Managing Interactions Aquaculture Project 2012/13

Technical report on locational guidance and zones of sensitivity

November 2013

RAFTS
Rivers And Fisheries Trusts Of Scotland

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Executive Summary

The Managing Interactions Aquaculture Project (MIAP) is a programme of work aimed at understanding the interactions between aquaculture and wild fish populations. The work is funded by the Scottish Government and is designed to support the better coordination and management of wild fisheries in the West and North West of Scotland where much of the aquaculture industry operates. MIAP consists of three key priorities, which are:-

- Strategic programme of sea trout post smolt sweep netting and analysis;
- Programme of genetic sampling and analysis; and
- Locational guidance and zones of sensitivity analysis.

This Technical Report provides information of the Locational Guidance and Zones of Sensitivity Analysis, and provides guidance on the practical use of the models generated. The Locational Guidance Models were developed due to a need for the status of wild salmonid populations to be consistently represented and properly considered during planning applications for new aquaculture sites. The main interactions between aquaculture and wild fisheries that cause concern are the release of aquaculture-derived sea lice and escapes of farm origin salmon from fish farms. It is these interactions that influenced the development of the models.

The Locational Guidance Models consist of a Rivers and Fisheries Model, which focuses on the status of rivers and their salmonid populations, while the Coastal and Transitional Waters Model provides context information on the nature of the coastal waters. Both models use a combination of publically available information, such as Water Framework Directive classifications, and data held and supplied by fisheries trusts. The outputs of the Locational Guidance are in the form of Geographical Information System (GIS) map layers and are not hard copy maps.

The Rivers and Fisheries model generates a 5 class sensitivity assessment of coastal waters based on seven criteria relevant to rivers and salmonid fisheries, and is a function of the combined risk sensitivity score for each river in the area. The model covers some 414 catchments with an area of 13,757km^2.

The Coastal and Transitional Waters model covers an area of 12,855km^2 and combines information on the nature of the water that is relevant to sea lice, such as prevailing wind direction and post-smolt sea trout netting data collected by fisheries trusts.

The Locational Guidance models are specifically designed to allow fishery trusts and district salmon fishery boards the flexibility to incorporate local knowledge and information in order to provide local context to the output of the models. For this reason, fishery catch statistics are not included in the model, but instead are provided to trusts and DSFBs as important contextual information.

1. Project Background

In 2011, Rivers and Fisheries Trusts of Scotland (RAFTS) and its member fishery trusts and partner district salmon fishery boards on the west coast of Scotland began a programme of work associated with the interactions between aquaculture and wild fish populations. This work was funded by the Scottish Government. The Managing Interactions Aquaculture Project (MIAP) is designed to support the better coordination and management of wild fisheries in the areas of North West Scotland in which the aquaculture industry is present. Three programmes were identified as key priorities and work streams within the overall activities.

These were:

- Strategic programme of sea trout post smolt sweep netting and analysis;
- Programme of genetic sampling and analysis; and
- Locational guidance and zones of sensitivity analysis.

The three MIAP programmes are overseen by a Steering Group, chaired by RAFTS, which includes representatives from a range of west coast fishery trusts, district salmon fishery boards, Marine Scotland Science and Marine Scotland Policy.

This paper provides information on the Locational Guidance and Zones of Sensitivity analysis programme, and provides guidance on the practical use of the models generated. Further details on the other two Managing Interactions programmes are available on the RAFTS website[1] and are reported separately.

In 2012/13 the participating fishery trusts and district salmon fishery boards in the Locational Guidance work were:

- Argyll Fisheries Trust
- Argyll District Salmon Fishery Board
- Lochaber Fisheries Trust (to January 2013)
- Skye Fisheries Trust
- Skye District Salmon Fisheries Board
- Wester Ross Fisheries Trust
- West Sutherland Fisheries Trust
- Outer Hebrides Fisheries Trust
- Western Isles Salmon Fisheries Board

2. The Aquaculture Context and Project Need

Scotland has the largest farmed Atlantic salmon industry in the European Union, and there is an existing objective to grow the industry by 50% (from 2011 baseline) by 2020. Freshwater angling in Scotland results in the Scottish economy producing over £100 million worth of annual output, which supports around 2,800 jobs and generates nearly £50million in wages and self-employment into Scottish households, most of which are in rural areas (Radford et al, 2004).

[1] http://www.rafts.org.uk/aquaculture/

The location of salmon aquaculture in coastal areas adjacent to salmonid rivers can lead to a number of interactions that need to be considered and managed. Such potential interactions are currently managed via a number of mechanisms: voluntary codes, statutory inspection regimes and the statutory planning system. The latter ultimately involves a spatial choice as to whether a proposed location for a fish farm is suitable or not. The planning process must balance sometimes competing socio-political and environmental processes in reaching such final decisions on aquaculture developments.

The wild fisheries perspective on aquaculture is detailed in the ASFB/RAFTS Aquaculture Policy[2] paper, and specifically addresses three key areas that must be achieved to minimise the potential impacts upon the coastal and wild fisheries of Scotland. These are;

- *An aquaculture industry that operates alongside wild salmon and sea trout populations and other species, without negatively impacting them.*
- *An aquaculture industry that has negligible environmental impact through pollution, degradation of habitats or disease/parasite transfer.*
- *An aquaculture industry that inspires confidence and loyalty by communicating openly and transparently with stakeholders and the public.*

The Locational Guidance work within the MIAP arose following the identified need for a robust guidance tool for the planning process, that can support, at a regional level, the protection of sensitive coastal/freshwater environments using the best available information, and which is cost effective, user friendly and easily accessible for all potential stakeholders. The model outputs are principally to aid fishery trusts and district salmon fishery boards in presenting relevant information from a wild fisheries perspective to planners in order to ensure that such submissions to the planning process are consistent and logical.

It is important to recognise that whilst the models developed utilise the best available science and information, the information required to undertake a fully comprehensive approach to this issue is not available. Specifically information on salmon smolt migration routes do not exist within Scotland, and there are limited data available for the dispersal of sea lice from aquaculture installations. Therefore a risk assessment approach has been developed and undertaken which allows us to present site sensitivity despite limited ecological and biological data.

The models resulting from this work are solely based on a risk assessment from a wild fisheries perspective. No attempt has been made to assess the potential or suitability for aquaculture development on the West Coast of Scotland more generally or considering other constraints or limitations or views of other interests. Equally, the sensitivity analysis generated does not consider the effectiveness of control or management activities of the aquaculture industry currently and the ability, or inability, to manage, for example, numbers of sea lice on farms within any given areas of coastal water.

Zones of sensitivity from a wild fish perspective were generated using two models:

- Rivers and Fisheries Model
- Coastal and Transitional Model

[2] http://www.rafts.org.uk/wp-content/uploads/2013/01/ASFB-RAFTS-Aquaculture-Policy-Paper.pdf

As with any risk assessment the subsequent results are only as robust as the data available. The two models developed follow a standard risk-analysis process through which the project steering group identified and assessed relevant criteria, to derive a sensitivity risk for wild fisheries in terms of aquaculture development. A number of gaps where improved data is required are highlighted.

3. Developing the models using a Geographic Information System (GIS) Approach

The approach taken in the project has been to create sensitivity models for use within a Geographic Information Systems (GIS) framework. There are many examples of GIS development and application in planning and conservation areas including: regional and urban planning (Dai *et al*., 2001); aquaculture development (Falconer *et al*, 2013); land suitability analysis (Boroushaki and Malczewski, 2010); shoreline sensitivity to oil spills (Vafai *et al*, 2013); and identifying conservation areas for freshwater pearl mussels (Wilson *et al*, 2011).

GIS offers a flexible approach that can incorporate and link multiple factors and constraints to meet a specific objective; such as creating a sensitivity model. The GIS-based models developed here implement a three stage process to create two models that represent the sensitivities of wild fisheries to aquaculture development.

The first stage is a standardisation of the data layers, the second stage is a Multi-Criteria Evaluation process to combine the data layers and finally the third stage is a sensitivity reclassification of the model. The two models created in this three stage process are a Rivers and Fisheries Model and a Coastal and Transitional Model.

3.1 Study Area and Coverage

The study area is the North West of Scotland, covering six Fisheries Trust Areas (Fig. 1). This region is one where the majority of Scotland's salmon aquaculture takes place, although significant production occurs in the Orkney and Shetland Islands, this is outwith the current project area. This area of Scotland also supports a number of socially and economically important migratory salmonid fisheries.

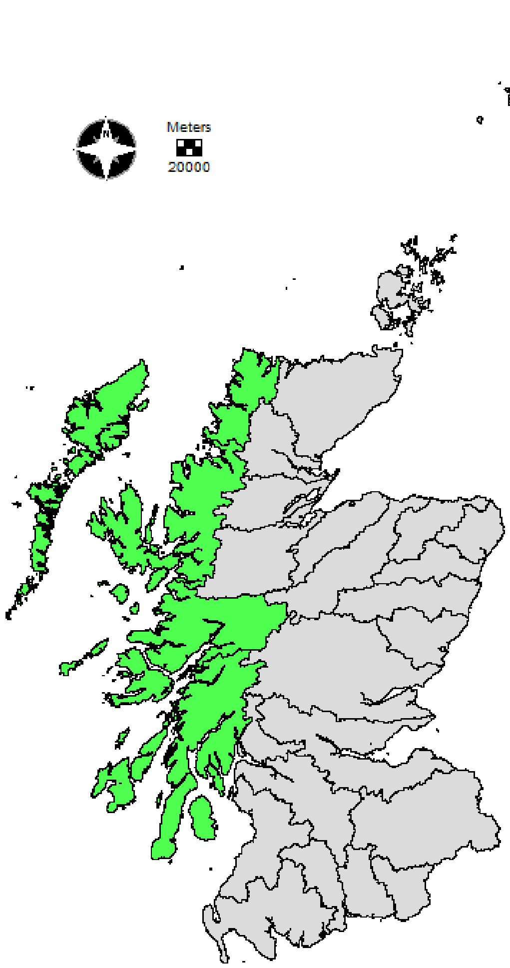

Figure 1: The study area for this project encompassed six fisheries Trusts on the North West Coast of Scotland highlighted in green.

3.2 Collection and pre-processing of data

The data used to populate the models were drawn from both publicly available data and data provided by participating fisheries trusts. All model components were developed in the IDRISI Taiga environment (Clark Labs, Worester MA) and all layers were geo-referenced to British National Grid with a spatial resolution of thirty metres. The output models are applicable within IDRISI and are fully compatible with a range of GIS software packages including ArcGIS 10 and above.

Data were requested from fisheries trusts in respect of the criteria summarised in sections **4.2.2.2 - 4.2.2.8** and for the criteria in the attribute structures set out in **Table 1** in **Appendix 1**.

3.3 Standardisation

The two models incorporate a range of criteria each having its own unit of measurement. However, in order to ensure appropriate integration into the multi criteria analysis, standardised data are required to ensure all criteria utilised are comparable. The methodology for this standardisation is known as 'Fuzzy Set Theory' (Zadeh, 1965 and 1978) and is the process by which units can be transformed and appropriately scaled into comparable units for integration into a multi criteria analysis.

By implementing Fuzzy Set Theory criteria combinations can be constructed on a rich mathematical basis and with identified uncertainties within the decision making processes. In the development of the two models all the criteria were standardised using the Sigmoidal membership function of IDRISI® which is characterized by a possibility output which ranges from 0 to 255, indicating a continuous increase from non-membership to complete membership of a pixel into a specific category (Eastman, 2001).

3.4 Multi Criteria Evaluation

The theoretical decision framework implemented for both the models in this work is a Multi-Criteria Evaluation (MCE) (Voogd, 1983; Carver, 1991). This is achieved by combining a set of criteria identified as relevant and important to the wild fisheries sector into a single output model. The MCE framework developed here consists of a number of selected, standardised criteria which were combined in a weighted linear combination (WLC). WLC is the most commonly implemented combination method for quantitative criteria that can be considered continuous i.e. in this study criteria containing sigmoidal standardised scores of 1 to 255 (Voogd, 1983). The WLC calculation is as follows:

$$S = \left(\sum WiXi\right) * \prod Ci$$

Where:
S = suitability
Wi = weight of factor i
Xi = criterion score of factor i
Ci = criterion score of constraints
$\sum$ = sum
$\prod$ = product

The MCE framework used in the MIAP models is a weighted combination. Weighted combination allow for the expression of each criteria's level of importance. Weightings were determined by identifying the relative importance of each criterion and considering the potential impact upon the model. The overall determination of the weights for each criterion was agreed by the Steering Group. In addition to the agreed criteria WLC can also incorporate constraints which limit the potential geographical area under consideration. The use of constraints is a common procedure and regularly implemented in land planning. For example certain terrestrial developments will be constrained from developing in lakes, rivers, urbanized or other industrial areas (Chang et al, 2008; Babana and Parry 2001). Two constraint layers were agreed upon by the steering group, for both sensitivity models; these were a Depth Exclusion of <15m and for the coverage of the Lochaber Fisheries Trust area. These constraints are discussed in more detail in the section **4.2.2.9**

Using the GIS-based MCE framework, the selected criteria, the risk-scored attributes of each criterion, and the established weights for each criterion were combined to create a GIS output layer.

4. Rivers and Fisheries Prioritisation Model

4.1 Model coverage

Within the study area the model coverage is broken into individual catchments as determined by SEPA for use within the Water Framework Directive implementation. A total of 414 catchments covering an area of 13,757km^2 have been identified by SEPA (see Figure 2) which are of two categories or types:

- Baseline:
  These catchments are each greater than 10km^2 and are recognised individually within WFD classification systems. Such catchments are generally broken down into units of management and classification for WFD purposes. These units are termed water bodies.
- Coastal:
  These catchments, individually, are less than the 10km^2 threshold for WFD classification. However, hydrometrically such catchments can be important and are often grouped together into coastal catchments. WFD classification in such catchments is made to single waterbodies covering the whole of the catchment.

Information and data on the criteria used in the models was sought for each of the catchment types within the Rivers and Fisheries Prioritisation Model.

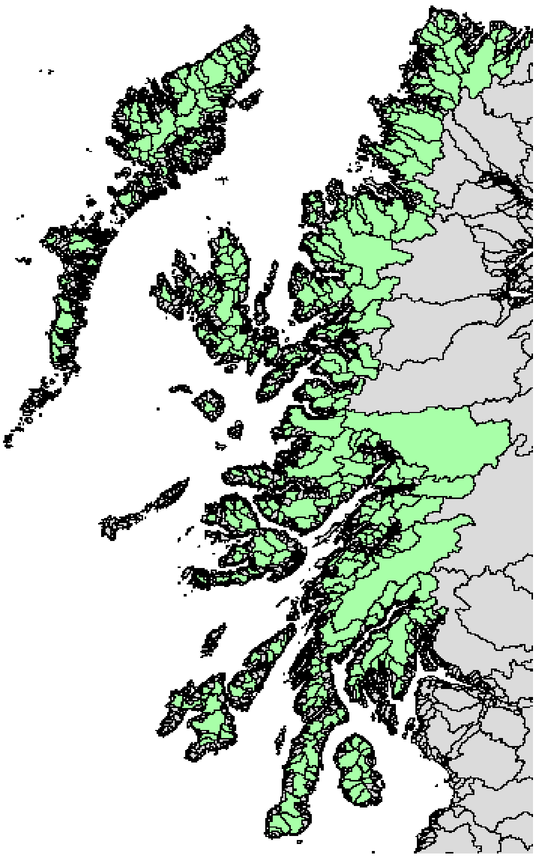

Figure 2: Showing the 414 baseline and coastal catchments used within the Rivers and Fisheries Prioritisation Model (Area = 13,757km^2)

4.2 Model components

The Rivers and Fisheries Prioritisation Model was developed with two components which will be made available to partner organisations. These are:

1. Context Information

This is a common analysis of the published catch statistics for salmon fishery districts in the study area. Salmon and sea trout catch statistics can be used by wild fishery groups to provide context information for an application for planning permission for a new aquaculture site. Long terms catch trends (i.e. declining, improving, stable) can be considered alongside the sensitivity analyses to allow informed representations to be made to planning authorities.

2. Rivers and Fisheries Sensitivity Model

This is the GIS layer generated from the information provided for the agreed criteria, associated with each catchment and combined at a range of distances from each river mouth within the model.

4.2.1 Context Information (Catch Statistics Analysis)

The Steering Group has agreed a common set of analyses to be undertaken on the catch statistics published annually since 1952 by the Scottish Government / Marine Scotland Science[3]. This sequence of data, although imperfect, represents the most consistent and comprehensive set of catch statistics available for each fishery district.

The analyses to be undertaken are:

- Total rod catch 1952-Present

This is a graphical presentation of the total rod catch over the total period from the first published catch statistics in 1952. This will be undertaken for salmon and sea trout separately.

- Total rod catch trends over shorter, defined periods

This will be the inclusion of best fit catch trend lines over shorter periods than the overall 1952 data series. Trends will be shown over 15, 25 and 50 year periods to allow comparison of changes in catch profiles over these periods.

- Calculation of average catch over fixed periods and ratio comparison to identify change over comparison periods

This will calculate the average catch over 15, 25 and 50 year periods and consider these in relation to each other to determine whether catch over these periods has increased, declined or remained stable.

- Application of adult rod catch assessment tool to assess seasonal catches

[3] http://www.scotland.gov.uk/Topics/marine/science/Publications/stats/SalmonSeaTroutCatches

As part of reporting obligations to the North Atlantic Salmon Conservation Organisation (NASCO)[4] Scotland submitted a Focus Area Report on the Management of Salmon Fisheries in 2008[5]. Within this submission a tool for the assessment of rod catch as a measure of adult abundance is set out (see **Figure 3**) and this methodology has been applied to the seasonal catch components in each fishery district in the study area. This assessment identifies whether conservation measures or local investigations are required for any of the spring, summer or autumn seasonal catch components based on catch records for each component over the last 20 years. These assessments of seasonal run components can then be used to inform consideration of the relative strength of the seasonal catch components within the total catch.

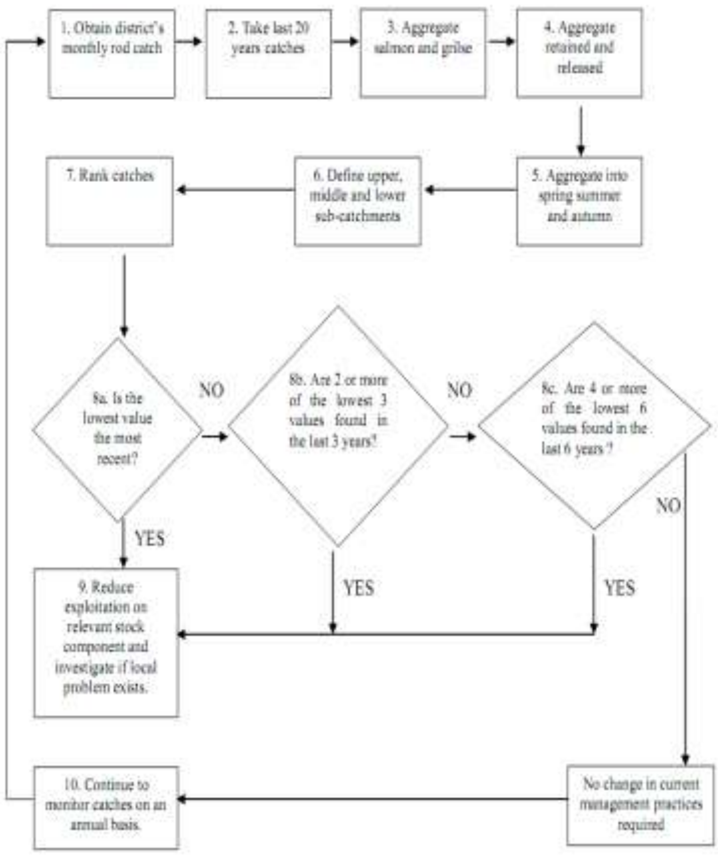

Figure 3: Summary flow chart of the NASCO rod catch assessment tool process

[4] http://www.nasco.int/
[5] http://www.nasco.int/pdf/far_fisheries/FisheriesFAR_Scotland.pdf

These analyses of catch statistics are continuing and will be available to participating partners for use in late 2013.

4.2.2 Rivers and Fisheries Prioritisation and Sensitivity Model

4.2.2.1 Criteria selection, weighting and combination

The project has identified and agreed seven criteria to be included in the sensitivity analysis and model. The criteria included are relevant to the assessment of the overall quality of the catchment in terms of fish populations and / or fishery strength and so criteria related to conservation and biodiversity, socio-economic and biological quality are represented. Analyses of these criteria present the sensitivity of coastal and transitional waters to aquaculture development from the perspective of fish and fisheries only. Other considerations, for example landscape, other conservation designations, or non-migratory fish populations were not included as these are the responsibility of other agencies, e.g. Scottish National Heritage (SNH,) to represent within development planning.

The seven criteria included, which are considered in the following sections, are:

- Designation and Features
- Water Framework Directive Classification
- Juvenile Salmonid Populations
- Catchment Availability and Access
- Habitat Quality
- Nature and Type of Fishery
- Rateable value of fishery district

For each criterion a set of attributes were identified to describe consistently how the criterion was to be considered. Each attribute was assigned a score (High/Medium/Low) to relfect the impact of that attribute on the sensitivity of the catchment to aquaculture. The criteria, attributes and scores are summarised in **Appendix 1, Table 1**. This approach will prioritise the areas of coastal waters associated with High scores as the most sensitive.

The project recognised that information and data for all seven attributes would not be available for all 414 catchments within the study area, and in many instances information would be available for only a sub-set of the selected criteria. As a result the model was designed to ensure that only catchments where sufficient data were available were included . Catchments were only included where the following minimum data requirements were met;

1. Minimum number of criteria for inclusion

To be included in the model and to contribute to the prioritisation at least five of the seven criteria must be scored. All catchments not meeting this threshold level are outside version 1 of the model.

2. Balancing scores from included catchments

Having met the threshold for inclusion in the model (see 1, above) a catchment may have five, six or seven scored attributes. To ensure that the prioritisation is not skewed in favour of catchments with the highest number of scored attributes, an averaging calculation was made for each catchment. This means that the prioritisation score for each catchment is based upon the average score of the five, six or seven attributes included in the assessment and is not a cumulative score of the five, six or seven attributes which would generally favour systems with the highest number of scored attributes.

The project considers that not all of the criteria used are of equal importance in the overall assessment. The Steering Group, therefore, introduced a weighted approach to the criteria used, with 'Habitat Quality' and 'Rateable Value of FIshery District' given a lower weighting in the model than the other five criteria. The general appropriateness of this approach was confirmed via the calculation of a consistency ratio between the weights of the criteria layers (Eastman, 2001). From initial discussion of the version 1 model outputs with stakeholders the validity of these weightings has been raised and the Steering Group will consider the retention of these weightings in version 2 of the model or the simplification of the system to have an un-weighted criteria set.

4.2.2.2 Criterion: Designation and Features

Atlantic Salmon are listed under Annex II and Annex V and the Freshwater Pearl Mussel under Annex II of the Habitats Directive. To support the protection and conservation of these species a total of seventeen Special Areas of Conservation (SACs) have been designated in Scotland. Information on the location of sites was provided by SNH and the designation or otherwise of an SAC for either species is included as a criterion in the model due to the direct conservation priority given to Atlantic salmon SACs and the integral importance of the presence of healthy salmon and/or trout populations in Freshwater Pearl Mussel SACs to support the life cycle of the mussel. This criterion was assessed by the scores and weightings in **Appendix 1, Table 1**.

4.2.2.3 Criterion: Water Framework Directive Classification

The Water Framework Directive 2000/60/EU[6] (WFD) was adopted in 2000 and transposed in Scotland by the Water Environment and Water Services (Scotland) Act 2003[7]. The WFD requires the delivery of a river basin planning system to take forward the achievement of environmental objectives set for waters within the scope of the Directive. Part of WFD implementation requires the classification of all identified water-bodies (units of management) within an ecological status or ecological potential quality system. A five stage classification exists for both ecological status and ecological potential surface water bodies (high / good / moderate / poor / bad) and all water-bodies within the catchments of the study area are classified in this way; after consideration of a range of biological, morphological, chemical and flow related quality elements. This classification, undertaken by SEPA, is used as a criterion within the model. This criterion was assessed by the scores and weightings in **Appendix 1, Table 1**.

4.2.2.4 Criterion: Juvenile Salmonid Populations

Electro-fishing surveys are undertaken by a range of bodies in Scotland to assess the health of juvenile salmonid populations within and between catchments and to inform, for example, the management of fisheries and fish stocks, inform WFD classification, and support the assessment of

[6] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0060:EN:NOT
[7] http://www.legislation.gov.uk/asp/2003/3/contents

designated sites such as SACs for Atlantic salmon. Such surveys undertaken by fisheries trusts in the study area are completed to a standard protocol[8] endorsed by the Scottish Fisheries Co-ordination Centre (SFCC)[9]. The status of juvenile salmonid populations was determined using classification systems based on theSFCC classification system for Scotland (Godfrey, 2005). Individual trusts adjusted the system based on juvenile salmonid densities found in the rivers in their area: for example, expected juvenile salmonid densities found in low productivity, lower temperature rivers in West Sutherland are lower than those found in relatively higher productivity rivers in Argyll. See **Appendix 1, Table 1**.

4.2.2.5 Criterion: Catchment Availability and Access

The extent to which a catchment can be naturally accessed by migratory salmonids is critical to the overall juvenile production from the catchment. Rivers where returning adult fish can gain access to all or large areas of the catchment will generally be more productive than systems where access is prevented or restricted. Fisheries trusts have a comprehensive knowledge of the catchments in their areas and were able to assess and score rivers based upon the extent to which the system was accessible to its natural limits for returning fish or the extent to which the natural accessibility is restricted by manmade structures. This criterion was assessed by the scores and weightings in **Appendix 1, Table 1**.

4.2.2.6 Criterion: Habitat Quality

The quality of the physical habitats associated with rivers (instream and riparian) are an important factor in determining the salmonid production from a catchment. In some instances fishery trusts have undertaken habitat assessment surveys across whole catchments or, more usually, have completed habitat surveys adjacent to electro-fishing sites. Habitat surveys follow a protocol developed by the SFCC that classifies the quality of river habitat for salmonid fish: this classification allows an assessment of the quality of habitat. Data collected from these surveys have been assessed by the fishery trusts and applied to the catchments in their area using the scores and weightings in **Appendix 1, Table 1.**

4.2.2.7 Criterion: Nature and Type of Fishery

Fisheries can be of a range of types and qualities and have a range of associated economic values and socio-economic uses and characteristics. To capture this the Steering Group developed a short list of fishery types which may be active in a catchment. These recognise the contribution of high rental value fisheries as well as socio-economically important resources serving local communities and residents. Based upon the fishery descriptors developed the fishery trust have assessed the catchments and associated fisheries in their area using the scores and weightings in **Appendix 1, Table 1.**

4.2.2.8 Criterion: Rateable value of fishery district

Each individual fishery within a fishery district has a rateable value calculated by the Assessor of the Local Authority. These values are used by DSFBs to calculate the levy applied to proprietors to

[8] http://www.scotland.gov.uk/Topics/marine/science/sfcc/Protocols
[9] http://www.scotland.gov.uk/Topics/marine/science/sfcc

support the activities to be undertaken to manage and protect the fisheries of the District. Rateable values are determined by the Assessor considering factors such as salmon and sea trout catches, size and extent of the fishery and rentals. In general, rateable values provide an index of the relative economic significance or value of the fisheries in a district and, from these, of the district as a whole when compared to others. In this study rateable values were used to help consider the values of the fishery districts in relation to others within the study area and was assessed by the scores and weightings in **Appendix 1, Table 1**.

It should be noted that the rateable value of the district is both a function of the combined value of the fisheries in the district and of the size of the district as a whole. It may be reasonably assumed that, for two districts with comparable fisheries within them that a larger district will have a larger rateable value. It was not possible to consider this issue further within the current use of the criterion.

4.2.2.9 Constraints:

The project has also considered the extent to which constraints can be introduced to the model coverage and analysis. Constraints exclude areas from the analysis and project outputs and may be introduced for technical or operational reasons. Two constraints have been applied in relation to the model: firstly a minimum depth (15m) below which aquaculture is presumed not to seek to operate; and secondly, to remove the coastal waters of Lochaber due to the decision of the Lochaber Fisheries Trust not to participate in this area of work. These constraints are summarised below.

Depth Exclusion (<15m)

Current recommendations for salmon aquaculture include advice proposing that operations should take place within a depth profile range of 15-70 metres to meet technical operational requirements (Greathead et al, 2012). Although future technical developments may allow operation in greater depths, it is less likely that a lower depth threshold would be used due to the need to retain clear depths below cages and the need to use sites with appropriate flushing rates and assimilative capacities. Therefore, all waters <15m in depth were excluded from the model. No such exclusion was applied to any maximum depth of operation.

Lochaber Coastal Area

Lochaber Fisheries Trust elected in January 2013 not to continue to participate in the development of the locational guidance model or sensitivity analysis or to provide information or data towards this work. As a result all analyses for Lochaber are masked from the model outputs as a constrained layer. However, coastal waters most obviously associated with the Lochaber area but which, due to the distances applied to the model from each river mouth, are of strategic importance to other partners, i.e. Skye, Argyll and Wester Ross, are still retained within the model output. Such outputs are based on the standard analysis of criteria summarised in section 4.2.2.1 but using only publically available information for Lochaber as set out in Section 4.2.2.11. This approach ensured that coastal waters of relevance to the trusts in Skye, Argyll or Wester Ross, in addition to Lochaber, were appropriately represented in the sensitivity analysis (see section 4.2.2.13).

4.2.2.10: Relating Catchments Risk Scores to the Coastal Zone

This model is developed to consider migratory salmonid fish and fisheries in relation to the farming of Atlantic salmon in open cages in the coastal environments. Therefore, it is essential both that the scores generated from the assessment of the agreed criteria relate to the coastal waters where aquaculture development and operations may take place and that the cumulative sensitivity of these areas is derived from all of the rivers relevant to these coastal waters. The sensitivity or priority of any one river over another is not an output of this model.

To deliver these requirements a methodology and approach was developed where four buffer zones were created emanating from the river mouth of each catchment within the model and draining to the coast. The use of buffer zones in riparian habitats is well established and documented (Xaing, 1996; Narumalani et al, 1997; Zeilhofer et al, 2011; Zhao et al, 2013). However, the distances to be associated to each buffer had to be determined.

Previous studies considering the relationship between fish farms, sea lice and wild salmonid infection indicated that the highest infection levels occur at rivers nearest a farm and are likely to have an impact up to approximately 25km but, potentially, be to ≥60km (Sharp et al, 1994; Mackenzie et al 1998 and Butler and Watt, 2001). However, Middlemas et al (2012) provides the most comprehensive assessment of this relationship to date and was used to determine the distances associated with each buffer zone. The analysis found that:

"*maximum range of effect of lice from farms predicted by the critical threshold model is about 31 km (range 13–149 km), and the intensity of infection falls progressively within this range*".

Having considered the above and consulted with the Steering Group and MSS the distances associated with the buffers from each river mouth were agreed to be 1km, 5km, 15km and 31km to reflect the evidence confirming that the highest lice infections occur at locations closest to farms and that the outermost limit of this relationship is proposed to be around 31km. Categorical buffers are used for this model rather than a continuous level due to technical difficulties with representing a continous change in risk of sea lice infection. To reflect the fall of infection intensity across these buffer distances each has an associated weighting where the 1km buffer has the highest weighting score, the 5km buffer has a high weighting score, the 15km buffer has a moderate weighting score and 31km buffer has a low weighting score (see **Figure 4).** It should be recognised that the buffer categories were not suggested by Middlemas et al (2012) and are solely for use within this project.

Were further information and evidence to be published to support the review of these buffer distances the model framework allows these distances to be varied.

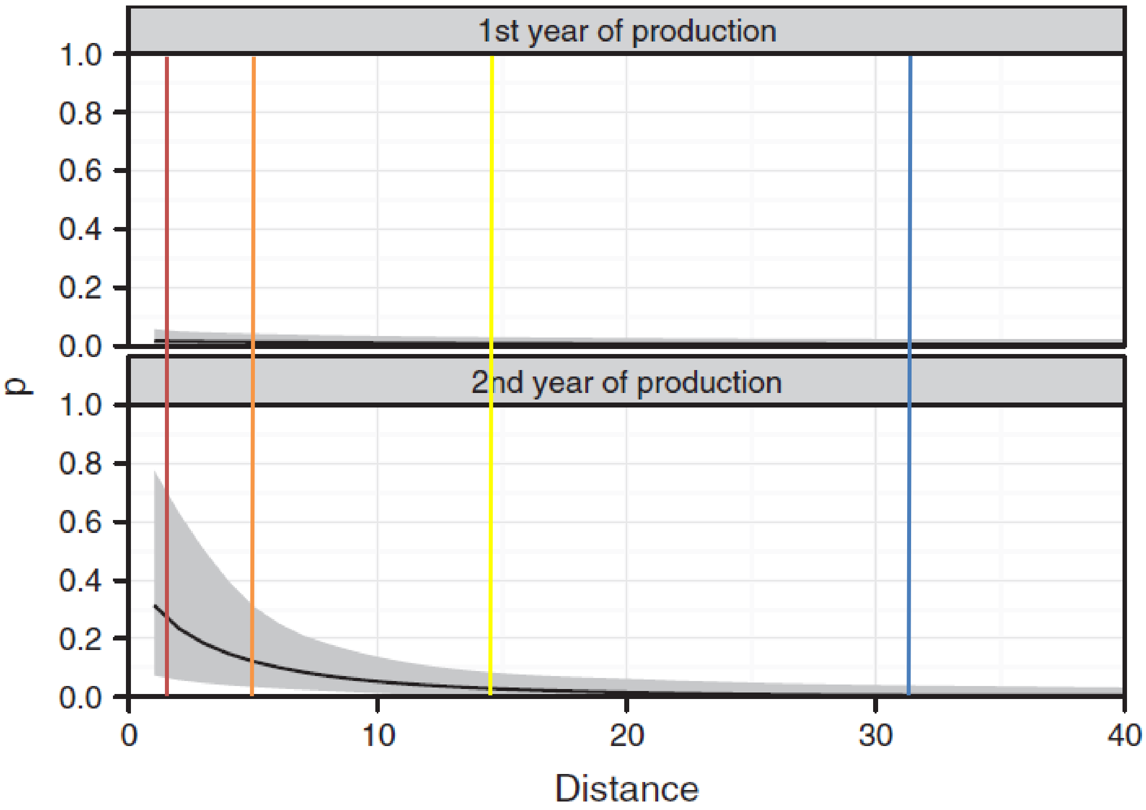

Figure 4: (Adapted from Middlemas et al 2012)

Fitted relationships between probability of sea trout exceeding critical lice burden (p) and distance to nearest farm (in km) calculated using the median fork length of sea trout (160 mm). Relationships presented using typical weight of individual salmon on farms in the first (0.2 kg) and second (3 kg) years of production. The line shows the fitted relationship with the shaded areas representing the 95% pointwise likelihood bands. Red line indicates the 1km buffer, orange line 5km buffer, yellow line 15km buffer and blue line 31km as applied in the MIAP model.

4.2.2.11 Developing an approach for Lochaber using publicly available data and information

Although Lochaber Fisheries Trust elected not to participate in the locational guidance part of the MIAP work, there are areas of coastal water which, due to the application of a 31km buffer from each river mouth, are 'shared' with neighbouring trusts in Skye, Argyll and Wester Ross. As the sensitivity analysis is cumulative and additional, the absence of any information on Lochaber catchments would have a direct impact upon these waters and under represent their sensitivity within the model.

In order to appropriately score these areas of coastal waters, alternative, publicly available, data sources were identified. A total of five data sources were identified and information from each of these collated for use in a Lochaber-only model output for subsequent combination with the other trust areas. Three of these criteria are common to the other modelled areas: Designations and

Features, WFD Classification and Rateable Value (see sections **4.2.2.2**, **4.2.2.3** and **4.2.2.8**). In addition two further criteria were developed for use; 'Salmon Presence' and 'NASCO River Database Classification'.

Criterion: Salmon Presence

MSS have developed and maintain a database for Scotland on the presence or absence of salmon. The database is populated with data from a range of sources from across Scotland. Information from this database relating to the presence or absence of salmon was supplied to the project from MSS. This criterion was assessed by the scores and weightings in **Appendix 1, Table 2**.

Criterion: NASCO River Database Classification

The presence or absence of salmon as considered in the criterion above was augmented by the use of data and information published by the North Atlantic Salmon Conservation Organisation. This information categorises rivers in order to reflect Atlantic salmon stock status. Data held within this database relevant to the Lochaber area were collated and this criterion was assessed by the scores and weightings in **Appendix 1, Table 2**.

Information associated with all five criteria to be used for Lochaber was brought together and applied within the model following the general process summarised in **section 4.2.2.13.**

4.2.2.12 Assessment and validation of public data only approach in Lochaber

To assess the validity of the approach taken for Lochaber catchments (see section **4.2.2.11**) a cross-tabulation analysis was undertaken for the other trust areas to assess and compare the outputs of the model generated for each area using both the full set of seven criteria (see section **4.2.2.1**) and the set of five criteria used in Lochaber (see section **4.2.2.11**).

When completed the model outputs using each approach were compared using Cramers V (the measurement of the degree of association between the values in each output) and Kappa (the measurement of agreement expected by chance alone) tests (see **Table 1**). These statistical assessments confirm that there is good agreement between the respective model outputs for each of the trust areas where a comparison was made. These results were used to confirm the validity of combining model outputs from Lochaber with those of neighbouring trusts using the different suite of criteria in order to generate a total sensitivity for shared waters.

Table 1: Cross-tabulation results for the five fisheries trusts

Trust Area	Cramers V	Kappa	P Value
Skye	69%	Substantial	0.000
West Sutherland	75%	Moderate	0.000
Wester Ross	76%	Moderate	0.000
Argyll	58%	Moderate	0.000
Outer Hebrides	62%	Moderate	0.000

4.2.2.13 Mechanics of the model process in West Sutherland, Argyll, Skye, Outer Hebrides and Wester Ross fishery trust areas

Having determined the criteria, scoring system, weightings and constraints to be used, the process for introducing data to the model is a summarised in the two stage process below:

Stage 1: Collation, scoring, standardisation and linear combination per trust

1. Data collated and populated into GIS database;
2. Criteria scored as per criteria scoring system;
3. Data standardisation;
4. Weighted linear combination and application of depth constraint layer;
5. Model outputs for individual trusts

Stage 2: Combination of individual trust models and overall sensitivity layer preparation

1. Individual trust outputs combined and overlaid;
2. Sensitivity reclassification and masking of Lochaber waters from outputs:
   Final river and fisheries model combining all trusts and all rivers in combination and represented as sensitivity map in GIS.

4.2.2.14 Sensitivity classification, GIS layer formation and model output summary

To create the Rivers and Fisheries Prioritisation Model the modelling process to combine the six trust area initial models was completed by a combination overlay addition process. That combination overlay process included the application of the Lochaber area constraint for all coastal waters solely relevant to Lochaber catchments. The final GIS procedure reclassified the outputs to create a new pixel distribution of 1 to 5 defined according to membership functions. This membership function was a qualitative sensitivity reclassification, where 1 = least sensitive and 5 = most sensitive, and is a refinement of the technique used by Falconer et al (XXXX). When complete the GIS layer showing the model output and distributed to the project partners.

As the model is a GIS layer there is no single physical map prepared for use. The layer allows the user to view data to a 30m resolution within the operating system. However, an overall representation of the model output is shown in **Figure 5,** with the outputs summarised in **Table 2**. This figure and table shows that the majority (65% of total area) of the waters included in the analysis are in the lower sensitivity zone 1 (yellow: 39%) and 2 (orange: 26%) with the higher sensitivity waters in zone 4 (purple: 14%) and 5 (blue: 5%) making up a total of 19% of the modelled area. The most sensitive areas are largely inshore areas into which multiple rivers drain and, often, with protected sites amongst the catchments, whilst the least sensitive areas are off shore waters outwith the 31km buffer zone from each river mouth.

When the analysis is considered in relation to the location of fish farm sites (**Table 2**) a high level of current aquaculture developments operate in the areas identified as most sensitive from the model analysis. A total of 57% of all aquaculture operates in the 19% of most sensitive waters identified.

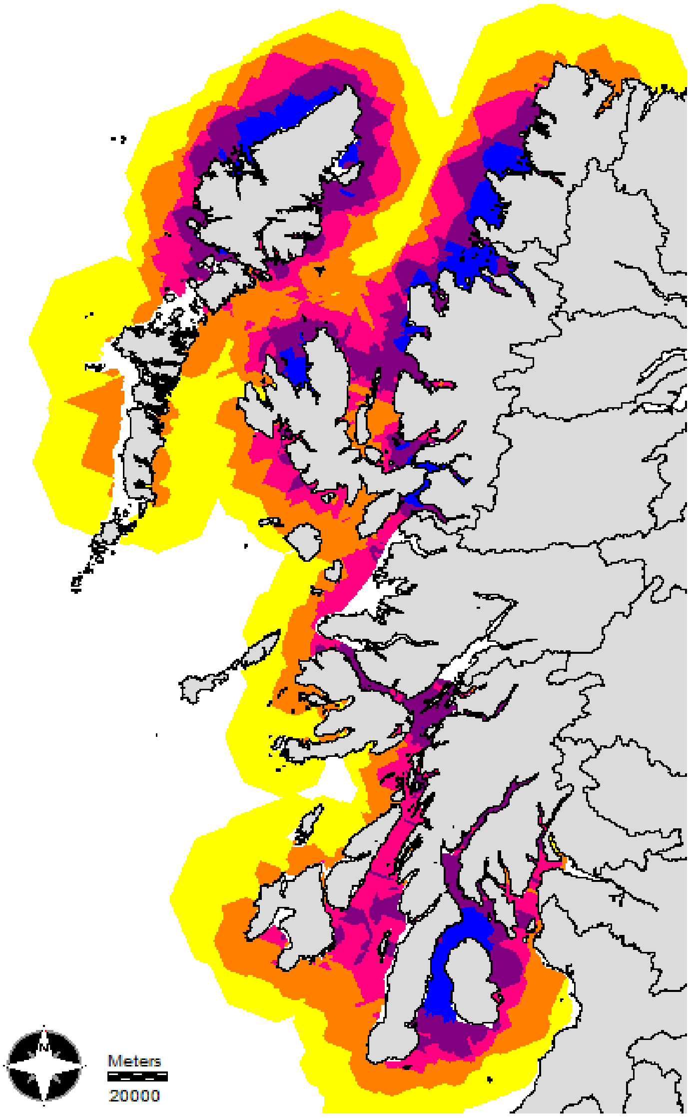

Figure 5: Version 1 of the Rivers and Fisheries Prioritisation Model Output

Table 2: Rivers and Fisheries Model Sensitivity outputs as km^2, % of total area and in relation to and current aquaculture operations. (Total Area: 29,267km2). (Lochaber catchments not included)

Sensitivity Colour Code	Sensitivity Score	Sensitivity	Area km^2	Area %	% Active Farm
Yellow	1	Low (<1km)	11479	39	4
Orange	2	Low –Medium (1-5km)	7585	26	18
Pink	3	Medium (5-15km)	4625	16	21
Purple	4	Medium-High (15-31km)	4009	14	39
Blue	5	High (>31km)	1569	5	18

4.2.2.15 Potential information and data refinements

As with any model we would expect a number of refinements and updates as new information becomes available. An initial summary assessment of these is presented below.

Extent of modelled area:

The large majority (88%) of the total area of the catchments in the study area have been modelled, i.e. the catchments met the requirement to have data available for at least five of the seven criteria selected. This means that the version 1 outputs are stable in terms of total coverage and the overall sensitivity generated. However, there are a number of catchments in the study area where the minimum criteria for inclusion were not met. These are shown in **Figure 6** and show modelled areas in green (88% of study area), catchments not modelled due to absence of fishery trust data in yellow (8% of study area) and catchments not modelled due to absence of both public and fishery trust data (3% of study area). Therefore, in order to further improve the coverage for version 2 of the model, fishery trust survey activities should be directed towards the catchments highlighted in yellow to allow these systems to meet minimum information requirements.

Boundary catchments:

To the south of the study area the waters of the Clyde have a sensitivity analysis derived from information provided by Argyll Fisheries Trust and public data sources. However, there are a number of catchments draining to the lower Clyde from Loch Lomond, the River Clyde and Ayrshire which, if assessed, would refine the sensitivity analysis of the Clyde waters. These catchments lie in the operational areas of the Loch Lomond Fisheries Trust (20 water bodies in one baseline catchment), Ayrshire Rivers Trust (87 water bodies in 13 baseline catchments), and Clyde River Foundation (116 water bodies in 10 baseline catchments). The model would be enhanced by the inclusion of scoring for these catchments and the application of these scores to the sensitivity analysis for relevant waters in the lower Clyde. In addition there are additional water bodies adjacent to West Sutherland which have not been scored.

Data not available:

The model has sought to make systematic use of the best available information related to salmonid fish and fisheries to help generate the sensitivity analysis. The project Steering Group is aware that other data sets would add significant strength to the model were they to be included. For example, information on salmon and sea trout genetics, smolt migration routes, sea lice dispersal models and sea trout behaviour would all be useful additions to refined models. However, at the current time such data do not exist. When and if such data becomes available the system will allow the incorporation of new data within the developed model architecture.

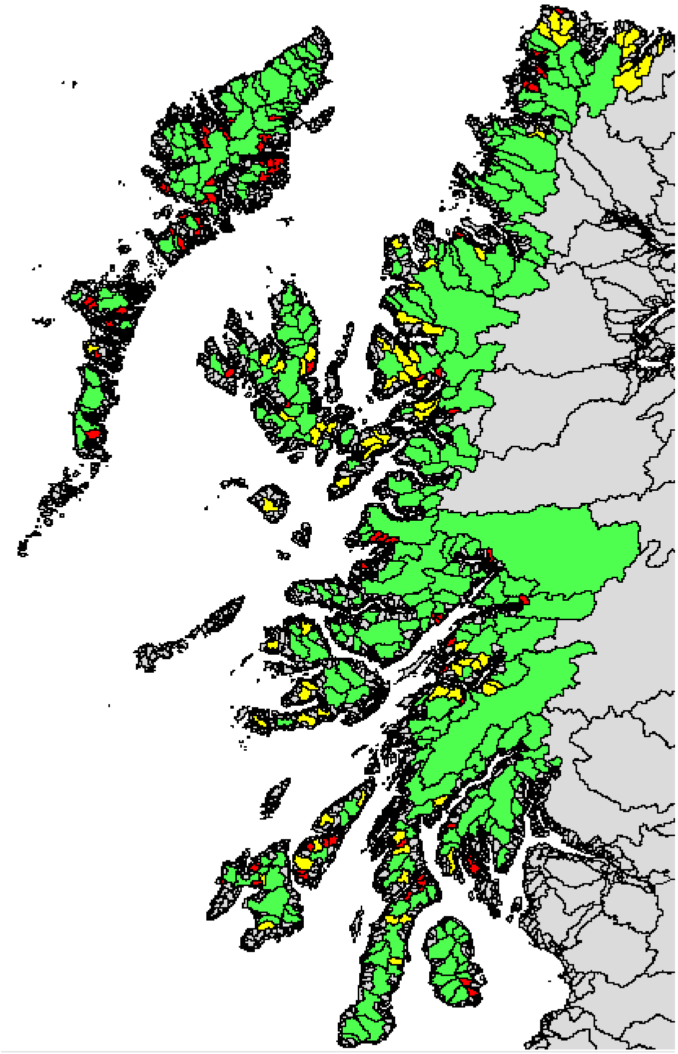

Figure 6: Showing extent of modelled catchment in study area (green: 88%), catchments not in model due to absence of fishery trust data (yellow: 8%) and catchments not in model due to absence of both public and fishery trust data (red: 3%)

5. Coastal and Transitional Waters Model

5.1 Model coverage

Within the study area the model coverage is defined by the water bodies used in WFD classification of coastal and transitional waters. These cover a total area of 12 855km^2 when the Lochaber area is removed from the coverage.

5.2 Model components and context information

The Coastal and Transitional Waters Model has been developed with two elements which will be made available to partner organisations. These are:

1. Context information

There are three components to the context information provided in this model. These are:

- The Water Body Characterisation
  Developed by MSS to assess the carrying capacity for Aquaculture Development in terms of predictive modelling to estimate nutrient enhancement and benthic impacts.
- WFD water body classifications for coastal and transitional waters
  Water bodies classified by SEPA as part of WFD implementation and reported in both annual classifications and the river basin management planning process
- Marine Protected Areas
  Areas of coastal water proposed by Scottish Natural Heritage for protection due to species and / or habitats of conservation importance or priority.

GIS layers for each of these data sets have been provided to the MIAP and distributed to partners. These provide additional context information for use by fishery groups in representations to aquaculture related planning processes. As these GIS layers are updated and revised by the public bodies holding the information, the MIAP GIS layers will be updated annually and distributed to project partners. Examples of map outputs of these layers is shown at **Figure 7**.

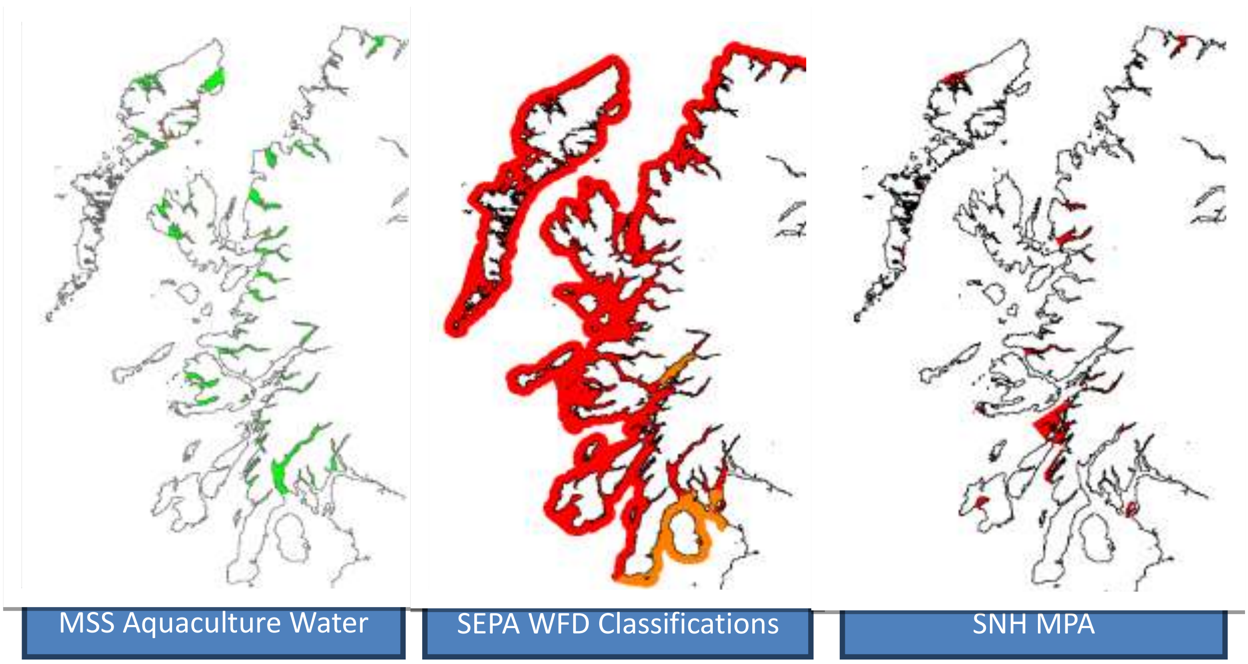

Figure 7: Example map outputs for Coastal and Transitional Model context information

2. Coastal and Transitional Waters Sensitivity Model

This GIS layer is generated from the data provided for the agreed criteria, combined via a multi criteria analysis and associated with each water body. Criteria have been developed which assess the potential risk of *L. salmonis* (sea lice) and water-borne diseases potentially arising from aquaculture development and activities in the project area.

5.3 Coastal and Transitional Water Prioritisation and Sensitivity Model: considering sea lice

The greatest concern for fisheries groups in respect of the interactions between aquaculture and wild fish in the coastal zone is associated with the impact from sea lice, specifically the species *Lepeophtheirus salmonis* (Krøyer 1837), upon sea trout and salmon post smolts. . The physical attributes of the sea loch or coastal water influence the likelihood that migrating post-smolts will be infected with sea lice. Criteria considering the type of loch, the orientation of the loch and the flushing rate (see below) were used as a proxy to the direct measurement of sea lice abundance and distribution. Currently, empirical data on sea lice abundance, infectiveness and distribution is scarce or absent in Scotland, and whilst some work is being carried out on sea lice dispersal modelling in Loch Linnhe and Loch Fyne (e.g. Adams *et al*, 2012; Salama *et al.* 2013), there is little strategic assessment of sea lice distribution in Scottish waters. Should information on sea lice dispersal or lice numbers on farms or in the open water become available this can be incorporated into the model in due course.

The basis behind the three criteria linked to the physical attributes of the loch or waterbody is the life cycle of *L. salmonis*. It has three free-swimming planktonic stages: nauplius I, nauplius II and copepodid (**Figure 8**). Boxaspen (2006) reported that at a water temperature of 10^{O}C it will take five days for the *L. salmonis* to develop through the nauplii stages to become a copepodid, which can then survive for up to a further ten days free-swimming (Tucker *et al*, 2000). Therefore, the life cycle of *L. salmonis* results in the presence of infective lice stages for a period of between five and fifteen days (at 10^{o}C), during which time the lice are largely (but not entirely) subject to currents and tidal movements. As a result their coincidence with salmonid post smolts over this period is, largely, subject to the physical attributes of the coastal waters and sea lochs and prevailing water currents, flushing rates and wind conditions.

In addition to the three physical attribute criteria a fourth criterion is included related to the sea trout post smolt sweep netting surveys undertaken in 2011[10] and 2012[11] as part of MIAP and reported on the RAFTS website. These reports present information on sea lice levels recorded on sea trout post smolt in each year and a range of sites over a specified sample period.

[10] http://www.rafts.org.uk/wp-content/uploads/2012/04/RAFTS-Regional-Monitoring-Report-2011.pdf
[11] http://www.rafts.org.uk/wp-content/uploads/2013/01/RAFTS-Regional-Monitoring-Report-2012.pdf

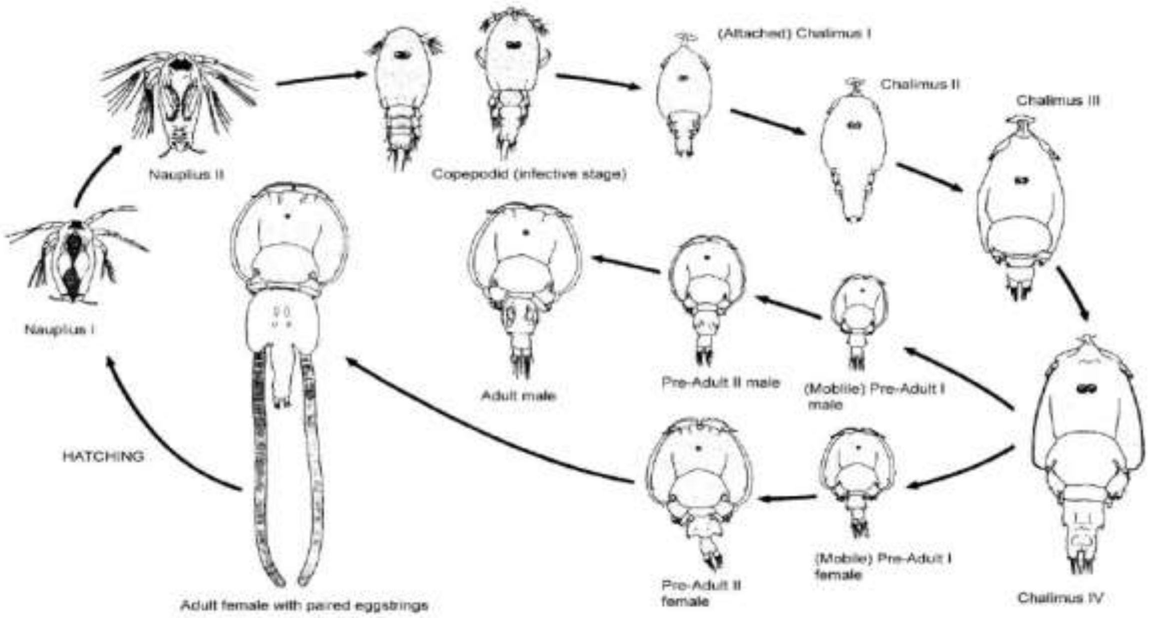

Figure 8 : The stages in the life-cycle of the sea louse *L. salmonis*. The Nauplius I & II stages and the copepodid stage are free-living planktonic stages (Schram, 1993). Maximum survival of the two stages combined is 15 days (Boxaspen, 2006).

5.4 Criteria development and combination

5.4.1 Criterion: Type of loch system

Fjordic loch systems are considered to provide more suitable environmental conditions for *L. salmonis* (Murray and Gillibrand, 2006) than open bay systems. Fjordic systems are defined by Dyer (1997) and this description has been used to identify fjordic systems in the study area. This criterion was assessed by the scores and weightings in **Appendix 1 Table 3**.

5.4.2 Criterion: Orientation of Loch System

The currents within the marine environment are a major driving factor in the advection of larvae (Siegel *et al*., 2003; Penston *et al*, 2011). Predominantly wind driven currents within a loch system may play a major role in the dispersion of sea lice planktonic stages (Amundrud and Murray 2007). As reported by the Metrological Office (2012) the western and northern parts of Northern Scotland are, on average, the windiest in the UK, being fully exposed to the Atlantic and closest to the passage of areas of low pressure. In these areas the greatest wind speeds and most prevalent directions are from the south west (Met Office 2012). Therefore, loch systems orientated to the south west will create advection of sea lice planktonic stages into those loch systems and towards the mouths of rivers, increasing the risk of interaction with wild fish. This criterion was assessed by the scores and weightings in the **Appendix 1 Table 3**.

5.4.3 Criterion: Flushing Rates of Loch System

Hydrographical flushing and current conditions can increase the infection success of *L. salmonis* within loch systems (Revie *et al*, 2003). Sharples and Edwards (1986) "*Scottish Sea Lochs: a Catalogue*" provides details on the flushing times of Scottish sea lochs in the study area which can be related to the infectiveness and maximum survival of the three free living stages. This criterion was assessed by the scores and weightings in the **Appendix 1 Table 3**.

5.4.4 Criterion: Post smolt sweep netting monitoring data

A programme of post smolt sweep netting and analysis has been undertaken by trusts participating in the MIAP and reported by RAFTS in 2011 and 2012 (RAFTS, 2011; RAFTS 2012). Wells *et al* (2006) established harmful effects in post-smolt sea trout (19 – 70g) when infected with 13 or more mobile sea lice. The scores and weightings were developed using this threshold. The prevalence of sea trout sampled in the sweep netting programme with sea lice burderns ≥13 sea lice determined the risk sensitity score assigned, i.e. more than 10% of sea trout caught in the previous two years at a site with a sea lice burden ≥13 would attract a "high" attribute score. See **Appendix 1 Table 3.**

5.4.5 Constraints:

As considered in section **4.2.2.9** the project has introduced constraints into the models.

Two constraints have been applied in relation to the model ; firstly a minimum depth (15m) below which it is assumed that new aquaculture developments will not seek to operate and secondly, to remove the coastal waters of Lochaber due to the decision of the Lochaber Trust not to participate in this area of work. The application of these constraints is as set out in sections **4.2.2.9** other than that water bodies which overlap between Lochaber and neighbouring fishery trusts are retained in the model output. As water body boundaries are defined by the WFD and SEPA these cannot be reasonably sub-divided within the current process.

5.4.6 Sensitivity classification, GIS layer formation and model output summary

To create the Coastal and Transitional Waters Model the two constraint layers were pre-processed and populated to the GIS database. The criteria were risk scored using the scoring attributes of **Appendix 1 Table 3** and the model outputs generated. The final sensitivity analysis was allocated to a five class system where 1 = least sensitive and 5 = most sensitive and the complete GIS layer showing the model output distributed to the project partners.

As with the Rivers and Fisheries Prioritisation Model, the Coastal and Transitional Waters Model is a GIS layer with no single physical map prepared for use. The layer allows viewing to a 30m resolution within the operating system. However, an overall representation of the model output is shown in the sensitivity map (**Figure 9)** with the outputs summarised in **Table 3**. This figure and table shows that the majority (84% of total area) of the waters included in the analysis are in the lower sensitivity scores 1 (yellow: 1%) and 2 (orange: 83%) with the higher sensitivity waters of score 4 (purple: 3%) and 5 (blue: 1%) making up a total of 4% of the modelled area. The most sensitive areas are largely fjordic, south west facing sea lochs which often have low flushing rates.

When the analysis is considered in relation to the location of fish farm sites (**Table 3**) a total of 24% of all aquaculture developments operate in the 4% of most sensitive waters identified. The majority of aquaculture activities (54%) are active in the middle sensitivity band (pink: 12%).

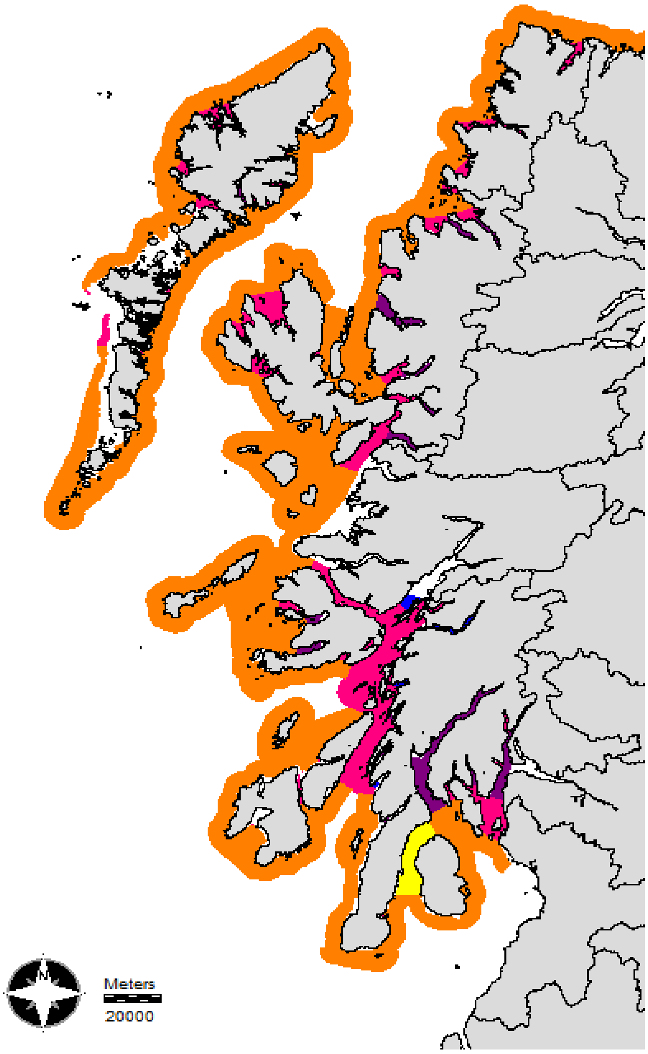

Figure 9: Version 1 for the Coastal and Transitional Water Bodies Prioritisation Model Output

Table 3: Coastal and Transitional Sensitivity outputs as km^2, % if total area and in relation to current aquaculture operations (Total Area Modelled: = 12,855km^2) Lochaber waters not included

Sensitivity Colour Code	Sensitivity Score	Sensitivity	Area km^2	Area %	% Active Farm
Yellow	1	Low	172	1	1
Orange	2	Low – Medium	10664	83	21
Pink	3	Medium	1584	12	54
Purple	4	Medium -High	395	3	19
Blue	5	High	40	1	5

5.4.7 Potential data refinements

As with any model we would expect a number of refinements and updates as new information becomes available. An initial summary assessment of these is presented below.

Additional data:

This model output is associated with the physical attributes of coastal water and how these are related to the sea lice life cycle. . The model may be refined by including the salinity profile of the coastal waters: areas of brackish water are not able to sustain sea lice. Similarly, temperature profiles of lochs may offer the potential for refined assessments of sensitivity by affecting the time free-swimming sea lice are in open water.

Data not available:

The model has sought to make systematic use of largely physical attribute criteria related to the sea lice life cycle as a proxy for detailed information on lice distribution, dispersal or presence / absence in coastal waters. Clearly, were such data to become available this would improve the model and allow validation of the sensitivities generated presently. However, at the current time such data do not exist. When and if such data becomes available the model allows incorporation of new data.

6. Discussion

6.1 Management and Maintenance

The Locational Guidance model should be maintained and updated on a regular basis to ensure that the data used to generate the sensitivity analyses are contemporary and as comprehensive as possible. The system has been designed to ensure that new or revised data can be included in future. An annual revision of the sensitivity analysis is proposed so that new or revised information can be incorporated appropriately.

For the public data sources an annual request to the data holders will be made for the most up to date information set available. This will allow the revision of data on catch statistics in the Rivers and Fisheries Model and re-distribution of up to date GIS layers for the Coastal and Transitional Waters Model. The WFD classification information held by SEPA is updated annually and when available should be obtained for use.

Information provided by fishery trusts will be updated for currently modelled catchments and gathered for those catchments which have not yet been modelled. A request to fishery trust partners to provide such information for the relevant criteria in the Rivers and Fisheries Model will be made annually.

Given that new information from fishery trusts is only likely to be available towards the end of each calendar year it is proposed that all new data and information is collected by the year end. A new version of the sensitivity analysis would then be run by March of the following year.

6.2 Prospective use and assessment of models

This project arose following the identified need for a robust prioritisation tool for the planning process, which can support at a regional level the protection of sensitive coastal/freshwater environments using the best available information. The model outputs are designed to aid fishery trusts and district salmon fishery boards in presenting relevant, consistent and logical information, from a wild fisheries perspective, to the aquaculture planning process.

The inputs to the models will be reviewed annually as new information becomes available. However, at the launch of the system 88% of catchments have been classified and therefore the base position for the model is considered to be stable. As stated earlier, it is recognised that information on sea lice dispersal and smolt migration routes/coastal habitats are not currently available and so cannot be incorporated. However, the models are designed to incorporate such data in the future as and when this data becomes available.

While the models are primarily designed for the use of the fishery trusts and DSFBs, it is intended an annual report on the updated model will be made publically available . Discussions with other interested parties including the Crown Estate, Local Authorities and Scottish Natural Heritage are ongoing and, if agreed by the Steering Group or funding body it may be appropriate for such parties to be issued with the GIS layer of the work.

The Locational Guidance models are specifically designed to provide fishery trusts and DSFBs with the flexibility to incorporate local knowledge in order to provide local context to the sensitivity analysis output of the models. It is important to understand that the models are based solely on a risk assessment from a wild fisheries perspective and there has been no attempt to assess the potential or suitability for aquaculture development on the West Coast of Scotland. On that basis, it is quite possible that there are legitimate reasons for significant concerns from a wild fish perspective to be raised with Local Authority planners in areas which, from the output of the model alone, may appear to be 'low' risk. It is vital that planners, decision makers and the industry understand that the model is only one of a number of information sources which may support Trusts and Boards submissions to the planning process.

ASFB and RAFTS have previously prepared guidance[12] for DSFBs and Fishery Trusts in dealing with the aquaculture planning process. This guidance will be reviewed and updated in due course to reflect the Locational Guidance models and feedback from planners.

7. Summary

Wild salmonids are important species requiring protection and conservation, and support economically important fisheries worth an estimated £100M (2003 figures) to the Scottish economy (Radford et al. 2004). Finfish aquaculture is increasingly an important economic industry to rural Scotland, contributing an estimated £500M to the Scottish economy in 2009 (SSPO). As with all human development, there are interactions with the environment, and the interactions need to be sustainably managed.

[12] http://www.asfb.org.uk/wp-content/uploads/2011/04/Advice-on-Aquaculture-Planning-Process.pdf

The locational guidance part of the MIAP has sought to provide two sensitivity models considering Rivers and Fisheries and Coastal and Transitional Waters, and spatially represent sensitivities to aquaculture development from a wild fish perspective.

The resulting models and sensitivity analyses are provided as GIS layers to support the consistent representation of wild fish sector responses to aquaculture planning applications. This enables wild fish sector concerns to be better represented within the planning process. The models are designed to combine existing data, use these data to develop sensitivities, and apply these cumulative sensitivities to coastal waters where aquaculture developments occur. Insufficient data on smolt migration routes and dispersal of sea lice from aquaculture sites exist, and are therefore not included in the analyses When such data are available, they can be incorporated into the models.

The Rivers and Fisheries sensitivity analysis demonstrate that the majority (65% of total area) of the waters included in the analysis are in the lower sensitivity scores 1 (yellow: 39%) and 2 (orange: 26%) with the higher sensitivity waters of score 4 (purple: 14%) and 5 (blue: 5%) making up a total of 19% of the modelled area. The most sensitive areas for wild salmonids are largely inshore areas with multiple rivers draining to these and, often, with protected sites amongst the catchments. Tthe least sensitive areas account for almost two-thirds of the total modelled area, are off shore waters and extend from 31km from each river mouth. When the analysis is considered in relation to the location of fish farm sites it is shown that 57% of all aquaculture developments operate in the 19% of most sensitive waters identified.

The Coastal and Transitional Waters sensitivity analysis, largely considering the risk of aquaculture-dervied sea lice infecting wild salmonidsk, shows that the 84% of the waters included are in the lower sensitivity scores 1 (yellow: 1%) and 2 (orange: 83%) with the higher sensitivity waters of score 4 (purple: 3%) and 5 (blue: 1%) accounting for 4% of the modelled area. The most sensitive areas are largely fjordic, south west facing sea lochs which often have low flushing rates. When the analysis is considered in relation to the location of fish farm sites, 24% of all current aquaculture developments operate in the 4% of most sensitive waters identified. The majority of aquaculture activities (54%) are active in the middle sensitivity band (pink: 12%).

These models will be maintained and revised annually using updated and new data available. Discussions are ongoing as to the distribution of the GIS layer to key stakeholders to better support a mutual understanding of the analysis and of the representations made considering the analysis by fishery trusts and boards.

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Appendix 1

Table 1: Rivers and Fisheries Prioritisation criterion, attributes and weighting descriptions

Rivers and Fisheries Prioritisation Criterion	Criterion Attributes	Criterion Attributes Score	Criterion Priority Weighting
Designations and Features	SAC (Atlantic Salmon or Pearl Mussel)	High	High
WFD Classification	Majority of sites/length High or Good Sites	High	High
	Majority of sites/length Moderate	Medium	
	Majority of sites/length Poor or bad	Low	
	Unclassified	Low	
Value of fisheries (by fishery district in study area)	In top 3rd of rateable value by district	High	Medium
	In middle 3rd of rateable value by district	Medium	
	In bottom 3rd of rateable value by district	Low	
Nature / Type of fishery (by fishery/catchment in database)	High value angling, opportunities and rentals with limited availability.	High	High
	Readily accessible angling opportunities via clubs, associations, day and weekly tickets.	Medium	
	Low cost or free angling opportunities to local communities/residents/visitors.	Medium	
	Fishery Protection Order accessible brown trout fisheries	Low	
	Rarely or never fished or no history of angling or economic benefit.	Low	
Catchment Accessibility and Availability	Natural catchment fully accessible/ Natural catchment accessible via fish pass mitigation	High	High
	Natural catchment access (<50%) restricted by barrier (man made)	Medium	
	Natural catchment >50% inaccessible due to manmade structures	Low	
Juvenile salmonid populations	Juvenile salmonid densities and age classes present/ as expected	High	High
	Juvenile salmonid densities depressed and/or missing age classes	Medium	
	Juvenile salmonid population totally absent or absent from majority of catchment	Low	
	No Data/No Survey	Low	
Habitat Quality	Natural/unmodified riparian/instream habitats (75%)	High	Medium
	Modified riparian/instream habitats (75%)	Medium	
	Modified damaged riparian/instream habitats subject to restoration actions	Yes = Medium No = Low	
	No data/No Survey	Low	

Table 2: Rivers and Fisheries Prioritisation criterion, attributes and weighting descriptions for use in Lochaber public information only model

Water Bodies (Transitional & Coastal) Criterion	Criterion Attributes	Criterion Attributes Score	Criterion Priority Weighting
Salmon Presence	Salmon Present	High	High
	Salmon Likely Present	High	
	Salmon Absent	Low	
	Salmon Likely Absent	Low	
	Unknown	Medium	
NASCO Rivers Database	Not threatened with loss	High	Medium
	Restored	High	
	Maintained	High	
	Unknown	Medium	
	Threatened with loss	Medium	
	Not present but potential	Low	
	Lost	Low	

Table 3: Coastal and Transitional Waters Prioritisation criterion, attributes and weighting descriptions

Water Bodies (Transitional & Coastal) Criterion	Criterion Attributes	Criterion Attributes Score	Criterion Priority Weighting
Loch Type	Fjord	Medium	Medium
	All Other Inlet Types	Low	
Loch Orientation	181^0 to 269^0	Medium	Medium
	All other orientations	Low	
Loch Flushing Rate	0 to 2 days	Low	Medium
	2 to 6 days	Medium	
	>6 days	High	
Sea trout post smolt monitoring data sites Percentage of sampled trout with harmful numbers of sea lice present	≥10% in the past two years	High	Medium
	>0 - <10% in the past two years	Medium	
	0% or No Survey Data	Low	