



## ASSESSMENT OF INITIAL INVESTMENT STRATEGIES FOR DIFFERENT FARM-SCALE SCENARIOS WITH ECONOMIC COST ANALYSES IN OFFSHORE SALMON FARMING

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### Abstract

The simulation of investment strategies with different farm-scale scenarios has been evaluated for best management plan in cage farming business for the establishment of a salmon production with either full capacity or progressive investment. Economical revenues were analyzed with business risk assessment based on operating and fixed costs for each of the four scenarios. In the theoretical model projected for the stimulation of best management plans, structural elements for the construction of an offshore Turkish salmon farm in the Black Sea were designed and investment costs for an annual production capacity of 4,000 tons were re-scaled by 25, 50 and 75% reduction, corresponding to 3,000, 2,000 and 1,000 tons per year, respectively. Economic variables of operational costs were comparatively evaluated with the revenues and annual profit conditions by sales of harvested fish. The break-even points for all investment strategies with different farm-scale scenarios were remarkably lower (on average 302,574.7 kg/year) than the harvest yields from the farms (on average 3,702,857.1 kg/year). Based on break-even points and margin of safety (MOS over 85%), all farms gained net profits with low risks in the first year, whether the farm received full investment, or initiated business with reduced investment expenditures for a gradual and progressive expansion plan. Findings of this study exhibit useful indications for farm management in understanding conditions of a step-wise establishment of business plans for salmon farming in offshore conditions.

**Key words:** aquaculture economics, aquaculture management, salmon cage farming, production volume, investment planning

The stagnation of capture fisheries and the increase of fish demand for the growing world population has increased the importance of world aquaculture in the last decades. Global aquaculture production reached a record 122.6 million tons, with a total value of USD 281.5 billion in 2020 (FAO, 2022 a). The consumption of aquatic food, excluding algae, increased more than five-fold over the last 60 years, with an estimate of 158 million tons, reaching a record of 20.5 kg consumption per capita in 2019 (FAO, 2022 a).

The rainbow trout (*Oncorhynchus mykiss*) is widespread and most widely cultured salmonid species in the world (Stanković et al., 2015), and Turkish aquaculture (Yoğurtçuoğlu et al., 2021). The biggest share of 26.7% of the total European production (539,343.8 tons) has been supplied by the Turkish aquaculture industry (144,282 tons), according to the latest available data provided by FAO (2022 b). As a salmonid species classified under the genus of *Oncorhynchus* sp., representing the Pacific salmon, the rainbow trout (*O. mykiss*) in the Turkish aquaculture is mainly produced in brackish water conditions of the Black Sea, and fish sized over 2.5 kg are sold for domestic and international market as “Turkish Salmon” (TMAF, 2020). Limitations in sites for coastal or land-based aquaculture expansion along with the developments in marine technologies brought new investments of cage farms in offshore marine sites (Ferreira et al., 2012). The expansion of cage farms in offshore conditions

has the potential of solving environmental problems caused by farm discharges, since offshore farm conditions enable the rapid and wide dispersal of dissolved waste materials (Holmer, 2010). The success of offshore aquaculture is strongly linked to technological developments, social and economic influences, and environmental conditions of marine sites (Edwards et al., 1997; Di Trapani et al., 2014; Grillone et al., 2014), that is a remarkable challenge for the cage aquaculture industry in the Black Sea, coupled with a growing market demand that triggers new investments for Turkish salmon production. However, credit constraints and unforeseen instabilities of global markets with shock waves such as pandemic outbreak and lockdowns that broke the market chain in 2020, raise concerns in new investments (CRS, 2021).

Therefore, the stimulation of investment strategies with different farm-scale scenarios for sustainable management of farm investment with either full scale or step-wise business-establishment plans for Turkish salmon farming may provide important indications for farmers and entrepreneurs. Hence, the aim of the present study was to evaluate the economic performance of farm scales with different initial investment strategies. Financial indicators such as economic revenue, investment costs and operational expenses were evaluated for different farm scales, with a full-scale investment at the beginning in respect to smaller farm scales receiving reduced initial investments.

## Material and methods

### Model definition and conjectures

A theoretical static model projected with the spreadsheet Microsoft Excel for Mac (version 16.66.1) using Mac macOS Big Sur (version 11.4) computer was designed to stimulate various investment strategies with farm-scale impacts on economic revenues for the Turkish salmon enterprises in the Black Sea, based on earlier reports of Cacho (1997), Gasca-Leyva et al. (2002), Pomeroy et al. (2008), Di Trapani et al. (2014), and Fernández-Sánchez et al. (2022). Two sub-models were used in this model, namely, (a) the production sub-model dealing with parameters such as biomass, feeding, growth and mortality, composing variables for the production phase, and (b) the economic sub-model with parameters related to economic conditions of the farm-scale investment projections such as capital issues, personnel, costs and revenues. As the target of this study was to evaluate the economic efficiency of the farm scale at initial investment of an offshore salmon farm with different investment strategies, other sub-models of biological or environmental issues, such as impacts of water temperature, feeding level, oxygen content, water supply, or influences in growth and mortality, related to the effects of genetic variations, etc., were not considered in this study.

Before running the deterministic model, some assumptions were made in order to standardize the parameters and variables used. It was assumed that the cost for economic variables were constant for all investigated cage farm models, and also the production variables such as fish stocking, fish feeding etc. were assumed to be constant. Since the production cycle in terms of bio-economic evaluation was not assessed in this study, it was further assumed that environmental conditions such as water temperature or other factors affecting production success such as survival rates, or common practices

in cage farms such as fingerling size, stocking density, dietary ingredients, diet quality, feeding management were also assumed to be at optimal level for Turkish salmon grow-out. Also, cage nettings were assumed to be in good shape in all scenarios with no biofouling growth that eventually could reduce oxygen concentrations in the cage and lead to stress or reduced welfare in fish (Bloecher et al., 2013; Klebert et al., 2013). Additionally, the hydrodynamic profile of the culture environment was also considered to be equal, as water current and seabed quality affect the mooring system and the selection of anchorage method (Kankainen and Mikalsen, 2014).

### Farm scale and mooring setup

Initially the equipment for the establishment of the mooring system was designed according to a full-scale farm with an annual production capacity of 4,000 tons. This was based on the principle of realizing the entire investment from the very beginning. Afterwards, the farm size was rearranged by reducing the initial investments by 75, 50 and 25%, respectively, according to the assumption of three different scenarios. In this case, the annual production capacities on farms basis were reduced to 3,000, 2,000 and 1,000 tons, respectively. The mooring system was designed according to the Black Sea conditions, where Turkish salmon production is intense. The flexibility of the mooring system was enhanced by submerged grid design and the arrangement of buoys, with the biggest at corner points which receive the highest forces of wind, waves and currents. In order to have a standard system layout, the grid-mooring design was adjusted according to a 2-bay grid system for all farm-scale scenarios, and grid layouts for the full-scale investment group (FSI, 100%), and the groups with 25, 50, and 75% reduced initial investments, were planned as 2x8, 2x6, 2x4, and 2x2, respectively (Figures 1–4).

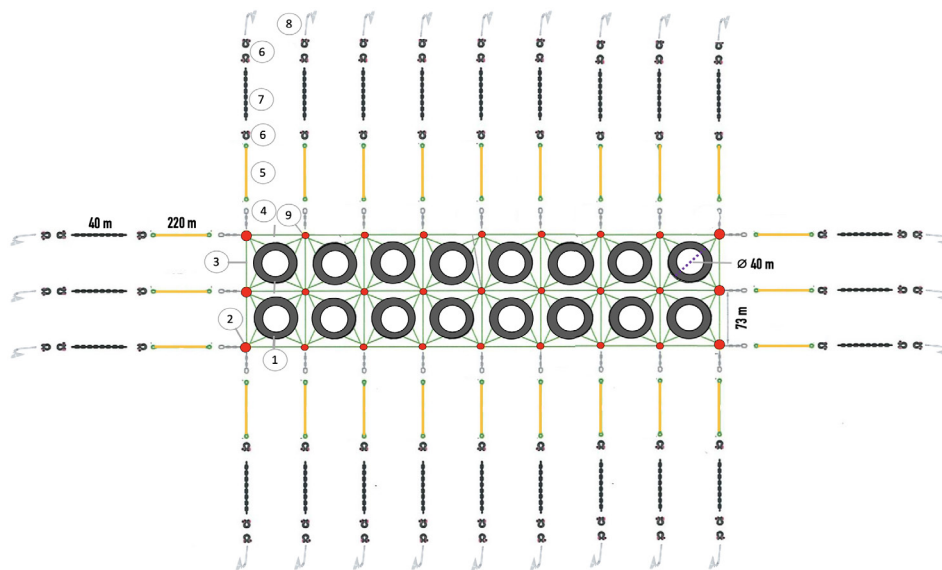


Figure 1. Full-scale farm design (4,000 tons, scenario 1)

1: cage frame, 2: corner buoy, 3: bridle line, 4: buoy chain, 5: anchor rope, 6: shackle and U-lock, 7: anchor chain, 8: deadweight anchor, 9: medium buoy

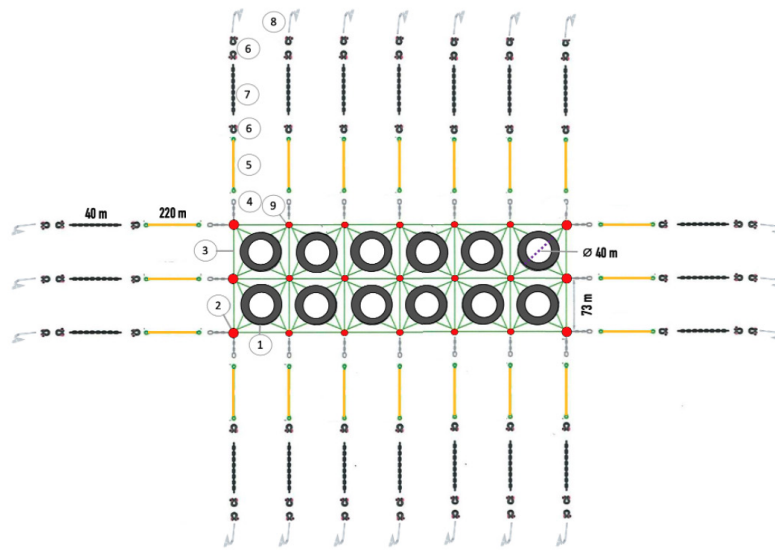


Figure 2. Farm design for reduced initial investment by 25%, 3,000 tons, scenario 2)

1: cage frame, 2: corner buoy, 3: bridle line, 4: buoy chain, 5: anchor rope, 6: shackle and U-lock, 7: anchor chain, 8: deadweight anchor, 9: medium buoy

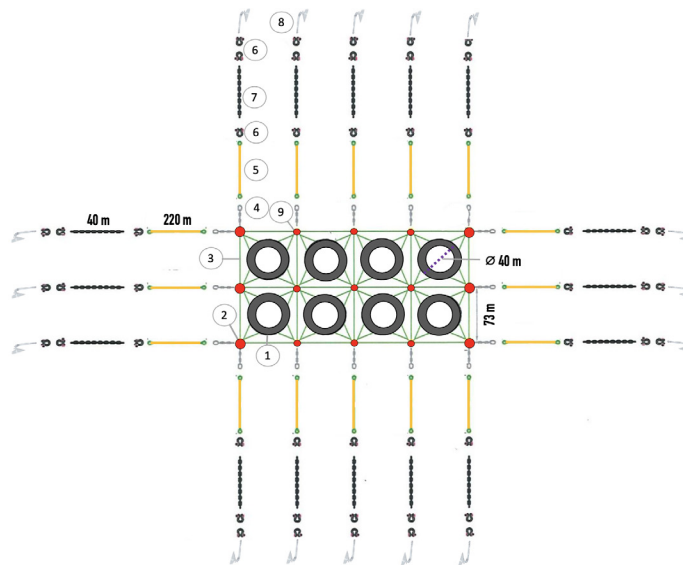


Figure 3. Farm design for reduced initial investment by 50%, 2,000 tons, scenario 3)

1: cage frame, 2: corner buoy, 3: bridle line, 4: buoy chain, 5: anchor rope, 6: shackle and U-lock, 7: anchor chain, 8: deadweight anchor, 9: medium buoy

The initial investment costs for the different scenarios of farm scales were calculated based on equipment value. The Turkish Ministry of Agriculture and Livestock, General Directorate of Fisheries, may grant permissions for offshore cage farms up to 4,000 tons/year depending on the environmental conditions and carrying capacity of the potential aquaculture sites set in areas with a minimum of 30 m depth, 0.1 m/s currents and a minimum of 0.6 miles distance from shore. It is worth noting that most of the off-

shore farms in the Black Sea are operating in more exposed marine locations nowadays. Therefore, a farm with 4,000 tons/year has been considered as the full-scale farm in the present study. The approach for initial investment strategies was that the offshore investment includes, in addition to cage manufacture and mooring system, the cage nets, net cleaning systems, installation and supervision, and the expenses for a feeding system. Items used for the cage farm setup based on four different scenarios are given in Table 1.

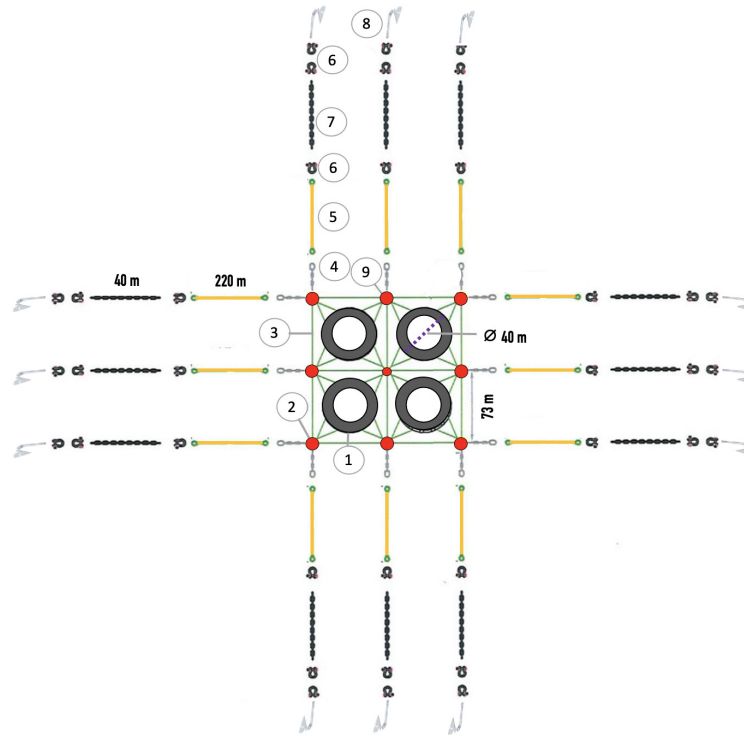


Figure 4. Farm design for reduced initial investment by 75%, 1,000 tons, scenario 4)

1: cage frame, 2: corner buoy, 3: bridle line, 4: buoy chain, 5: anchor rope, 6: shackle and U-lock, 7: anchor chain, 8: deadweight anchor, 9: medium buoy

Table 1. Investment costs for equipment used in farm setup for farm scales of different scenarios of initial investment

	Investment Strategy					
	full-scale initial investment (100%)	reduced initial investment (75%)	reduced initial investment (50%)	reduced initial investment (25%)		
Initial Investment Scenarios	Scenario 1	Scenario 2	Scenario 3	Scenario 4		
1	2	3	4	5		
<b>Production volume</b>						
Number of cages	16	12	8	4		
Annual production capacity (ton/year)	4,000	3,000	2,000	1,000		
Cage volume (m <sup>3</sup> /cage)	16,000	16,000	16,000	16,000		
Total volume (m <sup>3</sup> /unit)	256,000	192,000	128,000	64,000		
Total investment (\$)	1,805,754.0	1,531,525.05	996,462.8	598,807.5		
Equipment	Description	Unit price US\$	Price per farm US\$ (# items per farm)			
<b>Cage</b>						
HDPE cage	400 mm PN10 ATU PE100, 18.7 mm main pipe; 110 mm PN16 ATU 10 mm hand rim; twin-pipe, with rotation brackets, 56 brackets/cage; styrofoam-filled pipes 12–14 density	38,520	616,320 (16 pcs)	539,280 (12 pcs)	308,160 (8 pcs)	154,080 (4 pcs)
Sinker tube, Bottom rim	41 m diameter, 130 m circumference, 250 mm PN20, 25.2 mm thickness. HDPE pipe, 32 mm chain reinforced	12,513.5	200,216 (16 pcs)	175,189 (12 pcs)	100,108 (8 pcs)	50,054 (4 pcs)
Bird net float	6 m length, 6 m width, 4 m height, 250 mm float rim, 125 mm upper rim	1,728	27,648 (16 pcs)	24,192 (12 pcs)	13,824 (8 pcs)	6,912 (4 pcs)

Table 1. – contd.

	1	2	3	4	5	
<b>Mooring system</b> (location depth: 80 m, max wave: 6 m)						
Buoys, L	4000 tons	1,140	6,840 (6 pcs)	6,840 (6 pcs)	6,840 (6 pcs)	9,120 (8 pcs)
Buoys, M	1600 tons	678	14,238 (21 pcs)	10,170 (15 pcs)	6,102 (9 pcs)	678 (1 pc)
Deadweight anchor	2000 tons	3,480	55,680 (28 pcs)	69,600 (24 pcs)	83,520 (20 pcs)	97,440 (16 pcs)
Chains; Anchor chain	40–46 mm, 40 m	1,929	54,012 (28 pcs)	46,290 (24 pcs)	38,580 (20 pcs)	30,864 (16 pcs)
Chains; Buoy chain	24 mm, 8 m	450	12,150 (27 pcs)	9,450 (21 pcs)	6,750 (15 pcs)	4,050 (9 pcs)
Ropes; Anchor rope	72 mm PP, 220 m	1,942	54,376 (28 pcs)	46,608 (24 pcs)	38,840 (20 pcs)	31,072 (16 pcs)
Ropes; Grid rope	72 mm PP, 73 m	712	29,904 (42 pcs)	22,784 (32 pcs)	15,664 (22 pcs)	8,544 (12 pcs)
Ropes; Reverse anchor rope	40 mm, 110 m	298	8,344 (28 pcs)	7,152 (24 pcs)	5,960 (20 pcs)	4,768 (16 pcs)
Ropes; Cage bridle rope	32 mm	121	23,232 (192 pcs)	17,424 (144 pcs)	11,616 (96 pcs)	5,808 (48 pcs)
Locks; Anchor U-lock	1 ¼ 25 T	86	2,408 (28 pcs)	2,064 (24 pcs)	1,720 (20 pcs)	1,376 (16 pcs)
Locks; Buoy U-lock	1 ¼ 12 T	36	972 (27 pcs)	756 (21 pcs)	540 (15 pcs)	324 (9 pcs)
Shackles	Galvanized 72 mm	154	4,312 (28 pcs)	3,696 (24 pcs)	3,080 (20 pcs)	2,464 (16 pcs)
Rings; Oval ring	38 mm, 25 T	39	1,092 (28 pcs)	936 (24 pcs)	780 (20 pcs)	624 (19 pcs)
Rings; Collector ring	100 cm diam. iron, 60 mm thickness	450	12,150 (27 pcs)	9,450 (21 pcs)	6,750 (15 pcs)	4,050 (9 pcs)
Flash light	3 NML, Red	160	640 (4 pcs)	640 (4 pcs)	640 (4 pcs)	640 (4 pcs)
Signal buoy	25 L	14	56 (4 pcs)	56 (4 pcs)	56 (4 pcs)	56 (4 pcs)
Cage net; Dyneema	13+1 m, 40 m diameter, 210 d, 120 no, 24 mm mesh, 120 kg strength, total wt 1193 kg	13,221	211,536 (16 pcs)	158,652 (12 pcs)	105,768 (8 pcs)	52,884 (4 pcs)
Antifouling paint	1100 L/net (±%5) (NETWAX NI3)	3,942	63,072 (16 pcs)	47,304 (12 pcs)	31,536 (8 pcs)	15,768 (4 pcs)
Harvest net	40 m length, 20 m depth, 210 d 48 no 18 mm mesh, final wt 100 kg	634	2,536 (4 pcs)	1,902 (3 pcs)	1,268 (2 pcs)	634 (1 pc)
Bird net	41 m diameter, PP57 no 60 mm, final wt 85 kg ±%10	816	13,056 (16 pcs)	9,792 (12 pcs)	6,528 (8 pcs)	3,264 (4 pcs)
Net cleaning system	12 m <sup>3</sup> drum volume, 304 stainless steel, 40 m diameter net cleaning capacity, 18 kW motor, 22 kW panel, cylinder diam. 200 cm, cylinder length 400 mm, 1 1/4 inch water inlet, 4 inch water outlet	43,750	43,750 (1 pc)	43,750 (1 pc)	43,750 (1 pc)	43,750 (1 pc)
Installation & supervision	including site deployment (10000 \$ per 2x4 bay system)	10,000	20,000	20,000	10,000	10,000
Fish feeding system	onboard feeding machine, 8000 kg feed capacity; 2 storage, 304 stainless steel, hydraulic type	10,000	10,000 (1 pc)	10,000 (1 pc)	10,000 (1 pc)	10,000 (1 pc)
<b>Total investment</b>			1,530,300.0	1,297,903.0	844,460.0	507,464.0
<b>+ 18% VAT</b>			275,454.0	233,622.5	152,002.8	91,343.5
<b>Grand total*</b>			1,805,754.0	1,531,525.5	996,462.8	598,807.5

\*Quotations are for February 2020, and price of items is subject to change at yearly basis according to foreign currency variations, quality of items and farm site.

### Data processing and evaluation

The annual net operating profit (AOP) of farm-scale scenarios with different initial investment strategies have been estimated by subtracting the annual operating costs (AOC) from the annual operating revenues (AOR) using the following equation provided earlier by Fernández-Sánchez et al. (2022):

$$AOP (\$/year) = AOR (\$/year) - AOC (\$/year) \quad (1)$$

The AOR were calculated as follows:

$$AOR = P (\$/kg) \times BMP (kg/year) \quad (2)$$

where:

*AOR*: total operating revenues (\$/year),

*P*: unit sales price of fish (\$/kg),

*BMP*: annual biomass of fish produced (kg/year).

The annual biomass of fish cultured for all four farm-scale scenarios with different initial investment strategies has been estimated using the following formulae:

$$BMP = N \times \left( \frac{s}{100} \right) \times \left( \frac{w2}{1000} \right) \quad (3)$$

where:

*N*: annual quantity of fish produced (# fish/year),

*S*: survival rate (%),

*w2*: final fish weight (g/fish).

The annual quantity of fish produced was estimated by the equation as follows:

$$N = FSR \times CN \times \frac{12}{PP} \quad (4)$$

where:

*FSR*: fish stocking rate (# fish/cage),

*CN*: cage number (# cages at farm),

*PP*: production period (# months).

The production period has been calculated as follows:

$$PP = \frac{w2 (g/fish) - w1 (g/fish)}{AGR (g/months)} \quad (5)$$

where:

*w2*: final fish weight (g/unit),

*w1*: initial fish weight (g/unit),

*AGR*: absolute growth rate (g/months).

The total operating costs per year for the farms with different initial investment strategies were calculated by the sum of variable and fixed costs during the production period, that was 7 months for this study. In the present

study, initial fish cost and feed expenses were considered as variable costs, whereas the other expenses such as labor, energy + fuel, fish health maintenance, other operating costs and depreciation were considered as fixed costs. The annual costs for site renting were not included here, as the present study investigated the initial investment strategies with different scenarios for a farm that was granted permission of 4.000 tons/year capacity.

The average operating profit ( $AOP_{av}$ ) from fish sales, and the average operating cost ( $AOC_{av}$ ) for the production of fish in kilogram were obtained by dividing the annual operating profit (AOP) and the annual operating cost (AOC) between the annual biomass of fish (BMP) cultured in the production period, respectively, by using the following equations:

$$AOP_{av} (\$/kg) = AOP (\$/unit\ period) / BMP (kg\ fish/farm) \quad (6)$$

$$AOC_{av} (\$/kg) = AOC (\$/unit\ period) / BMP (kg\ fish/farm) \quad (7)$$

The break-even point (BEP) for each of the farms with different initial investment strategy, that is the level of fish cultured in a year (kg/year) where the farm begins to obtain benefits, were estimated using the following equation as earlier reported by Fernández-Sánchez et al. (2022):

$$BEP (kg/year) = \frac{FC}{p - \left( \frac{FC}{BMP} \right)} \quad (8)$$

where:

*FC*: fixed costs (\$/year),

*VC*: variable costs (\$/year),

*p*: unit sales price of fish (\$/kg).

The margin of safety (MOS) indicates the risk level of a farm in reaching the break-even point. That means, a greater ratio of MOS shows lesser risk of the business. The MOS ratio is an important parameter for business management in the measure of operating risks, providing information on how much reduction in profit may result in break-even (Weygandt et al., 1999). Following the results of BEPs for each farm, the margin of safety, representing the difference between the actual sales value and the break-even sales of the farm, was estimated by the following equations expressed in percent (Weygandt et al., 1999; Fernández-Sánchez et al., 2022):

$$MOS\ ratio = 100 \times (BMP - BEP) / BMP \quad (9)$$

### Parameters and values for farm scales with different initial investment scenarios

After the establishment of the model with definition and conjectures, cost parameters of different farm-scale scenarios based on initial investment strategies have been

estimated by sample data obtained from five offshore cage farms producing Turkish salmon in the Black Sea, comprising the periods of 2020–2022. All cage farms questioned for data in the Black Sea were located in offshore conditions with depth range of 40–60 m, water velocity of 0.149–0.158 m/s, and distance between 1.1 and 2.1 miles from shore, which were all within the range of Environmental Regulations set by the Ministry of Agriculture and Forestry in Turkey, that comprises minimum threshold levels of 30 m depth, 0.1 m/s current speed, and 0.6 miles distance from nearest shore for permissions for offshore cage farm enterprises. Initial fish cost and unit sales price at harvest were also obtained from these companies for export market, and all 5 farms questioned for fish size and price were in same range of production capacity of 1000–2000 tons/year, rep-

resenting the Black Sea salmon cage farms in general. The length of production period for Turkish salmon in the Black Sea is limited to 7 months only, due to the high temperature (over 23°C) conditions during summer time from June to October (MGM, 2022). Hence, the annual costs for parameters have been estimated for the production time that is 7 months in the Black Sea, as the indications for sales income and operational costs (fixed and variables) are also given for the length of the production period. The data provided in Table 2 are based on the assumption that no diseases or no net failures (no fish escapes) were seen during the course of the production, and harvested fish were more or less similar in health and weight range without any abnormal body shape that in turns would receive similar sales price in the market.

Table 2. Cost parameters of different farm-scale scenarios based on initial investment strategies

Parameters	Full-scale initial investment (100%)	Reduced initial investment (75%)	Reduced initial investment (50%)	Reduced initial investment (25%)
Initial Investment Scenarios	Scenario 1	Scenario 2	Scenario 3	Scenario 4
1	2	3	4	5
<b>Variable costs</b>				
<b>Fish expenses</b>				
Biomass (kg/m <sup>3</sup> )	15	15	15	15
Harvest weight (kg/unit)	4.0	4.0	4.0	4.0
Initial weight (kg/unit)	0.5	0.5	0.5	0.5
Initial fish cost (\$/kg) <sup>a</sup>	4.5	4.5	4.5	4.5
Number of initial fish (#fish/cage)	60,000	60,000	60,000	60,000
Total initial fish weight (kg/cage)	30,000	30,000	30,000	30,000
Number of total fish (#fish/farm)	960,000	720,000	480,000	240,000
Total initial fish weight (kg/farm)	480,000	360,000	240,000	120,000
Total initial fish cost (\$/farm)	2,160,000.0	1,620,000.0	1,080,000.0	540,000.0
<b>FEED EXPENSES</b>				
Investment per unit production (\$/ton fish)	451.44	510.51	498.23	598.81
Investment per unit production (\$/kg fish)	0.45	0.51	0.50	0.60
Feed cost (\$/ton fish) <sup>b</sup>	2,175	2,175	2,175	2,175
Feed cost (\$/kg fish) <sup>b</sup>	2.18	2.18	2.18	2.18
Feed cost (\$/farm) <sup>b</sup>	7,516,800.0	5,637,600.0	3,758,400.0	1,879,200.0
Total Variable Costs (\$/farm) <sup>c</sup>	9,676,800.0	7,257,600.0	4,838,400.0	2,419,200.0
<b>Fixed costs</b>				
Monthly salary per employee (\$/employee/month)	1,500	1,500	1,500	1,500
Total salary per employee (\$/employee × production period)*	10,500	10,500	10,500	10,500
No of employees per cage (# employees/cage)	0.5	0.5	0.5	0.5
No of employees per farm	8	6	4	2
Total employee cost per farm (\$/employee/farm × production period)	84,000	63,000	42,000	21,000

Table 2. – contd.

1	2	3	4	5
Total energy (+fuel) cost per cage (\$/cage × production period) <sup>d</sup>	105,000	105,000	105,000	105,000
Total energy cost per farm (\$/farm × production period) <sup>d</sup>	1,680,000	1,260,000	840,000	420,000
Total health maintenance cost per cage (\$/cage × production period) <sup>d</sup>	500	500	500	500
Total health maintenance cost per farm (\$/farm × production period) <sup>d</sup>	8,000	6,000	4,000	2,000
Other operating costs per cage (\$/cage × production period) <sup>d</sup>	4,000	4,000	4,000	4,000
Total other operating costs per farm (\$/farm × production period) <sup>d</sup>	64,000	48,000	32,000	16,000
Depreciation rate <sup>e</sup> (%) <sup>d</sup>	10	10	10	10
Total depreciation cost per farm (\$/farm × production period)	180,575.4	153,152.6	99,646.3	59,880.8
Total Fixed Costs (\$/farm) <sup>e</sup>	2,016,575.4	1,530,152.6	1,017,646.3	518,880.8
<b>Sales income (export)</b>				
Unit sales price <sup>e</sup> (\$/kg fish) <sup>a</sup>	7.0	7.0	7.0	7.0
Expected unit sales price (\$/ton fish)	28,000	21,000	14,000	7,000
Survival rate (%)	90	90	90	90
Harvested fish (tons/farm)	3,456	2,592	1,728	864
Total sales income (\$/farm)	96,768,000.0	54,432,000.0	24,192,000.0	6,048,000.0
Total operating cost (\$/farm)	11,693,375.4	8,787,752.6	5,856,046.3	2,938,080.8
Revenue per unit production (\$/farm)	85,074,624.6	45,644,247.5	18,335,953.7	3,109,919.3
Average profit per kg (\$/kg fish)	24.62	17.61	10.61	3.60
Revenue/Total operating expenses <sup>f</sup>	7.28	5.19	3.13	1.06
Revenue/Cumulative expenses <sup>g</sup>	6.30	4.42	2.68	0.88

<sup>a</sup>initial fish cost and unit sales price was obtained from five different companies for export market.

<sup>b</sup>feed cost based on 1.45 \$/kg feed and an FCR of 1.5 (FCR: kg feed per kg weight gain).

<sup>c</sup>total variable costs: initial fish cost + feeding cost.

<sup>d</sup>average estimated values obtained from five different farms in the Black Sea.

<sup>e</sup>total fixed costs: (labor cost + energy cost + health maintenance cost + other operational costs + depreciation).

<sup>f</sup>initial investment not included.

<sup>g</sup>initial investment included.

## Results

Figure 5 shows the ratio of economic revenue to cumulative expenses (R/CE) depending on initial investment strategies of different farm-scale scenarios. The R/CE, representing the ratio of “revenue to cumulative expenses” with initial investment costs included, were recorded as 6.30, 4.42, 2.68, and 0.88 for the different farm-scale scenarios of FSII-100%, RII-25%, RII-50%, and RII-75%, respectively. When the initial investment costs were excluded, and only variable costs and fixed costs considered for the operational period of 7 months, then the R/TE, representing the ratio of “revenue to total operating expenses” increased to 7.28, 5.19, 3.13, and 1.06 for the farm-scale scenario groups of FSII-100%, RII-25%, RII-50%, and RII-75%, respectively.

In Figure 6, values of the parameters analyzed for measuring economic performance of four farm-scale scenarios with different initial investment strategies were given based on assumptions provided in Table 2. It was

observed that an average operating cost of 3.38 \$/kg might be necessary for the production of 4 kg Turkish salmon in a full-scale farm with 4000 tons of production capacity, that was funded by full investment at initial stage (FSII-100%). For the other farm-scale scenarios with 25, 50, and 75% reduced initial investment, the operating costs for the same size of fish resulted in similar rates of 3.39, 3.39, and 3.40 \$/kg fish, respectively. The similar operating costs for all four farm-scale scenarios (FSII-100%, RII-25%, RII-50%, RII-75%), were due to the rational increase of fish biomass with the increase of production capacities for the different farm scales in the study. In contrast, however, average profit (\$/kg fish) was remarkably higher for the FSII-100% group (24.62 \$/kg) compared to the other farm-scale scenarios with reduced initial investment strategies of RII-25% (17.61 \$/kg), RII-50% (10.61 \$/kg), and RII-75% (3.60 \$/kg), and the net operation profits showed a gradual increase among the farm-scale scenarios with the increase of initial investment expenditures.

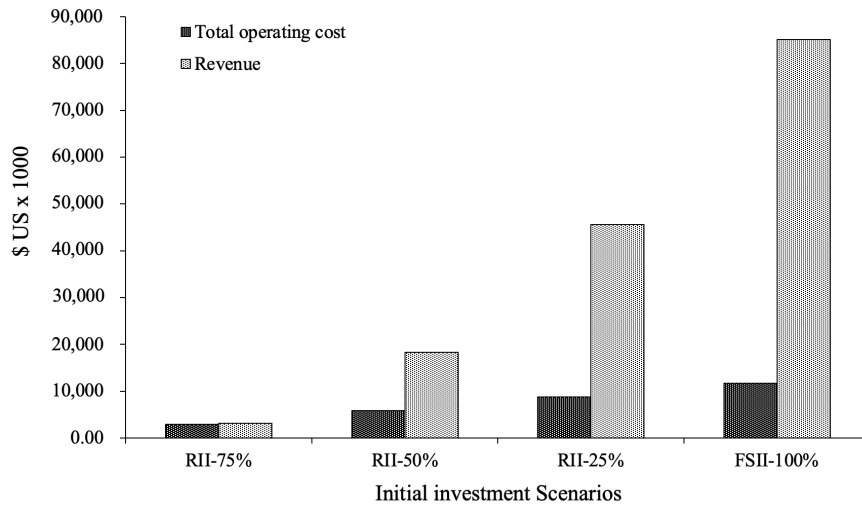


Figure 5. Total operating costs and economic revenues for different scenarios of initial investment (RII: reduced initial investment; FSII: full-scale initial investment; cumulative expenses: investment cost + variable cost + fixed cost)

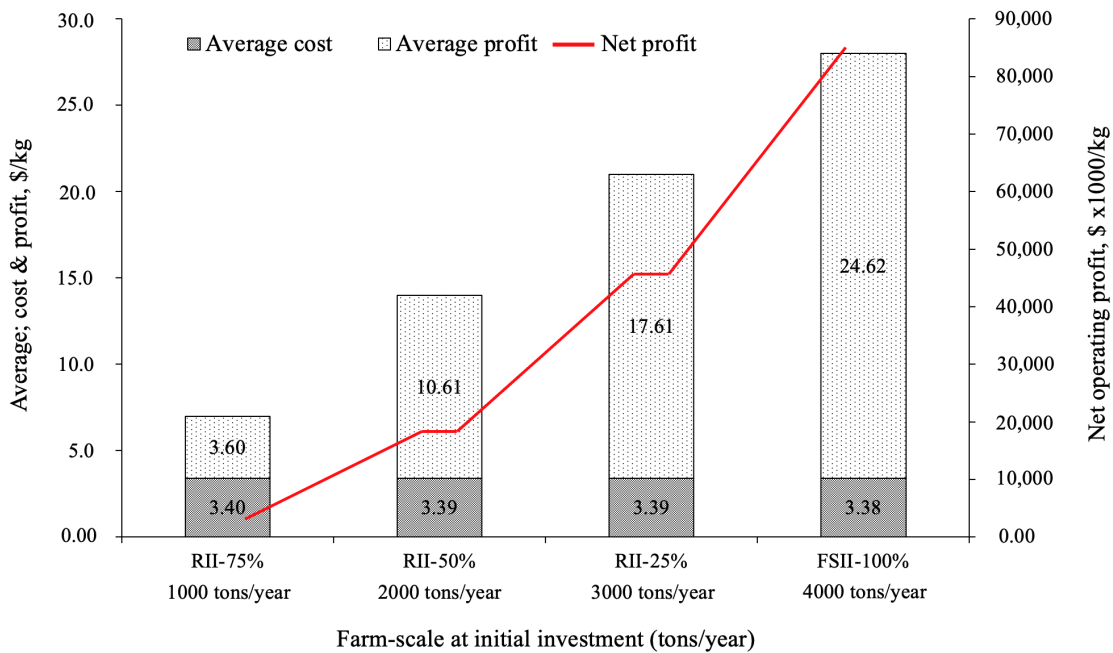


Figure 6. Economic performance of initial investment strategies under different farm-scale scenarios (RII: reduced initial investment; FSII: full-scale initial investment; cumulative expenses: investment cost + variable cost + fixed cost)

The break-even points for all investment strategies with different farm-scale scenarios (480,137.0, 364,322.0, 242,296.7, 123,543.0 kg/year) were far lower than the production amounts on yearly basis (5,924,571.4, 4,443,428.6, 2,962,285.7, 1,481,142.9 kg/year) for the FSII-100%, RII-25%, RII-50%, and RII-75% groups, respectively (Table 3). Thus, it can be underlined that there is no remarkable break-even point between financing farms with full investment in the first phase or reducing the initial investment by 25, 50 and 75%, and gradually expand the farm to full scale over years. Considering the operational risks given in Table 3, the MOS ratios were also remarkably high for all four initial

investment strategies with different farm-scale scenarios. Therefore, all farm-scale scenarios with different initial investment strategies tested here, would provide net profits to the investor, and the MOS ratios would be high as 85.70% for the FSII-100% group, and 85.98, 85.94, and 86.11% for the RII-25%, RII-50%, and RII-75% groups, respectively, showing remarkably low risks for the Turkish salmon enterprises, whether financing the farms with full investment in the very beginning, or reducing the initial investment by 25, 50 and 75% at initial stage, and gradually expanding the business over the following years with the cumulative inputs of annual revenues.

Table 3. Profits, break-even points and margin of safety for initial investment strategies with different farm-scale scenarios (calculated on yearly basis, unless otherwise stated)

Parameters	Full-scale initial investment (100%)	Reduced initial investment (75%)	Reduced initial investment (50%)	Reduced initial investment (25%)
Initial investment scenarios	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Annual net operating profit (AOP, USD/year)	73,381,249.2	36,856,494.9	12,479,907.4	171,838.5
Annual operating revenues (AOR, USD/year)	24,192.0	18,144.0	12,096.0	6,048.0
Biomass of fish produced in farm (BMP, kg/production period)	3,456,000	2,592,000	1,728,000	864,000
Biomass of fish produced in farm (BMP, tons/production period)	3,456	2,592	1,728	864
Annual quantity of cultured fish (AQF, N/year)	1,481,142.9	1,110,857.1	740,571.4	370,285.7
Annual quantity of cultured fish (AQF, kg/year)	5,924,571.4	4,443,428.6	2,962,285.7	1,481,142.9
Break-even point (BEP) (kg/year)	480,137.0	364,322.0	242,296.7	123,543.0
Margin of safety (MOS, %)	86.11	85.94	85.98	85.70

## Discussion

The relative values of different operating costs obtained from the model applied in this study were comparable and in agreement with those of earlier reports (Arru et al., 2019; Bozoglu and Ceyhan, 2009; Di Trapani et al., 2014; Hadelan et al., 2012; Fernández-Sánchez et al., 2022). The feed cost presented the highest value among the operating costs, with overall rates between 63.9 and 64.3%, while the initial fish costs demonstrated values between 18.38 and 18.47%. The total operating costs comprising fish and feed expenses showed values between 82.34 and 82.75, whereas the fixed costs were found between 17.25 and 17.66%. The level of feed costs found in this study (64.1% on average) were similar to earlier findings of Fernández-Sánchez et al. (2022), who reported 58.3% on average, but around 10% higher levels of operating costs were found in the present study compared to those of Fernández-Sánchez et al. (2022), which might be attributed to the different fish species produced, and variations in culture conditions.

Results from this study reveal that farm scale is an important factor for the economic revenues for cage farming at industrial level, regardless of the investment or production strategy, which is in agreement with earlier reports (Asche et al., 2013; Llorente et al., 2020; Fernández-Sánchez et al., 2020, 2022). It is evident that there is a high competition in offshore aquaculture industry, whose profitability depends on sensitive factors of harsh weather conditions, quality of materials used, operational management and practices, as well market demand. It was reported that high prices in the market, that provided remarkably high incomes for the companies triggered the production amount that in turns led to decline in the prices, as a result of overproduction. This has caused profitability challenges for smaller-sized fish farms (Fernández-Polanco and Llorente, 2019), with several struggle efforts against these challenges, either increasing production volume (high sales amount with less price), or increased quality and supply of a new product

with high quality. This indeed was the case of the cage farming business in the Black Sea. The successful production of rainbow trout (*O. mykiss*) in cage farms deployed in the brackish water conditions of the Black Sea dates back to the early 1994 (Yigit, 1996; Yigit and Aral, 1999). Due to the osmoregulation ability of rainbow trout, a member of the Pacific salmon genus (*Oncorhynchus* sp.), the production strategy of growing the fish in fresh water facilities to a certain size, and transferring to brackish water conditions from 10 to 30 grams (Turker et al., 2004) has become widespread over time. It has been noted that rainbow trout can adapt to even higher saline waters such as 28‰ salinity without adverse effects on fish health (Buyukates et al., 2023). In particular, the imports of rainbow trout from Turkey to the European Union member states have significantly increased due to increasing production and also to the custom agreement that was signed between Turkey and the EU in 1995. However, this has led to overproduction in following years that resulted in consecutive drops in the market price. Additionally, the high-water temperatures reaching over 23°C during the summer period between June and October (MGM, 2022), limit the production period of rainbow trout in the Black Sea to 7 months. As a solution for these profitability problems, companies introduced gilthead seabream (*Sparus aurata*) and European seabass (*Dicentrarchus labrax*) into their cages over the summer season, when rainbow trout was already harvested, and cages remained empty for a period of 4 month. The economic performance of the rainbow trout farms presented several variations in production strategies in the Black Sea, as was also reported for seabass aquaculture industry in the Mediterranean in the 2000s (Llorente et al., 2020). Further, several unexpected conditions such as Covid-19 pandemics or regional conflicts such as Ukraine-Russian war, that have been encountered recently in the European continent, may cause shock effects on the economies of the countries, which has also affected exports from Turkish aquaculture enterprises based on FAO reports (FAO,

2022 c). Overall, in order to survive, cage farms producing rainbow trout started a new business strategy, that was the production of large size trout over 2.5 kg, which was the road of recovery from difficult conditions, and paved the way for the formation of a large salmon production industry in Turkey, with the expansion of new market demands. The production strategy in terms of providing larger size fish for the market has been reported as an important decision for achieving economic sustainability in aquaculture (Fernández-Sánchez et al., 2022). Fernández-Sánchez et al. (2022) indicated that producing 450 g fish was the worst production strategy, whereas producing fish of 2 kg in weight was the best regardless of the farm scale, and the economic performance of the farm improves the larger the fish produced.

It is worth noting that environmental and technical challenges in building large cages for the rough weather in offshore conditions, increase risk concerns regarding impact of specific event, as the economic and environmental consequences in large cage systems can be much larger. That means, an accident that leads to salmon escaping the cage, there will be many more fish escapees in larger cages (Asche et al., 2013), with potential increased environmental impacts on the interaction between wild and farmed salmon, and especially as hosts for sea lice as reported by Torrissen et al. (2013). Therefore, learning from the past with considerations of instabilities and several shock effects, the Turkish salmon business nowadays goes forward with control of initial investment expenditures. Hence, considering the impacts of initial investment expenditures for a best farm management, findings in this study reveal that entrepreneurs may gain net profits with low risks, whether investing for a full-scale farm or forming their business plans in a step-wise establishment for salmon farming in offshore conditions as the break-even points for all investment strategies in the present study were below the level of apparent production amounts, with remarkably high MOS levels for all farm-scale scenarios. This result serves to validate the strategic decisions for economically sustainable farm management, because it is considered that getting cash rapidly may lower the risks from fish loss due to unexpected events such as disease outbreak, net failures and fish escapes from storms, etc., as well as shock waves from pandemic outbreaks, lockdowns, regional conflicts and eventually the breakage in trade chain. Further, in respect to credit constraints that is another significant challenge to consider for aquaculture investment (Mitra et al., 2019), a stepwise building of the farm business could be a choice of investment, that showed no risks for reduced initial investment plans according to the findings in this study.

However, it is also evident that the farm with larger scale received higher level of revenues with significantly higher rates of average profits and increased net operation profits compared to reduced farm scales in this study. This is in agreement with earlier report of Asche et al. (2013), who underlined that the degree of concentra-

tion with large salmon farms increased profits and these companies have grown bigger over time. This was also reported by Fernández-Sánchez et al. (2022), who noted improved economic performance of the farm with larger farm scale and larger fish size supply to the market.

### Conclusion

The results for break-even point and margin of safety proved that all investment scenarios received net profits with low risks for all investment scenarios. Hence, it can be suggested that the establishment of a farm can be initiated with gradual expenditures, if there are some concerns of market instability, or credit constraints, etc., and the reduction of initial investment up to 75% would not cause any risks for benefits in profit from harvest yields for the first year. Despite the fact that the average operating cost for all investment strategies resulted in similar rates in this study, it was observed that the average profit increased significantly for the large-scale farm with respect to the smaller farm-scale scenarios, that also increased the net operation profits among the farm-scale scenarios, the larger the farm scale the larger the net profits. It can be foreseen that the management benefits may depend on the accuracy of predicted data of variables, price fluctuations, and market variations. Hence, the best management practice cannot be directly underlined. However, results from this study provide useful indications for entrepreneurs in understanding the conditions of a full investment or step-wise establishment of business plans for salmon farming in offshore conditions.

### Acknowledgement

Many thanks to the anonymous reviewers and the journal editor for their valuable comments throughout the evaluation process of this paper. The support of Mr. Hüseyin Ek from Akuakare Aquaculture Equipment company (Mugla, Turkey) is acknowledged for providing data of investment costs for the establishment of different farm-scale scenarios in this study. Further, anonymous Turkish salmon companies in the Black Sea region are also acknowledged for their consultancy in the estimation of cost parameters for this study.

### Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

### Contribution of authors

Ümüt Yigit: conceptualization, data curation and evaluation, writing original draft, investigation, methodology, resources, validation, visualization, and finalizing paper.

### Ethical statement

The study is based on economic data collected from commercial Turkish salmon farms. Hence, no ethical approval required for this study as no animals were used.

### Conflict of interests

The authors declare that they have no conflict of interest.

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Received: 10 XI 2022

Accepted: 23 V 2023