The menace below
invasive seaweeds

Many dangers lurk beneath the ocean waves, but not all of them have sharp teeth.

by John Huisman and Cheryl Parker

The value of the marine environment to Western Australians is difficult to quantify. It is probably our favoured playground, whether for swimming, surfing, diving or other recreational activities. In addition, our marine industries generate around $5 billion per year, and employ more than 14,000 people.

On a less positive note, it receives much of our waste, which it mostly absorbs very efficiently. Thankfully, we no longer hold the perception that the marine environment can supply an inexhaustible harvest, and that it can be treated as a bottomless dumping ground. If we take care of our marine environment and treat it with respect, we should be able to maintain a healthy and productive system.

But our oceans are under threat. Pollution, global warming and overexploitation of the marine environment are major problems in many places already, potentially leading to the total collapse of the delicate balance of the marine ecosystem. In Western Australia, excessive nutrient pollution often leads to algal blooms visible from the surface. Now an additional menace looms, capable of reducing diverse and productive ecosystems to virtual monocultures, dominated by a single, all-pervasive species. The menace comes in many guises, but is collectively known as 'invasive marine pests'.

Feathery caulerpa

Caulerpa is a widespread genus of green algae that grows by sending out horizontal creeping stems, from which upright branches can arise. The uprights come in all manner of shapes. Some look like bunches of small grapes, some are flattened and almost fern-like, while others resemble thick blades of grass.

Some years ago, a particularly vigorous form of a common tropical species, feathery caulerpa (*Caulerpa taxifolia*), became a popular decoration in marine aquaria. Plants grew very rapidly, nothing ate or attacked them, they tolerated a wide variety of environmental conditions and new plants could be created from the smallest cuttings. Unfortunately, all of these characteristics also meant feathery caulerpa was an ideal weed, potentially able to colonise large areas of the world's shallow seafloor. And there were no constraints on transporting *Caulerpa* around the world; it could be ordered by mail from aquarium suppliers and delivered to your door!

It is widely believed that this 'aquarium strain' of feathery caulerpa is a genetically modified mutant of recent origin, as there are clear genetic

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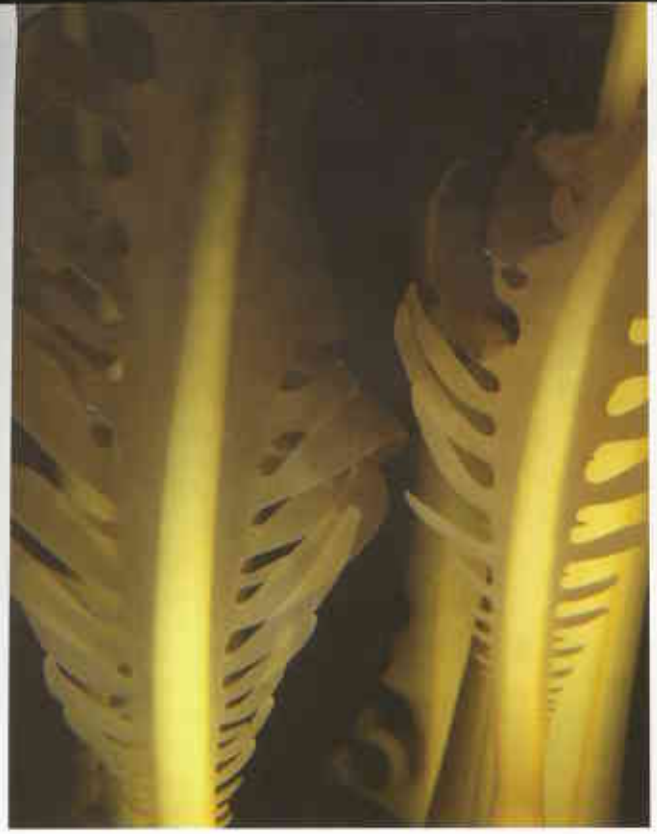
Main Sea berries (*Caulerpa sedoides*), a local green seaweed growing at Rottnest Island.
Inset Sea grapes (*Caulerpa racemosa* var. *cylindracea*), a green seaweed native to the Perth region, is now an invasive weed in many parts of the world.

Above The local green seaweed *Caulerpa distichophylla* looks similar to feathery caulerpa (*Caulerpa taxifolia*).

Left Two dried plants of feathery caulerpa (*Caulerpa taxifolia*)—the regular strain from Broome (far left) and the invasive strain from Adelaide (left)—are almost identical in appearance and hence difficult to distinguish from one another.
Photos – John Huisman



differences between the invasive plants and the tropical, non-invasive plants also known as feathery caulerpa. Recently published observations on a cold-tolerant variant of feathery caulerpa, which has been found in Moreton Bay (Queensland) since at least the 1870s, might indicate an alternative source of this pest.

In 1984, French marine biologist Alexandre Meinesz noticed an unusual green alga in the Mediterranean, which in his many years of experience he had never seen growing locally. The plants were adjacent to the Monaco Oceanographic Institute, where many display aquaria were in use. Meinesz identified them as feathery caulerpa, and attempted to raise the alarm that an introduced and potentially invasive species was growing in the Mediterranean. Unfortunately his concerns were largely ignored, as the prevailing feeling at the time was that it was a natural part of the Mediterranean ecosystem. How wrong this proved to be! In subsequent years, feathery caulerpa ran rampant throughout large tracts of the Mediterranean, displacing native seagrasses and radically altering the entire marine ecosystem. There now appears to be no means of containment. Mechanical removal is not viable, because the plant has spread so far and so rapidly.

Subsequent outbreaks also occurred in California, and in New South Wales and South Australia, but due to the experience gained from the Mediterranean, eradication was attempted before the species was able to gain a large foothold. The success of

Above left A close view of the blade of the invasive wakame (*Undaria pinnatifida*) shows the midrib distinctive to this species. Compare this to the local kelp.

Above The stem of wakame has distinctive ruffled reproductive branches. These do not occur in *Ecklonia*.
Photos – CSIRO

Left The common kelp (*Ecklonia radiata*) found in local waters.
Photo – John Huisman

Recognition of WA's marine flora

Unlike the terrestrial flora, the vast majority of marine plants are virtually unknown to all but a handful of biologists. The problem of introduced and invasive species is compounded by this general lack of awareness; if you didn't know that the plant you were looking at was introduced, you wouldn't think to be concerned. CALM's WA Herbarium is undertaking a project to increase awareness about our marine plants, by providing online information, including descriptions, photographs and distribution data of the marine flora. This will eventually be a major resource, accessible via CALM's FloraBase information system.

The first phase of this project included databasing the State's scientific collections of marine plants and was a joint venture between CALM's WA Herbarium and its Marine Conservation Branch. Coastwest/Coastcare provided funds for the initial stage and CALM received a Natural Heritage Trust grant to continue the project into 2006. Additional funding is being sought to support the project beyond this.

The WA Herbarium already had an extensive marine plant collection but only data on seagrasses were available through FloraBase. In collaboration with CSIRO, Murdoch University and The University of Western Australia, existing specimens collected by these agencies will be permanently housed at the Herbarium. A combined specimen database will provide information on more than 20,000 specimens.

The resulting database will be supported by an authoritative census of WA's marine plants, including around 1000 macroalgae and seagrass species, together with references to other sources of information about them. The comprehensive work carried out by Roberta Cowan from Murdoch University in compiling the Australian Marine Algal Name Index (AMANI) has provided a sound basis for the WA Marine Plant Census.

This project will provide extensive support to agencies and researchers contributing to conservation of WA's marine biodiversity. Scientists, community groups and volunteers will have ready access to up-to-date information on marine plants.

FloraBase is available on CALM's website at http://florabase.calm.wa.gov.au/.

eradication is subject to ongoing monitoring. Eradicating even small outbreaks is very expensive, costing $US 6 million (up to 2004) in southern California and $AUS 6–8 million in South Australia.

Is WA at risk? Most certainly. In the Mediterranean, water temperatures drop to 13°C over winter, and feathery caulerpa survives. It could certainly survive WA's winter sea temperatures, which are around 16-23°C in the vicinity of Perth. In New South Wales, feathery caulerpa survives in temperatures from 12–25°C, and elsewhere is reported to tolerate temperatures from 7–32°C. There seems no question that it could survive along most parts of WA's coastline.

But it has to get here first, and with proper management we might remain free of this pest. The invasive feathery caulerpa is apparently all male and does not reproduce sexually, so can only spread (other than by human means) by fragmentation and by growing laterally. Unfortunately, it can survive from the smallest fragments, and can also survive out of water for many days in humid conditions. The best means of control is to stop it getting here in the first place, so we need vigilant policing of quarantine procedures of living marine plants. Greater community awareness is also important, to stop people dumping aquarium contents into waterways. The species is now banned from import and sale, but remnant populations probably survive in many home aquaria.

Community awareness is also important for other reasons. An outbreak of feathery caulerpa might go unnoticed for years if no-one recognises it. Divers, snorkellers, fishers and others must be made aware of the problem so any suspect outbreaks can be immediately reported to the Department of Conservation and Land Management (CALM) or WA Fisheries.

Above left A diver collects seaweeds at the Houtman Abrolhos Islands, as part of ongoing surveys of Western Australia's marine plant biodiversity. *Photo – John Huisman*

Right After storms, the accumulation of drift seaweed on Perth beaches can be substantial.
Photo – John Huisman

Sea grapes

In the early 1990s, a second invasive species of *Caulerpa* was observed in the Mediterranean. This species appeared to be even more vigorous than feathery caulerpa, outgrowing it in head-to-head encounters. It was not identified until a study published in 2004 showed the invasive species was in fact sea grapes (*Caulerpa racemosa* var. *cylindracea*), a species with a natural distribution centred on the Perth region. The spread of this species in Europe has been described as a blitzkrieg, and it is proving to be as problematic as feathery caulerpa. Parts of South Australia are also now becoming inundated by this species, illustrating that pest species do not have to travel far to be problematic. As the Western Australian ecosystem has evolved to accommodate sea grapes, the species is unlikely to become a pest in our waters.

Wakame

Wakame (*Undaria pinnatifida*) is a largish (to three metres tall) brown kelp that is widely eaten in Asian and other cuisine. It is native to Japan, China and Korea and has been collected and eaten in Asia for centuries. Wakame has been accidentally introduced to New Zealand, California and the Mediterranean Sea (France, Italy). It was also deliberately introduced into the North Atlantic, to Brittany, for commercial exploitation, then was recorded in natural communities in France, Britain, Spain and Argentina. In 1988, populations were observed in Tasmania, and wakame now grows over a large area of Tasmania's east coast. It has also spread to Port Phillip Bay in Victoria.

Unlike *Caulerpa*, wakame grows upright from a single holdfast. This might lead one to think that it could not spread rapidly, but wakame has other means of getting around. Each plant produces many thousands of spores—from specialised branches called sporophylls that arise laterally on the stem—that can drift in the water and settle some distance away, eventually producing new plants. Wakame looks very similar to a Western Australian species, common kelp (*Ecklonia radiata*), and could possibly supplant that species if it took hold. Wakame generally inhabits only cold temperate coastal areas and grows best in waters below 12°C, but can survive in temperatures from 3–20°C, and the microscopic gametophyte stage can survive up to 25°C, so many parts of WA's coastline are probably at risk from an invasion.

As with *Caulerpa*, vigilance is important to keep this pest at bay. Sightings should be reported immediately. Wakame has a distinct midrib running through at least part of the blade and, when mature, produces specialised spore-bearing branches known as 'sporophylls'. These are convoluted and easily distinguished from the main frond. Common kelp has a flat blade with no distinct midrib and lacks specialised spore-bearing branches.

Fragile fingers

Fragile fingers (*Codium fragile* var. *tomentosoides*) is a large (sometimes more than 20 centimetres tall), dark green plant, regularly divided into paired branches. The branches, up to a centimetre in diameter, are spongy with tufts of whitish hairs just below the tips. The species is probably native to Japan, but is now one of the most

invasive seaweeds in the world, having found its way to New Zealand and then to south-eastern Australia, where it is forming dense populations. It generally grows on hard surfaces and attaches itself to shellfish, which makes it particularly unwelcome to aquaculturists.

It seems likely that this species will eventually spread across southern Australia to WA, probably by drifting or as a fouling organism. It looks similar to several WA species, and scientists need to examine its internal structure to identify this species. It survives in a broad temperature range and could easily invade WA waters.

Other seaweed invaders

The four species mentioned above have become invasive in Australia and many other parts of the world. But many more marine plant species are now regarded as pests. It is difficult to predict if a species is likely to become a pest in a new environment, as many introduced species remain relatively innocuous and do not dominate their new homes.

Some introductions of otherwise sedate species, however, have had disastrous consequences. In the 1970s, a well-meaning researcher at the University of Hawaii introduced several species of red seaweed to Hawaiian waters, to test their suitability for aquaculture. These studies resulted in major seaweed aquaculture industries in several tropical Pacific countries, including the Philippines and Indonesia.

Unfortunately, the test sites did not fare as well. The plants were left to their own devices and began to dominate

Above *Caulerpa racemosa* var. *laetevirens* at Dampier Archipelago, a variety very similar in appearance to the local *Caulerpa racemosa*.

Left Duthie's fingers (*Codium duthiae*), one of many native species of dead man's fingers (*Codium*) found in the Perth region. *Photos – John Huisman*

Below right Sea grapes is native to south-western Australia but a major pest elsewhere.
Photo – John Huisman

the ecosystem in parts of Hawaii. After southerly storms, Waikiki Beach (one of the world's most famous beaches and a major tourist destination) is inundated with large piles of beaded gracilaria (*Gracilaria salicornia*) derived from that first introduction. Kaneohe Bay now supports huge tracts of jellyweeds (*Eucheuma denticulatum* and *Kappaphycus alvarezii*), also introduced intentionally. On Maui, blooms of another red seaweed, hookweed (*Hypnea musciformis*), result in massive beach drift that eventually rots and becomes foul smelling. Once-pristine beaches have become intolerably tainted. The costs of cleaning the beaches are huge and ongoing, adjacent land values have dropped dramatically, and the local tourist industry has suffered. Manual eradication has been trialled, but is presently not feasible and there seems no way to halt the spread of these species.

What to do?

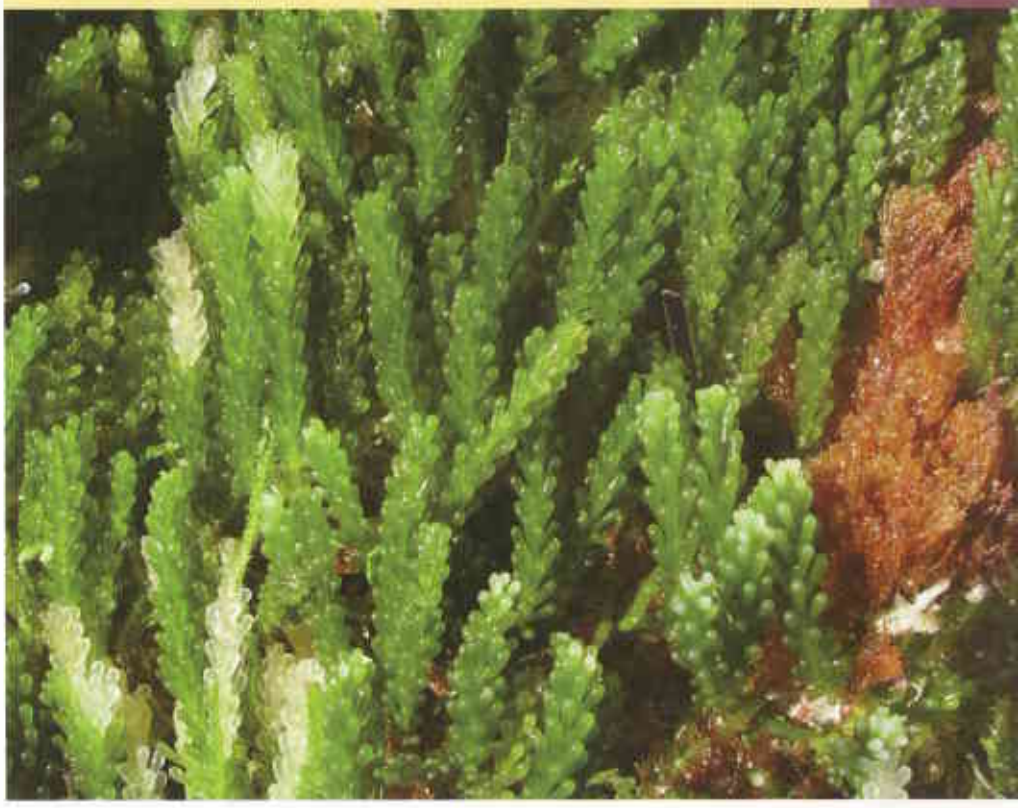
It is often impossible to predict how one species might fare in new environments, but it is painfully obvious that we should ban the intentional movement of living marine plants and do our utmost to prevent accidental introductions. Accidental introductions can occur by hull fouling and ballast water, and new regulations addressing at least some of those sources will soon come into force. Community awareness is vital, to prevent introductions and to alert the appropriate authorities if any invasive species are sighted. If only one or two people in WA can actually recognise a pest species, it is likely that any infestations will go unnoticed, but, if we all familiarise ourselves with at least the major pest species, then the chance of recognition is vastly improved. If you are regularly involved in marine activities, make a note of what you normally see. That way, you will be able to recognise any major changes, and notify the appropriate agency.

Once marine pests gain a foothold, it is very difficult—if not impossible—to eradicate them. By being vigilant and keeping a watchful eye over our marine environment, we can hopefully keep WA free of these unwanted aliens.

Introduced, cryptogenic, invasive or pest?

Many marine species have found their way around the world's oceans, either by natural means, such as currents, or unnatural pathways such as hitching a ride on a ship or yacht, or being imported for aquaculture or the aquarium trade. Most of these species are fairly innocuous and unlikely to have a major impact on the environment. In the past, these species were often described as 'cosmopolitan', indicating their widespread distribution. Nowadays they are also known as 'cryptogenic', which essentially means that their original source is unknown, obscured by their now-ubiquitous presence. They may, or may not, be introduced. 'Introduced' species are those that have clearly established a new population outside their natural distribution. They tend to be initially encountered in the vicinity of ports and harbours, and have not previously been recorded from local waters. Nowadays, further proof that a species is introduced comes from comparing DNA sequences between the newly established population and any possible source populations. Introductions do not necessarily have to come from a different country. Australia is a big place, and introduced species can also be translocated from elsewhere in the country.

Occasionally, some imports flourish in their new home, displacing native species and seriously affecting the marine environment. At this point, the species are described as 'invasive' or 'pest'.



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A forthcoming bush book, *Marine Plants of the Perth Region*, will be published by CALM in late 2006.

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