Cultivating the Danish Seas

Published in the Proceedings of the 3. Offshore Mariculture Conference in Croatia 2010

Karl Iver Dahl-Madsen, President of Danish Aquaculture

Flemming Møhlenberg, Head of Ecological Innovation, DHI

Per Bovbjerg Petersen, Head of Aquaculture, DTU Aqua

Abstract

Denmark is a global leader in producing healthy and tasty food with a low ecological footprint. We are a nation by the sea and living of the sea. We already have one of the most exposed and highly productive off-coastal trout farms in the world: Musholm A/S with a capacity of 3.000 tons / yr in the open part of the Great Belt. We aim to continue to be part of the nations cultivating the sea by producing significant quantities of food, feed, chemicals and biomass such as fish, mussels and seaweed on off-coastal and off-shore locations.

The Danish sea territory is 105.000 km2, about 2.5 times the land area of Denmark. By using 1 % of this area we can produce fish, mussels and seaweed to a value of 2 billion Euros pr. year. This production will account for 3 million tons of CO2 pr. yr. corresponding to about 5 percent of the Danish CO2 discharge. Furthermore, we can regain 100.000 tons of nitrogen and 10.000 tons of phosphorus from the sea and use it on land. The production will, as an example, substitute the use of much larger tracts of Brazilian rain forest, and save freshwater in an amount corresponding to 2.5 times the total water use of all Danish households. The associated industry will be located in rural and coastal areas, at present having difficulties in attracting people and companies.

We propose for the Danish Society to establish a platform for development of off-coastal and off-shore aquaculture technology. The development should primarily emphasize on cost-efficient and robust culture installations to be situated at open sea, cultivation technology and fully automated farms using state-of-the-art robot and information technology. Secondarily, advanced biotechnology should be used for refining culture species methods and usage of the produced biomass. An investment and demonstration program for risk-sharing in the pioneering installations should be implemented too.

High Quality Food for a Great World

In this policy paper is outlined the opportunities for producing food in Danish territorial waters, preferably in cooperation with our neighbors, particularly Norway.

We all share a planet, where the population is approaching 10 billion people, who are becoming richer and want more and better food. The food production sector, along with the energy & transportation sector, is having a large footprint on the global environment. Food production takes up a major part of the habitable part of the earth's surface. In Denmark, it uses e.g. two thirds of the land area for farming. 70 % of global freshwater[1] is used for the production of plants and animals. The speed of global cycling of nitrogen and phosphorus is accelerated because of fertilizer use in agriculture[2]. Finally, food production is discharging a substantial part of the world's greenhouse gases.

To provide more people with more and better food, including more meat[3], food production will need to at least double within the next hundred years.

It goes without saying, that if this increase is made at the current level of technology and with current methods, the ecological footprint would also be doubled, which is hardly realistic and acceptable. By continuing technological development and global dissemination of best practices it would certainly be possible to decouple the land based food production from the footprint. The foot print can by these means level out and perhaps decrease, even though food production is doubled.

Given that the current footprint already is (too) high, a golden opportunity exist to relieve the land based food production by moving a (large) part of the production of plants and animals out to the sea, where ample space, water and nutrients, including CO2, is available as input to the production.

This development is already underway. The global marine production is estimated from FAO[4] to around 34 million tons per year, worth app. 30 billion EUR pr. year. The table shows the breakdown of the various sectors globally and in Denmark.

		World			Denmark	
	Mio. tons/yr	Bio. EUR/yr	kg/Cap.	Tons/yr	Mio. EUR/yr	kg/Cap
Fish	7	7,7	1,2	8.000	2,1	1,6
Shellfish	13	3,7	2,2	2.000	0	0,4
Seaweed	14	20,8	2,3	0	34,1	0
Total	34	32,3	5,7	10.000	36,3	2

As seen from the table, Denmark is doing comparatively well in fish farming, but less well when it comes to shellfish and algae.

Along with fresh water production, the total aquaculture production is now approx. 60 million. tons per year, with an increase over many years of more than 5%.

Denmark is a major food producing nation situated by the sea, and for this reason uniquely well placed to become a big player also within marine food production. The authors are proposing for the Danish Government to conduct a feasibility study of a technology development platform and an investment program, with the aim of taking a part of the Danish food production to the Sea. This will increase the already high ecological efficiency of the Danish Food Production and present opportunities for being a supplier of knowledge and technology in this important area.

The associated industry will be located in rural and coastal areas, which are at present having great difficulties in attracting people and industry.

How Much Can be Produced?

Denmark's land area is 43,000 km2, as most Danish people know. It is less well known though, that the Danish territorial sea is 105,000 km2, ie. more than 2.5 times the land area. The full area is not available for food production, but ultimately it is not unrealistic to use up to 10 % of this area for this purpose.

How many tons of products can be produced and what turnover can be created? In the calculation example is assumed production on 1% of the area equal to approx. 1000 km2 divided into 10 "parcels" of 100 km2. In the table below is shown the calculated values of the total production of fish, shellfish and seaweed.

	Production	Area	Wetweight	Nitrogen	Price	Value
	kg C/m2/yr	Km2	mio. tons/yr	ktons/yr	EUR/kg	Mio. EUR/yr
Fish	2,5	10	0,25	10	1,33	333
Shellfish	1	100	1	-10	0,27	267
Seaweed	1	1000	10	-100	0,13	1.333
Total			11,25	-100		1.933

The key rates estimated by the authors to be used for the production of macroalgae is 1 kg C / m2 / year equivalent to 100 tons wet weight per. ha / year, which is comparable to a good yield of approx. 10 tonnes of grain per. ha / year (with a lower water content). The high growth rate is, among other things, due to the fact, that plant growth rates in the sea by definition are never water limited.

One advantage of production of aquatic plants in relation to terrestrial plants is, that the entire aquatic plant consists of material, which is relatively easy to exploit for higher value purposes, as water plants do not to the same degree as land plants need structural substances to fight gravity.

The prices used in the calculation are relatively low because some of the fish are expected to be herbivores and a portion of shellfish and algae production is expected to be used as raw materials among other for fish feed.

In addition, algae and mussels are producing substances that can be used for production of valuable fine chemicals, eg. omega3 fatty acids, and the residues from the production can be used for energy production.

The nitrogen - (and phosphorus accounts) are positive for the environment as seaweed and mussels take up nutrients from the water. The 100,000 tons N / year is a significant contribution compared to the Danish nitrogen cycle. The uptake of phosphorous is also a high number of approx. 10,000 tons per year.

Carbon substitution will be about. 1 million tons / year = approx. 3 million tons CO2/yr, which corresponds to approx. 5% of the total Danish emissions of CO2. At a CO2 price of EUR 15 pr. ton, this represents 45 mio. EUR in value.

The economic potential of making full use of 10,000 km ^{2} will be between 15 to 30 billion EUR / yr. equal to approx. 2-3 times the value of the current Danish food production value and approx. 10% of Danish GDP.

What will it take?

There is an existing and expanding market market for fish, mussels and algae grown in the sea. The question is whether it is or might be profitable to cultivate these organisms in the open Danish waters?

Fish

There is already a profitable production of salmonoids: rainbow trout in Danish waters. One of the Danish productions Musholm A/S, is situated at a very exposed "Off-Coast" location in the open part of the Great Belt and is, in an internationally context, high production on one site: 3.000 tons per year. There is today, however, no feasible methods for a profitable production in the North Sea.

"Off-Coast" and "Offshore" mariculture is being developed in many countries[5]. The development is mainly in fish farming, since livestock production is the most valuable and can for this reason carry the higher associated costs.

Technology exists to raise salmonoids at exposed "Off-Coast" sites in the inner Danish waters, which are identified by a national Danish mariculture committee as the area south of Djursland and to Bornholm[6].

In its strategic plan for Green Growth[7], Danish Aquaculture has estimated that production can be expanded to a level of approx. 100,000 tons in 2027.

An expansion in the North Sea requires technological breakthroughs in terms of cheap and powerful constructions, which can withstand the strong wave forces in the North Sea.

Mussels

The vast majority of mussel production takes place particularly in Southeast Asia at coastal sites and is labor intensive.

In the richer part of the world it will not be permitted to culture large quantities of mussels near the coast due to all sorts of conflicts with other interests. For this reason expansion will have to take place "Off-Coast" and "Off-Shore", and requires, in line with the fish, a development of strong and inexpensive constructions for the high seas. Mussels can be grown throughout the water column and it is therefore possible to work with submerged structures.

A profitable production of food cannot be labor intensive in a country like Denmark, because of high labor costs. The mussel production has to be technology intensive and automated.

Seaweed

As in the case of mussels the main part of seaweed is cultured by Asians coasts and is labor intensive.

The culture should mainly be seaweed, macro algae, which contrary to micro algae can be separated from the water without using excessive handling and energy.

Micro algae can be considered for special purposes and in cases, where the volume of micro-algae are limiting for mussel production, the amount of micro-algae may be increased by bringing nutrient-rich bottom water to the surface, so-called "Artificial Upwelling".

A profitable production of seaweed under Danish conditions requires mechanization. In other words, we need marine sowing and harvesting machines.

The algae require light to grow and cultivation must be done at sea level and the cultivation systems can therefore not the same degree as mussels and fish be submerged to avoid waves.

The production figures used in calculating the cultivation potential requires that algae growth in general is not nutrient limited. This will require large amounts of nutrient rich bottom water brought to the surface at various forms of 'artificial upwelling[8]', for example by wave-driven transport through pipes, that go down into the nutrient rich bottom water, or structures at the sea bottom, taking advantage of currents and tides to transport nutrients upwards.

Danish Effort Needed?

Denmark can support this effort by financing a technology development platform, and by supporting initial investments in off-coast and off-shore aquaculture.

The technology platform should in particular emphasize the development of cheap and robust constructions and methods for mechanization and automation. Furthermore, biotechnology to support the cultivation and the usage of the cultivated biomass, e.g. enzymes for digestion of the specific structures in the algae should be developed.

The European Fisheries Fund can support investments in aquaculture and should in particular support off-coastal and off-shore aquaculture with a high percentage. Because of the particularly high technical initial risk associated with establishing the first major construction on the high seas a 100% support for a large demonstration facility might be considered.

Assessing the Environmental Impact?

Farming the open seas is on-the-balance beneficial for the environment. Directly, through uptake of carbon, nitrogen and phosphorus, but mainly indirectly through displacement of land based production with its associated larger footprint.

The production of macro algae at sea is not in any way water limited, and as macro algae have a high content of useful biomass it can substitute deforesting for creating arable land with a sea/land ratio significantly above 1.

Land based crop production consumes high quantities of fresh water. E.g., the water footprint of one ton of wheat is one thousand cubic meter. The potential seaweed production on 1,000 km2 is 10 million tons, with much higher water content than wheat though. Based on a water footprint substitution of 100 m3 of freshwater pr. ton of macro algae the seaweed production displaces 1 billion m3 of freshwater pr. year, which is approx. 2.5 times more than the consumption of all Danish households and corresponds to the flow in the largest Danish river: Skjern å.

However, there can also be negative environmental effects of production. In the area, where the production takes place, the biological conditions will be significantly changed. Using 1000 km2,

corresponding to 1 % of the Danish territorial waters and in many different locations, the effects will be marginal.

For a potential area demand of 10,000 km2 the biological effects will be significantly larger. In addition large “Fields on the Sea” will cause changes in flow patterns and hydrography as well through physical interaction as by managed flow regimes for supplying the necessary nutrients.

To minimize the footprint and maximize the production, it is necessary to make a careful EIA including Marine Spatial Planning for mapping potential conflicts with nature, environment and other interests. It is obvious to investigate the possibilities of combining large-scale mariculture activities with other off-shore operations like Oil & Gas platforms and Sea Wind Mill sites.

Mariculture in Northern Europe Temperate Waters

Greentech & Cleantech is today’s fashion and most countries and many big companies are all running in the same direction with renewables, water treatment technology, biogas etc. A more sensible strategy for the small countries and regions in Northern Europe like Denmark, Norway, Sweden, Scotland, Ireland etc. might be to do something different, where we can exploit our unique comparative advantages.

We should recognize, that we do not solve global energy and environmental problems solely by end-of-pipe thinking and by procuring new energy resources, but by reengineering major production sectors, in our case food production, to secure a much smaller ecological footprint.

Cultivating the Northern Temperate Seas fits the bill perfectly, as it is very beneficial for production and environment, and at the same time something special, which not anyone can do.

Northern Europe is a global leader, when it comes to producing healthy and tasty food in a profitable manner and with a low environmental footprint. Denmark has the world’s third largest food industry cluster, and many biotech companies, which originated from using available biomass. Norway is global leader in salmon farming in net cages, and has through the DesignACT[9] project taken a European initiative on off-shore farming.

Many of the North European countries and regions are living by and off the sea. Together, we have the world's largest merchant fleets, we can build ships and we are great on fish and fisheries. In modern times, we are furthermore excelling in extracting energy from the sea.

Together, we have all prerequisites for success in developing large scale off-shore food production in temperate seas.

The authors propose for the countries in the North European region, particularly Denmark and Norway to join forces in conquering the sea for food production. In Denmark we will do our bit to convince the Danish Society to support this highly promising endeavor. And we are looking forward for our neighbors in the region to join.

---

[1] http://www.weforum.org/pdf/water/managing.pdf
[2] http://europa.agu.org/?uri=/journals/gb/1999GB900015.xml&view=article
[3] http://www.fao.org/docrep/012/i0680e/i0680e00.htm
[4] http://www.fao.org/docrep/011/i0250e/i0250e00.htm
[5] http://ooa. bnunh.edu/

[6] http://www.aqua.dtu.dk/Om_DTU_Aqua/Afdelinger/IT-T/GIS/Placering%20af%20havbrug.aspx In Danish
[7] http://www.danskakvakultur.dk/files/Dokumenter/Groen_vaekst_jan09.pdf In Danish
[8] http://www.greenseaupwelling.com/downloads/bk_ocm_articleaspublished.pdf
[9] http://www.aceaquaculture.com/arkiv/2010/02/1266568983/Impactevaluationreport.pdf