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Economic comparison between offshore and inshore aquaculture production systems of European sea bass in Italy

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ABSTRACT

Offshore production system is predicted to increase in the near future driven by the lack of coastal space and lower environmental impacts.

The aim of this paper has been to evaluate the economic performance of offshore production system respect to inshore one, by comparing net present value (NPV), discounted payback time (DPBT) and internal rate of return (IRR) of two Italian mariculture farms that produce European sea bass.

Results showed a better economic profitability of offshore farm, even if sensitivity analysis revealed that financial indicators of both aquaculture production systems have been very sensitive to market condition changes.

So, offshore production system could represent an opportunity for fish farmers to increase their profitability, obtaining a more sustainable production and avoiding possible conflicts with other human activities in coastal areas.

1. Introduction

Importance of aquaculture in the world has increased in the last decades, due to stagnation of capture fishery production and increase of fish demand (FAO, 2008). Nowadays, aquaculture production (fish, crustaceans and molluscs) reaches to 62.7 million tons and it meets 40.1% of the world fishery supply, becoming a necessary complement of fisheries (FAO, 2013).

Among aquaculture species, European sea bass (*Dicentrarchus labrax*) is widespread and very important commercial marine fish species in the Mediterranean Sea (Arechavala-Lopez et al., 2012). Italy, according to the latest available data (FAO, 2014), with a production of 6700 t represents the fifth world producer of European sea bass, after Turkey (65,512 t), Greece (42,500 t), Spain (14,455 t) and Egypt (13,798 t). Among the Italian regions, Sicily plays a significant role and covers about 20% of Italian euryhaline fish production (Santulli and Modica, 2009).

With aquaculture steadily expanding, the need for suitable space has been followed by the development of more efficient, cost-effective, and environmentally sustainable methodologies as well as offshore fish farming (Maricchiolo et al., 2011). Limited possibilities for expansion on land and in inshore coastal areas, and technological improvements in farming structures, have led to widespread interest in offshore aquaculture (Ferreira et al., 2012).

Offshore fish farming, in fact, avoiding possible conflicts between the development of commercial aquaculture operations and the environmental impact in coastal areas could represent the greatest potential for expansion of the aquaculture industry in most regions throughout the world (Benetti et al., 2010).

Submerged cages may solve several of the substantial operational challenges that exist in surface-based fish farming: heavy storms, algal and jellyfish blooms, unsuitable temperatures, high pollutant levels and biofouling of net cages, repeated attacks by predators as well as sea birds and aquatic mammals for high concentration of fish easy to capture (Dempster et al., 2009; Fioravanati et al., 2004; Sepùlveda and Oliva, 2005). Predation is a significant economic damage for farmers firstly for reduction of fish numbers (Beveridge, 2001), but also for the stress on cultured fish that grants a poor feed conversion efficiency and, hence, a not maximized weight at harvest (Nash et al., 2000). Moreover, offshore cages allow a rapid and wide dispersal of dissolved waste products (Holmer, 2010).

The sustainability of aquaculture production system is mainly expressed in three aspects: production technology, social and economic impacts, and environmental and climatic influences, which are interrelated (Agnese et al., 2008; Edwards et al., 1997; Grillone et al., 2014).

So, the aim of this paper has been to evaluate the economic performance of offshore aquaculture production system with respect to inshore one. In particular, in order to express an economic judgment on two different investments, as well as in other studies (Zhang et al., 2009; Zheng et al., 2009), it has been carried out as a cost–benefit analysis (CBA) of two Sicilian mariculture farms that produce European sea bass. Financial indicators to compare two different investments have

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been net present value (NPV), discounted payback time (DPBT) and internal rate of return (IRR).

2. Materials and methods

The study was conducted on two representative mariculture farms located in the Southern coast of Sicily that produced European Sea bass (*D. labrax*).

The first one was an inshore fish farm with 17 surface-based cages of 750 m^3, each with a flotation structural part constituted by annular tubes of high density polyethylene (HDPE).

The second one was an offshore farm that had two submerged cages of 6650 m^3 and four of 2000 m^3, with a roof of black netting, the same mesh of surface cages and their tops were around 5 m below the surface.

The annual average production of European sea bass was equal to 154 t (inshore farm) and 130 t (offshore farm), deriving from a fish density, respectively, of 10.2 t/1000 m^3 and 11.7 t/1000 m^3. In both farms gilthead sea bream (*Sparus aurata*) was also cultivated.

The culture cycle was 24 months. In particular, fingerlings have been bought from commercial hatcheries when they had a size equal to 5–8 g and the fattening period is finished when the sea bass reached a weight of about 300 g. After the harvest fishes were commercialized in 5 kg polystyrene boxes destined to the Large Organized Distribution (LOD) with an average sale price of 6.10 €/kg for both mariculture farms.

In order to estimate the economic performance of offshore production system with respect to inshore one, it has been carried out an economic analysis by comparing the two different systems. Since the aim of paper was to evaluate the economic profitability of two aquaculture production systems, analysis did not take into consideration environmental benefits.

The survey was conducted in January 2014 and information needed to describe the culture systems were obtained from direct interviews with producers by means of a specific questionnaire (Cih-Dzul et al., 2011; Sgroi et al., 2014a; Testa et al., 2014a; Tudisca et al., 2013a,b), referring both the yield and the cost items to the current prices of the previous year (2013).

All economic parameters have been referred to a unit of area (cage of 1000 m^3), in order to make a comparison among the detected enterprises.

Economic analysis has been carried out by means of cost–benefit analysis (CBA). This is a financial valuation technique used to predict the effects of a project, a program or an investment, verifying if from its realization the investor can obtain or not a benefit (Almansa and Martínez-Paz, 2011; Molinos-Senante et al., 2010; Testa et al., 2014b).

CBA is a widely accepted economic tool for rational and systematic decision-making in aquaculture sector (Bhattacharya and Ninan, 2011; Poot-López et al., 2014; Shamshak, 2011; Zúñiga, 2010).

In this study the objective of the economic analysis is to determine the direct costs and the benefits of mariculture farms and to quantify their economic performance with the determination of appropriate financial indicators (de Oliveira et al., 2012; López et al., 2012; Shi et al., 2013; Vilela et al., 2013).

The first financial indicator was the net present value (NPV), according to the following formula:

$$\mathrm{NPV} = \sum_{t=0}^{n} \frac{C_t}{(1+r)^t} \tag{1}$$

where C_t represents the discounted annual cash flows; t is the time of the cash flow; n corresponds to the lifetime of investment and r is the discount rate. The discounted cash flows generated from each investment have been calculated for 15 years, equal to life cycle of investments. As regards the discount rate, it was assumed equal to Weighted Average Cost of Capital (WAAC) with a value of 6%.

The NPV is the main criterion for assessing the suitability of any investment program and according to this financial indicator, the greater is its value, the higher will be the convenience of the investment (Zuniga-Jara and Goycolea-Homann, 2014).

The discounted annual cash flows have been obtained from the difference between the annual benefits (inflows) and direct costs (outflows). Annual benefits included the revenues deriving from the harvest of European sea bass, considering an average wholesale price of 6.10 €/kg.

Among direct costs were both the initial cost of investment and production costs. The investment period was equal to two years and cost was considered net of non-returnable public grant according to Regulation (EC) no. 1198/2006 on the European Fisheries Fund (EFF). Production costs included all monetary costs related to productive cycle: feed, juveniles, fuels, electricity, medicines, veterinary and other services, packaging, state concessions, labor required from start of the culture until harvest, costs of repair, maintenance and insurance.

The second financial indicator was the discounted payback time (DPBT), that represents number of required years so that the cumulative discounted cash flows equate the initial investment costs (Bedecarratz et al., 2011).

The last financial indicator was the internal rate of return (IRR) that has been determined as follows:

$$\sum_{t=0}^{n} \frac{C_t}{(1+r)^t} = 0. \tag{2}$$

The IRR is the discount rate at which the discounted benefits are equal to the discounted costs, determining a net present value equal to zero. According to this indicator, an investment will be convenient if its IRR is higher than a predetermined reference discount rate to which the investor otherwise could invest his financial liquidities (Tudisca et al., 2013c, 2011).

IRR, conversely to NPV, does not depend on the reference discount rate chosen but only on the entity and temporal evolution of the benefits and costs, allowing a more exhaustive economic comparison among several investments (Guerrieri et al., 1995).

However, IRR has three main shortcomings. First, it can generate two very different values for the same project when future cash flows switch from negative to positive (or vice versa). Then, since IRR is expressed as a percentage, it can make small projects appear more attractive than large ones, even though large projects with lower IRRs can be more attractive on an NPV basis than smaller projects with higher IRRs. Besides, IRR do not take into consideration interim cash flows and their discounted rates (Kelleher and MacCormack, 2004).

Finally, given the large uncertainty in production performance for both systems, it has been repeated the economic analysis by applying Monte Carlo analysis (Aiken et al., 2009; Chen, 2006; Smith, 2008). From the operational point of view, in business decisions the distinction between risk and uncertainty, based on the notion of subjective assessment of the probability of occurrence of an event, is not always possible. In particular, this happens for some investments in the medium and long terms, characterized by fluctuations in the value of currencies or technical breakthroughs. To remedy this situation stochastic models, such as Monte Carlo analysis, can be applied to business decisions (Solari and Natiello, 2014). These models, by overcoming the determinism of conventional profitability indices, prove themselves better suited to grasp the essence of the entrepreneurial decision-making process, which is the result of rational choice in the light of appropriate information, while weighing economic and technical risk (Clemen and Ulu, 2008; Santeramo et al., 2012).

In the specific case of the investments' evaluation in terms of risk, given the forecast estimates of the cash flows intended as statistical variables, the Monte Carlo analysis allows to obtain an estimate of the probability distribution of the chosen output as an economic indicator of analysis (Lewy and Nielsen, 2003). In this way, it is possible to make