This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773330

GAIN

Green Aquaculture Intensification in Europe
Grant Agreement Number 773330

GAIN D6.6

Industry focused website built on AquaSense engine, with a rich UI/UX

Due date of deliverable: 31/10/2021
Actual submission date: 31/10/2021

Lead beneficiary: Longline Environment Limited (LLE)
Authors: Ferreira, J.G.; Pastres, R; Royer, E., Fernandes, A., Lencart-Silva, J., Lima, A., Lopes, A.
WP 6 – Dissemination, Exploitation, and Communication
Task 6.4 – Broadening Industry Connections
Sub-task 6.4.1 - Exploitation of the Information Management System (IMS)

Dissemination Level:		
PU	Public	Y

Document log

Version	Date	Comments	Author(s)
V1	25/10/2021	First draft	Lopes, A., Lencart, J., Lima, A.
V2	27/10/2021	V2	Ferreira, J.G., Pastres, R., Royer, E.

Recommended Citation
Ferreira, J.G.; Pastres, R; Royer, E., Fernandes, A., Lencart-Silva, J., Lima, A., Lopes, A. "Industry focused website built on AquaSense engine, with a rich UI/UX" - Deliverable 7.1 GAIN - Green Aquaculture INtensification in Europe. EU Horizon 2020 project grant nº. 773330. 17 pp.

The project has received funding from the European Union's Horizon 2020 Framework Research and Innovation Programme under GA n. 773330

Table of Contents

The project has received funding from the European Union's Horizon 2020 Framework Research and Innovation Programme under GA n. 773330

Summary

GAIN is an EU-funded research project that brings together partners from academia, industry and associations with the primary aim of supporting ecological intensification of aquaculture in the European Union (EU) and the European Economic Area (EEA). The core focus of GAIN is to increase production and competitiveness of the industry, while ensuring sustainability and compliance with EU regulations on food safety and the environment.

One of GAIN's ambitions was the development of precision aquaculture tools for management of shellfish and finfish farms. In order to implement these tools in the EU, they need to be able to bridge not only the technology gap that exists in some aquaculture sectors, characterized by small-scale farms, but also the reduced financial investment characteristics of these stakeholders.

The text below provides details on the industry-facing tools developed in GAIN for precision aquaculture. These build on the concepts and scientific and technical work developed in WP1 and WP4, outlined in D1.8 and D4.7. The deliverables themselves are the customer-facing tools, but in the sections below on AquaSense and AQUARADAR, we show examples of output screens and discuss some of the information that can be gleaned from these, wherever relevant highlighting the practical use to the industry.

As explained in D4.7 with respect to the data and security models adopted for AquaSense, the platform has a built-in role called *Curator*, which allows a third party to review the application, run a model, and browse the various different screens accessible to industry users.

The client-facing part of AQUARADAR was designed with one specific target user in mind, so it does not use or require a data security model with distinct user roles, or user and password credentials. The AQUARADAR platform was designed for a member of the Affiliate Farm Programme (AFP) and can easily be cloned for other target users. Security features will be added as necessary in the GAIN legacy programme.

Both applications add considerable value to the exploitation of GAIN results in the topic of Precision Aquaculture, and have a high (8-9) Technology Readiness Level.

The project has received funding from the European Union's Horizon 2020 Framework Research and Innovation Programme under GA n. 773330

General introduction

The Information Management System described in Work Package 1, Deliverable 1.8, is at the core of subsequent technical work developed in Work Package 4 and described in deliverable 4.7. The final element of this framework is the client-facing part of the development work and is briefly described in this report for Deliverable 6.6.

The typology of the deliverable itself (see GAIN Amended Project Document, reference AMD-773330-16) is: *websites, patents filing, etc*, but nevertheless the consortium opted to provide supporting information to contextualise the customer-facing development for two tools, which are the actual products for this Work Package task.

In the report for D 4.7, we highlighted the following four characteristics as essential for a successful industry-facing product:

1. Deployment of sensors that supply environmental data on drivers of growth, welfare, disease, and mortality;
2. Detection of measurable response metrics from cultivated species—growth and mortality rates are the most significant;
3. Coupling and interpretation of these input and response data in order to obtain quasi- or real-time information on the cultivation process;
4. Integrated platforms where industry stakeholders can easily access, process, and make use of data and information.

The first three aspects are reviewed in D4.7, with additional materials presented in the report for D6.8, Evaluation of the Affiliate Farm Programme (AFP), particularly with respect to the AquaPrime software.

The final point is the subject of this short report.

AquaSense

Concepts, features, and functionality

The key elements required for industry actors to use a platform of this nature are:

- Relevance
- Security
- Ease of use

The issue of relevance was discussed in D4.7, but briefly, the AquaSense platform (https://www.aquasen.se) allows the industry to simulate the growth of an animal, and use it as a proxy for a farm, defined here as a collection of cultivation structures, which might be cages on an open water salmon or bass farm, or trestles on an intertidal oyster farm.

The simulation allows a farmer to visualise growth and environmental effects forecast by a state-of-the-art model selected from those available in the AquaFish and AquaShell libraries,

The project has received funding from the European Union's Horizon 2020 Framework Research and Innovation Programme under GA n. 773330

and to obtain a synthesis view of the performance of the farm with respect to production (people), environment (planet), and economic outcomes (profit).

These visualisations are shown, together with a brief comment, in the figures below.

Fig. 1 shows a model run for a farm belonging to the GAIN partner Lebeche (owned by Culmarex, part of the Cooke Aquaculture group). The manager defined the culture period as 503 days (around 500 days is typical for seabass culture), using the time bar at the top of the screen to set the desired range, based on available sensor data. The total timespan available is from March 16th 2019 to 5th April 2021, and the farmer is looking at a cultivation cycle that began on the 12th of May of 2019.

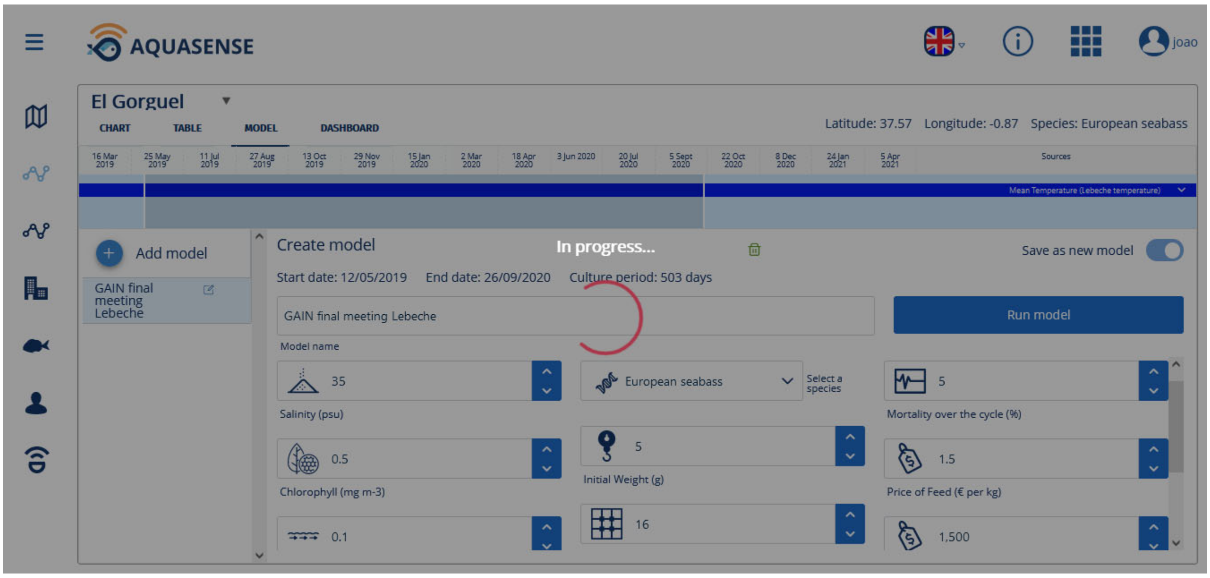


Fig. 1. A model run being executed in AquaSense.

In addition, the farm manager adjusted twelve key parameters, as shown in Table 1.

Table 1. Parameters required to run a finfish model in AquaSense.

Parameter type	Parameter name	Value	Units	Comment/purpose
Individual	Species	European seabass	-	Choice of farmed animal
	Initial weight	5	g	Model initial condition
Environment	Salinity	35	psu	Typical for seawater
	Chlorophyll	0.1	mg m^{-3}	Typical oligotrophic water/eutrophication
	Current speed	0.1	m s^{-1}	Conditions growth rate
	Dissolved oxygen	8	mg L^{-1}	Typical value at El Gorguel farm
Husbandry	Nº fish per cage	400,000	ind.	Typical value at El Gorguel farm
	Nº of cages	16	-	Two rows of eight cages
	Mortality	5	%	For estimating correct harvest
Financial	Price of juveniles	1500	€ per 1000 ind.	Example value
	Price of feed	1.5	€ per kg	As above
	Sale price	10	€ per kg	As above, all three are confidential info

The model was then run: AquaSense retrieves the key driver data from the cloud, where sensor outputs are stored, and sends them to the model engine, which calculates the outputs and returns the results to the platform. A model run is performed in a few seconds.

The project has received funding from the European Union's Horizon 2020 Framework Research and Innovation Programme under GA n. 773330

A farmer will only be able to run simulations for farms to which access has been granted. This allows a large company such as Cooke Aquaculture, that has farms in several different countries, to segment access for farm managers, but will allow a company or regional manager to be able to compare the performance across different farms.

Fig. 2 shows *two example runs* for farms in the western Mediterranean. Both grow European sea bass, and both have an identical set of cultivation parameters (see Table 1), including a growth period of approximately 500 days.

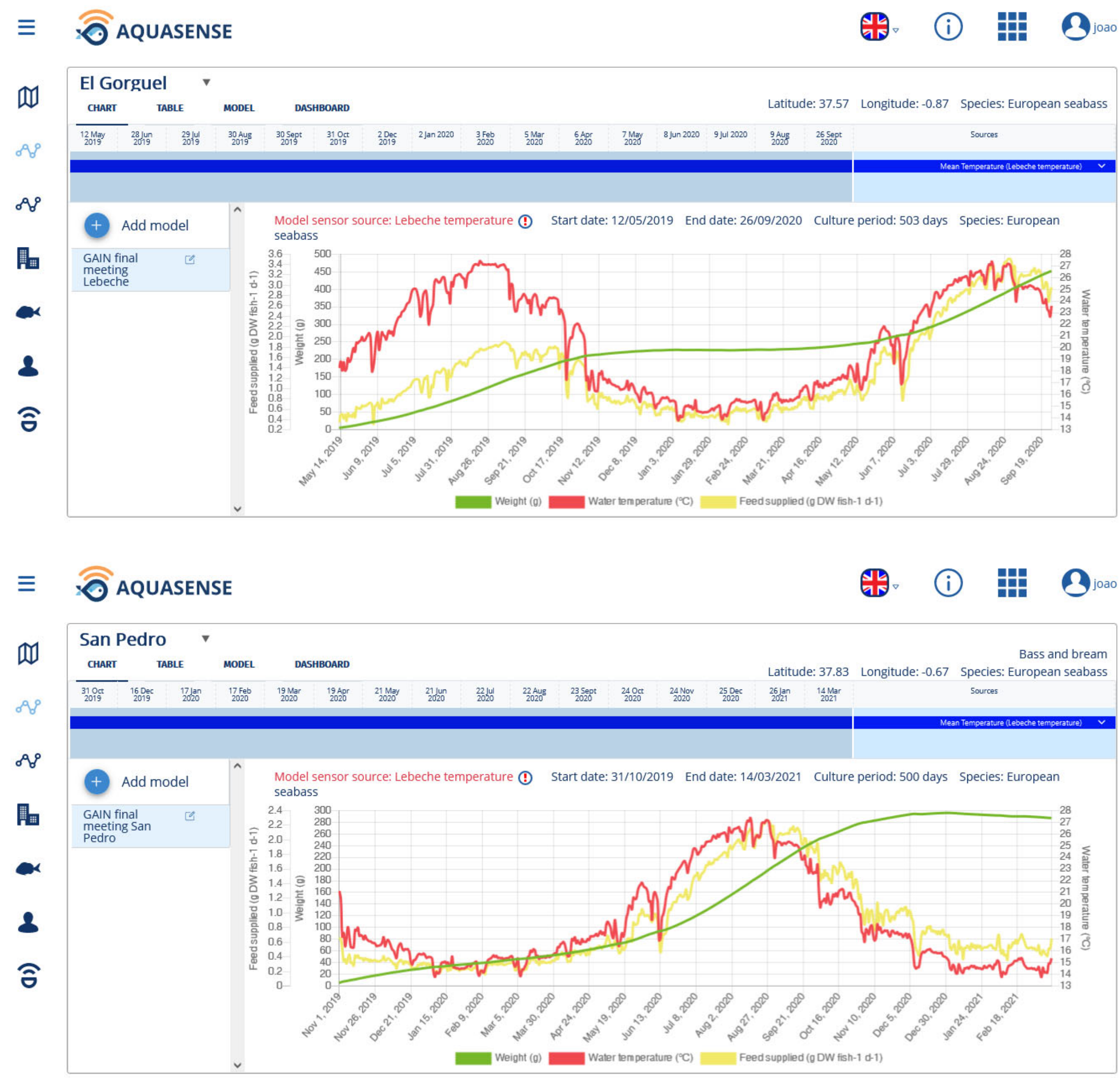


Fig. 2. Results and comparison of Aquasense runs for two Lebeche farms: El Gorguel (upper pane) and San Pedro (lower pane), both off the southern coast of Spain.

The project has received funding from the European Union's Horizon 2020 Framework Research and Innovation Programme under GA n. 773330

Both show an identical pattern of reduced growth during the winter, due to lower temperatures, and a reduction in feed supplied due to lower temperatures. However, because cultivation starts at different times of year, the performance is quite different between the two scenarios simulated. El Gorguel sees two summers of growth and a harvest in September, with fish that reach an individual biomass of about 450 g, whereas San Pedro sees two winters, and the seabass reach a biomass of under 300 g.

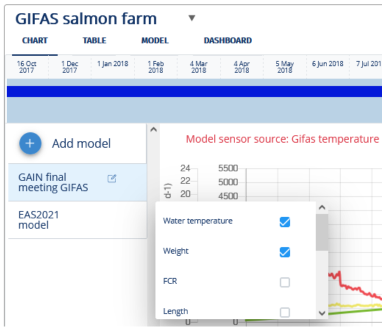


Fig. 3. Changing chart variables.

Furthermore, they lose weight at the very end of the cycle due to the lower water temperature. The variables displayed on the graph can be changed very easily (Fig. 3).

The results can also be tabulated—an example was shown in D4.7 and will not be repeated here. It is useful to note however, that the full results for all model timesteps can be downloaded at the click of a button as a CSV file for further analysis if required.

Switching between chart, table, model, and dashboard is very straightforward—it is a one-click operation on the tabs below the farm name (Fig. 2).

For bivalve shellfish farms, a similar approach is used. Despite the fact that bivalves feed on organic particles, with phytoplankton constituting an important part of their diet, surprisingly few shellfish farmers monitor chlorophyll, either through water sampling or by means of fluorescence sensors.

The two shellfish farms presently on the AquaSense platform are DOMA, in Dundrum Bay, Northern Ireland, and Finisterra, in the southwestern Algarve, Portugal—both are equipped with chlorophyll sensors, and this provides much more accurate application of growth models.

The project has received funding from the European Union's Horizon 2020 Framework Research and Innovation Programme under GA n. 773330

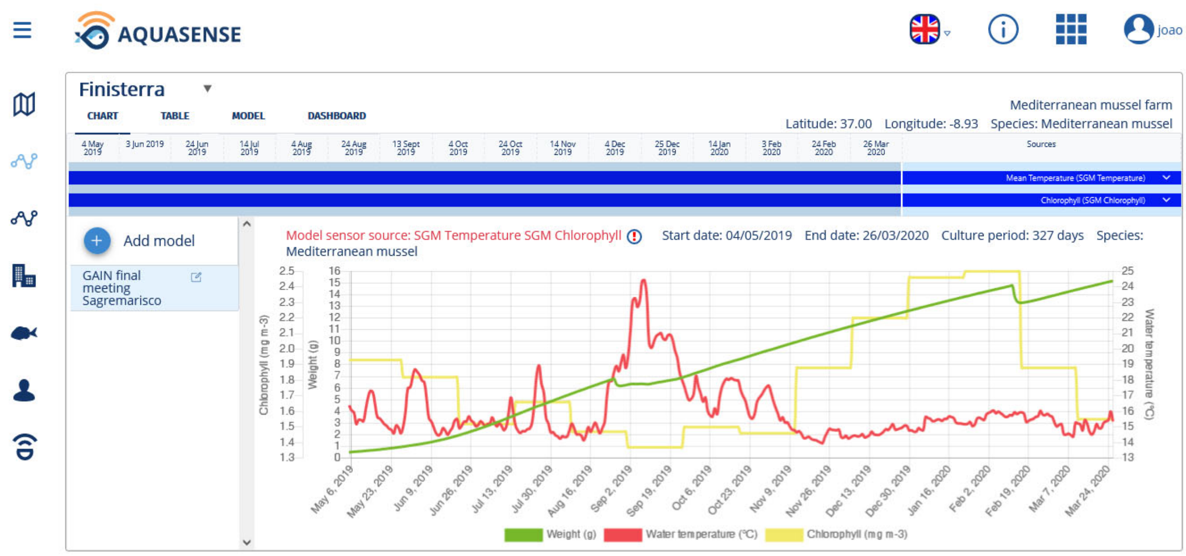


Fig. 4. Results of Aquasense runs for the DOMA Pacific oyster farm (upper pane) and the Finisterra Mediterranean mussel farm (lower pane).

The results for a 175-day run at DOMA are shown in Fig. 4, upper pane. Dundrum is a small bay with a short residence time, and the chlorophyll curve reflects the semi-diurnal tidal cycle, with higher values at low tide. The temporal span of the dataset is only about half a year, but since DOMA typically puts half-grown Pacific oysters (*Magellana gigas*) in the water for growout, the chart shows the biomass curve starting at 35 g live weight.

The Finisterra farm (Fig. 4, lower pane), grows the Mediterranean mussel *Mytilus galloprovincialis* from seed, and after slightly under one year, a mussel of about 15 g live weight is obtained. During this period, the animal spawns twice. The sensor data for chlorophyll are not a continuous register, but discrete (approximately monthly) outputs. The temporal resolution of these data will affect the growth curve obtained, since phytoplankton peaks are often of short duration, of the scale of one week, as can be seen in Dundrum.

The project has received funding from the European Union's Horizon 2020 Framework Research and Innovation Programme under GA n. 773330

Fig. 5. Dashboard synthesis of Aquasense runs for the GIFAS salmon farm (tables: upper pane; charts: lower pane).

The final presentation of AquaSense results is a dashboard synthesis (Fig. 5) that uses tables and charts to report the mass balance of the culture cycle in terms of people, planet, and profit.

Both of these elements can be downloaded to a local computer or other device in pdf format. The first three rows of the table (upper pane) present the mass balance for the farm itself, and the lower two rows show data for the individual model run.

These data are also shown in chart form (lower pane), with positive terms (e.g. income and profit) shown in shades of green and negative terms (e.g. costs) shown in shades of red.

Overall, the AquaSense app fulfils the necessary criteria of ease of use and relevance to the industry. The security of industry data and model results have been discussed in D4.7. As the Affiliate Farm Programme expands, we are confident that the industry uptake will be considerable. As an SME with a mission to supply disruptive aquaculture technology, we are committed to maintain AquaSense and enhance it as a significant contribution to industry onboarding of precision aquaculture.

AQUARADAR

As for AquaSense, the scientific and technical development of AQUARADAR falls under the purview of Work Package 4, *Eco-intensification*, and as such has been fully described in D4.7. Although the present deliverable (D.6.6) is a client-facing web platform, we have nevertheless added some details below about what has been developed for exploitation.

Data visualisation

AQUARADAR includes a user-friendly web application for a quick visualization of environmental parameters, e.g. dissolved oxygen and temperature, at farm sites. An R

The project has received funding from the European Union's Horizon 2020 Framework Research and Innovation Programme under GA n. 773330

downstream data pipeline allows to download from the IBM cloud the data from the various Preore probes (that were previously uploaded in accordance with IMS strategy).

It then formats and aggregates dissolved oxygen (DO) data related to the same raceway to obtain a visualization that fits better with the premises (and not only singles probes which position is not clear to the user). In this way, a farmer can have an overview of water quality parameters at each raceway. A dedicated GitHub repository was created were formatted data is stored and can be accessed for further processing.

This repository is updated every time a new datum is made available by the farm. An R Shiny web interface (https://univegain2020.shinyapps.io/leodashboard/) was designed and developed by UNIVE team in order to make these data easily available to the farmer. Fig. 6 shows the web interface accessible to the farmer wherever it may be, using a simple web connection, also via smartphone.

Feedbacks from the trout farmer were very positive and this service could now be enriched adding data from other sources (biomass from management software, others environmental data from new probes), but also adding the other Troticoltura Leonardi, production sites. Furthermore, this service could be made available to other farmers within the framework of the Affiliate Farm Program (AFP) as this service represents a simple first step toward an efficient use of sampled data using Data Assimilation (DA) methods.

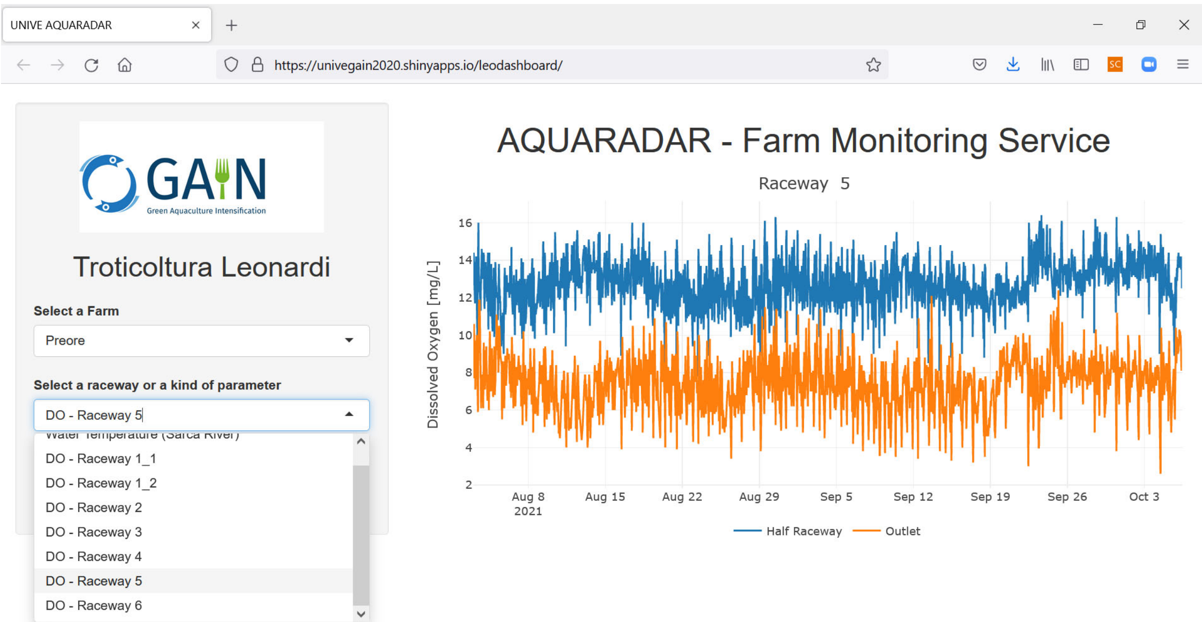


Fig. 6. AQUARADAR - Land-based data visualization web service.

The project has received funding from the European Union's Horizon 2020 Framework Research and Innovation Programme under GA n. 773330

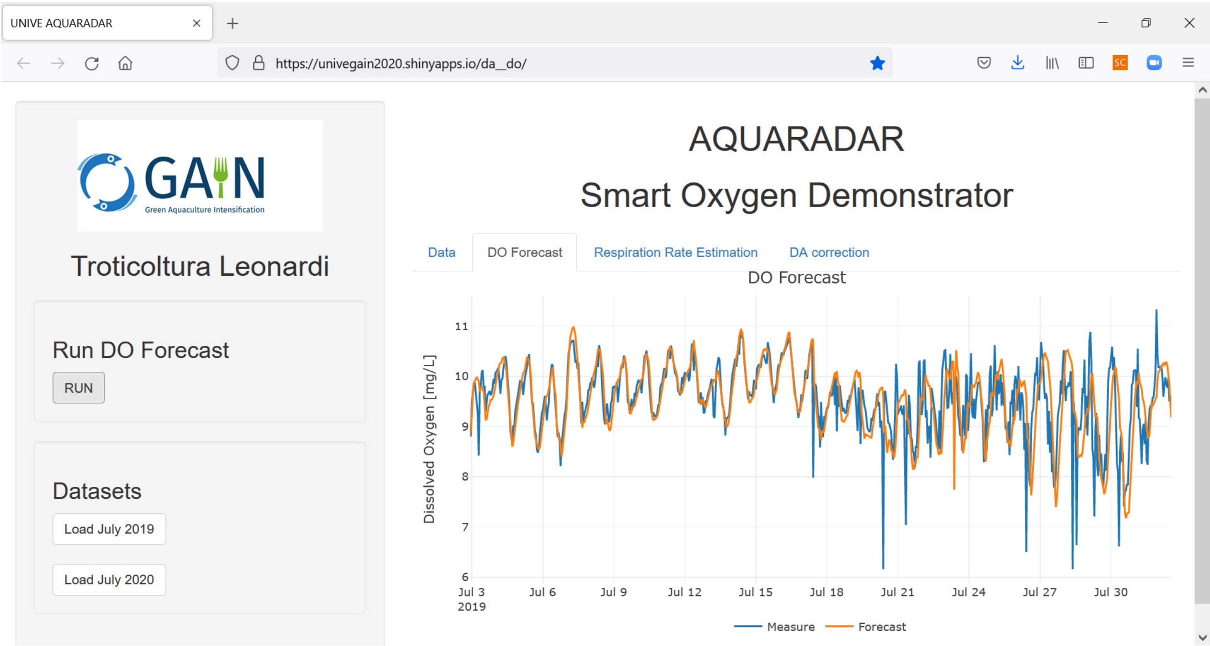


Fig. 7. AQUARADAR - Smart Oxygen Demonstrator web service – DO forecast.

As shown in Fig. 7, the first output of the process is an accurate and real-time forecast of the oxygen concentration within the raceway. The main benefit of using DA approach is its ability to deal with rapid changes in DO concentration due to non-monitored changes in surrounding conditions as during the second part of the graph. This aspect is even more evident if we look at the second output of the model (Fig. 8), the fish respiration rate dynamic estimation, that presents two kinds of evolution that were not taken into account by the process-based model, and however well estimated using DA method: one is the daily oscillation due to both the circadian rhythm and the feeding routine (Royer, 2021a), and the other is a mid-term evolution due to changes in feeding quantities from one day to another.

The project has received funding from the European Union's Horizon 2020 Framework Research and Innovation Programme under GA n. 773330

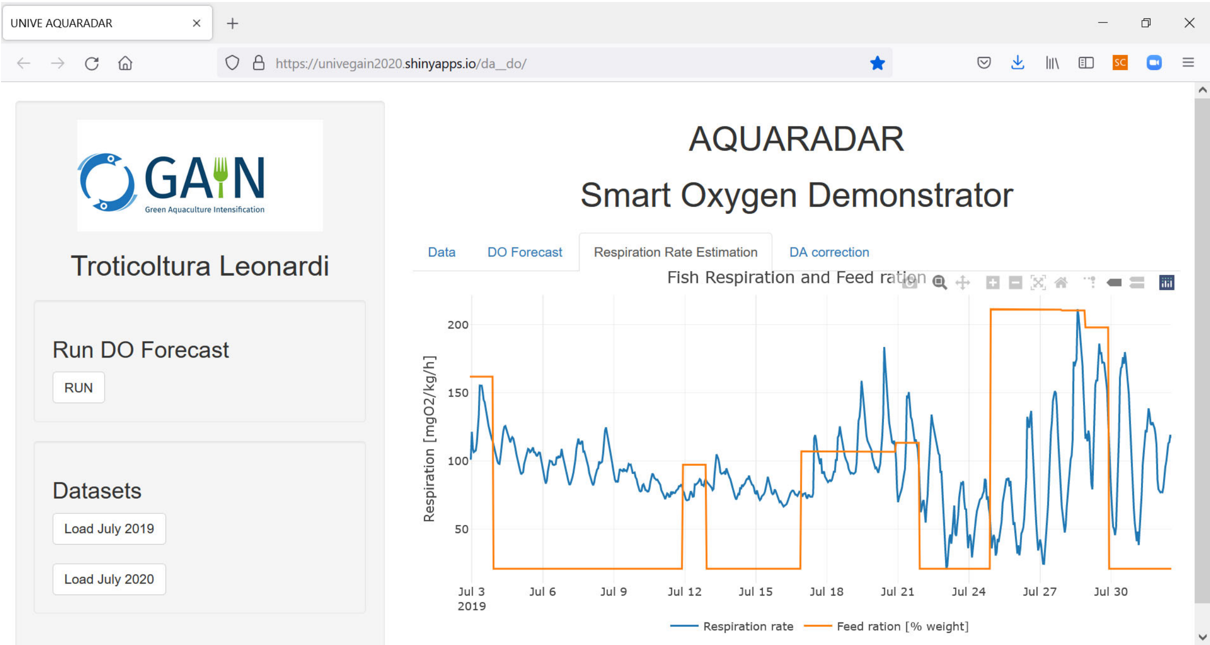
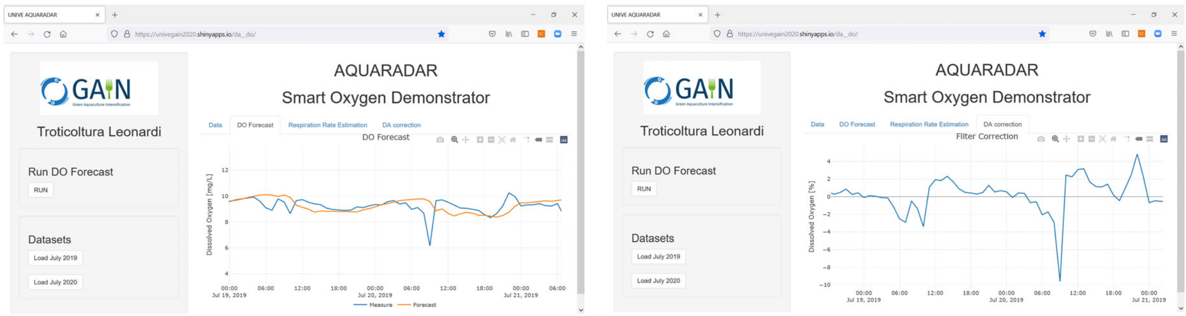


Fig. 8. AQUARADAR - Smart Oxygen Demonstrator web service – Fish respiration estimation and Feed ration.

These results open the way to an efficient control of oxygen supply to the raceways based on the ability to forecast biomass corresponding need. Moving from a static approach to a dynamic approach could be of high interest from the management of the farm as it would allow to adapt the quantity of supplied oxygen to the current request by the fish.



(a) (b)

Fig. 9. AQUARADAR - Smart Oxygen Demonstrator web service – Quality monitoring. On the left side (a), the DO measurement (blue) by the probe and the forecast (orange) by the model. On the right side (b) the corresponding correction computed and set by the Kalman filter.

A control strategy based on this forecasted request and on the respect of minimal threshold means more sustainability (due to economic and environmental costs of oxygen production) and more welfare for the fish (prevention from anoxia condition). These results were presented at EAS 2020 and are described in detail in (Royer et al., 2021b). Troticoltura Leonardi, GAIN end user, expressed interest in implementing an automated system of oxygen supply: this hardware investment would be completed by a software control strategy, to be included in AQUARADAR.

The quality of input data is a very relevant issue, in particular when dealing with Big Data collected by automatic probes, which needs maintenance. Data Assimilation can also be used

The project has received funding from the European Union's Horizon 2020 Framework Research and Innovation Programme under GA n. 773330

for data quality assessment, as described in Ciavatta et al., 2004. This DA application is illustrated in Fig. 9, which shows the DO dynamics (a) and forecast, and the corresponding DA correction (b).

To the negative peak of measured DO that occurs at 09:00, corresponds a correction which is much higher (nearly 10%) than the one observed on a two-days window. This indicates a very high discrepancy between the sampled data and the model forecast and could be interpreted, with not much doubt, as a non-reliable data point. Looking at a more extended time window it would be possible to define a 'reliability threshold' that would allow to identify unreliable data to be removed from the analysis. Such a preventive approach would thus highly increment the quality of the results, and then of the support given to farmer's decision process.

Exploitation: a digital twin of a raceway farm

The results presented could be further developed in the framework of the Digital Twin approach. UNIVE developed a Digital Twin prototype for land-based finfish farms with the aim of supporting producers in optimizing feeding practices, oxygen supply and fish population management with respect to 1) growth performances; 2) fish welfare, and 3) environmental loads. After testing, the Twin could be customized and provided as a service through AQUARADAR. Digital Twins are virtual, digital representations which mirror and are connected to real objects (Grieves & Vickers, 2017; Fuller et al., 2020), enabling real-time and remote management, as well as the reproduction of real or forecasted scenarios. The Digital Twin relies on integrated mathematical models which are fed with farm and external data sets and simulate several dynamic processes, allowing the estimation of key parameters describing the environment and fishes. Digital Twins in aquaculture, as in other field applications, generally foresees a real-time and remote connection between the real and virtual counterparts, with IoT being a key technology (Marr, 2017).

Despite its potential and notable advances, the development of Digital Twins is still at its early stage, as simulations applied along the operational phase of an implemented system have received little attention compared to those based on theoretical and static model aimed at verifying, validating and optimizing a system in its planning stage (Liu et al., 2021). Furthermore, most of research works on Digital Twins were either on a theoretical level only, or implement-ed in laboratory (Liu et al., 2021). To bridge this gap, and using the lesson learnt from our work on pilot site n°8, we develop a Digital Twin which mirrors a raceway farm, employing an approach based on the quantitative processing of environmental data and bio-responses that makes it possible to optimise the feeding, oxygen supply, water quality and fish biomass transfers. This Digital Twin incorporates the four management phases of PFF, i.e., observing, interpreting, deciding, and acting, with a target on the controls of feed, oxygen and biomass along the fish growth from fingerlings up to the commercial weight. Fig. 10 depicts the information flow diagram of the cyclic control structure of the digital twin, with control functions and information flows distributed along the four phases of farm management.

The project has received funding from the European Union's Horizon 2020 Framework Research and Innovation Programme under GA n. 773330

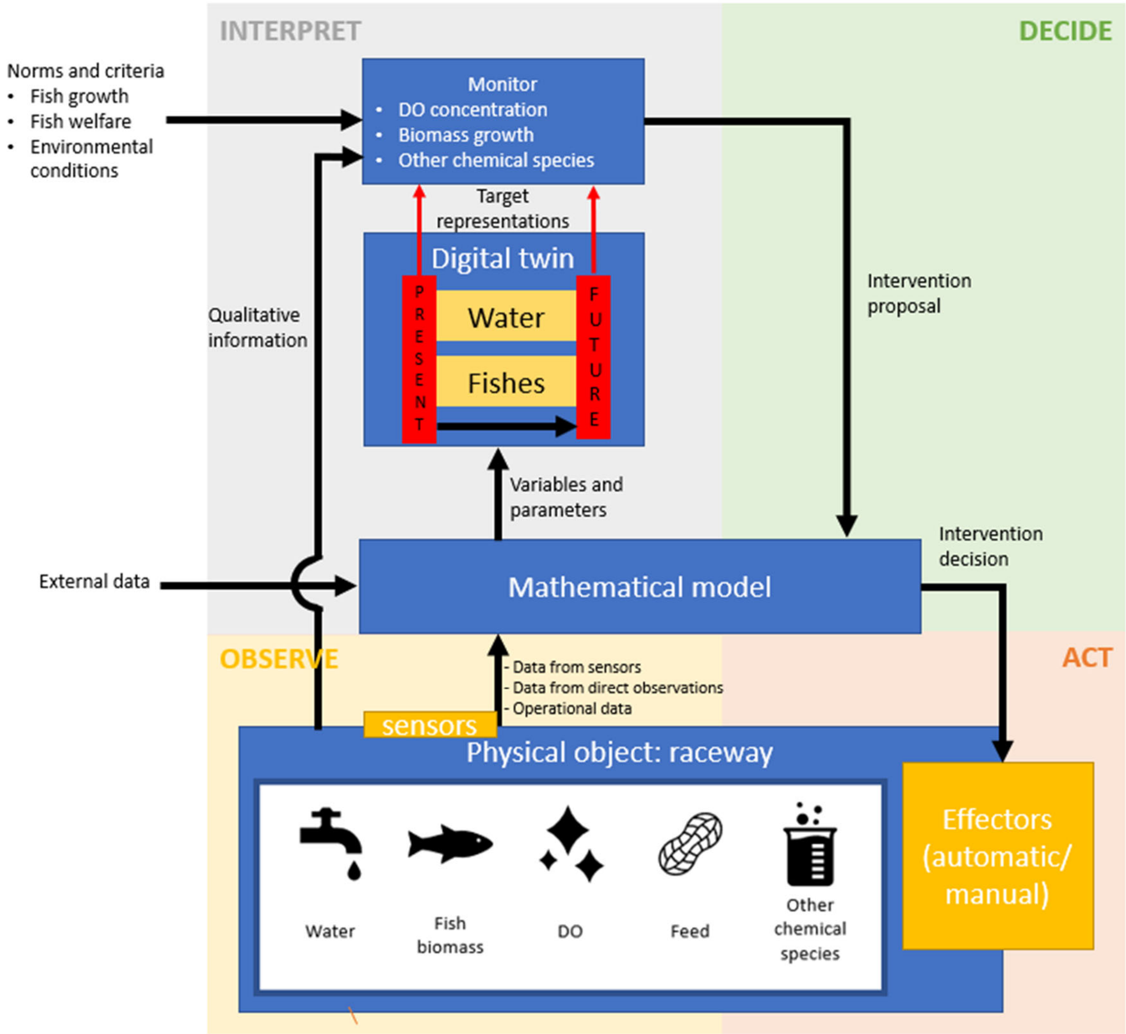


Fig. 10. Information flow diagram for the Digital Twin conceptual model.

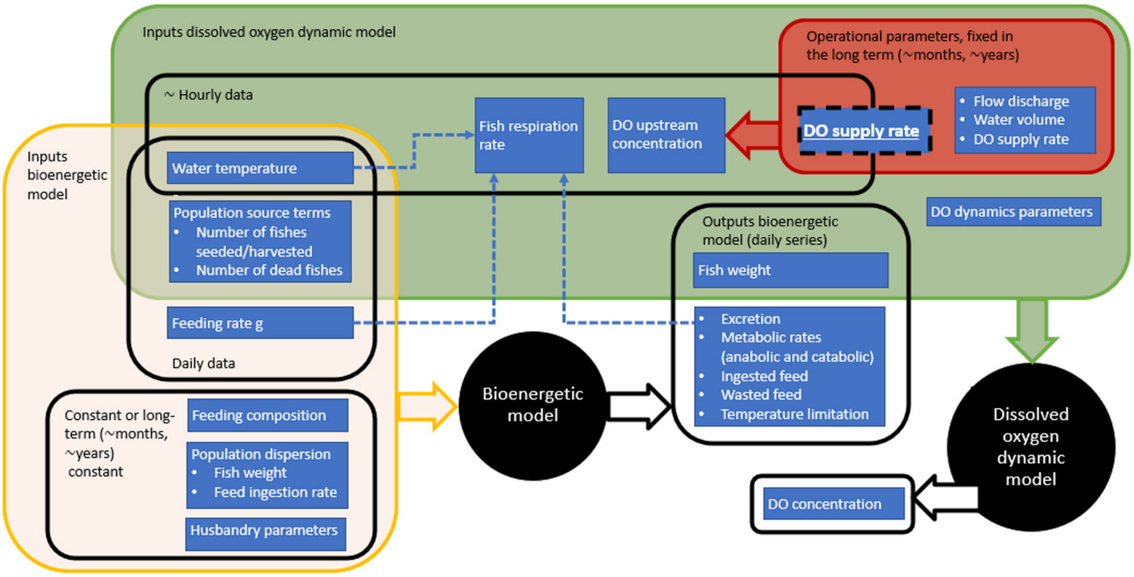


Fig. 11. Scheme of inputs and outputs to the bioenergetic and dissolved oxygen dynamic models.

The project has received funding from the European Union's Horizon 2020 Framework Research and Innovation Programme under GA n. 773330

The core component of the Digital Twin control system is the mathematical model which unifies disparate data streams and provide real-time and forecasted pictures of the state of the physical object. In the present application, the mathematical model is composed by two modules, specifically a bioenergetic model and a DO dynamic model (Fig. 11).

Upon securing the target datasets to describe the state of the system, the digital twin is constructed based on the organization of the datasets into the environmental (water) and animal (fishes) components. The list of major variables for each component, along with illustrative views of the digital representations are shown in Fig. 12. The water component shows a selected view of the DO concentration covering the full streamwise distance of the raceway (0 to 200m), from July 3rd to 13th., 2019. The sinusoidal-like daily oscillation the downstream decay of the DO concentration can be visualized. The fish view highlights the average fish growth and its standard-deviation bounds along a period of approximately 4.5 months.

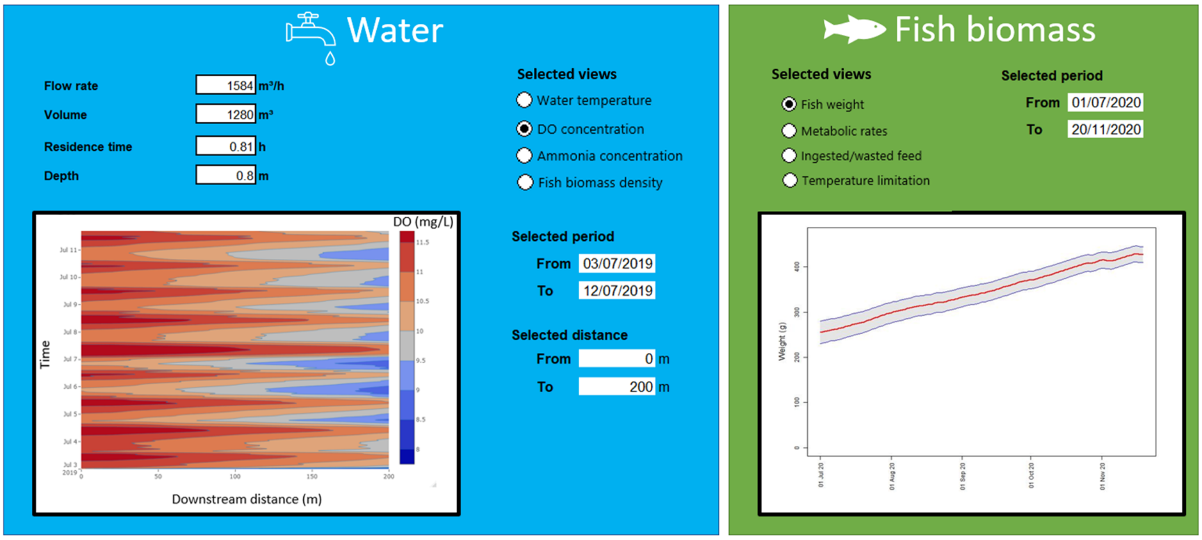


Fig. 12. Selected views of the digital twin.

Based on the previous it is possible to build scenarios for the transfer of fish cohort. For example, it is possible for the user to define two scenarios: A, in which the one third of the fish biomass is transferred one day before the baseline density is reached, and Scenario B, in which the fish transfer of one-third of the total biomass is delayed one week compared to Scenario A. The utilization factor presented in Fig. 13 corresponds to the fish biomass density in relation to a baseline density for transferring fish of 20 kg of fish per m^3.

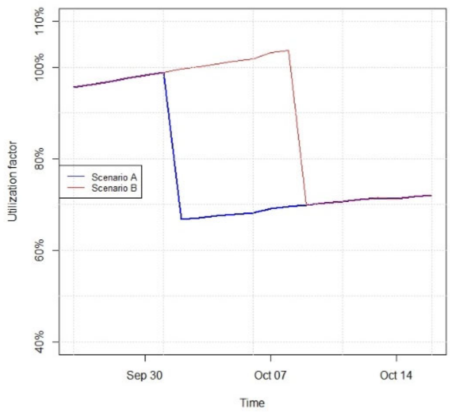
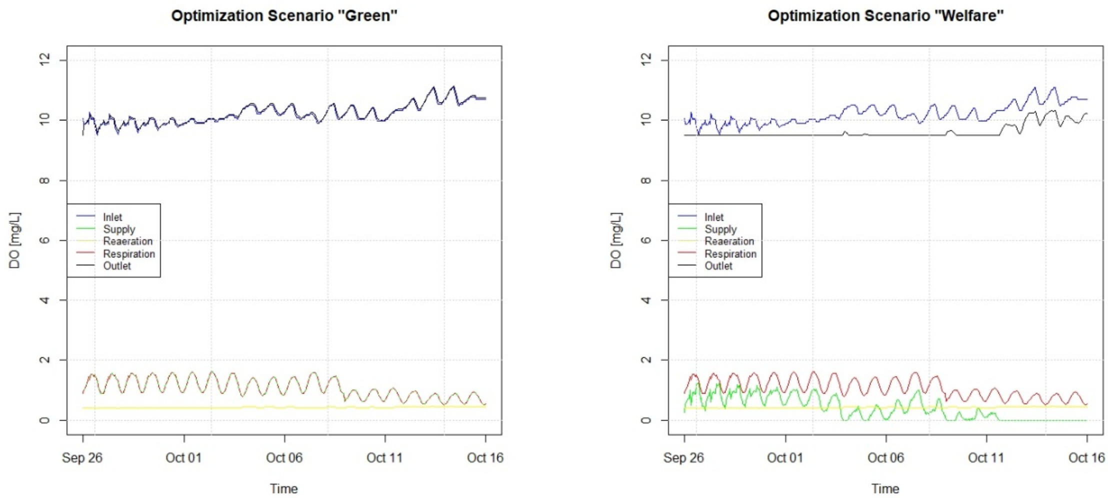


Fig. 13. Utilization factor for Scenarios A and B, envisaged based on different intervention proposals for fish transfer.

The project has received funding from the European Union's Horizon 2020 Framework Research and Innovation Programme under GA n. 773330

These results show that the use of Digital twin can be of high relevance to support the decision process in land-based farm management, and a decisive tool to better plan the operations linked to the production process. Possible developments of this twin toward a prescriptive level, i.e. investigating the acting phase would be of high relevance for land-based aquaculture.



(a) (b)

Fig. 14. Closed-loop control scenarios (a) Green and (b) Welfare.

First results were obtained in this direction establishing two different control strategies of oxygen supply: 1 – "Green" scenario in which the aim of the control loop is to ensure that water at the outlet has the same concentration than the one at the inlet, in order to warranty the river ecosystem. 2 – "Welfare" scenario assumes that the DO concentration at the outlet should be at least 9.5 mg L^{-1}, ensuring then a high level of fish welfare. Fig. 14 shows the results of these two scenarios in terms of DO concentration evolution in time. As it can be seen on this figure, total quantities of oxygen supply would be quite different showing the need to precisely the scope of an automated oxygen supply control, together with the capacity of digital twin to improve sustainable management of land-based aquaculture. These results were fully described in Lima et al., 2021.

Conclusions

The materials presented in this deliverable report provide explanations and examples for industry-facing platforms AquaSense and AQUARADAR. The main objective of this document was to inform the reader about this functionality, underscoring the design element, of great importance to end-users, the stand-alone nature, and the relevance of outputs to the day-to-day challenges of the aquaculture industry.

Please refer to D4.7 for a description of the various scientific and technical aspects that govern functionality, multi-user capability, and development for the two applications. The focus of the text presented herein was to emphasise customer-facing aspects of AquaSense and AQUARADAR which fulfil the final requirement for a useful real-world tool in the context of

The project has received funding from the European Union's Horizon 2020 Framework Research and Innovation Programme under GA n. 773330

precision aquaculture, i.e. an integrated platform where industry stakeholders can easily access, process, and make use of data and information.

References

Ciavatta, S., Pastres, R., Lin Z.; Beck, M.B.; Badetti, C., Ferrari, G., 2004. Fault detection in a real time monitoring network for water quality in the lagoon of Venice, (Italy).Water Science and Technology, vol. 50, pp. 51-58.

Fuller, A., Fan, Z., Day, C., Barlow, C., 2020. Digital Twin: enabling technologies, challenges and open research. IEEE Access 8, 108952–108971.

Grieves, M., Vickers, J., 2017. Digital Twin: Mitigating unpredictable, undesirable emergent behaviour in complex systems. In: Kahlen, F.-J., Flumerfelt, S., Alves, A. (Eds.), Transdisciplinary Perspectives on Complex Systems. Springer International Publishing.

Kalman, R. E. 1960. A new approach to linear filtering and prediction problems. *Journal of Basic Engineering* 82: 35– 45.

Lima, A. C., Royer, E., Bolzonella, M. & Pastres, R., 2021. Digital twins for land-based aquaculture: a case study for rainbow trout. Open Research Europe, Under review.

Liu, M., Fang, S., Huiyue Dong, H., Xu, C., 2021. Review of Digital Twin about concepts, technologies, and industrial applications. Journal of Manufacturing Systems 58, 346–361.

Marr, B., 2017. What is Digital Twin technology - and why is it so important? Forbes. https://www.forbes.com/sites/bernardmarr/2017/03/06/what-is-digital-twin-technology-and-why-is-it-so-important/

Pastres, R., Ciavatta, S., Solidoro, C., 2003. The Extended Kalman Filter (EKF) as a tool for the assimilation of high frequency water quality data. Ecol. Modell. 170, 227-235

Royer, E., Faccenda, F., Pastres, R., 2021a. Estimating oxygen consumption of rainbow trout (Oncorhynchus mykiss) in a raceway: A Precision Fish Farming approach. Aquacultural Engineering, 92, 102141.

Royer, E., Lima, A., Pastres, R., 2021b. Data assimilation as a key step towards the implementation of an efficient management of dissolved oxygen in land-based aquaculture. Computers and Electronics in Agriculture, Under review.

The project has received funding from the European Union's Horizon 2020 Framework Research and Innovation Programme under GA n. 773330