

Supporting the sustainable expansion of aquaculture in the South West

By directly addressing a range of critical issues constraining the development of the marine aquaculture (seaweed and shellfish mariculture) sector in SW England, this SWEEP project has contributed to its advancement in the following ways:

1. Implementing a source-to-sea modelling application of a wholescape approach in the Exe estuary catchment demonstrating that modest long-term changes in catchment land use (e.g. strategic tree planting +0.5% land cover) can improve water quality and shellfish production in the Exe Estuary. However, reductions in Combined Sewer Overflow (CSO) spills in closer proximity to estuarine and coastal shellfish beds would likely have even greater benefits.
2. Policy and evidence contributions towards meeting the ambitions of Seafood2040 and the English Aquaculture Strategy (relating to marine spatial planning and Marine Protected Areas), Exe Estuary Catchment Management Plan and Natural England seaweed culture sector review.



SWEEP Impact Summary

3. Raising the profile of critical 'constraining' issues through extensive stakeholder engagement, development of the 'One Health' concept to sustainable food systems, application of the 'Positive Tipping Points' framework, assessment and mitigation of Harmful Algal Blooms and contribution to the Exe Catchment Investigation Programme.
4. Developing evidence to support Food Standards Agency consideration of adopting a more flexible, risk-based approach to shellfish food safety assessment and testing.

1st application of wholescape land use and water quality modelling approach to the River Exe Estuary Catchment



21 publications, reports, policy statements and briefing notes



14 models, tools, and resources developed



Ways of Working



Why it mattered?

Sustainable growth in marine aquaculture (mariculture), involving the farming of seaweeds, shellfish and finfish, will be essential in helping to provide global food security for the ever-expanding human population. Shellfish and seaweed mariculture are highly sustainable; they use natural sunlight, available nutrients and/or marine planktonic microalgae to grow.

Seaweeds remove nutrients, shellfish help curb eutrophication¹ and seaweed and shellfish mariculture can also contribute to climate change mitigation, through carbon sequestration and net zero carbon emissions respectively, and to habitat enhancement for biodiversity.

Shellfish mariculture production in the South West (SW) is currently estimated at 7,300 tonnes per year (£8m; 2022) from across 35 registered production sites, with around 53 individual beds (Figure 1).

The predominant species produced by value is blue mussel, followed by Pacific oyster and clams. Production methods include rope, net/cage, trestle and bed culture (Figure 2). Seaweed mariculture is in early stages of development, with production levels currently limited to <100 tonnes (wet weight) per year.

Poor water quality is the main environmental constraint to bivalve shellfish production and results from microbial contamination originating from Combined Sewer Overflows (CSOs), extensive grazing of livestock on grassland, indoor livestock

rearing and poor slurry management. Production sites compete for space with capture fisheries and Marine Protected Areas (MPAs). The sector is also at risk from Harmful Algal Blooms (HABs). A rigid testing regime and highly precautionary approach to interpreting results (including outliers) for authorisations also inhibits growth².

There is potential to grow the mariculture sector around the SW coastline in coastal and estuarine areas, as well as less congested offshore areas. However, this would require a holistic catchment-wide approach to water quality management and an integrated approach to marine spatial planning.

¹ Eutrophication is an overabundance of nutrients in water, which can induce Harmful Algal Blooms (HABs). HABs (or excessive algae growth) are algal blooms that causes negative impacts to other organisms by production of algal toxins, mechanical damage to other organisms, or by other means. HABs can occur naturally or appear as a result of human activity.
² Seafood 2040. English Aquaculture Strategy.

The 2020 English Aquaculture Strategy (EAS), to which this project contributed evidence, recognises the sector's potential in its central vision:



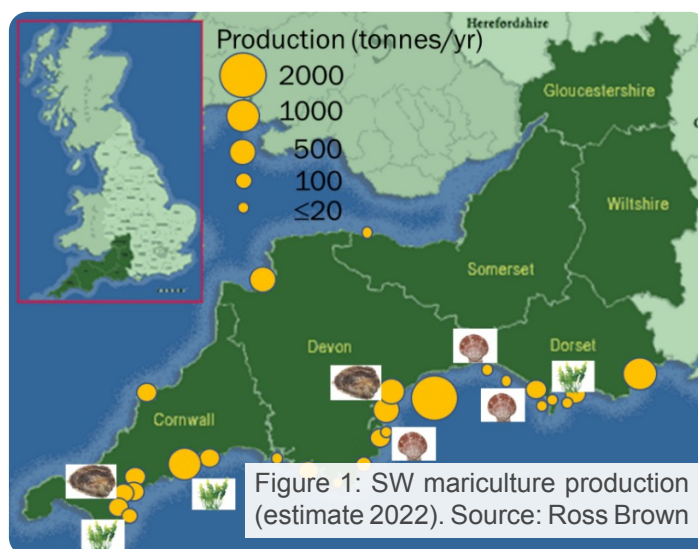
By 2040 English aquaculture is a significant contributor to seafood consumption and the Blue Economy, providing sustainable, healthy food and rewarding employment opportunities."

English Aquaculture Strategy. Seafood 2040



The neglect of water quality over the past 30 years has severely damaged the shellfish industry inshore and now threatens the survival of developments offshore."

John Holmyard, Offshore Shellfish Ltd



	rope	net/cage	trestle	bed
	✓			✓
		✓	✓	✓
				✓
				✓
				✓
		✓		✓
	✓			

Figure 2: Mariculture methods by species

Species shown (in order down the table) are blue mussel, Pacific oyster, clam, cockle, native oyster, scallop, seaweed. Source: Ross Brown

What we did

During 2019-2022, the SWEEP team worked flexibly on issues relating to the SW mariculture sector development according to their specialisms, and was comprised of:

- University of Exeter – Prof Charles Tyler (Principal Investigator), Dr Ross Brown (Technical Lead), Dr Donna Carless, Dr Ben Jackson, Dr James Webber, Dr Sara Zonneveld, Dr Carly Daniels, Dr Amy Binner, Prof Richard Brazier, Dr Diana Tingley.
- Plymouth Marine Laboratory – Dr Riccardo Torres, Dr Yuri Artioli, Dr Giovanni Galli, Dr Peter Land, Dr Peter Miller.
- University of Plymouth – Prof Mel Austen.
- QUEx Institute of Global Sustainability and Wellbeing - Dr Phoebe Stewart-Sinclair.
- UoE SWEEP-affiliated PhD student – Sophie Corrigan.

Activities included:

1. Development of a unique wholescape modelling application - to examine the effects of potential future land use changes on water quality in the Exe Estuary catchment, and associated impacts on shellfish farmed in the Estuary and adjoining coastal waters. Summary modelling results are available [here](#). Detailed results will be published in 2023.

This **keystone project activity** was strengthened by a range of supporting work packages including development of:

- Series of integrated catchment models** – for predicting nitrogen, faecal pathogen indicator (*E. coli*) and copper inputs from agricultural and urban land use and riverine concentrations and loads throughout the Exe Estuary catchment
- Estuary and shellfish production (growth) models** - to assess the impact of riverine loads on the estuary water quality of and to predict mussel growth in response to nitrogen and copper exposures in the Exe Estuary and the accumulation of *E. coli*
- Future land use scenarios to 2050** affecting water quality and under climate change – co-created with stakeholders, these scenarios and related resources are available [here](#).
- Farmscoper models** - linking land use change and water quality in the Exe catchment
- Acid herbicide wash-off exploration tool** - exploring the potential impacts of acid herbicide wash-off (i.e., agricultural run-off from grassland) during periods of intense rainfall, on phytoplankton in South West's estuaries. The tool, guidance document and report are available [here](#).
- Natural Environment Valuation (NEV) model extension work**: (1) for Exe Catchment linked to Future Land Use Scenarios, and (2) Clyst Catchment linked to Future Land Use Scenarios for NEIRF-funded Clyst Bond Canopy Project. Details of the NEV models are available [here](#).



2. Extensive programme of stakeholder engagement - over 34 events were attended or organised in the SW to promote SWEEP work, develop networks for information sharing and provide strategic input. Engagement occurred with a wide range of stakeholders from industry, with interests in mariculture, water quality, regulation, farming and land use.

Partner organisations actively engaged with and supported by SWEEP include:

- Dorset Marine Aquaculture Strategy
- One Health Dorset Local Enterprise Partnership
- Connecting the Culm
- Exe Estuary Management Partnership
- East Devon Catchment Partnership
- East Devon District Council's Clyst Canopy Project
- Aquaculture Research Collaborative Hub-UK
- South West Aquaculture Network
- Wholescape Approach to Marine Management.

A Water Quality and Aquaculture resource Hub was set up to share SWEEP information and resources.

A workshop attended by >100 participants at the SWEEP 2020 Expo developed Stakeholder perspectives on the importance of water quality and other constraints for sustainable mariculture to inform modelling work. Paper available [here](#).

3. Baseline review of SW mariculture sector – presented at the Aquaculture Research Hub ARCH-UK meeting (21 April 2021).

4. Policy briefs developed for links between mariculture and Marine Protected Areas (MPAs):

- [Report](#) 'Developing general rules to facilitate evidence-based policy for mariculture development in and around Marine Protected Areas (MPAs) in England'
- [Policy Brief](#) 'Potential for Marine Aquaculture Development in and around Marine Protected Areas (MPAs) in England'
- [Policy Statement](#) and [Policy Brief](#) 'Supporting Mariculture Development: Evidence for Informed Regulation'

5. Sustainable aquaculture through the One Health Lens - led by the Centre for Sustainable Aquaculture Futures (a joint initiative between Cefas and the UoE),

Sustainable aquaculture through the One Health Lens applies a 'One Health' approach to the Aquaculture industry which recognises that societal buy-in, equity of access to the food produced, and environmental protection must be adequately addressed as the industry expands over the coming decades. Paper available [here](#). Further paper 'A seafood risk tool for assessing and mitigating chemical and pathogen hazards in the aquaculture supply chain', available [here](#).

6. Positive Tipping Points workshop for mariculture in SW – workshop held 'Applying a positive tipping points framework for the sustainable development of the mariculture sector in the SW England' (15 Sep 2022) linked to UoE meeting '[Tipping Points - from climate crisis to positive transformation](#)' (12-14 Sep 2022).

7. Investigation work around incidences of offshore faecal pollution – paper 'Identifying possible sources of faecal pollution in coastal shellfish waters using particle back trajectory modelling' submitted to the journal 'Environmental Monitoring and Assessment'. Report with Food Standards Agency.

8. Exe Estuary Catchment investigation - Wholescape Assessment of Water Quality status, drivers and impacts in the Exe Estuary Catchment and implications. Report produced with West Country Rivers Trust. Available [here](#).

9. Harmful Algal Blooms monitoring and modelling – 'Assessing risks and mitigating impacts of harmful algal blooms on mariculture and marine fisheries' - critical review and analysis of HAB impacts on mariculture (and wild capture fisheries) and recommend research to identify ways to minimise their impacts on the industry. Available [here](#).

Papers on 'HAB monitoring and modelling' available [here](#), [here](#), and [here](#).

10. SWEEP-affiliated PhD studentship – Maximising the environmental benefits of SW seaweed farming potential - work focused on how commercial seaweed farms influence local biodiversity, physical conditions and dissolved nutrient chemistry in the South West. Sophie Corrigan carried out field work at a Cornish Seaweed Company's farm working alongside the company to maximise benefits for both their harvest and the local environment. Details are available [here](#) including paper on Quantifying habitat provisioning at macroalgal cultivation sites, available [here](#).



Impacts & benefits delivered



Knowledge/Capacity

Development of a unique wholescape modelling application:

the modelling work provided a 'proof of principle' exposition of a complex, whole-system modelling approach developed for the Exe Catchment, connecting future predicted land-use scenarios to freshwater catchment water quality, to estuarine and coastal water quality and effects on shellfish growth and quality (mussels).

Summary findings from this work are:

- By linking a number of modelling approaches, this 'whole catchment' approach provides the first highly-integrated method for comprehensively evaluating the effects of potential future land use changes on water quality, and their associated impacts on shellfish farming in estuarine and adjoining coastal waters. Innovations notably include modelling the shellfish uptake of the faecal pathogen indicator *E. coli* (via ShellSIM) and the valuation of costs and benefits throughout the aquatic system (via the NEV models).
- The application of this approach to water quality in the Exe Estuary catchment and shellfish farming in the Exe Estuary, brings to life the UK's National Ecosystem Assessment scenarios in the South West for the first time.
- Adopting more sustainable land-use approaches, than currently in operation, will have broadly similar, positive effects on water quality and shellfish production, due to reductions in *E. coli* and nitrogen inputs. Scenarios: 2) Extensive regenerative agriculture; 4) Increased renewable energy and 5) Strategic tree planting - have similar positive effects on water quality.
- Strategic tree planting is arguably the most straightforward to implement. Extensive regenerative agriculture requires a broad cultural change. The Increased renewable energy scenario is based on positive assumptions about ability to maintain land use for grazing on solar and wind farms and to limit impacts on soil erosion from biofuel cropping, including short coppice rotation.
- A warmer and wetter climate will likely result in increasing waterborne concentrations of nitrogen and copper, due to increasing land runoff, but is likely reduce faecal pollution (*E. coli*) overall, due to reducing bacterial survival with increasing temperature.
- Whilst agricultural sources of faecal pathogens may be equally as important as those from urban and municipal discharges (Brown et al, 2022), the biggest single risk to shellfish production comes from the proximity of mariculture sites to these inputs.



The SWEEP modelling process and approach is innovative. The South West appears to be leading the way in developing a holistic approach to predicting future water quality, especially when also taking into account, for example, the work of the North Devon Biosphere Reserve testing real-time monitoring of environmental and water quality parameters to predict water quality lower down in the catchment. These advances will potentially lead to the development of a more risk-based approach to managing shellfisheries in the South West, which would deliver significant benefits for both shellfish producers and consumers."

Martin Syvret, Aquafish Solutions Ltd



It's good that this work shows this is not just a livestock issue, which is often seen as the key problem, but also one of municipal effluent discharges and Combined Sewage Overflows."

Hattie Severinsen, Environment and Land Use Adviser, National Farmers Union South West



Valuing wider ecosystem services across the Exe catchment provides more evidence to support growth of the bivalve shellfish sector."

Keith Jeffery, Principal Aquaculture Scientist, Cefas



These insights can be used by SWW to guide and support future investment strategies and planning and will translate out as learning that can be applied to other large catchments in the SW."

David Smith, Natural Resources Team Manager



Westcountry Mussels of Fowey



Knowledge/Capacity

Novel application of positive tipping points framework to SW mariculture sector:

this workshop helped to reframe issues constraining development of the SW shellfish mariculture sector as a series of critical interventions required to address the constraints.



Policy & Legislation

Policy briefs developed for links between mariculture and MPAs:

This work informed policy recommendations within Seafish's 'English Aquaculture Strategy', setting out vision and plan for ten-fold increase in food production from sector 2020-2040.



Policy & Legislation

Shaped Exe Estuary Management Partnership strategy:

Dr Ross Brown was invited to Chair the water quality breakout group, which shaped partner priorities in the Exe Estuary Management Plan 2022 – 2027.

An article on the SWEEP Wholescapes Exe Estuary Catchment Investigation was published in Newsletter of the Exe Estuary (Management) Partnership. Exe Press Issue 60, Autumn/Winter 2021, (8th Nov 2021), page 7.



Policy & Legislation

Informing Natural England's evidence review:

Drawing on her PhD literature review (Maximising the environmental benefits of SW seaweed farming potential), Sophie Corrigan contributed to the recently published Natural England Report, Seaweed aquaculture and mechanical harvesting: an evidence review to support sustainable management (NECR378); leading on section 3.6 Artificial Habitat Creation. This document will be used to inform best practice.



Attitudinal/Capacity

Strengthening collaboration and knowledge:

Collaborative development of 'Future land-use scenarios 2050 affecting water quality in South West' developed connections and common understandings around water quality issues between West Country Rivers Trust, South West Water, National Farmers Union, Food, Farming & Countryside Commission, Natural England Catchment Sensitive Farming, Cefas and Sustainable Aquaculture Futures.



Organisational Function

Business support: Support was given to Offshore Shellfisheries Ltd through the back-trajectory particle modelling to identify (possibly anomalous) FSA test results indicting that sources of faecal pollution were found to be present in waters at their offshore mussel rope cultivation sites in Lyme Bay.



This SWEEP workshop gave stakeholders an opportunity to apply the new Positive Tipping Points framework to long-recognised issues faced by the South West's aquaculture sector. This novel process identified critical interventions (e.g. regulatory, technical and market-related) which, if addressed, could help to realise growth targets for the shellfish industry, as set out in the English Aquaculture Strategy (2020). Bringing new insights and perspectives to old problems, this novel approach is helping to build the momentum needed to deliver positive change - both in the short and longer-term, and in the South West and potentially further afield too."

Tim Huntington, Director, Poseidon Aquatic Resource Management. Co-author of English Aquaculture Strategy, Seafood 2040

Leveraged and Affiliated funding

Leveraged funding:

- £54k for Artificial Intelligence for predicting Harmful Algal Blooms (HABs) funded by Regulators Pioneer Fund (total project funding £200k)
- £70k for 'Sustainable Future Global Aquaculture – Water Resources, Pollution and Biodiversity Protection'
- £30k for workshop 'Applying a positive tipping points framework for the sustainable development of the mariculture sector in the SW England'
- £48k 'Transitioning towards more sustainable food systems through the application of a positive tipping points framework'
- £2.5k for MSc Data Science solutions (2021) for sustainable aquaculture (seaweed element) funded by 5G Rural Dorset (total project funding £4.6m). Two further MSc projects in Data Science & Global Sustainability Solutions linked to modelling work
- £3k for 'Extractive Aquaculture in the UK and its Human and Environmental Health Benefits'.



Exmouth Mussels

Affiliated funding:

- £250k European Maritime and Fisheries Fund - Development of seaweed cultivation
- £100k European Maritime and Fisheries Fund - Assessing risk of harmful algal blooms to marine fisheries and aquaculture
- £10k Research England – Strategic Priorities Fund - Developing a policy brief on the compatibility of aquaculture and MPAs
- £15k HEFCE Fund - Data Science tools statistical models for predicting HABs
- £1.7m for affiliated BBSRC funding into co-location of UK king shrimp production on terrestrial farming sites.

Looking to the future

- A major research proposal is being developed with SWW, for potential funding under the UoE's Centre for Resilience in Environment, Water and Waste (CREWW; jointly funded by SWW and Research England), to investigate the nature and impact of CSO spills and to develop a risk assessment approach that could be applied more widely across the SWW network and used to inform policy and CSO regulation guidance.
- When published (anticipated in 2023), the investigation 'Identifying possible sources of faecal pollution in coastal shellfish waters using particle back trajectory modelling', will be considered by the Food Standards Agency as evidence to support a more flexible approach to shellfish hygiene testing in the face of potentially anomalous results.
- A £50k research proposal to extend the application of the Positive Tipping Point Approach to sustainable international development of seaweed, crustacean shellfish and finfish aquaculture is being developed between UoE and Cefas as part of the collaborative centre for Sustainable Aquaculture Futures.
- A series of journal publications are planned as outputs from the modelling work:
 1. Integrating land use and climate change in future predictions of water quality throughout the Exe Estuary catchment
 2. Understanding the consequences of future land use and climate driven changes in water quality for shellfish aquaculture in the Exe Estuary
 3. Valuing terrestrial and aquatic ecosystem services under future land-use and climate change scenarios in the Exe Estuary catchment

For more information contact sweep@exeter.ac.uk

Organisations we've worked with

- West Country Rivers Trust
- South West Water
- Natural England
- Catchment Sensitive Farming
- Food, Farming & Countryside Commission
- Cefas
- Sustainable Aquaculture Futures
- Offshore Shellfisheries Ltd
- Exmouth Mussels
- Aquafish Solutions
- Dorset Marine Aquaculture Strategy
- One Health Dorset Local Enterprise Partnership
- Connecting the Culm
- Exe Estuary Management Partnership
- East Devon Catchment Partnership
- East Devon DC's Clyst Canopy Project
- Aquaculture Research Collaborative Hub-UK
- South West Aquaculture Network
- Wholescape Approach to Marine Management

Underpinning NERC Science

- NE/P011004/1 - ShellEye
- BBSRC/NERC (BB/M026221/1) Risks and Opportunities for Sustainable Aquaculture
- NE/P016944/1 - Web-based tools for natural capital management and investment
- NE/R015953/1 - Climate Linked Atlantic Sector Science
- NERC/TSB KTP Understanding the impact of moorland restoration on water quality
- NE/K00722X/1 - Developing a biomonitoring tool to identify and quantify the impacts of particulate matter in freshwater ecosystems
- EU (H2020- SFS-11b-2015 – contract 678396) Tools for Assessment and Planning of Aquaculture Sustainability (TAPAS)
- BBSRC/NERC (BB/P017215/1) Aquaculture Initiative network
- NE/R011524/1 - DTP in Freshwater Biosciences and Sustainability
- BBSRC/NERC (BB/S004343/1) - AquaLeap: Innovation in Genetics and Breeding to Advance UK Aquaculture Production
- BBSRC/NERC (BB/S004122/1) - ROBUST-SMOLT Viability of Atlantic salmon from Recirculation Aquaculture Systems

About SWEEP

The South West Partnership for Environmental & Economical Prosperity (SWEEP) is a partnership between the University of Exeter, the University of Plymouth, and Plymouth Marine Laboratory. Funded by the Natural Environment Research Council and stakeholders together to solve key challenges faced by those working with our natural resources. www.sweep.ac.uk



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