AQUA EXCEL 2020

AQUAculture infrastructures for EXCELlence in European fish research towards 2020 — AQUAEXCEL2020

Deliverable D5.3 First prototype model on water quality and water temperature for experimental facilities

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Executive Summary

Objectives:
The purpose of this document is to describe the functionality and technical implementation of the water quality model. This numerical model prototype is one of the main components in the AQUAEXCEL2020 virtual laboratory, which will be developed in WP5: "Virtual laboratories and modelling tools for designing experiments in aquaculture research facilities".

The main components are:

- Task 5.1; Growth, nutrition and waste production models for different fish species
- Task 5.2; Water quality and water treatment modelling
- Task 5.3; Modelling of hydrodynamic flow fields in tanks and cages

The objective of this sub-model is to develop a generic tool that enables a user of a research facility to predict the water quality in an existing research infrastructure prior to the start of an experiment and to (re-)design a system which results in the desired water quality for the experiment envisioned. The tools will enable teaching of TNA users, research infrastructure technicians and others involved in the principles of water quality control in fish culture units. The model uses input on waste production from task 5.1 as a starting point. Since the hydraulic conditions at tank level are a determinant for water quality, input from task 5.3 will also be used.

Rationale:
One of the main research activities in AQUAEXCEL2020 is to develop a virtual laboratory system that enables virtual experiments in aquaculture research facilities. This system will feature a framework that allows the integration of mathematical models of different subsystems in common simulations, replicating the system operation of research laboratories.

Main Results:
The water quality prototype model is developed and tested, and it is shown that this model component can be integrated with the other main components, coming from task 5.1 and 5.3. The model describes flow schemes and experimental set-ups, and covers relevant conditions such as load of fish/feed, system type, plug-flow/mixed-flow and treatment systems.
Additional parameters that influence the water quality are yet to be incorporated in a later version of the model, such as temperature.

Authors/Teams involved:
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1. BACKGROUND

This document is part of the AQUAEXCEL2020, WP5/Joint Research Activity 1 – Virtual laboratories and modelling tools for designing experiments in aquaculture research facilities.

Experiments with fish usually involve extensive use of laboratory facilities and run for long periods of time. Both from an ethical perspective (3R's) and from a cost perspective, tools for design and planning of experiments are increasingly important. In aquaculture research as well as other domains, numerical models are increasingly used preparatory to the actual experiments.

One of the main research activities in AQUAEXCEL2020 is to develop a virtual laboratory system that enables virtual experiments in aquaculture research facilities. This system will feature a framework (see Bjørnson et al., 2016) that allows the integration of mathematical models of different subsystems in common simulations, replicating the system operation of research laboratories. The overall system architecture is shown in Figure 1.

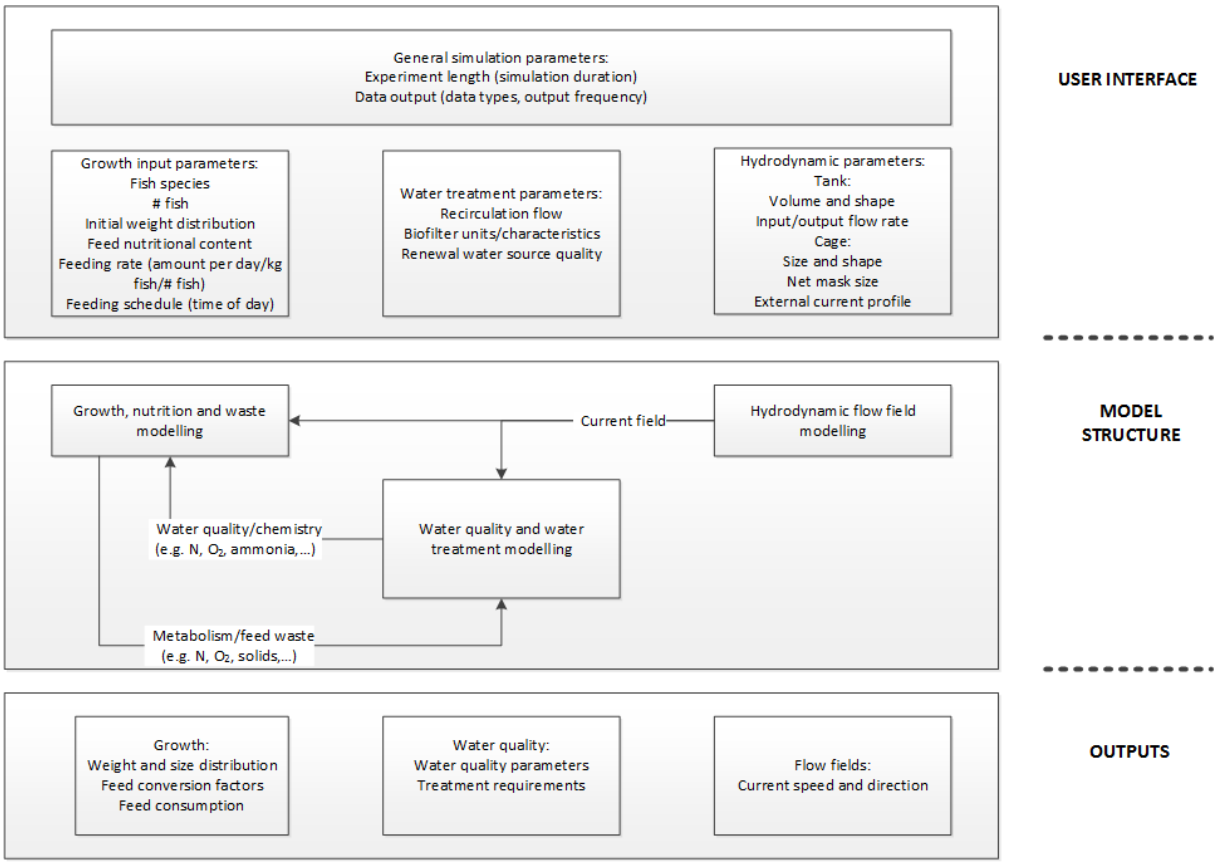

Figure 1. Virtual laboratory system architecture

This document describes the technical implementation and functionality of the water quality model.

2. MODEL DESCRIPTION

The water quality prototype model is developed and tested, and it is shown that this model component can be integrated with the other main components, coming from task 5.1 and 5.3. The model describes flow schemes and experimental set-ups, and covers relevant conditions such as load of fish/feed, seawater/freshwater, system type, life stage of the fish, plug-flow/mixed-flow and treatment systems. The sub-model is designed in Excel and works with input parameters that are based on the production plan and the experimental design, coming either from task 5.1, and/or should be known by the user in advance. The model output describes the (maximum) stocking density and feed load throughout the experiment based on the given input parameters.

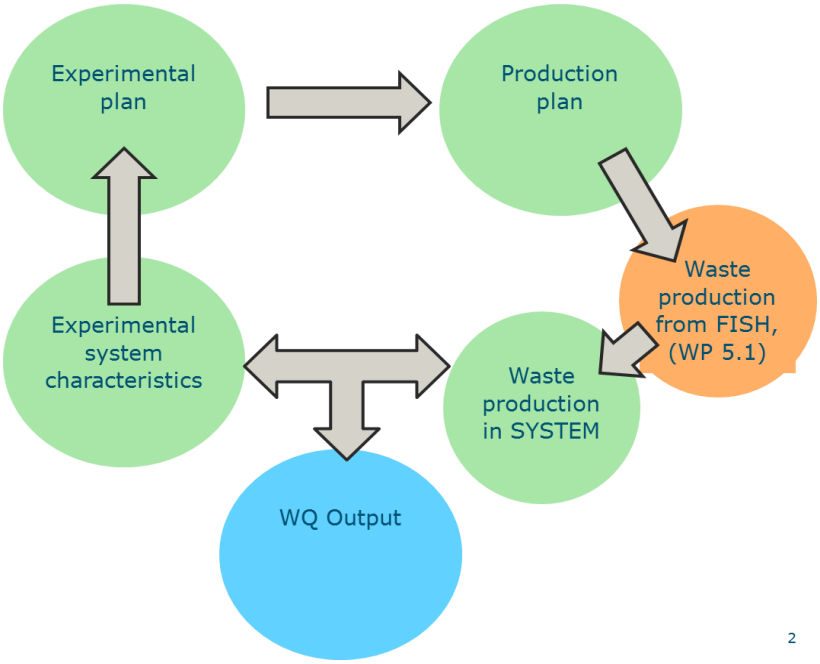

Figure 2. The main components of the model, with the input parameters; the experimental plan, production plan, waste production of the fish and the system, and the experimental system characteristics, leading to a water quality output as a result.

Model input from the production plan:

Ammonia production	g N/kg feed
SGR	%/d
FCR	
Initial weight	g
Initial number of fish	
Mortality	%/d
Oxygen consumption	g/kg feed

Model input from the system:

[oxygen] tank in	(mg/L)
Tank volume	L
Total system volume	L
Recirculation flow rate Qr	L/d
System exchange flow rate Qex	L/d

Total flow rate Qr + Qex	L/d
Biofilter water volume	L
Biofilter media volume	L
Total biofilter volume	L
Filling percentage	%
Specific surface area	m2/m3
Biofilter area	m2
Ammonia conc. System renewal water	(mg N/L)
Nitrate conc. System renewal water	(mg N/L)

Model output:

Stocking density	kg/m3
Max fish density	kg/m3
Max. feed load	g/d
Max feed load to BF	kg/m3

The model output results in a water quality for the most crucial parameters ammonia and nitrate in the system (tanks and filters). The time interval in the model is set at hours, to allow for diurnal variation.
The model calculates values for each time point for ammonia production by the fish, nitrification rate, nitrification capacity, ammonia load to the biofilter, ammonia removal rate, ammonia concentration in the water, nitrate production, nitrate in the tanks.

Future Refinement
The current version translates the main components of the model (Figure 2) into a prototype that models ammonia and nitrate. Further refinements of the model include the oxygen consumption by bacteria in the system, and the background NO_2 production during the activation of the bio filter before the actual experiment starts, using non experimental fish at a low density and low feed load.
Additional parameters that will be studied and incorporated into the model where possible towards the final version, are temperature and total soluble solids.

Parameters used in the calculations:

Time	(hr)
Time	(day)
Dt	(day)
Individual weight	(g)
Feed load per fish	(g/dt)
# fish	
Total feed load	(kg/dt)
Ammonia production fish	(mg N/dt)
Nitrification rate	(g N/m2/d)
Nitrification capacity	(mg N/dt)
Ammonia load to the biofilter	(mg N/dt)
Ammonia removal filter	(mg N/dt)
Ammonia present in biofilter	(mg)
Ammonia biofilter in	(mg)
[Ammonia] in bioreactor	(mg/L)

N present in tank	(mg)
Ammonia tank in	(mg)
[ammonia] tank out	(mg/L)
[ammonia] bioreactor	(mg/L)
[ammonia] tank in	(mg/L)
Nitrate production	(g N/dt)
Nitrate system	(mg/L)
Fish density	(kg/m3)

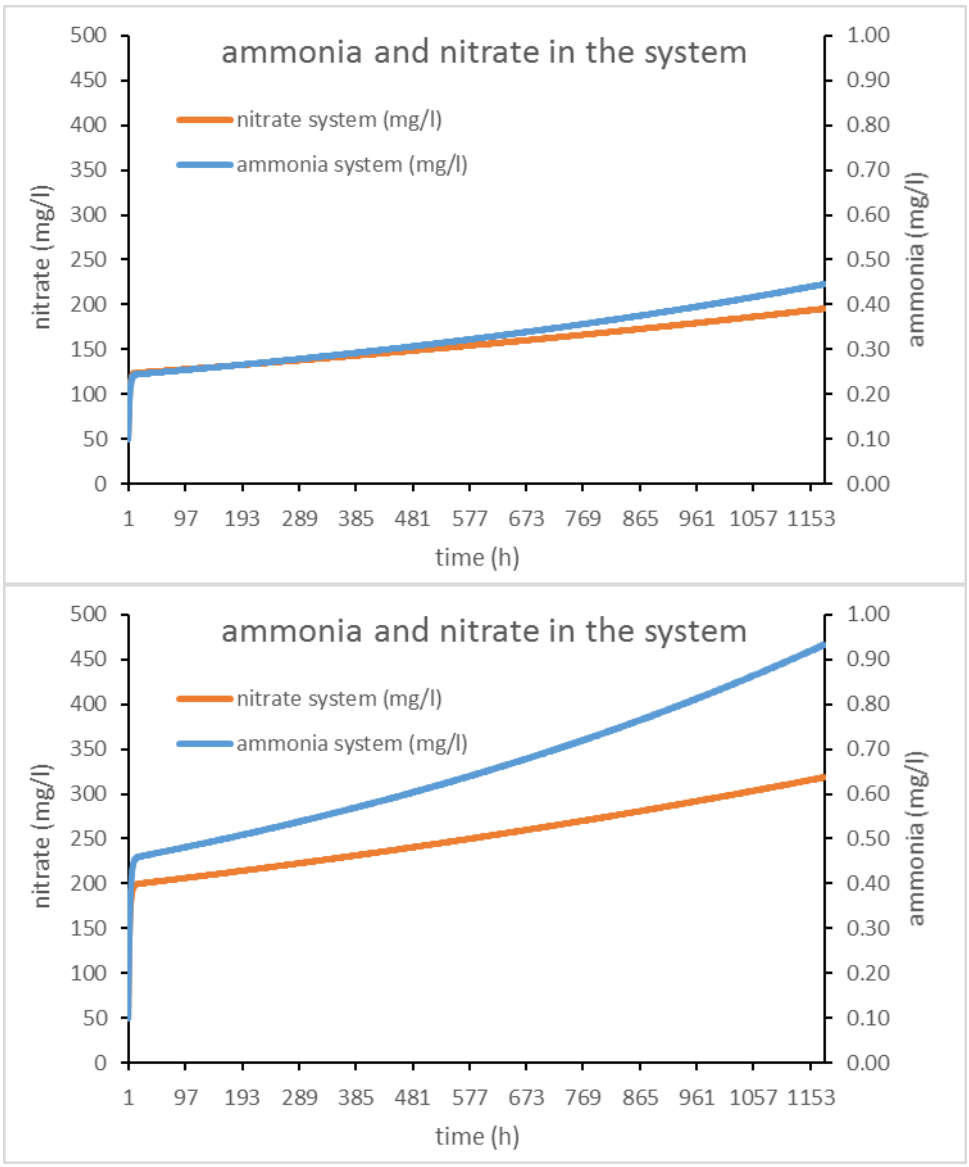

Figure. 3. Example of the results for ammonia and nitrate as a function of time. Both figures show ammonia and nitrate levels in a given system during an experimental period of 48 days. The difference between the two figures is the input parameter FCR in the model; 0.9 (top) and 1.5 (bottom). In the prototype model, the levels at the start of the experiment for ammonia and nitrate are set at zero. Further refinements towards the final model will provide for background start levels (t = -xx hours) for nitrogenous waste products.

References

Bjørnson, F. O. et al.: *D5.1 Model development guidelines*, AQUAEXCEL[2020] Report

Document information

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		CO Confidential, restricted under conditions set out in Model Grant Agreement			
		CI Classified, information as referred to in Commission Decision 2001/844/EC.			

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dd/mm/yyyy			Ex: first version/first review by WP leader etc/accepted version

Annex 1: Check list

Deliverable Check list (to be checked by the “Deliverable leader”)

	Check list		Comments
BEFORE	I have checked the due date and have planned completion in due time		*Please inform Management Team of any foreseen delays*
	The title corresponds to the title in the DOW		*If not please inform the Management Team with justification*
	The dissemination level corresponds to that indicated in the DOW		
	The contributors (authors) correspond to those indicated in the DOW		
	The Table of Contents has been validated with the Activity Leader		*Please validate the Table of Content with your Activity Leader before drafting the deliverable*
	I am using the AQUAEXCEL^{2020} deliverable template (title page, styles etc)		*Available in “Useful Documents” on the collaborative workspace*
The draft is ready			
AFTER	I have written a good summary at the beginning of the Deliverable		*A 1-2 pages maximum summary is mandatory (not formal but really informative on the content of the Deliverable)*
	The deliverable has been reviewed by all contributors (authors)		*Make sure all contributors have reviewed and approved the final version of the deliverable. You should leave sufficient time for this validation.*
	I have done a spell check and had the English verified		
	I have sent the final version to the WP Leader, to the 2nd Reviewer and to the Project coordinator (cc to the project manager) for approval		*Send the final draft to your WPLeader, the 2nd Reviewer and the coordinator with cc to the project manager on the 1st day of the due month and leave 2 weeks for feedback. Inform the reviewers of the changes (if any) you have made to address their comments. Once validated by the 2 reviewers and the coordinator, send the final version to the Project Manager who will then submit it to the EC.*