ONE OCEAN FOUNDATION

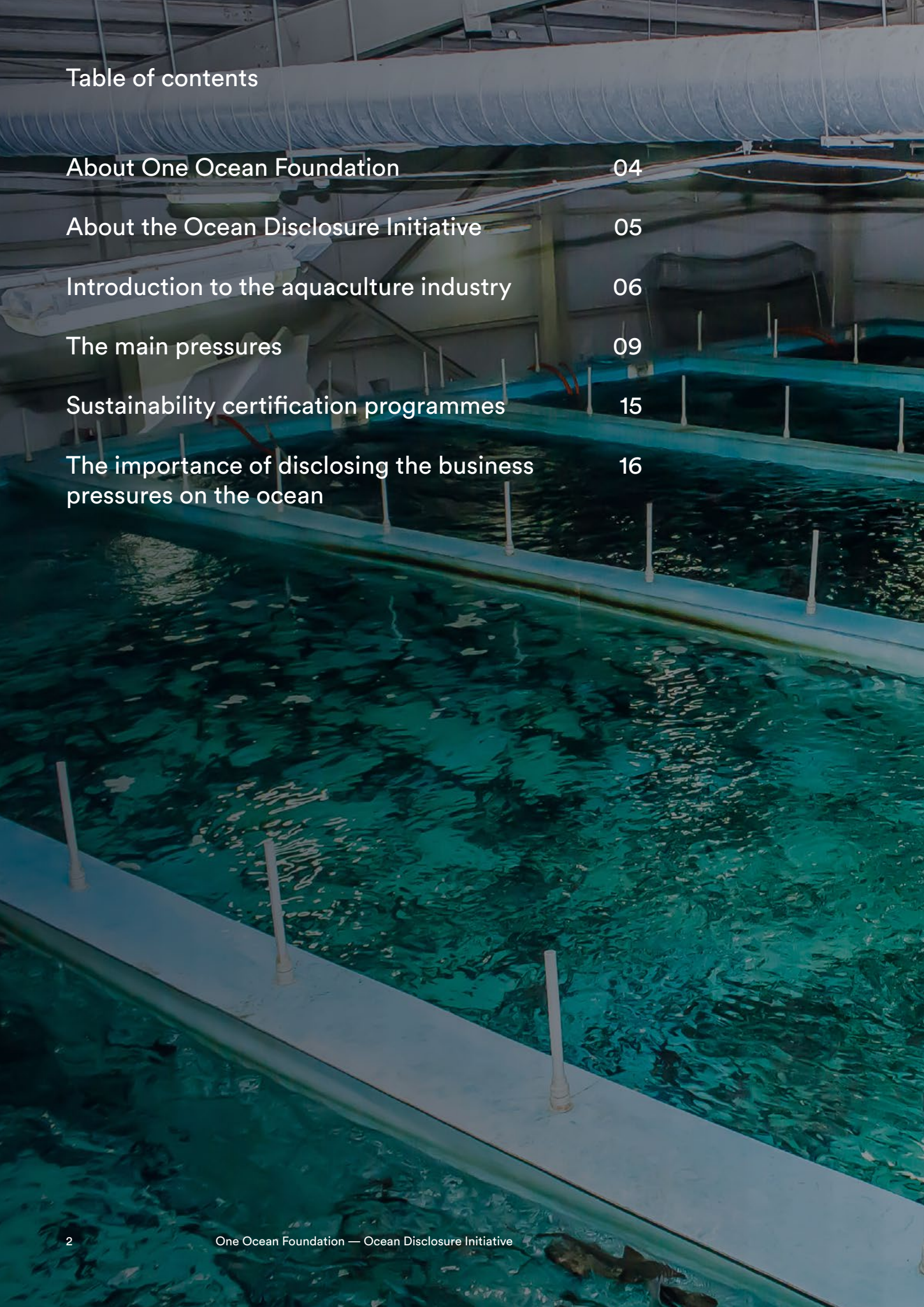
Ocean Disclousure Initiative

AQUACULTURE INDUSTRY REVIEW

SDA Bocconi SCHOOL OF MANAGEMENT
SUSTAINABILITY LAB

McKinsey & Company

CSIC
Consejo Superior de Investigaciones Científicas



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About One Ocean Foundation

This research is an initiative of the One Ocean Foundation, as part of its project Ocean Disclosure Initiative.

The mission of the Foundation is to accelerate solutions to Ocean issues by inspiring international leaders, institutions, companies, and people; promoting sustainable blue economy and enhancing ocean knowledge through ocean literacy.

Thanks to an international network of contacts (companies, institutions, entrepreneurs, sportsmen, yacht clubs, influencers, etc.) the One Ocean Foundation intends to develop a leading platform, bringing together and strengthening the voices speaking out on behalf of the ocean around the world, from a collaborative, not competitive, perspective.

The distinctive feature of One Ocean Foundation is its scientific scope and, at the same time, its strong educational drive, in order to increase awareness and establish constructive relationships between all stakeholders engaged in marine preservation at different levels.

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About the Ocean Disclosure Initiative

The Ocean Disclosure Initiative project is part of the multi-year research “Business for Ocean Sustainability” promoted by the One Ocean Foundation (OOF), in collaboration with SDA Bocconi School of Management Sustainability Lab, McKinsey & Company and CSIC (Consejo Superior de Investigaciones Científicas) and aimed at building knowledge about the relationship between the business and the ocean.

The project started in 2019 with the goal of investigating the role of companies in addressing ocean challenges, focusing on the pressures on marine ecosystems, the level of awareness within the business community and the main (technological and organizational) responses implemented.

The Ocean Disclosure Initiative has the ambition to be a science-based framework and methodology aimed at supporting businesses from all industries in taking action on ocean-related issues, promoting prevention and/or mitigation responses and favouring disclosure and reporting.

Introduction to the aquaculture industry

The aquaculture industry is defined by the Food and Agriculture Organization (FAO) as the aquatic equivalent of agriculture on land, covering the farming of both animals (including crustaceans, finfish and molluscs) and plants (including seaweeds and freshwater aquatic plants growing in or near water)[1].

It is one of the world's most rapidly expanding food production sectors but also an industry that has the potential to exert several pressures on marine ecosystems. For this reason, it has been analysed in the framework of the Ocean Disclosure Initiative (ODI) by reviewing relevant material and sectoral publications on the environmental pressures of the industry, along with sustainability reports from the main stakeholders in the sector. The core objective of the analysis is to map and better understand the pressures exerted on marine ecosystems thus creating the basis for the industry-specific edition of the ODI tool dedicated to aquaculture. To this end, the following paragraphs introduce the industry and present its main pressures on the ocean.

Marine resources, especially seafood, are critical to human life on a Planet Earth that has recently reached a record 8 billion inhabitants. Consequently, the need for nutritious, safe and attainable food is growing exponentially, as is the risk that its availability will not be sufficient to satisfy the necessities of future populations, mainly due to the consequences of anthropogenic pressures on the environment.

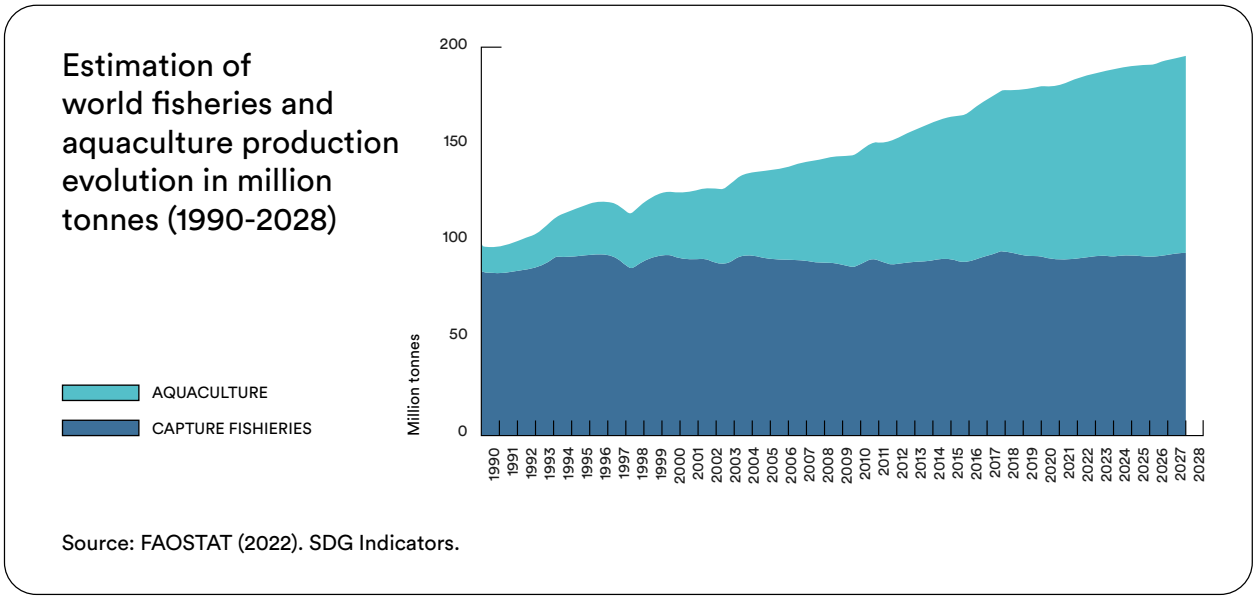
Aquatic food, which includes all sorts of fish, shellfish and plants including seaweed, represents an important source of protein, contributing more than ever to global food security and nutrition. In this context, the aquaculture industry is expanding to meet the increasing demand for aquatic food. Indeed, according to the FAO

1. FAO. Definitions. https://www.fao.org/3/x6941e/x6941e04.htm

TODAY, ABOUT 50% OF AQUATIC FOOD CONSUMED BY PEOPLE IS FARMED AND AQUACULTURE WILL PROVIDE TWO-THIRDS OF THE GLOBAL SEAFOOD SUPPLY DESTINED FOR HUMAN CONSUMPTION BY 2030.

State of World Fisheries and Aquaculture report, total production from fisheries and aquaculture reached a record 214 million tonnes in 2020, comprising 178 million tonnes of aquatic animals and 36 million tonnes of algae, the majority of which is generated by the fish farming industry[2]. Moreover, FAO forecasts that aquaculture will provide two-thirds of the global seafood supply destined for human consumption by 2030, while about 50% of aquatic food consumed by people today is farmed.

FIGURE 1: Estimation of world fisheries and aquaculture production evolution in million tonnes (1990-2028)



Source: FAOSTAT (2022). SDG Indicators.

Aquaculture is practiced in very different environments around the world. These mainly include:

i. **Freshwater** (or inland). Fish farming is carried out either in fishponds, fish pens, fish cages, tanks or, to a lesser extent, in rice paddies;
ii. **Brackish water**. Fish farming is done mainly in fishponds located in coastal areas;
iii. **Marine water**. Fish farming in offshore and coastal waters uses either floating cages or substrates for molluscs and seaweeds, such as stakes, ropes, and rafts.

2. FAO (2022). The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. Rome, FAO

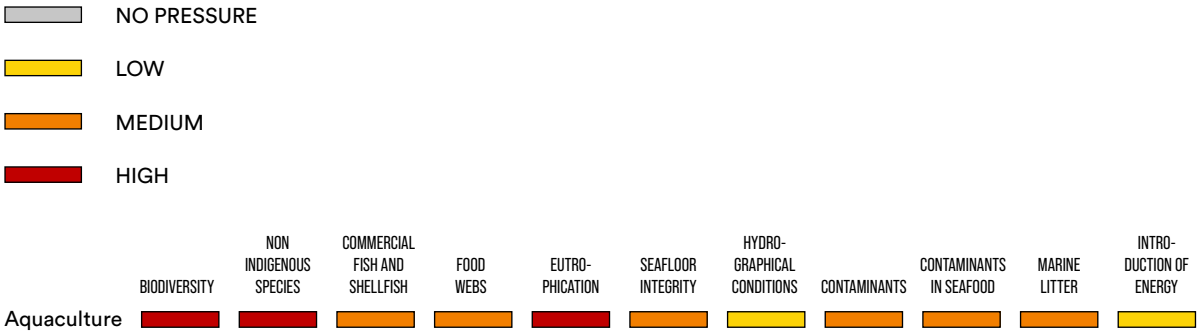
Therefore, as aquaculture is undoubtedly an important source of farmed protein with a lower environmental footprint compared to other terrestrial industries[3], it can certainly assume an important role in moving towards a more sustainable food system. In order to continue to benefit from marine resources and limit the pressures exerted on the marine environment, it is essential to secure and produce nutritious seafood in the most sustainable way possible.

The rapid growth and development of global aquaculture has raised questions regarding its potential negative consequences on the marine environment, associated with the possible mismanagement of operations. Indeed, a better understanding of the possible negative consequences of the aquaculture industry is essential to support decision makers in guaranteeing the sustainability of economic activities as well as the protection of the marine environment.

As the scientific review conducted in the framework of our research has revealed (see figure 2 below), the most significant pressures exerted by the aquaculture industry on the marine environment include:

— Loss or reduction of biodiversity
— Introduction of non-indigenous species (NIS)
— Eutrophication of seawater through the introduction of nutrients

FIGURE 2: Review of the negative pressures of the aquaculture industry*



Source: Ocean Disclosure Initiative, One Ocean Foundation, 2021

* Pressures exerted on the eleven Good Environmental Status descriptors (GES) of EU marine waters, listed in the figure as identified in the Marine Strategy Framework Directive of the European Union. https://ec.europa.eu/environment/marine/good-environmental-status/index_en.htm

3. MacLeod, M. J., Hasan, M. R., Robb, D. H., & Mamun-Ur-Rashid, M. (2020). Quantifying greenhouse gas emissions from global aquaculture. Scientific reports, 10(1), 11679.

The main pressures exerted by the aquaculture industry

The environmental pressures caused by some of the practices used in the aquaculture sector have far-reaching consequences on the marine ecosystem and its biodiversity. In particular, the loss and/or degradation of habitats caused by the construction of aquaculture farms is one of the main impacts caused by this sector on the environment, mainly affecting mangrove forests and saltmarsh ecosystems in coastal areas. Moreover, the use of wild fish stock to produce feed for farmed species can contribute to several environmental impacts, including those caused by overfishing and eutrophication of water bodies due to the load of nutrients and chemical compounds.

Overall, the main pressures identified for the aquaculture industry include:

1. Introduction of farmed native species and non-indigenous species (NIS)

THE AQUACULTURE SECTOR IS THE SECOND BIGGEST CAUSE OF THE INTRODUCTION OF NON-INDIGENOUS SPECIES IN THE MARINE ENVIRONMENT, AFTER SHIPPING.

The aquaculture sector is the second biggest cause of the introduction of non-indigenous species into the marine environment after shipping[4]. In fact, when fish farms are connected to a natural water source, meaning oceans, rivers, or lakes, individual farmed fish, both native and non-native, can accidentally escape and end up directly in the surrounding environment, thereby contributing to biological pollution. Escapes may occur due to several reasons, including damage to fish farm structures and equipment, often caused by extreme environmental events (e.g. storms), attacks by predators, especially in open ocean farming, human error and accidental release during fishing operations or reproduction activities and direct release of eggs into the marine environment.

The presence and farming of exotic species could impact wild populations through i) competition for food, habitat and partners ii) transmission of parasites, pathogens and diseases and, iii) displacement of native species. In general, farmed fish have a greater tendency to

4. Hewitt, C. L., and Campbell, M. L. (2007). Mechanisms for the prevention of marine bio invasion for better biosecurity. Mar. Pollut. Bull. 55, 395–401

develop diseases that can be transmitted to wild stock and push them to extinction[5]. Another important aspect linked to the introduction of such species in the marine environment is related to the genetics of wild populations; indeed, if farmed individuals, both native and non-native, interbreed with their wild counterparts, the genetic makeup of their offspring may be less adaptive to the ecological niche and less likely to survive, eventually leading to a decline in species abundance[6]. Finally, the ecological impact that the introduction of individual farmed fish could have on food webs needs to be considered, as it has the potential to alter species interactions within and between various trophic levels.

Best practices. To avoid the potential spread of non-indigenous species from aquaculture farms with all the related consequences, such as possible population outbreaks, it is preferable to select only native species as target fish, also in consideration of the fact that it could be very expensive and difficult to maintain the broodstock of exotic populations. Moreover, in the case of open ocean farms, it would be better to locate nets and cages in areas where there are no sensitive wild fish populations. With regards to inland aquaculture technologies, recirculating systems are highly preferable as they are enclosed circuits, less open to the environment and with a minor risk of pollution, including biological. An example is represented by land-based recirculating aquaculture systems (RAS), indoor tanks equipped with pumps, filters and aerators that treat and clean water before returning it to the tanks.

In terms of escapes of both farmed native species and non-indigenous species, the installation of monitoring systems on cages could certainly contribute to controlling and preventing possible escapes and any kind of damage to the farm. A response plan that includes specific procedures to apply in the event of an escape is essential, as is the implementation of international and national regulations that control the handling of non-indigenous species to limit the risk of detrimental effects from their intentional introduction and transfer in marine waters (e.g. Code of Practice on the Introductions and Transfers of Marine Organisms by the International Council for the Exploration of the Sea, ICES 2005).

5. Atalah J., Sanchez-Jerez P. (2020), Global assessment of ecological risks associated with farmed fish escapes, Global Ecology and Conservation, Volume 21.
6. Ibidem

2. Discharge of contaminants and waste

AQUACULTURE OPERATIONS CONTRIBUTE TO THE EUTROPHICATION OF MARINE WATER DUE TO THE INCREASE IN THE AMOUNT OF NUTRIENTS ENTERING WATER SYSTEMS.

Shellfish and fish farming may significantly increase the amount of nutrients entering water systems through the deposition of faeces, fish food, live shellfish, and shells. Such substances, nitrogen and phosphorous in particular, contribute to the eutrophication of marine water, which entails a proliferation of algal blooms and oxygen depletion (hypoxia). Indeed, several data sources show that, from the total nitrogen supplemented to cultivated organisms, only 20% to 50% is retained as biomass by the farmed organisms, while the rest is incorporated into the water column or sediments, causing various impacts including the above-mentioned phytoplankton blooms and the death of benthic organisms[7].

Additional substances used in the sector include various pharmaceutical products utilised to prevent disease outbreaks among farmed fish (e.g. antibiotics) but also anti-fouling paints employed for tank and pond maintenance. Although not all of these substances are harmful, several can be, especially for filter-feeder organisms such as shellfish. In general terms, these include certain chemicals that have the potential to bioaccumulate in fish, such as dioxins, polychlorinated biphenyls (PCBs) and heavy metals like mercury which move up the food chain through all the trophic levels. In the case of inland fish farming, the use of such substances might also pollute clean water sources and represent an issue for human consumption[8]. Overall, even if it is clear that chemicals used in the aquaculture industry contribute to imbalances in the different ecosystems, the full environmental implications of the use of these substances, such as growth hormones, have yet to be studied in depth by scientists[9].

Aquaculture activities can further contribute to altering the pH of water through the release of waste products, such as fish faeces and uneaten food, and the use of chemicals, such as the ones found in antibiotics and pesticides, leading to water acidification and toxicity.

Best practices. The design of adequate water inlet and outlet systems, which take various parameters into account such as water quality, weather conditions and currents for safety reasons, may reduce environmental pollution. Moreover, associating the farming of fish

7. Martinez-Porchas M., Martinez-Cordova L.R. (2012), World Aquaculture: Environmental Impacts and Troubleshooting Alternatives, The Scientific World Journal
8. https://niwa.co.nz/our-science/freshwater/tools/kaitiaki_tools/land-use/aquaculture/impacts/chemical-contaminates
9. Martinez-Porchas M., Martinez-Cordova L.R. (2012), World Aquaculture: Environmental Impacts and Troubleshooting Alternatives, The Scientific World Journal

with the farming of mussels and seaweed can lead to beneficial effects since these organisms are able to filter or absorb waste particles produced by fish. Another identified best practice is related to the simultaneous farming of two or more species (defined as polycultures or integrated multitrophic aquaculture), which has proven to be one of the most effective ways to recycle carbon, nitrogen, and phosphorous compounds supplied to the system, known to cause water eutrophication. Finally, the improvement of the composition of feed, which is considered a main source of water contamination, is of paramount importance to make aquaculture production more sustainable[10].

3. Use of unsustainable feeding techniques

Aquaculture still relies on natural wild resources to feed farmed species and, although the industry has been proclaimed a solution to avoid overfishing, it is, to some extent, contributing to the collapse of fishery[11]. The use of wild fish as the main feed supply can lead to several environmental impacts, including those related to disruption of food webs and depletion of fish stocks. It has been reported that every year millions of tons of crustaceans and small forage fish like sardines, anchovies, and herrings, are caught and processed into fishmeal and fish oil to feed farmed species, especially piscivorous ones like salmon[12]. This represents a major issue considering that forage fish play an important role in marine ecosystems by feeding on plankton and transferring energy from the bottom of the food chain to seabirds, marine mammals and larger fish[13].

THE USE OF WILD FISH AS THE MAIN FEED SUPPLY HAS THE POTENTIAL TO CONTRIBUTE TO THE DISRUPTION OF FOOD WEBS AND TO DEPLETION OF FISH STOCKS.

Moreover, when the density of fish is high in aquaculture farms, natural food sources may not be sufficient to sustain the whole production and growth and supplemental feed must be integrated. Supplemental feed includes mainly nutrients like fat, proteins, minerals and vitamins, organic matter and vegetable compounds, usually produced in form of dry and moist pellets. However, as mentioned above, these substances are considered one of the main sources of water contamination caused by the aquaculture sector.

Best practices. As reported by the World Benchmarking Alliance, around 10% of global seafood production is used to produce marine ingredients[14], therefore a good practice to reduce the impact on ocean forage fish stock would be to select fish feed from other sources,

10. Ibidem
11. Ibidem
12. Limit wild fish use as feed, https://www.seafoodwatch.org/seafood-basics/sustainable-solutions/limit-wild-fish-use-as-feed
13. World Ocean Initiative (2020), Fish feed of the future
14. https://www.worldbenchmarkingalliance.org/publication/seafood-stewardship-index/findings/companies-must-demonstrate-how-key-aquaculture-impacts-are-addressed/

such as insects, bacteria, yeast, and reuse fish scraps where feasible. Moreover, a more sustainable aquaculture system would rely on farmed species that can be fed through a vegetarian diet, and do not require feed or require fewer supplies to grow.

The use of advanced technologies in aquaculture systems based on a circularity approach may avoid environmental impacts related to water pollution; examples are the land-based recirculating systems cited above, aquaponics – meaning the coupling of aquaculture with hydroponics – to recycle fish scraps and food waste, and multi-trophic techniques to reduce nutrient accumulation and improve water quality thanks to the farming of filter feeder organisms along with target fish.

4. GHG emissions

The main source of emissions in this sector is associated with ecosystem change related to the destruction of mangrove forests and saltmarshes to create space for fish farming operations. The issue is that mangroves, like other coastal wetlands, play an important role in mitigating greenhouse gas emissions as they are important carbon sinks; indeed, mangroves absorb CO_2 from the atmosphere and store it in roots and branches, as well as in the surrounding sediments. Scientists have discovered that mangrove forests have the potential to store substantial amounts of carbon and thus their reduction entails a higher level of GHGs in the atmosphere[15].

THE MAIN SOURCE OF EMISSIONS IN AQUACULTURE IS ASSOCIATED WITH ECOSYSTEM CHANGES RELATED TO THE DESTRUCTION OF MANGROVE FORESTS AND SALTMARSHES TO CREATE SPACE FOR FISH FARMING OPERATIONS.

In addition to ecosystem change, emissions can be the result of activities across the whole aquaculture value chain, from the production of feed to the transportation of materials and the farming of fish stock itself. Among these sources of emissions, the production of feed represents the main driver; for instance, scientists have found that the production of crops for aquaculture feeds accounted for 39% of the industry's emissions[16].

Literature reports that the aquaculture industry, aquatic plant farming excluded, accounted for approximately 0.49% of anthropogenic GHG emissions in 2017[17], which is clearly not comparable to land livestock. In fact, aquaculture is considered an efficient way of producing animal protein, especially considering the low emissions intensity of its operations due to the smaller quantity of feed required, the high fertility of the animals and the absence of enteric CH_4 compared to

15. Nyanga, C. (2020). The role of mangroves forests in decarbonizing the atmosphere. In Carbon-Based Material for Environmental Protection and Remediation. IntechOpen.
16. Ibidem
17. MacLeod, M. J., Hasan, M. R., Robb, D. H., & Mamun-Ur-Rashid, M. (2020). Quantifying greenhouse gas emissions from global aquaculture. Scientific reports, 10(1), 11679.

terrestrial livestock (in particular cattle, sheep and goats). Nevertheless, actions to reduce such emissions deserve attention, including in view of the future development of the sector.

Best practices. Considering that the aquaculture industry is an expanding sector, and is still fairly young, there is great potential to apply new technologies to the various farming operation phases in order to improve efficiency and sustainability as a means to mitigate the pressures anticipated to be exerted on the marine environment. In particular, broad technological approaches with the potential to reduce GHG emissions from aquaculture include, inter alia, i) breeding and genetics, ii) disease control, iii) nutrition and feeding, and iv) low impact production systems[18].

18. Ibidem

Sustainability certification programmes

AQUACULTURE STANDARDS AND CERTIFICATION SCHEMES PROVIDE PRACTICAL SUSTAINABILITY BENCHMARKS THAT CAN HELP CONSUMERS AND PROMOTE THE SUSTAINABILITY OF THE SECTOR.

The aquaculture sector is benefitting from the existence of voluntary and fully independent certification programmes that strive to improve the sustainability and accountability of seafood supply chains through raising awareness, driving the development of commitments and engagement in improvements by companies. Aquaculture standards and certification schemes provide practical sustainability benchmarks that can help consumers to make more informed choices related to sustainable production methods when it comes to buying seafood. The main criteria that the most important certifications track with their checklists, standards and procedures include impacts on critical habitat (e.g. mangroves, wetlands, etc.); water quality parameters; escapes of animals; the use of harmful antifouling or growth hormones; compliance with social accountability and carbon footprint.

The final objective of the certification programmes is also to establish mechanisms that can lead to tangible improvements in terms of the industry's sustainability.

The importance of disclosing the business pressures on the ocean

The industry-specific edition of the Ocean Disclosure Initiative tool dedicated to the aquaculture sector, developed by One Ocean Foundation in collaboration with its partners, reflects the main pressures exerted by this sector with the aim to support companies in becoming aware of their impacts on marine ecosystems, assessing the related risks, and disclosing key information and strategic responses on the significant issues related to the fish farming activities. As identified in our research and reflected in the industry-specific tool, these pressures include i) the overexploitation of marine resources; ii) the release of hazardous substances or contaminants into water bodies; iii) the operations that may alter sea-floor integrity, such as anchoring and grounding; iv) the potential escapees of farmed fish that may cause the introduction of non-indigenous species into the marine environment; and v) the unstainable use of feeding techniques.

The importance of the Ocean Disclosure Initiative is related to the fact that, for the first time, companies, scientific and financial communities, and civil society can rely on a common language to measure, address, and mitigate the most relevant pressures that humanity exerts on the marine environment, sector by sector, with significant advantages for the health of the ocean.

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