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BENEFISH: A European project to put a cost on fish welfare actions

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Abstract

BENEFISH is a research project funded under the European Commission Sixth Framework initiative. It aims to develop bio-economic models that establish the effects of welfare actions (i.e. measures taken to safeguard welfare) on value chains within the European aquaculture industry, including both production related elements such as growth and feed efficiency, and societal elements such as consumer added value. The project includes wide and integrated scientific competence, which incorporates biological knowledge about fish welfare, industrial knowledge about practical farming, societal knowledge about consumer perception and economical knowledge about bio-economical development. This paper provides an overview of BENEFISH and explains how the project is structured to address its complex multidisciplinary aims. It also outlines how the project consortium plans to achieve its goal of developing bio-economic models relating to fish welfare.

Background

The welfare of farmed fish is currently a prominent issue, which has been the subject of recent review articles (e.g. Ellis *et al*. 2002, Huntingford *et al*. 2006) and a book (Branson 2008). Researchers and the farming industries have expended considerable effort to improve our understanding of the welfare of fish that are reared for human consumption or for recreational activities. Much of the research conducted on farmed fish has focused on functional aspects of welfare, specifically how fish respond to incidences of poor welfare (e.g. Turnbull *et al*. 2005, North *et al*. 2006). In particular, significant research has involved identifying specific, measurable responses to poor welfare that can be used as practical and reliable operational welfare indicators (OWIs) to assess the welfare of farmed fish populations. However, efforts have also been made to understand the ethical issues that surround fish welfare within a farming context (Lund *et al*. 2007).

Unlike some terrestrial farming systems (e.g. broiler farming), the welfare of farmed fish is believed to be positively correlated with productivity. However, despite increasing pressure to protect the welfare of farmed fish, the economic implications of improved fish welfare have not yet been examined. Aquaculture is a young and innovative industry, and it is generally open to new practises if the benefits exceed the costs. Any practical welfare actions will thus be taken up by the aquaculture industry more rapidly if the economical benefits can be demonstrated, and such benefits may include a range of elements, including direct production or added values such as industrial reputation. Previously, the biological and economic implications of changes to current practise in other industries have been examined, for example to quantify the financial effects of management strategies that influence welfare in extensively farmed sheep (Stott *et al*. 2005). However, it is not currently possible to accurately predict the costs and benefits of any change in fish farming practice and sound economic justification for such changes is likely to be influenced by strong moral appeals to increase the standards of fish welfare. An accurate assessment of the financial implications of fish welfare improvements is not without its problems, not least because it involves the merging of various disparate disciplines: fundamental biology, aquaculture, ethics, economics, modelling and marketing. This necessity for expensive and intellectually challenging integration of multidisciplinary expertise has been an obstacle to the development of models which explain the financial and production-based consequences of improved fish welfare. However, in 2007 the EU funded a project bringing together these disciplines to attempt to model the biological and economic effects of improved welfare in farmed fish, throughout production and all the way through the value chain to the consumers. This project is called BENEFISH.

BENEFISH: Introduction

To address the need for a better understanding of the consequences of welfare actions for farmed fish, a multidisciplinary consortium of biologists, aquaculture scientists, market perception specialists, economists and modellers successfully applied for Specific Targeted REsearch Project (STREP) funding under the European Commission Sixth Framework programme. The project, *BENEFISH: evaluation and modelling of BENEfits and costs of FISH welfare actions (referred to as "interventions" in the project proposal) in European aquaculture* runs from 2007 until 2010 and aims to develop a decision tool which will allow the costs and benefits of welfare actions to be estimated throughout the value chain. This paper outlines the aims, structure and scientific approach of the project, reviewing its current progress (as of October 2008) and what further work is to be conducted before the project achieves its goals.

Although ambitious the outputs of this project are both timely and important for the sustainable development of European aquaculture. To improve the chances of success BENEFISH will address three specific aims:

1. To use a set of widely applicable operational welfare indicators (OWIs) to define relationships between selected welfare control measures (i.e. actions) and their consequences for production, product quality and consumer perception.
2. By utilising specific case studies, estimate the costs and benefits associated with potential welfare control measures.
3. To develop a decision analysis tool allowing comparison between various welfare control measures on the basis of their biological and monetary consequences.

To briefly summarise, BENEFISH aims to identify actions which will improve farmed fish welfare. The project will then characterise the effects of those actions on productivity and product values. Finally, these actions and their effects will be used as case studies to develop and test a decision tool for modelling the effects of specific welfare actions throughout the value chain.

The BENEFISH project is only engaged in limited novel data collection. Instead, the project utilises existing datasets for the identification of candidate welfare actions. These datasets have, in most cases, been collected through EU and national funding initiatives, adding considerable value to existing datasets which may have been previously used for only one project or to answer a specific research question. This also allows BENEFISH to investigate the effects of welfare actions on a much broader range of species and rearing systems applicable to European aquaculture than might have been possible if the project relied totally on novel experiments and data collection (see Table 1).

TABLE 1: The range of species and systems to which BENEFISH has access to data.

Species	Originating country of the dataset	Life stage	System type
Atlantic salmon *Salmo salar*	Norway UK	Juvenile, adult	cages, tanks
rainbow trout *Oncorhynchus mykiss*	UK France	Juvenile, adult	cages, ponds, raceways, tanks, RAS*
sea bass *Dicentrarchus labrax*	France	Juvenile, adult	cages, tanks, RAS*
sea bream *Sparus aurata*	France	Juvenile, adult	cages
turbot *Psetta maxima*	Netherlands	Juvenile, adult	RAS*, flow through tanks
sole *Solea solea*	Netherlands	Juvenile, adult	RAS*
brown trout *Salmo trutta*	France	Juvenile, adult	raceways
Arctic charr *Salvelinus alpinus*	France	Juvenile, adult	raceways
brook trout *Salvelinus fontinalis*	France	Juvenile, adult	raceways

* RAS denotes recirculating aquaculture systems

BENEFISH: The structure of the project

The BENEFISH project has three research and technological development blocks (Fig. 1) within which the project partners (Table 2) work on nine specific work packages (WP) (Fig. 1, Table 3).

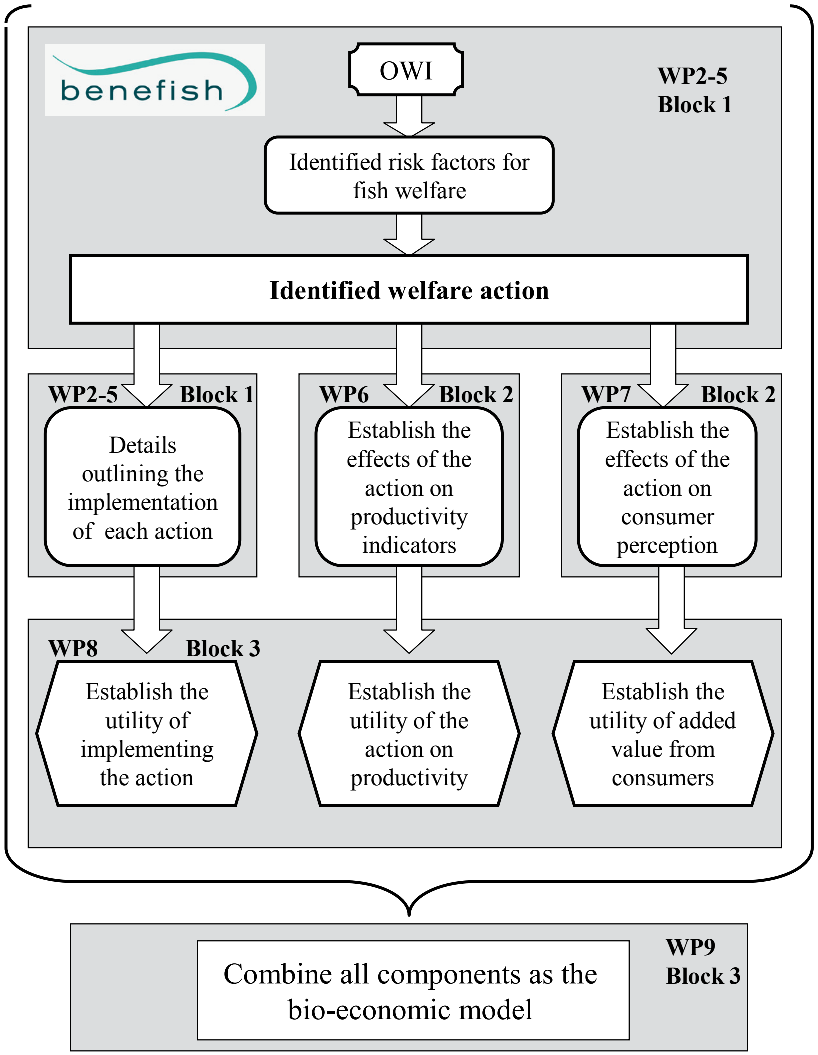

FIG 1: The structure of the bio-economic model which describes the effects of fish welfare actions on the value chain in European farmed fish and how each component of the BENEFISH project contributes to the model.

TABLE 2: The partners/institutions involved in the BENEFISH project.

Project partners	Abbreviated name
Trans-National Consulting Partnership, Germany	TNC
University of Glasgow, UK	UGLA
Nofima, Norway	NOF
University of Stirling, UK	USTIR
Institute of Marine Resource and Ecosystem Studies, Netherlands	IMARES
Finnish Game and Fisheries Research Institute, Finland	FGFRI
Institut Français de Recherche pour l'Exploitation de la Mer, France	IFREMER
National Veterinary Institute, Norway	NVI
Agrotechnology and Food Innovations B. V., Netherlands	AFSG

TABLE 3: The work packages (WP) within the BENEFISH project as well as the work package leaders and contributing partners. See Table 2 for an explanation of the project partner acronyms.

WP	Title	WP Leader	Contributing project partners
1	Project management	TNC	
2	OWI 1: mortalities	USTIR	TNC, NOF, IMARES, IFREMER
3	OWI 2: Fin damage	NOF	TNC, UGLA, USTIR, IFREMER, NVI
4	OWI 3: Deviation from expected feed intake	IMARES	TNC, UGLA, NOF, USTIR, IFREMER
5	OWI 4: Carbon dioxide	NOF	TNC, USTIR, IMARES, IFREMER
6	Productivity modelling	USTIR	TNC, NOF, IMARES, FGFRI, IFREMER
7	Added value/consumer perception	AFSG	TNC, NOF, IMARES, NVI
8	Utility modelling	FGFRI	TNC, AFSG
9	Decision tool development	FGFRI	TNC

Block 1: Welfare actions and indicators

Block 1 has worked to identify welfare actions related to specific OWI's. Biologists and aquaculture experts (Table 2) have investigated existing research and commercial datasets to identify specific risk factors for fish welfare. For example, poor husbandry practises and water quality outside the natural biological tolerance of fish may be considered as risk factors to fish welfare. However, each risk factor used within the project has been identified and characterised within a specific dataset so that the statistical relationships surrounding the risk factor and the OWI can be understood and modelled. For example, low oxygen levels are undoubtedly a risk factor for poor fish welfare, but unless we in BENEFISH characterise how oxygen levels and fish welfare are related to one another within a specific dataset the effects on the value chain cannot be modelled within the project.

Once risk factors were identified, those working in Block 1 established actions to address each risk. The development of actions was not a direct product of data analysis but followed scientific interpretation of the results and consultation with commercial farmers. Block 1 has also established the efficiency with which each action influences welfare. We needed to have data to model how each action affects the risk factor and how that in turn affects welfare (Fig. 1). In the example here we would need to know how an action such as artificial aeration of the water would affect oxygen levels and also how oxygen levels affect fish welfare. Additional data on various sizes of fish, temperature variation, and the effects of feeding rates would also be needed. Whilst there are many indicators of farmed fish welfare BENEFISH has focused on four specific OWI's: mortality, fin damage, deviation from expected feed intake and carbon dioxide (CO_2) levels. These indicators were chosen due to their relevance to the industry, the relative expertise within the consortium and the availability of suitable datasets.

Mortality (Work Package 2)

Work Package 2 (WP2) has been tasked with identifying actions which reduce mortality. The causes of mortalities in farmed fish are numerous and complex, with some mortalities being inevitable as in any population of animals. However, in many cases increases in mortality are a clear indication that welfare has been compromised. Mortalities are a good OWI since many farmers record mortality levels on a regular basis. Therefore, both commercial and research databases had the potential to provide case studies

for inclusion in BENEFISH. One challenge was deciding what could be considered acceptable levels of mortality and what levels should be considered a welfare problem.

Fin damage (Work Package 3)

Damage to the fins can be an indication of various welfare related problems within commercial fish farms, for example aggressive interactions or contact between individuals and other fish, the holding system and farm equipment (Ellis *et al*. 2008). Any damage to fins is a strong visual indication that welfare is being, or has been, compromised. Quantitative measures (e.g. number of fin splits, percentage fin erosion, ranked scoring systems, e.g. Hoyle *et al*. 2007) have been used to assess levels of fish damage. Fin damage has then been used as a variable for identifying risk factors for poor fish welfare in both commercial and research datasets.

Deviation from expected feed intake (Work Package 4)

Maintaining optimal feed rates and maximising conversion efficiencies in farmed fish is vital to the economic viability of commercial farms. Reduced feed intake can occur naturally in fish but may also indicate suboptimal husbandry or environmental conditions which might result in poor welfare. For example, Dutch farmers using recirculating aquaculture systems consider negative deviations (i.e. less feed intake than expected) as a sign that water quality or the system might be compromised. Consequently, deviations from expected feed intake can act as a useful operational welfare indicator. Work Package 4 (WP4) has attempted to identify deviations from expected feed intake and has then identified welfare actions or prevention methods, which might avoid or reduce deviations from normal intake. This data evaluation has been executed for a wide range of freshwater and marine species. WP4 is the only WP which has collected original data through experimental studies using turbot cultured under different management strategies.

CO_2 levels (Work Package 5)

CO_2 is an important water quality parameter for farmed fish, being a metabolic waste product, which is expired by fish through their gills. On commercial farms, high stocking densities and low rates of water exchange, combined with the use of additional aeration and oxygenation, can lead to CO_2 reaching levels which might be harmful to fish. However, CO_2 levels are often not routinely monitored on farms, possibly because of limitations in the methods available for measurement. In BENEFISH, Work Package

5 (WP5) is concerned with investigating the biological consequences of elevated CO_2 levels in four different farmed fish species, produced in either land-based flow through or recirculating systems. Further, we are evaluating the different methods of monitoring CO_2 and possible actions to reduce CO_2 levels in specific rearing systems. WP5 has taken a slightly different approach to the other OWI work packages, as CO_2 is not just an OWI but is also a risk factor for poor welfare and can be targeted directly for specific actions. This is quite different from, for example fin damage where there are a wide range of risk factors that can be targeted for actions. However, fin damage is undoubtedly an indication of poor welfare whereas CO_2 levels are an indirect operational welfare indicator.

Ultimately the goal of Block 1 has been to use existing datasets to identify welfare action case studies that can develop and test the bio-economic model produced in Block 3. A range of specific welfare action case studies have been established by Block 1 and the project partners are now able to investigate how those actions affect productivity and consumer perception.

Block 2: Consequences of welfare indicators in the value chain

Following the identification of welfare case studies within Block 1, BENEFISH is currently working towards characterising the effects of those actions on the value chain. Specifically, this requires an understanding of how each welfare action might affect productivity and also how the resulting improvements in welfare might affect the added value of fish as a consumer product. These two distinct areas are dealt with in Block 2 under two separate work packages.

Productivity (Work Package 6)

Work Package 6 (WP6) involves characterising the effects of welfare actions on productivity but focuses only on biological effects and does not consider any economic effects. Changes to growth, feed conversion efficiency and mortality are used extensively by fish farmers as practical measures of productivity. These are used as indicators of productivity within BENEFISH. Following the identification of welfare actions from Block 1, WP6 will characterise the relationships between those actions, the specific OWI's within Block 1 and each productivity indicator (Fig. 1). Since improved productivity is seen as an influential driver for change in the fish farming industry, welfare actions that do not exhibit a clear effect on productivity will not be

modelled within BENEFISH. This is not to say that those actions are not of importance to fish welfare but since BENEFISH aims to provide case studies to develop and test a bio-economic model there must be clear effects in order to develop an informative model.

Consumer perception and added value (Work Package 7)

Most welfare actions are likely to involve a financial cost implication, for example adding oxygenation to a rearing system will involve the purchase of equipment and oxygen as well as labour to install, operate and service the equipment. Therefore, for producers to invoke a particular welfare action they must see an appropriate return in terms of revenue. Whilst increases in profit can come from direct improvements in productivity (usually due to improvements in the efficacy of production and thereafter savings from inputs as opposed to higher income) (as modelled in WP6), fish that are reared under improved welfare conditions may also command a price premium. Work Package 7 (WP7) is quantifying this added value to provide a complete picture of the potential effects of welfare actions. Understanding how much added value can be gained from a product is complex. WP7 is assessing the effects that both intrinsic (i.e. appearance, taste, shelf life) and extrinsic product qualities (i.e. price, labelling, packaging) have on consumer perception and their willingness to pay more. Both social background and nationality are likely to influence consumers' response to welfare and willingness to pay, this WP will also characterise any such effects. The WP is using traditional questionnaire style approaches, stakeholder exercises (e.g. interviews, focus groups) and alternative approaches (e.g. mock auctions) to assess added value from improved fish welfare. Importantly, this WP is considering both business-to-business and business-to-consumer market routes by which revenue can be gained from changes in welfare. Within Block 2, WP7 will attempt to categorise the scope for improved added value from welfare actions. Specific financial values linked to those changes in consumer perception with then be established in Block 3.

Block 3: Welfare utilities and bio-economic models

Block 3 involves establishing the financial costs and benefits (i.e. utilities) of welfare actions throughout the value chain and also developing the bio-economic decision tool. These components of the project are addressed in WPs 8 and 9 respectively (Fig. 1).

Utilities (Work Package 8)

The previous Blocks and WP's have focused on assessing the effects of welfare actions on biological and productivity-based measures, as well as the response of consumers to those changes. However, they have done so without considering the financial implications of each action. Work Package 8 (WP8) is working towards assigning a financial value to all functions of the value chain characterised in Blocks 1 and 2 (Fig. 1). These financial implications (utilities) include the costs of implementing each welfare action, the effects from increases in productivity and the added revenue that consumers are willing to pay for fish produced under demonstrably better welfare conditions. These financial values are providing direct inputs to test the bio-economic model produced in WP9. The accuracy of the outputs from the bio-economic model are dependant on the accuracy of the financial data collected as well as the accuracy of the biological models that are generated in Blocks 1 and 2, for example those modelling the effects of aeration on growth. Information relating to each welfare action case study includes the direct costs of implementation (e.g. changes to animal purchase costs, changes to feed costs, equipment, staff time) as well as any indirect costs (e.g. interest payable on any loans). Similarly, changes to productivity may incur both direct and indirect costs and these are being characterised. Financial changes due to consumers' willingness to pay may be more difficult to define, since consumer preferences are notoriously fickle. However, BENEFISH is gathering information from a range of sources to support each case study, including literature bases, specific data websites, industry bodies and directly from consumers. Furthermore, the BENEFISH team is continually reviewing the accuracy of the data that is gathered to ensure it, and the model outputs, are up-to-date.

Bio-economic modelling (Work Package 9)

The development of the bio-economic model or decision tool is conducted within Work Package 9 (WP9; Fig. 1). However, to ensure that the model is representative of the aquaculture value chain it is being developed in consultation with all other WP's, which have considerable experience in the aquaculture industries and in consumer responses to welfare. The model is based on influence diagrams solved by Monte Carlo simulations. Specifically, graphical models allow relationships between different model components (for example a productivity indicator and a welfare action) to be described within the decision tool and statistical relationships then allow specific data to be incorporated into the model.

The development of the bio-economic model involves a number of stages. Initially, a general model structure was created by experts in computational modelling. This general structure has been amended through consultation with those working within Blocks 1 and 2 so that it is representative of the aquaculture value chain. Now that the structure of the model is established it is being further adjusted to allow the incorporation of specific aquaculture data. This requires detailed descriptions of the type and availability of welfare action (WP2-5), productivity (WP6) and consumer perception (WP7) data from Blocks 1 and 2 and similar descriptions of the utility (WP8) data from Block 3. These descriptions must include information on the nature of the relationships between different components of the model, for example whether components can be compared proportionally, by a regression equation, or by another mathematical/statistical relationship. This information then feeds directly into the graphical modelling aspect of the decision tool.

The decision tool is able to include both point estimates of parameters (e.g. averages, medians, modes) and variability or uncertainty estimates (e.g. ranges, minimum/maximums, distributions, standard deviations). The uncertainty estimates allow us to quantify how confident we can be of our model output or decisions. It is also possible to evaluate what additional data would result in the greatest reduction in uncertainty and allow the model to produce more reliable decisions.

Following the development and refinement of the model, it will be tested with simulated data. Finally, the model will be applied to, and validated with, the specific welfare action case studies identified in WP's 2–5. This final stage of the project will ensure that the bio-economic model provides a valid predictor for the effects of welfare actions. The final stage will bring together all of the outputs from each WP in BENEFISH and, will set out to prove the concept of the bio-economic model (Fig. 1).

Concluding remarks

BENEFISH is an ambitious project and the first that has aimed to categorise the effects of welfare actions on the value chain in European aquaculture. With increased focus on the welfare of farmed fish it is appropriate to understand the financial consequences of actions which improve fish welfare. Within the boundaries of the BENEFISH project, we cannot aim to provide a tool with which farmers can assess the impacts of potential welfare actions prior to implementation. What the project will provide is a prototype bio-economic model that can inform policy and that may, in the future, be developed into a practical tool for the industry. However, the project has provided a mechanism by which researchers can work together to address complex multidisciplinary problems.

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Further information

BENEFISH: http://www.benefish.eu/
EC Sixth Framework Programme: http://ec.europa.eu/research/fp6/index_en.cfm

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