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Chilean Salmon Farming on the Horizon of Sustainability: Review of the Development of a Highly Intensive Production, the ISA Crisis and Implemented Actions to Reconstruct a More Sustainable Aquaculture Industry

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1. Introduction

Historically the Chilean economy has been based in exports accounting for 35% of the gross domestic product and mining is the main export income in the country. However, since 1980s as a part of a promotion the Chilean economy has diversified in part away from its dangerous over-reliance on copper exports. The growth of earnings in the fruit, wine, wood and forestry, fisheries and aquaculture sectors in particular, has been rapid since the early 1980s as Chile has exploited its comparative advantage in environmental endowment and low labour costs on the global market (Barton, 1997; Barton & Murray, 2009). The salmonid cultivation is restricted to regions with particular water temperature ranges in both fresh and seawater environments, sheltered waters and critically excellent water quality. Thus, salmonid aquaculture has become an important activity and the main development gear in the southern regions of Chile. The Chilean salmon industry has shown a fast development over the last 20 years and, therefore; today, Chile is the largest producer of farmed rainbow trout and Coho salmon, and the second worldwide of Atlantic salmon. This situation is the result from the application of innovation and development of value added products, which produced an average annual growth rate of 22% from 1990 to 2007 and an increase of exports from USD 159 million in 1991 to USD 2,242 million in 2007 (SalmonChile, 2007a). In 2006, salmon exports represented 12.94% of the non-mining-related national exports and 38.75% of the Chilean food exports that decreased due to a sanitary crisis down to 9.94% and 31.08% in 2010, respectively (Banco Central de Chile, 2010). The latter indicated that the salmon industry has become an important factor in economic diversification and one fundamental base in the strategy towards positioning Chile in the top rank of world food producers (SalmonChile, 2007b). The growth of aquaculture also impact positively other important sectors of the national economy, such as transport, processing, feed and engineer suppliers, laboratories, veterinary services and many others.

The success of the salmon aquaculture in Chile has been the product of the appropriate assimilation of foreign technologies and development of local technological capabilities. Although national investors played a major role in the early development phases of the industry, the entry of large foreign companies in the last two decades has facilitated the introduction of technologies, enlargement of production, vertical integration, merging and increasing the size of companies. This industry has also contributed to the general development of the economically depressed and rural regions in southern Chile. Although the Chilean salmon aquaculture has performed an astonishing development over the last 20 years, there have been demonstrated severe knowledge gaps before and during the devastating sanitary crisis caused by the infectious salmon anaemia (ISA) outbreaks that nearly led to a collapse of the industry.

The aim of the present chapter is to give an overview of the salmon aquaculture in Chile. Firstly, we describe how salmon farming rose up in a country without native salmonids, and the succeeding establishment of a highly organized and globalized industry. Secondly, we review the congestion of disease problems that peaked with the ISA outbreak that nearly collapsed the whole Chilean salmon industry, and finally the strategies and concrete measurements that have been implemented by the authorities and the industry to remerge the salmon aquaculture in Chile.

2. The Chilean salmon industry

The interest in introducing salmon to the water bodies of Chile began in second half of the 19th century with the first import of salmon and trout eggs in 1885 (Bluth et al., 2003). In 1905, the first Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*) eggs were imported and successfully produced in Chile (Bluth et al., 2003). Since 1920s government institutions carried out several attempts to introduce Pacific and Chinook salmon in lakes and rivers driven by the interest on sport fishing. However, it was not until 1969 when the program to introduce Pacific salmon in Chile was formalized by an agreement between the Japan International Cooperation Agency (JICA), the Fisheries Association of Japan, and the Chilean National Fishing Agency. As a part of the project, salmon fish farms with egg incubation facilities were constructed and also a training program carried out in Japan. In order to strengthen this sector, the Chilean government created the Office of the Undersecretariat for Fisheries (Subpesca) and the National Service for Fisheries (Sernapesca) under the Ministry of Economy, Development and Reconstruction in 1978. In 1974, the first private initiative to farm rainbow trout took place in Chile; hence, the company Sociedad de Pesquerías Piscicultura Lago Llanquihue Ltda had successfully exported trout to France, and soon after, Chilean farmed trout reached North America and other countries in Europe. During the 1980s, Fundación Chile, a private and non-profit organization played an essential role in the development of salmon aquaculture supporting technical and commercial issues toward large-scale salmon farming. It also focused on research and the implementation of new technology for raising salmon, artificial reproduction, behavioural studies and breeding, as well as the creation and exploitation of new fresh and seawater farm sites (Bluth et al., 2003). One of the final state initiatives to introduce salmon in Chile was through the cooperation between the Subpesca and the Canadian International Development Agency (CIDA). This was implemented by Hatfield Consultants Incorporate that technically advised many companies and fish farms and supported to consolidate companies operating as a technological bridge and providing services that helped the development of the salmon industry (Bluth et al., 2003).

2.1 Emergence of industrial aquaculture

The emergence of foreign companies in the salmon-farming business stimulated interest among local investors and firms in the commercial viability of the industry. Some of the first enterprises were founded by biologists, veterinarians and marine biologist experts. They had acquired substantial experience and knowhow regarding fish farming management of foreign species and production of fish eggs (Norambuena & González, 2006). In the late 1980s, Chile officially entered the group of salmon and trout producing countries and a number of local salmon farming companies increased and production grew tremendously. In 1985, 36 salmon farms were operating in Chile and the production reached near 1,200 tonnes increasing up to 60,000 tonnes by 1991 (Bjørndal, 2002). Thus, the industry grew in technology focused to farming, feed and fish processing. In the early stages, the production of salmonid in fresh and seawater has been centred in Los Lagos region. However, in the last 20 years, the development of connectivity, fish handling and transport technologies lead to a wide spread in egg, fry, parr and smolt production up north to Valparaíso region (V), and also fresh and seawater production further south to Magallanes region (XII), see Figure 1.

2.2 Structure and organization of the industry

The salmon industry emerged as a mature cluster, with several companies undertaking different aspects of salmon production and marketing. In Chile there has been a strong tendency towards vertical integration in the production of salmonids from egg production to market. Even minor producers will process, market and export their own production. Furthermore, it is common for farmers to have two or three salmon species, in order to spread the risk, both on more species and on more markets. This also contributes to smoother harvesting patterns and consequently cash flow, throughout the year. Large companies have moved to vertical integration in order to reduce production costs, implementing egg production, feeds and processing plants within their business (Iizuka, 2004; Norambuena & González, 2006).

Interestingly some farming companies are now producing most of their feed in-house or are part of holding-groups, thus part of the feed is addressed to the fish farmers within the holding. The Chilean industry has organized merges differently from that seen in the European salmon industry. After merging process towards larger enterprises, the original smaller companies were not integrated completely. Hence, they have changed the ownership and some restructuring, but kept most of the structure in each daughter companies and the original names.

The number of companies controlling most of the salmonid production in Chile has decreased from 35 to 10 companies between 1997 and 2006. However, today 19 companies contribute with more than 80% of the production of salmonids (Table 2).

More than 60% of the employment in the salmon industry is within processing and value added production today. About 90% of the Atlantic salmon production and 30% of Coho salmon and rainbow trout production is processed in the country. The main centres for processing salmonids are in the southern regions around Puerto Montt and Quellón area.

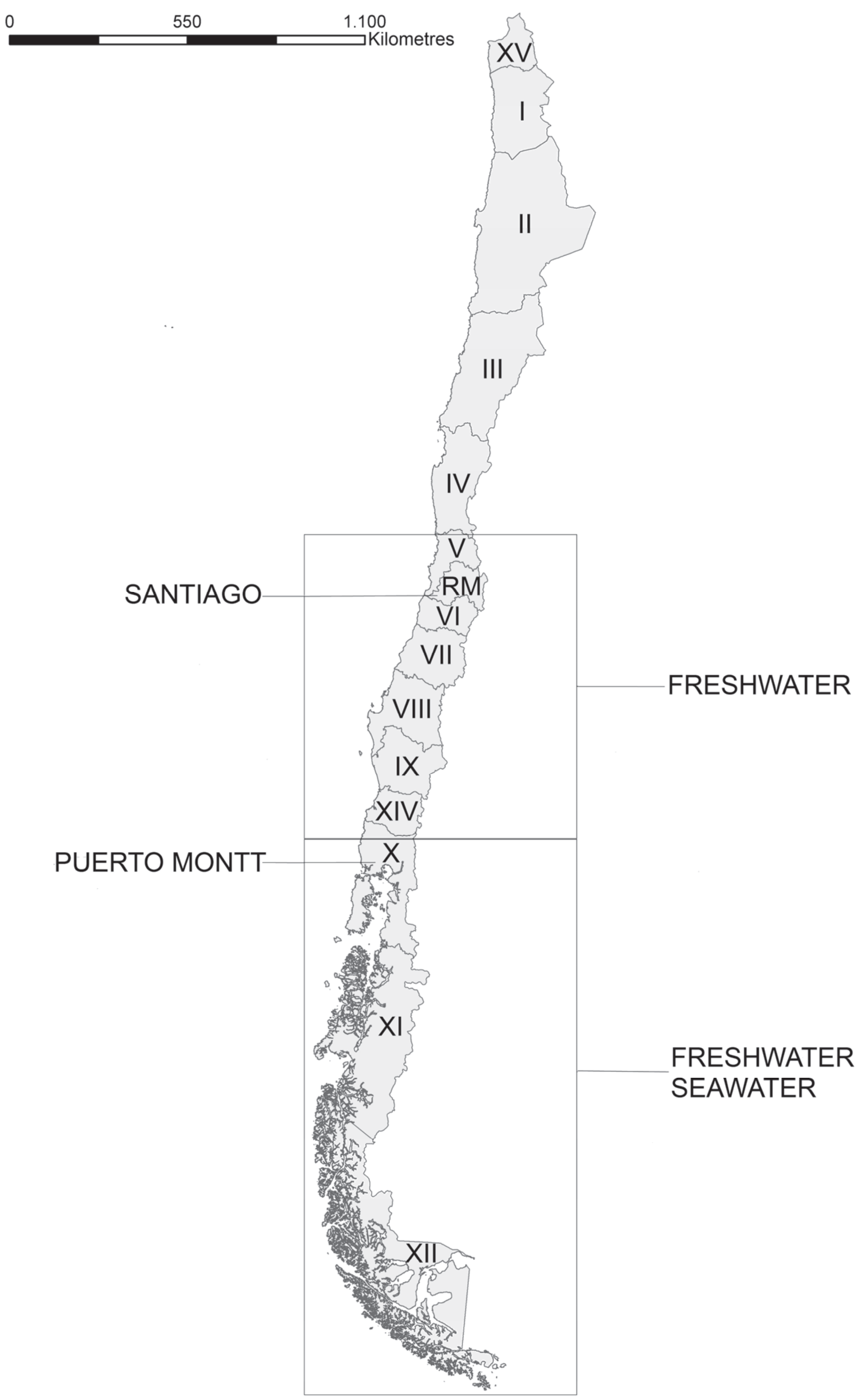

Fig. 1. Map of Chile and areas related to salmon aquaculture activities (exclusively fresh water production and fresh/sea water production, MR: Metropolitan region) (map source: GeoAustralis).

The consolidation of the salmon farming industry was the creation of the Association of Salmon and Trout Producers of Chile (APSTC) gathering 17 companies in 1986. In 2002, the name changed to the Association of the salmon industry of Chile, SalmonChile A.G., which also includes supplier firms. Nowadays, SalmonChile A.G. has a total of 76 companies as partners, where 25 are solely salmonid producers. Furthermore, companies related to salmon production established their own associations. For instance, the Association of Net and Net Service Industries (ATARED), Regional Association of Ship-owners and Maritime Services (ARASEMAR) and Association of Diving Companies were all established in 2001 and represent more than 70% of each sector. In order to further strengthen and enhance competitiveness, in 1995 the Association of Salmon and Trout Producers created Intesal, the Salmon and Trout Technology Institute, with financial support from the Production Development Corporation of Chile, CORFO. This institution was established to develop, share and prospect quality control technologies and improved food safety in the salmon industry. Intesal provides technical assistance and training in sanitary and quality control standards for its partners. Currently, Intesal has an important role in supporting the institutional consolidation of the salmon cluster and the introduction of quality control management systems.

In 2009, Trout and Coho salmon producers created their own association (ACOTRUCH) in order to represent medium and small companies not producing Atlantic salmon and not directly affected by sanitary events triggered by ISAv.

The salmon cluster has an important role in the development of the industry, due to the increasing service requirements every year. Continuous investment has been necessary while industry moves forward to informatics and automation in processes. The National Statistic Institute (INE) estimated that around 1,200 companies take part in the salmon industry where of 500 are key actors, 100 as input suppliers and 400 as service companies.

Association	Members	N° of companies	Capacities
ARASEMAR	The Association of Regional Ship-Owners for Shipping Services	14	200 vessels and 16 well boats
ADEB	Association of Diving Companies	8	500 professional and 3000 not professional divers
ATARED	Association of Net Workshops	14 (30)*	Net manufacturing and maintenance
ALAVET	Association of Veterinary Laboratories	18	pharmaceutical labs**
ARMASUR	Association of Southern Ship-Owners	10	Ship builders
SALMONCHILE	Association of the Chilean Salmon Industry	76 (25***)	Farming companies and suppliers
ACOTRUCH	Association of Coho salmon and trout producers	10	Farming companies

* not associated; ** related to the salmon cluster; ***only producers/farmers

Table 1. The key members of the salmon cluster.

2.3 Salmon production in Chile

The larger fresh water (FW) production is based in La Araucanía region (IX), Los Ríos (XIV) andLos Lagos (X). Seawater (SW) production has been mainly developed in Los Lagos region; in 2006, on a rather small area from Puerto Montt in the north to Quellón on the Chiloé Island a total of 499,512 tons of salmonids were produced. Due to the increase of SW production in Los Lagos region, Quellón was expected to become the biggest centre for salmon processing in Chile. However, before the ISA crisis in 2008, the production has been expanded to Aysén region (XI) and Magallanes region (XII) having the total harvest of 208,961 tons and 6,053 tons, respectively. In 2005, SalmonChile A.G. projected an annual growth of about 8-10% for the following 5-10 years. These expectations were based on exploiting the potential of moving most of the production to Aysén and Magallanes regions and to expand the FW production using highly advanced recirculation plants.

Historically the salmon cluster, including producers, processing plants, and services, has demanded up to 28,368 and 7,631 direct and indirect job positions, respectively (SalmonChile, 2007b). Specifically, the industry covers 0.7% of the job positions in the country and accounted for 11% of the employment in the Los Lagos region (X). The latter has contributed significantly and positively to the improvement of poverty in those municipalities where salmon aquaculture has been developed. Usually, the employment within producers is distributed in each of these stages of production with approximately 65% of total workers in sea farms, 30% in smolt production and 5% in hatcheries producing eggs. However, the number of employees decreased drastically down to 50% due to the sanitary crisis and the lower production in 2009.

2.3.1 Freshwater production

Current FW operations in Chile include lake-based, tank and cage systems, estuary cage systems, stream-based flow-through systems and recirculation tank systems. In 2008, the Chilean FW farms produced over 741 million salmonid ova and 298 million smolts, out of which 29% came from estuary-based farms, 30% from lakes and 41% from land-based facilities, or nurseries. While most hatcheries supply smolts for grow-out in farms owned by their parent company, many hatcheries also contract to supply smolts to unrelated farms, either using eggs from their own broodstock lines or using eggs provided by the contracting farms (Olson & Criddle, 2008). There are 169 FW facilities in Chile out of which 20 are recirculation systems (Silva, 2010a). Historically, in Chile, to produce one smolt has required from 2 to 5 eggs doubling the current needs in Norway (Águila & Silva, 2008).

Chilean-spawned eggs were available as early as 1980, but Chilean hatcheries remained largely dependent on fertilized eggs from foreign broodstock through the 1990s. Since the year 2000, nevertheless, Chilean egg production increased dramatically (Figure 2) and 79% of all eggs used in Chilean hatcheries were produced from local broodstock in 2009 (Sernapesca, 2011a). The decrease of near 70% observed in the national production of Atlantic salmon eggs is based on the effects of the ISAv crisis, going from near 500 million eggs in 2008 to close to 160 million in 2009. In addition, the import of egg fell substantially in 2009, mainly due to the lower production, but also based on restrictions, fear of importing new pathogens and changes in production strategies implemented by different companies. However, the import of rainbow trout egg increased more than double in 2010. Both rainbow trout and Coho salmon production grew approximately 25% and 37% with an increase in production due to the lower sanitary risk involved in their production between 2009 and 2010.

	Total Exports (ton net)		Value (thousand USD FOB)		Price (USD/kg FOB)	
	2009	2010	2009	2010	2009	2010
Total	369,216.1	297,160.3	2,101,643.7	2,060,909.0	5.7	6.9
Aquachile SA (Aquachile, Salmones Chiloé, Salmones Maullín, Aguas Claras)	47,715.6	34,172.7	254,794.0	206,918.70	5.3	6.1
Mainstream Chile SA	33,927.1	23,607.4	172,820.8	136,795.60	5.1	5.8
Pesquera Los Fiordos	27,304.6	16,368.7	129,961.2	106,239.10	4.8	6.5
Marine Harvest Chile, Deli Fish SA	23,731.9	12,702.2	144,049.5	116,118.20	6.1	9.1
Multiexport Foods, Salmones Multiexport SA	23,358.8	21,046.7	120,780.6	164,539.10	5.2	7.8
Cia Pesquera Camanchaca SA	15,667.5	9,906.3	115,634.8	66,684.90	6.7	6.7
Salmones Antártica Ltda	14,600.0	13,847.9	98,780.7	102,868.20	6.8	7.4
Granja Marina Tornagaleones Ltda	12,478.1	11,911.6	63,182.4	62,948.90	5.1	5.3
Trusal SA	12,165.8	13,465.2	70,212.7	103,529.80	5.8	7.7
Salmones Cupquelan SA	12,083.5	8,842.7	70,252.7	72,912.80	5.8	8.2
Ventisqueros SA	10,613.5	12,550.1	70,247.6	90,768.40	6.6	7.2
Acuinova Chile SA	8,737.0	9,441.4	51,403.4	67,303.00	5.9	7.1
Salmones Pacific Star	8,614.8	8,845.6	42,578.1	49,275.50	4.9	5.6
Cultivos Marinos Chiloé SA	8,553.8	8,242.0	67,692.3	74,819.70	7.9	9.1
Salmones de Chile SA	6,318.4	7,438.0	33,671.9	43,918.10	5.3	5.9
Australis Mar SA	5,177.9	7,942.6	32,418.2	56,505.30	6.3	7.1
Caleta Bay Export Ltda	4,958.9	5,733.8	28,792.8	49,116.70	5.8	8.6
Salmones Itata SA	4,413.1	9,518.1	33,901.1	75,612.50	7.7	7.9
Salmones Aysén	3,345.9	9,827.7	15,926.3	54,930.60	4.8	5.6
Others	85,449.3	51,749.6	484,542.1	359,103.90	5.7	6.9

*source TechnoPress, 2010

Table 2. Ranking of salmonid exporting companies 2009-2010.

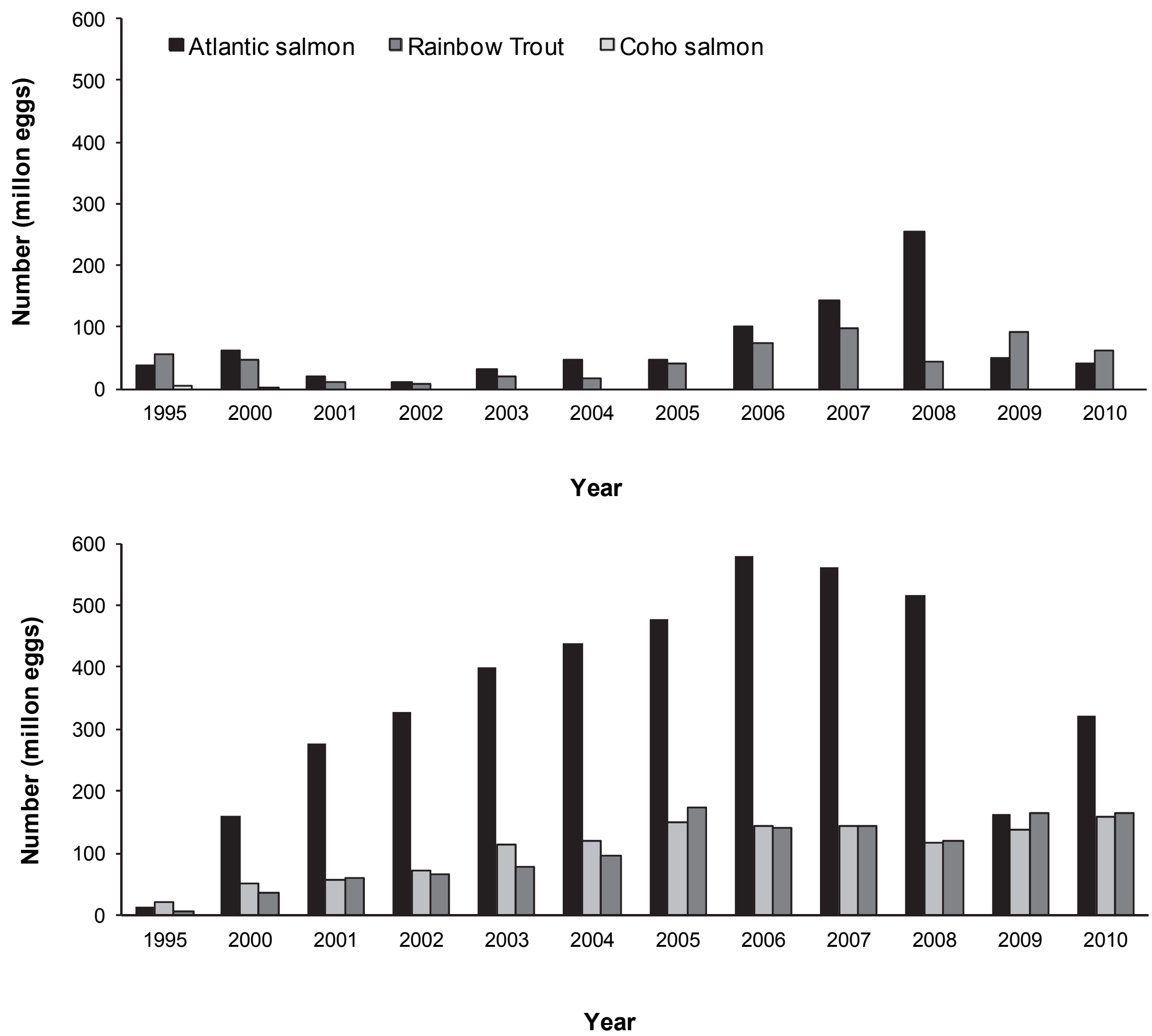

Fig. 2. Incubated imported eggs (upper) and incubated national eggs (bottom). Source: Sernapesca, 2011a

Various strategies have been used for smolt production in Chile. It was estimated that the majority of current smolt production comes primarily from flow-through fish farms that produce fry, followed by the smolting process in lake, river and estuary-based farms. No further growth in lake production is foreseen, since the regulation prohibits the authorization of new farms, considering that "Suitable Areas for Aquaculture" have not been designated in any Chilean lakes since year 1990. This means that the current production in lakes takes place on sites that were authorized prior to the aforementioned regulation, and that the growth of these farms is based solely on production increases in restricted spaces. Thus, a single company may have only one or a mix of smolt production strategies that range from a complete land based production to a mixture of using land based facilities, lake and estuarine areas (Figure 3).

Due to the existence of imported eggs, and offseason spawning, smolts are produced throughout the year (Figure 4) and smoltification is carried out using natural photoperiod, artificial lights and specialized feed additives. In contrast with the smolt types in Northern hemisphere; 1-year smolt (S1, S1 ½), 2-years smolt (S2) and half-years smolt (S ½ or 0+), in

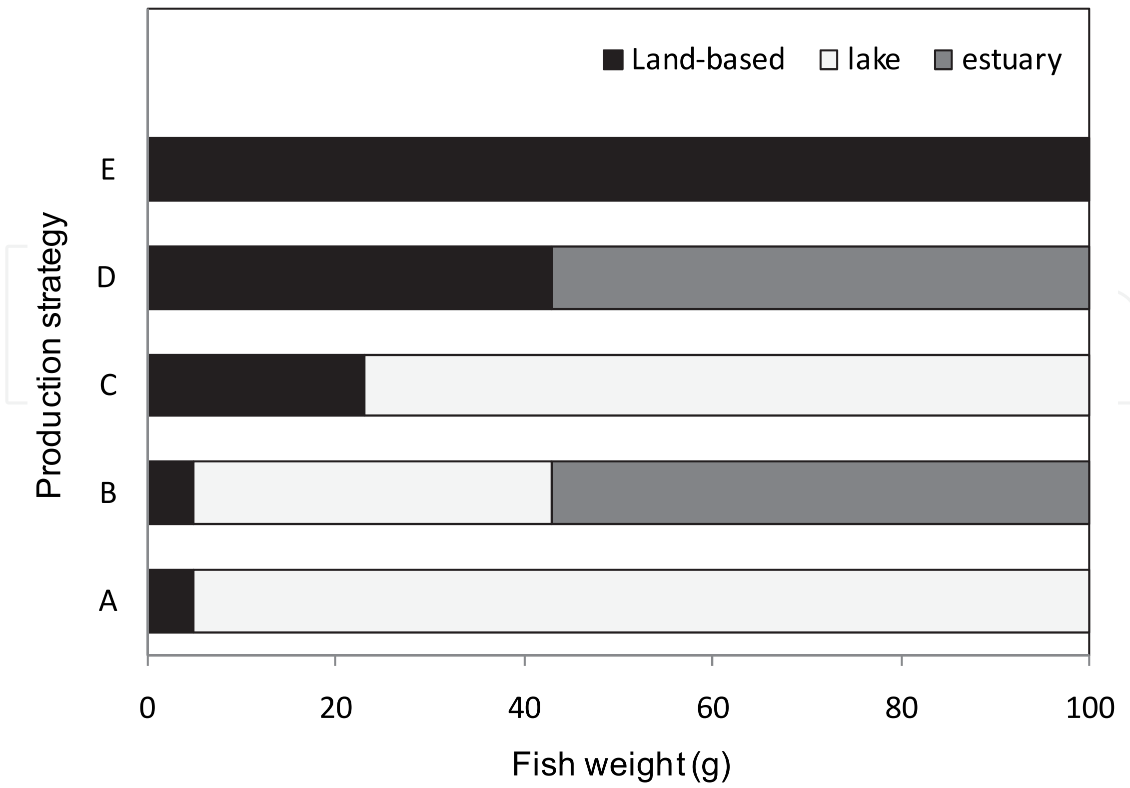

Fig. 3. The graphic shows 5 smolt production strategies in Chile. A. Eyed eggs to fry on land-based, fry to smolt on lake. B. Eyed eggs to fry on land-based, fry to fry on lake and fry to smolt on estuary, C. Eyed eggs to fry on land based and fry to smolt on lake, D. Eyed eggs to fry on land-based and fry to smolt on estuary, E. Eyed eggs to smolt on land-based facilities.

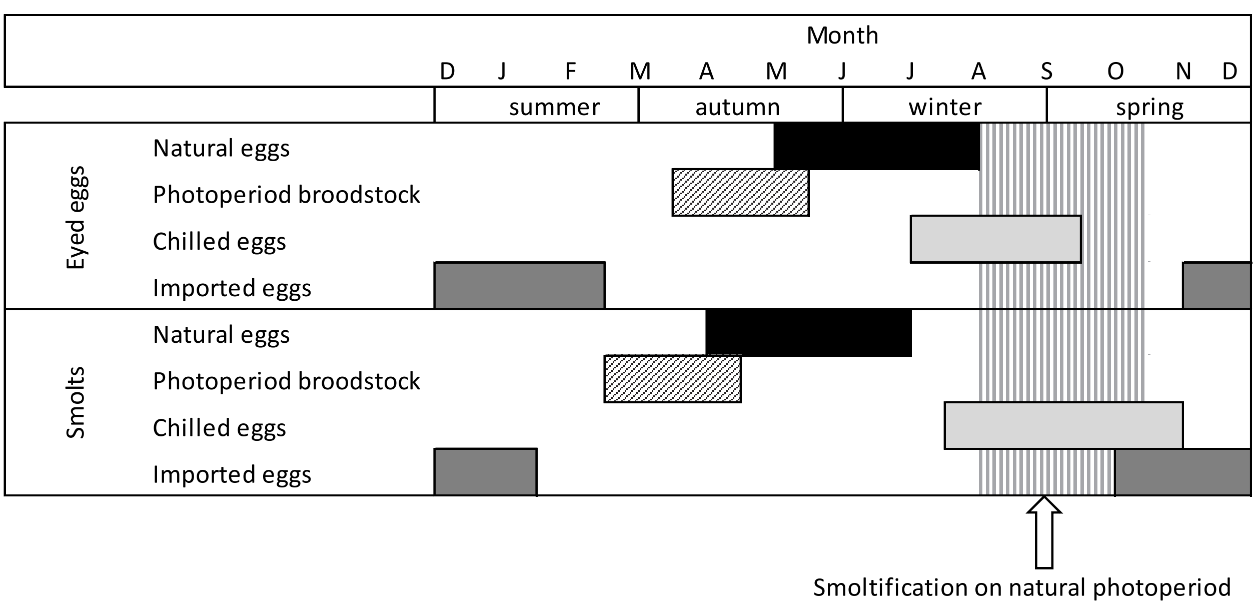

Fig. 4. Season and off-season smolt production year around in Chile. In the southern parts of Chile, the four year seasons are well defined with markedly differences between summer, autumn, winter and spring.

Chile smolts are called according to the production method as in-season smolt, late smolt, and early smolt, depending mainly on broodstock´s photoperiod manipulation, chilled egg, and imported egg. Therefore, smolt size regardless production method will normally range between 90 g and 120 g. Furthermore, the transportation of smolt over 250 g is prohibited and a certain small amount of smolts between 60 g and 90 g are produced by land-based facilities.

Smolt production reached its historical peak production in 2007, presenting a significant decrease in 2008 and 2009 (Figure 5), going from close to 400 million in 2007 to 160 million in 2009. This abrupt decrease in smolt production, mainly in Atlantic salmon, was caused by the sanitary crisis. Commonly smolts are transported by road and wellboat to their final ongrowing site in the sea. Due to the widespread FW areas in Chile fish are frequently transported on land over 300 kilometres prior wellboat transportation. In addition, fish may be transported to a lake or estuary then following land transport, wellboat and final ongrowing destination. This has been a major challenge in welfare and adequate water quality for the smolt transport systems.

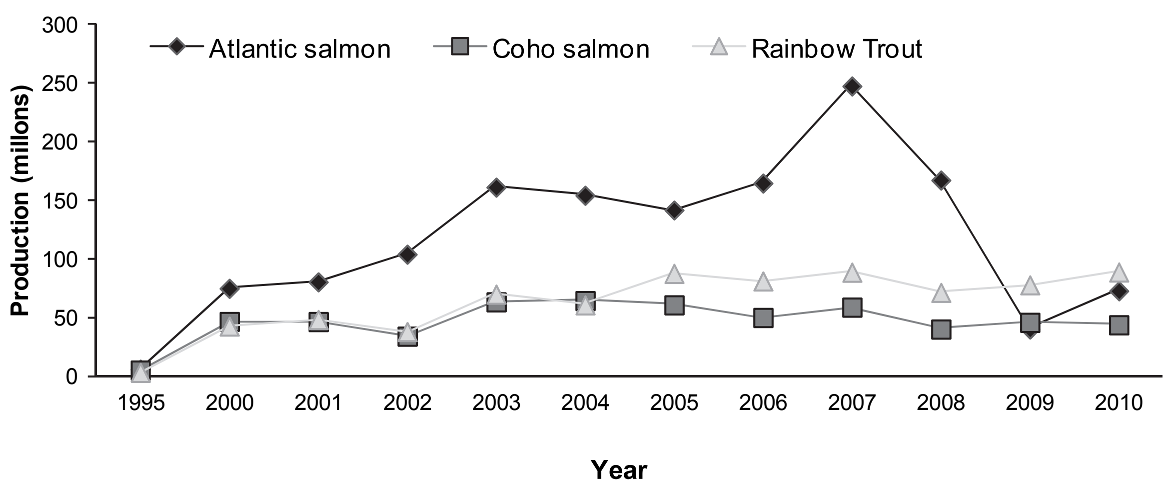

Fig. 5. Number of smolts produced (data available from year 1995). Source: Sernapesca 2011a

2.3.2 Seawater production

The technology used for salmonid on-growing in Chile is very similar to the rest of the salmon producing countries, it is carried out in cages and today most operations are automatized. At the end of the 1980s the sea cages were usually few square wooden modules of approximately 1.100 m^3 (10x10x11) and located near-shore or in sheltered waters. However, the size, location and type of cages have undergone profound development during the 1990s and 2000s. Sea sites developed to over 12 modules of circular high-density polyethylene cages of 12.725 m^3 (d. 30m) or square modules hinged steel cages of 25.600 m^3 (40x40x16) provided with modern automated systems. Thus, large integrated sites are also provided with pontoons including all comfortable living needs. The feeding and fish-waste cleaning procedures have been changing enormously from 1980s. In the early days of the salmon aquaculture, mainly hand control was performed that today is carried out by automatic feeding systems, satellite and under water video devices. An important development in anti-predators devices have been carried out due to huge losses caused by sea lions. Nearly 90% of the Chilean salmon farms had reported attacks by sea lions and losses around USD140 million in 2009. Sea lion manages to cleave regular nets and avoid acoustic harassment, alarm devices and fake killer whales. Nowadays predator nets are the only effective method towards sea lion attacks (Oliva et al. 2003; Vilata et al. 2010).

The SW production have been spreading further south in Aysén region, where many concessions have been granted in the past years and activities are starting far south in Magallanes region. Today from 1063 concessions granted, 441 are in Los Lagos region, 572 in Aysén region and 50 in Magallanes region, however, a nearly 15 times growth is expected by 2013. In the Southern hemisphere there are inverse seasons in respect to Northern hemisphere, thus allowing the supply of fresh salmon during winter time in importing countries as USA and Japan. During summer, the temperature in the sea ranges between 8°C and 18°C in Los Lagos region, but in Aysén and Magallanes seldom reach up to 15°C. In addition, in winter temperatures could reach down to 5°C but never around freezing point.

2.3.3 Salmonids processing

Chilean salmon farming processing technology has evolved from fully-manual systems to a mixed semi-automated systems, where some phases of the system are automated and other phases are carried out manually to ensure quality standards. Nevertheless, processing facilities in Chile employ twice of the workers as equivalent facilities in competitor countries, due to the labour costs. Thus, providing a comparative advantage in labour-intensive activities such as the production of fillets and boneless portions of salmon. The main salmon products are fresh and frozen fillets, loins and portions, but also smoked, and marinated products are significant parts of production. There has been an increase in value-added products obtained from salmon, mainly in Atlantic salmon and rainbow trout. This triggered by intense competition in the generic salmon market and prices trend in value-added products. Each farming company has 2 to 4 major customers that define the product range; however, very often these customers bring special equipment and procedures for production of innovative products with the brand of these customers. The reaction to this situation has been differentiation: creation of brands, greater variety in processing (fresh, smoked, frozen, salted, canned salmon) production of related products (fresh or frozen fish portions of specific weight and sizes to fill the specific requirements of clients, salmon cuts designed to facilitate fish preparation and decrease waste, etc.), client labelling and packaging for final consumption, and food traceability. These actions however, have increased production costs (Perlman & Juárez-Rubio, 2010).

2.4 Chilean salmon market

In the late 1990s, the development of the industry was driven by market needs. The fall in salmon prices on the international market in the late 1980s and early 1990s led to collapse of the smaller companies and established a consolidated industrial aquaculture in salmon producing countries such as Chile, Norway and Scotland. Consequently, the Chilean salmon industry realised the risk of relying almost exclusively on two major markets; hence, a group of 13 local companies formed Salmocorp in order to face existing markets and explore new ones. Although this joint venture company operated only for three years, it certainly contributed to opening up new markets. Despite the main markets of Chilean salmon have traditionally been USA and Japan; in the last decade, new markets have been expanded to

Latin America as well as to Asia (Iizuka, 2004). Therefore, exports to these markets are expected to grow relatively faster in the following years than the established markets in Japan and USA (Table 3).

Year	1999	2005	2006	2007	2008	2009	2010
	USD (million)						
Japan	471	638	704	648	713	824	921
USA	259	606	792	862	795	554	466
EU	34	236	308	279	284	162	73
Latin America	39	88	156	202	268	290	357
Other (Asia)	15	153	246	250	333	270	314

Table 3. Main market shares of Chilean salmon aquaculture from year 1999 to 2010 (USD million). Source: TechnoPress, 2010.

2.5 Production cost of Chilean salmon aquaculture

The production cost of salmonids in Chile has been low in relation to other salmonid-producing countries (Figure 6). Lower costs for labour force and lower prices for feed ingredients have been the major factors for the cost advantage in Chile. Historically, Chilean feed producers could pay significant lower prices for fishmeal and fish oil in South America than producers in the Northern Hemisphere. However, with increasing fishmeal and fishoil prices, improving life standards and education the Chilean cost advantages may be reduced significantly in the future. Furthermore, the production cost will considerably increase because the new enforcements of the regulation from the year 2011.

3. Diseases in salmon farming in Chile

Unfortunately, in Chile the advantage of a disease-free environment for farmed fish has been gradually lost the past two decades. This situation is acknowledged and majorly explained by the introduction of exotic pathogens, mainly through imported eggs (Smith et al., 2001; Claude et al., 2000). Chile has imported more than 1,900 million eggs over the years from various countries and continents of the Northern hemisphere, Figure 2. It is known that when moving fish or their gametes, their pathogens are moved along with them. Notwithstanding, in the case of some diseases in salmon farming in Chile, a relatively opposite phenomenon could have been possible, namely that some unknown etiologic agents could be endemic in native species without causing apparent damage and have adapted to it. On the other hand, non-native fish species such as salmonids would not have a proper genetic makeup or effective defence mechanisms against these new organisms, presenting a diminished health status with consequent outbreaks. Intensive systems used in aquaculture i.e. huge biomass grown along with high densities of fish per unit of water volume, have contributed to increase the prevalence of pathogens and to increase contact rates with hosts, all of which translates into a higher risk of disease.

3.1 Time-course of disease emergence

The appearance of important diseases posing a risk to the salmon industry in Chile has been related directly to the increase in production (Figure 7), where volumes went from

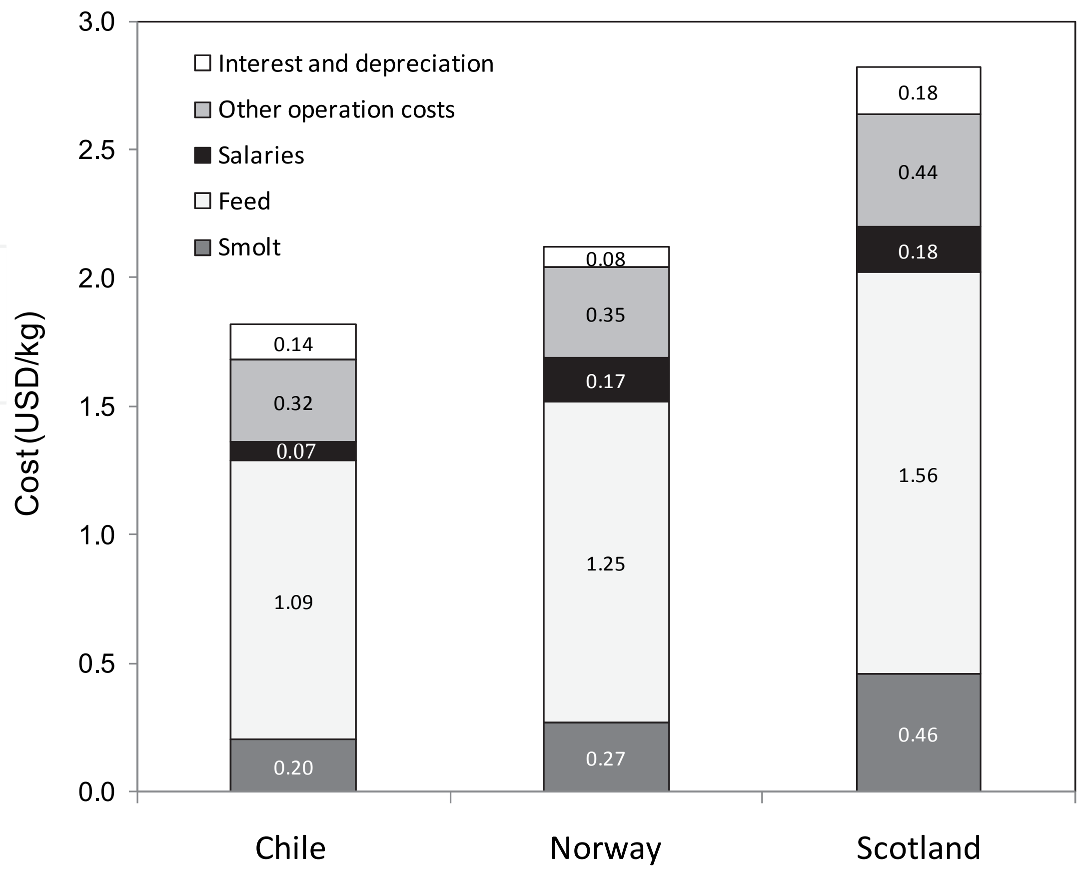

Fig. 6. Cost structure in salmon production in Chile, Norway and Scotland (until 2010)

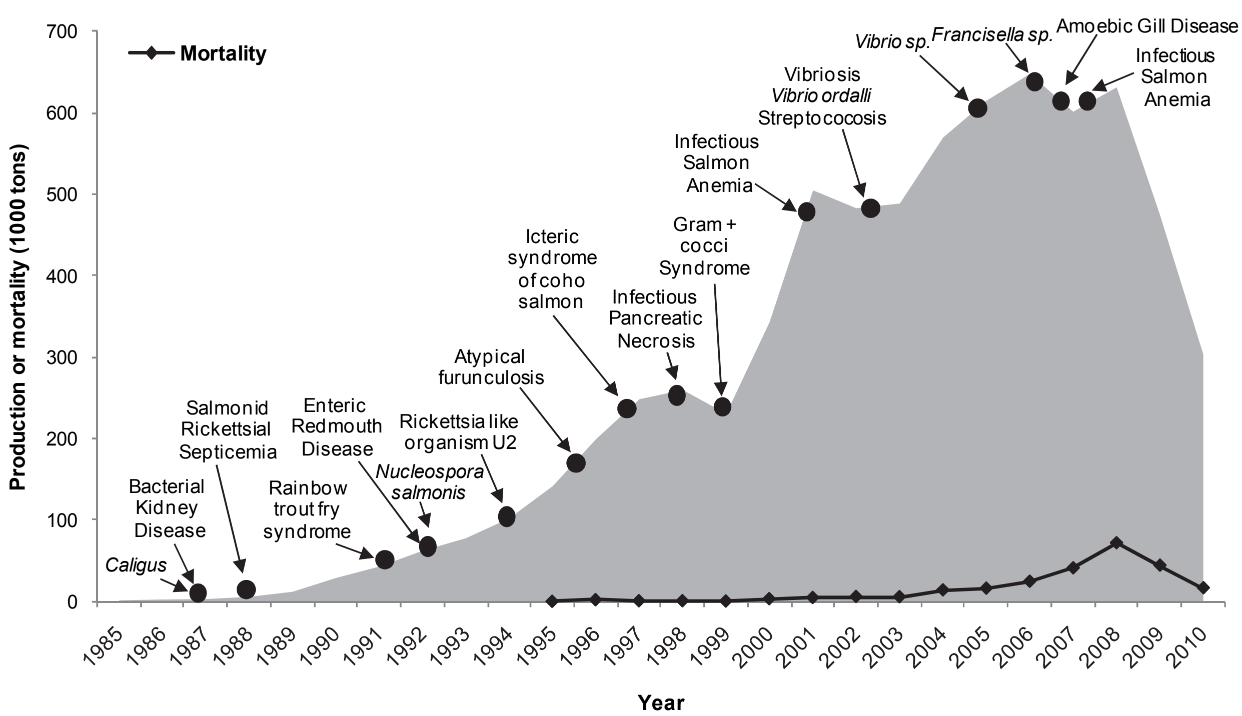

Fig. 7. Time line of production, disease emergence and mortality in salmon farming in Chile (period 1985-2010). Source: Sernapesca, 2011b; TechnoPress, 2010.

approximately 10,000 gross tons in the early 1990s to over 545,000 tons exported in 2008 (TechnoPress, 2010). Mortalities caused by infectious diseases increased over the years and dropped after the sanitary crisis as less salmon where transferred for grow-out purposes.

In the early 1990´s, the main diseases present in Chilean salmon farming were the Bacterial Kidney Disease (BKD), affecting rainbow trout, Atlantic salmon and Coho salmon, throughout their entire production cycle. Piscirickettsiosis (Fryer et al., 1992) or Salmonid Rickettsial Septicemia (SRS), a disease detected for the first time in the world, endangered at that time mainly Coho salmon during grow-out phase (Bravo & Campos, 1989a, 1989b; Fryer et al., 1990). The etiological agent was first described in southern Chile (Cvitanich et al., 1991; Fryer et al., 1990). The pathogen was extremely aggressive, and farms in the southern part of the country were devastated over a very short period (Branson & Diaz-Muñoz, 1991). Until now, piscirickettsiosis caused by the facultative intracellular bacteria, *Piscirickettsia salmonis*, is one of the diseases most threatening to the sustainability of the Chilean salmon industry (Olivares & Marshall, 2009). Piscirickettsiosis affects all salmonid species farmed in Chile, causing up to 90% mortality in some sites. First calculations estimated mortality of 1,5 million of Coho salmon, which represented an estimated loss of USD 10 million for year 1989 (Larenas et al., 2000). According to further calculations, the industry attributes annual losses of USD 50 million to piscirickettsiosis (Smith et al., 1997). Currently data from SalmonChile estimate losses of USD 19 million considering direct costs due to mortalities but not considering indirect costs i.e. treatment, decreased performance, and other costs related to the disease. Global losses have been estimated to USD 120 million for each year (InnovaChile, 2008). Different factors contribute to the occurrence of a persistent clinical course, much more as a chronic presentation of the disease with abscess observation (Godoy, 2010). Today, piscirickettsiosis represents 90% of the infectious-disease-caused mortalities (Intesal pers. comm., 2011) and is the pathogen agent mostly diagnosed in SW (Subpesca, 2010). In addition to the appearance of BKD and SRS, the first intensive productions of eggs and fries were visibly affected by diseases caused by funguses (*Saprolegnia* sp.) and flavobacteria (mainly *Flavobacterium columnare* and *F. psycrophilum*) in hatcheries and fry farming sites located in lakes. These infections are considered the major problems in FW, where infections with flavobacteria can result in 5% to 70% mortality rate of fingerlings (Valdebenito & Avendaño-Herrera, 2009). In 2008, *Saprolegnia* showed a monthly average mortality in Coho salmon of 0.06%, in Atlantic salmon of 0.02% and in rainbow trout of <0.01% (Intesal, 2009). The first clinical case of enteric redmouth disease (ERM, caused by *Yersinia ruckeri*) in Atlantic salmon fries and smolts in FW net pens was described at the end of 1992 (Troncoso et al., 1994). This case was related to increasing water temperature during the spring and summer seasons. Concurrently, during the same season a fresh water *Rickettsia* (Unidentified Agent-2, UA2) was confirmed to have caused mortalities of Atlantic salmon in lakes (Cvitanich et al., 1995). Subsequently, in June 2006 the gram-negative bacteria *Francisella* was confirmed as the agent responsible for UA2, which caused severe mortalities in Atlantic salmon farms located in Lake Llanquihue (Birkbeck et al., 2007). *Francisella philomiragia* presented high rates of morbidity and outbreaks with cumulative mortality ranging from 5% to 20% (Bohle et al., 2009). This bacterium presented 100% homology with *F. philomirhagia* subsp. *noatunensis*, currently denominated *F. noatunensis* comb. nov (Mikalsen & Colquhoun, 2010; Ottem et al., 2009).

Sea lice infestations in salmonids were first reported in Chile in 1982 (Reyes & Bravo, 1983) caused by the ectoparasite *Caligus* sp. Historically in Chile the most problematic parasite infection in salmonids reared in SW has been caused by *C. rogercresseyi*. The monitoring program of Intesal reported an average value of 3.38 adult *Caligus* per fish between 1999 and 2002. However, an increasing load between 2004 and 2007 was observed with an average of 3, 5 and 10 *Caligus* per Coho salmon, rainbow trout and Atlantic salmon, respectively. Moreover, the abundance levels increased up to 29, 20 and 34 *Caligus* per fish in the same mentioned species in 2007 (Rozas & Asencio, 2007). In order to get relevant information and establish strategic control measures, the national fisheries service –Sernapesca- established the Official Monitoring Program focused in marine and estuarine areas (Sernapesca, 2009). After this program was established and executed, the average load has significantly dropped (Sernapesca, 2010). However, the lower number of fish in sea sites may also explain this decrease in parasite loads after the infectious salmon anaemia event in 2007.

Between 1993 and 1994, new pathogens were detected, such as the protozoan *Nucleospora salmonis* (Bravo, 1995), which clinically affected certain strains of Atlantic salmon in SW; the metazoan *Kudoa* sp. has been sporadically diagnosed in Atlantic salmon, and the protozoan *Hexamita*, has been described in trout and Atlantic salmon fries in FW (Bluth et al., 2003). In 1995, the presence of an atypical form of *Aeromonas salmonicida* causing mortalities in Atlantic salmon in SW was confirmed, but was restricted to only a few areas in Los Lagos region (Bravo, 1999, 2000). However, in recent years, this bacterium has been diagnosed in other locations of the country and spread widely over many host species, and reported from FW sites (Godoy et al., 2010). The infection is restricted to Atlantic salmon reared in FW. It has been more frequently registered in lakes, usually after stress events. Infections are common in broodstock kept in FW from areas where the infection is endemic. There have been cases in which infection with atypical *A. salmonicida* is considered secondary in relation to other infections by bacterial agents such as *Flavobacterium sp*. or *Francisella sp.* and viral such as Infectious Pancreatic Necrosis virus, IPNv (Godoy, 2009b).

Among the emerging diseases of bacterial etiology with economic impacts in salmonid farming, *Vibrio ordalli* (Colquhoun et al., 2004) and *V. anguillarum* (Avendaño-Herrera et al., 2007) are the most important. In Chile, vibriosis occurs mainly in estuarine and sea sites, resulting in cumulative mortality up to 20%. Since 2003, vibriosis outbreaks due to *V. ordalli* have been occurring in Chile affecting initially Atlantic salmon (Colquhoun, 2004) and subsequently rainbow trout and Coho salmon.

The first cases of Amoebic Gill Disease (AGD) were reported in Atlantic salmon in 2007 (Bustos et al., 2011; Rozas, 2011). The pathogen agent in Chile is *Neoparamoeba sp*. with 99.61% of relatedness with *N. perurans* (Bustos et al., 2011; Rozas, 2011). Clinically affected fish show white patches over the gill arches, excess of mucus and bad general condition. High salinity due to low rainfall is associated to higher prevalence of the disease. Farm sites reported with AGD infection showed two times higher risk of ISA outbreaks (Rozas, 2011). Before 1997, Chilean salmon aquaculture was hit primarily by bacterial diseases. However, by mid-1998 the presence of a new disease in Atlantic salmon stock was confirmed, known as viral Infectious Pancreatic Necrosis (IPNv). In Chile, IPNv was first isolated from rainbow trout with no clinical signs (McAllister & Reyes, 1984). This event was the first report in South America, suggesting that IPNv was introduced through imported eggs from North America (McAllister & Reyes, 1984). The virus is widely distributed in the different areas where salmon farming takes place. IPNv affects Atlantic salmon, and cases in Coho salmon are considered sporadic; however, in recent years the frequency and virulence of the pathogen have increased, as well as broadened the geographical distribution. Cases have also been reported in FW recirculation systems as well as in open-flow and estuary. The disease shows high prevalence increasing from 19% in 2006 to 31.96% of total diagnoses in the year 2007 (Sernapesca, 2008a). In 2008, the monthly mortality average associated with IPNv in Coho Salmon was below 0.01%, in Atlantic salmon 0.01% and in rainbow trout 0.03% (Intesal, 2009). In 1999, ISA virus (ISAv) was first detected in SW farmed Coho salmon in Chile (Kibenge et al., 2001). In contrast to the classical presentation of ISAv in Atlantic salmon, the presence of ISAv in Chile was associated with a clinical condition characterized by jaundice in Coho salmon (Smith et al., 2002, 2006) and the virus isolation was sporadically and unsuccessful. During the winter of 2007, unexplained mortalities occurred in market-size Atlantic salmon in a grow-out site located in Chiloé (Sernapesca, 2008b). The outbreak was caused by a virulent variant of ISAv different from common European ISAv isolates. The clinical signs and lesions were consistent with the classical descriptions of the disease in marine farmed Atlantic salmon in Europe and North America (Godoy et al., 2008). The re-emergence of ISAv in Chile has resulted in one of the largest ISAv epidemics reported in the world (Mardones et al., 2009).

Upon analyzing the susceptibility of Chilean farmed salmon to the mentioned diseases, there are important differences in pathogen prevalence as well as associated losses between the three cultivated species. In terms of mortality rates, the Coho salmon is mainly affected by piscirickettsiosis during SW phase, and secondly by BKD, especially in the southern areas. The Atlantic salmon is affected mainly by IPN in FW and when first transferred to SW. After being established in SW the most relevant pathogen is ISAv, since it causes significant mortalities among infected groups (Subpesca, 2010) and secondly by piscirickettsiosis. In some cases, related to specific environmental conditions in certain geographic areas, there are important losses of Atlantic salmon due to *Caligus* sp. and atypical *A. salmonicida* and other bacterial diseases. The impact of diseases may significantly differ among farming companies, cultured species, farm sites and geographic locations.

3.2 Commercial vaccines in Chile

Nowadays 44 commercial vaccine formulations have been authorized for the use in salmonids in Chile (Servicio Agrícola y Ganadero, SAG, 2011). In Chile, the use of vaccines began in the early 1980´s, with vaccines against vibriosis (Bravo & Midtlyng, 2007). Then, after the occurrence of ERM in 1992, vaccines to protect Atlantic salmon came into use (Bravo, 1993). In 2010 a total of 6,4 million doses were used more than 6 times compared to the doses used in 2009 (Sernapesca, 2011c, 2011d). Vaccines against IPNv in Chile were rapidly available, because they were already in use in salmon farming countries. Since 2002, bivalent vaccines came into the market and were used to provide protection against IPNv and atypical furunculosis or IPNv and SRS. Currently, bivalent, trivalent, quadruple and quintuple formulations are available from international and local laboratories (SAG, 2011).

More than 10 years have passed since the first vaccine against *P. salmonis* was launched in the Chilean market. The vaccines against this bacterium apparently have no effect on reducing mortalities (Bravo et al., 2005). As of today, 26 vaccines against *P. salmonis*, both monovalent and polyvalent, have been registered in Chile (SAG, 2011), and amount of doses have increased since 2005 (Table 4). Spite the use of vaccines, piscirickettsiosis still remains a major sanitary threat for salmon farming in Chile. After the crisis caused by ISA virus, the use of vaccines to prevent the disease was necessary (Table 4). Thus, in April 2009, a Chilean pharmaceutical laboratory obtained a provisional registration to commercialize the first vaccine against ISAv, which has been sold since June of that year. There are currently 12 commercial vaccines registered to be used against ISAv in the domestic market (SAG, 2011).

Year	2005	2006	2007	2008	2009	2010
Disease						
IPN	38,390,234	48,639,681	16,931,232	93,356,750	145,140,655	379,817,821
IPN,SRS	248,769	-	-	18,889,551	35,086,897	61,977,044
IPN,SRS, Vibriosis	251,539	-	10,524,627	36,141,507	53,851,414	74,438,348
IPN, SRS, Vibriosis, Atypical furunculosis	-	-	16,704,008	46,689,055	19,684,380	13,106,428
IPN-Atypical furunculosis	7,840,849	4,590,883	-	-	-	-
IPN, Vibriosis	64,732,058	64,423,621	25,791,390	20,395,269	1,282,166	40,880,625
IPN, Vibriosis, Atypical furunculosis	31,762,691	23,010,340	12,412,470	3,859,378	4,228,818	885,332
ISA	-	-	-	-	11,430,448	38,599,867
IPN, Vibriosis, Atypical furunculosis, SRS, ISA	-	-	-	-	-	8,036,670
IPN, Vibriosis, SRS, ISA	-	-	-	-	-	15,634,191
SRS	27,842,546	29,926,809	16,340,430	35,439,138	41,904,431	69,057,300
SRS, BKD	nd	nd	nd	nd	nd	10,681,601
BKD	nd	nd	nd	nd	nd	770,444
Yersiniosis/ Columnaris disease	54,400,781	18,883,786	7,037,977	30,255,690	1,333,973	6,400,000*
Other	505,136	-	4,814,978	2,727,235	14,545,613	1,008,187

nd: no data available; *only doses against Yersinia

Table 4. Number of vaccine doses used in Chile during 2005-2010.

3.3 Antibiotics and chemotherapeutants in Chilean aquaculture

Within the national policy regarding the use of antibiotics, procedures for control and prevention of diseases are established. Nevertheless, these measures are general and there is a legislative gap in this area. Currently, with the amendments of the regulatory framework a number of changes in this area will be established. A program of surveillance of good practices in the use of antibiotics is being generated, aiming to improve antibiotic use in the country and to detect patterns in the use of these compounds (San Martin, 2010). In relation to the use of antibiotics in Chile, a decline in the use of quinolones and fluoroquinolones (oxolinic acid and flumequine, respectively), and an increase in the use of florfenicol has been observed in recent years, Table 5 (San Martin et al., 2010).

During the years 2005-2009, the use of other antibiotics have been relatively stable, with significant use of oxytetracycline, and a marginal share of sulfa/trimethoprim, and amoxicillin (San Martin et al., 2010). The use of florfenicol, represented over 61% of the total of antibiotics used in 2009. According to Sernapesca, piscirickettsiosis accounted for the highest diagnostic number, using over 65% of the therapeutic stock. In Chile, there are 6 antibiotics approved for use in aquaculture, this narrows the options when treatment is the choice. It is known that the rotation of antibiotics is a low frequency practice in the Chilean salmon industry, which over

Year	2005	2006	2007	2008	2009	2010
Active principle						
Oxolinic acid (kg)	50,713	39,035	74,582	25,325	2,900	1,192
Amoxicillin (kg)	97	253	1,732	349	473	863
Erythromycin (kg)	1,994	1,972	2,139	7,981	1,542	2,586
Florfenicol (kg)	33,258	102,838	143,009	184,715	113,137	74,431
Flumequine (kg)	96,751	95,575	74,773	32,293	3,233	1,588
Oxitetracycline (kg)	56,354	104,135	89,309	74,931	63,172	62,506
Sulfa+trimethoprin (kg)	0	1	91	22	11	-
Total (kg)	239,167	343,808	385,635	325,617	184,469	143,165

Table 5. Amount of antibiotics used by the Chilean salmon industry, by active principle and year.

the course of the years has led to the emergence of resistant organisms (San Martin et al., 2010). Due to the low number of antibiotics approved, it is suggested to register new drugs in the country, or to allow the extra-label use of antibiotics, because the latter would allow veterinarians to use other drugs that are not registered for salmon but within the legal framework. However, this process is not authorized (San Martin et al., 2010).

Several chemotherapeutants have been used to control caligidosis in Chile, e.g. metriphonate (Neguvon™) was the first product used to control *Caligus teres* between 1981 and 1985, replaced by another organophosphate, diclorvos (Nuvan™) between 1985 and 2000, both used as bath treatment. Ivermectin use in feeds was introduced in Chile at the end of the 1980s, but between 2000 and 2007 the only veterinary product authorized for this use in Chile was the avermectin (emamectin benzoate EMB), without alternative treatments available. When EMB (Slice™) was introduced into the Chilean market in 1999, one standard treatment with the product (50 µg of active ingredient per kilogram biomass daily for 7 day) controlled the sea lice infestations on the salmon for at least five weeks in the summer and even longer in the winter (Bravo, 2003). Since early 2005, a notable loss of efficacy was observed in several fish farms, resistance development was the main cause (Bravo et al., 2008). Within the management of this parasitic disease, a strategy of coordinated treatments was established by the authority, which aimed to reduce the infestation levels over subzones or groups of concessions. Today, there are 10 commercial products for caligidosis treatment authorized by SAG. The current compounds for treatments are deltametrine 1%, diflubenzuron 80% and emamectin benzoate 0.2% (Table 6). The last antiparasitic drug authorized was cipermetrin 5% (Betamax) (SAG register No. 2085, 2010).

4. Sanitary crisis of the Chilean salmon industry

The ISAv crisis may not be exclusively related to the rapid spread of a highly virulent pathogen. Prior to the ISAv outbreak, the industry struggled with serious caligidosis and piscirickettsiosis outbreaks, especially in Los Lagos region (X). In addition, several factors affecting the quality of the smolt has not been fully tackled such as excessive handling, grading, varying FW quality, high density, and water quality and welfare in long distances on land and sea transport. Perhaps one of the most threatening practices in Chilean salmon farming that relate to spreading of diseases was the inadequate disinfection management of wastes from processing facilities. Additionally, boat travel between the farming facilities

Year	2005	2006	2007	2008	2009	2010
Active principle						
Emamectin benzoate (kg)	240	443	595	285	65	47
Diflubenzuron (kg)	0	0	0	162	3878	3639
Deltamethrin (1%)*	0	0	516	10524	3168	3431
Cypermethrin (5%)*	-	-	-	-	-	593

*values are given in litres

Table 6. Antiparasitic drugs used through feed or bath treatments.

may have contributed to the risk of disease transfer in Chile. In spring of 2007, barely four months after the detection of ISAv in two sites around Chiloé Island, the number of infected sites had tripled (Carvajal, 2009). Nevertheless, the industry was optimistic and considering that as an isolated event limited to one farming company, and there were little sense that this could be a catastrophic event. Although the industry argued that the media was blowing the situation out of proportion, a few months later ISA had reached all salmon producing regions in Chile, affecting almost every salmon farming company. At this point, the need of a consorted action between the authorities and the industry was evident. The disease began to spread in late December 2007. Outbreaks were reported in Aysén region and ISAv positive fish in different sea sites and broodstock were reported late in 2008. Between July 2007 and July 2008, 74 sea sites, presented positive results to virus detection, out of which 44 were classified as focal outbreaks. Among the positive farms, 89% were located in Los Lagos region and the remaining 11% in Aysén region. Furthermore, the impacts of this disease account for the elimination of >11,000 tons of fish distributed in 250 sites which belonged to 13 different companies. The ISA outbreak reached its peak in 2008 affecting 93 sites (Silva, 2010b). However, there was a progressive decrease in outbreak reporting since 2008, with 3 outbreaks in late 2009 and 4 outbreaks in 2010. This decline is explained by the decrease in active sites, where the industry capacity of 550 authorized sites was operating in only its 20%. It can also be noted that the area with most outbreaks was Central and Southern Chiloé where barely 180 sites were operating during 2009 (Silva, 2010b). As a consequence of ISA, Chile stopped earning more than USD 883 million in 2008 (Silva, 2010b). In 2009, the industry export volumes fell by 16% and earnings experienced a decrease of 12% compared with the previous year (Silva, 2010c). When ISA outbreaks started, the smolts transferred in to sea sites decreased in about 600 thousand a month. In 2006 about 12 million smolts were transferred per month. The smolt release in 2009 was reported to be less than the tenth of what was in 2007 (Asche et al., 2010), and a fall of 83% in January 2009 when compared with the same period in 2008. In mid-2009 the situation began to improve, and in mid-2011, every 30 days, four million smolts were transferred and the figure is increasing. This is due to changes in the production model, which has reduced mortality. During January 2010, the number of fish in farms was 61% of what was in 2008. During 2010, the exports reached 352,637 tons a 23% less than the previous year, showing a variation in earnings of only -2% (TechnoPress, 2010). As of July 2011, about 20 sites have been reported as ISAv HPR0 positive, a low-pathogenic variant, only one site has been confirmed to remain in outbreak due to a pathogenic strain (HPR2). This number of infected sites well correlates with increasing aquaculture activities after the crisis.

5. Aquaculture governance

During the 1980s, the incipient salmon aquaculture was ruled by a supreme decree for the practice of fishing, which was clearly inadequate for the forthcoming rapid growth of the sector. However; since 1991, the regulation towards any aquaculture activity in Chile has been regulated by the General Law of Fisheries and Aquaculture (Ley General de Pesca y Acuicultura, LGPA, Law No.18.892). This law also regulates fisheries and conservation of living resources, industrial and small-scale capture, scientific and recreational fisheries. In addition, some articles regard commercialization, processing, storage and transportation of fishery products. The main administrative authority responsible for aquaculture and fisheries is the Ministry of Economy, Development and Reconstruction. Within this ministry, the Subpesca provides all the information and technical support required to allow the Minister to take actions and measures towards aquaculture and fishery activities. In addition, functional matters, including enforcement, are carried out by Sernapesca. Moreover, the Undersecretary of Marine Affairs, the Environmental Commission (CONAMA), the Directorate of Boundaries and State Limits, CORFO, the Land Registry and the Directorate General for Water intervene in some of the procedures for the granting of concessions and other authorizations within aquaculture.

5.1 Aquaculture regulatory framework (1991-2010)

The enactment of the LGPA aimed to organize the responsibilities of authorities and delegates to dictate the regulations pertaining to the sustainable operation of aquaculture. The law provided Subpesca an improved organization in order to expedite its surveillance and faculties. During the 1990s, there were several Supreme Decrees (S.D.) implemented that were relevant for aquaculture such as the S.D. No.475 and S.D. No.499, clarifying national policy for the use of Chile’s littoral coastline and national register of aquaculture in 1994, and the regulation on information of fishery and aquaculture activities by S.D. No.464 in 1995. In addition, in 1993, the S.D. No.550 and No.290 stated regulations towards site´s size, authorization, concessions and inscription in aquaculture activities such as portion of water used according to the area, kind of system and type of organism. Furthermore, the general basis for environmental regulation (Law No.19,300) established the national environmental commission, CONAMA, and introduced the obligatory environmental impact evaluation for any productive activity, including aquaculture. CONAMA and later the regional (COREMA) are responsible for the environmental management and supervision. Regular environmental controls and level for contaminants and emissions, but also quality of water, air and soil are established, as well preventive management, environmental programs and decontamination. This law also establishes punishment for environmental damage. Implementation of the system for evaluation of environmental impact SEIA, S.D. No.30 in 1997 and S.D. No.95. in 2001, that obliges to provide a study of environmental impact or environmental impact assessment to any investment project, which could cause impacts according to the Law. Therefore, the LGPA has been actively amended since intensive and extensive aquaculture begun in Chile.

5.2 Environmental and sanitary regulations

The environmental regulation for aquaculture RAMA, S.D. No.320 in 2001, states the environmental requirements for approval of aquaculture activities. It demands that net changing, washing and antifouling treatment must be conducted in inland sites, using water treatments. It also introduced the preliminary site characterization (CPS) for any inland or marine sites, demanding an environmental impact assessment, which improves the evaluation process. Furthermore, it establishes annually environmental monitoring as part of the environmental information program (INFA). Operating sites should annually present an INFA-report with the impact on the oxygen conditions at the bottom below the cages. This is of especial relevance for remaining sites located in lakes. When anaerobic condition is stated, the production can be on hold for one year, if the anaerobic condition is kept, the site should reduce 30% of the production and consecutively for the following years when the condition is not improved. Both CPS and aerobic conditions will be surveilled by competent persons or companies approved by the authority. In 2003, a score system for the sites based in type, production size, bathymetry and bottom conditions was introduced. In addition, the methodology for analysis of CPS and INFA according to the score was established in 2006. Various measurements were introduced towards management for solid and liquid residues, for harvesting, mortality and processing plants in 2008.

The sanitary regulation for aquaculture RESA, S.D. No.319 in 2001, stated that a sanitary condition depends on the prevention and control of events. This regulation was enacted to prevent and control high risk diseases in aquatic species securing sanitary controls, surveillance and eradication of infectious diseases in farmed fish within the country. Sernapesca was provided with larger resources to cover the increased inspection needs. It established a classification of the high risk illness, basic conditions for production sites, experimental sites, processing plants, transport, waiting sites, harvesting, egg´s import, domestic egg´s production, certifications, also conditions and task of the reference and diagnostic laboratories. It also established that only registered pharmaceutical products for aquatic species might be used. This regulation was recently updated (September 2011) including major pillars regarding pathogens such as bioexclusion, biocontainment measures and sanitary management as well as reinforcement of preventive measures in FW systems.

5.3 Specific sanitary programs and regulations

Since 2003, the general sanitary programs have been implemented through 12 resolutions (Rs. 60 to Rs. 72) by Sernapesca to regulate sanitary issues in aquaculture. The Rs. 60 regulates the registration, proceedings and conditions for vaccination of farmed fish. The Rs. 61 to 63 established proceedings towards information, data processing, reporting, surveillance and actions to be taken when detection and outbreak of high risk diseases (HRD list 1 and 2, Table 7), but also for unknown aetiology and non-described diseases in a specific zone. Farm sites and diagnostic laboratories may be evaluated towards diseases of HRD list 2 and confirm absence of HRD list 1, at least twice a year.

These resolutions tackle transport of fish, eggs, high risk biological material, feed, equipment, and materials in any farming activity according with the zoning, also proceedings for disinfection and traceability applying for domestic and imported eggs, conditions, procedures and management for mortality such as frequency and methods for mortality check, necropsy, and disinfections. In order to prevent outbreaks, every farm should have procedures for treatments and handouts for a correct medication, which is also ruled by the Rs. 67. The Rs. 68 establishes the management and proceeding for all kind of waste in farming, slaughter and processing plants (liquid, solid, organic and inorganic), introducing proceedings for personal, disinfection and

List 1	List 2
Epizootic Haematopoietic Necrosis (EHN)	Infectious Pancreatic Necrosis (IPN)
Infectious Haematopoietic Necrosis (IHN)	Piscirickettsiosis
Oncorhynchus masou virus disease (OMVD)	Streptococcosis
Viral hemorrhagic septicaemia (VHS)	Infectious Salmon Anaemia (ISA)
Spring viraemia of carp (SVC)	Jaundice/Icteric syndrome
Viral encephalopathy and retinopathy (VER)	Atypical furunculosis
Enteric septicaemia of channel catfish (ESC)	Vibriosis
White sturgeon iridoviral disease(WSIVD)	Caligidosis
Furunculosis	Amoebic gill disease (AGD)
Epizootic ulcerative syndrome (EUS)	Renibacteriosis (BKD)
Gyrodactylosis	
Pancreas Disease (PD)	
Red sea bream iridoviral disease (RSIVD)	

Table 7. Classification of High Risk Diseases (Rs. 2352, 2008, Subpesca).

treatments. The Rs. 70 introduces procedures for the sanitary control of broodstock and general sanitary conditions for domestic broodstock, spawning, egg and reproduction, including physical barriers for facilities, in/out water treatment. In broodstock, an individual sanitary control for HRD list 2 including PD and BKD should be performed. The Rs. 71 or sanitary management for feed establishes the use of medicated feed (personal, storage, traceability, corrective actions, monitoring proceedings, etc.). The Rs. 72 provides cleaning and disinfection procedures in fish production, hence establishes conditions for proceeding towards cleaning and disinfection in fish farming facilities applying for facilities, tools, equipment, personal, working clothes, and water. It also applies for vessels, trucks, wellboats, etc. Furthermore, specific programs regarding surveillance and control of diseases in farmed fish have been launched by Sernapesca since 2004. The specific program for control and surveillance of caligidosis established proceedings and obligatory managements for sea and estuarine water production including treatments, reporting data, and others. The specific sanitary program for the control of *Caligus* was enacted in 2008. Further, in 2010 the Rs. No. 873 strengthens the control and certification for the origin of imported egg from countries where PD and ISA are present. The resolution demands individual screening for the broodstock, especially for keeping the country free of the HRD list 1 (Table 7). The Specific Surveillance and Control Program for ISAv went into effect in 2008. Currently, a new regulation came into force in 2011, although having the same focus as the former in 2008; it is stricter in immediate notification and relies in a risk-based surveillance.

6. Restructuration of the industry and new legislations

The latest amendment of the LGPA was performed in 2010 driven by the severe social and economic consequences of the sanitary and production crisis. Although the draft of amendment for the LGPA was developed during first quarter of 2009, it was not until March of 2010 that it was enacted. This amendment has been the largest and most significant for the Chilean aquaculture. Some of the essential issues in this law are attribution to establish appropriate areas for aquaculture activities (AAA), which is a place with common epidemiologic, oceanographic, operational or geographic characteristics. It also has complementary environmental and sanitary regulations and procedures for licence and concession´s sites. It contains reliable information regarding alternative uses of the site such as natural reserve or protected, touristic, indigenous population, harbour conflicts, hydro biological resource and especially natural banks. Since 1991, a concession site was granted for indefinable time where nowadays it is established for 25 years and renewable. In addition, it considers development of farming density regulation, strengthens regulations towards waiting and slaughter centres, zoning of the coastline border and strengthens the regulation regarding egg imports. Furthermore, the cost of an aquaculture concession has been increased from around 26 USD /ha, in 1991, to 80 USD /ha, in 2010. One of the most important changes set by the new amendments is the ban on fish movements from and between sea sites that affects the movement of broodstock from sea sites to FW facilities as well as the temporary use of estuarine sites. Several companies have begun to secure their broodstocks in FW facilities and to perform whole cycle in FW. Interestingly, these amendments also include the concept of animal welfare where aquaculture production should carry out procedures that avoid unnecessary suffer of animals; however, the criteria for welfare have not been established. In general, it should be considered by transport, design, farm density, treatment, light exposition, among others.

6.1 Aquaculture neighbourhoods

The LGPA states that concessions should be relocated within an AAA; hence, the distribution of several sites should be modified and relocated. Thus, within the farms in an AAA, coordinated actions should be carried out as fish inputs, prophylaxis and therapeutic treatments, sanitary issues, harvest, and resting periods. Each concession will hold one vote to agreements within the "neighbourhood" which should be approved, public published and carried out according the regulations by Subpesca. Therefore, there have been major challenges in the relocation of salmonid farms in neighbourhoods in the extensively used areas within Los Lagos and Aysén region.

The zoning of Los Lagos and Aysén regions was established by the Rs. No.450 in 2009. It states several suitable zones for aquaculture activities following the oceanographic, epidemiologic and operative, logistic characteristic towards ISAv infection and control. In 2010, it was established a total of 24 aquaculture producing neighbourhoods in Los Lagos region and 56 in Aysén region (Figure 8). While in Magallanes region there is still no established geographic zoning of the coastal border, and neither neighbourhoods nor new concession can be granted. But, it should be defined by 2011. A discussion and process that are currently carried out by local fishery associations, tourism entities, mining companies, aquaculture producers, NGOs and regional government with the support of the congress commission for fisheries. The distance between neighbourhoods have been established in minimum of 3 nautical miles (ca. 5.6 km) and aquaculture sites must be spaced out at least in 1.5 nautical miles (ca. 2.8 km) from marine protected areas (natural park and reserve) and from another site. When a land protected area has a sea border, the coastal zoning should establish a secure distance to the closest aquaculture site.

6.2 Agreements and certifications

Unlike the mandatory government policies used in other countries, Chile has promoted voluntary implementation of traceability and quality assurance systems. This has allowed

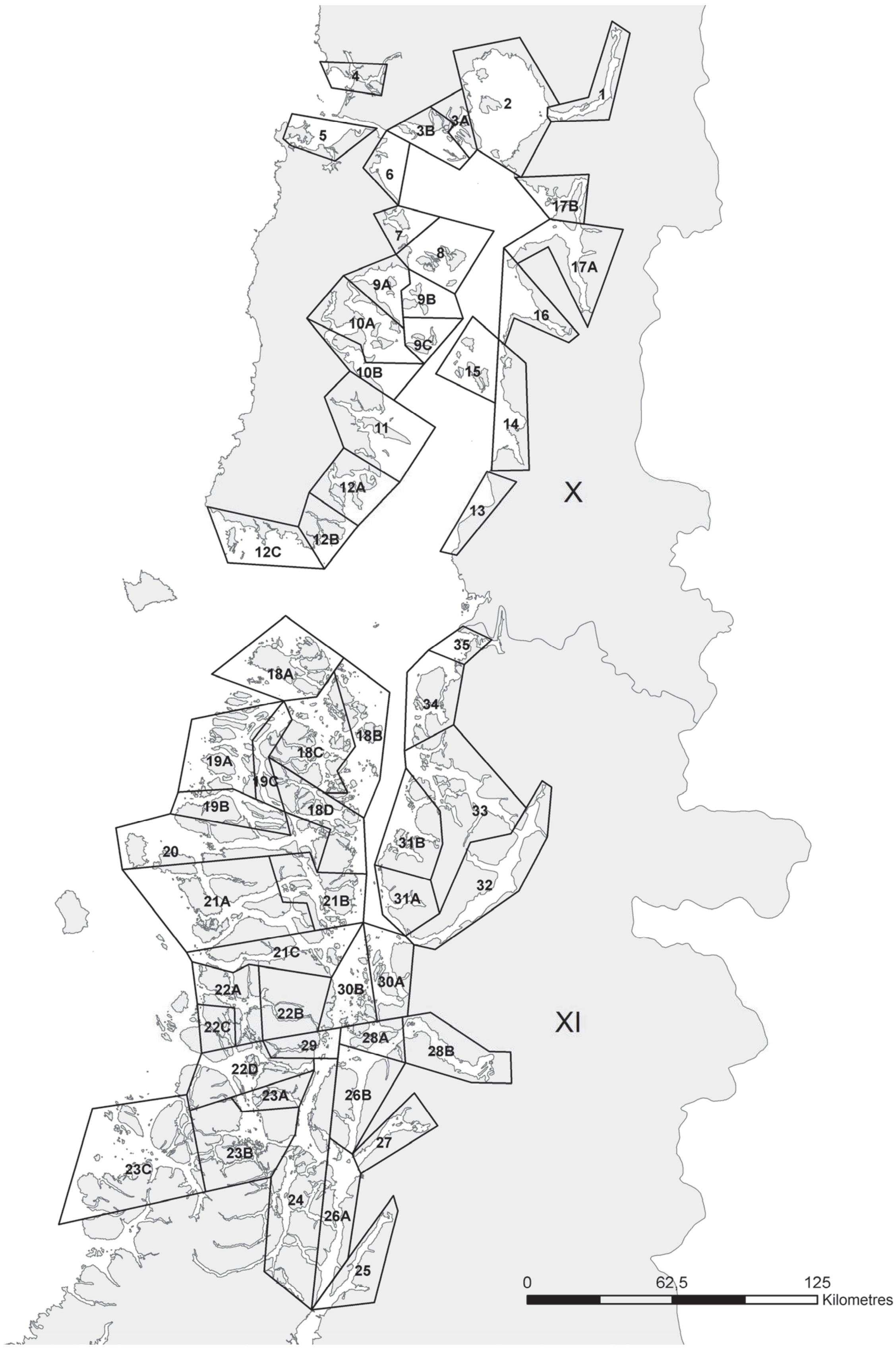

Fig. 8. Salmonid aquaculture neighbourhoods in Los Lagos region (X) and Aysén region (XI). (map source: GeoAustralis).

the private sector time to plan for and adapt to export requirements and develop systems without imposed financial pressure or deadlines. Intesal released sanitary measurements for the associates in December 2009, which was further improved and re-edited in August of 2010. The effects of these actions may be confirmed subsequently in the next 5 years. It proposes 44 measurements, whereas 20 are complementary to the new resolutions and amendments of the LGPA, 6 are partially a part of the regulation and 18 are part of regulation (Intesal, 2010). To a large degree, Chile has allowed large export markets to define traceability requirements for Chilean products. In response to emerging international requirements for traceability, SalmonChile facilitated the development of an Integrated Management System (SIGES) in 2003. In order to obtain the SIGES certification, companies must commit to adhere to otherwise voluntary protocols (e.g., information system software, ISO, OSHA, HACCP, best practice guidelines, etc.). The SIGES is a voluntary agreement for the associated companies that implement standards of quality, welfare, clean production, environment, and working health and security, recognized by domestic and international regulations. It facilitates the implementation of ISO 9,001, ISO 14,001 and OHSAS 18,001. Although in 2006, the worldwide biggest food-market chain, Wal Mart (USA), recognized SIGES-SalmonChile and Safe quality Food (SQF-SIGES) it is still not recognized by shareholders worldwide.

In October 2010, SalmonChile signed an agreement with GLOBALG.A.P. to launch standards for salmon production also called SALMONG.A.P., which is the first internationally recognized standard for the cultured salmon in Chile. SALMONG.A.P. aims improvement of salmon production and processing towards best practices, which considers multi-criteria task such as feed, health, safety, quality, environmental issues, working conditions, welfare and biosecurity.

In 2000, a special programme for public-private association was created by CORFO in the field of cleaner production, operated by the National Clean Development Council. Clean production agreements (APL) have strategies for production and environmental management, which are voluntarily joined by industry and government partners; however, once an APL is signed the different tasks and steps should be reached and in case of non-fulfilment, the authority may punish partners according to the regulation. In 2010, producers and Intesal improved their production practices by the first APL within Los Lagos region, ratified by all the members of SalmonChile, 48 companies at that time, representing one of the most important public-private agreements towards sustainable aquaculture. This agreement covers 46 action points that have been carried out. The second APL within the industry was ratified by FW producers of La Araucanía region where 28 FW producers signed an APL in 2010.

6.3 The role of the NGOs

Similarly to other salmon producing countries several non-governmental organizations (NGOs) have watched all the impacts of the industrial aquaculture and published several reports and launched campaigns regarding aquaculture´s negative effects on the local and global environment as well in the communities and social issues. In Chile, especially since 2000s several NGOs have being active such as Terram, Olach, Oxam, Oceana and WWF. Nevertheless, WWF has published a number of reports regarding impacts of the Chilean aquaculture. These promote dialogue between NGOs, community, producers and public entities suggesting solutions as aquaculture standards. Lately, WWF Chile has published 5 reports regarding the effect and assessment of the FW production, environmental issues, salmonid escapes, and carrying capacity of fjords (Díaz & León-Muñoz et al., 2006; León-Muñoz et al., 2007; Nieto et al., 2010; Sepúlveda et al., 2009; Tapia & Giglio, 2010).

7. Perspectives

The experience from all fish producing countries including Chile has demonstrated that the fish health situation plays a major role when expecting good biological and economical performance in aquaculture farming. On a larger level, this aspect is determinant to success or failure of an industry focused on the artificial farming of fish (Smith et al., 2001). Because of the rapid aquaculture expansion, diseases have emerged with disastrous economic consequences. Estimated disease losses in aquaculture worldwide are in the order of USD 8 billion per year, which represents 15% of the value generated by the global aquaculture production (Enright, 2003). The economic losses attributed to diseases are mostly attributed by mortality caused directly by diseases; although weight losses, quality losses and costs incurred because of control and prevention are also important cost drivers (Bravo et al. 2005). Severe sanitary events occurred in salmon producing countries in the early 1990´s; in Norway, and in the middle and late 1990´s in Scotland, Faroe Island, Canada, USA and Chile in the 2000´s (Gustafson et al., 2005; Lynstad et al., 2008). It has been clearly demonstrated that in Chile the regulatory system was ineffective by reducing environmental and sanitary threats prior to the ISA crisis in 2007, despite RAMA and RESA. Furthermore, the voluntary agreements (APL) were either inadequate or insufficient or delayed. Thus, it is evident that the industry itself fails to implement adequate and timely measurements in response to threats. Although Chile has been the largest producer of rainbow trout and Coho salmon, and the second producer of Atlantic salmon worldwide since 1990s, it was not until 2010 that authorities and the industry developed together the designing, regulation and ruling of organized aquaculture neighbourhood with several measurements regarding mainly biosecurity and production. Although up to date about 21 sites have been reported with the low pathogenic ISAv-HPR0 strain, only 2 site has been reported as ISAv-HPR7b recording clinical disease and mortalities. In addition, in the beginning of 2011, reports from the industry indicate that the salmon production in Chile will be back to 2007 level in 2013. The fast comeback has been possible due to willingness from the banks to reorganize the debts of the companies, extremely high salmon prices and risk willing investors. In Chile, research and development is needed to secure a sustainable development of the industry. The sanitary crisis, caused by an industry that were allowed to grow too fast considering the unsolved disease problems, e.g. SRS, *Caligus*, IPNv and finally the epidemic ISAv, has shown that Chile has the obligation as a country to stimulate the industry to invest more resources into R&D. Clearly, Chilean challenges require local solutions and there cannot be good regulation or good production models without a sound scientific and technical rationale. Historically in Chile, the public investment in research and development in aquaculture yearly, which involves private partners, has been at average below USD 10 per ton of farmed fish (Medina, 2008 pers. Comm.). Most of these resources have been used to implement knowledge developed in other countries, but also to build up a research infrastructure for aquaculture at Universities. More recently, also international research institutes as Nofima, Sintef, VESO and NIVA have established in Chile. Further, several farming and feeding companies are building up their own R&D departments in Chile with the aim to develop a more sustainable industry. Altogether, we have an optimistic view on the future of Chilean salmon farming.

8. Conclusions

In the 2000s the growing projections in Chilean aquaculture were very optimistic, but Chilean salmon production has not increased according to these expectations in the last four years. The major set-back is caused by severe sanitary events appearing at the same time. Specifically, permanent losses due to piscirickettsiosis (SRS) as well as the spread of treatment-resistant *Caligus* and lately the occurrence of epidemic ISAv have presented sanitary challenges of a magnitude that surprised the industry and rendered earlier growth projections obsolete. The sanitary crisis that led to economical, environmental and social problems, forced the authorities to improve and strengthen aquaculture regulations, providing more governmental control. In addition, the industries' own organisation, SalmonChile, through Intesal has established several measures towards sanitary, production, and logistics management that complements the new governmental regulations, where an essential issue is the fact that neighbourhood will operate in an organized manner. Although the industry are facing increased production cost, these new regulations and measurements are massively accepted as the unique way to reborn the Chilean salmonid aquaculture.

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10. References

Águila, M.P. & Silva, G (2008). Salmonicultura en Lagos: En la Senda de la Sustentabilidad, A*qua Acuicultura* + *Pesca,* Vol.20, No.120, pp 8-14

Asche, F.; Hansen, H.; Tveterås, R. & Tveterås, S. (2010). The Salmon Disease Crisis in Chile. *Marine Resource Economics*, Vol.24, No.4, pp. 405-411, ISSN 0738-1360

Avendaño-Herrera, R.; Silva-Rubio, A. & Toranzo, A. E. (2007). First Report of Vibrio *anguillarum* in chilean Salmon Farms. *American Fisheries Society/Fish Health Section Newsletter*, Vol.35, No.2, pp. 8-9

Banco Central de Chile (2010). Estadísticas Económicas. In: *Series de Indicadores*, 27.05.2011, Available from http://www.bcentral.cl/estadisticas-economicas/series-indicadores/index.htm.

Barton, J. R. & Murray W. E. (2009). Grounding Geographies of Economic Globalisation: Globalised Spaces in Chile's Non-Traditional Export Sector, 1980–2005. *Tijdschrift voor economische en sociale geografie*, Vol.100, No.1, pp. 81-100, ISSN 1467-9663

Barton, J. R. (1997). Environment, sustainability and regulation in commercial aquaculture: The case of Chilean salmonid production. *Geoforum* Vol.28, No.3-4, pp. 313-328, ISSN 0016-7185

Birkbeck, T. H.; Bordevik, M.; Froystad, M. K. & Baklien, A. (2007). Identification of *Francisella* sp from Atlantic salmon, *Salmo salar* L., in Chile. *Journal of Fish Diseases*, Vol.30. No.8, pp. 505-507, ISSN 1365-2761

Bjørndal, T. (2002). The competitiveness of the Chilean salmon aquaculture industry. *Aquaculture Economics & Management,* Vol.6, No.1, pp 97-116, ISSN 1365-7305

Bluth, A.; Espinosa, L.; Guzmán, C.; Hidalgo, C.; Martínez, S.; Mellado, M.; Sánchez, V. & Tang, M. (2003) *Aquaculture in Chile*, TechnoPress S. A., ISBN 956-8042-02-4, Santiago, Chile

Bohle, H.; Tapia, E.; Martínez, A.; Rozas, M.; Figueroa, A. & Bustos, P. (2009). *Francisella philomiragia*, bacteria asociada con altas mortalidades en salmones del Atlántico (*Salmo salar*) cultivados en balsas-jaulas en el lago Llanquihue. *Archivos de Medicina Veterinaria*, Vol.41, No.3, pp. 237-244, ISSN 0301-732X

Branson, E. J. & Nieto Diaz-Muñoz, D. (1991). Description of a new disease condition occurring in farmed coho salmon, *Oncorhynchus kisutch* (Walbaum), in South America. *Journal of Fish Diseases*, Vol.14, No.2, pp. 147-156, ISSN 1365-2761

Bravo, S. & Midtlyng, P. (2007). The use of fish vaccines in the Chilean salmon industry 1999-2003. *Aquaculture*, Vol.270, No.1-4, pp. 36–42, ISSN 0044-8486

Bravo, S. (1993) Diseases reported in pen reared salmonids from Chile. *American Fisheries Society/Fish Health Section Newsletter*, Vol.21, No.3, pp. 3

Bravo, S. (1995). Reporte de *Enterocytozoon salmonis* en Chile. *Chile Pesquero*, Vol.18, No.87, pp. 23-25, ISSN 0716-1956

Bravo, S. (1999). Atypical Furunculosis in Atlantic salmon. *American Fisheries Society/Fish Health Section Newsletter*, Vol.27, No.4, pp. 2

Bravo, S. (2000). Occurrence of atypical furunculosis in Chile. *Bulletin of the European Association of Fish Pathologists*, Vol.20, No.5, pp. 209–211, ISSN 0108-0288

Bravo, S. (2003). Sea lice in Chilean salmon farms. *Bulletin of the European Association of Fish Pathologists*, Vol.23, No.4, pp. 197-200, ISSN 0108-0288

Bravo, S., Campos, M. (1989a) Síndrome del Salmón Coho. *Chile Pesquero*, Vol.12, No.54, pp. 47-48, ISSN 0716-1956

Bravo, S., Campos, M. (1989b) Coho salmon syndrome in Chile. *American Fisheries Society/Fish Health Section Newsletter*, Vol.17, No.3, pp.3

Bravo, S.; Dolz, H.; Silva, M.; Lagos, T.; Millanao, C. & Urbina, A. (2005). Diagnóstico del uso de fármacos y otros productos químicos en la acuicultura. *Report Proyect Nº 2003-28.* Available from http://www.fip.cl/FIP/Archivos/pdf/informes/inffinal%202003-28.pdf

Bravo, S.; Sevatsal, S. & Horsberg, T. (2008). Sensitivity assessment of *Caligus rogecresseyi* to emamectin benzoate. *Aquaculture*, Vol.282, No.1-4, pp. 7-12, ISSN 0044-8486

Bustos, P.A.; Young, N.J.; Rozas, M.A.; Bohle, H.M.; Ildefonso, R.S.; Morrison R.N. & Nowak, B.F. (2011). Amoebic gill disease (AGD) in Atlantic salmon (*Salmo salar*) farmed in Chile. *Aquaculture*, Vol.310, No.3-4, pp. 281-288, ISSN 0044-8486.

Carvajal, P. (2009). ISA and the reshaping of Chile's salmon industry. *Industry Report*. IntraFish Media US. Norway. Available from http://www.intrafish.no/global/industryreports/article247570.ece

Claude, M.; Oporto, J.; Ibañez, C.; Brieva, L.; Espinosa, C. & Arqueros, M. (2000). La ineficiencia de la Salmonicultura en Chile: Aspectos sociales, económicos y ambientales. In: *Fundación Terram*, Available from http://www.terram.cl/nuevo/images/storiesrppublicos1.pdf

Colquhoun, D.J.; Aase, I.L.; Wallace, C.; Baklien, Å. & Gravningen, K. (2004). First description of *Vibrio ordalii* from Chile. *Bulletin of The European Association of Fish Pathologist*, Vol.24, No.4, pp. 185–200, ISSN 0108-0288

Cvitanich, J.; Garate O.; Silva, C.; Andrade, M.; Figueroa, C. & Smith, C. (1995). Isolation of a new Rickettsia-like Organism from Atlantic Salmon in Chile. *American Fisheries Society/Fish Health Section Newsletter*, Vol.23, No.1, pp. 3

Cvitanich, J.; Gárate, O. & Smith, C.E. (1991). The isolation of a rickettsia-like organism causing disease and mortality in Chilean salmonids and its confirmation by Koch`s postulate. *Journal of Fish Diseases*, Vol.14, No.2, pp. 121-145, ISSN 1365-2761

Díaz, S. & J. León-Muñoz (2006). Synopsis of salmon farming impacts and environmental management in Chile, In: *Consultancy Technical Report*, World Wildlife Fund (Ed.), 1-88, Valdivia, Chile.

Fryer, J.; Lannan, C.; Garcés, L.; Larenas, J. & Smith P. (1990) Isolation of a rickettsiales-like organism from diseased coho salmon (*Oncorhynchus*) in Chile. *Fish Pathology*, Vol.25, No.2, pp. 107–114, ISSN 0388-788X

Fryer, J.; Lannan, C.; Giovannoni, S.J. & Wood, N.D. (1992). *Piscirickettsia salmonis* gen. nov., sp. nov., the causative agent of a epizootic disease in salmonid fishes. *International Journal of Systematic Bacteriology*, Vol.42, No.1, pp 120-126, ISSN 1466-5034

Godoy, M. (2009a). Síndrome Rickettsial Salmonídeo (SRS) en Trucha Arcoiris (*Oncorhynchus mykiss*) I: Presentación Clínica Crónica, Abscedativa. In: *http://www.marcosgodoy.com*, 3.08.2010, Available from http://www.marcosgodoy.com/foro/?p=393.

Godoy, M. (2009b). Furunculosis atípica (*Aeromonas salmonicida atípica*) en Salmón del Atlántico (*Salmo salar*) cultivado en agua dulce I: Signos clínicos macroscópicos. In: *http://www.marcosgodoy.com*, 27.05.2011, Available from http://www.marcosgodoy.com/foro/?p=136

Godoy, M.; Aedo, M.; Kibenge M.; Groman D.; Yason, C.; Grothusen, H.; Lisperguer, A.; Calbucura, M.; Avendaño, F.; Imilán, M.; Jarpa ,M. & Kibenge, F. (2008). First detection, isolation and molecular characterization of infectious salmon anaemia virus associated with clinical disease in farmed Atlantic salmon (*Salmo salar*) in Chile. *BioMed Central Veterinary Research*, Vol.4, No.28, pp. 1-13, ISSN 1746-6148

Godoy, M.; Gherardelli, V.; Heisinger, A.; Fernandez, J.; Olmos, P.; Ovalle, L.; Ilardi, P.; Avendaño-Herrera, R; (2010). First description of atypical furunculosis in freshwater farmed Atlantic salmon, *Salmo salar* L., in Chile. *Journal of Fish Diseases*, Vol.33, No.5, pp. 441–449, ISSN 1365-2761

Iizuka, M. (2004). Organizational capability and export performance: the salmon industry in Chile, Proceeding of DRUID Winter Conference, pp 1-23, Aalborg, Denmark, January 22-24, 2004

InnovaChile (2008). Desarrollo y producción de vacuna oral y de fármaco inocuo contra *Pisicirickettsia salmonis* para aumentar la competitividad y sustentabilidad de la industria salmonera . In: *Concurso nacional de proyectos de innovación de interés público e innovación precompetitiva 2007*. CORFO. 27.05.2011. Available from http://www.corfo.cl/incjs/download.aspx?glb_cod_nodo=20080701143625&hdd_nom_archivo=Proyectos_aprobados.pdf

Intesal (2009). Programa Zonal Instituto Tecnológico del Salmon, Intesal 2008. pp. 24-28.

Intesal (2010). Medidas Sanitarias de la Industria del Salmón de Chile, In: *Intesal de SalmonChile*, medidas sanitarias, documentos, medidas sanitarias y anexos, 27.05.2010, Available from http://www.intesal.cl/

Kibenge, F. S.; Garate, O. N.; Johnson, G.; Arriagada, R.; Kibenge, M. J. & Wadowska, D. (2001). Isolation and identification of infectious salmon anemia virus (ISAV) from coho salmon in Chile. *Diseases of Aquatic Organisms*, Vol.45, No.1, pp. 9-18, ISSN 1616-1580

Larenas, J.; Contreras, J. & Smith, P. (2000) Piscirickettsiosis: Uno de los principales problemas en cultivos de salmones en Chile. *Tecno Vet*, Vol.6, No.2, ISSN 0718-1817

León-Muñoz, J., D. Tecklin, A. Farías and S. Díaz (2007). Salmon farming in the lakes of Southern Chile - Valdivian Ecoregion - History, tendencies and environmental impacts. In: *History, Tendencies and Environmental Impacts*, World Wildlife Fund (Ed.), 1-44, Valdivia, Chile.

Mardones, F.; Perez, A. & Carpenter, T. (2009). Epidemiologic investigation of the re-emergence of infectious salmon anemia virus in Chile. *Diseases of Aquatic Organisms,* Vol.84, No.2, pp. 105–114, ISSN 1616-1580

McAllister, P. & Reyes, X. (1984) Infectious pancreatic necrosis virus: isolation from rainbow trout *Salmo gairdnieri* Richardso, imported into Chile. *Journal of Fish Diseases*, Vol.7, No.4, pp. 319–322, ISSN 1365-2761

Mikalsen, J. & Colquhoun, D.J. (2010). *Francisella asiatica sp. nov.* isolated from farmed tilapia (*Oreochromis sp.*) and elevation of *Francisella philomiragia subsp. noatunensis* to species rank as *Francisella noatunensis comb. nov., sp. nov. International Journal of Systematic and Evolutiuonary Microbiology* doi:10.1099/ijs.0.002139-0. ISSN 1466-5026

Nieto, D., R. Norambuena, E. González, L. González and D. Brett (2010). Smolt production systems in Chile. In: *Analysis of alternatives from the environmental, sanitary and economic perspectives*, World Wildlife Fund (Ed.), 1-48, Valdivia, Chile.

Norambuena, R. & González, L. (2006). National Aquaculture Sector Overview: Chile, In: FAO Fisheries and Aquaculture Department, 27.05.2011, Available from http://www.fao.org/fishery/countrysector/naso_chile/en#tcN900AF

Oliva, D.; Sielfeld, W.; Durán, L. R.; Sepúlveda, M.; Pérez, M. J.; Rodríguez, L.; Stotz, W. & Araos, V. (2003). Interferencia de mamíferos marinos con actividades pesqueras y de acuicultura, *Report of Proyecto FIP 2003-32,* Available from http://www.fip.cl/FIP/Archivos/pdf/informes/inffinal%202003-32.pdf

Olivares, J. & Marshall, S. (2010). Determination of minimal concentration of *Piscirickettsia salmonis* in water columns to establish a fallowing period in salmon farms. *Journal of Fish Diseases,* Vol.110, No.2, pp. 468-476, ISSN 1365-2761

Olson, T. K. & Criddle, K. R. (2008). Industrial Evolution: A Case Study of Chilean Salmon Aquaculture. *Aquaculture Economics & Management,* Vol.12, No.2, pp 89-106, ISSN 1365-7305

Ottem, K.; Nylund, A.; Karksbakk, E.; Friis-Møller, Kamaishi, T. (2009). Elevation of *Francisella philomiragia subsp. noatunensis* Mikalsen et al. (2007) to *Francisella noatunensis comb. nov.* [syn. *Francisella piscicida* Ottem et al. (2008) syn. nov] and characterization of *Francisella noatunensis susbsp. orientalis subsp. nov.*, two important fish pathogens. *Journal of Applied Microbiology*, Vol.106, No.4, pp. 1231-1243. ISSN 1365-2672

Perlman, H. and F. Juárez-Rubio (2010). Industrial Agglomerations: The Case of the Salmon Industry in Chile. *Aquaculture Economics & Management,* Vol.14, No.2, pp 164-184, ISSN 1365-7305

Reyes, X. & Bravo, S. (1983). Nota sobre una copepoidosis en salmones de cultivo. *Investigaciones marinas Valparaiso*, No. 11, pp. 55-57. ISSN 0716-1069

Rozas, M. & Ascencio, G. (2007). Evaluación de la situación epidemiológica de Caligiasis en Chile: hacia una estrategia de control efectiva. In: *Salmociencia*, Vol.2, No.2, pp. 43-59, ISSN 0718-5537

Rozas, M. (2011). Descripción patológica y epidemiológica de Amoebic Gill Disease (AGD) en salmón del Atlántico, *Salmo salar*, en Chile. Tesis de Magister en Ciencias Veterinarias. Universidad Austral de Chile, Valdivia.

SAG (2011). Productos biológicos inmunológicos con registro provisional uso en salmónidos, Servicio Agrícola y Ganadero. In: *http://www.sag.gob.cl*, 27.05.2011, Available from http://www.sag.gob.cl/common/asp/pagAtachadorVisualizador.asp?argCryptedData=GP1TkTXdhRJAS2Wp3v88hIh98jlQCnaLAaTC9s9%2FJWY%3D&argModo=&argOrigen=BD&argFlagYaGrabados=&argArchivoId=37391

SalmonChile (2007a). Análisis estadístico y de Mercado, In: *www.salmonchile.cl*, 10.2010, Available from http://www.salmonchile.cl/frontend/seccion.asp?contid=117&secid=4&pag=1&subsecid=21

SalmonChile (2007b). La Contribución de la salmonicultura a la economía Chilena, In: *www.salmonchile.cl*, 10.2010, Available from http://www.salmonchile.cl/frontend/seccion.asp?contid=397&secid=33&secoldid=33&subsecid=117&pag=1

San Martín, B. (2010) Uno de los principales problemas es la escasez de arsenal terapéutico. In: *Revista Aqua*, 27.05.2011, Available from http://www.aqua.cl/entrevistas/entrevista.php?doc=294

San Martín, B.; Yatabe, T.; Gallardo, A. & Medina, P. (2010). Manual de Buenas Prácticas en el Uso de Antibióticos y Antiparasitarios en la Salmonicultura Chile Laboratorio de Farmacología Veterinaria, Universidad de Chile & Sernapesca. In *http://www.sernapesca.cl*, 27.05.2011, Available from http://www.sernapesca.cl/index.php?option=com_remository&Itemid=246&func=startdown&id=4097

Sepúlveda, M., F. Farías and E. Soto (2009). Salmon escapes in Chile. In: *Incidents, impacts, mitigation and prevention*, World Wildlife Fund (Ed.), 1-52, Valdivia, Chile.

Sernapesca (2008a) Unidad de Acuicultura Servicio Nacional de Pesca. In: *Informe sanitario de la Acuicultura en Chile, 2007*

Sernapesca (2008b). Balance de la situación sanitaria de la Anemia Infecciosa del Salmón en Chile de Julio del 2007 a Julio del 2008, Unidad de Acuicultura Servicio Nacional de Pesca. In *http://www.sernapesca.cl*, 27.05.2011, Available from http://www.sernapesca.cl/index.php?option=com_remository&Itemid=246&func=fileinfo&id=2659

Sernapesca (2009). Programa sanitario específico de vigilancia y control de Caligidosis. Resolución Nº 2117 In *http://www.sernapesca.cl*, 27.05.2011, Available from http://www.sernapesca.cl/index.php?option=com_remository&Itemid=246&func=startdown&id=3702

Sernapesca (2010). Informe técnico: Resultados del diagnóstico general por jaula anual de Caligidosis en Chile (DGJA) de 2010, Unidad de Acuicultura Servicio Nacional de Pesca. In: *http://www.sernapesca.cl*, 27.05.2011, Available from http://www.sernapesca.cl/index.php?option=com_remository&Itemid=246&func=startdown&id=4481

Sernapesca (2011a). Solicitud de información pública Ley 20.285. Solicitud SIAC No. 460131711, 10.03.2011, Valparaíso.

Sernapesca (2011b). Solicitud de información pública Ley 20.285. Solicitud SIAC N°460274611, 11.05.2011, Valparaíso

Sernapesca (2011c). Solicitud de información pública Ley 20.285. Solicitud SIAC No. 460645210, 01.2011, Valparaíso

Sernapesca (2011d). Solicitud de información pública Ley 20.285. Solicitud SIAC No. 460299811, 06.2011, Valparaíso

Silva, G (2010a). Producción de *smolt* en agua dulce: Los desafíos del confinamiento. *Aqua Acuicultura + Pesca,* Vol.22, No.145, pp 8-13

Silva, G. (2010b) Efectos del virus ISA: Una industria convaleciente. A*qua Acuicultura + Pesca*, Vol.22, No.139, pp. 28-33

Silva, G. (2010c) Producción de salmónidos 2009: El principio del ajuste. *Aqua Acuicultura + Pesca*, Vol.22, No.139, pp. 8-16

Smith, P. A.; Larenas, J.; Contreras, J.; Cassigoli, J.; Venegas, C.; Rojas, M. E.; Guajardo, A.; Pérez, S. & Díaz, S. (2006). Infectious haemolytic anemia causes jaundice outbreaks in seawater–cultured coho salmon, *Oncorhynchus kisutch* (Walbaum), in Chile. *Journal of Fish Diseases*, Vol.29, No.12, pp. 709-715, ISSN 1365-2761

Smith, P.; Contreras, J.; Larenas, J.; Aguillon, J.; Garces, L.; Perez, B. & Fryer J. (1997). Immunization with bacterial antigens: piscirickettsiosis. *Developments in biological standardization*, Vol.90, No.1, pp. 161-166, ISSN 0301-5149

Smith, P.; Larenas, J.; Vera, P.; Contreras, J.; Venegas C.; Rojas, M. & Guajardo, A. (2001). Principales enfermedades de los peces salmonídeos cultivados en Chile. *Monografías de Medicina Veterinaria*, Vol.21, No.2, pp 3-19, ISSN 0716-226X

Smith, P.A.; Larenas, J.; Contreras, J.; Cassigoli, J.; Venegas, C.; Rojas, M. E.; Guajardo, A.; Troncoso, O. & Macías D. (2002). Infectious haemolytic anaemia of salmon: an emerging disease occurring in seawater coho salmon (*Oncorhynchus kisutch*) in Chile. *Proceedings of the 4th International Symposium of Aquatic Animal Health*, New Orleans, September, 2002.

Subpesca (2010). Primer Informe Técnico: Propuesta de modificación D.S. 319 2001. Reglamento de medidas de protección, control y erradicación de enfermedades de alto riesgo para las especies hidrobiológicas, Subsecretaría de Pesca. In *http://www.subpesca.cl*, 27.05.2011, Available from http://www.subpesca.cl/controls/neochannels/neo_ch878/neochn878.aspx

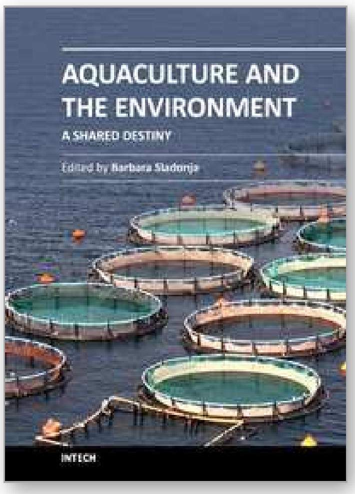
Tapia, F. and S. Giglio (2010). Fjord Carrying Capacity Assessment Models Applicable to Ecosystems in Southern Chile. In: *Technical Report*, World Wildlife Fund (Ed.), 1-22, Valdivia, Chile.

TechnoPress (2010). Ranking of Chilean Salmon and Trout Exports, January-December 2009-2010, In: *Directorio Aqua*, 03.05.2011, Available from http://www.directorioaqua.com/contenido/dapel_esalmonidos.php

Troncoso, M.; Toledo, M. S.; Portell, P. & Figueroa G. (1994). Aislamiento de *Yersinia ruckeri* en salmónidos de cultivo. *Avances en Ciencias Veterinarias*, Vol.9, No.2, ISSN 0716-260X

Valdebenito, S. & Avendaño-Herrera, R. (2009). Phenotypic, serological and genetic characterization of *Flavobacterium psychrophilum* strains isolated from salmonids in Chile. *Journal of Fish Diseases*, Vol.32, No.4, pp. 321–333, ISSN 1365-2761

Vilata, J.; Oliva, D. & Sepúlveda, M. (2010). The predation of farmed salmon by South American sea lions (*Otaria flavescens*) in southern Chile. *ICES Journal of Marine Science*, Vol.67, No.3, pp 475-482, ISSN 1095-9289



Aquaculture and the Environment - A Shared Destiny
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Aquaculture is the art, science and business of cultivating aquatic animals and plants in fresh or marine waters. It is the extension of fishing, resulted from the fact that harvests of wild sources of fish and other aquatic species cannot keep up with the increased demand of a growing human population. Expansion of aquaculture can result with less care for the environment. The first pre-requisite to sustainable aquaculture is clean wate, but bad management of aquatic species production can alter or even destroy existing wild habitat, increase local pollution levels or negatively impact local species. Aquatic managers are aware of this and together with scientists are looking for modern and more effective solutions to many issues regarding fish farming. This book presents recent research results on the interaction between aquaculture and environment, and includes several case studies all over the world with the aim of improving and performing sustainable aquaculture.

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