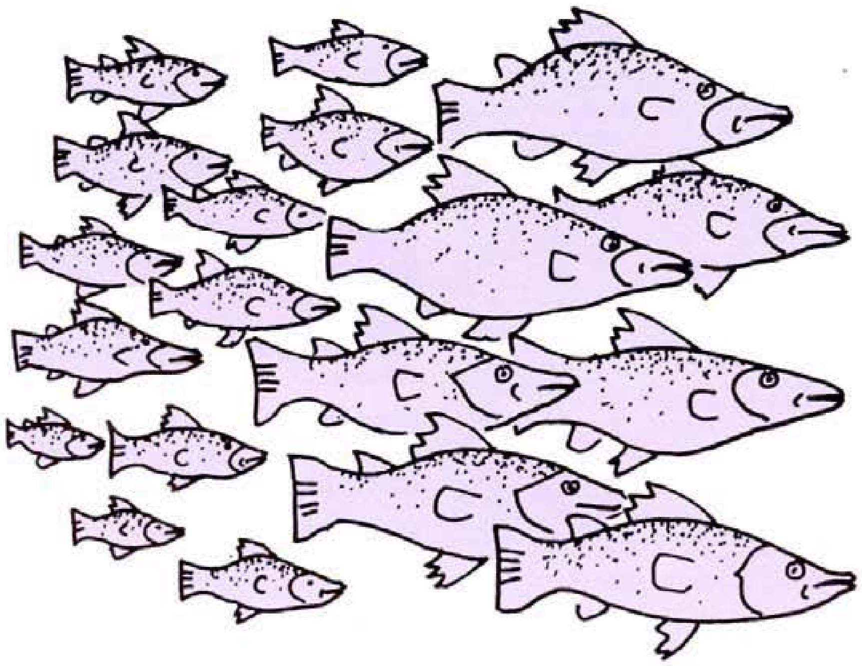


Farming the sea

For thousands of years humans have cultivated useful plant and animal species in large numbers and thereby enjoyed the benefits of agriculture. But virtually all of this has taken place on only a fraction of the Earth's surface, the land — and not all of that is suitable.

Of course, we have always collected the 'fruits of the sea', but fishing essentially consists of just taking what is already there, in much the same way as our hunter–gatherer ancestors did on land before the advent of settled agriculture.

In the western world, the idea of real agriculture in the sea (marine agriculture) has only come about in the last century. Shortened now to mariculture, it means the controlled rearing, at high density, of marine animals (and occasionally plants) of commercial value. Until recently our mariculture industry was virtually non-existent compared with the well-established ones in North America, Europe, and Japan, but that is changing and, following considerable investment, Australia now possesses an important new area of primary production, worth more than $105 million a year.

Animals already 'maricultured' here are molluscs, such as oysters, mussels, clams, scallops, and abalone; crustaceans, such as prawns, rock lobsters, and even mud crabs in Queensland; and fish, including barramundi, salmon, trout, and even dolphin-fish and whiting.

The first stage in any mariculture operation is the hatchery, which, by providing optimal conditions, can culture larval animals at densities far higher than occur in Nature — so producing millions of juvenile forms of the species in question. These then mature in the nursery, where conditions, although monitored, become more like the natural environment.

After several weeks here, young animals are ready to be put into a farm site, such as an oyster tray, prawn pond, or fish cage, where they may feed on naturally present food in sea water or be given food until they reach market size. Alternatively, scientists can use the large numbers of animals from the nursery to restock natural areas depleted by overfishing or other causes.

Culturing animals in a hatchery, as well as achieving much faster growth rates than occur in wild populations, also enables you to grow a species that is not naturally available in a certain place or during a particular season. What's more, compared with harvesting from the sea, mariculture gives you a product that is predictable and reliable in both quantity and quality.

But, to grow your oysters or barramundi in such large quantities in the hatchery you need to feed them well, and although that may sound simple it requires a lot of expert knowledge. Put simply, you need the right food crops for the baby fish and shellfish. For this, scientists use a number of species of microscopic algae, which form the base of the vast food pyramid in the oceans.

Grass of the sea

The micro-algae are tiny floating plants (collectively called phytoplankton) that by using the energy of light in photosynthesis provide food for nearly every living thing in the sea. It is this unseen 'grass' of the sea that is responsible for the great productivity of many marine ecosystems. Scientists have now 'domesticated' several micro-algal species for use as basic 'feed crops' for marine agriculture. They can also use some species in their own right, as a source of commercially important chemicals. (*Ecos* 29 described how algae are grown and harvested for the large-scale production of *beta*-carotene.)

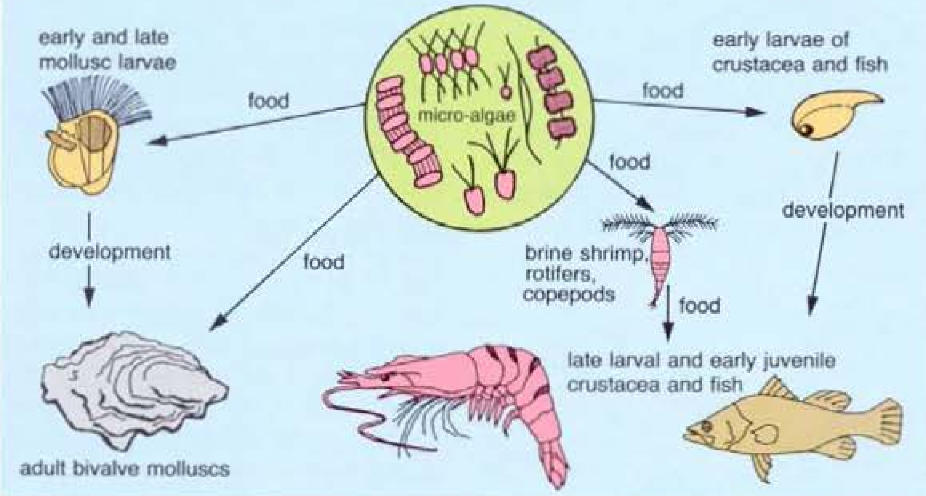
Micro-algae are the direct food for the larvae and adults of many shellfish and for crustacean larvae, as well as for some young fish. They are also eaten by small animals like brine shrimps, rotifers, and copepods that themselves are the food for larger fish and crustaceans. In sea water, however, they seldom occur in sufficient concentration to support the great densities of animals that mariculturists need in their hatcheries. Hence, we need to culture the algae on a large scale.

In Australia one of the leading researchers in this field is Dr Shirley Jeffrey, a marine biochemist with the CSIRO Division of Fisheries in Hobart, who runs the CSIRO Algal Culture Collection. Dr Jeffrey has carried out research on the physiology and biochemistry of different micro-algal species, but has recently added a new role to her work. With the help of $300 000 from the Fishing Industry Research and Development Trust Fund (FIRDTF), granted to her and Dr Christian Garland of the University of Tasmania, since March 1987 her laboratory has provided starter cultures of micro-algae, and expert advice, to mariculturists throughout the country, and even overseas.

For a small fee, the CSIRO section will dispatch within 3 days a 20-mL or 200-mL starter culture of suitable micro-algae from its stocks. So far, it has sent out more than 700 cultures to 61 different establishments. About 95% of the country's mariculture industry is now using the FIRDTF-funded CSIRO supply service.

The role of micro-algae

Micro-algae are at the base of many food chains.



From the species supplied in the starter culture from CSIRO, the mariculturist then needs to grow a crop to feed his animals, much as on the land we need to go from seed to animal feed. In hatcheries and nurseries, the hungry hordes of young fish, crustaceans, or molluscs can consume hundreds or thousands of litres of micro-algae every day. So the 'farmer' needs large culture ponds or tanks with clean sea water in which to grow these necessary quantities.

Inevitably, some marine bacteria exist in the hatchery, consuming useful nutrients like weeds in a field, or even causing disease directly. Most of the common ones are harmless to the animals; indeed, some may actually grow in association with algae and provide substances necessary for algal health, just as some weeds — with the help of their root bacteria — can fix nitrogen. But disease-causing species of bacteria, once present, can quickly ruin a hatchery and even a nursery. For this reason, Dr Jeffrey and Dr Garland take great care to supply starter cultures that are bacteria-free, thus ensuring that harmful species cannot inadvertently be spread into hatcheries.

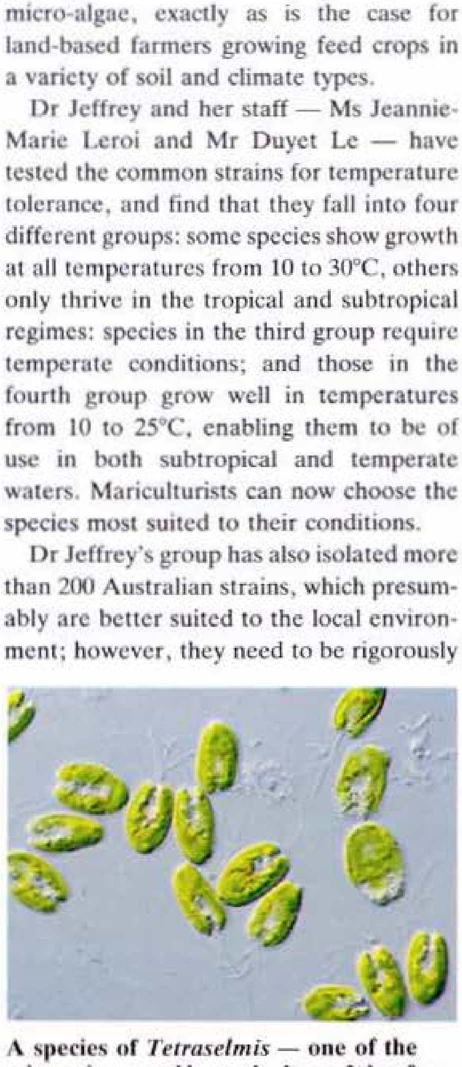
They also advise on how to minimise bacterial problems in the hatchery, and other aspects of the use of micro-algae in mariculture, by means of workshops and hatchery visits. (The Rural Credits Development Fund has given a grant of $53 000 to Dr Jeffrey, Dr Garland, and Mr Roger Calvert of Shellfish Culture Pty Ltd, to assist in the building of an experimental hatchery and outdoor ponds for the scientists to carry out feeding trials 'in the field'.)

Algal culture cringe

Currently, mariculture uses about ten species of micro-algae, all of which are derived from isolates of Northern Hemisphere strains, although other strains of the same species do occur around our shores naturally. The research of Dr Jeffrey and her colleagues includes examining the suitability of the imported strains for the wide range of conditions around Australia. The environment in which they grow can greatly affect the nutritional quality of the micro-algae, exactly as is the case for land-based farmers growing feed crops in a variety of soil and climate types.

Dr Jeffrey and her staff — Ms Jeannie-Marie Leroi and Mr Duyet Le — have tested the common strains for temperature tolerance, and find that they fall into four different groups: some species show growth at all temperatures from 10 to 30°C, others only thrive in the tropical and subtropical regimes: species in the third group require temperate conditions; and those in the fourth group grow well in temperatures from 10 to 25°C, enabling them to be of use in both subtropical and temperate waters. Mariculturists can now choose the species most suited to their conditions.

Dr Jeffrey's group has also isolated more than 200 Australian strains, which presumably are better suited to the local environment; however, they need to be rigorously tested before being offered to the industry, and Dr Jeffrey and her team are in the process of doing this.



A species of *Tetraselmis* — one of the micro-algae used in mariculture. It has four flagella at one end, which it uses for swimming.

Some of the 300 strains of algae in the CSIRO collection.

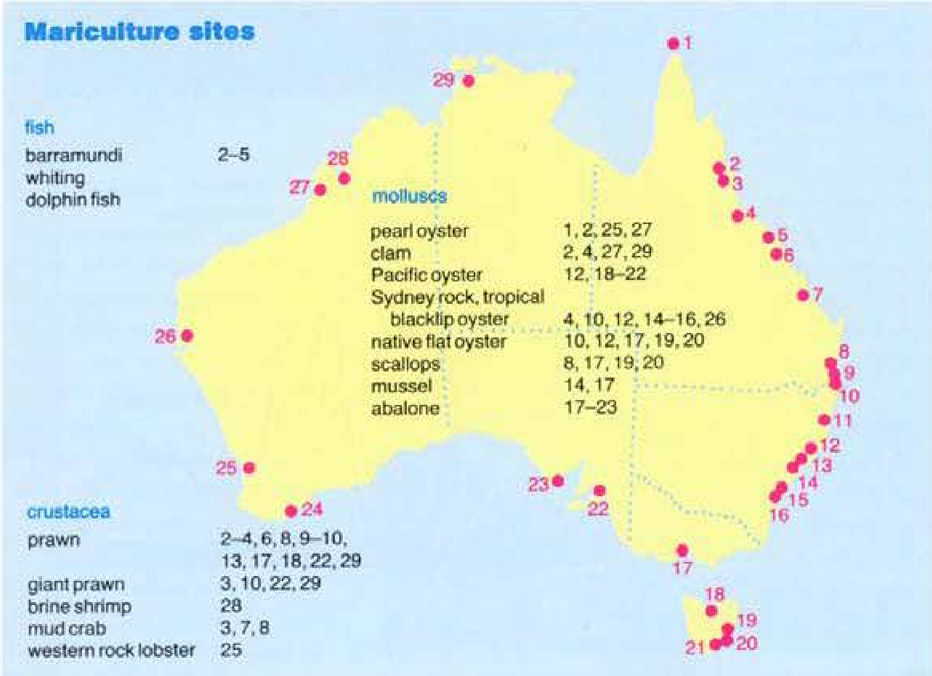
Nutrition

The type of micro-alga used as feed is important because the species vary in their nutritional value and hence the extent to which they support the growth of various animals. So as to ensure a balanced diet for their animals, mariculturists usually use a mixture of at least two different species.

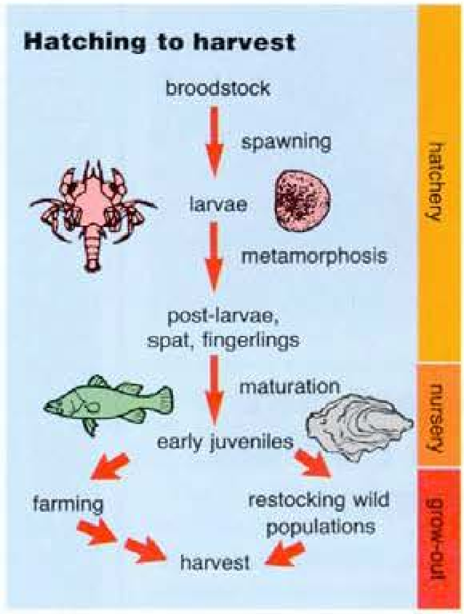
Of course, you can't just use any type of alga to feed your oysters or lobsters. Some species would be unsuitable as food because of their size or shape, or because they may have a thick wall and so be indigestible. Others may be deficient in an essential nutrient, lack the correct nutritional balance, or, worse still, contain toxins.

Our knowledge of the micro-algal species most suitable for the nutrition of maricultured animals in Australian conditions is poor. Dr Jeffrey's team, along with Divisional biochemist Dr Malcolm Brown and colleague Dr John Volkman of the Division of Oceanography, is currently undertaking a detailed research program on nutrition. To help, FIRDTF has recently awarded the group a grant to carry out analysis of polyunsaturated fatty acids in micro-algae.

Environmental conditions — such as the wavelength and intensity of light, the temperature and pH of the water, and the presence of unknown biochemical factors — affect their rate of growth and nutritional content. In general, the algae used are rich in protein — from 30 to 50% of the dry weight of the cells — and also contain significant amounts of fat, carbohydrate, and minerals. Certain polyunsaturated fatty acids are vital for the growth of maricultured animals, and some species of algae are particularly good sources of these, whereas others are not. (Incidentally, the polyunsaturated fats eventually reach the human consumer, where their benefits to health in helping prevent heart disease are now being recognised.)

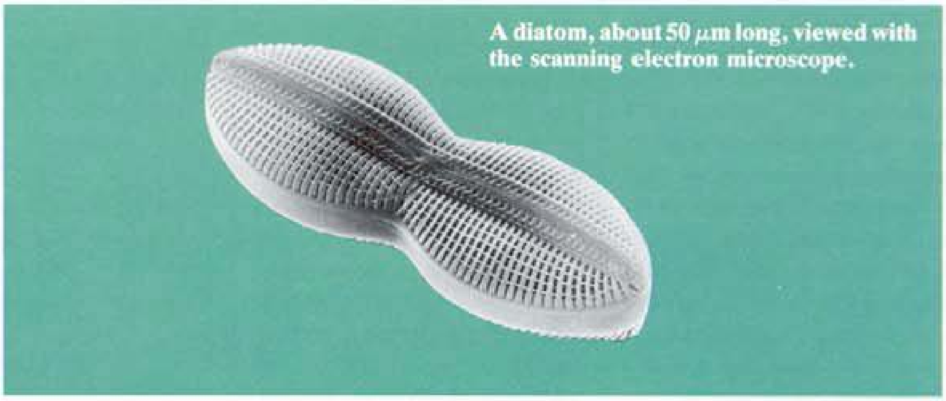


Major mariculture hatcheries in Australia (as at August 1988) and the species grown.



Production stages in a typical mariculture operation.

CSIRO staff transferring algae to fresh culture media.



A diatom, about 50 μm long, viewed with the scanning electron microscope.

It may be possible to improve the nutritional composition of the algae by manipulating their environment. Dr Jeffrey has found that blue light leads to an increase in their production of protein, fat, and pigments, and slows down their aging. In the future, the scientists are hoping to discover more information like this and use it to improve still further the efficiency of the grass in the agriculture of the sea.

Roger Beckmann

More about the topic

Microalgae in Australian mariculture. S.W. Jeffrey, C.D. Garland, and M.R. Brown. In 'Marine Botany', ed. N.N. Clayton and R.J. King. (Longman: Melbourne, in press).

Mass culture of microalgae essential for mariculture hatcheries. S.W. Jeffrey and C.D. Garland. *Australian Fisheries*, May 1987, **46**, 14–18.

The sea's plants

The seaweeds we see on a trip to the beach are not really representative of marine plants. These slimy ribbons are large, multicellular algae, restricted to habitats close to the shore. The major part of the plant life of the oceans consists of the floating phytoplankton — millions of single-celled, microscopic algae. They can live throughout the breadth of the oceans, down to about 200 metres, below which the sunlight becomes too dim for photosynthesis.

But what exactly are algae? They are sometimes defined as the most 'primitive' form of plant, but this is a little unfair. Algae are highly successful, and differentiated into many forms — some large, like kelp, but the majority microscopic like the species comprising the phytoplankton. However, the multicellular ones all lack the specialisation of cells to form many different tissue types and the complex reproductive structures of land plants.

Certainly, algae are an ancient life form. They lived for billions of years in the sea before any life colonised the land. One group — the green algae — are thought to have given rise to all the green plants that now dominate the land and fresh water.

Although we are more aware of seaweeds, the micro-algae have much more importance for life in the sea. Just one litre of sea water may contain as many as a million algal cells, representing possibly 60 different species, with an immense diversity of structure and photosynthetic pigments.

There are brown, golden, red, green, and blue-green algae. The colour of their light-harvesting pigments shows the portion of the spectrum where they absorb most strongly. Sunlight changes with depth, as the water preferentially absorbs the red wavelengths; so algae that live at greater depths, where the light is bluer, have pigments suited for that.

Shapes range from the well-known pillbox of the diatoms, encased in their ornately patterned silica walls, to long thin cells propelled by a single whip-like flagellum.