Development of a GIS-based tool to assist planning of aquaculture developments

A report to
The Scottish Aquaculture Research Forum

Donna C Hunter
Trevor C Telfer
Lindsay G Ross

Institute of Aquaculture
University of Stirling
April 2006

© University of Stirling, UK
Executive Summary

Introduction

- In March 2005 the Institute of Aquaculture, University of Stirling, commenced an R&D contract entitled “Development of a GIS-based tool to assist planning of aquaculture developments”. The project has been part funded by SARF, with additional resource input from the Institute of Aquaculture.

- The project undertook to develop a preliminary GIS-based tool encompassing a case study area, which can model the actual and/or future implications of fish farms on environmentally sensitive parameters, areas or places of conservation interest in the coastal area of Scotland. The intention is that the tool(s) could be further developed for the whole of the Scottish coastline.

- There were a number of interim objectives:
  - Map sites through GIS which are environmentally sensitive and of conservation importance in relation to aquaculture location using existing databases and available information.
  - Implement modelling through GIS using simple dispersal models to investigate the impact of fish cages on these sensitive habitats.
  - Formulate “what-if” scenarios to look for alternative sites for existing and future fish farm developments.
  - Rationalize the results from sensitivity mapping, environmental impacts modelling and “what-if” scenarios to develop a final decision support tool for use by trained personnel at appropriate organizations, and in a format that could be developed into a web-based system in the future.
  - Provide a training workshop on the use of the initial tools developed through the project.

- The Western Isles was selected as the case study area because the conditions for productive and successful fish cage aquaculture are favourable and this has led to a large and well established industry, within a discreet geographical area. In addition, the Islands are host to numerous internationally recognised protected habitats and species.

Approaches to model development

- A conceptual model was developed for Western Isles aquaculture in which three initial principal sub-models were selected:
  - A cage suitability sub-model was developed to address the importance of siting different types of cage technologies based on their physical design capabilities. This sub-model incorporated the previously identified important criteria of Currents, Bathymetry and Wave Climate. As a prerequisite for the cage suitability sub-model a wave climate sub-model was developed based on previous work at Institute of Aquaculture
  - A Biodiversity sub-model was developed in order to identify ecologically sensitive habitats and both land and marine species of conservation concern.
  - A Waste Dispersion sub-model appropriate for large-scale multi-site analysis was developed in the form of a footprint model. Not all fish farm hydrological data was available and so only a small number of sites in the study area were modelled.
• The majority of the data used for these sub-models was sourced from internet sources and relevant governing agencies. Development of the spatial database was, as always, a lengthy process. Most data was supplied in varying formats and projections which needed conversion before incorporation into the database. All data was geo-referenced to UTM-29n.

• To address aquaculture siting on a holistic level both the cage suitability and biodiversity sub-models were combined to create a final outcome of aquaculture site location using physical and biological criteria.

• These sub-models and overall final model address many current issues in aquaculture cage siting in an informative and coherent way. This approach is easily adaptable to the whole of the Scottish coastline, given the appropriate data, and with the ability to integrate additional data and model aspects as specifically relevant to individual study areas.

Outcomes
• The cage suitability model for the Western Isles modeled cages was designed for sheltered, semi exposed and exposed locations. The model results show that the most appropriate type of cage for the Western Isles is that designed for exposed regions. The model also assessed how well located current fish farm installations were. It was found that the majority of cages used were designed for semi-exposed regions and on the whole are sited appropriately.

• The biodiversity sub-model highlighted certain areas of high biodiversity, particularly Loch Roag, West Loch Tarbert, Loch resort, Loch Maddy and the Sound of Barra. Within the biodiversity sub-model constraint layers, (i.e. fishing and fish nursery areas) were also developed which demonstrated the capability of the sub-model to reflect current developments in legislation.

• The waste dispersion model showed how well relevant multi-site modelling and large scale modelling can be achieved within a GIS environment. The model gave deliberately conservative results and showed that solid waste dispersion has a relatively local impact extending, in most cases, up to 45m from the edge of the cage array. Although some aspects of this model are still being developed and assessed this is a solid basis on which to develop a multi-site model.

• The Overall model combines the Cage suitability sub-model and the Biodiversity sub-model to give an integrated outcome based on these aspects of site selection for decision makers. This enables policy decisions and “trade-offs” between parameters to be assessed. The end result achieved is a set of high level and holistic development tools.

General conclusions
• The great strength of this GIS-based model is that it uses ranking and weighting of variables which can allow regulators and environmental managers the flexibility to appropriately fine-tune the decision-making rules for different areas.

• All sub-models and models are written as macros which can be easily edited, modified and re-run to reflect changing opinion, regulation or legislation. The sub-models have been developed within a graphical environment that allows the construction and execution of multi-step models. The advantage of this method is that it allows batch processing (running many inputs through the same model to produce many outputs) and dynamic modelling (using the output of one iteration of a model as an input into the next iteration). Both these aspects of the Macro modeller are a strong tool in the implementation and process of modelling. In addition, these sub-models can be run as free-standing models or in combination with other sub-models developed now or in the future.

• These tools could be further developed for the whole of the Scottish coastline and have the potential to be made available via the Internet.
The GIS models developed are discussed within the framework of an overall conceptual model for the development and management of aquaculture incorporating on-farm technology, ecosystem, society and policy components (Institute of Aquaculture, unpublished)