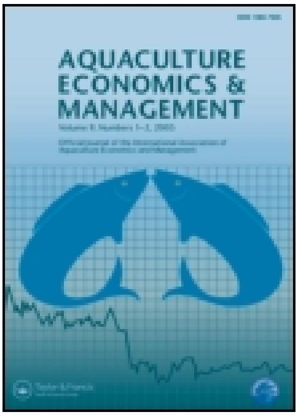

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WELFARE INTERVENTIONS IN FLATFISH RECIRCULATION AQUACULTURE SYSTEMS AND THEIR ECONOMICAL IMPLICATIONS

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SHORT COMMUNICATION

WELFARE INTERVENTIONS IN FLATFISH RECIRCULATION AQUACULTURE SYSTEMS AND THEIR ECONOMICAL IMPLICATIONS

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INTRODUCTION

Flatfish culture in re-use or recirculation aquaculture systems (RAS) is a relatively young production sector and is hardly practiced on commercial scale (Blancheton, 2000; Labatut & Olivares, 2004; Martins et al., 2005b; Schneider & Verreth, 2008). There are only few land-based farms in The Netherlands, France, Spain and Scandinavia producing several hundreds of tons of turbot, sole, halibut or other flatfish species. Only three Dutch farms are practising true turbot and sole RAS culture using water refreshment rates of less than ~500 l/kg feed (industry data; Blancheton et al., 2010; Martins et al., 2005a). Despite the low production at present, RAS have according to the European Commission and based on literature a high potential to provide future finfish production in a more sustainable manner (Blancheton et al., 2009; European Commission, 2009; Losordo 1998a, 1998b; Martins et al., 2005b; Schneider et al., 2006). However, next to the frequently quoted RAS advantages over flow through and cage systems, there are some issues potentially affecting RAS operation and viability.

These issues include relatively high cost price through operational costs and high up-front investment, issues in water quality and water treatment management and maintenance, fish performance and growth retardation, product quality and consumer acceptance. Some of these issues are directly or indirectly affecting fish welfare. Water quality and its management have a

The economic data are presented as Euros, where 1 Euros = 1.32172 USD on 5/3/2012.

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direct effect on fish. Fish metabolites are several times more, e.g., up to 150 times for smolts (Sindilariu & Brinker, 2009), concentrated in RAS than in flow through systems.

Water quality management plays a more important role in RAS, than in systems with higher water exchange rates, such as cages or flow through systems. If water quality decreases, through e.g., inappropriate removal of particulate substances e.g., expressed as COD (chemical oxygen demand), increase of ammonia (total ammonia nitrogen, TAN) and nitrite through insufficient or incomplete nitrification, or increase of carbon dioxide concentrations or decreased oxygen levels then fish welfare and performance are potentially impaired (Foss et al., 2007; Schram et al., 2009; Singh et al., 1999; Summerfelt et al., 2000).

Such impaired welfare might express itself through, parameters directly related to fish performance such as lower growth rates, higher mortalities and lower feed intake. The present study relates management and management interventions, such as improving water quality and fish welfare directly with economical implications, as management interventions impact on the cost price structure.

This short communication focuses therefore on two water quality management interventions in flatfish RAS improving water quality and fish welfare and the resulting bio-economical changes in the cost price structure. These changes might result in improved profit for the farm as expenses might be counterbalanced by increased growth rates, better FCR (feed conversion ratio) and other utilities. The first intervention focuses on the improvement of water quality through the integration of an additional treatment component into a sole RAS. The second intervention is the improvement of water quality by providing an increased specific flow rate in turbot RAS.

METHODOLOGY

In this study the effects of two management interventions on fish performance in flatfish RAS were studied: water quality improvement through extended water treatment in a sole RAS and the effect of an increased specific flow rate on turbot, as cultured in a RAS. The interventions are based on literature and farm data sets (Schneider et al., 2009a, 2009b; Schram et al. 2009). To evaluate the economical effect of the interventions a bio-economical decision tool (Kankainen et al., 2012a, 2012b) was used.

Using this model, it was estimated how changes in fish performance and welfare through improved water quality management impact fish cost price and market position. The model uses utilities that are categorized as intervention, implementation, bio-economical productivity factors, supply chain utilities and aspects concerning welfare monitoring.

The assumptions used in decision tool are listed by intervention measure (Appendix table). The methodology of the model is presented elsewhere in full detail (Kankainen et al., 2012a, 2012b). The management interventions are implemented by either using a protein skimmer including ozone application to improve water quality for sole or by increasing the specific flow rate through the tanks up to a maximum of five volume exchanges per hour as described in literature (Schram et al., 2009). For these two measures effects on fish growth were estimated using farm and literature data from related experiments (Schneider et al., 2009a, 2009b; Schram et al., 2009).

For the first measure historical farm data from a commercial sole farm was sourced and a relation between sole specific growth rates and water quality was established using regression analysis (Schneider et al., 2009b). Different time series over 1–3 years on weekly basis were available. These data include information on number of fish, mean weights, feed load and management intervention (sorting, add on grading, harvest, etc.). Based on data from literature and the famer's judgment an expected feed load was established. This feed load could then be compared to the realized feed load. These data were then subsequently translated into deviations from expected feed intake in percentage over time ranging for 80% of the data sets in values below expected feed intake. Here the expectations were not met by about 20–30% (commercial data reported in Schneider et al., 2009b).

Several (water) parameters were related with the observed deviations, such as pH, turbidity, mortality. For example, higher particle load is in RAS often related with increased populations of heterotrophic bacteria utilizing this organic load. This impairs fish welfare and health due to oxygen depletion from the water and by the general interaction of a high bacterial load including pathogenic bacteria and fish. Based on the present farm data, it was concluded that decreased water quality (higher organic load) relates to lower feed intake rates and fish welfare status.

The present basic RAS design of the sole farm comprises a mechanical filtration unit, drum filter, and a trickling filter for nitrification. Furthermore the water is treated with UV light. Water quality is always multi-factorial in RAS, e.g., nitrification influences pH, TAN, NO_2 and NO_3 concentrations, filtration influences, COD loads, which influence oxygen consumption etc. Therefore, the chosen intervention, a protein skimmer with ozone application, would influence several aspects of water quality: turbidity, COD, oxygen, TAN, bacteria counts and many more (Brazil et al., 1996; Summerfelt & Hochheimer, 1997). The improvement in fish performance could only be estimated based on studies showing fish in optimal conditions during experiments (Ende et al., 2009b; Schram et al., 2006).

Additional costs of monitoring were estimated based on experiences with comparable installations in other RAS farms. An effect on mortality was not estimated as results would be purely speculative. The experimental results were extrapolated to farm level and the additional requirements for installations estimated. The related productivity gains were for growth 5% and improved FCR 10% based on performance differences. In sole, growth and feed intake are linearly related (own data). Considering the negative deviations from expected feed intake presented in Figure 1 a growth improvement of 5% is a conservative estimation.

This is furthermore supported by the comparison between experimental data and farm data, showing specific growth rates 10–20% higher under optimized conditions using more sophisticated water treatment installations (Ende et al., 2009a, own data and commercial data,). A predicted improvement of 10% for FCR is argued by less basic metabolism due to better fish growth efficiency in more optimized conditions. About 20% of feed intake is directed to basic metabolism for this specific diet under optimal experimental conditions (Ende et al., 2009a). Less feed spill, although better feed intake rates will also lower practical FCRs on the farm. A predicted improvement of 10% FCR is rather conservative.

The second intervention, increase of specific flow rates is based on the finding that turbot specific growth rate increases when held at higher specific flow rates Schram et al. (2009). This increased flow rate led to lower CO_2 concentration will have improved the micro-climate around the flatfish, e.g., oxygen supply. These improvements are related directly to a better welfare of the animal. The experimental result was extrapolated to the entire production cycle at farm level and the additional requirements for installations estimated. For the turbot the intervention would gain 20% in fish growth as demonstrated in Schram et al. (2009).

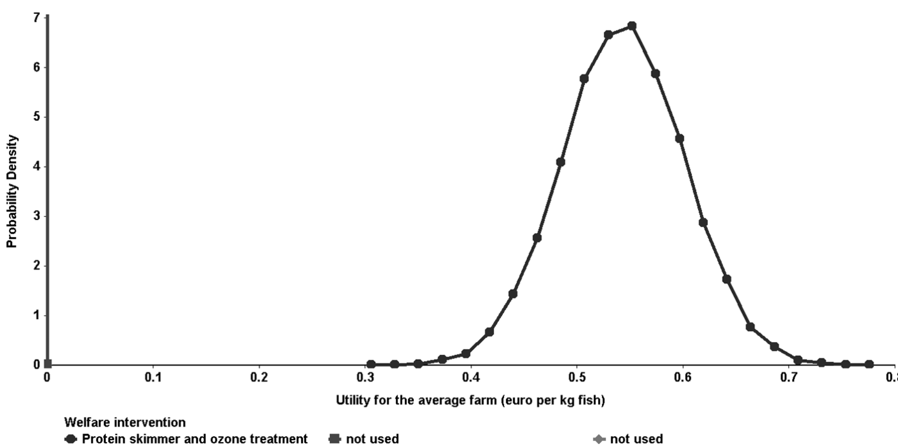

FIGURE 1 Utility costs for the implementation of a protein skimmer into a RAS farm, based on the bio-economical model of Kankainen et al., 2012a, 2012b) and the model input data referred in the appendix.

Here, increasing flow rates through the tank lead to a significant higher specific growth rate in turbot (initial weight 100 g, with a SGR of 0.96 for one volume rate/h, 199%/d for 4 volumes/h 1.27%/d for 8 volume rates/h). In that study there was no significant difference anymore detected between 4 till 8 refreshment rates. In a commercial farm evaluated data sets of 3 years showed growth rates of about 1%/d for comparable size range of fish using as well about 1 volume rate/h). The estimated improvement in 20% derived from the experiment is therefore appropriate and conservative considering the achieved improvement of 30%. Improved FCR and survival are not included in the model. It is expected that those parameters will improve along with improved growth rate.

RESULTS

The bio-economical model (Kankainen et al., 2012a; Kankainen et al., 2012b) estimated subsequently the effect of the intervention on the cost price and related this to a potential willingness of the consumer to pay 15% more for a product that is cultured under conditions, ensuring a higher welfare of the animal in comparison to its normal market price. About 20% of this premium is arriving at the farm gate. The used initial values are presented in the appendix.

For the first intervention, incorporation of a protein skimmer in an existing sole RAS, the utility values were estimated (Figure 1). The utility value refers to the additional costs, savings and increased income achieved from categorized utility factors (Figure 2). Figure 3 shows, how the intervention implementation effects to RAS cost factors. Figure 4 illustrates

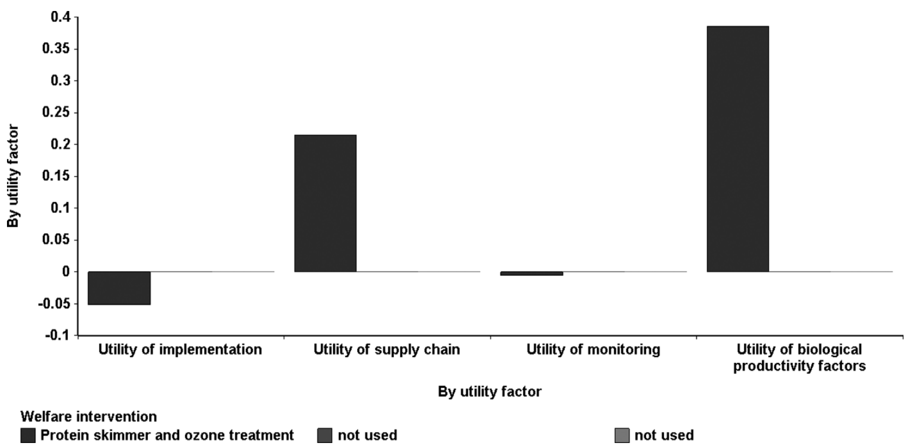

FIGURE 2 Utility costs per category for the implementation of a protein skimmer into a RAS farm, based on the bio-economical model of Kankainen et al., 2012a, 2012b) and the model input data referred in the appendix.

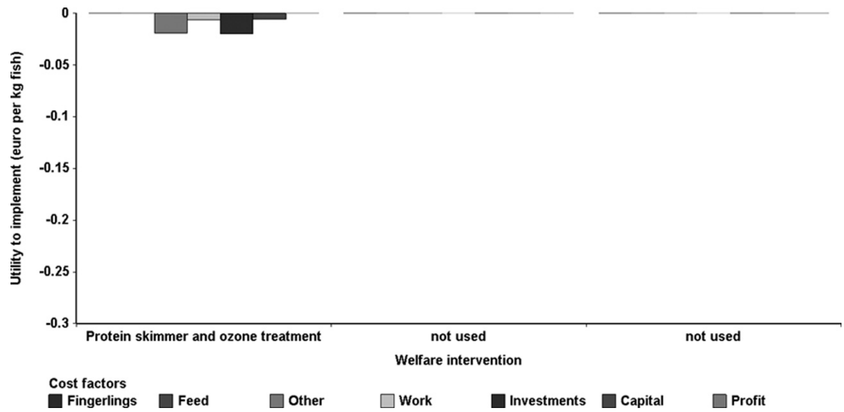

FIGURE 3 Intervention implementation effects on costs, based on the bio-economical model of Kankainen et al. (2012a, 2012b) and the model input data referred in the appendix.

how the growth and FCR affect savings and Figure 5, the potential benefit and related marketing costs from consumer and supply chain, respectively.

Similarly, as calculated for sole and the first intervention the effects of the second intervention have been calculated for turbot. Here the specific flow rate through the tanks was increased either to five times (5 V/h, option 1), 80% (4 V/h) of that increase and 50% (2.5 V/h) of that increase. This change impacted the utilities and the overall profit (Figures 6–11).

The results for the first intervention indicate that it would be beneficial for the sole farming situation to integrate protein skimmers with ozone in the overall operation. The integration will result in an overall increase in profit of above 0.5€ ($0.66) for the average utility, +0.2 from consumer,

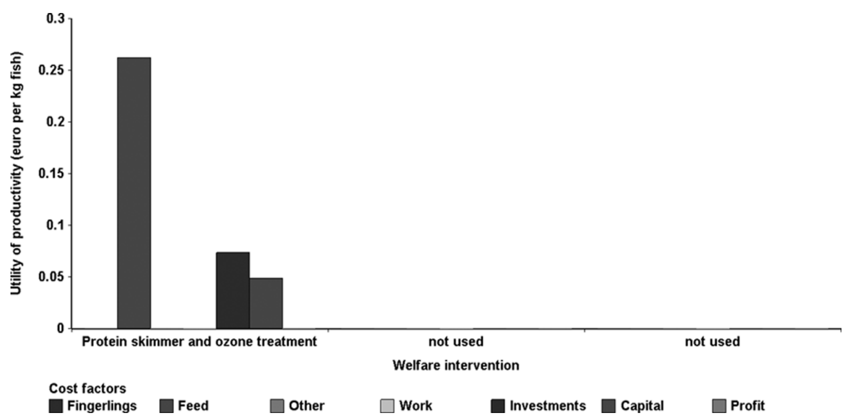

FIGURE 4 Effect of improved growth and FCR on the utilities, based on the bio-economical model of Kankainen et al. (2012a, 2012b) and the model input data referred in the appendix.

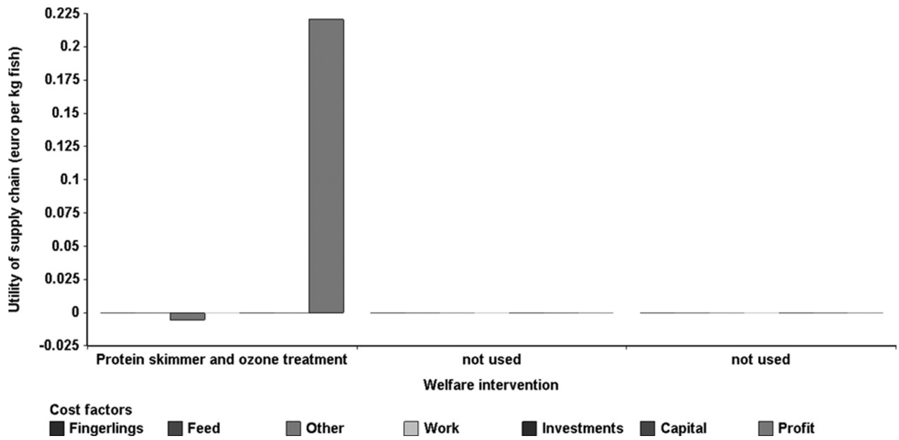

FIGURE 5 Effect of the utility supply chain, based on the bio-economical model of Kankainen et al., 2012a, 2012b) and the model input data referred in the appendix.

+0.35 from growth and FCR, -0.05 from investment utilities (Figure 2). This is in accordance with results presented on ozone use in other RAS installations, predicting higher productivity (Brazil et al., 1996; Bullock et al., 1997; Summerfelt et al., 1997; Summerfelt & Hochheimer, 1997).

In the present calculation the costs for investment and additional electricity consumption were rather small compared to increased productivity (10% growth rate and 5% FCR). However, data needs to be verified on farm scale to judge the overall validity of the model. Recent farm designs, as practiced in the Netherlands for turbot using protein skimmers and ozone, indicate a positive economical effect based on improved fish performance

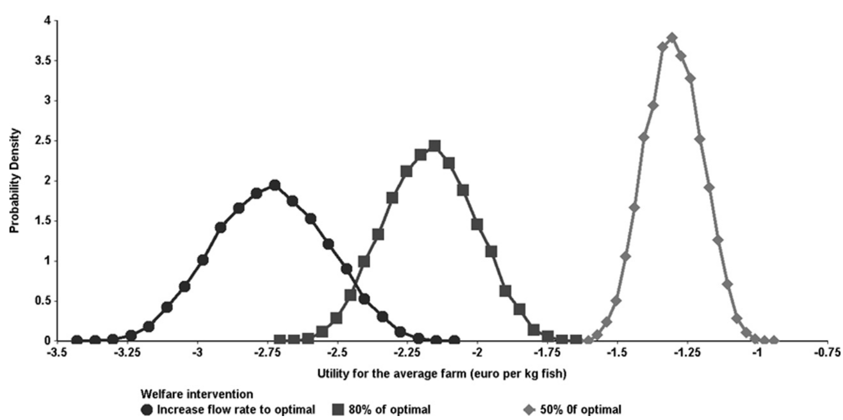

FIGURE 6 Utility costs for the implementation of increased flow rates in a RAS farm, based on the bio-economical model of Kankainen et al. (2012a, 2012b) and the model input data referred in the appendix.

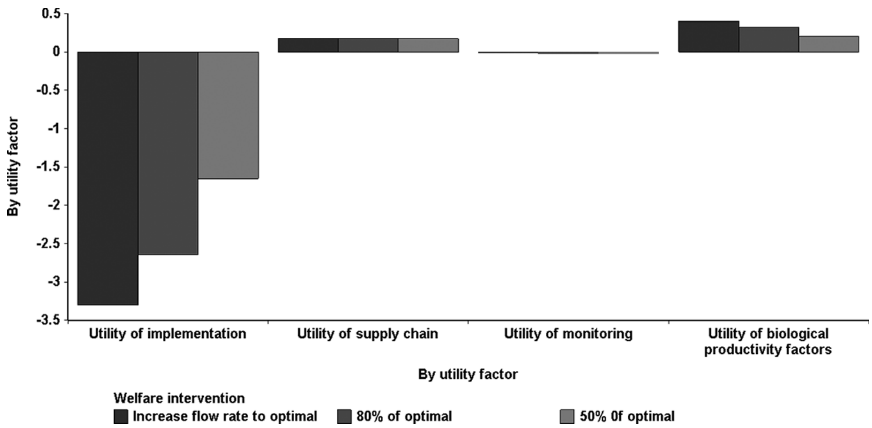

FIGURE 7 Effects on the different utility factors based on increased flow rates in a turbot RAS farm, based on the bio-economical model of Kankainen et al. (2012a, 2012b) and the model input data referred in the appendix.

(personal communications, 2008). Further validation will be needed to assess the economical consequences in sole farming further.

For turbot, no net profit increase was estimated. On the contrary higher running and up-front costs result in higher production costs. This in return leads to negative results based on cost price and market price, even if fish could be sold at a higher price based on a premium for welfare and improved husbandry and even though fish performance was increased significantly with 20%. These calculations indicate that interventions such as increase in flow rate are positively impacting on fish growth but not in terms of economical viability.

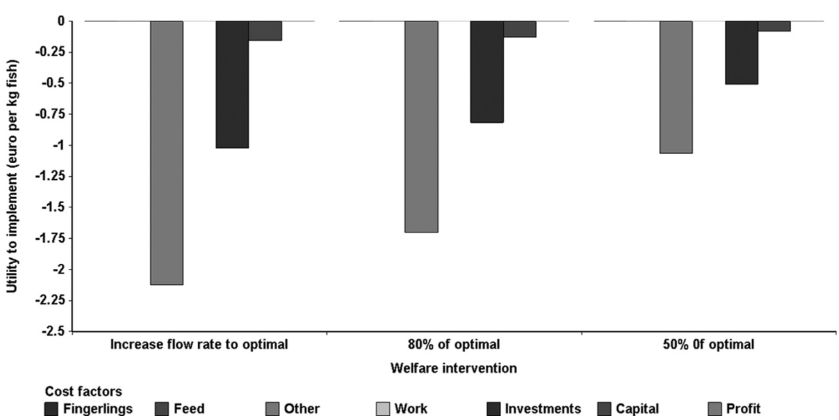

FIGURE 8 Effects on the different utility factors for the implementation of increased flow rates in a turbot RAS farm, based on the bio-economical model of Kankainen et al. (2012a, 2012b) and the model input data referred in the appendix.

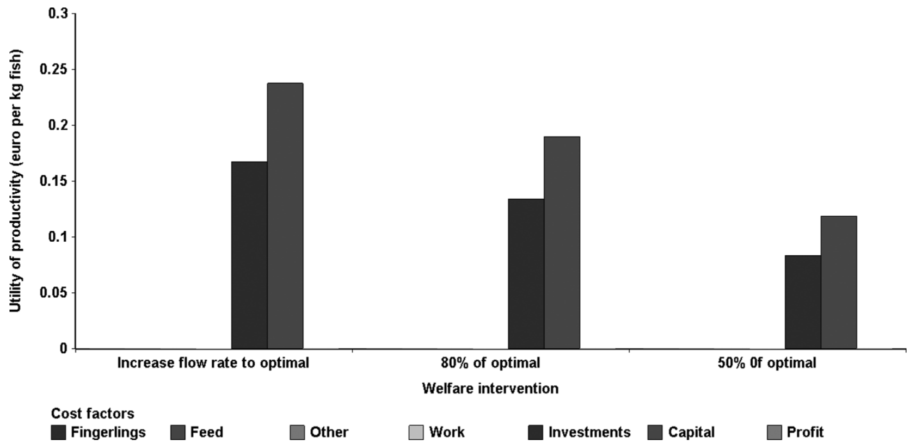

FIGURE 9 Effects on the different utility factors on productivity based on increased flow rates in a turbot RAS farm, based on the bio-economical model of Kankainen et al. (2012a, 2012b) and the model input data referred in the appendix.

Other welfare interventions might here be more effective such as the integration of other water treatment methods (carbon dioxide stripping or solid management or e.g., the use of tanks with less volume and therefore shorter hydraulic retention time by similar flows). The intervention was based on lab-scale experiments. A validation of the model on farm scale is still pending. First results of commercial farms with increased flow rates are supporting the findings presented here (Industry Communication, 2009).

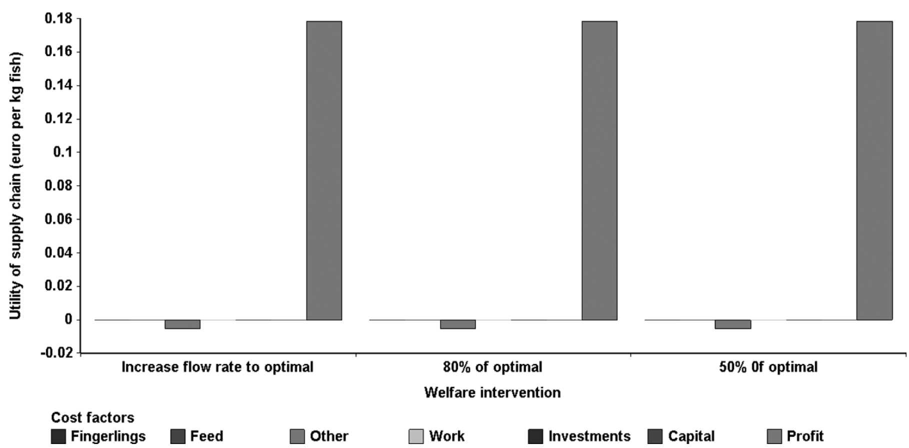

FIGURE 10 Effects on the different utility factors on the supply chain based on increased flow rates in a turbot RAS farm, based on the bio-economical model of Kankainen et al. (2012a, 2012b) and the model input data referred in the appendix.

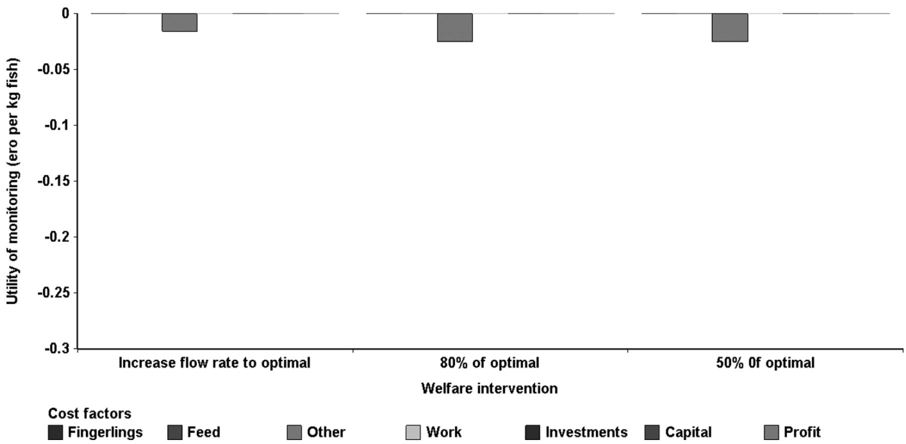

FIGURE 11 Effects on the different utility factors on the monitoring costs based on increased flow rates in a turbot RAS farm, based on the bio-economical model of Kankainen et al. (2012a, 2012b) and the model input data referred in the appendix.

CONCLUSIONS

In conclusion, management interventions, such as improvement of water treatment installations or the increase in flow rates can relate to improved flatfish performance in marine flatfish RAS. The implementation and operational costs, however, can outweigh the improved fish performance and the economical viability of the intervention has to be questioned as in the turbot case. In the sole case, a simple investment in a protein skimmer will lead to increased profit, next to an increased fish performance and due to better water quality improved fish welfare.

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APPENDIX

Model Data Used for the Intervention on the Sole Farm Using the Model (Kankainen et al., 2012a, 2012b)

Name of Input	Value/Averages Option 1	Unit	Uncertainty*	Year of the Data	Variability Estimate	Source Reference
System description						
Production volume	100	Tons				Model input
Volume affected by welfare intervention	100	%/of total				Model Input
Ave, starting weight	5	gram		2008/2009	C&R	Farm data
Ave, end weight in period	290	gram		2008/2009	C&R	Farm data
Ave, Production cycle	100	weeks		2008/2009	C&R	Farm data
Ave, mortality	5	%/total pieces/period		2008/2009	C	Farm data
(Cumulative mort biomass for period)		%/production volume				
Ave. FCR	1.25	Feed kg/fish kg		2008/2009	C&R	Farm data
System economy						
Producer price	10.5	€/kg		2008/2009	C	Farm data
Cost/benefit factor share of producer price						
Fingerlings	20	%		2008/2009	C	Farm data
Feed	25	%		2008/2009	C	Farm data
Other	29	%		2008/2009	C	Farm data
Work	10	%		2008/2009	C	Farm data
Investments	15	%		2008/2009	C	Farm data
Capital	10	%		2008/2009	C	Farm data
Profit	0	%		2008/2009	C	Farm data
Welfare intervention effects						

Costs for implementation for average company						
Investments	2000	€/year	+−20%	2008/2009	E&C	Commercial offer
Change in capital costs	2804	€/year	+−20%	2008/2009	E&C	Commercial offer
Added work	705	€/year	+−20%	2008/2009	E	
Electricity	1971	€/year	+−20%	2008/2009	E&C	Commercial offer
Intervention efficacy	100	%				
Utility for productivity factors						
Growth effect	5	%	SD20%		E	Unpub. data
Feed effect	10	%	SD20%		E	Unpub. data
Survival effect	0	%	SD20%		E	Unpub. Data
Monitoring effects						
Annual monitoring costs	0.25	€/kg			E	Unpub. Data
Monitoring method implementation share	0	%			E	Unpub. Data
Supervising costs	435	€/year	SD15%		E	Unpub. Data
Company's share of supervising expenses	100	%			E	Unpub. Data
Supply Chain Effects						
Processing premium	0	%			E	
of which targeted to case	0	%			E	
Consumer premium	15	%	SD10%		R	Olesen et al., 2010
of which targeted to case	20	%			E	
Change in total demand	0	%			E	
Changed share of welfare labeled product	70	%units			E	
Marketing expenses	0.0077	€/kg			E	
of which are targeted to case	100	%			E	

Data based on industry input and experimental results. Options 1: Protein skimmer and ozone treatment. *Uncertainty is determined according to quality of reference. R = Research data; C = Commercial sources; E = Expert opinion.

Model Data Used for the Intervention on the Turbot Farm Using the Model (Kankainen et al., 2012a, 2012b)

Name of Input	Value/ Averages	Unit	Uncertainty*	Year of the Data	Variability Estimate	Source Reference
System description						
Production volume	300	Tons				Model Input
Volume affected by welfare intervention	100	%/of total				Model Input
Ave, starting weight	17.5	gram		2008/2009	C&R	Farm Data & GRRAS Project
Ave, end weight in period	1200	gram		2008/2009	C&R	Farm Data & GRRAS Project
Ave, Production cycle	104	weeks		2008/2009	C&R	Farm Data & GRRAS Project
Ave, mortality	15	%/total pieces/ period		2008/2009	C&R	Farm Data & GRRAS Project
(Cumulative mortality biomass for period)		%/production volume		2008/2009	C&R	Farm Data & GRRAS Project
Ave. FCR	1.3	Feed kg/fish kg		2008/2009	C&R	Farm Data & GRRAS Project
System economy						
Producer price	8.5	€/kg		2008/2009	C&R	Farm Data & GRRAS Project
Cost/ benefit factor share of producer price						
Fingerlings	13	%		2008/2009	C&R	Farm Data & GRRAS Project
Feed	20	%		2008/2009	C&R	Farm Data & GRRAS Project
Other	25	%		2008/2009	C&R	Farm Data & GRRAS Project
Work	13	%		2008/2009	C&R	Farm Data & GRRAS Project
Investments	12	%		2008/2009	C&R	Farm Data & GRRAS Project
Capital	17	%		2008/2009	C&R	Farm Data & GRRAS Project
Profit	0	%		2008/2009	C&R	Farm Data & GRRAS Project
Welfare intervention effects						
Costs for implementation for average company						

Investments	306000	€/year	+−20%	2008/2009	C&R	Commercial offer
Change in capital costs	47391	€/year	+−20%	2008/2009	C&R	Commercial offer
Electricity and other operating expenses	637500	€/year	+−20%	2008/2009	C&R	Commercial offer
Intervention efficacy	100	%		2008/2009	E	
Utility for productivity factors						
Growth effect	20	%	SD20%		E	
Feed effect	0	%			E	
Survival effect	0	%			E	
Monitoring effects						
Annual monitoring costs	0	€/kg			E	
Monitoring method implementation share	0	%			E	
Supervising costs	435	€/year	SD15%		E	
Companys share of supervising expenses	100	%			E	
Supply Chain effects						
Processing premium	0	%			E	
of which targeted to case	0	%			E	
Consumer premium	15	%	SD10%		R	Olesen et al. 2010
of which targeted to case	20	%			E	
Change in total demand	0	%			E	
Changed share of welfare labeled product	70	%units			E	
Marketing expenses	0.0077	€/kg	+−15%		E	
of which targeted to case	100	%			E	

Options 1: Optimize water quality (5 times faster); Option 2: 80% of optimal; Option 3: 50% of optimal, *Uncertainty is determined according to quality of reference; Data based on industry input and experimental results. R = Research data; C = Commercial sources; E = Expert opinion. The GRRAS Project is a Project in the framework Research for Benefit for SME of the EU, whose reports are not public.