DIVERSEAFOOD

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Evaluating the potential of IMTA to build RESILIENCE of aquaculture systems in the UK

Theory and objectives

- Change is integral to aquaculture socio-ecological and economic systems, and its consideration in aquaculture management systems is key to assure resilience.
- Diversifying seafood consumption and production, through sustainable approaches such as Integrated multi-trophic aquaculture (IMTA), could improve resilience of aquaculture systems to changes and derive sustainable benefits.
- We define resilience in aquaculture systems and present a framework to investigate the role of IMTA in increasing systems' resilience.

Defining resilience

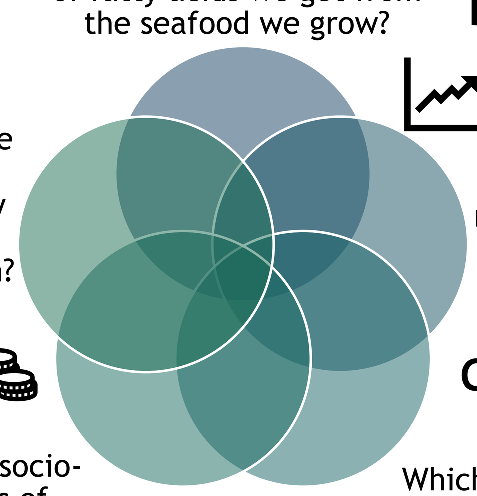
- **Resilience of what?** UK aquaculture, to be able to (i) sustainably and profitably produce diverse and nutrient-rich seafood, (ii) operate under sustainable business models, suitable policy-frameworks and be socially acceptable, (iii) market and increase consumption of a diverse range of healthy and sustainable seafood;
- **Resilience to what?** (i) Environmental stresses (e.g. variability, ecological/biogeochemical/water quality deterioration) and shocks (e.g. HABs, disease outbreaks); (ii) Market, economic and political shocks and stresses (e.g. competition, supply); (iii) Sociocultural and institutional shocks and stressors (e.g. social acceptability of aquaculture sites, regulatory reform, demographic changes);
- **Resilience for whom?** Producers (e.g. profit diversification), supply chain (e.g. increased volumes), retailers (e.g. product range, steady supply), consumers (e.g. facilitated healthier/sustainable consumption), citizens (e.g. higher environmental responsibility); etc.
- **Resilience over what time period?** Long-term, though improvements at some levels (e.g. consumers) can be absorbed quicker.

DIVERSEAFOOD at a glance

Nutrition
Under which conditions can IMTA optimise the amount of fatty acids we get from the seafood we grow?

Policy
How does diverse aquaculture contribute to wider ecosystem services? Which policy interventions can support diversification?

Business innovation
How can seafood companies develop innovative business models that support aquaculture diversification?



Economy
What optimises the socio-economic benefits of sustainably diversifying aquaculture?

Consumer choices
Which factors increase consumer purchase of seafood? What drives acceptance of novel seafood?

Acknowledgments

DIVERSEAFOOD is funded through the Global Food Security's Resilience of the UK Food System Programme with support from BBSRC, ESRC, NERC and Scottish Government.

SOURCES & USEFUL READINGS

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Klinger & Naylor (2012). Searching for Solutions in Aquaculture: Charting a Sustainable Course. Annual Review of Environment and Resources, 37(1), 247-276.

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Development of a bioeconomic model to value ecosystem services in IMTA systems

To develop a bioeconomic model for resilience management of aquaculture systems, the following steps are proposed as a base to operationalize resilience in socio-ecological aquaculture systems, from an interdisciplinary perspective, and understand the role of IMTA in resilience management.

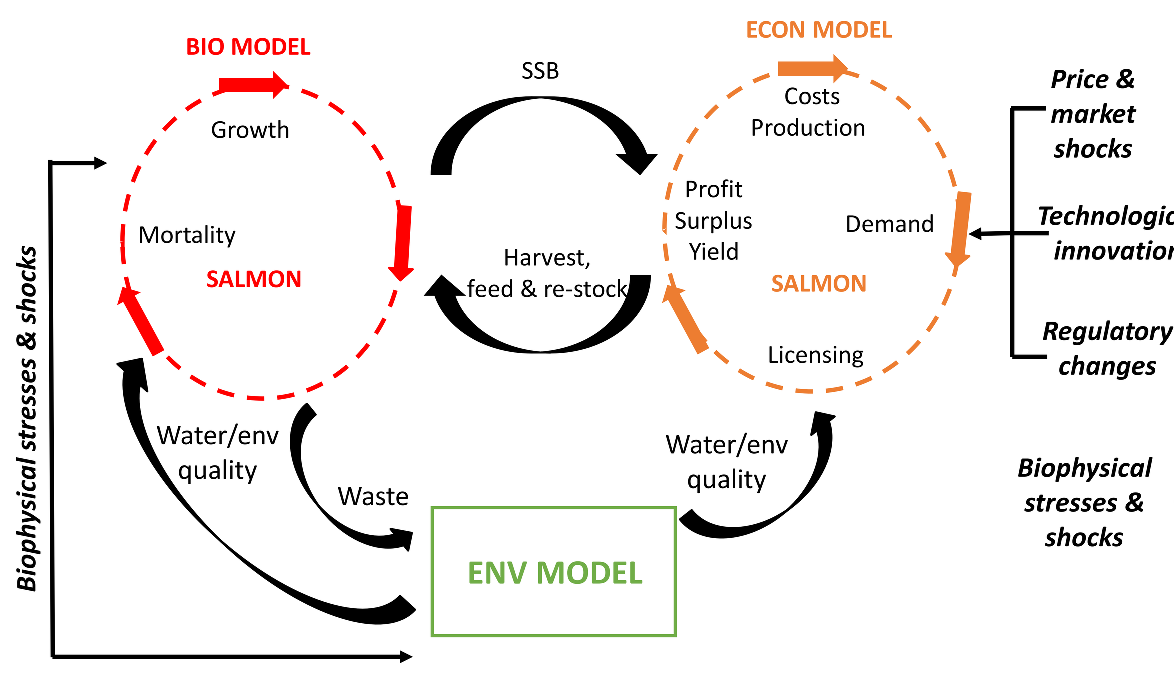
STEP 1: Identification of the key steps of resilience management

System definition, boundaries and drivers	Stakeholders	Metrics	Viability goals and metrics	Adverse events	Quantification of resilience measurements	Resilience management actions
Monoculture systems vs. IMTA systems. System dynamics depend on biological mechanisms (e.g. growth, survival), farming operations (e.g. feed, farm size, stocking density/weight, harvestable weight, production time), and environmental drivers (e.g. temperature, DIN/POM/Chl_a, hydrodynamics).	Producers, consumers, regulators, community residents and NGOs.	Estimates and indicators of performance (e.g. biomass, FCR, survival, yield), profitability (e.g. gross income/margin, profit/PI), environmental sustainability (e.g. fish farm discharges)	Minimum profit levels, variability, carrying capacity and other environmental interactions/ thresholds.	Losses or interruptions of production due to HABs predation, disease outbreaks, net/rope failure/loss, market crashes, etc.	Resistance: viability analysis of key environmental variables Recovery: responses to regime shifts, climate change and socio-economic shocks Robustness: probability of producer profits not falling below pre-defined thresholds.	Active adaptive management as a response to unpredictable and adverse events.

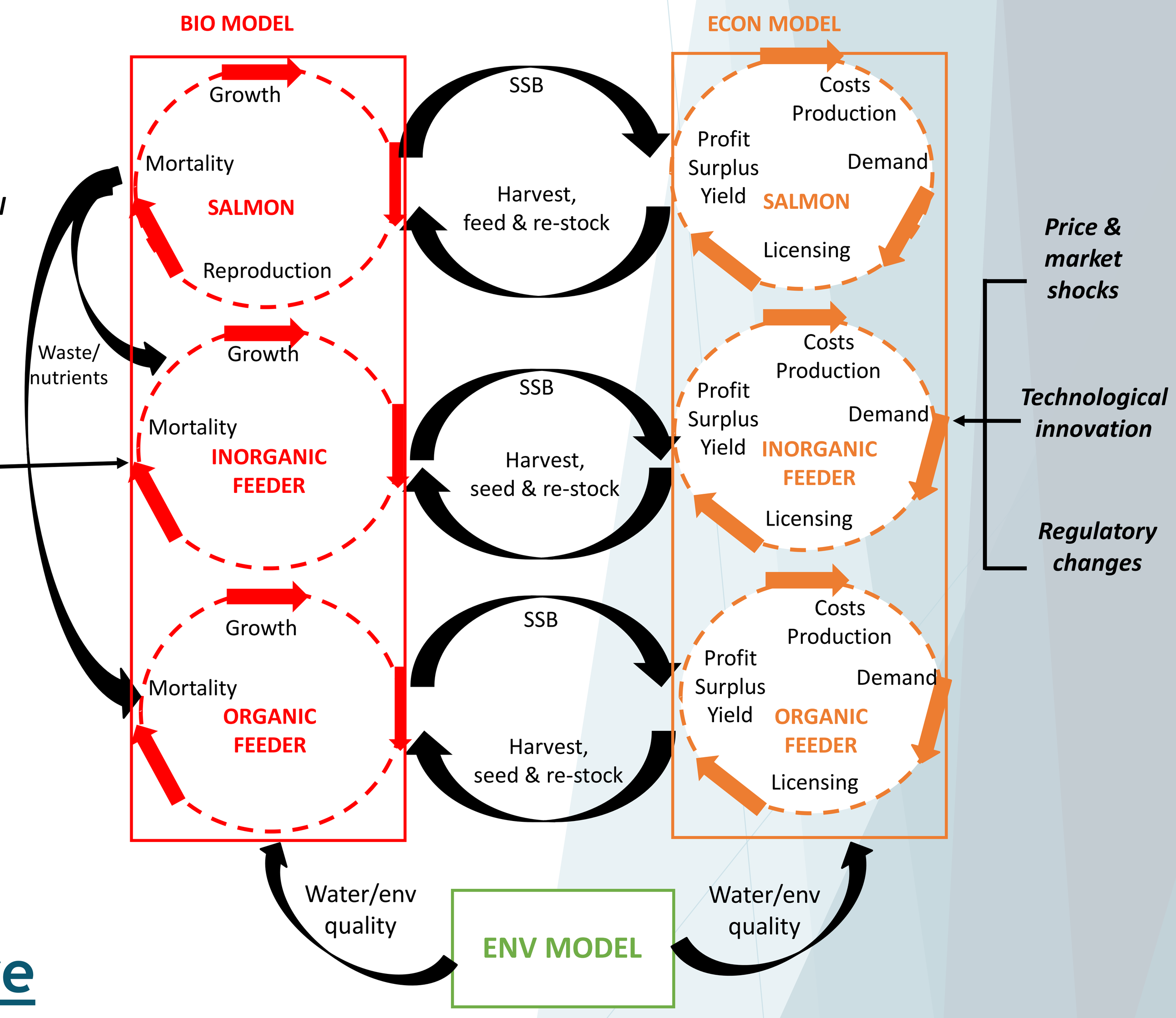
Abbreviations: DIN dissolved inorganic nutrients; POM particulate organic matter; Chl_a chlorophyll a, NGOs non-governmental organisations, FCR feed conversion ratio, PI profitability index, HABs harmful algal blooms.

STEP 2: Contextualisation of key steps using a bioeconomic model

(a) Monoculture system (i.e. salmon)



(b) IMTA system (i.e. salmon, seaweed, bivalves



STEP 3: Comparison of the monoculture and IMTA models

	WHAT'S BEST	WHAT IF: ALTERNATIVE SCENARIOS	WHAT IF: STRESSES & SHOCKS
MONOCULTURE	1. Optimal harvest rate of salmon 2. Net present value of profits 3. Optimal water quality and sedimentation	Variation in 1, 2 & 3 under different scenarios of: a. Investment costs b. Seafood prices c. Discount rate d. Bio & env parameters e. Regulatory standards	Quantification of resilience measurements under stochastic stresses & unpredictable shocks in: a. Investment costs b. Seafood prices d. Bio & env events
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IMTA	1. Optimal harvest rate of salmon and co-cultured species 2. Net present value of profits 3. Optimal water quality and sedimentation	Variation in 1, 2 & 3 under different scenarios of: a. Investment costs b. Seafood prices c. Discount rate d. Bio & env parameters e. Regulatory standards	Quantification of resilience measurements under stochastic stresses & unpredictable shocks in: a. Investment costs b. Seafood prices d. Bio & env events
	Difference in OPTIMAL MANAGEMENT: deterministic viability goals	*Difference in SIMULATION: viability goals under different scenarios*	*Difference in RESILIENCE MANAGEMENT: resilience measurements (resistance, recovery & robustness)*

STEP 4: Next steps

Parameterise the bioeconomic model, calculate relevant metrics, analyse its results and resilience implications.

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