



Salmon farming 2040: expected and desired futures

Organisers:

SALMANSVAR- Responsible Innovation in Salmon Farming
Centro de Estudios del Desarrollo Regional y Políticas Públicas (CEDER), Universidad de Los Lagos.

Place: Universidad de Los Lagos, Puerto Montt, Chile.

Date: 27 March 2023

Time: 09:00- 13:00

Context

The workshop - Salmon farming 2040: expected and desired futures - was held on Monday, 27 March at the Universidad de Los Lagos, Puerto Montt, Chile. The objective of the workshop was to generate a discussion on different factors that could impact the salmon industry over the next 17 years, focusing the discussion on Chile but taking into consideration the global dynamics linked to the development of the industry.

At the beginning of the activity, the Salmansvar project was presented, highlighting that responsible innovation is a current topic on the industry's agenda at a global level, something that could be reflected in Chile's productive development policies in the short term. Consequently, this workshop was introduced by highlighting the importance of having spaces for reflection on the future that could be a contribution in terms of planning and action within the salmon industry.

The methodology was based on the guidelines of UNESCO's Futures Literacy Learning Lab, based on the experience of the 'Future Literacy Lab on the Norwegian salmon industry' workshop held in September 2022 in Norway, by Salmansvar and AFINO. Although both workshops shared the exercise of imagining possible futures, the Norwegian workshop focused on projecting, from current conditions, a desired scenario, a realistic one and then one proposed by the organisers, while on this occasion five scenarios were presented on which the discussion was based.

The dynamic of the workshop was focused on these five future scenarios: the first, called *Business as usual*, invited the participants to imagine the salmon industry in 2040 based on the current situation, that is, without involving new technologies or regulations, etc. For the four subsequent scenarios, participants were given a brief description (Annex 1) as a

contextualisation to start the discussion, indicating the elements that would drive the change and the consequences for producers, consumers, workers, communities and the environment. These scenarios are: *Floating farms (closed offshore systems)*; *Fake fish (plant-based alternatives)*; *Internalizing externalities (highly regulated production)*; and *Urban-industrial salmon (land-based production)*. In conclusion, participants were asked to summarise - in one sentence - what they expect the salmon industry in Chile to be like in 2040. Approximately 20 minutes were allotted for each of the scenarios. The main ideas for each scenario were written by the participants on sticky notes and placed on the room's whiteboard to illustrate the discussion.

There were 7 participants plus the Salmansvar and CEDER team: a total of 12 people. Due to the small number of participants, it was decided to organise the activity around one discussion group rather than parallel groups.

Table 1. Participant identification.

| Name | Institution |
|----------------------|---|
| Débora Torrealba | Pontificia Universidad Católica de Valparaíso |
| Daniel Vulasich | Salmonera Camanchaca |
| Skarleth Chinchilla | Pontificia Universidad Católica de Chile |
| Pablo Ibieta | Pincoy |
| Rodrigo Carrasco | Consejo del Salmón |
| Doris Soto | INCAR, Universidad de Concepción |
| Adolfo Alveal | Club Innovación Acuícola |
| Joaquín Zenteno | Equipo organizador |
| Emil Lindfors | Equipo organizador |
| Katherine Bassaletti | Equipo organizador |
| Jonathan Barton | Equipo organizador |
| Álvaro Román | Equipo organizador |

The workshop began with an activity that allowed us to get to know the participants and stimulate the exercise of projecting themselves into the future from their personal narratives. First, they were asked to introduce themselves and then to tell us what they were doing 17 years ago, and then to imagine where they would be in the year 2040. The answers were varied since we had participants of different ages and disciplines, however, several agreed that in one way or another their work would continue to be linked to the field of salmon farming. One participant expressed the need to write down his memories of working in the sector: "There are human things, successes and failures. They are stories to tell." We consider that this activity was appropriate from the outset in that it opened up the conversation in an engaging way and fulfilled the objective of getting to know the position of the attendees.

Subsequently, the scenarios were discussed. The following is a synthesis of the discussion of each of these.

A. Business as usual

In this first scenario, the participants discussed various topics, which served as a general overview of the concerns and expectations of the industry. First, the need for technologies that ensure animal welfare was discussed, which is part of the current demands of consumers due to a generational change. Then, the reduction of the ecological footprint, produced mainly by transportation. The biggest obstacle was the cost it would entail. This opened the debate by questioning the implications of selling fresh produce to distant markets. A solution to the above would be to target local markets such as Latin America and the Caribbean, considering that Japan no longer has the preponderance it had before, and the differences between Chile and Norway in terms of access to these markets. The strategy should then be multi-faceted: on the one hand, new markets and new technologies, but also regulations that allow companies to access carbon credits.

In terms of targeting local markets, the need to massively increase salmon consumption in Chile was discussed. The main disadvantage is the cost for consumers, resulting in a product to which people do not have regular access. One way to make salmon prices more accessible is to make changes in the fish diet, taking as an example other meat industries, such as chicken, but the concern is the future access to fishmeal and microalgae oil for feed. It is expected that the salmon feed source will be scarcer so that feed costs in this industry would not be comparable to that of other meat industries. Another proposal is that by targeting new markets, prices would be lowered to access these markets.

The salmon industry must move towards linking existing data in decision making, projections and governance of the industry, which is especially important in the face of extreme events. Similarly, there should be greater coordination between companies, since currently each company works separately, generating similar studies and testing new technologies repeatedly. This is something that could be done more efficiently and with better use of resources.

From a social perspective, it is thought that the image that people have of the industry will not improve, because despite the work that the companies have been doing, they have not been able to connect to the public. Likewise, off-shore cultivation and cultivation in tourist areas could be problematic due to the visual impact. The implementation of new technologies could have a strong impact on employment, something that would call into question the justification of this type of industry for the State; in this sense the social impact should be considered in the externalities. At this point, one of the participants affirmed that it is a complex issue to deal with in activities such as this because there is a lack of more

critical positions towards the industry that would nurture the discussion, while other participants also agreed that criticism and dialogue with different actors is necessary.

Finally, the participants agreed that production will not increase, but will be more efficient.

B. Floating farms

The focus on off-shore systems and recirculating aquaculture system (RAS), is regarded as highly possible scenario at scale, however it is foreseen that the industry will not grow because of a lack of technology but rather a lack of market. In this scenario, production would become seasonal, there would be no fish in spring-summer due to the risk and the shorter cycles in the sea; cell cultures were also mentioned, emphasising food safety. The salmon industry is seen as a 'closed box', since it does not dialogue with other activities in the same production areas, which is another significant difference with the industry in Norway. Another option could be to work sea-land, linking it to other products such as the production of mussels (*Mytilus chilensis*). Similarly, the Patagonian internal sea can be managed in a more balanced way. An interesting technology to develop would be mobile off-shore centers, moving factories that imitate the natural movement of the fish, which would produce fewer impacts. Among the negative aspects are the possibility of damage or sinkings, and the security that would be needed to confront piracy on the high seas.

Once again, the concern arose that the incorporation of new technologies in genetics, robotics and remote systems would require less human labour. In response to this, it was stated that this is a process that will also be seen in other types of industries; therefore, the salmon industry alone cannot be held responsible for a drop in employment. On the other hand, the departure of the salmon farms from the fjords could lead to a change in employment for the local population, with tourism being an important option. The question arises about the visual impacts of the cages, considering that they are installed in places with a significant tourist potential. There are similarities with wind farms and the response that the communities have had to these. In Norway, some farming centers have been designed so that they are not so disruptive, minimising visual contamination. It was concluded that this would not be a problem because the sites would be located far from the coast and tourist areas, so they would not generate a negative visual impact. Nevertheless, work with communities was still necessary.

One aspect that hinders this scenario is the lack of regulation. Chile does not have an aquaculture law that covers this type of operation yet, and the creation of legislation is a slow process, making it difficult to assume investment risks. At the institutional level, concepts are not handled in a standardised way. Since this is a process that is recently underway, it is more difficult for companies to plan due to the lack of clear criteria.

C. Fake fish

To introduce this scenario, the current situation was presented: the production of salmon from cells is something that is beginning to be worked on in the USA, but in Bergen, Norway, it is still not well known. In Chile this type of product is called "vegan salmon".

This scenario requires advances in biotechnology, involving gene selection and regulatory challenges. It would be a more sustainable option as it would be produced in tanks on land. It would imply a change in the salmon industry as a producer of marine protein, something that is already observed in meat plants where beef biceps or chicken meat is produced: a Lab Meat within a normal processing plant. The main question is where these centers would be located: there is such a large amount of biomass to produce that there would not be enough space in coastal areas (not even in China), compared to production in the sea.

The participants agreed that this type of product would not be competition for traditional salmon, but would be another market since fish consumers are a niche, while vegans who consume alternative fish for taste are not that common, although this might well change by 2040. Emphasis was placed on the cultural part of the food, since consumers appreciate wild salmon and natural salmon. On the other hand, a salmon whose production is not fed with pork by-products could open up other markets such as Saudi Arabia.

D. Internalise externalities

By way of contextualisation, the work done in Norway with the 'traffic light system' for cultivation sites was explained. Another participant explained that Chile has also worked on a similar proposal where 'green' means that there is no significant impact not only on health but also on environmental wellbeing in general, since it is thought of in a broader way, not only in terms of the operation of the sites. On the one hand, it was stated that more regulation would mean more costs; it was noted that more regulation is not necessary, but rather more effective regulation.

It was emphasised that the industry should be thought of in a sustainable, ethical and useful way. Today, growth is in turnover, but not necessarily in production. In the future, growth must be sustainable and there must be marketing based on this sustainability.

Another issue that was raised was transparency in the industry. Companies do not openly share certain types of information due to competitiveness issues. In Chile, information is shared only at a precompetitive level and there should be a move towards an idea of neighborhoods where the performance of one affects all. As mentioned above, in Chile the same ecosystem is used for aquaculture, artisanal fishing and miticulture, so it is necessary for the salmon sector to dialogue with these other actors regarding the use of the same space and its impacts, since the impacts are often shared.

The systems of the state institutions that record data and statistics should be updated. Currently the systems are outdated, making management difficult in bureaucratic terms and delaying response times to observations that the companies must correct.

E. Urban-industrial salmon

This scenario was characterised as the least likely. It is a new form of production that could involve yet unknown problems. Although it is an interesting option to be closer to the target markets, it would generate challenges related to costs, energy required, water availability, infrastructure, etc. It could even be more expensive than production at an offshore facility. In view of this, it was envisioned that in 20 years there could be new forms of energy generation that could be a contribution in this aspect. It was suggested that an alternative could be to produce by ship on the high seas, approaching the market and finishing the process on land, but it was considered that this would have the same risk of piracy mentioned above in the case of floating farms. Both smolt and RAS require fresh water and to be located near the sea, so how this could be done in the case of Chile is an unresolved issue.

Regarding the product, it has been observed that it has a different taste compared with sea cultivation and this is something that is currently being worked on by incorporating bacteria. However, this use of bacteria in turn generates a new risk given the difficulty of managing them in a balanced way. Currently, there have been no positive experiences with this type of farming, with examples in the USA (Miami), Russia and China, although results have been seen in other species such as tilapia.

Keys to 2040

Considering that, , several of the concerns for the future are repeated regardless of the scenario, the final analysis of the participants gathered together the ideas of what the salmon industry should ideally look like by 2040.

Production itself is planned to use various combined systems: RAS, closed system at sea, and even cultivation on ships at sea. It is expected to be more efficient production, with more and better technology and innovation in terms of biotechnology, taking special care of animal welfare. They agree that there must be greater transparency, with data that will make it possible to know and reduce the impact on the environment and promote its protection. It is also important that there should be greater links with the public world, science and consumers in the innovation process. In this sense, it is essential to have updated regulations, digitalised information and decentralised institutions.

Social license would be key for growth and innovation within the industry. Currently, social license indicators end up being checklists and therefore do not have a real impact. It is an issue that must be addressed beyond communications, taking care of issues that remain unsolved. It is possible to look at the example of other major industries in Chile, such as wine or fruit, that have a better social license than the salmon industry despite their ecological and community impacts. We must move towards ways in which the industry generates benefits that are not only by trickle-down, but as an industry that evolves from the local level.

The sea is regarded as everyone's environment, and the participants recognise that is the case, but what is striking is that it is something that is widely socialised. It is a concern that an industry uses everyone's space and that in the regions where it is produced, most of the population does not consume the product and only receives the impacts. Today the price is not accessible to the mass public and the sale of salmon is restricted to small, specialised stores; the salmon found in local street markets is of unknown origin and probably illegal. To remedy this, work should be done to strengthen the productive identity as a 'salmon region', making people feel part of it, and making it a source of employment for local communities, while ensuring that they have access to the product.

The industry must be more attractive to human capital so that people are able to project themselves in more than an executive role, attracting researchers and professionals from different fields. Finally, the industry is definitively linked to the south and especially to the Los Lagos region.

ANNEX 1: BASE SCENARIOS FROM WHICH THE DISCUSSIONS WERE GENERATED

Fake fish: Plant-based alternatives

In 2040, the biotechnological developments seen twenty years in others food products have encompassed the salmon aquaculture industry. Not only it is cheaper to work with plant-based equivalents rather than farming fish, but also the global demand for meat and fish products has stagnated and even gone into decline in some products. The principal innovations have included laboratory production of plant-based 'salmon' and similar salmonid products, now produced at a large scale in multiple locations around the globe, such as China. The traditional producer nations of Norway and Chile still produce farmed fish, but the market for these products has stagnated and the sector has gone into decline. It is now a luxury product, like the 1970s and 1980s and is sold to restaurants and is available in supermarkets at a premium price. The sector has consolidated and there are fewer producers around the world. The new firms producing plant-based fish products are not the traditional producers from the salmon sector but rather the largest food conglomerates.

Main drivers:

- Global demand for plant-based foods for dietary and planetary crisis reasons (vegetarianism has risen significantly among younger age groups)
- The global capture fisheries crisis has exacerbated and alternatives beyond aquaculture have received considerable investment.
- The global food industry has invested heavily in non-meat and non-fish products as a means of controlling the supply chain.

Impacts for:

- **Producers:** Traditional salmon producers have left the sector, leaving fewer larger producers in activities that are less viable than in previous decades, but still provide returns in a niche market for a premium product. In Chile, only two producers are still active, with production at levels that are below those registered in 2020. Producers are based in multiple locations, nearer to the largest markets.
- **Consumers:** There is a general trend in consumption towards healthier diets. Food costs have risen considerably, and laboratory production is able to keep costs lower than for fish farming.
- **Labour:** Labour in Chilean salmon aquaculture is at 5.000 workers in cages and in processing. This is concentrated in Los Lagos, as the higher costs of producing further south have closed sites.
- **Communities:** Many communities have lost their main employment activity, leading to higher unemployment and outmigration from smaller towns in Los Lagos, Aysén and Magallanes.
- **Environment:** Although environmental impacts from production remain for the remaining sites, the lower volumes and densities have led to no disease outbreaks and mass escapes.

Floating farms: Closed offshore systems

In 2040, most salmon production now takes place in closed offshore systems. 60% of production is in these systems with this figure expected to rise to 80% by 2050. These systems are capital-intensive and technology-intensive infrastructures that are able to provide controlled inputs and are resilient in the face of ocean storms. Although the first versions of these systems in the late 2020s were innovative but had limitations, the versions 2.0 in 2040 have improved designs and have larger capacities. The first versions of these systems were made in Norway with expertise from offshore energy infrastructures. They are intensive in materials but offer controlled systems with effective management of waste materials, no escapes, no disease risks, and low mortality. Production costs are high at the outset but there is cost recovery with each year of use, and with gains from improved production. The reduction in environmental impacts has improved the image of salmon production and it remains an increasingly attractive food for global consumers, with consistently rising demand. Labour costs are significantly reduced, with more capital-intensive elements to the system, although transport costs are high in moving inputs to the systems and in bringing harvested fish to processing sites on land. The geography of production has changed considerably, with water temperature the main factor, but with no limitations in terms of water column circulation and protected fjord landscapes.

Main drivers:

- Demands for reduced environmental impacts in coastal areas have led to increased public and private investment in these closed systems.
- Technological skills from other sectors have provided viable systems at large scales with low labour requirements.
- Lower mortalities and disease outbreaks, with more control over the farming process through the control of inputs.

Impacts for:

- **Producers:** The sector is now dominated by a handful of large producers who have operations in multiple locations, in traditional salmon aquaculture zones due to existing processing capacities and knowledge of the sector, but there are numerous new locations nearer to major markets. Investment from conglomerates is notable.
- **Consumers:** With more control over the product, and fewer negative impacts, consumption continues to rise as salmon aquaculture has an improved image.
- **Labour:** The impacts on cage and processing employment have been significant. Cages have reduced significantly in number, while processing now takes place in different countries, leading to fewer, larger processing sites in Chile.
- **Communities:** Community impacts have been significant, with lost employment and outmigration.
- **Environment:** Coastal impacts have been reduced significantly, with benefits for other species and users.

Internalise externalities: Highly regulated production

In 2040, many food sectors have been subject to increased regulation. These regulations relate to the environmental impacts of production in situ, the long supply chains and the carbon intensity of these chains, rising demands of labour for improved working conditions and pay, and increased opposition from communities towards productive activities that are regarded as environmentally damaging or that benefit the community marginally compared with their negative externalities. Since 2030 onwards, the strength of state regulation of salmon aquaculture has risen considerably, and this has led to increased costs in order to meet these demands. The early signs of this new regulatory drive were evident in Norway in the early 2020s with the introduction of the resource tax and the 'traffic light' system to control disease intensities. Since then, regulations are both more numerous and stricter in terms of how producers can operate. The consequences include few, larger producers, with the loss of smaller producers, due to the costs of internalising these new demands. Since these regulatory environments are increasingly global, there has not been a significant effect on the geographies of production and processing. However, the costs of salmon production have more than doubled which has reduced demand considerably.

Main drivers:

- Environmental, labour and community pressures in the face of information about the impacts of the sector. Knowledge has risen considerably with social media.
- Concerns about climate change, the rise of veganism and changing consumption habits more generally in higher income countries.
- Rising food costs, impacts of food production and supply chains, which have given rise to more seasonal product consumption and local products.

Impacts for:

- **Producers:** Rising costs have led to a concentration in the sector with smaller firms being bought out. This concentration has enabled some larger producers to maintain production in spite of the rising costs and falling demand.
- **Consumers:** Salmon is associated with more exclusive markets since it has a premium price. Consumers prefer cheaper fish alternatives such as tilapia. Demand in some city locations in the Global North has been maintained, as the higher price is off-set by the higher standards of production perceived by the consumer.
- **Labour:** Labour conditions have improved with rising regulations, including pay. However, there are fewer jobs available as production has stagnated.
- **Communities:** Communities have been benefited by fewer negative externalities and higher production standards. Salmon production is more acceptable, and fits alongside tourism and capture fisheries.
- **Environment:** Increased regulations have improved coastal landscapes and marine environments, with less water, contamination, diseases and escapes.

Urban-industrial salmon: On-shore production

In 2040, production has been shifted to controlled on-shore production sites where water is recirculated and temperatures are controlled. All wastes and inputs can be controlled more effectively and there are no longer impacts in marine environments in terms of benthic layer contamination, escapes and other impacts. The costs associated with these systems are higher than growing-on in marine environments, for example with larger land areas for production systems with access to water and energy for recirculation. The advantages are in location of production systems closer to markets, without marine transport costs. There are also less climate and ocean impacts on the systems, thus ensuring more controlled management. The geography of production has shifted to numerous locations around the world, where large metropolitan areas are close, and where water access is guaranteed, and energy costs are not excessive (renewable or non-renewable). The traditional production areas for salmon aquaculture have been severely impacted, and survive with considerably smaller capacity than previously, maintaining marine production cages. Employment has been decimated by these new systems in traditional production locations, although there is employment in new locations, albeit at smaller levels given the capital intensity of the systems. Production is now more industrial in scale and logic, with higher costs but with transportation benefits that are considerable.

Main drivers

- Access to markets, rising transportation costs and innovations in technology that make on-shore production viable.
- Increased demand for fish products, particularly in Asian markets, and changing consumption patterns globally, which favour non-meat diets and lower impacts.
- Lower cost regionally-generated renewable energy systems replace fossil-fuels.

Impacts for:

- **Producers:** The traditional aquaculture producers have diversified into on-shore systems but these are the larger producers. Smaller producers have persisted with marine systems. New investors in the sector have appeared from the industrial food sector, installing processing capacity alongside production systems.
- **Consumers:** Consumers favour low carbon supply chains and local markets, into which these on-shore local production systems fit: local, low impact salmon.
- **Labour:** New opportunities for employment are now more urban than rural. Employment persists in older production areas around the world, but these are reducing considerably as local metropolitan production gains ground.
- **Communities:** New communities for production have emerged in urban contexts, while impacts have been reduced in rural sites around the world as production has declined. Rural communities have looked to diversify in the process.
- **Environment:** Impacts are significantly reduced with the on-shore systems, although this requires more management and circular economy initiatives.

ANNEX 2: TRANSCRIPTION OF STICKY NOTES FOR EACH SCENARIO

Business as usual

- The image of the industry will not improve and will continue to be a major obstacle.
- By 2040 I see an aquaculture production sector focused on animal welfare.
- More efficient distribution with a smaller environmental footprint
- Reactive to extreme events, not proactive
- With strong application of artificial intelligence and digital technologies. Less labor intensive
- Increased production efficiency
- Increased production demand. Increased production. Expansion of cultivation areas
- Chilean salmon farming will be more restricted in production and distribution in coastal areas.
- Focused on a niche in the framework of strong competition with salmon produced by cell culture and vegetable ingredients.
- Need for resilience to climate change. Optimise production systems (important). Improve analysis and reaction at sector level
- RAS. Solving several gaps/challenges of the current model
- Simpler and more effective regulation
- A more clustered and sustainable industry, where the conversation between stakeholders has been strengthened.
- Greater understanding of animal rights
- Mass consumption of farmed salmon

Floating Farms

- Environmentally-friendly farming
- Highly efficient and popularly accepted on-farm cultivation.
- Very possible scenario: mobile offshore farming with low impact, higher yields.
- Lower impacts, less employment. Image of the sector does not improve much
- Increased foreign ownership and extractive production with little interaction with the Chilean economy.
- Based on mobile, efficient, lower carbon footprint cultivation sites.
- Very feasible. Norway and Chile remain world leaders with floating farms.
- By 2040 production systems with lower environmental impact and more systematic, i.e., greater use of AI and technology

Fake fish

- Fake fish is another item, I don't think it will replace salmon.
- 'Fake salmon' can only grow, but it will not replace the real one.
- Separate item. Difficult to produce in volumes. Does not threaten salmon production.
- Less consumer acceptance. Different niche
- Consumption is standardised at all levels worldwide.
- Standardised value chains of global protein production depend on pellets.
- 'Fake fish' is a realistic but long-term opportunity. It is not a technology that will be attractive in the short term.
- It will not replace salmon farming

Internalise externalities

- Well-regulated but not affecting production or production efficiency
- Production with more efficient/effective regulation stemming from public-private agreements
- More effective regulation that integrates salmon farming with other ecosystem activities
- Chile benefits from biotechnology because there is less regulation
- Increased production in Chile in closed systems due to taxation in Norway and increased regulation in Chile
- Improvements in data entry to the authority. Improvements in forecasting systems
- By 2040 a more regulated industry due to social-environmental pressure.
- Regulation that leaves room for innovation
- Similar regulation
- Essential regulation to allow industry growth (sustainable)

Urban-industrial salmon

- Not feasible on a large scale in 2040. New regulations
- RAS will move forward, but to solve challenges in the current model. Combine RAS with offshore production
- RAS is only part of production. Volume would not be very large or like at-sea production.
- RAS does exist but only to protect fish.
- More post-smolt and hybrid systems as in Norway.

- In 2040 the cost of this type of installation will still be expensive with a high percentage of risk. Unattractive for the industry
- By 2040 'urban-industrial salmon' will have slow growth. Resources such as water will be limiting

2040

- Efficient production. Reduced use of antibiotics. Reduced environmental impact
- Knowledge of the impact on the ecosystem. Transparency on challenges. Better science/industry/government communication.
- Data available to ensure that the salmon industry has reduced its environmental impact and improved animal welfare.
- Salmon available and affordable to local communities.
- A salmon industry that ensures jobs for neighbouring communities.
- Greater attention to animal rights. Greater public, consumer participation in innovation processes. Greater local identity with salmon in Chile
- Empowering localities with production.
- Various production systems: RAS, offshore, offshore vessel farming
- Increased/better technology and biotechnology for production. Fish, feed, diseases
- Not only avoiding impact to the environment, but protecting it.
- Modern regulation
- Social license, a valued industry
- Increased technology transfer
- Community acceptance of the salmon industry
- More massive consumption of the products nationwide

ANNEX 3: PHOTOGRAPHS





