On Potential AQUACULTURE OF SALMONIDS in Tierra del Fuego, Argentina

Forum for the Conservation
of the Patagonian Sea
and Areas of Influence

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CONTENTS

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FORUM FOR THE CONSERVATION OF THE PATAGONIAN SEA AND AREAS OF INFLUENCE

The Patagonian Sea deserves to be protected, for its forms of life and its ecological and economic importance for the nations around it. Science can guarantee its conservation and the sustainable use of its resources. All it's required is the integration of cultural, ethical and aesthetic values with scientific and economic ones. The result will benefit albatross, whales, penguins… and human beings.

With all this in mind, in June 2004, the *Forum for the Conservation of the Patagonian Sea and areas of influence* (http://marpatagonico.org/) was created, with the aim that conservation interests should become paradigms as relevant and genuine as those of any other value admitted by society. Since then, the Forum provides a framework for the organizations that integrate and support it, allowing them to join forces and offer consistent communications, as well as promoting objectives that each organization can't achieve on its own, or in smaller alliances. Some of the objectives include:

- Promoting an integral understanding of the Patagonian marine ecosystem and its conservation status;
- Supporting projects devoted to the creation of Marine Protected Areas;
- Encourage effective implementation of sustainable development policies, with precautionary management principles and participative, transparent and responsible governance practices;
- Facilitate information, education and communication initiatives on the importance and value of the seas as a reservoir of natural resources, provider of ecological services, and object of contemplation and aesthetic value.

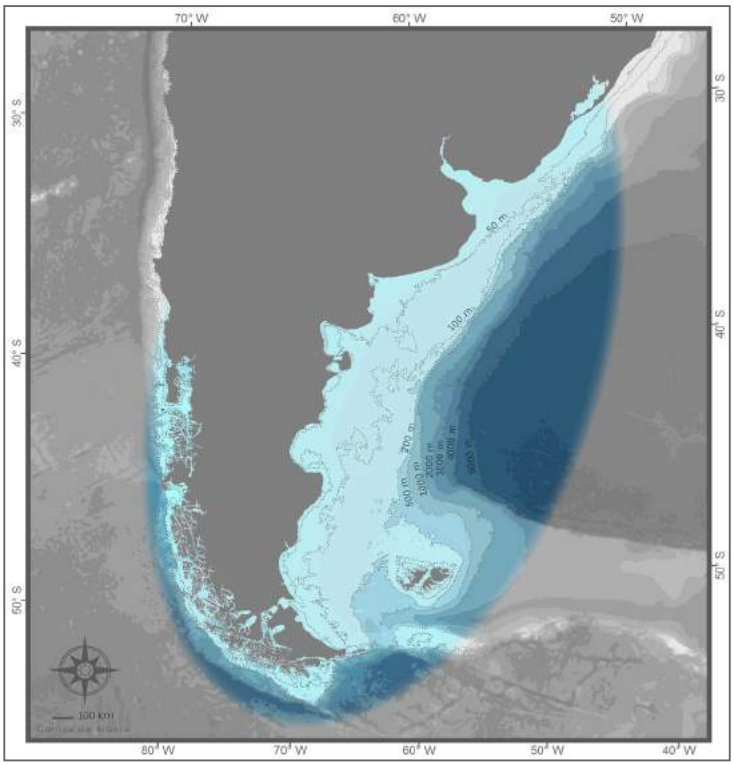

Figure 1. Target area.
We identify the "Patagonian Sea and areas of influence" as the area circumventing the Southern Cone of South America, that includes the waters of the Pacific and Atlantic Oceans, exclusive economic zones of Brazil, Uruguay, Argentina, and Chile, as well as the surrounding international waters or high seas.

ORGANIZATIONS

Unique in its representation of non-governmental organizations (NGO) dedicated to conservation and its wide geographic scope, the *Forum* has currently 24 members:

EXECUTIVE SUMMARY

In Argentina, aquaculture does not have the relevance it has achieved in other countries, even in the Southern Cone region. However, the development context at the national level is changing. On one hand, the initiative " Innovation in Aquaculture Argentina - INNOVACUA" is currently in force, managed by the Ministry of Science, Technology and Productive Innovation (MinCyT), which has signed a technical collaboration and cooperation agreement with the Government of Tierra del Fuego in order to set up an integrated multi-trophic farm to grow different marine species, including trout. On the other hand, the Government of Argentina signed an agreement with the Kingdom of Norway to carry out the "National Aquaculture Project", and to evaluate the feasibility of salmon-based aquaculture development in Tierra del Fuego.

The objective of this report from the Report by the Forum for the Conservation of the Patagonian Sea and areas of influence is to offer the technical and conservation arguments sustaining the unanimous position of its organizations: the aquaculture of salmonids (including salmons and trouts) in Argentina cannot be allowed.

The example of salmon farming in Chile illustrates the environmental, health, social and economic impact of an activity that is, in its essence, contrary to sustainability. Argentina can still fulfil its sustainable development responsibilities, and this document offers the necessary information to support this conclusion.

INTRODUCTION

The objective of this paper is to provide technical support, based on existing data showing the impact salmon farming has, specially the open cages one, in lakes and in the sea, and in ecosystems where the target species are introduced, as would be the case in Argentina. We know there are already introduced fish species in the rivers and lakes of the country, and some species may complete life cycles involving marine environments[02]. We are as well aware of existing introduced species affecting the marine environment under national jurisdiction[03]. However, a salmon farming activity on a large scale in the sea has no precedents in the country, and will be another error added to those made in the past.

Thus, we aim to offer National Authorities, the Government of Tierra del Fuego and all stakeholders, information and recommendations about the environmental implications of salmon farming.

Tierra del Fuego has exceptional conditions for a development based on the sustainable use of its natural resources, through activities like responsible fishing and nature tourism, among others. These activities can create direct and indirect sustained sources of employment, but depend, among other factors, on the the healthy continuity of the natural conditions they are based on. The growth of exotic species impact these necessary conditions, degrade environments and produce irreversible consequences.

02 Pascual, M., Bentzen, P., Riva Rossi, C., Mackey, G., Kinnison, M.T. & Walker, R. (2001). First Documented Case of Anadromy in a Population of Introduced Rainbow Trout in Patagonia, Argentina. Transactions of the American Fisheries Society, 130: 53-67.

03 Orensanz, J.M., Schwindt, E., Pastorino, G. Bortolus, Casas, G., Darrigran, G., Elias, R., López Gappa, J.J., Obenat, S., Pascual, M., Penchaszadeh, P., Piriz, M.L., Scarabino, F., Spivak, E.D. & Vallarino, E.A. (2002). No longer the pristine confines of the world ocean: a survey of exotic marine species in the southwestern Atlantic. Biological Invasions, 4: 115-143.

Based on the motives exposed in this paper, our main conclusion is that salmon farming in Argentina, as an activity based on exotic species, would have serious environmental, health, social and economic impacts, and would not comply with the basic sustainability conditions required by the modern development initiatives.

So, we do not recommend the installation and operation of salmon farming centres in Tierra del Fuego, nor other locations on the Argentine marine coastline.

BACKGROUND ON AQUACULTURE IN PATAGONIAN ECOSYSTEMS

The term "aquaculture" refers to the growth of several marine and freshwater species. In Argentina, the activity is not important when compared with other countries, even in the same region[04]. If we think of the recent agreement with Norway to allow feasibility studies for the possible implementation of aquaculture of salmonids[05], the development context of the activity in the country is changing.

In the world, aquaculture is the activity related to growing food-production, responsible of an important part of the global production of fish and molluscs[06]. It's understood as a food security strategy, although its dependency on marine and land natural resources diminishes its benefits, and may impede the ultimate goal of achieving stability in the global supply of food[07]. The direct impact of the activity varies with the management and species. Some aquaculture practices have high impact on marine ecosystems[08], others are low impact. In order to minimize undesired effects, marine fish growth have been developed on pools situated on land, avoiding the contact with the sea and its inevitable consequences[09].

A good example is the experience in Chile with salmon farming in their Patagonian ecosystems, run by Norwegian, Canadian, Chilean and Japanese companies. Chile is the world's second farmed salmon and

04 Foro para la Conservación de Mar Patagónico y Áreas de Influencia (2008). Síntesis del Estado de Conservación del Mar Patagónico y Áreas de Influencia. Puerto Madryn, Argentina. Edición del Foro.

05 http://www.sur54.com/desarrollo_de_acuicultura_el_apoyo_de_noruega_es_fundamental_porque_es_lider_mundial_destaco_zara

06 FAO (2016). Informe El Estado Mundial de la Pesca y la Acuicultura. Contribución a la seguridad alimentaria y la nutrición para todos. Roma. 224 pp.

07 Troell, M., Naylor, R.L., Metian, M., Beveridge, M., Tyedmers, P.H., Folke, C., Arrow, K.J., Barrett, S., Crépin, A.S., Ehrlich, P.R., Gren, A., Kautsky, N., Levin, S.A., Nyborg, K., Österblom, H., Polasky, S., Scheffer, M., Walker, B.H., Xepapadeas, T. & de Zeeuw, A. (2014). Does aquaculture add resilience to the global food system? Proc. Natl. Acad. Sci. USA, 111(37): 13257-13263.

08 Davenport, J.C., Black, K., Burnell, G., Cross, T., Culloty, S., Ekaratne, S., Furness, B., Mulcahy, M. & Thetmeyer, H. (2009). Aquaculture: the ecological issues. John Wiley and Sons, Oxford.

09 https://thefishsite.com/articles/a-fresh-take-on-closed-containment-aquaculture

trout after Norway[10-11-12], with 791,000 tons produced in 2017[13], and it has a long experience addressing the serious environmental and health problems that have aroused in more of 30 years.

Salmon farming is done in the Chilean Patagonian fjords in sequence, from the Lakes Region in the north, passing through the Aysén Region and reaching eventually the Magallanes Region, next to Tierra del Fuego in Argentina[14]. The farming centres are situated in areas of high ecological value and fragility, even in national reserves of the National System of Protected Wildlife Areas of the State, and in areas belonging to aboriginal people[15].

The intensive salmon farming has had a high environmental impact in the Chilean Patagonia, as well as in production leading countries like Norway, Canada, Ireland and Scotland[16]. In countries like Chile or Argentina, this is complicated by the fact that salmonids are an exotic species, leading to different impacts to those felt in areas where the species is native.

IMPACTS OF AQUACULTURE OF SALMONIDS

The main documented environmental problems associated to this industry are:

1. Salmonids escape, which introduces exotic species from the farming cages into the natural environment;
2. Abuse of antibiotics, anti-parasitics and other chemical substances;
3. Introduction and spread of diseases and their causal agents;
4. Accumulation of solid and liquid waste on the seabed, derived from unconsumed feed, faeces and dead salmonids;
5. Industrial waste left behind by the companies in the fjords, like cages, plastics, buoy, ends, etc.;
6. Fishing pressure on wild species used as fishmeal and fish oil that end up as salmonids' food;
7. And negative direct and indirect interactions with marine mammals and birds, some of whom are in delicate conservation status.

10 Buschmann, A., Cabello, F., Young, K., Carvajal, J., Varela, D. & Henríquez, L. (2009). Salmon aquaculture and coastal ecosystem health in Chile: Analysis of regulations, environmental impacts and bioremediation systems. Ocean & Coastal Management, 52: 243-249.

11 https://www.seafoodsource.com/features/chile-and-norway-atlantic-salmon-farmers-cope-with-fallout-from-environmental-catastrophes

12 Bjørndal, T. (2002). The competitiveness of the Chilean salmon aquaculture industry. Aquaculture Economics & management. 6: 97-116.

13 http://www.estrategia.cl/texto-diario/mostrar/1010095/cosechas-salmon-crecieron-169-2017

14 http://www.subpesca.cl/portal/619/w3-article-81329.html

15 https://www.elciudadano.cl/chile/exigen-proteccion-mar-adyacente-al-parque-nacional-kawesqar-frente-industria-salmonera/03/07/

16 Wilson, A., Magill, S. & Black, K.D. (2009). Review of environmental impact assessment and monitoring in salmon aquaculture. In: Environmental impact assessment and monitoring in aquaculture. FAO Fisheries and Aquaculture Technical Paper, 527: 455-535. FAO, Rome.

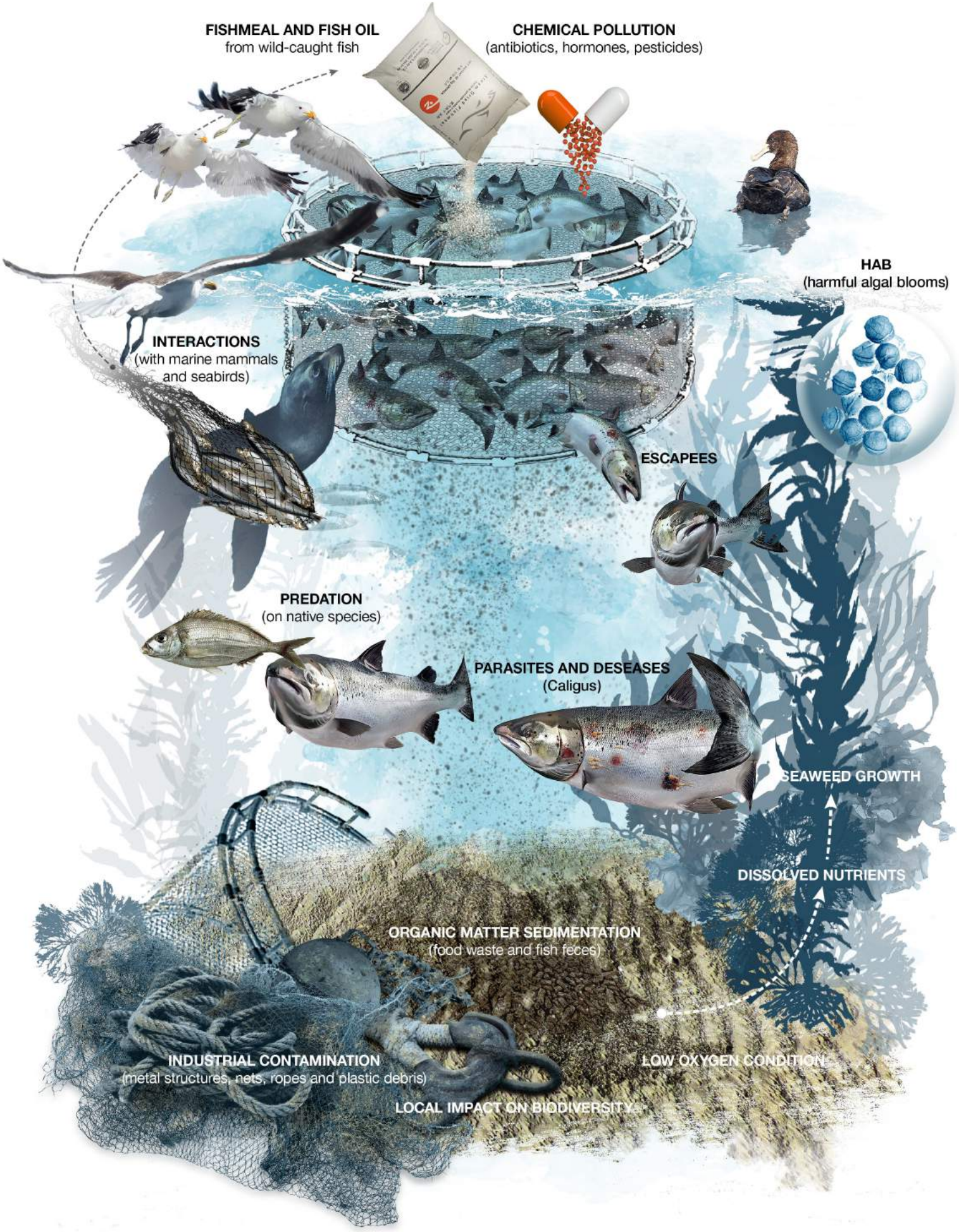

Figure 2. Environmental impacts of aquaculture of salmonids.

1. Salmonids escape, from farming cages to natural environment

Exotic species are the second cause of biodiversity loss, after habitat loss. Salmons and trouts are introduced species in Chile and Argentina, and fish escape from farms into the natural environment is a constant problem since the beginning of the activity. Salmonids alter ecosystems, predating on native species and competing with them for food.

Salmonids are native in the North Hemisphere countries[17]. All salmons and trouts in Chile and Argentina are exotic species, introduced into an environment they do not naturally belong to. The escapes of species target of mariculture impact on the environment[18]. An example is the competence with native fish for food and habitat, but there are other long term effects on native water biodiversity, as exotic species are the second cause of biodiversity loss after habitat loss[19]. This long term potential effect can have great impact in world biodiversity, considering the high endemism of local fish. Also, the relative isolation of the freshwater watersheds make them specially sensitive to biological invasions, like salmonids in Chile[20].

The escape of anadromous species[21], with fresh and marine water life cycle, has additional effects, like marine nutrients flow to freshwater environment, as salmon species dying in rivers and lakes after spawing introduce marine nutrients in freshwater systems[22]. The escape of these fish from farms into the natural environment is a permanent problem since the start of the activity[21]. Escapes happen for precise situations, like storms, vandalism, material stress, predators, human error and inadequate handling[22]. It also happens as "leakage", the persistent escape of fish from the cages with no reporting to authorities or relevant services[21]. In Chile, up to a million escaped fish have been reported in one event. The recapture rate are usually 2%[22].

Once in open sea, salmonids alter natural ecosystems predating on native species and competing for food with them[21].

17 Análisis sobre la maricultura del salmón atlántico (*Salmo salar*) en el mar argentino, en jaulas off-shore. Ministerio de Agroindustria, Argentina. https://www.agroindustria.gob.ar/sitio/areas/acuicultura/maricultura/

18 Melo, T. (2005). Evaluación de la posición trófica y la eficiencia de los métodos de recaptura en salmónidos escapados de centros de cultivo. Informe Técnico, Fondo Investigación Pesquera, Pontificia Universidad Católica de Valparaíso, Chile.

19 Gajardo, G. & Laikre, L. (2003). Chilean Aquaculture Boom Is Based on Exotic Salmon Resources: a Conservation Paradox. Conservation Biology 17(4): 1173-1174.

20 Correa, C. & Gross, M.R. (2007). Chinook salmon invade southern South America. Biological Invasions, 10(5): 615-639.

21 Anádromas: organismos que pasan la mayor parte de su ciclo vital en el mar y sólo regresan a los ríos a reproducirse.

22 Furci, G. (2009). Escapes de salmones y truchas de cultivo en Chile. OCEANA.

An expansion in the salmons distribution has been documented, indicating there may be no place in Chilean Patagonia safe from future colonization[23-24].

During the farming first stage, salmonids are farmed in cages in freshwater lakes, and they they are moved to centres in the sea for their fattening. In the lakes in northern Chilean Patagonia, where intensive salmonids farming takes place, there's a correlation between the amount and diversity of farmed species, and the abundance of free living trouts and salmons of the same species[23]. In these areas, the presence of "escapees" has been demonstrated[25]. Also, there is an inverse relation between the relative abundance of fee living salmonids and native fish in those Patagonian lakes[24]. Similarly, when freed from the nets of the cages, it's been shown that salmonids feed on native species of insects, crustaceans, mulloscs and fish[26], impacting as a top predator. Being introduced predators, they impact trophic chains but resist natural biological control[25]. Few species in the chain, except some birds (when fish are small) and South American fur seal, predate on salmons.

There are differences in the impact escaped salmonids have in Chile, where they are exotic, and the rest of the North Hemisphere producing countries, where salmonids are native. In those countries, the escaped fish affect wild population in several ways, one of the most important is the transmission of "captivity" genes to wild species by hybridization. Predation on native species, competence for space and resources, disease and parasites transmission, and destruction of the habitat of native salmonids are other relevant effects[21].

23 Becker, L.A., Pascual, M.A. & Basso, N.G. (2007). Colonization of the southern Patagonia ocean by exotic Chinook Salmon. Conservation Biology, 21(5): 1347-1352.

24 Riva Rossi, C.M., Pascual, M.A., Aedo Marchant, E., Basso, N., Ciancio, J.E., Mezga, B., Fernández, D.A. & Ernst-Elizalde, B. (2012). The invasion of Patagonia by Chinook salmon (*Oncorhynchus tshawytscha*): Inferences from mitochondrial DNA patterns. Genetica, 140(10-12): 439-453.

25 Arismendi, I., Soto, D., Penaluna, B., Jara, C., Leal, C. & León Muñoz, J. (2009). Aquaculture, non-native salmonid invasions and associated declines of native fishes in Northern Patagonian lakes. Freshwater Biology, 54: 1135-1147.

26 Soto, D., Jara, F. & Moreno, C. (2001). Escaped salmon in the inner seas, Southern Chile: Facing ecological and social conflicts. Ecological Applications, 11: 1750-1762.

2. Use and abuse of antibiotics, anti-parasitics and other chemical substances

The high stocking densities of caged fish favour the spread of parasitic and infectious diseases. To control them, antibiotics and anti-parasitic products are administered, at doses that may affect human health. Besides the economic cost, pesticides have associated an environmental and health cost not taken into account by the industry nor the authorities.

One of the most serious environmental and health problems from this industry is the high use of antibiotics and other chemicals[27]. The high stocking densities of caged fish, and the close proximity between farming centres, favour the spread of diseases and parasites, and expose the exploited species to infections. As an strategy to control diseases, producers use antibiotics and anti-parasitic products on a massive scale.

The use of antibiotics in the Chilean salmon industry reached 557 tons in 2015, or little less than a gram of antibiotic per kilogram produced, according to the National Fisheries Service (SERNAPESCA). Dosage used in Chile, administered orally by food, and also by IV, exceed in 32,000 % the amount used by Norway, country producing more farmed salmons than Chile, where the rate was 0.18 /salmon tonne during 2015 (0.00018/kg)[28]. The high presence of antibiotics leads to resistant strains of bacteria[29] and areas devoted to aquaculture present the highest development of bacteria resistance[30-31-32-33].

27 World Health Organization, Food and Agriculture Organization of the United Nations & International Office of Epizootics (2006). Report of a joint FAO/OIE/WHO Expert Consultation on antimicrobial use in aquaculture and antimicrobial resistance, Seoul, Republic of Korea, 13–16 June 2006.

28 https://salmonfacts.com/fish-farming-in-norway/is-farmed-salmon-in-good-health/

29 Miranda C.D. & Zemelman, R. (2012). Antimicrobial multiresistance in bacteria isolated from freshwater Chilean salmon farms. Sci. Total Environ., 293: 207-18.

30 Baquero, F., Martinez, J.L. & Canton, R.A. (2008). Antibiotics and antibiotic resistance in water environments. Curr. Opin. Biotechnol., 19: 260-265.

31 Taylor, N.G., Verner-Jeffreys, D.W. & Baker-Austin, C. (2011). Aquatic systems: maintaining, mixing and mobilizing antimicrobial resistance? Trends Ecol. Evol., 26: 278-284.

32 Cabello, F.C., Godfrey, H.P., Tomova, A., Ivanova, L., Dölz, H., Millanao, A. & Buschmann, A.H. (2013). Antimicrobial use in aquaculture re-examined: its relevance to antimicrobial resistance and to animal and human health. Environ. Microbiol., 15: 1917-1942.

33 Cantas, L., Shah, S.Q., Cavaco, L.M., Manaia, C.M., Walsh, F. & Popowska, M. (2013). A brief multi-disciplinary review on antimicrobial resistance in medicine and its linkage to the global environmental microbiota. Front Microbiol., 4: 96.

Some native fish have been found with traces of antibiotics, as they fed on pellets imbued with these substances[34-35].

The use of antibiotics in the industry affects human health[36-37-38]. The World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO), and the World Organisation for Animal Health (OIE) have declared that the indiscriminate use of antibiotics is serious regarding the world's health[39]. Thus, they have developed action plans, principles and guidelines to use antibiotics in such a way that help to prevent or contain their most damaging effects[40].

Sea louse (*Caligus rogercresseyi*) is the most important pathogen and it has the greater economic impact for the salmon industry in Chile. The economic damages by Caligus are related to the loss of quality in the final product, delay growth of parasite infested fish, increase of sensibility compared with other pathogens and cost by treatments[41]. Products used to control sea lice have adverse effects for the water environment if improperly used. One of the main problems in Chile and other countries, is the drug resistance of the sea lice after repetitive used of the same drug[49].

According to data on anti-parasitic medication use reported by the National Fisheries Service of Chile, and prices reported by pharmacological laboratories, the costs associated with the control of the sea lice were USD 80 millions in 2013, equivalent to USD 0.10/fish kg, 112% higher than the previous year. These figures do not take into account the costs of application nor other effects of the sea lice. Besides the economic cost, anti-parasitic drugs carry an environmental associated cost, not considered by the industry nor the authorities[49].

34 Fortt, Z.A. & Buschmann, R.A. (2007). Uso y abuso de los antibióticos en la salmonicultura. Oceana.

35 Fortt, Z.A., Cabello, F.C. & Buschmann, R.A. (2007). Residuos de tetraciclina y quinolonas en peces silvestres en una zona costera donde se desarrolla la acuicultura del salmón en Chile. Revista Chilena de Infectiología, 24: 8-12.

36 Cabello, F.C. (2003). Antibiotics and aquaculture. An analysis of their potential impact upon the environment, human and animal health in Chile. Fundación Terram. Análisis de Políticas Públicas, 17: 1-16.

37 Tomova A., Ivanova, L , Buschmann, A.H., Rioseco, M.L., Kalsi, R.K ., Godfrey, H.P. & Cabello, F.C. (2015). Antimicrobial resistance genes in marine bacteria and human uropathogenic Escherichia coli from a region of intensive aquaculture. Environmental Microbiology Reports, 7(5): 803-809.

38 Cabello, F.C., Godfrey, H.P., Tomova, A., Ivanova, L., Dölz, H., Millanao, A. & Buschmann, R.A. (2013). Antimicrobial use in aquaculture re-examined: its relevance to antimicrobial resistance and to animal and human health. Environ. Microbiol., 15: 1917-1942.

39 Burridge, L.M., Cabello, F., Pizarro, J. & Bostick, K. (2010). Chemical use in salmon aquaculture: A review of current practices and possible environmental effects. Aquaculture, 306: 7-23.

40 Organización Mundial de la Salud (2017). Directrices de la OMS sobre el uso de antimicrobianos de importancia médica en animales destinados a la producción de alimentos.

41 Bravo, S., Veronica Pozo, V. & Silva, M.T. (2015). Evaluación de la efectividad del tratamiento con agua dulce para el control del piojo de mar *Caligus rogercresseyi* (Boxshall & Bravo 2000). Lat. Am. J. Aquat. Res., 43(2).

3. Introduction and spread of diseases and parasites

The susceptibility of salmon to infectious diseases is critical to the activity, and the consequences vary from reduction of the product value for damages to grand scale death. In 2008, Chilean salmon farming suffered a health crisis by the ISA virus, resulting in social and economic problems of catastrophic dimensions.

In the previous section, the susceptibility of the activity to infectious diseases was reported. This is the most critical unresolved problem for the sustainability of the Chilean salmon industry, and where urgent innovations are required. Health worsening is the result of a continuous process of adding new pathologies, accompanied by an effective process of horizontal transmission, and a re-cycling of diseases through the productive and reproductive process, with multiple points of cross contamination, resulting in an efficient path of spread and amplifying each health problem[42].

The presence of new diseases may be due to the pre-existence of the pathogen for the farmed species, the adaptation of a pathogen from one species to another, the introduction of a pathogen by way of ballast water of ships, and the introduction of pathogens through imported eggs[42].

In 2008, Chilean salmon farming suffered a serious health crisis caused by presence and propagation of the infectious salmon anaemia, known as ISA virus, and by other diseases[43-44]. This crisis led to the loss of more than 15,000 direct jobs, out of the 32,000 jobs in the industry[45], leading to a social and economic problem of catastrophic dimensions in cities where most of the industry workers lived. It's believed the ISA virus was introduced in Chile by imported infected eggs from Norway, which revealed the inefficient health controls[46].

42 Parada, G. (2010). Tendencias de la acuicultura mundial y las necesidades de innovación de la acuicultura chilena. Informe para el Consejo Nacional de la Innovación para la Competividad.

43 Barton, J.R. & Fløysand, A. (2010). The political ecology of Chilean salmon aquaculture, 1982-2010: A trajectory from economic development to global sustainability. Global Environmental Change, 20: 739-752.

44 Asche, F., Hansen, H., Tveteras, R. & Tvete, S. (2009). The Salmon Disease Crisis in Chile Marine Resource Economics, 24(4): 405-411.

45 http://www.emol.com/noticias/economia/2012/10/31/567503/industria-del-salmon-ya-casi-ha-olvidado-la-crisis-del-virus-isa-con-sus-numeros-recuperados.html

46 http://diario.latercera.com/edicionimpresa/crisis-del-salmon-fue-provocada-por-virus-que-llego-en-1996-y-luego-muto/

Piscirickettsiosis (SRS) is the most common bacterial disease, and with the greatest impact in the production system of salmon in Chile. It produces loss associated to clinical signs of disease, large scale deaths, and final product reduced value, due to macroscopic damages and lesser productive performance[47].

Another health problem present in all countries with salmon farming is sea lice, a parasitic disease caused by a copepod, *Caligus rogercresseyi*, resulting in direct losses in the industry due to salmon mortality and impact on fish growth. Also, this parasite is an agent for the spread of diseases and the stress resulting from the infestation causes a higher susceptibility in fish stocks to infectious diseases[42]. The sea lice and the SRS cause more than USD 800 million losses per year, only in the Lakes Region and Aysén Region[48].

47 Servicio Nacional de Pesca, Chile (2013). Informe Sanitario de Salmonicultura en Centros Marinos.

48 http://www.aqua.cl/2016/11/30/aqua-en-ruta-hasta-donde-puede-llegar-la-expansion-de-la-salmonicultura-en-magallanes/

4. Accumulation of solid and liquid waste

The build up of organic waste under the cages resulting from unconsumed food by the fish, and their faeces, leads to loss of biodiversity of the seabed. It also promotes the presence of microalgae, including toxic phytoplankton responsible for red tides impacting public health and the state of health of natural populations.

During the feeding of caged salmons, 75% of nitrogen, phosphorus and carbon present in the feed is not consumed by the fish, producing an excess of nutrients under the cages and in the nearby waters[49]. These excessive nutrients lead to a loss of biodiversity underneath the cages[50], and an increase of ammonium concentration released in fish faeces stimulate microalgae growth, including toxic phytoplankton[51]. This organic waste concentration can promote the presence of algae, both the kind affecting salmons as the kind producing the red tide and impacting molluscs and public health.

49 Buschmann, A. & Fortt, A. (2005). Efectos ambientales de la acuicultura intensiva y alternativas para un desarrollo sustentable. Ambiente y Desarrollo (Chile), 21: 58-64.

50 Soto, D. & Norambuena, F. (2004). Evaluation of salmon farming effects on marine systems in the inner seas of southern Chile: a large-scale mensurative experiment. Journal of Applied Ichthyology, 20: 493-501.

51 Buschmann, A.H., Riquelme, V.A., Hernandez-Gonzalez, M.C., Varela, D., Jimenez, J., Henriquez, L.A., Vergara, P.A. Guinez, R. & Filun, A. (2006). A review of the impacts of salmon farming on marine coastal ecosystems in the southeast Pacific. ICES Journal of Marine Science, 63: 1338-1345.

5. Polluting waste

Industry activity produces polluting rubbish: floating plastic waste, toxic paintings and sunk structures impacting the biodiversity of the seabeds. After the crisis of the ISA virus, the structures damaged by the sea were abandoned in Chile.

Among other damages, the waste from salmon farming present risks to sailing and spoil the beauty of landscapes with enormous tourism potential.

The activity produces polluting waste. Among the most frequent rubbish found in large numbers where salmon and mussels are farmed in Chile are feed bags. These industries are responsible of a large part of the floating wastes in the sea. The activity also uses concrete blocks to fix the cages to the seabed, impacting benthic systems at local level. The affected species include some native ones, including cold water coral and sponges.

After the ISA virus crisis, some companies abandoned their plants, leaving behind cages, pontoons and walkways damaged by the sea, thus presenting a risk to sailing and spoiling the beauty of landscapes with enormous potential for nature tourism[52].

When an artificial structure, like a cage, is placed for a long time in the sea, marine organisms attach and grow upon them. To avoid this phenomenon, salmon farming companies used anti-fouling paint, which is toxic and created to eliminate marine life. Recently, in the island of Chiloé, there was a spill of 10,000 litres of anti-fouling paint in a river and part of a lake of pure waters, dying them red and polluting them seriously[53].

52 http://www.ellanquihue.cl/prontus4_nots/site/artic/20100604/pags/20100604001006.html

53 http://www.australosorno.cl/impresa/2018/03/29/full/cuerpo-principal/7/

6. Fishing pressure on wild species for fishmeal and oil

Salmon farming growth increased the exploitation of wild species for fishmeal and fish oil. The collapse of some fisheries, like the one dedicated to yellowtail amberjack in Chile, is related with the production of food for salmons. Without the correct management, the growth of fish eating other fish, can be an aggravating factor of overfishing.

Some decades ago, aquaculture was presented as an alternative to food offer, specially proteins to the world. However, this statement has been challenged by research showing that some aquaculture forms, like salmon farming, has implied and increase in the demand of wild species used to feed the introduced species, reducing the global quantity of protein available to human consumption[54].

Salmonids are fed with pellets made up by fishmeal and fish oil, with vegetable ingredients added[55]. Fishmeal and fish oil are by-products of forage fish species like anchovy and sardine[56]. Species like yellowtail amberjack and hake were occasionally used, over exploiting them to the point of exhaustion. World fishing of these forage species makes up one third of all world fishing practices, contributing to the fisheries' collapse[57]. This is serious, given their key role as food for marine mammals and birds, and commercial fish.

Some years ago the conversion rate, i.e., the amount of wild fish necessary to produce one kilogram of salmon was 5:1, or even more. Thus, efforts were made to reduce this rate and replace animal proteins and lipids with vegetable components. Effectively, the conversion rate decrease up to a rate between 1,2:1 and 1,5:1[58].

54 Naylor, R.L., Goldburg, R.J., Primavera, J.H., Kautsky, N., Beveridge, M.C.M., Clay, J., Folke, C., Lubchenco, J., Mooney, H. & Troell, M. (2000). Effect of aquaculture on world fish supplies. Nature, 405: 1017-1024.

55 http://www.fao.org/fishery/affris/perfiles-de-las-especies/atlantic-salmon/produccion-de-alimentos/es/

56 http://www.emol.com/noticias/economia/2002/09/04/93894/produccion-de-harina-de-pescado-crecio-134-enero-julio-2002.html

57 http://www.sonapesca.cl/el-colapso-del-jurel-que-preocupa-al-sector-pesquero/

58 Fry, J.P., Mailloux, N., Love, D.C., Milli, M.C. & Cao, L. (2018). Feed conversion efficiency in aquaculture: do we measure it correctly? Environ. Res. Lett., 13.

Food for this industry is not guarantee,. The available fishmeal is 6 million tons per year, and the available fish oil is less than 1 million ton per year, and possibly these figures will not increase. On the contrary, fishing for reduction shows a decline during El Niño phenomenom[59].

Salmon farming growth has implied and increased in demand, which led to an increase in the exploitation of wild species for fishmeal and fish oil. There have been exploitation cases, and even fisheries collapse, like the case of the yellowtail amberjack in Chile, to produce food for salmon[60]. Without the correct fishing management, the growth of fish eating other fish, like salmonids, can be an aggravating factor of overfishing.

59 Deutscha, L., Gräslund, S. Troell, M., Huitric, M., Kautsky, N. & Lebel, L. (2006). Feeding aquaculture growth through globalization: Exploitation of marine ecosystems for fishmeal. Global Environ. Change, 17: 238-249.

60 http://ciperchile.cl/2012/01/25/sin-control-gigantes-pesqueros-diezman-el-pacifico-sur/

7. Direct and indirect interactions with marine mammals and birds

The place used by the salmon farming industry, the chemical pollution, the industrial waste, the traffic of ships and the acoustic pollution, all impact negatively on the habitat or migration routes of marine mammals, provoking y many cases these species exclusion. There are also accidental tangling in the nets and illegal killings of sea lions and dolphins.

Although salmon farming can impact ecology and marine mammals conservation, this problem has been omitted from the management plan by most aquaculture companies[61]. The physical placement of the centres is one of the most important factors affecting possible interactions between marine mammals and aquaculture[62]. The main interactions between aquaculture activities and these animals are mainly negative[63-64] and have been caused by the modification or exclusion of the habitat by salmon farming. The spaces used by the physical structures associated to aquaculture[62-65], the high concentrations of nutrients and organic matter[66], chemical pollution[67], acoustic pollution[62-68], vessel traffic[61] and large amounts of waste produced by the industry[69] have modified the habitat and provoked the exclusion and displacement of these animals.

61 Markowitz, T., Harlin, A., Würsig, B. & Mcfadden, C. (2004). Dusky dolphin foraging habitat: overlap with aquaculture in New Zealand. Aquatic Conservation: Marine and Freshwater Ecosystems, 14: 133-149.

62 Clement, D. (2013). Literature review of ecological effects of aquaculture. Effects on marine mammals. Ministry for Primary Industries Manatu Ahu Matua. New Zealand.

63 Würsig, B. & Gailey, G.A. (2002). Marine mammals and aquaculture: conflicts and potential resolutions. En: R.R. Stickney and J.P. McVey (Eds.). Responsible Marine Aquaculture, pp. 45-59.

64 Kemper, C., Pemberton, D., Cawthorn, M., Heinrich, S., Mann, J., Würsig, B., Shaughnessy, P. & Gales, R. (2003). Aquaculture and marine mammals: co-existence or conflict? En: Marine mammals: fisheries, tourism and management issues. CSIRO Publishing. Collingwood, Australia, pp. 208-225.

65 Watson-Capps, J. & Mann, J. (2005). The effects of aquaculture on bottlenose dolphin (*Tursiops sp.*) ranging in Shark Bay, Western Australia. Biological Conservation, 124: 519-526.

66 Buschmann, A., López, D. & Medina, A. (1996). A review of the environmental effects and alternative production strategies of marine aquaculture in Chile. Aquaculture Engineering, 15: 397-421. López, B. (2012). Bottlenose dolphins and aquaculture: interaction and site fidelity on the north-eastern coast of Sardinia (Italy). Marine Biology, 159: 2161-2172.

67 López, B. (2012). Bottlenose dolphins and aquaculture: interaction and site fidelity on the north-eastern coast of Sardinia (Italy). Marine Biology, 159: 2161-2172.

68 Gómez, C., Lawson, J., Wright, A., Buren, A., Tollit, D. & Lesage, V. (2016). A systematic review on the behavioural responses of wild marine mammals to noise: the disparity between science and policy. Canadian Journal of Zoology, 94(12): 801-819.

69 Price, C., Morris, J., Keane, E., Morin, D., Vaccard, C. & Bean, D. (2017). Protected species and marine aquaculture interactions. NOAA Technical Memorandum NOS NCCOS, 211.

The use of protection nets, anti-sea lion nets and ropes have led to the tangling in the nets and death by immersion of several animals[69-70-71]. Direct clandestine and illegal killing of cetaceans have also been performed. Interactions between marine mammals and salmon farming industry happen as there's an overlapping of spatial placement of the aquaculture plants and the habitat and/or migration routes of the animals[62].

Main known impacts for marine mammals:

- Use of space, habitat exclusion and modification.
- Nutrients and organic matter concentration.
- Chemical pollution: e. g., several chemicals have been used to treat parasitic infestations, like sea lice. The indiscriminate use in Chile could increase the level of resistance of parasites. These products can negatively impact other crustaceans that are part of the zoo-plankton, and make up an important part of the preys of marine mammals (krill, squat lobster), modifying then food webs and increasing the risk of harmful algal blooms (HABs)[69].
- Acoustic pollution and displacement.
- Vessel traffic.
- Accidental tangling in nets: since the very beginning of salmon farming in Chile, there was conflict between growth centres and marine mammals, as some of them, like sea lions, attack the net pens to obtain food[72]. As a consequence, the companies implemented protection nets (anti-sea lion nets) to protect salmons from these mammals. The use of nets in the net pens, protection nets and anti-sea lion nets has provoked net tangling and death by immersion in many cetaceans. These negative interactions have been documented with dolphins and baleen whales[63-73-74]. In the southern region of Chile, there were reports of net tangling and death of Chilean dolphins (*Cephalorhynchus eutropia*), Peale's dolphins (*Lagenorhynchus australis*) and humpback whales in anti-sea lion nets used by the salmon farming industry[71-74-75-76]. The risk of net tangling in cetaceans is even higher when cages lured small wild fish which later live around them[63]. Cetaceans may be attracted to the cages to feed on the farmed fish or the ones living around the cages[63].
- In order to protect salmons from alleged predators, Chilean dolphins (*Cephalorhynchus eutropia*), Peale's dolphins (*Lagenorhynchus australis*) and occasionally minke whales (*Balaenoptera acutorostrata*) have been eliminated in Chile[72].

70 Cassoff, R., Moore, K., McLellan, W., Barco, S., Rotstein, D. & Moore, M. (2011). Lethal entanglement in baleen whales. Diseases of Aquatic Organisms, 96: 175-185.

71 Hucke-Gaete, R., Haro, D., Torres-Florez, J., Montecinos, Y., Viddi, F., Bedriñana, L. & Ruiz, J. (2013). A historical feeding ground for humpback whales in the Eastern South Pacific revisited: the case of northern Patagonia, Chile. Aquatic Conservation: Marine & Freshwater Ecosystems, 23: 858-867.

72 Claude, M. & Oporto, J. (2000). La ineficiencia de la salmonicultura en Chile: Aspectos sociales, económicos y ambientales. Fundación Terram, Registro de Problemas Públicos Informe N°1, Invierno 2000.

73 Oporto, J. & Gavilan. M. (1990). Conducta del Delfín Austral (*Lagenorhynchus australis*) en la Bahía de Manao (Chiloé), Chile. 4° Reunión de Trabajo de Especialistas en Mamíferos Acuáticos de América del Sur. 12–15 de noviembre, Valdivia, Chile.

74 López, B. & Shirai, J. (2007). Bottlenose dolphin (*Tursiops truncatus*) presence and incidental capture in a marine fish farm on the north-eastern coast of Sardinia (Italy). Journal of the Marine Biological Association of the UK, 87: 113-117.

75 Christie, C. (2015). El Delfín Chileno. Ediciones UACh, Valdivia, Chile.

76 Heinrich, S., Fuentes, M. & Hammond, P. (2008). Conservation status of small cetaceans in the Chiloe Archipelago, southern Chile. Document SC/60/SM23 presented to the Scientific Committee of the International Whaling Commission.

FINAL WORDS AND RECOMMENDATIONS

The governments of Argentina and Tierra del Fuego could set an example of responsibility regarding the Sustainable Development Goals (SDGs), adhered to by the province in 2016, by forbidding aquaculture with introduced species, like salmonids, which would have environmental, health, social and economic impacts.

The Patagonian marine and freshwaters are not the natural environment of these species. Their willing introduction would imply ignoring the contributions of the science about the costs of these practices. The impact exotic species have is undeniable (IUCN[77], Convention on Biological Diversity[78], FAO[79]). In the special case we are debating, there's no biological bench base allowing us to evaluate the future impact.

Salmonids aquaculture is an activity requiring investment and development of institutional capacity, as well as regulations and impact control. In the case of Chile, with more than 30 years of experience and successive updating of their rules and regulations (RAMA and RESA) to improve compliance, the impacts are still serious and the health, social and economic crisis are current[80-81].

The province of Tierra del Fuego has based its development strategy on tourism of its natural wonders, and the potential growth of this industry is significant. The installation of growth centres and net pens in the coastline or the lakes, would imply a loss of patrimonial and landscape value.

Given the fragility, richness and pristine quality of the waters in Tierra del Fuego, the presence of a high impact industry is a threat to the conservation of species and ecosystems. As a result, we recommend to protect these environments from the serious consequences of exotic salmon farming, forbidding this particular aquaculture in Tierra del Fuego and in any other point of the national sea coast.

77 https://www.iucn.org/es/node/19061

78 https://www.cbd.int/invasive/about.shtml

79 http://www.fao.org/docrep/005/V9878S/V9878S00.htm

80 "Baja cooperación virtuosa y un sistema científico y tecnológico sin las capacidades, competencias y habilidades suficientes para expandir y aplicar nuevo conocimiento científico y tecnológico dirigido a resolver problemas concretos de productividad, eficiencia, competitividad, gestión medioambiental y para asegurar el manejo sustentable de recursos naturales." La Salmonicultura en Chile: Situación Actual y Estrategia de Desarrollo al 2030. Programa Estratégico Salmón Sustentable. Prospectus Consulting (2016).

81 http://www.emol.com/noticias/economia/2012/10/31/567503/industria-del-salmon-ya-casi-ha-olvidado-la-crisis-del-virus-isa-con-sus-numeros-recuperados.html

Salmon farming takes place in natural sites of extraordinary beauty and value. Not far from the Beagle Channel (Argentina), in Chilean fjords, the risks of this industry are clearly seen: coastline alteration, water and seabed pollution and impact on local communities. Photo credit: Oceana, Dany Casado.

LEGAL APPENDIX

Argentinian authorities of all levels have the duty to preserve the environment and protect the biological diversity:

- Wild fauna has been declared of public interest in Argentina by the Law 22.421, as well as its protection, conservation, propagation, re population and rational use. All inhabitants of the Nation have the duty to protect it.
- The National Constitution, in article 41, recognizes the right to a healthy environment and the duty to preserve it. Authorities shall provide for the protection of this right, the rational use of natural resources, the preservation of the natural and cultural heritage and of the biological diversity, and shall also provide for environmental information and education. The National Government is entitled to sanction the minimum budget for environmental protection, and the provinces must have the necessary rules to complement them, without the former affecting local jurisdictions.
- Law 27.231 on the sustainable development of aquaculture sector is targeted to production and extremely weak on weighting and preventing impacts, and it's not aligned with the requirements and principles of environmental law applicable to the activity. Law 27.231 only refers to an aquaculture that is able to maintain itself, in as much as possible, ecologically sustainable in time, making the aquaculture company accountable, in the case of exotic species, for ensuring the contention of the farmed fish in the exploitation space, forbidding access to waterways that drain in the sea, in the case of marine species in order to avoid, in as much as possible, any genetic contamination of the native fauna. Any aquaculture project with exotic species can only be started after fulfilling the requirements on assessment and prevention of impacts required by the National law of minimum budget for environmental protection.
- The Ley General del Ambiente or LGA (General Environmental Law) 25.675 states that the harmful or dangerous effects of human activities on the environment must be prevented to allow ecological, economic and social sustainability of the development. It establishes the prevention principle (the causes and sources of environmental problems will be taken into consideration in an integral and prioritised way, trying to prevent possible negative effects on the environment) and the precautionary principle (when there's serious or irreversible danger, lack of information or scientific certainty can't be used as a reason to delay the adoption of effective measures, based on costs, that will prevent the environment degradation). The principle of progressiveness, on the other hand, states that environmental goals must be gradually achieved, by intermediate and final objectives. Progressiveness also implies that the goals and objectives met in the protection of the right can't be later on sacrificed and reduced. Once achieved an objective, this can't be undone. LGA also establishes that any task or activity performed in the Argentinian territory that can degrade the environment, any of its components or affect the quality of life of the population in a significant way, will be subject to an assessment procedure of environmental impact, before its implementation. Said process must foresee an instance of citizen involvement, as everybody has the right to be consulted and participate in administrative proceedings related to the preservation and protection of the environment, either general or particular, and with general scope.

  The Estrategia Nacional de Biodiversidad o ENB (National Biodiversity Strategy) in Argentina, passed by Resolution 151/2017 recognizes that invasive alien species (IAS) have been identified as one of the main causes of biodiversity loss, affecting also the provision of ecosystem services. Particularly, it highlights that invasive alien species have been detected as an important threat to biodiversity conservation, and that alien species have been identified which produce negative impact

in biodiversity with economic and social consequences. It also stresses the negative impact of the introduction of salmonids in freshwater ecosystems.

The ENB assigns one of the priority national objectives to invasive alien species (19) to implement a system coordinated and integrated by national authorities with expertise to warn, early detect, control and/or eliminate invasive or alien species, naturalized or not, that may affect negatively biodiversity. Axis 1 of ENB, titled "Conservation and sustainable use of biodiversity" has as the general objective preserve biodiversity with the focus on ecosystems, based on a landscape scale to improve the conservation state of wild species, and ensuring the well-being and quality of life of people who depend on them. Also, sub axis 1 of Axis 1 of ENB has one point destined to prevention, control and audit of invasive alien species, with a series of specific objectives regarding IAS in the country, including: development of a strengthen governance framework in all the country allowing effective protection of biodiversity against impacts from IAS; strengthen institutional capacities, at national and provincial levels to manage IAS; strengthen regulatory framework and financing mechanisms supporting the implementation of the National Strategy of IAS; validate and implement protocols to handle IAS prioritized in taxa and ecosystems included in the National Strategy of IAS; and develop programs to eradicate exotic species, particularly those that could have irreversible impacts on species considered extreme endemisms. Aligned with it, the Ministry of Environment and Sustainable Development of Argentina (MAyDS) with participation from several organisms, is implementing project GEF GCP/ARG/023/GFF "Fortalecimiento de la Gobernanza para la protección de la biodiversidad mediante la formulación e implementación de la estrategia nacional sobre especies exóticas invasoras (ENEEI) (Strengthening governance to protect biodiversity by formulation and implementation of a national strategy on invasive alien species).

At the international level, Argentina has assumed several commitments relating to alien species, including agreements ratified by the country, and thus valid as domestic legislation:

- By the Convention on Biological Diversity (CBD), Argentina is committed to do no harm to other states or areas situated outside the national jurisdiction by exercising its sovereign right to exploit its own resources, and to notify them about it. This could be the case with aquaculture of invasive alien species. Also, the protection of ecosystems and natural habitats, the preservation of viable population of species in natural environments, and prevent the introduction of exotic species, or control and eradicate those that threaten ecosystems, habitats or species. Within the CDB framework a strategic plan 2011-2020 was adopted, together with the Aichi Biodiversity Targets. Within the framework of the strategic goal B of that plan (reduction of direct pressures on biological diversity and promotion of sustainable use by 2020), the Parties to the CBD, Argentina included, have committed to reach Target 7 "By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity" and Target 9 "By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment". It's due to CBD that Argentina developed the National Biodiversity Strategy and its derived actions.
- The Convention on the Law of the Sea urges States to take all necessary measures to prevent, reduce and control the pollution of the marine environment caused by the use of technologies under their jurisdiction or control, or the intentional or incidental introduction of foreign or new species in a certain part of the marine environment that may provoked considerable and harmful changes in it.
- Within the framework of the Sustainable Development Goals (SDGs), Argentina has assumed additional commitments related to the IAS. Goal 15 aims to "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse

land degradation and halt biodiversity loss". And target 15.8 aims "by 2020 introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems, and control or eradicate the priority species".

To learn more about national and international environmental legislation, as well as formal requests to access to public information on the subject and the official answers received up to the date of closure of this document, visit https://farn.org.ar/archives/25337.