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Lisac D., Muir J.

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Comparative economics of offshore and mariculture facilities

D. Lisac* and J. Muir**
*Maraqua, Golfo Aranci, Sardinia, Italy
**University of Stirling, Stirling, Scotland, UK

SUMMARY – A key concern for offshore aquaculture is the comparative investment cost of productive facilities and the consequent operating costs of production. This affects the decisions of potential producers to develop in offshore areas, the competitive potential of different production sectors in various regions, and the future opportunity for offshore system designers and manufacturers to develop and improve the sector. Based on contemporary data in the Mediterranean region, an outline is presented of the current capital and operating costs of typical systems, and of their comparative position with respect to land-based intensive aquaculture.

Key words: Aquaculture, economics, offshore, cages.

RESUME – *"Economie comparative des installations de mariculture et offshore". La comparaison entre le coût de l'investissement initial et les coûts opérationnels de production représente un des points clés de l'aquaculture offshore. Ceci va influencer d'une part les décisions des producteurs potentiels pour un développement dans des zones offshore, d'autre part le potentiel compétitif des différents secteurs de production dans différentes régions et enfin l'opportunité pour les constructeurs de systèmes offshore de développer et d'améliorer le secteur. Basées sur des données récentes relatives à la région méditerranéenne, les grandes lignes concernant le capital et les coût opérationnels de systèmes typiques sont présentées, et comparées à celles de l'aquaculture intensive terrestre.*

Mots-clés : *Aquaculture, économie, offshore, cages.*

Introduction

Comparative financial analyses of commercial aquaculture projects are important in determining both individual project opportunities and strategic development decisions. However, beyond the pricing of specific components such as cages or work vessels, or internal company analyses of specific investment decisions, there are few analyses of the potential costs and returns of current approaches to offshore aquaculture, or of their comparative performance against conventional alternatives. Though Scott *et al.* (1993) and Bugrova (1996) provided a theoretical comparison between different types of offshore cage system for production of Mediterranean marine species, this was not based on a longer term assessment, as techniques were just becoming established. Other analysis (e.g., Croker, 1996; Forster, 1996) are based on wider concepts of offshore mariculture, primarily based on salmonids. The present analysis attempts to extend information on the comparative aspects of offshore cage culture in the Mediterranean using data based on current industry practice.

There have been two parts to the work. The first is a theoretically based comparison of land and offshore based intensive installations, both representing the potential alternatives to the current, typically inshore based intensive culture, or semi-intensive land based culture of seabass and seabream. The second part of the exercise has been developed during the course of the CIHEAM workshop, in which participants assisted in developing cost profiles for a range of different offshore options using standard operating parameters. These two parts are described in turn.

Comparative analysis

The following installation concepts have been considered: (i) land-based installations – concrete tanks of 1000-2000 m^3 unit rearing volume; and (ii) sea-based installations – open sea cages of 2500-3500 m^3 unit rearing volume.

In both cases, the investment has been quantified for a complete operational farm, including the rearing structures, fish farming equipment, general infrastructure and back-up facilities. In land-based facilities the cost of land and that of the sea water intake/discharge can vary considerably from location to location, while for sea facilities the degree of exposure and distance from nearest port play an important role.

A medium-intensity land-based facility is analysed, comprehensive of all accessory items (such as packing stations, stores, office) on-site, while for the typical sea farm we have considered open-sea conditions with cages (flexible rubber hose, semi-submersible, etc.), workboats and feeding equipment in the sea, served from a shore base which includes store, packing station, office.

Assumptions

Table 1 describes the basic assumptions and developed costs used in the comparative analysis. Investment costs are based on current estimates of per m^3 capacity, together with the necessary infrastructure elements. EU investment support is assumed to be 50% of this total amount in both systems, though in practice it may apply differentially to separate elements, and be varied according to specific local incentives. Capital costs are assumed to be covered by equity and grant (see below).

Table 1. Assumptions made in the analysis

		Land-based	Offshore
Production	MT	408	400
Volume	m^3	20,000	25,000
Density	kg/m^3	20	16
Investment	US$ 1000	2,830	1,887
EU grant	US$ 1000	1,415	943
Juvenile input	pcs 1000	1,200	1,200
Loss	%	8	10
Harvested number	pcs 1000	1,104	1,080
Juvenile size	Grams	15	15
Feed conversion rate		2.3	2.3
Harvest weight	Grams	370	370
Sales price	US$/kg	8.02	8.02
Variable Costs			
Juvenile price	US$/pc	0.63	0.63
Feed price	US$/kg	0.79	0.79
Electricity cost	US$/kg	0.94	–
Oxygen cost	US$/kg	0.31	–
Fuel cost	US$/kg	–	0.08
Insurance fish	US$/kg	0.24	0.28
Medication costs	US$/kg	0.11	0.06
Harvest and packing	US$/kg	0.24	0.31
Fixed costs			
Maintenance	US$ 1000	63	38
Labour costs year 1	US$ 1000	189	189
Labour	US$ 1000	220	220
Operational capital	US$ 1000	–	–
Other fixed costs	US$ 1000	126	157
Depreciation	Years	12	8
Interest bank deposits	%	5	5
Interest operating capital	%	15	15

To simplify the analysis, the following initial assumptions have been made: (i) production of 50%-50% bass and bream; (ii) value of fish in year 1 = total variable costs; (iii) first year of sales: production year 2; (iv) production = sales; (v) harvest and packing costs in year 1 = 0; (vi) less stock is lost in land-based farms – no escape of fish; (vii) feed, electricity, oxygen, fuel and medication expenses in year 1 are 70% of those budgeted in subsequent years (for both cases); (viii) investment is financed by EU grant and equity; and (ix) operating capital is financed by a working capital loan.

Internal rate of return

Based on a sales price of US $8.02 per kg harvested and packed fish ex-farm, as outlined above, the internal rate of return (IRR) for the two options would be: (i) land-based 2%; and (ii) offshore 16%.

In order for an investment to be profitable, the IRR must be higher than the available return on capital in alternative placements of funds, normally defined by the equivalent of the prevailing base rates plus a risk related premium, which in the case of aquaculture may typically be 5-15%. Land-based systems may be considered as less risky, though reduced risk to environmental exposure may be balanced by higher technical risk associated with physical complexity. Though the IRR is a rather inexact measure of financial merit, the present outline suggests that a land based system is unlikely to offer a sufficient return at the market prices set, and would either have to target higher prices, or lower costs, e.g., by reducing input factor costs and/or increasing productivity. The offshore installation would appear to be within the range of viability provided risks could be contained, though for ventures of similar levels of risk, IRR values in the range of 20-25% or more might be sought.

Cost of production

Production in the various installations based on the assumptions described previously gives the following cost of production (Table 2), in US$/kg harvested and packed in year three, at which the operation could be assumed to have reached a steady state condition.

Table 2. Cost of production sea bass/sea bream (year 3)

	Land-based	Offshore
Juvenile costs	1.85	1.89
Feed costs	1.81	1.81
Harvest and packing	0.24	0.31
Insurance	0.24	0.28
Medication	0.11	0.06
Oxygen cost	0.31	0.00
Electricity cost	0.94	0.00
Fuel costs	0.00	0.08
Net financial costs	0.69	0.26
Total variable costs	*6.19*	*4.70*
Labour	0.54	0.55
Maintenance	0.15	0.09
Other fixed costs	0.31	0.39
Depreciation	0.58	0.59
Sum fixed costs	*1.58*	*1.63*
Cost of production per kg	*7.77*	*6.33*
Price per kg	*8.02*	*8.02*
Profit per kg	*0.25*	*1.69*

The analysis shows a large difference in margin per kg for the two installation concepts. Based on the same sales price, the offshore installation obtains a margin of US $1.69, while the land-based installation only returns US $0.25 per kg. The major differences between per unit cost in the two installation concepts are higher variable costs in the land-based installation, i.e., higher costs of oxygen and electricity. Since sales prices are assumed equal for the two concepts, the land-based installation generates lower surplus, and therefore demands more operating capital, which in turn leads to higher financial costs. If a sales price premium can be obtained for land-based stocks (e.g., through easier access to markets, better year-round availability) this difference may be reduced, but the profit difference indicated is significant compared with typical market price ranges.

Since the example is based on investment financed by equity, higher investment in the land-based facility does not influence the fixed costs.

Based on the assumptions made in this analysis, and as suggested earlier, fish from land-based installations should attain a higher sales price than fish from offshore installations, in order to be competitive. In cases where the land based installation has benefits of secure and predictable production (e.g., harvest access unaffected by storms), and closer proximity to markets, some advantage might be gained, but this is by no means certain.

Capital requirements

In order to produce approximately 400 t of bass/bream per year, the installations need the following financing for investment and operation (Table 3).

Table 3. Total capital cost of land-based/sea-based production

	Investment	Operating capital	Total capital requirement
Land-based	1415	2351	3767
Offshore	943	1943	2886

Because of higher investment, and the lower returns on operating costs, there is a larger risk related to land-based installations.

Summary

Given the assumptions, the offshore system shows better profitability with regard to internal rate of return, cost of production, margin per kg, total capital requirement and accumulated profit (Table 4).

Table 4. Actual profit of land-based/offshore production

	Internal rate of return (%)	Cost of production (US$/kg)	Margin per kg	Total capital required (US$ 1000's)	Actual profit[†] (US$ 1000's)
Land-based	2	7.77	0.25	3767	824

[†]In a project period of 8 years.

The land-based installation shows lower profitability primarily because it demands larger investments without resulting in increased efficiency, lower operating costs or better prices. This influences the internal rate of return. The land-based concept also has higher costs related to oxygen and electricity, which results in higher production costs and lower margins. The low margin makes the land-based installation concept very sensitive to variations in the sales price. Investments in land-based installations therefore involve a higher risk compared to investments in well installed and managed offshore systems. Based on the assumption given, there is some potential to improve performance in the onshore system; stocking densities, in particular could be raised above 20 kg/m^3, though electricity and oxygen costs would be primarily related to biomass and would hence act primarily as variable costs. By doubling stocking density, which brings its own risks, costs of production might be lowered by some $0.50/kg, but this is still substantially less cost effective than an offshore system.

Evaluation of current offshore systems

Data was collected on a range of current offshore cage farming systems, with the objective of assessing comparative installation and operating costs. Table 5 shows the capital costs and capital cost breakdown for a number of such systems, based on sufficient capacity for 300-400 t production of seabass or seabream. Figures are developed to show the overall costs for complete installation, and the equivalent costs per m^3. The data indicates the wide range of installed cost, from $13 to 82/$m^3$, the polythene rings being the cheapest, the Refa cages only slightly dearer, Sadco, Dunlop and Ocean Spar at intermediate levels and the Farmocean the most expensive.

Though these analyses are based on quotations at 1996 levels, the comparative features of these systems are likely to remain broadly similar. Though not mentioned in this analysis, the effective cost, i.e., based on replacement rates, maintenance costs, operational, safety and reliability performance will also be important. Thus high reliability systems requiring little maintenance and providing good stock security and convenient working conditions, possibly requiring less sophisticated service vessels and handling equipment, may deliver a better overall performance. The comparative features of systems, as outlined in earlier parts of this volume, could be consulted. A key constraint in evaluating such systems more fully is the relatively limited cumulative performance data, and the difficulty of compiling it from a range of sites and systems.

A further exercise examines the composite production costs of a range of commercial systems currently in operation. These are coded for confidentiality. Table 6 summarizes the capital costs reported for these systems, while Tables 7 and 8 describe the biotechnical and operating cost parameters respectively.

The final comparative costs, excluding the costs of finance, are presented in Table 9, demonstrating a wide variability in actual production cost, in specific cost components and in profitability. This shows in particular the relatively poor performance of the inshore and land based systems in cases 10 and 11, and, except for case 8, the generally favourable performance of the systems designated as offshore. However, it may be difficult to generalize from these individual cases, as it is clear that cost compositions, and the means of defining various costs, are not completely standardized.

In particular, fry costs vary more than three-fold from $0.93/kg to $3.12/kg, feed costs with a two-fold range from $1.30/kg to $3.00/kg – with a surprisingly high level for case 10, a sheltered site, and only an average cost level ($1.70/kg) for the land-based site. Poor variable cost performance may of course be due to higher than normal mortalities. As may be expected, the land-based project offered the highest energy costs ($0.58/kg), though case 8 (abandoned due to losses) also has high energy costs, as does case 10. Interestingly the reported energy costs are lower than the figure of $0.94/kg derived for the cost projection earlier, and might be explained by lower pumping head, better energy efficiency and/or lower local energy prices. Other costs, including insurance, maintenance and labour also showed notable variation; the land-based example appeared to be relatively competitive, except for the surprisingly high labour costs. Offshore systems did not appear to have significantly higher costs than others.

Conclusions

This exercise has attempted to demonstrate the typical levels of capital cost involved in installing a semi-offshore or offshore cage system, and to compare costs on a capacity basis. This demonstrates the considerable range of initial installed costs, and the generally greater expense of systems which can be designated as capable of withstanding more exposed conditions. However, as already noted, net operating costs, including amortization, maintenance, and associated performance factors such as feeding efficiency, labour costs and vessel servicing, are the critical factor, and there is evidence (Scott *et al.,* 1993; Bugrova, 1996; Croker, 1996) that capital cost difference may be levelled out when effectiveness parameters are taken into account.

Table 5. Comparison of offshore farming cage costs for a 300-400 t production facility

Cage type	Prices in NOK (x 1000) – 1996 data										US$ (x 100) @ 142	
	Cage vol. (m^3)	Price cage	Price nets	Price mooring	Price freight	Cage assem.	Moorg. install	Total install	NOK/m^3	Cost ratio	Total install.	US$/$m^3$
- Polyethylene, 19 m Ø	2,500	80	42	18 lines								
8 cages PET	20,000	640	336	540	30	90	150	1,786	89	1	254	13
- Dunlop 16 x 16 m	2,500	370	62	28 lines								
8 cages Dunlop	20,000	2,960	496	800	250	150	240	4,896	245	2.7	695	35
- Refa TLC 20 m Ø	3,000	320	††	42 blocks								
7 cages TLC	21,000	2,240	0	105	70	120	140	2,675	127	1.4	380	18
- Ocean Spar Sea Station	2,500	520	†††	Blocks								
8 cages Ocean Spar	20,000	4,160	0	80	30	100	140	4,510	226	2.5	640	32
- Pro Ocean 15 x 20	3,000	††††	45	18 lines								
8 cages Pro Ocean	24,000	5,600	360	730	400	120	150	7,360	307	3.4	1,045	44
- Farmocean 20 m Ø	4,500	2,100†	†††	15 lines								
5 cages Farmocean	22,500	10,500	0	1,200	700	360	180	12,940	575	6.4	1,837	82
- Sadco Shelf 2000	2,000	645†	†††	30 blocks								
10 cages Sadco	20,000	6,450	0	120	840	320	150	7,880	394	4.4	1,119	56
- Refa TLC 20 m Ø	3,600	360	††	36 blocks								
6 cages	21,600	2,160	0	90	70	120	120	2,560	119		361	17
- Farmocean 20 m Ø	4,500	2,100†	†††	15 lines								
5 cages	22,500	10,500	0	1,200	700	360	180	12,940	575		1,825	81
- Sadco Shelf 2000	2,000	645†	†††	30 blocks								
10 cages	20,000	6,450	0	120	840	320	150	7,880	394		1,111	56
- Refa TLC 20 m Ø	3,600	360	††	36 blocks								
Feeding platform complete with generator, 50 ton siloes, radio control, rooms								2,000				
6 cages + platform.	21,600	2,160	0	90	70	120	120	4,560	211		643	30

†Including feeder; ††Including antifouled net; †††Including net; ††††Including platform.

Table 6. Baseline parameters for comparison of offshore and other farms: general investments

Case	1	2	3	4	5	6	7	8	9	10	11	12
Open-sea (O) Sheltered (S) Land (L)	O	O	O	O	O/S	O	S	O	O	S	L	O/S
Single unit vol. (m^3)	1,800	1,000	1,000	550	2,000	1,800	700	4,500	2,000	3,000	10	1,150
No. of unit (pcs)	12	12	8	9	10	12	10	2	10	75	20	42
Total vol. (1,000 m^3)	41.6	12.3	8.3	5.5	20.0	21.6	7.8	9.0	20.0	27.0	1.1	75.6
Total investment ($'000)	1,357	600	814		800	706	2,086	1,616	950	1,000	60	3,767
Investment covered by grants (%)		14	67						7		100	
Total investment/m^3 ($)	63	49	98	0	40	33	37	180	48	37	55	50
Depreciation of Investment (years)	8	12	8	8	5	10	5	8	10	4	10	5
Yearly invest. payback/m^3 (US$)	8	4	12		8	3	7	22	5	9	5	10

Table 7. Biotechnical parameters for comparison of offshore and other farms

Case	1	2	3	4	5	6	7	8	9	10	11	12
Size of fry at stocking (g)	10	11	10	10	2	2	3	2	4	20	8	2
Size of harvested fish (g)	375	400	400	375	350	350	330	350	350	350	275	275
Survival (%)	92	95	90	92	92	88	75	82	77	60	70	85
Density (kg/m^3)	17	15	17	17	10	11	18	11	20	15	10	20
Feed conversion rate	2.05	1.85	2.16	2.05	2.10	2.00	2.70	1.55	2.30	3.00	2.00	2.30
No. of fry stocked x 1000	660	320	360	660	450	450	400	350	1000	1800	25	6,400
Total output (MT)	228	122	130	228	145	139	99	100	270	378	5	1,496
Invest MT output (US$)	5,960	4,934	6,281	0	5,521	594	2,889	16,186	3,525	2,646	12,468	2,518
Sales price US$/kg)	7.00	9.00	7.50	7.50	8.70	9.00	6.60	9.00	8.00	7.00	9.50	6.50
Income (1,000 $)	1,594	1,094	972	1,594	1,261	1,247	653	899	1,156	2,646	46	9,724
Invest/1,000 US$ income	851	548	837		635	566	438	1798	441	378	1,312	387

Table 8. Operating cost parameters for comparison of offshore and other farms

All prices $US	1	2	3	4	5	6	7	8	9	10	11	12
Price of fry ($/pc)	0.45	0.50	0.47	0.34	0.30	0.33	0.36	0.94	0.29	0.29	0.60	0.08
Price of feed ($/kg)	0.70	0.70	0.60	0.80	0.90	0.90	0.60	1.13	0.78	1.00	0.85	1.00
Energy (1,000 $/yr)			3		2	5	8	53	15	80	3	84
Insurance (1,000 $)			19	20				36	125			330
Medications (1,000 $)		3					3		16			50
Market preparation/packing (1,000 $)		60		90	40	40	7		340	1	1	120
Maintenance (1,000 $)		66	18	7	0	68	20	2	65	240	1	16
Labour (1,000 $)	120	165	120	72	80	125	103	140	104	480	18	202
Other fixed costs (1,000 $)		100		5		185	29	3	29	240	2	107
Yearly invest. payback (1,000 $)	170	50	102	0	160	71	57	202	95	250	6	753

Table 9. Cost of production comparison for offshore farms (in US $/kg)[†]

Case No:	1	2	3	4	5	6	7	8	9	10	11	12
Fry	1.30	1.32	1.31	1.01	0.93	1.07	1.45	3.30	1.08	1.38	3.12	0.34
Feed	1.44	1.30	1.30	1.64	1.89	1.80	1.62	1.75	1.79	3.00	1.70	2.30
Energy			0.02		0.01	0.03	0.08	0.53	0.06	0.21	0.58	0.06
Insurance			0.15	0.09				0.36	0.46			0.22
Medications		0.02					0.03		0.06			0.03
Market/packing		0.49		0.40	0.28	0.29	0.07		1.26		0.26	0.08
Maintenance		0.54	0.14	0.03		0.49	0.20	0.02	0.24	0.63	0.10	0.01
Labour	0.53	1.36	0.93	0.32	0.55	0.90	1.04	1.40	0.39	1.27	3.74	0.14
Other fixed costs		0.82		0.02		1.33	0.29	0.03	0.11	0.63	0.42	0.07
Yearly invest. payback	0.74	0.41	0.79	?	1.10	0.51	0.58	2.02	0.35	0.66	1.25	0.50
Total cost production	*4.01*	*6.26*	*4.62*	*3.51*	*4.77*	*6.43*	*5.36*	*9.41*	*5.80*	*7.79*	*11.16*	*3.75*
Gross Profit	2.99	2.74	2.88	3.49	3.93	2.57	1.24	-0.41	2.20	-0.79	-1.76	2.75

[†]Notes: for some companies certain data is grouped together under "other fixed costs"; depreciation (years) is highly variable between some producers; Case 7 is from a planned budget; Case 8 is no longer in operation, due to self-pollution; some farms are still in their expansion phase, which complicates assessment of real costs and revenues.

The relative performance of an offshore system, compared with a intensive land-based system, indicates their potential (see also Blakstad *et al.,* 1996). Though set out under a range of assumptions which approximately correspond to financing and operational conditions in Europe, the comparative advantages demonstrated are likely to hold under a wider range of assumptions. Only in circumstances where ideal low-head, well-flushed land-based site are to be found – increasingly difficult in the Mediterranean coast, and where investment and energy costs are well subsidized, would land-based systems be competitive. However, it should be emphasized that these comparisons would only hold true were offshore systems well-established and fully reliable. Arguably, the risks on some of these systems has been high, to date, but there is every evidence now (1999) that well-planned, designed and managed system are achieving their performance and production targets.

The final comparison of actual systems, carried out at the time of the workshop, shows a wide variation in operating performance and financial return, with offshore systems appearing to demonstrate competitive performance in the conditions described. The range of performance is typical of a diversified sector whose operations had not become standardized through competitive pressures. However, as farms were rather dissimilar, had experienced differing operating histories, and were at different stages of development, the comparison has to be treated with caution. In present day conditions, with steady decline in market prices, competitiveness is becoming extremely important, and it is likely that many of the poorer performing businesses will fail or be taken over. In these circumstances, the arguments presented by Forster (1996) are relevant – opportunities for offshore aquaculture have to be seen very strictly in the context of the projected market price trends of the product. Here, the potential for economies of scale, and possibly reduced regulatory costs in large open-sea sites will become an important competitive issue. Finally, though not explored in this set of analyses, the competitive potential of offshore aquaculture, possibly carrying additional costs for licenses to discharge wastes, may have to be compared with (probably land-based) closed containment systems, carrying greater capital and energy costs but with less environmental expense, and possibly better market response. Nonetheless, as such systems are some distance from practical and commercial reality, the potential for offshore aquaculture appears good.

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