I SEE RED...

From Ningaloo to the Kimberley and offshore atolls, tropical Western Australia abounds with spectacular and diverse marine life. Amongst the corals and myriad fish, live a group of largely unheralded primary producers, the seaweeds. Research by Department of Biodiversity, Conservation and Attractions biologists has uncovered a startling array of species, and here we take a closer look at one group, the red seaweeds, arguably the least conspicuous, but certainly the most diverse assemblage of marine plants.

photos and words by John Huisman

Seaweeds are unjustly perceived as some of the least charismatic of marine organisms. But despite the negative connotations of the term, this diverse group of plants includes very few actual weeds, and many can be justifiably regarded as some of the most attractive and unique marine organisms. Unfortunately most people's perceptions of seaweed are tainted by visits to the beach where they have encountered large, smelly mounds of wrack; the pungent odour is certainly something to avoid. But seaweeds deserve a closer look, perhaps best while diving or snorkelling and observing living plants. And those who take a moment to enjoy the undersea garden will see colours, shapes and patterns that are sure to amaze.

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Main *Ganonema robustum,* one of the many new species discovered in north-west Australia.

Above *Rhytimenia maculata* had not been seen for more than 100 years.

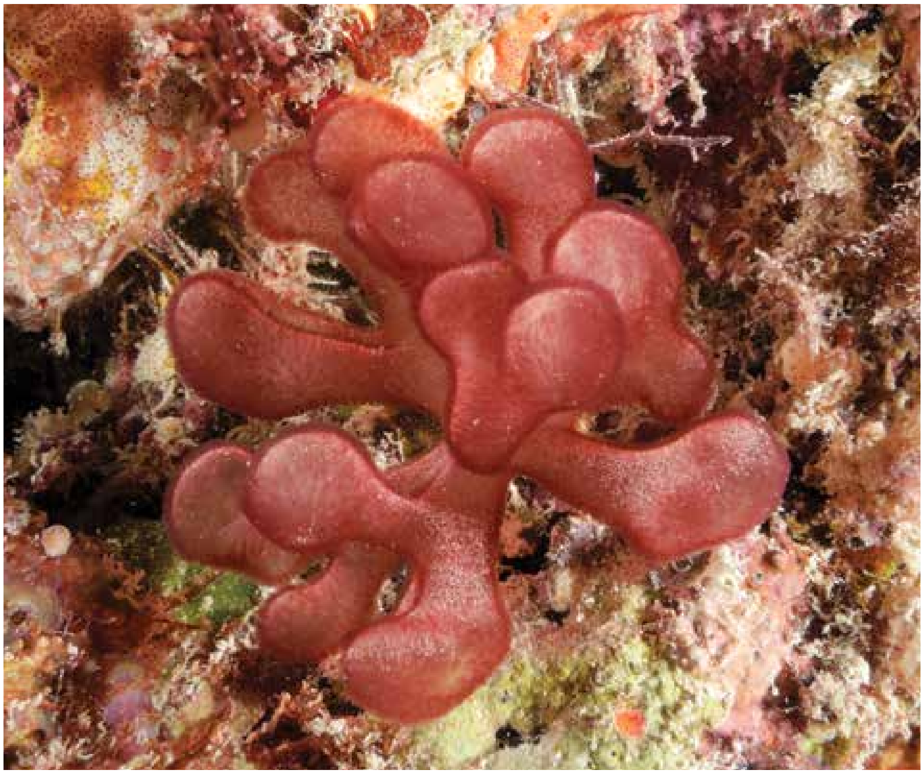
TRUE COLOURS

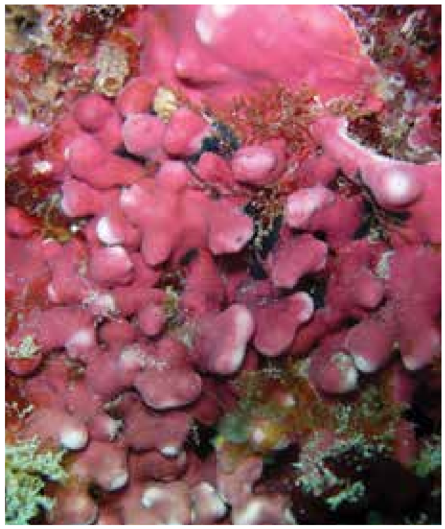
The seaweeds, or 'marine benthic algae' as they are often called, come in a variety of colours, but from a taxonomic perspective they can be divided into four groups: blue-green, green, brown and red, each equating to a different division or phylum. The blue-green algae are actually photosynthetic bacteria, more accurately known as cyanobacteria, and are very widespread in most habitats. In the marine environment they are commonly small turfs that mostly go unnoticed, but anyone that has taken a tumble on slippery intertidal rocks after inadvertently stepping on the 'black tar' coating will know them well. The green seaweeds include several that are well-known, perhaps the most familiar being the 'sea lettuce', the common name of species of the genus *Ulva*, which can be prolific on intertidal rocky shores. Brown seaweeds are easily the most conspicuous, as the group includes the kelps and other large species that wash up on the beach after a storm, forming the banks of wrack that most people do their best to avoid. In terms of biomass, which is essentially the amount of seaweed, the brown algae come out on top. However, if we consider diversity, or the number of different species, the red seaweeds are clearly the winner. If you add up the number of species of green and brown algae combined in a particular region, the total will be less than half the number of species of red algae for the same region. For the most part this diversity goes unnoticed, as the majority of the red algae are relatively small in stature and inconspicuous. Despite this, from a biologist's perspective, they are often the most interesting.

LET'S TALK ABOUT SEX

The red algae are the most structurally and reproductively complex, with most species having three phases in their life cycles and a mind-boggling array of reproductive structures and pre- and post-fertilisation processes. Indeed, red algae have 'sex', but the act is unique to the group, as the process is entirely passive. The tiny sperm cells, known as 'spermatia' and mostly with a diameter of less than 5 µm (1 µm = 1/1000th of a millimetre) do not have flagella (tail-like appendages) and therefore cannot swim. They are released into the ocean and somehow find their way to the egg cell, which is hidden within the female plant. Fortunately, this is made slightly easier by the egg cell having a receptive hair that can project about 100 µm above the surface of the alga. Once fertilisation occurs, the newly formed young is not released, but undergoes even more complex steps to multiply the number of offspring, with the resulting mass of spores from a single fertilisation often numbering in their thousands.

Until relatively recently, the seaweed flora of tropical Western Australia was virtually unknown, with fewer than 30 species recorded for the region. Remedying this gap in our knowledge has been an ongoing mission of mine. And so, for the past 20-odd years, I have regularly joined Western Australian Museum marine expeditions to the Pilbara and Kimberley coasts, as well as offshore atolls such as the Rowley Shoals and Ashmore Reef. The seaweeds I encountered on these trips were photographed, collected and preserved as specimens with the WA Herbarium, with the results compiled into a pair of books with the slightly unwieldy title of *Algae of Australia: The marine*





Top *Gibsmithia indopacifica*, a mucilaginous species that often accumulates sand grains, giving it a dusted appearance.

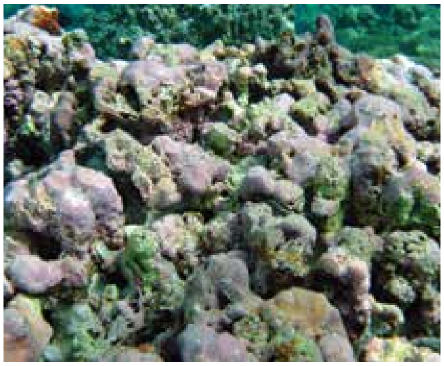
Above *Lithothamnion proliferum,* a coralline alga with a distinctive lumpy surface.

benthic algae of north-western Australia. Part one covered the green and brown seaweeds and was published in 2015, while *Part 2: the red algae* has just been completed. Between them they describe and illustrate more than 520 species, of which 91 are new to science. As might be expected, the red algae were the more diverse, with 351 species recognised, including 88 new species.

HISTORY REPEATING

While historically the seaweeds of north-western Australia have been ignored, those of slightly further north in Indonesia and the southern Philippines were collected and studied as part of the Dutch Siboga Expedition, one of the most significant marine biological surveys of the region. The H.M.*Siboga* visited what was then known as the 'Dutch East Indies' in 1899–1900 and on board was phycologist Anna Weber-van Bosse, who subsequently described the seaweeds collected during the expedition in a series of landmark publications, sometimes in collaboration with other phycologists. Weber-van Bosse's efforts were recognised when she was awarded an honorary doctorate from the University of Utrecht, and became the first Dutch woman to receive one. While the *Siboga* did not visit Australia, many of the species that Weber-van Bosse described have been found on our northern coasts (see 'Rare seaweed rediscovered', *LANDSCOPE*, Winter 2010). Some, such as *Rhytimenia maculata*, were first discovered during the Siboga Expedition but not seen again until the present surveys. This does not mean that the species are necessarily rare; the more likely explanation is that no-one has been looking for them.

Rediscovering species that have not been seen for more than a century also enables us to examine them from a modern perspective, to gain a better understanding of their taxonomic relationships. This is invariably undertaken using molecular methods, or DNA sequencing. This method enables us to examine how closely the species are related to one another, and also to generate a unique 'barcode' that can then be used to assist in the identification of specimens. In the case of *Rhytimenia maculata*, when first described by Weber-van Bosse for specimens collected from Makassar Strait (off Borneo) it was placed in the genus *Kallymenia*, based on the taxonomic concepts of the time. DNA sequencing of the recent collections from Ashmore Reef gave a different perspective and showed the species to be incorrectly placed in *Kallymenia*, and that a new genus was necessary. The name *Rhytimenia* was coined for this species, taken from the Greek *rhyti* (wrinkle) and



Above *Champia stipitata*, one of several iridescent red algae.

Far left Pink coralline, strengthening and consolidating the reef crest.

Left *Trichogloea requienii,* an extremely mucilaginous species with a calcified core.

Below left *Dichotomaria sibogae,* another species first described from the Siboga Expedition.

hymen (membrane), in reference to the wrinkled surface of the blade.

THIS IS THE MODERN WORLD

Molecular approaches have revolutionised modern taxonomy, and as methods are streamlined and automated they will be further embedded in taxonomic schemes. There have been numerous positive outcomes, but of greatest significance to the seaweeds is that there are clearly many more species than previously envisaged, and some of these are ‘cryptic’, differentiated only by molecular tools. Whereas previously many seaweeds were thought to be widespread, we now know that is not the case and some, but not all, species have very restricted distributions. The difficulty arises in matching these cryptic species to names used in the past; how do you know which of the many cryptic species is the one that the name should be applied to? The best solution is to undertake DNA sequencing of the original, or ‘type’ collections, to generate a definitive barcode, but in some cases this is not feasible. Another option is to revisit the location of the original collection, to re-collect authentic material and generate a barcode from the fresh specimens. Aligning the results of molecular studies with historical perspectives, to ensure that each species is known by the appropriate name, will undoubtedly keep taxonomists busy for many years to come.

Understanding the diversity of the red algae, while important in itself, might feed into other studies that aim to preserve habitats and conserve species. Coral reefs, particularly the outer reef crests that bear the full force of waves, are often strengthened by a coating of coralline red algae, which appear as layers of pink or red paint coating the reef surface. These algae incorporate a calcium carbonate skeleton as part of their structure and, as a result, can be as hard and tough as rock. Most scenarios of future ocean chemistry predict increased acidity, which could potentially remove, or at least lessen, the capacity of algae and corals to produce their calcium carbonate skeletons, leading to a weakening of the reef crest and possible damage. The long-term effects of this are unknown.

In addition to their ecological value in the marine world, red algae have certainly

Above *Martensia denticulata*, with its unusual lace-like fronds.

Above right *Eucheuma arnoldii*, mimicking *Acropora* coral.

Below right Mixed coralline algae, often found growing on shaded reef undercuts.

had a positive impact elsewhere. Their culinary use is well-known, particularly in Japanese cuisine. Nori, the purple-green wrapping around sushi rolls, is in fact a red seaweed known as *Pyropia* (formerly *Porphyra*). Several species of cartilaginous red algae are farmed for carrageenan, a component of their cell walls that is used as a thickening agent. Others are grown for agar, used extensively in laboratories as a substrate for growing micro-organisms and germinating seeds. Perhaps the most unusual potential use of red algae has been the subject of recent research. It was discovered that the addition of small amounts of *Asparagopsis taxiformis* to cattle feed drastically reduced the amount of methane that the cows produced. As the methane in the gaseous expulsions from cows is a significant contributor to greenhouse gases, red algae might have an impact on slowing climate change.

BEAUTIFUL GARDENS

Practical values aside, the red algae command attention due to their amazing appearances. Some species are iridescent, such as *Champia stipitata*, which glows under sunlight in opal-like patterns. Others, such as *Trichogloea requienii*, are highly mucilaginous, but strangely with a flexible calcified core that appears as a white backbone. Many red algae are calcified, but the calcification can take several forms. In *Ganonema robustum*, a new species found at Ashmore Reef and several offshore atolls, the calcium carbonate forms a powdery layer in the outer tissues that remains flexible. In *Dichotomaria sibogae* the calcification is minimal, imparting only a slight whitish hue to the branches. Other uncalcified species, such as the membranous *Martensia denticulata*, form delicate lace-like tissues, the result of very precise simultaneous realignments of cells during growth. The environmental trigger for this still unknown. One very unusual species of red algae is the cartilaginous *Eucheuma arnoldii*, whose appearance precisely mimics that of *Acropora* corals, even down to the presence of a polyp-like growth at the tips of branches. This mimicry has presumably evolved to deter herbivorous fish and is so convincing that during surveys the alga was overlooked by everyone except WA Museum coral biologist Zoe Richards, who was stunned to find that what she thought was a hard coral was actually flexible (see 'Now you see me', *LANDSCOPE*, Spring 2016).

The red algae are aesthetically pleasing, environmentally important, and scientifically intriguing, undoubtedly with numerous new species yet to be discovered. It's no wonder that those in the know are enthralled by them, and hope to spread the enlightenment to those that aren't.

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John Huisman is the curator of DBCA's Western Australian Herbarium and a seaweed specialist. He can be contacted at john.huisman@dbca.wa.gov.au.

Parts 1 and 2 of Algae of Australia: The marine benthic algae of north-western Australia *are available from from CSIRO Publishing (publish.csiro.au).*