Fishing Industry Dynamics: Is fish farming sustainable? An Exploratory Study of the Chilean Salmon Industry

Martin Kunc
Assistant Professor of Management Sciences
ORMS Group
Warwick Business School
University of Warwick
CV4 7AL Coventry, UK

Martin.Kunc@wbs.ac.uk

Lorenzo Andrade
Vicerrectoría de Planificación y Desarrollo
Universidad de los Lagos
Osorno, Chile

landrade@ulagos.cl

Abstract

In recent years, there has been an increase in the interest for fishery dynamics in the System Dynamics field but most of the work has been related to the management of wild fish stocks. In this paper, we present an exploratory study of the effect of fish farming on the stock of wild fish stocks based on the case of Chilean Salmon industry. Fish farming does not reduce the impact of fishing activities but it increases their effects since it is necessary almost 6 kilograms of wild fish for each kilogram of salmon produced.

Introduction

In recent years, there has been an increase in the interest for fishery dynamics in the System Dynamics community. However, most of the paper addresses the management of the actual stock of wild fish except Robadue and Simanek (2007). In this paper, we present a real case simulation model that describes the future path of one of the largest aquaculture industry; Chilean Salmon. The model clearly addresses a very important topic since the recent years; the production of fish from fish farms has increased achieving almost 50% of the world production. Moreover, fish farming seems to be promise for future generations to obtain protein as the FAO (2006) report suggests. However, the promise may become into a nightmare if the fish farmed is carnivorous and, consequently, there is an additional pressure in already exhausted fisheries.

The Salmon Farming Industry in Chile

The salmon production in Chile increased from 50000 tones in 1992 to more than 600000 tones in 2008, which implies exports of approximately 400000 tones for US$ 2.2 billions (figure 1). This situation positions Chile as the second largest producer of salmon in the world just below Norway production level of more than 650000. The industry has been an important generator of employment with almost 30,000 people employed directly and 13,500 indirectly, but almost 80% of the activity is concentrated in 8 companies.

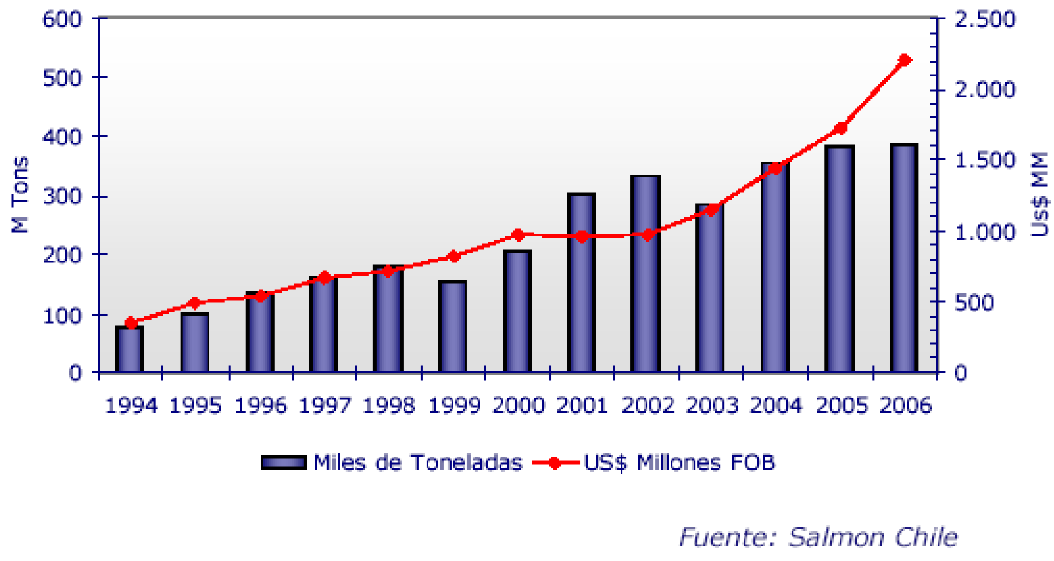

Figure 1. Salmon production and price per tones (source: Salmon Chile)

Production centers are located in areas defined by the Chilean government separated each other by 3 Km. The production of each of these centers varies between 1500 and 2550 tones. The industry has been growing at an extraordinary rate of 21% per year in the last years. Among the many reasons is Foreign Direct Investments from largest Norwegian firms due to the proper conditions for salmon farming as well as the growth in demand. Chilean Salmon industry has grown from a small producer to become the main supplier in the world. In the case of Chile, Salmon industry has contributed directly to the development of two poor regions in the south of Chile. Figure 2 shows an image of a salmon farm.

Figure 2. Salmon Farm

Salmons are fed with pellets elaborated using fish oil and fishmeal, which have partially been replaced with grain. Fish oil and fishmeal is produced using pelagic fish. As the industry expands, it requires more fishmeal and fish oil. In a free environment, salmon populations will be checked by predators or even by the lack of food. Under fish farming management, there is no limit to the level of the salmon population, except government regulations, and the pressure on the actual stock of fish employed to produce fishmeal and fish oil. Therefore, salmon population can be higher than its natural sustainability level. Consequently, the economic development obtained by these poor Chilean regions may not be sustainable in the long term. This paper shows the results of a preliminary model about the future evolution of the population of fish (pelagic) employed for fishmeal and fish oil for feeding the growing salmon industry in Chile.

The Model

The model in this stage is exploratory. Therefore, we assume some exogenous variables that may be considered endogenous in a second phase of the model development. The data has been obtained from diverse sources such as Salmon Industry annual reports and reports from the Fund for Research on Fisheries. The model can be divided into two sectors: the first sector represents the demand from the salmon industry and the second sector the impact of its requirements on the stock of pelagic fish (mackerel). Figure 3 shows the first sector that calculates the amount of pelagic fish required for Salmon food. Salmon food requires fishmeal and fish oil. The requirements in terms of fishmeal depend on the percentage of fishmeal on Salmon food. The industry has been doing some research on replacing fishmeal for grains like soybean but it has proved not successful as well as reducing the percentage of fish oil. The amount of pelagic fish required for Salmon food also depends on the yield of raw fish.

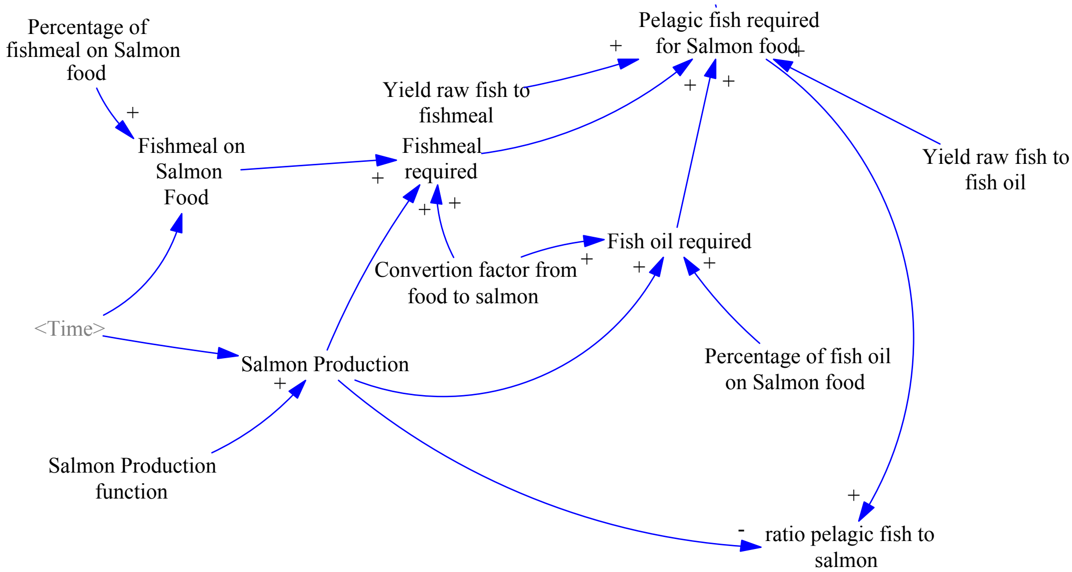

Figure 3. Demands from the salmon industry to the pelagic fish stock

The impact of the salmon production on the requirements from the pelagic stock of fish was calculated following information from the Salmon Industry Reports. The industry suggests that they need 1.35 kg of food to obtain 1.00 kg of salmon, which is included in the variable "conversion factor from food to salmon". We did not have the evolution of the amount of fish oil in the food for salmon, variable "percentage of fish oil on salmon food", from 1994, so we run two scenarios with the level of oil as of 2006: a usage of 20% of fish oil in salmon food in one scenario, and only 16% in the other scenario. Both percentages have been provided in the salmon industry report. Finally, the requirements of fish to be captured in order to obtain food for salmon were included in the variables “yield raw fish to fishmeal” and “yield raw fish to fish oil”. In the case of fishmeal, the yield from raw fish to fishmeal is 24% so for every kilogram of fishmeal is necessary to capture 4 kilograms of wild fish approximately. In the case of fish oil, the yield is 5% so for every kilogram of fish oil is necessary to capture 20 kilograms of wild fish. The resulting computation of these relations provided the value of pelagic fish that has to be captured in order to feed the increasing volume of salmon, as figure 4 shows. The simulation named “current” includes the usage of 20% of fish oil and the simulation named “current1” includes a usage of only 16%.

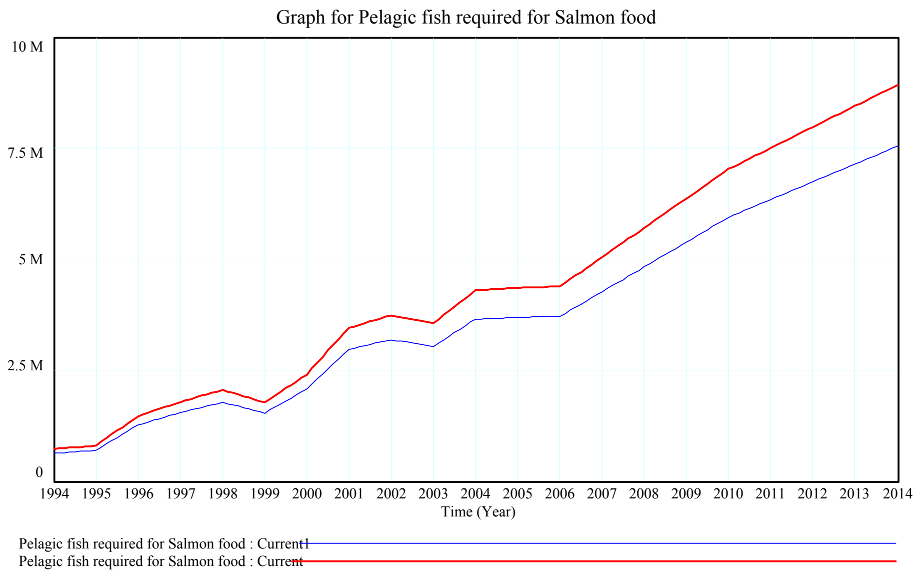

Figure 4. Estimated pelagic fish requirements of the salmon industry from 1994 to 2014

The level of fishmeal required for the salmon food, which is included in the variable “percentage of fishmeal on salmon food”, have been decreasing since year 2000 from 45% to a 28% in 2006, as fishmeal is replaced by soybean and other grains. Even considering this innovation in feeding technology, the rate of consumption of pelagic fish keeps increasing. This effect is captured in figure 5.

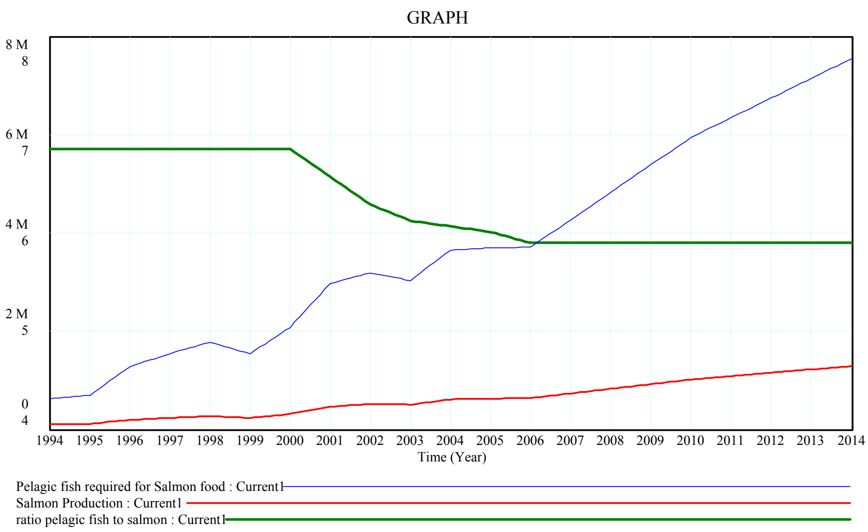

Figure 5. The evolution of the requirements of pelagic fish from the evolution of salmon and the ratio salmon to pelagic fish

The model employs the information provided by the industry with the production of salmon from 1994 until 2006 and a projection for 2010 and 2014, which is included in the variable "Salmon Production function", see figure 5. There are endogenous factors that generated the exponential growth in the production of salmon according to industry reports such as increasing world demand of salmon, high profitability due to low production costs compared to other salmon farming areas like Norway or Scotland, and the availability of locations for salmon farming. In this model, the reinforcing feedback process determining the exponential growth observed in the industry is not represented and it is considered for future research (and a second version of the model).

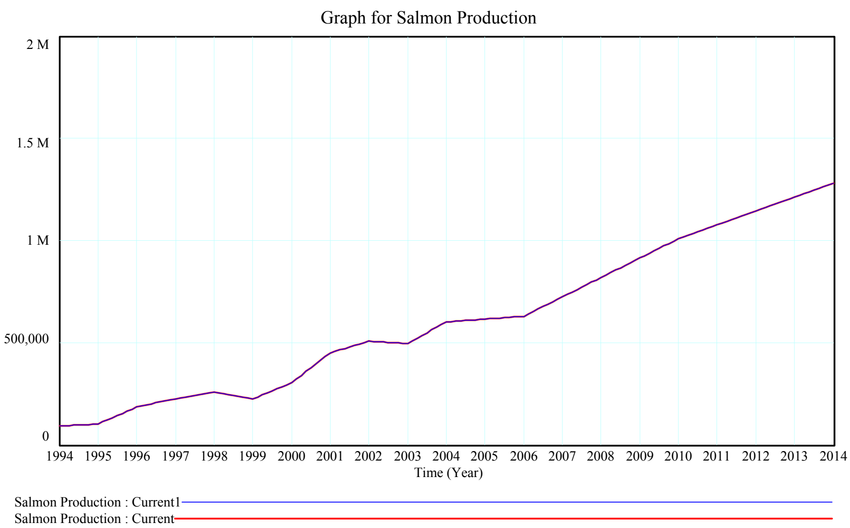

Figure 4. Development of the Chilean salmon industry from 1994 to 2014 (projected)

The second sector represents the evolution of the stock of pelagic fish due to the effect of recruitment and fishing efforts. The stock of pelagic fish was obtained from a report obtained from the Fund for Fishery Research. In the model, we employ the lowest values available for fish stock since the values for the stock varied from 20 to 40 million tones depending on the method employed to estimate it. The recruitment depends on two variables: *r* is the recruitment rate which we estimated in 0.2 based on fishery management reports, and *k* is the saturation effect on recruitment that it was considered to be the maximum of the values of the stock estimated by the Fund for Fishery Research. The structure of the model is represented in figure 6.

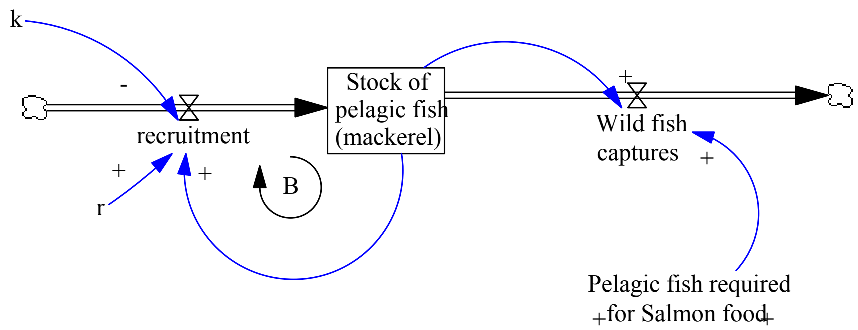

Figure 6. The natural resource dynamics

The equation for recruitment represented below captures the balancing feedback process determined by the natural limit for the fishery

recruitment = r"Stock of pelagic fish (mackerel)"*(1-("Stock of pelagic fish (mackerel)"/k))*

The increasing pressure on wild fish requirements due to the expansion of the Chilean Salmon industry implies that the stock of pelagic fish may be depleted by the end of 2014 as figure 7 displays.

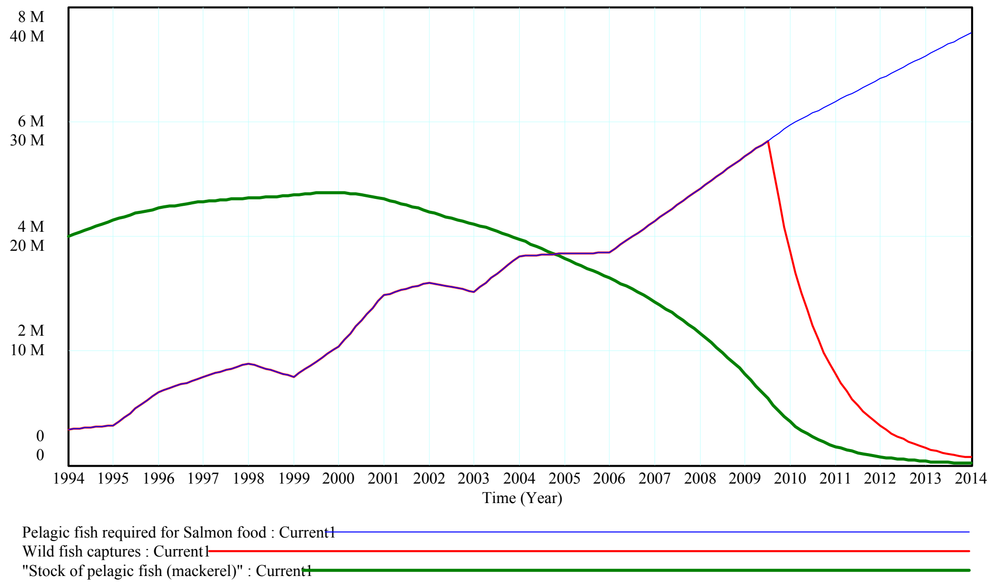

Figure 7. The evolution of the stock of pelagic fish

The last figures from fish captures obtained from the Chilean government agency responsible for fishery management show a decline in the volume captured as line ‘Pelagic fish captures’ in figure 8 shows. The captures seems to be stable because the government has established limits to the fishing industry. However, the fishing industry has been importing raw fish from other fisheries like Peru as the gap between requirements and actual fish captures increase.

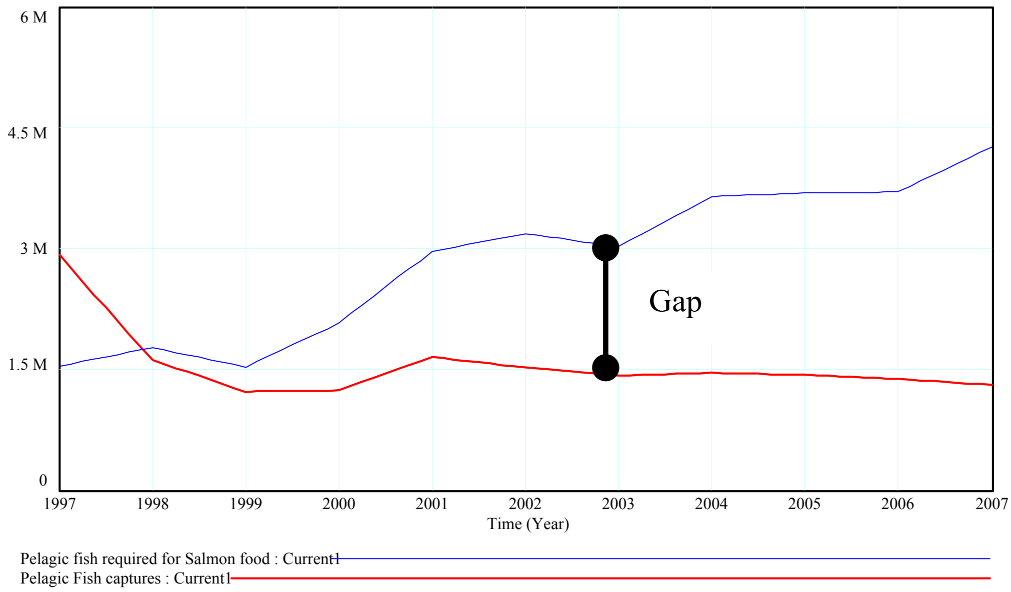

Figure 8. Fish captures from 1997 to 2007 based on Sernapesca report and Pelagic fish requirements based on the model.

Conclusions

The results of the simulation are worrying. The increasing investment in fish farming of species at the top of the food chain implies increasing efforts to capture wild fish at even faster rates. Even though the ratio of pelagic food to salmon production fell due to substitution processes explored in the industry, salmon consumes almost six times its weight from pelagic fish incorporated in fishmeal and fish oil. The global markets increasingly demand fish of good quality like salmon but they do not consider the implications of this demand on the stocks of other less fashionable fish species. The current economic crisis may have postponed the inevitable result for few years.

The results clearly show that shifting the burden of fishing effort to fish farming are not improving the situation but it makes things even worse. Fish farming may have better effects on wild fish stocks if the fish species are at the lower end of the food chain rather than at the top end. There has to be changes in demand requirements in a similar fashion when salmon became a fashionable fish to consume in the mid 1990s.

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