AdriAquaNet

Enhancing Innovation and Sustainability in Adriatic Aquaculture

Deliverable WP3

Control sheet

"D 3.2.3 Development of the model for simulation of environmental impact of fish cages"

Venezia, 27.06.2022

This report is prepared by the working group WP3 (Bluefarm Srl and LP), under the coordination of the WP leader, prof Emilio Tibaldi

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Layout of the document and adaptation of the service to the project needs

This technical report summarizes the activities carried out in the context of the support service for the AdriAquaNet ID 10045161 project. The document is structured as follows:

Section 1 introduces the modeling tools used, presenting, in particular, some improvements on the user interface, which were implemented as part of this service. To illustrate the functioning of the model, some growth simulations carried out in the two pilot sites are presented in the following section 2 using the interface described in the previous paragraph, and taking into consideration environmental and zootechnical data collected within the project. In these simulations, the model output was also compared with the data sets collected for testing the performances the innovative feed formulations developed during AAA versus the commercial ones. This comparison was extended to the simulation of depositional footprints and associated benthic community indices.

The service was adapted, in agreement with the client and without any further increase in costs, to achieve AAN objectives. The two main changes were the following:

- As requested by the client, the duration of the service was extended by one year, without any cost increase. The extension allowed Bluefarm to carry out the activities foreseen at point 2 of the technical proposal (assessment of the local impact in 2 plants) taking into account the laboratory and field data concerning the feed trials which could be collected only in 2021, due to outbreak of the covid-19 pandemic in 2020.

- In order to enhance the accuracy of the simulation of the dispersion and deposition of organic matter released by the fish cages, Bluefarm, in collaboration with the project partner IZSV, installed a current meter at the two pilot sites of Friskina (PP8) and Orada Adriatic (PP10). These measurements were not included in the original AAN data collection plan.

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1. Models for the simulation at the farm scale

In accordance with the methodological proposal, Bluefarm made the FiCIM dynamic model, previously developed in (Brigolin et al., 2010) and (Brigolin et al., 2014), available to the stakeholders of the project through a web-based service. The model is made up of 4 modules, see Fig. 1, which allow one to simulate the evolution of the fish stocked a cage and the environmental impact related to the release of Organic Matter.

Figure 1. Partitioning of modules within the FiCIM model.

More specifically, **FiCIM includes:**

1) **a module which simulates the growth of a seabass/seabream individual, based on the energy balance, in response to the temperature of the water and the quality and quantity of the feed supplied;**

2) **a module that allows one to simulate the evolution of the stocked biomass and cage emission of organic particles, using Monte Carlo-type resampling methodologies.**

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3) **A module for the prediction of organic matter flows, in terms of C, N and P, starting from the simulation of the dispersion of non-ingested food and feces released by a cage considering the characteristics and location of the plant, both in terms of bathymetry and exposure to sea currents;**

4) **A module to predict organic enrichment in the superficial sediment, starting from the flows simulated by the 3rd module, and considering the degradation processes of organic matter, a function of the main characteristics of the sediment.**

The first module was improved within the project, developing a new user friendly interface which facilitates the entry of input data, such as the quantity and composition of the feed and the temperature of the 'water, which can also be entered as temporal sequences of daily values. This activity enables operators with no specific skill in modelling, to carry out in a simple way the growth simulations at their own site interest, and using data collected in-situ through monitoring tools. This form is freely accessible through the company website https://www.bluefarmenvironment.com/.

The modules in points 2, 3 and 4 have been made available via the web to the stakeholders of the project, for which a personal profile has been created. Free access will be maintained for 5 years.

1.1. Development of an interface for the growth models

This section briefly describes the use of the "individual" module, freely accessible through the site https://www.bluefarmenvironment.com/. Through the interface, the user can upload a predefined file for the definition of the model parameters (deriving for example from previous simulations), or to create one from scratch. (see Figure 2). The Param file contains information about the duration of the grow-out cycle (*nt*), the simulated species (*in*) and the weight at the beginning of the cycle (*wini*). Similarly, the user can specify the feed composition, in terms of, percentages of proteins (*Pcont*), lipids (*Lcont*) and carbohydrates (*Ccont*) using the “Diet” file. This information can also be entered using an existing file, or specified from scratch, using the user-friendly interface.

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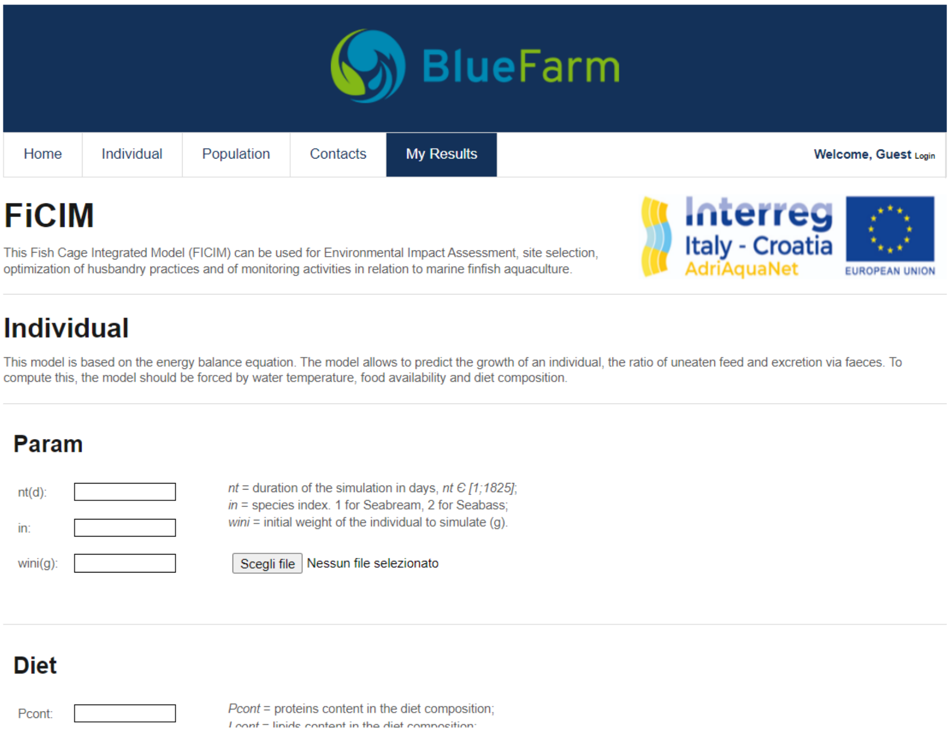

Figure 2. Configuration page for the growth module.

Figures 3 and 4 instead show the methods set up for the insertion of historical data series within the growth model. These time series are related to the amount of feed administered (Food file), and the temperature of the water in the farm (Temperature file). As exemplified in figures 3 and 4, the user is able to specify this information both by entering the individual values, each of which corresponds to a different date, and by copying-pasting from a sheet calculation, in which the data were stored (for example excel or open office calc).

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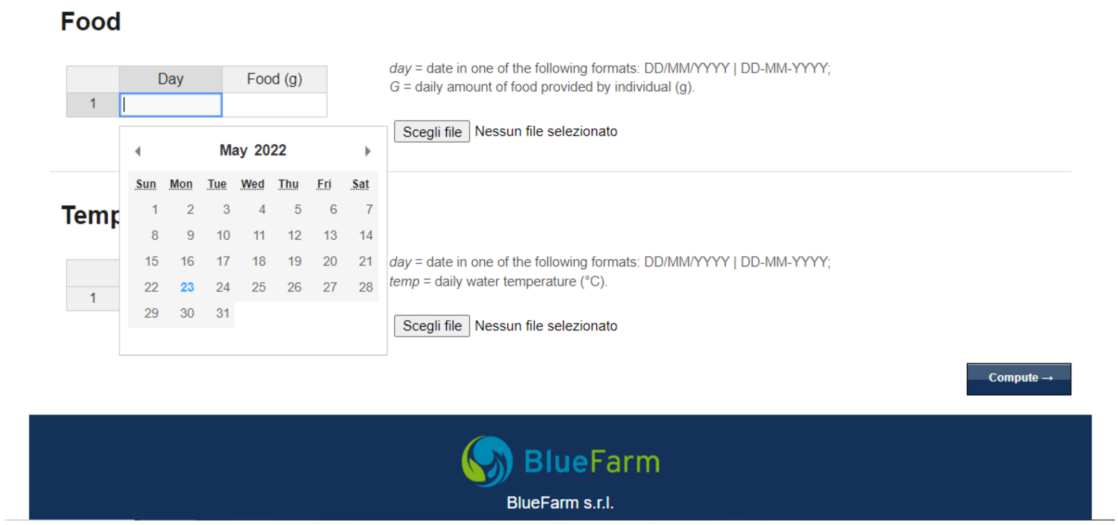

Figure 3. Manual input of the time series using the user-friendly interface developed within AAN project.

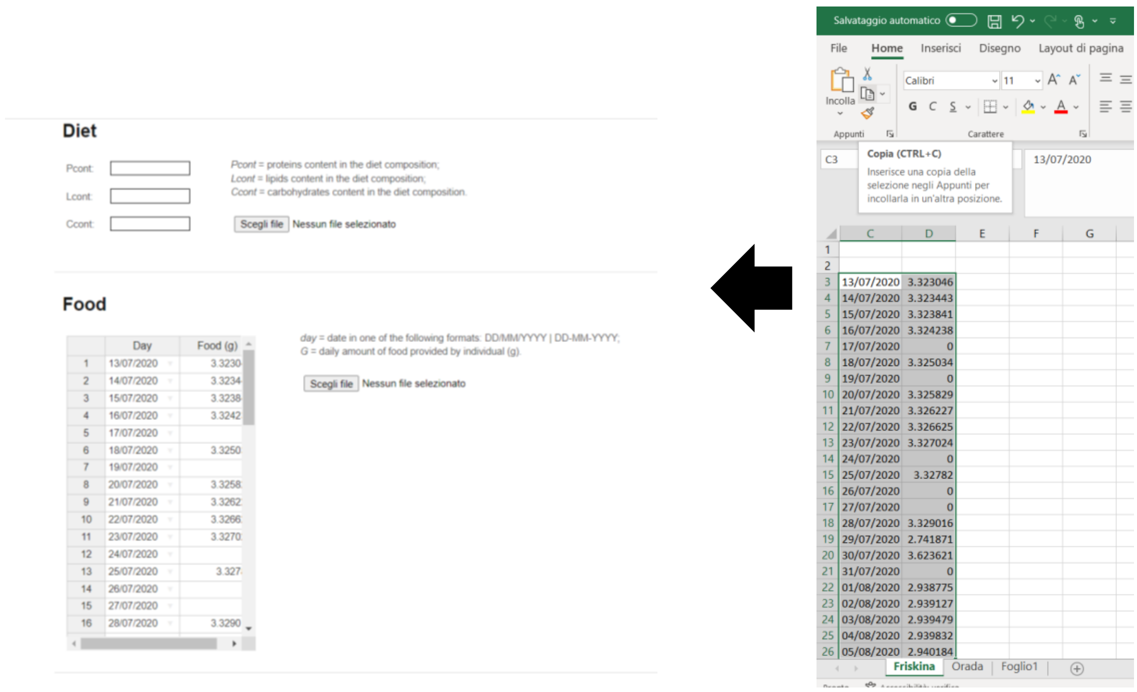

Figure 4. Data copy-paste from an existing archive (e.g. from a data spreadsheet). Feature developed within the AAN project.

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The data is entered using the following sequence of operations:

Definition of basic parameters (Param file);

Definition of the composition of the diet (Diet file);

Definition of the historical data series of feed supplied (Food file);

Definition of the historical series of water temperature data (Temperature file).

Once the entry is complete, the user by pressing the "Compute" button launches the simulation (Figure 5), which is carried out online at the Bluefarm server. Subsequently, the user will be able to view and download the results to their device, proposed both by means of a set of Cartesian graphs (Figure 6), and as a numerical matrix, containing the output data of the model. The set of information output by the model includes:

Historical series of growth, in terms of weight and length (total);

Historical series of wastewater, expressed in grams of C, N and P relative to faeces and food not ingested (the two are supplied separately);

Amount of oxygen consumed and amount of ammonium excreted throughout the day.

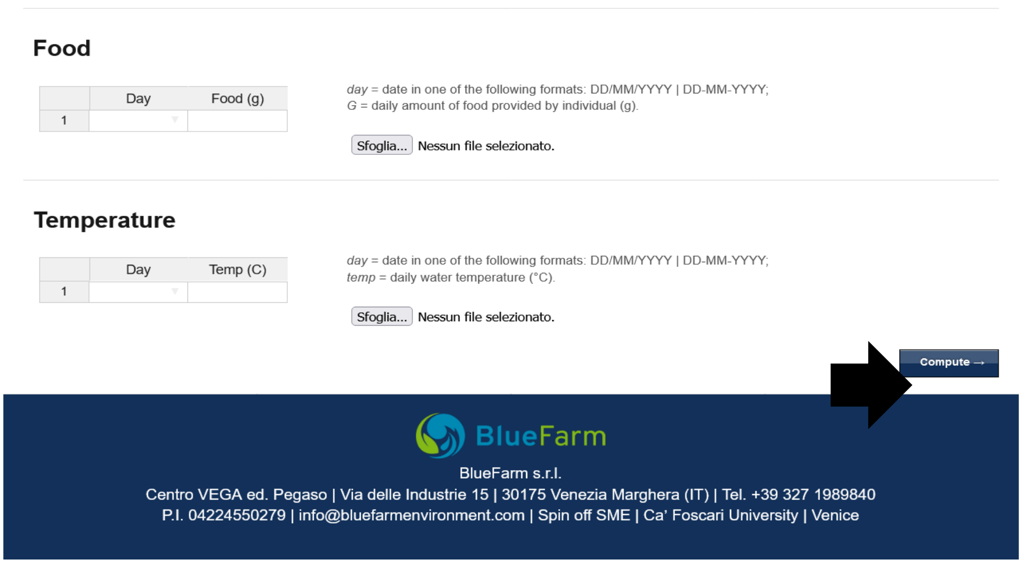

Figure 3. Launch of a new simulation.

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Figure 4. Example of the type of output provided by the model. By means of the "download" button it is possible downloading information, both in graphic and numerical format.

1.2. Deposition simulation

This module looks similar to the previous one (see Figure 7). Data entry takes place here using the following sequence of operations:

Definition of basic parameters (Param file);

Definition of the bathymetry of the area (Bathymetry file) - if not available, it is possible to impose a homogeneous bathymetry by specifying it in the Param file;

Definition of the historical series of current data (Currents file);

Definition of the historical series of organic waste data predicted by the previous modules (Total_waste file).

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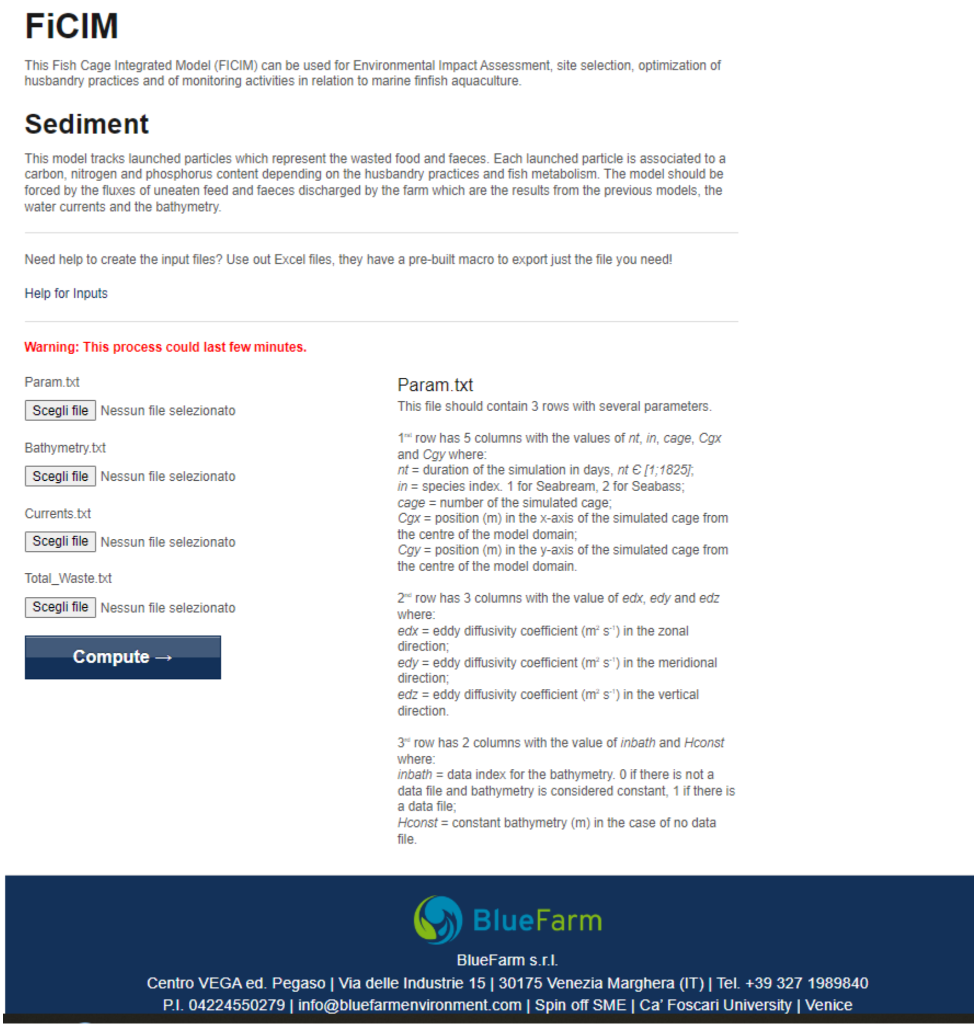

Figure 5. Sediment module interface.

Once the entry is complete, the user by pressing the "Compute" button launches the simulation (Figure 8), which is carried out online at the Bluefarm server. Subsequently, the user will be able to view and download the results to their device, proposed both by means of a set of contour plots (Figure 9), and as numerical matrices, containing the output data of the model. The set of information output by the model includes:

- Depositional maps (contour plot), referring to the average flows at the bottom of C, N and P, relating to feces and non-ingested food - these flows are averaged over the entire period.

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- The matrices containing the values of the flows of C, N and P at the bottom averaged over the entire period and every 15 days.

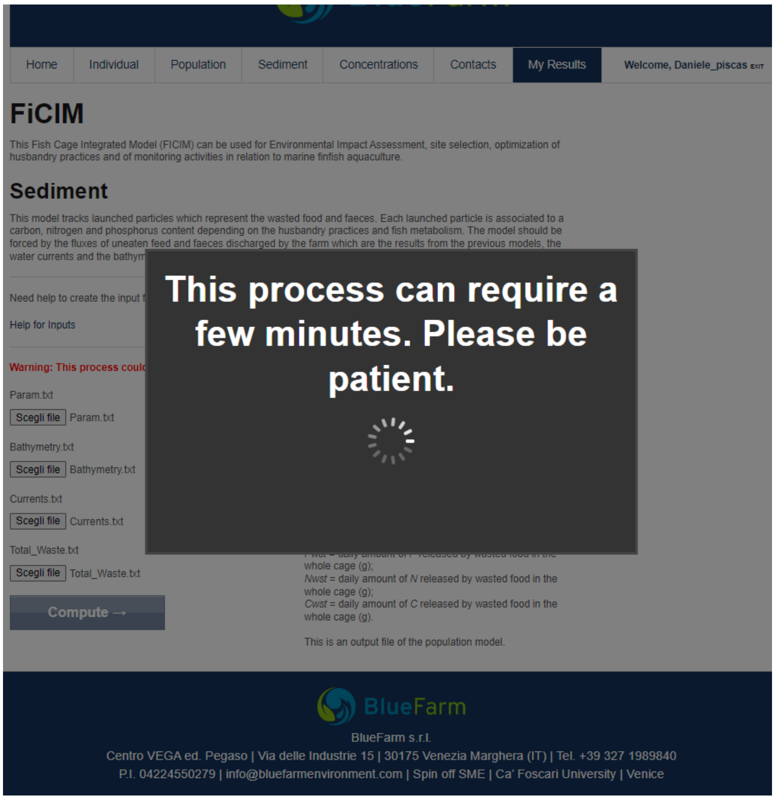

Figure 6. Simulation running in the online server.

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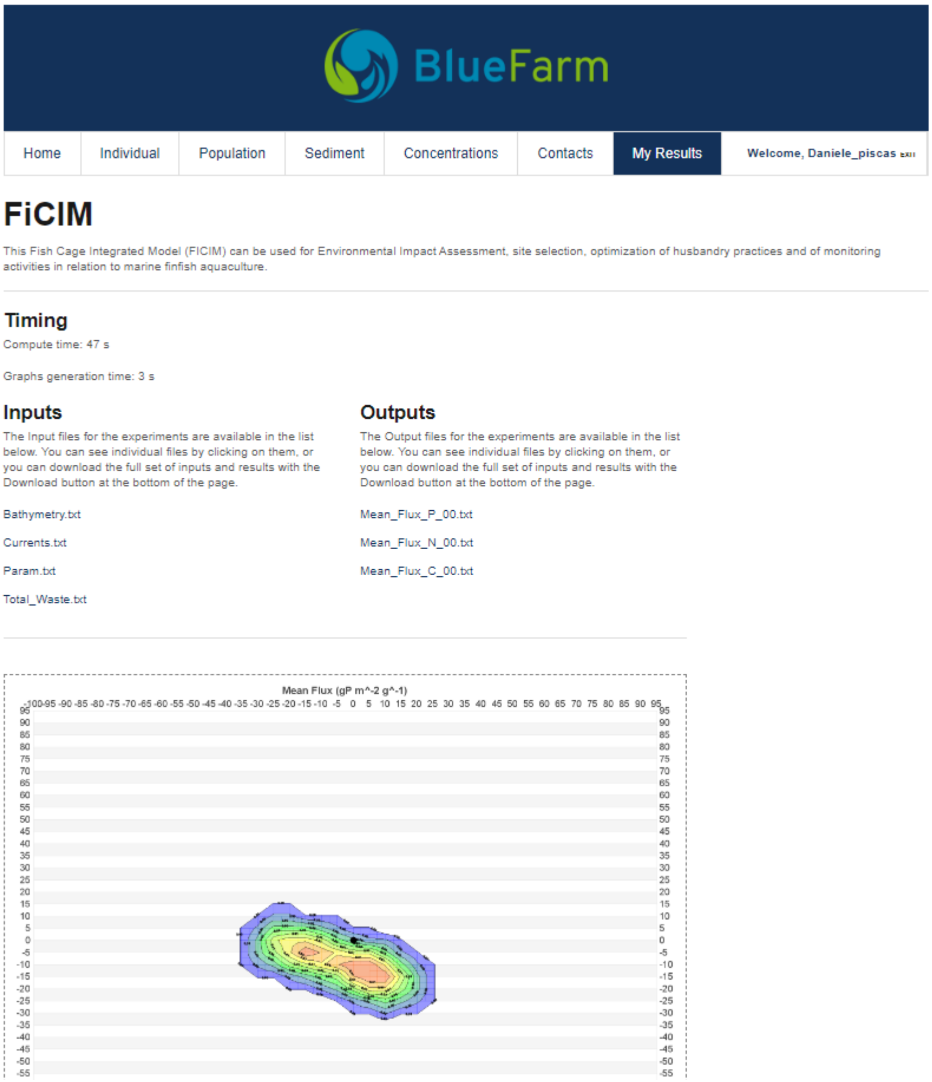

Figure 7. Model output page, providing simulation results.

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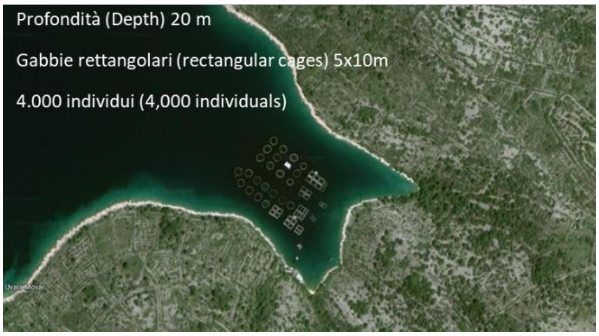
2. Farm-environment interactions at the two pilot sites

The main purpose of this activity was to compare the impact on the sediment of "AAN" feeds with that of commercial ones. To this end, two simulations were conducted using the integrated FiCIM model, described in detail in Brigolin et al. (2010) and Brigolin et al. (2014), in which equations and parameters of the model are presented in detail. The simulations concerned the two pilot sites shows in Fig. 10of the project. The main features of the sites and the collection of input data, and some details of the simulations are summarized in the next section.



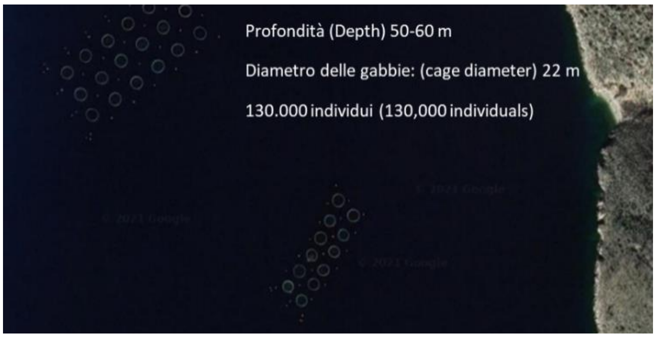


Figure 10. Pilot sites investigated within the AAN project and their key characteristics.

2.1. Collection and analysis of experimental information and methodologies for applying the models

The composition of the feed, presented in Table 1, was detailed for each plant starting from the information on the feed used, collected by farmers and UNIUD. The percentage carbohydrate content (C) was calculated starting from the total, subtracting the fractions relating to moisture, proteins, fibers and lipids. The time series of individual food ration were estimated from the quantities supplied to the cages used for the feed trials and the number of individuals per cage. If necessary, the data were linearly interpolated to obtain the daily values. The graphs in Figure 11 show the daily individual feed ration at the two pilot sites. The seasonal evolution of the water temperature in the AAN pilot sites was estimated on the basis of experimental data collected in-situ, thanks to the AAN experimental probes (fig 12). Where not available, these data were integrated with Sea Surface Temperature L4 downloaded from Copernicus Marine Service. (https://marine.copernicus.eu/). Overall, the growth simulations took into consideration a period of 6 (Orada Adriatic, PP10) and 7 (Friskina, PP8) months respectively, during which

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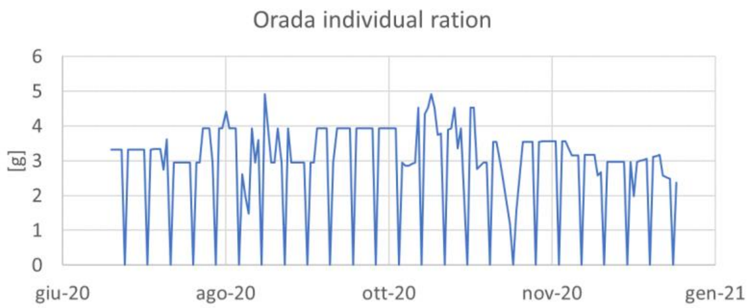
the in situ feed tests were carried out, simultaneously collecting the experimental data relating to the water temperature.

		Mangime AAN (AAN feed)	Mangime commerciale (Comm. Feed)
ORADA	P	0.401	0.434
	L	0.266	0.22
	C	0.244	0.275
FRISKINA	P	0.443	0.441
	L	0.21	0.21
	C	0.247	0.258

Table 1. Diet composition used in the simulations at the two experimental sites, referring to the two types of feed, commercial and innovative (AAN).



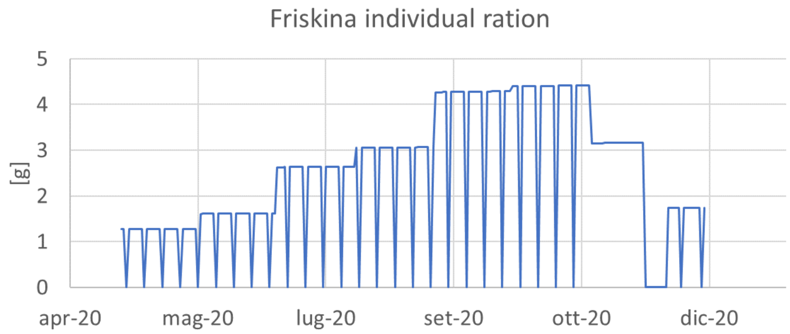


Figure 11. Time series of feed ration used as an input at the two experimental sites.

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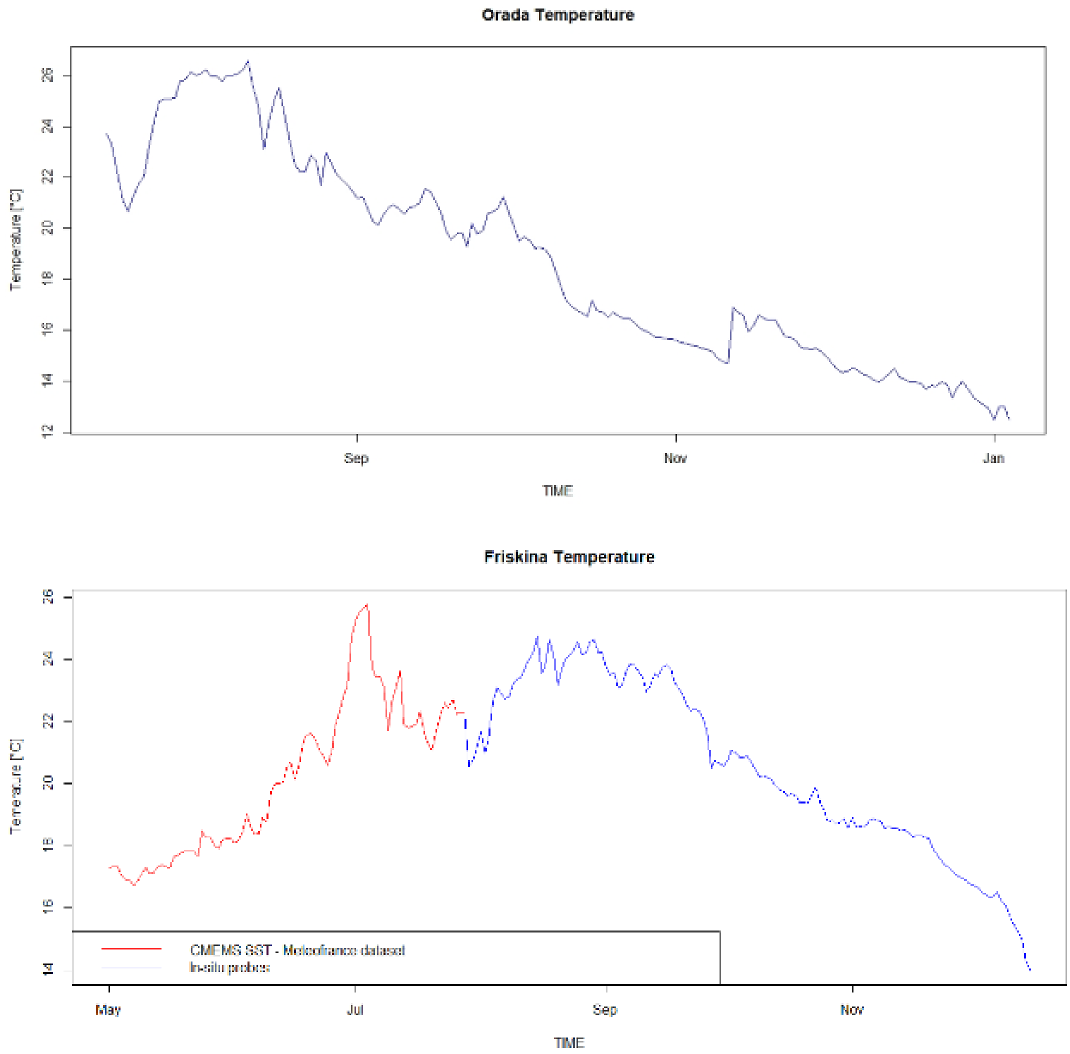

Figure 12 Water temperature time series used as an input at the two experimental sites.

The basic information relating to the two plants was collected through a series of technical meetings carried out first in presence, in December 2019, and subsequently remotely, due to the limitations imposed by the Covid-19 health emergency. The meetings were organized with the following project partners: UNIUD (client), the Institute of Oceanography and Fisheries, and the two Croatian farms, Friskina and Orada. Figure 13 shows an example of a questionnaire used for the initial data collection, which led to some preliminary simulations, and a gap analysis, relating to the missing information.

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BLUE FARM

3 Synthesis of available Friskina Parameters

3.1 SITE DESIGN

LAT	LONG	Species	Depth of the water column (m)	Cage type
43.509773	15.960781	Seabass Seabream		Circular model

Cage dimensions - size or circumference (m)	Cage depth (m)	number of cages	spacing between cages	Ave. stocking density (Kg/m3)	n° of fish per cage	Máx. stocking dens Kg /m3

Figure 13. Section of the data collection spreadsheet used to collect the husbandry information used in simulations from the farmers.

Based on this first survey, it was possible to identify the need to complete the observation system by acquiring site-specific current data. For this reason, Bluefarm srl carried out two field surveys, initially not foreseen in the activity plan. Figure 8 shows a summary of the data collected using a current meter (Valeport model 106, see image in figure 14). The time series of current meter data were acquired in the two sites, respectively first in Friskina between August and November 2020 and in Orada, between July and August 2021.

Figure 14. Current velocity [m s^{-1}] at the tewo pilot sites (sx Orada; dx Friskina), recorded by means of current meter, Valeport model 106.

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The simulated intervals at overlap with the feed trials at the two pilot sites , i.e. from 13/07/2020 to 02/01/2021 at Orada and from 01/05/2020 to 15/12/2020 at Friskina. The results of the individual simulations made it possible to simulate the quantities of organic waste released (non-ingested food and faeces). Starting from these predictions and considering the number of individuals present in the experimental tests, two simulations were compared for each pilot site, each of which referred respectively to the innovative AAN and commercial feed. In order to correctly carry out this comparison, Bluefarm collaborated with UNIUD in the planning of a set of experimental laboratory tests for determining the sinking rate of the feeds. The average value was found to be 0.09 m s-1 for innovative feeds (AAN), and 0.12 m s-1 for the control ones. This information was entered in the "sediment" module of the FiCiM model, used to simulate the depositional impressions at the plants.

2.2. Results: Simulation of growth in the two pilot sites in response to the different diets

The results of the simulations and the growth data collected in situ are compared in Figures 15 and 16. The growth curves show that the innovative AAN feeds performed slightly better, compared with the control ones. The bioenergetic model responds correctly to the forcing and enable one to predict fish weight with sufficient accuracy, albeit the final weight reached at the Orada site was slightly underestimated. It is however interesting to note how the model responds to the different composition of the feed at the Orada farm, where the difference in final weight achieved with the AAN feed is reproduced appropriately. In the case of the Friskina plant, the final weight is reproduced more accurately, however, no substantial differences are visible in the tests carried out by comparing the two feeds.

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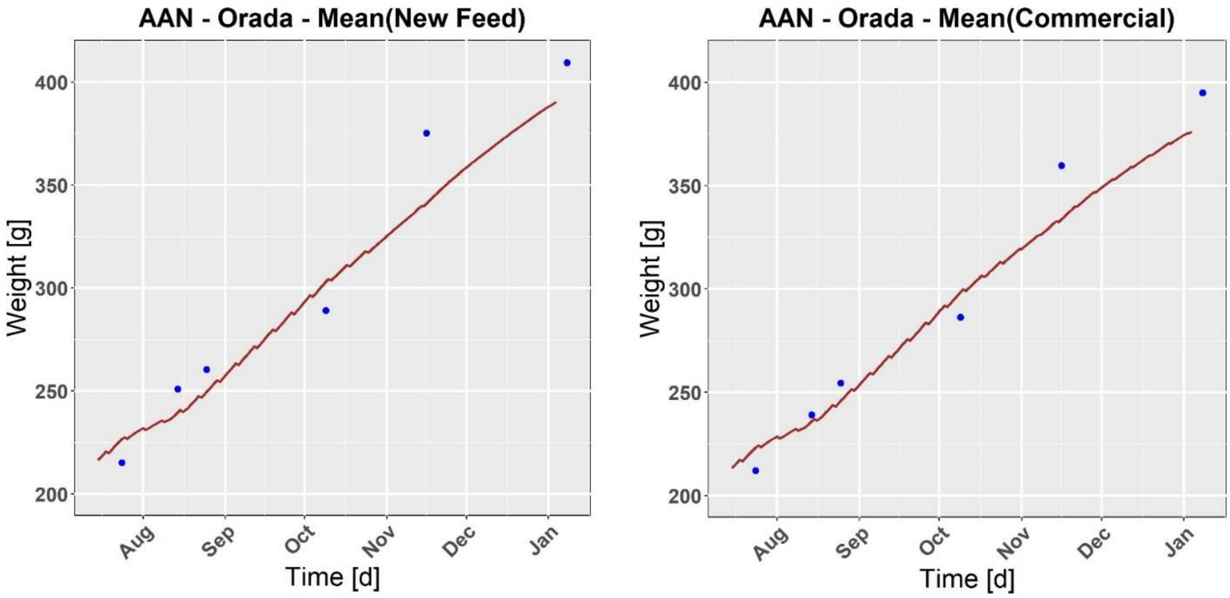

Figure 15. Model results. Orada site. Model growth predictions (red line), and comparison with experimental data collected in situ. Simulations and data refer to individuals fed with innovative feeds - AAN (figure left), and commercial ones (figure right). Data and simulations refer to the period 13/07/2020 - 02/01/2021.

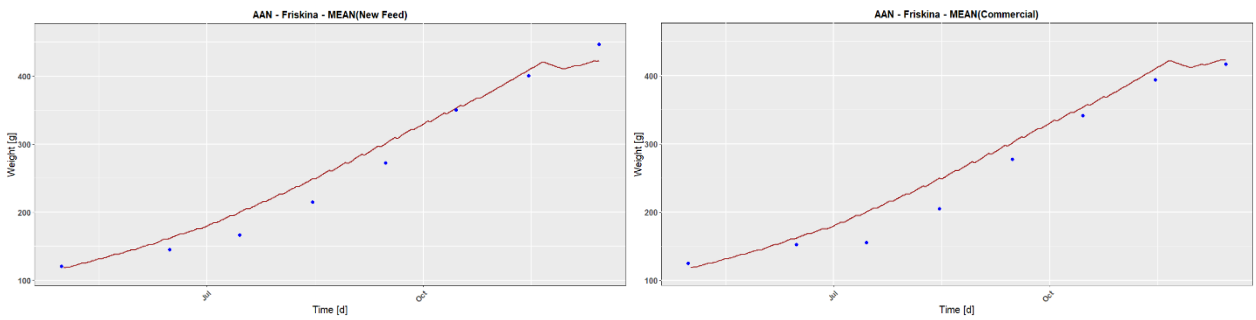

Figure 16. Model results. Friskina site. Model growth predictions (red line), and comparison with experimental data collected in situ. Simulations and data refer to individuals fed with innovative feeds - AAN (figure left), and commercial ones (figure right). Data and simulations refer to the period 01/05/2020 - 15/12/2020.

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2.3. Results: deposition and benthic community indexes at Friskina and Orada farms

The results of the simulated depositional footprints at the two pilot sites are shown in Figures 17 and 18. The model allowed the simulation of the flows of organic matter, here expressed in g C m^{-2} d^{-1}, and their composition, in terms of C: N: P ratio. Similar footprints were therefore produced by the model for the elementary flows of N and P. As can be seen from the figures, the greater density of fish biomass presents during the tests at the Orada site, ~ 41 ind m^{-3}, produced higher flows of organic matter, even though in a large fraction of the impacted area they were lower than the threshold of 0.8 g C m^{-2} d^{-1}, taken as a indicative level of potentially harmful organic enrichment in surface sediment. The result of interest is the difference in the extension of the area affected by the higher flows, reduced in the case of innovative AAN feeds. These differences between depositional footprints are not visible in the simulations carried out at the Friskina site, where the caged biomasses are around 8 ind m^{-3}, with C fluxes that largely remain confined below the value of 0.1 g C m^{-2} d^{-1}. Finally, these flow forecasts were associated with the levels of diversity expected in the macrobenthic community, using the threshold values proposed in Hargrave et al. (2008). In this case, the results are presented only for the case of the Orada site (see Figure 19), as the Friskina site in the simulated conditions presents values that are homogeneously positioned on high values, throughout the domain studied.

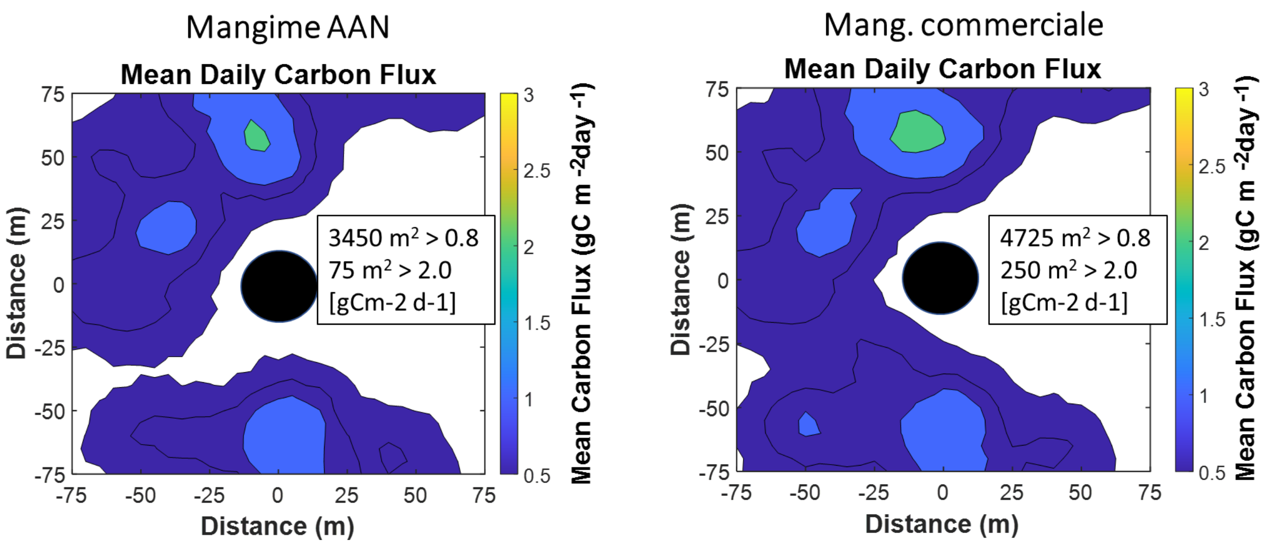

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Figure 17. Simulated depositional impressions at the Orada experimental site. The breeding cage, in the center of the figures, is represented in black. The boxes in the figure show some summary indices relating to the footprints. The simulation considered the stocking density used in the tests, equal to ~ 41 ind m^{-3}.

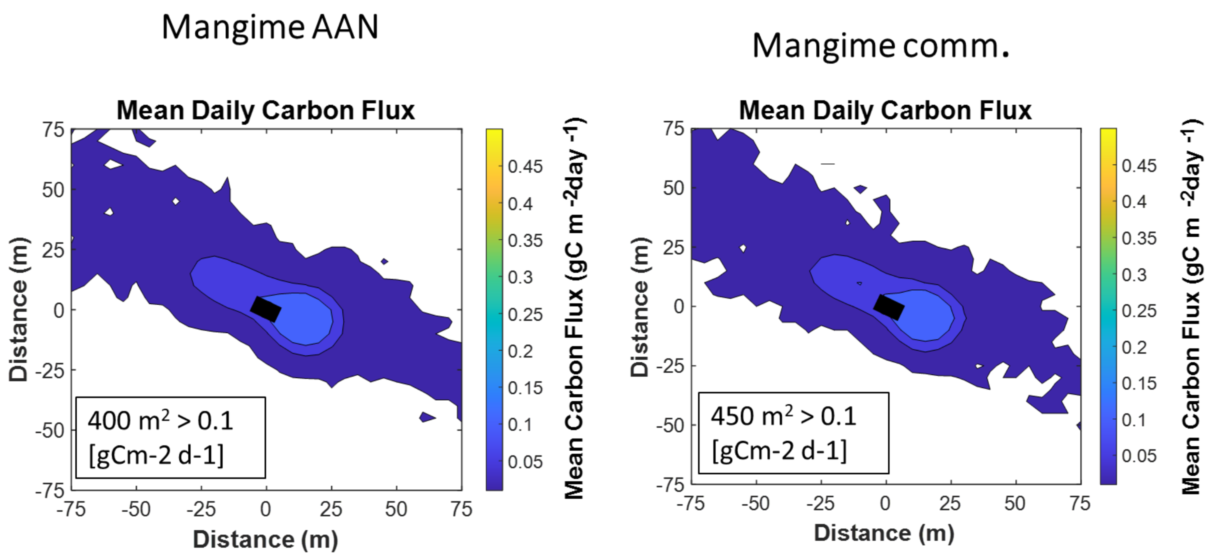

Figure 18. Simulated depositional impressions at the Friskina experimental site. The breeding cage, in the center of the figures, is represented in black. The boxes in the figure show some summary indices relating to the footprints. The simulation considered the stocking density used in the tests, equal to ~ 8 ind m^{-3}.

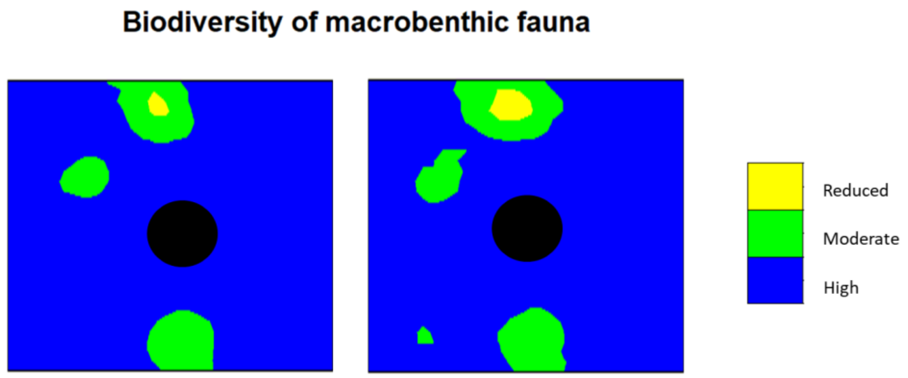

Figure 19. Macrobenthos biodiversity, with respect to the scale proposed in Hargrave et al. (2008)

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Those data were presented to stakeholders during the training events occurred throughout the final project period. In early summer of 2022, the current-meter previously deployed in Ragosnica (**PP8** fish farm), was moved to the farm site of **PP10** in Cres. On site-environmental data were continuously recorded thereafter. The comprehensive dataset (including environmental, farming data), was used by LP-subcontractor BlueFarm srl, for a fine tuning the FiCIM integrated model, also implemented with laboratory measurements performed by **LP** on floating/sinking velocities of the two feed pellets compared in farm-scale trials, under the range of water salinities and temperatures encompassing those actually occurred at farm sites. A new series of simulations/predictions of fish growth, waste release and dispersion underneath the cages and in the surrounding areas with regular or prototype AAN feeds have been obtained. The graphs below show an example of one of the outputs generated by the FiCIM integrated model, i.e. maps of the daily Carbon flux dispersion area around a fish farming cage obtained at Friskina by using in-situ collected environmental and farming data as inputs and lab-trials results for model parameterization. In the figures below the black spot represents a cage. The map on the left refers to the condition when using the AAN diet and that on the right the situation with the commercial feed. Also those model simulations were shown and shared with stakeholders during training activities which took place during the reporting period.

3. Training events and outreaching

As part of the service, Bluefarm participated to the following project events, aimed at disseminating the project results and enhancing their exploitation by stakeholders:

1) Ostuni, September 18th 2020, training event

The presentation "***Un sistema esperto per monitorare e predire la crescita dei pesci e la dispersione dei reflui nelle gabbie marine: concetti teorici e applicazioni pratiche con esempi applicativi ottenuti negli allevamenti del progetto AdriAquaNet (An expert system to monitor and predict the growth of fish and the dispersion of wastewater in marine cages: theoretical concepts and practical applications with application examples obtained in the farms of the AdriAquaNet project)***." was given on line by Roberto Pastres.

2) Padua, November 19th 2021, training event

The lesson entitled **"*From Husbandry Practices to Carrying Capacity: An Integrated Modelling Approach*"** was presented in presence by Roberto Pastres.

3) Ostuni, May 6th 2022, training event

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The lesson ***"Dalle pratiche di allevamento alla capacità di carico: un approccio modellistico integrato (From breeding practices to carrying capacity: an integrated modeling approach)"*** was presented by Roberto Pastres.

During the final conference in Udine, June 20th 2022, Roberto Patres summarized the results of service provided by BLuefarm s.r.l. within the framework of WP3 AAN activities. The presentation was put online.

In the context of these events, the tools developed within the project and described in this document were presented. The results of the simulations carried out for the performance of commercial and innovative feeds (AAN) were also presented and discussed with the stakeholders, collecting useful feedback on the model hypotheses and refining the simulations.

In addition to these events and the technical meetings mentioned in the previous point 3, upon the client request, Bluefarm took part in the project meetings, such as the steering committee meetings, in order to coordinate activities with the other project partners. Finally, Bluefarm presented a contribution in the form of a poster, concerning the simulations carried out at the Friskina site, at the international congress of the European Aquaculture Society, held in Madeira last October 2021.

These activities contributed to reach the Program output indicator 1.104- Participants to training activities and it is linked to the project's SO.2 – Technology transfer to SMEs and SO.3- Training workforce.

4. References

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- Hargrave, B.T., Holmer, M., Newcombe, C.P., 2008. Towards a classification of organic enrichment in marine sediments based on biogeochemical indicators. Marine Pollution Bulletin 56, 810-824.

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PART 2

The second part provides the final results and a collection of data from the WP and project in relation to the General objectives at the Programme level that we will need to add to the final report.

A. CONTRIBUTION TO EUSAIR

Please provide a description of the project contribution to the EUSAIR in terms of synergy with the Strategy's pillars and alignment of implemented project's activities with the Action Plans and labelled projects.

The project directly involved researchers from University and public Institute, fish farms and hatcheries, enterprises (SMEs being part of the aquaculture business chain such as companies for feed producing, recycling wastes, fish food transforming), and different type of stakeholders (experts, general public, productive associations, policy) from Italy and Croatia in order to improve the competitiveness of the mariculture sector Adriatic Sea. The results of task 3.2.3 will ensure important positive impacts on innovation, economic development, job creation, and environmental sustainability. The project approach and outcomes can be transferred to other territories of the EUSAIR macro region, thus multiplying the positive effects of project outputs. In this case, the dynamic models created allowed to follow the fish growth condition in cages and simulate the of the pollutant emissions and dispersions from fish cages and the new systems to treat wastewater from intensive fish farms, that were tested during the project and are proposed for an application in sea bass/bream intensive farming, will contribute to reduce the marine pollution and maintain the marine biodiversity, as required by EUSAIR action plan that identifies aquaculture as a key sector in the blue economy of Italy, Croatia and Greece, having the potentiality to play a pivotal role in the entire area.

B. CONTRIBUTION TO HORIZONTAL PRINCIPLES

Please provide a description of the project contribution to the horizontal principles of equality between men and women, non-discrimination and sustainable development.

Within the project, no distinction was made based on gender, culture, religion or origin. The project engaged technical and administrative staff based on personal characteristics, complying with the equal opportunities and without discriminations. The focus was on the one common goal, or rather on the promotion of a healthy and sustainable product from the Adriatic regions, bringing together farmers, scientists, consumers, veterinarians and experts in the field. New efficient technologies for saving energy were tested and improved in order to ensure a better productivity and profitability of fish farms, providing permanent employment opportunities and increase the sustainability of the aquaculture sector

C. COMMUNICATION ACTIVITIES

Please refer to the Final Communication Report template and provide a summary on the main achievements trying also to identify which were the most successful communication tools in reaching general public/decision makers/other target groups.

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All the activities performed to reach the present DL have been documented with photos and videos taken by LP, PP3, PP8, PP10 and PP2 communication specialists. The material has been uploaded on the Intranet website of the project. Some of the materials was used to produce this report (see above), and to produce communication materials. The aforementioned activities have been presented at the training events held in Padua, Ostuni and online. During the final conference in Zadar (3 June 2022) and Udine (20 June 2022) a summary of the most important results have been presented by LP, PP3, PP8, PP10 staff. Numerous reports, meetings, brochures, training courses, conferences, a website and a YouTube channel have been produced to communicate the results. **These activities contributed to reach the Program output indicator 1.104- Participants to training activities and it is linked to the project's SO.2 – Technology transfer to SMEs and SO.3- Training workforce.**

D. **NATURA 2000**

Please describe, if it is the case, measures foreseen and implemented by the project:

a) In case the project involved Natura 2000 sites, describe what measure the project envisaged and implemented to avoid any negative impact: No Natura 2000 sites are included in the areas where the project activities have been carried out; therefore, no measures have been envisaged and implemented during the project in order to avoid negative impacts.
b) In case the project had a positive effect on Natura 2000 sites, please describe which measure the project has foreseen and implemented in order to reach a direct or indirect positive impact: No Natura 2000 sites are included in the areas where the project activities have been carried out; therefore, no measures have been foreseen and implemented during the project in order to reach positive impacts.

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E. TYPES OF ACTIONS ADDRESSED (as defined in the Cooperation Programme)

These are our primary objective's types of actions, that we addressed by the Project:

Specific Objectives	***Types of action***	***the most relevant one within the SO addressed by your project***
1.1 Enhance the framework conditions for innovation in the relevant sectors of the blue economy within the cooperation area	*Joint projects and actions aimed at creating platforms, networks and at supporting exchange of good practices in order to enhance the knowledge transfer and capitalization of achieved results in the field of blue economy*	***X***
	Actions aimed at cluster cooperation, joint pilot initiatives in order to boost the creation of marketable innovative processes and products, in the field of blue economy	***X***

F. TYPES OF OUTPUTS PRODUCED

Specify the types of outputs generated by your activity that are reported here and provide a brief description

Output typology	**Description**
Trainings	Lessons and presentation were given during 3 training cycles in Ostuni in September2021, in Padua 2021 and again Ostuni 2022. In the context of these events, the tools developed within the project and described in this document was presented. The results of the simulations carried out for the performance of commercial and innovative feeds (AAN) were also presented and discussed with the stakeholders during 8 partners' meetings and 2 final conferences in Zadar and Udine. Moreover, during the meetings partners' and stakeholders' feedback on the model hypotheses and refining the simulations have been collected. The lessons and presentation were put on intranet and collected in training materials WP3 that are uploaded on project website.
Monitoring systems	The model is itself a monitoring system for pollutant emissions from fish cages (dissolved inorganics, organic particulate, uneaten feed and faeces, organic carbon) used in fish farms.

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SMEs clusters	PP8 (Friskina ltd) and PP10 (Orada Adriatic ltd.) were directly involved in testing through the project lifetime. The goal was to compare the impact on the sediment of "AAN" feed with that of a commercial feed one. The results of the simulated depositional fingerprints at the two experimental sites are shown in Figures 17 and 18 of this document. The model allowed to simulate the flows of organic matter, here expressed in g C m^{-2} d^{-1}, and their composition, in terms of C: N: P ratio. The results achieved **in PP8 farm were better for 10% of the conversion rate with the news diets respect to the conventional diets, so it is really a huge achievement for the diet application.** The model has been given at disposal to all the SMEs involved in the project free of charge for the next five years.
New networks	PP3 (the Institute of Oceanography and Fisheries) was involved for the collection of basic information relating to the two experimental plants. A contribution in the form of a poster, concerning the simulations carried out at the Friskina site, was presented at the international congress of the European Aquaculture Society, held in Madeira last October 2021 with the LP. A second contribution was submitted to the 2022 edition of the same symposium, which will be held in Ravenna next October.
Platforms	The monitoring system is reached through a platform **- web interface http:/bluefarmenvironment.com. AAN partner will have access to the web based model for the next five years.**
Adaptation plan	N.A.
Building renovation	N.A.
Others (please specify)	N.A.

G. TYPOLOGY OF IMPACTS

Please indicate what type of impact(s) your project has had. You can choose more than one answer. For each tangible impact selected, please provide a concrete example from your project, where possible supported by quantitative information.

TANGIBLE IMPACTS

Tangible impacts	**Example/ quantitative information**
Improved access to services	N.A.
Cost savings	The model developed can reduce cost for fish production in relation to environmental condition of fish cages and fish health. In combination of the new feeds developed by the project and testing of sinkability of feeds that was completed and fine-tuned on the biomodel, the use of model can produce cost savings for the fish farmers.
Time savings	The model developed will reduce working time of the operators in situ thanks to cameras put in the cages and fast observation of the condition in the farm. The model can help to reduce time in monitoring of fish in relation to environmental condition of fish cages and fish health.

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Reduced energy consumption	
Reduced environmental impact	The applications of the FiCIM integrated model can be used to simulate the waste load from sea bass and bream cages fed novel or conventional feeds. The assessment of the Carrying Capacity - CC is very important for the implementation of a farm management system based on an ecosystem-based management approach. The aim is to estimate the maximum production, taking into account the environmental impact and social acceptability, in order to avoid unacceptable changes in the ecosystem and the socio-economic system. The "carrying capacity" can be defined as the level of use of resources that can be sustained for a long time by the regenerative capacity of the environment. The **«FiCIM»** integrated model allows one to obtain a **quantitative relationships between standing stock and sediment quality** by simulating the following processes: release (faeces, uneaten feed), dispersion, deposition on the sea bed, of the organic matter.
(Man-made, natural) risk reduction	The model also reduces the man-made risk on the fish cages environmental condition and fish feeding.
Business development	New expertise and skills were achieved by learning and using the biomodel. This skills can create new type of operators for the fish farm sector.
Job creation	New expertise and skills were achieved by learning and using the biomodel. These skills can create new type of operators for the fish farm sector.
Improved competitiveness	The use of the model can improve the competitiveness of the fish farms.
Other tangible impacts (specify)	N.A.

INTANGIBLE IMPACTS

Intangible impacts	**Example/quantitative information**
Building institutional capacity	N.A.
Raising awareness	The project has stimulated the attention of fish farmers regarding the issues of reduction of the farm environmental impacts through the study of new techniques and models for the simulation and monitoring of the wastewater from hatcheries and sea cages to improve the sustainability of Mediterranean aquaculture.

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Changing attitudes and behaviour	The project provide to fish farmers new techniques through the study of new techniques and models for the simulation and monitoring of the wastewater to be applied in hatcheries and sea plants, so to improve the sustainability of Mediterranean aquaculture and consequently the competitiveness of sector.
Influencing policies	N.A.
Improving social cohesion	N.A.
Leveraging synergies	The project lead to the strengthening of relations between Italian and Croatian research groups, as well as between universities or centres of excellence and fish farmers. This collaboration may be exploited in the future for the drafting and implementation of new research projects aimed at improving aquaculture farming systems and waste/energy management in fish farms.

These activities had a positive impact on project objectives and helped to reach the Programme output indicators:

CO01 – 24 enterprises received support,
CO02 – 4 enterprises received grants,
CO04 – 20 enterprises received non-financial support,
CO42 – 7 research institutions participated in cross-border, transnational or interregional research projects
CO44 – 578 participants involved in joint local employment initiatives and joint training

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