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Pre-feasibility Study for the Installation of a Chilean Mussel *Mytilus chilensis* (Hupé, 1854) Seed Hatchery in the Lakes Region, Chiles

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Abstract

Chile is the fourth world's largest producer of mussels, concentrating 90% of the production of *Mytilus chilensis*, the Chilean mussel or Patagonian mussel, in the Lakes Region (40°13' to 44°3' S, 74°49' to 71°34' W). The mussel seed production in Chile depends exclusively on natural collection and currently faces a serious seed shortage crisis, with a decrease of 15% in natural collection during 2012. This study evaluated the pre-feasibility of producing Chilean mussel seed in hatchery. Results showed that although there is technical, legal, environmental, political and managerial viability, the current financial conditions are not adequate to produce mussel seed under modeled hatchery conditions, the NPV: Net Present Value is >0. Seed production in hatchery was not profitable due to both the low price of Chilean mussels in national and international markets and the high cost of production, mainly associated to the production of microalgae (91% of total cost of production). Therefore, despite the significant economic and social impact of the mussel production in Chile and its 20% annual growth, the activity is threatened by the high variability in natural settlement and the economic infeasibility posed by the current seed production technology under controlled conditions.

Keywords: Economic feasibility; Hatchery; Marine aquaculture; Mussel seed; *Mytilus chilensis*

Introduction

The world production of mytilids is 1,700,000 t, and 95% of it comes from aquaculture. Chile is the fourth largest producer with 9.2% of the total production based on the cultivation of the species *Mytilus chilensis* [1]. The Chilean mussel, is distributed in Pacific coast from Callao (Peru) to the Strait of Magellan and Beagle Channel (Chile), extending its dispersal range to Atlantic coast until southern Brazil, including the Falkland Islands [2]. The Chilean mussel cultivation relies on natural spatfall. Spatfall process, begins with the installation of collectors in the spring, each collector has 4 to 8 m in length and is hunged in a long-line system. The farms with seed collectors are located in areas close to natural Chilean mussel banks. Once the competent larvae settle on seed collector are grown until the shell length of 1-3 cm, then which unfold to start ongrowing. The ongrowing ropes are hunged at the beginning of summer month and farmed for 10-18 months to market size at 7 cm length [3].

Chilean mussel farming focuses specifically on the Lakes Region with 99.7% of the total mussel harvest in 2011, and has a strong impact on the local economy, generating more than 12,000 jobs [4]. Mussel farming began to develop during the 80s due to the growing international demand for this product. Since 2000, the industry reached a yearly average growth rate of 34% [5], peaking in 2008 with an export volume of 45,000 t valued at $ 131,800,000 USD [6]. However, the historic explosive growth of aquaculture in Chile was mainly due to an increase in the number of concessions granted by Chilean government for new mussel's farming's and not to an increase in farming productivity [7].

During 2009 and 2010, the industry faced a historic drop in selling prices due to the international financial crisis of the time, and also because of environmental factors such as lack of phytoplankton in the environment, which affected the growth of the resource. In 2011 the industry recovered, exporting $ 1,784,443 USD FOB [6].

Currently, the industry is facing a new crisis because of the shortage of seed in natural environment, causing a 15% reduction in its collection in 2012 when compared to 2011. To date, the cause of this reduction is unknown, although problems have been proposed relating to climate change that could affect the seston availability in quantity and/or quality, as well as oceanic acidification that could affect the recruitment of postlarvae, at least for 2013 it was expected a drop in seed collection of up to 60% compared to 2012 [8-11]. In addition, the industry faces other problems associated with natural collection such as variable growth rates, settlement of competing species, and occurrence of Harmful Algal Blooms (HABs) [12]. During the 2009-2010 periods, there was a decrease in the abundance of phytoplankton in the total of the region, being the dynamism of the environment and the variability of the environmental factors, the main reasons. Since in the consecutive years has not become to register this reduction [9].

The workshop "Culture of bivalve molluscs: development and sustainability of seed production in hatchery and through natural collection developed" held in May 2012 in Castro, Chile (42°28′S and 73°48′W, Chiloé Island, Lakes Region), organized in the frame of INNOVA-CORFO project by the Universidad Austral de Chile, with purposes of recognize the importance of maintaining a sustainable production of seeds and how to reach eventually an impact of the

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scientific research and a wise-policy for mussel culture, insisted on pointing out:

1. The need to protect natural banks to promote a natural collection that supports on-growing production.

2. The need for urgent studies to determine the origin of the larvae currently sustaining natural seed collection.

3. The requirement for studies allowing the modeling and prediction of the response of seed catchment versus multiple environmental and anthropogenic variables.

4. The requirement of an ecosystemic approach to predict the natural seed settlement [13,14].

Consequently, it is necessary to have a reliable extra supply of seed that allows the sustainability of the industry over time. Therefore, the production of Chilean mussel seed in hatcheries appears as an alternative.

Currently, several private companies in the world commercialize mussel seed grown under controlled conditions. Besides, some private companies are vertically integrated with hatchery seed production in a profitable and environmentally sustainable way. Among countries with success in mussel hatcheries either experimental, pilot level or at the industry level are: New Zealand, Belgium, UK, Spain, The Netherlands, South Africa, USA, Australia and Canada. The companies that already develop cultivation commercially from controlled seed production are: Penn Cove Shellfish, LLC and Taylor Shellfish in USA; Innovative Aquaculture Products, LTD and Aboriginal Aquaculture Association in Canada, and Victoria Shellfish Hatchery and Spring Bay Seafoods in Australia [3,15].

In Chile, there have been several studies on mussel seed production in hatchery including *M. chilensis*, the *Chilean mussel or Patagonian mussel*, *M. galloprovincialis*, the *Araucanian mussel*, and *Choromytilus chorus*, the shoe mussel, demonstrating the technical feasibility of this process, with even the generation of protocols potentially transferable onto the mussel farming sector [16-19]. On the other hand, private initiatives are scarce, only three companies have built hatcheries and have produced *M. chilensis* seed at experimental level, however, until now none of them is producing seed [20].

The following study aims to analyze the pre-feasibility of installing a mussel hatchery in the Lakes Region, based on the current level of development of production technology with mussels under controlled conditions.

Methodology

The study was carried out on the basis of the methodology used by Sapag, since it gives important emphasis on two aspects of the formulation and evaluation of projects: one is the technical considerations that are critical for the optimization of production processes, and the other is economic approach that gives great importance to the markets in terms of price sensitivity [21].

Market research is the key both for the determination of the expected demand as the costs and expected prices. For a correct formulation, must be considered four studies: Provider market, competitor market, dealer market and the consumer market [21]. The study of provider market allows it to know the price, availability and quantity of inputs, while the competitor market survey is used to know the dynamics of similar businesses, strengthening with it the commercial strategy. The design of the employed methodology required the market studies, followed by a characterization of the studies made in technical aspects of production, framework of political, legal and environmental requisites, and economic study of farming costs and benefits, to finish with an evaluation of the pre-feasibility of the project (Figure 1). The information was obtained from scientific publications, official databases, and personal communication with entrepreneurs of the mussel farming industry.

A cash flow was built with an evaluation horizon of 10 years. Physical goods linearly depreciated according to the product life table provided by the Internal Revenue Service of Chile. The project was evaluated regardless of the source of finance (pure project), and a discount rate was estimated at 18% based on the Weighted Average Cost of Capital [21]. For the economic evaluation, we used the Net Present Value (NPV) and Internal Rate of Return (IRR). The NPV was determined as the difference between all revenues and expenditures expressed in up to date currency. The following formula was applied [21]:

$$NPV = \sum_{t=1}^{n} \frac{BN_t}{(1+i)^t} - I_0$$

Where BN_t accounted for net profit flow at time t, I_0 the initial investment and i was the discount rate of the project.

The IRR corresponds to the rate which makes the NPV of a project equal to zero [21]:

$$\sum_{t=1}^{n} \frac{BN_t}{(1+r)^t} - I_0 = 0$$

Where r is the internal rate of return. The IRR was compared with the discount rate of the project.

Results

Market study

Provider Market: Among the necessary inputs are:

1) The breeding stock which can be supplied by more than 800 on growing centers located in the Lakes Region (South of Chile), with prices near 500 Chilean pesos (CLP) per kilogram;

2) Collecting ropes, there is a wide offer in the region and the price fluctuates between 56-1600 CLP per meter depending on the garment; and

3) The culture media and inocula and/or strains of microalgae, they can be provided by various institutions and marine science research

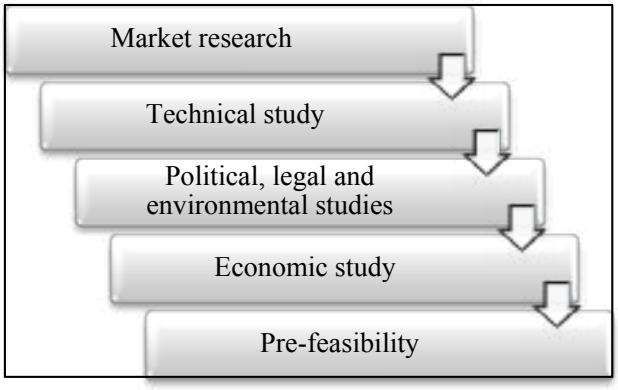

Figure 1: Methodological design. Source: authors elaboration.

centers located in the Lakes Region and the country, and as for laboratory supplies and products for the development of the medium, there are over 3 distributors in the country, with prices ranging between 100-1,700 CLP, depending on the quality [15].

Competitor Market: this market comprises companies or individuals owning aquaculture concessions aimed at the natural seed collection, the industry depends 100% on them. The catching is conducted via suspended systems of "long-line" type, and some have already requested both the permit to capture seed and the permit to fatten, in the same concession. In the Lakes Region, there are about 63 seed centers located in just five natural catchment areas, mostly away from the adult fattening area [15].

By regulation, seed collectors can be placed in the wild since October 1 of each year until May 31 of the following year. The service offered is collectors for sale (6-15 kg) with seed between 1-3 cm, with or without flotation system (buoy), between 5-15% belong to other species [22].

The cost per collector generally fluctuates between 750 and 1,200 CLP, depending on the amount of seeds and whether it includes flotation system. The cost per kilogram tends to fluctuate between 30-70 CLP [22]. In times of crisis, the kilogram of seed reached 150 CLP, and the collector between 800 and 3,000 CLP. Thus, 3,000 CLP are considered as the peak. Regarding potential competition, currently there is an ongoing pilot project in the estuary Pitipalena (47°77'S, 79°90'W). This service would be similar to current seed services [15].

Business Strategy: to commercialize Chilean mussel seed, valvular length greater than 1 mm, attached to 8 m collectors, reared in a controlled environment with high quality standards. Available in most of the years. Selling price of 3,000 CLP + 19% Value added tax per collector [4].

Dealer Market: The sale will be direct, transferred by land. There is a wide range of companies transporting hydrobiological resources in the region. The cost of transport is approximately 10 CLP kg^{-1} seed [4]. The distance from hatchery to rearing centers will be shorter, since both will be located in the same region.

Consumer Market: based on data from the National Census of Fisheries and Aquaculture [6], there are 72 aquaculture establishments at enterprise level, farming in over 10 ha of concession each and 195 small-scale producers (with less than 10 hectares of concession). 62.5% of corporate aquaculture establishments have some sort of certification: 51.4% applies the Bivalve Shellfish Sanitation Program of EU, 19.8 % follows the Bivalve Shellfish Sanitation Program of USA, and 16.7% follows the standard Norm of Hazard Analysis and Critical Control Points (HACCP), among other certifications. Regarding small-scale establishments, representing 95.1% of total establishments engaged in the area, only 34.9 % have some sort of validation with the most certified norm being that of the Health Program of Shellfish Bivalve of the EU [6]. The small scale producers are focused on the local market, in contrast to large companies, which have a high degree of food safety certification for export to the European Union. There are more than 1,050 farms in the Lakes Region, and about 800 of them reported activity in 2008. Mussel farms that are temporarily not active could have productive motifs, or environmental reasons. For example when the concession where the farm is located has exceeded the capacity of the water body (i.e., according to the environmental regulations for aquaculture in Chile, when sedimentation area or water column, have anoxic conditions). Regarding the culture volumes, each center produces between 200 and 500 t, with the total landing of *M. chilensis* in 2011 being 288,996 t. One hanging contains an average of 500 mussels per meter, therefore 400-800 seeds per meter should be planted [15].

Technical study

The aqua culture farms for mussel on growing in Chile are usually found in rural areas by such reason the hatchery would be in an area of such features. Preliminarily, it is proposed to build the hatchery on the sea shore in a land of 20,000 m^2 located in the rural sector of Agoni (42°74'86"S, 73°58'75"W, Lakes Region).

This is a rural area, near Route 5, and it complies with all the features required by a bivalve hatchery [23]. The production target will be to provide enough seed to harvest 12,000 t per year of adult mussels (total weight), equivalent to approximately 20% of the annual production volume of *M. chilensis* exported in 2011 [24].

It is estimated that to produce 200 t of commercial size mussels, 36.6 t seeds (18,285,714 seeds about 2 cm Lt) are required [25]. Therefore, to produce 12,000 t will require 215.9 t seeds (1,097,142,840 seeds) Chilean mussel seeds to supply 24 or 60 farms producing 500 or 200 t per year, respectively. Consequently, it is required to build about 4,560 m^2 for the implementation of this project, including growing areas and services.

The production process has been widely studied with key recommendations about broodstock conditioning, larval rearing and settlement, and postlarval culture for *M. chilensis* and other mussels in [17,18,26-32].

In short, the production process lasts about 6 months at 16° C, from fertilization to commercial size seed. Reproductive fitness can last 45 to 81 days, depending on the initial maturity conditions, temperature and feed [29]. Then, if there is not natural availability of mature broodstock the commercial seed production could last 8 to 9 months. Also [29], propose to collect broodstock at different times of the year in latitudinally separated natural banks, to optimize the larval production of *M. chilensis* in hatchery.

The feed consisted in the use of intensive microalgae batch culture, using extra strong polyethylene bags within steel mesh brackets [23]. In addition, larvae and early postlarvae were fed with microalgae of high protein obtained by increasing nitrogen in culture medium as recommended [33]. While seeds (last 50 days) and broodstock were fed using microalgae grow in agricultural fertilizer [34].

Legal, environmental and political study

In Chile, aquaculture is regulated by the Law on Fisheries and Aquaculture (LPGA) (Law 18,892). To perform this project, it is necessary to apply for a concession of beach shoreline, beach, and water portion or for sea bottom. In general, the application for an aquaculture concession has a moderate cost. It requires the approval of the project and the inscription of the aquaculture farm in the National Register of Aquaculture. The administrative actions are carried out by the Undersecretary of Fishing and Aquaculture (SUBPESCA) and the Service of National Fisheries and Aquaculture (Sernapesca) of the Ministry of Economy, Development and Tourism; and by the Undersecretary of the Armed Forces of the Ministry of National Defense.

The environmental issues are regulated by the Law on General Principles of the Environment, administered by the Ministry of Environment. By regulation, the project must undergo a System of Environmental Impact Assessment with a Declaration of

Environmental Impact. However, it is not expected to require an Environmental Impact Assessment if the project meets the criteria specified by law. Additionally, all aquaculture activities must comply with the Environmental Regulations for Aquaculture Activities.

To encourage the development of aquaculture, the Chilean government provides a variety of support tools for innovation, they are usually administered by the Corporation for the Promotion of Production (CORFO) and the National Commission for Scientific and Technological Research (CONICYT). On the other hand, the Chilean government promotes the consumption of *M. chilensis* due to its high nutritional quality through a program called Choose Healthy Living, and also supports the promotion and spread abroad of the brand "Patagonia mussel", through the Program for the Promotion of Chilean Exports (ProChile) of the Ministry of Foreign Affairs. One of the goals of these programs is to change the culture of low intake of marine products by Chileans and the other is to promote the export of Chilean products despite its remoteness to the target-markets.

Economic Study

For a private investor interested in a project of seed production of mussels the amount of the initial investment was calculated as 683,589,900 CLP which included costs for physical works, equipment and land purchase. For the income, it was only considered the sale of collectors, at an estimated price of 3,000 CLP per collector, therefore the second year revenue projections were 620,655,41 CLP. The fixed costs were those regarding human resources and services (internet, electricity, fuel, etc.), generating over 145,000,000 CLP. Variable costs included microalgal feed, mussel broodstock, transport, electricity and others, adding to a total value of more than 1,700,000,000 CLP with the higher cost being the microalgal feed, reaching 1,600,000,000 CLP (Figure 2).

As a result of the projection, cash flow assessment on the horizon of the evaluation did not reach positive values, therefore, the NPV obtained was 5,898,261,645 CLP and the criterion of the IRR could not be applied. Thus, it was established that the modeled project was not financially viable.

Conclusion and Discussions

The negative NPV value was due solely to the high cost of production of the microalgae, equivalent to 91% of the estimated total costs. Although this cost is excessive, it is known to be the most

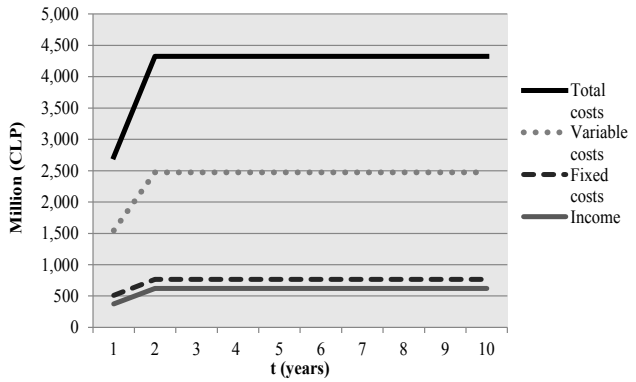

Figure 2: Costs and incomes (million CLP) over time (years) of the project "Chilean mussel seed M. chilensis in a hatchery in the Xth Region of Chile". With permission of Astorga et al. 2012b, CLP: Chilean pesos.

significant cost of a project of this nature [35], however, its percentage in the total costs can be decreased even more [23]. In the South of Chile the intensive cultivation of microalgae are low productive because the ambient temperature in greenhouses is below 20° C and low light intensity on the greater part of the year and only for 3-4 months can be obtained naturally temperatures higher than 30°C and high luminous intensity. For this reason, crops must be run at indoor facilities with a high cost in electricity and they do not reach cultivation densities exceeding 4 million cells ml^{-1} in relevant species such as T-Isocrysis aff galbana [36]. For this purpose, it is necessary to implement alternatives to the batch culture that is the method of microalgal cultivation most used in the South of Chile. Among these alternatives are the continuous or semi-continuous systems, which despite their high investment costs allow optimizing the production. There is also the possibility of using microalgae substitutes as preserved algae paste, dried algae, heterotrophic cultivation of microalgae, yeast, micro encapsulates, lipid emulsions and others that have been relatively successful at experimental level, representing a real and cheap alternative to optimize feed costs [37,38].

On the other hand, based on the data of this study, the cost of producing 1 kg of Chilean mussel seed equals 2,025 CLP, a much lower cost compared to producing seed of congeneric species in hatchery in countries like United States, Canada and Australia (Blue Seed Project). However, seed cultivation in these countries is profitable, since they have a low harvest volume (adults), and the market they are targeting is local. Moreover, there is no alternative seed supply in the areas where farms are located (there is no natural seed collection), and most importantly the selling price of the final harvested product (adult mussels) is high: 7 euros per kilogram, i.e. around 4,321 CLP. The Chilean reality is very different, it has one of the biggest harvests worldwide, the *M. chilensis* market at national level is small and the profitability of the industry is based solely on exports, with a low selling price compared to that of competing mussel species [15]. Thus, it is interesting to consider not only the feasibility of a hatchery as an isolated business but also as part of a vertically integrated enterprise that markets the final product with added value. Besides it is necessary to improve the positioning and price of the Chilean species in the national and international markets.

To date there have been several approaches to the genetics of M. chilensis, standing out the reports on molecular markers by [39,40], and studies in quantitative genetics in this species that suggest that, in the long term, genetic improvement programs through selection can become very successful, allowing for increased crop productivity [14]. Mussel genetic studies have been funded with State resources for the I & D, there is virtually no private investment in research of mussel genetics.

The workshop on development and sustainability of seed production in hatchery [14] concluded based on the major economic and social impact of the Chilean mussel farming industry, and specifically for the Lakes Region, efforts should be joint toward ensuring a reliable seed supply, by both recovering the ecosystem service of natural seed collection and developing technical and economic feasibility of mussel hatchery culture. To use a combination of both sources of seed, as in other parts of the world, is the only way to develop a industry sustainable in time. Moreover, an increased knowledge and technology in cultivation systems at all stages of production is needed to achieve technical and economic feasibility, mainly with regards to feeding alternatives for bivalves under controlled conditions [9,14].

However, the current study showed the seed production costs by mussel hatchery culture will remain high, if compared to the natural

spawning, then the mussel hatchery still are technically feasible but they are not profitable. Therefore it is required a State policy to develop seeds hatchery, that could be mussels or other species of commercial value, which must be connected to a long-term strategy for the application of genetic improvement programmes to domesticate and improve native species of interest. This idea has been already proposed for some key species of mariculture in Latin America by [41], as a way of promoting the development of native species for aquaculture. As conclusion, to make the production of Chilean mussel seed profitable, two conditions are required: better positioning of the Chilean mussel in domestic and international markets to increase its commercial value and to reduce seed production costs through microalgal feed optimization. This will contribute to the sustainability of the mussel industry in Chile.

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