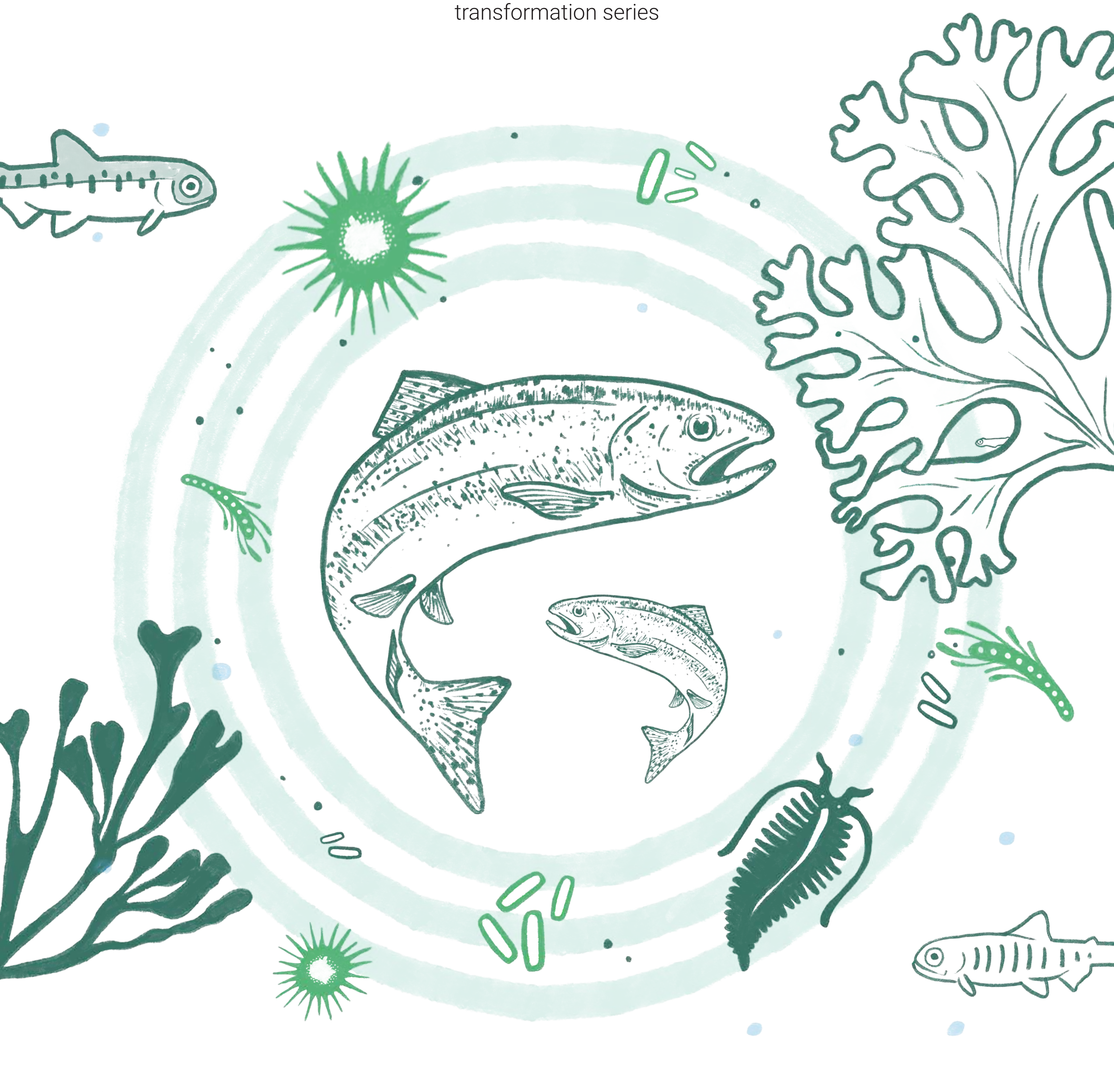
Investing in sustainable aquaculture for a resilient food system

Summa report in the food system transformation series



Investing to solve global challenges | SUMMA EQUITY

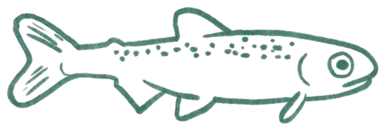


Figure: **Smolt**

About this report

Thank you for reading Summa Equity's ("Summa") report on *Investing in sustainable aquaculture for a resilient food system*. This report aims to provide a comprehensive overview of the current state and future prospects of the aquaculture industry. It places particular focus on overcoming challenges in the salmon value chain and connecting these challenges to the investment opportunities we see within this space. We hope that this report not only serves as an informative resource but also encourages further discussion and collaboration among stakeholders.

Thanks to

Planethon and Leidar Norway for support on the content.

Images

STIM, Nofitech, Milarex
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Disclaimer

The content draws on and references the latest insights in sustainability science with a focus on research on sustainable aquaculture. This includes scientific work published by researchers at the Stockholm Resilience Centre, Stockholm University, but not exclusively. Planethon provided support as a knowledge partner on the writing of this report. Researchers in sustainable aquaculture were also interviewed during the preparation phase.

Investing in sustainable aquaculture for a resilient food system

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Image: STIM

Executive summary

Aquaculture, or the farming of aquatic plants and animals, plays a vital role in addressing the growing global demand for sustainable protein sources.

This report explores the opportunities and challenges within the aquaculture sector, particularly the farming of salmon. It focuses on sustainable practices that align with ecological boundaries and the broader goals of the global food system.

Aquaculture, and particularly farmed salmon, is one of the building blocks in the sustainable food system of the future due to its low carbon footprint, scalability, and high feed efficiency. But as a young industry, it has its challenges such as management of parasites and pathogens, escapes of farmed fish, and unsustainable sourcing of certain feed ingredients. Yet, innovative solutions and technologies are emerging, including closed-loop systems, land-based farming and alternative feed ingredients. These innovations not only address environmental concerns but also offer compelling investment opportunities, solving the industry's main challenges.

Summa's investment strategy aligns with these opportunities, targeting areas such as land-based and closed-pen farming, preventative measures to improve fish health and alternative feed ingredients. Investments in Nofitech and STIM exemplify commitment to supporting sustainable aquaculture practices that enhance both industry profitability and environmental responsibility.

As the aquaculture industry evolves, a systems-based approach that anticipates and adapts to emerging challenges will be essential. Summa is well-positioned to lead in this transformation, ensuring that aquaculture contributes to a more sustainable and resilient global food system.

Martin Gjølme
Partner
Summa Equity

Jon Hindar
Thematic Partner
Summa Equity

The future state of salmon aquaculture could yield EUR 1bn in savings, close half of the anticipated feed gap, and cut CO_2 emission by two-thirds.

Aquaculture is a critical focus area for Summa due to its potential as a cornerstone of the future food system. Despite being a relatively young industry, it presents significant opportunities and its respective challenges that we are eager to address and invest behind. By advancing sustainable practices and innovative solutions, we aim to overcome these challenges and unlock the full potential of aquaculture, ensuring it becomes a vital component in meeting global food demands sustainably.

The future state of salmon aquaculture could yield EUR 1bn in savings from reduced mortality and improved fish quality, close half of the anticipated feed gap, and cut CO_2 emission by two-thirds. Further, we estimate that the respective markets behind this transition could increase five-fold by 2040 given the significant investments and advancements it would require.

The projected growth from 2024 to 2040 highlights a strong investment opportunity within the aquaculture sector, underscoring its promising future driven by innovations and a heightened focus on sustainability. New production methods, particularly land-based and closed systems, represent the largest segment today and in the future. This indicates a move towards more sustainable and efficient production techniques. Additionally, significant investments in sustainable feed and fish health products/services reflect the industry's commitment to sustainability and animal welfare, as well as ever-improving productivity and farming practices.

To understand the drivers behind these estimates and the changes needed to arrive at this future, one must take a system change based approach.

Summa is dedicated to driving systems change to ensure a long-term positive impact on our world. Recognizing that issues such as climate change, biodiversity loss, inequality, and civil unrest stem from the systems we have built, we understand that these systems are functioning as designed. Therefore, if we seek different outcomes, it is essential to fundamentally transform these systems. The theory of change framework helps to conceptualize the systems we aim to transform, envision their future state, and adopt a structured approach to tackling challenges.

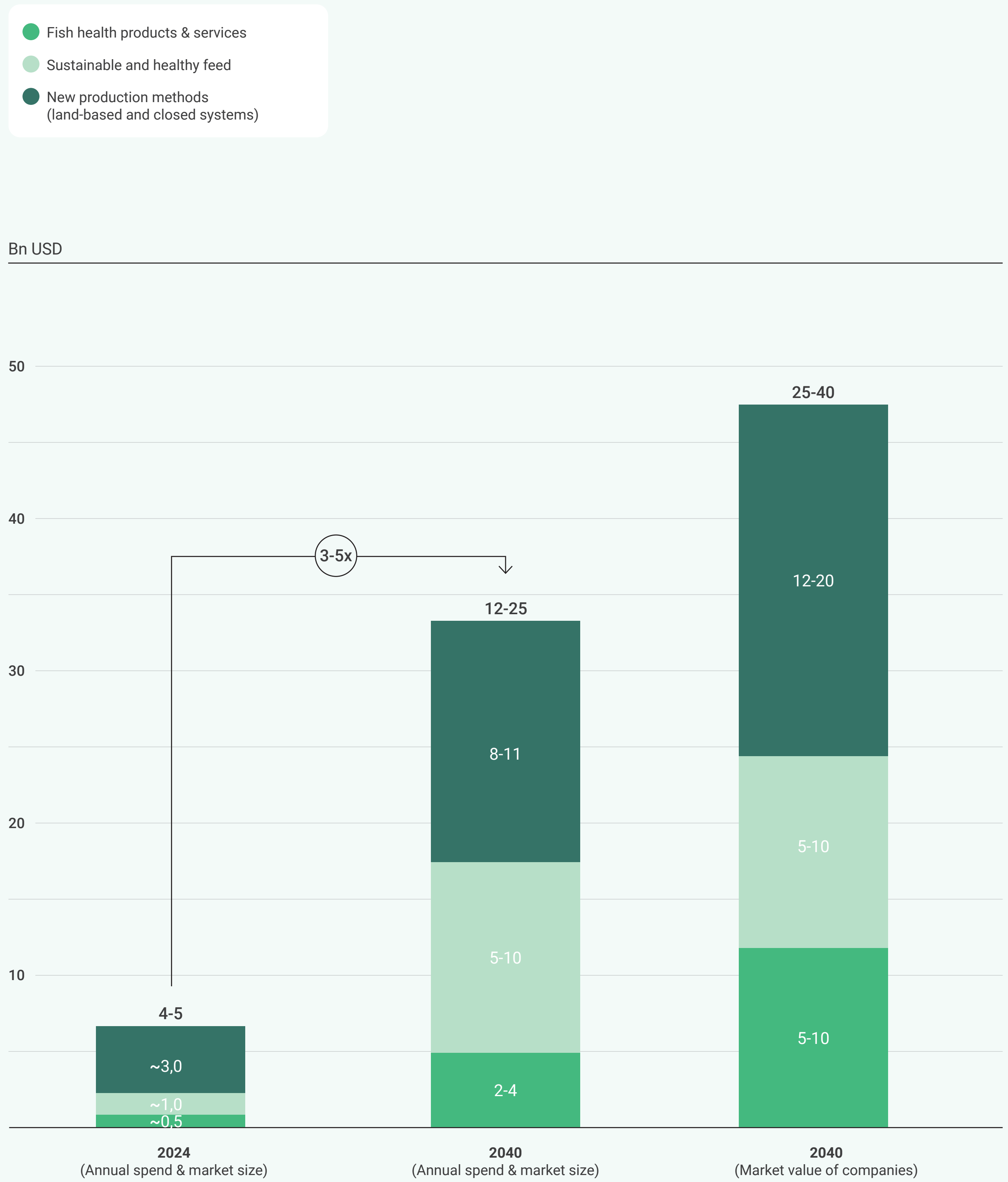
As illustrated in Figure 01, the current salmon value chain faces several challenges. However, with the right incentives, we can strive towards an ideal future state - a more sustainable and resilient aquaculture industry where fish health is enhanced, resources are used more efficiently, and emissions and pressures on the marine environment are further reduced.

Figure 01
Current challenges and ideal future state of salmon aquaculture

*Global perspective **High-level estimates	Current challenge	Future state	Improvements
Biodiversity	110k escaped fish	Zero escapes given closed farming environments	△ 110k reduction
Fish welfare	EUR 1,100m revenue loss due to 95m in dead fish	EUR 100m revenue loss due to 9.5m in dead fish	△ EUR 1bn in savings due to 90% reduction in dead fish and improved fish quality
CO_2 footprint	19.4 kg CO_2e/wfe* *whole fish equivalents	6.5 kg CO_2e/wfe as local production eliminate airfreight whilst substituting soy protein concentrate reduce land-use change	△ -67% reduced CO_2 footprint
Feed	4m tonnes global shortage in aquafeed exp. in 2040 if no new ingredients	2m tonnes est. shortage in aquafeed by 2040 covered by scaling novel and sustainable feed ingredients	△ 2m tonnes reduction in aquafeed shortage

* Norwegian numbers are scaled to global levels by assuming that Norway equals 52% of global production. ** All numbers are high-level estimates and should only be regarded as directional. Escaped and dead fish values are estimated by using the production costs/kg of 70 NOK (6.54 USD) and the average weight of an escaping/dying fish of 2 kg
Source: McKinsey & Company estimates based on figures from Norwegian Directorate of Fisheries; Norwegian Veterinary Institute (2022)

Figure 02
Investable market – Summa



Source: McKinsey & Company

A food system at a crossroad

To meet the future demand of a growing population, the global food system must change.

Today, our food system is facing challenges with food waste and inequitable distribution, public health, land scarcity, CO_2 emissions and water shortages, to name just some of the most prominent challenges. Current efforts to meet the demand exacerbates the environmental challenges that will make it much more difficult to feed humanity in the future. The following statistics make this challenge very clear, and speak to the systemic nature of the challenge:

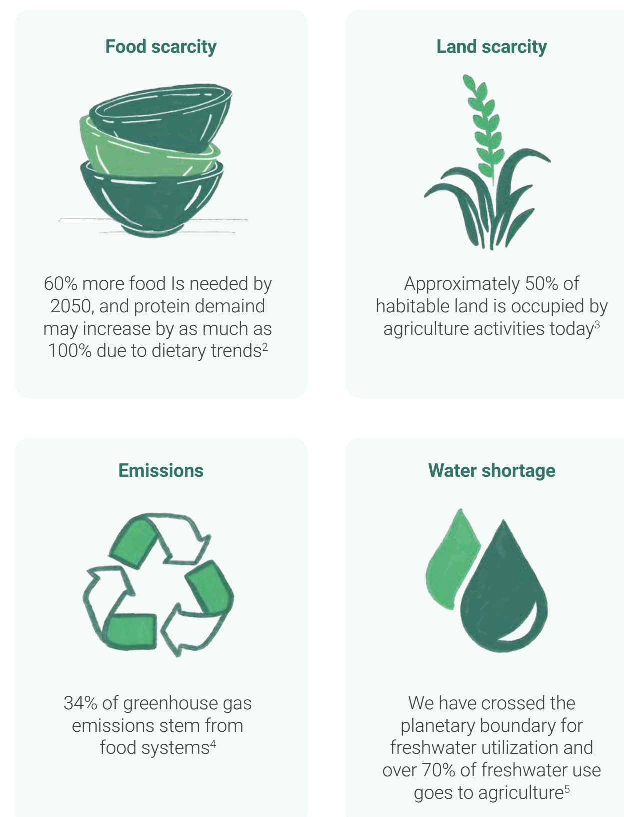


Figure 03
Global food production is a wicked problem characterized by multiple interwoven complexities.

2. United Nations (2012) 3. Ritchie, H., et. al (2019) 4. Crippa, M., D., et al (2021). 5. Wang-Erlandsson, L., et al. (2022).

Building a sustainable and resilient food future

Building a sustainable and resilient food future will therefore rely on responsible practices that ensure the long-term health of ecosystems and the communities that depend on them, while also providing worldwide access to nutritious and balanced diets.

As identified by the Food and Agriculture Organization ("FAO") and the EU's Farm to Fork Strategy, sustainable aquaculture of blue foods, is an important part of the solution for solving issues in the modern food system.

The FAO, a specialized United Nations agency that focuses on improving nutrition and food security, recently made a call for partners around the world to support the development of innovative technologies and best practices to ensure efficient, resilient and sustainable operations across geographies, species and production methods.[6]

Global demand for aquatic food products is expected to grow, driven by population growth, economic development and sustainability of marine protein sources compared to land-based protein sources.[7] However, current aquaculture is at a crossroads, facing its own sustainability related challenges that must be solved in order to offer a fully sustainable and regenerative solution for the future.

Challenges within the current food system that sustainable aquaculture can solve for

Aquaculture undoubtedly plays an important role in the global food system. It provides a diverse range of nutritious and affordable proteins to billions of people,[8] helping to take the pressure off land-based food systems and marine wild capture fisheries alike. Aquaculture in many cases provides a model for producing food in a way that is more resource efficient and with lower environmental impacts than some other food sources.

According to Blue Food Assessment and SINTEF, farmed salmon emits 87% lower emissions, uses 87% less fresh water, and requires 84% less feed when compared to industrial beef production at a global level.[9]

Sustainable aquaculture can address the growing demand for food from aquatic sources, while also enhancing food and nutritional security.

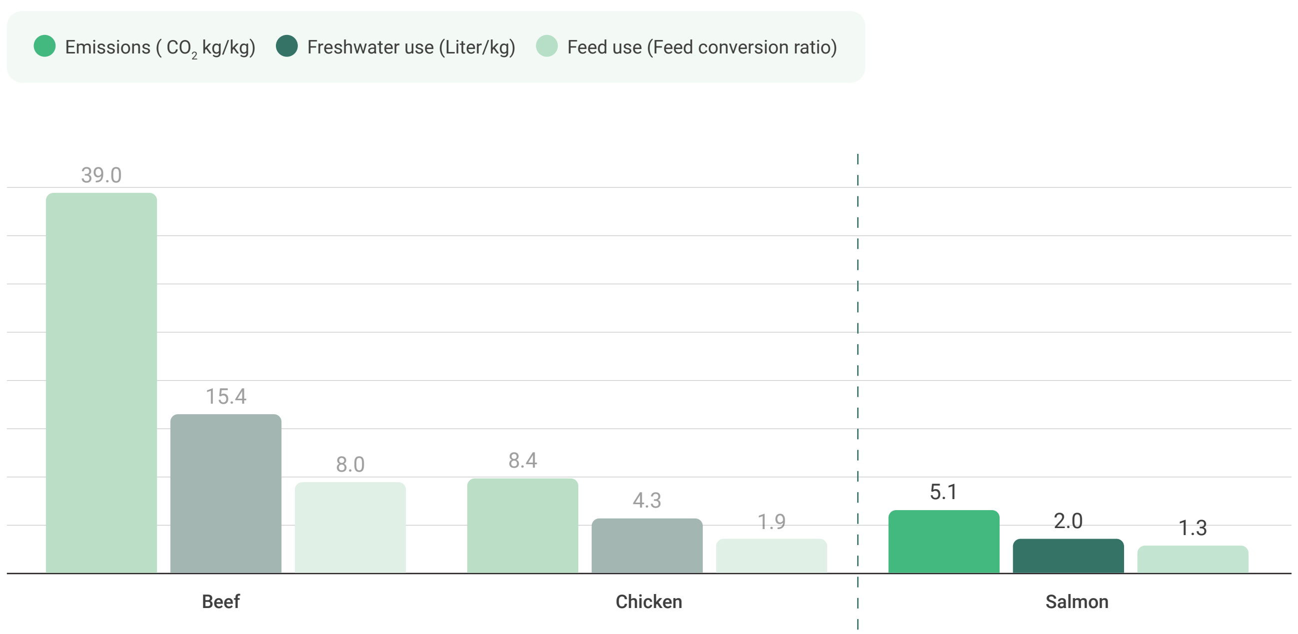
It is a production system that can thread the needle between growth and the maintenance and even restoration of ecosystem health. The graphic below highlights the many connections between aquaculture and the United Nations Sustainable Development Goals ("SDGs").[10]

Five principles have been put forward by leading aquaculture researchers to enable a sustainable, circular and regenerative global aquaculture system:[11]

1. Safeguarding and regenerating the health of aquatic ecosystems
2. Avoiding the production of non-essential products and minimizing the waste of those that are essential
3. Prioritizing biomass streams for basic human needs
4. Using and recycling byproducts of agro- and aquatic ecosystems, and
5. Using renewable energy while minimizing overall energy use.

No such system is currently in place at scale, but these principles represent the gold standard for sustainable aquaculture and are valuable guide future development in this space. The farmed salmon sector is well-positioned to apply some, if not all of these principles, which we discuss further in this paper.

Figure 04
Farmed seafood is a healthy source of protein with a relatively low environmental footprint[9]



6. FAO. (2022) 7. Costello, C., Cao, L., Gelcich, S., et al. (2020) 8. FAO. (2020) 9. Ziegler, F., Nistad, A. A., Langeland, et al.. (2024) 10. Troell, M., Costa-Pierce, B., Stead, S., et al. (2023) 11. Chary, K., van Riel, A. J. et al (2023)

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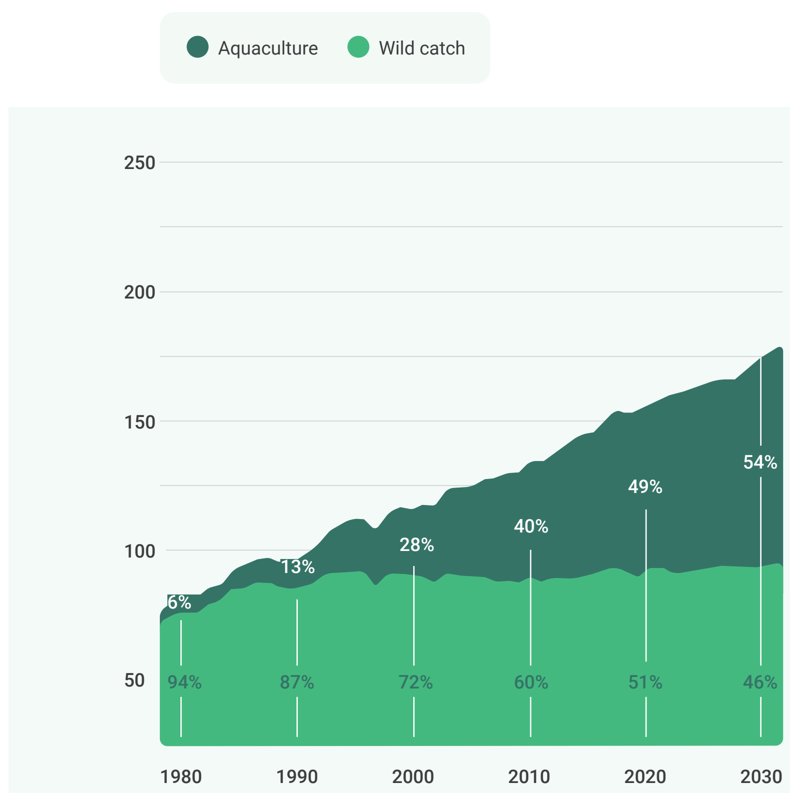
Figure 05
The connection between aquaculture and the SDGs[10]

Direct	SDGs 2, 3	Most obvious are those related to eliminating hunger and improving health (SDGs 2, 3)
Indirect	SDGs 6, 12, 13, 14, 15	Increasing environmental sustainability of oceans, water, climate, and land through responsible production/consumption (SDGs 6, 12, 13, 14 and 15)
Associated	SDGs 1, 5, 8, 10	Reducing poverty, achieving gender equality, improving livelihoods, and reducing inequalities (SDGs 1, 5, 8 and 10)
Related	SDGs 7, 9, 11, 17	Potential for energy production, adding food production in cities, contribution to technology development and development of various partnership (local to global) (SDGs 7, 9, 11 and 17)

Balancing growth and ecosystem health

The FAO forecasts that by 2030, aquatic food production is expected to increase by a further 15 percent.[12] Furthermore, a new FAO report reveals that, for the first time in history, farmed fish production has overtaken wild catch as illustrated in Figure 05.[13] However, this growth must not come at the expense of ecosystem health. For this growth to be sustainable, it must grow in line with environmental and social factors. Pollution, biodiversity, animal welfare and social equity are all facets that must be at the heart of this growth. Innovative and equitable strategies are essential for the development of sustainable aquaculture. Many of these strategies require a shift from past practices, particularly those used during the rapid and sometimes unchecked expansion of the global aquaculture industry. This shift presents a significant opportunity and a compelling investment case.

Figure 06
Global seafood production, million metric tonnes[13]



A recent 20-year review by leading scholars highlights that the sustainability of aquaculture and its impacts have been intensely debated since around the turn of the millennium.[14] This discourse was sparked by a 2000 paper in Nature that attempted to quantify aquaculture's net contribution to global food supplies.[15] Recent scientific work defines sustainable aquaculture as practices supported by innovation and regulation that enhance food security and nutrition. At the same time, it must positively impact marine ecosystems without degrading land or ocean systems.

Right now, at the global level, more than 80 million tonnes (Mt) of fish and shellfish and 30 Mt of seaweeds are derived from around 400 farmed species[16]. These are grown in diverse systems under diverse conditions. Therefore, aquaculture practices must be tailored to reflect this diversity. While this paper focuses on farmed salmon and its investment opportunities, other aquaculture systems face similar challenges and will also benefit from a more sustainable food system.

Aquaculture's role in addressing global blue food demand and enhancing food security & nutrition

Over the past decades, aquaculture has played a crucial role in addressing the growing demand for blue foods (i.e., those foods that are derived from aquatic animals, plants or algae), contributing to global food security and nutrition. This role has become increasingly vital due to the escalating pressures on marine ecosystems caused by wild capture fisheries, human activities, and the stagnation or decline in global catches for numerous marine species.[17] Studies indicate that aquaculture has and will continue to add resilience to the global food system in the face of climate change and the growing demand for protein worldwide.[18]

With added demand, global consumption of fish eaten by humans has increased by over 3% a year from 1990 to 2018.[19] This rate is higher than any other sources of animal protein over the same period. In line with this, global aquaculture production has increased by over 500% since the late 1980s.[20]

12. FAO. (2023) 13. FAO. (2024) 14. Naylor, R. L., Hardy, R. W., Buschmann, A. H., et al. (2021) 15. Naylor, R. L., Goldburg, R. J., Primavera, et al. (2000) 16. Blue Food Assessment. (2024) 17. Herbert-Read, J. E., Thornton, A., Amon, D. J., et al. (2022) 18. Costello, C., Cao, L., Gelcich, S., et al. (2020) 19. FAO. (2020) 20. FAO. (2022)

Aquatic food is a nutritional powerhouse in that it is typically rich in protein, essential fatty acids, vitamins and vital minerals. It can therefore play an important role in the dietary shift to mitigate emissions due to a lower GHG footprint relative to other food sources.[21] Well-managed fisheries can ensure a continuous food supply for generations by replenishing fish populations. The aquaculture industry also provides income and jobs for millions of people, particularly in coastal regions, thereby bolstering local economies and communities.[20]

Sustainable aquaculture is identified as a building block to secure a sustainable food system. One of the key objectives of global efforts, such as those outlined in the COP28 UAE declaration on sustainable agriculture, resilient food systems, and climate action, is to maximize the climate and environmental benefits associated with food production. This involves shifting from higher greenhouse gas-emitting practices to more sustainable production and consumption approaches, including reducing food loss and waste and promoting sustainable aquatic blue foods. By adopting these practices, aquaculture can play a pivotal role in addressing food security challenges while minimizing environmental impacts, ensuring that the global food system remains resilient and sustainable.

Understanding the challenges in aquaculture practices

Aquaculture is interconnected and dependent on a wide array of ecosystem services and resource systems, including land, space, water, seeds and feed. Additionally, it is both directly and indirectly influenced by climate change, including temperature changes and ocean acidification. Simultaneously, it contributes to climate-related impacts through feed practices, improper waste management and more.

This can be seen in fish farming, which in certain cases is associated with substantial resource consumption and environmental impacts, including overconsumption of water and energy, emissions of greenhouse gases, eutrophication of surrounding waters, and degradation of aquatic, seafloor (benthic) and coastal habitats and ecosystems. There is also a risk of loss of biodiversity connected to appropriation of land and sea areas for aquaculture production.[22]

The nature and severity of these impacts varies widely depending on the species being grown, production methods, geographical locations and other factors. However, as aquaculture expands in both production area and resource intensity, the environmental impacts are highly likely to escalate unless drastic interventions are implemented.

Aquaculture is also impacted, sometimes severely, by other stressors such as pollution and the emergence of novel diseases, invasive species, parasites crossing species boundaries as well as shifts in market dynamics, trade policy and other aspects related to globalization. While the aquaculture sector in low latitude countries is expected to bear the brunt of negative impacts from climate change, inadequate consideration and adaptation planning for climate change and various other stressors can significantly impede the sector's potential contributions on a global scale.

In the case of farmed salmon, the main environmental challenges include:

1. Escape of farmed salmon, which poses a threat to biodiversity through the risk of farmed salmon mixing with wild salmon populations[23], and in some cases transmitting sea lice and pathogens.
2. Animal welfare issues resulting from treatments of parasites, diseases (from pathogens) and fish health concerns, such as winter ulcers[24]
3. Certain feed ingredients are becoming scarce such as fishmeal and fish oil derived from wild-caught fish[25], and others such as soy protein have significant carbon footprints[26]
4. Global climate impact, including emissions related to production and transportation of feed and consumer products

These challenges also provide a useful shorthand for understanding where the best investment opportunities are within aquaculture, and specifically the farmed salmon sector. Investment opportunities in this area are assessed not just based on the potential for competitive financial returns but also for the potential to address sustainability challenges. A solution for a specific issue in the cultivation of farmed salmon may also help solve similar issues for other marine species, creating a positive spillover effect and accelerating the transition to more sustainable aquaculture practices.

Zooming in on farmed salmon

Salmon, and particularly farmed Atlantic salmon, has been one of the major contributors to growth in the global trade of fisheries and aquaculture products in recent decades. As a versatile and high-value species suitable for large-scale aquaculture, salmon occupies a strong competitive position in the world market. Growth in demand for salmon has outstripped other fish categories in almost every region and Atlantic salmon aquaculture has risen to become one of the most profitable and technologically advanced industries.[27] The sector has also led the way in funding, coordinating, and executing large-scale international marketing campaigns, and has successfully established logistical infrastructure to supply fresh aquatic foods to foreign markets mainly by truck and boat, but also via air freight routes.

In 2020, exports of salmon were worth USD 27.6 billion, led by Norway and Chile. Salmon and trout exports accounted for 18.4 percent of the value of all exported aquatic products in 2020, compared with 5.1 percent in 1976. Norway's primary export market is the European Union, while Chile supplies Atlantic salmon to the United States, Mexico and Brazil and farmed coho to Japan, and certain other markets.[27] Salmon is the most consumed farmed seafood in the EU and there is no indication that demand is likely to decline.[28]

The farmed salmon value chain can be described as below, in which feed production and transportation, services and equipment serve as inputs along the value chain.

1. Genetics and hatchery
2. Smolt and post smolt production
3. Grow-out phase
4. Harvest
5. Primary and secondary processing

21. Ziegler, F., Nistad, A. A., Langeland, et al. (2024) 22. Henriksson, P. J. G., Troell, M., et al. (2021) 23. Besnier, F., Ayllon, F., Skaala, Ø., et al. (2022) 24. MacKinnon, B., Jones, P., et al. (2019) 25.Sarker PK. (2023) 26. Johansen, U., Nistad, A.A, Ziegler, F., et al. (2022) 27. FAO. (2022) 28. Gudbrandsdottir, I. Y., et. al (2021)

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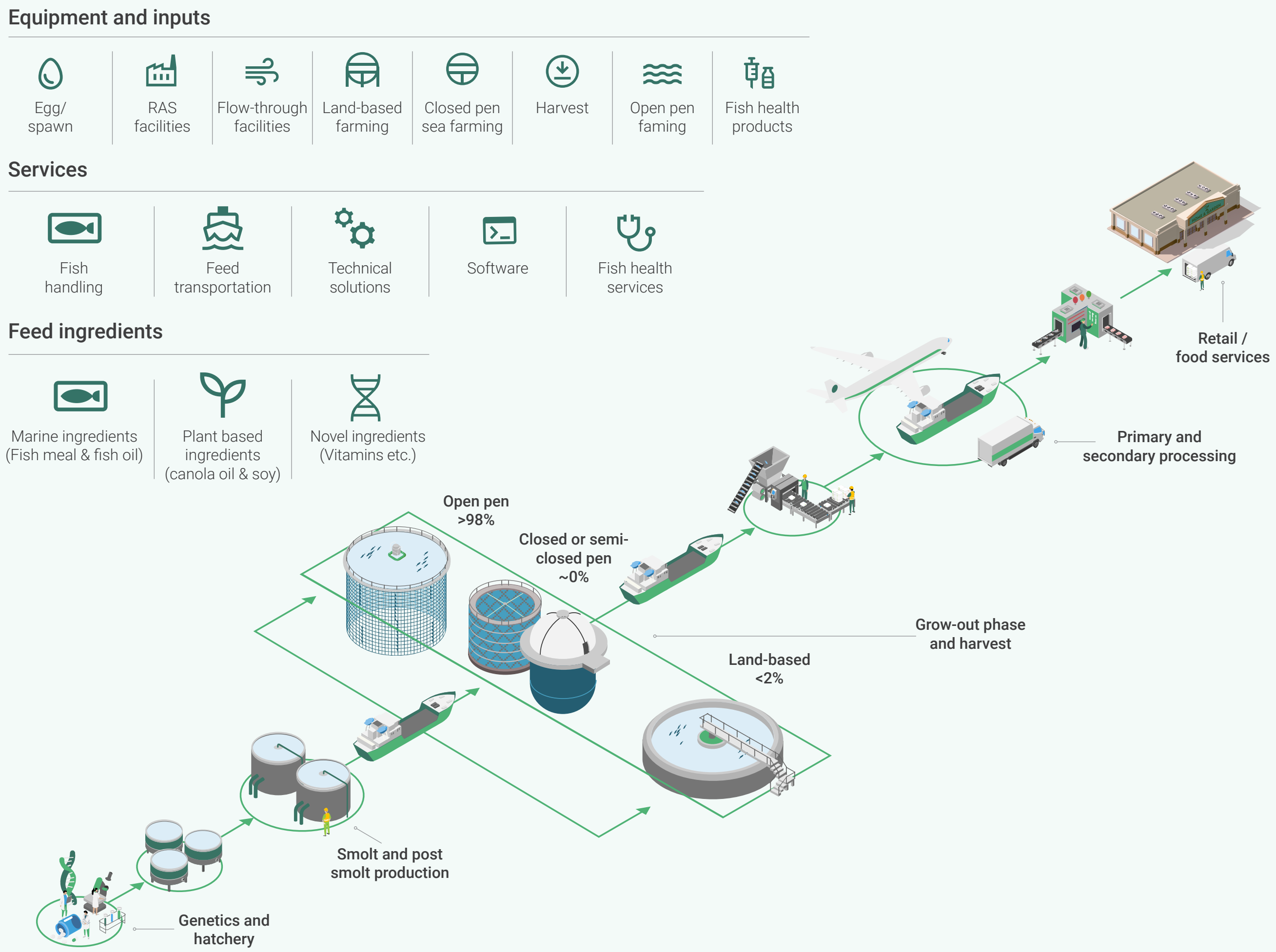
Figure 07
Today's aquaculture value chain begins with land-based smolt, transitions to sea for grow-out, and ends with harvest and processing for end markets.



Currently, the value chain for farmed salmon value chain mainly includes traditional sea-based aquaculture. However, current trends signal gradual shifts towards innovative production methods in response to environmental pressures. As identified in a recent TNFD sector guidance report[29], the most notable impact drivers in upstream value chain and direct operations are typically freshwater ecosystem use and GHG emissions, but also water and soil pollutants, solid waste and marine- and terrestrial ecosystem use. One of the solutions to address many of these impacts are land-based production systems. However, it is important to consider potential impact drivers of land-based aquaculture to ensure it is done right, considering factors such as impact on biodiversity and marine and freshwater ecosystems.

Land-based production is present today at negligible volumes - but is expected to become more fully integrated into the aquaculture value chain in the coming years and presents an opportunity to lower the environmental impacts of the industry. On the longer horizon, it can contribute to Norway's ambitious goals of doubling its production of salmon with a less pronounced environmental impact.[30]

Addressing sustainability issues in the salmon farming value chain

With reference to the above, salmon farming as we know it today has the potential to create significant positive impact on both human and environmental health. At the same time, the farmed salmon value chain has sustainability issues that must be addressed to maximize its impact potential.

Transitioning from unsustainable sourcing and production of feed
The expansion of aquaculture in recent decades, along with its potential for future growth, has been and continues to be driven by innovations in aquatic animal nutrition and advancement in extruded feeds. Feed aquaculture remains a significant and growing contributor to the sector's output, highlighting the crucial role of feed in the industry's success.

Life cycle assessment ("LCA") studies have indicated that aquafeeds are often the dominating contributor to undesir-

29. Taskforce on Nature-related Financial Disclosures. (2024) 30. Martin, S. J., Mather, C., Knott, C., & Bavington, D. (2021)

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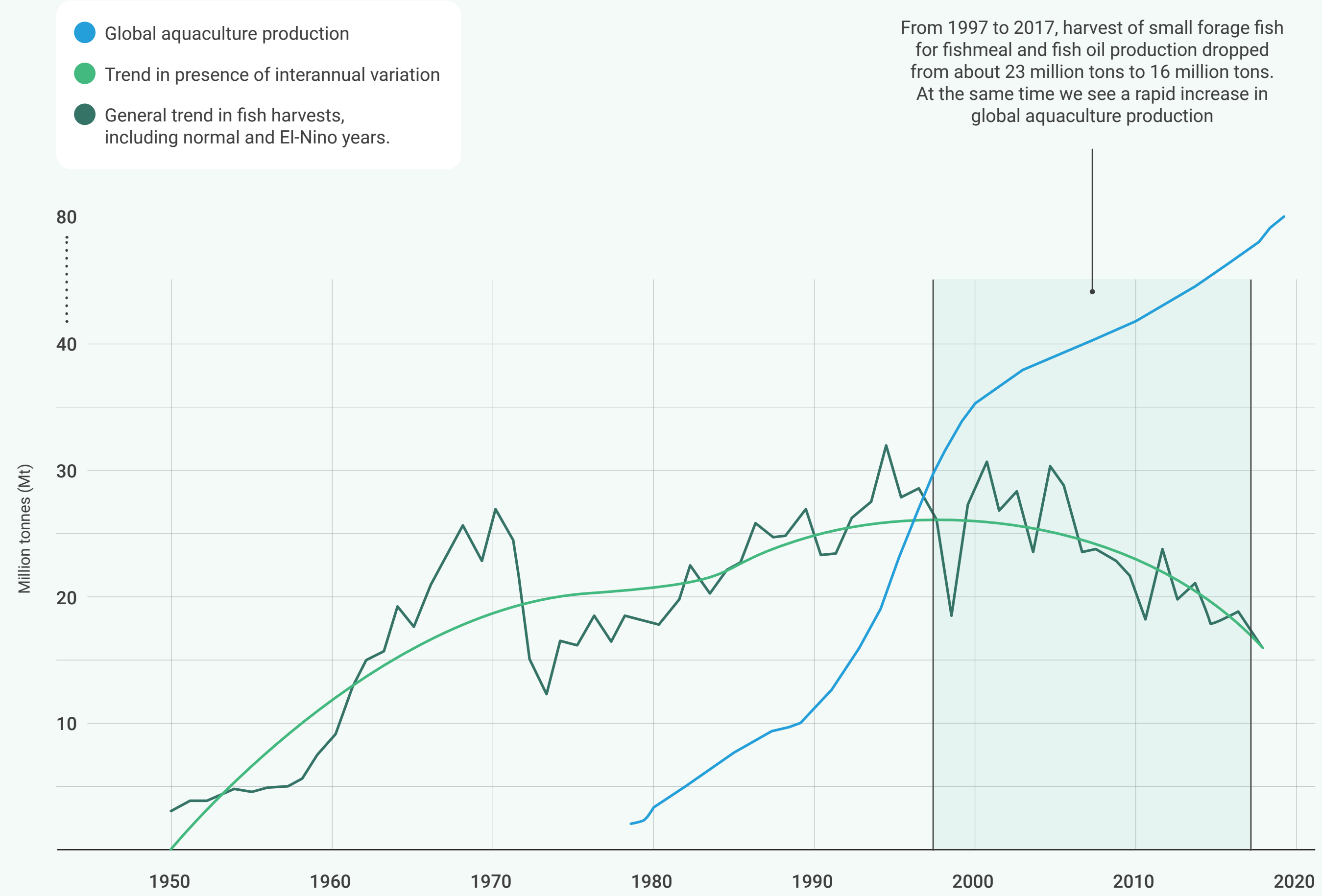
Figure 08
Forage fish landings for fishmeal and fish oil production (million tonnes)[13, 22]



The trend in presence of interannual variation represents how the harvests vary from year to year under normal conditions, without extreme events like El-Nino affecting them.

able environmental impacts associated with commercial aquaculture activities.[31] High-value aquaculture species (e.g., salmon and seabass) require high-protein diets, which traditionally – but not to the same extent today - meant relying on fishmeal and fish oil extracted from wild pelagic fish resources. These present their own sustainability related issues, including overfishing. By 2050, the aquaculture industry is projected to nearly double its current production, thereby putting even more pressure on feed sources.[32]

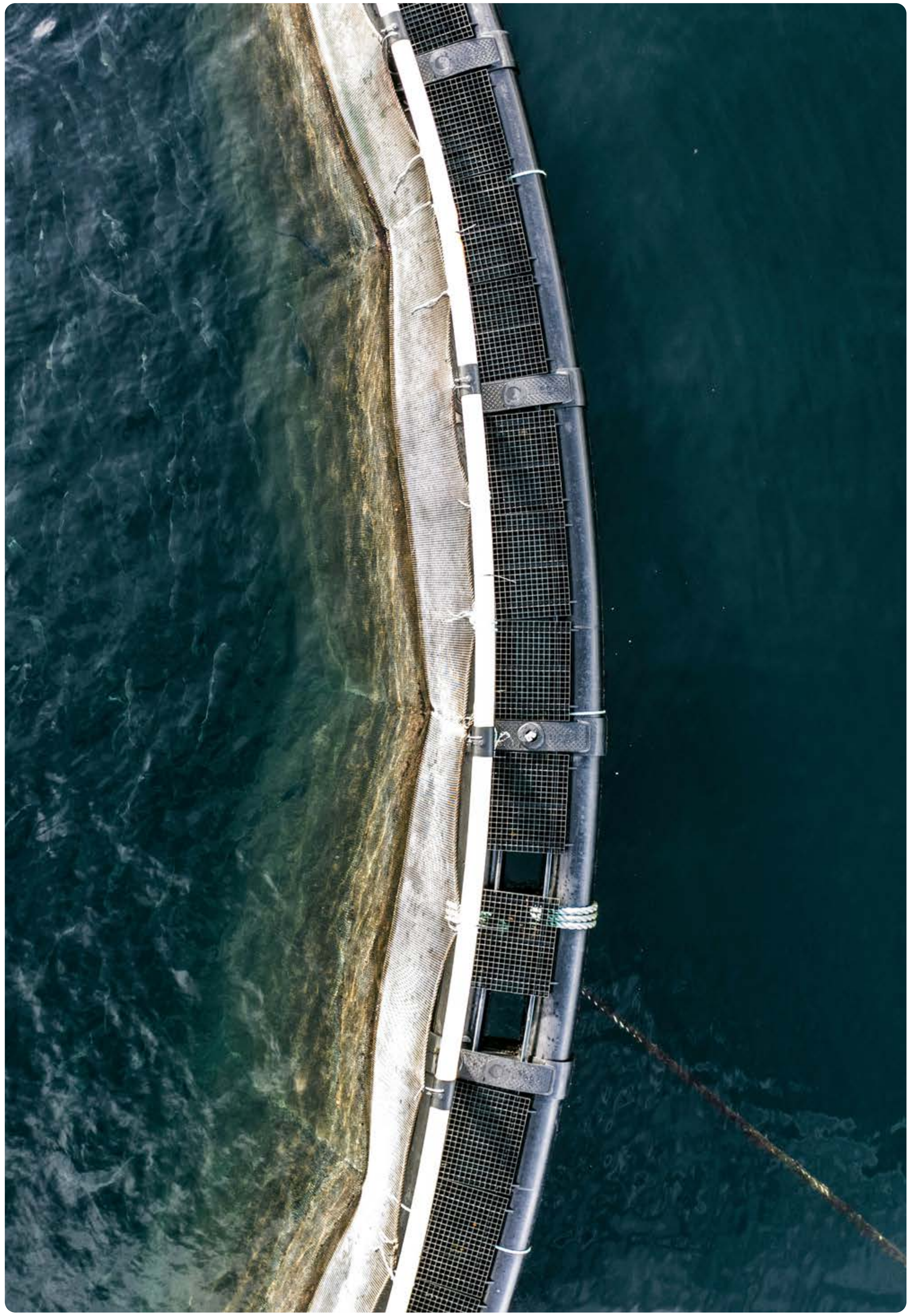
To sustain such production levels, large volumes of feed will be needed to provide affordable protein, essential amino acid, additives, omega-3 fatty acids, key minerals, vitamins and energy sources. This will require the sourcing of additional raw materials that are currently unavailable or used for other purposes. Recent scientific work has demonstrated significant progress in increasing production volumes while simultaneously decreasing the reliance on small forage fish as a component in feeds. From 1997 to 2017, the yearly harvest of small forage fish for fishmeal and fish oil production dropped from about 23 million tons to 16 million tons.[33]

While this reduction is a positive development, the rapid increase in global aquaculture production – as demonstrated in Figure 06 – places even greater pressure on the aquatic ecosystem. As aquaculture continues to grow and outpaces capture fisheries, it becomes crucial to intensify efforts on sourcing sustainable fishmeal and implementing sustainable practices across the sector to mitigate environmental impacts.

Accelerating progress in aquaculture is crucial for its continued growth in scale and intensity. However, this transition is complex, as replacing small forage fish with alternatives like soy protein concentrate introduces new challenges. For example, forage fish have a significantly lower climate impact compared to soybean monoculture. Additionally, a substantial portion of soybeans used in animal feed is grown in the Brazilian Amazon, contributing to deforestation, a major driver of climate change.[34]

Navigating a complex transportation system
Modern and efficient food production operates on a large scale and relies on complex distribution networks to reach

31. Costello, C., Cao, L., Gelcich, S., et al. (2020) 32. FAO. (2022) 33. Naylor, R. L., Hardy, R. W., & Buschmann, A. H. (2021) 34. Parker, R. W. R., Blanchard, J. L., et al. (2018)



consumers. This process involves substantial transportation and energy use, contributing to a significant carbon footprint. Salmon farming is no exception, as the predominant methods involve the use of open sea pens, requiring cold water and protection from heavy swells and wind.

Consequently, optimal farming locations include the fjords of Norway, Chile, Canada, Scotland, Tasmania and the islands in the North Atlantic. However, these sites are often distant from both the primary feed ingredient resources and the major consumer markets, leading to extensive transportation needs. Additionally, many essential feed ingredients are sourced from geographically distant areas, further exacerbating the environmental impact.[35]

Optimizing smolt and post-smolt production
In farmed salmon, the terms smolt and post-smolt refer to specific stages in the salmon life cycle, particularly during their development in aquaculture. These activities are done on land in closed containment and require purified water at the correct temperature, making the process energy intensive. Smolt and post-smolt facilities use either flow-through systems, which consume large amounts of water, or recirculating aquaculture systems ("RAS"), which use limited water.

Smolt refers to the young salmon that have undergone a physiological transformation. This process, known as smoltification, involves changes in the salmon's body that prepare them for the saline conditions of the ocean. Post-smolt refers to the salmon after they have been transferred from freshwater to saltwater environments and are continuing to grow towards market size.

Inadequate smoltification is a persistent issue in aquaculture, leading to physical ailments and increased stress when poorly smoltified fish are introduced to the sea. This impacts the efficiency and sustainability of aquaculture operations.

There are several strategies to address these challenges. For instance, modifications of light and salinity is frequently used, as well as fish feed with additives which can significantly enhance the smoltification process. This provides a signal for the fish to smoltify, especially when combined with appropriate light and temperature conditions.

Addressing sustainability issues in the growth phase
It is primarily during the grow-out phase where the sustainability issues are most pronounced. The predominant farming technology used for the grow-out phase today is farming in open pens. Although the pen architecture differs between farms, all the systems are open net based, exposing the fish to the surrounding marine environment. The most concerning issues associated with open pen farming include:

- Escapes of farmed fish to the wild leading to dilution of wild salmon genetic pools
- Sea lice infection
- Treatment of sea lice and other parasites, leading to elevated mortality rates
- Fish welfare
- Discharge of feces, nitrogen, phosphate, unconsumed feed and chemicals affecting marine life
- Mortality due to pathogens, and discharge from pathogen treatment

Protecting wild salmon from farmed salmon escapes
Farmed salmon, bred for rapid growth, possess genetic compositions that significantly differ from those of wild salmon. Wild salmon have undergone thousands of years of local adaptation, resulting in genetics finely tuned to their specific environments. When farmed salmon escape and interbreed with wild populations, their offspring typically exhibit low survival rates due to this genetic mismatch. Studies have shown that the introduction of farmed salmon genes can lead to reduced fitness and survival rates in wild salmon populations, potentially resulting in their decline in affected rivers.[36]

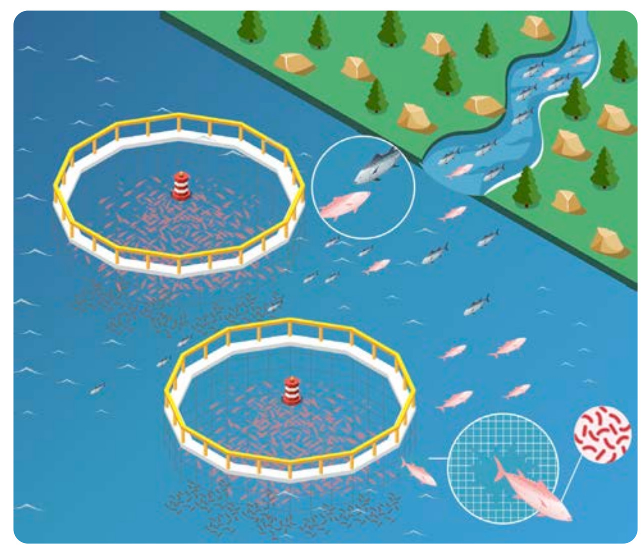
The risk becomes particularly severe when the number of escaped farmed salmon is high relative to the local wild populations. In Norwegian waters for instance, the number of farmed salmon is approximately 200 times greater than the total population of wild salmon. Consequently, even a minor escape event can lead to significant genetic dilution and ecological disruption.[37]

Figure 09
Salmon escape and genetic impact on wild salmon populations in Norway

~455,000
salmon escaped from aquaculture farms in Norway over the last five years[38]

2/3
of Norwegian wild salmon stocks have shown genetic differences due to mixing with escaped farmed salmon[39]

>50%
Reduced survival rate for hybrid offspring of wild and farmed salmon vs. wild salmon, hence escapees mixing with the wild population could lead to reduced wild salmon populations over time[40]



35. Papatryphon, E., Petit, J., et al. (2004) 36. Bicskei, B., Bron, J. E., Glover, K. A., & et al. (2014) 37. Solberg, M. F., Dyrhovden, L., Matre, I. H. (2016) 38. Norwegian Directorate of Fisheries (2022) 39. Norwegian Scientific Advisory Committee for Atlantic Salmon (2023) 40. Skaala, et al. (2019)

The fight against pathogens, parasites and pests
Despite significant investments and advancements in detecting, preventing and treating diseases in the salmon aquaculture industry, new threats continue to emerge. While diseases such as infectious pancreatic necrosis virus and infectious salmon anaemia have been effectively managed, others such as salmon rickettsial syndrome ("SRS") remain problematic. These diseases are costly for producers and harmful to wild salmon due to the lack of available treatments or the development of resistance by the target organisms.[41] In addition, parasites, such as sea lice, represents a significant problem in all farming areas, and sea lice treatments are considered as the root cause of increased mortality and significantly reduced animal welfare.

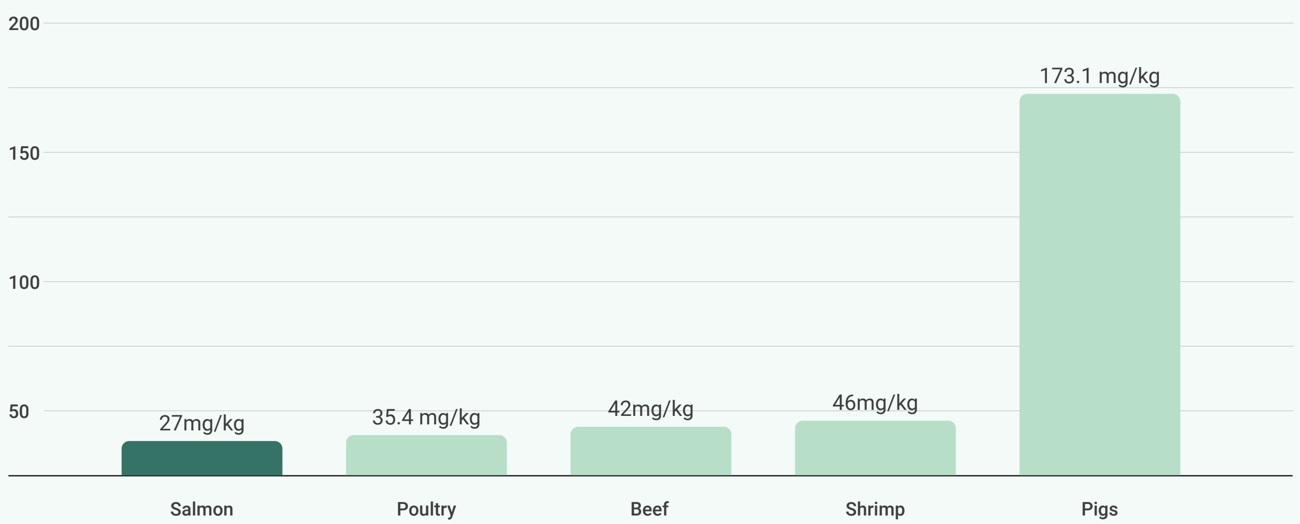
Additionally, winter ulcers, primarily caused by the bacterium Moritella viscosa, are a significant and growing problem in the salmon aquaculture industry. These ulcers initially appear as superficial skin lesions but can progress into deep, persistent wounds that damage underlying tissues.[42] This condition not only harms fish welfare, but also results in increased mortality and reduced slaughter quality. In addition to this, the bacterium develops new strains, requiring development of new vaccines.[43]

To mitigate these issues, good farming practices is essential, particularly in relation to vaccination. Preventive measures, such as maintaining proper hygiene and disinfection protocols, can significantly reduce the incidence of diseases. While the majority of farmers utilize standard vaccines, crucial autogenous vaccines are being developed for newer diseases and strains, such as Moritella and Pasteurella. Additionally, bacteriophages have been developed to target specific bacterial fish diseases such as Moritella and Yersinia. Bacteriophages are viruses that infect and kill bacteria, offering a natural and effective method to control bacterial infections in aquaculture. By using these bacteriophages as preventive measures, farmers can reduce the need for treatments later on, leading to healthier and more sustainable aquaculture operations.

Antibiotics are used in the industry primarily to treat diseases for which no effective vaccines exist, such as SRS. The high usage of antibiotics is mainly notable in Chile, which is solely related to SRS, but this trend is now decreasing. In contrast, antibiotic use in Norway is minimal, with only about 1% of farmed fish undergoing antibacterial treatment.[44] Strict regulations ensure that antibiotic use is carefully controlled and contained and the overall contribution of aquaculture to antimicrobial resistance ("AMR") globally is relatively small, especially when compared to antibiotic use in the livestock industry. In the livestock industry, the usage is larger in terms of the amount of antibiotics used, partly because it is used to increase the growth rate of livestock, which is not the case in aquaculture.[45]

Enhancing salmon harvesting
Typically, salmon is harvested at an average size of 5-6 kg. Harvesting involves transferring batches of up to 300MT into well boats, which transport the fish to "waiting cages" in preparation for processing near the harvesting facilities. However, these transfer processes can stress the salmon, leading to mortality in some cases. To improve welfare and reduce losses, fish can be extracted and gutted directly from salmon farms which minimizes the need for multiple transfers. These alternative methods include the Hav Line vessel (Norwegian Gannet), and barges equipped with stunning and bleeding equipment which ensures that fish are quickly rendered unconscious, thereby reducing suffering and stress. This stage of the process also requires significant energy use which needs to be addressed through energy savings and use of renewable energy sources.

Figure 10
Average global antibiotic use in animal protein sources[45]



Antibiotics use in aquaculture. Adapted from Antibiotics in aquaculture: Factsheets, by FAIRR Initiative, n.d., https://www.fairr.org/resources/reports/antibiotic-factsheets.

41. Naylor, R. L., Hardy, R. W., & Buschmann, A. H. (2021) 42. Ghasemieshkaftaki, M. (2024) 43. Karlsen, C., Ytteborg, E., et al. (2023) 44. Norwegian Seafood Council. (n.d.). 45. FAIRR Initiative. (2022)

Balancing efficiency and sustainability in primary and secondary processing
Primary processing involves slaughtering, gutting and sometimes filleting the fish, usually near the grow-out facilities. Most output from Norway is sold as "head on gutted" fish to secondary processors, whereas Chile exports substantially more of the secondary processed product. These secondary processors, often located far from the primary sites in Norway, handle significant cold storage and transportation. Key factors for profitability in secondary processing include scale, food safety, operational efficiency and labor costs, which is why many large processors are in Poland and Lithuania. However, long transportation distances pose sustainability challenges due to the need for freshness and the pressure to deliver quickly. Trucking in cold storage trucks remains the dominant method for transportation. This energy-intensive process is a concern in food production in general, similar to other protein sources, with currently few viable sustainable alternatives available.

Image: Milarex

Systems change: Overcoming challenges in the salmon value chain

Summa is guided by systems thinking to solve global challenges and ensure long-term positive impact.

The systems change approach focuses on tackling the growing pressures of carbon-intensive food and agriculture sectors. It considers that there needs to be a change to the current approach to ensure that yields increase sustainably, and that scale does not come at the cost ofecosystem degradation and loss of natural capital.

The new system envisioned

Aquaculture, as highlighted at the outset, plays an important role in reducing pressure on the food system and finding new pathways for sustainable growth. It has the potential to meet humanity's needs without undermining the functioning and wellbeing of the biosphere. Achieving this kind of transformative change is about achieving net positive societal impact while driving value creation.

Summa sees the farmed salmon sector as a useful starting point for this transformation. Ultimately, the aim of Summa's investments in this sector is to pursue solutions with the intent of not simply optimizing the current challenges, but achieving a transformational outcome by completely disrupting and reinventing the food system into one that is more sustainable and equitable.

The food future we want:

1. A sustainable and resilient food future: A world with responsible practices that ensure the long-term health of ecosystems and the communities dependent on them, while providing worldwide access to nutritious and balanced diets.
2. ...supported by a sustainable salmon farming value chain...: With its health advantages and lower carbon footprint, the salmon industry can be an enabler of this food future. In addition, it has some of the most advanced technology of any sector within aquaculture, highlighted by its innovations in genetics, feed and vaccines which can provide the building blocks for improvements across other aquatic species.
3. ... to provide healthy, accessible and lower-carbon proteins: Ultimately, consumers can access a healthy lower-carbon protein to meet global food needs.

By integrating this systems-based approach, Summa is well-positioned to drive meaningful change and promote a sustainable future for the food and agriculture sectors. Sustainable aquaculture contributes to a number of specific investment themes where Summa's aim is to generate significant impact in line with EU commitments, including the Farm to Fork strategy. Concretely, this includes investment focus towards:

1. More resource and energy efficient production
2. More resilient and localized food production
3. Reduced food waste across the supply chain
4. Lower emission protein sources
5. Healthier and more nutritious consumption

To reach this ambition, the proposed systems change for the salmon farming sector indicates a focus to develop investment understanding and opportunities within:

- Alternative feed ingredients
- Land-based farming
- Closed containment grow-out farming in sea
- Preventative measures to improve fish health (e.g. vaccines)
- AI operational control systems

Each of the solution spaces presented within farmed salmon contributes across one or more of these investment themes, while also addressing specific challenges facing the shift towards more sustainable aquaculture.

Up to

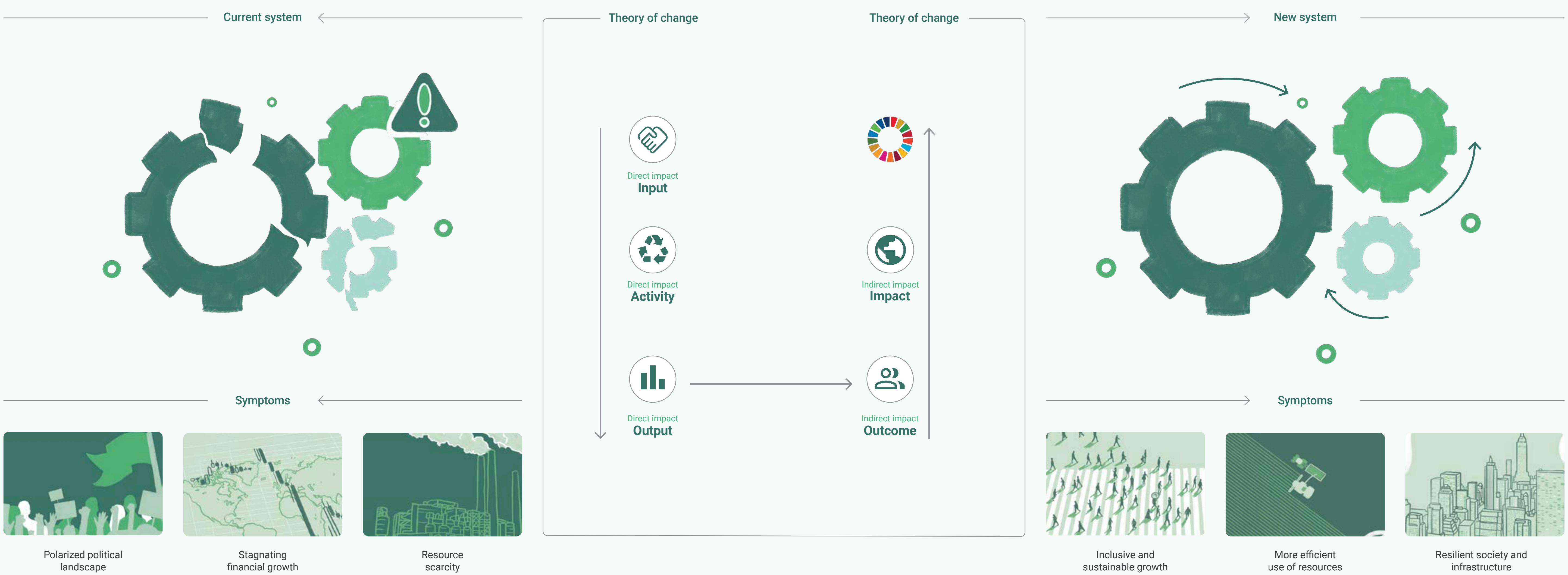
19%

emission reduction potential from measures across the value chain, for farmgate salmon at 3.8 kg CO_2e/kg liveweight[46]

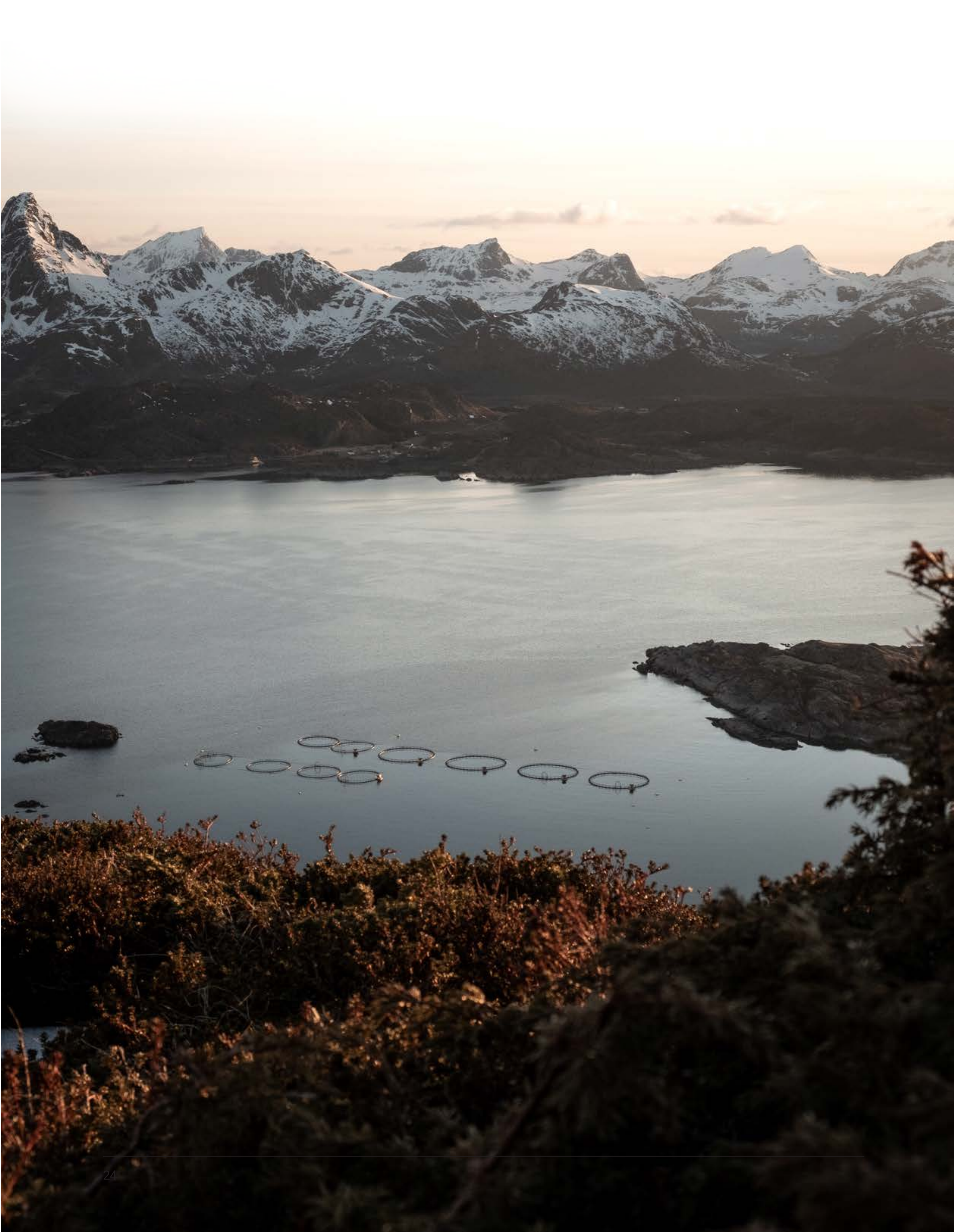
15%

expected increase in aquatic food production by 2030[47]

Figure 11
Theory of change – a framework to conceptualize the systems we aim to transform, envision their future state, and adopt a structured approach to tackling challenges.



46. SINTEF (2022) 47. FAO (2022)



Theory of change: Connecting systems change to investment opportunities and measurable impact

To obtain the food future we want, we recognize that the aquaculture industry needs to continue to innovate and adapt to meet the growing demand for blue foods in a sustainable way.

Summa uses the theory of change framework to map out the road to realize our long-term vision; to contribute to a sustainable food system where aquaculture plays an important role, as laid out by FAO and in the EU Farm to Fork Strategy. We envision an aquaculture industry that operates with fish health and sustainability at its core. To achieve this, the investments we make need to contribute to positive outcomes, such as decrease in fish mortality, increase in fish welfare and farmer productivity, decreased lifecycle emissions from fish farming and/or improved biodiversity under water.

The indirect effects or outcomes of our investments are not always easy to measure, however all our investments are in line with the trajectory laid out below. This starts with measuring outputs directly linked to their activities, while gradually moving towards measuring outcomes. Within Summa's aquaculture theme, our portfolio companies should measure outputs such as emissions per kg farmed fish, the number of individual fish treated through preventive measures, farming data including fish mortality, number of escapes, growth rates and more. The KPIs chosen by each company to measure its contribution to the theory of change should align with the company's core products and services. Companies are also expected to set ambitious targets to maintain a strategic focus on achieving the desired positive outcomes. In the case where this is not possible, customer case studies, surveys and other stakeholder activities should be done.

Summa has invested significantly into partnerships, industry- and investment expertise and portfolio community collaboration to be able to support companies within the aquaculture industry on this journey. Our team is supported by extensive industry and senior expertise, with thematic experts like Geir Molvik, Tore Valderhaug and Jim Roger Nordly. Their deep knowledge and experience in the field are instrumental in guiding our strategies and ensuring we stay at the forefront of industry advancements. Fish health for instance, is a key area where deep knowledge of the entire value chain is needed and collaboration among multiple stakeholders along that value chain and beyond is essential to be effective.

To ensure that our theory of change considers the latest scientific findings, we have partnered with leading research institutions such as the Stockholm Resilience Centre and Harvard Business School. These collaborations focus on assessing the environmental impact of our initiatives and driving research that supports sustainable practices in the food and agriculture sectors, as well as advancing the measurement of outcomes.

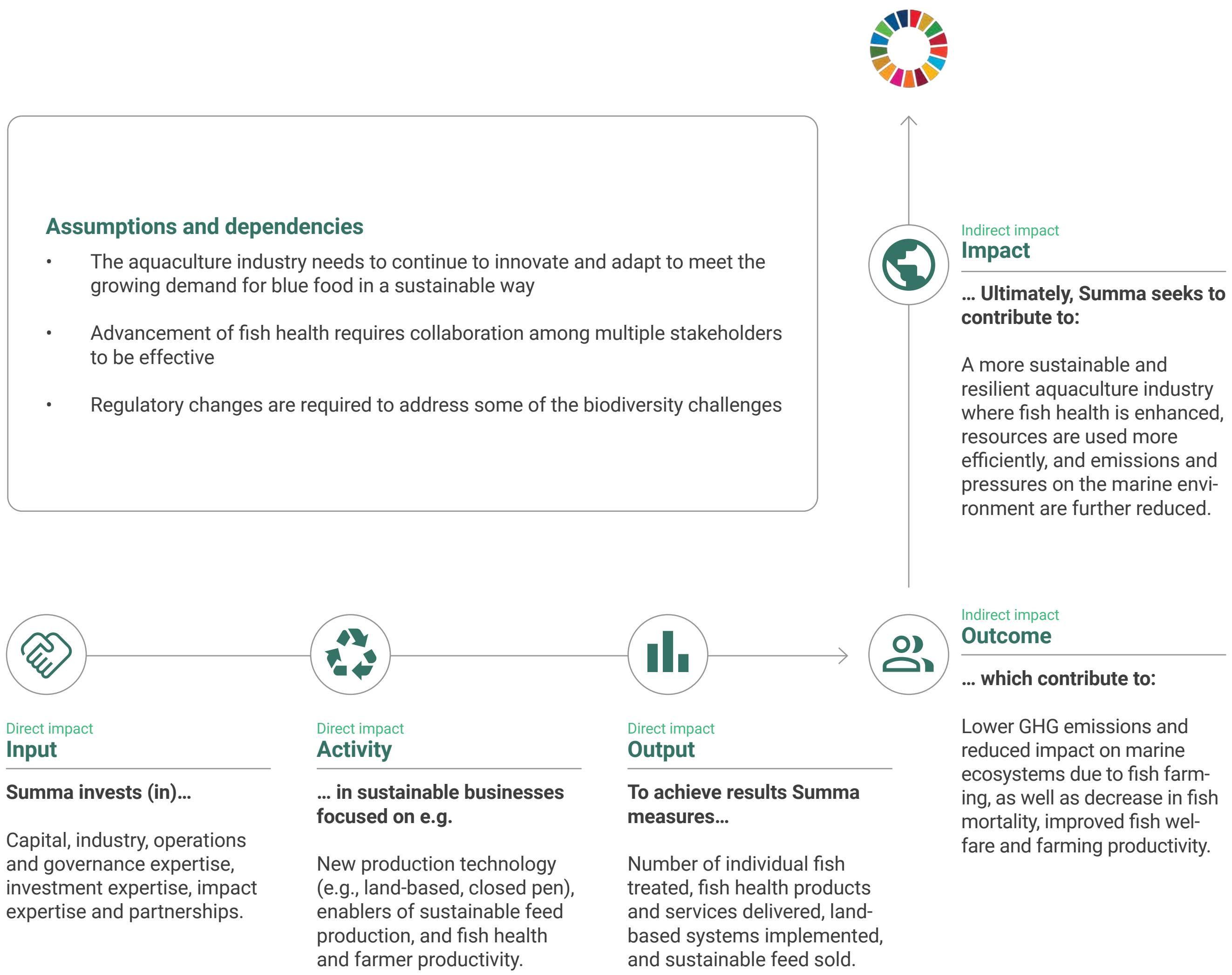
Summa's investment, operational and impact experience is a cornerstone of our success. Through our investment and ownership strategy, Via Summa, we have implemented effective strategies that have yielded significant returns while also delivering positive societal impacts. This includes synergistic organic and inorganic investments, operational support and support from Summa's impact team from day one of the investment period. Our track record of successful investments underscores our commitment to creating long-term value through a unique ownership model.

The Summa community of portfolio companies is a vibrant network of knowledge sharing, events, and company collaborations, which is key to our ongoing success and impact. We regularly host events that bring together industry leaders, researchers and stakeholders to inspire, foster innovation and share best practices.

Looking ahead, we realize that this long-term vision cannot be realized by Summa in isolation. It requires collaboration among multiple stakeholders, including industry experts, academia and regulators. For some of the challenges, regulatory changes are necessary to drive change.

This theory of change guides all our activities and ensures that we remain focused on creating a positive, lasting impact on the global food system. The next section dives deeper into the aquaculture activities that we invest or seek to invest in, and their alignment to our theory of change.

Figure 12
Theory of change for aquaculture – cultivating a sustainable food future



Activities that we seek to invest in: Summa solutions

Ensuring sustainable and healthy feed for aquaculture within planetary boundaries
To meet future aquaculture feed demand and avoid substituting one problem for another, there is a need for novel feeds that reduce dependency on marine ingredients. Beyond the salmon industry, lower-value commodity species can also benefit from targeted interventions to improve feed quality and environmental impact.

To enhance sustainability, salmon farming should preferably be more widely distributed across multiple regions and located closer to consumers, with locally produced feed ingredients. This involves two major shifts: moving more of the salmon farming onto land or to closed or semi-closed systems in the sea for controlled water quality. The second shift involves the development of alternative feed ingredients to replace fish oil, fish meal and soy.

Technological advancements now enable alternative feed production at scale, but significant investments will still be needed to reach cost parity. Additionally, rising costs of traditional open-pen salmon farming have made alternative farming practices more economically viable. While not all technologies may be universally applicable due to species and production method variations, there is substantial potential to support sustainable growth in salmon aquaculture and promote broader industry sustainability.

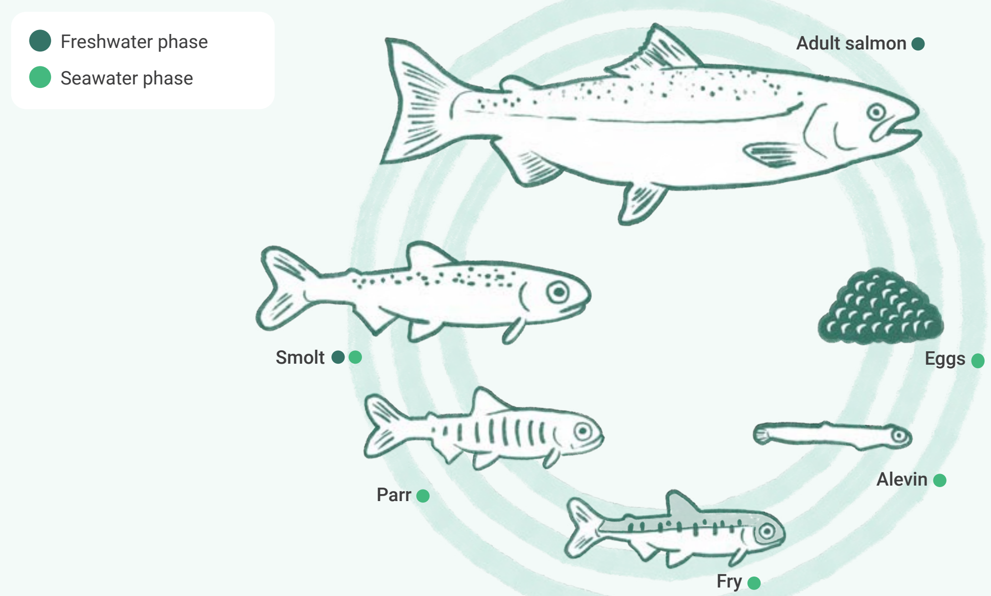
Optimizing smolt stages with RAS and feed
Summa's approach emphasizes the effective management of smolt and post-smolt production stages, which is crucial for several reasons. Farmers are increasingly moving earlier parts of the growth cycle onto land in recirculating aquaculture systems ("RAS"), growing fish up to 500 grams or more before being transferred sea (compared to legacy practices of 100 grams). This allows better utilization of farmer's biomass constraints, and if managed well should lead to a larger and more robust salmon once set in the sea.[48]

However, while RAS and on-land post-smolt production are important for growth, it is critical that the fish undergo the necessary biological changes before entering seawater. In nature, this process happens in the spring, as fish migrate towards the sea, allowing them to naturally build their immune systems. To replicate this process in controlled environments, fish farmers must ensure proper smoltification through specific farming practices, such as light and temperature management, and specialized smoltification feed. If the fish is transferred to seawater without being properly smoltified, it will likely be more prone to disease, see slower growth, and have a higher rate of mortality than its smoltified peers.[49]

Therefore, to drive industry growth, investing in post-smolt production in RAS is essential. At the same time, it's equally important for farmers to implement effective smoltification solutions, ensuring the fish are biologically prepared to thrive and grow in the sea. Proper smoltification feed plays a critical role in triggering the necessary biological changes in the fish, preparing them for the transition to seawater.

By integrating these solutions, producers can improve survival rates, fish growth and the overall sustainability of aquaculture, increasing production volumes while reducing mortality rates.

Figure 13
Salmon lifecycle



48. Government of New Brunswick. (2022) 49. Iversen, M. H., & Finstad, B. (2023)

Innovative land-based and closed containment systems boost sustainability
Advancements in aquaculture technology, particularly innovative land-based and closed-pen solutions are pivotal in promoting sustainability and addressing industry challenges. Land-based farming systems, such as flow-through systems and RAS, offer controlled environments that minimize fish escapes, improve disease and parasite management, and reduce environmental pollution.

Flow-through systems pump large amounts of seawater into tanks, but their use is limited to specific locations that meet stringent environmental conditions. In contrast, RAS operate with minimal water input, recycling it to maintain optimal conditions, which significantly reduces water use and waste discharge.[50] These systems are increasingly enhanced by digital technologies like AI, big data, and automation, which optimize feed usage, energy efficiency, and overall productivity by providing early warnings of deviations in key production parameters and enabling automatic corrective actions.

Land based systems provide a significant opportunity to improve fish welfare, reduce mortality rates, and lower the ecological footprint of aquaculture. However, they also come with challenges, such as high space, resource, and energy requirements, which must be carefully considered to assess scalability and impact. For example, the potential capacity for land-based salmon farming globally could reach up to 2.6 million tons when considering all announced projects to date - which nearly matches the current annual output of 2.9 million tons.[51] However, practical and financial constraints may limit actual production to around 200,000 tons by 2030.[52]

Closed-pen salmon farming solutions present a promising alternative to traditional open ocean aquaculture. These systems are designed to mitigate the environmental impact on marine ecosystems by preventing waste, residuals and fish escapes.

One of the primary benefits of closed-pen systems is their ability to shield farmed fish from pathogens and other oceanic threats. By isolating the fish from the open ocean, these systems reduce the risk of disease and parasite transmission, leading to healthier and more sustainable fish populations.[53] This protective measure is crucial for maintaining the health and welfare of farmed salmon, and it also benefits surrounding wild fish populations by reducing the likelihood of disease and parasite spread from farmed to wild fish.

Despite their advantages, closed-pen systems are still relatively expensive and less proven compared to conventional open-pen farming methods. However, they represent a forward-thinking approach to sustainable aquaculture, with the potential to significantly reduce the environmental footprint of fish farming. The feasibility of farming in closed containment vs open pen is currently hampered by the fact that current licenses are needed for both practices. However, it is expected that by 2025 the Norwegian government will put forward a revamped license regime which will incentivize open-pen farmers to convert some of their licenses to closed containment farming. This will likely substantially improve the feasibility of closed containment farming.

By revisiting the challenges associated with both land-based, and closed-pen aquaculture systems, we emphasize the need for a comprehensive, multi-faceted strategy that leverages systems thinking to integrate technological innovations, sustainability goals and market demands. Summa's approach focuses on developing scalable, efficient and sustainable aquaculture practices that can transform the industry and contribute to a more sustainable food future.

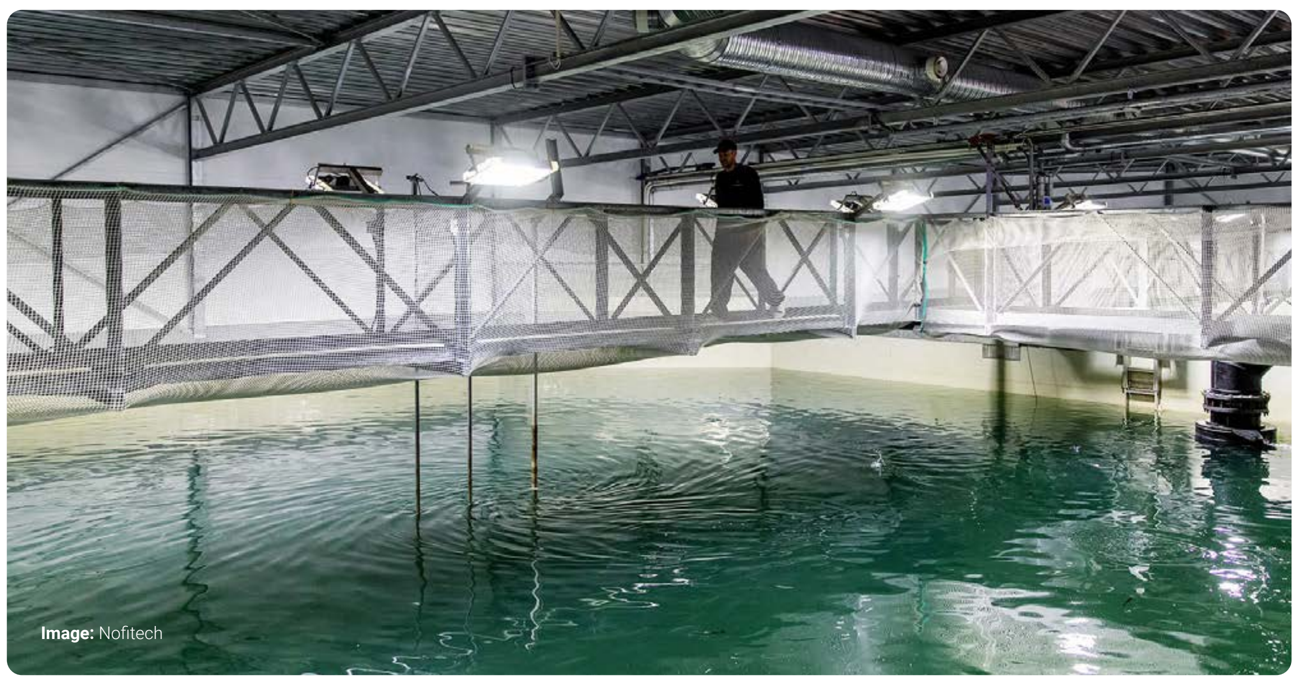
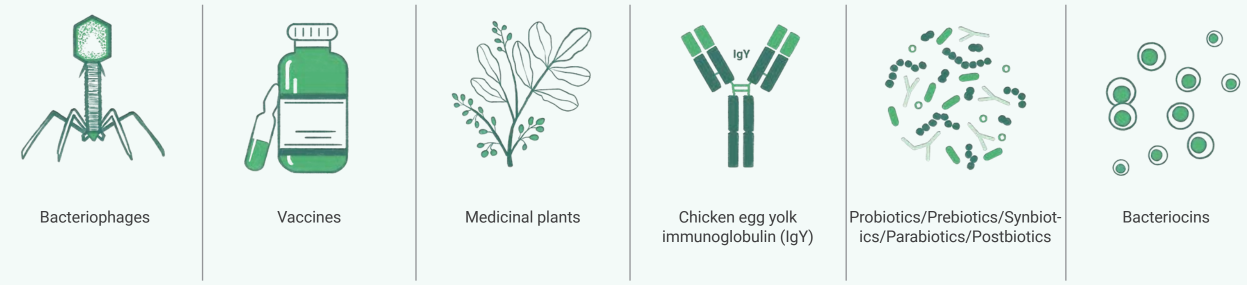


Image: Nofitech

50. Ahmed, N., & Turhini, G. (2021) 51. Fish Farming Expert. (2023) 52. SalmonBusiness. (2021) 53. Rurangwa, E., & Verdegem, M. C. J. (2015)

Figure 14
Alternative approaches to reduce the use of antimicrobials in aquaculture[54]



Innovation in fish health to address current challenges and future growth opportunities
Farmed salmon will always be vulnerable to some degree of pathogens, parasites and pests. However, this vulnerability can be better managed through vaccine developments and other innovations, such as a switch to closed containments that would allow all water intake to be treated with ultraviolet light and related treatments. Promoting and implementing these types of safer farming practices is a key focus of Summa's aquaculture investments.

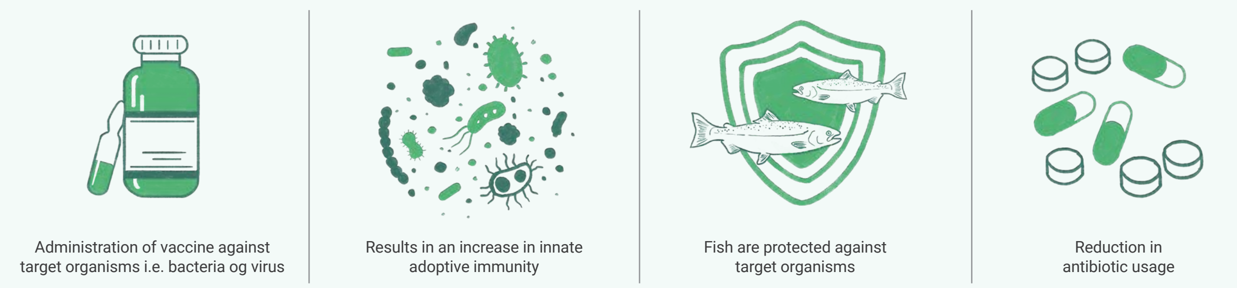
There are many solutions to solve this which are becoming more sophisticated and targeted over time. These solutions range from boosting natural immunity through vaccination programs, improving health management, increasing biosecurity measures to supportive regulatory changes and a range of alternative treatments.

To combat the chameleon that is pathogens and parasites, constant innovation is required as well as approaching fish health and its sustainability implications through supporting a suite of solutions. Alongside addressing the pathogens, and parasites themselves, the challenge of ensuring that aquaculture does not further contribute to the growth of antimicrobial resistance. This requires equally stringent attention and provides significant opportunities.

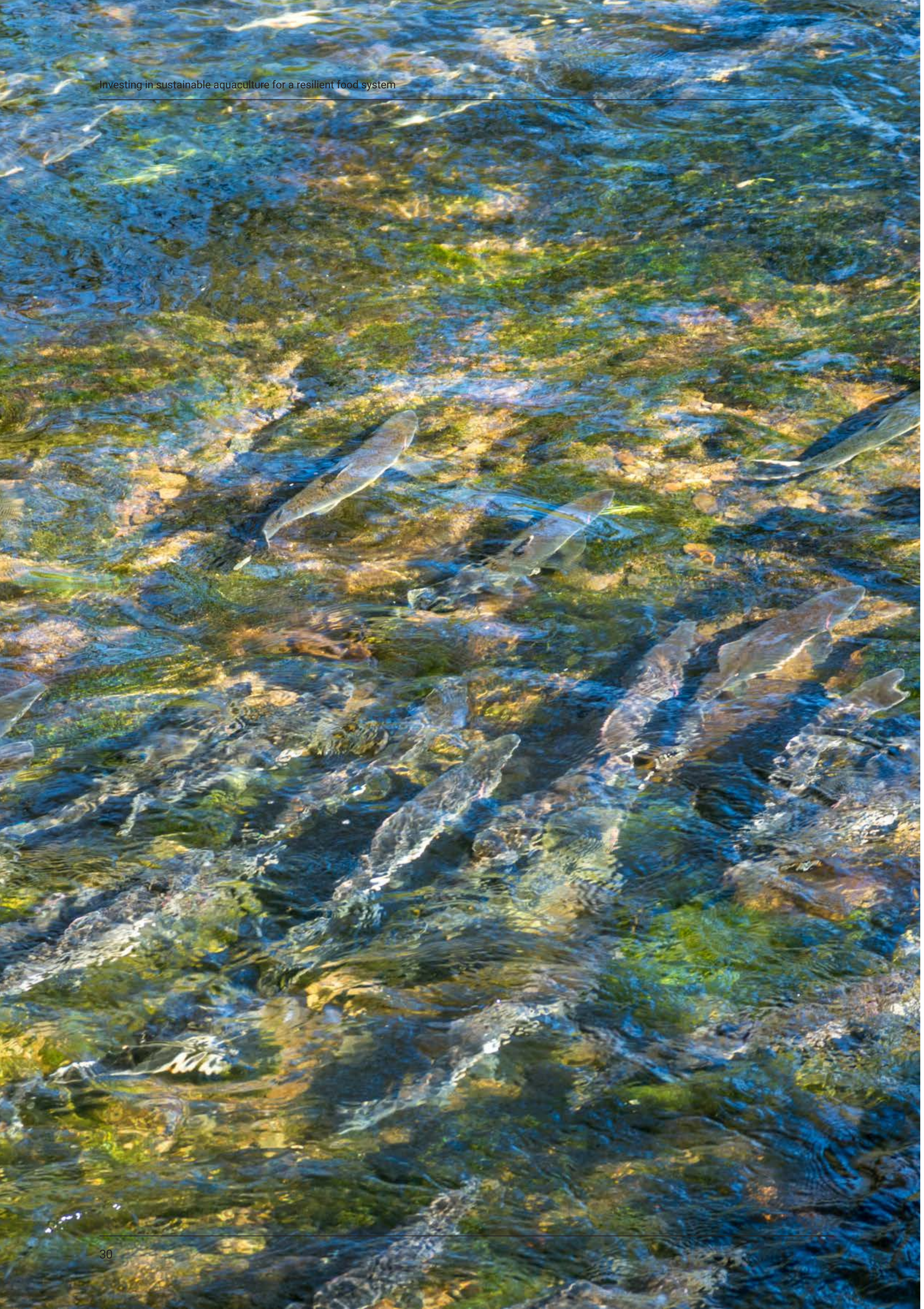
Potential investment opportunities include developing and distributing vaccines built on new mRNA architectures (leveraging learnings from the development of the COVID-19 vaccines), working with feed additives to boost the antibacterial properties of feed diets, increasing the number of naturally derived ingredients included in treatments, as well as continuing to experiment with selective breeding. Addressing fish health through application of new technologies and techniques is and will remain foundational to ensure the sustainable scaling of aquaculture.

There are already a number of established, growing companies that focus on innovations in support of fish health that are actively working with one or more types of treatment, each of which could present an investment opportunity. The alternatives presented in the graphic below are not only alternatives to antibiotics but represent different routes for bolstering fish health in support of sustainable and effective scaling of farmed salmon aquaculture.

Figure 15
Administrative routes: Oral, injection, immersion[54]



54. Bondad-Reantaso, M. G., MacKinnon, B., & Karunasagar, I. (2023)



End notes: How Summa charts new waters in aquaculture

Summa sees several new and compelling investment opportunities within the salmon farming sector.

These include alternative feed ingredients, closed containment grow-out farming in sea, land-based farming, preventative measures to improve fish health (vaccines and anti-parasite), suppliers of equipment to support closed-pen, land-based farming and AI operational control systems.

Investments in Nofitech and STIM are direct results of these focus areas. With their land-based fish farming services and equipment, Nofitech positively impacts the industry by facilitating the production of post-smolt and has the potential to simplify the grow-out of salmon to harvest size. The most significant anticipated change in the salmon farming industry will be the transfer from open-pen farming to closed- and semi-closed pen. This shift could have a massive impact as farming locations may be less dependent on water temperature and sheltered fjords. Consequently, salmon farming closer to large population centers can over time become feasible, opening new opportunities for the entire value chain, from genetics to feed to processing. The success and feasibility of this concept will, however, depend on an effective and already established local infrastructure.

STIM is the largest supplier of high-quality fish health products and services within the aquaculture industry. The company strives for a holistic perspective, building on the experience from vaccines and pharmaceuticals with expertise in a range of areas within fish health services. This includes marine environmental surveys, support for area applications and plans as well as regulatory advice. For over three decades, STIM has contributed to a more sustainable aquaculture industry by providing transformative innovations that improve fish health, growth and profitability. The company is well-positioned in several markets through its knowledgeable teams and unique cross-disciplinary competence.

As always, it is crucial not only to understand the unfolding changes but also to anticipate which developments will emerge as the winning concepts with sustainable economic impact. The systems-based nature of the challenge outlined in this paper, along with a clear understanding of the positive outcomes we aim to achieve through our theory of change, provides valuable insights to guide Summa in identifying promising investment opportunities in this sector going forward.

By continuing to focus on these insights, Summa can strategically support the most promising developments in the salmon farming sector, ensuring sustainable growth and a positive impact on the aquaculture industry. And in turn, contribute to a sustainable and resilient food future.

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