*The Benefish Consortium 24 month report*

# WP6: Productivity modelling of OWI's and welfare intervention measures.

D6.3: Report on the effects of feed intake on productivity and attributed costs and benefits of welfare interventions

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# Contents

# 1 Introduction

In order to accurately model all costs and benefits associated with welfare interventions for farmed fish it is necessary to establish how any welfare actions affect productivity. Productivity modelling within Benefish has been conducted in WP6 (Block 2).

WP6 aimed to model relationships between welfare interventions, changes in OWI's and measures of productivity. It did so focusing only on the effects which were biological in nature: economic costs and benefits attributed to changes in productivity are addressed in WP8.

WP6 has 4 objectives addressing productivity modelling for each OWI:

1. To relate OWI's to productivity indicators.
2. To determine the relative costs and benefits of interventions to improve welfare on productivity.
3. To explore the relationships between different OWI's, productivity and welfare interventions.
4. To consolidate outputs from WP's 2-5 to facilitate smooth transfer into WP8 & 9.

Objectives 1 to 3 aimed to understand the biological relationships between a) each OWI, b) any welfare interventions linked to that OWI and c) productivity. Objective 4 (which is ongoing) focuses on the transfer of those data and information to Block 3 for bio-economic modelling.

Productivity modelling within WP6 was reliant on the successful completion and transfer of outputs from Block 1 to WP6: it was not until risks to farmed fish welfare for each specific OWI, and interventions to address those risks, had been identified within Block 1 that productivity modelling could commence. Therefore, although WP6 worked within Block 2, considerable interaction between WP6, Block 1 and Block 3 has been necessary throughout the project.

WP6 has focused on the relationships between OWI's, interventions and three commonly used measures of productivity: growth, feed efficiency and survival. Whilst other measures of productivity are available these were considered the most widely-used, practical and appropriate for inclusion in Benefish. Data on growth, feed efficiency and survival are widely available from commercial and experimental datasets, as well as in the literature.
This report details productivity modelling relative to the feed intake OWI (data originating from WP4 in Block 1). Consequently this report serves to address the following deliverable:

*D6.3: Report on the effects of feed intake on productivity and attributed costs and benefits of welfare interventions.*

## 1.1 Feed intake OWI

Commercial fish farmers often state that their fish are doing just fine as they relate the fish feed intake or realized feeding level with their expectations (Vis, Lamboi and Schneider 2008). However, fish feed intake is not necessary stable and might vary due to different reasons. A number of commercial aquaculture species exhibit daily feeding rhythms in food intake and appetite (Noble et al., 2005) and there is variability in daily feed intake between days and groups. Feed intake can be defined as the amount of food an animal actually consumes. Feed intake can be affected by a number of abiotic variables including, but not limited to: changes in the daily light/dark cycle (Boujard and Leatherland, 1992); temperature (Fraser et al., 1993); light intensity (Noble et al., 2005); oxygen levels (Thetmeyer et al., 1999); ammonium concentrations (Beamish and Tandler, 1990); wave action (Bégout Anras, 1995); wind speed, rainfall (Bégout and Lagardère, 1993) and turbidity (Ang and Petrell, 1997). Biotic factors might include: gastric emptying time (Ruohonen et al., 1997); disease or increased parasite loads (Bloch and Larsen, 1993); group size (Boujard, 1995) and intraspecific competition (Brännäs and Alanärä, 1997). Other management variables that might impact upon feed intake can include water refreshment rate of the system, handling, disturbance and system cleaning (Strand et al, 2007 and references therein). These changes in feed intake can either be structural, so a deviation from expected feed intake can be observed over several days or be incidental, as during a meal or during a short period of time. Based on these considerations, it is of scientific and commercial interest to investigate the hypothesis that feed intake is affected by the welfare status of fish. If this can be validated for aquaculture species a simple but effective operational welfare indicator becomes available and the - above named- empirical observations by fish farmers are confirmed. To prove that hypothesis it is necessary not only to investigate data that might be obtained in rather artificial situations in laboratories but as well under commercial conditions. The objective of the present study is therefore to relate deviations in expected feed intake to farm management practices for various species and culture systems.

# 2 Methods

Productivity modelling was conducted only on those datasets from which practical welfare interventions had been identified. Each intervention case study moving into Block 2 for productivity modelling had undergone rigorous screening to ensure suitability for bio-economic modelling. This screening had taken place both within each OWI WP (Block 1) and during the 3rd and 4th Benefish meetings (Turku and Faro). Therefore by the time the intervention case studies were transferred into Block 2 (WP6) it was envisaged that all could progress through to Block 3 for bio-economic modelling.

Modelling to identify relationships between the feed intake OWI (see WP4) and productivity indicators was conducted using different statistical methods that are describe in deliverable 4.1 (Deviation from expected feed intake in relation to farm management at turbot, sole, trout, salmon, seabass farms). Through ongoing discussions between the WP6 leader and Block 3 (Objective 4), FGFRI developed a spreadsheet which outlined indicated all the data requirements for bio-economic modelling. To transfer productivity modelling data to Block 3, WP6 partners completed all relevant components of that spreadsheet. Outputs from WP6 have now been entered onto this spreadsheet and sent for inclusion into the bio-economic model (Block 3).

# 3 Results

## 3.1 Datasets entering WP6 from Block 1.

WP4 (Block 1) identified a list of datasets early in the project and from this list a number of practical welfare intervention case studies were considered for bio-economic modelling. The datasets that were identified by WP4, the risk factors for deviation from expected feed intake and proposed intervention strategies to address those risks are shown in Table 1.

*Table 1. Details of the datasets identified in Block 1, risk factors for deviation from expected feed intake identified from those datasets and proposed welfare interventions to address those risk factors. Commercial (1) or experimental dataset (2)*

| Dataset | Dataset details (species, country, life stage, system) | Risk factors identified | Possible welfare interventions | Proposed welfare interventions for Benefish |
|---|---|---|---|---|
| ba-lab-T° | Juvenile seabass<br>Tanks2 | No risk factors identified | No interventions identified | No practical intervention identified |
| ETHIQUAL | Juvenile seabass<br>Tanks2 | No risk factors identified | No interventions identified | No practical intervention identified |
| FASTIFSH 1 | Juvenile seabass<br>Tanks2 | No risk factors identified | No interventions identified | No practical intervention identified |
| FASTIFSH 2 | Juvenile seabass<br>Tanks2 | No risk factors identified | No interventions identified | No practical intervention identified |
| BC1/ Heritabolum | Juvenile seabass<br>Tanks2 | No risk factors identified | No interventions identified | No practical intervention identified |
| Density 1 | Juvenile & Adult Seabass<br>Tanks2 | No risk factors identified | No interventions identified | No practical intervention identified |
| Density 2 | Junvenile Seabass<br>Tanks2 | No risk factors identified | No interventions identified | No practical intervention identified |
| Hypercarbox | Juvenile seabass<br>Tanks2 | No risk factors identified | No interventions identified | No practical intervention identified |
| Cortisol | Juvenile seabass<br>Tanks2 | No risk factors identified | No interventions identified | No practical intervention identified |
| DEB_SOLE | Dover sole<br>Aquaria2 | No risk factors identified | No interventions identified | No practical intervention identified |
| FT Benefish EXP | Turbot<br>Different Flow through and RAS2 | No risk factors identified | No interventions identified | No practical intervention identified |

| | | | | |
|---|---|---|---|---|
| ZLV Benefish | juvenile/adult turbot<br>RAS1 | No risk factors identified | No interventions identified | No practical intervention identified |
| Solea | juvenile/adult Dover Sole<br>RAS1 | Water quality | Improvement of water quality through ozone and protein skimmer | idem |
| GFI0 | juvenile 0+ Atlantic salmon<br>3 x 12x12x4m Freshwater production cages2 | No risk factors identified | No interventions identified | No practical intervention identified |
| GFI1 | juvenile Atlantic salmon<br>3 x 12x12x4m freshwater production cages 2 | No risk factors identified | No interventions identified | No practical intervention identified |
| LEFI | Atlantic salmon post-smolts<br>5x5x4m marine cage2 | No risk factors identified | No interventions identified | No practical intervention identified |
| RTFI | juvenile rainbow trout<br>3x 200 l RAS tanks2 | No risk factors identified | No interventions identified | No practical intervention identified |
| cagesalmon | Adult atlantic Salmon<br>Cage system1 | No risk factors identified | No interventions identified | No practical intervention identified |
| IPN2002 | Juvenile atlantic Salmon<br>Flow thorugh tank system2 | No risk factors identified | No interventions identified | No practical intervention identified |
| AW1205 | juvenile/adult rainbow trout<br>Freshwater ponds, raceways, tanks and cages1 | No risk factors identified | No interventions identified | No practical intervention identified |
| RTGE | juvenile/adult rainbow trout<br>Freshwater ponds, raceways, tanks and cages1 | No risk factors identified | No interventions identified | No practical intervention identified |

One welfare intervention case studies (solea) relating to deviations from expected feed intake was identified by WP4 (Block 1) as appropriate for bio-economic modelling. These were transferred to Block 2 for productivity modelling.

## 3.2 Productivity modelling

Details of the intervention case study identified and the outputs of productivity modelling are provided below.

## 3.3 Intervention case study: Introduction of ozone and protein skimmer as water treatment units in sole RAS

### 3.3.1 General notes and description of the intervention

Water quality expressed as concentration of suspended solids, turbidity and other parameters can significantly be improved through the use of ozone and protein skimmers. This holds especially in marine recirculation aquaculture systems, where often pristine water quality is required. Sole seems to be sensitive to decreased water quality and reacts to it with decreased feed intake. In addition particles and organic loads that can be removed easily by protein skimming enhanced by ozone, affect nitrification filter performance through shifts in the C:N ratio in the water. This leads again to decreased water quality through increased concentrations of ammonia nitrogen in the water, which impacts the fish again negatively. Low feed intake and in connection with overfeeding then relates to bad water quality in a self enforcing spiral lowering fish performance leading to bad water quality leading to lees feed intake, which results again in lower water quality.

### 3.3.2 Productivity modelling – collated data

Production data was available for analysis from dataset solea (IMARES) as described in detail in deliverable 4.1 and 4.3. The data is based on direct reports from the farm (as this is the only RAS farm for Dover sole worldwide at the time of production). The communicated data was:

Table 1:

| | | | | |
|---|---|---|---|---|
| **Case description report** | "Appendix1: ...." | | **Overall cost structure** | "Appendix1:" |
| | | | | |
| Species | Dover sole | | Ave production farm volume | 100 |
| Production environment | tanks & raceways | | Ave personel in farm | 3 |
| Production type | table production | | Ave producer price | 8 |
| Total market production volume | 100 | tonnes/year | | |
| Of which intervention affects | | % | ***Break-down to cost factors*** | |
| | | | fingerling | 19% |
| Ave, starting weight | 5 | gram | feed | 20% |
| Ave, end weight in period | 250 | gram | other | 31% |
| Ave, Production cycle | 100 | weeks | work | 10% |
| Ave, mortality | 5 | %/totalpieces/period | investment | 10% |
| (Cumulative mort biomass for period) | | %/production volume | capital | 10% |
| Ave. FCR | 1.5 | feedkg/fishkg | profit | |
| | | | | **100%** |

Table 2:

| | | |
|---|---|---|
| **Intervention description report** | "Appendix1: " | |
| **Presumed welfare effect:** | Decreased deviations from expected feed intake | |
| **Intervention:** | Improved water quality | |
| **Intervention efficacy:** | 100% | |
| **Implementation:** | we use protein skimmer and ozone as additional water treatment | |
| ***Option A*** | | |
| ***Option B*** | | |
| ***Option C*** | | |

| **Implementation costs** | | | | | **Uncertainties** | | | %-change in cost factor | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Option A | Option B | Option C | Option A | Option B | Option C | Option A | Option B | Option C |
| ***change in fry costs*** | €/kgfry/year of totals | 0.00 | | | | | | 0.00% | 0.00% | 0.00% |
| ***change in feed costs*** | €/kgfeed/year of totals | 0.00 | | | | | | 0.00% | 0.00% | 0.00% |
| ***change in other costs*** | €/year | 1971 | | | | | | 0.79% | 0.00% | 0.00% |
| ***change in labour costs*** | €/year | 564 | | | | | | 0.71% | 0.00% | 0.00% |
| ***change in investment costs*** | €/year | | | | | | | 0.00% | 0.00% | 0.00% |
| ***change in capital costs*** | €/year | | | | | | | 0.00% | 0.00% | 0.00% |

**Calculation models for cost factors**

| | | |
|---|---|---|
| **Change in fry costs** | 0 | €/kg/year costs |
| Actual change in fry cost | | €/kg |
| Implementation option effectiveness | | annual fry costs |
| **Change in feed costs** | 0 | €/kg/year costs |
| Actual change in feed cost | | €/kg |
| Implementation option effectiveness | 0% | annual feed costs |

Additional cost:
Investment
Capital
Other costs (electricity)

| | | |
|---|---|---|
| **Change in other costs** | 1971 | €/year |
| Energy | 1971 | €/year |
| Vaccination/other medicine | 0 | €/year |
| External services | 0 | €/year |
| Oxygen | 0 | €/year |
| Other | 0 | €/year |

| | | |
|---|---|---|
| Installed power | 1.5 | kW |
| Consumption | 13140 | kWh/year |
| Unit price | 0.15 | E/kWh |
| Total costs | 1971 | Euro/yr |

| | | |
|---|---|---|
| **Change in labour costs** | 564 | €/year |
| Added work activities | 365 | occations/year |
| Time of one occation | 0.1 | hours |

| | | |
|---|---|---|
| **Change in investment costs** | #NAME? | year |
| Value of intervention investment | 10000 | € |
| Write of period/depreciation | 10 | years |
| Old investment resale value | 0 | € |
| Long term rate | 5.00% | |

| | | |
|---|---|---|
| **Change in capital costs** | #NAME? | year |
| Long term capital rate | 5.00% | |
| Value of intervention investment | 10000 | |
| Write of period | 10 | |
| Old investment resale value | 0 | |

Table 3

**Productivity description report**

| | |
|---|---|
| **Effect on growth:** | Better growth due to increased feed intake |
| **Effect on feed efficiency:** | Reduction of feed loss, therefore improved feed efficiency |
| **Effect on survival:** | None |
| **Option A** | Apply protein skimmer and ozone |
| **Option B** | not used |
| **Option C** | not used |

**Productivity factor change**

| | | | | Uncertainties | | |
|---|---|---|---|---|---|---|
| | **Option A** | **Option B** | **Option C** | **Option A** | **Option B** | **Option C** |
| **change in growth** | 5% | | | | | |
| **change in feed efficiency** | 10% | | | | | |
| **change in survival** | 0% | | | | | |

**Change in growth productivity costs**

| | | Option A | Option B | Option C |
|---|---|---|---|---|
| ***change in fry costs*** | €/kgfry/year of totals | 0.00 | 0 | 0 |
| ***change in feed costs*** | €/kgfeed/year of totals | 0.00 | 0 | 0 |
| ***change in other costs*** | €/year | 0 | | |
| ***change in labour costs*** | €/year | 0 | | |
| ***change in investment costs*** | €/year | 0 | | |
| ***change in capital costs*** | €/year | 0 | | |

**Change in feed efficiency productivity costs**

| | | Option A | Option B | Option C |
|---|---|---|---|---|
| ***change in fry costs*** | €/kgfry/year of totals | 0.00 | 0 | 0 |
| ***change in feed costs*** | €/kgfeed/year of totals | 16000 | 0 | 0 |
| ***change in other costs*** | €/year | 0 | | |
| ***change in labour costs*** | €/year | 0 | | |
| ***change in investment costs*** | €/year | 0 | | |
| ***change in capital costs*** | €/year | 0 | | |

# 4 Concluding discussion

Fish feed intake and within limits realized feed load can be related to expected feed intake and therefore translated to deviation of expected feed intake. This can within limits be related to fish welfare, when fish welfare data are measured or established to the observed conditions a-priori. Feed intake might therefore serve as operational welfare indicator on fish farms under certain conditions. It has to be remarked that several datasets which are related back to fish welfare do this based on literature data and circumstantial evidence.

# 5 Outputs

There are no specific other outputs in relation to deliverable 6.3.

# 6 Literature and selected reading


Ang, K.P., Petrell, R.J., 1997. Control of feed dispensation in sea cages using underwater video monitoring: effects on growth and food conversion. Aquacult. Eng. 16, 45–62.

Beamish, F.W.H., Tandler, A., 1990. Ambient ammonia, diet and growth in lake trout. Aquat. Toxicol. 17, 155–156.

Bégout Anras, M.L., 1995. Demand feeding behaviour of sea bass kept in ponds: diel and seasonal patterns, and influences of environmental factors. Aquacult. Int. 3, 186–195.

Bégout, M.L., Lagardère, J.P., 1993. Acoustic telemetry: a new technology to control fish behaviour in culture conditions. In: Barnabé, G., Kestemont, P. (Eds.), Production, Environment and Quality, Bordeaux Aquaculture '92. Ghent, Belgium, EAS Spec. Publ. No. 18, pp. 167–175.

Bloch, B., Larsen, J.L., 1993. An Iridovirus-like agent associated with systemic infection in cultured turbot Scophthalmus maximus fry in Denmark. Dis. Aquat. Organ. 15, 235–240.

Boujard, T., Leatherland, J.F., 1992. Demand feeding behaviour and diel patterns of feeding activity in Oncorhynchus mykiss held under different photoperiod regimes. J. Fish Biol. 40, 535–544.

Boujard, T., 1995. Diel rhythms of feeding activity in the European catfish Silurus glanis. Physiol. Behav. 58, 641–645.

Brännäs E., Alanärä, A., 1997. Is diel dualism in feeding activity influenced by competition between individuals? Can. J. Zool. 75, 661–669.

Di-Poï C., Attia J., Millot S., Bégout M.-L., Schrama J. & Beauchaud M. Analysis of the self-feeding behavior in European sea bass juveniles using X-radiography. J. Fish Biol., submitted.

Fraser, N.H.C., Metcalfe N.B., Thorpe, J.E., 1993. Temperature-dependent switch between diurnal and nocturnal foraging in salmon. P. Roy. Soc. Lond. B. Bio. 252, 135–139.

Millot S., Bégout M.-L., Person-Le Ruyet J., Breuil G., Di-Poï C., Fievet J., Pineau P., Roué M. & Sévère, A. 2008. Feed demand behavior in sea bass juveniles: effects on individual specific growth rate variation and health (inter-individual and inter-group variation). Aquaculture 274 : 87-95.

Millot S. & Bégout M.-L. Feed-demand behavior in sea bass juveniles: influence of individual activity on the group feeding behavior. J. fish Biol. submitted..

Noble, C., Mizusawa, K., Tabata, M., 2005. Does light intensity affect self-feeding and food wastage in group-held rainbow trout and white-spotted charr? J. Fish Biol. 66, 1387–1399.

Ruohonen, K., Grove, D.J., McIlroy, J.T., 1997. The amount of food ingested in a single meal by rainbow trout offered chopped herring, dry and wet diets. J. Fish Biol. 51, 93–105.

Strand, Å., Magnhagen, C., Alanärä, A., 2007. Effects of repeated disturbances on feed intake, growth rates andenergy expenditures of juvenile perch, Perca fluviatilis. Aquaculture 263, 163–168.

Thetmeyer, H., Waller, U., Black, K.D., Inselmann, S., Rosenthal, H., 1999. Growth of European sea bass (Dicentrarchus labrax L.) under hypoxic and oscillating oxygen conditions. Aquaculture 174, 355–367.

# 7 Justification

Rapport C039.09
Project Number: 4304301501

The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of Wageningen IMARES.

Approved: Henk van der Mheen
Head Department of Aquaculture

Signature:

Date: 15 april 2009

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