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THE ENVIRONMENTAL COST OF CHILEAN SALMON FARMING

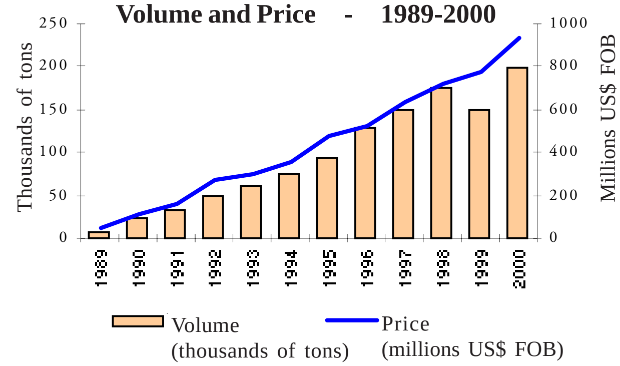
I. Introduction

During recent years, aquiculture has experienced explosive growth in Chile. Currently there are more than 800 aquiculture production areas functioning within the country, with the majority specializing in salmon and trout which are destined for external markets. As can be seen in graph Nº1, salmon and trout exports have experienced an exponential growth rate, starting with a total shipment of 20,000 tons in 1990 and growing to 200,000 tons in the year 2000, reaching almost US$ 1,000,000,000 in exports.

The Gross Domestic Product (GDP) of the fishing industry, within which is the aquiculture sector, has grown at an average annual rate in excess of 10%, reaching, for the year 2000, approximately US$ 1,205,000,000. A large part of the growth in the added value of this industry is due to the increase in aquiculture production and specifically to salmon farming because since the second half of the prior decade the industrial fishing has experienced a significant decline in its catches, approximately 5.8% annually.

Nevertheless, there exists growing concern for the environmental impact caused by aquiculture activity and more specifically by salmon farming. Because the natural resources accounting system, within its economic indexes, does not consider the productive role of ecosystems, the sector figures regarding the GDP give a distorted perspective of the sector's economic development. The purpose of this study is to give an estimate of the fishing industry's GPD when adjusted to include the environmental losses generated by aquiculture.

Graph N°1: Salmon and Trout Exports
Volume and Price - 1989-2000



Source: Chilean Central Bank

II. The Problem with the National Accounting System[1]

The national economic accounting system is the specific tool used in Chile to record important economic activity. The National Accounting System (in Chile, SCN) is the conceptually organized framework into which all available statistical information is input.

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[1] This section is taken from Claude and Pizarro, 1996, where this argument is given in greater detail.

Regarding the ecological problematic, the criticism that questions the SCN does not only emphasize the internal limits of the system but also the theoretical concept that put economic and industrial activity into a closed and self-sustaining system. In general terms, three main faults can be discovered in the SCN -starting with the perspective given to environmental problems- which forms part of a widely accepted consensus.

First, according to the SCN, the depletion of natural resources is accounted for within the framework of production -for example, felling of trees is considered to be forestry production. Therefore, the industrial exploitation of natural resources and their depletion cause the GDP to increase and so, as these resources are exploited and the rate of depletion increases, greater will be the macroeconomic success the goodwill associated with the growth indicators.

The observation cited in the previous paragraph, can be clearly deduced from the definitions included in the manual of the SCN which corresponds to a prior revision (1968). In the manual Consumptive Use of Fixed Assets or Depreciation corresponds to "value, to the ordinary cost of replacement, from reproducible fixed assets, except highways, dams and other forms of construction which have structural differences, part of the public administration, consumed during the period considered to be the result of normal deterioration, of predictable obsolescence, of large catastrophes y of the normal rate of unexpected damages. Consideration for the depletion of natural resources is not included[3] and the unexpected obsolescence"[4]. This is proof that the hypothesis that systems of macroeconomic accounting and in general, modern economic theory have used until now consider natural resources as unlimited and substitutable.

Consequently a country which exploits its mineral resources, over fishes its waters, fells its forests will see an increase in its income without making any adjustment for the depletion of natural capital. At the same time, the country, through its macroeconomic indicators will perceive greater economic growth and thus can authorize greater levels of consumption, without considering whether these levels of consumption can be maintained once these natural resources have been deleted, unless a substitute is discovered.

In this case, the indicators, which are used by the SCN, will not allow for authentic, sustainable development. It is proposed, then, to have an accounting process so that the use of natural resources will be reflected in the GDP. If the resources are dealt with as assets, or in other words, if the concept of capital is broadened to include natural capital, it would be necessary to adjust the indicators of the GDP as the natural resources are exploited in a non-sustainable fashion[5].

In the case of aquiculture, this is especially evident since the greatest input of the sector is the ecological environment through its use of aquatic ecosystems, without taking into consideration, the ecosystem cost of the use of water resources.

The second criticism regards the expenses associated with "protection" or "repair" of the environment. These refer to those costs which are incurred by the government, private individuals and businesses remedy the negative effects caused by the contamination of the environment and the destruction of natural resources. According to Anglo-Saxon literature, these expenses are known as "defensive expenditures" and the criticism formed regarding them is that they are recorded in such a way that they increase the national income.

Schematically speaking, the greater the contamination, the greater are the demand and incentives to develop activities which decontaminate and this, in turn, contributes directly to the increase of the indicators for growth and well-being (GDP). For example, if as a result of aquiculture activities, services are used for allaying the consequences or cleaning up the environment of a lake and this activity generates an added value, this, in turn, would increase the indicators of the GDP. Therefore, the sectoral GDP increases by generating contamination which is not considered to be an expense but later, the activities or services which mitigate those effects generate an additional added value en other sectors. The GDP increases but the well-being of the people has not ostensibly increased.

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[3] *Underlining done by Buschmann*
[4] *UNSTAT, (1970)*
[5] *Here the definition of "income" by John Hicks is implicitly used, in that, income is the maximum consumption in which the capital remains constant. If you recognize that natural resources and the environment comprise natural capital so that the GDP might reflect a true measure of "income", the adjustment for the losses of natural capital must be taken into account.*

This discussion leaves to someone's judgment the problem of the level of well-being associated with the GDP as a growth indicator. Clearly, different levels of well-being are associated with the same level of GDP. Moreover, the well-being can increase or decrease by changing the internal make-up of the goods and services which are grouped within the GDP, decreasing the production of goods which are highly contaminating, in the same proportion as the increase in the production of goods and services which generate a lower level of contamination, or additionally, well-being can increase with a reduction of the GDP. Finally, there is the possibility of reduction of well-being when the level of the previously mentioned indicator is increased.

Generally speaking, two proposals have been presented to correct this problem. The first calls for an accounting of the expenses for environmental protection that are incurred by families and public entities as intermediate consumption expenses, creating negative adjustment for the GDP. The other alternative is to consider the environment as fixed capital and inventory stocks, such that the expenses associated with its protection would compensate for its use and deterioration and thus replenish this capital or avoid its destruction. Considering this viewpoint, defensive expenditures should increase the GDP.

The third criticism refers to the fact that the deterioration of the environment is not taken into account by the SCN. Excessive exploitation and the overabundance of waste associated with certain economic activities can contribute to such a level of deterioration of the environment that certain industrial activities could reach a point of collapse. Let's consider the case of a salmon-farming production center which is located in a lake. The center increases its production and profits during a period of several years but at the same times generates an enormous amount of organic waste which is deposited in the ecosystem. After a period of time, the eutrophication of the lake will be so great that not even the very aquiculture activity will survive, thus leaving it with neither production nor income.

The aforementioned does not mean that the negative impact on the environment will not have, at some time, an impact on the growth indicators. When the lake is dead and generates no more production, naturally, there will be a loss in the GDP because these contaminating economic activities will cause future indicators of the GDP to be adjusted downward. But, at that time the SCN will not be able to explain the fall in its indicators but within the short-term, it is not possible to prevent these effects that will occur in the future.

From a long-term or sustainable development perspective, the SCN gives out insufficient data to make proper decisions because it does not take into account the negative impact upon the natural (green) assets and for this reason does not consider the diminution of future capacity to assure an equal or greater income.

The proposed solution, the same as in the case of the depletion of natural resources, has been to record the degradation of the fixed capital or the decrease in the inventory stock.

In the case of aquiculture, there is a large amount of environmental impact, the greatest is associated with the waste generated in the water columns as a result of the food and fecal waste of the fish. In the section which follows, a proposal is given regarding a way to place monetary value on environmental impact and how to make the necessary adjustments to the sectoral income of the PIB-Fishing Industry.

III. Economic Evaluation of Environmental Impact on Aquiculture

Aquiculture generates diverse and multiple environmental impact, to the degree that recent studies estimate that the "ecological imprint" left by the salmon industry is of the order of 10,000 times . This is to say that for each square meter of salmonoid floating cages, the environmental impact, in terms of consumption of resources and waste created, is equivalent to 10,000 square meters. The most significant of these are the organic waste and the food residue whose primary effect is the eutrophication of the water[7].

The quantity of nutrients which produces a ton of fish, in captivity, has been diminishing since 1974, from 31 kilograms of phosphorus (P) and 129 kilograms of

[6] *Folke, 1998*
[7] *See Buschmann, 2001, for a detailed discussion regarding the environmental impact of salmon farming in Chile.*

nitrogen (N) to approximately 9.5 kilograms of phosphorus and 78 kilograms of nitrogen in 1994, primarily due to the changes in the make-up of the food and the improvement of the conversion indexes. These values, considering the gross production of 100 tons of salmon, mean a secondary production of 78,000 kilograms of nitrogen and 9,500 kilograms of phosphorus per day depending on the methods used and quality of the fish food.

Organic, urban and/or industrial waste have the same potential for eutrophication of water as does the production of fish in captivity. In the case of man, the average, daily production of waste is 1.5 grams of phosphorus and 10 grams of nitrogen. Considering these values, 100 tons of fish, grown in captivity, produce the same amount of chemical waste as do 2,800 to 3200 people in developed countries.

The production of 80,000 tons of salmon in Chile during 1994, would produce then, an equal amount of waste as 2.2 to 2.6 million people, which is 3 times greater than that produced by the entire human population that lives in the salmon production zone. During the year 2000, 345,000 tons of salmon and trout were produced in Chile, thus producing an equivalent amount of waste to that of 9.6 - 10.9 million people. But, let's assume that because of better management and technology in feeding during the past 5 years, that the figures for nitrogen and phosphorus have dropped to 33 and 7 kilograms, respectfully, per gross ton of salmon produced. Given the fact that salmonoid production has increased significantly since 1994, to reach 342,000 tons in the year 2000, the level of waste generated by the aquiculture production would be equivalent to that of a human population of 3.03 - 4.6 million inhabitants. This shows that in spite of the efforts to improve the technology used, expansion of the industry continues to produce a sustained growth of waste which impacts the environment.

Information concerning the cost of waste treatment is necessary to be able to calculate the environmental costs de the Chilean aquiculture industry but this data is not available in Chile since waste water treatment is new in Chile. For this reason, values from developed countries have been chosen and can be used with the proper restrictions to analyze the environment costs associated with the Chilean aquiculture industry. In Sweden, the cost to eliminate nitrogen from a certain volume of water varies from 6.4 to 12.8 US$ per kilogram while the removal of phosphorus costs 2.6 to 3.8 US$ per kilogram. Since these are the prices that are currently charged, they should be considered that which the industry is willing to pay for waste water treatment. It is true, that because of lower income, the willingness to pay that price in Chile is less, nonetheless, the effective costs would be about the same.

If we consider these prices and the level of production in Chile, during the decade of the 90's, an estimate can be made of the annual environmental cost caused by the discharge of nutrients from salmonoid production. We have estimated this cost for the decade of the 90's. The results of our calculations are to be found in Table Nº1.

According to Table Nº1, the environmental costs generated by this sector for the year 2000 is estimated to be 78 to 153 million US$. This figure is high since other environmental damages have yet to be considered.

To properly understand the dimensions of these figures, it is necessary to use the GDP for the fishing sector. In the year 2000, it reached 1,205 million US$ but this included other activities not associated with salmon-farming, such as the production of algae and other species, and fishing by family-owned and industrial companies. Without making a specific estimate of the GDP for salmon-farming, that is to say, the added value generated by salmon and trout production, we can give it a rough estimate such as 40% of total fishery (fishery excludes fish meal). With these calculations in mind, we believe an estimate of 16-32% of the added value generated by salmon-farming, should be set apart for environmental costs or consumption of environmental

[8] *Enell & Ackerfors, 1991*
[9] *Persson, 1992*
[10] *Folke, et al, 1994*
[11] *Buschmann et al, 1996*
[12] *Troell, personal communication*
[13] *Sernap 2000*
[14] *Folke et al, 1994*
[15] *This is a rough estimate that the exporters gave in the year 2000 - approximately 1,000 million US$ and the added value of the sector is 50% of the gross value of production for the year 2000, which would total 500 million US$. Nevertheless, this is a high estimate. We must take into account that within the sector is included the remainder of the aquiculture production, small or family fishermen and factory or industrial fishing companies. Because of the aforementioned, this figure should be considered the upper limit.*

Table Nº1: Environmental Impact Costs for the Aquiculture Industry										
Year	Salmon and Trout Production (ton)	Estimate of Waste		Nitrogen Cost US$/ton		Phosphorus Cost US$/ton		Environalmental costs Total US$ (millions)		
		Nitrogen	Phosphorus	Bajo	Alto	Bajo	Alto	Bajo	Alto	
		kg/ton	kg/ton	6.4 US$/kg	12.8 US$/kg	2.6 US$/kg	3.8 US$/kg			
1990	28,615	78	9.5	499.2	998.4	24.7	36.1	14.99	29.6	
1991	42,480	78	9.5	499.2	998.4	24.7	36.1	22.26	43.95	
1992	62,147	78	9.5	499.2	998.4	24.7	36.1	32.56	64.29	
1993	77,475	78	9.5	499.2	998.4	24.7	36.1	40.59	80.15	
1994	101,958	78	9.5	499.2	998.4	24.7	36.1	53.42	105.48	
1995	141,377	33	7	211.2	422.4	18.2	26.6	32.43	63.48	
1996	199,085	33	7	211.2	422.4	18.2	26.6	45.67	89.39	
1997	247,970	33	7	211.2	422.4	18.2	26.6	56.88	111.34	
1998	259,236	33	7	211.2	422.4	18.2	26.6	59.47	116.4	
1999	230,188	33	7	211.2	422.4	18.2	26.6	52.81	103.35	
2000	342,406	33	7	211.2	422.4	18.2	26.6	78.55	153.74	

Fuente: SERNAP, Buschmann, et al 1996, Folke 1994

capital. The sum total of the environmental costs during the period 1990-2000 would be 490-961 million US$. See Table Nº2 for greater details concerning this figure.

Another way to look at these results is to consider that the value of salmonoid varies between US$ 3.1 and US$ 3.5 per kilogram (FOB), but if these environmental costs were included, the price would increase 15-57% depending on the amount of nitrogen and phosphorus in the feed. See Table Nº3.

Since the price has decreased from approximately US$5 per kilogram at the beginning of the 90's to values of less than US$4 and even less than US$3 during the year 2001, it is to be assumed that the Chilean salmonoid industry would not be capable of covering the environmental costs unless high quality feed is used in a well-ordered fashion. Similar calculations made in developed countries have indicated that they are unable to absorb the environmental costs .

Table Nº2: Sectoral GDP and Environmental Cost						
Year	Fishing GDP MM pesos (1986)	Fishing GDP MM US$ (regular)	Environmental Cost/GDP Sectoral		Environmental Cost/GDP Aquiculture (40%)	
			Bajo	Alto	Bajo	Alto
1990	54,685	466	3%	6%	8%	16%
1991	60,275	633	4%	7%	9%	17%
1992	70,281	798	4%	8%	10%	20%
1993	74,195	691	6%	12%	15%	29%
1994	83,316	786	7%	13%	17%	34%
1995	100,040	932	3%	7%	9%	17%
1996	109,771	993	5%	9%	12%	23%
1997	120,014	1,100	5%	10%	13%	25%
1998	122,947	1,055	6%	11%	14%	28%
1999	125,032	1,050	5%	10%	13%	25%
2000	146,151	1,205	7%	13%	16%	32%

Source: Banco Central, estimates by the authors

[16] *Folke et al 1994*

Table Nº3: Incremental Costs for assuming the the Environmental Impact

Nitrogen cost	Phosphorus cost	Conversion Efficiency feedkg/nutrientkg/fish		Additional costs US$		Additional costs (%)	
US$/kg/nutrient	US$/kg/nutrient	Bajo	Alto	Bajo	Alto	Bajo	Alto
6.4 - 12.8	2.6 - 3.8	0.0310 P - 0.129 N	0.0095 P - 0.078 N	0.94-1.77	0.53-1.04	27%-57%	15%-33%

Production cost increments (U$/kg of fish) when internalizing the costs of purification of the N and P produced by salmon farming. The analysis is sensitized considering different levels of efficiency in the feed conversion.
Source: Updated from Buschmann et al., 1996.

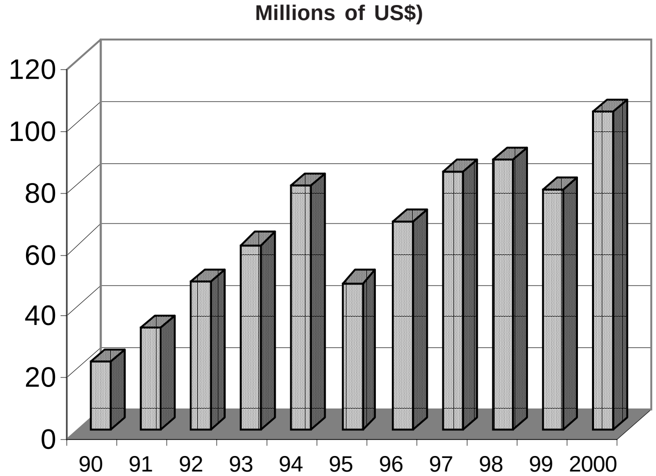
Notwithstanding the aforementioned, there currently are technologies that permit the reduction of environmental impact . A recent publication shows that using a system of production which recycles waste allows for profitability in spite of assuming the environmental costs. Consequently, it is hoped that the adoption of this clean technology will allow current production capacity within the sector and at the same time significantly improve its environmental sustainability.

IV. Conclusion

From a traditional economic perspective, it can be argued that Chile has a comparative advantage in the production of salmon and trout, which means, in practice, it is taking advantage of, among other things, environmentally clean ecosystems. Nevertheless, the preceding results show that Chile is developing its economy at the expense of environmental destruction which certainly affects other current or future economic activities plus people's health. The fall in salmon prices this year increases the gap between added value and the environmentally adjusted one because the environmental damages are proportionally greater. Moreover, it should be pointed out that in this analysis only the cost associated with nitrogen and phosphorus introduced into the ecosystems was taken into account and no other environmental impact caused by this industry was considered.

Environmental Costs of Salmon Farming

Millions of US$)



Since water use is necessary for many human activities, it is of great importance to maintain its high level of quality. Within this context, the current methodology can be extended to analyze how the different anthropic activities are affecting it and might help in reaching a consensus concerning the rational use of Chile's aquatic environment.

The environmental impact caused by salmon farming is of significance. By way of comparison, the waste created by salmonoid farming is more than four times the amount of waste generated by the resident human population of the tenth and eleventh regions of Chile, location of the majority of salmonoid activity. Moreover, the impact has significant economic costs which, in the long term, negatively affect the overall society or other economic activities.

Given the conditions of existing salmon farms, the industry has the capability to completely assume the environmental costs and to perform its activity according to a sustainable criteria. However, without an active involvement by the State, through a framework of adequate regulations and an industry concerned with its social role and the environmental impact that it causes, not only the ecosystem is in danger but also the future projections of this very industry.

[16] see Buschmann, 2001, for other examples
[17] Chopin, 1996

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