English Aquaculture Strategy

Final Report

November 2020

SEAFOOD 2040

POSEIDON AQUATIC RESOURCE MANAGEMENT

Report Information

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FOREWORD FROM THE MINISTER FOR FARMING, FISHERIES AND FOOD

Aquaculture is a valued part of England's seafood industry. It supports local jobs and provides sustainable, low carbon produce for consumption at home and for export around the world. The sector's ability to co-exist with wild fisheries and other maritime uses, such as renewable energy, maximises the sustainable use of England's precious marine environment with exciting potential for growth in the future.

The ongoing pandemic presents the sector with considerable challenges. I recognise these challenges and am pleased that the Government provided support to the sector earlier in the year as part of the £10 million Fisheries Response Fund. Eighty aquaculture businesses benefitted from grants of up to £10k and a 'virtual visit' has allowed me to see how this scheme helped one trout farm to survive. However, demand from the domestic hospitality trade and international export markets has made a slower than hoped for return to normal and continues to affect production and business growth.

I welcome the English Aquaculture Strategy which sits within the context of these uncertainties while looking beyond them across the next two decades. The strategy focuses on a combination of national and local actions to achieve growth aspirations for the sector. Working successfully alongside the regional marine planning process and aquaculture strategy initiatives, such as the Dorset Mariculture Strategy (2020), is key to realising these aspirations.

The strategy comes at a time of very significant opportunity for our seafood industry as the end of the Transition Period means the UK will be an independent coastal State for the first time in 40 years. Opportunities for the aquaculture sector include the expansion of exports and the growing investment in Recirculating Aquaculture Systems (RAS) in England. Technology opportunities continue to develop particularly in the digitisation of the entire supply chain to ensure traceability, sustainability and accountability. Together, with the strategy, these elements represent a watershed for English aquaculture.

I would like to thank the SF2040 Aquaculture Leadership Group and the Seafood Industry Leadership Group, Seafish, and Poseidon Aquatic Resource Management Ltd for their efforts in supporting England's aquaculture sector with this English Aquaculture Strategy.

It is my sincere hope that it will help the sector take advantage of the opportunities that will result in a sustainable and thriving future.

Victoria Prentis

Minister for Farming, Fisheries and Food

FOREWORD FROM THE CHAIR OF SEAFOOD 2040

I am delighted to write the introduction for the English Aquaculture Strategy produced by Tim Huntington and Rod Cappell at Poseidon Aquatic Resource Management Ltd. This report, and the strategy and delivery that are included, was developed through the Seafood 2040 (SF2040) initiative and brings England into alignment with the devolved administrations in the UK in having a strategy for aquaculture development. There are great opportunities here for all stakeholders to work together in support of a growing industry that shows promise and potential for the provision of high value, nutritious and healthy seafood. The relevance and importance of increasing domestic food production, and employment opportunities in the more fragile rural economies, will be appreciated by all during a current period of uncertainty underlined by the double impacts of Covid-19 and Brexit. This work is much needed, and long overdue.

The SF2040 Aquaculture Leadership Group (ALG) has been particularly important in steering this work, and my thanks go out to the members especially, many of whom have provided long hours of input into this process in their own time and at their own cost. For ALG, and the aquaculture industry, this strategy represents a pathway forward, and one which it is hoped will help to position England's aquaculture industry as a leader with the application of innovation and technology to the sustainable development of the industry. The opportunities are clearly defined in the report, but the resounding message is that there is potential for development across the different sectors of freshwater and marine finfish, shellfish, and a pioneering macroalgae-farming industry.

This scope for growth has been estimated through the interpretation of the current evidence-base for aquaculture production in England. It was seen as important to base any future predictions on more recent trends for production volume, thereby providing a realistic foundation for estimates. This is an important point to realise for the reader who may look at a total volume of production for 2040 listed at something less than 100,000 tonnes and wonder why that relatively moderate production level would need a strategy in support of development. This work was based on current production in an industry that is a long way from achieving its potential, and the fact remains that if we manage to put in place the highlighted aspects of the strategy, namely the combination of innovation, integration and proportionate regulation, then these estimates may readily be exceeded.

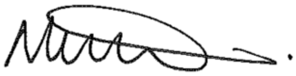
There are particular characteristics of the English aquaculture industry that require further work and a combination of national and regional actions, including site planning and location in often busy waters, and a regulatory framework that in many instances has not been developed with aquaculture as the primary focus. These are major restrictions when it comes to the accessibility of production sites, and the provision of data and information inputs into the bioeconomic production modelling that is a central tenet of investment. Where prospective entrepreneurs and new entrants to the industry are unable to see a clear route to success, there will clearly be impacts on sustainable development, and this is something to be tackled.

Amongst the opportunities it is clear that some are to be seen in the development of offshore aquaculture, and with England already the home of a major mussel farm in offshore exposed conditions that are more extreme than seen in many other aquaculture-producing countries, the pathway is already being created. England can build on these already substantial contributions in a way that can make valuable contributions to seafood production and aquaculture systems technology in a developing segment of the industry that is being pursued the world over. Similarly, investment in Recirculation Aquaculture Systems (RAS) technology has expanded greatly in recent years, and although there is much yet to be achieved with RAS there are obvious opportunities in England as there are in other countries. The rapidly developing opportunities in seaweed farming are also in a similar position, where important information on systems technology, growth, health and an appropriate regulatory regime are much needed. In support of all these sectors, England has access to world-class science across several universities and other research providers.

All this will, however, rely not only on having the personnel with the expertise to work within the industry itself, which is another important point to be tackled, but also ensuring that England has the resource required in policy departments and regulatory organisations that reflects the needs for the growing size and potential output of aquaculture in England.

Seafood 2040 has a vision for a thriving and sustainable seafood sector and in that regard we see a developing aquaculture industry as one that can also support fisheries, with the two industries having mutual interest in other seafood industry aspects such as infrastructure and secure access to the processing sector. Both fisheries and aquaculture contribute much more together in ensuring that the processing industry has enough product to maintain its own operations, or that supply chains continue to operate effectively for retailers and consumers.

Aquaculture development has much to gain over time, perhaps even more than may be estimated currently, but working in unison with the fisheries and processing sectors the benefits are potentially even greater for the overall seafood industry, and society.



Dr Neil Auchterlonie
Chair, SF2040

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Introduction

This document sets out a Strategy and Delivery Plan for the sustainable development of English aquaculture over the next twenty years. It is bold and aspirational, seeing a ten-fold increase in production volume to around 90,000 tonnes by 2040, which can be achieved through a combination of expansion, innovation, integration and proportionate regulation.

The current situation, with aquaculture production stagnating over the last decade, and the industry facing the uncertainties of the ongoing COVID-19 pandemic and the prospect of a no-deal exit from the European Union, means that delivering the Strategy will need clear leadership, and effective and sustained collaboration between the industry and regulators. The English Aquaculture Strategy (EAS) will be implemented through a combination of national and local actions, capitalising both on the regional marine planning process and on provincial aquaculture strategy initiatives, such as in Dorset.

We are at a watershed for English seafood production with the opportunity for aquaculture to make a significant future contribution. Wild fisheries – which are mostly at or near maximum sustainable yield - have limited potential for expansion, but aquaculture is less constrained. Aquaculture can develop a greater role within the wider 'blue economy', working with capture fisheries and other maritime users such as offshore energy production. Growth is likely to be supported by the increasing scale and economic viability of land-based aquaculture, especially through the use of technological approaches such as in-pond raceways and recirculating aquaculture systems. The rewards will be substantial, with English aquaculture providing a critical contribution to Seafood 2040's (SF2040) aspiration for a 75% increase in seafood consumption by 2040 as well as important jobs for coastal communities.

The Vision for English Aquaculture

By 2040 English aquaculture is a significant contributor to seafood consumption and the Blue Economy, providing sustainable, healthy food and rewarding employment opportunities

Objectives and Principles for English Aquaculture

Strategy Objectives	Strategy Principles
1. A ten-fold growth and diversification of aquaculture in England over the next 20 years. **2. English farmed production contributes at least 15% of overall seafood consumption in England by 2040** **3. Produce sustainable, safe and nutritious food.** **4. Provide up to 5,000 secure and rewarding jobs by 2040.** **5. An integral component of the English 'Blue Economy'.**	**Aquaculture production should be environmentally, economically and socially sustainable.** **Aquaculture development should be regulated in a proportionate and balanced way.** **Effective co-existence of aquaculture with other maritime activities, including wild capture fisheries, is key.** **A co-management, partnering approach is developed between regulators, the industry and other stakeholders.** **Innovation will be core to the development of new production systems, feeds and products.** **Encourage the development of low trophic species and the use of integrated multi-trophic aquaculture to contribute to England's net-carbon zero ambitions.**

Actions and Delivery Plan

The Strategy will be delivered via specific actions across three sub-sectors and six cross-cutting areas:

Sub-sectors	Cross-cutting elements
1. **Finfish**	4. **Governance and regulation**
2. **Shellfish**	5. **Knowledge, Innovation and Technology**
3. **Macroalgae**	6. **Common Infrastructure Development**
	7. **Financial Support**
	8. **Human Capacity Development**
	9. **Aquaculture in the Blue Economy**

Implementation

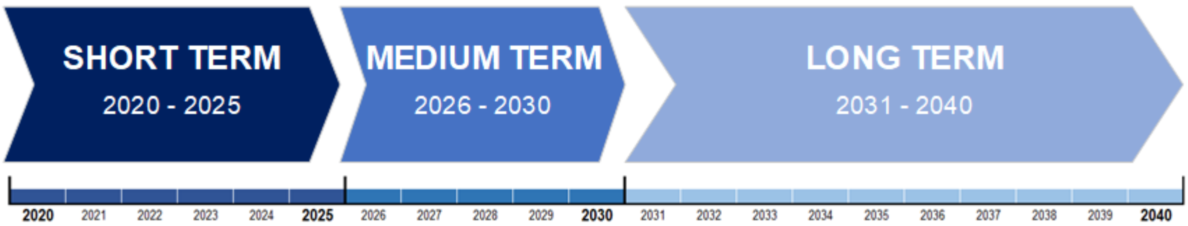
The Strategy was commissioned through the SF2040 Seafood Industry Leadership Group (SILG). Its delivery will be overseen by the SF2040 Aquaculture Leadership Group (ALG).

The Delivery Plan provides a series of prioritised and time-bound actions to be undertaken taken by the sector over the next 20 years. Some of these will require sector-wide collective action whilst others are specific to certain parts of the sector. A co-management approach between the *industry* and the *regulators and their advisory agencies* is needed. This will ensure that aquaculture will develop as part of a sustainable 'blue economy'.

The EAS is a document to support all of English aquaculture. Within this national framework there will necessarily be local initiatives to plan and develop aquaculture in line with the Government's regional approach to marine planning. Dorset has already published its own short-term mariculture strategy (2020 – 2025) and other regions are planning similar initiatives, mainly through the Inshore Fisheries and Conservation Authorities (IFCAs).

Timeline

The Strategy will be implemented through the remaining SF2040 timeframe i.e. a 20 year period from 2020 to 2040. It will be delivered over three distinct time frames as follows:



There are clear milestones in the first three years of the EAS. The ALG – with its membership of industry, government and regulators – plays a critical role in supporting the SF2040 Secretariat to monitor progress and impact.

As the SF2040 Strategic Framework notes, the period on the horizon (2031 to 2040) is highly uncertain and specific deliverables for this period are not proposed at this time.

Growth Aspirations for English Aquaculture up to 2040 (tonnes)

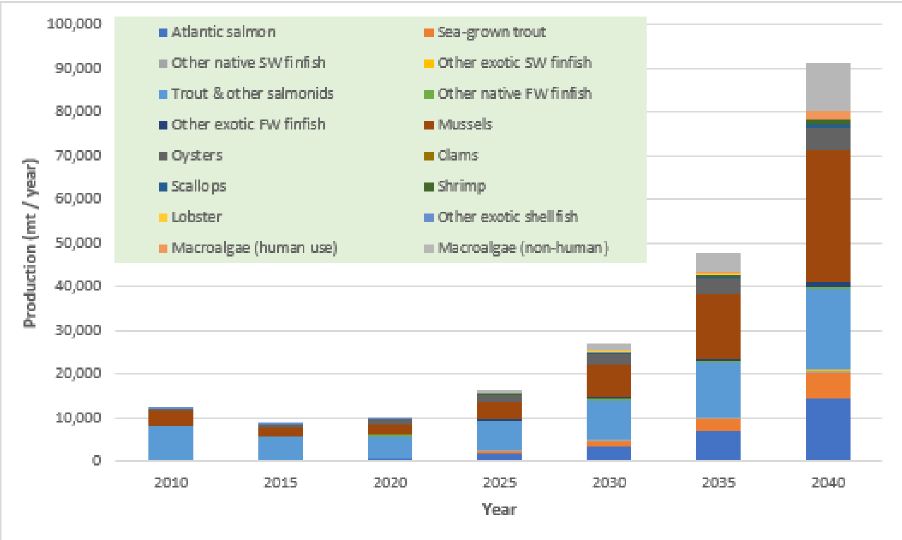
ALL SPECIES GROUPS

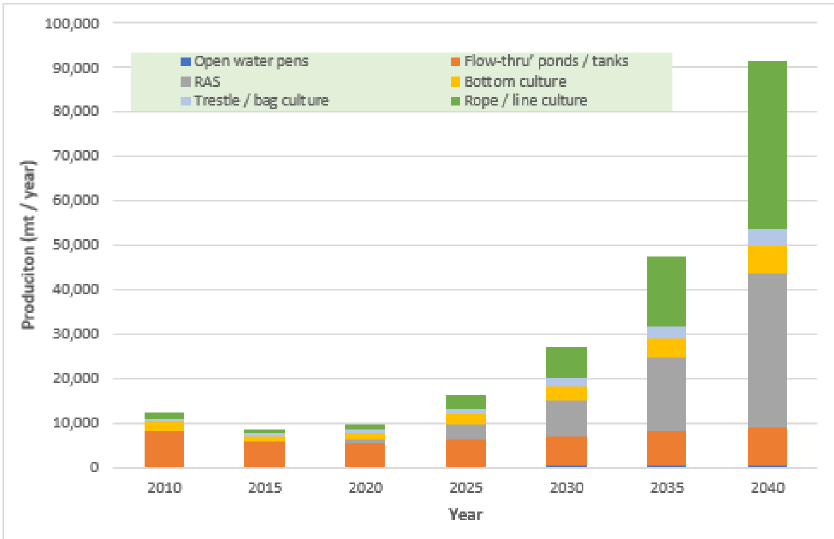
A. By species

Species	2010	2015	2020	2025	2030	2035	2040
Atlantic salmon	0	0	500	1,749	3,518	7,076	14,232
Sea-grown trout	8	9	279	608	1,176	2,546	5,905
Other native SW finfish	0	0	0	126	203	358	669
Other exotic SW finfish	0	0	11	135	172	220	281
Trout & other salmonids	7,972	5,593	5,186	6,616	9,096	12,453	18,439
Other native FW finfish	166	165	159	175	188	211	253
Other exotic FW finfish	135	4	113	203	365	658	1,186
Mussels	3,233	1,909	2,233	4,003	7,529	14,803	30,197
Oysters	735	1,034	1,123	1,675	2,429	3,528	5,141
Clams	0	0	21	27	34	44	56
Scallops	0	0	20	69	155	346	776
Shrimp	0	0	100	180	325	585	1,055
Lobster	0	0	2	4	10	22	50
Other exotic shellfish	27	8	12	12	12	12	12
Macroalgae (human use)	0	0	0	91	273	724	1,928
Macroalgae (non-human)	0	0	0	531	1,464	4,038	11,139
Grand Total	**12,275**	**8,721**	**9,759**	**16,205**	**26,949**	**47,625**	**91,316**

B. By system

System type	2010	2015	2020	2025	2030	2035	2040
Open water pens	8	9	219	298	330	367	409
Flow-thru' ponds / tanks	8,138	5,757	5,345	6,027	6,798	7,670	8,657
RAS	135	4	783	3,592	8,217	16,767	34,608
Bottom culture	2,184	1,366	1,497	2,143	3,069	4,397	6,304
Trestle / bag culture	517	821	902	1,293	1,854	2,660	3,815
Rope / line culture	1,293	764	1,012	2,852	6,680	15,764	37,523
Grand Total	**12,275**	**8,721**	**9,759**	**16,205**	**26,949**	**47,625**	**91,316**





Acronyms used

AB-SIG .... Algal Bioenergy - Special Interest Group
ADF .... Agriculture Development Fund (Saudi Arabia)
ALG .... SF2040 Aquaculture Leadership Group (England)
ARCH-UK ... Aquaculture Research Collaboration Hub
ASC .... Aquaculture Stewardship Council
AWC .... Animal Welfare Committee
AZA .... Allocated zones for aquaculture
BBSRC .... Biotechnology and Biological Sciences Research Council
BCE .... Before Common Era
BIM .... Bord Iascaigh Mhara
BTA .... British Trout Association
CAGR......... Compound Annual Growth Rate
CCS............ Closed Containment System
Cefas .... Centre for Environment, Fisheries and Aquaculture Science
CFP .... Common Fisheries Policy
CO_2............. Carbon dioxide
COVID-19... Corona Virus Disease 2019
CSAR .... Centre for Sustainable Aquatic Research (Swansea University)
DAFM .... Department of Agriculture, Food and the Marine (Ireland)
DASSHH ... Developing an assurance scheme for shellfish and human health
Defra........... Department for Environment, Food and Rural Affairs
DFID.......... Department for International Development
DSSS.......... Domestic Seafood Supply Scheme
EA............... Environment Agency
EAS .... English Aquaculture Strategy
EEA .... European Environment Agency
EIA.............. Environmental Impact Assessment
EMFF.......... European Maritime and Fisheries Fund
EU.............. European Union
FAO............ Food and Agriculture Organisation of the United Nations
FaSS .... Fisheries and Seafood Scheme
FAWC......... Farm Animal Welfare committee (now AWC)
FHI.............. Fish Health Inspectorate
FLAG .... Fisheries Local Action Group
FRF .... Fisheries Response Fund
FSA .... Food Standards Agency
FTE............. Full Time Equivalent
GBP............ Great Britain Pound

GDP............ Gross Domestic Product
GHG........... Greenhouse Gas
GIS .... Geographic Information System
HCD............ Human Capacity Development
HIE .... Highlands and Islands Enterprise
HMG........... Her Majesty's Government
HPMA......... Highly Protected Marine Area
HRA............ Habitats Regulations Assessment
IFCA........... Inshore Fisheries and Conservation Authority
IFREMER ... French research institute for the exploitation of the sea
IMTA........... Integrated Multi-Trophic Aquaculture
IPRS........... In-pond Raceway Systems
ISCF........... Industrial Strategy Challenge Fund
ITT.............. Invitation to Tender
JNCC.......... Joint Nature Conservation Committee
JRC .... (EU) Joint Research Centre
KTN .... Knowledge Transfer Network
LAG .... Local Action Group
LEP............. Local Enterprise Partnership
LFA............. Logical Framework Analysis
MANP......... Multiannual National Plan
MCAA......... Marine and Coastal Access Act (2009)
MCZ............ Marine Conservation Zone
MEA............ Maritime Economic Activity
MFF............ Maritime and Fisheries Fund
MHCLG ...... Ministry of Housing, Communities and Local Government
MMO........... Marine Management Organisation
MPA............ Marine Protected Area
mt .... Metric tonnes
MWR .... Marine Works Regulations
NAFC.......... North Atlantic Fisheries College
NE .... Natural England
NGO........... Non-Governmental Organisation
NHS............ National Health Service
NZG............ New Zealand Government
OMC........... Open Method of Co-ordination
PA............... Per Annum
PHE............ Public Health England
PMS............ Project Method Statement
RAS............ Recirculating Aquaculture System
RTFS.......... Rainbow Trout Fry Syndrome

RYA .... Royal Yachting Association
S .... Score
SAC .... Special Areas of Conservation
SAF .... Collaborative Centre for Sustainable Aquaculture Futures
SAIC .... Scottish Aquaculture Innovation Centre
SARF .... Scottish Aquaculture Research Forum
SDG............ Sustainable Development Goal (United Nations)
SDP .... Single Department Plan
Seafish .... Sea Fish Industry Authority
SEP .... Seafish Expert Panel
SF2040....... Seafood 2040
SFC .... Scottish Funding Council
SIF .... Seafood Innovation Fund
SILG .... SF2040 Seafood Industry Leadership Group
SME............ Small to Medium-Sized Enterprise
SSIG .... Seafood Science and Innovation Group (now SEP)
SSWG .... Shellfish Stakeholder Working Group
STECF........ Scientific, Technical and Economic Committee for Fisheries
SWAN......... South West Aquaculture Network
SWEEP ...... South West Partnership for Environmental and Economic Prosperity
TGP .... Total Gas Pressure
UK .... United Kingdom
UKCP .... UK Climate Projections
UKRI .... United Kingdom Research and Innovation
USD............ United States Dollar ($)
WFD .... Water Framework Directive (2000/60/EC)
WS.............. Weighted Score

1. Background, Objectives and Approach

1.1 Background

Aquaculture is the farming of fish, molluscs, crustaceans and aquatic plants. It differs from capture (or wild) fisheries in that the stock is owned during most or all of its life-cycle (see Section 1.3.1 for more details on the scope of aquaculture in this Strategy) and often subject to management through genetic selection, artificial feeding and other husbandry activities.

Fish farming first developed in China before 1,000 BCE and was adopted by the Romans in 500 BCE. Carp farming appeared in England during the Middle Ages. Mussel farming was recorded from the 13th Century and the technique remained largely unchanged until the 1960s. The 19th Century was a turning point as industrial development in Europe brought about the demise of wild populations, leading to the development of hatchery and grow-out technologies. It was not until the 1950s where the increasing availability of formulated feeds further stimulated fish farming and its intensification.

To date English aquaculture has been dominated by inshore shellfish culture and trout in freshwater. This has mainly been driven by small to medium (sized) enterprises (SMEs), with relatively little external investment. English aquaculture currently produces around 8,000 metric tonnes (mt) of which around two-thirds (by volume) is freshwater finfish and one-third is shellfish with combined worth at first sale around £26 million a year (see **Figure 1** overleaf). Rainbow trout (61%) and mussels (20%) make up the majority of this.

In terms of change over the period 2009 – 2017, rainbow trout production in freshwater has fallen by 5% in volume terms and 3% in value. Mussels have declined by 10% in volume and 4% in value and Pacific oysters have grown by 1% and 11% respectively. Over the last ten years English aquaculture has declined by 5.6% in volume and increased by 1% in value, a slight decline in real terms (see **Table 1** overleaf for more details).

Table 1: Change in production & value over 2009 - 2017 for main English aquaculture species

Species group	Species	% Production		% Value		Change (CAGR)	
		2009	2017	2009	2017	Vol	Value
Freshwater finfish	Arctic char	0.1%	0.2%	0.2%	0.3%	7.9%	7.9%
	Brown trout	2.9%	2.7%	7.7%	7.2%	-6.1%	-0.1%
	Common carp	1.2%	2.5%	1.6%	11.0%	-7.4%	-7.2%
	Nile tilapia	0.9%	0.0%	1.1%	0.0%	-48.7%	-36.8%
	Rainbow trout	57.1%	61.2%	72.6%	62.3%	-4.8%	-1.9%
Marine finfish	Brown trout	-	0.0%	-	0.0%	n/a	n/a
	Other salmonids	0.1%	0.2%	0.1%	1.1%	3.8%	1.5%
Shellfish	European flat oyster	0.4%	0.1%	0.4%	0.1%	-20.3%	-18.9%
	Japanese carpet shell	0.1%	0.3%	0.1%	0.5%	3.8%	11.6%
	Northern quahog	0.0%	0.0%	0.0%	0.0%	-11.7%	-10.5%
	Pacific cupped oyster	6.5%	12.3%	6.5%	9.1%	1.3%	10.9%
	Sea mussels	30.6%	20.3%	30.6%	7.2%	-9.8%	-4.0%

Source: Cefas (unpublished). Values are farm gate (excludes coarse fish). Marine brown trout production first reported in 2018, so returns zero values for 2009 - 2017.

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Figure 1: English aquaculture production and value (2009 - 2018)

Source: Data supplied by Cefas (unpublished)

The sector employs around 1,080 persons in England, of which the full-time equivalent is around 740[1] (Hambrey & Evans, 2016; Pye & Tait, 2020). The *c*. 8,000 mt worth *c.* £26 million produced by aquaculture in England compares to English wild landings of 104,000 mt of finfish and shellfish in 2019 (MMO, 2020) with a value of £209 million.

Although a tenth the size of capture fisheries, English aquaculture is an important component of the wider English seafood industry for a number of reasons, including:

- It is mainly small to medium enterprise (SME) based and an important livelihoods opportunity in depressed economic areas with limited alternative employment opportunities.
- It serves niche markets such as for freshwater trout that capture fisheries cannot meet.
- Wild fisheries are constrained by variable and finite stock levels and therefore unable to expand significantly in volume – although aquaculture has its own constraints, there is more potential for increased production through sustainable growth, especially over the long-term.
- Although current production levels are very small, aquaculture is capable of producing warm-water species and other exotic species (such as tilapia and shrimp) that are currently imported. Again, this has the potential to grow, especially given changes in the trades and markets following EU-Exit and COVID-19.
- Aquaculture does, and has the potential to further, maintain and increase marine biodiversity and ecosystem health, through the use of 'extractive'[2] aquaculture process such as shellfish and seaweed farming.

Given this potential, why has English aquaculture production declined by 5.6% per annum since 2009, especially given the success of aquaculture development in Scotland[3]? There are a number of factors that combine to inhibit growth and new investment into the sector, including:

- Competition for space and resources in a densely populated country with mostly exposed, shallow and heavily utilised sea areas;
- An opaque and sometimes highly precautionary approach to aquaculture authorisations;
- Limited domestic consumer demand in traditionally farmed species
- The sometimes pervasive negative public perception and understanding of larger-scale aquaculture development and farmed products versus wild-caught equivalents;
- Current poor linkages between industry and research, despite breadth and depth of experience and knowledge at UK / English universities.
- The vulnerability of marine shellfish farming to poor water quality.

An additional reason for the inconsistent, variable growth is the lack of strategic direction. Any sector needs to overcome emerging challenges and to take advantage of opportunities for sustainable growth. This strategic direction needs to be holistic, wide-ranging and long-term, and must allow both industry and supporting sector actors (such as research, capacity-building and governance) to invest time and effort into ensuring that that sector remains relevant and competitive well into the future.

[1] Of this 531 (72%) is in finfish and 211 (28%) in shellfish aquaculture.
[2] Extractive means that there is the net removal of nutrients
[3] Scotland produced 169,848 mt for the table in 2018, of which 92% was Atlantic salmon, 2% rainbow trout and 4% blue mussels (Munro, 2019; Munro, 2020)

Aquaculture in England currently lacks this strategic thinking. Salmon-dominated Scotland has a 'Strategic Plan for Farming Scotland's Seas' (2016) that builds upon the 'Renewed Strategic Framework for Scottish Aquaculture' (2009), and Wales developed a 'Wales Seafood Strategy' in 2016. England has a high level framework for the entire supply chain in 'Seafood 2040' (2018) that includes an ambition to "Grow a sustainable aquaculture sector." This includes both (i) the establishment of an Industry-Government joint coalition, the 'Aquaculture Leadership Group' (ALG) to drive sustainable growth and (ii) the subsequent delivery of an 'English Aquaculture Growth Strategy' (Recommendation 13 within the SF2040 Strategic Framework). This resulting EAS will therefore be coherent with the wider framework and timescale in SF2040.

1.2 Purpose of the English Aquaculture Strategy

1.2.1 Background

In October 2015, a Task Force representing all sectors of the seafood industry in England was established at the request of George Eustice MP, Minister of State for Agriculture, Fisheries and Food. The Task Force was asked to explore the challenges and opportunities facing the English industry and to shape a long-term ambition that could help realise the full potential of the industry by 2040. A vision was established for the seafood value chain by 2040.

"*Our ambition is to see a seafood industry that is sustainable and truly thriving, in every sense of the word. Where a whole supply chain approach has fostered collaborative working practices, yet allowed the space to fully celebrate the diversity of our different sectors and regions; where seafood is highly valued, driving consumption figures at home and abroad; and where science and a supportive regulatory framework drive innovation and foster best practice from catch and farm to plate*."

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Source:https://www.seafish.org/about-us/working-locally-in-the-uk/working-with-the-seafood-industry-in-england/seafood-2040/seafood-2040-history-and-purpose/

SF2040 is an England-only strategic and collaborative programme facilitated by Seafish in partnership with the Department for Environment, Food and Rural Affairs (Defra) and seafood industry partners. The SF2040 Strategic Framework[4] consists of 25 recommendations that set out a vision for a thriving seafood industry with collaboration, research, innovation and good practice as important drivers throughout the Framework.

After receiving Defra Ministerial support the SF2040 Strategic Framework[5] was published in December 2017. Funded by the European Maritime and Fisheries Fund (EMFF) this enabled the establishment of a standalone SF2040 programme with a Secretariat (Chair and Programme Manager). The Chair is independent from Seafish. The SF2040 programme currently runs from September 2018 – February 2021.

[4]https://www.seafish.org/about-us/working-locally-in-the-uk/working-with-the-seafood-industry-in-england/seafood-2040/

[5]https://www.seafish.org/about-us/working-locally-in-the-uk/working-with-the-seafood-industry-in-england/seafood-2040/

In addition to the Secretariat, there are two committees within the SF2040 governance structure.

1. The **SF2040 Seafood Industry Leadership Group** (SILG) oversees the programme and is comprised of stakeholders across the supply chain and government.
2. The **SF2040 Aquaculture Leadership Group** (ALG) for England comprises membership from across the aquaculture industry, academia, government and regulators. ALG works to champion and advance the relevant SF2040 aquaculture recommendations on behalf of SILG.

Following the establishment of the ALG, the first task was to "***Deliver an English Aquaculture Growth Strategy****, with Government supported growth targets and a revised short, medium and long term delivery plan*". This is the basis for this current Strategy.

The timing of this Strategy is fortunate. The United Kingdom will leave the European Union (EU) on 31 December 2020, with considerable consequences for seafood supply chains to and from England. The COVID-19 pandemic is also another 'game-changer'. There is also a sea change in terms of technology, especially with the growing investment in recirculating aquaculture systems (RAS), the emergence of offshore aquaculture technology, increased interest in Integrated Multi-Tropic Aquaculture (IMTA) and IT and communication systems that will revolutionise remote monitoring, reporting and data communication. Together these elements represent a watershed for English aquaculture.

1.2.2 The Purpose of the English Aquaculture Strategy

The **purpose of the EAS** is three-fold:

1. Provide a vision and associated development of objectives for English aquaculture that allows for the identification of short, medium and long-term actions by participants across the sector;
2. Demonstrate that aquaculture can be a significant contributor to the English 'blue economy', co-existing with wild fisheries, other maritime activities and conservation objectives to maximise the sustainable use of England's extensive but crowded marine space; and
3. Contribute to the SF2040 target of doubling seafood consumption that reflects an increased acceptance of sustainable and responsible aquaculture as an increasingly important economic activity in English waters.

The **EAS** is required to:

1. Be action-oriented and forward-looking.
2. Present a series of evidence-based growth aspirations for the next 20 years.
3. Outline a short-, medium- and long-term delivery plan, to enable the industry to realise its sustainable growth potential, encourage a strong government mandate and increase attractiveness to private investors.
4. Strike a balance between high-level / big picture and practical delivery.
5. Energise a strong political mandate and support for sustainable growth in English aquaculture.
6. Be written in a manner suitable to engage a wide range of relevant stakeholders and to grow awareness and understanding of both constraints and solutions.

1.3 Scope and Methodology

1.3.1 Scope

According to the Food and Agriculture Organisation (FAO) of the United Nations, aquaculture is "*The farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated, the planning, development and operation of aquaculture systems, sites, facilities and practices, and the production and transport"* (FAO, 2003). This Strategy will align with FAO's universally agreed definition.

Geography: The Strategy will cover all of England, including the Isles of Scilly and the Isle of Wight.

Environment: The Strategy will cover aquaculture in *freshwater* (e.g. in lakes, rivers and using ground water), *transitional waters* (e.g. in estuaries, lagoons and other saline areas substantially influenced by freshwater flow) and *sea water* out to England's jurisdictional limits.

Species: The Strategy is predominantly focused on aquatic animals and plants for human consumption. It will therefore include finfish, molluscs and crustaceans, both when reared in captivity to full-size, or when hatchery-produced juveniles are released into the wild for subsequent recapture and consumption.

The Strategy includes the farming of macroalgae for both human-consumption and non-human use[6]. It also acknowledges the rearing of microalgae, invertebrates and other species where they have an important role in an aquaculture system, such as a feed input.

Timing: In general, a strategy is a high level document that outlines how policy objectives will be achieved. This EAS has been written with the same ideal and covers a 20-year time period to 2040.

Policy framework: The EAS objectives reflect existing and emerging policies that provide direction to any food production system in England. These include seafood production in particular, and food security, health and nutrition, environmental sustainability (e.g. striving towards a net zero carbon production).

A strategy as such does not usually articulate implementation methods; it simply provides the strategic direction in how policy objectives will be achieved. However, in the case of the EAS, a high level delivery plan has been included that allows the short, medium and long-term strategic objectives to be achieved. Therefore this document is a strategic development plan and not just a strategy.

[6] Additional uses including, animal feeds, fertilisers, biopolymers, cosmetic products, biomass etc.

1.3.2 Methodology

This Strategy was developed over a five-month period from May to October 2020, adopting the following overall approach:

Extensive stakeholder engagement

As the Strategy development has coincided with the peak of the COVID-19 pandemic, stakeholder engagement was conducted remotely by telephone and video-conferencing. We have spoken to around 55 stakeholders directly, covering a wide range from producers (marine and freshwater finfish, shellfish and macroalgae), researchers and research initiatives, the IFCAs, seafood processors and wholesalers, Non-Governmental Organisations (NGOs) and national regulatory bodies such as the Marine Management Organisation (MMO) and Defra.

In addition, we have presented the scope and anticipated outputs of the EAS to two wider stakeholder events: Exeter University's workshop entitled 'Supporting Mariculture Development: Evidence for Informed Regulation' (3rd July 2020) and the South West Aquaculture Network (SWAN's) meeting on 21st July 2020. We presented our progress and outputs to the SF2040 ALG at two summer online meetings and held separate sub-group meetings to discuss the growth aspirations for different production segments. Finally we also held a number of meetings with Defra, including the Fisheries Minister Victoria Prentis MP, to ensure that the Strategy is as coherent with current and emerging Government policy as possible.

Logical framework approach

Our general approach to developing an action-oriented strategy for English aquaculture is to use the logical framework analysis (Logframe or LFA) approach. This method has been widely used by the World Bank, the European Commission and the UK's Department for International Development (DFID). The LFA is a hierarchical project design methodology which ensures that the activities and outputs of a plan or programme are firmly linked to the higher level outcomes, objectives and overall goal. In terms of the EAS, the logical framework normally consists of the following structure:

- **Overall goal or vision**: A clearly stated vision of what English aquaculture will look like in 2040. This should clearly reflect the long-term policy objectives of the English government and the aspirations of the aquaculture industry.
- **Strategic objectives**: In order to achieve this goal or vision, a number of strategic objectives will have to be achieved.
- **Outputs or deliverables**: Tangible products and services that emerge from the delivery plan over the EAS' lifetime. Without these, the strategic objectives cannot be achieved.
- **Activities**: The actions that need to be undertaken to deliver the required outputs. These activities are time-bound and need to have clearly available resources e.g. financial and human.

Growth Aspirations

At present there is no specific policy for the size or direction of sustainable growth in English aquaculture. The UK's multi-annual plan for the Development of Sustainable Aquaculture (2014 – 2020) (Defra, 2015) and its update (Defra, 2018a) provides quantified growth targets for Scotland and Wales, but not for England or Northern Ireland. More recently SF2040 has suggested a 75% increase in sales value (from £35 million to £60 million) and employment (720 FTEs in 2014 to 1,260) from English aquaculture by 2040, but this does not reflect any official Defra targets.

The original project design called for the development of future growth scenarios. Given the long-term nature of this Strategy (20 years), it was agreed with the ALG that these would be 'aspirational', based upon what might be achievable if the Delivery Plan is fully implemented and no new major risks or externalities appeared. The growth aspirations have been developed using an Excel-based sector growth potential model. The core processes involved are as follows:

1. Compiling existing data on past English aquaculture production and disaggregating it by production system type and species to give individual baseline production levels.
2. Identifying the key factors affecting growth potential for (i) six different English aquaculture production systems and (ii) 17 different species groups, resulting in 44 different species / production system combinations.
3. Assigning scores for each system / market related factor. We have then weighted these to manage their relative influence as in **Table 2** below e.g. 'Access to finance' (50%) is only half as important as 'Site availability' (100%). Weighted scores are then combined to produce a notional 'growth potential index' for the 44 species / production system combinations.
4. A 'relative growth potential index' was calculated by relating each 'species / production system' combination to the one with the lowest growth potential which is designated as the baseline zero growth point. These relative growth potential indices (e.g. relative to the baseline) are then used to calculate the compound annual growth rate (CAGR) and applied to the baseline production levels prepared in step 1. Where no baseline production levels are available (e.g. for Atlantic salmon in RAS), we have used our own baseline estimates derived from discussions with stakeholders such as investors in aquaculture development.
5. We have then used multipliers to estimate future employment levels, value & gross value added.

Table 2: Production system and market-related factors used in the sector growth model

System-related factors	Weighting (%)
Access to finance	50%
Site availability	100%
Regulator complexity	100%
Social licence to operate	30%
Pollution control	80%
Escape control	70%
Spatial conflict	100%
WQ sensitivity	80%
Biosecurity	100%
System scalability	100%
Skill availability	80%
Knowledge of system	70%

Market-related factors	Weighting (%)
Market acceptance	100%
Market growth potential (inc. export)	100%
Value-adding potential	80%
Price stability	80%
External competition	100%
Seed availability	80%
Brexit sensitivity	80%
Social sensitivity	50%

While the resulting estimates are aspirational, they are based on an analytical framework that attempts to balance the growth potential with the specific challenges facing the production systems and species that could be part of English aquaculture in 2040.

There are also methodological limitations to the sector growth potential model, including:

1. The model uses a smooth annual growth rate for a particular species / production system combination, based upon its calculated relative growth potential index. In reality this is unlikely, with a stepped increase more likely as new operations come online (e.g. scallops take five years to get to harvest size) and regulations change. This is obviously impossible to model in advance and does not impact the estimated outcome.
2. The weightings are applied across all production systems / species groups.

1.3.3 Key Externalities

The EAS is influenced by assumptions regarding the main externalities affecting both the seafood industry in particular, and wider society in general. Three operate at macro level (**COVID-19, EU-Exit**) and **climate change**, but others operate more at the seafood sector level.

COVID-19: At the time of writing (early August 2020) the first wave of the COVID-19 pandemic is subsiding but persisting for some time, with unprecedented long-term economic implications globally. Our first assumption is that the current tiered regional lockdowns continue over the next 6 – 12 months before an effective vaccine is developed. In the short-term, the production, processing and distribution of seafood could be affected by labour shortages and new regulations aimed at containing the pandemic and blockages to transportation routes, as well as by a contraction of demand. Small-scale operators, who represent the largest share of those employed in the sector are likely to be heavily impacted if they cannot sell their products or buy the required inputs. A global contraction of trade is also expected, which potentially has significant implications for both the fisheries and aquaculture sectors, as fish is a highly traded commodity (OECD-FAO, 2020).

Our second assumption is that this is a global situation, and that whilst seafood supply chains have shown remarkable resilience, moves will be made to reduce their vulnerability to future pandemics, which will likely mean a slow-down and possible reduction in global trade for some commodities. At a local level this suggests that some of the mitigation activities by English seafood businesses (e.g. direct selling, an increase in local supply chain for locally caught fish, digital innovation and a shift towards web-based selling, online services and improved product traceability and sustainability) will be maintained and accelerated.

EU-Exit: The current uncertainty over agreement with the EU, including fishing access suggests – together with the uncertainty caused by the Internal Markets Bill - that a hard, no-deal EU-Exit remains a strong possibility. In terms of this Strategy, our third assumption is that there will be considerable disruption to trade with the EU over the short-term e.g. the possible imposition on tariffs by both sides and consequent re-adjustment of supply chain agreements, with a 'new normal' becoming established over the medium and long-term periods of the Strategy. We assume that exports will continue to be a strong focus of the sector, with the 75% increase in exports expected by SF2040 still achievable. EU markets, especially for shellfish, will still be important, but will be supplemented by other markets.

Climate-change. This issue is examined at the sectoral level in **Section 2.1.6**, but is briefly discussed here in terms of its wider sense. There is clear evidence to show that climate change is happening. Measurements show that the average temperature at the Earth's surface has risen by about 1°C since the pre-industrial period. 17 of the 18 warmest years on record have occurred in the 21st century and each of the last three decades have been hotter than the previous one. While the temperature rise at the Earth's surface may get the most headlines, the temperature of the oceans has been increasing too. This warming has been measured all the way down to 2 km deep. The chemistry of the oceans is also changing as they absorb approximately a third of the excess carbon dioxide being emitted into the atmosphere. Carbon dioxide absorption is causing the oceans to become acidic more rapidly than perhaps any point in the last 300 million years. More damaging extreme weather events are being seen around the world. Heat waves have become more frequent and are lasting longer. The height of extreme sea levels caused by storms has increased. Warming is expected to cause more intense, heavy rainfall events. Together these developing impacts are likely to have a profound affect worldwide, with their effects likely to be seen over the lifetime of this Strategy.

Markets and consumers: Seafood consumption has been in general decline since 2007 and unless the decline slows, seafood eaten 'in home 'is projected to hit a new record low before 2040. The decline is being driven by a fall in retail, seafood consumption; which has declined by -25% over the past 10 years, equating to around £5.5bn lost out of retail seafood sales (Seafish, 2019). Seafood consumption in foodservice has remained more resilient, remaining flat and returning to growth in recent years. UK seafood consumption (both in and out of home) stood at 152.8g (approx. 1.15 portions) / person / week. in 2018 resulting in the UK population only eating around half of the amount of seafood recommended by health professionals. Reversing this trend and reaching a target of two seafood portions per week by 2040, is a major objective of both the Government and the SF2040.

Labour versus technology: the English aquaculture sector currently employs around 1,080 persons, of which the full-time equivalent (FTE) is around 740 (Hambrey & Evans, 2016; Pye & Tait, 2020). With the ten-fold increase in production volume envisaged by 2040, this implies that over 8,000 FTE could be provided directly by aquaculture by is date. However it is likely that increasing scales of economy as well as technological innovation will mean that this is unlikely to be achieved, and we consider that up to 5,000 FTE is a more likely scenario.

Sustainability: Since the Rio 'East Summit' in 1992, 'sustainability' has become an increasingly important consideration for producers, seafood buyers and consumers. In most cases this is considered from an environmental standpoint but is also covers the two other legs of the 'three-legged stool', economy and society. Potential sustainability issues in aquaculture include changes to the aquatic environment from nutrient enrichment (from uneaten food and faeces), habitat damage from anchors and other infrastructure, biodiversity impacts from escaped stock amongst others. It is essential that the Strategy consider these issues to ensure that any development is sustainable and maximises the emergence of low trophic aquaculture (e.g. of shellfish and seaweed) where possible.

Social license for aquaculture: In some cases, there is significant opposition to development applications from non-local stakeholder groups that are committed to opposing aquaculture (Hambrey and Evans 2016) through the planning system. As a relatively new sector in the UK, aquaculture developments may be judged by different standards than sectors perceived as more traditional such as fisheries, even though these traditional sectors may in fact be highly industrial and have significant ecological-social impacts (Schlag and Ystgaard 2013; Black and Hughes 2017). At present, a large proportion of the UK population were born before the extensive development of aquaculture in the UK, but by 2040 most of the population will have grown up with aquaculture. There has been a shift in both public perceptions and media coverage of aquaculture with time and demographic change (Verbeke *et al*, 2007; Fernández-Polanco and Luna, 2012), and an increasing social license for aquaculture may be expected (Black and Hughes, 2017).

1.3.4 Information sources

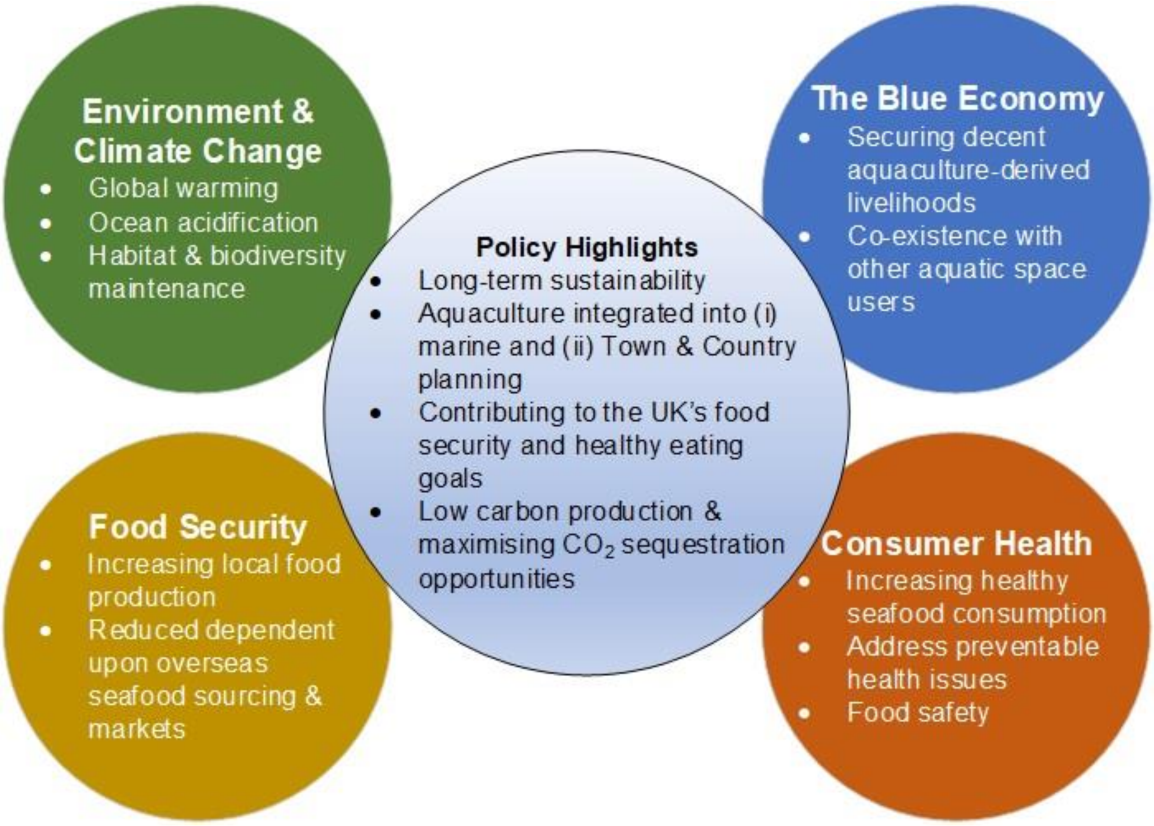
The main source of information for this Strategy has been discussions with the ALG and individual stakeholders across the wider aquaculture supply chain (see above). Stakeholder insight was supplemented with published sources of information referenced in **Appendix A.**

2. Policy and Strategic Framework

2.1 The Policy Environment for English Aquaculture

Policies are the means by which governments translate their political vision into programmes and actions to deliver outcomes (Huntington & Shelley, 2013). As with any strategy, the EAS will be underpinned by the prevailing policy framework, thus ensuring that the associated delivery plan is fully aligned with current government thinking. Importantly this will also provide a link between high-level policy intent and the practical needs of the English aquaculture sector. There are a range of policies that will have an impact on the direction and nature of aquaculture development in England. These are summarised in **Figure 2** and explained in the following text.

Figure 2: Key policy areas driving aquaculture development in England



2.1.1 Sustainable Development Goals

The UK Government has stated its commitment to the delivery of the United Nations (UN) Sustainable Development Goals (SDGs) for 2030. Whilst this Strategy has relevance to all 17 SDGs, the following lists those where the sector can potentially have most positive impact:

- Goal 3: Good Health and well-being
- Goal 6: Clean water and sanitation
- Goal 8: Decent work and economic growth
- Goal 13: Climate action
- Goal 14: Life below water
- Goal 12: Responsible consumption and production
- Goal 17: Partnerships for the goals

The Government implements the SDGs through single department plans (SDPs). Defra's SDP[7] has specific links to all the above SDGs for the different departments of the Defra Group.

[7] See https://www.gov.uk/government/publications/department-for-environment-food-and-rural-affairs-single-departmental-plan/department-for-environment-food-and-rural-affairs-single-departmental-plan--2

2.1.2 The Blue Economy

Fisheries and Aquaculture

Since the 2013 Common Fisheries Policy (CFP) reform, aquaculture policy has been jointly managed by EU Member States and the EU under their 'Open Method of Co-ordination' (OMC). The OMC is based upon a set of strategic guidelines for the sustainable development of EU aquaculture that includes (i) the simplification of administrative procedures and (ii) securing the sustainable development and growth through coordinated spatial planning as key elements. Member States, including the UK, also produced 'Multi-Annual National Plans for Aquaculture' over the EMFF period of 2013 – 2020. These plans were designed to implement the 2013 EU strategy and were a pre-cursor to using EMFF funds (European Commission, 2013).

Following the UK's decision to withdraw from the EU, the UK Government has introduced the Fisheries Bill[8], which has recently completed its final parliamentary scrutiny. The Bill covers "fisheries, fishing, aquaculture and marine conservation" and has a series of policy objectives relevant to aquaculture (see **Box 1** below). In time, a Joint Fisheries Statement will be developed to set out the policies relevant to the delivery of these objectives.

Box 1: Aquaculture-related objectives of the proposed UK Fisheries Bill

Sustainability Objective: long-term sustainability that achieves economic, social (including employment) and environmental benefits and contributes to the availability of food supplies.

Precautionary Objective: the precautionary approach to fisheries management is applied.

Ecosystem Objective: using an ecosystem-based approach so as to ensure that their negative impacts on marine ecosystems are minimised and, where possible, reversed.

Scientific Evidence Objective: scientific data relevant to the aquaculture activities are collected and that aquaculture activities are based on the best available scientific advice.

Climate Change Objective: the adverse effect of aquaculture activities on climate change are minimised and aquaculture activities adapt to it.

Source: Summarised from the (draft) UK Fisheries Bill, 2020

Whilst covering aquaculture including aquatic animal health, other than the high level objectives given in Box 1, the Fisheries Bill is focused on wild fisheries and does not really provide any further guidance on where and how aquaculture might be developed except for acknowledging that any growth must be industry-led. The Fisheries Bill does make provision for a Fisheries and Seafood Scheme (FaSS, the replacement for the EMFF scheme) and sustainable aquaculture will remain in scope.

This said, the CFP's Article 34 on sustainable aquaculture has been rolled into the Common Fisheries Policy (Amendment etc.) (EU Exit) Regulations 2019 No. 739[9], stating that "*With a view to promoting sustainability and contributing to food security and supplies, growth and employment, a fisheries administration must in conjunction with the other fisheries administrations, seek to establish non-binding strategic guidelines on common priorities and targets for the development of sustainable aquaculture activities*".

Essentially the headline policy is that the Government will support industry-led growth, in a way that will contribute to delivering the objectives set out in **Box 1**.

[8] See https://publications.parliament.uk/pa/bills/lbill/58-01/071/5801071.pdf
[9] See https://www.legislation.gov.uk/ukdsi/2019/9780111178720

One area of policy ambiguity relates to the farming of Ordinarily Resident Non-Native ('Alien') species[10]. This is particularly relevant because the Pacific oyster (*Magallana gigas*[11]) has been farmed in English waters since the 1960s. With *c*. 980 mt produced in 2018 this is an important component of English aquaculture. In the 1950s and 60s government advice was that sea temperatures were not warm enough in the UK for Pacific oysters to successfully reproduce. It is now recognised that the species can reproduce in the UK and that there are a growing number of self-sustaining wild populations. Defra Group are in the process of reviewing their position regarding the farming and management of Pacific oysters in MPAs. Natural England (NE) are the statutory nature conservation body for activities in MPAs. In January 2020 after protected features in two MPAs shifted into 'unfavourable condition' as a result of an increase in Pacific oyster numbers, NE instructed that they now advise against authorisation of new Pacific oyster aquaculture businesses in MPAs as adverse effects on conservation features could not be ruled out. This position is subject to review, which will be informed by the forthcoming results of a Cefas study on the contribution to the further spread of Pacific oysters by farmed and wild Pacific oyster populations (the report is due in March 2021).

Co-existence with other marine space users (inc. conservation)

Aquaculture can co-exist with other Maritime Economic Activities (MEAs) and other marine users (such as recreational users and environmental conservation needs), so it is important to understand how Government policy towards growth in the different MEAs balances this development with environmental conservation objectives. The prevailing legislation is the Marine and Coastal Access Act (MCAA) 2009[12], specifically in Section 58[13]. In England this establishes regional Marine Plans as the main tool for marine planning – these are intended to set out priorities and the direction of future development within a Plan area. There are 11 Marine Plans around the English coastline with a long-term (20 years) timeframe[14] that are required to be kept under continued review[15]. Whilst some Marine Plans have been adopted (in South and East Marine Plan areas), others (the North East, North West, South East and South West Marine Plans) are being developed concurrently and are due for adoption in 2021, although the current drafts. It should be noted that even in draft form they are a material consideration in all decision-making in the marine area. These Marine Plans can be viewed online[16] and are accompanied by a geographic information system (GIS) based 'Explore Marine Plans'[17] digital service.

The framework for developing regional marine plans is the UK-wide Marine Policy Statement (HMG, 2011), a key policy document resulting from Section 44 of the Marine and Coastal Access Act 2009. Section 3.9 of this Policy Statement specifically covers aquaculture and states that:

"*marine plan authorities should take account of existing aquaculture activity in the area and seek information on possible future aquaculture operations in areas not previously used, assessing the suitability of those areas for development. Marine plan authorities should also take account of the financial and environmental impact that new aquaculture operations might have on existing marine activities in the area and ensure that activities are consistent with the environmental objectives of the Water Framework Directive (2000/60/EC) (WFD)*". In the absence of an adopted Marine Plan, the Marine Policy Statement is the "appropriate marine planning document" for decisions.

[10] https://www.gov.uk/government/publications/preventing-the-release-into-the-wild-of-certain-plants-and-animals-guidance '*for a species to be considered 'ordinarily resident*', the population should have been present in the wild for a significant number of generations and should be considered to be viable in the long term.
[11] The current taxonomic name for *Crassostrea gigas*
[12] See https://www.legislation.gov.uk/ukpga/2009/23/contents
[13] See https://www.legislation.gov.uk/ukpga/2009/23/section/58
[14] See https://www.legislation.gov.uk/ukpga/2009/23/section/61
[15] See https://www.legislation.gov.uk/ukpga/2009/23/section/54
[16] See https://www.gov.uk/topic/planning-development/marine-planning
[17] See https://www.gov.uk/guidance/explore-marine-plans

One of the adopted Marine Plans, the South Inshore and Offshore Marine Plan (HM Government, 2018a) has two policies specifically for aquaculture:

- S-AQ-1: "*Proposals for sustainable aquaculture in identified areas of potential sustainable aquaculture production will be supported. Proposals in existing or within potential sustainable aquaculture production areas must demonstrate consideration of and compatibility with sustainable aquaculture production. Where compatibility is not possible, proposals must demonstrate that they will, in order of preference: a) avoid, b) minimise c) mitigate significant adverse impacts on sustainable aquaculture, d) if it is not possible to mitigate significant adverse impacts, proposals should state the case for proceeding*".
- S-AQ-2: "*Proposals that enable the provision of infrastructure for sustainable fisheries and aquaculture and related industries will be supported*".

The East Inshore and Offshore Marine Plans (HM Government, 2014) have a single aquaculture-specific policy, this being:

- AQ-1*: "Within sustainable aquaculture development sites (identified through research), proposals should demonstrate in order of preference:*
  - *a. that they will avoid adverse impacts on future aquaculture development by altering the sea bed or water column in ways which would cause adverse impacts to aquaculture productivity or potential*
  - *b. how, if there are adverse impacts on aquaculture development, they can be minimised*
  - *c. how, if the adverse impacts cannot be minimised, they will be mitigated*
  - *d. the case for proceeding with the proposal if it is not possible to minimise or mitigate the adverse impacts"*

The draft wording for the North East, North West, South East and South West Marine Plans' Aquaculture policies is currently as follows[18]:

- AQ-1: "*Proposals within existing or potential strategic areas of sustainable aquaculture production must demonstrate consideration of and compatibility with sustainable aquaculture production. Where compatibility is not possible, proposals must demonstrate that they will, in order of preference:*
  - *a. avoid*
  - *b. minimise*
  - *c. mitigate significant adverse impacts on sustainable aquaculture production*
  - *d. if it is not possible to mitigate significant adverse impacts, proposals should state the case for proceeding.*
- AQ-2: *Proposals enabling the provision of infrastructure for sustainable aquaculture and related industries will be supported".*

MMO have undertaken various evidence-building projects to support aquaculture in marine planning, including MMO 1305 (MMO, 2013a), MMO 1040 (MMO, 2013b), MMO 1051 (MMO, 2013c), MMO 1128 (MMO, 2017) and MMO 1184 (MMO, 2019).

[18] The North East, North West, South East and South West Marine Plans are due to be adopted in 2021 and the text may have been updated following draft consultation.

It is important, however, not to review these policies in isolation - there are a number of policies that intersect with aquaculture including managing social, economic and environmental impacts that might be relevant to any development (litter, noise, heritage) including aquaculture as well as inter-sectoral interactions (e.g. displacement) and benefits realisation (employment).

At present proposed aquaculture activities within Marine Plan areas require a marine licence from the MMO. This said, shellfish farming is largely exempt from Marine Licensing with some exceptions[19]. Licence applications for all marine space use, including aquaculture development, must be evidence-based and applicants must prove that their development is not going to significantly affect other users of the sea, including their conservation value and environmental and other impacts e.g. on navigation. The main focus of the evidence that must be provided in support of an application is the potential impacts to the environment, human health and other marine users from the project.

If the application is located in designated sites then this evidence needs to be particularly robust in order for the MMO to undertake advanced assessments e.g. Habitats Regulations Assessments and Marine Conservation Zone assessments. If a project may impact such a site, then the assessments are mandatory in order for the MMO to comply with Regulation both national and international. In terms of other alternative uses, what must be considered is the impact on existing and potential developments in the area. The application must comply with all Marine Plan Policies that apply for the area, this does not mean only providing the policies that support the development as evidence of support for the project.

This puts the onus on developers to justify their project. In the eyes of some aquaculture developers this is too precautionary, especially when many applications are small in scale and cover low trophic species[20] such as bivalve shellfish and seaweed which are increasingly seen as benign, if not positive in relation the ecosystem services they provide (this issue is discussed more in Section 3.2.1). MMO consider that they are bound to consider all the potential impacts of any additional marine infrastructure e.g. of shading, scour and accretion of the seabed and detritus, etc, regardless of the trophic nature of the species.

This policy-led precautionary approach, as set out in Defra's 25 Year Environment Plan (see Section 2.1.3), is unlikely to change after the UK's EU-exit, as conservation interests will likely remain vigilant over any proposed changes. Intensive fish farming (finfish and shellfish, but currently not algae) is also listed under Schedule A2 of the Marine Works Regulations (MWR) (Environmental Impact Assessment (EIA) 2007) (as amended), requiring 'screening by determination' to determine if effects are likely (because of its size, nature or location) to have a significant effect on the environment or to undergo voluntary EIA and 'Screen-in by agreement' (under Regulation 5 of MWR).

2.1.3 Environment

The UK '25 Year Environment Plan' (HM Government, 2018b) sets out government action to help the "natural world regain and retain good health". It sets out to deliver a "Green Brexit" and tackle the effects of long-term climate change. Although set as UK level, it recognises that some aspects of environmental policy are the responsibility of the devolved administrations. This Plan sits alongside two other important government strategies: the 'Industrial Strategy'[21] and 'Clean Growth'[22] strategy.

[19] https://www.gov.uk/government/publications/marine-licensing-exempted-activities

[20] Low trophic species are those at the bottom of the food chain.

[21] https://www.gov.uk/government/publications/industrial-strategy-building-a-britain-fit-for-the-future

[22] https://www.gov.uk/government/publications/clean-growth-strategy

2.1.4 Food Security

The security of UK food supply (e.g. "*access at all times to sufficient, safe, sustainable and nutritious food, at affordable prices*"[23]) is a key priority for the Government, particularly in light of the UK's withdrawal from the EU and the disruption to global seafood supply chains due to the COVID-19 pandemic. Policy options for maintaining UK food security (Houses of Parliament, 2017) include:

- supply-side measures such as increasing UK productivity and diversifying production;
- demand-side measures such as changing consumption patterns;
- reducing food waste; and
- ensuring equitable distribution of food.

The UK government is currently conducting a review into England's food production and supply chains and has recently published Part 1 of a White Paper on a 'National Food Strategy'[24].

English aquaculture currently has a very small role in supporting the UK's food security. However both trout and especially mussels – the current mainstays of production - have potential to expand their UK / export markets. Costello *et al.* (2020) considers that bivalves in particular may contribute substantially to food security by providing relatively low-cost and thus accessible food, because they have a high production potential at low costs compared to finfish production.

To make a significant contribution to food security, English aquaculture will have to both diversify to produce species with more mainstream consumer interest and grow in volume. The UK currently imports around 800,000 mt seafood per year, mainly tuna (14%), cod (13%) and shrimp (10%) (MMO, 2019). Whilst English aquaculture may not be able to produce exactly the same species (tropical tuna farming is unlikely to be viable in our cooler seas), there are possibilities for similar whitefish and shrimp, especially if RAS are scaled up, creating the potential to produce both temperate species (such as salmon), as well as warm-waters species such as penaeid shrimps[25]. An advantage of RAS systems is that they can be used to produce exotic and consumer-preferred species with the higher levels of biosecurity afforded by a completely closed production system under strict environmental controls and without the attendant problems of sea lice and other issues facing open water cages systems in the marine environment.

2.1.5 Consumer Health

The EAT– Lancet Commission on healthy diets from sustainable food systems (Willett *et al*, 2019) has emphasised the importance of food systems that have the potential to nurture human health and support environmental sustainability. From a dietary perspective, seafood provides many human health benefits, especially the provision of important omega 3 fatty acids.

The SF2040 Strategic Framework recognises Public Health England's (PHE) advice to eat at least two portions of seafood a week. Studies over several decades have suggested a preventative link between fish consumption and reductions in ill-health. National Health Service (NHS) guidelines recommend that "*a healthy, balanced diet should include at least two portions of fish a week, including one of oil rich fish*" (NHS, 2019). However, household purchases of fish and fish products have fallen steadily since 2006 (Defra, 2018b) following the 2007 recession and has been in general decline since, struggling to offer the value for money to compete effectively against other animal and plant proteins (Seafish, 2019). The current estimate for seafood consumption across England is only half the

[23] See https://publications.parliament.uk/pa/cm201415/cmselect/cmenvfru/243/243.pdf

[24] https://www.nationalfoodstrategy.org/

[25] England already has a RAS farm producing a penaeid shrimp, the white-legged shrimp (*Litopenaeus vannamei*) in its Lincolnshire facility. See FloGro Fresh- https://flogrosystems.com/

recommended level, i.e. just over one portion a week (*c*. 140 g) (Defra, 2018b). A recent study as yet unpublished study (Anastasi *et al.*) suggests that the net socio-economic impacts from increasing seafood consumption by one additional portion a week across the English population can be valued at between £14.5m and £58.2m per week in benefits (from avoided cases of type-2 diabetes and cancer).

At a global level all currently available estimates of future seafood production show limited growth for the capture sector, indicating that the majority of future seafood demand will have to be produced through aquaculture (Troell *et al*, 2019). Stentiford *et al.* (2020) advocate the 'One Health' approach to aquaculture e.g. a collaborative, multi-sectoral and transdisciplinary achievement of beneficial health and well-being outcomes for people, non-human organisms and their shared environment.

Meeting the target of two portions of seafood a week will be a challenge, both in terms of production and consumer education. **Table 3** overleaf demonstrates that, even if English aquaculture meets its aspirational growth goal and other UK aquaculture production increases by 50%, a further 900,000 mt of seafood will be required to provide two portions of seafood a week, based on the UK's predicted population in 2040. Clearly English aquaculture will not fulfil this role by itself.

Table 3: UK Seafood supply and consumption (current 2018 and estimated in 2040)

Current supply and consumption (2018)		Comment / assumption
UK capture fisheries production (mt)	395,000	MMO fisheries statistics
UK aquaculture production (mt)	184,891	
Imports into the UK (mt)	797,000	MMO fisheries statistics
Exports from the UK (mt)	484,000	MMO fisheries statistics
Net supply (mt, live weight)	892,891	
Net supply (mt, consumable weight)	446,446	Assumes 50% overall yield
UK population	66,400,000	Office of National Statistics (ONS)
Consumption (g/person/week)	129.3	
Consumption (140 g portions/person/week)	0.9	

Future supply and consumption (2040)		Comment / assumption
UK capture fisheries production (mt)	395,000	Assumes no change
England aquaculture production (mt)	91,316	Growth aspiration
Other UK aquaculture production (mt)	300,000	Assumes Scottish production grows by 50%
Imports into the UK (mt)	800,000	Assumes no change
Exports from the UK (mt)	774,000	Assumes c 332,000 mt increase in exports, mainly from aquaculture
Surplus supply required (mt)	*900,000*	
Net supply (mt, live weight)	1,712,316	
Net supply (mt, consumable weight)	1,027,390	
UK population	72,000,000	Based on ONS estimate for 2043
Consumption (g/person/week)	274.4	
Consumption (140 g portions/person/week)	2.0	

2.1.6 Climate Change

Global aquaculture accounted for approximately 0.49% of anthropogenic greenhouse gas (GHG) emissions in 2017, which is similar in magnitude to the emissions from sheep production (MacLeod *et al*, 2020).

Climate change will have a profound effect on aquatic ecosystems and their productivity over the next few decades. The most recent (2019) UK Climate projections are broadly consistent with those from 2009, suggesting warmer, wetter winters and hotter, drier summers. This will be accompanied by sea level rises of 53 – 115 cm (in London, under the high emission scenario) and increasing sea surface temperature (models suggest a mean projected rise in temperature for 2069-89 relative to 1960-89 is over 3 °C for most of the North Sea, English Channel, Irish and Celtic Seas (Hughes *et al*, 2017).

In June 2019, Parliament passed legislation[26] requiring the government to reduce the UK's net emissions of GHGs by 100% by 2050, relative to 1990 levels. Doing so would make the UK a 'net zero' emitter (hence the 'Carbon Net Zero' moniker). For English aquaculture this has two implications:

Firstly, aquaculture development under the Strategy (until 2040) needs to become increasingly aligned with the Carbon Net Zero agenda. For instance, moving aquaculture offshore has the potential to increase emissions from support vessels. This impact can be reduced by sourcing green-tariff electricity and the pro-active adoption of low-carbon innovations such as hybrid / electric power units in marine vessels or the use of floating wind / solar power plants at sea. Higher trophic level aquaculture products (e.g. shrimp tilapia, catfish, salmon) have low carbon emissions (*c.* 4 kg CO_2 / kg) compared to beef (12 – 16 kg CO_2 / kg), pork (4 – 8 kg CO_2 / kg) and similar to chicken (3-4 kg CO_2 / kg)[27]. Production of lower trophic species can reduce carbon further, with molluscs (e.g. mussels and oysters) amongst the lowest (Hilborn *et al*, 2018; MacLeod *et al*, 2020; Suplicy, 2020), provide a number of ecosystem services (van der Schatte Olivier *et al*, 2020) and are able to sequester carbon through the production of geologically stable calcium carbonate shells (Smaal *et al,* 2019), although this is currently being contested (Morris & Humphries, 2019). The cultivation and harvesting of seaweeds can also play a role in carbon sequestration and the reduction of GHG emissions (Chung *et al*, 2011). As well as sequestering carbon, seaweed can absorb nutrients, offering the potential for remediation services in areas adjacent to terrestrial nutrient run-off.

Secondly, aquaculture is itself vulnerable to the consequences of climate change. For example, the possible increased frequency of severe storm events has implications for moving aquaculture offshore, especially in the exposed North Sea and Western Approaches, and seawater temperature increases will provide both opportunities (new species) and problems (warmer water holds less oxygen). Oceans absorb around 25% of the CO_2 that humans release into the air. The oceans are becoming less alkaline, a process called 'ocean acidification', which has negative effects on zooplankton and calcifying organisms such as mussels (Petrou *et al*, 2019), although is currently less of an immediate threat in temperate waters like ours. On a more positive note, sea temperature increases will provide opportunities for the farming of warmer water species such as sea bass and sea bream, although growth rates will be lower than in the Mediterranean. Recent research (Maltby *et al*, 2020) suggests increases in the availability and catchability of red mullet, Dover sole, John Dory and lemon sole, all of which could be candidates for use in English aquaculture.

2.2 Summary of the Policy Framework for English Aquaculture

The main policy drivers for English aquaculture development are as follows:

- Growth will be industry-led, but subject to Government support where the wider enabling mechanisms are concerned;
- Any growth must be conducive with long-term sustainability that provides environmental, economic and social (including employment) benefits;
- The English Marine Plans and their more detailed local interpretation will be the primary mechanism for identifying areas for potential sustainable growth in marine aquaculture production – this will enable more focused investigation and the most suitable location(s) for a particular species and/or culture method to be identified;

[26] The Climate Change Act 2008 (2050 Target Amendment) Order 2019 – see www.legislation.gov.uk/uksi/2019/1056/contents/made

[27] https://www.aquaculturealliance.org/advocate/assessing-carbon-footprint-of-aquaculture/

- Aquaculture development and permitting will be based on the best scientific advice. It is likely the onus will remain on the applicant to prove that aquaculture is the most appropriate use for a particular sea space, based upon environment, human health and other user considerations;
- The use of alien species[28] is discouraged, especially in sensitive habitats, unless strong evidence can be provided of their containment and biosecurity (e.g. land-based systems);
- EU-Exit and COVID-19 have shown the vulnerability of both imports and exports of seafood, with implications for both food security and market-led production. The policy is therefore to encourage increasing and diversified UK production. In terms of seafood, this is more likely to come from aquaculture than wild capture production;
- There are strong health policy drivers to encourage increased consumption of aquaculture food products to contribute to the Government's target of two seafood portions per week; and
- Aquaculture development will need to contribute to the UK's Carbon Net Zero objectives and provide opportunities for carbon mitigation, including sequestration.

2.3 Strategy Principles, Vision and Objectives

Looking at the English aquaculture sector now, one could be forgiven for being pessimistic. Production has not grown over the past decade and both EU-Exit and the COVID-19 pandemic have created considerable short-term uncertainties. This, combined with other issues such as the vulnerability of marine shellfish farming to poor water quality and the complexity of regulation for new and expanding aquaculture businesses on our busy seas, create a challenging environment for English aquaculture development.

But the longer-term prospects could be much brighter. As observed in **Section 1.2.1**, this current period is a watershed for English seafood production. Wild fisheries – which are mostly at or near maximum sustainable yield – have limited potential for expansion, but aquaculture is less constrained. There are prospects for transition to an improved risk-based approach to shellfish production area testing in English waters. There is also the opportunity for increased recognition of aquaculture as an aspiring MEA in English waters, which will encourage both new entrants and successful current operators to grow and diversify the sector as a more integrated 'blue economy' emerges. This is likely to be supported by the growing scale and economic viability of land-based aquaculture, especially through improved RAS. The rewards could be substantial, with English aquaculture potentially providing the main national contribution to SF2040's aspiration for a 75% increase in seafood consumption by 2040.

This process will not be easy. In order to succeed, the Strategy will require considerable commitment from central and regional government to facilitate sustainable aquaculture growth and diversification as a key component of the blue economy, UK food security and preventative healthcare. If this fails to materialise, the ambitious growth aspirations within this Strategy (see **Section 3**) will simply not be possible and the sector will continue on its current static trajectory.

[28] The case of Pacific oyster – an ordinarily resident non-native species is considered separately – see **Box 3**.

2.3.1 Strategy Principles

The future development of English aquaculture and implementation of this Strategy are based on the following core principles:

- **Aquaculture production should be environmentally, economically and socially sustainable**. It should be within the carrying capacity of the aquatic environment, have no significant impacts on aquatic biodiversity and habitats, be responsive to climate change and be balanced with the needs of other users.
- **Aquaculture operations both establish and follow good practice across the supply chain in terms of animal health and welfare, environmental stewardship, food safety and conducive working conditions**.
- **Aquaculture development should be regulated in a proportionate and balanced way**. The spatial planning and permitting of aquaculture should be responsive to the needs of the industry and sensitive to the scale and nature of proposed development, taking into account the levels of environmental risk it presents. Regulatory decisions will be evidence-based and where appropriate, precautionary.
- **Innovation will be core to the development of new production systems, feeds and products**. These will contribute to a circular economy through maximising the use of domestically-produced raw materials, locally-manufactured containment systems and a focus on local and regional markets to maximise value added and socio-economic benefits.
- **The development of low trophic species or the use of integrated multi-trophic aquaculture** should be encouraged to contribute to England's net-carbon zero ambitions. The focus is on the open-water culture of extractive species such as shellfish and macroalgae, with fed species e.g. finfish farmed mainly in enclosed or semi-enclosed systems.
- **Effective co-existence of aquaculture with other maritime activities, including wild capture fisheries, is key**. This will require collaboration with other marine technology research and development providers to maximise joint opportunities, as well as working with other legitimate users of the marine environment to avoid conflict and maximise synergies.
- **Aquaculture can develop at different scales**. There is role for the local production and marketing of seafood, as well as the larger-scale production of finfish and shellfish for more extended supply chains, including exports.
- **Aquaculture can provide a diverse range of job opportunities across the supply chain**. It is important that the strategy provides an enabling environment for secure and rewarding jobs, and that the necessary skills development processes are in place.
- **A co-management, partnering approach is developed between MMO and Defra, the industry, universities and research organisations, local communities and other key sector participants**. This should be based upon a mutual understanding and respect, common ambition and open communication.
- **Strategy implementation will occur through a combination of national and regional actions**. This Strategy will provide a high-level action plan and framework for regional initiatives, such as area-specific aquaculture strategies and maritime spatial planning.

2.3.2 Vision

In 2040 English aquaculture is a significant contributor to increased seafood consumption in England, providing sustainable, low carbon food and rewarding livelihood opportunities as a recognised participant in the Blue Economy

2.3.3 Strategic Objectives

- **Growth and diversification of aquaculture in England over the next 20 years.** The Strategy is to support both (i) development and expansion of current production e.g. to further offshore development of mussels and (ii) the introduction of new species and production systems such as seaweeds and RAS to diversify the sector and create further growth opportunities.
- **Aquaculture is an innovative and integral component in the English 'Blue Economy'.** The Strategy is to work with, rather than compete against, other legitimate marine economic activities. This includes integrating aquaculture into capture fisheries operations and integrating aquaculture into offshore and coastal structures and operations. This co-existence will require considerable joint efforts in researching and developing compatible and economically viable systems and processes.
- **English farmed production contributes at least 15% of overall seafood consumption in England by 2040**[29]. The Strategy is to grow production to meet the current English wild fisheries production of around 92,000 mt of seafood and provide substitutes for some of the 674,240 mt of finfish and shellfish currently imported into the UK[30].
- **English aquaculture is sustainably produced and its products are regarded by wider domestic seafood processors, retailers, and wider society as just that, as well as being safe and nutritious.** The Strategy is to improve the public perception of farmed seafood, both in terms of its environmental sustainability and its position as a healthy and tasty alternative to other animal proteins. English aquaculture will be recognised for its contribution to the circular economy and domestic supply chains.
- **English aquaculture provides up to 5,000 secure and rewarding jobs by 2040, thus contributing to rural and coastal economies, especially in economically deprived areas.** The Strategy is to support sustainable growth by positioning aquaculture as a modern, safe and rewarding food production system, supporting new entrants and upskilling existing businesses through vocational and technical training as well as business development activities.

2.3.4 Outcomes

- **The barriers to sustainable growth in aquaculture production are identified and reduced**.
- **English aquaculture maximises the use of technology and innovation** to drive growth, improve its overall sustainability, in economic, social and environmental terms.
- **Aquaculture contributes to England's seafood production and overall food security**.
- **English aquaculture products are seen by wider society to be healthy and sustainably produced** and are accepted as an increasingly important part of the UK's seafood industry.
- **The aquaculture sector is seen as an attractive and rewarding employment opportunity** that contributes to the well-being and cohesion of English rural and coastal communities.

2.3.5 Activities, Risks and Assumptions

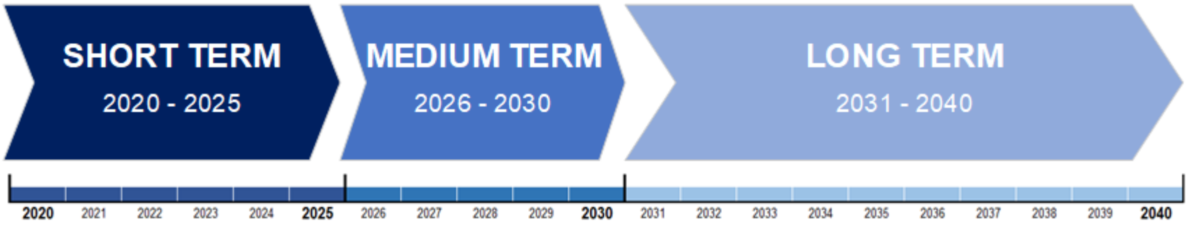
The Strategy's ***activities***, ***risks and assumptions*** are provided in **Section 3** under the individual sectoral and cross-cutting elements.

[29] Current contribution is <2%
[30] Figure is for 2018. From MMO (2019)

2.4 Timeline and Implementation Process

2.4.1 Timeline

The Strategy will be implemented through the remaining SF2040 timeframe i.e. a 20 year period from 2020 to 2040. It will be delivered over three distinct time frames as follows:



As the SF2040 Strategic Framework notes, the period on the horizon (2031 to 2040) is highly uncertain and specific deliverables for this period are not proposed at this time.

2.4.2 Implementation Process

How will it work?

This Strategy is owned by the SF2040 SILG and delivered by the SF2040 ALG.

Partnership and collaboration between government and industry across the supply chain – the foundation of the SF2040 business model – is fundamental to programme and to the future success of the EAS. Without that participation and buy-in from both government and industry via SILG and ALG, the Strategy would be very different in structure, content and aspiration. It is hoped, therefore, that even without the strategic overview and steer from the SF2040 programme, the EAS will be delivered upon by future governments and industry groups. There is an expansive list of primary and secondary partners who have strategic roles to play in developing English aquaculture (see "*Who is it for*?" below).

This breadth of stakeholders demonstrates the importance of England's aquaculture sector industry and government partners in ensuring a thriving and sustainable future. Like SF2040, the EAS is committed to the principles of collaboration, communication, best practice and science when engaging with those stakeholders.

The Delivery Plan (**Section 4**) provides a series of prioritised and time-bound actions to be undertaken taken by the sector over the next 20 years. Some of these will require sector-wide collective action whilst others are specific to certain parts of the sector. This plan will progress the EAS and drive SF2040's aquaculture-related work programme. Adhering to project management principles there will be determined checkpoints in the first two - three years to monitor progress and impact. The ALG – with its membership of industry, government and regulators – plays a critical role in supporting the SF2040 Secretariat at each checkpoint.

It is important that the EAS is revisited every two - three years to ensure the Delivery Plan continues to be appropriate and achievable. The growth aspirations set out in the EAS are bold and realistic, especially given the prevailing difficulties and uncertainties. The strength of this document will be its relevance and flexibility to adapt as the landscape changes, notwithstanding EU-Exit challenges and opportunities as well as ongoing COVID-19 recovery.

The EAS provides a structured approach to future growth, including establishing common goals and actions. Whilst some actions will be implemented at national level, it is envisioned that regional development will be led at regional level under the common framework provided by this Strategy.

Who is it for?

A wide range of stakeholders have been involved in developing this Strategy, including:

- Individual **aquaculture producers** and **supply chain partners;**
- **Aquaculture Producer Organisations** and other representational groups;
- **Regional partners** such as local authorities, Local Enterprise Partnership (LEPs), regional maritime groupings, etc.;
- **Strategic partners** such as water companies, harbour authorities, marine clusters, feed and equipment manufacturers, etc.;
- **Science, education** and funding partners such as Cefas, universities, vocational collages and private sector research organisations and United Kingdom Research and Innovation (UKRI);
- **Regulators** and **Government bodies** such as the MMO, Defra, the IFCAs, the Food Standards Agency (FSA), the Environment Agency (EA), NE, and The Crown Estate;
- **Other public bodies** such as Seafish and such as the National Institute for Health Protection (formally Public Health England);
- **Other legitimate marine interests**, including commercial wild fishers and their representatives; and
- **NGOs and wider civil society** who have an interest in aquaculture activities and its products.

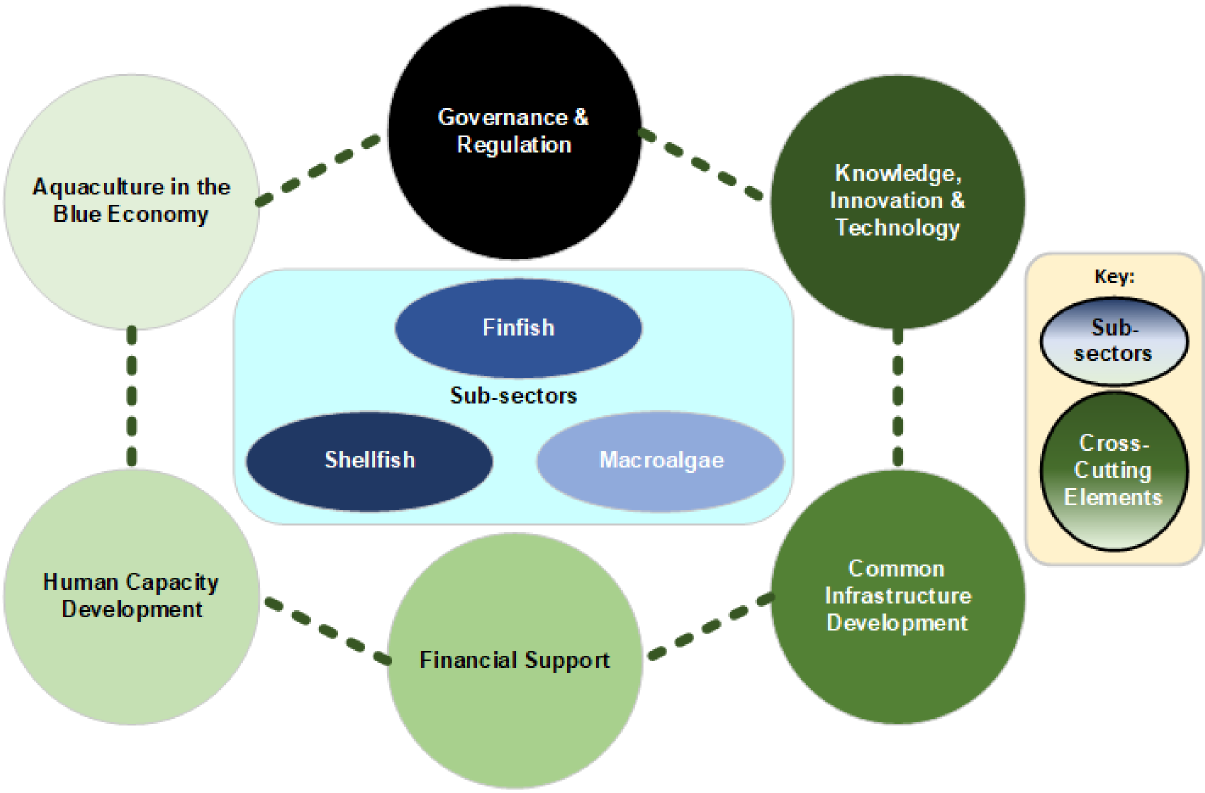
It is likely that the same stakeholders will be involved in the implementation of the Strategy. The proposed Delivery Plan (see **Section 4**) is time-bound and lists the aquaculture players within government, Seafish, industry, SF2040 ALG, etc. which are key to achieving the actions.

3. Strategic Actions

The following section provides a more detailed analysis of the ***current status***, ***growth potential and barriers***, ***key actions, risks and assumptions*** of the different elements of English aquaculture. These elements are presented under two broad types as described below and shown in **Figure 3:**

1. **Sub-sectors** i.e. the three distinct aquaculture sub-sectors composed of *finfish*, *shellfish* and *macroalgae*.
2. **Cross-cutting elements**: i.e. the six areas that are common to each sub-sector:
    a. Governance and regulation
    b. Knowledge, Innovation and Technology
    c. Common Infrastructure Development
    d. Financial Support
    e. Human Capacity Development
    f. Aquaculture in the Blue Economy

Figure 3: Sub-sectors and Cross-cutting Elements covered by the EAS



3.1 Sub-Sector Strategic Actions

3.1.1 Finfish

Current Status

Marine finfish covers both sea fish as well as anadromous species that can be reared in full or brackish seawater, such as Atlantic salmon and sea-grown rainbow trout[31]. There have been attempts in the past to develop marine finfish farming in England, especially in the south-west. Few have developed past the pilot stage, with inshore water quality, high peak water temperatures, price competition with Scottish products and opposition to open-water cage farming identified as key constraints.

At present the culture of marine finfish in English waters is almost non-existent and in 2018 only around 17 mt of sea-grown rainbow trout was produced in cages in SW England.

English **freshwater finfish** aquaculture is currently mainly rainbow trout (*c*. 4,500 mt per annum) grown in flow-through ponds and tanks and the native brown trout, which is widely used for restocking. Traditionally grown as 'portion size' (e.g. *c.* 400 g), there is a recent trend towards larger fish (1.5 - 3 kg) to diversify production to compete with cheap imported potion-size sea bass and sea bream fillets. The trout farming sector has strong representation in the form of the British Trout Association (BTA), which has supported prices in the face of fierce competition through a combination of marketing and facilitating producer co-operation. Other freshwater species include common carp and other cyprinids, much prized by Eastern Europe, mostly reared in ponds. Warm-water tilapia has also been farmed for many years, mostly in heated or industrial wastewater, but market demand and issues over control of the warmed water and its cost has meant that production has been variable, with only about 1 mt produced in 2017. There is also some production of Atlantic salmon smolts in northern England freshwater sites for the Scottish salmon farming industry which in 2011 was worth £6 million (cited in Hambrey & Evans, 2016).

The vast majority of English finfish production is currently conducted in river-based flow-through systems, contrasting with Scotland's reliance on caged fish along its highly indented coastline and in freshwater lochs. These river-based systems usually abstract water from reasonably fast flowing, oligotrophic (e.g. low in nutrients) water such as from chalk streams. Aquaculture is therefore competing with agricultural, industrial and urban abstraction needs. Abstraction competition, combined with drier winters and summers, has meant that both riverine and ground water is highly regulated and will be a key constraint to future expansion of traditional flow-through farming systems.

There is however increasing interest in semi-contained open water systems (including in-pond raceway systems, IPRS) and land-based production in RAS for table fish such as Atlantic salmon and trout, as well as cleaner fish e.g. lumpfish and wrasse for use in the Scottish salmon farming industry. RAS has had a chequered history, both in the UK and overseas, struggling to viably compete with wild fisheries and traditional aquaculture production, especially on price and taste. One RAS farm in an industrial unit in the New Forest near Lymington aimed to produce 400 mt of Asian seabass (or barramundi, *Lates calcarifer),* but failed in 2008 after two years of operation, despite a contract with John Lewis to supply fish to Waitrose. A number of early RAS systems, especially for warm water tilapia production were compromised by poor design and operation, resulting in low growth performance and achieving less than half their design production capacity and most continued to fall far short even after significant remedial investment (Murray *et al*, 2014). Another issue is tainting through the production of geosmin and Methyl-Isoborneol (MIB) as secondary by-products of bacterial metabolism. For more on RAS, see **Box 2** on page 29.

[31] Rainbow trout (*Oncorhynchus mykiss*) have diverse life histories, including both freshwater-resident and anadromous "steelhead" life-history forms. See Courtier *et al*, 2013

Growth Potential

Despite the current low production of **marine finfish**, this Strategy sees a prospect for considerable growth in this sub-sector, mainly through the use of RAS (see **Box 2** on page 29). There is growing investor interest in the land-based production of Atlantic salmon close to major English cities (e.g. for ultra-fresh sashimi), with a number of projects at the advanced planning stage. This Strategy aspires for around 14,000 mt production of Atlantic salmon in RAS by 2040, but this could be a large under-estimate (see **Figure 4** overleaf). The Strategy does not assume growth in traditional open water pens for salmon production (as in Scotland) due to a number of environmental issues (e.g. high surface seawater temperatures and a lack of sheltered sites) as well as strong resistance from wild salmon conservation interests.

We also see growth in the production of trout grown in sea water. Both rainbow trout (a long-established introduced species that has very limited self-sustaining populations in English waters) and the native brown trout can thrive in full seawater, with their sea-grown variants popular in restaurants. Some of this could be in open-water sea cages - sea-grown rainbow trout do not seem to be as susceptible to sea lice infections as Atlantic salmon (O'Donohoe *et al*, 2016), but infection monitoring will need to be established. Otherwise there is the potential to produce trout in seawater RAS systems, although the lower price point compared to salmon will limit commercial update and viability.

There are a number of other marine species such as European sea bass, gilthead sea bream, sole, halibut and yellowtail that can also be farmed in RAS. Volumes are likely to be low, as they will need to compete against established, mostly open-water cage farming operations in the Mediterranean and elsewhere and will mainly be for niche food service markets.

In terms of **freshwater finfish**, the Strategy aspires to growth in both the traditional flow-through systems (around an extra 3,500 mt, mostly of rainbow trout) as well as a growth in trout (c. 9,000 mt) and other fresh water species (c. 1,200 mt) raised in RAS systems (see **Figure 5** on page 28).

The expansion of the traditional systems will have to overcome limits in abstractable fresh water referred to previously by more efficient growing technologies, including tank systems, use of oxygenation, partial recirculation and integration into aquaponic systems. Advancements in the electronic monitoring of stock biomass, health and environmental conditions may all play their part (Føre *et al*, 2018). However it is recognised that most increases in the open-water farming of trout will likely take place in the sea as discussed above.

RAS - as practised in Denmark - is now a well proven and effective solution for growing trout in an environmentally responsible way. The use of RAS for trout production in England needs to be considered carefully, especially if it is to be based on the Danish model farms[32] where partial RAS is used extensively to produce 300 – 400 g portion-sized fish, as the UK market is moving towards larger, higher value fish for fillets. One scenario is that RAS systems take over the production of these smaller fish, whilst the traditional flow-through farms focus on the larger fish, capitalising on the taste and quality derived from open, flowing water, as is now the case in much Scottish salmon production. RAS has the potential to reduce 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 (Prof. Rasmus Nielsen, University of Copenhagen, pers. comm., 20 Aug 2020; Nielsen *et al*, 2016). The extent to which this can be achieved in England is still uncertain.

[32] Over 30% of Danish freshwater aquaculture now takes place in RAS.

Figure 4: Growth Aspirations – Marine finfish

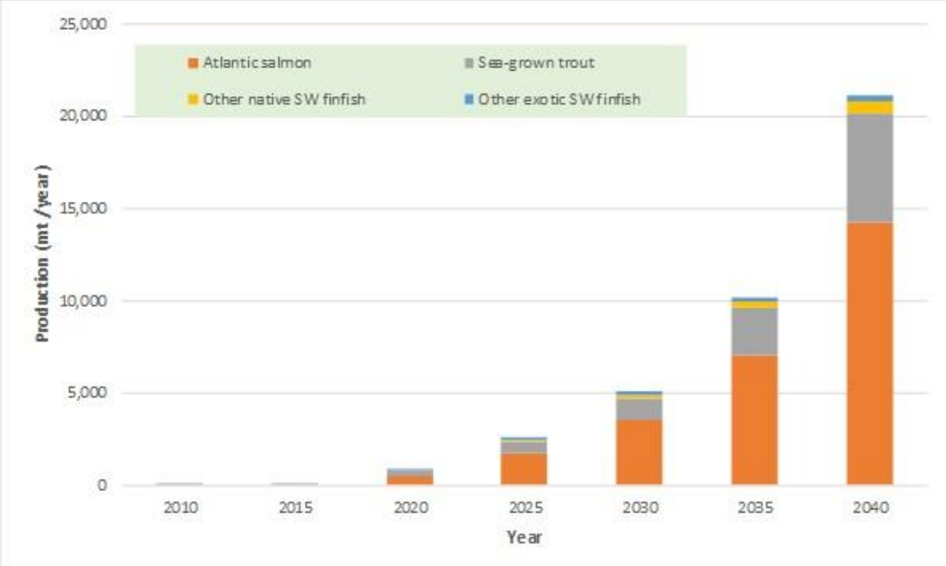
Marine finfish (tonnes per annum)

A. By species

Species	2010	2015	2020	2025	2030	2035	2040
Atlantic salmon	0	0	500	1,749	3,518	7,076	14,232
Sea-grown trout	8	9	279	608	1,176	2,546	5,905
Other native SW finfish	0	0	0	126	203	358	669
Other exotic SW finfish	0	0	11	135	172	220	281
Grand Total	8	9	790	2,618	5,069	10,199	21,087

B. By system

System type	2010	2015	2020	2025	2030	2035	2040
Open water pens	8	9	219	298	330	367	409
Flow-thru' ponds / tanks	0	0	0	0	0	0	0
RAS	0	0	571	2,320	4,739	9,832	20,678
Grand Total	8	9	790	2,618	5,069	10,199	21,087



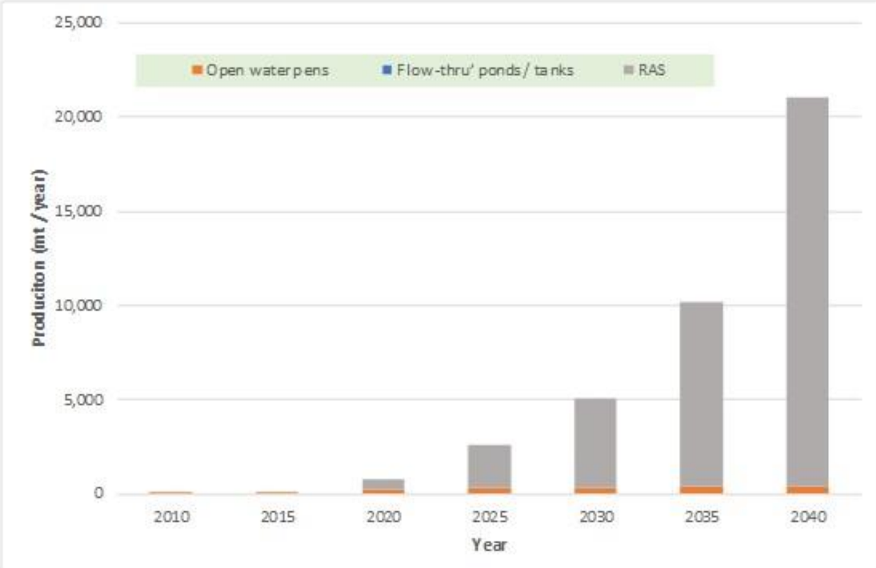


Figure 5: Growth Aspirations – Freshwater finfish

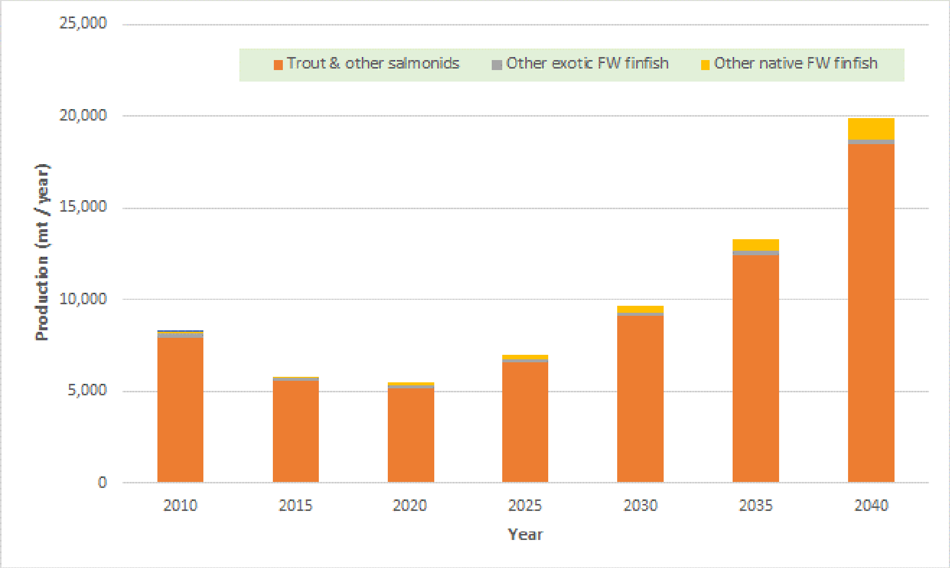
Freshwater finfish

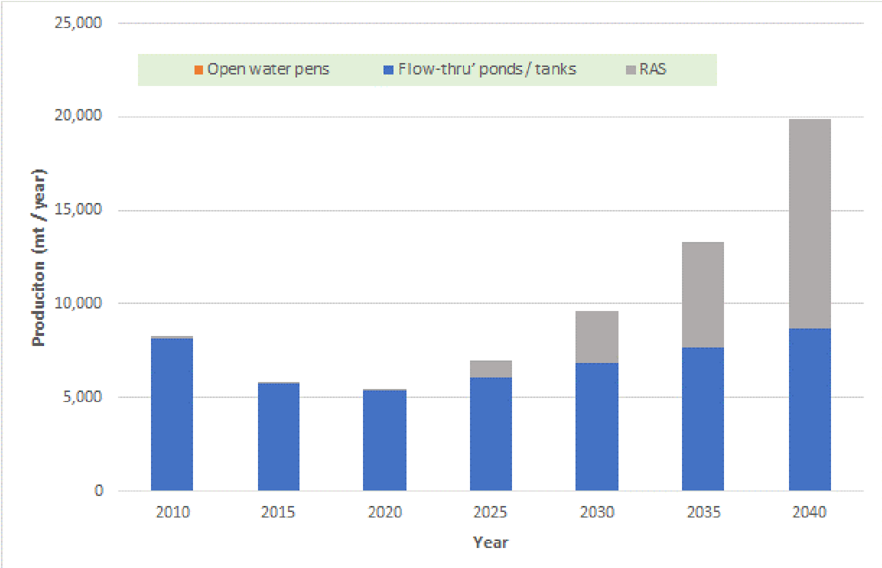
A. By species

Species	2010	2015	2020	2025	2030	2035	2040
Trout & other salmonids	7,972	5,593	5,186	6,616	9,096	12,453	18,439
Other exotic FW finfish	166	165	159	175	188	211	253
Other native FW finfish	135	4	113	203	365	658	1,186
Grand Total	**8,273**	**5,761**	**5,458**	**6,994**	**9,649**	**13,323**	**19,878**

B. By system

System type	2010	2015	2020	2025	2030	2035	2040
Open water pens	0	0	0	0	0	0	0
Flow-thru' ponds / tanks	8,138	5,757	5,345	6,027	6,798	7,670	8,657
RAS	135	4	113	967	2,851	5,653	11,221
Grand Total	**8,273**	**5,761**	**5,458**	**6,994**	**9,649**	**13,323**	**19,878**





Box 2: Recirculating Aquaculture Systems (RAS)

Recirculating Aquaculture Systems (RAS) are designed to minimise water consumption, control culture conditions and allow effective management of waste streams. They can also provide some degree of biosecurity through measures to isolate the stock from the external environment. They are currently used in Scotland to produce salmon smolts and to extend the land-based freshwater stage to produce c. 1 kg juveniles for stocking to sea cages. They are also potentially of use for producing fast-growing and higher unit-value warm water species such as European sea bass *Dicentrarchus labrax*; gilthead sea bream *Sparus aurata*; Senegal sole *Solea senegalensis* and yellowtail *Seriola lalandi* (Murray *et al*, 2014) although they will face competition from imported cage-farmed fish from the Mediterranean and elsewhere, and prices will be sensitive to over-supply.

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.

One authority (Russell, 2015) cited the main issues leading to failure with salmon in RAS to be:

1. Choosing a freshwater site with limited ability to use and discharge water
2. Building at too small a scale
3. Building in a location that requires chilling
4. Building in a place with no existing aquaculture and associated support industry
5. Building a facility in a pre-existing building, for multiple reasons
6. Stocking the facility with live fish rather than starting with eggs, which can be disinfected
7. Skipping the use of vaccines due to the assumption that disease is a non-issue
8. Use of continuous production models with no extra infrastructure to allow for individual RAS system downtime for cleaning and system resetting to break disease establishment
9. Pushing the limits of system carrying capacity and stocking density
10. Use of continuous production models in which systems are always stocked, with no downtime for system cleaning and resetting to break disease cycles and to eliminate carriers of disease
11. Use of pressurized oxygenation systems with inadequate total gas pressure (TGP) regulation
12. Inadequate degassing infrastructure for CO_2 stripping and TGP associated with warming of cold source water
13. Skipping the use of pathogen control on the source water
14. Using cheaper lower quality feeds without consideration of impact on water quality

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 adoption of accreditation and quality labelling schemes.

If these issues can be overcome, then RAS has the potential become a major contributor to English aquaculture and seafood production. Investment interest in RAS is currently very high and is likely to 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. Furthermore BP consider that long-term energy prices – one of the major cost components of RAS farms – to be lower than previously assumed at around USD 55 per barrel for Brent (BP, 2020). RAS will also need to access renewable energy in order to reduce its carbon footprint.

The UK – and England in particular – is well placed in terms of managing its disease status and also has strong skills in genetic analysis and services. As such there is potential to be globally competitive in generating exports of eggs and providing genetic services, and underpinning production of high performing fish for restocking and the table market (Hambrey & Evans, 2016; Strategic Innovation Ltd, 2020).

Barriers to Growth

There are a number of ***barriers*** to increasing **marine finfish farming** in England. For open water culture, cage systems will need to be offshore, requiring substantial investment and long-term security of tenure. In addition, they face a challenging wave conditions with limited shelter, high levels of marine traffic and a hostile public perception of open water fish farming systems and their environmental impact. These can be addressed by a combination of cautious permitting and the development of new technology such as Closed Containment Systems (CCS) in open waters that are being adopted outside the UK, mainly to reduce the time salmon spend in open-water systems (Stirling Aquaculture, 2018; Gorle *et al*, 2018). They can also reduce lice infestations by drawing in deeper water below the 'lice zone', which also tends to be cooler and therefore better oxygenated.

Freshwater aquaculture faces different barriers. The sub-sector is more mature and thus further growth will be mainly focused on refinement, improved economic and environmental performance and producing a better product. Finding new and expanding existing sites will be a challenge given limitations on surface and ground water availability, and many sites – both existing and potential – are found in environmentally sensitive areas. For instance most chalk streams are Special Areas of Conservation (SACs). Farms will have to improve their environmental performance (e.g. use more digestible diets, achieve better food conversion ratios and produce cleaner effluent water) and move to more intensive systems with greater mechanisation e.g. partial recirculation, oxygenation and filtration.

This suggests that any significant increase in production volume will have to come from RAS. However as can be seen from **Box 2**, the farming of finfish in land-based systems such as RAS also faces barriers, where this be for full production and the culture of market-sized fish, or in the initial growth stages of the stock ready for re-location to open water grow-out facilities. Whilst permitting might be less cumbersome compared to the multi-agency approach required for marine farming, it can still be a challenge to find sites. Although RAS technology is highly efficient with water use, economically competitive RAS aquaculture is very much dependent on the quality and quantity of water available and the ability of the operation to discharge the water after use. For salmon, a site with seawater access is important because their performance and the quality are generally better in seawater than in freshwater. Equally important is having the ability to access more water than is needed for water quality, as it is very useful in eliminating the need for chillers and high electric costs for cooling in summer. For many locations, the use of saltwater may not even be an option due to permitting constraints. Saltwater reclamation technology for the reuse of discharge is yet to be proven commercially viable and is associated with costly failures in non-salmonid species (Russell, 2015). As a result, most large-scale salmon RAS projects in England will probably use freshwater systems utilising ground water sources, thus freeing them from many of these constraints.

Another key challenge for RAS will be the position of its products in the market. RAS produced English salmon will face fierce competition from Scottish marine cage reared fish and will need to differentiate itself to compete. In particular it will have to promote its novel environmental credentials to create its own market niche (e.g. no impacts on wild salmonids through sea lice, no impact on the sea bed, no landscape visual impact and lower food miles compared to its Scottish equivalent). However it will need to consider how to reduce energy consumption and better access renewable energy in order to reduce its overall carbon footprint. This suggests that it is unlikely to compete effectively with other low cost salmon products, but will have to focus on more selective, high-end markets. The Strategy supports this approach, being mindful that the development of open-water marine cage farming (for trout, not salmon) is also part of the strategic mix. In terms of trout in RAS, another issue is the stocking densities involved. RAS systems often involve densities of 30 – 40 kg / m^3 which may have animal welfare implications (FAWC, 2014).

Other considerations (inc. cross-cutting issues of particular relevance to the finfish sub-sector: There are a number of other issues that are considered in the Strategy. Some of these are cross-sectoral in nature and are considered in more detail in **Section 3.2**. These include:

- **Consumer resistance to alternative feed ingredients, feed sustainability and GMO**. The move to improved growth rates and food conversion, better environmental performance (both on the farm and in the wider supply chain) and lower costs will require a number of changes to the feed ingredients that are used. This in turn raises a number of questions. First, the move away from expensive and increasingly limited supplies of fish meal to other plant or insect-based proteins raises questions over their own environmental impact and the use of genetically modified organisms (GMO) in agriculture. Second, there is some question over both retailer and consumer acceptance of these novel feed ingredients.
- **Vulnerability to diseases and the continued susceptibility to Rainbow Trout Fry Syndrome (RTFS).** A long-established bacterial disease affecting salmonid farms, there is yet to be an effective commercial vaccine for RTFS. The implementation of strategic biosecurity plans and optimisation of disinfection and husbandry practices have reduced the overall impact of this disease. However, the impact of these control measures is limited by the widespread nature of this bacterium in the UK's freshwater bodies.
- **The increasing number of third-party certification schemes**. There are now third-party certification schemes covering a wide variety of environmental, social, food safety and animal welfare issues. Whilst it is recognised these have a role in English aquaculture, their constantly evolving nature, high cost, and the over-lapping nature of the different schemes and the differing demands from retail buyers complicates producer investment in such schemes.
- **Competition from cheaper, wild-sourced alternatives**. Farmed seafood sales have continued to grow despite having an average price typically over twice that of cod or haddock (Seafish, 2019). This said, one of the main challenges to aquaculture is keep production costs competitive with wild caught equivalents. One example is cod, a species much loved by English consumers. Cod farming is entirely feasibly, but it has to compete with the large volumes produced by Norwegian and Russian fisheries in the Barents Sea, which currently has spawning stock biomass of over 1 million tonnes (ICES, 2020) which wholesale for around £2 / kg.
- **Lack of timely, accurate, detailed production and economic data**. Currently there is a lack of detailed production and associated economic data for aquaculture in England as farms are not legally obliged to supply this data. If the Strategy is to be successful, it is essential to be able to monitor the nature, scale and economic performance of all types of aquaculture, including finfish production. This subject is discussed separately in **Section 3.2.1**.

Key actions – Finfish sub-sector

Action		Outcome					Timing		
		OC1	OC2	OC3	OC4	OC5	2025	2030	2040
FF 1	Develop commercial marine finfish hatchery capacity and capabilities, especially for proven species such as sea bass, sole and 'cleaner fish' species (wrasse, lumpfish).	✓	✓	✓				✓	
FF 2	Prepare models for more efficient (in terms of growth and water use), less polluting and cost-efficient finfish farming in marine and freshwater. This may include, but not be limited to, closed containment systems in sea water, and partial recirculation in freshwater (e.g. via IPRS). Models may be developed at different scales e.g. <500 mt/pa, 500 – 2,000 mt/pa and >2,000 mt/pa and include options for integration with other forms of aquaculture (i.e. IMTA), agriculture and aquaponics, as well as alternative energy generating technologies such as wind and solar).	✓	✓	✓	✓		✓		
FF 3	Develop mooring, power supply, feeding, stock monitoring and other support systems for use in exposed and offshore sites in English waters.	✓	✓		✓		✓		
FF 4	Establish assessment protocols to examine the environmental benefits of, and services provide by, developing extensive terrestrial aquaculture in different water bodies / wetland habitats, both independently and in combination with other agricultural uses in order to optimise the sustainable use of these areas.		✓		✓			✓	
FF 5	Expand and enhance current skill and service base in genetics, disease prevention and vaccine development, etc.	✓	✓					✓	
FF 6	Investment into novel, IT connected stock and environmental monitoring systems for application in English and other aquaculture systems, focusing on improving growth and food conversion, detecting risk issues such as deteriorating water quality, disease and predation.		✓		✓		✓		
FF 7	Draft a policy and guidance for land-based RAS, inc. use of industrial and agricultural land, abstraction and discharge of water, and use and discharge of sea water in terrestrial environments.	✓	✓	✓	✓			✓	

Assumptions and risks

- Aquaculture is considered fairly and proportionally in marine and terrestrial space planning.

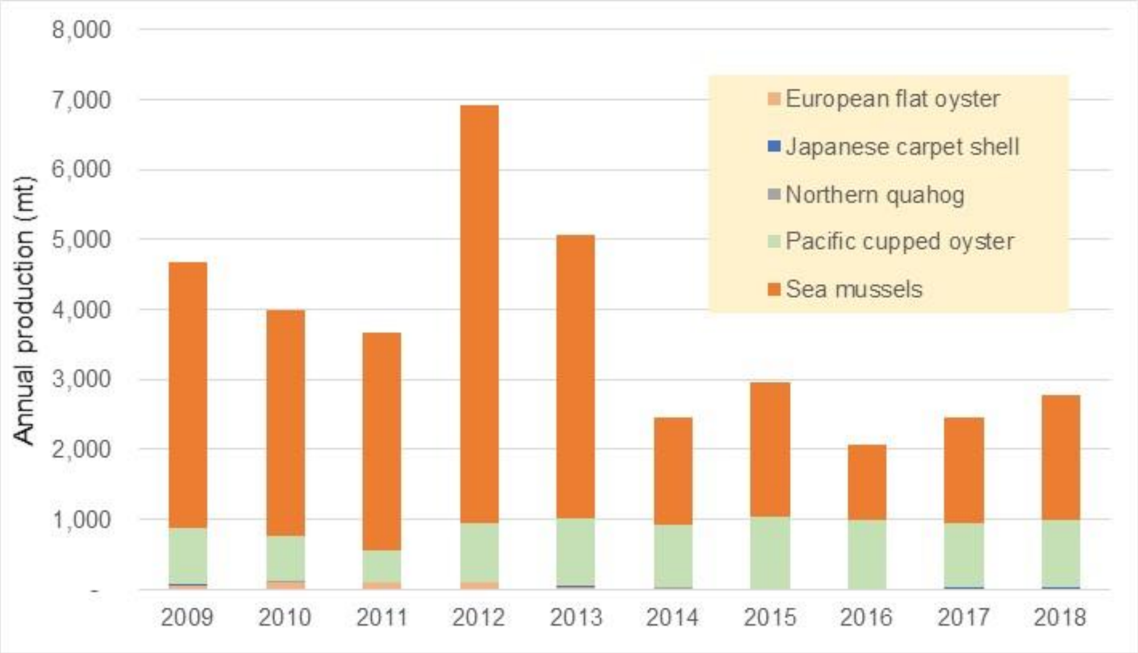
Key to Expected Outcomes (OC)	OC 1: The barriers to sustainable growth in aquaculture production are identified and reduced
	OC 2: English aquaculture maximises the use of technology and innovation to drive growth to improve its overall sustainability
	OC 3: Aquaculture contributes to England's domestic seafood production and overall food security
	OC 4: English aquaculture products are seen by wider society to be healthy and sustainably produced
	OC 5: The aquaculture sector is seen as an attractive and rewarding employment opportunity

3.1.2 Shellfish

Current Status

English shellfish production has ranged between 2,000 and 7,000 mt over the last decade and is composed almost entirely of blue (sea) mussels (mainly *Mytilus edulis*) and Pacific oysters (*Magallana gigas*) which constitute 65% and 35% of production respectively. The native European flat oyster (*Ostrea edulis*) and introduced Japanese carpet shell (*Venerupis philippinarum*) are also produced, but in much lower quantities.

Figure 6: Shellfish aquaculture production in England (2009 - 2018)



Source: Cefas data (2020)

Mussel production has decreased, but is likely to increase as larger, suspended culture sites further offshore come online (STECF, 2018), indicating a partial shift from traditional bottom and trestle-based systems to more sophisticated rope suspension systems. STECF (2018) also noted that the UK as a whole had failed to achieve an "aspirational target" to increase shellfish production by 33%. Oyster production is currently based on the relatively fast growing, high yielding Pacific oyster that has strong markets throughout the EU. The market for the native oyster is smaller and could be easily flooded, but there is an opportunity nonetheless for niche high-value "genuine native" production (Hambrey & Evans, 2016).

The English shellfish aquaculture sector is currently facing a number of serious issues. These are discussed more fully in the next section (***Growth potential and barriers***) but are worth outlining now as immediate threats to the short-term viability of this sub-sector:

1. **Increased pressure on space**, especially in the intertidal areas and is going to increase. All sectors face this same pressure.
2. **Uncertainty over the future policy for Pacific oysters**. Under the current 'holding' position, applications for new facilities culturing Pacific oysters within (i) designated MPAs (which account for 40% of English waters) and (ii) in areas where it is not present in the wild will not be allowed. This policy will be reviewed in 2021 when Cefas has reported on possible management and control scenarios (see **Box 3** on page 37).

3. **Lack of seed supply for some species e.g. oysters, scallops & clams**. There are currently only two hatcheries in the UK producing oyster juveniles. Hatchery capacity and hatchery technology (such as producing sterile polyploid juveniles) is key to potential growth, but new investment is discouraged by a lack of firm permitting policy (again see **Box 3**).
4. **Variable water coastal quality**. Coastal water quality is generally very good. However England receives high rainfall and has a population and agriculture densely clustered along the coast. Run-off from the land and via combined sewer overflows (the necessary safety valves that prevent homes flooding with sewage) during high rainfall causes periods of lower estuarine and costal water quality. During these episodes filter feeding shellfish accumulate and thrive on the enriched waters which can include faecal contamination. This is picked up by the food hygiene monitoring and may result in shellfish water classification down-grades to protect consumers. However this results in both producer and consumer uncertainty and has limited investment in shellfish aquaculture.
5. **Precautionary testing regime**. The current reliance on sampling and laboratory-based testing of samples (rather than risk- or flood event- based sampling and analysis) means that farmers and harvesters face considerable uncertainty over classification compliance. As a result, shellfish production areas can be re-classified for a long period of time (up to 3 years), leading to the need for depuration, heat treatment and possibly relaying in better quality waters. A key issue is the use of monitoring designed to inform the (long-term) classification of waters for food safety purposes – which is rightly random, in the same way as bathing waters monitoring is, so that it captures the long-term quality of an area of water – also being used to inform the short-term response to high rainfall and the subsequent contamination of shellfish. One potential solution would be to separate these into two systems.
6. **Supply chain challenges resulting from EU-Exit and continuing COVID-19 resurgences**. Another source of uncertainty is over how both the EU-Exit as well as continued COVID-19 resurgences might have on the internal and external markets for shellfish and associated supply chains. Currently around 30% of English farmed mussel production is sold abroad, almost all to the EU tariff-free, but the future of this tariff-free status is uncertain. The Strategy's assumptions on both EU-Exit and COVID-19, are listed in **Section 1.3.2**).

Growth Potential

The UK has suitable temperatures for oyster (native and Pacific), scallop and clam production, all of which are in high demand in national and international markets. Whilst once a European leader in shellfish hatchery technology, the French and the Norwegians have overtaken the UK in recent years. The UK has comparative advantage as an island nation in terms of disease control (Hambrey & Evans, 2016), and parts of England remain clear of diseases such as *Bonamia* and OsHV-1 µvar (oyster herpes virus), a status that will have to be continued following EU-Exit with effective import controls.

Notwithstanding the issues raised in the previous section, recent investment in offshore mussel farming suggests that there is potential to use deeper, cleaner water for the large-scale production of mussels. Such systems, as pioneered by Offshore Shellfish Ltd[33] in South Devon provide the basis for an expansion of mussel production, although it is not without its own challenges and risks. In particular, offshore aquaculture is more difficult and expensive to service due to its distance from shore and may be vulnerable to storms (becoming more frequent and severe with climate change) and collision damage. As a result it is only really viable at larger scales.

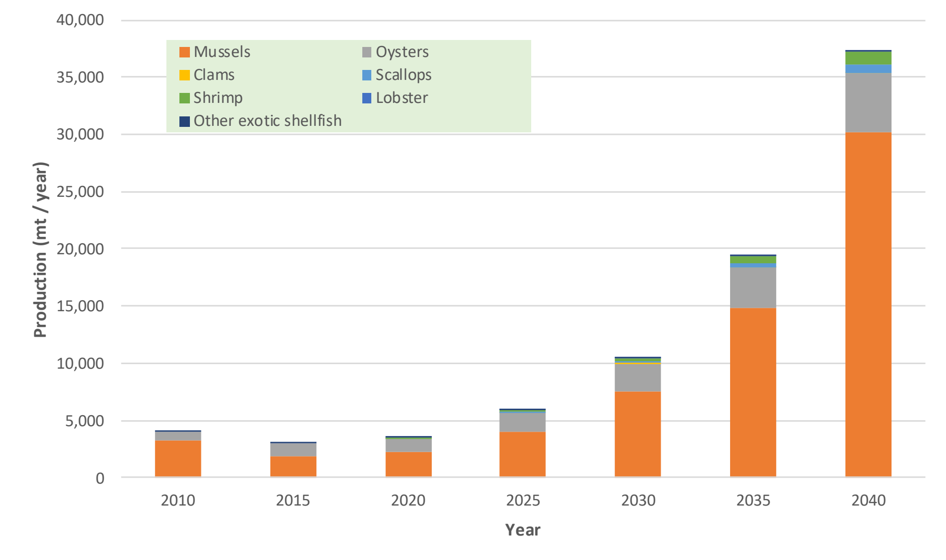
[33] https://offshoreshellfish.com/

Figure 7: Growth Aspirations – Shellfish

Shellfish

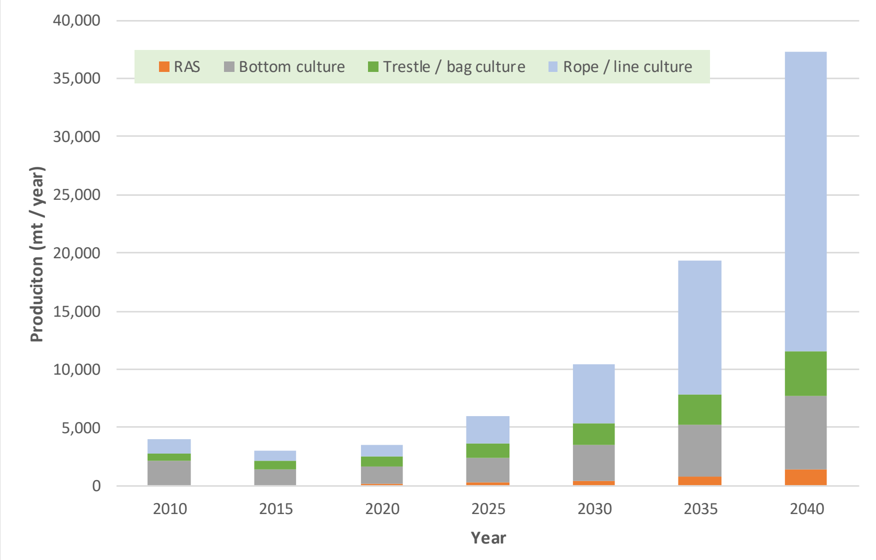
A. By species

Species	2010	2015	2020	2025	2030	2035	2040
Mussels	3,233	1,909	2,233	4,003	7,529	14,803	30,197
Oysters	735	1,034	1,123	1,675	2,429	3,528	5,141
Clams	0	0	21	27	34	44	56
Scallops	0	0	20	69	155	346	776
Shrimp	0	0	100	180	325	585	1,055
Lobster	0	0	2	4	10	22	50
Other exotic shellfish	27	8	12	12	12	12	12
Grand Total	**3,994**	**2,951**	**3,511**	**5,971**	**10,493**	**19,341**	**37,285**



B. By system

System type	2010	2015	2020	2025	2030	2035	2040
RAS	0	0	100	243	439	791	1,425
Bottom culture	2,184	1,366	1,497	2,143	3,069	4,397	6,304
Trestle / bag culture	517	821	902	1,293	1,854	2,660	3,815
Rope / line culture	1,293	764	1,012	2,291	5,132	11,493	25,742
Grand Total	**3,994**	**2,951**	**3,511**	**5,971**	**10,493**	**19,341**	**37,285**



The **growth aspirations** for shellfish above (**Figure 7**) envisage a substantial increase in English rope-grown mussel from around 717 mt in 2018 to around 25,000 mt in 2040, mostly in new offshore locations. The bottom culture of mussels is projected to increase at a much slower rate from the current 1,076 mt to just over 5,000 mt. Growth in Pacific oyster production is also foreseen from around 1,000 mt to 5,000 mt (see Box 3: EAS position on the future of Pacific oyster aquaculture in England). There are also minor increases in scallops (775 mt), native oysters (37 mt), clams (to 60 mt) and lobsters (50 mt). The EAS also expects there to be over 1,000 mt of warm-water shrimps in RAS by 2040.

Barriers to Growth

The growth aspirations for shellfish show in **Figure 7** on the previous page are considered conservative, and there are currently two major barriers before the potential growth can be achieved:

Coastal and estuarine shellfish testing. One key issue affecting shellfish growers is ***water quality***. It is essential that seafood, and especially filter-feeders like bivalves, are safe for consumers. Coastal and estuarine waters where shellfish and shellfish larvae grow are protected in order to support shellfish life and growth and to contribute to the high quality of shellfish products suitable for human consumption. Shellfish waters are protected by both environmental (Water Environment (Water Framework Directive) Regulations 2017 and Shellfish Water Protected Area Directions 2016) and food hygiene (see below) legislation. They have different standards and requirements but the primary objective is the same, the protection of consumers from microbial contamination of shellfish flesh. Routine shellfish flesh monitoring takes place for all classified shellfish production areas and is used both to assess compliance with environmental standards and to comply with the EU Hygiene Regulation (EC 2019/627), which prescribes the classification requirements for commercial bivalve shellfish harvesting. Shellfish waters are covered by the Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 and the Shellfish Water Protected Areas (England and Wales) December 2016. The classification status (based on *E. coli* colony counts per 100g shellfish) under the hygiene regulation determines what level of treatment is required prior to placing product on the market. The testing regime is unique in food safety terms in that it is based entirely on live bivalve sampling from routine monitoring points and subsequent testing in the laboratory.

In the short-term there is the potential to refine the policy (within the current regulatory limits) regarding shellfish water classification and the management of anomalous results, to give greater confidence in the data for production areas. Shellfish farmers would benefit from having greater insight into source apportionment and catchment-wide impacts on water quality to target mitigation and give higher levels of confidence in the management of water quality, and shellfish harvesting with reduced risk (Brown *et al*, 2020a). River Basin Management Plans are collaborative, proactive plans led by the EA to look at opportunities for improving coastal water quality. Active involvement in their development and for shellfish farmers to join their local catchment partnership, which exist across the whole of England will achieve broadly these aims[34]. The long-term solution is better control of intermittent sewer overflows to reduce faecal contamination, but this is constrained by the high investment in infrastructure required and ongoing coastal and urban development adding to the effluent load.

The Shellfish Stakeholder Working Group (SSWG) is currently researching environmental risks and potential mitigations to identifying higher risk scenarios and the management of impacts to improve consumer safety. This is currently being researched by the 'Developing an Assurance Scheme for Shellfish and Human Health' (DASSHH) project[35]. This could lead to the 'active management' of

[34] Published River Basin Management Plans and the Shellfish Action Plans that form a part of them, describe source apportionment and assess catchment impacts and solutions

[35] Contract let by Seafish, with Seafish, FSA, ERDF & EMFF funding. Delivery over April 2019 – March 2022.

shellfisheries using real-time environmental parameter monitoring i.e. opening/closing and general management of production in response to predicted periods of lower water quality. The report is due at the end of 2021.

Improve hatchery capacity and capability. A current barrier to shellfish aquaculture is the limited capacity in hatcheries to artificially produce juveniles in hatcheries. Hatcheries are relatively expensive facilities to build and run and thus private investors need certainty in terms of sustained demand for their production. It is noted that the Scottish Aquaculture Innovation Centre (SAIC) has a number of projects piloting commercial shellfish hatcheries, and developing genetic tools for mussel hatchery broodstock, and a similar approach (possibly in combination with the SAIC) could be undertaken in England.

Given the current uncertainty over Government policy for the farming of Pacific oyster and shellfish farming in general, there is little incentive to either support the current two hatcheries or invest in new ones. This policy uncertainty will not be resolved until 2021 at the earliest, but we have assumed that some level of Pacific oyster farming will be allowed around the English coast as wild populations expand and temperature-dependent recruitment extends northwards as a result of climate change (see **Box 3** on page 37 for more details).

The associated issue of hatchery capability is also significant. The UK used to be a leader in shellfish hatchery technology but the French and Norwegians are now at the forefront. One technology that is used extensively in both France and the UK Channel islands is polyploidy[36] to improve growth and reduce the spawning potential of Pacific oysters. One effective technology for producing 'natural' triploids (see footnote #36 below) has been developed in the USA and licensed through Government support in rival producers in France (via the French Research Institute for the Exploitation of the Sea [IFREMER], which, which also serves Channel Island producers) and in Ireland (via Bord Iascaigh Mhara [BIM]) but is yet to be licensed in mainland Britain, putting English producers at a considerable commercial disadvantage.

Other considerations (inc. cross-cutting issues of particular relevance to the shellfish sub-sector: There are a number of other issues that are considered in the Strategy. Some of these are cross-sectoral in nature and are considered in more detail in **Section 3.2**. These include:

- **The need for more regional management of shellfish farm permitting and monitoring**. The 2007 English Shellfish Industry Development Strategy (Lake & Utting, 2007) raised the need for the more local management of aquaculture activities in inshore waters e.g. <12 nm[37]. It is not suggested that the current marine licensing responsibility should be transferred from MMO to the IFCAs (within 6 nm) but there is a need for more regional involvement in identifying areas of potential sustainable aquaculture production and identifying and addressing potential spatial conflict issues with other sea users, especially capture fisheries interests. This will assist potential investors in selecting sites with less potential licensing issues.

[36] Polyploidy is where an animal has more than the normal two sets of chromosomes (e.g. diploid). Triploid animals grow faster (they do not divert growth to sexual organs and products) and are largely sterile. Triploidy is either induced via egg shocking or can be 'naturally' produced via tetraploid parents.

[37] See https://www.gov.uk/guidance/marine-licensing-definitions

Box 3: EAS position on the future of Pacific oyster aquaculture in England

The English Aquaculture Strategy considers that the Pacific oyster will remain the mainstay of English oyster production, with an aspiration for around 5,000 mt production by 2040. However, the Defra Group is not currently supportive of new Pacific Oyster farms or extensions to existing Pacific Oyster farms within Marine Protected Areas or where the species is locally absent.

Herbert *et al.* (2012) conducted an independent assessment of the nature, pathways and forward-looking trends of Pacific oysters in UK waters and concluded the following:

1. The non-native Pacific oyster was introduced into the UK under licence by the UK government to support the wild-capture oyster industry that was suffering from the decline of the native oyster as a result of a succession of extreme winters, disease, pollution and over-fishing. This introduction was based on the presumption that sea temperatures were not warm enough in the UK for Pacific oysters to successfully reproduce. However, with hindsight and a better understanding of climate change, this no longer holds true.
2. The origin and subsequent development of wild settlement is largely in the vicinity of licensed Pacific oyster farms and other aquaculture production business. Populations can now be found mainly in SE England, but more sporadically elsewhere, including Northern Ireland.
3. This said, it is unlikely that the UK cultivation of Pacific oysters is the only pathway causing wild settlement. There are several areas where wild settlement is occurring some distance from aquaculture production areas. Introduction from marinas and ports via boat traffic (e.g. from France where there is extensive cultivation of this species) is not proven but highly suspected.
4. Total eradication of the Pacific oyster is not feasible. Indeed continental experience suggests that if predictions of continued sea water warming under current UKCP scenarios (Met Office, 2019) are realised, the frequency and magnitude of settlement will increase, causing existing populations to expand and new populations to become established.
5. The issue of Pacific oysters is located between two policy areas: one concerning the conservation of protected habitats, the other relating to livelihoods and the socio-economics of coastal fishing and farming communities.
6. The report concluded that [in line with the approach in this Strategy] regional management of wild Pacific oysters in the UK is likely to be the most effective approach, based on (i) the extent of biodiversity / habitat risk and (ii) a socio-economic opportunity costs analysis.

As discussed in **Section 2.1.2**, NE's current position is that new Pacific oyster farms or extensions to existing Pacific oyster farms within designated Marine Protected Areas (MPAs) are not advisable. This position will be reviewed once the results of an on-going Cefas study on the contribution to further spread by farmed and wild Pacific oyster populations is published in March 2021.

The Strategy's <u>working assumption</u> is that over the longer-term (e.g. up to 2040) wild Pacific oyster populations will continue to expand as our waters become warmer and that the farming of this species will no longer be the primary driver for this expansion, as is currently the position in neighbouring France. **However it must be emphasised that this is not the current UK Government policy and that this position is not endorsed by Defra.** Therefore if the current advice does not change in the light of Cefas' forthcoming report, then future aquaculture production of Pacific oyster will be considerably lower than the estimates made in this Strategy.

- **Limited infrastructure.** Increasing shellfish production, especially if some segments move offshore, will require shore-side landing, depuration, primary processing and operations support facilities. At present many port and shoreside facilities are restricted, either by tidal conditions or through sharing with other, more economically dominant interests. This is already limiting businesses by adding costs and affecting operational efficiencies. See **Section 3.2.3 (Common Infrastructure Development**) for more information and proposed actions. It is noted that this issue this is covered in all marine plans apart from the East.
- **Development of distinct markets for farmed shellfish products.** The cultivation sector is in a position where its products are both distinct and also directly competitive with wild fisheries production. Again Lake & Utting (2007) identified the need to "*develop production opportunities based on specific marketable products in the face of competition from both fisheries and imports*". With an aspiration to increase mussel production to over 30,000 mt by 2040, further market development is essential. The recent COVID-19 lockdowns have shown the importance of local and regional markets for fresh produce, focusing on the quality of the products and local production credentials. These experiences could be built on and assisted through third-party certification and regional food group assurance schemes. To target the wider national and export markets or develop processed products, the sector requires higher volume production of consistent quality in order to achieve economies of scale and regular supply. These should be key development targets for the English mussel cultivation industry.
- **Ecosystem services from aquaculture.** There is limited understanding of the ecosystem services that can be provide by extractive aquaculture in particular. These need to be quantified to demonstrate the advantage of aquaculture over other marine space use in this regard.

Key actions – Shellfish sub-sector

Action	Outcome					Timing		
	OC1	OC2	OC3	OC4	OC5	2025	2030	2040
SH 1 Finalise a formal policy for the use of Pacific oysters in English waters balancing the potential harm from further farmed introductions with the socio-economic benefits of producing this now established species.	✓		✓	✓		✓		
SH 2 Develop the risk-based approach to the classification of shellfish production waters that ensures food safety for consumers but provides increased assurance and certainty to shellfish farmers, investors and markets.	✓		✓	✓		✓		
SH 3 Improve industry dialogue and partnership with the EA, Defra and other agencies, as well as local government bodies and the water companies to make the case for and encourage further investment into improving coastal water quality, especially through the prevention of spikes in faecal contamination following intermittent sewage overflows as well as reduced agriculture waste entering England's waters. This dialogue should be extended to other MEAs with a common interest in better water quality e.g. tourism	✓	✓		✓			✓	
SH 4 Review and revision of seabed lease and Several Order mechanisms to provide long-term security and promote investment in shellfish growing areas, both inshore and offshore.	✓					✓		
SH 5 Develop a certified hatchery network for different shellfish species with increased public support to develop, test and demonstrate new technologies in polyploidy, live feed and larval rearing systems.	✓	✓	✓			✓		
SH 6 Explore opportunities for hi-value invertebrate aquaculture e.g. sea cucumber, sea urchins, abalone etc. in both open water and closed systems, including IMTA and RAS.	✓	✓	✓				✓	
SH 7 Create product value-addition, market and branding opportunities for English shellfish products at regional, national and international levels			✓	✓	✓		✓	

Assumptions and risks

- A balanced policy for the cultivation of Pacific oysters is agreed between all the statutory agencies. Our assumptions on this can be found in **Box 3**.
- The permitting and regulatory framework is clarified and streamlined under the current regulatory review (see Section 3.2.1).
- Further investment in improving water quality will depend upon Government priorities at the time. SH 3 should help make this case.

Key to Expected Outcomes (OC)	OC 1: The barriers to sustainable growth in aquaculture production are identified and reduced
	OC 2: English aquaculture maximises the use of technology and innovation to drive growth to improve its overall sustainability
	OC 3: Aquaculture contributes to England's domestic seafood production and overall food security
	OC 4: English aquaculture products are seen by wider society to be healthy and sustainably produced
	OC 5: The aquaculture sector is seen as an attractive and rewarding employment opportunity

3.1.3 Macroalgae

Current Status

Over 32 million tonnes of aquatic plants were produced globally in 2018 but seaweed farming in England is still in its infancy. Most commonly cultivated seaweed species that could be farmed in the UK include *Saccharina latissima* (sugar kelp), *Laminaria digitata* (oarweed), *Alaria esculenta* (winged kelp), *Palmaria palmata* and *L. hyperborea*. Farming of seaweeds with a potential higher value and demand, such *Porphyra* (laver) and *Osmundea pinnatifida* is still at the experimental stage (Capuzzo *et al*, 2019).

There are a number of farms in development off the North Sea, Eastern and Western Channel coasts, but they are yet put product on the market. The SeaGas project[38] identified a need to instigate a step-change in technology for viable, large-scale seaweed farming in European waters as well as creating market 'pull' for seaweed farming at a large scale. In 2017 20 mt of *S. latissima* was harvested by the project, the UK's largest amount of harvested seaweed to date. Macroalgae aquaculture will likely use a combination of ***longline systems*** (the growing line, usually at 1.5 m depth is loose, allowing it to be easily pulled to the surface for inspection - this system is not economical on a large scale due to the need for a large number of anchors) and ***grid lines*** (likely to be most suitable for larger farms and/or where space is restricted). A rope grid is positioned at a set depth below the surface (e.g. 3 m). This is anchored in all directions using embedment anchors or pilings. Surface buoyancy prevents the grid from sinking. Cultivation lines are then attached onto the grid at a set distance apart) (SAMS, 2019).

Growth Potential

The farming of macroalgae – termed as inorganic extractive aquaculture - has the potential to contribute to a number of the policy objectives outlined in **Section 2**. These are low trophic species, fast growing, highly productive and will contribute to direct sequestering CO_2 or indirect lowering of GHG emissions, for instance from other livestock sectors if incorporated into their feed. Prospective growing areas are mapped on the MMO online 'Explore marine plans' guidance[39], albeit at a broad scale.

Water temperature is a key environmental variable as it affects the metabolic rate of seaweeds so has a direct effect on their growth (Kerrison *et al*, 2015; Capuzzo *et al*, 2019). Kelps, such as *S. latissima*, *L. digitata* and *A. esculenta*, are generally tolerant of low temperatures in winter (i.e. just below 0 °C), although with reduced growth rates. Many seaweeds are more sensitive to high temperatures, particularly during summer and their geographical range is dictated by specific isotherms (e.g. 16 °C for *A. esculenta*). Salinity, light availability, nutrient concentration and water movement are other aspects to consider (Wood *et al*, 2017; Capuzzo *et al*, 2019).

Seaweed can be grown alone as a primary crop or can be used in combination with other species from different trophic levels[40] as a form of polyculture that is designed both to maximise growth across the different species as well as improved nutrient flows. It can also be combined with static structures such as windfarm turbine bases. There is a considerable interest in macroalgae as seaweeds can be used for a variety of uses including for human consumption, in agriculture (e.g. as a source of fertilizer or feed ingredient), for bioenergy production, the extraction of chemicals and bioactive components, for cosmetics and nutraceuticals. Further details on their uses can be obtained from Capuzzo & McKie 2016, Capuzzo *et al*, 2019.

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[38] See http://seagas.co.uk/. Under SeaGas Cefas, in collaboration with SAMS and Queen's University, is investigating the potential environmental effects of large-scale seaweed farms at different locations in the UK and reviewing the legislation/licensing process for seaweeds.

[39] https://www.gov.uk/guidance/explore-marine-plans

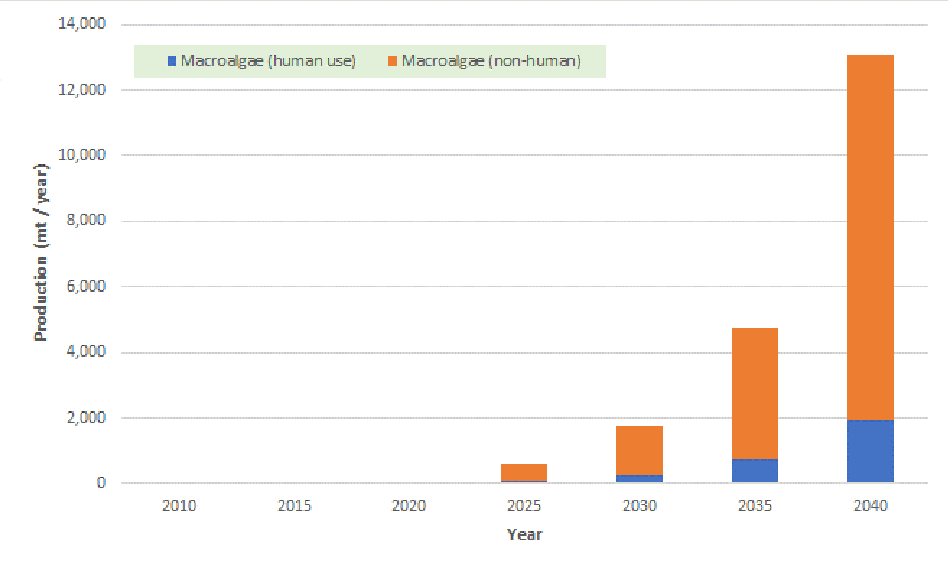
[40] E.g. high trophic level carnivorous fish, medium trophic level organic extractive shellfish and low trophic level inorganic extractive seaweeds.

Figure 8: Growth Aspirations – Macroalgae

Macroalgae

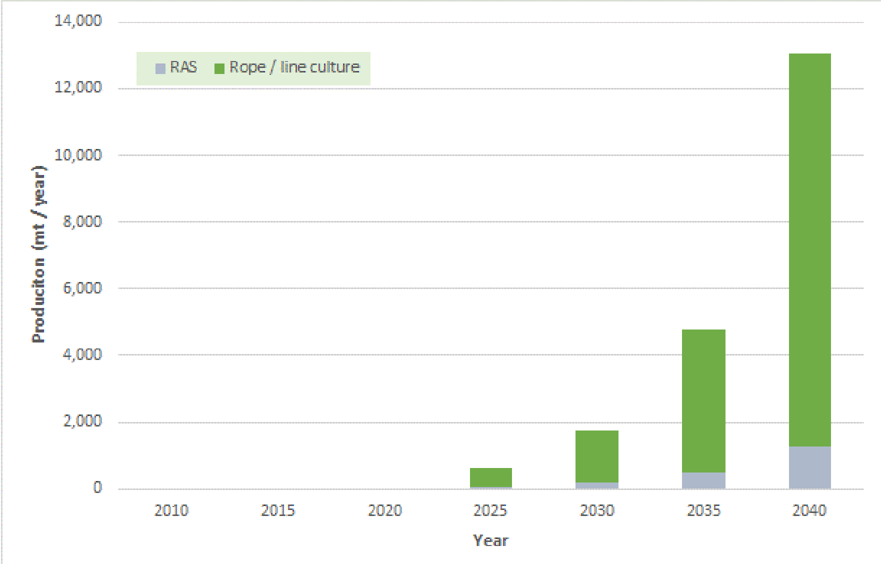
A. By species

Species	2010	2015	2020	2025	2030	2035	2040
Macroalgae (human use)			0	91	273	724	1,928
Macroalgae (non-human)			0	531	1,464	4,038	11,139
Grand Total	0	0	0	622	1,736	4,762	13,066



B. By system

System type	2010	2015	2020	2025	2030	2035	2040
RAS	0	0	0	61	188	491	1,285
Rope / line culture	0	0	0	561	1,548	4,271	11,781
Grand Total	0	0	0	622	1,736	4,762	13,066



The growth aspirations for macroalgae show in **Figure 8** on the previous page are considered conservative. For the purpose of the Strategy we assume that *c.* 13,000 mt (wet weight) of macroalgae could be produced annually by 2040, of which around 2,000 mt will be for human consumption and 11,000 mt for other, non-human use. The majority (*c*. 90%) will be produced on longline systems and the larger-scale 'grid' approach described in above, but there may also be some production in RAS. The latter is still at a research stage but has potential as RAS can be used to manipulate the colour, taste and texture of seaweed for high-end human consumption (Paul Howes, CSAR, pers. comm., 12 June 2020).

Seaweed species for farming should be chosen considering their yield and reliability, value and demand, market end-uses and environmental conditions at the site particularly, temperature, salinity, light availability, nutrients, water movement at the farm site (Capuzzo *et al*, 2019)). Considering the latter point, local species are best suited for farming, as they are adapted to the local conditions (Barbier *et al*., 2019). The Strategy assumes that only native macroalgae species would be produced.

Barriers to Growth

Seaweed farming is in its infancy in the UK, therefore there are a number of technical, market and supply chain challenges to its adoption and scaling up in England.

Poor knowledge of suitable sites for seaweed production in English waters. MMO, with Cefas, have also identified areas of aquaculture potential in English waters, but again at a broadscale (MMO, 2019). The MMO has provided broadscale mapping of strategic areas of sustainable aquaculture production for use in marine planning for 14 species (including four macroalgae species).

Cefas is currently undertaking more fine-scale mapping for the Dorset and East Devon Fisheries Local Action Group (FLAG) which is a first step towards identifying potential aquaculture zones at a local level (Kershaw, 2020). The detailed mapping and zoning of aquaculture areas also needs to consider the potential for polyculture in IMTA (see Tew, 2019) as well as the possibility for co-existence with other marine space users, including capture fisheries and renewable energy structures (see **Section 3.2.6 Aquaculture in the Blue Economy**).

Poor knowledge of productivity and yield of farmed seaweeds in English waters, particularly at larger scales. Given the lack of experience for farming macroalgae in English waters to date, it is difficult for investors to prepare biological models (e.g. on stocking levels, growth rates, mortality levels, etc) under different conditions in the sea areas around England. This creates uncertainty for business planning, which impacts on borrowing and other funding arrangements.

Lack of robust algal cultivars[41]. Algal strains should be selected for certain traits of interest e.g. higher growing rates or resistance to higher water temperatures. The best cultivar characteristics should match the market's demand criteria. Selection can necessitate a combination of genotypes (i.e. gene assemblies) that is not found in the wild through forced sexual reproduction. The challenge is then to identify the strains that (i) hold the trait of interest and (ii) will be able to cross each other with no reproduction incompatibility. Usually cultivars should combine robust characteristics (disease and epiphyte resistance) and rapid growth. Strain selection is an intensive, time-consuming and expensive process. However, there is no way to bypass it (Barbier *et al*, 2019).

[41] Plants obtained by targeted selection (breeding). Different cultivars can be obtained from the same species.

Offshore farming challenges. The early seaweed farms are likely to use existing longline technologies designed for mussels, but these are not ideally suited for seaweed which need different cultivation depths and spacing. It will be necessary to identify and develop systems specifically for different macroalgae species and end uses[42].

Disease risks. Disease susceptibility is a problem in seaweed farms, encompassing up to 50% of farm running costs (Kim *et al*, 2014). Historically, to tackle this problem, seaweed farming has pursued selection of strains by choosing parents with desirable features and backcrossing them for several generations (Zhang *et a*l, 2007). However the potential nature and scale of possible disease problems for macroalgae reared in English waters is currently unknown. This suggests that seaweed juvenile and stock movement protocols need to be put in place as seaweed production expands.

Possible scale of operations and perceptions from other marine users and local communities. Seaweed farming is a novel activity in England at present but has considerable potential to scale up over the Strategy's timeline. As seaweed is essentially a two-dimensional crop e.g. lays as a sheet to maximise photo-exposure, it could potentially occupy fairly large areas of the sea surface e.g. one hectare is needed to produce 33 mt (wet weight) of seaweed. This can be minimised through the use of different twines and substrates, effectively doubling productivity per unit area. Although the likely trend of seaweed farming is a move offshore, the likelihood is that over the shorter-term most seaweed farming installations will be within six nm to benefit from easier logistics, calmer sites and higher nutrient levels. This potentially brings them into conflict with capture fisheries operations, both mobile (e.g. trawls) and static (e.g. pots and gillnets), as well as other sea space users. One seaweed farm developer stated that hostility from commercial fishermen was one of the biggest challenges in finding suitable sites. However, with effective consultation and conflict resolution, there is potential for both activities to co-exist. Indeed there is evidence that fixed aquaculture sites can benefit wild stocks of species such as scallops (Bridger, 2019), and both static and mobile fishers can benefit if aquaculture sites are laid out in a suitable manner. The Strategy promotes model approaches that will allow this (see **Section 3.2.6**).

Environmental impacts: Seaweed is generally considered to be a benign form of aquaculture or even providing net environmental gains in that it sequesters carbon, absorbs nutrients and does not produce any solid metabolic by-products. However some aspects do need consideration, such as the shading effect of seaweed farmed on surface waters and the excessive removal of inorganic nutrients so that it affects primary productivity (Campbell *et al*, 2018). There is also the potential for introducing non-native species that may be growing on seaweed seed plants (e.g. epiphytes and epifauna). Other possible impacts include the accumulation of organic debris under the seaweed mats, habitat damage from anchors and chains, as well as localised changes in wave climate and water circulation.

Size and location of markets for seaweed-derived products. A key constraint is the market for seaweed and seaweed products. In the past most were derived from wild harvested seaweed and then macroalgae farmed in tropical waters such as Japanese kelp (*L. japonica*), *Eucheuma* and *Gracilaria* spp. However, increasing concerns over heavy metal contamination, the 'food miles' involved, and uncertainty of supply suggests that UK and other European seaweed processors will start focusing on domestic species and production which has better traceability and quality assurance.

[42] For instance macroalgae produced for alginate extraction is better produced in more dynamic locations that increases alginate content.

Other considerations (including cross-cutting issues of particular relevance to the macroalgae sub-sector): There are a number of other issues that are considered in the Strategy. Some of these are cross-sectoral in nature and are described in more detail in **Section 3.2**. These include:

- **Permitting and licensing needs to recognise the specific nature of seaweed and its farming methods.** At present, unlike most forms of shellfish farming[43], seaweed farming requires a marine licence from the MMO. It may need a Habitats Regulations Assessment (HRA) if the site falls within a European or Ramsar site[44] or an MCZ Assessment if it falls within a Marine Conservation Zone (MCZ). The issue is that there is little institutional experience of seaweed farming and its potential impacts within the statutory agencies (Wood *et al*, 2019), so applications are considered with the utmost caution. Likewise many new entrants into the seaweed farming sector lack the knowledge industry as to what is required in terms of the licence application process. This has imposed extra costs, time and other constraints on even the smallest research or pilot operation and is a major disincentive to potential investors. It is, however, recognised that the regulators have to operate within a fixed legal framework, and thus changes to the legislation e.g. the HRA (European level) and MCZs (national level) may be required.
- **Infrastructure needs**: Like other forms of marine aquaculture, the logistics of establishing and servicing farms, as well as harvesting products is complex and expensive. This is particularly the case with macroalgae, whose relatively low value per tonne and considerable wet weight biomass requires particular techniques and skills. If the sub-sector is to expand it will need either dedicated or suitably shared facilities to moor service vessels, land product and conduct any primary processing e.g. washing and drying, etc upon landing. See **Section 3.2.3** for proposed actions.
- **Expertise**: The Biotechnology and Biological Sciences Research Council (BBSRC) investigated the level of algae-related expertise in biological and environmental sciences and engineering in the UK in 2011 (Capuzzo & McKie, 2016). The investigation highlighted that UK has expertise in the environmental and ecological sector for macroalgae. Algal culture collections in the UK are highly regarded internationally and UK experience in algal taxonomy, physiology, metabolism, biochemistry and molecular biology is a key strength. In addition, UK is well places to produce technologies associated with the scaling up of algal growth (e.g. optimizing productivity, lowering costs for growth, harvesting and processing (AB-SIG, 2013). The AB-SIG report (2013) concluded that: "*The UK therefore has a highly valuable base of expertise […]. However, continuity of funding is essential to maintain this advantage: both R&D funds to attract and retain academic excellence, and resources to provide continuity and expansion of the support network that facilitate successful project development between academia and industry, will be essential if the UK is to establish a globally competitive algal commercial sector*".

[43] See https://seafish.org/media/Clarification_and_guidance_on_the_shellfish_exemption_v3_2020.pdf for a clarification of exemptions. For instance, suspended rope-grown bivalve farms do require a Marine Licence since they may pose a risk to navigation.

[44] Under The Conservation of Habitats and Species Regulations 2017 and The Conservation of Offshore Marine Habitats and Species Regulations 2017 an Appropriate Assessment is required in order to assess the Likely Significant Effects (LSE) of a plan or project either individually or in combination with other plans or projects on protected nature conservation sites (European/Ramsar sites). This can mean that an activity takes place outside of a site but still has an impact on European/Ramsar sites

Key actions – Macroalgae sub-sector

Action		Outcome					Timing		
		OC1	OC2	OC3	OC4	OC5	2025	2030	2040
MA 1	Development of specific marine licensing guidance for macroalgae culture that reflects its nature, scale and impact of these extractive, low trophic species.	✓		✓	✓		✓		
MA 2	Prepare models and pilot projects for seaweed farms in English waters. These may vary in scale and purpose e.g. for human or non-human uses and will be used to obtain data on ecological impacts, operation costs and yields. These will be essential for business planning and for regulators to assess the cumulative impact of large-scale seaweed farming as it develops.	✓	✓	✓	✓		✓		
MA 3	Quantify and model ecosystem service provision by cultured seaweed species e.g. evaluate nutrient uptake to develop commercial and public service opportunities for farm-based bio-remediation initiatives.		✓	✓	✓			✓	✓
MA 4	Investigate and develop seaweed supply chains, product development and market diversification opportunities for both human and non-human uses. In particular, examine possibilities for using algal-based products for aquaculture feeds and nutrient additives.	✓	✓	✓		✓	✓	✓	✓
MA 5	Establishment of a professional trade body to provide a voice for the developing macroalgae farming sub-sector, as well as supporting knowledge-sharing, supply chain and development and coordinated harvesting.			✓	✓	✓	✓		
MA 6	Develop models for integrating seaweed farming into IMTA (and related co-location systems) with shellfish and finfish and establish pilot systems to prove the concept through developing technology, logistics, economics, site establishment and social acceptance.	✓	✓	✓	✓			✓	✓

Assumptions and risks

- Changes to the current marine licensing and EIA arrangements so that pilot-scale and innovative macroalgae research production is encouraged.
- The demand for English / UK-sourced macroalgae expands with the production base.

Key to Expected Outcomes (OC)	OC 1: The barriers to sustainable growth in aquaculture production are identified and reduced
	OC 2: English aquaculture maximises the use of technology and innovation to drive growth to improve its overall sustainability
	OC 3: Aquaculture contributes to England's domestic seafood production and overall food security
	OC 4: English aquaculture products are seen by wider society to be healthy and sustainably produced
	OC 5: The aquaculture sector is seen as an attractive and rewarding employment opportunity

3.2 Cross-cutting elements

3.2.1 Governance and Regulation

In order to grow and thrive over the longer-term, English aquaculture must develop within a clear policy framework that promotes sustainable (economic, social and environmental) development whilst balancing the needs of other water space and resource users as well as the ecosystems services that support them. Marine planning, licensing and other regulation applicable to aquaculture should be proportionate and fit for purpose; be responsive to the needs of the farmed fish, shellfish and seaweed industries without compromising the aquatic environment or interests of other stakeholders; and decision-making should be efficient, fair, transparent and inclusive.

Current Status and Issues addressed by the Strategy

Policy: Given the low level of aquaculture production in England, it is not surprising that it currently takes second place to capture fisheries. This is exacerbated by the legacy of capture fishery as a totemic industry with management and funding mechanisms that have evolved within this historic/political context. In addition the dichotomy of capture fisheries being managed under the original Common Fisheries Policy (CFP) since the 1970s and aquaculture only being included in the CFP in 2013. The UK's exit from the EU creates an opportunity to forge a new approach for aquaculture governance, one which reflects aquaculture's potential to contribute more substantially to the UK's food security and health. This is mentioned in the new Fisheries Bill (see Section 2.1.2), which is still highly capture-fisheries focused. There is a need for clear policy on aquaculture development in England that reflects the aspirations in this Strategy. Daniels *et al.* (2020a; 2020b) suggest that this policy should be collaborative, better reflect the actual impacts and benefits of aquaculture and have a clear roadmap for licensing. A key role of this policy will be to demonstrate government ambition and support for the sustainable growth of the English aquaculture sector, and for it to be seen as an integral part of a sustainable English seafood sector as a whole.

Regulation: The purpose of regulation is to achieve a balance between developing aquaculture whilst protecting and, where possible, enhancing the environment, human health and the interests of others sharing the same space and resources. This has always been a difficult balance to achieve – the 2013 'Strategic Guidelines for the sustainable development of EU aquaculture' (EU, 2013) included the 'simplification of administrative procedures' as one of its four main pillars. After seven years, this has only been partially achieved - a recent review of the EU OMC considered that "*Overall, the main success factor for the simplification of administrative procedures is the tight collaboration between administration and professionals to establish a new administrative process to attribute exploitation licenses. The most common hindering factor is the complexity of institutional and regulatory frameworks and the number of administrations involved*" (Huntington *et al*, 2019).

Most aquaculture producers in England are SMEs, and they are disproportionately affected by 'red tape': the relative weight of regulatory and administrative costs compared to turnover and the number of employees can be up to ten times higher for SMEs than for large companies in the general economy[45]. Defra commissioned Cefas to prepare an 'Aquaculture Regulatory Toolbox for England' (hosted on the Seafish website[46]) to assist businesses deal with aquaculture business applications.

This is also recognised by Defra who are currently conducting a review of the aquaculture regulatory framework in England (see **Box 4** overleaf).

[45] See https://ec.europa.eu/growth/content/models-reduce-disproportionate-regulatory-burden-smes-0_en
[46] See https://www.seafish.org/article/aquaculture-regulatory-toolbox-for-england

Box 4: Defra's review of aquaculture regulations 2020

Defra have initiated a review of the aquaculture regulation regime in England over two phases.

Phase 1 is to document the existing aquaculture regulation process, so that any applicants are clear on all their considerations from the outset and understand the potential timeline and costs involved in setting up an aquaculture business. This work is a 'next step' on from the 'Aquaculture Regulatory Toolbox' as it should make the information provided through the toolbox easier to navigate. This guidance is being developed by a working group formed of representatives from agencies within the Defra Group. Work is well underway but not yet in the public domain.

Phase 2 will build on Phase 1 and looks to reduce any undue regulatory burden by identifying opportunities to streamline the current process and align regulators. It is intended that this will be stakeholder-driven, with a public workshop in early 2021. The first Phase 2 'product' will be a roadmap showing what can be delivered when and how.

Source: Defra, Pers. Comm., July 2020.

Hambrey & Evans (2016) summarised the main aspects associated with the regulatory problem:

- **Cost**: Satisfying regulatory requirements takes substantial senior management time.
- **Delay**: Delays in gaining permits can undermine business plans and cash flow, limit access to funding, increase the total up-front investment, and lengthen payback time.
- **Investment uncertainty**: Substantial investment may be required without clarity or predictability of planning/regulatory outcome.
- **Operational uncertainty**: In terms of potential closures or quarantine (e.g. due to disease, contamination) for indefinite periods of time.

It is also recognised that some of the current legislation covering aquaculture is unsuitable, sometimes unnecessary and insufficient to guide an aspiring and diversifying English aquaculture sector. With the forthcoming Fisheries Bill and other changes as a result of the UK's exit from the EU, together with the current Defra review of the aquaculture regulatory framework, there is currently an opportunity to recast the system to ensure it encourages progressive, sustainable aquaculture that can meet both the policy objectives outlined in **Section 2** as well as provide good quality livelihoods for many areas of rural and coastal England with limited alternative opportunities.

Sector planning and support: Another element of governance is sector planning. As discussed in Section 1.1, there has been only limited strategic planning for aquaculture development in England. The 2015 'UK Multiannual National Plan (MANP) for the development of sustainable aquaculture' (Defra, 2015) and its more recent review (Defra, 2018a) provided some direction, but was mainly produced as it was an ex-ante conditionality to receive EMFF funding.

One of the main issues has been a policy presumption that any growth in English aquaculture must be 'industry-led'. Whilst it is true that any growth over the Strategy timeline will be largely instigated by the entrepreneurial spirit that has characterised the shellfish sector in particular, this growth must be enabled and facilitated by an empathetic and informed governance and regulatory system. The first stage in this is strategic planning – which is indeed the *raison d'être* for this Strategy.

The second is a delivery and support service that helps establish and grow aquaculture businesses through a combination of informed permitting, targeted financial support where needed and assurance of a 'level playing field' across all MEAs. This Strategy considers the following approaches as a pre-requisite for future growth in this sector:

1. **Strengthened central management by MMO and Defra**: If the growth aspirations in this Strategy are to be realised, the Government must invest in central support to the sector. Defra needs to have a permanent group of specialists[47] tasked with supporting policy development and strategic planning (Defra) and implementation (MMO). Ideally the MMO / Defra team would form a 'one stop shop' to ensure a coordinated, informed response to industry requirements, as well as being able to liaise with, and be supported by, other relevant areas of the Defra Group (e.g. marine conservation, food security and animal health, etc) and wider government. However this has a number of structural and budgetary implications.
2. **Greater support to marine and inland aquaculture planning at a regional level**: The current marine planning approach is predicated upon regional spatial and temporal planning to ensure sustainable development and ensure an evidence-based allocation of sea space usage (see **Section 2.1.2**). This in turn will require regional support to ensure that aquaculture development is well informed of local needs and constraints, and thus able to work with other marine space users in a proactive yet even-handed way in identifying 'Allocated Zones for Aquaculture' (AZAs[48]) in the Marine Plans. Until the MCAA in 2009 and the resultant regional marine planning process, there was little capacity or willingness for aquaculture planning and management at regional level. Following the inclusion of aquaculture within the MPS and all relevant aquaculture policies in all regional marine plans, and MMO's work on identifying areas of aquaculture potential in English waters (MMO1184, MMO 2019) and Cefas' Aquaculture Mapping Project (Kershaw, 2020), Dorset has recently publishing a five-year mariculture (all species, including seaweed) strategy (Dorset & East Devon Aquaculture, 2020) and the Devon & Severn IFCA is following suit (shellfish only). Dorset and East Devon Aquaculture[49] - which has a full-time 'Aquaculture and Fisheries Development Officer' - is being managed by the Dorset Coast Forum DCF (with assistance from the Southern IFCA) and is a model for development and replication into other English regions. Key attributes include:
    a. a strategic approach, as evidenced by the publication of a five year strategy.
    b. strong linkages with the Southern IFCA that attempts to balance local aquaculture, capture fisheries and marine conservation objectives.
    c. working with the Dorset LEP to promote aquaculture as a high potential growth sector.
    d. a strong, high resolution spatial planning focus, which includes identifying possible AZAs through consultative, proactive regional planning.

    SWAN – chaired by the DCF Aquaculture and Fisheries Development Officer - is another example of how regional co-operation and stakeholder engagement can assist directly address regional planning needs. A recent stakeholder workshop in SW England highlighted that that collaboration across sectors is essential to provide relevant evidence to inform regulation and particularly developing an effective framework to connect research, government bodies, stakeholders and industry (University of Exeter and Sustainable Aquaculture Futures, 2020).

[47] It is recognised that the UK's Civil Service policy is that staff are employed as generalists, and thus there are structural barriers to achieving this aim

[48] In line with the UK MANP for the development of sustainable aquaculture (Defra, 2015), marine plans in England identify areas for potential aquaculture development, but there is no accompanying scheme for facilitating licencing (SPF workshop, 2020). One solution is the establishment of allocated zones for aquaculture 'AZA' (Sanchez-Jerez *et al*, 2016), where aquaculture development could be directly aligned with MPA or other marine use objectives.

[49] See https://www.dorsetaquaculture.co.uk/

Environmental Impact Assessment: Intensive fish farming (finfish and shellfish, but currently not macroalgae) is listed under Schedule A2 of the Marine Works Regulations (MWR) (Environmental Impact Assessment (EIA)) 2007 (as amended), requiring 'Screening by determination' to determine if effects are likely (because of its size, nature or location) to have a significant effect on the environment or undergo voluntary EIA and 'Screen-in by agreement' (under Regulation 5 of MWR). "Intensive Fish Farming" (the addition of feed) is deemed a Schedule A2 project and will require an EIA if it is likely to have significant effects on the environment[50]. Industry stakeholders suggest that some improvements could be made to the screening and EIA process to make it more accommodating to the nature and spatial scale of impacts from aquaculture, especially for low trophic, extractive aquaculture like shellfish that might provide ecosystem services in their own right. This said, (i) small-scale projects that are not likely to have a 'significant effect' do currently undergo a separate process and (ii) the EIA process does take into account negative and positive effects of projects.

Other permitting: There are a number of other regulatory requirements for prospective aquaculture start-ups and expansions in England, including (i) a Navigation Risk Assessment (dependent upon the sale and location of the works) and (ii) an Archaeological Written Scheme of Investigation. Evidence of pre-application engagement with other marine space uses, particularly the fishing industry, is also recommended by MMO. The main regulating and advisory organisations include the MMO (licencing), Cefas (scientific advice), EA (waste & veterinary discharges), the Crown Estate (seabed / foreshore rights), NE (natural heritage protection), Food Standards Agency (classification of shellfish harvesting areas), IFCAs (permitting of certain activities in <6 nm zone) and the Marine and Coastguard Agency (safety at sea). In addition planning permission may be required from local authorities, especially land-based facilities. This all adds up to a complex and off-putting regulatory environment.

Aquaculture Sector Monitoring: The capture fisheries sector is subject to intensive monitoring and evaluation with monthly and annual statistics publications covering fishing effort, landings and supply chain activities[51]. In comparison there is less dedicated monitoring of English aquaculture production and effort, and collated data for England has not been published recently (although it is available on request to Cefas). The UK has been required to compile and report annual aquaculture production and employment to the FAO and Eurostat / Joint Research Centre. In England, production and employment data is collected / checked during routine annual visits by the Fish Health Inspectorate (FHI) (a Cefas accredited team reporting to Defra). As with all aquaculture statistics, these are self-reported. Additional data are collected on the economic performance of English aquaculture but through a small-scale survey to ensure compliance with the Data Collection Framework regulation; response rates are low as farmers are not legally obliged to provide the data and often seem unwilling to supply the potentially complex, intrusive and confidential data requested. Compulsory reporting would add to the regulatory burden. Independent researchers cannot access data in its raw form because of confidentiality; if needed they would need to conduct their own additional data collection. There has not been a previously identified need for Government officers to undertake exploratory analysis (Hambrey & Evans, 2016). More resources would need to be committed if changes are considered necessary to the collection, collation, analysis and publication of more extensive and timelier data on English aquaculture.

[50] See https://www.gov.uk/guidance/marine-licensing-impact-assessments#environmental-impact-assessment

[51] See https://www.gov.uk/government/organisations/marine-management-organisation/about/statistics

If the sector is to expand, it is important that accurate production and economic data are available to sector planners and regulators, and that this information is analysed and evaluated on a regular basis. This role is currently undertaken at Member State level by the EU's Joint Research Centre (JRC), but presumably this will cease after the UK's exit from the EU. It is noted that in Scotland, Marine Science Scotland undertakes formal annual production surveys for both farmed finfish and shellfish[52]. As observed by Hambrey & Evans (2016) outsourcing of data collection and analysis may further distance Government from industry and undermine the capacity of government to support the industry more effectively.

In summary, as recognised by Hambrey & Evans (2016) the current marine planning system, despite its goals and objectives, is more constraint than opportunity focused. If significant growth is to be achieved, it needs to be more pro-active in identifying opportunities for sustainable development.

[52] See https://www.gov.scot/collections/scottish-fish-farm-production-surveys/

Key actions – Governance and Regulation

Action		Outcome					Timing		
		OC1	OC2	OC3	OC4	OC5	2025	2030	2040
GR 1	A clear policy for English aquaculture development is prepared within the framework of the Fisheries Bill, The Common Fisheries Policy (Amendment etc.) (EU Exit) Regulations 2019, and the wider policy environment.	✓	✓	✓	✓	✓	✓		✓
GR 2	Following completion of Defra's review of aquaculture regulations (see **Box 4**), implement the agreed approach for transparent, streamlined and proportionate regulation. This includes the level of evidence required for the permitting of different types and scales of aquaculture. There is a need for clarity on the decision criteria that will be used and the nature of any trade-off analysis, as well as standards relating to response and decision times	✓		✓		✓	✓		
GR 3	Develop a regional approach to aquaculture development, management & regulation, creating regional hubs that can (i) lead on regional spatial marine planning, (ii) act as a 'one stop shop' for new and expending aquaculture businesses and (iii) provide a forum for co-existence with other MEAs and marine space use. Operational approaches include (i) operating at the IFCA spatial level, (ii) identifying suitable institutional leads and partners (options include local authorities, coastal fora, the IFCAs), (iii) the funding of Aquaculture Development Officers for each region and (iv) engaging with sector participants and other stakeholders.	✓	✓	✓	✓	✓	✓	✓	
GR 4	To support both the revised aquaculture regulatory framework and to assist implement this Strategy, seek capacity-building within the statutory agencies responsible for aquaculture permitting, regulation & management. This should include structural reforms, where possible, to develop a cadre of experienced, informed personnel working within single, cohesive units e.g. in Defra's policy development and MMO's regulatory implementation roles, as well as in other aquaculture-relevant regulators and advisors.	✓		✓		✓	✓		
GR 5	Review and develop the planning and permitting regulatory regime for land-based aquaculture e.g. RAS systems e.g. in terms of using industrial and agricultural land, waste treatment and disposal, welfare, planning and environmental issues.	✓	✓	✓		✓	✓	✓	
GR 6	Establish and promote the direct benefits of aquaculture (feed and seafood production) and its economic value as well as those indirect ecosystem services that can be provided such as carbon capture, coastal protection, biodiversity enhancement and their monetary value for comparison with other MEAs and marine space uses.	✓	✓	✓	✓	✓	✓	✓	
GR 7	Report, compile and analyse English aquaculture production, economic performance and supply chain activity at a suitable level of granularity (e.g. species, production system, scale, location, employment, etc.) to allow analysis and evaluation on a recurrent basis. This should be included in a database and made available to stakeholders via an online portal.	✓		✓	✓		✓	✓	✓
GR 8	Formation of an English Aquaculture Producer Organisation to represent all production and supply chain sub-sectors.	✓			✓	✓	✓		

Assumptions and risks

- The current three-yearly Government Comprehensive Spending Review is an opportunity to increase funding commitment to aquaculture development and regulation. However, given the cost of recent economic support over the C-19 pandemic, competition for future funding is expected to be fierce.

Key to Expected Outcomes (OC)	OC 1: The barriers to sustainable growth in aquaculture production are identified and reduced
	OC 2: English aquaculture maximises the use of technology and innovation to drive growth to improve its overall sustainability
	OC 3: Aquaculture contributes to England's domestic seafood production and overall food security
	OC 4: English aquaculture products are seen by wider society to be healthy and sustainably produced
	OC 5: The aquaculture sector is seen as an attractive and rewarding employment opportunity

3.2.2 Knowledge, Innovation and Technology

Much of England's current aquaculture production is by traditional systems such as bottom-farmed mussels and flow-through trout ponds. The industry is starting to innovate, with mussels moving offshore on longlines and RAS gaining scale and confidence. The growth aspirations in this Strategy (see **Section 3.1**) are predicated on an accelerating pace of innovation and production diversification. This reflects the high demand from other sectors for inshore marine sites and freshwater resources; the need to move production offshore; increased productivity through polyculture and other IMTA approaches; as well as the development of new production systems on land and at sea.

English aquaculture needs are very different to those in Scotland, where the industry already operates at scale and its Strategy focuses more on consolidation and improvement, rather than transformation. As a result, harnessing England's industrial skill-base and world-leading academic capabilities is an essential part of this Strategy. This said, there are synergies too (common research issues and a UK-wide consumer base that sometimes struggles with some aspects of aquaculture-produced seafood). As a result cooperation and collaboration across the UK remains essential as we jointly combat the C-19 pandemic and the challenges of exit from the EU on the seafood sector as a whole.

Current Status and Issues to be addressed by the Strategy

The main issue is the current dependence on traditional production systems and species, with little change in the broad profile of English aquaculture production over the last two decades. Traditional production will remain important over the duration of the Strategy, but to obtain the growth in the sector over the next 20 years, this suggests that the following is needed:

- A move offshore to cleaner, less contested water.
- New production systems with better growing conditions and environmental performance e.g. CCS.
- New species that can substitute for traditionally consumed fish, as well as reflect the nation's changing tastes and demand.
- Innovation, including in genetic services, novel fish feeds, husbandry systems and disease prevention, to maximise the economic and environmental performance of the above.

The Strategy focuses on facilitating research and development to support these aims. In addition a recent review of the need for innovation in UK aquaculture considered there are two fundamental challenges to be addressed.

1. Viable alternatives to fishmeal and fish oil from processing of wild captured species.
2. Reduce the farming intensity, whilst improving or maintaining commercial viability.

This may require a disruptive shift in the industry towards a systems view (i.e. a holistic, multi-species approach), where the measure of the commercial outcome is at the system level and not the single species level. This may in turn allow aquaculture to move away from being a net extractive operation to being 'regenerative', analogous to emerging 'regenerative agricultural' systems that are showing promise (Strategic Innovation Ltd, 2020).

A third challenge is to ensure that aquaculture capitalises on the fast-moving developments in digital innovation and communication technology, including cloud computing and artificial intelligence. These technologies can be used to make English aquaculture more competitive e.g. using stock monitoring systems to automate husbandry tasks[53] as well as performing environmental and security monitoring etc, especially when moving further offshore. A key to this will be working with other maritime sectors to jointly develop synergistic systems, both at an academic and in industrial settings (see **Section 3.2.6 Aquaculture in the Blue Economy**).

Current research provision: Industry and academia both contribute to aquaculture research and innovation in England. Key aspects of this include:

1. Much of the practical research has been led by the more progressive elements of the industry, such as moving mussel farming to offshore sites.
2. There are UK-wide research initiatives, such as the Aquaculture Research Collaborative Hub UK (ARCH-UK[54]). ARCH-UK is funded largely through UK Research and Innovation (UKRI) which works in partnership with universities, research organisations, businesses, charities, and government to assist research and innovation to flourish. It is notable that (i) only 24% of the 516 members are based in England and (ii) the eight Working Group teams are managed by the University of Stirling (in Scotland) and Swansea University (in Wales) with the University of Aberdeen and the University of Exeter participating in the overall partnership. This said, the ARCH-UK Advisory Board is more widespread[55].
3. Public sector research, mainly through Cefas. Much of this is based on supporting government decision-making (e.g. the role of aquaculture in Pacific oyster population expansion), marine spatial planning or providing aquatic animal health services.
4. University research programmes. For example, the Collaborative Centre for Sustainable Aquaculture Futures (SAF) is a joint initiative between Cefas and the University of Exeter. SAF seeks to develop further collaborative partnerships with academia, governments and industry, both nationally and internationally, to establish a network of world leaders in the fields of aquatic animal health, food safety, and protection of the aquatic environment. Other English universities, such as Plymouth, Southampton and Newcastle, also conduct aquaculture-related research.
5. Business-focused networks such as the Knowledge Transfer Network (KTN) that is tasked with accelerating innovation through knowledge transfer partnerships, facilitating government finding such as the Industrial Strategy Challenge Fund (ISCF) and Horizon 2020 across a number of sectors including agri-food.

Whilst continued participation in UK-wide initiatives such as ARCH-UK is essential, given the particular direction that England is taking in terms of product and system diversification, a more English-centric approach is also needed. Such an approach needs to be linked to wider funding schemes, such as through Innovate UK, the Biotechnology and Biological Sciences Research Council (BBSRC) and the Natural Environment Research Council (NERC).

[53] See Cermaq's 'ifarm' as an example https://www.youtube.com/watch?v=JsGPwjEIeio as an example

[54] See https://www.aquaculturehub-uk.com/

[55] See https://www.aquaculturehub-uk.com/about

Issues and approach: A key challenge is to agree the different roles government, industry, academia and private sector research can play, and how to best combine the different skills and strengths of these groups. For instance research might be categorised into different elements such as:

- **Fundamental, long-term (blue sky) thinking** where 'real-world' applications are not immediately apparent.
- **Addressing short-term critical constraints** to development
- **Developing initial research into commercially viable applications**
- **Applied research** to further develop / refine existing commercial models
- **Replicating successful models** and to transfer knowledge and best practise
- **Quantifying sustainability including ecosystem services from aquaculture** beyond food production

It is not in the scope of this Strategy to assess this and propose a detailed approach, but this would seem a necessary first step in the Strategy's implementation. It is important that the SF2040 Secretariat and SILG and the Seafish Expert Panel (SEP) – the SEP Chair sits on the SILG – work together in this formative process.

Once the roles and overall approach have been established, a mechanism needs to be put in place to enable this. The outgoing Scottish Aquaculture Research Forum (SARF[56]) and its successor the Scottish Aquaculture Innovation Centre SAIC[57]) is one possible model. Emerging from the 2003 'Strategic Framework for Scottish Aquaculture' (Scottish Executive, 2003), SARF was an independent company created to promote, encourage and support research and development in Scottish aquaculture. SARF research was usually applied, problem solving research and development to address specific industry requirements, inform policy development and improve regulation. SARF also had an aim to enhance the public understanding of aquaculture. The SARF Secretariat, through its 12 trustees (including Seafish, Shellfish Association of Great Britain (SAGB) and BTA) facilitated its members to identify and prioritise research issues within specified research topic areas and then issues a call for proposal to respond to these.

In 2020 SARF is being wound down, with aquaculture-related research funding being focused on SAIC. Launched in 2014 with £11.1m of Scottish Funding Council (SFC) support, SAIC is one of eight Scottish Innovation Centres aimed at increasing the pace of innovation in sectors of key economic and social importance. In November 2019 a further £10m of core funding was provided to drive, nurture and share innovation across the Scottish aquaculture sector during a second phase of operation, with the aim of attracting a minimum of a further £3.5m of funding into industry–academic applied R&D over the next five years. SAIC is based in the Stirling University Innovation Park.

It is also important to recognise the relationship of aquaculture research with other research areas. In particular, in order to address the challenges stated at the beginning of the section there is a need to work with offshore engineering (e.g. mooring and containment structures), renewable energy development, marine biotechnology (e.g. developing new products, especially from microalgae) and nutrition (e.g. developing specialist diets for novel species and production systems such as RAS).

[56] See http://www.sarf.org.uk/

[57] See https://www.scottishaquaculture.com/

To date the direction of most aquaculture research has been driven by either industry or the research providers themselves. It is important that a third element is added to this, namely consumer interest. In a recent study (Zander and Feucht, 2018), consumer 'willingness to pay' across the EU changed with production as follows:

- Highest for organic (+14.8%);
- Followed by sustainable (+14%) with higher animal welfare (+14%);
- Local (+12.6%);
- By coastal fisheries (+11.7%);
- Without discards (+10.3%); and
- European (+9.4%).

Thus, organic and sustainable production, as well as higher animal welfare standards, appear to be the most promising attributes for consumers.

Knowledge transfer: It is important to ensure that research findings and accrued knowledge are made available and disseminated to a wide range of stakeholders. This will become increasingly important as English aquaculture research and innovation efforts are increased. It is also important to retain access and involvement in wider UK level research, as well as research in the EU and elsewhere. Organisations such as KTN are important to facilitate collaboration between academia and industry, as are initiatives such as ARCH-UK.

Online aquaculture knowledge-sharing platforms such as 'The Fish Site[58]' can also play a role. Some important considerations are how I research results can be applied to industry situations, overcoming intellectual property and commercial sensitivity issues and also how knowledge transfer can be made between regions in England, especially given the current focus on marine aquaculture development in the south-west, which will have lessons for elsewhere in the country.

Funding: A key consideration for research, innovation and knowledge transfer is funding. Currently the £10 million Seafood Innovation Fund (SIF[59]) is administered by Cefas on behalf of Defra. Launched in 2019 for an initial three-year period (the third and final round is to open in early-mid 2021), the overall aim of the SIF programme is to kick-start a step-change in the productivity and sustainability of UK seafood in the future and supports projects, ideas and technologies that aim to "disrupt the seafood sector".

With the UK leaving the EU, the UK is committed to reaching 2.4 per cent of GDP invested in R&D by 2027 and three per cent of GDP in the longer term (HM Government, 2019). If a similar proportion (2.4%) of the economic contribution of English aquaculture as aspired to in this Strategy were committed to sector research, this would amount to around £23 million per year. This is a substantial amount and would need careful administration, monitoring and evaluation.

[58] See https://thefishsite.com/
[59] See https://www.seafoodinnovation.fund/

Key actions – Knowledge, Innovation and Technology

Action		Outcome					Timing		
		OC1	OC2	OC3	OC4	OC5	2025	2030	2040
KI 1	Development of a research sub-strategy for English aquaculture. Will need to map clients against different service provider types and identify different collaboration pathways and mechanisms, as well as funding models. Will also identify research needs assessment, prioritisation, delivery, knowledge dissemination and impact assessment mechanisms. Industry and other stakeholder involvement will be key.	✓	✓	✓	✓		✓		✓
KI 2	Provide funding to support the establishment of an Aquaculture Innovation Hub in KI 3. It is suggested that this be delivered through a co-management approach between industry and government to encourage ownership and maximise value for money.		✓				✓		
KI 3	Establish an Aquaculture Innovation Hub and online forum for English aquaculture covering research, knowledge transfer, promotion of good practise, regulatory requirements, consumer information, etc. Where necessary this could be linked to (i) wider UK & EU research, (ii) English regional initiatives and (iii) specific toolboxes, such as the Aquaculture Regulatory Toolbox and the Aquaculture Virtual Hub[60].		✓		✓		✓	✓	
KI 4	Based on the research sub-strategy in KI 1, develop a time-bound short, medium and long-term research programme for English aquaculture that addresses the differing needs identified in the sub-strategy.		✓				✓	✓	✓
KI 5	Establish an English aquaculture research & innovation group to manage the research programme, including on-going needs analysis, formulation of common research topics, organising call for proposals from suitable research providers, monitoring on-going research provision and conducting periodic research impact analyses to feed back to Strategy review and revision		✓				✓		
KI 6	Government to work with industry, academia and research organisations to determine the long-term, centrally-funded research needs that will address enduring regulatory barriers, identify and develop 'horizon-scanning' opportunities for English aquaculture, progress the path to carbon neutrality and to mitigate the impacts of climate change.	✓	✓	✓	✓	✓	✓	✓	✓
KI 7	Identify synergies with other MEAs and develop research and innovation linkages to (i) facilitate co-existence and (ii) build on any opportunities in joint research (e.g. with offshore engineering, renewable energy development, marine biotechnology, stock & environmental monitoring, automated husbandry systems, animal nutrition and food product development).	✓	✓				✓		

Assumptions and risks

- Government funds sector research over the long-term and industry agreement is reached on a model for funding contributions, and research dissemination.

[60] https://www.dorsetaquaculture.co.uk/

Key to Expected Outcomes (OC)	OC 1: The barriers to sustainable growth in aquaculture production are identified and reduced
	OC 2: English aquaculture maximises the use of technology and innovation to drive growth to improve its overall sustainability
	OC 3: Aquaculture contributes to England's domestic seafood production and overall food security
	OC 4: English aquaculture products are seen by wider society to be healthy and sustainably produced
	OC 5: The aquaculture sector is seen as an attractive and rewarding employment opportunity

3.2.3 Common Infrastructure Development

The South Inshore and South Offshore Marine Plans include a policy aim to ensure "*support is given to proposals that provide supporting infrastructure either at sea or on land for fisheries and aquaculture to support safe, profitable and efficient marine businesses. This encourages supporting infrastructure for these industries, enabling their benefits to be realised[61]*". With regard to aquaculture this includes (HM Government, 2018a):

- ports and harbours with offloading facilities, such as vessel berths for dry goods landing;
- storage and processing facilities, including depuration plants for shellfish and storage for wet fish, dry goods and other produce;
- repair and chandlery facilities;
- markets;
- local food establishments;
- transport of produce to shore and once on shore (logistics companies); and
- supporting structures at sea such as ropes or cages or similar fixed structures.

Current Status and Issues to be addressed by the Strategy

Aquaculture operations are logistically complex and this is likely to increase as (i) they move offshore and (ii) production systems diversify. Logistical challenges include installing, maintaining and decommissioning large structures on the sea bed and in the water column, husbandry functions such as feed storage, feeding and stock management and the harvesting and landing of crops. Aquaculture operators are therefore dependent upon access to good quality ports (e.g. all weather and tidal conditions), berthing, fuel and other shore-side facilities. In addition there will be increasing demand for the primary processing of harvested crops (e.g. washing, depuration and drying, etc) as close to the landing point as possible.

Discussion with stakeholders suggests that such facilities are either absent, full to capacity or subject to competition from other MEAs and marine space use. As most aquaculture operators are SMEs, it is difficult to secure individual facilities, which means they need to share with other, often more influential MEAs. For instance, one shellfish farming operator based in Cornwall is unable to land through his home port due to unaffordable health and safety regulations imposed by the primary port user, a large industrial business. In the south / south-west of England another issue is the competition for berthing space from recreational craft, with many harbour authorities able to charge high daily rates for berthing that are unaffordable for small businesses.

There are two approaches to solving this problem. Firstly, establishing seafood or aquaculture clusters that bring together individual seafood businesses with similar requirements would provide more leverage in sharing harbour and other shore-side facilities as well as enabling the funding and development of common facilities such as ice-making, processing and waste-water treatment that will enhance their individual profitability. For instance shellfish depuration could be moved inland to lower-cost industrial unit sites, but only if sufficient volumes are guaranteed to ensure that costs e.g. for salt dosing are spread across a sufficient volume of production. A number of business would need to commit to such a scheme, but this does provide a nucleus for further development e.g. cooking, processing and other supply chain activities, including the possibility of RAS facilities (see **Box 5: Advantages of Seafood Clusters** overleaf).

[61] South Inshore and South Offshore Marine Plan (July 2018): Policy S-AQ-2

Such clustering will also provide the economy of scale for installing renewable energy sources such as solar, wind and biomass systems to help lower costs and raise the environmental credentials of such facilities / sites and their products.

Box 5: Advantages of Seafood Clusters

The development of a cluster 'business park approach' can remove constraints infrastructure and logistical constraints through:

- Formation of an integrated cluster of value-added business by encouraging ventures to grow together.
- Clusters allowing for a sophisticated and efficient supply chain allowing gaps in the chain for example lack of cold stores to be identified and filled.
- The Business Park becomes a platform for investment in infrastructure improvements. Investment in road networks, communication and power systems attached to one concentrated industrial area maximises the value for money per investment.
- Consolidation of disparate resources to significantly reduce costs (transport, logistics) through external economies of scale
- Business incubation – a route for direct investment (national and international) and an interface for business advice

Long-term cluster / seafood business park establishment will lead to cultivation of a strong commercial culture. Networking between companies leads to further economies of scale and entrepreneurship encouraged within the wider community – leading to product diversification and additional innovation.

Source: Huntington *et al*, 2017

Secondly, seek synergies and collaborative approaches with other MEAs and marine space users. For instance, collaborating with a wind farm company to set up culture units within turbine arrays may provide access to landing and engineering facilities. There are also strong potential synergies of working together with the capture fisheries sector as many of the support facilities (e.g. vessel berthing, landing, ice, fuel) and downstream supply chain elements are common between the two sectors.

If a more collaborative and positive co-management approach can be agreed between industry and government, especially through regional initiatives (see **Section 3.2.1**), it is likely that the sector would have greater influence over public expenditure in harbour development and shore-side industrial planning.

At a wider level, a more positive and aspirational policy approach and recognition could also influence national and regional investment in waste water and sewerage treatment.

Key actions – Common Infrastructure Development

Action		Outcome					Timing		
		OC1	OC2	OC3	OC4	OC5	2025	2030	2040
IN 1	Harbour authorities are encouraged and supported to provide commercial operations with favourable rates for berthing and the use of other facilities. Where justified, e.g. on economic, socio-economic or cultural grounds, this might be subsidised through public funding.	✓					✓		
IN 2	Establish partnerships between aquaculture business and other MEAs where there are synergistic advantages. Regional maritime development organisations such as organisations such as the South West Aquaculture Network (SWAN) and South West Partnership for Environmental and Economic Prosperity (SWEEP) in SW England and Marine South East in SE England may be able to assist in identifying and facilitating these partnerships.	✓	✓			✓	✓	✓	
IN 3	Feasibility study to identify the potential for a strategic network of seafood clusters, servicing both aquaculture and capture fisheries interests. Primarily, but not necessarily, coastal-based, these would be focused on improving seafood production and value-addition, as well as improving economies of scale.	✓	✓	✓		✓	✓		

Assumptions and risks

- Aquaculture gains credibility as a regionally important MEA
- Willingness of capture fisheries and other MEAs to integrate with the aquaculture supply chain.

Key to Expected Outcomes (OC)	OC 1: The barriers to sustainable growth in aquaculture production are identified and reduced
	OC 2: English aquaculture maximises the use of technology and innovation to drive growth to improve its overall sustainability
	OC 3: Aquaculture contributes to England's domestic seafood production and overall food security
	OC 4: English aquaculture products are seen by wider society to be healthy and sustainably produced
	OC 5: The aquaculture sector is seen as an attractive and rewarding employment opportunity

3.2.4 Financial Support

Aquaculture, like any other form of cultivation system, requires considerable upfront funding in order to obtain operational permits, install equipment, purchase and stock juvenile and feed and care for the growing stock until it can be harvested and sold. For all aquaculture businesses, but especially those just starting, initial seed investment funding and subsequently for cash flow can be critical constraints. Furthermore, in addition to external economic and market pressures, aquaculture businesses have risks associate with disease, poor weather or pollution, all of which impact on funding requirements and the willingness of banks and others to lend to aquaculture businesses.

Current Status and Issues to be addressed by the Strategy

Public funding: In addition to normal business funding, aquaculture businesses have been able to access public funding for R&D purposes, expanding production and improving productivity. One of the main sources has been the EMFF. Since this opened in 2016 around 54 aquaculture businesses in England have benefited under Union Priority 2 (aquaculture), with a total eligible expenditure of around £7 million[62]. This has included expenditure on aquaculture support vessels, expansion of mussel farms, assistance for Pacific oyster farming in baskets and assistance to trout farming operations. EMFF allocation to aquaculture businesses is based upon the UK Multi-annual National Plan for Aquaculture (MANP). However this is only 5% of all EMFF expenditure over the same period.

With the EU-Exit, the UK introduced the Maritime and Fisheries Fund (MFF), but this is currently on hold due to Covid-19 crisis. Instead there is emergency funding of £1 million through the Fisheries Response Fund (FRF) to assist active trout or shellfish farms with their ongoing production costs and the £1 million Domestic Seafood Supply Scheme (DSSS) for businesses engaged in supporting the seafood supply chain in England. An evolution of the MFF is being formulated for 2021 called the Fisheries and Seafood Scheme (FaSS). At the time of writing there is no information on the amount of funding available, nor the eligibility criteria for English aquaculture businesses, but it is likely to be similar in structure to the outgoing EMFF. As discussed in the previous **Section 3.2.2**, there are a number of public funding schemes dedicated to research and innovation in fisheries, including the £10 million UK SIF.

Uptake of European funding (e.g. EMFF and from 2007 to 2013, its predecessor, the EFF) by English aquaculture has been low. EFF funding of aquaculture was only £417,706, supporting a total of 26 completed projects, representing only 3% of all projects funded and 1.4% of UK EFF funding (Arthur *et al*, 2017). This funding was also skewed regionally, being almost entirely focused on the SW, aimed at increasing shellfish production, a priority area for support. The distribution of EMFF funding has been less skewed, but 65% by value of EMFF funding has still been in SW England, with 13% in SE England and 10% in E England[63]. Two key findings and recommendations of the Arthur *et al.* (2017) review of EFF and its effectiveness with regard to aquaculture were:

1. Over half the projects receiving EFF funding for aquaculture were either declined or withdrawn, suggesting a need for greater clarity in funding objectives in this sub-sector. There is a need to recognise the relatively slow return on investment and high risk associated with on-growing.
2. Whilst it is useful to promote start-ups in areas where aquaculture is new, there should also be support to ensure that existing production is maintained and improved e.g. made more compatible with the environment.

[62] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/870907/Transparency_Initiative__31_Jan_2020_.csv/preview for MMO source data
[63] Author calculations from MMO data, see footnote 62 above.

Similarly, a finding of Hambrey & Evans (2016) was that over the last decade funding and support for the industry has been skewed in favour of major investments in high-risk, high-tech research driven projects, with inadequate attention to the basic needs and potential of the existing industry and well established technologies.

These issues suggest that future development funding for aquaculture must be carefully targeted, with (i) strong stakeholder involvement in identifying short, medium and long-term funding needs and (ii) careful analysis to calculate the potential impact each development might have. This can then be used to target funding and develop eligibility criteria that will have the most impact and will meet business and policy objectives. The MANP process was partially aimed at this objective e.g. to target EMFF funds to aquaculture but was based around the EU strategic guidelines rather than anything specific for the UK. A similar approach, but one more focused on English aquaculture needs as set out in this Strategy is warranted.

Public funding via grants has its shortfalls. In terms of effectiveness, grants are less desirable for obvious reasons, in that grantees are less rigorous in their financial planning than loan recipients. Grant aid, while sometimes justified, should be far more rigorously assessed (Hambrey & Evans, 2016). An alternative approach is the development of a dedicated aquaculture development / loan package, offering low interest loans, or other financial incentives such as tax breaks, to help cover the extended lead times and allow production to be established.

In general, development funding - whether grants or loans or a mixture of both, needs to be made more accessible to ordinary farmers by reducing time, complexity, jargon, etc., and through more direct facilitation services to support grant applications. It should also be supported by effective technical and economic mentoring.

Expenditure in any public funding programme should be carefully monitored and subjected to periodic evaluation to ensure that it is being well targeted and that it is meeting its designated strategic objectives. MMO has built up considerable expertise in this area through the EFF and EMFF, and this should be continued for future funding.

Private sector funding: As reported by Hambrey & Evans (2016), due to long, extended lead times typical of aquaculture development and the relatively short-term view taken by high street lenders, financial backing for aquaculture (and particularly anything other than finfish cage farming) is often hard to secure from the private sector, especially when starting a venture.

Ethical funding: A recent development is the linking of finance provision and sustainability. One example is a partnership between WWF and Environmental Finance Ltd (EF[64]) that is developing an impact fund targeting investment and innovation in the UK's sustainable blue economy (the Blue Impact Fund), where a proportion of returns are directed back into marine conservation through an aligned, charitable trust (the Ocean Recovery Fund). Aquaculture-related investment includes hatcheries, feed production, animal welfare, offshore farming and RAS. The current pipeline is focused on small-scale RAS (50 – 60%), offshore / estuarine shellfish mariculture (30 – 40%) and supply chain investment e.g. transport, packaging (10 – 20%) (Environmental Finance, Pers, Comm., 2nd June 2020). Working with funding organisations like the Ocean Recovery Fund will leverage other ethical private funding operations, as well as stimulate public sector funding where there is a similar interest in ethical finance.

[64] https://www.environmentalfinance.co.uk/

Key actions – Financial Support

Action		Outcome					Timing		
		OC1	OC2	OC3	OC4	OC5	2025	2030	2040
FS 1	Public funding of English aquaculture is reassessed in line with the aspirations set out in this Strategy. This could be developed into a post-EU-Exit, MANP style programme. Based on this, a suitable funding sub-strategy is developed. This needs to be stakeholder-focused but carefully designed to maximise both short-term outcomes as well as long-term impacts and aligned with both stakeholder aspirations and emerging policy directives. It should consider a mixture of affordable loans, tax breaks and where appropriate, grants.	✓	✓	✓	✓	✓	✓		
FS 2	Based on the recommendations in FS 1, the replacement for the European Fisheries and Maritime Fund and its successor public funding programmes should align with this funding sub-strategy. The Strategy and the resulting funding programme should be subject to periodic evaluation and revision (see FS 3).	✓		✓			✓		
FS 3	Any public sector development funding - whether grants or loans or a mixture of both - needs to be carefully monitored and subjected to periodic evaluation to ensure that it is being well targeted and that it is meeting its designated strategic objectives.	✓			✓		✓	✓	
FS 4	Engage with NGOs and existing ethical funding programmes to identify and support aquaculture businesses that can demonstrate environmentally sustainable growth and contribute to supporting ecosystem services. This could be supported by third-party certification of compliance with environmental and social best practises.				✓		✓		

Assumptions and risks

- Public funding levels are cut to address fiscal problems after the COVID-19 pandemic

Key to Expected Outcomes (OC)	OC 1: The barriers to sustainable growth in aquaculture production are identified and reduced
	OC 2: English aquaculture maximises the use of technology and innovation to drive growth to improve its overall sustainability
	OC 3: Aquaculture contributes to England's domestic seafood production and overall food security
	OC 4: English aquaculture products are seen by wider society to be healthy and sustainably produced
	OC 5: The aquaculture sector is seen as an attractive and rewarding employment opportunity

3.2.5 Human Capacity Development

Human Capacity Development (HCD) is "*the process by which individuals, groups, organizations, institutions, and societies develop their abilities - both individually and collectively - to set and achieve objectives, perform functions, solve problems and to develop the means and conditions required to enable this process*" (Macfadyen & Huntington, 2004). This Strategy envisages a progressive, well-functioning aquaculture sector by 2040 that will require capable, well-motivated individuals and organisations in order to succeed.

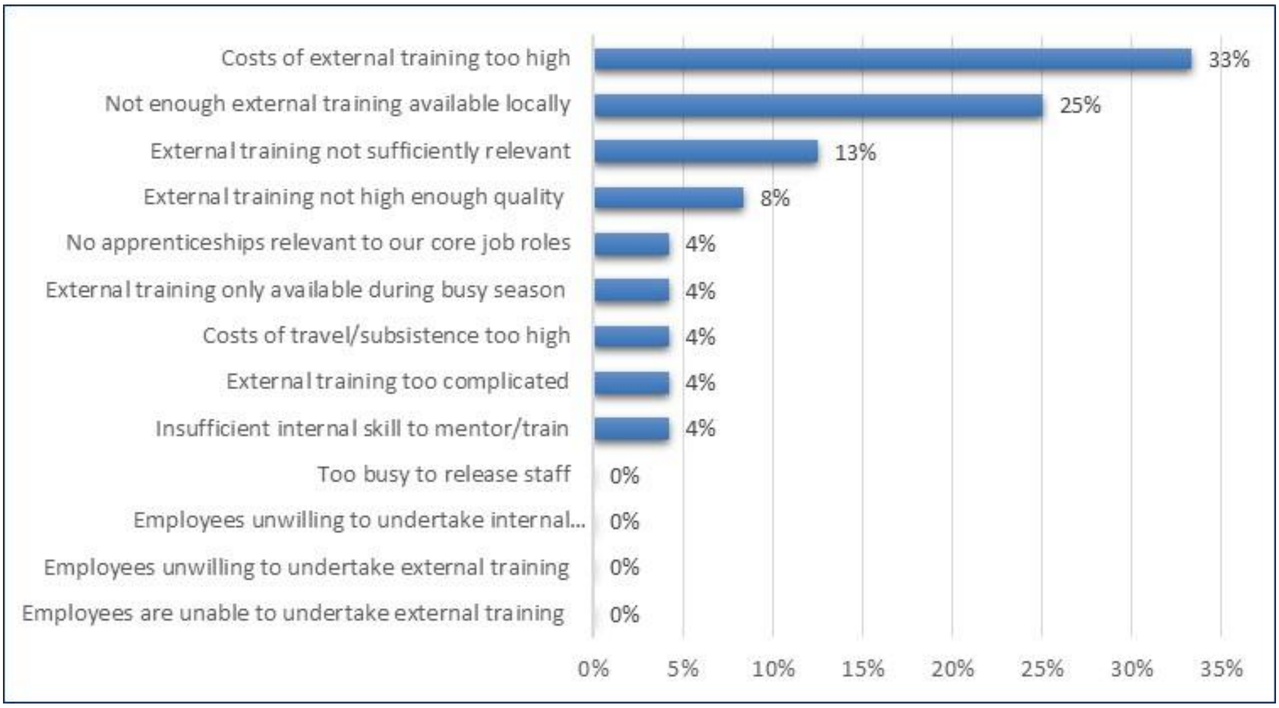
Current Status and Issues to be addressed by the Strategy

A recent report for SF2040 (Pye Tait, 2020) acknowledges that whilst aquaculture is a relatively small sector in employment terms, it is a growing one and requires very high levels of skill in its core workforce. The survey conducted by Pye Tait reported that:

1. 76.4% of aquaculture employees are full-time, 19% part-time and 4.6% seasonal
2. All permanent staff are UK nationals
3. Over 50% of seasonal staff are non-UK residents.
4. 57% are aged over 45 years.
5. 75% of permanent staff are "highly skilled' or 'skilled'.

The skill gaps identified by the Pye Tait report are prioritised in Figure 9 below:

Figure 9: Skill gaps in English aquaculture



Source: Pye Tait Consulting (2020)

Training service provision for aquaculture in England is currently limited, disparate and too expensive. At degree level, Cornwall College offers a FdSc[65] in Marine Science, the University Centre Sparsholt in Hampshire a BSc in Aquaculture and Fishery Management and a FdSc in Sports Fisheries and Aquaculture. Hadlow College in Kent offers (freshwater) Fisheries Management qualifications and FdSc/ BSc in Aquaculture and Fisheries Management. Kingston Maurward College in Dorset is developing a Level 3 Marine Aquaculture course. Bivalve purification training is offered by Seafish and the Southern Shellfish Training Centre. Various other providers including South Devon College offer workboat and Royal Yachting Association (RYA) powerboat handling courses.

With well over half the workforce over 45 years of age, there is a need to bring more young people into the industry, and to demonstrate that a career in aquaculture can be rewarding, reasonably well-paid, safe and progressive. In order for the aquaculture industry in England to develop and diversify as envisaged by this Strategy, a more comprehensive range of training, apprenticeship and education opportunities will be developed to provide the skills and knowledge required.

Seafish recently published a review of practical, operational training for aquaculture across the UK (Sutherland, 2020) which concluded that (i) companies did not report difficulties in finding staff with higher level educational qualifications but did find it more difficult to find people with useful technical skills and (ii) the industry, both finfish and shellfish, appears to indicate that it would benefit from apprenticeships across the UK despite availability being restricted to Scotland. Seafish also has a useful web page on careers and training in aquaculture[66].

A detailed needs analysis and HCD sub-strategy is beyond the scope of this national Strategy, but based upon both the growth aspirations presented as well as discussion with stakeholders, the following elements at least are required:

Technical skills

- Marine biology and ecology
- Genetics, biochemistry and immunology
- Biotechnology, microbiology & toxicology
- Feed formulation and development
- Biosecurity and disease management
- Animal welfare
- RAS engineering and management
- Business strategy and financial planning
- Marketing, sales & social sciences
- Marine engineering
- Marine electronics
- Marine health and safety management

Practical skills

- Engineering skills e.g. welding
- Fire-fighting
- Sea survival
- SCUBA and other diving
- Vessel handling and piloting
- Fish husbandry
- Marine electronics
- Shellfish depuration
- Food safety & hygiene
- Mainstream software uses e.g. Excel, Word, etc.

[65] Foundation degree combining academic & vocational qualification, equivalent to two thirds of an honours bachelor's degree

[66] See https://www.seafish.org/safety-and-training/careers-in-the-uk-seafood-industry/career-paths/careers-and-training-in-aquaculture/

As noted by a recent study on skill requirements in Scotland (HIE, 2018) (i) there are skill need differences between the sub-sectors e.g. finfish, shellfish & macroalgae, (ii) there are skill requirements across a wide range of supply chain elements in aquaculture and (iii) aquaculture will need a resilient and agile workforce that can adapt quickly to a constantly changing sector and (iv) retaining talent, especially in remote locations, can be challenging. Six recommendations were identified that equally apply to English aquaculture:

1. The need to promote the sector as a career destination
2. Develop leadership, management and business capacity
3. Ensure consistency and transferability of training and education
4. Develop a digitally-enabled workforce
5. Enhance provision of work-based learning and vocational training
6. Widen the recruitment pool.

It is also important that any HCD sub-strategy consider the regional differences within England in terms of both the scale and type of local aquaculture development and (ii) the nature of local skills and education establishments and capabilities to ensure an equitable yet targeted focus across the country.

In addition to formal education, apprenticeships will be key to providing young people with a pathway into a career in aquaculture. Unlike Scotland, England currently does not have any formal aquaculture apprenticeship schemes. There are currently moves to develop an aquaculture apprenticeship standard through the Institute for Apprenticeships & Technical Education[67].

[67] Based on a presentation given by Oliver Symons, Deputy Principle for Learning and Performance, Kingston Maurward College to SWAN on 21st July 2020) .

Key actions – Human Capacity Development

Action		Outcome					Timing		
		OC1	OC2	OC3	OC4	OC5	2025	2030	2040
HC 1	Building on the SF2040, Seafish, & Pye-Tait (2020) report, develop a training needs analysis for human capacity development for English aquaculture up to 2040. This should identify (i) the main skills required by the different regions, sub-sectors and supply chain elements, (ii) how they should be delivered e.g. formal education, short-courses, on-line courses, in-house training or apprenticeships and (iii) address any skill type / geographical gaps through existing institutions where possible and investigate the need for new approaches where necessary.	✓		✓		✓	✓		
HC 2	Assist in the establishment of an aquaculture apprenticeship scheme accredited by the Institute for Apprenticeships and Technical Education. Will require a 'trailblazer group' to establish occupation profiles, knowledge, skill and behaviour requirements, and an end point assessment plan.					✓	✓		
HC 3	Promote aquaculture as a growing sector in the Blue Economy and a progressive career choice. To attract people into aquaculture, the sector and the roles within it must be clearly communicated and reinforced amongst potential recruits, people and organisations that influence career decisions. The profile of the sector must be raised and it should be promoted as fast growing and technology driven.		✓			✓	✓	✓	
HC 4	Identify cross-sectoral learning opportunities e.g. with sectors such as oil and gas in relation to technology and offshore operations. The oil and gas sector has a large number of staff in transition including health and safety and engineers who could bring knowledge and transferrable skills to aquaculture. Other areas include marine biotechnology and offshore renewable engineering.		✓			✓	✓		
HC 5	Provide support for general management, leadership and business skills. This is likely through ensuring that both formal training (e.g. degree level courses) and on-the job training includes the development of these skills in addition to more technical skills development requirements.					✓	✓		

Assumptions and risks

- The promotion of aquaculture as a growing, well-rewarded and progressive career choice is predicated on growth within aquaculture businesses and their long-term viability.

Key to Expected Outcomes (OC)	
	OC 1: The barriers to sustainable growth in aquaculture production are identified and reduced
	OC 2: English aquaculture maximises the use of technology and innovation to drive growth to improve its overall sustainability
	OC 3: Aquaculture contributes to England's domestic seafood production and overall food security
	OC 4: English aquaculture products are seen by wider society to be healthy and sustainably produced
	OC 5: The aquaculture sector is seen as an attractive and rewarding employment opportunity

3.2.6 Aquaculture in the Blue Economy

The World Bank defines the 'blue economy' as the "*sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystem*[68]", whilst the EC defines it as "*all economic activities related to oceans, seas and coasts. It covers a wide range of interlinked established and emerging sectors*." (EC, 2018). The essential point is that aquaculture is an important MEA that must co-exist and collaborate with other marine space users in order to thrive and diversify. This partnership approach crosses a number of areas including research and innovation, human capacity development and joint financing opportunities (EC, 2017).

Current Status and Issues to be addressed by the Strategy

Although the UK is now leaving the EU, the EU's 'Blue Growth Strategy' is instructive here. This focuses on growth across five areas: aquaculture, ocean energy, maritime tourism, blue biotechnology and seabed resources. This is echoed by Maritime UK South-West's focus on (i) Autonomy and Geospatial Data, (ii) Marine Manufacturing, (iii) Offshore Renewable Energy and (iv) Ocean Technology and Aquaculture[69] and the benefits of developing a "ocean technology cluster'[70].

Whilst there is a perception that different marine space users 'compete' against each other for marine space and influence in the regional Marine Plans, it is also recognised that there are many potential synergies with these different activities. These include:

Co-ordination and co-existence with other aquaculture operations. At present, most aquaculture businesses in England are SMEs that lack the economies of scale and institutional presence of larger operations. It therefore makes sense to combine operations in an optimal ecological and commercial manner that allows IMTA solutions to be deployed, common logistical tasks pooled and a greater influence in marine spatial planning decisions. These are best formalised by identifying priority aquaculture areas and developing aquaculture parks or clusters. These can be both offshore or nearshore, depending upon the local environmental and investment conditions. It should be recognised that IMTA solutions are largely untried commercially and will need to be built into English aquaculture gradually.

Co-ordination and co-existence with capture fisheries interests: shellfish farms – and potentially seaweed farms - can provide ecosystem services such as extra habitat and spatial protection with benefits for neighbouring wild fish stocks. Likewise, the use of IMTA can provide a 'spatial protection effect' by excluding or restricting other activities which in turn may lead to species aggregation, environmental protection, and/or biodiversity benefits, even though these installations many have not been designed on conservation grounds. Co-location e.g. via seasonal spatial agreements with static gear fishing in particular may be a positive and achievable option for shellfish and seaweed aquaculture operations, helping to win support from the wider inshore fleet, and ultimately leading to smoother planning applications for new farms (Seafish, pers. comm., 2020). Joint strategies for utilising Several Orders, spatial fallowing and marine conservation could be developed together. Integrating marine conservation objectives into aquaculture development will be able to leverage green finance.

The role of the IFCAs are essential here – most IFCAs are focused on capture fisheries at present but are beginning to recognise the potential for mariculture in their districts. The challenge will be for the IFCAs and others to come up with local spatial and operational strategies to maximise co-existence and co-operation between the two sectors and build resilience into local seafood supply chains in general.

[68] See https://www.worldbank.org/en/news/infographic/2017/06/06/blue-economy
[69] See https://maritimeuksw.org/
[70] See https://maritimeuksw.org/

Co-existence with other MEAs, such as wind farms: offshore wind farm turbine arrays could provide a co-location for aquaculture, sharing services such as accommodation platforms, power, metrological monitoring, supply vessel costs and even staff. Aquaculture units can provide wave attenuation that can benefit the offshore structures. The challenges include (DTU, 2015; Martin Syvret, pers. comm.):

- Co-operation requires a positive attitude of the industries involved. This is not always easy as company cultures can differ;
- Industries need to see 'what's in it for them', whether this is cost reduction, access to new markets, a good image, or easier permission procedures;
- Issues over possible damage to both parties infrastructure, as well as lower standard of operational practises / lack of insurance;
- Successful co-production requires a site suitable for both energy and food production. This is not self-evident and there might be a lack of suitable ocean space;
- Policy-makers show interest in co-production of energy and food but permitting procedures for upcoming industries, such offshore aquaculture, and co-production are lagging behind;
- Even if corporate and political goodwill is present, technical challenges can be difficult to solve. The harsh offshore environment is a serious challenge to new structures; and
- Higher risks that negatively affect economic feasibility.

Co-existence with primary producers like aquaculture is attractive to energy companies to demonstrate their commitment to doing social good. Some reassurance against the challenges mentioned above can be provided through the energy developer having the main license, with aquaculture licensed as a secondary activity in the same area. Co-existence with other MEAs is not restricted to marine areas, as a number of the shore-based skills are synergistic. There are common interests in research and development (see **Section 3.2.2**) as well as manufacturing (e.g. of work boats, mooring and longline systems, remote telemetry, power and communications, etc.) and engineering / maintenance, and therefore the development of shared facilities in port areas or nearby business parks. These could be developed into 'blue growth clusters'.

Co-existence with Marine Protected Areas (MPAs): Almost half i.e. 49% (25,102 km^2) of English inshore waters (out to the 12 nautical mile territorial limit) is occupied by 154 MPAs, while 37% (66,504 km^2) of offshore waters contain 40 MPAs (JNCC, 2019). The majority (>70% in England, and >90% in SW England) of mariculture (predominantly shellfish mariculture) sites are located within MPAs and have been shown over time to be (i) compatible with some habitat features e.g. mud, sand and gravel habitat (having negligible impact on their condition) and (ii) sustainably and efficiently managed through a range of fisheries orders and byelaws (Brown *et al,* 2020b). Brown *et al.* also consider that (i) the current levels of feature condition monitoring (for assessing MPA status) are generally insufficient for traditional feature-based and alternative zonal ecosystem-based licensing and management of mariculture sites, (ii) clearer guidance of what constitutes a significant adverse effect on MPA feature condition is required, as well as more accurate tools for quantifying the contribution of mariculture developments towards any (cumulative) adverse effects and (iii) the licencing of new mariculture sites within MPAs is impeded by traditional precautionary feature-based conservation approaches. This situation may be further complicated with the possible introduction of Highly Protected Marine Areas (HPMAs[71]).

[71] See https://www.gov.uk/government/publications/highly-protected-marine-areas-hpmas-review-2019

A further feature of improved coexistence is capitalising on **English aquaculture as part of a circular economy in which resources are sustainably managed.** The Strategy is focused mainly on either extractive aquaculture of low trophic species, or the development of environmentally sustainable finfish farming. For the latter, responsibly sourced feed will be key. Most finfish farming relies heavily on imported raw materials, such as fishmeal (e.g. from small pelagic stocks in the NE Atlantic or SE Pacific Ocean) and soy protein concentrate (mainly imported from Brazil) (Shepherd *et al*, 2017). Given the relatively low volumes of finfish to be produced by English aquaculture in 2040 (when compared to Scotland), there is an opportunity to develop novel feed ingredients from both arthropod (e.g. insect) and non-arthropod (e.g. worms and annelids) invertebrates, as well as single-celled organisms and fungi. With a focus on RAS, it will also be important to develop feeds that work well with recirculation systems e.g. provide optimal growth and are sufficiently stable so that uneaten food and faeces do not to impact on the filtration units (Tillner, 2020).

Social obstacles to offshore aquaculture constitute another challenge to developing aquaculture as a key component of the English blue economy. Many consumers and other stakeholders are either oblivious to what aquaculture is, or view it with suspicion, mainly due to persistent negative press, and mainly relating to the open water farming of salmon and the implied impact on wild stock (through sea-lice infestations and interbreeding with domesticated escapees) as well as impacts on benthic communities from cage clusters. In addition, some consumers prefer wild-caught fish over their farmed equivalent for environmental, welfare or taste reasons, although the price of farmed production is often higher (Villasante *et al*, 2013).

The Strategy partially addresses these issues by focusing on extractive aquaculture and only advocates the use of species such as sea-grown rainbow trout (which cannot interbreed and do not have the same sea lice issues as Atlantic salmon) in open water systems. However it is clear that this is insufficient, and that a more open, balanced and progressive discussion is needed with regulators, supply chain components, consumers and NGOs on the both the benefits of sustainable, well planned and managed aquaculture and any environmental or socio-economic trade-offs involved.

Key actions – Aquaculture in the Blue Economy

Action		Outcome					Timing		
		OC1	OC2	OC3	OC4	OC5	2025	2030	2040
BE 1	Develop local alliances and partnerships for co-location of aquaculture, MPAs and fishing areas (e.g. static gear). Will initially require awareness raising and confidence-building activities to align interests and to discuss and agree conflicts and their mitigation approaches. Mainly conducted at IFCA level. Could include the development of a Code of Practise for co-existence between aquaculture and wild fisheries, as well as local management strategies for particular sea areas to maximise sustainable seafood production.	✓		✓			✓		
BE 2	Conduct an independent national 'Strategic Environmental Assessment' (SEA) of English aquaculture and its likely development pathways and develop the evidence base to (i) identify and put in place mitigation approaches where necessary and (ii) develop a public engagement and awareness campaign that demonstrates how responsible and well planned aquaculture can have major societal benefits and manage its impact within acceptable limits.				✓	✓	✓		
BE 3	Develop partnerships at local level in priority aquaculture areas. Work to develop 'Aquaculture parks' at a local level, identifying possible partnerships / IMTA opportunities between different production operations and how common needs (e.g. slip ways / landing facilities / security, etc) could be jointly addressed. Partnerships could be formalised to engage in joint marine licensing, EIAs and other regulatory / planning needs.	✓	✓	✓	✓	✓	✓	✓	
BE 4	Assess ways of including aquaculture and it's supply chain components in the blue economy e.g. through the development of land-side 'blue growth' clusters, including R&D service providers, manufacturers (work boats, mooring and longline systems, remote telemetry, power & communications, etc) and other service providers (e.g. genetic services, certification, insurance, veterinary).	✓	✓	✓				✓	
BE 5	Collaborate with both offshore energy companies and aquaculture to develop conceptual models for multi-use operational platforms at sea, including design, operation, permitting, environment impact and benefits.	✓	✓	✓				✓	
BE 6	Identify and promote supply chain opportunities for English aquaculture, such as novel feed raw material production, feed manufacturing, equipment recycling and disposal, etc.		✓	✓		✓	✓		

Assumptions and risks

- Regional 'champions' in the form of aquaculture development officers can be funded to drive through local solutions for co-existence and co-operation.

Key to Expected Outcomes (OC)	OC 1: The barriers to sustainable growth in aquaculture production are identified and reduced
	OC 2: English aquaculture maximises the use of technology and innovation to drive growth to improve its overall sustainability
	OC 3: Aquaculture contributes to England's domestic seafood production and overall food security
	OC 4: English aquaculture products are seen by wider society to be healthy and sustainably produced
	OC 5: The aquaculture sector is seen as an attractive and rewarding employment opportunity

4. Delivery Plan

This Section includes a preliminary, high-level delivery plan, provided in the form of a series of tables. The colour codes are the same as in the sub-sector action tables above e.g.:

Sub-sector (code)
Finfish FF
Shellfish SH
Macroalgae MA
Governance and Regulation GR
Knowledge, Innovation and Technology KI
Infrastructure IN
Financial support FS
Human Capacity Development HC
Blue Economy BE

Three tables are presented, aggregating all the actions provided in earlier sections, into three different priority levels:

1. **Critical**: Key actions are those which are essential to the success of the Strategy. These are often pre-cursors to other, usually lower priority actions.
2. **High**: Actions that whilst not critical are highly important to the success of the Strategy.
3. **Medium**: Actions that may not be critical nor high priority but are nevertheless essential to the long-term success of the Strategy.

Within each of these tables, each action is associated with the following:

- **Potential participants**: We have suggested what organisations might be involved in each action. It should be noted that this is a preliminary, non-exclusive allocation, and that further discussion will be needed to agree who will lead and partner each action.
- **By when**: Provides a timeline (either 2025 or 2030[72]) by when the Action should be completed.

This Delivery Plan will be overseen by ALG.

[72] As the SF2040 Strategic Framework notes, the period on the horizon (2031 to 2040) is highly uncertain and specific deliverables for this period are not proposed at this time.

Table 4: Critical Actions

Action	Potential participants	By when
KI 1: Development of a research sub-strategy for English aquaculture. Will need to map clients against different service provider types and identify different collaboration pathways and mechanisms, as well as funding models. Will also identify research needs assessment, prioritisation, delivery, knowledge dissemination and impact assessment mechanisms. Industry and other stakeholder involvement will be key.	SF2040 SILG / SF2040 ALG Academia Industry Others	By 2025
KI 2: Provide funding to support the establishment of an Aquaculture Innovation Hub in KI 3. It is suggested that this be delivered through a co-management approach between industry and government to encourage ownership and maximise value for money.	The SF2040 programme Defra Seafish	By 2025
KI 3: Establish an Aquaculture Innovation Hub and online forum for English aquaculture covering research, knowledge transfer, promotion of best practise, regulatory requirements, consumer information, etc. Where necessary this could be linked to (i) wider UK and EU research, (ii) English regional initiatives and (iii) specific toolboxes, such as the Aquaculture Regulatory Toolbox and the Aquaculture Virtual Hub.	Seafish Innovate-UK UKR&I Cefas Others The SF2040 programme	By 2030
SH 1: Finalise a formal policy for the use of Pacific oysters in English waters balancing the potential harm from further farmed introductions with the socio-economic benefits of producing this now established species.	NE FHI-CEFAS Defra Other statutory agencies	By 2025
SH 2: Develop the risk-based approach to the classification of shellfish production waters that ensures food safety for consumers but provides increased assurance and certainty to shellfish farmers, investors and markets.	FSA Seafish Cefas Other statutory agencies Academia	By 2025
MA 1: Development of specific marine licensing guidelines for macroalgae culture that reflects its nature, scale and impact of these extractive, low trophic species.	Defra MMO Cefas Producers	By 2025

Action	Potential participants	By when
GR 1: A clear policy for English aquaculture development is prepared within the framework of the Fisheries Bill, the Common Fisheries Policy (Amendment etc.) (EU Exit) Regulations 2019, and the wider policy environment	Defra Producer Organisations (e.g. British Trout Association, Shellfish Association of Great Britain, etc.) IFCAs	By 2025
GR 2: Following completion of Defra's review of aquaculture regulations, implement the agreed approach for transparent, streamlined and proportionate regulation. This includes the level of evidence required for the permitting of different types and scales of aquaculture. There is a need for clarity on the decision criteria that will be used and the nature of any trade-off analysis, as well as standards relating to response and decision times	MMO Defra Other statutory agencies The SF2040 programme	By 2025
GR 3: Develop a regional approach to aquaculture development, management and regulation, creating regional hubs that can (i) lead on regional spatial marine planning, (ii) act as a 'one stop shop' for new and expending aquaculture businesses and (iii) provide a forum for co-existence with other marine space users. Operational approaches include (i) operating at the IFCA spatial level, (ii) identifying suitable institutional leads and partners (options include local authorities, coastal fora, the IFCAs), (iii) the funding of Aquaculture Development Officers for each region and (iv) engaging with sector participants and other stakeholders.	Regional bodies & organisations (e.g. IFCAs and Local Authorities) POs	By 2025
FS 1: Public funding of English aquaculture is reassessed in line with the aspirations set out in this Strategy. This could be developed into a post-EU-Exit, MANP style programme. Based on this, a suitable funding sub-strategy is developed. This needs to be stakeholder-focused but carefully designed to maximise both short-term outcomes as well as long-term impacts and aligned with both stakeholder aspirations and policy development. It should consider a mixture of affordable loans, tax breaks and where appropriate, grants.	The SF2040 programme Defra	By 2025
FS 2: Based on the recommendations in FS 1, the replacement for the European Fisheries and Maritime Fund and its successor public funding programmes should align with this funding sub-strategy. The Strategy and the resulting funding programme should be subject to periodic evaluation and revision (see FS 3).	Defra SF2040	By 2025
HC 1: Building on the SF2040, Seafish & Pye-Tait (2020) report, develop a training needs analysis for human capacity development for English aquaculture up to 2040. This should identify (i) the main skills required by the different regions, sub-sectors & supply chain elements, (ii) how they should be delivered e.g. formal education, short-courses, on-line courses, in-house training or apprenticeships and (iii) address any skill type / geographical gaps through existing institutions where possible and investigate the need for new approaches where necessary.	Seafish SF2040 SILG SF2040 ALG POs	By 2025

Table 5: High Priority Actions

Action	Potential participants	By when
GR 4: To support both the revised aquaculture regulatory framework and to assist implement this Strategy, seek capacity-building within the statutory agencies responsible for aquaculture permitting, regulation and management. This should include structural reforms to develop a cadre of experienced, informed personnel working within single, cohesive units e.g. in Defra's policy development and MMO's marine planning and permitting roles.	MMO Defra SF2040 ALG SF2040 SILG	By 2030
GR 5: Review and develop the planning and permitting regulatory regime for land-based aquaculture e.g. RAS systems e.g. in terms of using industrial and agricultural land, waste treatment and disposal, welfare, planning and environmental issues.	Producers Ministry of Housing, Communities and Local Government (MHCLG)	By 2030
GR 6: Establish and promote the direct benefits of aquaculture (feed and seafood production) and its economic value as well as those indirect ecosystem services that can be provided such as carbon capture, coastal protection, biodiversity enhancement and their monetary value for comparison with other MEAs and marine space uses.	The SF2040 programme Cefas Others	By 2025
GR 7: Report, compile and analyse English aquaculture production, economic performance and supply chain activity at a suitable level of granularity (e.g. species, production system, scale, location, employment, etc.) to allow analysis and evaluation on a recurrent basis. This should be included in a database and made available to stakeholders via an online portal.	Defra Cefas Producers	By 2025
GR 8: Formation of an English Aquaculture Producer Organisation to represent all production and supply chain sub-sectors.	SF2040 ALG Producers Industry	By 2025
KI 4: Based on the research sub-strategy in KI 1, develop a time-bound short, medium and long-term research programme for English aquaculture that addresses the differing needs identified in the sub-strategy.	Cefas Others Academia SF2040 ALG	By 2025
KI 5: Establish an English aquaculture research & innovation group to manage the research programme, including on-going needs analysis, formulation of common research topics, organising call for proposals from suitable research providers, monitoring on-going research provision and conducting periodic research impact analyses to feed back to Strategy review and revision.	SF2040 ALG Seafish	By 2025

Action	Potential participants	By when
KI 6: Government to work with industry, academia and research organisations to determine the long-term, centrally-funded research needs that will address enduring regulatory barriers, identify and develop 'horizon-scanning' opportunities for English aquaculture, progress the path to carbon neutrality and to mitigate the impacts of climate change.	MMO Defra Academia Cefas Others SF2040 ALG	By 2030
KI 7: Identify synergies with other MEAs and develop research and innovation linkages to (i) facilitate co-existence and (ii) build on any opportunities in joint research (e.g. with offshore engineering, renewable energy development, marine biotechnology, stock & environmental monitoring, automated husbandry systems, animal nutrition and food product development).	Seafish Cefas Others	By 2025
FF 1: Develop commercial marine finfish hatchery capacity and capabilities, especially for proven species such as sea bass, sole and 'cleaner fish' species (wrasse, lumpfish).	Producers Industry Cefas Academia	By 2030
FF 2: Prepare models for more efficient (in terms of growth and water use), less polluting and cost-efficient finfish farming in marine and freshwater. This may include, but not be limited to, closed containment systems in sea water, and partial recirculation in freshwater (e.g. via IPRS). Models may be developed at different production scales and include options for integration with other forms of aquaculture (i.e. Integrated Multi-Trophic Aquaculture IMTA), agriculture and aquaponics, as well as alternative energy generating technologies such as wind and solar).	The SF2040 programme SF2040 ALG Producers Cefas Others	By 2025
FF 3: Develop mooring, power supply, feeding, stock monitoring and other support systems for use in exposed and offshore sites in English waters.	Producers Cefas / Others Academia	By 2025
FF 4: Establish assessment protocols to examine the environmental benefits of, and services provided by, developing extensive terrestrial aquaculture in different water bodies / wetland habitats, both independently and in combination with other agricultural uses in order to optimise the sustainable use of these areas.	The SF2040 programme Cefas Others	By 2030
MA 2: Prepare models and pilot projects for seaweed farms in English waters. These may vary in scale and purpose e.g. for human or non-human uses and will be used to obtain data on ecological impacts, operation costs, yields. These will be essential for business planning and for regulators to assess the cumulative impact of large-scale seaweed farming as it develops.	The SF2040 programme Producers Academia	By 2025

Action	Potential participants	By when
MA 3: Quantify and model ecosystem service provision by cultured seaweed species e.g. evaluate nutrient uptake to develop commercial and public service opportunities for farm-based bio-remediation initiatives.	SF2040 Cefas Producers	By 2030
MA 4 Investigate and develop seaweed supply chains, product development and market diversification opportunities for both human and non-human uses. In particular, examine possibilities for using algal-based products for aquaculture feeds and nutrient additives.	POs Producers Seafish	By 2030
MA 5: Establishment of a professional trade body to provide a voice for the developing macroalgae farming sub-sector, as well as supporting knowledge-sharing, supply chain and development and coordinated harvesting.	Producers Regional bodies & organisations SF2040 ALG	By 2025
HC 2: Assist in the establishment of an aquaculture apprenticeship scheme accredited by the Institute for Apprenticeships & Technical Education. Will require a 'trailblazer group' to establish occupation profiles, knowledge, skill & behaviour requirements, and an end point assessment plan.	SF2040 ALG Seafish Academia Cefas Others	By 2025
HC 3: Promote aquaculture as a growing sector in the Blue Economy and a progressive career choice. To attract people into aquaculture, the sector and the roles within it must be clearly communicated and reinforced amongst potential recruits, people and organisations that influence career decisions. The profile of the sector must be raised and it should be promoted as fast growing and technology driven.	SF2040 ALG Seafish Regional bodies & organisations	By 2025
BE 1: Develop local alliances and partnerships for co-location of aquaculture, MPAs and fishing areas (e.g. static gear). Will initially require awareness raising and confidence-building activities to align interests and to discuss and agree conflicts and their mitigation approaches. Mainly conducted at IFCA level. Could include the development of a Code of Practise for co-existence between aquaculture and wild fisheries, as well as local management strategies for particular sea areas to maximise sustainable seafood production.	Regional bodies & organisations (e.g. IFCAs) SF2040 SILG SF2040 ALG Industry	By 2025
BE 2: Conduct an independent national 'Strategic Environmental Assessment' (SEA) of English aquaculture and its likely development pathways and develop the evidence base to (i) identify and put in place mitigation approaches where necessary and (ii) develop a public engagement and awareness campaign that demonstrates how responsible and well planned aquaculture can have major societal benefits and manage its impact within acceptable limits.	The SF2040 programme Academia Cefas Others	By 2025

Action	Potential participants	By when
BE 3: Develop partnerships at local level in priority aquaculture areas. Work to develop 'Aquaculture parks' at a local level, identifying possible partnerships / IMTA opportunities between different production operations and how common needs (e.g. slip ways / landing facilities / security, etc) could be jointly addressed. Partnerships could be formalised to engage in joint marine licensing, EIAs and other regulatory / planning needs.	Regional bodies & organisations Producers Industry SF2040 ALG	By 2030
BE 4: Assess ways of including aquaculture and its supply chain components in the blue economy e.g. through the development of land-side 'blue growth' clusters, including R&D service providers, manufacturers (work boats, mooring and longline systems, remote telemetry, power & communications, etc) and other service providers (e.g. genetic services, certification, insurance, veterinary).	Regional bodies & organisations Academia SF2040 SILG SF2040 ALG	By 2030
SH 3: Improve industry dialogue and partnership with the EA, Defra and other agencies, as well as local government bodies and the water companies to make the case for and encourage further investment into improving coastal water quality, especially through the prevention of spikes in faecal contamination following intermittent sewage overflows as well as reduced agriculture waste entering England's waters. This dialogue should be extended to other MEAs with a common interest in better water quality e.g. tourism	POs MMO Defra EA FSA Regional bodies & organisations (e.g. Local Authorities)	By 2030
SH 4: Review and revision of seabed lease and Several Order mechanisms to provide long-term security and promote investment in shellfish growing areas, both inshore and offshore.	Defra The Crown Estate Producers	By 2025
IN 1: Harbour authorities are encouraged and supported to provide commercial operations with favourable rates for berthing and the use of other facilities. Where justified, e.g. on economic, socio-economic or cultural grounds, this might be subsidised through public funding.	Regional bodies & organisations SF2040 SILG	By 2025
IN 2: Establish partnerships between aquaculture business and other MEAs where there are synergistic advantages. Regional maritime development organisations such as organisations such as the South West Aquaculture Network (SWAN) and SWEEP in SW England and Marine South East in SE England may be able to assist in identifying and facilitating these partnerships.	Regional bodies & organisations SF2040 ALG The SF2040 programme	By 2030

Table 6: Medium Priority Actions

Action	Potential participants	By when
BE 5: Collaborate with both offshore energy companies and aquaculture to develop conceptual models for multi-use operational platforms at sea, including design, operation, permitting, environment impact and benefits.	Academia Producers Industry Other MEA interests	By 2030
BE 6: Identify and promote supply chain opportunities for English aquaculture, such as novel feed raw material production, feed manufacturing, equipment recycling and disposal, etc.	Producers Industry Seafish Cefas Others	By 2025
FS 3: Any public sector development funding - whether grants or loans or a mixture of both - needs to be carefully monitored and subjected to periodic evaluation to ensure that it is being well targeted and that it is meeting its designated strategic objectives.	MMO Defra	By 2030
FS 4: Engage with NGOs and existing ethical funding programmes to identify and support aquaculture businesses that can demonstrate environmentally sustainable growth and contribute to supporting ecosystem services. This could be supported by third-party certification of compliance with environmental and social best practises.	The SF2040 programme SF2040 SILG POs	By 2025
FF 5: Expand and enhance current skill and service base in genetics, disease prevention & vaccine development, etc.	Cefas Others Academia	By 2030
FF 6: Investment into novel, IT connected stock and environmental monitoring systems for application in English and other aquaculture systems, focusing on improving growth and food conversion, detecting risk issues such as deteriorating water quality, disease and predation.	Producers Academia Cefas	By 2025
FF 7: Draft a policy and guidance for land-based RAS, inc. use of industrial and agricultural land, abstraction and discharge of water, and use and discharge of sea water in terrestrial environments.	Defra EA Producers Cefas	By 2030

Action	Potential participants	By when
MA 6: Develop models for integrating seaweed farming into IMTA (and related co-location systems) with shellfish and finfish and establish pilot systems to prove the concept through developing technology, logistics, economics, site establishment and social acceptance.	Cefas Others Producers Industry Academia	By 2030
SH 5: Develop a certified hatchery network for different shellfish species with increased public support to develop, test and demonstrate new technologies in polyploidy, live feed and larval rearing systems.	Producers Cefas MMO Defra	By 2025
SH 6: Explore opportunities for hi-value invertebrate aquaculture e.g. sea cucumber, sea urchins, abalone etc. in both open water and closed systems, including IMTA and RAS.	Producers Cefas Academia	By 2030
SH 7: Create product value-addition, market and branding opportunities for English shellfish products at regional, national and international levels	POs	By 2030
IN 3: Feasibility study to identify the potential for a strategic network of seafood clusters, servicing both aquaculture and capture fisheries interests. Primarily, but not necessarily, coastal-based, these would be focused on improving seafood production and value-addition, as well as improving economies of scale.	Seafish	By 2025
HC 4: Identify cross-sectoral learning opportunities e.g. with sectors such as oil and gas in relation to technology and offshore operations. The oil and gas sector has a large number of staff in transition including Health and Safety and engineers who could bring knowledge and transferrable skills to aquaculture. Other areas include marine biotechnology and offshore renewable engineering.	Seafish Regional bodies & organisations SF2040 SILG Industry	By 2025
HC 5: Provide support for general management, leadership and business skills. This is likely through ensuring that both formal training (e.g. degree level courses) and on-the job training includes the development of these skills in addition to more technical skills development requirements.	Seafish Academia SF2040 SILG	By 2025

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