Risks and Opportunities for Sustainable Aquaculture

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ROSA Risks and Opportunities for Sustainable Aquaculture

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RATIONALE

There is an urgent requirement for aquaculture model tools that account for increasing temperature, storminess, wind and wave exposure, harmful algal bloom event frequency and indirect impacts from changes in carbon and nutrient cycling. This underpins the sustainable and profitable development of the aquaculture industry following EU and UN guidelines.

This can only be achieved by coupling dynamic physical, ecosystem and aquaculture models capable of downscaling climate and weather driven impacts to local scales.

Our ambition is to realise such a system, initially within the context of UK aquaculture, but eventually worldwide.

SPECIFIC OBJECTIVES

- Establish a state of the art predictive modelling system that resolves appropriate coastal, estuarine and sea loch processes, describing key environmental variables and processes, plus interrelations with shellfish aquaculture.
- Evaluate the sustainable carrying capacity for shellfish aquaculture in different parts of the UK, at scales ranging from local to national, accounting for cultivation practice.
- Make an initial assessment of the potential risks and benefits both of inter-annual variability and climate change on shellfish aquaculture.
- Provide a capability for the modelling of disease and parasite spread.
- Develop a stakeholder friendly GIS decision support tool (and training) with above-stated capabilities, supporting the UK shellfish aquaculture industry.
- Collaboratively agree a roadmap for the further development of decision support tools for sustainable aquaculture in the UK by building a community of marine system modellers, aquaculture scientists and stakeholders.

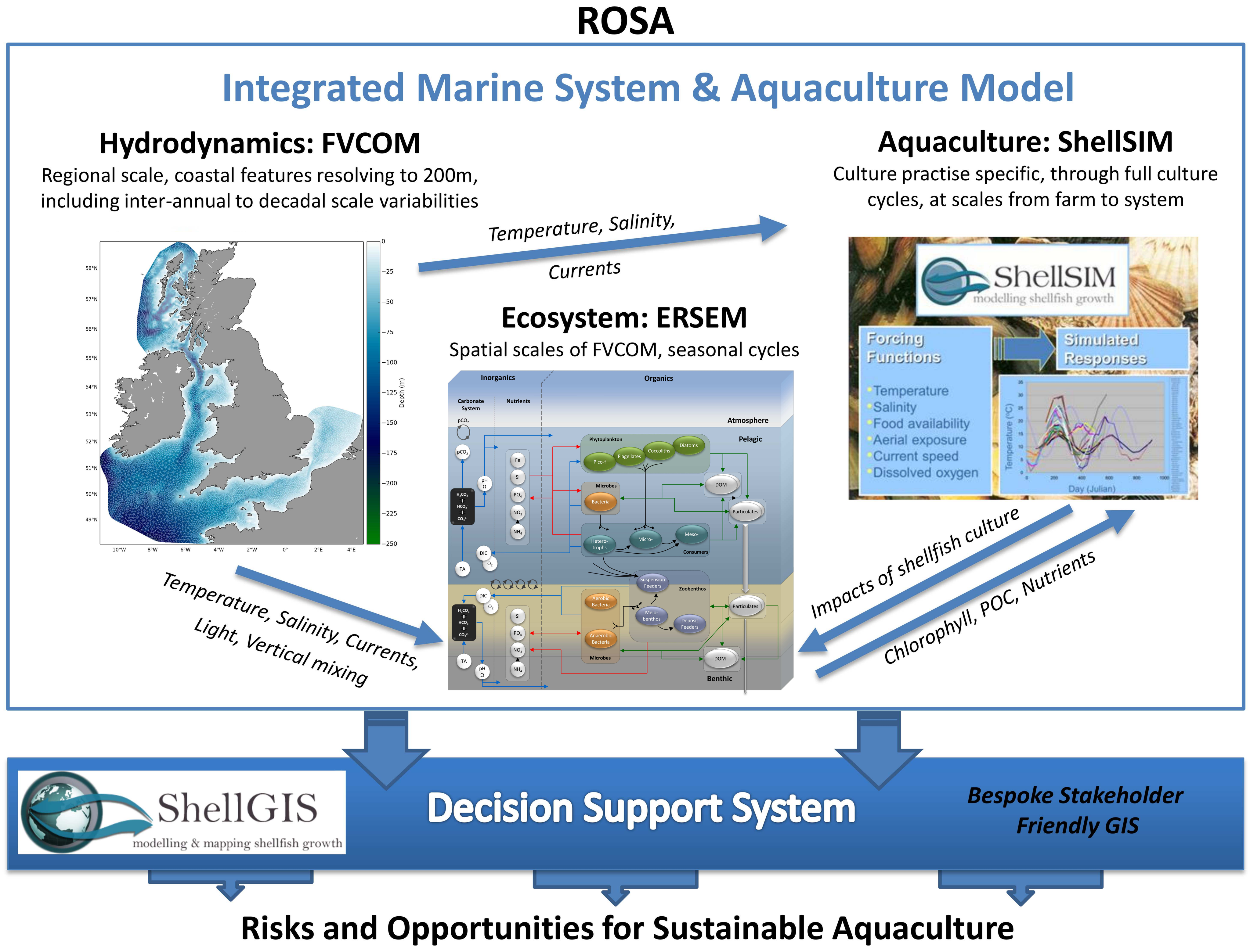
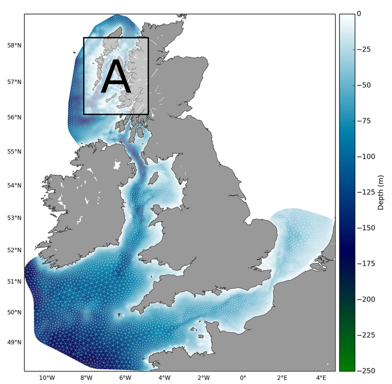


Figure 1 Schematic diagram of the ROSA model system and decision support tools, highlighting the link between the three modelling systems (FVCOM, ERSEM and ShellSIM) and how they are being brought together to form a decision support system which is tailored to the aquaculture industry. This system will enable stakeholders to identify areas in which impacts may be generated and develop aquaculture so as to maximise aquaculture sustainability.

METHODS

Due to the complex morphology and highly dynamic nature of many shellfish aquaculture sites (e.g. estuaries and sea lochs), modelling responses to environmental change frequently requires resolution of environmental conditions at fine spatial and temporal scales. This requirement will be addressed using a complimentary suite of mature and well-tested numerical models: the Finite-Volume Community Ocean Model (FVCOM) (Chen et al., 2003) (figure 2), the European Regional Seas Ecosystem Model (ERSEM) (Butenchön et al., 2015, www.shelfseasmodelling.org) (figure 3), and ShellSIM (Hawkins et al. 2013, www.shellsim.org) (see figure 5), interfaced by ShellGIS (www.shellgis.com) (figure 4).

Currently ShellSIM/ShellGIS is designed to answer questions about optimal siting, optimal densities, likely interannual variation etc. towards maximizing profitability. We will extend its capability to address questions relevant to system managers and regulators (e.g. regional carrying capacity, risks of disease transmission, effects on water quality and HAB likelihood). This can only be achieved by placing ShellSIM/GIS in a coupled climate/weather driven 3D hydrodynamic-ecosystem context, as provided by FVCOM-ERSEM. By using model data we save expense and open the possibility to regional scale and forward looking scenarios.



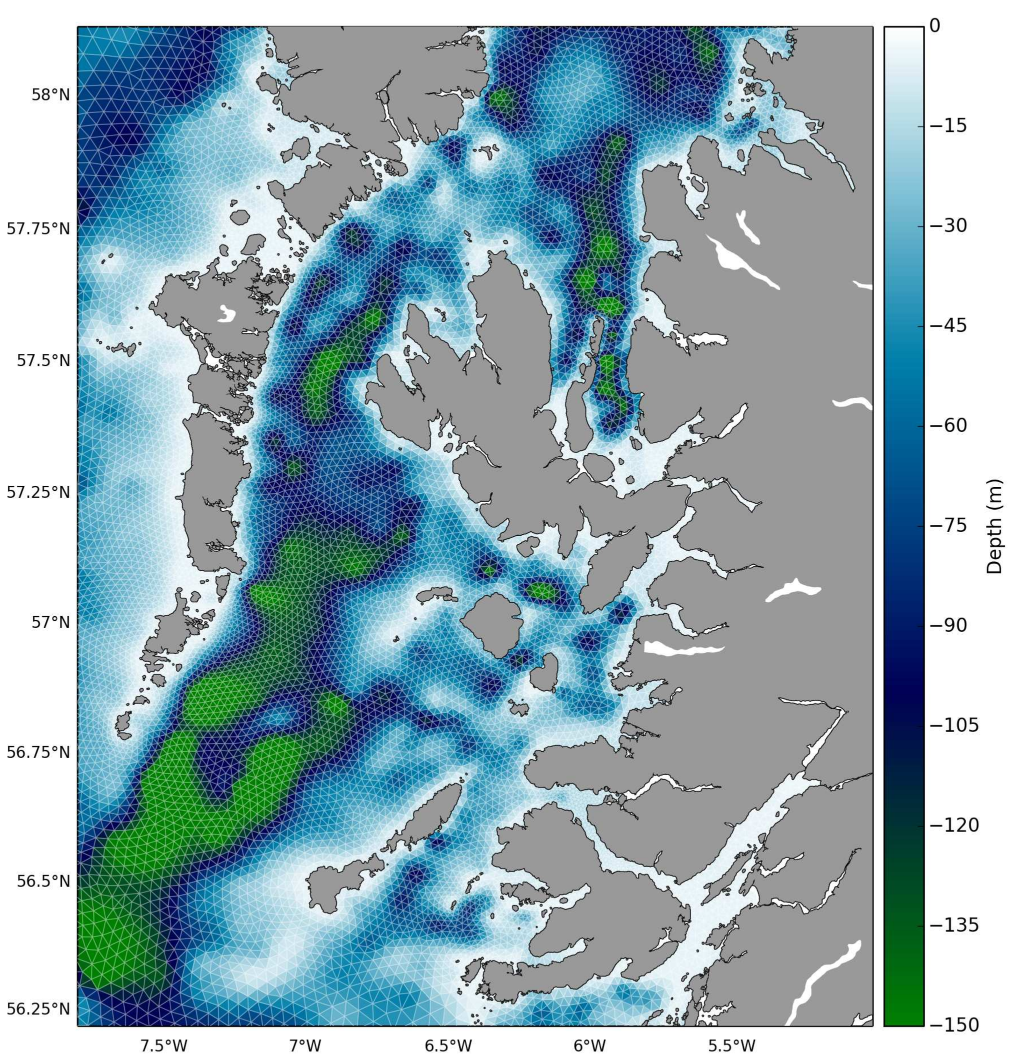


Figure 2 The model domain (top) within which the hydrodynamics are simulated with FVCOM. The horizontal grid elements vary in size and shape over the domain based on the bathymetry, gradient, proximity to the coast and coastline curvature (see right). Grid resolution at the open boundaries is 15km reducing to 200m in the areas of interest. The model is forced with tidal elevation at the boundaries and heating is calculated from the NCEP reanalysis 2 product. The model output from FVCOM is used to drive the ecosystem model (ERSEM) to calculate nutrient cycling and the spatial and temporal evolution of plankton.

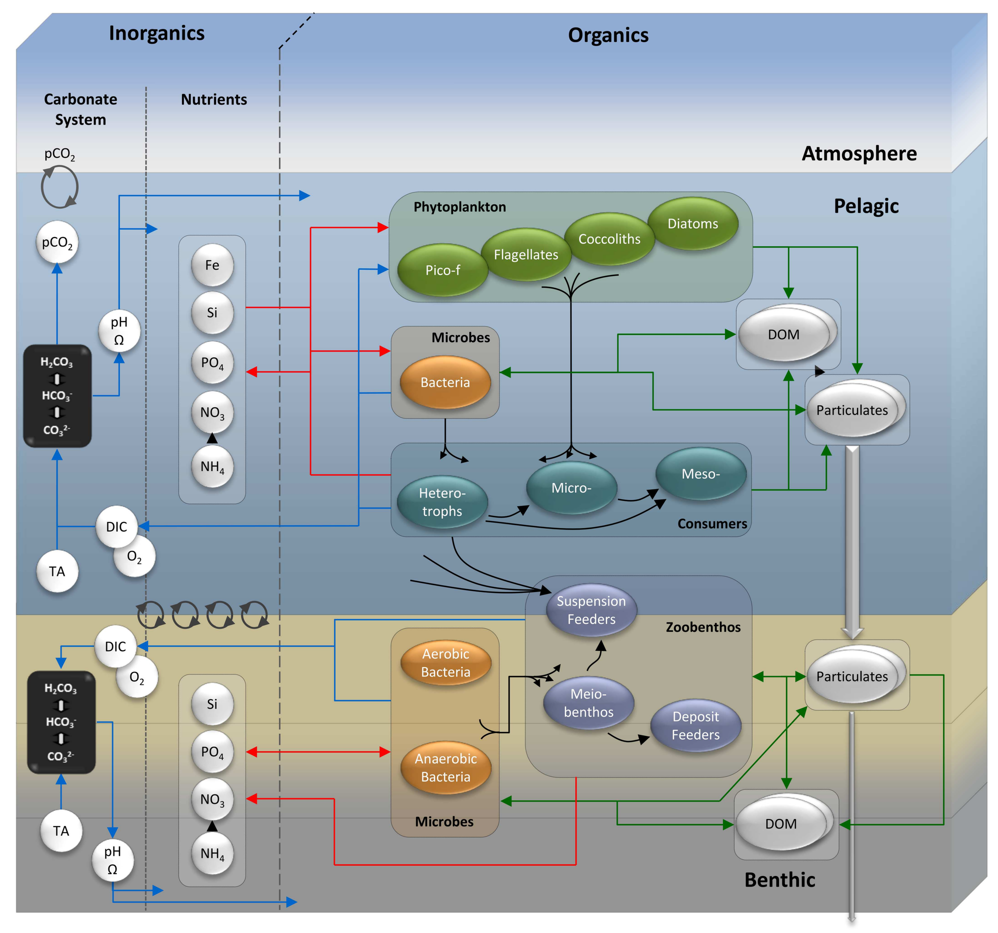


Figure 3 ERSEM is a generic ecosystem model, which, when coupled to a qualitatively correct physical model, is able to simulate the principle dynamics of the marine system from global to coastal shelf seas. Among other outputs, ERSEM simulates chlorophyll a, total particulate organic matter and food quality.

Effects of seeding date on time to market can be further optimized upon comparison through the domain

Time to market simulated as the days taken for *Crassostrea virginica* to grow from 26 to 50 g fresh weigh following seeding at 500 individuals m^{-2} during week 21 for bottom culture in the Damariscotta River, Maine

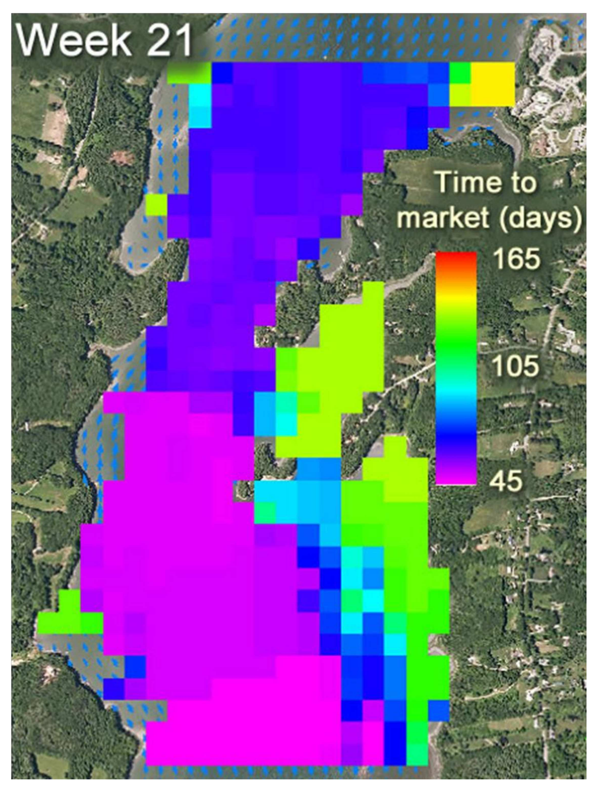


Figure 4 Data delivery will be via the ShellGIS system within which ShellSIM has been embedded. This transferable desktop-based software tool simulates population dynamics and profitability at the farm scale. Bespoke interfaces enable users to choose from options that define spatial distribution (i.e. farm size and location) and farm practice (i.e. from 14 commonly-cultured shellfish species, seeding date and densities, mortality rates, harvesting date and size, suspended or on-bottom culture) to answer from a set of optional questions.

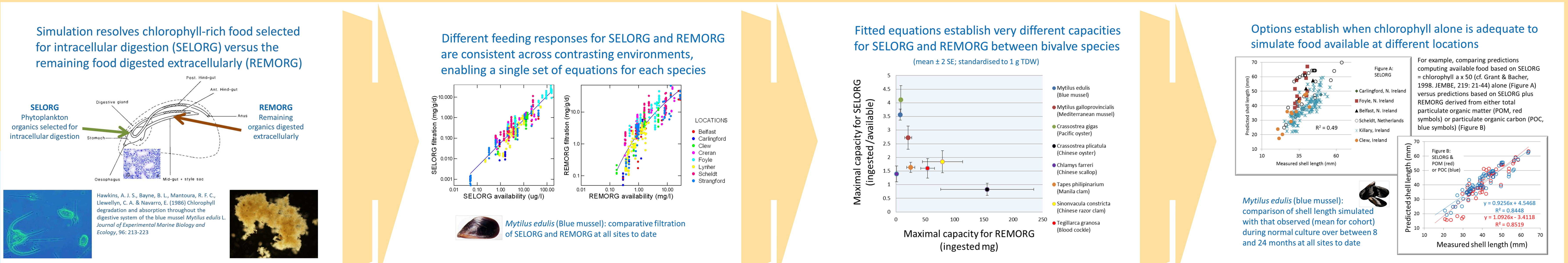


Figure 5 ShellSIM™ is a computer-based tool for bivalve shellfish aquaculture with outputs tailored for integrated applications helping to manage aquaculture, whether in terms of production capacity, internalisation of wastes within multi-trophic systems or effects on wider ecosystem services, each according to the EU Water Framework Directive and FAO guidelines for ecosystem approach. In contrast to previous shellfish models that have only been validated in a single species and in a single or similar environment, ShellSIM predicts time-varying rates of feeding and metabolism as component processes of growth, reproduction,condition and population dynamics, not only in different species, but also across contrasting environments.

CONCLUSIONS AND FUTURE APPROACHES

- This modelling approach to the risks and opportunities for sustainable aquaculture highlights our ability to investigate how changes in the physical environment propagate to ecosystems.
- FVCOM-ERSEM will provide primary production estimates which will improve the estimation of carrying capacity, currently parameterized based on current flow rate. The combined models (FVCOM-ERSEM and ShellSIM/GIS) will be used to evaluate consequences of multiple culture sites for water quality and ecological status at representative scales.
- How the ecosystem responds is critical to our policy making decisions and without sufficient information to back up those decisions, the likelihood of negative impacts on the aquaculture industry increases.

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