Aquaculture: Ocean Blue Carbon Meets UN-SDGS

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Aquaculture: Ocean Blue Carbon Meets UN-SDGS

Authors: David Moore, Matthias Heilweck, Peter Petros

Compares carbon sequestration by aquaculture with that by forests

Reviews human use of shellfish as food from emergence of early humans to intensive oyster dredging

Offers plan for activities from simple 'do it tomorrow' level to bivalve mollusc farms tens of thousands of hectares

Book is part of the ***Sustainable Development Goals Series*** book series (SDGS)

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Introduction

This book presents a solutions based approach to reducing and removing CO2 from the atmosphere transforming it into solid (crystalline) CaCO3 through the ability of marine organisms such as molluscs, crustacea, corals, and coccolithophore algae. The overwhelming advantage of this approach is that it promises enhanced climate mitigation in comparison to planting forests, industrial/engineering carbon capture and storage process. It also provides a sustainable food resource. Furthermore, it would improve the ocean's biodiversity at the same time as the excess atmospheric CO2 released by our use of fossil fuels is returned to the place it belongs - as a present day fossil, safely out of the atmosphere to the distant future. If the level of finance and global effort that are readily foreseen for forest management and flue gas treatments were applied to expansion of global shellfish cultivation, curative amounts of carbon dioxide could be permanently removed from the atmosphere within a few decades. The concept presented in this book could have a profound influence on the life of the planet.

Keywords: Atmosphere Remediation Bivalve Farm Blue Carbon Carbon Capture and Storage Carbon Sequestration

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About the authors

David Moore's first degree was Hons Botany and Zoology, completing a PhD in Fungal Genetics and awarded DSc in Mycology (genetics, molecular biology, enzymology, developmental biology, mathematical modelling, evolution). David also has interests in space biology and planetary sciences. Published books include: *21st Century Guidebook to Fungi*, now in its second edition; *Fungal Biology in the Origin and Emergence of Life*; *Fungal Conservation: Issues and Solutions*; *Fungal Morphogenesis*; *Biological and Medical Research in Space*; *Evolutionary Biology of the Fungi*; *Developmental Biology of Higher Fungi*.

Matthias Heilweck has 30 years' experience of business administration and management during his career as an independent industrial supplier. Oceanography has always been the focus of his spare time, despite living about 1000 km away from the coast. Matthias is now close to retirement and can devote more time to oceanography. In the best traditions of European amateur scientists, he is a non-academic freethinker who has developed ideas to help preserve the oceans as a healthy and sustainable food source for mankind.

Peter Petros is a research analyst and trained engineer working in mycological aspects of water and environmental engineering (fungi contribute to 10 out of the 17 UN SDGs). Presently working for Kääpä Biotech, a biotechnology company committed to healthier humans and ecosystems, which researches and develops novel industry solutions with fungi. His projects are aimed at ecological restoration, bioremediation and wastewater treatment. Skills are in Soil and Water engineering, Water Science, Civil Engineering, Biotechnology and Conceptual Analysis.

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8.2 **Executive Summary of Chapters** 1–7

8.2.1 Chapter 1. Diagnosing the Problem by David Moore, Matthias Heilweck and Peter Petros

In this chapter we give a plain language guide to the Earth's carbon cycle by briefly summarising the observations and origins of increased levels of greenhouse gases, mainly CO_2 but including CH_4 and N_2O, in our present-day atmosphere. They are increased in the sense that they have not occurred naturally in the Earth's atmosphere at any time during the past 420,000 years. The only tenable explanation for our atmosphere's present state is that it is the consequence of mankind's excessive use of fossil fuels since the Industrial Revolution onwards. Something that has been described as a planetary-scale experiment in which humans return to the atmosphere and oceans the concentrated organic carbon that had previously been stored in sedimentary rocks for many hundreds of millions of years. We deal with the arguments that deny the truth of anthropogenic CO_2-driven climate change, then illustrate the Earth's global carbon cycle. Explaining how it was almost exactly in equilibrium for several thousand years while humans were evolving, before industrial humans intervened. We describe how the excess greenhouse gas emissions are projected to change the global climate over this century and beyond, and discuss 'dangerous anthropogenic interference' (DAI), 'reasons for concern' (RFCs) and climate tipping points. We give a short account of the various improved management, engineering and natural climate solutions advocated to increase carbon storage (sequestration) and/or avoid greenhouse gas emissions across global forests, wetlands, grasslands, agricultural lands and industry, and indicate how they are discussed in our later chapters. Finally, we outline the alternative natural carbon sink we propose that is currently so greatly undervalued and underdiscussed.

Chapter 2. Cultivate Shellfish to Remediate the Atmosphere by David Moore, Matthias Heilweck and Peter Petros

In this chapter the very recent research that indicates that massive tree planting is not the panacea that many believe, is discussed. Photosynthetic carbon capture by trees and other green plants is widely thought to be our most effective strategy to limit the rise of CO_2 concentrations in the atmosphere by pulling carbon from the atmosphere into the sinks represented by the plant body and the soil. However, practical experience indicates that putting such plans into effect could do more harm than good to our environment. Planting trees can release more carbon from the soil sink than the plants sequester into their biomass. And, in all cases, the plant biomass sink is only ever a temporary sequestration because when the plant dies its biomass rots, and its sequestered carbon is returned to the atmosphere. Forests should be planted for the intrinsic values of forests; for clean, oxygenated air, natural biodiversity and restorative conservation of terrestrial ecosystems, rather than tree planting as a means to sequester atmospheric CO_2. This chapter describes the basic message of the book, which is that shellfish cultivation as a carbon sequestration strategy is both more immediately rewarding and more helpful in the very long term. A considerable proportion of shellfish biomass is represented by the shells of the animals, and shellfish shell is made by converting atmospheric CO_2 into crystalline calcium carbonate which is stable for geological periods of time. The essentials of habitat conservation, ecosystem balance and carbon sequestration for carbon-offsetting programmes are also introduced; topics developed in chapters that follow.

8.2.3 Chapter 3. Aquaculture: Prehistoric to Traditional to Modern by David Moore and Matthias Heilweck

In this chapter it is pointed out that the human tradition of eating shellfish goes back to the time when Homo sapiens first started to migrate out of Africa, between 200,000 and 100,000 years ago. Archaeological finds of ancient meals of shellfish and ancient middens of shellfish shells track human migrations around the world. Middens do more than track migrations. They show that wooden artefacts and plant residues do not survive, but shells do. Illustrating the truth of our fundamental claim that shellfish shells sequester atmospheric carbon permanently. The coastal migrations of early humans continued across the Bering Strait to North America. Along the northwest coast of North America, early humans, referred to as First Nations in Canada, actively, and sympathetically, managed the resources of their shoreline habitats, engineering intertidal rock-walled terraces as clam gardens, ancient sustainable mariculture technologies. When we reach recorded history, we enter a phase of increasing exploitation of marine resources for an ever-growing human population. By the end of the nineteenth century oysters had become a cheap staple food on both sides of the Atlantic. The working man could get a decent meal of oysters at any street corner for a few cents in New York or a penny or two in London. The real price we all paid for this was that oyster dredging on both sides of the Atlantic destroyed 85% of the world's oyster beds. New Yorkers in the 1800s ate about 600 oysters a year each; the average American today eats about 3 oysters each year.

Farmed oysters account for 95% of the world's total present-day oyster consumption. The animal, which has been described as an ecosystem engineer for its reef-building abilities, is one of those that we have driven to the verge of extinction in the wild. In the twenty-first century, the oyster deserves to have the same vigour applied to its restoration and conservation as was applied to dredging it from the seabed during the nineteenth century.

8.2.4 Chapter 4. The High Seas Solution by Matthias Heilweck

In this chapter the case is made for greater use of the High Seas to replace forage fish with mussels in the diet of farmed fish and produce the increasing amounts of food that will be required by the growing human population, while at the same time pulling down carbon from the atmosphere with bivalve cultivation. The vision is to preserve the oceans as a healthy and sustainable food source for mankind by emphasising conservation and ecosystem balance beyond coastal waters. The plans are for huge (centralised) bivalve mollusc farming facilities on the high seas, using factory ships and offshore factory rigs (re-purposed disused oil rigs?) located on seamounts outside Exclusive Economic Zones and employing Perpetual Salt Fountains on the flanks of the seamount to bring nutrients to the farms. If properly designed (and the design and building capabilities exist throughout the offshore industries around the world), this will immediately provide (i) feed for animals and food for humans, (ii) sustainable marine ecosystems and (iii) permanent atmospheric carbon sequestration in the form of reefs of bivalve shells.

8.2.5 Chapter 5. Farming Giant Clams in 2020: A Great Future for the 'Blue Economy' of Tropical Islands by David Moore

In this chapter a specific and dramatic example for the tropics is detailed to avoid too much attention being diverted to Northern Hemisphere shellfish cultivation. There is nothing more dramatic than Giant Clams, which have been fished to extinction in many Indian Ocean and Pacific waters, but elsewhere contribute to a still thriving industry, though clam dredging is now doing immense damage to coral reefs in many areas. The topic of giant clam cultivation covers conservation and restocking of clams, but with the potential bonus of rehabilitating coral reefs degraded by bleaching induced by climate change, as well as food production, and development of remunerative local industry for local Pacific Island communities. It's not just the food value of the animal; the shells are used for carving (large!) ornaments, and several species are traded around the world for marine aquariums. Work towards 'seeding' and recolonising has been going on in the Pacific region for more than 30 years. Much of this work has been published and many of the faults in approach and problems of governance identified. In addition, though, several local enterprises have developed methods to produce economically large numbers of young giant clams for restocking tropical seas. The conservation and educational programmes that have resulted deserve wider and more prolonged attention and greater investment as they tie-in well with our call to 'cultivate shellfish to remediate the atmosphere'.

8.2.6 Chapter 6. Coccolithophore Cultivation and Deployment by David Moore

In this chapter the potential for cultivation of coccolithophore golden-brown algae for carbon sequestration is addressed. Coccolithophores have been major calcium carbonate producers in the world's oceans for about 250 million years. Today they account for about a third of the total marine $CaCO_3$ production by coating their single cells externally with delicately sculptured plates of microcrystalline $CaCO_3$. The possibility that these algae could be used to trap atmospheric CO_2 with existing technology has not been widely recognised. There is scope, however, for both high technology cultivation in bioreactors and low technology cultivation on the High Seas or in terraced raceway ponds or lagoons on tropical coastal sites. The latter could produce a sludge of pure $CaCO_3$ that could be harvested as a feedstock for cement production in place of the fossiliferous limestone that is currently used (cement production accounts for around 8% of industrial fossil CO_2 emissions). Bioreactor cultivation of genetically engineered coccolithophores could produce customised calcite crystals for nanotechnology industries. On the high seas coccolithophores naturally produce extensive blooms, and the blooms emit a volatile gas (dimethyl sulphide) to the atmosphere, where it promotes formation of clouds that block solar radiation. Imagine aquaculture nurseries onboard factory ships, cultivating both coccolithophores and bivalve molluscs. During their open ocean cruises the ships could produce biodegradable floats already spawned with fixed juvenile bivalve molluscs and streams of coccolithophore algae that could be released into the ocean currents and ocean gyres nourished by artificial upwelling of nutrient-rich waters when the ship deploys its perpetual salt fountains. The dual aim is to be creating and maintaining blooms of coccolithophores in the oceanic high seas to sequester carbon from the atmosphere, and generation of cloud cover to cool the immediate environment.

8.2.7 Chapter 7. Comparing Industrial and Biotechnological Solutions for Carbon Capture and Storage by Peter Petros and David Moore

In this chapter we deal with the current artificial/industrial Carbon Dioxide Capture, Utilisation and Storage (CCUS) solutions and shows their power and potential in curtailing greenhouse gas (GHG) emissions. Key valuation models of sustainability for current carbon capture and storage (CCS) infrastructure will be used to explain what problems could arise and potential ways to avoid the likely risks through drastic changes in fundamental attitudes. The shortfalls of each industrial solution are also presented in the context that all activities should be carried out with due regard for long-term human and environmental well-being, rather than economic growth alone. Overall, we discuss: solutions for atmospheric carbon reduction; the carbon market; industrial/artificial carbon dioxide capture, utilisation and storage systems; carbon emissions reduction targets. We make comparisons between 'soft' nature-based biotechnological solutions, including coastal blue carbon and the ultimate blue carbon, which is the ocean's calcifiers. Following a discussion of sustainability assessment of CCUS methods we conclude that changing the paradigm of shellfish farming from 'shellfish as food' to 'shellfish for carbon sequestration' places the value of the exercise of shellfish cultivation onto the production of shell, taking the food value of the animal protein as one of the several ecosystem services that bivalve molluscs supply. We calculate that this paradigm shift makes mussel farming, and by default other bivalve mollusc farming enterprises, viable alternatives to all the CCUS industrial technologies in use today.

8.2.8 Summary of Recommendations

In reading this section you should bear in mind that the key objective we wish to achieve is to enable the world's oceans to produce the increasing amounts of food that will be required by the growing human population in a sustainable manner, while at the same time permanently removing carbon from the atmosphere with ecologically friendly bivalve cultivation. To this we couple the determined use of coccolithophore algae cultivation, in the High Seas and in raceway lagoons on land, to extract permanently more carbon from the atmosphere and make further contributions to the amelioration of the dangerous anthropogenic interference that our industrial society has inflicted on the atmosphere.

In order to carry out our recommendations we need:

- planetary-scale funding, and
- central management with global authority to initiate, fund and maintain projects over several decades as necessary.

Most important of all, though, is that we (meaning humanity as a whole) must develop the determination to make the changes in human activity and human behaviour that are essential if we are to meet the challenge of climate change. Importantly, this means not only all the widely discussed matters involved in reducing fossil fuel usage but serious changes in the attitudes of the world's scientific communities in respect of the solutions they promote.

Most of today's scientists would recommend Negative Emissions Technologies, or NETs, which are technologies that remove and sequester CO_2 from the atmosphere with the intention of mitigating climate change. NETs that are currently most widely expected to be of value are:

- biological processes to increase carbon stocks in soils, forests and wetlands,
- generate energy from biomass, and capture and store the resulting CO_2 emissions,
- capture CO_2 directly from the air with chemical processes and sequester it in geological reservoirs,
- formal consideration has only been given to near-shore coastal Blue Carbon, namely, mangroves, tidal marshlands, and other tidal or saltwater wetlands, seagrass beds, and kelp 'forests'. However, these Blue Carbon options are, like terrestrial forests, reversible if the carbon sequestering practices are not maintained, because they depend on sequestering carbon in the biomass of living plants; when the plants die they are digested by microorganisms and their carbon is returned to the atmosphere as respiratory CO_2.

Focussing exclusively on near-shore coastal NETs wilfully ignores the oceanic options forCO_2 removal and sequestration that are offered by the 70%of the Earth's surface covered by the high seas.

We wish to remedy this exclusion. The central thrust of our argument is that the physiological chemistry of a few types of aquatic creatures, the calcifiers of the coasts and open seas, (coccolithophore algae, corals, crustacea and molluscs) enables them to extract CO_2 from the atmosphere and sequester it permanently as crystalline $CaCO_3$.

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