Why can't we save the atmosphere by cultivating more shellfish?

Planting trees may not be the answer

Photosynthetic carbon capture by trees is widely considered to be possibly our most effective strategy to limit the rise of CO_2 concentrations in the atmosphere, and there are several ambitious targets to promote forest conservation, afforestation, and restoration on a global scale. The Intergovernmental Panel on Climate Change (IPCC) Special Report of 2018 [ref. 1] suggested that an increase of 1 billion hectares of forest will be necessary to limit global warming to 1.5°C by 2050. Bastin *et al*. (2019) [ref.2] mapped the global potential tree coverage and estimated that the world's ecosystems could support an additional 0.9 billion hectares of continuous forest (corresponding to more than 25% increase in forested area) and that such a change has the potential to cut the atmospheric carbon pool by about 25%. I like trees and I'm all in favour of planting more of them, but as a mycologist I have to say that there is a negative side to these estimations that seems to be escaping notice. This is that forests don't only contain trees that can store gigatonnes of carbon in the wood they make; forests also contain wood-decaying fungi that can (and do) digest that wood, releasing greenhouse gases, including CO_2, in the process. Chlorinated hydrocarbons make a normal every-day contribution to the degradation of timber. The fungal chloromethane contribution to the atmosphere has been estimated at around 150,000 tonnes per annum [ref. 3], which is about 60% more than was released into the atmosphere by industrial coal burning furnaces worldwide in the year of publication. However, of course, the ultimate end-product of digestion is CO_2. On a global scale, decomposition of dead wood releases billions of tons of CO_2 to the atmosphere each year, a similar magnitude, in fact, to the annual CO_2 emissions from fossil fuel combustion [ref. 4]. So, if the forests can't save us, is all lost? Well, no, actually; you just need to change your focus; turn away from trees (but still plant them, they're good for you in so many ways) and concentrate on shellfish.

Shellfish shell is *permanently* solidified carbon dioxide

About half the mass of shellfish is shell, and shellfish-shell is solidified CO_2. So far, just like wood. But, and here's the advantage, shellfish shell is *permanently* solidified CO_2. The CO_2 comes from the atmosphere *and stays out of the atmosphere*. Intact shellfish shells are excavated regularly from the middens associated with coastal Palaeolithic communities (old Stone Age; from around 12,000 years ago). Intact shellfish shells abound in deep-water cores of ancient coastal sediments of hundreds of thousands of years ago. And remember the fossils from deep geological time: brachiopods (550 million years ago), trilobites (520 million years ago) and ammonites (240 - 65 million years ago). Certainly, these fossil shells are changed considerably in chemistry by now, but the shells did survive over geological time in order to be fossilised; and in vast numbers. How much more permanent, do you want permanent to be?

What is aquaculture?

The Food and Agriculture Organization of the United Nations Fisheries & Aquaculture Department maintains a database of Global Aquaculture Production that contains statistics on production volume. In this respect 'Aquaculture' is understood to mean the ***farming*** of aquatic organisms including molluscs and crustaceans. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. For statistical purposes aquatic organisms which are exploitable by the public as a common property resource, with or without appropriate licences, are the harvest of *fisheries*, not aquaculture.

Data from FAO Fisheries and Aquaculture Information and Statistics Branch (as of 25 May 2019) show that over the years 2010 to 2017 aquaculture harvests across the globe totalled 53,512,850 metric tonnes of **crustaceans** and 122,527,372 metric tonnes of **molluscs** (a combined total of 176,040,222 metric tonnes in 8 years.

If we assume that the shell represents 50% of the animal's mass, then the total shellfish-shell produced was 88 million tonnes over 8 years; which is an average of **11 million tonnes of shell per year**. Further assume that the shell is made from $CaCO_3$; on a molar mass basis, carbon represents 12% of the mass of calcium carbonate. So, 11 million tonnes of shell per year is equivalent to **1.32 million tonnes of carbon** per year being captured from the atmosphere by current aquaculture activities.

Global carbon emissions from fossil fuel use were 9.795 *billion* tonnes in 2014 (or 35.9 billion tonnes of carbon dioxide) [https://www.co2.earth/global-co2-emissions]. So, a thousand-fold increase in aquaculture would permanently remove about 14% of the global carbon emissions in each year.

Could that be done?

If we doubled aquaculture production of crustaceans and molluscs each year then in the 14th year we could be removing 10.7 billion tonnes of carbon from the atmosphere each year. Annual doubling may not be realistic; but this simple arithmetic enables us to calculate that with determined effort to increase aquaculture we could be permanently extracting significant amounts of carbon annually from the atmosphere within the timescale envisaged for carbon capture by trees.

If we're willing to contemplate planting a billion hectares of new forest trees, we should surely be willing to create a few more mussel farms [imagine a mussel farm on every offshore wind turbine, every oil and gas rig, every pier, wharf and jetty, every breakwater or harbour wall].

The carbon balance of the growth phase of the animals is not important. Nor do we need to harvest them, though the animals within the shells could be a valuable source of animal protein (with the profits from their sale providing ongoing finance for further expansion). The most relevant fact though, is that when the animal dies (either in the aquaculture farm or in your kitchen) it leaves behind a shell made of insoluble carbonates constructed using CO_2 (now permanently) removed from the atmosphere. The same considerations apply to crabs and lobsters, freshwater shellfish, and land snails, though, obviously, the cultivation techniques have to be tailored to each animal.

A realistic atmospheric remediation programme might feature three prime targets

1. Fund a development foundation that will invest cash immediately in every existing aquaculture enterprise with the aim of doubling their production each season for the next three seasons.

2. Fund research programmes to study:

- existing aquaculture farming methods to adapt them to wider ranges of sites and locations;
- new aquaculture farming methods to establish new organisms and new methods to enhance incorporation of atmospheric carbon into shells.

3. Fund developmental research into high-technology programmes. Could we grow coccolithophore algae in giant illuminated fermenters (maybe using the Quorn™ fermenters as a model)? These marine algae make calcium carbonate wall plates. Perhaps we could harvest from these fermenters a sludge of insoluble plates of calcium carbonate from which we could build our own 'white cliffs of

Dover'. Using this calcium carbonate as a feedstock for cement production would replace the fossil limestone that is currently used to make quicklime (in 2014, cement production accounted for 6% of the fossil CO_2 emissions from industrial sources).

We need a lot of funding and the determination to do it. So, if there's anyone out there with the odd billion dollars to spare just let me know and I'll get the programme rolling … Now, then; would anyone like another bowl of moules marinière; or maybe a crab salad?

References

[1] Intergovernmental Panel on Climate Change (IPCC) 2018 Special Report on the Impacts of Global Warming of 1.5 °C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways (https://www.ipcc.ch/sr15/).

[2] Bastin, J.-F., Finegold, Y., Garcia, C., Mollicone, D., Rezende, M., Routh, D., Zohner, C.M. & Crowther, T.W. (2019). The global tree restoration potential. *Science*, **365**: 76-79. DOI: https://doi.org/10.1126/science.aax0848.

[3] Watling, R. & Harper, D.B. (1998). Chloromethane production by wood-rotting fungi and an estimate of the global flux to the atmosphere. *Mycological Research*, **102**: 769-787. DOI: https://doi.org/10.1017/S0953756298006157.

[4] Rinne-Garmston (Rinne), K.T., Peltoniemi, K., Chen, J., Peltoniemi, M., Fritze, H., Peltoniemi, M. & Mäkipää, R. (2019). Carbon flux from decomposing wood and its dependency on temperature, wood N_2 fixation rate, moisture and fungal composition in a Norway spruce forest. *Global Change Biology*, **25**: 1852-1867. DOI: https://doi.org/10.1111/gcb.14594.

I think we need to get this idea registered in the consciousness of those involved in controlling climate change. It deserves, at least, to be considered alongside plans to expand tree planting on scarce agricultural land. About 71% of the Earth's surface is covered with water. We should exploit that.

I've tried sending this note to the scientific media, but none even replied. I've sent it to academic journals and though they did reply (and one even described it as 'intriguing'), none agreed to publish.

If you think this is an idea worth pursuing, you could download a PDF version of this page and send it to those you think might be interested; your MP, Congressman, representative, conservation group or even your local multi-millionaire.

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