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Economic assessment of investment in automatic feeding systems for sea bass grow-out farms of different sizes

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Abstract

The aim of this work was to run an economic assessment of investment in automatic feeding systems for grow-out farms of different sizes producing European sea bass in the Mediterranean Sea. For this, we have used an economic model to simulate the annual income statement of a typical farm with different production volumes: a small-sized farm with a production of 413 tons/year, a medium-sized farm of 1122 tons/year, and a large-sized farm of 2539 tons/year. With the values obtained in the simulation, we have carried out partial budget and investment analyses to estimate the economic value of this investment decision. To complement our economic assessment, a sensitivity analysis has also been run to include risk in the investment decision. Our findings show that the implementation of automatic feeding systems in sea bass grow-out farms would be a good economic decision, regardless of the farm size, since there are technological options suitable for different farm sizes and capital investment capacities. Consequently, innovation and investment in feeding management should not be impeded or limited by the farm size.

KEYWORDS
aquaculture, automatic feeding, feeding system, Mediterranean aquaculture, sea bass

1 | INTRODUCTION

European sea bass (*Dicentrarchus labrax*) and gilthead sea bream (*Sparus aurata*) are economically important fish species cultured along the Mediterranean coast. According to *Eurostat* data, in 2019 both species represented approximately 26.5% (€944 million) of the total value of EU27 aquaculture. Most of the European production is cultivated at industrial scale in floating sea cages, Greece and Spain being the largest producers in the EU27 (54.9% and 21.4% of the total production respectively).

Moreover, sea bass culture is an industry with high economic competitiveness in which the profitability of operations is very sensitive to different factors. The variation of firms' operating profits and margins cannot be explained only by changes in the sales prices, but also by other operational factors such as the cost of fingerlings or the cost of feed (Di Trapani et al., 2014; Fernández Sánchez, Llorente, et al., 2022). Technology development is transforming aquaculture from being extensive and labor-intensive to intensive and mechanized with more automated systems. These innovations result in labor productivity improvements and facilitate aquaculture production growth (Engle et al., 2020; Li & Li, 2020).

It is generally accepted that the highest recurring cost in grow-out aquaculture comes from feeding, one of the main management concerns of any cage aquaculture operation. Thus, feed is the main input factor in sea bream and sea bass aquaculture with a cost share of approximately 46% (Nielsen et al., 2021). Improvements in feed nutrition, feed management methods, and feeding systems may contribute to a better utilization of feed (reduced feed conversion rates) to improve fish growth and minimize environmental impact, which could reduce the cost of production (Luna et al., 2019). According to Hasan and New (2013), better management can reduce the feed cost by 15%–20%. For example, salmon aquaculture, in which this cost is over 50% (Asche & Oglend, 2016), has benefited from considerable improvements in feed efficiency and lower operating costs using pelleted diets, together with modern feeding technology (Blyth & Dodd, 2002). Hence, adopting specific measures to limit the magnitude and impact of feeding in fish farming would lead to improvements in production efficiency and, consequently, in operating profit margins.

One of the innovations in aquaculture feeding is the implementation of automatic feed technology on farms growing out different species.[1] Because personnel cannot be present or are unable to work every day on farms located in remote places or exposed to wind or waves, automated or remotely controlled feeding systems are crucial for farm operations (Føre et al., 2018). Furthermore, the outcomes of traditional hand feeding can vary among farms since they depend on the skills of the feeding staff, which introduces more uncertainty to the farms' economic results (Føre et al., 2018; Kousoulaki et al., 2015). Whereas investing in automatic feeding systems is simpler in inland/freshwater aquaculture (e.g., trout, tilapia, or shrimp) and their use is quite extensive in farms of different characteristics, the cost of the technology needed is higher for sea cage farming. These systems were successfully implemented in salmon farming many years ago and have been introduced more recently in big sea bream and sea bass on-growing cage farms. However, they are not so widely implemented in smaller farms where high investments can be very risky.

The aim of this work was to run an economic assessment of investment in automatic feeding systems for grow-out farms of different sizes producing European sea bass in the Mediterranean Sea.[2] This research is the first formal analysis of this kind so far and can be very useful for sea bass producers, especially for those of small- and medium-

[1]An automatic feeding system requires, in addition to the feeding equipment, real time sensors (for oxygen, temperature, etc.) and cameras, as well as specific software to monitor feeding operations (www.fishfarmfeeder.com).

[2]The implementation of this technology is not very extensive in the Mediterranean Sea compared with other marine regions in the world and for other species (e.g., the production of Atlantic salmon in the Nordic Sea).

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sized farms, to take more appropriate management and investment decisions. In the following section, we explain the methodology employed to continue presenting the results of this analysis. In the last section, we summarize the main conclusions of our work.

2 | METHODS

We have employed an economic model developed by Fernández Sánchez, Llorente, et al. (2022) to simulate the annual income statement of a typical grow-out farm producing European sea bass in the Mediterranean Sea for different production volumes.[3] Since there is no unique technology suitable for all volumes of production,[4] we propose to analyze three feeding systems, one specific system for each farm size. All reduce feeding effort and are designed for optimal feed distribution. Thus, we have the following systems[5]:

a. Feed cannon or blower: This is an individual feeder system mounted on a small boat to move and blow the feed from cage to cage. This technology is appropriate for small-sized farms because of its low investment cost and the low feed weight it has to transport.
b. Flexi-feed blower: This is a flexible fish feeding system since it can be moved to different-sized boats to feed fish in various cages at one time. Its storage capacity is larger than the former system, which reduces the number of trips needed in larger farms. This is the feeding technology proposed for medium-sized farms.
c. Centralized system (feed barges). This feeding system has a huge storage capacity located permanently on a large barge with different pipes so that fish stocked in multiple cages can be fed at any time and thus avoid having to transport the feed to the cages. This is the feeding technology recommended for large-sized farms because, despite its high cost compared with the former systems, a lot of fish can be fed at the same time.

The investment cost of the feed cannon would be around 5000 €, 140,000 € for the flexi-feed blower, and 1,800,000 € for the *centralized system*. Each technology includes the investment cost of the remote control with sensors, cameras, and software.

To estimate appropriate parameter values for the model, we have obtained data from a sample of grow-out facilities among a representative group of European firms producing sea bass in the Mediterranean Sea (five from Croatia, three from Spain, one from Italy, and one from Cyprus) collected in a survey conducted in the European project MedAID (www.medaid-h2020.eu). To validate our model, parameters were revised by a group of experts in sea bass production such as researchers specialized in feeding and breeding, production managers in grow-out farms, and industry professionals (e.g., veterinarians), who verified that these values could be representative of a typical farm. With the economic values estimated in the model, we have carried out partial budget and investment analyses to assess the economic profitability of implementing the former technologies. To complement our economic assessment, we have also run a sensitivity analysis to include risk in the investment decision.

2.1 | Baseline values of model parameters and impact values

To conduct the simulation, we need to hypothesize about the baseline values for model parameters. Moreover, we also have to set up the impact values of implementing each feed technology on the former production parameters. First, we present the model parameters assumed for each farm size in Table 1. We assume that the annual

[3]The same model has been used to assess the economic impact of fish diseases on sea bass grow-out farms (Fernández Sánchez et al., 2022a).
[4]The most efficient feed technology to be used in each farm depends strongly on the amount (weight) of feed necessary to deliver every day, which depends on the biomass cultured in the farm, as well as the number of cages in the facility, which will affect the number of trips and the time employed.
[5]This information was provided by a company supplier of fish feeding systems in December 2020.

TABLE 1 Model parameters by farm size (baseline values).

Concept	Unit	Small-sized farm	Medium-sized farm	Large-sized farm
Annual farm production	tons/year	413	1122	2539
No. of cages	# cages	14	38	86
Cage size (volume capacity)	m^3/cage	4000	4000	4000
Maximum biomass density	kg/m^3	15	15	15
Average wage	€/employee	16,440	16,440	16,440
No. of employees per cage	# employees/cage	0.8	0.8	0.8
Energy cost per cage	€/cage	3124	3124	3124
Veterinarian-medicine cost per cage[a]	€/cage	650	650	650
Other operating costs per cage	€/cage	3411	3411	3411
Annual depreciation rate	%	10	10	10
Capital investment per cage	€/cage	151,265	151,265	151,265

[a]We assume that there are no important disease outbreaks in the year.

production of a small-sized farm would be around 413 tons using 14 cages of 4000 m^3/cage, 1122 tons using 38 cages of 4000 m^3/cage for a medium-sized farm, and 2539 tons using 86 cages of 4000 m^3/cage for a large-sized farm.[6] All farms have a maximum biomass density in each cage of 15 kg/m^3. To facilitate the comparison, we have also assumed that all operating costs per cage are the same for all facilities (average values obtained from our sample of farms). Thus, the labor cost per employee is 16,440 €/year and the number of people employed in each facility is 0.8 workers per cage installed. We also assume that there are no important escape events or disease outbreaks in the year, so the regular veterinarian and medicine costs are around 650 €/year. The other operating costs per cage would be around 6411 €/year and the annual depreciation rate would be 10% with an invested capital of 151,265 € per cage.

With regards to the production process (see Table 2), we assume that each farm will grow-out European sea bass with a final market weight of 450 grams and a sales unit price of 5.80 €/kg.[7] We assume an average survival rate of 90% during the whole production period (around 24 months) since we have assumed an absolute growth rate (AGR) of 18 grams/month. We have also assumed that the initial weight of fingerlings is 11 grams/unit, which are bought from a hatchery or pre-growing external facility at the unit price of 0.31 €/unit. The average feed cost is fixed at 1.05 €/kg, whereas the feed conversion ratio (FCR) is 2.4.

Finally, the assumptions about the impact values of implementing each feed technology on the production parameters are presented in Table 3. Automatic feeding systems can impact positively on the growth rate, reducing the culturing period of the fish, as well as the FCRs (Kousoulaki et al., 2015). According to the information provided by the experts on sea bass production, we assumed improvements in both AGR and FCR of 0.5% using feed cannons, 1% using flexi-feed blowers, and 5% using centralized systems. On the other hand, we have assumed that each farm will increase its annual energy costs by around 2% in a small-sized farm using feed cannons, 5% in a medium-sized farm using flexi-feed blowers, and 10% in a large-sized farm using centralized systems because more energy (electricity and/or gas-oil) will be necessary to run feeding operations. Finally, according to the adopted technology, the invested capital will increase by 0.3% in a small-sized farm, 2.4% in a medium-sized farm, and 13.8% in a large-sized farm, which will increase the annual depreciation costs of each farm. Regarding labor costs, we have assumed that

[6]We have employed the typology of farm size suggested in the MedAID project (Aguilera et al., 2019).
[7]The sales unit price of sea bass was calculated taking the Spanish retail prices and discounting the added value over the ex-farm price (EUMOFA, 2019).

TABLE 2 Production parameters (baseline values).

Concept	Unit	Parameter value
Cultured species	name	European sea bass
Sales unit price[a]	€/kg	5.80
Fish harvested weight	grams/unit	450
Fingerling initial weight	grams/unit	11
Mortality rate[b]	%	10
Absolute growth rate (AGR)	grams/month	18
Cost of fingerlings	€/unit	0.31
Average feed cost	€/kg	1.05
Feed conversion rate (FCR)	ratio	2.4

[a]The sales unit price of sea bass was calculated by taking the Spanish retail prices and discounting the added value over the ex-farm price (EUMOFA, 2019).
[b]We assume that it is a standard rate of natural mortality or loss since we consider that there have been no important disease outbreaks or escape events in the year.

TABLE 3 Impact values in model parameters caused by the implementation of automatic feeding systems in sea bass grow-out farms (% of variation over baseline values).

		Model parameters			
Farm size	Feeding system	AGR	FCR	Energy cost	Capital invested
Small-sized farm	Feed cannon or feed blower	+0.5	−0.5	+2	+0.3
Medium-sized farm	Flexi-feed blower	+1	−1	+5	+2.4
Large-sized farm	Centralized system	+5	−5	+10	+13.8

Abbreviations: AGR, absolute growth rate; FCR, feed conversion ratio.

the employees in charge of fish feeding are also performing other tasks on the farm, so the impact of implementing automatic feeding systems would be zero over the farm's labor cost.

3 | RESULTS

3.1 | Partial budget analysis

The results of the partial budget analysis are presented in Table 4. The estimations of economic variables (operating unit cost and operating profit) are used to evaluate, through a what-if analysis, the economic impact of changes in some of the operational parameters in the model caused by the implementation of automatic feeders in the farms.

Looking at the figures in Table 4, we can observe that before the investments we can produce a 450-gram fish with an average operating cost of 4.70 €/kg regardless of the farm size. However, we estimate that the implementation of each technology would reduce the average operating cost by 0.01 €/kg in a small-sized farm, 0.02 €/kg in a medium-sized farm, and 0.11 €/kg in the case of a large-sized farm. This difference in the reduction of the average operating cost is explained by differences in the impact of each feeding system on the production parameters. Moreover, the net operating profit before the implementation of automatic feeders (baseline value) is positive in all cases, being 410,972 €/year in the small-sized farm, 1,115,495 €/year in the medium-sized farm, and 2,524,541 €/year in the large-sized farm. The implementation of automatic feeding systems will

TABLE 4 Economic variation in a sea bass grow-out farm implementing automatic feeding systems (partial budget analysis).

Concept	Unit	Small-sized farm	Medium-sized farm	Large-sized farm
Average operating cost (baseline value)	€/kg	4.70	4.70	4.70
Reduction in the average operating cost	€/kg	−0.01	−0.02	−0.11
Net operating profit (baseline value)	€/year	410,972	1,115,495	2,524,541
Increase in the net operating profit	€/year	7878	31,362	383,629

TABLE 5 Investment parameters and results of the investment analysis.

Concept	Unit	Small-sized farm	Medium-sized farm	Large-sized farm
Feeding systems[a]	name	Feed cannon	Flexi blower	Centralized system
Investment in capital (I)	€	5000	140,000	1,800,000
Investment horizon (n)	years	5	5	5
Annual discount rate (k)	%	8	8	8
Annual cash-flow variation (CF)	€/year	8513	45,157	563,150
Internal rate of return (IRR)	%	169.1	18.4	17.0
Net present value (NPV)	€	28,990	40,300	448,496
Benefit–cost ratio (BC)	ratio	6.8	1.3	1.2
Payback period (*P*)	months	7	37	38

Note: Investment prices (*I*) were obtained in December 2020.
[a]All systems include remote monitoring with sensors, cameras, and software.

increase net operating profits in all cases, the largest increase being in the large-sized farm, with an increase of 383,629 €/year (an improvement of 15.2%). In the case of the medium-sized farm, the increase in the net operating profit is 31,362 €/year (an improvement of 2.8%), whereas in the small-sized farm, the increase would be 7878 €/year (an improvement of 1.9%).

3.2 | Investment analysis

To assess the investment decision (i.e., whether the investment is worthwhile or not), we have set up specific values for the time horizon of the investment (n), the annual discount rate (k), as well as the amount necessary to invest (I) in each feeding technology (see Table 5). We have cautiously set up the investment time horizon at 5 years for all farms. To set the annual discount rate, we have considered that the risk-free interest rate is 2% per year (currently the long-term interest rate of public debt in Europe is around this value) and we have also added a conservative 6% risk premium. Hence, the annual discount rate employed in the investment analysis would be 8% (minimum remuneration required for equity) since we have not considered the external financing and its cost in this analysis.

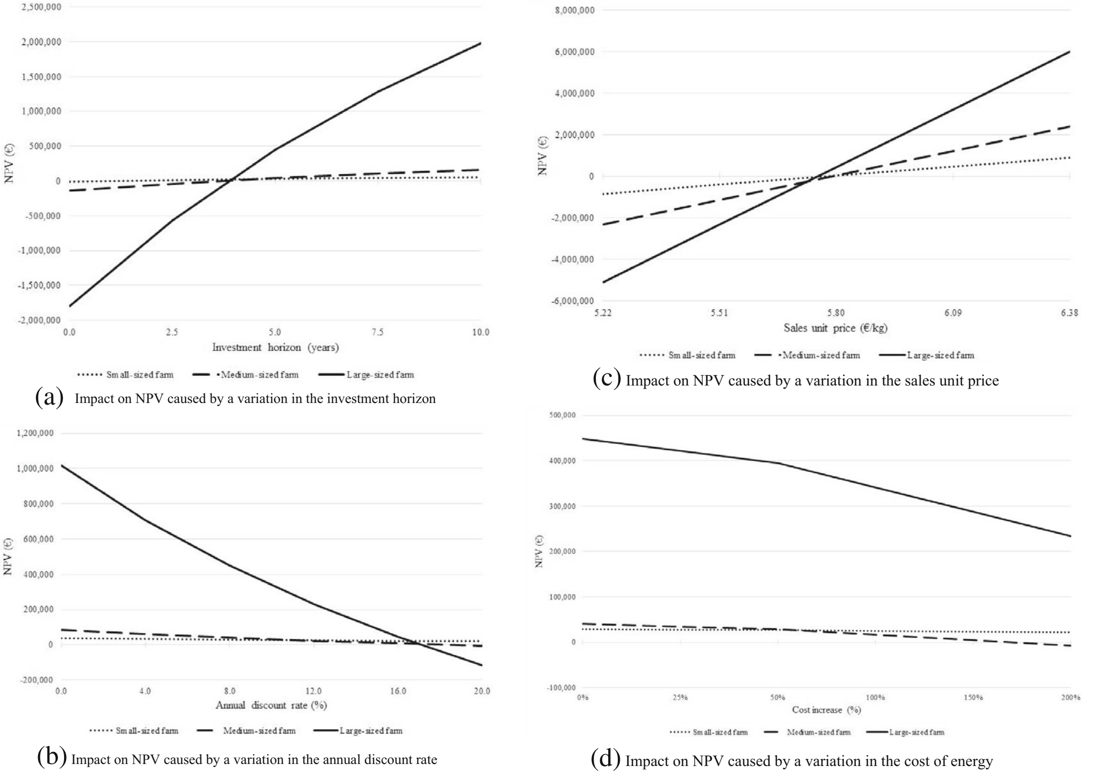
The results of the investment analysis are also presented in Table 5. According to these results, we can infer that the decision of implementing automatic feeders would be profitable for all types of farm because the net present value (NPV) is positive. In addition, the internal rate of return (IRR) is over 8% in all cases whereby the investment would be profitable. The largest NPV is for the large-sized farm with an economic value of 448,496 €, whereas the medium- and small-sized farms would obtain similar results of 40,300 € and 28,990 €

respectively. However, considering relative values, the small-sized farm would have the best result with a benefit–cost ratio (BC) of 6.8 versus 1.3 of the medium-sized farms and 1.2 of the large-sized farms. Likewise, the shortest payback period (P) would be for the small-sized farm (only 7 months) and the longest for the large-sized farm (38 months).

3.3 | Sensitivity analysis

To complete the former analyses, we have also carried out a sensitivity analysis considering variations in some of the investment and model parameters (i.e., the investment horizon, the annual discount rate, the sales unit price, and the energy cost). This kind of analysis allows us to introduce risk in the results obtained by changing the baseline value of those parameters to test the impact of their variation on the *NPV*. Each parameter has been varied, keeping the rest of the parameters constant (ceteris paribus) by a specific percentage above or below their baseline value. The results of this analysis are shown in Figure 1.

The results of the sensitivity analysis show that if we reduce the investment horizon by 50% from 5 to 2.5 years (see Figure 1a), the investment would only be profitable for the small-sized farms, whereas it would not be profitable for the medium- and large-sized farms since their payback period is over the 2.5 years. By contrast, if we increase the investment horizon by 50% up to 7.5 years, the large-sized farm would have the biggest increase in investment profitability, increasing the *NPV* from 448,496 € to 1,287,022 € (an improvement of 187%). The improvement in the *NPV* would be lower for the small- and medium-sized farm (43.7% and 166.8%, respectively), so these farms are less sensitive to the variation in this parameter. We can consider, hence, that small variations in this parameter would not



(a) Impact on NPV caused by a variation in the investment horizon

(b) Impact on NPV caused by a variation in the annual discount rate

(c) Impact on NPV caused by a variation in the sales unit price

(d) Impact on NPV caused by a variation in the cost of energy

FIGURE 1 Results of the sensitivity analysis.

introduce a high risk in the investment decision since the baseline investment horizon is very conservative (only 5 years) and the three investments are recovered in a very short period of time.

The increase in the annual discount rate would reduce the investment profitability for the three farms, the largest reduction being in the large-sized farm (see Figure 1b). The three farms would maintain positive results with a discount rate of 16% (an increase of 100% over the baseline discount rate). Only when the annual discount rate is increased to 20%, the large- and medium-sized farms would obtain a negative *NPV*. Therefore, we can conclude that the investment profitability would not suffer significantly because of small increases in the discount rate. Once again, we can consider that this parameter would not introduce a high risk in the investment decision since the three investments present a high *IRR*, especially in the case of small-sized farms.

On the other hand, small variations in the sales unit price would cause significant changes in the economic result obtained for the three farm sizes (see Figure 1c). Thus, a reduction of 5% in the price from 5.80 to 5.51 €/kg would generate negative *NPV* in the three farm sizes, the largest *NPV* variation being for the larger farms. Hence, the economic result obtained with the investment is very sensitive to small changes in the sales unit price of sea bass. In this case, on the contrary, we consider that this parameter would really introduce a high risk in the investment decision.

Finally, the increase in the energy cost would reduce the *NPV* of all farms, although the profitability of the three investments would continue to show positive figures with increases of 150% (see Figure 1d). The large-sized farm would be more sensitive to variations in the baseline parameter value than the small- and medium-sized farms. However, the large-sized farm can support larger increases in the energy cost than the small- and medium-sized farms because it presents the largest *NPV*. Only medium-sized farms would obtain a negative *NPV* when there is an increase of 200% in the energy cost. Hence, we can consider that the obtained results would not change significantly because of a reasonable increase in the energy cost whereby this parameter would not introduce a high risk in the investment decision.

4 | CONCLUSIONS

The aim of this work has been to run an economic assessment of investment in automatic feeding systems for grow-out farms of different sizes producing European sea bass in the Mediterranean Sea. For this, we have used an economic model developed by Fernández Sánchez, Llorente, et al. (2022) to simulate the annual income statement of a typical farm with different production volumes. Specifically, we have analyzed the results of a small-sized farm with a production capacity of 413 tons/year, a medium-sized farm with a production of 1122 tons/year, and a large-sized farm with a capacity of 2539 tons/year. We have also assumed that the final market weight of the fish is 450 grams. With the estimated values obtained in the simulation, we have carried out partial budget and investment analyses to assess the economic value of the investment decision. To complement our economic assessment, a sensitivity analysis was also run to include risk in the investment decision

Under the assumptions of this research, the largest profitability, measured by the net present value (NPV), would be obtained with the investment in the large-sized farm with a centralized system. By contrast, when the profitability is measured by the internal rate of return (IRR) or the benefit–cost ratio (BC), the most profitable investment would be in the small-sized farm with a feed cannon or blower because of the small investment that is necessary to do. Furthermore, the investment payback period (P) would be achieved before 4 years, regardless of the farm size, being shorter for the small-sized farm (only 7 months).

With regard to the risk of the investment decision, the economic result obtained with the large-sized farm seems to be the most sensitive to variations in the baseline values of the investment and model parameters such as the investment horizon, the annual discount rate, the sales unit price of sea bass, or the energy cost. On the other hand, the result of the small-sized farm seems to be the least sensitive to those variations. Regardless of the farm size, the sales unit price of sea bass would be the model parameter that more significantly would affect our economic results, since they would vary significantly to small variations in the sales unit price that has been assumed as baseline in this research.

Our findings show, therefore, that the implementation of automatic feeding systems in sea bass grow-out farms would be a good economic decision, regardless of the production volume, since there are feeding technologies available that fit different farm sizes and capital investment capacities. Consequently, innovation and investment in feeding management should not be impeded or limited by the farm size. The results and conclusions presented here can also be useful for sea bream producers, as production technology for this species is very similar to sea bass farming.

AUTHOR CONTRIBUTIONS

José L. Fernández Sánchez: Conceptualization; methodology; formal analysis; writing—original draft. **Bernardo Basurco**: Resources; validation; writing—review and editing. **Cristóbal Aguilera**: Resources; validation; writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no potential conflict of interest.

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