



Marine spatial planning for British aquaculture

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Improving the Marine Management Organisation's aquaculture model

The aquaculture model developed for the MMO, in MMO 1040^[1], was designed to map **environmental conditions** against **natural requirements** of cultured species and **infrastructure requirements** of aquaculture operations. It further considered **planning restrictions** imposed by other marine developments/uses and protected areas. The model aimed to **predict suitable areas** for current, near future and future **aquaculture development** and their associated **value**.

However, its **approach and data gaps limit its predictive capability**. During **this placement** at the Marine Management Organisation (MMO), the model's ^[1] approach and data were reviewed, to identify the sources of its downfalls, address research gaps and propose recommendations for improvement of future iterations.

The **results are shown below**, with the analysis of the model divided in nine key areas. For each, it is discussed the **model's features and capabilities**, outlining **evidence reviewed and data collected** during the placement and further **recommendations for the improvement of the model**.

Natural resource requirements

- **MMO 1040** reviewed the **environmental requirements** of finfish, crustaceans, bivalve and seaweed species, as culture conditions input to the model. However, there were **extensive data gaps** which limited the model's predictive capacity. Furthermore, species requirements were **pooled into functional groups** (e.g. rope grown bivalves).
- **For this work**, a **review of culture conditions** of the **most relevant species** was conducted to improve model input data and outline research gaps.
- It is **recommended** that (i) the **number of species considered is greatly reduced** to species currently cultured, (ii) the **model becomes species-specific** (rather than culture-type specific), (iii) **input conditions are updated and confirmed with farmers** for commercial relevance.

Environmental conditions

- **MMO 1040** considered 8 variables (temperature, salinity, substrata, tidal exposure, energy, primary productivity, water quality and depth) when reviewing environmental conditions. However, due to data gaps and executive decisions, **only energy, substrata and depth were included** as data layers.
- **For this work**, **existing datasets for the 8 variables were signposted** for inclusion in future iterations.
- It is **recommended** the (i) **update of baseline data**, (ii) **inclusion of the reviewed variables in the model** and (iii) consideration of the criteria for inclusion of variables of targeted relevance (e.g. spat availability, disease risk, biofouling pressure).

Future trends, species & systems

- **MMO 1040** mapped **current, near future (0-5 years) and future (10-20 years) aquaculture development areas**, using higher depth and distance offshore as **predictive factors**
- **For this work**, **trends for UK aquaculture, emerging species and systems** were discussed
- It is **recommended** the (i) **re-assessment of the relevance of previous predictors** and the **selection of other relevant predictors**, (ii) **inclusion of emerging species** as predictors of areas of (near)future development and **review of their requirements**, (iii) **regular model updating and stakeholder consultation**.

EEA & MPAs

- **MMO 1040** has not considered the **ecosystem approach to aquaculture (EAA)** or compatibility of aquaculture with **protected areas (MPAs)**.
- **For this work**, the **conditions for MPA-aquaculture coexistence, implementation pathways of EAA and carrying capacity models** were reviewed.
- It is **recommended** the (i) consideration of **criteria for MPA-aquaculture compatibility** (e.g. bioremediation, restocking) and mapping of these areas; (ii) consider in the model the **EAA and associated tools/metrics** (e.g. carrying capacity); (iii) review indicators of **environmental change**.

Future environment and climate change

- **MMO 1040** did not consider future changes in environment and climate
- **For this work**, projected **environmental and climatic changes were reviewed**, noting uncertainty and research gaps.
- It is **recommended** that future scenarios are revised according to (i) projected **environmental changes**, and (ii) known species **acclimatisation capacity**.

Environmental interactions & exotics

- **MMO 1040** gave an overview of **environmental interactions and negative impacts** of aquaculture activities, albeit considerable data gaps. Exotic species were treated as others for modelling purposes.
- **For this work**, these data gaps were briefly reviewed.
- It is **recommended** (i) an **extensive update to current research on environmental interactions**, and (ii) **separate mapping for exotic species**, with review of their culture conditions and distribution.

Planning constraints & other sectors

- **MMO 1040** reviewed **planning constraints in detail and compatibility of other activities** with aquaculture types. Potential for co-location was not considered.
- **For this work**, gaps in planning constraints were highlighted. Interactions with other sectors and **potential for co-location were discussed**, including cases for **aquaculture exclusivity and exclusion**.
- It is **recommended** the (i) **addressing planning constraints gaps** and (ii) updating of model to consider **co-location and integrated multi-trophic aquaculture**.

Area & value of aquaculture

- **MMO 1040** overestimated the area and value of aquaculture potential. The reasons were unclear and factors were equally weighed.
- **For this work**, causes of the mentioned overestimations are discussed, as well as **methodology for multi-criteria valuation**, considering trade-offs of aquaculture
- It is **recommended** that mapping is improved by (i) corrections to the model's assumptions and validation, with areas of existing culture, (ii) consideration of a **weighed-sum model**, (iii) **separate mapping of areas of multiple aquaculture interest** and clear definition of **valuation criteria** for these areas, (iv) **species-specific valuation**, (v) extension and verification of **economic data by farmers**, (vi) use of **trade-off analysis** of environmental, social and economic factors.

Web-GIS & national framework

- It is **recommended** to (i) develop **(fuzzy) expert systems** to assist decision-makers, (ii) **update the model** as described, followed by **release as Web-GIS**, and (iii) **extension to a national model**.

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