Integrated Multi Trophic Aquaculture in Norway

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Integrated multi-trophic aquaculture, or IMTA, is the cultivation of aquatic species for food, by using more than one organism from different trophic levels (levels in a food chain). It works by utilizing different species with different nutritional needs. Some species can feed on and grow from the bi-products of others, which reduces overall resource waste and improves farming efficiency by allowing the harvest of more than one species at a time. It can also help with ecosystem services like supporting and contributing to local biodiversity (Grassle 2013). Traditional aquaculture produces pollution and can be degrading to the environment and has limits on sustainability (Fossberg et al. 2018). Norway is the largest global producer and exporter of farmed salmon (FAO 2020). However, the growth of the industry has coincided with environmental impacts on the marine ecosystem and negative perceptions of salmon farming (Abdallah 2017; Fossberg et al. 2018).

With a focus on salmon (*Salmo salar*) and kelp (*Saccharina latissima*) farming in the Norwegian economic zone, this paper aims to emphasize the opportunities and problems of IMTA by identifying connections between IMTA, sustainable development goal (SDG) 14 - Life Below Water and the other SDGs. Furthermore, the paper will discuss if IMTA is a viable sustainable alternative to the present aquaculture food production systems.

Approach

With water currents, the wastes from the aquaculture will be transferred by the ocean, making the problems a global issue. Although coastline and open fjords with a strong enough water current can disperse sediment and fish feces, there is a lack of available areas that meet the requirements for low environmental impact fish farming.

Salmon farming alone emits inorganic nitrogen and CO2 from metabolic systems and phosphorus from the uneaten feed (Fossberg et al. 2018). The impact of those molecules can change/destroy habitats, e.g., eutrophication/hyper nutrification environments which in the worst case leads to dead zones (Kaiser et al. 2020), changes in community structure, and benthic impacts, such as changes in sediment chemistry and biology.

IMTA and its connections to the SDGs

IMTA is highly relevant to SDG 14 and can be directly connected to SDG 2, 8 and 13 (ICS 2017). SDG 14 calls for the protection of the marine environment and sustainable use of marine resources. As IMTA aims to reduce waste and pollution from aquaculture, it is very important for the success of SDG14's targets of marine protection. Since kelp uses nitrogen (N), phosphor (P) and carbon dioxide (CO2) in photosynthesis and growth, it can also reduce ocean acidification (Wang et al. 2013). Aquaculture aims to produce food and is therefore very important for SDG 2 - Zero Hunger (ICS 2017). IMTA is thought to be a more sustainable methodology of food production than traditional aquaculture. It can lead to more efficient production with a greater yield and can therefore contribute to healthy and sustainable economic growth. This connects directly to SDG8 - Decent work and economic growth. IMTA can also contribute to SDG 13s goals to combat climate change and reduce biodiversity loss. Any reduction of waste and pollution helps, even underwater, and so helps with the progression of SDG 13 (ICS 2017).

The different stakeholders

Norway's salmon industry is highly regulated, and there are multiple actors and stakeholders with different levels of influence throughout the process of creating policy, issuing a farming license, and the placement and operation of an individual farm. One of the more important stakeholder issues is the public concern for the environment. It is argued that the environmental perspective is a challenge for all stakeholders (Ellis and Tiller 2019). However, by allowing IMTA in Norway, we can get more benefits from it in the long run with increasing jobs and an improved marine environment for instance. This can connect with the SDG 14.1 target that aims to prevent and significantly reduce marine pollution of all kinds, but also with SDG 13 with climate action and SDG 9 that build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation (ICS 2017).

Another obvious yet important stakeholder is the aquaculture industry. The present aquaculture farms need to get something in return, as they must implement and adapt to the IMTA system. If the farm has to do more time-consuming work without getting a linear profitability growth, they might not believe that IMTA is worth the time and effort.

Kelp in mass-produced products

Macroalgae like brown and red algae have the best utility on the market today. There are several different uses of macroalgae such as for fertilization, cosmetics, and biofuels. Macroalgae has also a great value in a lot of food products. Brown and red algae can produce phycocolloid (Sjøtun 2003). The natural environment of brown and red algae can be very exposed, so algae have developed adaptations for these exposed areas in the form of mechanical support and flexibility in the cell wall. The material with the common name phycocolloid can make up 20-40% of the dry weight of the macroalgae. These are chemical compounds that have gel-forming properties (Rueness and Steen 2008). In Norway, we have a lot of brown algae like kelp, and alginate is produced from kelp. In the production process of brown algae, alignat is extracted. Guluronic acid is an important component that provides alginate gel-forming properties. Alginate can be used in a lot of different products, it gives products viscosity, gel strength and stability to liquid mixtures. In mass-produced products such as ice cream, margarine, mayonnaise, and ketchup alginate is used as an additive (Sjøtun 2003).

Opportunities

IMTA can improve perceptions of the industry, create skilled jobs in coastal communities, and provide the industry with new sustainable sources of marine ingredients for feed. IMTA could possibly be implemented in Marine Protected Areas under their strict regulations, which would enable more areas for food production (Chopin 2017). This would release pressure on presently used areas and their biosystems.

By producing kelp near the salmon cages (fig. 1), a study from Western Norway has found that the growth of kelp is greater closer to the cages (Fossberg et al. 2018).

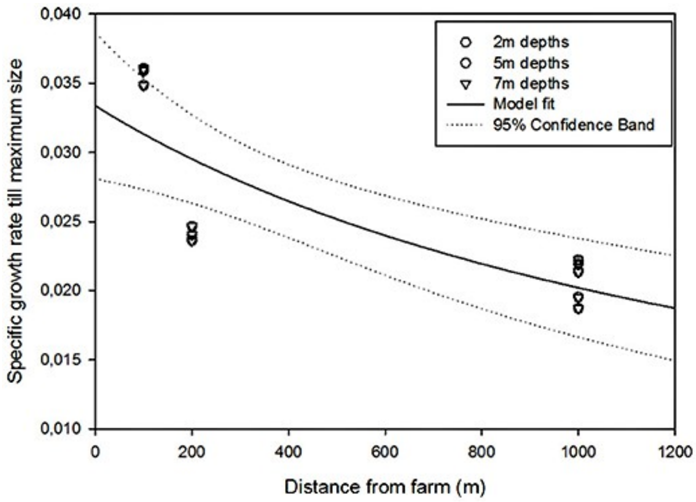

Figure 1: Specific growth rate till maximum size vs. Distance from the farm (m).

Aquaculture has significant potential in helping provide a healthy and sustainable protein source for future populations. However, a substantial increase in production is needed to ensure future demands. This increased production must be matched by significant reductions in any associated environmental impacts and improvements in resource efficiency. For this to happen, an increase in research is necessary (Global Salmon Initiative 2021).

Environmental concerns for the Norwegian coastline

Over the years salmon farming has been located in nearshore, sheltered and shallow water to make it easier to work with the feeding stations and maintenance, it is also better for safe operations (Huguenin et al. 1997). In Norway, we have focused on operating cost-efficiently which has led to many nearshore facilities reaching full capacity and operating a high-density salmon stock. These factors contribute to the accumulation of fish waste (e.g. sediments and fish feces) which again causes water pollution and environmental degradation (Stickney et al. 2002). (Kutti et al. 2007).

The Norwegian government has made their policies for allocating farm licenses more strict due to environmental concerns (Hersoug et al. 2019). A healthy marine environment and suitable locations are essential for the development of salmon aquaculture, and available space is a critical issue for the industry and the government (Sandersen et al. 2015; Gullestad 2011).

Challenges of IMTA implementation

IMTA has a big potential to change the aquaculture industry for the better, yet it hasn’t gained enough research coverage to convince a system change. Aquaculture relevant education is often focused on monocultures, not the diversity of polyculture that IMTA relies on (Chopin 2017). Local regulations are often based on specific single species, which may hamper IMTA implementation as they are not optimized properly.

Also, a study from central Norway found that kelp can absorb up to two/thirds of the dissolved inorganic waste from salmon production (Wang et al. 2013). Absorbing 100% of the waste from the salmon will then require large quantities of kelp, which can prove difficult to achieve.

Conclusion

With the present aquaculture systems in place today, sustainability will decrease without any changes. There are limited possibilities for salmon farming in nearshore coastal areas of Norway due to the lack of suitable farming conditions and government regulations, thus a system change is necessary. We have demonstrated that IMTA offers more sustainable farming conditions (better water quality), and despite the challenges of co-producing kelp and salmon might have, there is a bigger focus today on sustainable cultivation of organisms, and the cultivation of low trophic levels in the food chain is seen as an important measure against climate change and based on a growing population, the focus is more on green growth in the economy.

References:

Abdallah, Thomas. 2017. “Environmental Impacts.” *Sustainable Mass Transit*. Elsevier. 45-59 [online] Available at: <https://doi.org/10.1016/B978-0-12-811299-1.00004-6> [Accessed 5 May 2022].

Chopin, T. (2017) Challenges of moving Integrated Multi-Trophic Aquaculture along the R&D and commercialization continuum in the western world, *Journal of Ocean Technology,* 12 (August): 34-47.

Ellisa John and Rachel Tillerb. 2019. “Conceptualizing future scenarios of integrated multi-trophic aquaculture (IMTA) in the Norwegian salmon industry.” *Marine Policy*. 198-209.

FAO. 2020. *The state of world fisheries and aquaculture.* Sustainability in action. Rome. 75. https://doi.org/10.4060/ca9229en.

Fossberg, Julia, Silje Forbord, Ole Jacob Broch, Arne M. Malazahn, Henrice Jansen, Aleksander Handå, Henny Førde, Maria Bergvik, Anne Lise Fleddum, Jorunn Skjemo, and Yngvar Olsen. (2018). “The Potential for Unscaling Kelp (Saccharina latissima) Cultivation in Salmon-Driven Integrated Multi-Trophic Aquaculture (IMTA).” *Frontiers in Marine Science*. 418(5):1-13. https://doi.org/10.3389/fmars.2018.00418.

Global Salmon Iniciative. 2021. *The Future of Aquaculture*. [online] Available at: <https://globalsalmoninitiative.org/en/our-work/the-future-of-aquaculture/> [Accessed 16 May 2022].

Grassle, J. Frederick. 2013. “Marine Ecosystems.” *Encyclopedia of Biodiversity* (Second Edition). Academic Press. 45-55. https://doi.org/10.1016/B978-0-12-384719-5.00290-2.

Hersoug, Bjørn, Eirik Mikkelsen, and Kine Mari Karlsen. (2019). “‘Great Expectations’ - Allocating Licenses with Special Requirements in Norwegian Salmon Farming.” *Marine Policy* 100(2):152-162 https://doi.org/10.1016/J.MARPOL.2018.11.019.

Hersoug, Bjørn, Eirik Mikkelsen, and Tonje C Osmundsen. 2021. “What's the Clue; Better Planning, New Technology or Just More Money? - the Area Challenge in Norwegian Salmon Farming.” *Ocean and Coastal Management* 199. https://doi.org/10.1016/j.ocecoaman.2020.105415.

International Council for Science, (2017), *A Guide to SDG Interactions: From Science to Implementation.*

Kaiser, Michel J. Martin J. Attrill, Simon Jennings, David N. Thomas, David K. A. Barnes, Andrew S. Brierley, Nicholas A. J. Graham, Jan G. Hiddink, Kerry L. Howell, and Hermanni Kaartokallio. 2020. *Marine Ecology: Processes, Systems, and Impacts*. Third edition. New York: Oxford University Press.

Kutti, Tina, Arne Ervik, and Pia Kupka Hansen. (2007). “Effects of Organic Effluents from a Salmon Farm on a Fjord System. I. Vertical Export and Dispersal Processes.” *Aquaculture* 262 (2-4): 367–81. https://doi.org/10.1016/j.aquaculture.2006.10.010.

Kutti, Tina, Pia Kupka Hansen, Arne Ervik, Tore Høisæter, and Per Johannessen. (2007). “Effects of Organic Effluents from a Salmon Farm on a Fjord System. Ii. Temporal and Spatial Patterns in Infauna Community Composition.” *Aquaculture* 262 (2-4): 355–66. https://doi.org/10.1016/j.aquaculture.2006.10.008.

Sandersen, Haakan T, and Ingrid Kvalvik. 2015. “Access to Aquaculture Sites: A Wicked Problem in Norwegian Aquaculture Development.” *Maritime Studies* 14 (1): 1–17. https://doi.org/10.1186/s40152-015-0027-8.

Sjøtun, K. (2003) ‘MAKROALGER – HAUSTING OG DYRKING Kompendium til BFM 240 og Akvakultur Fjernstudium Kjersti Sjøtun Havforskningsinstituttet.

Wang, Xinxin., Kjetil Andresen, Aleksander Handå, Bjørn Jensen, Kjell Inge Reitan, and Yngvar Olsen. (2013). “Chemical composition and release rate of waste discharge from an Atlantic salmon farm with an evaluation of IMTA feasibility.” *Aqua. Environ. Inter.* 4, 147–162. https://doi.org/10.3354/aei00079