such as mussels and oyster.
- The most recent (2021) **Strategic guidelines for sustainable EU aquaculture** focus on building resilience, encouraging innovation and participating in the green transition.
- As a result, EU aquaculture **needs to both diversify** in terms of both the **number of species** produced and the **ways in which they are produced**.
- This likely to mean an even greater focus on **low and multi-trophic aquaculture**, the greater and innovative use of **circular materials** in aquafeed production and a **more holistic** adoption of the **ecosystem approach** to aquaculture.

3.1. Background

3.1.1. Production

The European Union (EU) is a **net food exporter and top agri-producer**, producing EUR 336 billion worth of agricultural goods (mainly vegetables 26.5%, cereals 21% and fruit 14.1%) and EUR 141 billion of animals (mainly pigs 24.9%, cattle 17.3% and poultry 12.2%) in 2020 (European Commission, 2021). While largely self-sufficient for many agricultural products, it is a **net importer** for some specific products such as **feed protein**. This vulnerability, together with high input costs, such as fertilisers and fossil energy, is causing production challenges for farmers and risks driving up food prices. Underlying this geopolitical uncertainty is the longer-term and more fundamental challenge of climate change and its impacts on global food production.

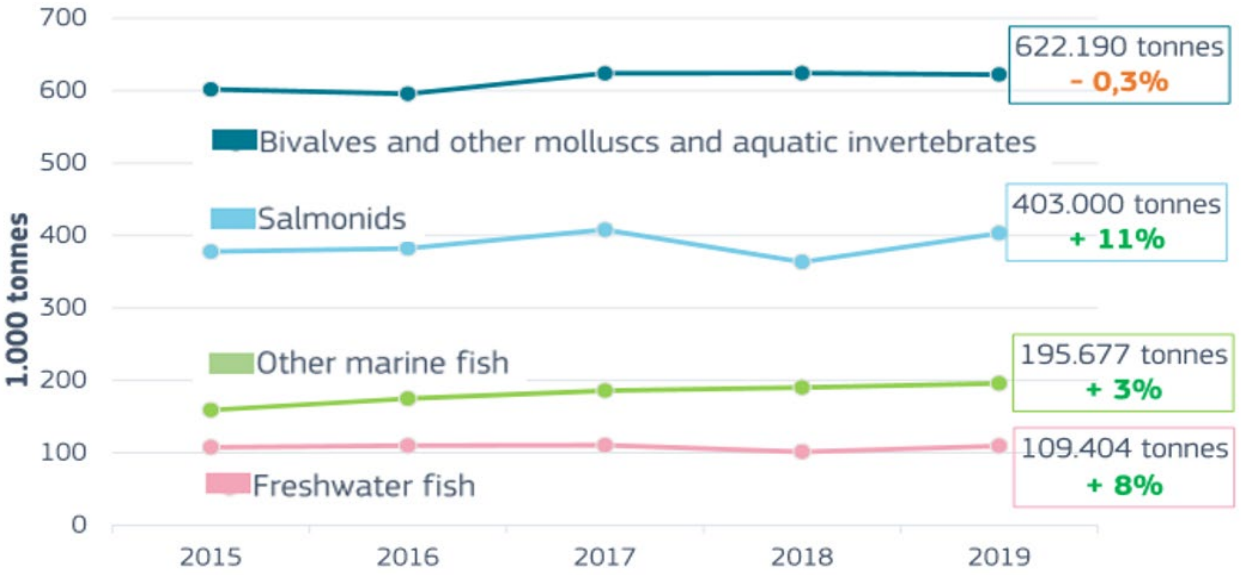
The EU-28 is currently ranked **seventh in the world in terms of fisheries production**, producing around 3.9 million metric tonnes of catches and 1.1 million tonnes from aquaculture in 2020 (EUMOFA, 2022). In 2020, the EU trade of fisheries and aquaculture products[33] was the highest in the world, totalling EUR 31.17 billion and 8.72 million tonnes. Imports amounted to EUR 24.21 billion and 6.15 million tonnes and exports amounted to 2.21 million tonnes.

Looking at **aquaculture** in particular, the **EU imported 2.11 million tonnes** of farmed products in 2020 and exported 0.3 million tonnes. In 2020, total EU aquaculture production declined to 1.09 million tonnes due to the UK's exit from the EU and COVID-19 disruption. The years prior to this saw growth in aquaculture production with an 11% increase from 2010 to 2019 in volume terms, while its value grew by 40% in real terms to nearly 5 billion Euros.

Almost half of EU aquaculture production volume consists of bivalves and other molluscs and aquatic invertebrates, mainly thanks to the productions of mussel in Spain and oyster in France. Salmonids and the grouping "*other marine fish*" follow, with salmonids mainly including salmon and trout, and other marine fish mainly including gilthead seabream and European seabass. Freshwater species come next, largely comprising carps (see **Figure 14**).

[33] Presented here as the combined amounts of imports and exports with third countries.

Figure 14: Volumes of main farmed species groups in the EU and % change 2018 / 2019



Source: EUMOFA, based on Eurostat (online data code: fish_aq2a) and FAO data.

Farmed fin and shellfish represent an important source of healthy protein, with farmed salmon containing 20.4 g protein / 100 g portion, sea bass 20.4 g protein / 100 g portion, common carp 17.8 g protein / 100 g portion, and mussels containing 12.1 g protein / 100 g portion [34].

3.1.2. Governance

The development of aquaculture (marine and inland) in the European Union is supported through the **Common Fisheries Policy** (CFP) to ensure that aquaculture (and fishing) activities contribute to long-term environmental, economic, and social sustainability[35]. The Commission recently adopted new "***Strategic guidelines for*** *a more sustainable and competitive* ***EU aquaculture*** *for the period 2021 to 2030*" [36], providing a long-term approach for the development of sustainable aquaculture in the EU and guidelines for the development of the sector in EU Member States. These guidelines were supported in Europe through the H2020 programme[37].

These guidelines are transcribed at the national level through the elaboration of Multi-annual National Strategic Plans for aquaculture (MNSPs). The Strategic guidelines are in line with the development objectives set by the EU Green Deal, including the development of sustainable food systems. The potential of EU aquaculture to support the development of sustainable fish and seafood production is also highlighted by the Farm to Fork Strategy. Together the European Green Deal, the biodiversity strategy and the Farm to Fork Strategy aim to achieve a carbon-neutral Europe by 2050 and make food systems fair, healthy and environmentally friendly across the Union. The European Maritime Fisheries and Aquaculture Fund 2021-2027 (EMFAF) provides specific financial support to ensure the sector develops sustainably.

[34] Salmon, sea bass and mussels: https://www.seafish.org/promoting-seafood/health-benefits-of-seafood/#nutritional-profiles-for-fish-and-shellfish; common carp https://www.nutrition-and-you.com/common-carp.html

[35] *" The scope of the CFP includes the conservation of marine biological resources and the management of fisheries targeting them. In addition, it includes, in relation to market measures and financial measures in support of its objectives, freshwater biological resources and aqua culture activities, as well as the processing and marketing of fishery and aquaculture products, where such activities take place on the territory of Member States or in Union waters"* Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013.

[36] COM(2021) 236 final.

[37] European Commission, DG RTD, Dimitrova, N., Doneva, T., Hranilovic, M., et al. 2020.

Aquaculture is supported by the EU's **Open Method of Coordination** (OMC) that facilitates the exchange of best practices in sustainable aquaculture across the EU. The **Aquaculture Advisory Council** (AAC) also provides advice to the European Commission and Member States on any new legislative, regulatory or legal measure at European or national level that affects aquaculture. In addition, the Aquaculture Assistance Mechanism, launched in June 2022, aims to support the implementation of the Strategic guidelines adopted in 2021, providing technical expertise, training, and developing an online knowledge base within the Aquaculture community.

In 2021 with its communication "*On a new approach for a sustainable blue economy in the EU*"[38], the Commission promoted the transformation of the "*EU's Blue Economy for a Sustainable Future*". This communication sets out a detailed agenda for the blue economy. Among the objectives, "*sustainable aquaculture is to complement the natural limits of wild captures and algae production as an alternative to agriculture*" to ensure sustainable food production**.**

In 2022 the European Parliament resolution of 4 October 2022 (A9-0215/2022) on '*striving for a sustainable and competitive EU aquaculture: the way forward*' (European Parliament, 2022b) provided a succinct analysis of the contribution of aquaculture to food security in the EU and the barriers to expanding this. Some of its key points can be summarised as follows:

- EU aquaculture contributes a very small proportion (1.15%) of global aquaculture production, providing only 10% of seafood consumed in the EU, with a declining trend in both sales and consumption;
- One of the main constraints to the expansion of aquaculture is the slow and complex legal procedures required for the establishment or expansion of farm operations, hindering the development of the sector, discouraging corporate investment and generating excessive costs for the sector, while promoting imports from non-EU countries;
- On a more positive note, much of the EU's aquaculture in relatively small-scale, focusing lately on shellfish production that is well integrated into the local environment;
- Organic aquaculture is also increasing in some – but not all – Member States. In addition, freshwater pond aquaculture, algae and shellfish farming can all contribute to decarbonising the EU economy and mitigating climate change; and
- It should be noted that carbon sequestration by algae and shellfish farming is limited, depending on the production method and use when the product is harvested.

3.2. Unlocking the potential of EU aquaculture production for sustainable food security

The CFP states that aquaculture should contribute to the preservation of food production potential on a sustainable basis throughout the EU so as to guarantee long-term food security, including food supplies, growth, and employment for Union citizens, and contribute to meeting the growing world demand for aquatic food (European Parliament, 2022b). Given the current geopolitical uncertainties facing terrestrial food production and the longer-term threat of climate change on all forms of food production, an adaptive and innovative European aquaculture industry indeed has considerable potential to provide an increasing contribution to the Union's food security.

With the modest 11% growth in EU aquaculture volume over the last 10 years, it is evident that there will not be any quick wins. For example, one area that sparked a flurry of investor interest in recent years has been the intensive farming of finfish, mainly salmonids, in recirculating aquaculture systems

[38] COM(2021) 240 final: A new approach for a sustainable blue economy in the EU Transforming the EU's Blue Economy for a Sustainable Future.

(RAS). Based on having a high degree of control over growing conditions, RAS offers a modern approach that allows the use of near-market sites and is largely independent of climatic conditions. However, the expected rapid uptake has been curtailed by increasing energy costs as well as technical and financial barriers to scaling up production to commercially viable levels (EUFOMA, 2020). For more on the potential for RAS in the EU, see the next section.

The recent EU Strategic guidelines of sustainable aquaculture development have a number of strategic approaches, including:

- building resilience and competitiveness;
- participating in the green transition;
- ensuring social acceptance and consumer information; and
- increasing knowledge and innovation.

These are further examined below.

3.2.1. Building resilience and competitiveness

Including aquaculture as part of Europe's diverse and crowded blue economy has necessarily resulted in numerous regulations and different governance systems to ensure that does not compete with other productive sectors nor have adverse effects on the ecosystems on which it depends. However, as has long been recognised, the resulting **administrative burden** can also inhibit both the expansion and diversification of aquaculture, both as a food production system as well as a potential ecosystem service provider. This was addressed in the original Strategic guidelines for aquaculture development in 2013 and is still in central theme in their replacement in 2021.

One key approach to reducing institutional and administrative overlap is **maritime spatial planning** (MSP). A recent review of how aquaculture has been integrated into Member State MSPs (Riclet et al., 2023) concluded that the MSP process has a role to play in providing a cross-sectoral platform for coordinating spatial planning and a basis for data and information exchange at both vertical (e.g., transboundary / national / local) and horizontal (e.g., cross-sectoral) levels. Riclet et al. also recommended that institutional mapping should be carried out/reviewed by Member States to ensure aquaculture representativeness in MSP governance and to improve aquaculture licensing. This mapping process would also assist to develop more integrated and possibly 'one-stop-shop' approaches for aquaculture licensing by identifying institutional and process gaps and overlaps.

A second approach for ensuring resilience is **adapting aquaculture production to climate change**. Short-term climate change causing large-scale loss of production from extreme events such as floods, increased risks of diseases, parasites and harmful algal blooms. Longer-term impacts can include reduced precipitation leading to increasing competition for freshwater (Barange et al., 2018; Holmyard, 2014). An often-unrecognised impact of climate change is on food and human safety, for example through changes in the growth rates of pathogenic marine bacteria (see Cascarano et al., 2021), or on the incidence of parasites, food-borne viruses and the possible emergence of zoonotic diseases.

A recent report to the Aquaculture Advisory Council (Huntington, 2022) suggests a number of routes to **improve the resilience of European aquaculture to climate change**, including (i) geographically realigning traditional aquaculture production to reflect changing thermoclines and other environmental factors, (ii) moving away from current open water systems to those with a greater degree of containment and environmental management, (ii) increased use of resilient, high performing fin and shellfish stock lines and (iii) the use of remote environmental monitoring systems, combined with artificial intelligence (AI), that predicts and manages aquaculture system management to maximise growth and survival as well as minimise energy and material inputs into the system.

Compared to aquaculture in Asia - the largest and fastest growing region in the world – European aquaculture is limited to a small number of species and farming system approaches. Therefore, **diversification into new and less-used species**, with a tendency towards lower-trophic animals and plants, will be key for European aquaculture over the next decade or two. This will allow emerging environmental niches to be occupied (e.g., tilapia in warmer ponds), large-scale carbon sequestration and remediation (e.g., via seaweeds), and efficient in-combination systems through integrated multi-trophic aquaculture (IMTA) and polyculture. In particular, the Farm to Fork Strategy and the new Strategic guidelines on EU aquaculture recognise the enormous potential of algae to contribute to multiple objectives of the European Green Deal. The Commission has adopted a specific Communication to support the sustainable production, safe consumption and innovative use of algae and algae-based products (European Commission, 2022b; European Commission, 2023a).

3.2.2. Participating in the green transition

Aquaculture is itself dependent upon a healthy, fully functioning ecosystem. With the increasing maturity of the sector comes a growing understanding that aquaculture can mitigate its environmental impact and carbon footprint through intelligent design, good planning and governance.

As discussed above, a key move will be towards **lower-trophic species** such as seaweeds, non-fed species such as shellfish and herbivorous finfish species. Already practised in many parts of the EU (e.g., shellfish in Spain, France and the Netherlands, and finfish such as carps in Eastern Europe), this needs to be encouraged and diversified as an overall shift towards 'plant-forward' diets comprised of plant foods with modest amounts of low-trophic level animals (i.e., forage fish, bivalve molluscs, insects).

For aquaculture too, the **increased energy prices** are a threat to profitability and viability, both directly through increased energy costs and indirectly through higher feed prices and other input costs. Depending on the type of aquaculture, energy is needed for a variety of different purposes. In marine aquaculture, energy may be needed in the form of fuel to power service vessels. In freshwater aquaculture, energy is needed in the form of electricity for feeding systems, water pumps, and remote-control tools, to monitor farming conditions, and to recirculate/clean the water. The share of costs for energy consumption differs widely depending on both the type of species farmed and the production technique used (European Commission, 2023c).

There are extensive options including the use of **renewable energy** on site (e.g., solar, wind and possibly tidal) supported by ever-improving battery storage solutions, move to hybrid-powered well and support vessels. **Life cycle analyses** (LCAs) and **carbon footprint modelling** can introduce carbon footprint elements in decision-making e.g., comparing the GWP costs of different land and sea-based systems. At a wider level, artificial intelligence (AI) has the potential to revolutionise modelling and forecasting in aquaculture production and markets.

There has been much discussion about the **potential for aquaculture to go beyond climate change mitigation and to contribute to global carbon sequestration** e.g., the process of capturing, securing and storing carbon dioxide from the atmosphere. Some authors (Moore, 2020; Moore et al., 2022) strongly advocate the shellfish farming to permanently store CO_2 as mineralised $CaCO_3$). However, Jones et al. (2022) consider that, because bivalve shell formation and respiration are a net source of CO_2 from sea to atmosphere, the potential for bivalve monocultures to directly sequester carbon is limited (see also Filgueira et al., 2015, Munari et al., 2013).

Jones et al. (2022) considered the potential for seaweed farming to capture and sequester anthropogenic CO_2 in a similar way to carbon farming initiatives on land (Froehlich et al., 2019), an approach that relies on a non-harvest mariculture model, where biomass is either retained *in situ* or

allowed to sink to the deep sea (less than 1 000 m) where the carbon can be sequestered for long periods of time (Froehlich et al., 2019). However, the potential negative impacts of these practices are unknown, and scaling up will be a challenge.

3.2.3. Ensuring social acceptance and consumer information

The **welfare of aquatic animals** under aquaculture is a relatively recent focus of the sector, governance bodies, policy advocates and, increasingly, consumers. A recent report to the AAC (Saraiva et al., 2022) suggests that the priorities for improving the welfare and production of farmed fish in the EU include (i) validation of welfare solutions at commercial scale, (ii) validation of humane stunning and slaughter solutions, also at commercial scale, (iii) the adoption of humane stunning and slaughter solutions in companies, (iv) wide-spread industry training and (v) the development of 'good welfare awards' for well-performing companies. The recent EU Strategic guidelines also see development by EU Member States and the EU aquaculture industry of common, validated, species-specific, and auditable fish welfare indicators throughout the production chain, including transport and slaughtering.

One constraint to the expansion of aquaculture in the EU is the persistent public perception that it can be unsightly and will denigrate the local community (Nimmo et al., 2011). While these issues can be addressed directly e.g., through improved visual incorporation into the seascape and better environmental management, **integration in local communities** can also be facilitated by local level spatial planning, assimilation into the local 'blue economy' e.g., via tourism and the seafood value chain and through better community engagement. One such concept, promoted by the Global Ghost Gear Initiative, is the development of community engagement and reporting over marine litter by aquaculture companies (singly or in collaboration), including beach clean-ups and environmental awareness development to both the public and local schools (GGGI, 2021).

As stated by the revised Strategic guidelines, there are many **reporting obligations** on the aquaculture sector under different pieces of EU and national legislation. However, the data collected are mostly socio-economic or data on animal health, and limited data are reported on environmental indicators specific to aquaculture, nor on areas of concern to consumers, such as animal welfare (e.g., sea lice loading), escape levels and interactions with iconic species such as seals or otters. If aquaculture is to expand, increased transparency is essential, a process that can be facilitated through appropriate public access to online licensing portals and maritime spatial planning portals.

Producer Organisations are less prevalent in aquaculture compared to fisheries[39], enabling the collective implementation of the CFP at producer's level. This is achieved by requiring each PO to draw up and implement production and marketing plans (PMPs). Aquaculture producers acknowledge that the revision of the CMO Regulation has helped provide a more appropriate legal framework for aquaculture POs (European Commission, 2023b). Product promotion, awareness and communication measures led by aquaculture POs have been particularly successful. However, there is still a limited number of aquaculture POs in the EU, so they are not fully succeeding in grouping supply, which could help them face the high structural concentration of retail. Promoting the benefits of setting up POs among aquaculture producers is one of the actions under the 2001 EU Strategic guidelines for a more sustainable and competitive EU aquaculture.

[39] On November 2022, there were 204 POs (163 in fisheries and 41 in aquaculture) in 18 Member States (European Commission, 2023b).

3.2.4. Increasing knowledge and innovation

The Strategic guidelines require that decisive action for aquaculture is taken to ensure that research and innovation: (i) respond faster to the current and future challenges and opportunities of the sector; (ii) avoid duplication of efforts; and (iii) create synergies across different research areas.

Horizon Europe funding is key to this. This EU funding mechanism is designed to create a framework for cooperation that brings together public authorities, industry, researchers, and educators, both at national and regional/local levels (including the development of innovation clusters for sustainable aquaculture), as well as foster the development and matching of research and innovation strengths across Member States and regions. This should include smart-specialisation strategies aimed at building full value chains across the EU.

Apart from funding, a second key element is research planning and coordination. Research needs to be targeted both the long-term and more immediate constraints and barriers to diversifying and building resilience into European aquaculture. Short-term priorities might respond to immediate researchable constraints such as disease treatments and equipment development, with the private sector usually taking the lead, albeit with technical partners such as universities. Long-term research – which may not lead to immediate commercial benefits – needs to take a more strategic approach and may require more public sector involvement in terms of both funding and service provision. Given many of the issues, requiring long-term research needs are common across Europe, regional collaboration is essential. This has long been recognised, and mechanisms such as the **European Aquaculture Technology and Innovation Platform** (EATiP) and the evolution of its **Strategic Research and Innovation Agenda** (SRIA) have been key in ensuring a stakeholder-driven agenda for European aquaculture.

One area of improvement required is the linkages between the new **Multi-annual National Strategic Plans for Aquaculture** (MNAP) produced by the EU Member State in preparation for targeting funding from the **European Maritime, Fisheries and Aquaculture Fund** (EMFAF) from 2021 to 2027 and wider European research agenda for aquaculture. The MANPs are structured around the new EU guidelines of sustainable aquaculture and therefore included a common area of 'Increasing knowledge and innovation'. It is therefore important that efforts are made to consolidate the individual national research needs with the wider regional needs and thus to build research coalitions across the EU to solve common, pressing issues.

Another opportunity is to build on the current impetus for 'blue growth', linking aquaculture value chain development with other maritime sectors, especially but not exclusively from capture fisheries. In particular, the rapid growth in offshore renewable energy development provides prospects for both collaboration over offshore structures and mooring designs, as well as possible co-development e.g., combining wind farm structures and logistical arrangements with aquaculture production. This can be accelerated through the clustering of maritime research in key, often coastal locations and promoting complementarity and synergies across different areas of maritime science and technology research.

3.3. Best practice examples of sustainable aquaculture production

This section of the report provides a brief review of current and emerging practices in aquaculture that can lead to a more diverse, resilient and lower carbon industry. It does not present to be an exhaustive analysis but is intended to provide an understanding of where European aquaculture might head in the next decade or so.

3.3.1. Low and multi-trophic aquaculture

Low-trophic aquaculture utilises aquatic animals and plants low down in the food chain. This has a number of advantages, including (i) these species are either non-fed or require low-trophic feeds themselves, (ii) some low-trophic species e.g., algae provide opportunities for carbon sequestration, habitat enhancement, eutrophication remediation and other ecosystem services, and (iii) have lower environmental impacts i.e., lower GHG emissions and reduced land and freshwater uses. We also look at polyculture and IMTA that combines species with different ecological niches / trophic levels to provide spatial, resource input and GHG production efficiencies within a single system. A recent roundtable discussion hosted by the Horizon 2020-funded 'AquaVitae' project suggested that "*Low-trophic species' aquaculture shows great potential to support a shift in our food production from degenerative to regenerative systems and support a restoration of the marine environment for the benefit of our society*"[40].

a. Low-trophic species

For the purposes of this report, low-trophic species include both level 1 species (e.g., *producers* such as plants and algae make their own food) and Level 2 species (*primary consumers* such as herbivores eat plants). Level 1 low-trophic aquaculture species grown in European waters typically include macroalgae such as *Laminaria* spp. and *Saccharina* spp., with Level 2 species including bivalves (such as oysters, mussels and clams) that feed on phytoplankton) as well as herbivorous fish such as grass carp traditionally grown in earthen ponds. Species that are more novel include echinoderms (e.g., sea urchins), sea cucumbers, new macroalgae species (e.g., *Ulva* spp.) and microalgae. Some of these approaches are examined below, looking at the current state of the art and the barriers to their further uptake:

Macroalgae: The EU Farm to Fork Strategy specifically mentions "*well-targeted support for the algae industry, as algae should become an important source of alternative protein for a sustainable food system and global food security*". The EC communication on sustainable, competitive aquaculture[41] recognises that "*the farming of algae …, when appropriately managed, can offer many ecosystem services, [including] the absorption of excess nutrients and organic matter from the environment or the conservation and restoration of ecosystems and biodiversity*".

The EU Algae Initiative ("*Towards a Strong and Sustainable EU Algae Sector*") supports the production, safe consumption and innovative use of algae, address the challenges and opportunities of algae farming and propose concrete actions. It foresees macroalgae production moving in two, different directions (EC, 2023 e):

- **into deeper water**, potentially using infrastructure of other offshore activities such as wind farms or as extensive, floating, tethered/anchored or even mobile arrangements covering tens

[40] https://aquavitaeproject.eu/aquavitaes-policy-roundtable-how-to-sustainably-develop-europes-low-trophic-aquaculture/

[41] COM(2021) 236 final of 12 May 2021 on Strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021 to 2030.

or, conceptually, thousands of hectares and avoiding much of the MSP difficulties of closer-to-shore installations; in these conditions, brown seaweeds, mainly the kelps, are favoured.

- **onto land**, in raceways or tanks, equivalent to, and integrated with, trout and salmon RAS, or in juxtaposition with horticulture, or in tidal saltwater earthen ponds as practised by AlgaPlus Portugal, where growing conditions and the impacts of diseases can be better controlled; in these conditions, green and red seaweeds are favoured.

The EU Algae Initiative and others, as summarised in European Commission (2023), provide an extensive review of the barriers to expanding algal production in Europe. Many of these are either technical, market or regulatory in nature, largely stemming from the novelty of this rapidly growing sub-sector of EU aquaculture. On the latter, it is recognised that "*the single major stumbling block is the broad span of regulation covering algae, which limits the access of farming and harvesting to crop agricultural support regimes and allows production, processing, co-location and other activities to be subject to uncoordinated and incoherent systems of sea- and land-based legislation, permits and licensing operated by differing farming, fishing, marine spatial use and land-zoning authorities across the EU*" (European Commission, 2023 e). A key tool for solving this is MSP, but the first generation of marine spatial plans across the EU have largely been insufficiently forward-looking to recognise this (Riclet et al., 2023).

b. Polyculture and IMTA

Polyculture – the farming of species of different trophic levels to maximise efficiency - has been practised in Europe and elsewhere for many years e.g., with different species of carp in ponds. With both spaces becoming a premium, as well as the increasing cost of aquafeeds, polyculture models are being revived with new combinations of species and production systems (Amoussou et al., 2022). IMTA is an extension of this approach but puts more emphasis on the bioremediation and ecosystem services provided by differing crop combinations e.g., fed finfish / filter-feeding bivalves / extractive macroalgae. As monoculture is hampered by high input costs (such as electricity, medicine, and feed), environmental challenges (such as worsening waste and water quality), and social and economic concerns (such as vulnerability to shocks and loss of low-cost local protein sources), these IMTA potentials become ever more valuable (Hossain et al., 2022).

Although IMTA has been long advocated, including more recently by the new EU sustainable aquaculture guidelines, commercial-level uptake has been slow. This has been attributed to a variety of reasons, in particular monoculture-orientated aquaculture governance mechanisms e.g., permitting and regulation rarely support integrated, ecosystem-based aquaculture projects, thus inhibiting implementation and not rewarding the wider sustainability effects of IMTA operations. The lack of direct financial benefits for the farmer, and the need for more efficient integrated farming systems to reduce complexity and allow processing of all crops, as well as the need for better multi-disciplinary research support have also been blamed for the slow adoption of IMTA (Kleitou, et al., 2018).

3.3.2. Novel approaches to diversifying European aquaculture

The European aquaculture development has remained stubbornly slow and limited in diversity. With climate change-driven changes in environmental conditions, increasing raw material costs and changing consumer preferences, it is widely recognised that aquaculture will need to change in order to become more resilient, affordable and relevant. There are a number of approaches to achieving this, with some of these examined overleaf.

a. Enclosed and semi-enclosed open water systems

Much of the EU's finfish production, especially in seawater (e.g., salmon, sea bass and sea bream) is conducted in open water pens. A reasonably affordable, passive (e.g., relies on water currents rather than pumps) and relatively low-tech' approach, its expansion is increasingly limited by spatial limits, environmental concerns as well as conflict with other marine space users such as coastal tourism, vessel traffic and marine conservation requirements. One option is to move operations offshore into larger units away from the busy inshore coastal space, but this inevitably incurs higher costs as well as additional constraints such as adverse weather conditions and interactions with offshore marine activities e.g., shipping and wind farms.

Another option being increasingly explored, especially by the salmon farming industry in Norway and Scotland, is the use of enclosed or semi-enclosed open water systems. These allow more controllable conditions, including the ability to access colder water below the pens (important when summer sea temperatures can impact growth and mortality levels, as well as disease morbidity), as well as controlling the environmental impact of these usually high trophic level species production systems. These can vary in scale from the totally enclosed 21 metre (m) high composite 'Egget®' solution by Norwegian Hauge Aqua[42] to the Certus range (10 000 – 30 000 m^3) of semi-closed open water containment systems that use an industrial tarpaulin combined with pumps to control water exchange and waste collection[43]. Although considerably more expensive than traditional open water systems, they are being increasingly utilised in sensitive locations or where more controlled conditions may be required, either for local environmental reasons or to improve regulatory compliance.

b. Recirculating aquaculture systems

Recirculating aquaculture systems (RAS) are often advocated as the future for European aquaculture. These land-based systems use a combination of water treatment and multiple-level filtration, strong environmental monitoring and controllability to farm high densities of finfish in sites closer to markets than traditional open water systems. Increasingly used to produce 300 – 400 g portion-sized trout in Denmark, RAS systems have the potential takeover of the production of these smaller fish, while the traditional flow-through farms focus on the larger fish. RAS has the potential to reduce the emission of nitrogen, phosphorus, and organic material by 35%, 60% and 90%, respectively, per kilogram of produced fish (Technical University of Denmark, 2008).

However, RAS farms must operate at a large-scale in order to be profitable as the cost of filtration and effluent polishing is considerable (Nielsen et al., 2016). RAS businesses have a poor record for longevity, and a number of ventures have failed. Jeffery et al. (2014) identified poor system design, lack of attention to economic factors (e.g., electricity costs), and low demand for products (resulting in low price and sales volume) as the causes of failure. New entrants need to proceed with caution and optimise system design, economies of scale, input costs, and marketing and sales plans. In addition, experienced staff, system flexibility and further development of surrounding industry (i.e., fry supply and technological progress) remain critical if the RAS sector is to grow. Issues that remain can be addressed through a combination of research and development and the adoption of accreditation and quality labelling schemes.

If these issues can be overcome, then RAS has the potential to become a major contributor to European aquaculture and seafood production. Investment interest in RAS is currently very high and is likely to

[42] https://haugeaqua.com/technology/egget.
[43] https://fiizk.com/en/product/semi-closed-cage/ .

continue, even in the face of continued venture failures. With these failures comes experience, with new technology and operating procedures gradually reducing risk and increasing scalability.

c. Circular feed materials

Most aquafeeds, especially for higher trophic levels species such as salmonids, sea bass, sea bream and meagre, contain high levels of protein derived from both animals and increasingly, plant-based sources. The increased use of life cycle analyses (LCAs) (e.g., including Product Environmental Footprint, PEFs) are allowing decision-makers to factor in carbon footprint considerations to other commercial factors when purchasing raw materials. Most finfish LCAs have been conducted for salmon farming, where aquafeed production accounts for between 75 and 95% of the GWP, depending upon the nature and source of feed materials, where the use of animal proteins and by-products (i.e., poultry meal and oil, blood and mammalian meal) in the feed accounted for 70% of the final GWP (BIM, 2023). As a result, there is also increasing interest in the substitution of fish meal with circular feed materials such as black solder fly meals, as well as improved recycling of processed animal proteins from rendering plant facilities, such as feather meal (Ghamkhar & Hicks, 2020).

Various studies have looked at the potential for including insects as feed ingredients for finfish farming. Magalhães et al. (2017) looked at black soldier fly pre-pupae meal (BSFLM) as a fish meal replacement in diets for European seabass (*Dicentrarchus labrax*) and determined that up to 19.5% of BSFLM, corresponding to 22.5% of total dietary protein, may successfully replace fish meal in diets for juvenile European seabass, without adverse effects on growth performance, feed utilisation or digestibility. Alfiko et al. (2022) examined the potential for applying meals of eight insect species in formulated aquafeeds and discussed the issues of replacing fishmeal in fish feeds with insect meals. They suggest that most insect meals can be used to replace up to 30% of fish meals in diets, with higher rates in some aquaculture species, with the BSFLM being the closest substitute in terms of amino acid profile to fish meal.

Alfiko et al. (2022) noted a number of conditions for the successful substitution of fish meal with insect meals, such as the use of the right substrates to feed insects. They also recognise the challenges in scaling up insect meal production to industrial levels, such as the automation of insect culturing systems to reduce the cost of staff and energy. To compete with traditional protein sources, insect meals must have advantages in nutritional value and price, as well as year-round availability and consistent quality. More research is needed to optimise the nutritional values of insect meals for fish feeding. The use of insect meals as a replacement of fishmeal in aquafeeds requires the development of a legal framework and legislation, as well as the improvement of risk assessment procedures. It is also necessary to conduct research on the impact of feeding aquaculture species with insect meals on the safety, quality, and societal acceptance of seafood.

3.3.3. Application of the ecosystem approach to aquaculture

The ecosystem approach to aquaculture (EAA) was formalised by the Food and Agriculture Organisation (FAO) over a decade or so (FAO, 2010). The EAA has been defined as a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological systems (FAO, 2010). It is guided by three strategic principles:

- Aquaculture development and management should take account of the full range of ecosystem functions and services and should not threaten the sustained delivery of these to society.

- Aquaculture should improve human well-being and equity for all relevant stakeholders.
- Aquaculture should be developed in the context of other sectors, policies and goals, as appropriate.

A review of the application of the EAA (Brugère et al., 2019) that mainstreaming the EAA in planning processes has raised awareness of the usefulness of holistic and participatory approaches in aquaculture and helped to steer the sector towards greater sustainability. However, the approach has had varying degrees of resonance and uptake with different user groups, with limited actual buy-in from policy makers and regulators beyond high-level statements.

The emphasis on MSP that has developed as part of the EAA implementation efforts has been – and remains – an important part of the EU's approach to EAA (Galparsoro et al., 2018). However, efforts to mainstream the EAA in policy making have largely remained sectoral (i.e., focused on the fisheries and/or aquaculture sectors) and the EAA has fallen short of facilitating interaction with other users of resources, in spite of the fact that it involves multiple aquaculture and non-aquaculture interests (Brugère et al., 2019; Riclet et al., 2023). Galparsoro et al. (2020), when examining a vision for ecosystem-based marine aquaculture expansion from coastal to offshore areas, recommended that further aquaculture growth would be assisted by the standardisation and simplification of regulatory frameworks, improvement of governance, and the adoption of participatory processes to facilitate meaningful and productive stakeholder engagement.

On a more positive note, the recent EU aquaculture guidelines for sustainable aquaculture firmly recognises the role of responsible aquaculture in both minimising its environmental impact and maximising the opportunity for aquaculture to provide a wide range of ecosystem services. Given the linkages between these guidelines with the Member State Multi-annual National Strategic Plans for aquaculture and the EMFAF 2021-2027 public funding programme, there is a funded, medium-term policy implementation process for the EAA in Europe, although the degree to which this is actually undertaken in variable in practice.

4. POLICY RECOMMENDATIONS

Based on the analysis and the knowledge collated, it is evident that the EU's food security can be improved by ensuring the sustainability of fisheries and aquaculture production and its trade in seafood with the rest of the world. This final section provides policy recommendations centred on measures for effectively supporting **sustainable food production regarding fisheries and aquaculture** operations and their value chains, including:

- Policy measures to **unlock the benefits** of sustainable fish and aquaculture production.
- Policy measures that would further **strengthen EU's food security**, while not compromising the food security of non-EU countries.

4.1. Improving food security from sustainable EU fisheries production

4.1.1. Sustainable stocks targeted by EU fleets

Food security can only be assured if the supply of that food is from **sustainable production**. This principle should apply to all fisheries products, irrespective of source, i.e., **EU fisheries** production (EU stocks, shared stocks (with Norway, the UK etc.), as well as those targeted by EU fleets under SFPAs) and **fish imports**.

The improvements seen in many EU stocks show that fisheries **management is effective** when decision-making is based on **sound science**, and ideally within long-term management plans. The EU must continue efforts domestically under the CFP and internationally through its negotiations on shared fish stocks and SFPAs to move towards fisheries that are exploited at sustainable levels.

Ensure there is adequate funding and training for **fisheries science** to deliver on expanded suite of assessed stocks. The most appropriate management measures should be determined on a **fishery-by-fishery basis**. The level of compliance and investment in management measures is enhanced through **co-management** approaches that actively involve operators in decision-making.

Revision of the Control Regulation (EU) 1224/2009 is required to ensure EU stocks are fished sustainably and so will contribute to food security in the long term.

The EU should identify where additional efforts are required to comply with the **IUU Fishing** Action Alliance pledge[44].

SFPAs contain checks to try and avoid negative impacts on food security for the local population in the non-EU country. If designed with the right provisions within the protocols, such as is seen with Mauritania, could directly support food security in those non-EU countries.

The **social and cultural aspects** of fishing are important elements of ensuring a sustainable food system. Fishing needs to be presented as an attractive career option for young people, supported by training opportunities, presenting a clear career pathway and improvements to work conditions. Fishing remains one of the most dangerous professions: **health and safety improvements** should be an important part of any sustainable production policy.

[44] https://www.gov.uk/government/publications/illegal-unreported-and-unregulated-fishing-action-alliance-pledge/illegal-unreported-and-unregulated-fishing-action-alliance-pledge .

4.1.2. Reducing the emissions from the fishing vessels

Two mutually reinforcing strands of actions can be pursued to **reduce the energy intensity** and **carbon footprint** of fisheries and aquaculture:

- **lower the energy needs** per kilogram of landed or farmed fish and,
- switch to **clean and renewable energy** sources.

Substantial **funding** is required to support the sector in improving **fuel efficiency** in the first instance and ultimately to decarbonise the sector. Structural funding should also extend to support the **infrastructure** required to enable fishing fleets to take up **alternative fuels**, recognising that this may well be in collaboration with other maritime sectors.

The fisheries and aquaculture sector should learn from **innovations in other sectors**, such as shipping and maritime transport. Effective cooperation is needed to link seafood producers and supply chain operators with those researchers, technology providers and operators in other sectors to ensure synergies and knowledge-sharing. The **Energy Transition Partnership** (ETP) knowledge-sharing platform that is to be established by the Commission should ensure innovators from other sectors are included.

Part of the ETP work stream should include addressing **regulatory and management** measures to identify where **fuel efficiency can be incentivised**, and barriers removed.

The **EMFAF eligibility** conditions (including fleet capacity imbalance) should be reviewed to ensure they do not prevent investments by the fleet segments that are most in need of fuel efficiency improvements.

Other potential measures to encourage energy efficient fisheries include:

- **Preferential quota allocation** towards more fuel-efficient gears and vessels.
- International harmonisation of **fuel taxes**.
- **Fuel-monitoring** tools on board vessels.

4.1.3. Addressing the environmental impacts of fisheries production

Sustainable stocks are only one part of ensuring sustainable fisheries production. There is also a need to tackle the most significant impacts of wild capture fisheries on the environment, through **reducing benthic impact** on sensitive habitats and **reducing bycatch** of unwanted catch (juveniles and vulnerable species).

Expanding the EU's **MPA network** and providing **effective protection** to habitats and species in those MPAs can be positive for EU fisheries production due to spill over effects.

The consequences of **fleet displacement** must be addressed, including the environmental impact of more intensive fishing in 'open' sea areas and the socio-economic impact of restrictions.

A transition to **low-impact fishing gears** where feasible (driven by lower fuel use as well as reduced benthic impact) should be supported with independent and robust research, funding and regulation, e.g., via preferential licensing and quota allocation.

A transition to low-impact gears has the **potential to impact EU production** as static gears tend to catch less than mobile gears such as bottom trawl. This is likely to only be **partially compensated** by the increased productivity from sustainable stocks. For economic operators, lower catches can be partly compensated by **higher prices** being paid for improved **catch quality** (e.g., line-caught hake

compared to trawl caught) and **premiums** for this lower environmental impact, if effectively communicated to consumers. In terms of **food security**, compensating for a lower volume of wild catch is likely to be **compensated for with aquaculture production**, which itself needs to be sustainable (see below).

Technical gear measures intended to **reduce bycatch** of sensitive species and benthic impact should not in most instances significantly impact EU fisheries production. Improving the **selectivity of gear** to reduce juvenile bycatch can help to **optimise catches** and **stock productivity**.

4.2. Improving food security from EU aquaculture production

This section provides a synthesis of policy approaches for more environmentally friendly **aquaculture** production.

4.2.1. Formal adoption of the ecosystem approach to aquaculture

The key premise to the **ecosystem approach to aquaculture** (EAA) is integrating aquaculture sector into the wider **environmental and social-economic space** that underpins the sustainable development of the **blue economy**. While – as mentioned above – the Strategic **guidelines for a more sustainable and competitive EU aquaculture** do fully embrace both the need to be environmentally responsible and provide ecosystem services where appropriate, they do not specifically acknowledge the EAA, nor does this seem to be part of the wider EU policy approach to sustainable aquaculture development. Based on this we recommend the following:

- DG MARE, together with partners such as DG ENV and the Aquaculture Advisory Council (AAC), conduct a formal **review of the EAA** and how EU aquaculture policy and member State guidance might be updated to reflect lessons learned from this exercise. This might be conducted with the newly established Aquaculture Assistance Mechanism (AAM).
- Following this, the **AAM work with Member States and the industry** (e.g., via the AAC) to ensure the EAA is fully embedded in the national **MANPs and EMFAF Operational Programmes** over the funding period of 2021 to 2027, focusing on both those incremental elements that facilitate fulfilling the Green Deal and those addressing gaps in a holistic ecosystem approach to a sustainable aquaculture development.
- The AAC and Member States follow-up with the aquaculture industry, developing **codes of good practice** and other mechanisms to encourage responsible behaviour in the sector.

4.2.2. Encourage low-trophic aquaculture and healthy consumption

Food production from **low-trophic aquaculture** in the EU is **currently mainly in the form of bivalve production**, such as mussels, oysters and clams, with some lower-trophic finfish such as herbivorous carps. There are two main policy approaches to expand and diversify this rather staid and traditional part of European aquaculture:

- Most bivalve aquaculture is currently extensive in nature and largely practised by small holders. This works well, providing both good jobs for coastal communities and integrates efficiently into the local blue economy. However, there is a **need to develop** a parallel bivalve and other edible **low-trophic species in deeper water**, more **offshore** locations and at a larger scale. This will both expand production as well as help the industry adapt to warming waters and other environmental issues. This will need Member State encouragement, including sympathetic and forward-looking permitting as well as technical developments that will allow offshore low-trophic aquaculture to remain commercially viable in these challenging offshore

locations. Again, the progressive and enlightened use of **MSP in allocating space** for such aquaculture will be key.

- Kim et al. (2020) emphasis that **shifts towards 'plant-forward' diets** comprised of plant foods with modest amounts of low-trophic level animals (i.e., forage fish, bivalve molluscs, insects) with comparably small GHG and water footprints would have a combination of net-zero, health and resource benefits. This suggests that encouraging and enabling **consumers** to increase the contribution of these lower-trophic alternatives as part of a **balanced diet** could have considerable cumulative advantages (Ghamkhar et al., 2021). This will need to be implemented through a range of approaches, including product development as well as consumer information provision. The Danish Ministry of Food, Agriculture, and Fisheries has recently announced their funding the development of a 'climate label' for food, making Denmark the first EU country to do so[45].

4.2.3. Encourage the provision of ecosystem services from aquaculture

Combining aquaculture production with **ecosystem service** provision is not a new strategy. It is increasingly recognised as a progressive approach that can be used for bay or even sea basin level ecosystem accounting e.g., nutrient budgets. It is therefore suggested that a more proactive approach is considered to the use of aquaculture-derived ecosystem services e.g., carbon **sequestration** or **nutrient assimilation** for sea basin management. This would be primarily a **public sector** function, but could also engage the **private sector**, either through **public – private partnerships** to establish large-scale, hybrid / non-commercial solutions e.g., algal culture that was used to remove carbon, nutrients and possibly heavy metals for either harvesting for terrestrial use or sinking in deep water as a long-term sequestration approach.

4.2.4. Use of innovative technology and approaches to reduce the environmental impact of aquaculture

While the emphasis of this report has been on encouraging the production of low-trophic species, there is a recognition that the **farming of higher trophic species** such as sea bass, sea bream, trout and others **will continue to thrive**, especially as wild fisheries are unable to fulfil demand. There are two areas of particular interest to policy makers which are described briefly below.

- **Adding controllability to open water pen farming**. Open water pen (cage) farming is now a familiar sight in the bays of the Mediterranean and elsewhere and is a proven, affordable system. However, a combination of climate change and the increasing scale of production has made these systems both vulnerable to – and a contributor to – local environmental changes (e.g., eutrophication). There is a need to provide additional control to these systems e.g., water circulation, temperature and waste management, to ensure they remain resilient and sustainable as production systems. Again, this will require innovative thinking in terms of pen design and stock containment, as well as in how these systems are permitted, located and overall capacity controlled. Much of the current **MSP** lacks this imagination and forward thinking, as does most **licensing** and **permitting systems**.
- **Environmental management of coastal and marine aquaculture sites**. Many open water pen systems are located in environmentally dynamic locations in order to maximise water exchange, with an increasing tendency to move installations offshore. These are at a higher risk of equipment failure and loss (GGGI, 2021), adding to the marine plastic pollution load. **Codes of good practice**, as well as **regulatory mechanisms** where possible, need to encourage

[45] https://www.dailyscandinavian.com/voluntary-climate-labelling-in-denmark/

responsible behaviour, reduced risk and ensure adherence with the new single use plastic (**SUP**) and ports reception facility **(PRF) directives**.

4.2.5. Encourage the use of circular techniques

The increasing use of LFA or PER analytical techniques have revealed the true environmental costs (e.g., in terms of the global warming potential) of **aquaculture value chains** that have been shaped by commercial and logistical considerations. It is important that these hitherto **hidden** or **unaccounted** for **costs are now included** in both political and business **decision-making** and a broad reset in thinking made to ensuring **affordable yet sustainable seafood** across the value chain, from producer to consumer. A key area of this will be in **aquafeed** production and **transportation**, given this contributes to the bulk of the GWP of farmed finfish in Europe (BIM, 2023).

As discussed above, the commercial development of **novel circular feed materials** such as black solder fly meals, as well as improved recycling of processed animal proteins from rendering plant facilities, such as feather meal is an important approach to this. This implies that **policy support** to scaling up the commercial production of these new raw materials, as well as ensuring their short, low-carbon distribution to feed mills and farming sites, is provided. Again, this will likely require a **strong partnership** between the **public** sector, **research** and the **private** sector.

In addition, a responsible, **circular approach** by aquaculture companies can reduce raw material costs and wastage. For instance, the improved decommissioning and recycling of pen collars and other large and single use plastic components could have substantial gains in both GWP and other environmental terms[46].

4.2.6. Encourage climate change mitigation

Finally, the **aquaculture** sector will need to **contribute to climate change mitigation** e.g., avoiding and reducing aquaculture's contribution of emissions of heat-trapping greenhouse gases e.g., from animal respiration, refrigeration and transportation. Approaches include:

- Use **audits** of energy and other ecological resources **across aquaculture value chains** as a guide for management decisions.
- Make **information** on energy and other ecological resource impacts and efficiency measures **accessible to producers**.
- Review and improve **certification standards**, Good Aquaculture Practices, Codes of Practices and other industry management codes and guidance documents to ensure they reflect ecologically efficient approaches to farm management and value chains.
- Facilitate **cross-sectoral comparisons** and **dialogue on best practices** in food production within the livestock, fisheries and agriculture sectors.
- Examine thoroughly the relative benefits of the various animal production sectors and consider **policy drivers** that can **shift towards a more ecologically efficient production** portfolio.
- **Avoid siting aquaculture farms** in those wetland or **coastal ecosystems with high values** as sinks for sequestration of carbon, other greenhouse gases or nutrients.

[46] Sundt et al in 2014 estimated that 11 kg of plastic waste is generated for every tonne of aquaculture product output in Norway. More recently, Sundt (2018) estimates that in Norway 25,000 tonnes of plastic from aquaculture is discarded at sea annually (e.g. net pen collars, pipes, nets, feed hoses and ropes).

4.3. Improving food security of imported seafood

Trends in consumption and trade show that the **EU will continue to rely on seafood imports**. It must make every effort to support sustainable production and supply from those imports so that it is not supporting unsustainable practices in non-EU countries.

4.3.1. Support international producers in sustainable seafood production

- **Improved regional management** via support to Regional Fishery Management Organisations and ensuring the EU is proactive in decision-making by RFMOs that improves the sustainability of fisheries and reduces their impact on marine ecosystems, i.e., ensuring consistency with the principles of the CFP.
- Support **marine resource management** initiatives by **non-EU countries**, including via **EU development funding** and sector development support provided through **SFPA protocols**.
- Increase **knowledge-sharing** from EU expertise and capacity building **in non-EU countries** on sustainable aquaculture production.

4.3.2. Ensure a level playing field for EU producers

A **level playing field** through **equitable trade policies** is required to encourage EU producers to operate sustainability and remain competitive, including:

- Ensure **imported seafood** is produced to high and well-defined **environmental standards**, including through the revision of **marketing standards** to cover more imported seafood products and the inclusion of environmental criteria within those market standards;
- Improved **traceability systems** in the EU and non-EU countries exporting to the EU to minimise seafood fraud, including supporting improvements in compliance with the Catch Certificate Scheme;
- Implementing and enforcing clear consumer **labelling** rules (preventing 'greenwashing' from misleading or environmental information) and promoting consumer awareness-raising activities.

4.4. Improving food security in the seafood supply chain

The **huge variety of species** and products that makes up 'seafood' will continue to be **widely traded**. **Improved supply chains** can actively contribute to food security by ensuring supplies and reducing food waste. Food security can also be enhanced if the future **demand from EU consumers** is more sustainable.

4.4.1. Improving the efficiency of supply chains

Efficient supply chains improve food security through **reducing food waste** and **reduce emissions**. This can be achieved through:

- Incentivising **shorter supply chains** to reduce long-haul transport of seafood, which **reduces** supply chain **emissions** and the risks to food security from **disruptions to logistics**, as experienced during the COVID-19 pandemic;
- Increasing **value added processing** at point of EU production. Doing **more at point of landing** reduces supply chain emissions and has socio-economic benefits for European producers. Recognising the labour shortages in EU seafood processing, this is expected to rely on **increased automation** with fewer, but **higher skilled jobs**; and

- Reduce **spoilage/wastage** by developing **improved catch/harvest** from point of production and more **efficient cold chains** in the EU and non-EU country suppliers.

4.4.2. Sustainable diets and consumption

Encourage **EU dietary shifts** towards sustainable choices and **consumption patterns**:

- Promoting **'low-carbon' and healthy seafood** choices, such as small pelagics and low-trophic cultured species;
- Product **innovation** to create attractive, convenient products from low-carbon sources and to increase the use of by-products from seafood production and processing; and
- Improved consumer **information on nutrition** and environmental impact of seafood production.

REFERENCES

- AAC (2022) *Recommendation on carbon sequestration by molluscs AAC* 2022-16 April 2022. https://aac-europe.org/en/publication/aac-recommendation-on-carbon-sequestration-by-molluscs/
- AECID (2016) *Évaluation à mi-parcours du programme Amélioration de l'Accès de la Population Mauritanienne à la Consommation de Poisson comme Renforcement de la Sécurité Alimentaire* https://www.cooperacionespanola.es/evaluation-de-lacces-de-la-population-mauritanienne-a-la-consommation-de-poisson-comme-renforcement-de-la-securite-alimentaire/
- Alfiko, Y., D. Xie, R. Tri Astuti, J. Wong & L. Wang (2022). *Insects as a feed ingredient for fish culture: Status and trends*, Aquaculture and Fisheries, Volume 7, Issue 2, 2022, Pages 166-178, https://doi.org/10.1016/j.aaf.2021.10.004.
- Amoussou, N., M. Thomas, A. Pasquet & T. Lecocq (2022). *Finding the Best Match: A Ranking Procedure of Fish Species Combinations for Polyculture Development.* Life 2022, 12, 1315. https://doi.org/10.3390/life12091315
- Barange, M., T. Bahri, M. Beveridge, K. Cochrane, S. Funge-Smith & F. Poulain, eds. (2018). *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options*. FAO Fisheries and Aquaculture Technical Paper No. 627. Rome, FAO. 628 pp. https://www.fao.org/3/i9705en/i9705en.pdf
- Bastardie, F., Feary D. A., Kell, L., Brunel, T., Metz, S., Döring, R., Ritzau Eigaard, O., Basurko, O. C. (2022a). *Climate change and the Common Fisheries Policy: adaptation and building resilience to the effects of climate change on fisheries and reducing emissions of greenhouse gases from fishing. Final Report*. https://op.europa.eu/en/publication-detail/-/publication/74753858-3fab-11ed-92ed-01aa75ed71a1/language-en
- Bastardie F, Feary DA, Brunel T, Kell LT, Döring R, Metz S, Eigaard OR, Basurko OC, Bartolino V, Bentley J, Berges B, Bossier S, Brooks ME, Caballero A, Citores L, Daskalov G, Depestele J, Gabiña G, Aranda M, Hamon KG, Hidalgo M, Katsanevakis S, Kempf A, Kühn B, Nielsen JR, Püts M, Taylor M, Triantaphyllidis G, Tsagarakis K, Urtizberea A, van Hoof L and van Vlasselaer J (2022b). *Ten lessons on the resilience of the EU common fisheries policy towards climate change and fuel efficiency - A call for adaptive, flexible and well-informed fisheries management.* Front. Mar. Sci. 9:947150. https://doi.org/10.3389/fmars.2022.947150
- BIM (2023). *Carbon Footprint report of the Irish Seafood Sector.* 98 pp. https://bim.ie/wp-content/uploads/2023/02/BIM-Carbon-footprint-report-of-the-Irish-Seafood-Sector-1.pdf
- Brugère, C., Aguilar-Manjarrez, J., Beveridge, M.C.M. and Soto, D. (2019). *The ecosystem approach to aquaculture 10 years on – a critical review and consideration of its future role in blue growth*. Rev Aquacult, 11: 493-514. https://doi.org/10.1111/raq.12242
- Caillart, B., Cappell, R., Defaux, V. & Macfadyen, G. (2021). *Evaluation and analysis of the Sustainable Fisheries Partnership Agreements (SFPAs) between the EU and third countries including an in-depth analysis of the sectoral support component of the SFPAs*. Report to EC DG MARE, December 2021.
- Cappell, R. & Nimmo F. (2020) '*Sustainable European Fisheries: Are We There Yet? Progress and Challenges for Fisheries Management.' In "Too Valuable to be Lost. Overfishing in the North Atlantic"* edited by Álvaro Garrido and David J Starkey. In press.

- Cappell, R., MacNab, S. & Holland, A. (2022). *Assessment of NI Fleet Emissions*. Report for ANIFPO/NIFPO May 2022.
- Carpenter, G., N. Carvalho, J. Guillen, R. Prellezo, S. Villasante, J. L. Andersen, E. Avdic Mravlje, J. Berkenhagen, C. Brigaudeau, B. Burke, A. Calvo Santos, S. Cano, F. Contini, J.-M Da-Rocha, I. Davidjuka, F. M. Fernández Martínez, I. Fontaneda-López, M. Gambino, E. Garcia Caballero, O. Guyader, J. Herring, G. Hoekstra, M. Ioannou, E. Jackson, A. Jung, E. Kazlauskas, M. Keatinge, E. Kuzebski, S. Leonardi, C. Le Grand, J. Lees, C. Margarita Mancebo-Robledo, M-D Minne, A. Mol, M. Moran Quintana, S. Nicheva, H. Pokki, J. Ramos Do Ó, A. Rodríguez, R. Felicità Sabatella, A. Sciberras, A. Souffez, C. Stroie, H. Swahnberg, I. Tzouramani, M. Valiente Viana, K. Verlé, J. Virtanen, I. Vukov, K. Zhelev (2023). *The economic performance of the EU fishing fleet during the COVID-19 pandemic*. Aquat. Living Resour. 36 2 (2023). DOI: 10.1051/alr/2022022
- Cascarano, M, Stavrakidis-Zachou, O., Mladineo, I., Thompson, K., Papandroulakis, N. & Katharios, P. (2021). *Mediterranean Aquaculture in a Changing Climate: Temperature Effects on Pathogens and Diseases of Three Farmed Fish Species*. Pathogens 2021, 10, 1205. https://doi.org/10.3390/pathogens10091205
- DAI (2015). Étude sur l'évolution des pêcheries de petits pélagiques en Afrique du Nord-Ouest et impacts possibles sur la nutrition et la sécurité alimentaire en Afrique de l'Ouest. Rapport final. DG DEVCO ARES (2015) 2984964
- DG Agri (2023) Monitoring EU Agri-food Trade. Developments in 2022. Published March 2023. https://agriculture.ec.europa.eu/system/files/2023-04/monitoring-agri-food-trade_dec2022_en.pdf
- EASME (2018) European Commission, Executive Agency for Small and Medium-sized Enterprises, Hattam, C., Russi, D., Haines, R., et al., *Study on the economic benefits of marine protected areas : literature review analysis*, Publications Office, 2018, https://data.europa.eu/doi/10.2826/40733
- European Commission (2019). *The European Green Deal*. COM(2019) 640 Final of 11 December 2019.
- European Commission (2019b) Study – Evaluation of the marketing standards framework for fishery and aquaculture products.
- European Commission (2020) *Farm to Fork Strategy. For a fair, healthy and environmentally-friendly food system.*
- European Commission (2021a). *Statistic Factsheet – European Union*. 23 pp. Downloaded from https://agriculture.ec.europa.eu/system/files/2022-01/agri-statistical-factsheet-eu_en_0.pdf on 5 January 2023.
- European Commission (2021b) Evaluation and analysis of the Sustainable Fisheries Partnership Agreements (SFPAs) between the EU and third countries including an in-depth analysis of the sectoral support component of the SFPAs. Main authors: Benoit CAILLART, Rod CAPPELL, Vincent DEFAUX, Graeme MACFADYEN Date: 9 December 2021
- European Commission (2022a). *Facts and Figures on the Common Fisheries Policy*. https://op.europa.eu/en/publication-detail/-/publication/c2f39f4a-29a2-11ed-975d-01aa75ed71a1
- European Commission (2022b). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Towards a Strong and Sustainable EU Algae Sector*, COM(2022) 592 final. of 15 November 2022.

- European Commission (2023a). *The common fisheries policy today and tomorrow: a Fisheries and Oceans Pact towards sustainable, science-based, innovative and inclusive fisheries management*, COM(2023) 103 final of 21 February 2023.
- European Commission (2023b). *Implementation of Regulation (EU) No 1379/2013 on the common organisation of the markets in fishery and aquaculture products*. Report from the Commission to the European Parliament and the Council. COM(2023) 101 final of 21 February 2023.
- European Commission (2023c). *On the Energy Transition of the EU Fisheries and Aquaculture sector*. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. COM(2023) 100 final of 21 February 2023.
- European Commission (2023d). *EU Action Plan: Protecting and restoring marine ecosystems for sustainable and resilient fisheries*. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. COM(2023) 102 final of 21 February 2023.
- European Commission (2023e). *Blue Bioeconomy Report*. EUFOMA Report, January 2023. https://www.eumofa.eu/documents/20178/84590/blue+bioeconomy+report+2022+final.pdf/eb889d94-74a6-2c15-e136-4d2204118c6a?t=1673441855108
- ECA (2022) EU action to combat illegal fishing: Control systems in place but weakened by uneven checks and sanctions by Member States. Special report 20. https://www.eca.europa.eu/Lists/ECADocuments/SR22_20/SR_Illegal_fishing_EN.pdf
- EUFOMA (2020). *Recirculating Aquaculture Systems*. December 2020. Directorate-General for Maritime Affairs and Fisheries, B-1049 Brussels. 45 pp. https://www.eumofa.eu/documents/20178/84590/RAS+in+the+EU.pdf/c9ee5f4c-a41d-160e-e9cc-17a19228d669?t=1606927186649
- EUMOFA (2021). *The EU Fish Market. Highlights the EU in the world market supply consumption import – export landings in the EU aquaculture*. 2021 edition. Directorate-General for Maritime Affairs and Fisheries, B-1049 Brussels. 105 pp.
- EUMOFA (2022) The EU Fish Market 2022 Edition. https://eumofa.eu/documents/20178/521182/EFM2022_EN.pdf/5dbc9b7d-b87c-a897-5a3f-723b369fab08?t=1669739251587
- European Parliament (2022a). European Parliament resolution of 9 May 2023 on *co-management of fisheries in the EU and the contribution of the fisheries sector for the implementation of management measures* (2022/2003(INI)). Downloaded from https://www.europarl.europa.eu/doceo/document/TA-9-2023-0132_EN.pdf.
- European Parliament (2022b). European Parliament resolution of 4 October 2022 on *striving for a sustainable and competitive EU aquaculture: the way forward* (2021/2189(INI)). Downloaded from https://www.europarl.europa.eu/doceo/document/TA-9-2022-0334_EN.pdf.
- FAO (2010). *Aquaculture Development. 4. Ecosystem Approach to Aquaculture*. FAO Technical Guidelines for Responsible Fisheries. No. 5, Suppl. 4. FAO, Rome. http://www.fao.org/docrep/013/i1750e/i1750e00.htm
- FAO (2020). *The State of Mediterranean and Black Sea Fisheries 2020. General Fisheries Commission for the Mediterranean*. Rome. https://doi.org/10.4060/cb2429en Last updated 10/03/2021.

- FAO (2022). *The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation.* Rome, FAO. https://doi.org/10.4060/cc0461en
- FAO. (2020b). *Proceedings of the International Symposium on Fisheries Sustainability: strengthening the science-policy nexus.* FAO Headquarters, 18–21 November 2019. FAO Fisheries and Aquaculture Proceedings No. 65. Rome. https://doi.org/10.4060/ca9165en
- Filgueira R, C. J. Byron, L. A. Comeau, B. Costa-Pierce, P. J. Cranford, J. G. Ferreira, J. Grant, T. Guyondet, H. M. Jansen, T. Landry, C. W. McKindsey, J. K. Petersen, G. K. Reid, S. M. C. Robinson, A. Smaal, R. Sonier, Ø. Strand & T. Strohmeier (2015). *An integrated ecosystem approach for assessing the potential role of cultivated bivalve shells as part of the carbon trading system.* Marine Ecology Progress Series 518: 281–287.
- Fox, M., Mitchell, M., Dean, M., Elliott, C., & Campbell, K. (2018). *The seafood supply chain from a fraudulent perspective.* Food Security: The Science, Sociology and Economics of Food Production and Access to Food, 10(4), 939. https://doi.org/10.1007/s12571-018-0826-z
- Froehlich H.E., J.C. Afflerbach, M. Frazier & B.S. Halpern (2019). *Blue growth potential to mitigate climate change through seaweed offsetting.* Current Biology 29: 3087–3093.e3083.
- Froehlich, H.E., Gentry, R.R. & Halpern, B.S. (2018). *Global change in marine aquaculture production potential under climate change.* Nat. Ecol. Evol. 2, 1745–1750 (2018). https://doi.org/10.1038/s41559-018-0669-1
- Galparsoro, I., Murillas, A., Pinarbasi, K., Sequeira, A.M.M., Stelzenmüller, V., Borja, Á., O´Hagan, A.M., Boyd, A., Bricker, S., Garmendia, J.M., Gimpel, A., Gangnery, A., Billing, S.-L., Bergh, Ø., Strand, Ø., Hiu, L., Fragoso, B., Icely, J., Ren, J., Papageorgiou, N., Grant, J., Brigolin, D., Pastres, R. and Tett, P. (2020). *Global stakeholder vision for ecosystem-based marine aquaculture expansion from coastal to offshore areas.* Rev. Aquacult., 12: 2061-2079. https://doi.org/10.1111/raq.12422
- Galparsoro, I.; A. Murillas, K. Pinarbasi, Á. Borja, A. M. O´Hagan E. MacMahon, A. Gangnery, R. Corner, J. Ferreira, R. Ferreira, A. Gimpel, A. Boyd, J. Icely, Ø. Bergh, C. Donohue, H. Lui, S. Billing, J. M. Garmendia, L. Lagos and L. Arantzamendi (2018). *Synthesis of the lessons learned from the development and testing of innovative tools to support ecosystem-based spatial planning to aquaculture. Deliverable 5.1;* AquaSpace: EcosystemApproach to making Space for Aquaculture. EU Horizon 2020 project grant nº. 633476. 106 pp. http://www.aquaspace-h2020.eu/wp-content/uploads/2018/09/AquaSpace-D5-1-Synthesis-revised-Apr2018.pdf
- García-Isarch, E., Gascuel, D., Guijarro, E., Gaertner, D., Merino, G., Coelho, R., Rosa, D., Murua, H., Wakeford, R., Jouffre, D., Figueiredo, I., and Abaunza, P. 2016. *Scientific advice on the estimation of surplus for Sustainable Fisheries Partnership Agreements.* Specific Contract No. 10 under Framework Contract No. MARE/2012/21. Final Report. April 2016. 133 pp.
- Ghamkhar, R., & A. Hicks (2020). *Comparative environmental impact assessment of aquafeed production: Sustainability implications of forage fish meal and oil free diets.* Resources, Conservation & Recycling 161 (2020) 104849. https://doi.org/10.1016/j.resconrec.2020.104849
- Ghamkhar, R., S. Boxman, K. Main, Q. Zhang, M. Trotz & A. Hicks (2021). *Life cycle assessment of aquaculture systems: Does burden shifting occur with an increase in production intensity?* Aquacultural Engineering 92 (2021) 102130
- Global Ghost Gear Initiative (2021). *Best Practice Framework for the Management of Aquaculture Gear.* Prepared by Huntington, T. of Poseidon Aquatic Resources Management Ltd. for the Global

Ghost Gear Initiative. 81 pp. plus appendices. https://www.ghostgear.org/news/aquaculture-best-practice-framework

- Hoegh-Guldberg. O., et al. 2019. *The Ocean as a Solution to Climate Change: Five Opportunities for Action*. Report. Washington, DC: World Resources Institute. Available online at http://www.oceanpanel.org/climate
- Holmyard, N. (2014). *Climate Change: Implications for Fisheries & Aquaculture*. Key Findings from the Intergovernmental Panel on Climate Change (IPCC). Fifth Assessment Report. University of Cambridge.
- Hossain, A., P. Senff & M. Glaser (2022). *Lessons for Coastal Applications of IMTA as a Way towards Sustainable Development: A Review*. Appl. Sci. 2022, 12, 11920. https://doi.org/10.3390/app122311920
- Huntington, T (2022). *European Aquaculture and Climate Change Adaptation and Mitigation - Advice to the Aquaculture Advisory Council*. Final Report produced by Poseidon Aquatic Resources Management Europe Ltd for the AAC. 27 pp plus appendices.
- IPBES (2019) The global assessment report on Biodiversity and Ecosystem Services: Summary for Policymakers https://www.ipbes.net/sites/default/files/inline/files/ipbes_global_assessment_report_summary_for_policymakers.pdf
- IPCC (2019). *Summary for Policymakers. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3–35. https://doi.org/10.1017/9781009157964.001.
- Jeffery, K., N. Stinton & T. Ellis (2014). *A review of the land-based, warm-water recirculation fish farm sector in England and Wales*. Project FES220, Cefas contract report <C3529 >. 48 pp.
- Jones, A., H. Alleway, D. McAfee, P. Reis-Santos, S. Theuerkauf and R. Jones (2022). *Climate-Friendly Seafood: The Potential for Emissions Reduction and Carbon Capture in Marine Aquaculture*, BioScience, Volume 72, Issue 2, February 2022, Pages 123–143, https://doi.org/10.1093/biosci/biab126
- Kim, B., R. Santo, A. Scatterday, J. Fry, C. Synk, S. Cebron, M. Mekonnen, A. Hoekstra, S. de Pee, M. Bloem, R. Neff & K. Nachman (2020). *Country-specific dietary shifts to mitigate climate and water crises*. Global Environmental Change, Vol. 62, https://doi.org/10.1016/j.gloenvcha.2019.05.010.
- Kleitou, P., D. Kletou & J. David (2018). *Is Europe ready for integrated multi-trophic aquaculture? A survey on the perspectives of European farmers and scientists with IMTA experience*, Aquaculture, Volume 490, 2018, Pages 136-148, https://doi.org/10.1016/j.aquaculture.2018.02.035.
- Lawrence, S. J., Elliott, C., Huisman, W., Dean, M., & van Ruth, S. (2022). *The 11 sins of seafood: Assessing a decade of food fraud reports in the global supply chain*. Comprehensive Reviews in Food Science and Food Safety, 21, 3746– 3769. https://doi.org/10.1111/1541-4337.12998
- Love, D., E. H. Allison, F. Asche, B. Belton, R. S. Cottrell, H. E. Froehlich, J. A. Gephart, C. C. Hicks, D. C. Little, E. M. Nussbaumer, P. Pinto da Silva, F. Poulain, A. Rubio, J. S. Stoll, M. F. Tlusty, A. L. Thorne-Lyman, M. Troell & W. Zhang (2021), *Emerging COVID-19 impacts, responses, and lessons for*

building resilience in the seafood system, Global Food Security, Volume 28, 2021, 100494, ISSN 2211-9124, https://doi.org/10.1016/j.gfs.2021.100494.

- Magalhães, R., A. Sánchez-López, R. Silva Leal, S. Martínez-Llorens, A. Oliva-Teles & H. Peres (2022). *Black soldier fly (Hermetia illucens) pre-pupae meal as a fish meal replacement in diets for European seabass (Dicentrarchus labrax)*, Aquaculture, Volume 476, 2017, Pages 79-85, https://doi.org/10.1016/j.aquaculture.2017.04.021.
- Melnychuk M. C., Baker N., Hively D., Mistry K., Pons M., Ashbrook C. E., Minto C., Hilborn R. & Ye Y. (2020). *Global trends in status and management of assessed stocks: achieving sustainable fisheries through effective management*. FAO Fisheries and Aquaculture Technical Paper No. 665. FAO, Rome. https://doi.org/10.4060/cb1800en
- Moore, D. (2020). *A biotechnological expansion of shellfish cultivation could permanently remove carbon dioxide from the atmosphere*. Mexican Journal of Biotechnology 2020, 5(1):1-105. 1-10. http://dx.doi.org/10.29267/mxjb.2020.5.1.1
- Moore, D., M. Heilweck & P. Petros (2022). Cultivate Shellfish to Remediate the Atmosphere. In Aquaculture: Ocean Blue Carbon Meets UN-SDGS. http://dx.doi.org/10.1007/978-3-030-94846-7_2 .
- Munari C, E. Rossetti & M. Mistri (2013). *Shell formation in cultivated bivalves cannot be part of carbon trading systems: A study case with Mytilus galloprovincialis*. Marine Environmental Research 92: 264–267.
- Nielsen, R., F. Asche & M. Nielsen (2016). *Restructuring European freshwater aquaculture from family-owned to large-scale firms – lessons from Danish aquaculture*. Aquaculture Research 47, 3852–3866 https://doi.org/10.1111/are.12836
- Nielsen, R., S. Villasante, J. M. Fernandez Polanco, J. Guillen, I. Llorente Garcia & F. Asche (2023). *The Covid-19 impacts on the European Union aquaculture sector*, Marine Policy, Volume 147, 2023, 105361, ISSN 0308-597X, https://doi.org/10.1016/j.marpol.2022.105361.
- Nimmo, F., R. Cappell, T. Huntington and A. Grant (2011). *Does fish farming impact on tourism in Scotland?* Aquaculture Research 42(s1). 132-141 https://onlinelibrary.wiley.com/doi/full/10.1111/j.1365-2109.2010.02668.x
- Perry, A.L., Blanco, J., Fournier, N., Garcia, S. & Marín, P. (2020). *Unmanaged = Unprotected: Europe's marine paper parks*. Oceana, Brussels. 52 pp. https://europe.oceana.org/wp-content/uploads/sites/26/d_files/oceana_2020_unmanaged_equals_unprotected_marine_paper_parks.pdf
- Quaas MF, Hoffmann J & Kamin K (2016) *Fishing for proteins. How marine fisheries impact on global food security up to 2050. A global prognosis*. WWF Germany, Hamburg
- Riclet, E., T. Huntington & F. Herpers (2023). *Access to space and water for marine aquaculture*. Produced by the European MSP Platform under the Assistance Mechanism for the Implementation of Maritime Spatial Planning. 60 pp. https://cinea.ec.europa.eu/system/files/2023-01/HZ-08-22-345-EN-N.pdf
- Saraiva, J., J. Volstorf, M. Cabrera-Álvarez & P. Arechavala-Lopez (2022). *Using ethology to improve farmed fish welfare and production*. AAC 2022. 67 pp. https://aac-europe.org/images/AAC_ethology_and_welfare_final.pdf

- Scholaert, F. (2021). *EU climate action in ocean governance and fisheries policy*, EPRS, European Parliament, April 2021. https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/690572/EPRS_BRI(2021)690572_EN.pdf
- Schuhbauer, A., D. Skerritt, E. Naazia, F. Le Manach, R. Sumaila (2020). *The Global Fisheries Subsidies Divide Between Small- and Large-Scale Fisheries*. Frontiers in Marine Science. Vol. 7. https://www.frontiersin.org/articles/10.3389/fmars.2020.539214
- Skerritt, D. & R. Sumaila (2021). *Broadening the global debate on harmful fisheries subsidies through the use of subsidy intensity metrics*. *Mar. Pol*. 128 (2021) 104507. https://www.researchgate.net/publication/350562841_Broadening_the_global_debate_on_harmful_fisheries_subsidies_through_the_use_of_subsidy_intensity_metrics#fullTextFileContent
- Skerritt, D. et al. (2023) Mapping the unjust global distribution of harmful fisheries subsidies. Daniel J. Skerritt, Anna Schuhbauer, Sebastian Villasante, Andres M. Cisneros-Montemayor, Nathan J. Bennett, Tabitha G. Mallory, Vicky W.L. Lam, Robert I. Arthur, William W.L. Cheung, Louise S.L. Teh, Katina Roumbedakis, Maria L.D. Palomares, U. Rashid Sumaila. Marine Policy 152 (2023) 105611. https://doi.org/10.1016/j.marpol.2023.105611
- STECF (2022). *The 2022 Annual Economic Report on the EU Fishing Fleet* (STECF 22-06), Prellezo, R., Sabatella, E., Virtanen, J. and Guillen, J. editors, Scientific, Technical and Economic Committee for Fisheries (STECF) Publications Office of the European Union, Luxembourg, 2022, doi:10.2760/120462, JRC130578. https://stecf.jrc.ec.europa.eu/documents/43805/35330729/STECF+22-06+-+AER+2022.pdf.semiold/f6767415-2962-4fdd-9baf-2fa8e9cbf3c7
- STECF (2023) *Monitoring of the performance of the Common Fisheries Policy* (STECF-adhoc-23-01), Publications Office of the European Union, Luxembourg, 2023.
- Technical University of Denmark (2008). *Modeldambrug under forsøgsordni*ngen. Faglig slutrapport for: "Måleog dokumentationsprojekt for modeldambrug." DTU Aqua – Rapport nr. 193–08. Hirtshals, Denmark. https://backend.orbit.dtu.dk/ws/portalfiles/portal/6582169/Rapport_193_08_samlet.pdf
- Willett, W., J. Rockström, B. Loken, M. Springmann, T. Lang, S. Vermeulen, T. Garnett, D. Tilman, F. DeClerck, A. Wood, M. Jonell, M. Clark, L. J Gordon, J. Fanzo, C. Hawkes, R. Zurayk, J. A Rivera, W. De Vries, L. Majele Sibanda, A. Afshin, A. Chaudhary, M. Herrero, R. Agustina, F. Branca, A. Lartey, S. Fan, B. Crona, E. Fox, V. Bignet, M. Troell, T. Lindahl, S. Singh, S. Cornell, P. Srinath Reddy, S. Narain, S. Nishtar, C. J L Murray (2019). *Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems*. The Lancet Commissions, Volume 393, Issue 10170, P447-492, 2 February 2019. 16 January 2019. DOI: https://doi.org/10.1016/S0140-6736(18)31788-4

ANNEX: THE EU FARM TO FORK STRATEGY: BEST PRACTICES AND LESSONS LEARNED

A. EU Farm to Fork Strategy and aquatic food production

The F2F Strategy perhaps inevitably has its focus on land-based food production systems, but it does recognise that a shift to sustainable fish and seafood production must also be accelerated and makes some specific reference to aquatic food production systems.

The Commission will step up efforts to bring fish stocks to sustainable levels via CFP where implementation gaps remain (e.g., by reducing wasteful discarding), strengthen fisheries management in the Mediterranean in cooperation with all coastal states and re-assess, by 2022, how the CFP addresses the risks triggered by climate change.

The EU will apply zero tolerance in the fight against IUU and combat overfishing, promote sustainable management of fish and seafood resources and strengthen ocean governance, marine cooperation and coastal management[47].

In addition to the significant support by the EMFAF for sustainable seafood farming, the Commission envisages adopting EU guidelines for Member States' sustainable aquaculture development plans and promote the right kind of expenditure under the Fund. It will also set out well-targeted support for the algae industry, as algae should become an important source of alternative protein for a sustainable food system and global food security.

B. Ensuring sustainable EU food production

The EU Farm to Fork Strategy sets out actions to ensure sustainable food production, which is focused on land-based examples of best practices in food production. These are summarised in **Table 3** along with related suggestions for aquatic food production.

Table 3: EU Farm to Fork best practices in ensuring sustainable food production

Farm to Fork best practices	Suggestions for fisheries and aquaculture
Carbon sequestration	
Farming practices that remove CO_2 from the atmosphere contribute to the climate neutrality objective and should be rewarded, either via the Common Agricultural Policy (CAP) or via other public or private initiatives (carbon market). A new EU carbon farming initiative under the Climate Pact will promote this new business model, which provides farmers with a new source of income and helps other sectors to decarbonise the food chain. As announced in the Circular Economy Action Plan (CEAP), the Commission will develop a regulatory framework for certifying carbon removals based on robust and	Low-trophic aquaculture has the potential to reduce the global warming of seafood production and, potentially, provide longer-term carbon sequestration opportunities e.g., through shellfish farming to permanently store CO_2 as mineralised $CaCO_3$ or the sinking of large quantities of macroalgae biomass in deep waters. However, both approaches have their limitations and independent, mass balance analyses and standardised impact assessments are required for different potential models.

[47] Through the Regional Fisheries Management Organisations, Sustainable Fisheries Partnership Agreements and our cooperation with third countries on IUU and on sustainable value chains in fisheries and aquaculture, cooperation is particularly relevant with countries affected by climate change.

Farm to Fork best practices	Suggestions for fisheries and aquaculture
transparent carbon accounting to monitor and verify the authenticity of carbon removals.	An expert group should further investigate carbon storage involving bivalve culture (AAC, 2022).
Biorefineries	
Advanced biorefineries that produce bio-fertilisers, protein feed, bioenergy, and bio-chemicals offer opportunities for the transition to a climate-neutral European economy and the creation of new jobs in primary production.	Microalgae, produced by using both intensive bioreactors as well as more extensive methods, has a wide range of uses. Biorefineries can also be supplied by seafood processing wastes and aquaculture mortalities. In the EU, technical constraints to up-scaling and regulatory challenges need to be addressed.
Reduce farm-level emissions and energy use	
Reduce emissions from livestock by investing in anaerobic digesters for biogas production from agriculture waste and residues, such as manure. Farms also have the potential to produce biogas from other sources of waste and residues, such as from the food and beverage industry, sewage, wastewater and municipal waste. Farms and barns are often perfect for placing solar panels and such investments should be prioritised in the future CAP Strategic Plans.	Farm-level emissions in EU aquaculture can be reduced through a move from fossil-fuel based vehicles and work boats to hybrid and then fully electric solutions. In northern climes, this will need port and small-harbour electrification, with possible micro-level wind power generation and in southern climes a greater focus on local solar energy production. In both cases, battery storage, both on land and on farm, will be important.
Reduce sector emissions	
Facilitate the placing on the market of sustainable and innovative feed additives to reduce livestock emissions. Introduce alternative feed materials such as insects, marine feed stocks (e.g., algae) and by-products from the bioeconomy (e.g., fish waste).	At sector level, the focus should be on reducing the GWP of aquafeed production and distribution (accounts for 75 – 95% of total GWP), including the use of circular feed raw materials and the inclusion of GWP costs in formulating aquafeed production and distribution strategies.
Better animal welfare	
The Commission will revise the animal welfare legislation, including on animal transport and the slaughter of animals, to align it with the latest scientific evidence, broaden its scope, make it easier to enforce and ultimately ensure a higher level of animal welfare. The Commission will also consider options for animal welfare labelling to better transmit value through the food chain.	The Strategic Plans and the new EU Strategic guidelines on aquaculture will support this process, especially through rewarding good practices (see **Section 3.2.3**).
Reduce chemical pesticides	

Farm to Fork best practices	Suggestions for fisheries and aquaculture
Enhance provisions on integrated pest management (IPM) and promote greater use of safe alternative ways of protecting harvests from pests and diseases. IPM will encourage the use of alternative control techniques, such as crop rotation and mechanical weeding,	In aquaculture, the use of cleaner fish is well established to reduce ectoparasite loads, but further work is needed to ensure it is both affordable and accessible. Further work is also needed to reduce biofouling e.g., of nets and seedstock without the need for chemical treatment.
Reduce excess nutrients and soil deterioration	
Applying balanced fertilisation and sustainable nutrient management through the use of precise fertilisation techniques and sustainable agricultural practices, notably in hotspot areas of intensive livestock farming and of recycling of organic waste into renewable fertilisers.	In aquaculture, the analogous situation is nutrient production from uneaten feed and faeces in finfish farming. A combination of good spatial planning combined with biomass /other restrictions to ensure cumulative production is within the receiving water carrying capacity with good feeding practices / environmental monitoring appear key.
Reduce anti-microbial resistance (AMR)	
Reduce overall EU sales of antimicrobials for farmed animals and in aquaculture by 50% by 2030 using new Regulations on veterinary medicinal products and medicated feed.	Responsible use and delivery of antimicrobials, combined with good husbandry and animal welfare to reduce stress-induced morbidity.
Organic farming	
In addition to CAP measures, such as eco-schemes, investments and advisory services, and the Common Fisheries Policy (CFP) measures, the Commission will put forward an Action Plan on organic farming.	In aquaculture, the focus needs to be on producing affordable, well-performing organic fish diets, combined with ensuring a distinct and rewarding market for organically produced fish.

Source: European Commission, 2020 and authors' own elaboration.

C. Other elements of the EU Farm to Fork Strategy

The Farm to Fork Strategy contains many elements in addition to sustainable EU food production explored above, which must be addressed to deliver a sustainable food system. These are set out below along with the implications for fisheries and aquaculture.

Table 4: Farm to Fork elements and implications for fisheries and aquaculture

Farm to Fork elements	Implications for fisheries and aquaculture
Improving food security	

Farm to Fork elements	Implications for fisheries and aquaculture
The considerations of workers' social protection, working and housing conditions as well as protection of health and safety will play a major role in building fair, strong and sustainable food systems. The Commission will develop a contingency plan for ensuring food supply and food security to be put in place in times of crisis. The agricultural crisis reserve will be revamped, the plan will set up a food crisis response mechanism. It will be comprised of various sectors (agriculture, fisheries, food safety, workforce, health and transport issues) depending on the nature of the crisis.	Fishing remains one of the most dangerous professions: health and safety improvements should be an important part of the policy. 2012 saw agreement on the implementation of the ILO C188 Work in Fishing Convention, which triggered its transposition into EU law through EU Directive 2017/159. The revised 2021 Strategic guidelines for sustainable EU aquaculture acknowledge the Farm to Fork Strategy and the need to reduce seafood imports, but do not address the need to reduce aquaculture dependency on external resources such as aquafeed raw materials and other inputs.
Food processing and marketing	
Improve the corporate governance framework, including a requirement for the food industry to integrate sustainability into corporate strategies. Facilitate shift to healthier diets and stimulate product reformulation, including restricting the promotion of foods high in fat, sugars and salt. Scale-up and promote sustainable and socially responsible production methods and circular business models in food processing and retail. Food packaging legislation revised, supporting innovative and sustainable packaging solutions and materials, and contribute to food waste reduction. Revise marketing standards to provide for the uptake and supply of sustainable products and to reinforce the role of sustainability criteria. Reducing dependence on long-haul transportation.	Fisheries and Aquaculture initiatives need to include the supply chain. Aquafeed production requires a wide range of marine and terrestrial raw materials, energy-intensive processing and finished feed transportation and distribution. Fishery and aquaculture products (FAP) should be an important element of encouraging healthier diets, which can be consistent with food security with species choices (e.g., small pelagics and low-trophic culture species). The EC Communication on the CMO describes potential revised marketing standards for FAP (COM(2023) 101)[48]. Additional environmental information provided to consumers is currently proposed on a voluntary basis. Private sector seeks shorter seafood supply chains due to economic and logistical drivers. Increased EU value added processing at point of landing/production (with increased automation to address labour shortages) shortens supply chains and will reduce dependence on long-haul transportation.

[48] COM(2023) 101 Implementation of Regulation (EU) No 1379/2013 on the common organisation of the markets in fishery and aquaculture products, see: https://oceans-and-fisheries.ec.europa.eu/system/files/2023-02/COM-2023-101_en.pdf.

Farm to Fork elements	Implications for fisheries and aquaculture
Sustainable food consumption	
Empower consumers to make informed, healthy and sustainable food choices. Improve the availability and price of sustainable food and to promote healthy and sustainable diets in institutional catering. Tax incentives to drive transition to sustainable food systems and consumption	The shift to lower-trophic species will be driven by consumer demand and a shift to 'plant-forward' diets. Product development will be important e.g., developing affordable, appealing meals from low-trophic seafood, a sustained effort to reduce the proportion of higher trophic animals in diets is required. Improved seafood labelling and certification schemes help to inform consumers of sustainable seafood choices.
Reducing food waste	
Set a baseline and propose legally binding targets to reduce food waste across the EU. Prevent losses through the supply chain.	Improving operational efficiency in seafood processing and improved cold chains to increase yields and reduce wastage; the re-use of by-products and other circular approaches.
Combating food fraud	
Zero tolerance policy with effective deterrents strengthen the powers of control and enforcement authorities' dissuasive measures, and better import controls	The proposed revision of the EU's fisheries control system will contribute to the fight against fraud through enhanced traceability. Mandatory digitalised catch certificates will also help prevent IUU fish entering the EU. Seafood fraud is often unreported and a more in-depth understanding of vulnerabilities in the supply chain is required.
International trade and cooperation	
Enhance cooperation and promote international standards. Obtain commitments from non-EU countries on animal welfare and use of pesticides. Pursue Green Alliances and focus on food research and innovation in climate change adaptation, agro-ecology, etc.	3rd party certification focuses on large-scale operators. EU external action should focus on smaller producers too, building awareness and sustainable production. Support can also be provided to the Competent Authorities of seafood exporting nations outside of the EU to improve their own regulatory, food certification and monitoring frameworks, especially into the use of illegal or unauthorised veterinary products.

This study is the third in a series of three research papers, prepared for a PECH Committee Workshop. It explores how initiatives within the European Green Deal may impact food security in fisheries and aquaculture. The Farm to Fork Strategy's aim of sustainable food production indicates prioritising low-trophic species like bivalves and algae. 'Fit for 55' requires greater fuel efficiency and a transition to clean energy by the fishing fleet. A net positive long-term impact on food security is expected from sustainable production. As two thirds of the EU's seafood consumption is imported, such ambitions should be extended to non-EU country producers.

PE 752.437
IP/B/PECH/IC/2022-116

Print ISBN 978-92-848-1164-9| doi:10.2861/28234 | QA-03-23-376-EN-C
PDF ISBN 978-92-848-1165-6 | doi:10.2861/991050| QA-03-23-376-EN-N