DEPARTMENT OF INTERNATIONAL AND EUROPEAN ECONOMIC STUDIES

ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS

Techno- and socio-economic models of production with application to aquaculture: Results from the BlueBRIDGE Project

Gerasimos Antzoulatos

Charalampos Dimitrakopoulos

Eleni Petra

Stella Tsani

Phoebe Koundouri

Working Paper Series

20-18

May 2020

Chapter 6

Techno- and socio-economic models of production with application to aquaculture: Results from the BlueBRIDGE Project

Gerasimos Antzoulatos[1], Charalampos Dimitrakopoulos[2], Eleni Petra [3*], Stella Tsani [45], Phoebe Koundouri[678]

Abstract

This chapter[9] presents in brief the work completed within the scope of the BlueBRIDGE project with the aim to support the sustainable management of aquaculture production. The work completed is the result of an interdisciplinary team of IT experts, economists, biologists, social scientists and marine professionals that have joined forces with the aim to develop IT advanced tools and integrated models of production. A very important part of work within the scope of BlueBRIDGE concerned Cloud Computing Infrastructure, Virtual Research Environments (VRES) and the development of integrated production models with focus on aquaculture. These can support well-informed site management and sector related decision making.

Key words: Virtual Research Environments, Cloud Computing Infrastructure, aquaculture, BlueBRIDGE

[1] Olokliromena Pliroforiaka Sistimata, Greece
[2] Communication & Information Technologies Experts, Greece
[3] National and Kapodistrian University of Athens, Greece
[4] University of Ioannina, Greece
[5] International Centre for Research on the Environment and the Economy, Greece
[6] School of Economics, Athens University of Economics and Business, Greece
[7] United Nations Sustainable Development Solutions Network Greece
[8] EIT Climate-KIC Hub Greece, ATHENA Research and Innovation Centre, Greece
* Corresponding Author. E-mail address: elenipetra4@gmail.com
[9] This work has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement N° 675680

6.1 Introduction

BlueBRIDGE, a HORIZON 2020 project responded to the Juncker Investment Plan opening funding opportunities for e-infrastructures, innovating current practices in producing and delivering scientific knowledge advice to competent authorities[10]. The project aimed at the enlargement of the spectrum of growth opportunities in distinctive Blue Growth areas. BlueBRIDGE has built on existing EU and international e-infrastructures providing capacity building in interdisciplinary research communities of scientists, data managers and educators in academic institutions and industries focusing on 4 major challenges: 1) stock assessment, 2) socio-economic performance analysis in aquaculture, 3) fisheries and habitat degradation monitoring, 4) education and knowledge bridging on protection and management of marine resources. BlueBRIDGE capitalized on past investments and used a proven e -infrastructure connecting 1500+ scientists, integrating +50 repositories, executing +13,000 models and algorithms/month; providing access to over a billion quality records in repositories worldwide, with 99,7% service availability. BlueBRIDGE also focused on user needs, opening services and data to actors and liaising with competent agencies and SME Innovation Clusters.

BlueBRIDGE brought together an authoritative and complementary consortium with expertise in multiple scientific domains. It bundled forces from International Government Organizations (FAO– Italy, ICES – Denmark, ASSOCIATION POLE MER BRETAGNE (PMBret) - France), research institutes (CNR - Italy, ERCIM- France), IRD France, FORTH - Greece), STIFTELSEN GRID ARENDAL - (GRID Arendal) – Norway), industry ENGINEERING – Italy, CLS - France), SMEs (TRUST-IT - United Kingdom, OLOKLIROMENA PLIROFORIAKA SISTIMATA (I2S) - Greece, COMMUNICATION & INFORMATION TECHNOLOGIES EXPERTS ANONYMOS ETAIREIA SYMVOULEFTIKON KAI ANAPTYXIAKON YPIRESION (CITE) – Greece), education and computer science domains (ETHNIKO KAI KAPODISTRIAKO PANEPISTIMIO ATHINON (UOA) - Greece), establishing a network with a proven track in VREs and e-infrastructures, marine, environmental and fisheries science and economy.

A very important part of work within the scope of BlueBRIDGE concerned Cloud Computing Infrastructure, Virtual Research Environments (VRES) and the development of integrated production models with focus on aquaculture. The VRES aimed to deliver economic growth and environmental planning capacity-building instruments to confront modern science and economic analysis challenges, as identified by both scientists and aqua-farming industry and investors. VRES have been developed within the project with the aim to allow for the first time to address in an integrated way the problem of global knowledge access, seamless data exchanges and reuse between aquaculture companies and its related stakeholders. The tools have been developed through the cooperation of different experts (computer scientists, biologists, economists, sociologists, etc.) with the intention to give new instruments to policy makers and scientists for supporting their research and well-informed decisions.

The technology developed allows: (a) companies to improve efficiency, increase profitability and do business in a sustainable, environmentally friendly way, enabling them to convert their operation data into knowledge and actionable results; (b) researchers access datasets concerning the practices and performance of aquaculture producers, generating new knowledge and evaluating the practical indicators of aquafarming performance; (c) governments and

[10] See: https://www.bluebridge-vres.eu/

environmental agencies to evaluate the current situation and define policies; (d) SMEs and academic institutes to provide training for executives and decision makers on the sector; (e) investors to efficiently take decisions using, for instance, multifactor evaluation approaches. The delivering of these technologies has been completed through a continuous development process in which: (i) detailed needs for related capacity-building instruments are collected and verified, (ii) service and data offerings is delivered, and (c) results and effectiveness of the instruments are validated.

Integrated production models developed within the scope of the project, try to fulfill the basic demand of incorporating all the possible factors that are vital for global sustainable development within the process of productivity-potential. The methodology proposed as well as the type of models that have been developed are easily applicable to several different domains such as agriculture, food production, industry, etc. Integrated production models, are developed for the aquaculture sector, in order to: (1) assess and conceptualize the social, economic and environmental impacts of climate change, over the same time period; (2) gather intelligence and data that will assist decision making plagued with uncertainty, (3) fostering innovation and (4) strengthen the transition towards a Blue Economy by incorporating specific socio- and techno-economic factors. Sustainability indicators within a socio- techno- and ecological context are utilized in order to examine and record developments over a specific time period, and assist in producing qualitative and quantitative data, within a much larger system that includes consumers and the chain of production.

This chapter provides a brief overview of the VREs developed within the BlueBRIDGE project with focus on aquaculture. Section 2 discusses VRES for aquaculture. Section 3 reviews the socio-economic extensions of the production models developed. Section 4 briefly presents the option to run and examine alternative future production scenarios. Last section concludes.

6.2 VRES for aquaculture production

Two identified VREs have been examined within the BlueBRIDGE scope. The first includes: Performance evaluation, benchmarking and decision making in aquaculture VRE. This approach focuses on capturing and confronting the dual challenge of understanding: (a) the performance of an aqua-farming operation, allowing on one hand investors and entrepreneurs to conform to environmental rules and optimize the use of resources (monetary and non-monetary ones) and (b) the pressure on investment and on environment produced by such operations, so that scientists and policy makers can craft guidelines or even regulations, taking into account the economic interest and socio-economic impact of those operations. To achieve the goal, a VRE is provided, granting aqua-farming sector entrepreneurs, investors, scientists and decision makers with access to: (a) open data combining performance, environment, regional and socio-economic datasets, (b) a framework to support performance analysis and benchmarking and, (c) a fundamental baseline set of indicators and models that provide the performance metrics in question.

In order to accomplish the goals, the provided services consist of three main components, namely Site management, Model management and What-If Analysis. In Site management, aqua farmers set up the profiles of their Sites (thermal and environmental characteristics) to provide useful information to the model's creation. In model management, the supplied historical production data in combination with environmental and thermal site profile are analyzed to create models which are capable to evaluate the production performance. The What-If analysis service (discussed in more detail in section 4 of this chapter) provides to fish farm managers the opportunity to determine what-if scenarios, evaluate the vital key performance indicators for the fish growth and make efficient and accurate production plans. The service is developed with the intention to allow for future benchmarking analysis, comparing one's company Key Performance Indicators (KPIs) against other aquacultures which operate under "similar" circumstances.

The second VREs option examined within the BlueBRIDGE scope regards Strategic Investment analysis and Scientific Planning and Alerting. This alternative aims to satisfy the need for intelligent identification of locations of interest under an open-ended set of criteria, as required by both investors seeking optimization of intended investments and by scientists seeking areas that are becoming of environmental importance. Building on the products of the previous as other VREs offerings (services, models and datasets) and extending those with techniques of computational intelligence, more algorithms/ indicators/datasets, this VRE delivers a cutting edge geospatial multi-factor optimization and alerting platform, of unprecedented value tool for scientists and the aqua-farming industry and vast opportunities for inter-disciplinary exploitation beyond its definition.

This VRE is based on a cost-driven techno-economic evaluation model for aquaculture investment analysis. Breaking down the costs of building and running an aqua farm while estimating sales from its' main business activities the model can provide a 10-year estimation for the cash flows of the specific aqua farm. This model also takes into consideration the output of production models in order to estimate costs of production and it is currently being enhanced with variables of socioeconomic impact. Net Present Value (NPV), Internal Rate of Return (IRR), Yearly Net Profit Margin and several other KPIs and financial metrics are produced from this model aiming at a more complete investment analysis that will support a solid scientific planning and decision-making procedure for aquaculture.

6.3 Socio-economic and environmental monetization extension in aquaculture management tools

A core advancement within the scope of the BlueBRIDGE project is the integration of social, economic and environmental variables in the decision support tools developed for aquaculture production. The research on the modelling of aquaculture production is ongoing. Available models look at the financial and economic aspects of aquaculture, while others are developed along the lines of cost-driven production. The work completed for BlueBRIDGE bring socio-economic and environmental impact into consideration when analyzing aquaculture operation performance. The multi- and intra-disciplinary work completed for the project responds to challenges of identifying, conceptualizing and monetizing the social and environmental impact of aquaculture. Once identified these model parameters have been combined in a workable way with specific techno-economic and production models of Blue Economy, considering data and computational resources in reach.

For this the research team has undertaken a thorough Social Costs Benefit Analysis SCBA in which the costs and benefits of fish production are identified, modelled, evaluated and monetized. SCBA aims at incorporating the effects that extend beyond private costs and revenues and regard the broader impact which aquaculture has on the society. The SCBA systematically identifies, organizes and valuates the benefits and the costs of aquaculture. The approach is detailed in Tsani and Koundouri (2018) and it aims at: i) extending the identification of the costs and benefits of aquaculture beyond pure financial metrics and monetary terms, and ii) extending the modelling of aquaculture production beyond the quantification of private costs and benefits and including in the analysis the social costs and benefits associated with aquaculture (a graphical summary of the methodology is provided in Figure 1). The modelling approach consists of three parts: i) Ecological part where the modelled relationships aim at capturing the interactions of aquaculture and associated costs and benefits as regards the environment (CO2 emissions, water pollution, spatial limitations etc.), ii) Economic: This part makes provision for the explicit incorporations of economic determinants in production models and iii) Social part that introduces social costs and benefits in the aquaculture production and management decision process. Appropriate relationships are formulated which quantify and introduce the socio-economic and environmental costs and benefits of aquaculture into the decision support system of aquaculture management.

The costs and benefits considered include among other financial production, social interactions and environmental impacts, translated into effects on ecosystem services and social effects evaluated over time and space. This framework allows decisions that are consistent with the concepts of environmental sustainability, economic efficiency and social equity. The main goal of this work has been the contribution to an interdisciplinary and participatory framework of analysis of technical, environmental, economic, social aspects of Blue Growth, which can provide policy recommendations for improved implementation of the Initiative, allied with the relevant Sustainable Development Goals (SDGs) and the Marine Strategy Framework Directive (MSFD) and Marine Spatial Planning (MSP).

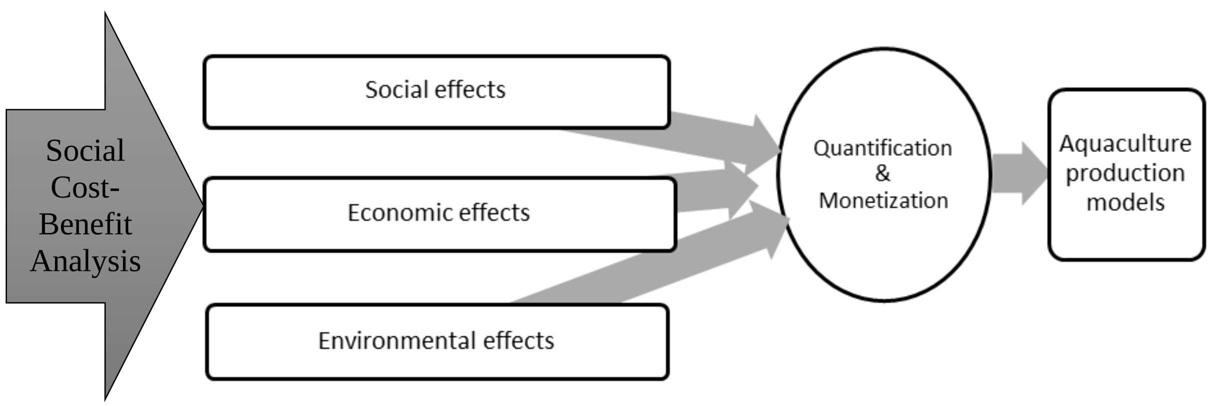

Figure 1 - Identification of socio-economic and environmental impact of aquaculture and their integration to aquaculture production models (Source: Tsani and Koundouri, 2018)

Drawing on the resent research the working team on this model extension has identified and quantified the socio-economic and environmental costs and benefits associated to aquaculture in a way compatible to the techno-economic and cost-driven production models available. The work undertaken allows for the development of an integrated production model for aquaculture that takes into consideration and incorporates the complex feedbacks between ecological and economic aspects of aquaculture production. In this way: i) it can be met the integrated management of aquaculture production that take into consideration both the private costs and benefits but also the social costs and benefits associated with externalities and effects not appropriately captured by market-driven functions and factors, and ii) it can be provided quantified insights to the social costs and benefits that producers internalize or can internalize, which can complement policies targeting aquaculture management and financing (e.g. subsidies, environmental taxes, etc.).

6.4 What-If Analysis in aquaculture production models

In aquaculture, the accurate estimation of the fish growth is a cornerstone of an efficient and profitable production. Without information on expected growth, it would be impossible to assess feed requirements for specific period and additionally to approximate the date that fish are ready for harvest. Growth depends upon the quantity and quality of food ingested, as well as environmental factors such as sea temperature, oxygen, currents etc. In recent decades, the prediction of growth rate and feed consumption of cultivated fish have gained increasing attention and many empirical models based on mathematical/statistical methods have been proposed. Models can be used to estimate the growth and feed intake in terms of specific factors rely on the experimental data and the experts' knowledge (Petridis & Rogdakis, 1996), (Zhou, Xu, Lin, Sun, & Yang, 2017), (Jobling, 2008), (Mayer, Estruch, Blasco, & Jover, 2008), (Arnason, Bjornsson, Steinarsson, & Oddgeirsson, 2009).

A core output of the work within the BlueBRIDGE project, has been the creation of models able to predict production indicators such as Feed Conversion Rate (biological FCR), Feeding Rate (FR) and Mortality Rate based on the study of historical production data. The models are established via the state-of-the-art regression methods, such as Generalized Additive Models (GAMs) and Multivariate Adaptive Regression Splines (MARS). For each indicator the model with the highest accuracy is employed in order to estimate the values of indicators in various growth levels (fish weight) and different temperatures. The outcome of this process is a representation of empirical models, which simulates the relationship between growth, feeding and temperature. Specifically, the modeling results in the development of tables for biological FCR, Feeding Rate and Mortality Rate in terms of fish weight and temperatures. Figure 2 provides an example graphical representation of a biological FCR table indicative of the developed model. For each weight category and temperature, it can be estimated the indicator value by the modeling of real production data.

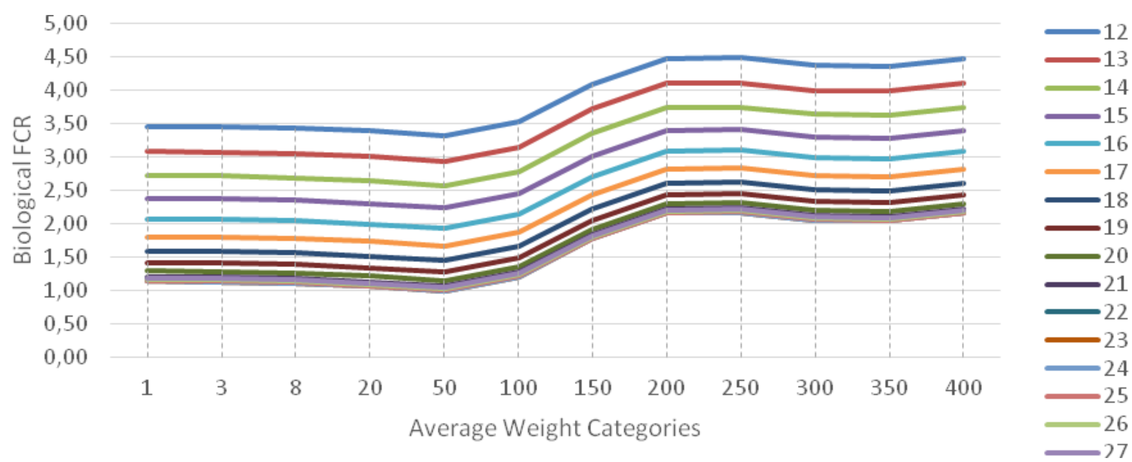

Figure 2 - Representation of Biological FCR table per Weight Category grouped by Temperature

Having these information aqua farmers can perform production plans and assess vital Key Performance Indicators (KPIs) by the examination different hypothetical statements (what-if scenario). Specifically, they can define easily the conditions of hypothetical scenarios by setting the number and the average weight of fish population and the period of interest that cultivate the fish, (stocking date and harvest date) and forecast the evolution of KPIs in this period. Through this simulation process, they can alter the hypothesis and compare the results of each scenario in terms of LTD Biological FCR, LTD Economical FCR, LTD SGR, LTD Growth, and LTD Mortality. Simultaneously, they can benchmark their aquafarm performance against the competition. The core idea behind benchmarking process is to provide a tool in which aquafarmers can compare their farms' performance against the performance of other farms with similar characteristics in terms of the crucial KPIs without sacrificing the confidentiality and privacy of their data. More specifically, using Blue Economy tools aquafarm managers achieve to estimate and benchmark the performance of their farms' production by carrying out simple steps as illustrated in Figure 3 and discussed in brief next.

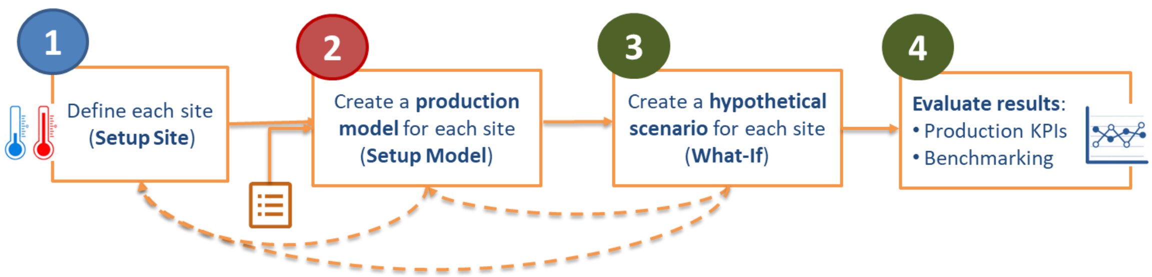

Figure 3 Steps of Performance Evaluation and Benchmarking process

Setup the site of interest (Setup Site tool): The user can define the specific environmental characteristics of the site of interest providing the average temperature fortnightly and the geographical location of the site.

Create models (Setup Model tool): The user can develop reliable and powerful Machine Leaning models, which are capable to estimate vital production indicators, such as biological FCR, FR and Mortality Rate, providing historical data and details regarding the production of the specific fish species of the site of interest.

Create a hypothetical scenario (What-If Analysis tool): The user can draw a hypothesis and evaluate it by using an already existing model. The system using the user-defined conditions and the output of the modeling process (tables of FCR, FR and Mortality Rate) can grow the population up to a particular date (harvest date).

Evaluate and benchmark the performance: The results of the previous step are presented by various interactive graphs and tables exhibiting the performance of Key Performance Indicators (LTD Biological FCR, LTD Economical FCR, LTD SGR, LTD Growth, LTD Mortality, monthly feed consumption and average weight per day). In addition, system compares the performance of user's production against the competition. The benchmarking process is carried out over the sites with similar environmental characteristics implying that they will have similar productions. The system executes a back-end process hidden from the end-users, detects all the sites, which are similar with the site of interest. Then, it creates a 'global' production model. The same what-if scenario is fed to the global model and the results are compared with the results coming from aquafarm's production model. The process is iterative and users can go backward to create new sites and/or models or evaluate new scenarios and so on.

6.5 Concluding remarks

Aquaculture can be core to Blue Growth targets with benefits exceeding the private benefits. The sustainable and efficient management of aquaculture production, at micro- but also at macro-level, requires the use of cutting-edge technology, novel IT applications and integrated socio-economic tools. The tools and the methodology developed within the scope of the BlueBRIDGE project allow for the use of advanced IT applications and facilities and the introduction of the wider socio-economic and environmental effects of aquaculture into the production management. This can support well informed management and decision making. The tools and methods developed facilitate the estimation of an integrated value of production that looks beyond output maximization. Developing and proposing easy to use tools enables all producers and the sector overall to engage in the technology race and use it at their own benefit. From a policy perspective the outputs of the project enable the well-informed and forward-looking decision making and target setting.

REFERENCES

Arnason, T., Bjornsson, B., Steinarsson, A., & Oddgeirsson, M. (2009). Effects of temperature and body weight on growth rate and feed conversion ratio in turbot (Scophthalmus maximus). Aquaculture (295), 218-225.

Jobling, M. (2008). Environmental Factors and Rates of Development and Growth. In P. J. Hart, J. D. Reynolds, & L. John Wiley & Sons (Ed.), Handbook of Fish Biology and Fisheries (Vol. Volume 1: Fish Biology, pp. 97-122). Blackwell Publishing Ltd. doi:10.1002/9780470693803.ch5

Mayer, P., Estruch, V., Blasco, J., & Jover, M. (2008). Predicting the growth of gilthead sea bream (Sparus aurata L.) farmed in marine cages under production conditions using temperature- and time-dependent models. Aquaculture Research, 1-7.

Petridis, D., & Rogdakis, L. (1996). The development of growth and feeding equation for sea bream, Sparus aurata L., culture. Aquaculture Research, 27, 413-419.

Tsani, S. and Koundouri, P. (2018) A methodological note for the development of integrated aquaculture production models, with P. Koundouri, Frontiers in Marine Science, 4, 406, https://doi.org/10.3389/fmars.2017.00406

Zhou, C., Xu, D., Lin, K., Sun, C., & Yang, X. (2017). Intelligent feeding control methods in aquaculture with an emphasis on fish: a review. Reviews in Aquaculture, 1-19.