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SID 5 Research Project Final Report

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Project identification

1. Defra Project code: SARF028

2. Project title:
   Development of a scheme for monitoring sentinel farms in the UK trout industry

3. Contractor organisation(s):
   Prof. James F. Turnbull
   University of Stirling
   Stirling
   UK
   FK9 4LA

4. Total Defra project costs (agreed fixed price): £ 117,445

5. Project: start date ..... 01 March 2007
   end date ..... 28 February 2009

6. It is Defra's intention to publish this form.
Please confirm your agreement to do so.....**YES** ☒ **NO** ☐

(a) When preparing SID 5s contractors should bear in mind that Defra intends that they be made public. They should be written in a clear and concise manner and represent a full account of the research project which someone not closely associated with the project can follow.

Defra recognises that in a small minority of cases there may be information, such as intellectual property or commercially confidential data, used in or generated by the research project, which should not be disclosed. In these cases, such information should be detailed in a separate annex (not to be published) so that the SID 5 can be placed in the public domain. Where it is impossible to complete the Final Report without including references to any sensitive or confidential data, the information should be included and section (b) completed. NB: only in exceptional circumstances will Defra expect contractors to give a "No" answer.

In all cases, reasons for withholding information must be fully in line with exemptions under the Environmental Information Regulations or the Freedom of Information Act 2000.

(b) If you have answered NO, please explain why the Final report should not be released into public domain

Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

Major Conclusions of the Project

This project was a feasibility study for the sentinel farms scheme. The main aim of this project was to develop a scheme for collecting, compiling, analysing and reporting production, mortality and other data from the trout industry. The outcomes from this project will enable industry to provide government and other interested stakeholders with indicators relating to objectives and priority actions necessary for the strategic development of Scottish aquaculture. The project was directed by a steering group consisting of representatives from a wide range of organisations working with the trout and other aquaculture industries. In consultation with farmers and the steering group it was agreed that the project should concentrate on mortality data. As with any scheme for the collection of strategic data from producers, while strategic advantages may be obvious the necessary effort by producers must be encouraged through provision of more immediate benefits, not necessarily of a strategic nature. The project has addressed many challenges associated with the exchange, analysis and reporting of data across the trout industry, ran a pilot trial of a prototype scheme and developed a plan for the long term viability of the initiative.

There were three main aspects to this project: 1) to develop a software application to handle industry-wide data and provide reporting tools to users (Obj 2,3,4), 2) to test the system in a pilot study (Obj 5) and 3) to develop a plan for the long term viability of the initiative (Obj 6). The system was developed as a web-based application. Web-based applications can be maintained with little if any efforts by the user, all changes are made to the central systems allowing any system updates to be rolled out rapidly to all users in a single update. Web-based applications also allow the easy sharing of data, as all data is stored on a central server. The server for this application (mySQL Database Management System) was selected due to the high levels of security and its ability to receive and store amounts of data in excess of the requirements of this project or any future developments. The open source language, PHP Server Side Programming, used to develop the application is a scripting language designed specifically for web-based applications, reducing development time through utilising some predesigned components for aspects of the application. The application comprises benchmarking reporting tools, allowing farmers to compare the performance of units, farms or groups of farms against industry averages, and also basic farm management tools. Following rigorous testing throughout the development stages (Obj 2,3,4) and the pilot study (Obj 5), we have developed a robust system that will handle industry-wide data in an efficient, convenient and effective manner. Through consultation with SARF and trout industry representatives, we developed a plan for the long term viability of the Sentinel Farms scheme (Obj 6). This plan entails the creation of an independent company to administrate and handle the industry-wide data. The activities of the company will be overseen by a Board of Directors/Trustees, while ownership of the data will remain with the British Trout Association. It is highly probable the Sentinel Farms project will lead to a long term,

independently financed and strategically important scheme; we have developed a robust, customised web-based application that is capable of handling industry-wide data, and produced a viable plan with industry approval for the implementation of the scheme.

All milestones were met, although the duration of the pilot study had to be reduced. In some cases outputs have exceeded the expectations of the initial proposal, for example in the scope and complexity of the web based application. The outputs and findings of the specific scientific objectives are summarised below.

Obj 1. Recruit staff.

Obj 2. Data issues and collection
A number of major issues relating to the security, confidentiality and ownership of data were addressed at an initial stakeholders' workshop and in individual discussions with stakeholders. The extent of the available information on participating farms were examined in combination with the functions of existing farm management software. Samples of historical data were collected for subsequent analysis in obj 3.

Obj 3. Explore methods of data exchange and develop prototype database for data
A number of issues were addressed as part of this objective:
-the confidentiality of data necessary for enlisting participants in the pilot study (Obj 5) and for the long term future of the initiative;
-data security for access to the database and the data stored therein;
-the structure of the database;
-acquisition of data by the system;
-development of a plug-in to retrieve data from a major farm management commercial software, FarmControl (Akva).
The proposed use of historical data to back date the system was not followed through due to concerns over the reliability and accuracy of such data.

Obj 4. Conduct preliminary analysis on data and develop prototype analysis and reporting tools.
Preliminary analysis was conducted on data provided by participants of the pilot study (Obj 5) to enable development of reporting tools. Benchmarking tools were developed, allowing farmers to compare performance of fish within a farm, between farms within the same company, and against industry averages. Basic farm management tools were also developed during this objective, such as growth rate and feed conversion calculators in order to encourage wider participation in the scheme.

Obj 5. Conduct a pilot test of the system on a small number of farms.
A pilot study ran from November 2008 until February 2009. Four trout producers participated in the study, utilising various methods of data entry. Other people directly involved in the industry were also asked to trial the system. Those piloting the system were asked to provide feedback on the application throughout the study, with many user suggested amendments incorporated into the system. The pilot study demonstrated the capability of the sentinel farms system to handle multiple data entry methods, to store data securely, to conduct basic farm management operations and to calculate farm production parameters accurately. Due to a delay producing an automatic data upload for FarmControl it was not possible to run the pilot test for a full production cycle.

Obj 6. Develop a strategy for the long term implementation of a data exchange, and management system.
A strategy was developed for the long term viability of the initiative in consultation with industry representatives. It is proposed that an independent, not-for-profit company is established to administrate and manage the data generated by the scheme, while ownership of the data would remain with the industry. With the agreement in principle from the trout industry regarding the plans for implementation, the intention is to take this scheme forward. With the BTA, we are preparing applications to fund start up costs of a demonstration project or start up the business to extend the scheme across the entire trout industry.

Project Report to Defra

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also

seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:

- the scientific objectives as set out in the contract;
- the extent to which the objectives set out in the contract have been met;
- details of methods used and the results obtained, including statistical analysis (if appropriate);
- a discussion of the results and their reliability;
- the main implications of the findings;
- possible future work; and
- any action resulting from the research (e.g. IP, Knowledge Transfer).

INTRODUCTION

The main aim of this project was to develop a scheme for collecting, compiling, analysing and reporting production, mortality and other data from the trout industry. With the agreement of farmers and the steering group the project concentrated on mortality data. The outcomes from this project will enable industry to provide government and other interested stakeholders with indicators relating to objectives and priority actions necessary for the strategic development of Scottish aquaculture. The steering group, consisting of representatives from a wide range of organisations working with the trout and other aquaculture industries, directed the project. As with any scheme for the collection of strategic data from producers, while strategic advantages may be obvious the necessary effort by producers must be encouraged through provision of more immediate benefits, not necessarily of a strategic nature. The project has addressed many challenges associated with the exchange, analysis and reporting of data across the trout industry, ran a pilot trial of a prototype scheme and developed a plan for the long term viability of the initiative.

Scientific objectives and extent to which they have been met.

Obj. 1. Recruit staff.
An information technology (IT) specialist has already been identified for the project and we have a number of potential aquaculture specialists who could start work on the project from March 2007.
Completion milestone 01/03/07. Completed in full and on time.

Obj. 2. Data issues and collection
There are a number of major issues relating to the security, confidentiality and ownership of data. These issues would be addressed at an initial stakeholders' workshop and in individual discussions with participants. The extent of the available information on the participating farms and though other sources will be examined in combination with the functions of existing farm management software. Simultaneously samples of historical data will be collected for subsequent analysis.
Completion milestone 31/07/07. Completed in full and on time.

Obj. 3. Explore methods of data exchange and develop prototype database for data
The most efficient options for data collection and handling will be explored, including web based, e-mail or SMS. The IT specialist would explore the most efficient and flexible method for data storage, analysis and reporting. The exact nature will depend on an analysis of the nature of existing farm management software (Djournal and FarmControl).
Completion milestone 31/10/07. Completed in full and on time.

Obj. 4. Conduct preliminary analysis on data and develop prototype analysis and reporting tools.
This will involve two main aspects first those analysis that will be necessary for real time feedback to participating farmers will be identified and conducted, secondly other production related questions which might be asked of the data will be identified. The first aspect will be completed in detail the second as far as resources allow. Mechanisms for analysing and reporting data in real time will be examined and prototype software developed.
Completion milestone 31/03/08. Completed in full and on time.

Obj. 5. Conduct a pilot test of the system on a small number of farms.
Once a pilot system is developed it would be trialled on a small number of farms. The system would be run live for a pre-defined period covering at least one production cycle. At the end participating farmers would be individually interviewed to evaluate the system. This would provide additional information for the long term strategy.

Completion milestone 15/12/08. Although the pilot test has been run and fulfilled all of the original purposes, delays, especially obtaining a plug-in to acquire data from FarmControl, have resulted in the pilot study running for less than a full production cycle on participating farms.

Obj. 6. Develop a strategy for the long term implementation of a data exchange, and management system.
A strategy will be developed for the long term development of the system including rolling it out to more of the trout industry and also other aquaculture industries.
Completion milestone 01/03/09. Completed in full and on time.

Methods and results

Objectives 2 & 3: Data issues and collection & Explore methods of data exchange and develop prototype database for data.

Technology
Appendices I-V describe the technologies chosen to build this application. The Sentinel Farms system is a web-based application, which is discussed in appendix I. The application was developed utilising open source tools (appendix II) and scripted using PHP Server Side Programming (appendix III). The code for this application is not open source.

Confidentiality
The issue of confidentiality was identified early on as a major concern. Of particular relevance to the project were the Freedom of Information (Scotland) Act 2002 and more importantly, the Environmental Information (Scotland) Regulations 2004. We addressed this issue in an appropriate manner following consultation with the University's research office. The University's legal team advised that the following Terms and Agreements statement was inserted into the registration form.

> *"Data submitted through this package will be treated confidentially and data identifiable to individual farms will not be made available to other participating farms through the package. However, as a public authority, the University of Stirling is subject to the Freedom of Information (Scotland) Act 2002 and Environmental Information (Scotland) Regulations 2004, which means that anyone can request access to information held by the University and these requests must be considered and answered in terms of this legislation. There are exemptions from disclosure which are applicable in circumstances where releasing data attributable to an individual farm would result in harm. In such cases the University would seek to consult with the farm concerned and expect to refuse where it can be shown that actual harm would result from disclosure. However, notwithstanding any such refusal, the University may be ordered to disclose information on appeal to the Scottish Information Commissioner, or subsequently by the Court of Session."*

These terms were acceptable to the participants in the pilot test.

Confidentiality is a major issue for participating farmers and it was very clear from all discussions that none of the farmers would be prepared to make all the data freely available to governmental bodies, government agencies or non-governmental organisations. This is extremely important for the sustainable future of the project since industry participation will only occur if the scheme is independently run and under industry control. This in no way precludes the strategic objectives described in the proposal but allows industry representative to manage access to data.

Security
Farmers are understandably concerned about their sensitive data being obtained by those who might wish to use it to the detriment of the industry. It is imperative that the system for the pilot study and the subsequent scheme guards against attempts by malicious users. Therefore the following security features were implemented:

General Access: As would be expected, the pilot system was only available to users who passed a thorough screening process. It is envisaged that in the long term scheme any user could create an account, however they will not able to access their account until certain checks have taken place. These checks will decide whether they have a legitimate reason for accessing the system or not, at the discretion of the board. Once registered, individual farmers will not be able to access any other users' data unless that user has granted them permission. Unregistered users will not be able to access any information stored in the database.

Stored Data: In order to guard against a direct attack on the database, the server will be protected by a firewall. In addition, the data within the database will be encrypted using secure mCrypt encryption techniques. To decipher such data requires both the algorithm being used as well as the 64 to 256 bit key string being employed. Further, all user passwords will be stored using one-way encryption. This means that they are not decryptable, however, it also means that users will have to reset their password should they forget it.

Prior to initiating the long term scheme across the industry a full analysis of security by independent security advisers would be commissioned.

Data storage
The data storage system is located on a single, secure, centralised server to which all participating farms can easily connect and upload their data to via the Internet. A powerful, industry standard database management system (DBMS), which can cope with simultaneous uploads of very large amounts of data efficiently, has been selected for the task. For more information on the choice of DBMS and reasons behind the choice, see appendix IV.

Data acquisition
The data storage tools within the system were originally developed based on a dataset acquired from a selected number of farms that used FarmControl. This allowed us to examine the way the application stored the data, establish how our application could most effectively synchronize with this key piece of management software, and then plan the best means of presenting data in real time via the web application. From this starting point, we were also able to develop tools for farmers without FarmControl (or other farm management packages) that will allow them to manually upload/directly submit their data using html entry forms that would fit with the existing data storage structure.

In built data acquisition tools
Initially, the data entry tools built into the application were to provide farmers without (or with unsupported) farm management software with a way of adding data to the system. The aim of this was to make the system accessible to a wider range of farms. The data acquisition tools consisted of two separate html forms:
1. to upload data from spreadsheet format (predefined template).
2. to directly add desired data (daily mortality data).

However, the second of these forms was redeveloped to provide limited farm management tools (see Farm Management Tools below).

FarmControl plug-in
For users of FarmControl farm management software, the team behind the system, Akva, undertook to develop a plug-in that can schedule uploads of data into our central server. This plug-in was unfortunately not developed by the end of the project. This is an issue that will need to be addressed prior to implementation of the industry wide scheme. This caused a delay in the start of the pilot study and prevented it running for a whole production cycle.

Historical Data
Our initial plan was to set the system up so that when it went “live” it would upload historical data from farms that use FarmControl (and possibly other systems) to provide a history of mortalities prior to that point in time. From then on the data uploads would work on, for example, a three year rolling basis whereby data older than three years would no longer be included in the graphs displayed. However, we rejected this approach, instead treating time zero as the point when the system goes “live” i.e. no historical data prior to the start of the project. There are two reasons why this approach is more appropriate:
1. Our system will only practically be able to upload data from management packages (i.e. no paper files can realistically be uploaded due to time constraints). This would limit the historical data to a certain number of farms.
2. We have found many errors in the data held by farm management packages. Usually the reasons for these errors are clear (e.g. data such as mortalities recorded in the wrong column). There would seem to be little or no validation of input in FarmControl and this makes it very difficult to control the quality of data being obtained from this package. In short, it does not guard against farmers providing erroneous results. These errors are very easy to find within the datasets. However, the sheer number of minor errors in these large historical databases makes it a very difficult problem to tackle effectively.

These two issues would bring into question the accuracy of the historical data at a time when the system was in its infancy and under scrutiny. By contrast our system contains an alert feature that highlights when a probable error or anomalous result has been input (Figure 1). These alerts occur at the moment of submission so allowing farmers to check these problematic entries prior to them entering the database. The sheer size of the historical databases would make them impractical to deal with prior to going live. Therefore we would not be confident the graphs produced were accurate for this historical data. For current data, the farmers themselves will have the responsibility for the accuracy of the data within the system with a great deal of help from the validation tools provided by the application.

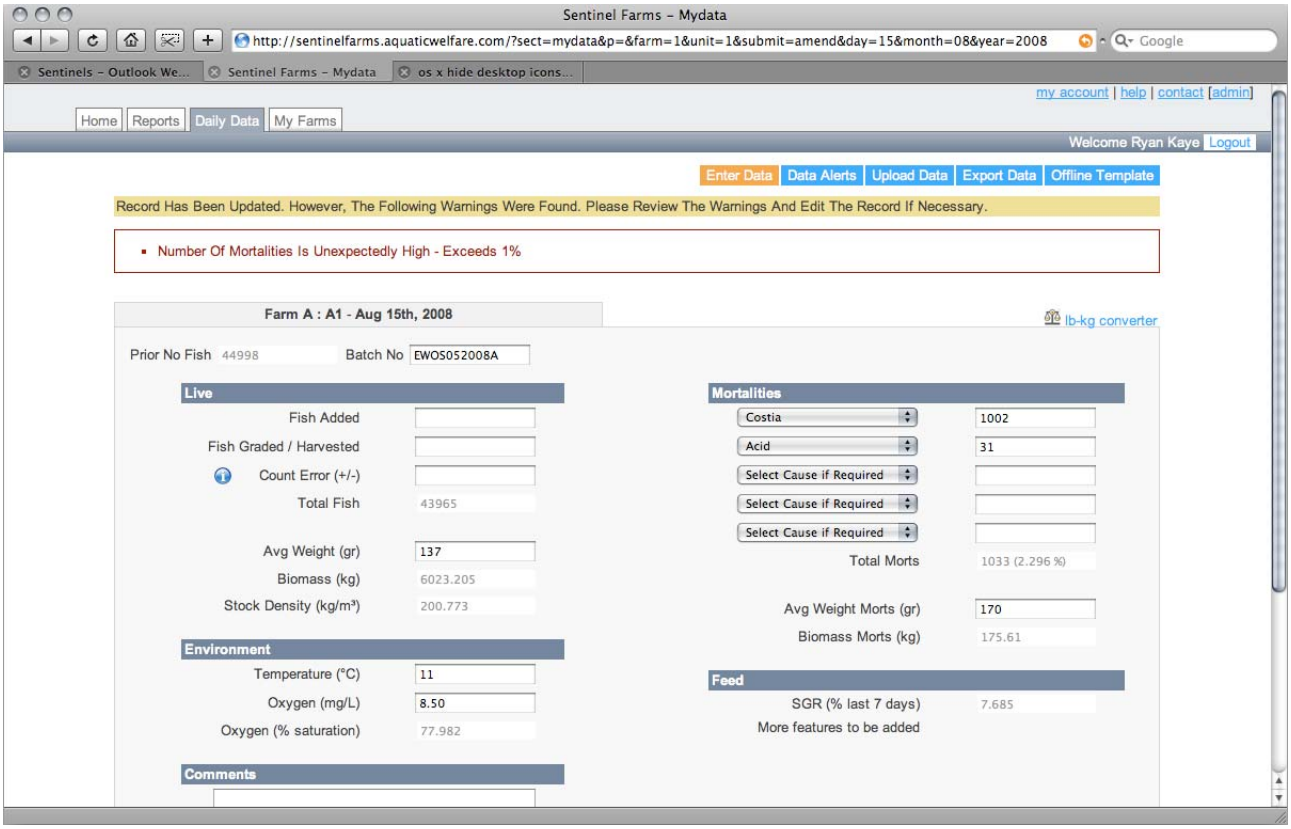

Figure 1. An example of an error message on the data entry screen.

Objective 4: Conduct preliminary analysis on data and develop prototype analysis and reporting tools.

Preliminary Analysis

Mortality records were sourced from 17 UK trout farms using data downloaded from farm management software (i.e. FarmControl and Djournal). These records allowed us to benchmark the number of daily mortalities (% of stock) and also the biomass of these mortalities (kg) for i) a single unit against a specific farm's daily average, ii) a specific farm against the industry's daily average. These data were cleaned and extensively analysed, using 7 day and 14 day rolling means, to provide input into the development of the analysis and reporting tools (data used as an example for figure 2).

Benchmarking Tools

Early in the design process, the decision was made to develop the benchmarking tools as a web based application. By moving the application away from the desktop and onto the web server, many of the installation and maintenance complexities identified by users of software such as FarmControl are avoided. In the process, the development team is provided with greater control over future performance, maintenance, and enhancement tasks during the application's lifecycle. Further, by building the software as a web based application the tools will become more widely available within the trout farming industry, allowing farmers with older computers and operating systems to use all the resources of the application. As long as the farmer has a computer with a web connection s/he has the ability to access the tools within the application. For more information on web based applications and the advantages and disadvantages associated with them, see appendix I. For more information on the tools being used to build the application see appendices II to V. An example of the application appearance is contained in Figure 2. The application will employ AJAX technology (see Appendix V) to make it feel as responsive as and functionally equivalent to a desktop application as possible.

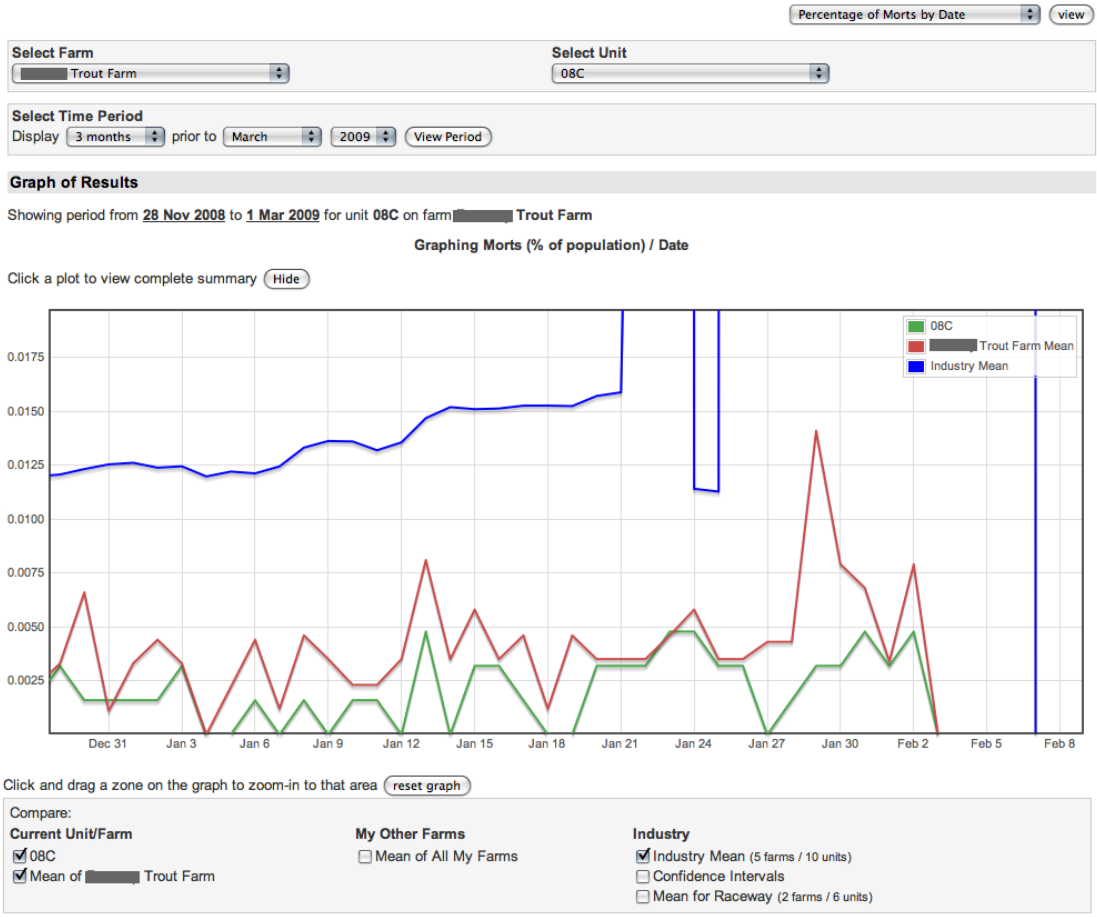

Figure 2. An example of a complex comparison between mortalities on a unit, a farm, a group of farms and the industry with industry confidence intervals. Options are removed or added by simply checking the boxes below the graph.

The benchmarking tools will provide an effective marketing tool and an incentive for farmers to use the system. These tools will in the first instance do three things:

1. Provide farmers with a set of graphs to allow them to easily analyse the general performance of their individual farms and units against that of their farms as a group and of the industry as a whole. Confidence levels will be calculated in real time and then plotted to provide guidance on acceptable gradation.
2. Alert users when their results are different from those of the industry as a whole – for example, mortalities are a defined level above the average of the data from all the other farms stored within the database.
3. Provide industry wide data on trends in mortalities. Simple and rapid analysis could alert the industry to the timescale and extent of mortalities and also the size of fish affected, thus fulfilling part of the original sentinel farms objective.

Farm management tools

Basic Farm Management Tools were developed to provide farmers (particularly small-scale farmers) with an application for managing their farm and thereby encourage participation. The application automatically performs a number of practical and beneficial tasks such as:

- Automation of everyday essential calculations based on daily supplied core variables e.g. stocking density; specific growth rate, mortality rates.
- Maintaining records of production parameters.

In effect, the system will provide farmers with an effective means of fulfilling their legal obligations as set out by the Registration of Fish Farming and Shellfish Farming Businesses Order 1985 (as Amended) and the Aquaculture and Fisheries (Scotland) Act 2007. To this end, an export tool has been provided which will allow all the farms' data to be easily exported from the database to spreadsheet format. It is hoped that these farm management tools will provide another effective marketing tool for the application assisting it in its long-term sustainability.

Objective 5. Conduct a pilot test of the system on a small number of farms.

Once a pilot system is developed it would be trialled on a small number of farms. The system would be run live for a pre-defined period covering at least one production cycle. At the end participating farmers would be individually interviewed to evaluate the system. This would provide additional information for the long term strategy.

Initially, three of the largest trout producers in the UK agreed to participate in the pilot study, which was due to commence in August 2008. However, at the behest of two of these companies due to work commitments, we agreed to delay the start of the pilot study. There were further delays to the start of the pilot study as we had many more discussions with the trout farmers regarding data security and access to data by third parties under Freedom of Information Acts than we originally anticipated. Unfortunately, one of the trout farmers withdrew from participating in the pilot study.

The pilot study continued with two trout producers, both of which use FarmControl (Akva). In order to export data from FarmControl to the Sentinel Farms system, a plug-in from Akva is required (see FarmControl plug-in above). Akva were unable to provide a plug-in within the project time-frame and we therefore created our own software script to extract the required information from FarmControl as a temporary measure and provided this to the farmers. This also led to delays with the pilot study. We approached the British Trout Association with a view to garnering the participation of more trout farmers, and two further trout farmers agreed to participate in the pilot study with effect from 26 January 2009.

The pilot study ran from November 2008 until February 2009. The exercise was a success, demonstrating that the system can accept and handle data entry in a variety of formats. The trial identified a number of important issues regarding usability and feature set. A table of user suggested amendments from the pilot study can be found in appendix VI. Although the pilot test has been run and fulfilled all of the original purposes, delays, especially obtaining a plug-in to acquire data from FarmControl, have resulted in the pilot study running for less than a full production cycle on participating farms.

Objective 6. Develop a strategy for the long term implementation of a data exchange and management system.

A strategy will be developed for the long term development of the system including rolling it out to more of the trout industry and also other aquaculture industries.

We have developed a strategy for the long term sustainability for this project. Several strategies were explored to determine the most efficient and suitable method for advancing the project aims. The data exchange and management system will continue to be a web-based application with some farm management tools that, it is intended, will be beneficial to trout farmers (see Farm Management Tools above). To administer and handle the information collected by the system, an independent, not-for-profit company will be established, which will take over ownership development and maintenance of the software. Industry representatives have emphasized that farmers will only use the system if it is independent of government regulators. The optimal format for the company needs to be investigated (i.e. limited company, charity etc). Whatever the format of the company, the activities would be overseen by a Board of Directors or Board of Trustees, which would contain representatives of industry trade organisations. The company would administer and handle all data, while ownership of the data will be retained by the British Trout Association, which would enable protection of potentially sensitive industry information from applications under the Freedom of Information Act 2000, Freedom of Information (Scotland) Act 2002, Environmental Information Regulations 2004, or Environmental Information (Scotland) Regulations 2004. We propose that the company would contract annually with the University of Stirling to maintain and develop the web-based application. Discussions with the BTA are continuing, however the BTA have agreed in principle with our recommendations for the future of Sentinel Farms. Discussions have taken place with an expert contracted to the Scottish Government employee to supply independent advice on Intellectual Property rights.

Following the end of this research project a meeting will be held to nominate a group of people who will be responsible for establishing the company as a legal entity and may form the core of the subsequent Board of Directors or Board of Trustees. Initially it is anticipated there will be a demonstration project phase leading on to a self financing business entity.

Additional Security
Prior to the system going "live", and as part of the next stage in the development of the scheme, we intend contracting a software security consultant to fully test system security.

As an additional security measure, we may consider implementing shttp (secure hyper text transfer protocol) as the data transfer mode. The shttp encrypts data sent between the client and server ensuring that malicious users cannot intercept data during the transfer process. It is normally used for transferring credit card details and other sensitive customer data by online shopping applications. The shttp is a very useful tool but it requires expensive

certification to implement. It is a feature that would only be employed if truly required after consideration of the risks involved and consultation with industry.

Extending to other industries
In addition to benefiting the UK trout industry, the UK salmon industry is also interested in the system as a data collection and management resource. Discussions are underway with the Scottish Salmon Producers' Organisation regarding how the web-based application could best be applied to meet their needs.

Funding
It is anticipated that eventually the running costs of the data management company will be borne by the respective trade organisations. Funding is required for start up costs for the company, and potentially a demonstration project including the following:-

- fees for legal advice relating to intellectual property and how the company might interact with trade organisation.
- funding for staff time to prepare a business plan, form the company, and apply for extra funding.
- develop material for online help for farmers.
- employ a software security consultant to test security measures of system.

We have identified a potential source of funding for the above and an application is in preparation.

Discussion of the results and their reliability

All aspects of the data collection, storage, acquisition, farm management tools and benchmarking tools were exhaustively tested. The process of developing the system was dynamic, with many amendments made to the original system. The most reliable and robust test for this system was through the pilot study, which tested all the aspects of data management mentioned above. The system performed well, demonstrating that it is able to handle different types of data acquisition tools, and that data storage is stable. All issues identified by users were addressed, however none of the issues identified during the pilot study were major: most suggestions were concerned with navigation between screens. We would have preferred to have had the FarmControl plug-in for the pilot study, nevertheless we do not believe this affected the success of the pilot study. The plug-in would have extracted data from FarmControl and sent it to the Sentinel Farms database, however the software script developed within this project as a stop gap performed essentially the same task except that farmers e-mailed the data to us, which was then fed into the system. We are confident that the system is well designed and can perform as expected when the system goes "live".

The plan for the long term viability for the initiative was developed through consultation with the trout industry and SARF, and we are confident that this is the best way to proceed. Independent ownership of the data under industry control is an essential component of this scheme and farmers have frequently expressed the view that they would not participate on any other basis.

Major conclusions

There would appear to be unanimous agreement that the trout industry requires accurate industry wide data to identify and deal with challenges, comply with official and unofficial requests for information and to work with government and other stakeholders for a sustainable future. The reality is that such data requires effort on behalf of already very busy farmers and they will only participate if the system is easy to use and they see some form of immediate benefit which justifies any additional effort. Therefore a great deal of time and effort was spent on an iterative process of discussing with and promoting the project to farmers and adapting the application. During this project and as part of the plans for the future we have had to listen to the concerns of farmers and businesses regarding the necessity for independence from regulatory authorities and data security. Having worked closely with stakeholders we are confident that this project has a high probability of future success. The interest shown by the Scottish Salmon Producers' Organisation is testament to the value of this strategic initiative.

Ease of use
The system was developed as a web-based application designed to meet users' demands, not strategic objectives or database functions. Web-based applications are easy to maintain, allowing any system updates to be rolled out rapidly to all users in a single update. Web-based applications also allow the easy sharing of data, as all data is stored on a central server.

Immediate benefit
The benchmarking tools, farm management and potential to fulfil reporting obligations all make the system valuable to farmers and therefore more likely to be widely used.

Security
The application, data transfer and storage are all highly secure and will be evaluated by independent experts prior to further development.

Independence
We envisage the creation of an independent company to administrate and handle the industry-wide data collected should the scheme be implemented. The activities of the company will be overseen by a Board of Directors/Trustees, while ownership of the data will remain with the British Trout Association.

Future work

The aim of this project was to test the feasibility of the Sentinel Farms scheme and to develop a plan for the long-term viability of the scheme. We have established that the scheme is feasible and have produced a plan to implement the scheme. Funding is required for the start-up costs associated with implementing the scheme (see *Funding* above). The process of implementing the scheme has begun, as a meeting with an Intellectual Property Rights expert was held in Perth on 12th February to clarify the position regarding IPR. We have identified a suitable funding opportunity, and an application for funding for start-up costs associated with developing the initiative is underway.

Discussions are ongoing with the UK salmon producers' organisation to determine how aspects of the Sentinel Farms scheme may be best applied to that industry. The system as it currently stands is not suitable for the salmon industry and will require to be developed specifically for that industry.

Should the Sentinel Farms scheme be fully implemented, it will produce large amounts of strategic, industry-wide data on a range of production parameters. There are many uses to which this information can be put, for example providing government regulators with information on emerging health problems, allowing better understanding of disease patterns within the industry and facilitating active surveillance for aquatic animal health. Information gathered from this scheme could contribute to the development of welfare indices for aquaculture species in conjunction with the Scottish Executive and Aquaculture Health Joint Working Group. The possibility also exists for the scheme to be developed at a future date to include the collection of environmental data for improved environmental modelling and assessment. These are only a few of the possibilities for utilising information collected as a result of the implementation of this scheme. Collection of industry-wide strategic data presents many more opportunities for the trout industry, for government regulators and for researchers to improve the efficiency and profitability of the trout industry and health and welfare of the farmed fish.

Action resulting (IP, knowledge transfer etc)

Discussions with the trout industry have been an integral aspect of this project, and the industry has been kept fully aware of all developments throughout the project. A presentation was given at the British Trout Association AGM in August 2008. There have been numerous informal discussions between the participants in this project and a wide range of stakeholders including retailers, legislators, a range of animal welfare organisations (RSPCA Freedom Foods, Compassion in World farming etc.), and researchers. A formal presentation of the Sentinel Farms scheme was given at a meeting "Evaluation and Modelling of Benefits and Costs of Fish Welfare Interventions in European Aquaculture (BENEFISH)" at Turku, Finland in April 2008. A full list of discussions and presentations are provided in table 1.

Intellectual property has been identified for the software of the scheme. The IP for this presently resides with SARF, per the contract conditions. SARF have indicated a willingness to transfer the IP for the software to the company set up to administrate and handle data management should the scheme be implemented.

Table 1 Discussions, presentations and published material relevant to the project.

Month 2008	*Presentations or Discussions*	*Location*
April	European bio-economic modelling project	Turku, Finland
May	Chris Hempleman, Derek Ferguson, Lead Developer, Akva (FarmControl)	Maritech, Perth
June	Berrill, I., Kaye, R. & Turnbull, J.F. (2008) Sentinel Farms FinFish News, 6.	Published article
July	Oliver Robinson Managing Director Test Valley Trout Darren Butterworth Trafalgar trout	Test Valley Trout HQ, Hampshire
July	Cefas, FRS, EA, University of Liverpool	University of Stirling
July	John Carmichael of DawnFresh (ScotTrout)	University of Stirling
August	Chris Hempleman, Akva	University of Stirling
August	Chris Hempleman, Akva	Phone
August	BTA AGM	Lechlade
September	John Carmichael, DawnFresh	University of Stirling
September	Nick Read and David Bassett, BTA	Phone and emails
September	Oliver Robinson, Test Valley Trout	Phone
September	Cefas, FRS, EA, University of Liverpool	University of Liverpool
September	European bio-economic modelling project	Amsterdam, Netherlands
October	David Bassett, BTA	University of Stirling
November	Nick Read and David Bassett, BTA	Phone and e-mails
November/December / January 2009	John Carmichael, Dawnfresh/ Oliver Robinson, TVT/ Tim Small, Lechlade	Phone and e-mails
December	Phil Thomas, SSPO	SSPO, Perth
December	FRS	University of Stirling
Month 2009		
January	Phil Thomas, SSPO/David Bassett, BTA	SSPO, Perth
January	Iain Hain, SSPO	Phone
February	Derek Ferguson, Akva	University of Stirling
February	Alan Garratt, ICASS	Perth

Appendices

Appendix I - Web-based applications

Web-based applications are in principle the same as traditional desktop applications such as Microsoft Word, or Excel. However, the user accesses the application via the Internet rather than a user installed program. A web-based application is installed on a web server and is then made accessible to multiple users via a web browser (such Internet Explorer). The application waits for a request from the user via the front-end provided in the form of a web page. The request is then sent to the server application via http (hyper text transfer protocol), it is processed by the application (usually some kind of calculation or data retrieval is performed) and the result of this processing is then sent back to the users machine and displayed in their web browser. An example of popular web applications currently in the public domain are the Google Docs suite of applications, which are provided as a web-based alternative to the Microsoft Office suite. Web Applications will typically employ some kind of data storage system and allow this data to be accessed from any computer, anywhere (for example web mail applications).

Advantages

Web-based applications have become very popular over the last few years. This is because they hold a number of distinct advantages (for both developer and end user) over traditional desktop-based systems.

- Web-based applications are platform independent. They are, in general, available to anyone with a web browser and Internet connection. This is the case whether they own a Linux variant, an Apple Mac, or a Microsoft Windows system. From this point of view, web-based applications are inclusive by nature.
- Web-based applications are easier to maintain. Because only one version of the application exists (located on the web server), updates, bug fixes, and security fixes can all be rolled out rapidly to all users of the system via a single update to the application installed on the server.
- Web-based applications allow easy access/sharing of data. Because the data is located on a single server, the data can be made easily available to any user from any location. A user can access the application (and their data) from someone else's computer on the other side of the world by simply opening the application in their browser and entering their username and password. The user can also make their data available to any other user of the application very easily, with no need to re-upload their data. If it's in the interest of the community, all data can be easily made available to all users of the system in one form or another. All this is achieved without the need to sync multiple data stores.
- The developer has complete control over the performance of the system. Because the developer has control of the technology serving the application, the programmer can build the application in any language s/he pleases and deliver it on any hardware/software s/he deems appropriate. This means there are no problems with system requirements at the client end lower overheads on the users' resources, the burden is passed to the server. It also means the serving machine can be tailored and upgraded depending on the requirements of the application. Indeed all other processes on that machine can be controlled in order to optimise the performance of the main application. Because there is no need to port the application for other platforms, similar, reliable performance can be achieved via a single build for all users. This will all usually result in a more stable and reliable end system.
- A major advantage is the end user cannot compromise a well-built and tested application in any way (for example, by accidentally deleting a required file or by performing an unexpected OS upgrade). The developer has complete control of the system serving the application and if a problem is detected with the performance of the application, a developer can be on hand to deal with it directly at the application layer. Therefore, there is no need for the user to call a central help system to deal with their problems. This, in turn, means that many problems can be dealt with before the majority of users realise they even existed. Therefore administration and service costs are dramatically reduced and a better service provided.

Disadvantages

- Security is a greater concern since all user data is stored on single server, which is directly accessible via the web interface. Web-based applications place more pressure on the developer to produce a more securely designed system. By their very nature, web applications are easier for attackers to find and launch attacks against.
- Web applications can regularly place a heavy load on the server. Busy periods of activity may compromise the service of a web-based application. At worst, the application may be stopped altogether. More regularly, performance will be slow resulting in a less responsive application.
- Traditionally designed web-based applications are less responsive than desktop applications. This is because after every user action, data has to be sent to the server, a response obtained from the server, then sent back again to the end user. Traditionally this requires the loading and reloading of a web page to complete the operation. Therefore, the overheads involved for performing any task are far greater for traditionally designed web applications than for their desktop counter parts resulting in overall slower performance.

- Web applications require a reliable, speedy web connection. In order for the web-based system to be as responsive as a desktop application, it is preferable that all users have a broadband connection to the Internet. This can be restrictive if your user base is one without good Internet connectivity.

However, the impact of the above disadvantages is not as great as first may appear. This is particularly true for the first three issues which can all be addressed and resolved by the development team. By providing adequate server resources, carefully implemented coding practices and designs, and using modern testing technology, none of these issues should be a serious problem. For example, by using more modern development techniques such as AJAX (see below) the burden on the server is dramatically decreased and the application becomes far more responsive. In addition, the problem of slow web connections (final point) is fast becoming a less relevant issue as technology and infrastructure in the United Kingdom continues to improve and expand making fast connections more widely available and affordable. Therefore, the overall feeling within the software industry is that the benefits provided by building a web-based system far outweigh the disadvantages traditionally associated with them.

Appendix II - Open Source

Many of the technologies employed by the Sentinel Farms Project are based on using open source philosophy. Open source is a development method for software that harnesses the power of distributed peer review and transparency of process. The promise of the open source movement is better quality, better reliability, more flexibility, and lower cost. Open source software source code is available under a licence (or arrangement such as the public domain) that permits users to use, change, and improve the software, and to redistribute it in modified or unmodified form. It is often developed in a public, collaborative manner. The benefit of open source development is that participants in such a culture are able to freely modify the collective outcomes and then in turn share them with the community resulting in the production of more stable, flexible and secure applications.

Appendix III - PHP Server Side Programming

PHP was chosen as the language for building the main application layer. PHP is a widely used, general-purpose open-source scripting language that was designed for and, therefore, especially suited to web development and the rapid production of web-based applications. An open source technology, PHP provides a new and efficient set of features that benefit both developer and end-user. A major advantage of using PHP is that a vast number of popular web-based applications, currently freely available for use by the general public, have already been created with this technology. Additionally, there is also a large library of existing functions built into the language that can be employed when building a website. This both saves development time (and therefore cost to the client) and allows the website to benefit from a proven functions. Many popular web applications currently in use are powered by a PHP e.g. Facebook.

Appendix IV - MySql Database

Fundamental to the Sentinel Farms set of tools is a means of capturing and storing the large amounts of data on the server that can then be retrieved both quickly and efficiently. A mySQL powered Database Sever has been chosen for this purpose. MySql Server is currently the most popular open source database server on the web, and has built up a strong reputation for its security, consistent fast performance, and high levels of reliability. It is an industrial power application with the capacity to handle small-scale deeply embedded web applications with a footprint of only 1MB or to run massive data warehouses holding terabytes of information. In addition it is also optimized to run efficiently with PHP scripting.

Appendix V - AJAX

Ajax, or AJAX, (also known as Web 2 technologies) is a web development technique used for creating interactive web applications. The intent is to make web pages feel more responsive by exchanging small amounts of data with the server behind the scenes, in a way that means an entire web page does not have to be reloaded each time the user requests a service. This is intended to increase the web page's interactivity, speed, functionality, and usability. Ajax can be seen as not so much a technology but rather a new way of thinking about the way data is streamed on the internet. Ajax actually employs traditional web technologies (based on open standards) such as xml, css and JavaScript, but employs them in a new way that leaves behind the traditional slow, cumbersome mode of representation that relies on constant page refreshes to produce new information.

Additionally, these new ideas have brought with them a multitude of possibilities for displaying and manipulating data and content that is currently changing the way we think about the web. This includes such things as drag-and-drop.

Ajax is already a standard on the web following its adoption by many of the major players within the industry, particularly Google (gmail, Google Maps), Yahoo (flickr) and Microsoft (Windows Live). Even the smallest amount of Ajax technology can greatly enhance the browsing experience and function of a website without breaking any standards.

Appendix VI User Suggested Amendments To System From Pilot Study

Alternate row colour in tables	New Icons
Finish about pages	Add help videos
Jump to last entry bug on daily data list form	Add farm form shortcuts
Add shortcuts to farm form	Add shortcuts to unit form
Farm form shortcut link - edit farm x / y / z drop down	Unit form shortcut link - edit unit x / y / z drop down
Add daily data form shortcuts	Fix region names
Fix region order	Dashboard - alerts
Dashboard - news	Dashboard - data input short cuts
All units for day view (daily data list form)	Tidy up ajax report summary
Tidy up ajax converter display	Tidy up ajax alerts/info display
Change order of columns in list view	Autofill batch no
Autofill mean weight	Clean up data entry scripts
Add count error ajax info	Fix 'now add units' bug (Richard)
Upload form	Enter data = default page in data section
Fish moved to farm/unit [dropdown] (autofill new Unit)	Graphical representation of fish movements
Set up cron scripts	Flot staggered bars
Fix temperature error handling bug	Add unit name to alerts list
Feature - tool to add accounts with permissions (ie what farms they can see)	Finish - add summaries to reports
Feature - unit/farm deletes active/not active Feature - user settings area	Feature - add compare region mean to reports Feature - upload data form
Bug - speed up weight cron's	

References to published material

9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.

Publication

Berrill, I., Kaye, R. & Turnbull, J.F. (2008) Sentinel Farms FinFish News, 6.