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Feasibility of Integrated Fish and Algae Offshore Farms

Submitted by Mr. Imri Ketzef,
Ramot Yam High-School, Michmoret

Academically advised by Mr. Raphael Yavetz

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Abstract

The increase of the world's population, which expected to rise up to 9 billion by 2050, along with the rise of the awareness of healthy eating habits, have led to a higher demand for protein and healthy fatty acids derived from the ocean, specifically fish and algae, due to their high nutritional value. The increasing demand has led to over fishing and destruction of habitats. To deal with this problem mariculture industry, which allows to reduce fishery while still meeting the growing demands has developed rapidly.

This development also allows us to save fresh water as it curbs the volume of production of fish in freshwater aquaculture. It also allows to reduce the volume of meat and poultry production, which requires vast amounts of fresh water (400-15,500 liters taken to produce 1 kg of meat). Moreover, algae, which hardly needs fresh water for its cultivation, may in turn serve as substitutes for vegetables such as lettuce and chicory in our diet, which also leads to water saving. Yet, as any growing industry, mariculture can also cause water pollution by releasing nitrogen, as an excess of fish food, rich in protein, and fish excretions. **The aim of my research is to use these polluting compounds as a fertilizer for algae, which is able to absorb them, thus dealing with the pollution and improving algae cultivation**.

Consequently, in my research I examined the potential of algae cultivation in close proximity to marine offshore fish cages, creating an integrated farm model, which produces animal and plant protein, using negligible quantities of fresh water-resources. I have attached net devices,[1] designed for growing *Ulva* algae, in four locations for a total of seven days, placing them on the northern and southern sides of the offshore fish cage, at 7 and 11.5 meters under water, utilizing natural flow and natural lighting conditions in order to find optimal conditions for algae growth. At the beginning and the end of the experiment I weighed the algae, measured organic matter production and calculated nitrogen uptake by measuring chlorophyll-a content.

The results proved *Ulva* algae to be suitable for use as a bio filter, which reduces the environmental negative impact of offshore fish cages by assimilating excess nutrients and nitrogenous compounds emitted from fish production. Cultivation of algae and fish in an integrated system may reduce inland beef, poultry, and vegetable agriculture, thus significantly reducing the use of fresh water, potentially saving large volumes of water.

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[1] Developed by Dr. Meiron Zollmann of the faculty of engineering, Tel Aviv University (Chemodanov, A Et al. 2019)

Introduction

Water is an essential resource for sustaining life. In recent decades, however, urbanization processes, increased irrigation of agriculture inland and changing climate patterns have led to a substantial and ongoing water shortage in various parts of the world. Conversely, it should be noted that technological advances taking place nowadays, may provide human population with various solutions for dealing with water crises (Shiri Spector-Ben-Ari, 2017).

The demand for fresh water has been growing globally at more than twice the rate of the population's growth rate during the last century. Growing number of areas are reaching the point where water services cannot be sustainably delivered, especially in arid regions (UN-Water, 2021). According to the World Bank, nowadays, 70% of global freshwater is being used for agricultural purposes (Khokhar, 2017).

The growth of public awareness in recent years, regarding the need for animal protein and the depletion of fishing catches on one hand, and the increase in demand for food from the sea on the other hand, have contributed to accelerate the development of the mariculture industry, at a rate of 5-10% per year. For instance, it is forecasted that by 2030, production of edible fish in the Mediterranean will be over one million metric tons/year.

Beginning 1990, the growing rate of fishing was halted due to overfishing and harm caused to natural fish populations (figure 1). Concurrently, continuous growth of farmed fish population took place. However, presently, the production of fish from inland, fresh water-based sources pools, is greater than from seawater sources. The extent of mariculture is still a small part of the global fish supply due to the complexity of raising fish in marine cages. On the other hand**,** increasing agriculture-sourced food supply as the one investigated here leads t**o** a reduction in fishing and finding of a solution to overfishing, along with reducing freshwater growth and thus reducing fresh water consumption.

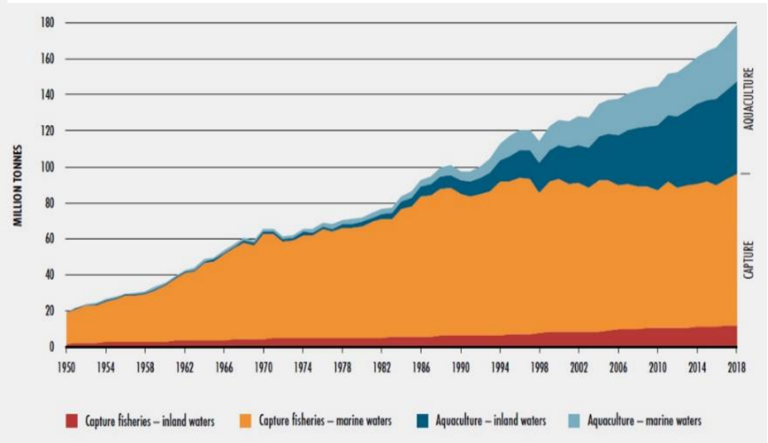


Figure 1: Fish supply sources worldwide (FAO, 2020)

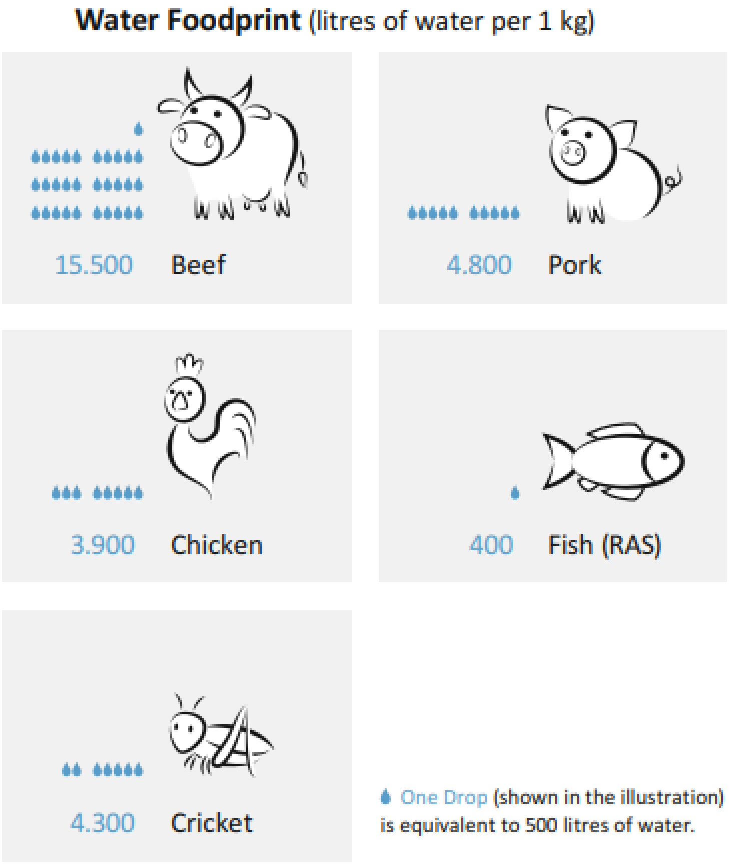


Figure 2: Animal protein sources water footprint (Joyce A. et al, 2019)

Comparison of the water footprint of various animal industries, show vast water consumption differences among sectors. The fin fish in this report (figure 2) were cultured in a recirculating aquaculture system using fresh water (Joyce A. et al, 2019).

In contrast with the water food prints of Fig. 2, the ones of vegetables is much lower, e.g., the spinach aquatic footprint is 292 l/kg and lettuce water footprint was measured at 237 l/kg (Mekonnen, M. M. et al, 2011).

Marine fish cages are floating devices (Fig. 7), used for intensive growth of edible fish. The concept of marine offshore fish farming is to use the sea as a large buffer to maintain favorable conditions for the fish. (carrying away waste emitted, supplying oxygen-rich water, maintaining natural temperature and photoperiod conditions) without the need to invest additional energy. Yet, fish cages, being man-made artificial installations in the sea, have ecological effects. Thus, the zone neighboring the cage is affected by uneaten food and fish excrement. In fact, fish cages produce a variety forms of waste - both particulate and dissolved - that flows directly into the marine environment.

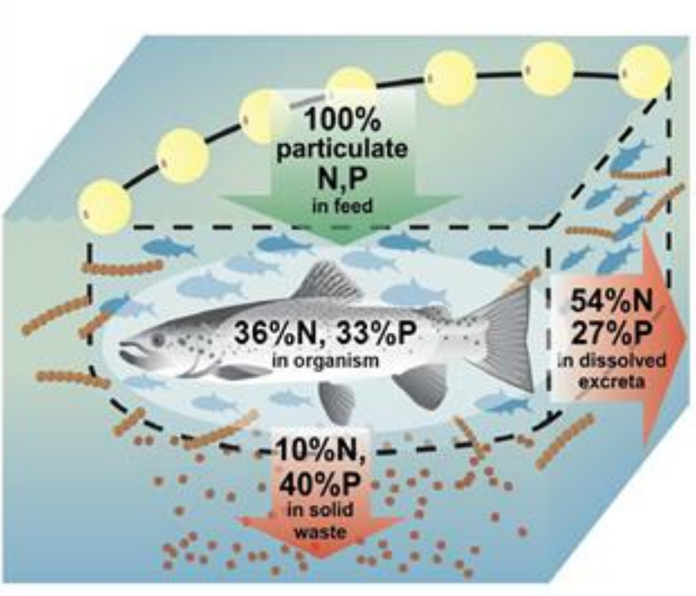


Figure 2: Nutrients (N, P) emitted from fish net cage
(Lex Bouwman, et al. 2013)

Figure 3 depicts the dispersion of nutrients from a cage, based on studies conducted on salmon and rainbow trout species. According to various studies and models of fish farming in marine cages, fish assimilate 22% - 36% of the nitrogen in the food, while the rest is excreted into the water as dissolved nitrogen (54% - 61%), and as particulate matter that sinks to the bottom (10% - 17%). Even though fish considered to have a good food conversion rate, more than half of the nitrogen and phosphorus of the food is released into the marine environment as dissolved or particulate compounds. This nutrient-rich flow can cause various environmental effects. The main effects, around fish cages, include dissolved nutrient (N, P) release that can increase productivity up to 150 meters downstream, thus cause HAB (harmful algal blooms), hypoxia, change in biodiversity and reduce water quality (Lex Bouwman, et al. 2013; Lupatsch I., & Kissil, G. W., 1998); (Lachman E., 2007; Shanin A., 2013).

Still, according to models of secretions dispersal from fish cages, it was proved that the environmental impacts have been shown to be much smaller than those due to growing fish at land-based facilities, which consume fresh water and soil resources, creating polluting burdens, odors and visual hazards (Noam Moses, 2014). Thus, raising fish in a marine environment may reduce the volume of growing fish in land-based facilities, while reducing fishing pressure on natural fish populations.

Though the environmental effect of growing fish in cages is less detrimental than from other methods, it is desirable to reduce the anthropogenic effects of fish farming in offshore cages. This can be achieved by assimilation by marine organisms, and fish secretions and nutrients emitted from the fish cage can be turned into a secondary growth resource for photosynthetic organisms as well as filter feeders, as shown in fig. 4 (Muki Spiegel, 2014). Aquacultural effluents from cages are rich in nutrients and carbon dioxide. Furthermore, they are low in oxygen due to the fish's respiration, which consumes oxygen and emits carbon dioxide. Algae, on the other hand, utilize the carbon dioxide and nutrients in a process of photosynthesis, thus they re-enrich the water with oxygen. The fish lower the pH level in the water, while the algae raise it. It is seen that one form of life may contribute to the sustenance of the other form’s life processes. The nutrients are used by the algae in assimilation in two ways: (i) Photosynthesis and (ii) Protein anabolism. In photosynthesis, the organic materials formed are used to produce the energy essential for further growth processes and the production of valuable compounds. In order to absorb the nitrogen from the environment, the *Ulva* has a large number of membranes in the thallus, which is characterized by a high surface-area relative to volume, and gives it a high ammonia absorption rate. Ammonia is consumed by diffusion, compared to nitrate which is distributed by transporters in the cell membrane (Noam Rosinsky, 2019).

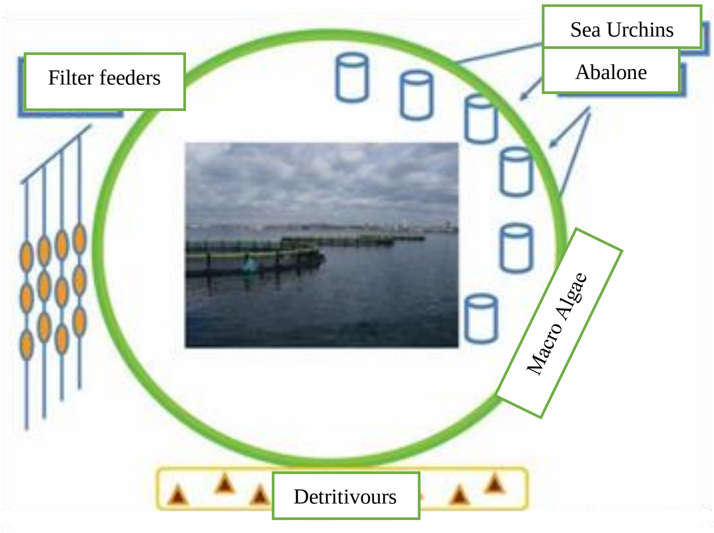


Figure 3: Integrated Multi Trophic Aquaculture – IMTA model (Muki Spiegel, 2014)

Since algae are primary producers, at the base of the marine food chain, the entire food cycle rests on them. Thus, they are of distinct ecological significance. For a long time, algae collected from nature have been part of regular human diet in Africa, Central and South America and Southeast Asia. Algaculture, however, has developed significantly only during the last few decades.

Growing algae on land produces almost no waste, other than the water used for growing them, which nevertheless may be reused. Like higher plants, algae use solar energy to turn atmospheric CO_2, which is dissolved into biomass and oxygen, through the process of photosynthesis. However, in order to produce biomass, algae need additional elements such as nitrogen, phosphorus and certain other micro-elements (Adi Levy, 2016). Besides, land based cultivation entails use of areas which is lost for other uses.

In addition to using algae as a food source, they can also provide various products for different industries such as biotechnology, pharmaceutics, cosmetics and for renewable energies such as bioethanol. Nowadays, bioethanol is mainly produced using terrestrial crops like corn, that requires vast amounts of fresh water, which could be used, instead, for food production.

Algae grown in an integrated aquaculture system, can be used for the production of bioethanol due to its fast growth rate and its high carbohydrates and lipids concentrations (Alvaro, I. et al, 2015) while using a negligible amount of fresh water for growing such plants.

An initial assessment carried out in Israel by Goldberg and Moses (2015), indicates that an increase of 100,000 metric tons of fish growing in fish cage would secrete a quantity of nitrogen that could be consumed by about 405,000 metric tons of algae. This volume of algae can produce about 81,000 metric tons of bioethanol (constituting about 3% of the fuel consumption used currently by vehicular transportation in Israel), while utilizing a maritime area of about 160 square kilometers (a 0.5% of Israel's maritime area) (Ofira Ayalon et al, 2015).

The alga considered here namely *Ulva* is a green one, common to the littoral zone. The *Ulva* is one of the most common species of algae in the world and can be found in tropical and subtropical marine environments. In winter, there is a significant increase in its biomass. *Ulva* can grow attached to a bed using a flat grip, rhizoids, or grow utterly detached from any surface. An individual *Ulva* length can reach up to 50 cm. The actual size of an individual algae is the result of many biotic causes, and the algae is the preferred nutrition of many herbivores (Racheli Einav, 2000).

Figure 4: *Ulva* sp.

Growing Conditions at Sea

The flow regime in the eastern Mediterranean basin includes a north-south flow vector most of the year, within which the flow is northward most of the time. The light properties in the aquatic environment are dynamic, and the light energy varies at different depths, seasonally and during the day.

Light energy depends on two main components: intensity and wavelength (color). Some of the radiance energy is reflected from the water (10% of such energy is lost due to the ocean surface) while the rest of it penetrates the water selectively and disperses upon reaching the upper water layers (Boeuf & Le Bail, 1999). Light is involved in developmental and growth processes, as well as in photosynthesis occurs in the photic zone (Dana Van Der Weiss, 2002). Figure 6 depicts the effect of water depth on light intensity at different wavelengths. The black line represents the average of all wavelengths. It is seen that a rapid decrease in light intensity occurs with depth.

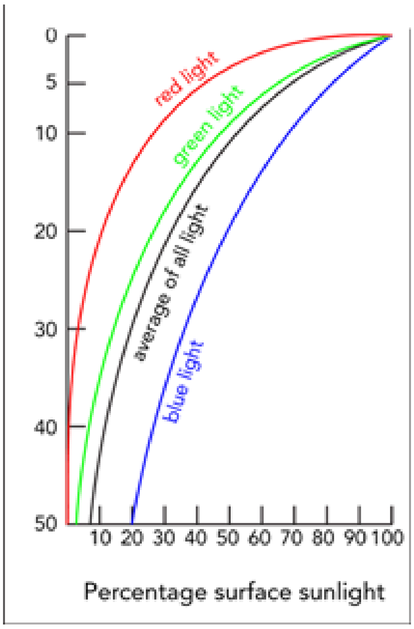


Figure 5: Light absorption in oceanic water (CEUH, 2021)

The pigment molecule *chlorophyll a*, has an essential part in the process of photosynthesis (Guy Schleyer, 2017). Xiaolong Yang, et al (2018), found a correlation between an increase in the total concentration of *chlorophylls a* and *b* and an increase in the amount of nitrogen in the plants. These findings are consistent with previous studies. It means that the amount of *chlorophyll* in the algae may serve as a reliable bio-indicator for the concentration of nitrogen in the environment and the amount of nitrogen consumed by algae (Xiaolong Yang, et al, 2018). In another study, that had examined the nitrogen content in algae, it was found that the total nitrogen in the *chlorophyll* molecules is about 1% of the total nitrogen in the algae, while the protein contains 43% of the nitrogen in algae. However, it has been found that there is a direct relationship between nitrogen enrichment and an increase in *chlorophyll* concentration as well as protein (Naldi M. & Wheeler. P.A., 1999).

The purpose of the study I have conducted was to examine the feasibility of algae growth in the vicinity of a fish cage, resulting from the addition of nutrients flowing from the fish cage, and to estimate the percentage of nutrients absorbed by the algae which thus are not released into the immediate marine environment. The impact of the marine conditions on this process was in the focus of the project. This was done in order to explore the possibility of creating a mariculture farm that could combine grows of animal and plant food products, as a substitute for freshwater consuming land-based crops.

Research Methods

The experiment was performed in an active Sea-bream fish cage belonging to Lev-Yam Co. (Fig. 7) located in the Mediterranean Sea, 3.2 km west of Ramot Yam nautical school, Israel. This cage utilizes the natural flow regime in the area to disperse fish excrement. Since the main flow vector during the year is North-South, I opted to place algae inside net devices south and north of the fish cage, in order to test the effect of the nutrient flow, both down- and upstream. I placed the algae next to the fish cage, facing southward and northward, at depths of 7 and 11.5 meters. Thus, the investigation focused on determining the effects of emplacement of the alga relative to the cage and of the depth. Each treatment had 3 duplicates. At the beginning and seven days thereafter, I performed a series of measurements that included weighing, determining the percentage of organic matter, and the concentration of *chlorophyll a*.

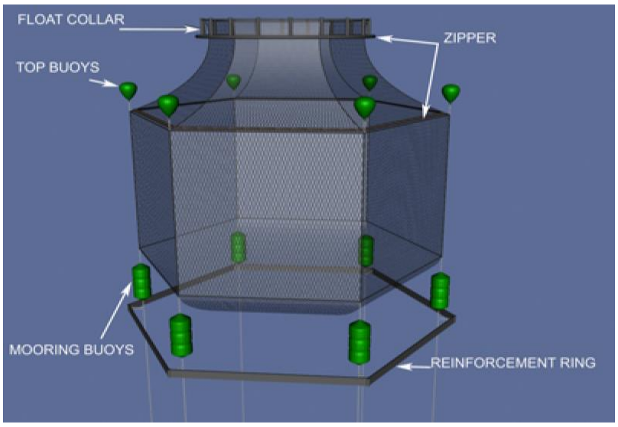


Figure 7: Fish net cage TLC model (RefaMed, 2015).

Figure 6: Algae net devices, similar to the ones I used in my research (Photography: Zollman M)

Streams Data

By the end of the experiment, I assembled the oceanographic data regarding the sea currents, which were downloaded from the records of the Israel Oceanographic and Limnological Research Institute research station in Hadera. I used only data relevant to the time when the experience was preformed (7-14 October 2020). The data was processed in progressive vector diagram analyses with the assistance of Prof. Gitai Yahel - Faculty of Marine Sciences, Ruppin Academic Center.

Calculating Food Quantities

The fish in the cage were fed by food containing 46% protein and a total of 7.37% nitrogen. During the seven days experiment, the fish were fed 60 kg of food per day, totaling 420 kg of feed (according to Dan Radkopf, of the Lev-Yam Company).

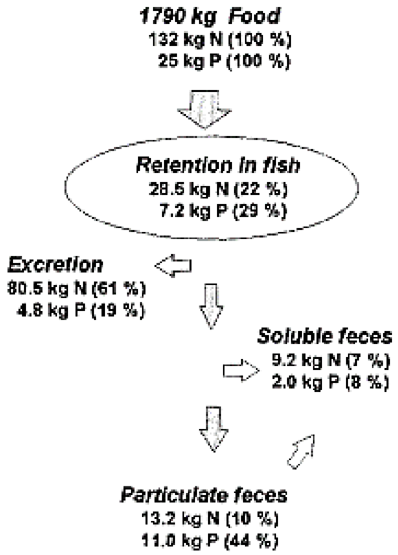
Food quantity	420 kg	
Nitrogen percentage in the food	7.3%	
Amount of nitrogen in the food	30.95 kg	
Amount of nitrogen assimilated by the fish (22%)	6.8 kg	
Dissolved nitrogen amount emitted to the water (7% + 61%)	17.95 kg	
Nitrogen amount in excrement (10%)	3.09 kg	

Table 1: Calculation of the nitrogen amount assimilated in fish according to the model of Lupatsch & Kissil (1998).

Formula for Calculating Algae Growth

$$[(W2-W1)/W1]/7=DGP$$

W2 -The weight of the algae by the end of experiment;

W1 - Initial algae weight

DGP - Daily growth rate.

Chlorophyll a concentration

Chlorophyll a concentration was extracted in DMF (dimethylformamide, an organic solvent), tested in spectrophotometer in 663 nm wavelength, and calculated according to the formula:

chl a = 0.012 x A663 x volume / fresh weight

The chlorophyll concentration is expressed in units of (mg *chlorophyll a)*/(g of algae).

Annual water consumption in the various growing industries

I had calculated it by multiplying the ecological water footprint data of the various crops, by the volume of their global production in 2018 (according to FAO 2020).

WF * AGP = AGWF

WF = Water Footprint

AGP = Annual Global Production

AGWF = Annual Global Water Footprint

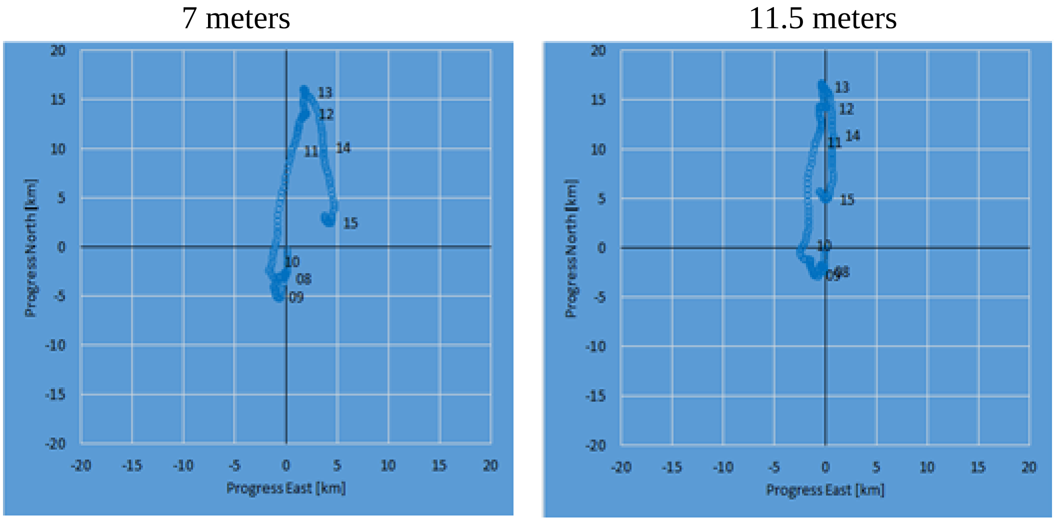
Organic Matter

Percentage of organic matter was tested by drying and burning it at a temperature of 580^0C and calculating based on this formula:

(100 - burnt weight) * 100/dry weight = percentage of organic matter.

Results

The following results include: stream data, daily growth rate, percentage of organic matter, quantity and concentration of *chlorophyll-a*.

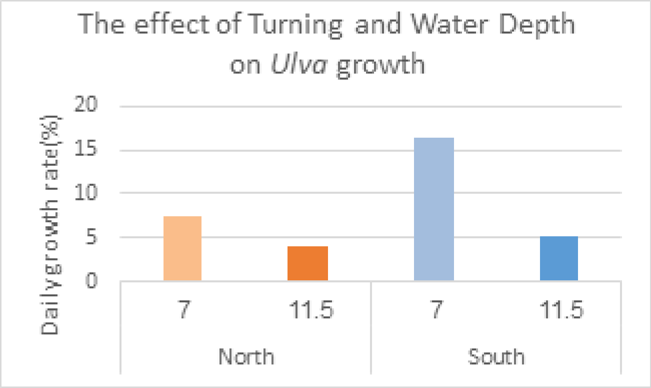


7 meters

11.5 meters

Chart 1: Hadera Monitoring Station Progressive Vector Diagram

Based on the analysis of the flow directions in the cages area, it could be seen that during 36 hours of the experiment's period, the flow to the north was rapid, while at the rest of the experiment's area the flow was slow and to the south. One can also see in the left chart an east-bound drift at 7 m depth.



Two-Way ANOVA P=0.008

Chart 2: The effect of depth and direction on Ulva' growth

Near the fish cages in the southward direction, at both depths, the daily growth percentage was higher compared to the algae placed at the northward direction. Likewise, the daily growth percentage in the shallower treatment was higher than the daily growth percentage in the deeper one. It can also be clearly seen that at a depth of 7 meters at the southward direction, the percentage of daily growth was the highest among the various locations and depths at a value of 16.41% as compared to 3.91% -7.49% in the other areas.

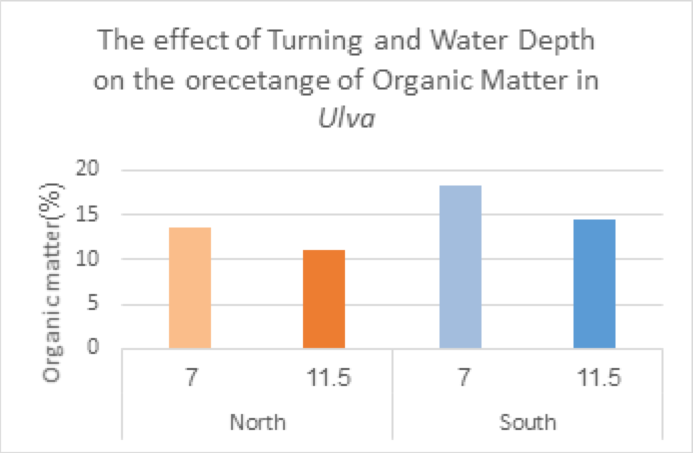


Chart 3: The effect of depth and direction on the percentage of organic matter in *Ulva*

The percentage of organic matter was about 20% higher at the southward direction in both depths, compared to the northward direction. It can also be seen that in both directions, the percentage of organic matter in the shallow emplacement was higher.

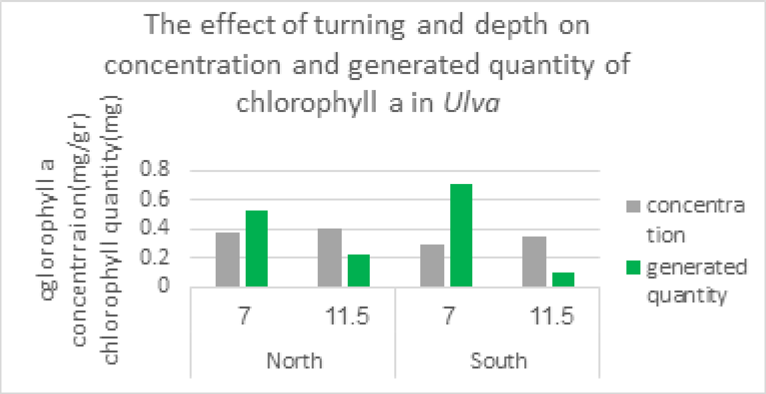


Chart 4: The effect of direction and depth on the concentration and amount of chlorophyll a in *Ulva*.

The amount of *chlorophyll a* which developed was weighted (adjusted) in relation to the biomass gain in the experiment. It was observed that at the northward direction, in both depths, the *chlorophyll a* concentration was higher than at the southward one. It was also noted that in both directions the *chlorophyll a* concentration found at the deep location was greater than the *chlorophyll a* concentration in the shallow position. However, those chlorophyll concentrations are quite similar and hover around values of about 0.38 mg per gram, except for the concentration at the southward direction at the 7 m depth, which was slightly lower, about 0.29 mg per gram. As to the amount of *chlorophyll a*: in the southward direction, in both depths, a greater amount of *chlorophyll a* was formed than in the northward direction, in both depths. It was also observed that in both directions a greater amount of *chlorophyll a* developed in the shallow treatment, than in the deeper one. In the shallow treatments, an inverse relationship was detected between the *chlorophyll a* concentration and its amount in the algae.

Discussion

In this study I have examined the effect of depth and position, relative to a fish cage, on the growth and chemical composition of *Ulva* algae. The algae in the experiment played three different roles: (i) as a bio-indicator for the presence of ammonia originating from the fish cage; (ii) as a bio-filter for nitrogenous secretions originating from the fish cage; and (iii) an economic valuable crop obtained from an offshore fish cage. Such cultivation would, in theory, provide a substitute for green leafy vegetables, as well as a source of raw materials with rich nutritional and mineral value for various products, whose land-based farming involves the utilization of freshwater and other valuable resources. The fish cage in this study had served as a nutrient source for algae. In this study I focused on finding the optimal location, in close proximity to the fish cage, for growing *Ulva*. Due to the coronavirus crisis a plan to grow *Gracilaria* species under identical conditions as conducted for *Ulva*, did not materialize.

What Is the Effect of Directional Position, in Relation to the Fish Cages, on Growth and Chemical Composition of the *Ulva* Algae?

Most of algae growth manifested in biomass and organic matter. In plants, glucose is not used solely as an energy source, but also as the primary building block of the plant. According to charts 2 & 3, in both depths in the southward direction, the daily growth percentage was about 50% greater than at northward direction. At the southward direction, the chlorophyll a concentration was high (chart 4) due to the influx of nutrients from the fish cage. This enabled an increase in the rate of photosynthesis and a faster transfer of glucose to cellulose production, which constitutes most of the organic matter in these algae. According to the measurements of flow data (Chart 1), it turned out that during a 1.5 days of the experiment period, the flow to the north was faster whereas for the rest of the time, there flow to the south was slower. In a strong current, the dilution effect of the nutrients flowing from the cage was greater, thus the effect of the fish cages on algae growth had lessened. In a slow flow, the algae are more able to absorb the ammonia emitted from the cages. Nitrogen availability is considered to be a limiting factor for the production of proteins and *chlorophyll a*. Therefore, as we can see in chart 4, the *chlorophyll a* content is higher at the southward direction, compared to the northward direction at both depths, and is particularly high at the "7m depth-South" growth area. The amount of *chlorophyll a* is indicative of the degree of nitrogen presence in the water. As mentioned, there is a direct relationship between the concentration of *chlorophyll a* in algae and the presence of nitrogen in the growth environment (Xiaolong Yang, et al, 2018; and calculations in Table 1), which, in turn, is indicative of the ability of algae to absorb nitrogen from the water and thus reduce the environmental impact of fish cages. The *chlorophyll a* concentration at the various treatments is similar in three of them (Chart 4) and the range is 0.35 - 0.40 mg. It was, however, slightly lower (0.29 mg) at the "7m- South" area, where, as mentioned, the highest growth rate was observed. This is because the rate of *chlorophyll a* production was sufficient, and the excess nitrogen absorbed was used to accelerate *Ulva* growth. It can be concluded that in a medium where nitrogen is not limited, and under optimal lighting conditions, the algae will use the excess nitrogen for growth and biomass accumulation. At a depth of 7 m, the lighting conditions were better at both ends, while at "7m- South" the algae enjoyed optimal lighting intensity, as compared to "7 North", where lighting was affected by the fish cage's shadow.

According to my research, it can be concluded that depth and direction have a synergic effect, as can be ascertained from the results and in the two-factor ANOVA test (P value =

0.008). That effect is due to a combination of lighting conditions and current conditions which affect the nutrient flow from the fish cage.

The global production of meat in 2018 was 341.16 million metric tons (FAO, 2020), meaning global water consumption of nearly 5.287980 trillion m^3/year.

The global production of lettuce (combined with chicory) in 2017 was 27 million metric tons (FAO, 2020), meaning global water consumption of nearly 6.399 billion m^3/year.

Thus, the combined consumption of water for the annual production of meat and lettuce stands on 5.294379 trillion m^3/year.

Integrated mariculture growth systems, as used in my research, enable the allocation of part of the global meat and vegetable production to the marine environment, thus significantly reducing the annual global fresh water consumption without compromising nutritional benefits, such as protein.

I did not find available data concerning the water footprint of marine offshore fish and algae production. Yet, I can assume that algae growth processes require a negligible amount of freshwater, less than required by lettuce and spinach, for instance. Moreover, algae contain more protein than either spinach or lettuce, 35.1, 28.6, 11.3 g/kg respectively (Nutrition Value, 2021).

Conclusions and Suggestions for Further Research

My research shows that there is a possibility of an integrated growth of animal and plant foods in a marine environment, with a reduction of detrimental environmental impacts compared to other sources. The common food production in terrestrial agriculture implies both direct use of freshwater as well as the depletion and pollution of natural water sources (groundwater and surface water, as a result of over-pumping and pollution by fertilizers, pathogens and other pollutants). Water used to raise fish inland, needs purification processes before reuse or their return to the environment, and the alternative, of using seawater in an open system, makes it possible to optimize growth and to significantly reduce the use of fresh water.

Based on the results of my research, in order to reduce the impact of fish cages on the marine environment, I recommend growing *Ulva* algae at depths between 7-11.5 meters south of the fish cage, although further research is needed in order to examine the effect of growing algae all year long, in additional directions (east-west) and adding other types of algae, as well as checking the percentage of protein in the various treatments.

Bibliography

1. Ayalon O., Trop T., Eshet T., Libes I., Zarbiv M. and Kerem E. (2015). "Development of Sustainable Mariculture in the Mediterranean Israel Waters." *Report of Neeman Institute, Technion, Israel.* (in Hebrew)
2. Boeuf, G., & Le Bail, P. Y., (1999). 'Does Light Have an Influence on Fish Growth?" *Aquaculture*, *177* (1-4), 129-152.
3. Bouwman Lex, Beusen Arthur, Glibert Patricia M, Overbeek Ciska, Pawlowski Marcin, Herrera Jorge, Mulsow Sandor, Yu Rencheng and Zhou Mingjiang, (2013). "Mariculture: Significant and Expanding Cause of Coastal Nutrient Enrichment." *Environ. Res. Lett. 8*.
4. Chemodanov, A., Robin, A., Jinjikhashvily, G., Yitzhak, D., Liberzon, A., Israel, A., & Golberg, A. (2019). Feasibility study of *Ulva* sp.(Chlorophyta) intensive cultivation in a coastal area of the Eastern Mediterranean Sea. Biofuels, Bioproducts and Biorefining, 13(4), 864-877.
5. College of Education, (2021)."Light in the Ocean." *Exploring Our Fluid Earth*. University of Hawai‘i. Retrieved from: https://manoa.hawaii.edu/exploringourfluidearth/physical/ocean-depths/light-oceanFAO, (2020). *The State of World Fisheries and Aquaculture: Sustainability in Action*. Food and Agriculture Organization of the UN. Rome, Italy. Retrieved from: https://doi.org/10.4060/ca9229en
6. Israel A., Gadnekn A., Shachter M., Shamir T. S., Korzen L., Abelson A., (2015). "Various Aspects of Production of Bio-ethanol from Macro-algae in Israel." *Ecology and Environment*, 6 (3) (in Hebrew)
7. Joyce, A., Goddek, S., Kotzen, B., & Wuertz, S., (2019). Aquaponics: Closing the cycle on limited water, land and nutrient resources. *Aquaponics Food Production Systems*, 19.
8. Khokhar, Tariq (2017). "Chart: Globally, 70% of Freshwater is Used for Agriculture." Retrieved from: https://blogs.worldbank.org/opendata/chart-globally-70-freshwater-used-agriculture
9. Lupatsch, I., & Kissil, G. W., (1998). Predicting aquaculture waste from gilthead seabream (*Sparus aurata*) culture using a nutritional approach. *Aquatic Living Resources*, *11* (4), 265-268.
10. Mekonnen, M. M., & Hoekstra, A. Y., (2011). The green, blue and grey water footprint of crops and derived crop products. *Hydrology and Earth System Sciences*, *15* (5), 1577-1600.

11. Naldi, M., & Wheeler, P. A., (1999). Changes in nitrogen pools in *Ulva fenestrata* (Chlorophyta) and *Gracilaria pacifica* (Rhodophyta) under nitrate and ammonium enrichment. *Journal of Phycology*, *35* (1), 70-77.
12. Nutrition Value, 2021. "Lettuce & Spinach." USDA National Nutrient Database. Retrieved from: https://www.nutritionvalue.org
13. RefaMed, (2015). "TLC System." Retrieved from: https://refamed.com/gabbie_mare/tlc_system.html
14. Spiegel M., (2014). Mariculture friendly to environment, from the book “Majesty of the Sea”, The Israeli Assoc. For Marine Science (in Hebrew).
15. UNDP & FAO, (August, 1990). Training Manual on *Gracilaria* Culture and Seaweed Processing in China, Retrieved from: http://www.fao.org/docrep/field/003/AB730E/AB730E00.htm
16. UN-Water. "Water Scarcity." Retrieved from: https://www.unwater.org/water-facts/scarcity/
17. Yang, X., Zhang, P., Li, W., Hu, C., Zhang, X., & He, P., (2018). Evaluation of four seagrass species as early warning indicators for nitrogen overloading: implications for eutrophic evaluation and ecosystem management. *Science of the Total Environment*, *635*, 1132-1143.