The Recovery of the Chilean Salmon Industry

The ISA crisis and its consequences and lessons

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The findings of this report reflect the personal views of the authors
and do not necessarily represent the opinion of the World Bank.

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EXECUTIVE SUMMARY

In almost 3 decades Chile transferred, adapted and developed technologies, products and markets to become the second largest producer of farmed salmon in the world, creating value for the entire country and for the regions where the industry operates. However, this impressive technical and commercial success was not accompanied by matching research, monitoring and regulation to guard against foreseeable biological risks. This imbalance impaired the industry's ability to avert and control an outbreak of ISA in 2007.

Productive, economic and social impacts of the outbreak were magnified due to the industry's size and the rapid spread of the pathogen, which was facilitated by a high concentration of farms in some areas and poor husbandry and biosecurity standards. .

A fast public – private coordinated effort ensured that basic infectious disease control measures were implemented and enforced as an immediate response. In parallel, longer term efforts involving the government, the industry and the financial sector allowed companies to continue operating while new laws and regulations laid the foundations for the industry's renewal.

In just 2 years since the first ISA declaration (July 2007), the industry saw improvement in productive rates and the decline in harvest volumes, which ISA had caused, began to reverse in 2011. These positive biological and production indicators, as well as the new regulations and improved production model, lead to increased stocking of fish in salt water in 2010 and 2011 and it is expected that in 2012 – 2013 production levels will be back to those achieved in 2006.

In spite of the new regulations and practices, there are still important issues to address including the need for:

- *mechanisms to ensure that over - concentration of farming activity in certain areas is avoided,*
- *improved pathogen dispersion control strategies,*
- *boundary definition of production zones,*
- *definition of zone carrying capacities,*
- *surveillance programs to detect and/or predict new environmental and disease issues before they can affect the industry.*

Overall lessons emphasize that aquaculture depends on the capacity of biological systems to support it and that defining the capacities of bodies of water to support salmon farms is essential in order to set limits on the maximum production in farming areas. Unless this is done, conditions will deteriorate leading to poor fish performance and eventually to disease. Also, when bodies of water are shared, regulations are required to ensure that all parties involved are good stewards of the environment and the larger the industry is the greater the risks and the harder it is to control a problem. Therefore, it is critical to have a system in place to ensure sound industry practices, and early detection and rapid control of a problem if one occurs.

ACKNOWLEDGEMENTS

As the authors of this study we want to express our greatest thanks to all individuals and institutions that collaborated on this project. Without their input this report would not have been possible. We sincerely hope that this study will benefit aquaculture industries based on the well documented Chilean case.

Adolfo Alvial
Coordinator
Expert Team

Puerto Montt, Chile, February 23rd 2012.

ABBREVIATIONS AND ACRONYMS

AAA	Adolfo Alvial Asesorías S.A. (Adolfo Alvial Consultancies)
ABIF	The Banks and Financial Institution Association
ACOTRUCH	Asociación de Productores de Salmón Coho y Trucha (Trout and Coho salmon Producers Association)
AGD	Amoeba Gill Disease
DGR	Daily Growth Rate
GAA	Global Aquaculture Alliance
GF	Growth Factor
GLFA	General Law on Fisheries and Aquaculture
GOAL	Global Outlook for Aquaculture Leadership
HPR(0-2)	Highly Polymorphic Region (0-2)
INTESAL	Instituto Tecnológico del Salmón (Technological Institute of Salmon)
ISAV	Infectious Salmon Anemia Virus
OIE	Oficina Internacional de Epizootias (International office of Epizootias)
PCR/RT	Polymerase Chain Reaction / Reverse Transcription
RAMA	Reglamento Ambiental de la Acuicultura (Environmental Aquaculture Regulation)
RESA	Reglamento Sanitario de la Acuicultura (Sanitary Aquaculture Regulation)
SAG	Servicio Agrícola y Ganadero (Agricultural and livestock Service)
SERNAPESCA	Servicio Nacional de Pesca (National Fisheries service)
SGR	Specific Growth Rate
SIGES	Sistema Integrado de Gestión (Integrated Management System)
SRS	Salmon Rickettsial Syndromee
SUBPESCA	Subsecretaría de Pesca (Undersecretariat of Fisheries)

1. TERMS OF REFERENCE

1.1.-Background and Objectives

This study has been an initiative of the Global Aquaculture Alliance (GAA) co - sponsored by The World Bank, the Undersecretariat of Fisheries-Chile and the Chilean Salmon Industry Association (SalmonChile). The GAA brought together an International Group of Experts to analyze the progression and recovery of the ISAV crisis in the Chilean Salmon Industry, extracting lessons learned that might prevent or mitigate impacts of similar outbreaks in aquaculture industries elsewhere.

The Chilean salmon farming industry is in the process of recovering from a serious outbreak of infectious salmon anemia (ISA) which began in 2007. This outbreak caused severe impacts on Atlantic salmon production which formerly represented two thirds of Chilean salmonid output. It also had important secondary impacts on employment, social welfare, and international market presence.

The epidemic marked the end of a period where the industry's priority was production and sales and where government oversight and research did not keep pace with the industry's growth. This is now recognized by the industry and government leaders and a new regulatory system has been implemented which facilitated the industry's recovery.
The experience of the Chilean salmon industry represents a valuable case study for other sectors of global aquaculture -- particularly for industries that are growing rapidly. The objective of this study was to analyze and report the evolution of the ISA crisis and to evaluate the recovery process from various perspectives.

1.2.-Methodology

The study is based on review of published data as well as other information supplied by the Chilean authorities, through Undersecretariat of Fisheries – SUBPESCA (Subsecretaría de Pesca), and by the Industry, through its association (SalmonChile). Documents were collected in Chile and sent to the expert team for review. These were subsequently discussed via teleconferences among the study team and were expanded upon during a visit to Chile by team members in September 2011 when interviews were conducted with several individuals that were working in the industry at the time of the ISA crisis. To ensure confidentiality we do not identify our sources in the document. Finally, a report based on the activities mentioned above was prepared according to the agreed Terms of reference of this study:

- ✓ Background on the Chilean industry
- ✓ The ISA crisis
- ✓ Measures taken
- ✓ The recovery
- ✓ Sustainability of the new Chilean Aquaculture
- ✓ Conclusions and Lessons for other countries

Our analysis considered the following elements (emphasizing pre and post crisis comparison):

a. <u>Science and technology</u>: with emphasis on environmental and epidemiological research, monitoring and management.
b. <u>Production factors and value chain</u>: emphasizing the production practices and general model applied in Chile.
c. <u>Market development</u>: Products and market evolution.
d. <u>Social issues</u>: Community and workers.
e. <u>Governance and regulations</u>: Principal regulations and institutional aspects.

f. Investment and financing: Evolution of investment and financing, particularly during the crisis.

1.3.-Expert Team

The Members of the Expert Team include:

Adolfo Alvial, Lic. Bio, MSc.,MBA, General Coordinator, AAA, Chile.
International consultant specialized in Aquaculture technology and environmental management. He has held several positions in the Chilean Salmon Industry. He coordinated this study.

John Forster, PhD, Expert Team Member, USA
International aquaculture industry expert, with strong experience in aquaculture strategic development and best management practices. He coordinated the development of Salmon Farming standards of GAA.

Frederick Kibenge, DVM, PhD, Expert team Member, AVC, UPEI, Canada.
Researcher specialized in Fish Health and biomolecular virology, particularly ISA virus (ISAV). He has worked on viral diseases in the Chilean salmon industry for more than 2 decades.

Other contributors:

Sophie St-Hilaire, DVM, PhD, Associate Researcher, AVC, UPEI, Canada
Researcher specialized in the epidemiology of aquatic animal diseases. She recently assisted the INTESAL of SalmonChile with their recommendations for the revised ISAV surveillance and control program in Chile.

José M. Burgos, Med. Vet., National Director of Aquaculture – Chile.

He has contributed with his expertise in fish health management and regulation development in the Chilean industry, as well as coordinating information and support from Undersecretariat of Fisheries - SUBPESCA to this study.

Rolando Ibarra, Med. Vet. Fish health specialist of INTESAL-SalmonChile, Chile

Dr. Ibarra is the veterinarian in charge of fish health monitoring and the voluntary good practices programs of SalmonChile. He has overseen several programs and projects associated to ISA control during and after the crisis.

1.4.-Output

The study reports on the changes in the Chilean Salmon Industry associated with the ISA crisis, especially those considered most important for the sustainability of the industry. It also identifies pending challenges and highlights lessons that might be helpful to other aquaculture industries elsewhere

1.5.- Plan of activities

Study activities over four months were:,

- ✓ Analysis of documents.
- ✓ Teleconferences to analyze the Chilean situation and information.
- ✓ Visit to Chile by 2 of the experts to confirm and complete the information.
- ✓ Integration and discussion of the draft report.
- ✓ Presentation to GOAL 2011
- ✓ Final report.

2. ORIGIN AND EVOLUTION OF THE SALMON FARMING INDUSTRY IN CHILE

2.1. Industry development phases

Salmon farming in Chile started at the end of the 70s. Fundación Chile played a vital role in importing and transferring technology, thereby triggering the new industry based in the Xth Region (Los Lagos). This is a relatively young industry, 1991 being the first year when production exceeded 10,000 tons. However, by 2005, Chile was the fastest-growing salmon producer in the world, having overtaken Scotland (in 2000) as the second largest producer of Atlantic salmon in the world (Figure 1) and was on a course to overtake Norway as the number one producer. This rapid development, which can be characterized by the phases shown in Figure 2, resulted in a noticeable cluster of salt water farms in the areas around Puerto Montt – Chile. The production and export of products from 2001 to 2011 are shown in the Figure 3.

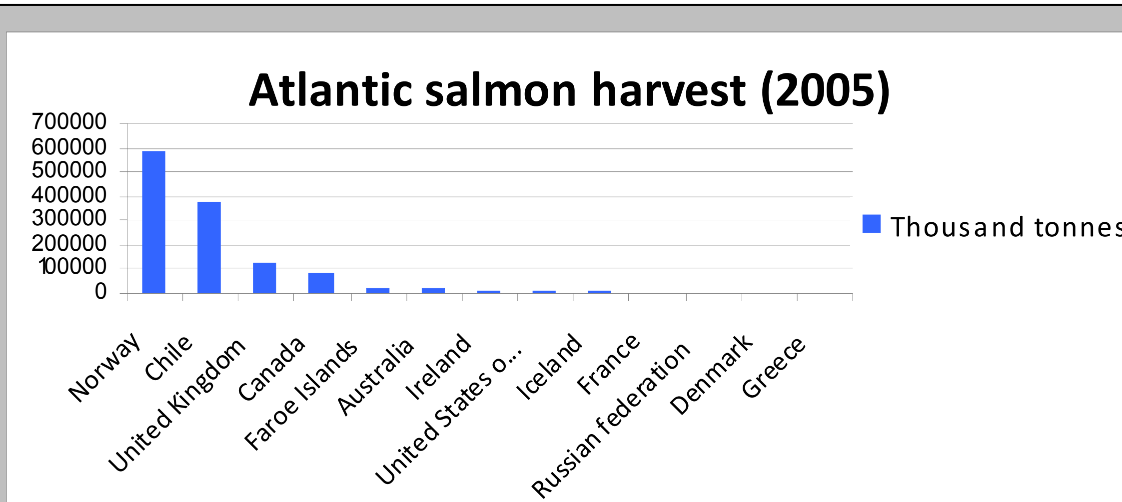


Figure 1. Total reported Atlantic salmon (*Salmo salar)* aquaculture production in 2005 (FAO, 2007). Source: Halwart *et al.* (2007).

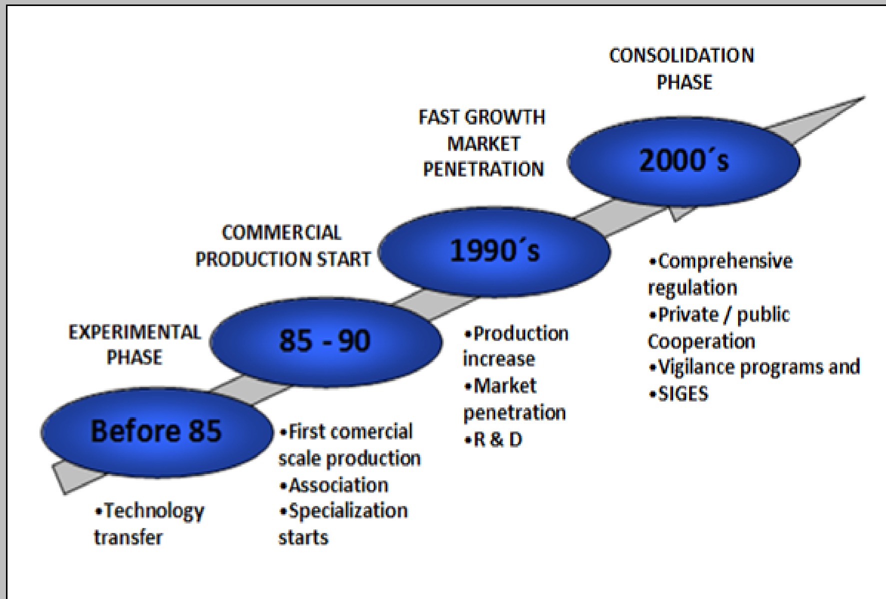
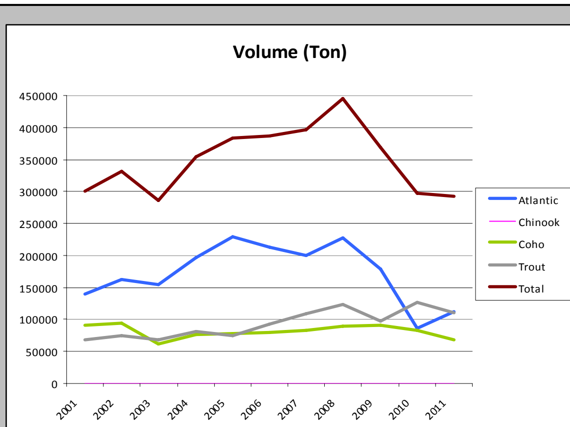


Figure 2. Evolution phases of the Chilean salmon industry (Source: Adapted from Alvial, 2011 a).



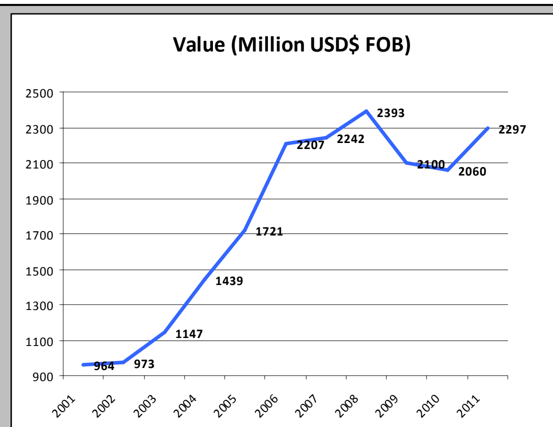


Figure 3a **Figure 3b**

Figure 3. Chilean salmon industry growth in terms of volume (a) and export value (b).

The rapid Industry growth was accompanied by a gradual development of regulations which were based on:

- The Fishery and Aquaculture Law with its three major sectorial regulation bodies: The Environmental regulation for aquaculture (RAMA), The Sanitary regulation for Aquaculture (RESA) and the Regulation for Aquaculture Licenses.
- The General basis for the Environment Law, which has several aspects connected to aquaculture, particularly environmental impact assessment regulations.
- The Navigation Law, principally in aspects related to coastal waters and land use and pollution control.

Figure 4 shows how the regulations developed from 1991 to 2010. The addition of new regulations concerning egg imports in 2011 is not shown. Only in the last decade can the regulations be considered to have been reasonably well integrated and complete.

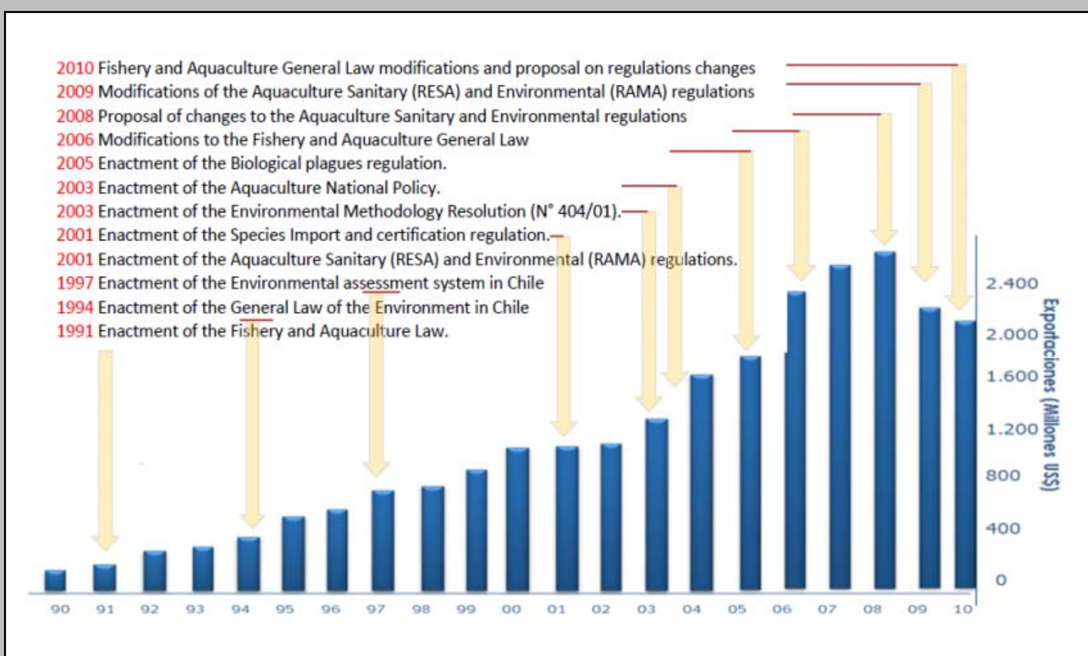


Figure 4. Evolution of Principal aquaculture regulations in Chile as the industry was growing (export volume). Source: www.subpesca.cl / Reglamentos.

In 2007, the industry provided around 25,000 direct jobs and 20,000 indirect jobs associated with a nucleus of approximately 40 companies and more than 1,200 affiliated suppliers. Much of the production was concentrated in the coastal areas of the Xth Region and most notably in the central and east coasts of Chiloé Island, where approximately 40% of the total salmon production was concentrated (Figure 5).

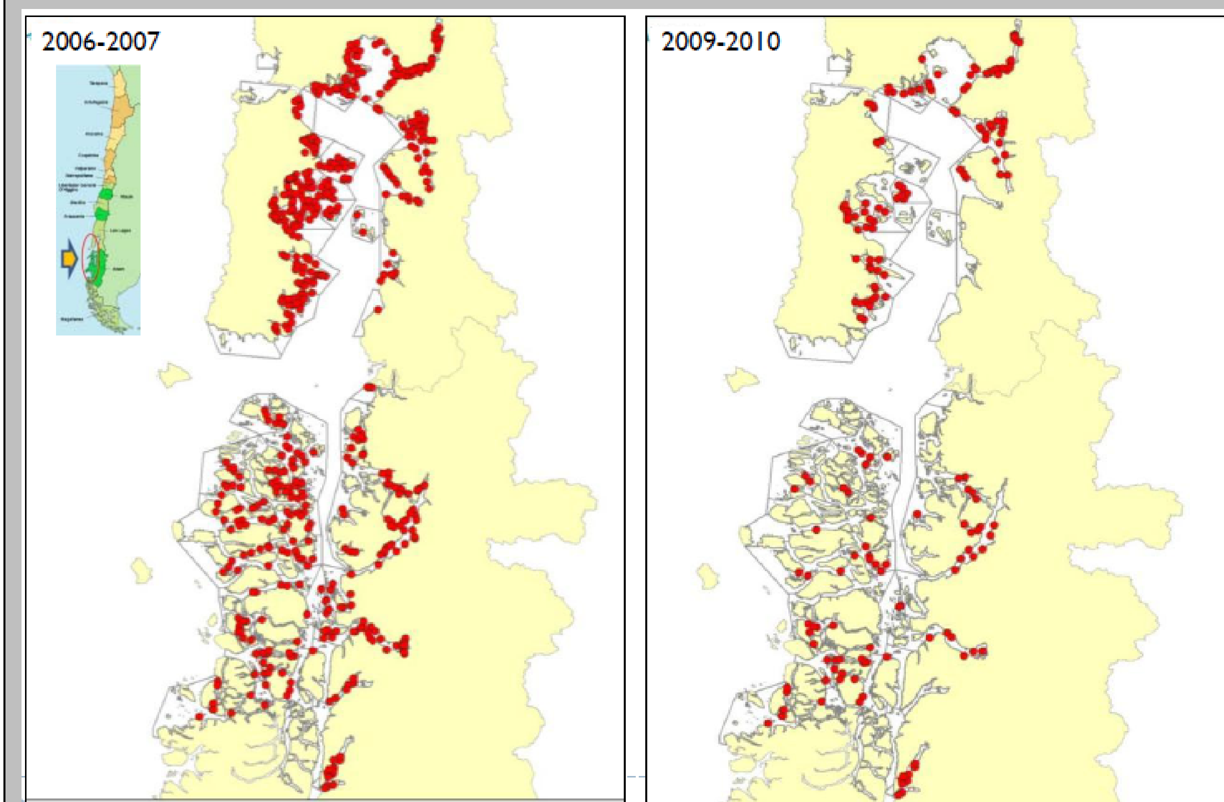


Figure 5. Sea water operating salmon farms distribution in Chile, Xth and XIth Regions: comparing 2006-2007 v/s 2009-2010. Source: Gárate (2011).

2.2. The Chilean salmon industry general features

Depending on the salmon species and the life stage (egg, fry, smolt, salt water grower or broodstock) fish facilities are located in rivers, lakes, estuaries or coastal sites near shore. At present there are approximately 30 companies that farm salmonids in the marine environment (grow-out phase).

In 2007, 533 of the 1041 authorized saltwater sites for salmon farming were active. Approximately 72% of these active sites were in Region Xth, 27% were in Region XIth, and the remaining 1% was in Region XIIth (SERNAPESCA 2008). The salmon species farmed included Atlantic salmon (*Salmo salar*), Coho salmon (*Oncorhynchus kisutch*), rainbow trout (*O. mykiss*), and Chinook salmon (*O. tshawytscha*). Of the 383 active sites in Region Xth in 2007 where the index case of the ISA outbreak occurred, 98% (375 sites) were farming Atlantic salmon: (Halwart *et al.,* 2007). The Xth Region had by far the highest concentration of farms and almost all were producing Atlantic salmon. However, by October 2011, the distribution of salmon farms operating in sea water per region had changed and was: 43% Xth, 51% XIth and 5% XIIth (Source: Salmonchile).

Over the years, the composition of cultured salmon species has also changed. In 1990, 59% of the farmed salmon species in Chile was Coho salmon, 25% rainbow trout, and 16% Atlantic salmon; by 2006, this had changed to 63% Atlantic salmon, 20% Rainbow trout and 17% Coho salmon (Figure 6). In October 2011, Rainbow trout comprised 38%, Atlantic salmon 38% and Coho salmon 24%. These changes occurred partly because of market demand and, more recently due to the ISA epidemic in Atlantic salmon.

It is noteworthy, however, that in November 2011 the distribution per species of fish stocked in sea water was 58% Atlantic salmon, 24% Rainbow trout and 16% Coho salmon (Source: SalmonChile), revealing the industry's confidence in the recovery of Atlantic salmon production.

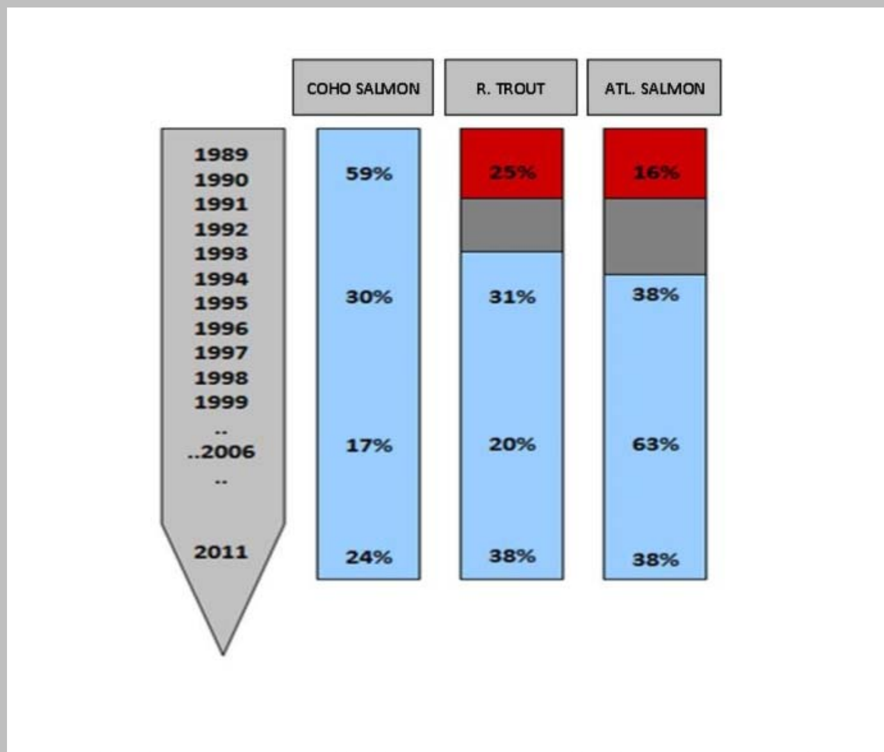


Figure 6: Chang*es* in marine-farmed salmon species composition in Chilean aquaculture from 1989 to 2006. Based on Dr. Marcos Godoy (2011), personal communication.

2.3. The Chilean salmon industry associations

SalmonChile is a private sector organization that was created in 1986 to represent producers of salmon and trout in Chile. It provided a mechanism through which the industry has been able to:

- develop guidelines for food quality and safety,
- develop policies for fish health,
- interact with local communities,
- represent itself in discussions with the government and international organizations.

SalmonChile's current membership includes 28 companies producing salmon and trout, which account for 67% of Chile's total salmonid production.

The technical arm of SalmonChile is the Salmon Technical Institute (INTESAL), responsible for technical coordination and monitoring of the industry in the areas of fish health, environmental responsibility and food safety, and matters important for trade at national and international levels. SalmonChile funds INTESAL's research and development costs through a levy on salmon exports.

ACOTRUCH is a separate association that was formed in September 2009 to represent small and medium sized Coho salmon and trout producers in Chile. Some of these companies were previously members of SalmonChile and decided to regroup as ISA in Atlantic salmon became SalmonChile's main focus. Other companies remain independent of either of these associations.

Apart from these producer organizations, the suppliers are also organized in associations, the main ones being those representing the maritime services, divers, net services, pharmaceutical labs and environmental labs. Even though the feed producers are the most important suppliers in terms of the industry's farming costs, they are not represented by an association.

2.4. The Chilean Government structure

The management of the Chilean aquaculture industry is the responsibility of two government agencies:

(1) The Undersecretariat of Fisheries - SUBPESCA in the Ministry of Economy, Development and Tourism, is responsible for developing regulations and rules that govern the aquatic animal resources in Chile in accordance with the General Law on Fisheries and

Aquaculture (GLFA) N° 18.892 and its subsequent amendments[1]. One of the objectives of Undersecretariat of Fisheries - SUBPESCA is to promote the sustainable development of fisheries and aquaculture.

(2) The National Fisheries Service, Servicio Nacional de Pesca (SERNAPESCA), is also under the Ministry of Economy, Development and Tourism. SERNAPESCA is responsible for overseeing compliance with the requirements and regulations provided in the GLFA and issued by Undersecretariat of Fisheries - SUBPESCA.

Prior to the development of Chile's salmon aquaculture industry, – SUBPESCA's main focus was on the regulation of capture fisheries, and SERNAPESCA's main focus was the enforcement of capture fisheries. Both agencies had few personnel with experience in aquaculture and fish health management. Since the development of salmon farming, however, SERNAPESCA has been given new responsibilities, and has had to reorganize its departmental structure to reflect these changes in function, especially increasing inspection (SERNAPESCA, 2009). Consequently, the agency's staff increased from 200 in 2007 to 729 in 2009, primarily in response to the ISA crisis and the new government regulations. Most recently GLFA N° 20.434 (published in April 2010) created the Aquaculture Subdivision in SERNAPESCA and reinforced SUBPESCA's National Direction of Aquaculture. These two organizational changes were intended to strengthen the government's role in inspection and enforcement and distinguish aquaculture activities from fisheries activities.

[1] http://www.subpesca.cl/controls/neochannels/neo_ch617/neochn617.aspx.: Full text and amendments of the GLFA (Ley General de Pesca y Acuicultura N° 20.560)

__2.5 Principal Health issues prior to ISA crisis__

Prior to the ISA crisis in Chile in 2007 several other infectious diseases were present in the industry. The date of the first record of their occurrence is illustrated in Figure 7 on a time scale with the growth of production and the amount of eggs imports.

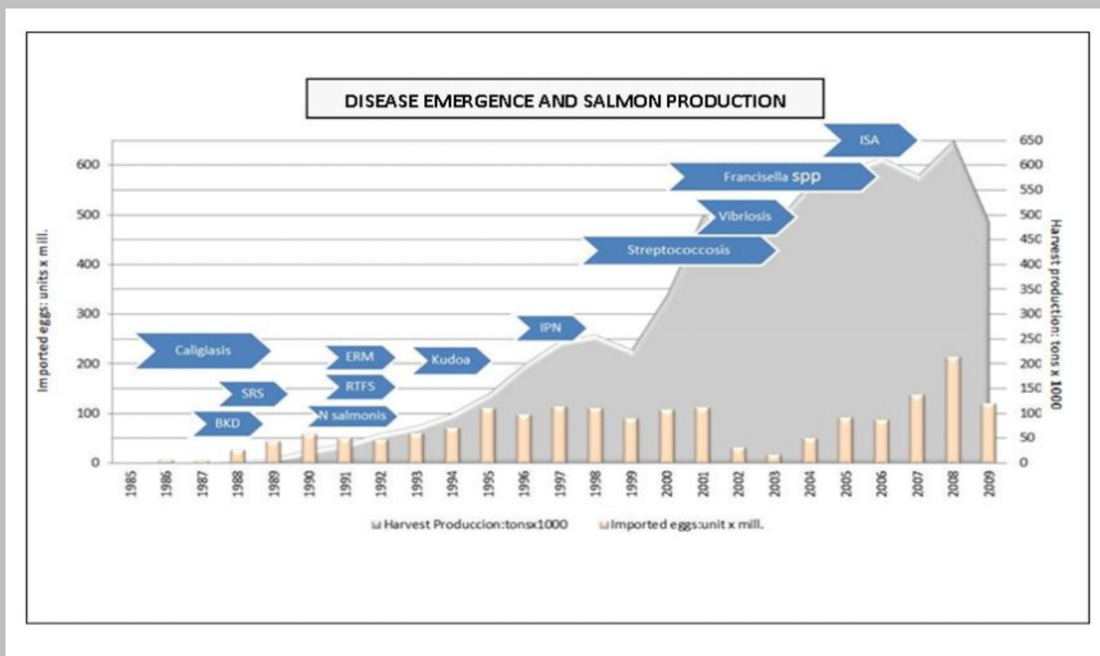


Figure 7. Timeline of salmon diseases occurrence, production, and egg imports in Chile. Source: Barros (2011).

The three primary fish diseases in the Chilean industry prior to 2007 were caligiasis caused by Caligus sea lice (*Caligus rogercresseyi*), salmonid rickettsial septicaemia (SRS) caused by *Piscirickettsia salmonis*, and infectious pancreatic necrosis (IPN), caused by the pancreatic necrosis virus (IPNV). IPNV affected fish in both fresh and salt water and the other two conditions are salt water diseases. The negative impact of these diseases on production was accepted and compensated for by increasing smolt numbers in salt water cages. SRS, the most significant disease, does not have an effective vaccine, but is treatable; so it has led to high levels of antibiotic use. Interestingly and as expected, the disease control measures implemented due to ISA crisis have also apparently decreased the number of SRS cases in the industry.

3. THE INFECTIOUS SALMON ANAEMIA (ISA) CRISIS

3.1.-What is the infectious salmon anemia (ISA)?

Infectious salmon anaemia (ISA) is a serious viral disease of marine-farmed Atlantic salmon (*Salmo salar*) caused by ISA virus (ISAV), which belongs to the genus *Isavirus*, family *Orthomyxoviridae*. Clinical signs of ISA include pale gills due to anemia, blood-tinged fluid in peritoneal and pericardial cavities, petechial hemorrhages of the visceral and parietal peritoneum, and red dark liver and spleen (OIE, 2011).

ISA, the disease associated with ISAV is arguably the most economically important viral disease of marine-farmed Atlantic salmon when considering production losses and loss of export markets and the associated social impacts. Therefore, eradication of the disease and/or control of the viral infection have been a priority for the Atlantic salmon industry wherever the disease has occurred.

In the Northern hemisphere, the first registered outbreak of ISA was in 1984 in Atlantic salmon (*S. salar*) "parr"[2], on the south western coast of Norway. The situation developed into an epidemic, which peaked with a total of 80 new cases in 1990. From 1989 to 1991, Norwegian authorities imposed a series of new biosecurity measures to try to control it, including

- A ban on use of sea water in hatcheries.
- A ban on movement of fish from one sea water site to another.
- Introduction of compulsory health certificates for aquaculture farms.
- Disinfection of waste water from slaughterhouses, processing plants, and smolt transport (Norwegian Veterinary Institute).

[2] A young salmon having dark cross-bars and spots on the sides, not yet ready to go down to the sea

Since 1994, the annual incidence of ISA outbreaks in Norway has varied between 2 and 23 (Norwegian Veterinary Institute reports).

The disease was first reported outside of Norway in 1996, in New Brunswick, Canada. Subsequently, ISA was detected in Scotland in 1998, in the Faroe Islands in 1999, and in Maine, USA, in 2000. The virus was also detected in marine-farmed rainbow trout (*O. mykiss*) with subclinical disease in Ireland in 2002.

3.2.-The Infectious salmon anaemia Virus (ISAV)

ISAV belongs to the family *Orthomyxoviridae*, together with influenza viruses. However, the virus is sufficiently different from influenza viruses to be assigned to its own genus, *ISA virus.*

ISAV occurs in two basic genotypes, North American and European (Kibenge *et al*., 2001a), which are shown in Figure 8. Further differentiation within these groups (genogroups) has been complemented by new investigations developed by Kibenge *et al.* (2007) and Nylund *et al*. (2007).

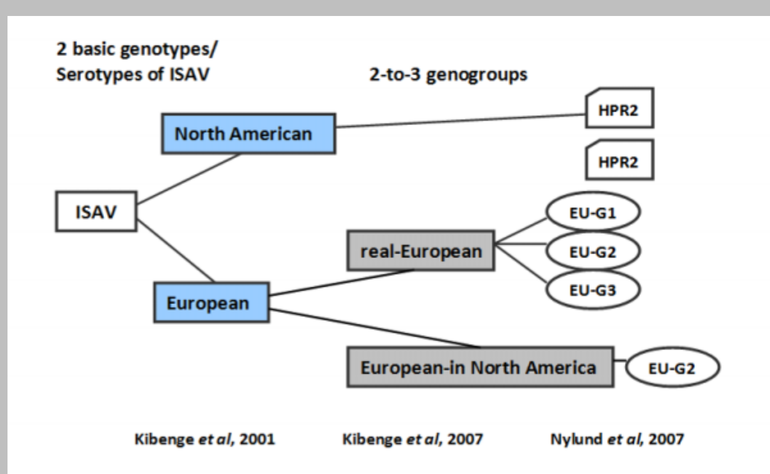


Figure 8. Infectious salmon anaemia virus (ISAV) strain identification. ISAV occurs in two basic genotypes, North American and European (Kibenge *et al*., 2001a).

ISAV HPR0 refers to the non-pathogenic variant of ISAV that has emerged in all countries with a history of ISA. It is commonly associated with gill infections but does not cause mortality. It also does not grow in cell culture. Because this type of ISAV does not cause clinical disease and does not grow in cell culture, infections are not regarded as significant by the regulatory agencies. The role this virus plays in the epidemiology of ISA is not clearly known (MacBeath *et al.,* 2009, Debes *et al.,* 2011).

3.3. The Chilean ISA index case and the crisis

Although ISAV had been detected in one group of Coho salmon that presented a disease named 'Jaundice coho salmon Syndrome' in Chile in 1999 (Kibenge *et al.,* 2001b), the virus had never been associated with ISA disease in the Southern hemisphere. During the winter (July) of 2007, unexplained mortalities, following recovery from an outbreak of SRS, were observed in pre-market (3.9 Kg) Atlantic salmon at a grow-out site located in central Chiloé in Region X. This was the area in Chile where salmon production was most concentrated at the time. Subsequent investigation confirmed ISA in its classic presentation (see clinical signs in Section 3.1 above), the first time it had been reported in Chile (Godoy *et al.,* 2008).

However, this does not mean that it was the first time that Atlantic salmon had been infected with this ISAV in Chile. Based on our recent interviews with key individuals in the Chilean aquaculture industry, it is possible that ISAV had been present and causing health problems a few years before the reported ISA index case in July 2007. INTESAL records suggested an increase in "non-identified" causes of mortality starting around 2004 specifically in areas with high number of farms (Adolfo Alvial, 2011, personal communication).

There are several reasons for suspecting that ISAV may have been in Chile prior to 2007. First, the phylogenetic analysis by Kibenge *et al*. (2009) showed that the Chilean ISAV was genetically similar to ISAV reported in Norway in 1996. Second, the virus found in the index case in Chile had more mutations than several other viruses isolated in subsequent cases, which suggests the origin of these other cases pre-dated the virus found in the index case (Figure 9).

Main characteristics of the new Chile ISAV strains

ISAV Clade (ISAV Strain)	No. of isolates sequenced	Fish companies[1]	Sampling period	Segment 5 (11-aa insert)	Segment 6 (HPR group)	Other comments
2.2.2.1.2.1 (Chile 1)	seven	3(1), 5(2), 6(2), 11(1), 14(1)	November 2007 to July 2008	No insert	HPRs 1c, 5, 9b, & new HPR (12-aa del)	1 from hatchery; 2 from history of amoeba disease; 1 without clinical disease
2.2.2.1.2.2 (Chile 2)	two	11(2)	August 2008	11-aa insert	HPR 7b	
2.2.2.1.2.3 (Chile 3)	seven	6(4), 9(2), 12(1)	May to August 2008	11-aa insert	HPR 7b, 7f	1 with HPR 7f; all others are HPR 7b
2.2.2.1.2.4 (Chile 4)	four	6(4)	May to July 2008	11-aa insert	HPR 7b	
2.2.2.1.2.5 (Chile 5)	eleven	1(2), 2(1), 6(2), 8(1), 10(5)	June to August 2008	11-aa insert	HPR 7b	
2.2.2.1.2.6 (Chile 6)	ten	2(1), 4(2), 7(2), 10(1), 13(4)	October 2007 to August 2008	11-aa insert	HPR 7b	
2.2.2.1.2.7 (Chile 7)	five	2(5)	June to November 2007	11-aa insert	HPR 2 & 7b	1 with HPR 2 & 7b; all others are HPR 7b; original ISA outbreak in Chile

[1]Fish companies are numbered 1-14; number in brackets represents number of isolates sequenced in a particular fish company

Marine Harvest is the Company #2 in the Table, and from all isolates to date sequenced is NOT represented in the group Chile 1, being only present in the groups Chile 5 (1 isolate), Chile 6 (2 isolates) and Chile 7 (5 isolates). The Puchilco isolate and most others MH isolates belong to group Chile 7.

MAIN CHARACTERISTICS OF GROUP CHILE 1, CLOSEST CHILEAN GROUP TO NORWAY 1997 ISOLATE

CHILE 1	WATER SOURCE	CLINICAL SIMPTOMS OR DIAGNOSTIC	FISH SIZE
Isolate # 1	FW Hatchery	?	Parr
Isolate # 2	SW	"Amebas"	Adult fish
Isolate # 3	SW	"Amebas"	Adult Fish
Isolate # 4	FW, but fish came from SW	w/o symptoms	Broodstock fish
Isolate # 5	SW	ISA	Adult fish
Isolate # 6	SW	ISA	Adult fish
Isolate # 7	SW	ISA	Adult fish

Figure 9. Characteristics of the ISAV strains found within the first year of the ISA outbreak in Chile. Taken from Kibenge *et al*., 2009

Third, consistent with this is the report that several fish farms in the same neighborhood as the index case were also experiencing high mortalities at the time. Many farms in the area attributed the increased mortalities to amoeba gill disease (AGD) and it is possible that co-infections with gill amoeba masked the ISA mortalities. In addition Caligus, a potential vector of ISA, was problematic towards the end of 2006 and beginning of 2007 affecting farms in extensive areas, particularly in the Reloncavi Gulf and Central Chiloé. Thus, it is possible that ISAV was present on several farms by the time the index case was first reported in July 2007.

Fourth, for several years prior to 2007, it is possible, as revealed in our recent interviews with people in the Chilean aquaculture industry, that some laboratories detected ISAV in Atlantic salmon[3] but these were not reported because they could not be confirmed. It is also mentioned by some individuals interviewed in Chile that the technology was not in place to detect ISAV properly. Basically, it was said that diagnostic tests for ISAV in Chile prior to 2007 were not well developed or validated, although techniques applied in surveillance programs were those recommended by the OIE. However, if ISAV was present in Chile prior to 2007, the virus was not causing massive mortalities in the Atlantic salmon industry.

In summary, the analysis done by Kibenge *et al.* (2009), the increase in mortality (particularly of the fraction due to "non-identified" causes), the large number of farms and the stressing factors: high fish densities and poor quality of smolt used between 2004 and 2007 (as mentioned in several of our interviews in Chile), suggests that the virus may have been present before 2007. The high levels of Caligus starting in approximately 2006 and the weak biosecurity measures at the time may then have permitted its dispersal.

[3] The technique used then was virus isolation on cell culture in CHSE – 214 cell line. As second option either EPC or BF-2 cell line

Although the precise time when ISAV was introduced to Chile remains a topic of debate, there is no question that in 2007, when the virus was officially detected, it spread rapidly throughout the industry. The affected farms in 2007 were stocked with high numbers of fish, which was also characteristic of the 1998 Scotland ISA epidemic (Stagg *et al.,* 2001; Halwart *et al.,* 2007).

For the purpose of this study we consider the ISA crisis to be the period between July 2007, when mortality from ISA was first reported in marine-farmed Atlantic salmon in Chile (Godoy *et al.,* 2008), and the time when the last clinical outbreak was recorded, September 2010 (SERNAPESCA, 2010).

The number of farms affected by ISA peaked at the end of 2008 (Figure 10), but the economic impact of the crisis was not completely felt until 2009-2010, when harvests and production were at their lowest. Production of Atlantic salmon dropped by about two thirds due to ISA mortality and culling of affected farms (Asche *et al.,* 2009). Additionally affected sites were not restocked with new Atlantic salmon smolts. Several companies attempted to compensate for these losses by raising rainbow trout and Coho salmon. It is remarkably that the total salmonids net production (tonnes) and exports (million USD) decreased from 2008 to 2010 in 33,3% and 29,6 % respectively.

The ISA virus crisis also had a significant social cost. It is estimated that 50% of direct and indirect job positions were lost, representing around 25,000 thousand workers laid off.

3.4. Conditions leading up to the ISA crisis and increasing the spread of ISAV.

There is consensus that the industry grew more rapidly than the government regulations could cope with. When Salmon farming first started there were few regulations in place to control disease introduction and dispersion. The industry was performing so well economically with relatively few issues that no consideration was given to the limitation of the biological system. According to Adolfo Alvial (2011, personal communication) several production indicators showed a gradual deterioration in Atlantic salmon performance from 2004 reaching its worse situation between 2008 and 2009 (Figure 11). Among the principal indicators and their observed deterioration can be cited: harvest weight: 4,5 Kg to 2,7 Kg; productivity (harvested Kg/planted smolt) 3,0 to 1,8; cumulative monthly mortality in sea water (in number of fish) 2% to 15 % (Alvial 2011b).

The industry was also growing and providing economic stability to an area that was historically deprived. Consequently, the government recognized the economic and social benefits and implemented the National Aquaculture Policy in 2002 which aimed at doubling aquaculture production by 2012 with very few restrictions or consideration for environmental vigilance and disease control. This goal was reached early (in 2005), demonstrating how fast this industry was permitted to grow.

However, salmon farmers recognized that disease was an issue particularly in some areas where indicators of production had declined. In response, SalmonChile, through INTESAL, added fish health and environmental vigilance systems to its sea lice and phytoplankton monitoring programs, as well as making a first attempt to define production zones in Chilean waters. Additionally, in 2003, the industry established a best practices system known as the Integrated Management System of the Salmon Industry, (SIGES), covering environment, fish health, food safety and social aspects. All these efforts were voluntary. There was limited appreciation at the time for the biological risks that the industry was taking.

Basically, prior to 2007 the industry was enjoying high prices for its product and increasing production. In hindsight, it is easy to see where problems were occurring, but at the time there was reluctance to recognize them. Further, it is difficult to know whether the industry would have made changes even if they had been proposed by government. Rapid growth was the priority and costly long and medium term infectious disease prevention strategies were ignored. The general reaction was to stock more fish to compensate for losses due to disease mortality.

In hindsight, several management issues were evident:

1) There were high concentrations of sites in some farming areas, especially Region X and central Chiloe.

2) There was an absence of zone management programs.

3) There was poor sanitary control on farms including poorly regulated importation of fish eggs, no fallowing periods, and lack of disinfection procedures.

4) There was insufficient attention paid to biosecurity including frequent fish movement between farms.

5) There was a lack of comprehensive Government regulations and control.

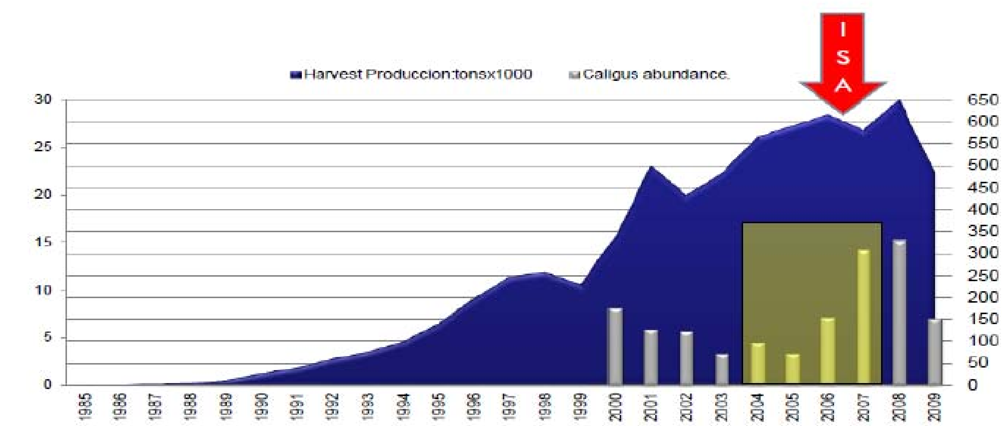


Figure 10. Production and Caligus infestation increase before ISA starting (Source: Barros, 2011).

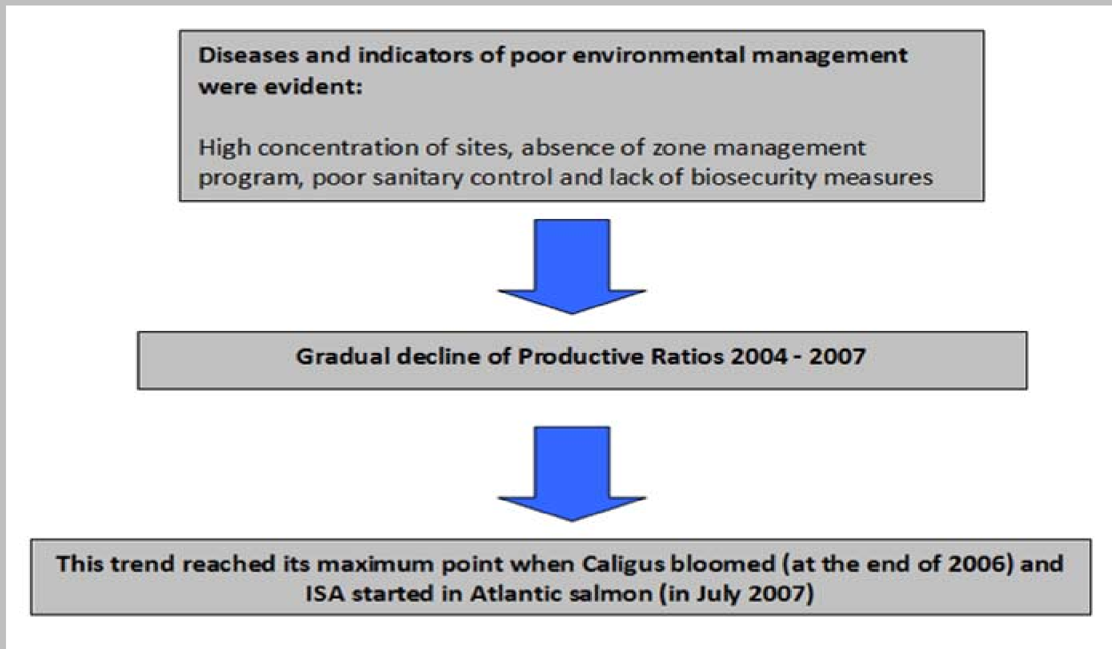


Figure 11. Poor management and decline of productive ratios before ISA starting as reported by Alvial (2011 b).

This resulted in a general increase in fish mortality, particularly in the major production areas. The cause of death was mostly undetermined, and there was an increase in the prevalence of the sea lice Caligus. The increase in Caligus infestation (as well as the increase in mortality from what looked like infectious causes) may have reflected a general over-population of susceptible fish in the area with minimal area-wide disease control measures in place.

The Caligus problem peaked at the beginning of 2007 with average farm abundance levels at 30 to 50 parasites per fish. These high levels may have been exacerbated by the combination of favorable oceanographic conditions (increased salinity as consequence of a period of low rain), the development of resistance to emamectine benzoate, and the general poor condition of the fish (stress, skin damage, co-infections with other pathogens such as amoebic gill disease and SRS and as a consequence, likely weakening of the immune response).

Thus, in the period immediately before the ISA crisis, Chile did not have sufficient biosecurity measures in place to reduce the spread of aquatic animal pathogens. Further there was minimal legislative support for and/or minimal organized national aquatic animal health regulations to keep exotic diseases out or to limit the spread of endemic diseases through the movement of aquatic animals.

Rapid spread of ISAV during outbreaks in the northern hemisphere has been associated with movement of virus in water, live fish, and of contaminated equipment between fish farms. For example, ISAV has been transmitted from site to site by feed boats (McClure *et al.,* 2005), by well boats carrying fish, and in ballast water (Murray *et al*., 2002), via movement of infected fish (Stagg, 2003), or through the water column due to proximity to other farms or processing plants with ISAV infected fish (Jarp and Karlsen, 1997). All of these routes of transmission were uncontrolled in 2007 in Chile; therefore, they could have led to the dissemination of the virus in this country.

In the Chilean case, Mardones *et al.* (2009) investigated the epidemiology of ISAV during the first year of the Chilean outbreak in the Xth Region and reported both clustering of cases as well as long distance dispersion of the virus, which suggests several routes of transmission. Examination of Chilean salmon farming practices at the start of the ISA crisis revealed many of them that could have resulted in virus dissemination. They were:

- Smolts were not screened as a general practice for health status or vigor before being stocked into farms; so, weak sickly fish were moved to salt water and were likely more susceptible to disease. This occurred because the incentive to increase production was stronger than the incentive to assure good fish performance. There was a demand for smolts as a result of the rapid growth in the industry. (i.e., value on smolt quality was determined by harvest price).
- Smoltification was often completed in estuaries where all three species and different age groups shared the same body of water. Therefore, if disease was

present in this area it was then spread throughout the industry when the smolts were transferred to grow out sites.

- High stocking numbers on farms (1.5 million fish and over) and high densities of fish in individual cages (25 to 30 Kg/m^3), resulted in high levels of virus being released from a farm once it was infected with ISAV.
- Close proximity of farms in some areas. Approximately 40% of Chile's total salmon production in 2007 was concentrated in the central and east coasts of Chiloé Island, which increased the likelihood of the outbreak and spread of a disease.
- Close proximity of farms to processing plants (within 5 km) was also an issue. The OIE suggests sites within 5 km of an infected farm or a processing plant harvesting infected fish are at high risk of acquiring the disease. However, Mardones *et al.,* (2011) suggest, that 10 km may be a more appropriate infection zone based on their evaluation of the Chilean epidemic, the number of fish on a site at the time of infection being a determining factor in the size of the zone.
- Mortality management did not consider pathogen inactivation and containers in which mortalities were transported were not adequately secured to avoid spillage or theft.
- Harvest systems that could not cope with the increased demand created by the elimination of infected fish. As the number of outbreaks increased, the demand on the system increased.
- Effluent disinfection at processing plants in 2007 was not practiced.
- Unrestricted and extensive movement of fish, equipment, and personnel between farms.
- Use of 'open' well boats to transport fish between farms, which means that water containing the virus would have been released along the vessel's entire route
- Sharing of equipment (nets, boats, barges etc.) between farms and lack of disinfection and/or oversight of cleaning when it was shared.
- There was no mandatory "break" between year classes of fish on a farm (i.e. fallow periods were voluntary).

- High sea lice levels most likely caused by the increase in active farms in Region X. Sea lice are known to move between farms in close proximity and can carry ISAV. Wild fish, such as the Common Snook or Robalo (*Eleginops maclovinus*) infested with Caligus may also have spread ISAV between farms as it was suggested by interviewed experts in Chile.
- Prior to 2007, there was insufficient surveillance for diseases on salmon farms and inadequate diagnostic laboratory capabilities to detect health problems early in the disease process. Single agent diagnostic assays such as singleplex PCR/RT-PCR that are used for pathogen surveillance/screening programs are severely limited since they are based on known pathogen nucleic acid sequence information. These assays are good in a characteristic disease outbreak or in situations suggestive of infection with one known pathogen but are not ideal in the absence of clinical signs or in situations where a particular disease is not known to occur such as ISA in Chile prior to June 2007 (Kibenge *et al.,* 2011).
- Long lag time between the diagnosis of ISAV and the harvest or elimination of the fish on the farm, which meant that infected farms served as reservoirs of infection. During the crisis, the SERNAPESCA estimated that on average it took 90 and 130 days for elimination and/or harvest of fish, respectively (Mardones *et al*., 2009).
- Inadequate awareness by senior management in companies of the problem as it was developing.

In summary, there were many conditions that favored the spread and potential outbreak of infectious pathogens in July 2007, as it finally happened (Figure 12).

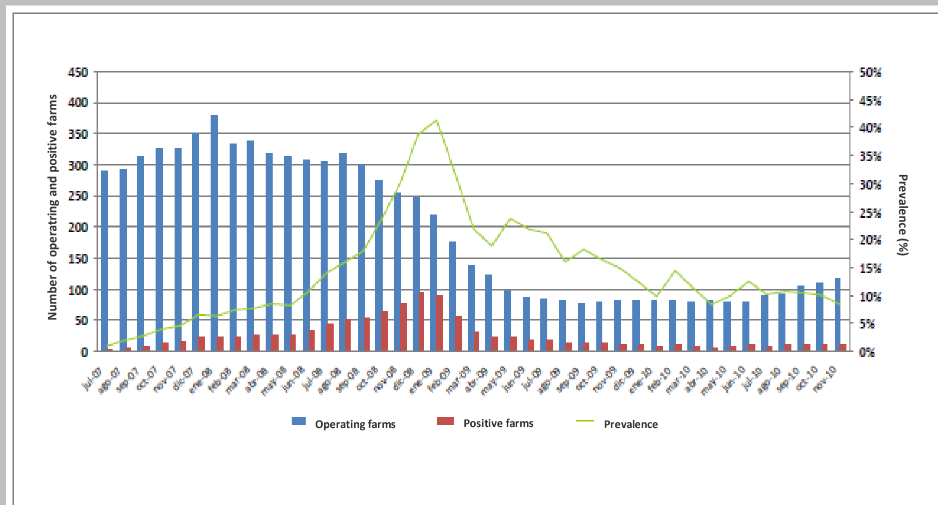


Figure 12. Number of operating Atlantic salmon farms (blue bars), ISA positive farms (red bars) and ISA prevalence (green line) between July 2007 to November 2010. Source: SERNAPESCA (2010, Technical Report).

3.5. Possible sources of ISAV

The evidence suggests that the ISAV that caused the ISA outbreak in Atlantic salmon in Chile originated in Norway. The ISAV in the first outbreak in June 2007 was most similar to isolates from Norway (Kibenge *et al.*, 2009; Vike *et al.*, 2009; Cottet *et al.*, 2010). The phylogenetic analysis of Kibenge *et al.* (2009) showed that the Chilean ISAV was genetically unique, although similar to ISAV isolates reported in Norway in 1996.

How ISAV entered into Chile is still debatable. A study by Vike *et al*. (2009) suggested that the virus was introduced to Chile through fish egg imports from Norway in the past 10 years. Fish egg imports started to rise from 1985 with increasing aquaculture production (Figure 7); there was a significant jump in 1995 when it reached 100 million units and remained at this level until 2001. There was a drop in 2002 and 2003, but imports returned to 100 million units in 2005, and peaked to > 200 million units in 2008 at the peak of the ISA crisis. Whether ISAV was introduced to Chile via fish egg imports or not, the importation of eggs directly reflects that demand correlates with the rapid and large aquaculture expansion around 1988, 1995, and again in 2005 (Asche *et al*., 2010). Although there were some restrictions on egg imports (i.e. they had to originate from ISAV negative farms), they were weak and insufficient, and additionally it would have been difficult for SERNAPESCA, to enforce these regulations on all imports with the limited number of personnel they had prior to 2008.

Although the virus introduction could have happened via egg importation, that could be as a consequence of pseudo vertical transmission, i.e. virus contaminating the egg surfaces or fluids. Although in those cases disinfection is believed to be sufficient to remove the pathogens, this procedure has to be applied regularly and rigorously. On the other hand, true vertical transmission of ISAV has not been reproduced experimentally (Melville and Griffiths, 1999). In fact, there has been no evidence of true vertical transmission of ISAV in New Brunswick, Maine, and Faroe Islands. In Norway, only 0.7% of ISA outbreaks occurred in the freshwater stage. Export of eggs from an infected farm in Norway being transported in 1986-87 to Iceland has not led to ISA in Iceland. Thus, an extensive review by a special scientific committee in Norway concluded that true vertical transmission of ISAV, if it occurs, is of little significance (Rimstad *et al*., 2006). A report sponsored by the European Commission on the issue of trading of fish eggs concluded that vertical transmission was insignificant in the epidemiology of ISAV infection (Bovo *et al*., 2005).

4. THE MEASURES TAKEN IN RESPONSE TO THE ISA CRISIS

4.1. The crucial approach

One of the most impressive and crucial aspects of the Chilean ISA recovery was the collaboration between the industry and Government to construct the platform for addressing the problem, from both short-term and long term perspectives. After the declaration of the index case, a partnership was established between the government and the industry, which permitted companies, particularly those having previous experience with ISA control, to make technical contributions to the initial emergency control and contingency plans. In addition, months later the Government established "la Mesa del salmon" (Salmon Committee) where all involved public sector agencies were represented.

All parties were consulted regarding the major changes to be introduced in the regulation. This response by government and industry, which targeted the factors most likely to be contributing to the spread of the virus, resulted in the control of the disease within a 3 ½ year period. The measures taken can be divided between those that were expected to have immediate effects and those whose benefits would be seen in the longer term. These are described below (SalmonChile, 2009: sanitary measures).

4.2.-Rapid measures taken with immediate effects

4.2.1. Voluntary measures adopted by the Industry

Less than 1 month after the first ISA case, the industry established the first voluntary agreements and initiated a series of collaborative actions to avoid the dispersion of ISAV and improve detection and depopulation of infected sites. There were many meetings between companies and the association to establish these first measures.

In addition, three months after the diagnosis of the index case, INTESAL and other companies and institutions organized an international workshop to provide government and the Industry with suggestions on monitoring, detection techniques, control measures, and regulation/enforcement tools. This workshop helped the government and INTESAL establish the first set of control measures for ISA. This initiative was repeated one year later, bringing more information and experience to the country.

INTESAL lead the industry efforts to establish good practices to control Caligus and ISA which were perceived to be associated. Independent of the government they developed the Salmon Industry Health Policy, which had five objectives and contained 44 measures to control and prevent disease and ensure sustainable growth of the salmon industry. This policy was supported by all the associated companies and was regularly reviewed and audited. Most of the 44 measures were integrated into the regulation by the Government several months later.

Three of the five objectives of the health policy specifically addressed pathogen spread: (a) to reduce the likelihood of perpetuating fish pathogens within the industry; (b) to minimize the risk of introducing exotic pathogens via the importation of eggs; and (c) to ensure the production of healthy smolts and minimize pathogen transfer from fresh water facilities. To achieve these objectives, the industry designed a list of recommended management practices in 10 parts covering all sectors of the industry. These were to be implemented within a five year period by the members of SalmonChile, beginning in 2009. Currently, about 90% of these measures have been implemented, and most agree that the top seven measures responsible for the recovery are:

1) All in all out farming with fallowing periods and zone management
2) Restriction of fish movements
3) Coordination of sea lice control
4) Vaccination,

5) The use of good quality smolts.

6) Reduction of Farm stocking numbers (total biomass)

7) Better surveillance and better diagnostic capacities.

Other measures included:

- Decreased use of transient estuary sites for all species, which increases the risk of pathogen dissemination between them.
- Decreased use of lake sites for Atlantic salmon smolt production, which permits mixing of fish populations and increases the risk of pathogen transmission.
- Proper inactivation of pathogens in dead fish.
- Freshwater-only rearing of Atlantic salmon broodstock.
- Weekly sea lice monitoring and treatment when there is an average abundance of 3 adult lice per fish.
- Two disinfections for eggs.
- Single species at all sites.
- Biosecurity protocols for visitors and farm staff.
- All sites must be fallowed in a coordinated way after a 24-month period.

As was mentioned above, many of these measures have been incorporated in the Government regulations, which apply to the entire salmon industry. The Voluntary Industry measures are audited by SalmonChile to ensure compliance, and company CEOs meet monthly to discuss implementation.

4.2.2.- Contingency Plan adopted by the Government to control ISA

Almost 2 months after the first case of ISA was detected the Government enacted the Contingency Plans to control ISA, and shortly afterwards the plan to control Caligus. These plans were based in on an intensive collaboration with foreign institutions and companies who had experience dealing with these diseases and targeted preventing and controlling the spread of infectious disease. Also SERNAPESCA increased its inspection capacity by reallocating resources and meeting frequently with the industry in the south of the country.

These government measures were aimed at:

1) Reducing the spread of ISAV and Caligus between farms by identifying and eliminating cases early in the disease process and preventing the introduction of the virus to uninfected sites. The measures targeted many of the epidemiological factors involved in the spread of ISAV, including sea lice control.

2) Reducing the likelihood of introducing ISAV from foreign sources.

3) Early detection through increased surveillance and mandatory removal of infected fish to prevent the spread to other farms.

These immediate measures taken by the Government in 2007 – 2008, which essentially intensified biosecurity on farms, quality assurance of diagnostic laboratories and mandatory reporting of ISA cases, are detailed in Box 1, "*Mandatory Reporting*",

The biosecurity measures reduced the likelihood of acquiring ISAV from foreign sources, as well as from neighboring farms. They also reduced the probability of viral transfer between facilities within Chile. The regulations for diagnostic laboratories were aimed at increasing the chance of early viral detection.

Box 1: Mandatory Reporting

ORIGINAL MEASURES:

One of the principal elements of the "Specific Sanitary Program of ISA Control and Surveillance" was the reporting of suspected or confirmed cases of ISA to SERNAPESCA. This reporting includes:

- Salmon farms must report immediately to SERNAPESCA, the reasonable suspicion or the detection of ISAV. The notification should be sent to notificacionisa@sernapesca.cl. Also, farms must send an Epidemiological survey plan, within 48 hours after the notification. That survey format can be downloaded from www.sernapesca.cl.

- Diagnostic and references laboratories: in case that any laboratory suspect or has a diagnostic of ISA in an official or private monitoring effort, the lab must notify immediately to SERNAPESCA about that finding. The notification should be sent to diagnosticoisa@sernapesca.cl or within the web page of SERNAPESCA.

- **Others:** Any person that has information about a suspicion of the presence of ISA, such as the appearance of the disease, unexplainable mortalities, etc., should notified to notificacionisa@sernapesca.cl or directly to agency offices.

REGULATION IMPROVEMENT:

It includes ISAV and other exotic pathogens and it has added:

- Independent auditing of labs and farms.
- Surveillance now includes multiple agent or pathogens, with increased sampling including wild fish in both fish water and sea water.
- Increased sanctions for individuals that violate regulations.
- Increasing the capacity and power of SERNAPESCA to enable monitoring for compliance of the sanitary measures and other regulations. They also enforced their ISAV and sea lice surveillance and control programs.
- Discussion in the Panel of experts of proposal to establish Regulations to restrict smoltification of Atlantic salmon in lakes and estuaries to prevent mixing of populations.
- All information on ISAV test results are made available to the public.

4.2.3. Industry changes that helped control ISA

In addition to the fish health measures implemented by the industry and enforced by the government (Box 2, "*A summary of the immediate measures taken by the Government in 2007 – 2008"* and Box 3, "*Biosecurity and sanitary regulations adopted by the Chilean Authority"*), several other changes were introduced by the salmon producers, including:

- A reduction in the number of fish on farms (from an average of 1.2 million to approximately 800,000). This reduced the number of cages used on a normal farm to between 18 and 20 and it allowed a cap on rearing densities to be set at maximum 17 Kg/m^3. In turn, this lowered the amount of virus produced by infected farms so the infectious zone around these farms was reduced.

- There was a change in the species farmed from predominantly Atlantic salmon to Coho and Trout (See Figure 6). Rainbow trout and Coho salmon are not as susceptible to the ISA disease as Atlantic salmon (Rolland and Winton, 2003). Mardones *et al.* (2011) recently reported that within the X^{th} Region, ISAV was reported in 4/80 (5.0%) of trout farms, and in the XI^{th} Region in 1/48 (2.1%) of trout farms. However, because it is difficult to detect ISAV in these carrier fish species, especially in the case of trout, they may contribute to making the virus endemic (Rolland and Winton, 2003; Kibenge *et al.,* 2006; MacWilliams *et al.,* 2007; Biacchesi *et al.,* 2007).

- There was a reduction in the number of Atlantic salmon farms (i.e. from 375 in 2007 to approximately 66 in 2009). In practice, this resulted in less farms concentration for this species.

- As a result of using fewer salt water leases, companies could be more selective in the sites they used. The industry now considers site selection one of the most important factors for reducing the risk of infectious diseases due to proximity to their neighbors. Some companies are even applying risk analysis systems to define priorities in terms of the sites to be stocked.

- There was a reduction in the demand for Atlantic salmon smolts (due to the reduced number of active salt water sites), which reduced the demand on the fresh water facilities and may have resulted in the elimination of poor quality fish at the fresh water life stage prior to salt water transfer.

- The use of good quality smolts[4] may have improved resistance to several pathogens.
- The industry also realized that introducing larger smolts on salt water sites decreased the time in salt water and the risk associated with this life stage.

- Some companies were able to eliminate their ISA infected fish more quickly because they had capacity in their processing plants due to the significant decrease in overall production.

- As the demand for diagnostic tests increased, the capacity and quality of the private diagnostic laboratory facilities improved. This increased the sensitivity and speed for detecting virus.

4.2.4. Virus characteristics that facilitated the effect of the measures taken

In addition to actions taken by the government, industry and companies that helped to reduce the spread of ISAV between farms, there were also key characteristics of ISAV that helped the control of this virus in the relatively short period of time.

- "True" vertical transmission of the virus is limited, if it exists at all, so eliminating infected broodstock and egg disinfection is likely an effective method of preventing the spread of the pathogen from parent to progeny in most cases.

- Although it has not been tested scientifically, it is possible that the non-virulent form of ISAV (ISAV HPR0) which is now endemic in Chile may be providing some level of herd immunity against the virulent forms of ISAV. In all regions where ISA has occurred in the world, including Norway, New Brunswick-Canada, Maine-USA, Scotland, and Faroe Islands, the non-virulent strain of the virus has become the predominant genotype.

[4] In general terms a fish evaluated to be physiologically ready to be transferred to sea water and free of disease.

Box 2: A summary of the immediate measures taken by the Government (2007 – 2008).

- Implementation of an ISAV surveillance program for both fresh and salt water facilities including:
  - Site visits every three months to farms for all salmonid species and more frequently if a farm was in close proximity to a virus positive farm.
  - Mandatory testing of 30 fish from each farm, at least every 3 months with sampling biased towards selection of weaker fish.
  - Individual testing of all broodstock
    - The practice of screening broodstock for ISAV and disinfecting eggs most likely prevented the introduction of ISAV in fresh water facilities after 2008.
  - Mandatory reporting as specified in Box 1.
  - Specific biosecurity conditions were established to harvest; transport and processing fish, and effluent disinfection in plants.
  - Surveillance study of wild fish in fresh and salt water.
- Implementation of an ISAV control program that:
  - Required all farms with ISAV to cull fish in positive cages or all the fish in the farm, depending on the prevalence.
  - Required all farms with ISAV to eliminate or harvest their fish in a manner that contained effluent liquid waste and then treated before disposal.
  - Required quarantine for all farms that were positive for ISAV and all farms in close proximity to ISAV positive sites until the infected fish were removed.
  - All farms in the infective zone were placed under increased surveillance.
- Implementation of a sea lice surveillance and control program that required:
  - farmers to report sea lice levels biweekly.
  - farmers to treat for sea lice once the average abundance was greater than 6 adult lice per fish.
  - Improved seal lice management by permitting the use of 3 treatment drugs.

Box 3. Biosecurity and sanitary regulations adopted by the Chilean Authority

- Reiteration and strict control of mandatory reporting of mortality on sea water sites.
- Testing of fish for list 1 and list 2 (see note below) pathogens no more than 15 days prior to any fish movement.
- A ban on movement of smolts from zones of poor sanitary condition to zones of better sanitary condition.
- Requiring that a designated fish health professional be appointed for each company.
- All in all out stocking, i.e. no mixing of separate year classes, including estuary and lake sites. Fish are required to all be introduced to a site within a 3 month period.
- Mandatory site fallowing between year classes, including estuary and lake sites.
- Designation of neighborhood zones, and coordinated fallowing within these areas.
- Strict enforcement of minimum distance between salmonid farms of 1.5 nautical miles.
- Minimum distance between processing plants and farms of 1.5 nautical miles
- No sharing of day-to-day equipment between salt water farms and mandatory disinfection of the larger equipment that is shared between farms
- Regulations on net cleaning operations
- No movement of fish after salt water entry
- Daily removal of dead fish and mortality treatment (silage).
- Regulation of fish densities in sea water
- Containment of liquid waste during harvest and treatment before disposal.
- Treatment of effluent water during transport for fish known to be infected with ISAV
- Reinforcement and control of all eggs disinfection
- Restriction of egg imports. No importation of eggs from countries with ISAV or Pancreas disease (PD).
- Mandatory disinfection of all processing plant effluents receiving fish from a quarantine area (since 2009).

NOTE: The high risk diseases are classified in List 1 or 2, considering their virulence, prevalence, dissemination level and economic impact for the country.
The List 1 is including high risk diseases that have to be declared to OIE or those which have not been detected before in the national territory or those with distribution restricted to some defined areas in the country. List 2 includes the rest of the diseases.

4.3. Measures Taken with longer term effects

4.3.1. The Role of the Banks.

By financing the growth of most of the major salmon farming companies in Chile, banks played a critical role in the industry expansion that preceded the ISA epidemic. At the heart of the crisis in 2009, it was estimated that salmon farming companies and their suppliers owed the banks a cumulative total of USD four billion (Murias, 2009). Cumulative debt of the farming companies was about half of this and individual companies were indebted in amounts up to USD 380 million. Clearly, without access to this financing, the industry would not have been able to expand as it did.

As the full impact of the ISAV epidemic became apparent early in 2009, the banks had to decide whether to cut their losses by forcing companies into bankruptcy or to continue to support them by renegotiating their loans. They chose the latter course and were advised in this process by the company Claro y Asociados which developed a valuation model of the 10 largest companies that had debt with them.

A key consideration in this decision was that the banks understood and believed in the underlying premise of salmon farming as a business:

- There was increasing global demand for seafood, which natural fisheries can no longer meet.
- Farmed salmon and trout were proven aquaculture products.
- It had been proven that Chile had excellent conditions for salmon farming.
- Salmon farming industries in other countries have previously suffered from ISA and have recovered.

Therefore, it was likely that the Chilean salmon farming industry would also recover and the value of the companies and their assets would be restored. Though not without risk, loan renegotiation rather than asset seizure and bankruptcy seemed to be the best course; and this decision has proven correct and fundamental to the industry’s recovery. For this, the banks and those who advised them deserve much credit. Their insight, patience and disinclination to panic serves as a model for new aquaculture industries elsewhere that might one day find themselves in a similar position.

However, the banks rejected the idea of any debt forgiveness and proceeded over a period of several months to renegotiate loans with each indebted company. This is documented in news reports published during this time in Chilean business newspapers and on the website www.FIS.com. Loan terms were extended, grace periods were granted on debt repayment, interest rates were reset and collateral was strengthened as companies were required to pledge more of their assets.

An especially important part of the collateral negotiations was the passing of modifications to The GLFA, which granted a perpetual property right in the aquaculture concessions. Through the Banks and Financial Institution Association (ABIF) the banks urged the Chilean Senate in June 2009 to pass this measure as a matter of urgency without which they argued "a good proportion of producer firms" will disappear along with supplier companies. They pointed out that the passing of this measure would also serve as a mortgage guarantee to activate a USD 450 million line of credit to which the Chilean government had pledged 60 per cent in collateral (Murias, 2009).

Loan renegotiations were conducted with each company by one lead bank on behalf of all lenders. In addition to changes in repayment, interest and collateral terms, lenders also required that a bank observer be placed with each company to ensure financial propriety and that the companies must comply with new sanitary rules established in the Law and those developed by INTESAL. These voluntary rules, which are described in Section 4.2.1, were timely and effective.

Not only did the banks demand acceptance of these new rules through covenants in the revised loan terms, but together with INTESAL and the Government they helped to fund a monitoring program to audit the salmon farmers' compliance with them. This program runs through August 2012 when it will be reviewed and when it will be necessary to decide if the new RESA rules and enforcement program are sufficient to replace it. In this respect, differences in rearing methods and disease status between Atlantic and Coho salmon and rainbow trout are significant. For example, farmers of Atlantic salmon are concerned about lack of mandatory vaccination of smolts of all species against ISA and other diseases in the new RESA rules, as well as the smolting and subsequent movement of live Coho salmon and Trout from estuaries (Corniola, 2010). Resolution of these issues must be part of whatever decisions are made.

Finally, as the salmon farming companies' prospects recovered early in 2011 and it appeared that the worst of the ISA crisis had passed, there was an opportunity for companies to try to raise new capital through public offerings of their shares. The money raised would allow them to pay down debt and/or to finance new inventory and capital improvements demanded by the new RESA rules (SUBPESCA, 2011, Decree 349). The opportunity seemed especially good because of a generally positive mood in financial markets at the time together with increasing prices for farmed salmon. Several salmon farming companies who went to the market early in 2011 were successful. However, later in 2011, as global financial confidence ebbed and salmon prices declined (Figure 13), prospects for raising new capital diminished. At least one company delayed its stock market debut due to unfavorable market conditions (Murias, 2011,b).

The principal achievements with expected long term effects are presented in Figure 14.

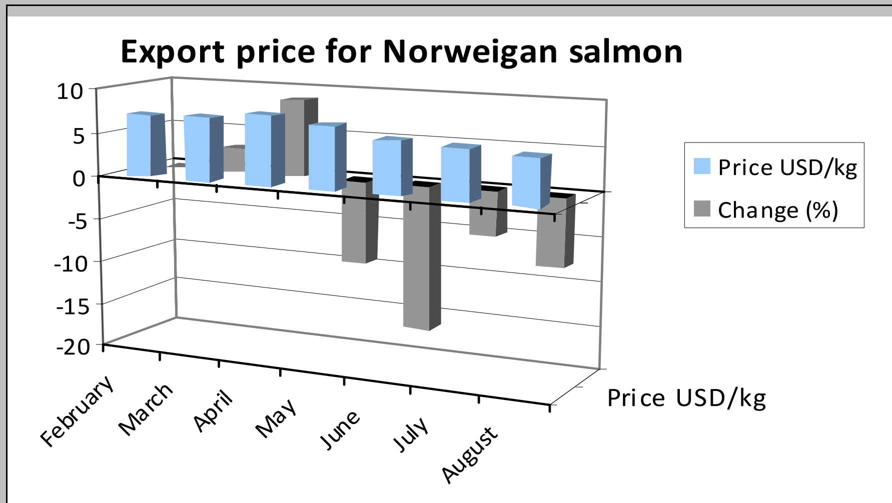


Figure 13. Export price for Norwegian salmon (February – August 2011). Source: IndexMundi, http://www.indexmundi.com/commodities/?commodity=fish

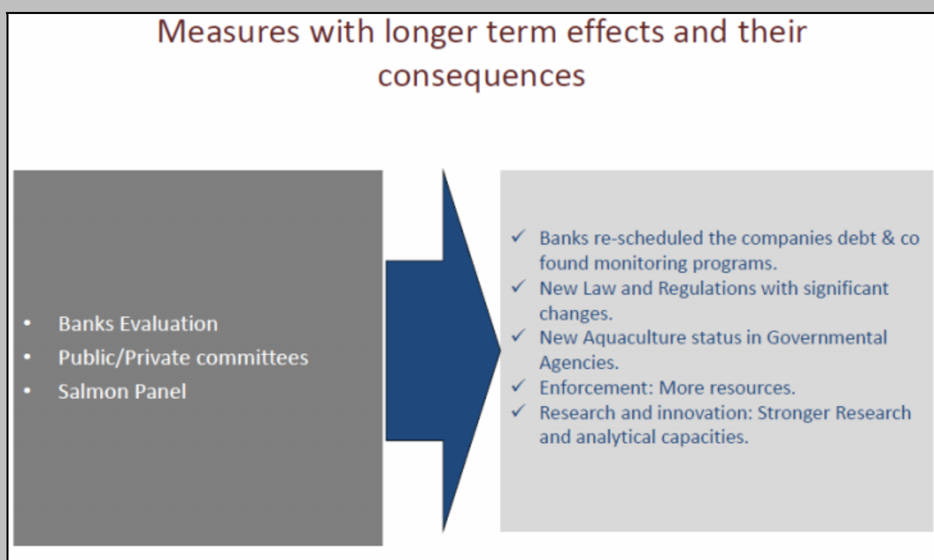


Figure 14. Principal consequences of measures with expected longer term effects.

4.3.2.-The Salmon Table (or Panel) and other initiatives to restructure regulation and institutional arrangement

In addition to the immediate disease control programs the Chilean government also formed "La mesa del salmon" (The Salmon Table). This group, comprising several branches of government was charged with further evaluating the industry with regards to practices that required regulations and to propose new laws and regulations to respond to these challenges.

Also they evaluated the experience of other countries facing similar problems and visited and interviewed all stakeholders connected with the aquaculture industry to obtain their perception and aspirations. Universities, research groups, and NGO´s were also invited to give their views on the main industry changes and its needs for organization, research and infrastructure.

The outcome of the Salmon Table initiative has been modification to the Fishery and Aquaculture Law and regulations. Recent (2011) specific modifications to the Law that directly affect disease control include:

New Licenses regime**.**

New licenses will not be issued for an indefinite time. They are granted for specific periods of time and subject to strict compliance with environmental and labor laws. Violation of regulations will lead to the termination of the lease permit. Some licensees that are in compliance with lease requirements may relocate, subject to certain conditions, which may enable a reduction in the number of companies operating in a particular zone, who can then better coordinate their activities as part of 'Area Management Regimes' .

Area management regime.

This is a system that developed from the establishment of environmental zones, which allows for more effective management of health and productivity issues. Area management has permitted coordination of fallow and harvesting periods as well as treatments for disease and parasite infestations, resulting in environmental and sanitary benefits for the different zones.

Area management has also been applied to fresh water and estuary systems to reduce their potential for pathogen dissemination, although the new regulation establishes that new licenses cannot be issued in lakes and rivers in Chile and severely restricts them in estuaries.

Improvement and new control of the environmental indicators.

The government has set standards for equipment on farms in order to reduce escapes of fish from farming systems and audits farms against these standards to ensure compliance. The government also established more rigorous environmental parameters that must be measured and met to ensure environmental sustainability of the farms.

Biosecurity throughout the value chain.

Due to the numerous independent stakeholders throughout the production chain of salmon aquaculture, it was necessary to ensure that all practices throughout the production process are conducted in a responsible manner. The government has taken steps to regulate auxiliary industries that can have an effect on fish health (i.e. net cleaning and disinfection harvest practices, boat traffic between farms, etc.).

Institutional Strengthening.

As a result of The Salmon Table, a panel of experts was established to make recommendations on scientific and technical matters relating to industry practices. This proactive group is one example of the changes that have occurred in the industry post ISA.

Public access to industry information**.**

Because it was recognized that good stewardship was an issue prior to and during the ISA crisis, The Salmon Table established a mechanism by which production and health information from farms was available to individuals in the industry and also reported to the general public. This was done to facilitate cooperation between neighbors regarding disease control and prevention as well as to encourage industry transparency, which was part of the new Government policy.

The most significant consequences of these changes are detailed in Box 4, "*Essential changes with long term effects*".

Box 4: Essential changes with long term effects

- New licensees are now for 25 years, and they may be relocated in specific cases complying with certain requisites.
- Licenses can be terminated if there are reiterated environmental faults and anti - union actions.
- Zoning based on biological characteristics allows relocation from areas that require strategic fallowing
- Implementation of macro zones to limit disease spread and tending to manage the zones separately as environmental zones.
- An improved annual environmental assessment of sediments and benthos contracted by the government but paid by the industry
- SERNAPESCA strictly controls mandatory reporting of ISAV and exotic diseases positive results from all private diagnostic labs.

5. THE RECOVERY AND OUTLOOK FOR FUTURE PRODUCTION

5.*1.-The gradual recovery along the value chain*

5.1.1.-The effect of measures taken at different levels.

The measures described above have clearly impacted the industry in a favorable way in the short term and have established the basis for better performance in the long term based on adequate regulation and voluntary agreements.

The effects of the changes were first apparent in sea water production in the second part of 2009 when several companies started experiencing lower mortalities and improved growth rates (A. Alvial, 2011, personal communication). As a consequence in 2011, the companies were ready to stock more Atlantic salmon.

These changes have also lead to a much improved perception of the industry among investors and the banks, which, in turn has meant that capital to finance renewed growth of the industry has been available

5.1.2.-Production ratios and costs

It is now generally accepted that the recovery of the Chilean salmon industry started in 2011 and the volume of Atlantic salmon harvested will reach its pre-outbreak level (Asche *et al.,* 2009) sometime between 2013 and 2015 (Figure 15). Evidence of the recovery can be found in several performance indicators as described below.

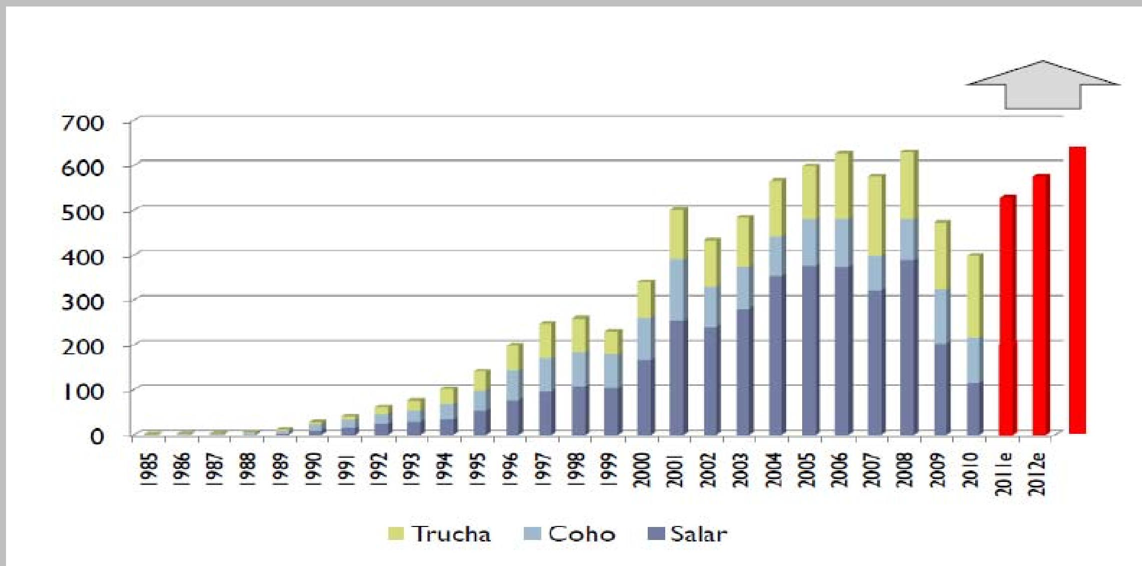
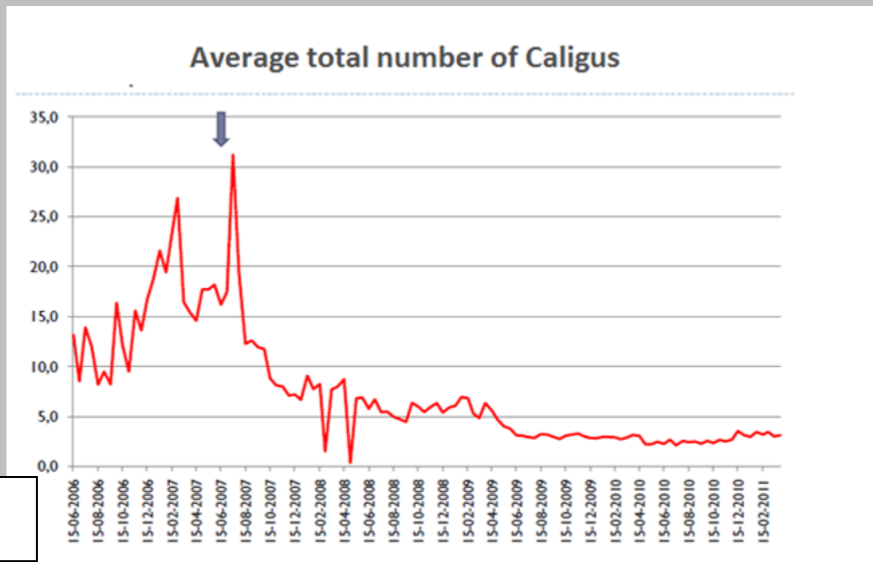


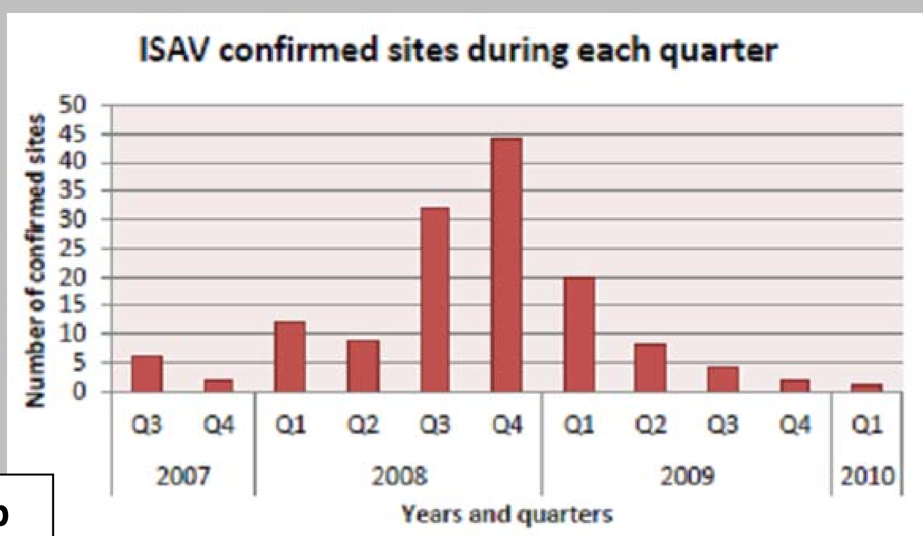
Figure 15. Evolution of Salmon production in Chile (3 color bars) and projections after ISA crisis recovery (red bars). Source: Adapted from Gárate (2011)

The improvement in fish performance has been especially good in Atlantic salmon, though advances have also been observed in the other two species. Control of Caligus and ISAV and the associated decrease in mortality is shown in Figures 16 a, b and c. Improved growth for groups closed (harvested) between 2008 to 2010 is shown in Figure 17, based on preliminary data from 2010, which lead to an increase in the kilograms produced per smolt stocked (Figure 18 a), and an increased average weight of fish harvested following the crisis (Figure 18 b). These indicators of farm performance have now surpassed pre-ISA levels, which suggest better management of fish production throughout the production cycle. In turn, this better performance has led to an increase in Atlantic salmon smolts stocked as shown in Figures 19 a and b.



Average total number of Caligus
35,0
30,0
25,0
20,0
15,0
10,0
5,0
0,0
15-06-2006
15-08-2006
15-10-2006
15-12-2006
15-02-2007
15-04-2007
15-06-2007
15-08-2007
15-10-2007
15-12-2007
15-02-2008
15-04-2008
15-06-2008
15-08-2008
15-10-2008
15-12-2008
15-02-2009
15-04-2009
15-06-2009
15-08-2009
15-10-2009
15-12-2009
15-02-2010
15-04-2010
15-06-2010
15-08-2010
15-10-2010
15-12-2010
15-02-2011

16 a



ISAV confirmed sites during each quarter
Number of confirmed sites
50
45
40
35
30
25
20
15
10
5
0
Q3
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
Q1
2007
2008
2009
2010
Years and quarters

16 b

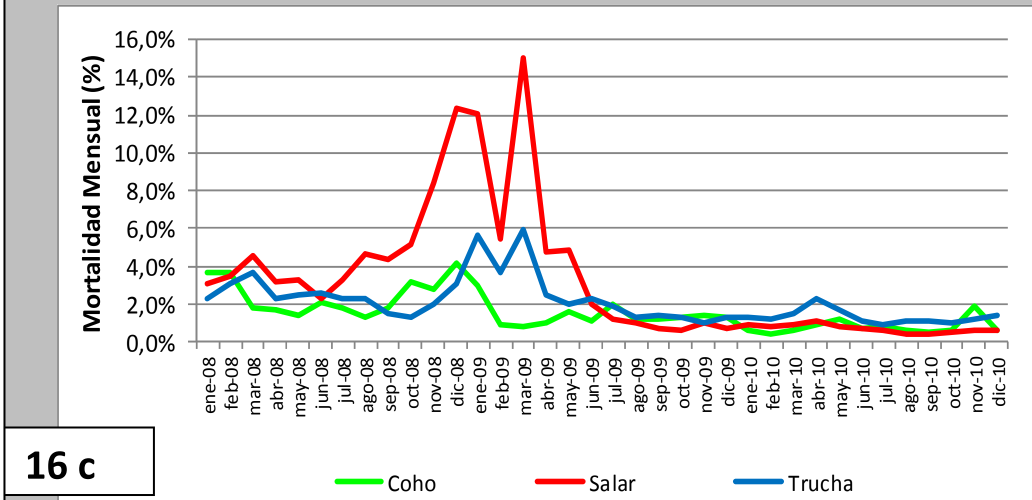


Figure 16 a, b and c. a: Average Caligus load per fish, b: ISA confirmed sites per quarter and c: monthly mortality for the 3 species.

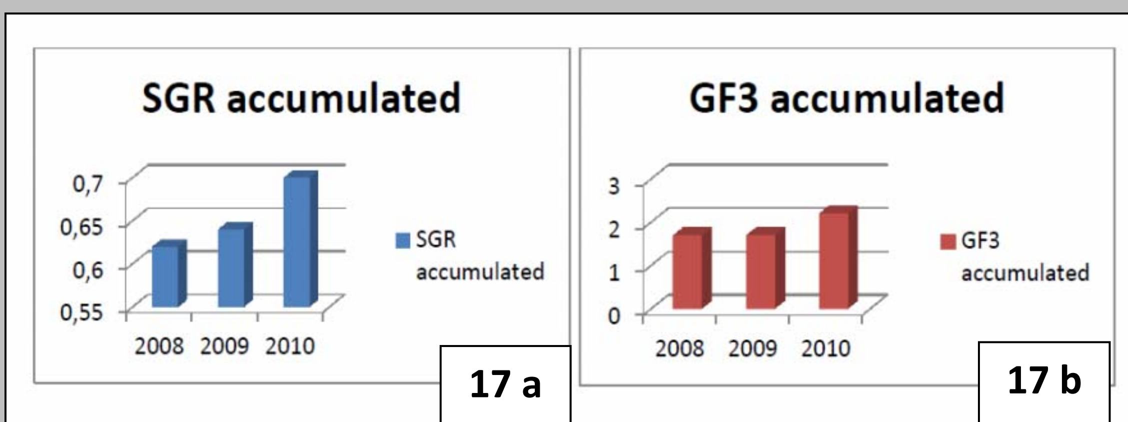
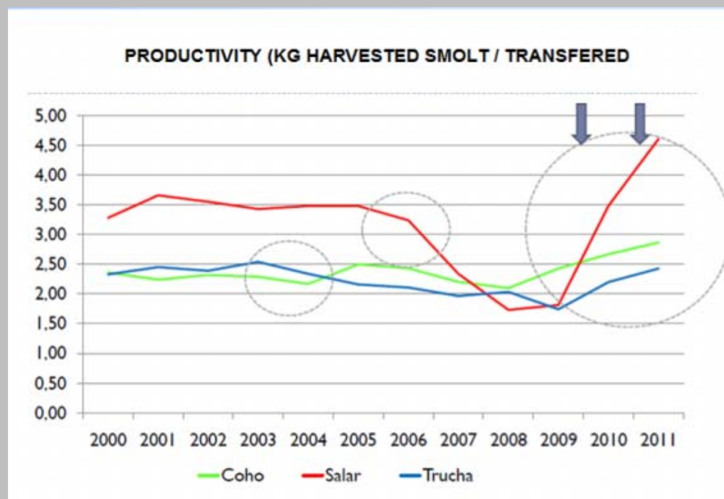


Figure 17. Accumulated growth rates for Atlantic salmon groups closed in 2008, 2009 and 2010, expressed as SGR[5] (a) and GF3[6] (b) (Source: SGS Chile – AAA joint venture: "Prácticas determinantes en la producción de salmonidos en Chile", based on statistical analysis of database representing 70% of Industry, March 2011).

[5] SGR: Specific Growth Rate: SGR=((ln (Final weight) – ln (Initial weight)) / days x 100 units: (gr/t)
[6] GF3: Growth factor: GF3 = ((Final weight)^1/3 – (Initial weight) ^1/3) * (100/DGR)
DGR= Days degree (daily average temperature in Celsius degrees * the number of days)

18 a



18 b

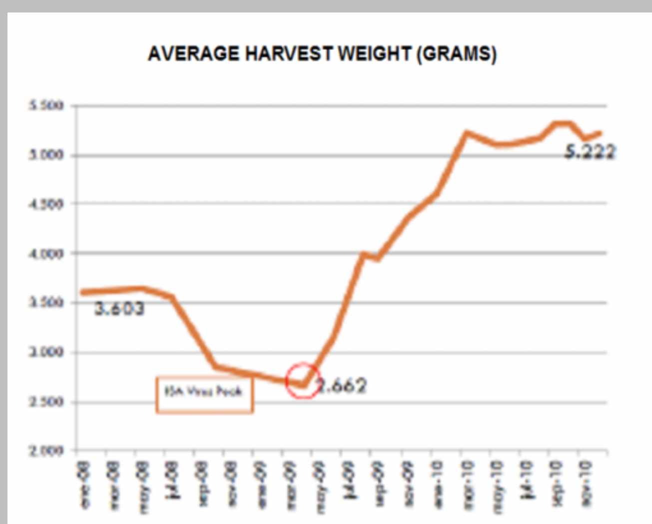
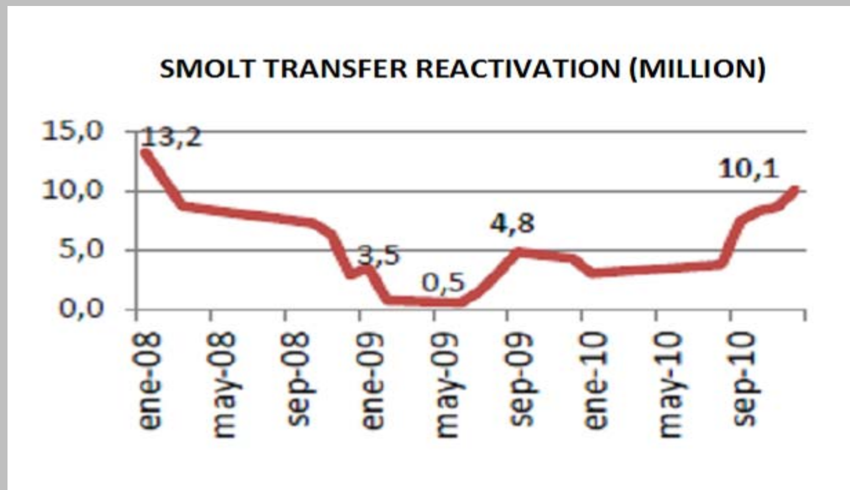


Figure 18. Productivity (Kg harvested per smolt stocked) (a) and average harvest weight (b) of Atlantic salmon, pre and post crisis.

19 a



19 b

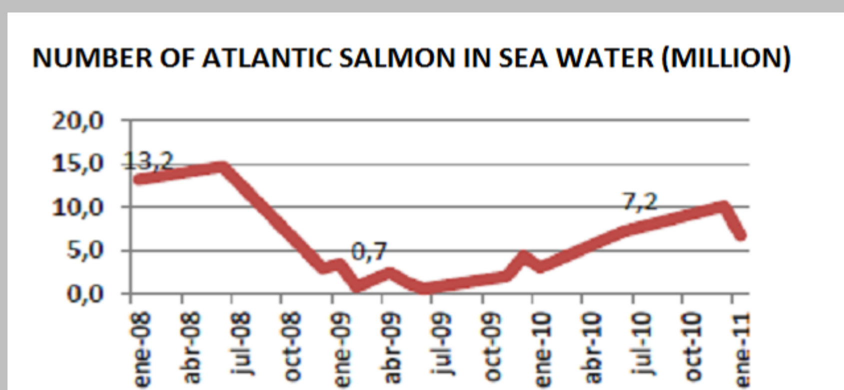


Figure 19. Atlantic salmon: smolt transfer into sea water per month (a) and number of fish in sea water (b), pre and post crisis.

During the visit to Chile, several people mentioned that another indicator of better performance was a reduction in the use of antibiotics in salmon farms and that some companies have excluded them in all or part or their operations. Antibiotic use indicates problems with bacterial pathogens. The major bacterial pathogens for the Chilean salmon industry are Piscirickettsia salmonis (SRS), Aeromonas salmonicida (furunculosis), Vibrio anguillarum (vibriosis), and Streptococcus phocae (streptococcosis). So, given the new measures in place a decrease in the total use of antibiotics in salmon farming in Chile and this should be introduced as an indicator of environmental/sanitary conditions.

Though no generic industry data is available presently, these performance improvements are also likely to have led to lower production costs, especially lower feed costs due to better food conversion rates. Some companies have estimated cost savings up to 30%. In turn, this means less waste production per kg of fish produced resulting in better environmental performance. Of course, these cost savings have been achieved as a result of stricter biosecurity measures, which increased other costs, estimates ranging between 20 to 25%. Whether or not cost savings due to better fish performance offset this increase remains to be documented and it would helpful to both industry and government if this were done.

5.2.-Recovery and Outlook for future production

5.2.1.-Production outlook

Improvements in production ratios have changed the expectations of future production and its increase from pre-crisis levels is now expected, albeit under the new regulations and production model. According to interviews with Industry people, the majority believe that in 2012 Chile will produce around the same volume as in 2006, therefore one year earlier than estimated by Asche *et al.* (2009). In addition, they think that the sustainable production level, considering measures in place and the present authorized licenses is about 700.000 tons. Any production beyond this will require expanding the geographic farming area (likely in the XIIth Region).

With the new laws, there will be likely changes in the industry structure with companies that can absorb the cost of the new regulations doing better than those that cannot. Companies with more concessions (licenses) are also likely to have opportunities created by wider geographical diversification, while smaller companies may find themselves restricted by new neighborhood rules and may need to merge or exchange licenses. The numbers of salmonids operating farms at October 2011 was 390 (Ansoleaga, 2011) over 1041 authorized licenses for this activity in the South of Chile (SERNAPESCA, 2009).

Consolidation of licenses, allowed by the new regulations, will favor sustainability of the industry as it will allow better environmental management of areas. Relocation of sites from X^{th} Region to XI^{th} and XII^{th} will also enable a better balance to be achieved in the use of these regions overall production capacity, which, in turn should be guided the best available scientific knowledge. At present the government is supporting studies to establish the dominant hydrodynamic characteristics of the regions on the basis of which it can then estimate carrying capacity in the salmon sea farming zones. There is general agreement that precautionary measures should be applied until sufficient information on the carrying capacity and dynamics of the areas is available, though the smaller companies are less receptive than larger ones about limiting biomass.

5.2.2.-Environment and fish health outlook

The limits on pen density and the breaks in production from the enforced fallow periods will result in a reduction in waste build-up in the environment.

The environmental indicators used to assess whether an aquaculture farm is operating within the biological capacity of its location include good water quality reflected in levels of dissolved oxygen at or near saturation, and healthy benthic conditions (i.e. oxic conditions in the first 2 or 3cm, normal biodiversity and low hydrogen sulphide levels). These parameters are monitored by government according to the clauses established in the Environmental Regulation for Aquaculture (RAMA), which was modified in 2010 to include new regulations that strengthened the evaluation of benthic sediments under farm concessions. Further all environmental monitoring now must be conducted by an independent entity approved and contracted by the Authority. Farms are required to meet the minimum standards, otherwise sanctions are imposed.

5.3.-Investment, financing and markets

5.3.1.-Financing and investment sources

As noted in Section 4.3.1, the banks have backed the industry recovery by extending the terms of existing loans, so that financing for most companies, at least to get back to where they were, seems assured.

However, the much improved fish performance, as well as notable market strength early in 2011, has encouraged visions of expansion beyond the pre-crisis level. Ambitions go as high as 1.5 million tons (Eposito, 2011) with annual sales of $5 billion per year. If that happens, it will mark a new chapter in the development of salmon farming in Chile and it will call for care and discipline by all involved if the industry is not to expose itself to the risk of another disease epidemic.

The banks and the investment community have a critical role to play in imposing such discipline. They are now well informed about the industry's strengths, weaknesses and risks. They accept its fundamental logic and understand the advantages that Chile has for its development. However, they have been chastened by the ISA crisis and will only back expansion if they can be satisfied that the lessons learned from it will be rigidly and relentlessly applied.

Both the industry and government have key roles in providing such assurances. First, the industry must repay its debt according to the new loan terms, or at least companies must demonstrate that they can repay it. If prospects for expansion continue to look good, both sides may determine that investment in new production is a better use of cash flow than debt repayment but, in the near term, it is essential for the farms to demonstrate continued good fish performance and financial vitality.

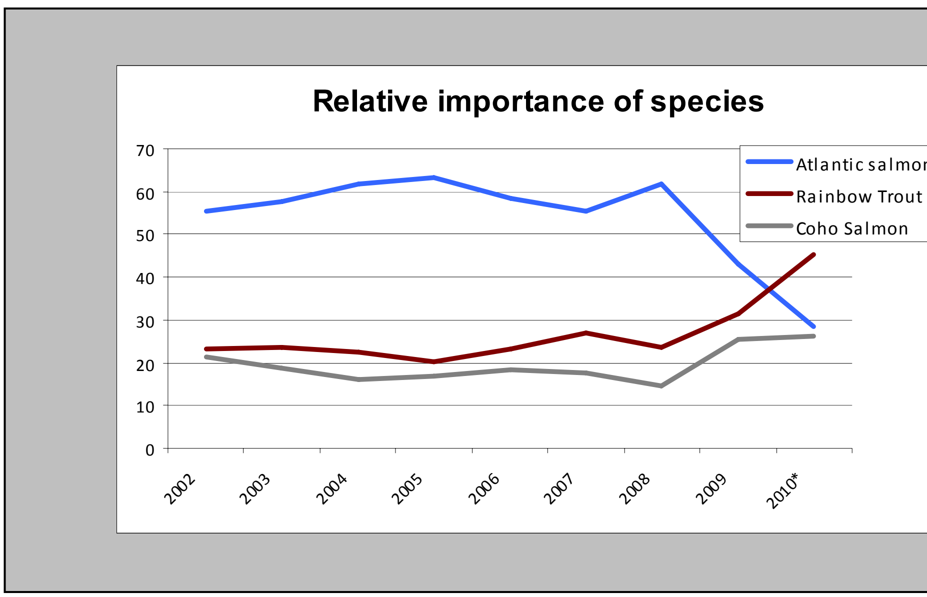
It is essential that the government press ahead with its program of surveillance and regulatory reform and demonstrate its commitment to enforcing the new rules. As discussed earlier, though there is a record of successful cooperation between government and the industry with mechanisms in place to assure effective public / private dialogue, there are several difficult issues still to be resolved. If industry expansion is to proceed smoothly and risks of another fish health crisis are to be avoided, government must drive this work forward and set policies and goals for the industry that ensure responsible growth.

All indications are that continued competitiveness of the Chilean salmon is highly probable, especially in view of the advantages that Chilean producers have in supplying markets in Japan, the U.S and Brazil. If the conditions described above are met, it seems likely that the banks and financial community will continue to be willing to make the needed capital available. According to one estimate (Murias, 2011, c), in order for the industry to achieve the full production potential of already approved concessions, it will require $700 million in new capital. To go beyond that to perhaps 1.5 million tons per year may need $1 to 2 billion more. Investors realize that by global investment standards, these are not huge sums and, though global financial markets are depressed presently, there are vast amounts of money now invested in cash accounts looking for better options. If it can be shown that expansion of Chile's salmon farming industry can be done safely, further investment will be attractive for the reasons that the financial community already understands. The question will then be: how quickly can or should expansion proceed? This must be guided by government policy, as discussed above, while it may be moderated by investors' perceptions of the future demand for farmed salmon and the outlook for salmon prices - see Section 5.6 below.

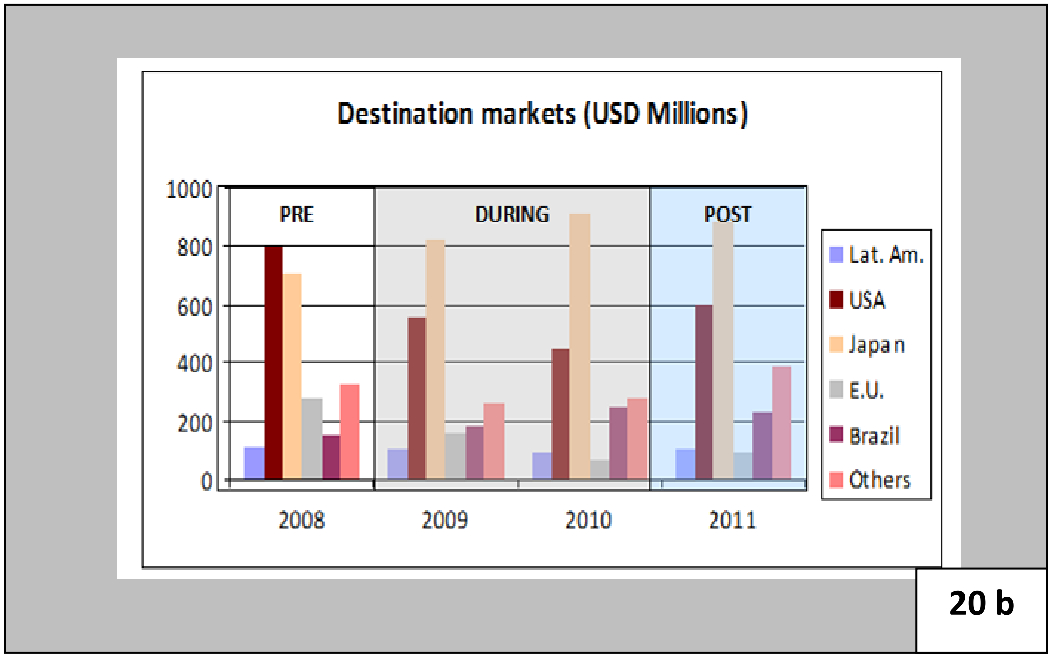
The recent experience has demonstrated that the changes introduced in regulation and in the production model has enabled a rapid recovery, but this has to be sustained to bring confidence and assure a better future for this strategic industry for Chile. Compliance with the new rules must also be accompanied by transparency to show that the industry is committed to a better way of doing things. That will be beneficial to both sides of the value chain, i.e. the markets and the investors, and will create a business environment where investment capital is available to an industry committed to the continuous improvement of its regulations and practices.

5.3.2.-Markets

The crisis caused changes in the relative importance of the salmonid species produced in Chile (Figure 20 a), due to the decrease of Atlantic salmon production. In turn, this led to changes in the relative importance of different markets served (Figure 20 b) while reduction in the total value of exports was moderated by an increase in prices caused by lower volumes of farmed salmon being available on world markets (Figure 20 c).



20 a



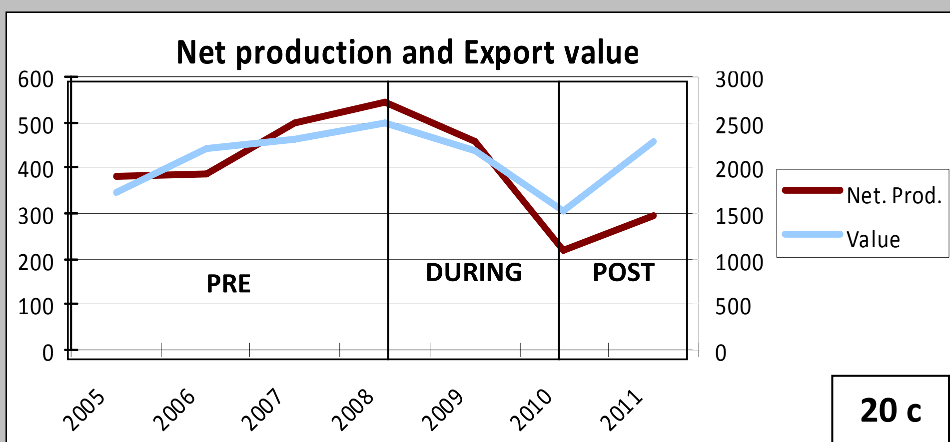


Figure 20 a, b and c. Changes, pre, during and post crisis in terms of a: species relative importance, b: destination markets and c: net production and export value. Source: adapted from Alvial (2011 b) and www.aqua.cl / Estadísticas.

As regards the future outlook, there is a general presumption among seafood business leaders, policy makers and investors that global demand for seafood will continue to grow while supply, unless it comes from aquaculture, will not. Therefore, it is presumed that market prospects for aquaculture products must be good. However, recent events in the market for farmed salmon show that good prospects do not mean ever-increasing or even stable prices; rather that consumers demand value in the food they buy and if seafood becomes too expensive they will stop buying it.

Spot prices in the farmed salmon market are usually quoted in Norwegian Kroner per kg for head-on, gutted fish ready for export from Norway. Earlier in 2011, the price was 40 NOK ($4.40/kg) and higher. For the week ending October 9th the price was 19 -20 NOK/kg ($2.09 - $2.20/kg), half what it was only a few months earlier. Market watchers, such as McDowell (2011), attribute this decline to three things.

First, buyers who pay spot market prices will only pay or can only afford so much. Fish smokers, for example, can only make their businesses work if the raw material they use is reasonably priced. Second, much farmed salmon is now sold under contract with prices agreed weeks or months ahead. Therefore, lower spot market prices do not affect the prices consumers see until it is time for contracts to be renegotiated, so there is a lag between spot market prices coming down and the stimulative effect this has on demand. Third, retailers are often slow to pass on cost savings to customers, choosing instead to benefit from higher margins, albeit on lower volumes.

Whatever the reason for the decline in salmon prices in different markets the events of 2011 serve as a warning that, however scarce seafood becomes and however good farmed salmon may be, now that it is a global commodity, price matters. Therefore, if Chilean salmon farmers contemplate expansion as discussed earlier, it will be essential for them to develop and expand their markets in parallel. In this respect, they have some advantages.

a) They continue to produce a mix of three species, the main market for two of which (Coho and Trout) is Japan (Figure 18b), where competition from salmon farmers elsewhere is less. This is because none of the competitors produce significant amounts of Coho and only Norway produces much sea trout. Investors in the industry see this spread of market risk as an advantage for the Chilean industry as a whole, even though the production of these different species introduces biosecurity and neighborhood management complications on the farming side.
b) Chilean salmon farming companies have logistic advantages over European producers in supplying fresh salmon products to the U.S. and increasingly now also to Brazil. According to SalmonChile, through July of 2011, 10% of Chilean salmon sales were to Brazil demand there having increased at the rate of 38% per year for the past five years. It is even thought possible that, one day, Brazil could become the main market for Chilean salmon (Murias, 2011 a).
c) Due to its naturally favorable salmon farming conditions and lower labor costs, Chile may have a cost advantage over producers in Europe or N. America in the production of value added salmon products, development of which is widely seen as a way to increase demand for farmed salmon in general. And, since such products are more easily branded than raw fish, they may make it easier to launch co-marketing programs with other Chilean agricultural products such as wine. Also, if they are made to be shelf-stable, they can be shipped by sea, thereby reducing the cost of freight and making it possible to pass on better value to the end user. Market observers, such as Callander McDowell, have long advised that the development and promotion of more value added salmon products is the best way to increase demand for farmed salmon and to provide for greater price stability.

Finally, Chilean salmon farms are mostly owned and run by vertically integrated companies with their own processing plants and marketing activities. They have developed in a relatively short time as sophisticated international businesses with the management resources to be able to identify and respond to market challenges or opportunities. Some are even part of international salmon farming companies with well established marketing activities elsewhere. They are more than capable of dealing with the uncertainties of their industry's expansion and making it a success.

5.4.-Social and economic regional aspects

The ISA crisis highlighted the strong dependency of the Xth and XIth Regions´ economies on the salmon farming industry. The first impacts were seen at the sea water farms where a reduction of workers was necessary due to the closure of many farms that focused too heavily on Atlantic salmon. This was followed by the reduction or closure of several hatcheries. However, in terms of laid-off workers the most significant impact occurred beginning in the middle of 2008 when several processing plants, which were labor intensive, had to lay off their people.

The industry recovery described above stimulated a gradual reactivation of the industry starting in the second half of 2009. First, fresh water facilities had to begin producing smolts to be stocked in the sea given the better sanitary / environmental conditions. Then, starting in 2010 additional people were required for reactivated seawater operations continuing through 2011 when partial or total reactivation of the first processing plants began.

Consequently, unemployment rates have come down (Figure 21) while the economic activity Index of the Regions X and XI has increased (Figure 22). This steady growth in employment has, once again, positioned these regions among those with lowest unemployment in Chile and re-emphasized the vital importance of salmon farming to these regional economies.

A government program to improve port facilities and roads for the industry's long term development also created more jobs, particularly in the Chiloé zone. The government has also established a subsidiary plan to co-finance initiatives to improve the environmental / sanitary situation of the industry through innovation. To do that it has funding through the National Promotion and Innovation Agency - CORFO.

Also, a number of foreign services companies have established in the south of the country noticing better opportunities especially for research, technology and equipment. Additionally several of the professionals laid – off from the producer companies due to the crisis have created their own companies focusing not just in the salmon industry but also in other aquaculture ventures in Chile and other countries, particularly Brazil, Peru, Ecuador and Central America.

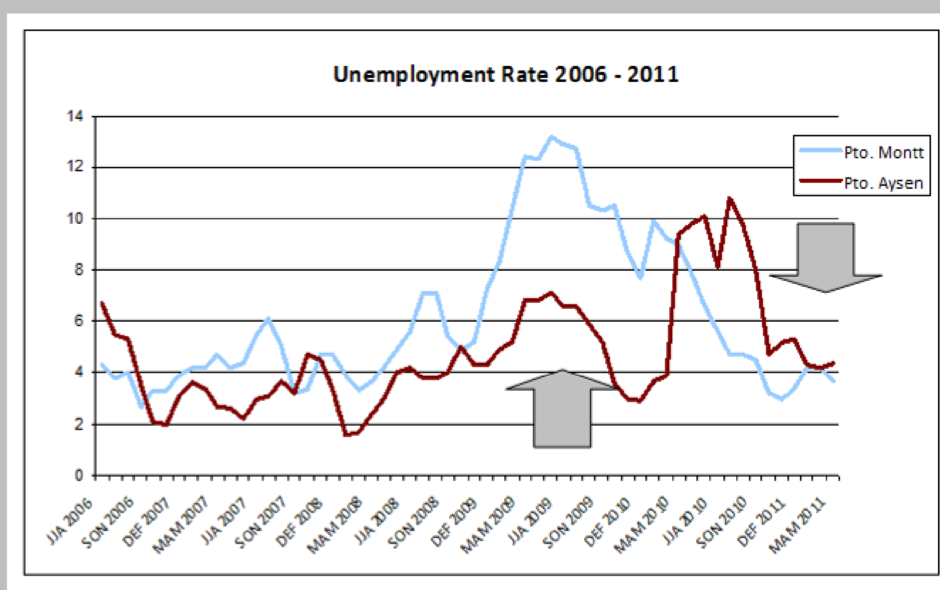


Figure 21. Unemployment rates in the capitals of the X^{th} region (Puerto Montt) and XI^{th} Region (Puerto Aysén). Source: Instituto Nacional de Estadísticas (2011): www.ine.cl / Boletines.

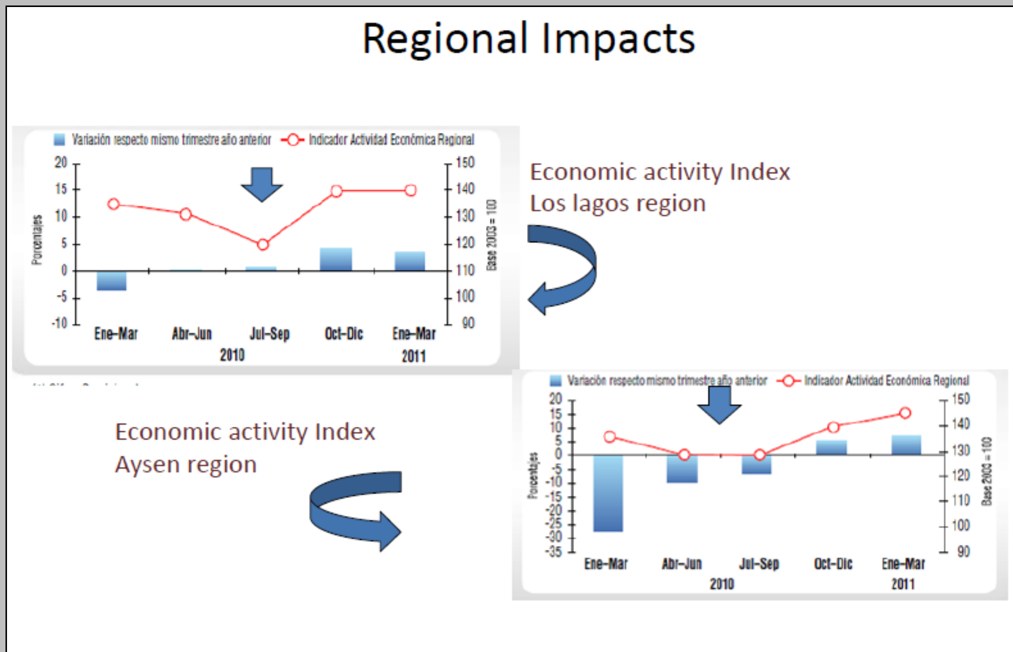


Figure 22. Economic activity index reflecting the ISA impact on the Xth and XIth Regions in 2010. Source: Instituto Nacional de Estadísticas (2011): www.ine.cl / Boletines.

6.-SUSTAINABILITY OF THE NEW CHILEAN SALMON INDUSTRY

6.1.-Key elements for a better future

The Chilean salmon farming industry has recovered quickly and well from the ISA crisis and there are reasons to have an optimistic view about its future. They include:

1. The importance of salmon farming to the Chilean economy, which means that Government is especially responsive to its needs in a way that was not always the case when the industry was smaller, or is the case in other countries where the industry is not such an important economic sector.

2. The intense efforts of SUBPESCA and SERNAPESCA during and since the crisis are evidence of this, as also is the Ministry of Economy's plan to establish a new Undersecretariat of Aquaculture later in 2011, or early in 2012, with the goal of growing the industry to USD five billion in sales by 2020.

3. Salmon farms are mostly corporately owned and professionally managed. Though overly aggressive farm expansion from 2000 to 2007 likely contributed to the ISA crisis, the industry's response, once the problem was recognized, was disciplined and professional. Members of SalmonChile, especially, showed themselves willing to learn from mistakes and to take the tough actions needed to bring things back under control.

4. The Chilean banks and financial community understand and believe in Chile's strengths as a salmon farming country, as illustrated by their supportive role during the crisis and the success of some public share offerings since.

6.2.-Challenges on the horizon

The question now is, will this impressive response from all the key players in the midst of a crisis be sustained to ensure the industry's long-term growth and viability? Some outstanding issues are going to be hard to resolve. For example:

1. The use of lakes and estuaries for producing smolts, especially of Coho salmon and trout. Can this be done in a way that maintains adequate biosecurity?

2. Definition and re-drawing of production 'neighborhoods' so that they are hydrographically accurate.

3. Definition of neighborhood capacity and how this should be allocated among concession owners within them.

4. Requirements for synchronized production and fallowing in neighborhoods that do not fit well with the production cycle of one or more of the three different species that may be grown there, or that make it difficult for smaller companies to maintain continuous production.

5. Simplification of the ownership of concessions within neighborhoods to make it easier to manage them on a single year class production cycle.

6. Creation of new Approved Aquaculture Areas (AAAs) to allow industry expansion while also accommodating the needs of existing users of the space.

These are all matters the resolution of which, ultimately, requires government policy, decision making and enforcement, though government recognizes that satisfactory outcomes are only likely if the industry, researchers and other private sector participants work together. These types of collaborations have been highly successful in the response to the ISA crisis, and mechanisms are now in place to allow such dialogue to continue. For example, in March 2011, -SUBPESCA appointed the Panel of Experts mentioned in point 4.3.2., to:

- Prepare the Health Regulations for Aquaculture (RESA).
- Analyze the potential for creating 'macrozones'.
- Review methods for the smoltification of salmon and trout.
- Complement the technical and health vision of the Ministry of Economy, whilst looking at the economic and social effects of the measures proposed.

This Panel's work has already resulted in the publication of proposed modifications to the sanitary regulations in August 2011 and recommendations on smoltification at the end of September 2011.

In addition, 'The Salmon Table" (Section 4.3.2), which was originally established to bring government and the private sector together to formulate the changes in the Fisheries and Aquaculture Law published in August 2011, has been reconstituted and now includes 'Sub-Committees' that will develop recommendations on:

- *Industry governance* - including information management; enforcement; transparency; timely communication and coordination within government, especially relating to the diagnostic and surveillance work it carries out.

- *Production model* - setting goals and controls for future production, trying to answer the question: how much salmon can Chile produce without risking another crisis?

- *Zoning* - dealing with all the issues relating to accurate definition and use of production zones (neighborhoods), including relocation of concessions where necessary and the setting of limits on production.

- *Research and Development* - identify research priorities, how work on them should be funded and how this should be coordinated between industry, universities and research centers. Examples include improving the efficacy of vaccines and compliance with food safety and other standards in foreign markets.

- *Infrastructure* - recommend improvements to facilitate farming in remote areas and to reduce biosecurity risks from infrastructure that is shared between neighborhoods.

Therefore the effective public /private dialogue that was established in the heat of the crisis is set to continue and suggests that the more difficult longer term issues will be resolved. If there is reason for concern, it is the challenge that government and its private sector collaborators will face in crafting and implementing new policy quickly enough to keep pace with the industry's renewed enthusiasm.

Understandably, Chilean salmon farming companies want to take advantage of the much improved performance they are now seeing in their fish and to recapture markets lost in the depths of the crisis. They are eager to increase production once more. But investment decisions to stock more smolts or to re-stock idle farms can be made more quickly than new policies can be developed and implemented. As the public / private dialogue continues it must seek to find a balance that will ensure that growth is sustainable.

6.3.-Production and Industry's responsibilities

As noted above, it is generally believed that sustainable production of farmed salmon for Chile is around 700,000 tons, based on the present number of licenses and fallowing periods. Monitoring environmental, health, and production indicators will determine whether this is indeed the biological capacity of the system. To achieve environmental and economic sustainability and to reduce the risk of another disease crisis, the industry will require discipline to abide by the new regulations and all companies in all sectors must be good stewards of the environmental resources they all share. To facilitate this, the industry must build a stronger relationship with its workers and the communities within which it operates, so there is a local sense of ownership of their product.

There are other challenges too. According to the former President of SalmonChile, César Barros, the challenges facing the new Chilean salmon industry in the near term (2011-2015) include:

a) Maintaining and preserving sustainable growth,
b) Establishing a new and improved reputation for care and responsibility in environmental, employment and political matters and
c) Recovering the market lost due to the ISA crisis.

In line with these points, the new SalmonChile Agenda considers as the essential aspects to be defined and improved within the next 3 years:

- Regulatory and production model
- Government Institutions
- Image and perception of the industry
- Markets and image
- Strength of the association
- Relationship with stakeholders
- Industry and science interaction.

7.-CONCLUSIONS AND LESSONS

The salmon farming industry recognizes that it will take more than laws, regulations and improved practices to prevent another disease crisis. The values and attitudes of those involved in the industry are a crucial component of preventing a future problem. Cooperation between groups is essential due to the nature of the shared water bodies used by closely interconnected producers.

7.1.-Conclusions

- In almost 3 decades Chile transferred, adapted and developed technologies, products and markets to become the second largest producer of farmed salmon in the world, creating value for the entire country and for the regions where the industry operates.
- However, this impressive technical and commercial success was not accompanied by matching research, monitoring and regulation to guard against foreseeable biological risks.
- This imbalance impaired the industry's ability to avert and control an outbreak of ISA in 2007.
- Productive, economic and social impacts were magnified due to the industry's size and rapid spread of pathogen facilitated by high concentration of farms in some areas and poor husbandry and disease control measures.
- A fast public – private coordinated effort enabled basic infectious disease control measures to be implemented and enforced.
- In parallel, longer term efforts involving the government, the industry and the financial sector allowed companies to survive while new laws and regulations laid the foundations for the industry's renewal.

- In just 2 years since the first ISA declaration (July 2007), the industry saw improvement in productive rates which in turn started to reverse the decline in harvest volumes in 2011
- These positive biological and production indicators as well as the new regulations and production model stimulated active fish stocking in salt water in 2010 and 2011 and it is expected that in 2012 – 2013 production levels will be back to those achieved in 2006.
- In spite of the new regulations and practices, there are still some important issues to address. They are:
  - Mechanisms to ensure that over - concentration of farming activity in certain areas is avoided.
  - Improved pathogen dispersion control strategies.
  - Boundary definition of production zones.
  - Definition of zone carrying capacities.
  - Surveillance programs to detect and/or predict new environmental and disease issues before they can affect the industry.

7.2.-Lessons from the crisis

The main lessons learned from the Chilean experience that contributed to a more sustainable industry are summarized graphically in Figure 23. We emphasize a few of the key points below:

a.- Government and Industries must develop national / local R&D programs to provide timely information to support effective regulations and enforcement.

b.- Development of a biosecurity system covering all sectors of the value chain. This system should target preventing the entry of pathogens. The system should also consist of a contingency plan for controlling the dispersion of pathogens should the prevention plan fail, which includes early detection within the country.

c.- The dynamics and biological carrying capacities of the environments hosting aquaculture activities should be understood in order to prevent deterioration that leads to fish distress and to disease.

d.-This understanding should allow the establishment of effective zone management programs and provide the basis for coordinated actions among users, such as fallow periods, programmed treatments, surveillance programs, etc.

e.- Prioritize practices based on fish welfare and close monitoring of key performance indicators such as levels of sea lice infestation, frequency of antibiotic treatments for bacterial disease, mortality, growth, FCR and harvest yield per smolt stocked.

f.- Reduce handling and use of drug treatments in order to improve long term farming sustainability and market acceptance of the products.

g.- Good communication between all industry stakeholders and government must be maintained to ensure issues are dealt with early and all parties involved are kept abreast of the situation.

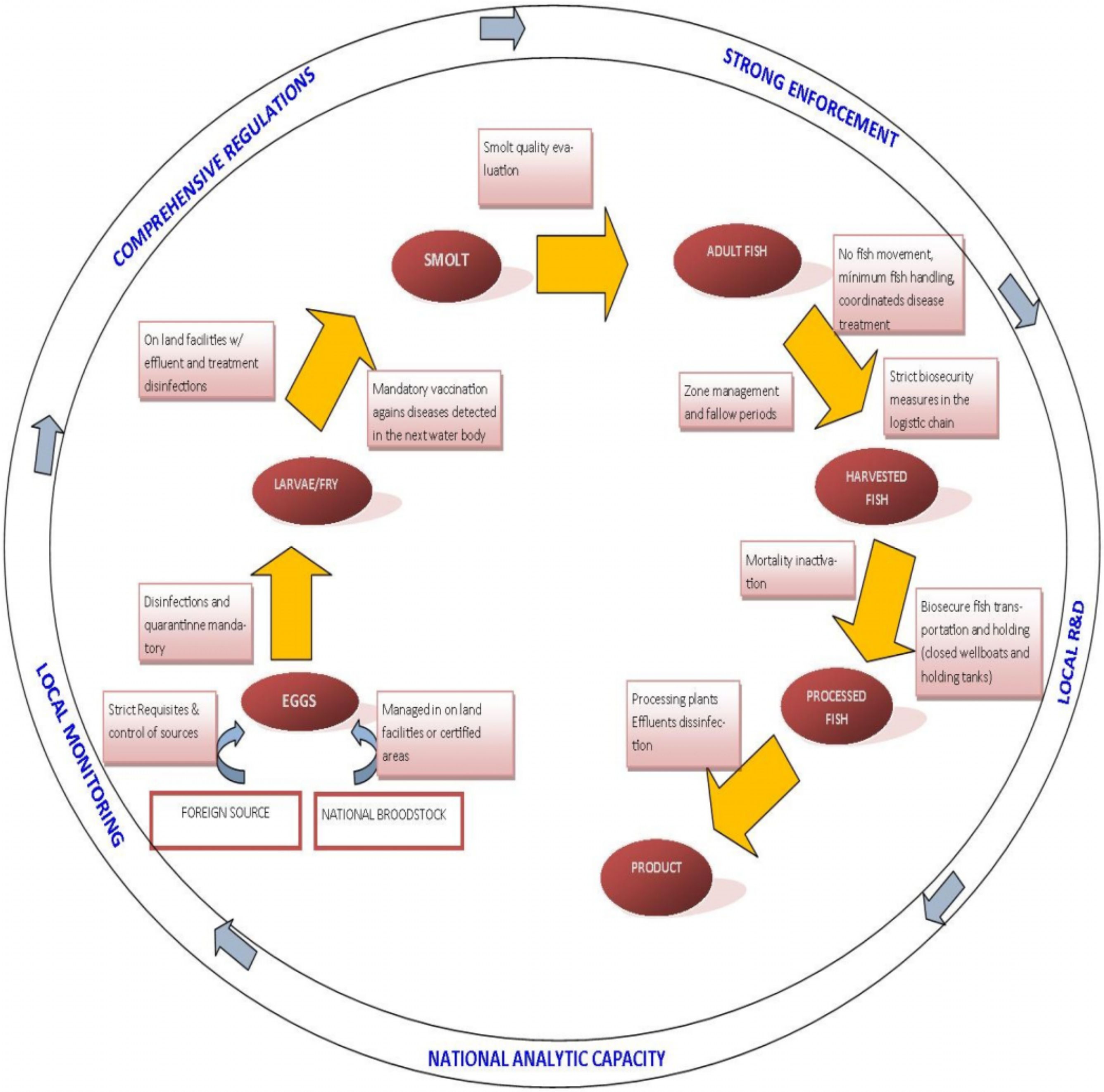


Figure 23. Essential macro and micro components extracted from the handling of the ISA Chilean case for a safer and long term industry.

7.3.-Overall lessons

- The overarching lesson is that successful aquaculture depends on the capacity of biological systems to support it.
- Defining the capacities of bodies of water is essential in order to regulate the number of farms and to set limits on the maximum production in farming areas. Unless this is done, conditions will deteriorate leading to poor fish performance and eventually to disease.
- When bodies of water are shared, regulations are required to ensure that all parties involved are good environmental stewards and neighbors. The larger the industry, the more risks there are and the harder it is to control a problem. So, it is critical to have a system in place to ensure sound industry practices, and early detection and rapid control of a problem if one occurs.

8.-REFERENCES

Alvial, A. 2011 a. Challenges for developing and emerging economies to engage in off-the-coast and offshore aquaculture: the perspective from a case study, FAO, Offshore Mariculture Initiative, in press.

Alvial, A. 2011 b. The Chilean salmon industry crisis: causes and prospects. E*uropharma Lofoten Seminar, Norway, 2011.*

Asche, F., Hansen, H., Tveteras, R., Tveteras, S. 2009. The salmon disease crisis in Chile. Marine Resource Economics 24, 405-411.

Asche, F., Hansen, H., Tveteras, R., Centrum, S.T. 2010. The Salmon Disease Crisis in Chile. Marine Resource Economics, 24: 405-411

Ansoleaga, J. L. 2011. Presentation: "Marco Regulatorio y el Rol de SERNAPESCA" Encuentro Nacional de la Industria del Salmon (ENASAL), November 2011. http://www.salmonchile.cl/frontend/seccion.asp?contid=1570&secid=2&secoldid=2&subsecid=182&pag=1

Barros, C. 2011. Recovery from ISAV: The story of the Chilean salmon Industry. SalmonChile Presentation, 2011.

Biacchesi, S., Le Berre, M., Le Guillou, S., Benmansour, A., Bremont, M., Quillet, E., and Boudinot, P. 2007. Fish genotype significantly influences susceptibility of juvenile rainbow trout, *Oncorhynchusmykiss* (Walbaum), to waterbone infection with infectious salmon anaemia virus. J. Fish Dis., 30, 631-636.

Bovo, G., Hill, B., Husby, A., Hastein, T., Michel C., Olesen, N.J., Storset, A., and Midtlyng, P.J. 2005. Report. European Commission QLK2-CT-2002-01546: Fish Egg Trade.

Corniola, S., 2010. Salmon industry leaders reveal faults with new health program. www.fis.com, 2010.

Cottet, L., Cortez-San Martin, M., Tello, M., Olivares, E., Rivas-Aravena, A., Vallejos, E., Sandino, A.M., Spencer, E. 2010. Bioinformatic analysis of the genome of infectious salmon anaemia virus associated with outbreaks with high mortality in Chile. J. Virol., 84, 11916-11928.

Debes, H.C., Østergaard, P.S., Snow, M., Dale, O.B., Falk, K. 2011. A low-pathogenic variant of infectious salmon anaemia virus (ISAV-HPR0) is highly prevalent and causes a non-clinical transient infection in farmed Atlantic salmon (*Salmo salar* L.) in the Faroe Islands. J. Gen. Virol., 92, 909-918.

Eposito, A. 2011. Chile's salmon industry on pace for record sales http://www.marketwatch.com/story/chiles-salmon-industry-on-pace-for-record-sales - 2011-10-04

FIS.COM.2011. http://www.fis.com/fis/worldnews/worldnews.asp?l=e&ndb=1&id=43441

Gárate, O. 2011. Presentation: "Tendencias en la productividad del cultivo de salmonídeos en Chile", Aquabench, May 2011.

Godoy, M.G., Aedo, A., Kibenge, M.J.T., Groman, D.B., Yason, C.V., Grothusen, H., Lisperguer, A., Calbucura, M., Avendaño, F., Imilán, Jarpa, M., Kibenge, F.S.B. 2008. First detection, isolation and molecular characterization of infectious Salmon anaemia virus associated with clinical disease in farmed Atlantic salmon (*Salmo salar*) in Chile. BMC Veterinary Research 4:28.

Halwart, M., Soto, D., Arthur, J.R. 2007. Cage aquaculture: regional reviews and global overview FAO Fish Tech Pap No. 498. Food and Agriculture Organization of the United Nations (FAO) Rome.

Instituto Nacional de Estadísticas (INE). 2011. www.ine/boletines, 2011.

Jarp, J., and Karlsen, E. 1997. Infectious salmon anaemia (ISA) risk factors in sea-cultured Atlantic salmon Salmo salar Dis. Aquat. Org. 28, 79-86.

Kibenge, F.S.B., Kibenge, M.J.T., McKenna, P.K., Stothard, P., Marshall, R., Cusack, R.R., and McGeachy, S. 2001a. Antigenic variation among isolates of infectious salmon anaemia virus (ISAV) correlates with genetic variation of the viral haemagglutinin gene. J. Gen. Virol. 82, 2869-2879.

Kibenge, F.S.B., Garate, O.N., Johnson, G., Arriagada, R., Kibenge, M.J.T., and Wadowska, D. 2001b. Isolation and identification of infectious salmon anaemia virus (ISAV) from Coho salmon in Chile. Dis. Aquat. Org., 45, 9-18.

Kibenge, F.S.B., Kibenge, M.J.T, Groman, D., and McGeachy, S. 2006. *In-vivo* correlates of infectious salmon anaemia virus pathogenesis in fish. J. Gen. Virol., 87, 2645-2652.

Kibenge F.S.B., Kibenge M.J.T., Wang Y., Qian B., Hariharan S., McGeachy S. 2007. Mapping of putative virulence motifs on infectious salmon anaemia virus surface glycoprotein genes. J. Gen. Virol. 88, 3100-3111.

Kibenge F.S.B., Godoy M.G., Wang Y., Kibenge M.J.T., Gherardelli V., Mansilla S., Lisperger A., Jarpa M., Larroquete G., Avendaño F., Lara M., Gallardo A. 2009. Infectious salmon anaemia virus (ISAV) isolated from the ISA disease outbreaks in Chile diverged from ISAV isolates from Norway around 1996 and was disseminated around 2005, based on surface glycoprotein gene sequences. Virol.J.,6, 88.

Kibenge F.S.B., Godoy M.G., and Kibenge M.J.T. 2011. Diagnostic methods for aquatic animal diseases: Global issues and trends. OIE Scientific and Technical
Review, in press.

MacBeath, A.J.A., Bain, N., Snow, M. 2009. Surveillance for infectious salmon anaemia virus HPR0 in marine Atlantic salmon farms across Scotland. Dis. Aquat. Org. 87, 161-169.

MacDowell, C. 2011. ReLAKSation No. 523 Callander McDowell relaks@callandermcdowell.co.uk

MacWilliams C., Johnson G.R., Groman D., and Kibenge F.S.B. 2007.Morphologic description of infectious salmon anaemia virus (ISAV)-induced lesions in rainbow trout, *Oncorhynchusmykiss* (Walbaum). Dis. Aquat. Org., 78, 1-12.

Mardones F.O., Perez A.M., and Carpenter T.E. 2009. Epidemiologic investigation of the re-emergence of infectious salmon anaemia virus in Chile. Dis. Aquat. Org. 84, 105-114.

Mardones, F., A.M. Perez, Valdés-Donoso, P. and Carpenter T. 2011. Farm-level reproduction number during an epidemic of infectious salmon anaemia virus in southern Chile in 2007-2009. PREVET (2011), doi:10.1016/j.prevetmed.2011.07.005.

McClure C.A., Hammell K.L., Dohoo I.R. 2005. Risk factors for outbreaks of infectious salmon anaemia in farmed Atlantic salmon, Salmo salar. Prev. Vet. Med. 72, 263-280.

Melville, K.J., and Griffiths, S.G. 1999. Absence of vertical transmission of infectious salmon anaemia virus (ISAV) from individually infected Atlantic salmon Salmo salar. Dis. Aquat. Org., 38, 231-234.

Murias, A., 2009. Salmon firms and suppliers owe USD 4 bln. http://www.fis.com/fis/worldnews/worldnews.asp?monthyear=62009&day=18&id=32729&l=e&country=&special=&ndb=1&df=1

Murias, A., 2011a. Brazil on the way to becoming the main market for Chilean salmon.http://fis.com/fis/worldnews/worldnews.asp?l=e&id=40323&ndb=1

Murias, A., 2011b. Cultivos Marinos Chiloé's stock market debut delayed www.fis.com

Murias, A., 2011c. Cultivos Marinos Chiloé looks for new partners. http://www.fis.com/fis/worldnews/worldnews.asp?l=e&ndb=1&id=43441

Murray, A.G., Smith, R.J., Stagg, R.M. 2002. Shipping and the spread of infectious salmon anaemia in Scottish aquaculture.Emerg. Infect. Dis. 8, 1-5.

Norwegian Veterinary Institute Reports. Available at http://www.vetinst.no/nor/Forskning/Publikasjoner/Fiskehelserapporten

Nylund A., Plarre H., Karlsen M., Fridell F., Ottem K.F., Bratland A., Saether P.M. 2007. Transmission of infectious salmon anaemia virus (ISAV) in farmed populations of Atlantic salmon (*Salmosalar*).Arch. Virol., 152, 151-179.

OIE, 2011. Animal Health Manual, 2011.

Rimstad, E., Biering, E., Brun, E., Falk, K., Kibenge, F.S.B., Mjaaland, S., Snow, M., and Winton, J. 2006. Which risk factors relating to spread of infectious salmon anaemia (ISA) require development of management strategies? Opinion of the Panel on Animal Health and Welfare of the Norwegian Scientific Committee for Food Safety, ad hoc group. (http://www.vkm.no/eway/default.aspx?pid=0&oid=-2&trg=__new&__new=-2:17005)

Rolland, J.B. and Winton, J.R. 2003.Relative resistance of Pacific salmon to infectious salmon anaemia virus. J. Fish Dis., 26, 511-520.

SalmonChile. 2009. Medidas sanitarias de la industria del salmón de Chile. Versión Diciembre 2009.

SERNAPESCA. 2008. Cifras preliminaries de desembarque, cosechas y agentes pesqueros y de acuicultura, 2007. Servicio Nacional de Pesca (SERNAPESCA), Valparaíso.

SERNAPESCA. 2009. FONDO DE MODERNIZACIÓN DE LA GESTIÓN PÚBLICA. INFORME FINAL PROPUESTA: *"Evaluación de un sistema de control de la bioseguridad para monitorear en línea factores de riesgo en la propagación de enfermedades en la futura actividad salmonera".* Elaborado por SERVICIO NACIONAL DE PESCA Instituciones vinculadas a la Propuesta: Ministerio de Economía ("Mesa del Salmón"). Julio, 2009. http://www.dipres.gob.cl/572/articles-49765_doc_pdf1.pdf

SERNAPESCA. 2010. Informe Técnico. Programa Sanitario Específico de Vigilancia y Control de la Anemia Infecciosa del Salmón (PSEC-ISA). Período: noviembre 2008 – noviembre 2010.

SUBPESCA. 2011. Reglamentos, in www.subpesca.cl/reglamentos

Stagg, R.M., Bruno, D.W., Cunningham, C.O., Raynard, R.S. 2001. Epizootiological investigations into an outbreak of infectious salmon anaemia (ISA) in Scotland. FRS, Marine Laboratory, Report No 13/01, Aberdeen.

Stagg R.M. 2003. The eradication of an outbreak of clinical infectious salmon anaemia from Scotland. In: Miller O., Cipriano R.C. (tech cords) International response to infectious salmon anaemia: prevention, control, and eradication. USDA, Animal Plant Health Inspect Serv, US Dept Interior, USGS, US Dept Commerce, Natl Mar Fish Serv, Washington, DC, p 111-124.

Vike S., Nylund S., Nylund A. 2009. ISA virus in Chile: evidence of vertical transmission. Arch. Virol., 154, 1-8.