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Seaweed farming could help clean up the oceans and the atmosphere, reports Michael Marshall

Kelp is on the way
AS A CHILD in South Wales, I was dimly aware that laverbread was a treasured cultural asset. Nobody I knew ate any, though, and it never turned up on my plate. I would probably have turned my nose up at it if it had. Far from being bread as most of us know it, this traditional Welsh foodstuff consists of seaweed boiled into a mushy paste, often dipped in oatmeal and fried before serving. Not my childhood self’s ideal dish.

For many people, seaweed is something we trip over on the beach, not take there in our lunch boxes. But for thousands of years, humans have harnessed seaweed in extraordinary ways. Our ancestors ate it, farmed it and used it as fertiliser. When humans first entered North America from Asia more than 13,000 years ago, their survival may have depended on fish that were plentiful thanks to coastal kelp.

Today, we still rely on seaweed’s many benefits. We use it as a delicacy to wrap round sushi, extract its chemicals for use in industry and turn it into recyclable plastics. But its potential doesn’t end there. Large-scale seaweed farms could clean up Earth’s oceans, restoring biodiversity and increasing the productivity of aquaculture. They could suck carbon dioxide from the air, and help curb the emission of other greenhouse gases.

Seaweed still has a long way to go to fulfil its potential. Some wild populations have been overharvested, and the potential for farming has barely been tapped. But even if it fails to meet the enormous expectations put on it, its versatility still makes it an incredibly valuable material.

Biologically speaking, seaweeds aren’t easy to define. Rather than being a single family, they belong to a loose grouping of life forms called algae, which shares a common ancestor with green plants like mosses and trees. All the familiar seaweeds, from the nori used in sushi to bladderwrack and kelp species, belong to one of three groups of algae commonly known as reds, browns and greens.

Many of these species are already farmed on a small scale or harvested wild, mainly for use as a foodstuff or as a source of useful chemicals. Eating seaweed offers many benefits (see “Super seaweed?”, page 36), but societies differ enormously in how much they consume. In China, Japan and Korea, seaweed is a major part of the national diet. But in many Western countries, consumption has historically been less conspicuous. “It was kind of frowned upon as ‘poor food,’” says M. Lynn Cornish at Acadian Seaplants in Dartmouth, Canada.

**Beyond food**

Many people do still ingest seaweed, or extracts of it, without realising it. Thickeners in sauces and yoghurts, for example, are made of carrageenans, compounds found in red seaweeds. Often listed as E407 on packaging, they are also a common ingredient in many cosmetics. “Nobody knows there is carrageenan from seaweed in toothpaste,” says Susan Holdt of the Technical University of Denmark in Kongens Lyngby. The rise of veganism has also boosted demand, pushing more food manufacturers to ditch animal-based ingredients like gelatine and turn to seaweed extracts instead.

Seaweed’s multitalented tendrils extend far beyond food. The long-chain molecules they contain are ideal for making plastic substitutes, and some such bioplastics are already on the market. UK start-up Notpla, for example, uses a mixture of seaweeds and plants to make materials it hopes could replace plastic water bottles and ketchup sachets. You may already have seen them in action: runners at the 2019 London Marathon were given pouches of sports drink made from Notpla’s bioplastic.

For now, though, seaweed harvesting remains a relatively niche industry. “It’s a product that you cannot find easily in the supermarket,” says Francisco Barba of the University of Valencia in Spain. According to a 2017 report co-authored by Cornish, 32 countries actively harvest wild seaweed, gathering more than 800,000 tonnes per year. That isn’t much compared with other crops: in 2018, farmers in more than 60 countries grew more than 2.5 million tonnes of cherries, for example.

Furthermore, some wild seaweeds have been overexploited. Cornish points to Prince Edward Island in Canada, where people used to harvest a red seaweed called Irish moss (Chondrus crispus), which is rich in carrageenans. “It’s been overharvested,” says Cornish. “That resource has pretty much disappeared.”

If we want seaweed in large quantities, we need to give it a helping hand by cultivating it. That’s why there is now a push towards creating and expanding seaweed farms. In the US, a non-profit organisation called GreenWave has been training seaweed farmers since 2014. In the UK, SeaGrow has recently launched a commercial farm in the North Sea.

The potential for open-ocean seaweed farming is enormous. The 2019 paper “The Future of Food from the Sea” by the High Level Panel for a Sustainable Ocean
“Seaweed forests covering 9 per cent of the ocean could reduce atmospheric CO₂ to pre-industrial levels”

Economy, an international group that works with governments and industry to promote sustainable use of the ocean, outlines a sparkling future for seaweed. It envisages the ocean supplying 364 million tonnes of animal protein – mainly in the form of fish and shellfish – per year. This is more than two-thirds the amount needed to feed the 9.1 billion human beings expected by 2050, and seaweed could be crucial to achieving this.

Farming it, the paper says, “may in some cases enhance wild fisheries by creating artificial habitats”. This is a key element of its appeal: seaweed fits well with other marine farming and harvesting. What’s more, seaweed farming is much more low-maintenance than land agriculture. All it takes is weighted lines seeded with seaweed floating a few metres below the surface, attached to buoys so they can be relocated. The seaweed is left to grow for a few months, then harvested by taking a boat out, lifting the lines with hooks and stripping the crop off, with no fertilisers required.

For Angela Mead, a marine biologist and founder of Biome (Algae) Ltd in Salcombe, UK, the challenge is to scale farms up. That means a new kind of location. “Usually, seaweed farming will happen in a sheltered region, like a loch or an inlet,” she says. “There’s very limited coastline that could support that. But we have this mass of coastline that is quite exposed and wild.”

Mead also hopes to maximise the benefits of seaweed by farming it on an existing mussel farm. This approach mimics that of GreenWave, whose farms combine kelp on lines with cultivated mussels, scallops and oysters. The kelp provides shelter for the shellfish, which in turn remove excess nitrogen from the water. Similarly, in the Pacific nation of Kiribati, islanders farm seaweeds alongside milkfish, sandfish and sea cucumbers, ensuring food security.

Such integrated farms promise large and varied food yields, and can also restore ecosystems. Many marine species shelter around the seaweed lines, and the benefits don’t stop there, because seaweed helps keep the water hospitable. For example, if water becomes too rich in nutrients and minerals, harmful algae grow rapidly and deplete the dissolved oxygen, killing fish. Seaweeds mop up excess nutrients, preventing this. They can also restore oxygen and combat ocean acidification. A 2019 study estimated that 48 million square kilometres of the ocean could be devoted to seaweed farming, providing benefits to 77 countries. As demand for food grows, seaweed and other algae could become a major component of our diet.

If scaled up quickly enough, seaweed farming could even contribute to stopping dangerous climate change.

Super seaweed?

The word “superfood” is a marketing term that has no rigorous scientific meaning. It is generally applied to foods that are unusually high in some nutrient that is considered particularly important to health. Examples include blueberries, which are rich in vitamin C; chia seeds, which contain a lot of omega-3 fatty acids that help your heart; and kale, which has lots of glucosinolates, pungent chemicals tentatively proposed to offer some protection against cancer.

By these standards, many seaweeds would surely count as superfoods. For example, they are high in iodine, which our thyroid gland needs, and in supposedly beneficial chemicals such as antioxidants. Some seaweeds also contain a pigment called fucoxanthin, which may have anti-obesity effects – in rats at least.

The problem is that we may not absorb these substances in meaningful quantities when we eat seaweed. “What happens in your intestines?” asks Susan Holdt at the Technical University of Denmark in Kongens Lyngby.

Seaweed contains a lot of fibre, which is good at binding to other chemicals. That may mean that the desirable trace metals and minerals stay trapped inside it rather than being taken up by our bodies. This is a recurring problem with other supposed superfoods: they may only give us vitamin-rich stools.

How we prepare the seaweed makes a big difference, says Holdt, as we don’t yet know which methods maximise our nutrient intake. Still, while seaweed isn’t technically a superfood, neither is anything else. What’s more, it is thoroughly nutritious and an excellent thing to add to your diet for other reasons.

Seaweed species contain a lot of protein, so they are good meat substitutes. There are other protein-rich foodstuffs that are vegan-friendly, such as soya, but they are often low in essential amino acids. Not so seaweed. Holdt highlights wakame and nori, a type of red seaweed that is wrapped around rice in sushi, as being particularly rich in these nutrients.

Cleaning the planet

At present, one of the most significant sources of greenhouse gases is livestock farming. Cows and other ruminants have microorganisms in their guts that break down fibrous material like hay, releasing nutrients that the animal can use. This process creates hydrogen gas, which gut microbes called methanogens feed on, releasing methane as waste. “The methane is then belched out of the animal,” says Ermias Kebreab at the University of California, Davis. This is bad news for the planet.

However, since 2008, evidence has accumulated that adding seaweed to ruminant
food reduces their methane emissions. Later studies found that a genus of red algae called *Asparagopsis* works especially well, but there was a drawback: many of these experiments were performed on microbes incubated in a lab, not in real cows.

“I was a bit sceptical,” says Kebreab. “Just because it works in the lab doesn’t mean it works in the animal.” However, when his team tried feeding 12 cows the red seaweed with their normal food, the results were dramatic. Over three weeks, methane emissions fell by up to 67 per cent. In unpublished results, the team found that adding seaweed to their diet remained effective over several months. Kebreab is now on the advisory board of California start-up Blue Ocean Barns, which is trying to get the approach approved in the US.

Methane reduction, though an important step in the right direction, is small change by comparison with the elimination of carbon dioxide. It is CO₂ that causes most global warming and bears the bulk of the responsibility for sea level rise. Remarkably, seaweed can help here too.

For one thing, it is a photosynthesiser just like plants, so can extract CO₂ from the atmosphere. A 2017 study found that commercial seaweed farms remove 2.8 million tonnes of CO₂ every year. While they aren’t as efficient as forests on land, storing 1500 tonnes of this greenhouse gas per square kilometre compared with more than 3600 tonnes, there is far more unused space available for new seaweed plantations than for forests.

But how long the CO₂ stays locked up will depend on what we do with the seaweed. If we eat it, the carbon will return to the air within months. Alternatively, the seaweed could be processed to make biofuels, which could replace oil and gas. This is promising, but still results in CO₂ being released.

More radical alternatives beckon. Of the four emissions scenarios used by climate scientists to simulate possible futures, only one keeps global temperatures from rising more than 2°C. It does so by removing CO₂ from the air and burying it underground. In this scenario, crops grown on land would be converted into biofuels and the CO₂ they emit subsequently trapped and buried.

This requires lots of land, threatening biodiversity and straining food supplies. However, obtaining the biofuels from seaweed might offer a way to remove CO₂ without any of those negative impacts.

A similar idea is championed by Tim Flannery at the Australian Museum in Sydney. Originally a palaeontologist who started his career by discovering new mammal species, he has become a prominent advocate for strong action on climate change.

Flannery’s plan is both simple and daring. He wants to create huge farms growing seaweed in the ocean and then sink the biomass into the deep, along with all the CO₂ it has absorbed. The idea has been proposed before. In 2012, Antoine de Ramon N’Yeurt at the University of the South Pacific in Suva, Fiji, estimated that seaweed forests covering 9 per cent of the ocean could reduce atmospheric CO₂ to pre-industrial levels. That is an area almost twice that of Russia, and more than 10 times today’s total space occupied by seaweed, both wild and farmed. Well aware this would be a monumental expansion, for now Flannery’s plans are more modest.

He founded the Ocean Forests Foundation to promote his idea, but has had to shutter it for lack of funding. Instead, Flannery wants to gather experts from relevant fields to figure out whether the idea is viable and how to proceed. “We’re in a paused stage, trying to get the funding that would be required to hold the meeting, and then waiting for the circumstances to arise so we can hold the meeting,” he says, wearily citing the covid-19 pandemic as an unexpected roadblock.

He admits there are “any number” of potential problems. “If you did it at scale, would you be disturbing the world’s nitrogen cycle?” he asks. “Are there issues with anoxia in the deep ocean, if you’re introducing so much decomposing material? Are the costs going to be so considerable that you can’t do it?” At a 2019 conference where his idea was presented, Peter Liss at the University of East Anglia in the UK raised the objection that seaweeds release halogen-containing gases that could interfere with atmospheric chemistry.

All told, it remains to be seen whether Flannery’s radical idea will float or sink. It is quite possible that the less drastic approach of using seaweed as biofuel and then burying the CO₂ released would be easier to manage. But either way, we are discovering that seaweed is nothing to turn your nose up at.

Seaweed farms like this one off the coast of Rongcheng, China, are more low-maintenance than land agriculture

Seaweed and mussels could benefit from being grown together

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