The Benefish Consortium reporting on WP 4

Data on costs and benefits of the implementation of farm management measures that improves fish welfare

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1 Introduction

Within WP 4 different datasets have been analysed and forwarded to Block 2 of the Benefish project. An overview of the communicated datasets is provided in this deliverable. For an elaborated overview and discussion of the different datasets, please refer to deliverable 4.1 In this study data from a number of intensively farmed species, collected from farms and during experiments were evaluated in order to examine the possibility of using any sub-optimal episodes of feed intake to be used as a relatively instantaneous and inexpensive farm welfare assessment tool and therefore as operational welfare indicator.

2 Individual datasets

In total 21 commercial and experimental datasets have been subjected to this evaluation (Table 1). They were collected by different international partners: Nofima (Norway), University of Glasgow (Scotland), University of Stirling (Scotland), Ifremer (France)and IMARES (The Netherlands). In several cases it was necessary to assume that feed load would equal feed intake, as otherwise no operational data would have been available. Especially in commercially operated farms it is hardly possible to measure feed intake on large scale. Therefore several obtained results on feed intake might be confounded by feed spillage, which was not accounted for.

Table 1: Overview of the evaluated datasets. Commercial (1) or experimental dataset (2)

No	Data set ID	Partner	Species	System type
1	ba-lab-T°	IFREMER	Juvenile seabass	Tanks[2]
2	ETHIQUAL	IFREMER	Juvenile seabass	Tanks[2]
3	FASTIFSH 1	IFREMER	Juvenile seabass	Tanks[2]
4	FASTIFSH 2	IFREMER	Juvenile seabass	Tanks[2]
5	BC1/ Heritabolum	IFREMER	Juvenile seabass	Tanks[2]
6	Density 1	IFREMER	Juvenile & Adult Seabass	Tanks[2]
7	Density 2	IFREMER	Junvenile Seabass	Tanks[2]
8	Hypercarbox	IFREMER	Juvenile seabass	Tanks[2]
9	Cortisol	IFREMER	Juvenile seabass	Tanks[2]
10	DEB_SOLE	IFREMER	Dover sole	Aquaria[2]
11	FT Benefish EXP	IMARES/IFREMER	Turbot	Different Flow through and RAS[2]
12	ZLV Benefish	IMARES/ZLV	juvenile/adult turbot	RAS[1]
13	Solea	IMARES/Solea	juvenile/adult Dover Sole	RAS[1]
14	GFI0	UGLA	juvenile 0+ Atlantic salmon	3 x 12x12x4m Freshwater production cages[2]
15	GFI1	UGLA	juvenile Atlantic salmon	3 x 12x12x4m freshwater production cages [2]
16	LEFI	UGLA	Atlantic salmon post-smolts	5x5x4m marine cage[2]
17	RTFI	UGLA	juvenile rainbow trout	3x 200 l RAS tanks[2]
18	cagesalmon	NOFIMA	Adult atlantic Salmon	Cage system[1]
19	IPN2002	NOFIMA	Juvenile atlantic Salmon	Flow thorugh tank system[2]
20	AW1205	USTIR	juvenile/adult rainbow trout	Freshwater ponds, raceways, tanks and cages[1]
21	RTGE	USTIR	juvenile/adult rainbow trout	Freshwater ponds, raceways, tanks and cages[1]

Each evaluated dataset was obtained during experimental work or from commercial farms under specific conditions. These conditions varied based on species, culture system, experimental layout, farm management and various other parameters.

2.1 ba-lab-T

The temperature experiment was carried out using duplicate groups of 84 fish each (initial weight 82g) held at constant temperature: 13,16,19, 22, 25, 29°C for 84 days (water quality was optimal). They were hand-fed twice a day to apparent satiation and FI was calculated for each meal as feed provided minus feed waste (collected in a waste trap).

2.2 ETHIQUAL 1, ETHIQUAL 2

a) Fish were raised in four experimental tanks, during 217 days, with 50 fish per tank. Each fish was tagged (with PIT-tag) and the fish were fed by self-feeder. The fish that activate the self-feeder was identified thanks to an antenna which red its PIT-tag. During the whole experiment, some fish were periodically removed from the tanks, killed and measured. FI was calculated for each day as feed provided minus feed waste (collected in a waste trap). Morphological and physiological measurement were performed for each fish, at the end of the experiment, all remaining fish were killed and measured. (Millot et al., Aquaculture 2008)

b) Fish were raised in three experimental tanks, during 84 days, with 50 fish per tank. Each fish was tagged (with PIT-tag) and the individual intake was monitored 4 times during the experiment with Ballotini glass bead method. FI was calculated for each day as feed provided minus feed waste (collected in a waste trap). Hence, individual growth and individual feeding have been recorded, which allowed to calculate an individual deviation of feed intake for each fish (Di Poi et al. J. Fish Biol. Submitted).

2.3 FASTFISH 1, FASTFISH 2

c) The 2 tested populations have been hatched and reared at the experimental research station of Ifremer in Palavas-les-Flots (France). The experiment was carried in Ifremer L'Houmeau on juveniles issued from either wild brood fish or a strain selected for growth. The effects on feed demand and feed intake of a standardized acute stress (tank drained and fish out of the water during 1 min) applied 2 times over 112 experimental days were monitored. The experiment was carried out testing each condition with a duplicate per strain (4x60 fish). The 4 tanks (450 l each) were supplied with recirculated seawater. Water temperature was maintained at 20.2 ± 1.5°C, oxygenation above 80 % of saturation in the water-outlet, and salinity was 22.3 ± 3.3 g l-1. At the beginning of the study, fish were 14 months-old, Wild fish weighted an average of 106 ± 3 g and Selected fish an average of 129 ± 4 g. Fish were placed under self-feeding conditions and food access was possible all day (24 h). Apparent feed tank consumption (feed amount dispensed minus wasted pellets counted on the bottom of the tank and in the sediment trap) was monitored daily. Triggering activity recordings were done continuously for 112 days except before (24 h) and during fish handling (8 days off in total). Growth measurements were taken every 3 weeks.

d) The 4 tested populations have been hatched and reared at the experimental research station of Ifremer in Palavas-les-Flots (France). The experiment was carried out in Ifremer Palavas with a triplicate per strain (issued from wild brood, domesticated and 2 strains selected for growth). The effects on feed demand and feed intake of a chronic stress situation (i.e. repeated acute stress) applied randomly over the second half of the experiment were monitored The 12 tanks (1m3 each) were supplied with semi-recirculated seawater. For each tank, the flow rate was 4 m3 h-1 and the water renewal, 30 % per day. Water temperature was maintained at 20.3 ± 1.1°C, oxygenation above 90 % of saturation in the water-outlet, and salinity was 36.3 ± 1.5. The experiment was realized over 91 days with 600 fish (50 fish per tank, 150 fish per strain). At the beginning of the study, fish were 24 months-old, Wild fish weighted an average of 468 ± 7 g , Domestic fish an average of 443 ± 6 g, Massal fish an average of 530 ± 8 g and Prosper fish an average of 523 ± 10 g. Fish were again weighted every 3 weeks. Fish were placed under self-feeding conditions. Apparent feed consumption within each tank (feed amount dispensed minus wasted pellets in the sediment trap) was monitored daily. Triggering activity recordings were done continuously for 77 days except 24 hrs before and during fish handling (8 days off in total).

2.4 BC1 / Heritabolum

The Heritabolum experiment was carried out to study the interaction between genetic x environment using family and individual variabilty (253 families) for SGR, morphometric traits (25), muscular fat content, fillet & carcass yields (7), weight of body compartments (5), sex. Fours groups of 1750 fish were followed during 2 years. They were hand-fed to apparent satiation and FI was calculated as feed provided minus feed waste (collected in a waste trap).

2.5 Density 1, density 2

800 kg of fish were raised in three experimental tanks, during 4 months. 5 modalities of density were tested (20, 40, 70 and 100 kg/m^3) with 3 replicates, which lead to 15 experimental units. Every 3 weeks, some fish were removed to keep the density constant. At the end of the experiment, the fish were killed and biometric and physiologic measurements were performed. The experiment was done twice : first in a flow through system and second in a semi-closed circuit.

2.6 Hypercarbox

Combined effects of hyperoxic and hypercapnic water conditions in seabass. The fish were submitted during 63 days to three levels of hyperoxia conditions associated with hypercapnia (control, medium and high) and were tested in triplicate tanks.

2.7 Cortisol

The experimental design was based on the comparison of effects in fish of three different treatments in duplicate tanks: fish non injected (control or T1), fish injected with implant without cortisol (0 µg hydroxycortisone /g body weight) or T2 and fish injected with cortisol implant (75 µg hydroxycortisone /g body weight) or T3. Two groups of 135-140 fish each were subjected at random at the same treatment in 2 different tanks and were maintained in satisfactory rearing conditions during 42 days. The total number of experimental tanks was 6.

2.8 DEB_SOLE

For this experiment fish (8-10 cm in length) were kept in isolation and under two conditions (1% or 2% ration) in 32 aquaria. Individual feed intake was followed for 90 days by counting uneaten pellets every day (4 hrs after meal distribution). Another batch of fish was left unfed for the same duration. Growth in weight and length was measured every 20 days.

2.9 FT Benefish EXP

As there might be effects of system water refreshment rates on feed intake in fish an long term experiment was set-up for turbot. For this experiment three systems were used. Recircualtion aquaculture system (RAS) 1%, RAS 5% and one flow through system. Each system comprised six culture tanks. The two RAS were designed similarly. The main difference between the two RAS is the refreshment rate of makeup water. Both systems consist of six fish tanks, a drum filter, pumps, a bio filter, six U.V. lights, a oxygenating column per tank and a ceramic oxygen diffuser per
More specific information on system design of the RAS systems and the flow through systems is provided in **Table 2**. In spring 2008 the water refreshment rates have been lowered to increase the potential effect of low water refreshment rates as result on feed intake and fish growth.

Table 2: system dimensions and characteristics of the three used cultured systems, 2 RAS and one flow through system

	RAS 1%	RAS 5%	Flow through
Total system volume (m^3)	25.69	24.53	16.8
Tank volume (m^3)	2.75	3.00	2.80
Tank surface area (m^2)	5.3	5.3	5.3
Tank flow rate (m^3/h)	2.27	3.00	2.24
Tank hydraulic retention time (tankvolume/h)	1	1	0.8
Averaged system refreshment rate (m^3/kg feed)	1.4	5.0	71
Averaged system refreshment rate (% of total volume/h)	0.9	3.8	80
Volume biofilter (m^3)	3.87	3.87	-
Drum filter mesh size (μm)	30	30	-
U.V. (W)	450	450	-

The flow through system had a water refreshment rate of 100 m^3/kg feed/day . This means no water was re-used, but all water was discharged after passing the tanks. This system lacks logically all water purifying components. Similar to the RAS the six tanks of the flow through system had their own oxygenating column and ceramic oxygen diffuser. In the present experiment, turbot, *Psetta maxima,* was stocked in the culture systems. There were two fish size groups stocked for the experiment: smaller and bigger fish. The small fish had an average weight of 400g (+/- 145g) and the large fish an average weight of 900g (+/- 217g). In all three systems there were three tanks with bigger fish and three tanks with smaller fish. The bigger and the smaller fish were divided into three groups; small, medium and large. Fish were fed with Turbot Label Rouge (floating) from Le Gouessant. The fish were fed by hand by meals (ad libitum).

2.10 ZLV Benefish

Growth and feed load data from a commercial turbot farm in The Netherlands were evaluated for deviations from expected feed intake. This farm has collected several data on fish growth, water quality and incidents over a period of several years.

2.11 Solea

Data from a commercial Dover sole farm in The Netherlands was evaluated based on datasets derived from their farm management base. Due to commercial sensitivities the access to the dataset was limited. Data was evaluated on tank level. Different time series over 1-3 years on weekly basis have been made available by the farm management. These data include information on number of fish, mean weights, feed load and management intervention (sorting, add on grading, harvest, etc.).

2.12 GFIO

Dataset GFIO investigated the impact of environmental variables upon deviations from expected feed intake in Atlantic salmon parr, using 0+ fish subjected to 24h light during the final stage of their freshwater phase. Three cages of parr (n = 61847 ± 2620 fish group^{-1}) were held in 12 x 12 x 4m production cages for 64 days. Fish were fed on-demand throughout the light phase using commercial AQ1 on-demand feeders. Potential factors affecting feed intake included: husbandry interventions such as weight sampling during 23rd – 26th August (n = 300 fish sample^{-1}), 28th – 30th September (n = 400 fish sample^{-1}) and 25th – 26th October (n = 500 fish sample^{-1}). Days where there were additional husbandry interventions (such as disease treatment), and the introduction of 24h light (day 55) were also noted. Environmental variables including daily water temperature, clarity, average daily windspeed (used as a proxy for wind driven water currents at the site), daylength, change in daylength were also measured.

2.13 GFI1

Dataset GFI1 on cage-held juvenile Atlantic salmon fed on-demand was evaluated for deviations from expected feed intake over a period of ca. 9 months.

2.14 LEFI

Dataset LEFI investigated the relationship between episodes of sub-optimal feed intake and husbandry incidents/interventions, biotic and abiotic factors in cage-held (n =1) Atlantic salmon post-smolts fed on-demand for 88 days. Potential factors affecting feed intake included: husbandry interventions such as weight sampling the fish on days 29, 57 and 88 (n = 100 fish sample^{-1}). Environmental variables including daily water temperature, clarity, average daily windspeed (used as a proxy for wind driven water currents at the site), rainfall, salinity, tidal range, daylength, change in daylength were also measured.

2.15 RTFI

Dataset RTFI investigated the relationship between episodes of sub-optimal feed intake and husbandry incidents/interventions, biotic and abiotic factors in tank-held rainbow trout (n = 15 fish tank^{-1}) fed on-demand using self-feeding systems for 62 days. Potential factors affecting feed intake included husbandry interventions such as weight sampling the fish on days 1, 30 and 62. The days where dead fish were removed from tanks by netting were also noted. Water quality parameters (nitrite, ammonia, pH and temperature) were monitored daily at 10.00h. An additional husbandry intervention (a 1ppm 8h Cu_2SO_4 treatment for an outbreak of white-spot) was also carried out on day 22.

2.16 Cagesalmon

The in this study used cages were 90 metres in diameter and 20 metres deep. Individually moored cages (e.g. not compact type of farm). The farm is located in Northern-Norway, in a relatively narrow sound, with dominating south-west water current direction. Surface water was more wind driven and the north-east direction dominates. The typical water current speed was between 5 and 10 cm sek^{-1}, thus not high but very homogenous the upper 45 metres. A small vertical water current of approximately 2 cm sek^{-1} also contribute to the water exchange. Despite that the location had a peak load of more than 3000 tonnes of salmon during the summer in question; there was no sign of aggregation of waste under the cages (surveyed by independent company). Water temperature declined from 10ºC (August) to7ºC (November), and the oxygen levels in the cages fell from 100% saturation (July) to 85% saturation (Agust) during the trial. The environmental conditions (water temperature, salinity, oxygen level and water currents) were regarded as good throughout the whole period. The site is regarded as relatively good for cage salmon farming. The fish were divided into two replicate groups (2 cages holding 48000 salmon each). One group was fed according to appetite between 7 am and 4 pm (cage 2 and 4; farm protocol), whereas the other was fed according to appetite during light hours (cage 1 and 3). Appetite was assessed using submerged cameras and the stop signal for feeding was according to the farms protocol in both groups. The fish were size graded and weighed (subsample) at the start of the experiment. The experiment was terminated at slaughter, providing a full record of individual fish sizes (slaughter weight, gutted head on). In addition, subsamples of 20 fish per cage were collected to check for round weight and weight loss during slaughter. Changes in body weight were assessed on a daily basis using biomass estimators. These calculate fish weight based on fish length and volume measurements (Storvik Biomass Estimators). Feed data was collected routinely by the farm operators, and the project had access to their data.

2.17 IPN2002

Dataset IPN2002 investigated the effect of three different levels of CO_2 upon the growth, mortality, feed intake and seawater performance of tank-held Atlantic salmon pre-smolts during the parr-smolt transformation. Additional water quality and physiological variables were also measured. 12 groups of 0+ pre-smolts (n = 320 fish tank^{-1}), were held in 500 l tanks at a stocking density of ca. 33-37 kg m^{-3} and specific water flow was high (1.3 l kg^{-1}min^{-1}), similar amongst all tanks. Different levels of CO_2 were tested in a 4 x 3 experimental design and treatments were subject to either 1) control: 5.4 mg l^{-1} CO_2, pH 6.63; 2) 12.7 mg l^{-1} CO_2, pH 6.21; 3) 17.6 mg l^{-1}

CO_2, pH 6.04; 4) 27.3 mg l^{-1} CO_2, pH 5.84. Growth performance (SGR) was measured on days 21, 42 and 84. Mortality was also tracked throughout the study and feed intake was recorded every third day throughout the experimental period.

2.18 AW1205

Dataset AW1205 was collected as part of a large epidemiological study investigating the effects of water quality on the welfare of farmed rainbow trout in the UK. The study involved collecting water quality, biological (morphological and physiological measures from fish) and farm (including feed - FCR) data from a large number of rainbow trout farms during both the summer and winter. The farms visited represented a significant proportion of the UK trout farming industry.

2.19 RTGE

Dataset RTGE was collected as part of a study investigating rainbow trout gastroenteritis (RTGE) in the UK. Biological data was collected from a large number of UK trout farms with husbandry and management (including feed) data collated from farm records and downloaded from farm management software (i.e. FarmControl and Djournal).

2.20 Communicated datasets towards Block 4

One dataset was identified as feasible to serve in Block 2: Solea. Generated data was collected in the provided spreadsheet and forwarded. The communicated data were

Table 1:

Case description report	"Appendix1: ...."	
Species	Dover sole	
Production environment	tanks & raceways	
Production type	table production	
Total market production volume	100	tonnes/year
Of which intervention affects		%
Ave, starting weight	5	gram
Ave, end weight in period	250	gram
Ave, Production cycle	100	weeks
Ave, mortality	5	%/totalpieces/period
(Cumulative mort biomass for period)		%/production volume
Ave. FCR	1.5	feedkg/fishkg

Overall cost structure	"Appendix1:"
Ave production farm volume	100
Ave personel in farm	3
Ave producer price	8
Break-down to cost factors	
fingerling	19%
feed	20%
other	31%
work	10%
investment	10%
capital	10%
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
Change in other costs	1971	€/year

Additional cost:

Investment

Capital

Other costs (electricity)

Energy	1971	€/year		Installed power	1.5	kW
Vaccination/other medicine	0	€/year		Consumption	13140	kWh/year
External services	0	€/year		Unit price	0.15	E/kWh
Oxygen	0	€/year		Total costs	1971	Euro/yr
Other	0	€/year				

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		

Justification

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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:

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