Common coralline algae of northern New Zealand

An identification guide

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Cover: Non-geniculate coralline algae on rock wall (left); geniculate coralline algae, and non-geniculate coralline algae growing epiphytically and on rock (right). Photos by Kate Neill & Tracy Farr, NIWA.

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Preface

Our group's work on non-geniculate coralline algae had its genesis in the early 1990s, when Bill Woelkerling and Wendy Nelson first discussed how to begin to document New Zealand's non-geniculate coralline flora and increase recognition of the importance of these species in coastal ecosystems. The gaps in our knowledge about the coralline algae of New Zealand had been obvious for many years but the technical difficulties involved in working with these calcified red algae, as well as the history of confused taxonomy and nomenclature for New Zealand species, meant that there were significant hurdles to overcome.

In 2001, the Ministry of Fisheries Biodiversity Programme funded our group to document the 'crustose' coralline algae of central New Zealand, and to develop a reliable and durable reference – *Coralline algae of central New Zealand: An identification guide to common 'crustose' species* (NIWA Information Series No. 57) – for use in fisheries and coastal management, as well as in marine resource protection and conservation. In that programme as well as the current programme, funded in 2005 to document the non-geniculate and geniculate coralline algae of northern New Zealand, we wanted to make information accessible to marine scientists and resource managers, and to improve understanding of these algae, both through the production of identification guides and through improved reference collections lodged in the herbaria at Te Papa (WELT), Auckland Museum (AK), and Landcare Research (CHR).

The taxonomic research using morphological and anatomical characters which forms the basis of this guide has been complemented with data from molecular sequencing. This forms a very important and exciting area of research, making use of new tools and approaches to better understand species relationships and identity. Using molecular sequencing to inform and confirm our "traditional" identification effort has allowed us to most efficiently make progress on understanding relationships within this challenging group of organisms. In this identification guide we also incorporate recently published changes to the taxonomy of coralline algae, perhaps most notably within the geniculate corallines.

The focus of this guide has been steered towards the field, incorporating field photographs of coralline species, and highlighting key characters that are observable in the field and the laboratory.

In treatments of coastal communities, even in recent publications, non-geniculate coralline algae have been referred to as "pink paint", and geniculate coralline algae as "turfs", completely overlooking the diversity that may be present and the complex ecological roles particular species may play. We hope that the production of this guide and the underlying research that has been supported by the Ministry of Fisheries will cause people to look more closely, and to recognise and document coastal diversity including these key organisms, and that this will lead to a better understanding of the dynamic relationships between these algae and other components of the coastal flora and fauna.

Scope of this identification guide

This guide deals with the identification of coralline algae in northern New Zealand, based predominantly on targeted collections made from 2005 to 2008 in a project (ZBD2004-07) funded by the Ministry of Fisheries Biodiversity Programme, but also drawing on previous collections and opportunistic sampling. The aim of this guide is to provide a reference tool for those wanting to identify coralline algae growing in northern New Zealand, and to provide information on the biodiversity of these organisms in the region. Our focus in producing this guide is to provide information that will be useful in the field. However, coralline algae are notoriously difficult to identify, and so we give several levels of information which should enable the identification of the species treated in this guide, although for some species this may require specialist equipment, techniques and experience. Species profiles are provided for 25 non-geniculate species and half a dozen geniculate species. Each species profile includes colour photographs, a map, and information on habitat, anatomy and reproduction, and distribution. Key characters are highlighted for each species, with a focus on characters that aid identification in the field. A range of keys to identification are provided throughout the guide, as well as a glossary of terms, and a list of references. This identification guide builds on the work carried out in a previous project, funded also by the Ministry of Fisheries, on crustose coralline algae of central New Zealand, and the identification guide produced as part of that project (Harvey et al. 2005).

Study area – geographical cover of this guide

This guide is based almost entirely on new collections of encrusting and geniculate coralline algae from northern New Zealand in a region covering 10 degrees of latitude – from the Kermadec Islands (29° S) through to northern Taranaki (39° S).

We obtained material from 91 field sites (see the detailed site map [Appendix 1] and list [Appendix 2] at the end of this guide) concentrating our collecting effort to the north of Mount Taranaki in the west, and East Cape (Figure 1). The southernmost collections from this study overlap at the margins with the study area of our previous work (Harvey et al. 2005), which covered central New Zealand including the Chatham Islands.

We obtained samples from both the intertidal/upper subtidal zone as well as subtidal collections, from a range of habitats and substrate types.

The collecting sites have been grouped into eight regions, seven in the North Island and 1 region for the Kermadec Islands: Kermadecs (4 sites in the Islands, 1 on the Kermadec Ridge), Far North (21 sites), Bay of Islands (12), Whangarei (7), Auckland/ Hauraki Gulf (13), Coromandel (16), Bay of Plenty /East Cape (9) and North Taranaki (10).

The algal flora of the Kermadec Islands shows strong affinities with other warm-water regions of the Pacific and Indian Oceans and is quite different from the flora of "mainland" New Zealand (Nelson & Adams 1984). The northeastern North Island is influenced by subtropical waters from the East Australian Current, whereas the west coast of the North Island experiences cooler waters of the West Auckland current.

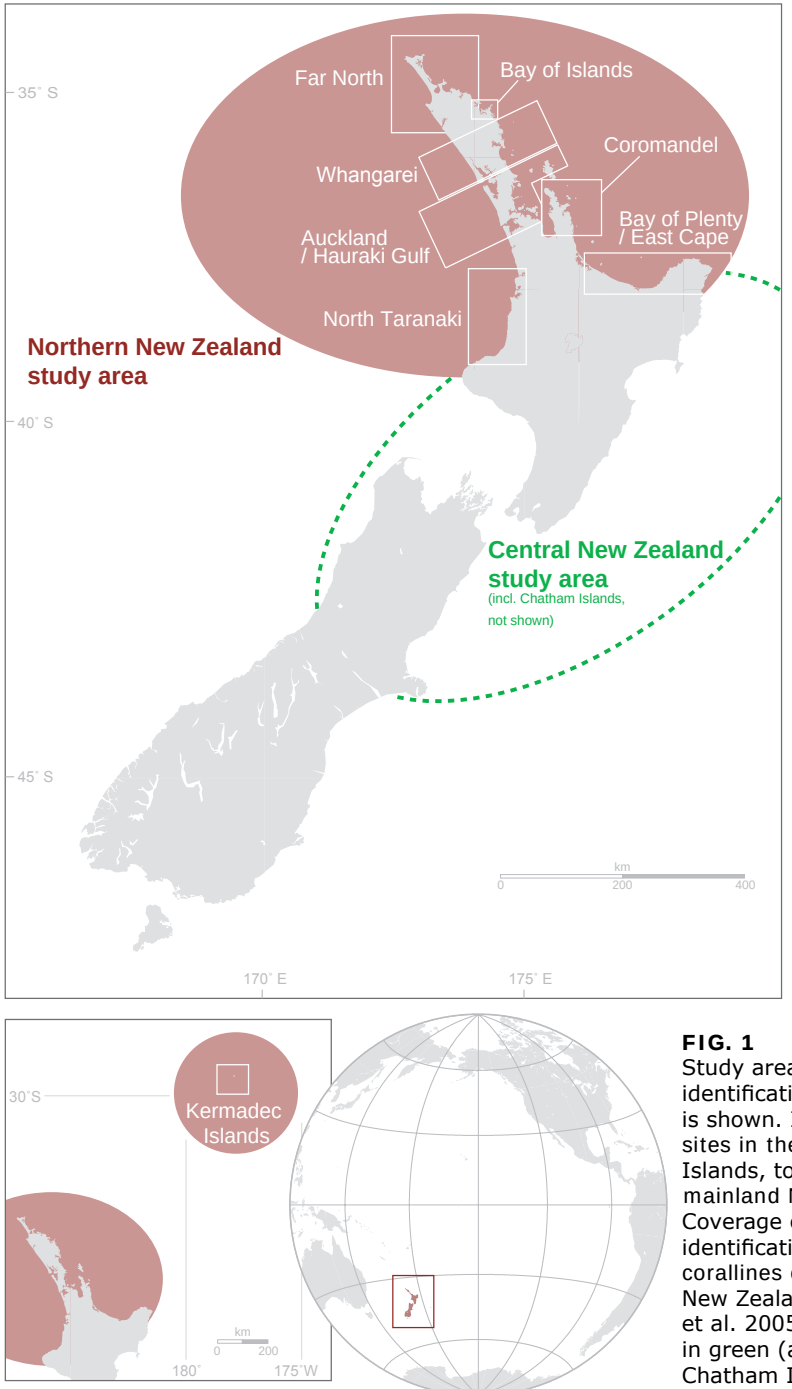

FIG. 1
Study area for this identification guide is shown. It includes sites in the Kermadec Islands, to the north of mainland New Zealand. Coverage of a previous identification guide to corallines of central New Zealand (Harvey et al. 2005) is outlined in green (also included Chatham Islands, not shown here).

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Authorship and contribution

Tracy Farr is in the Marine Biodiversity Group at the National Institute of Water & Atmospheric Research (NIWA), based in Wellington, New Zealand. She collected and photographed corallines, prepared thin sections and identified non-geniculate samples, and produced the majority of this guide.

Judy Broom (University of Otago) developed methods, sequenced samples, and carried out molecular analysis. Judy wrote the section on Molecular phylogeny in the *Coralline algal taxonomy* chapter of this guide.

Darren Hart (University of Otago) developed methods, sequenced samples, and carried out molecular analysis.

Kate Neill (Marine Biodiversity Group, NIWA) participated in field trips, photographed and processed samples, examined geniculate taxa, and prepared text.

Wendy Nelson (Marine Biodiversity Group, NIWA) participated in field trips, processed samples, examined geniculate taxa, and prepared text.

William Woelkerling and Adele Harvey were subcontracted for identification confirmation, assessment of identifications, and comments. See *Acknowledgments*, at the end of this guide.

Contents

Introduction to coralline algae

General information

Coralline algae – an introduction

About coralline algae

Coralline algae are red seaweeds with calcium carbonate in their cell walls. Found worldwide, they are classified in the order Corallinales. They are either branched (and partially calcified), or completely calcified.

The branched species, geniculate corallines, have alternating segments that are calcified and uncalcified. The uncalcified segments – the "gaps" or "joints" between calcified segments – are called genicula, and the calcified segments are known as intergenicula. Geniculate corallines are sometimes referred to as articulated, or turfing, corallines; they often form short, dense turfs on intertidal reefs and rocks and in pools.

The completely calcified species are called non-geniculate corallines, sometimes also known as crustose or encrusting corallines because of the growth form of most species. Free-living non-geniculate corallines are known as rhodoliths (or maerl – a term used mainly in Europe). These are not attached to any fixed surface but rather are able to be rolled on the sea floor by the action of water motion and currents.

FIG. 2
Non-geniculate corallines (encrusting as well as warty growth forms, with at least four species present) on intertidal rocks with geniculate or turfing corallines. Non-calcified seaweeds grow with and over the coralline algae.

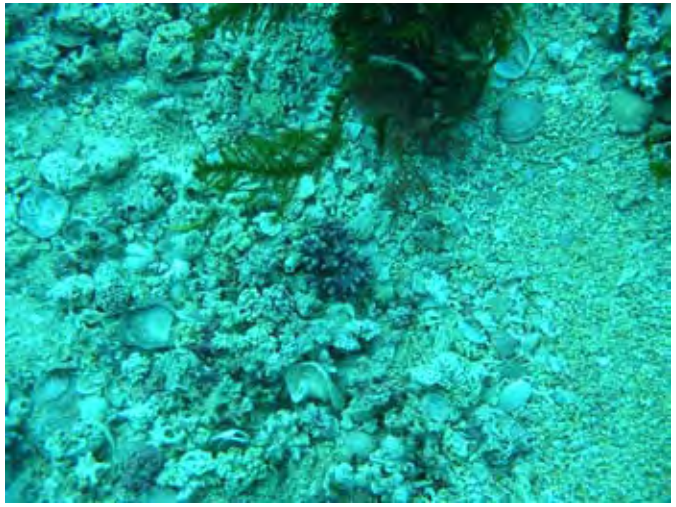

FIG. 3
Rhodoliths (free-living, unattached coralline algae) amid shell and rhodolith gravel in the Far North of New Zealand. Rhodoliths lie in channels at this site, with fleshy seaweeds (such as the green alga *Caulerpa flexilis*, seen here) stabilising adjacent sand ridges.

In the SPECIES PROFILES section, we include a short separate chapter on RHODOLITH-forming species

The coralline algae range in colour but are usually pink or purple in tone – from deep candy pink to purple, through to pale grey or creamy white when bleached by the sun. The encrusting corallines exhibit a variety of growth forms, from smooth encrusting, to warty, through to elaborately-layered forms with architectural struts. While growth form can be characteristic of a species, it is often variable within, and shared by several, species. For a summary of coralline algal growth forms, see the following chapter, *Coralline morphology & anatomy*.

Flat or raised structures – warts, pinpricks or pimples up to 1 mm across at largest – may be visible on the surface of coralline algae. These are the alga's reproductive structures. Their basic structure and features, as well as a simplified life cycle, are described in the following chapter, *Coralline morphology & anatomy*.

Coralline algae can be found in almost all coastal habitats where there is sunlight and hard substrate to attach to, from high intertidal tide pools through to deep subtidal reefs. The free-living rhodoliths are found subtidally in areas where there are no reefs but rather coarse sand, gravel or shell debris, often in areas with strong currents. As well as rock substrate, coralline algae can grow epizoically, on animals such as mussels, paua, and other shellfish, and sponges. Coralline algae can also grow epiphytically; substrates include geniculate coralline algae, a large range of red, green and brown marine macroalgae, as well as seagrass.

Significance of coralline algae

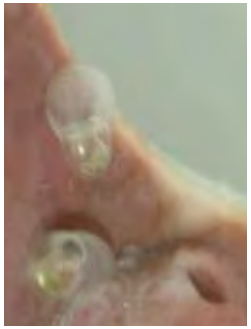

FIG. 4
Paua (abalone) larvae settled on non-geniculate coralline alga in the laboratory.

Coralline algae are found from the poles to the tropics and in clear waters can be found to great depths. They are very important in the global carbon cycle, as well as being critical to the stability of coral reefs, acting as stabilizers and helping to bind the reef framework together.

Coralline algae provide habitat, refuge and grazing areas for numerous fish and invertebrate species. Beyond this, they also influence settlement and recruitment of marine invertebrates such as paua, corals, and kina, by the action of chemicals associated with the surface of coralline algae which are known to induce larval settlement in a range of species.

Rhodolith beds provide three dimensional structures which are a complex, intricate and often stable habitat for invertebrates, fishes, and other algae. International studies have reported these beds to be biodiversity hotspots as they have been found to harbour rare and unusual species, as well as serving as nursery areas for some commercially important species of fish and also scallops.

Action to protect rhodolith beds from human induced changes has occurred relatively recently in European waters, although it is non-existent in most regions of the world.

Vulnerability to human impacts & climate change

Like other calcified marine organisms – corals, shellfish, bryozoa – coralline algae are vulnerable to the changes in the oceans that are already occurring as a result of increasing atmospheric CO_2 that we refer to under the umbrella of global climate change. With increasing atmospheric CO_2 and increasing temperature come fundamental changes in seawater chemistry including decreasing pH, increasing acidity, and disruption of the local and global carbon cycle. The ability of calcified organisms to build and maintain their structure, and the likely knock-down effects of disruption of their biology, are matters of current research globally.

Coralline algae are also vulnerable to other human-mediated effects such as nutrient enrichment and land or coastal developments which lead to increased sedimentation. As an example, research in Europe has shown the adverse impacts of sedimentation from marine fish farms on the rhodolith beds beneath them.

Understanding coralline algae

Insufficient attention has been paid to coralline algae to date. The research results so far, however, suggest that global and

FIG. 5
Fish grazing on rock wall with cover of several different species of non-geniculate and geniculate coralline algae.

local changes that have a negative effect on coralline algae will in turn have very serious implications for the recruitment of invertebrates and the maintenance of biodiverse and nursery habitats, with consequent impacts on human livelihoods.

A great deal more work is required to fully understand the ecosystem services that these algae provide and the roles/importance of coralline algae in global carbon processes. Much more information is needed to provide the basis for sound decision making and sustainable resource management.

To understand the impacts of human-mediated changes on coralline algae we need good baseline data and an ability to monitor communities and species of interest.

An important first step is to document and describe calcified algae: the taxonomy of coralline algae in many parts of the world is poorly understood and without an understanding of the species present, measurement of change and understanding of species-specific responses will not be possible.

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Coralline morphology & anatomy

Growth form

One of the first features we notice when looking at coralline algae in the field is their general external appearance and shape, or growth form. Ten different growth forms have been described for non-geniculate coralline algae, and eight of these occur in New Zealand. These growth forms are illustrated and defined in Figure 6.

The growth form of non-geniculate coralline algae may be described using a single term (e.g., encrusting; fruticose), or may be on a gradient of two or more terms (e.g., encrusting to warty; encrusting to warty to fruticose).

In some cases, growth form is a conspicuous feature of a genus or species – e.g., *Lithophyllum carpophylli*, a New Zealand endemic species, is always foliose in growth form – so growth form can be used with other characters to help in identification. In other cases, growth form is characteristic of a genus, e.g., growth of *Choreonema* is unconsolidated.

But in many cases, a single species may show a large range of growth forms, and many of these growth forms will be shared with other species. The take-home message: growth form is a useful character in coralline algal identification, with limitations.

Note: These terms don't apply to geniculate coralline algae, which grow attached to rocks and other substrate by a crustose base or holdfast. Geniculate corallines are branched, and have alternating calcified and non-calcified segments.

Reproduction

As identification of specimens is based largely on reproductive features, understanding the reproductive cycle of coralline algae is essential. As a starting point, a simplified sexual cycle for non-geniculate coralline algae is illustrated in Figure 7.

Discoid	unbranched, largely unattached discs
Encrusting	flat or wrapping crusts
Fruticose	longer branches, cylindrical to flattened
Foliose	flattened, plate-like branches at various angles (not horizontal)
Layered	flattened branches in horizontal layers (stepped or terraced)
Lumpy	short, swollen lumps, often crowded and joined, not branched
Warty	short, unbranched protuberances
Unconsolidated	"free" filaments, not grouped together in a thallus (see *Choreonema thuretii* species profile)

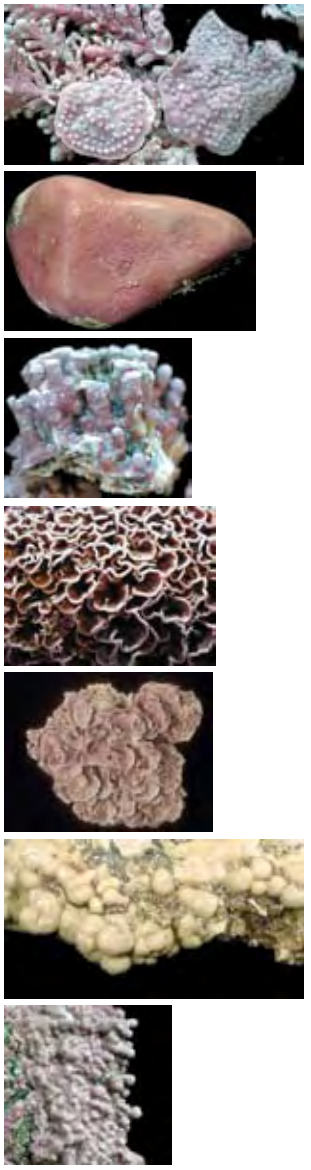
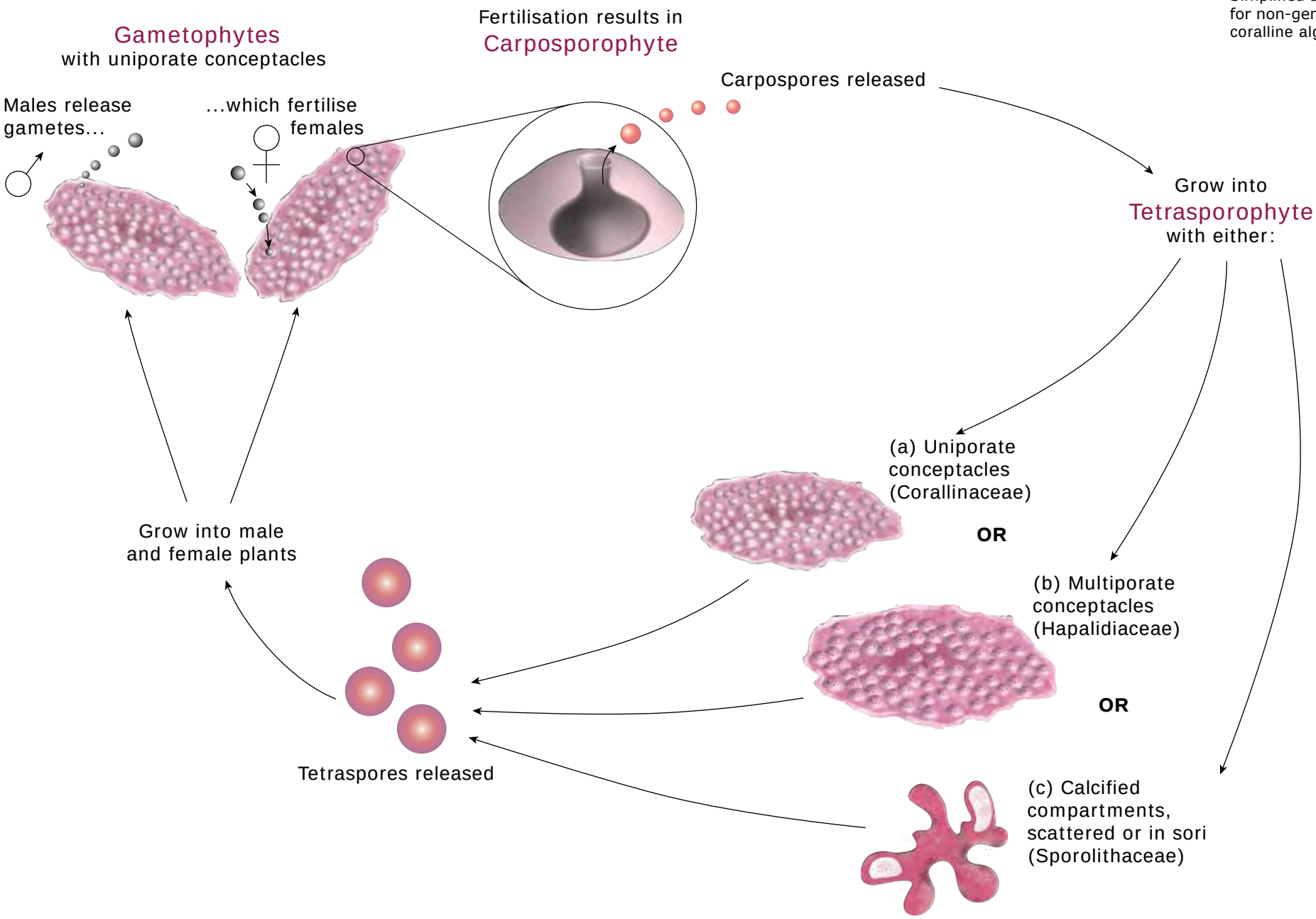


FIG. 6
Growth forms of non-geniculate coralline algae.

FIG. 7
Simplified sexual cycle for non-geniculate coralline algae.



Reproductive structures – basic morphology & anatomy

The type, arrangement and features of reproductive structures are generally critical in identifying coralline algae, and so fertile specimens are required for identification, particularly of non-geniculate corallines. Some basic facts and features of the reproductive structures you might observe are presented in this section. For definitions of terms in this section, refer to the *Glossary*.

Three reproductive structures occur in coralline algae: uniporate conceptacles, multiporate conceptacles, and calcified compartments. These occur as flat or raised structures – warts, pinpricks or pimples up to 1 mm across at largest – which may be visible on the surface of the alga.

REMEMBER:

Males and females **always** occur in **uniporate** conceptacles, for all coralline species.

In coralline algae, male and female gametes and carposporophytes (fertilised females) always occur in uniporate conceptacles. However, the type of reproductive structure holding tetrasporangia, and the arrangement of the tetrasporangia, differs according to family.

Family	Tetrasporangial conceptacles; tetrasporangia	Male, female, carposporophyte conceptacles
Corallinaceae	Uniporate; zonate	Uniporate
Hapalidiaceae	Multiporate; zonate	Uniporate
Sporolithaceae	Calcified compartments; cruciate	Uniporate

The three families that coralline algae belong to, and the features characteristic of each family, are dealt with in more detail in the following chapter, *Coralline taxonomy*.

REMEMBER:

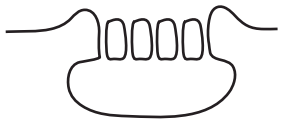
Uniporate conceptacles can contain males or females, or tetrasporangia.

Multiporate conceptacles and **calcified compartments** are *always* tetrasporangial.

Conceptacles and compartments

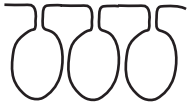
Conceptacles can be uniporate (have a single pore, or opening) or multiporate (have numerous pores, or openings).

uniporate conceptacle



multiporate conceptacle

Calcified compartments can be mistaken for tiny uniporate conceptacles, particularly when they occur scattered across the surface of the thallus. They can also be more tightly clustered in raised bodies called sori.



calcified compartments

Tetrasporangia

Tetrasporangia are divided zonately or cruciately.

zonately divided tetrasporangia

cruciately divided tetrasporangia

NOTE:
Tetrasporangial conceptacles are almost always required to identify a coralline alga to species

Zonately divided tetrasporangia are housed in uniporate conceptacles (family Corallinaceae) or multiporate conceptacles (family Hapalidiaceae). Cruciately divided tetrasporangia are in calcified compartments (family Sporolithaceae). *Tetrasporangial conceptacles are almost always required to identify a coralline alga to species.*

Male and female gametes and carposporophytes

In the coralline algae, spermatangia and carposporangia are always housed in uniporate conceptacles, regardless of family. Carposporophytes also develop in uniporate conceptacles in all families. *In the majority of cases, coralline algae can't be identified to species using only male and/or female reproductive material.* However, in some cases, characters from male or female conceptacles are required, in addition to tetrasporangial material, to identify a coralline to species.

Conceptacles – more detailed features

Figure 8 shows more detailed features of conceptacles and the vegetative cells around them. You can also refer to the TABLE AND KEYS section for a summary of these characters. Some of the identification tools in this guide – in the TABLES AND KEYS section and the SPECIES PROFILES section – refer to these features. You can also refer to the *Glossary* at the back of this guide for definitions. However, we don't deal with them in detail in this identification guide, and readers requiring more detail should seek out the references at the end of this chapter.

These features will be helpful if you intend to look at the contents of conceptacles under the microscope, using either simple or more complex lab methods, which are discussed later in the guide.

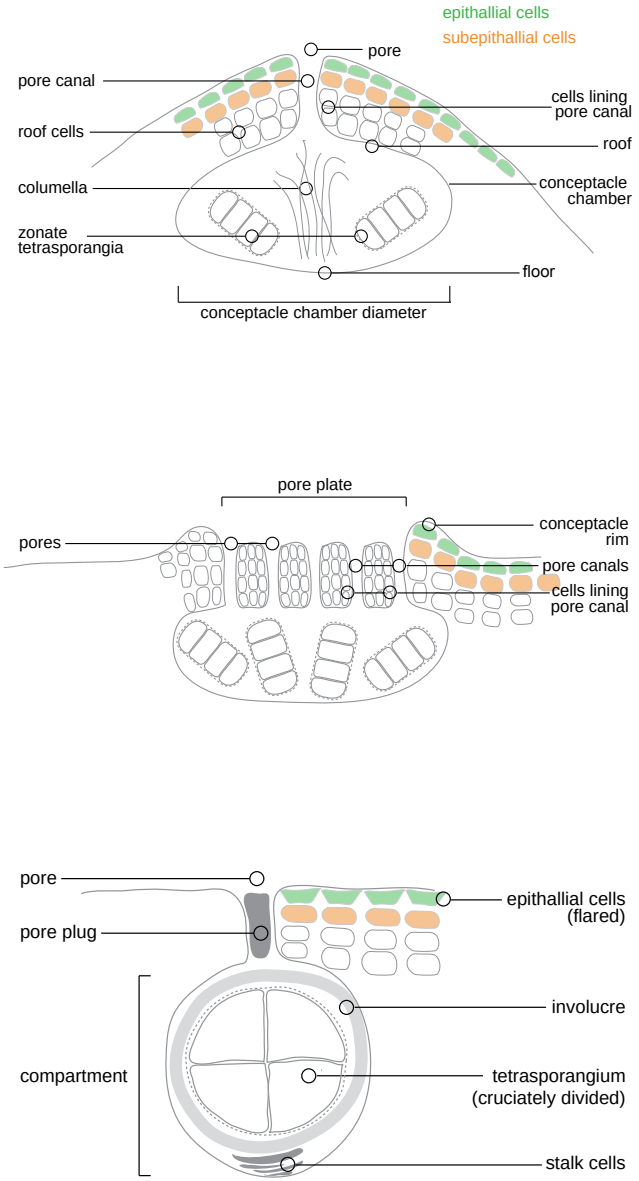


FIG. 8
Schematic of detailed features of reproductive structures in coralline algae. Three reproductive structures occur in coralline algae: uniporate conceptacles (top); multiporate conceptacles (centre); and calcified compartments (bottom). See the *Glossary* at the end of this guide for definitions of terms.

REMEMBER:

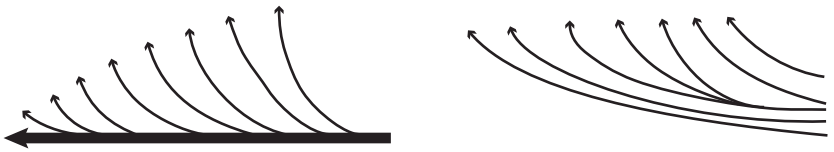
Uniporate conceptacles are illustrated above as tetrasporangial, but uniporate conceptacles can alternatively be male, female, or carposporophytic.

Vegetative characters

Vegetative characters are the features associated with the non-reproductive part of the thallus – the main body of the coralline algal plant. The following descriptions focus on the non-geniculate coralline algal thallus.

Thallus construction

The non-geniculate coralline algal thallus – the main body of the plant – is made up of filaments. Filaments can have a growth pattern, or construction, that is described as either monomerous or dimerous.



dimerous thallus

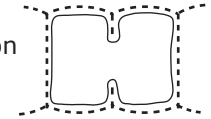
monomerous thallus

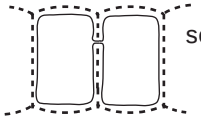
Observing thallus construction usually requires thin sections.

Cell connections

The cells in a filament are joined by primary pit connections.

cell fusion





secondary pit connection

Primary pit connections occur in all coralline algae. The cells in adjacent filaments are joined either by secondary pit connections or by cell fusions.

Cell fusions occur between some (not all) cells in adjacent filaments, while secondary pit connections occur between most (often all) cells in adjacent filaments. Cell connections can usually be determined by preparing a squash of material.

Epithallial cells

Epithallial cells terminate filaments at the thallus surface.

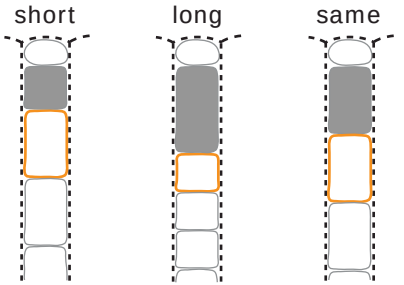
rounded to flattened (not flared) epithallial cells

flared epithallial cells

Epithallial cells are either flared, or rounded to flattened (not flared). Thin sections are usually required to determine epithallial cell shape.

Subepithallial cells

The subepithallial cell is immediately below the epithallial cell in each filament. Their size, relative to the cells immediately below them, is a good character for some taxa.



Subepithallial cells can be short, long, or the same size as the cells immediately *below* them (in orange). Thin sections are usually required to determine relative subepithallial cell size.

For more information:

About coralline anatomy & morphology

HARVEY A.S.; WOELKERLING W.J.; FARR T.J.; NEILL K.F.; NELSON W.A. (2005). Coralline algae of central New Zealand: An identification guide to common 'crustose' species. NIWA Information Series No. 57.

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Coralline algal taxonomy

All coralline algae belong to a distinct order, Corallinales, within the red algae (Rhodophyta). Three families are now recognised within the order: Corallinaceae, Hapalidiaceae, and Sporolithaceae. The evidence supporting this classification comes from both anatomical/morphological studies and molecular analysis, and the separation into three families is relatively recent (see Harvey et al. 2003).

Two of the three families are further divided into subfamilies, according to the schema below:

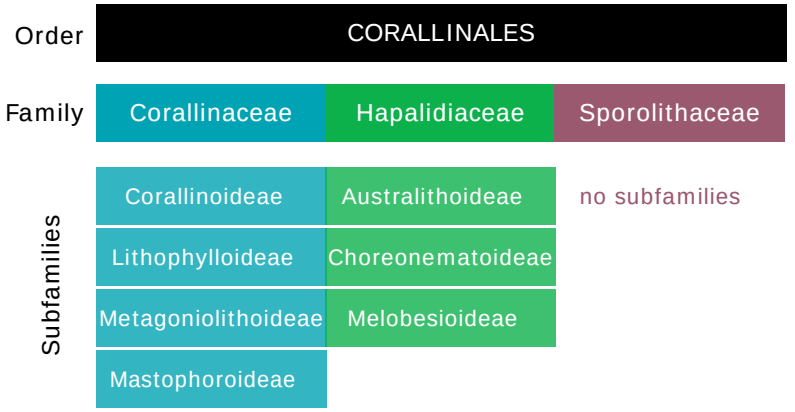

FIG. 9
Families and subfamilies within the order Corallinales (Rhodophyta). Reproduced from Harvey et al. 2005.

In northern New Zealand, we have collected corallines belonging to all three families of Corallinales. Only two subfamilies, Metagoniolithoideae (Corallinaceae) and Australithoideae (Hapalidiaceae), are not represented in our collections from northern New Zealand to date.

The characters diagnostic for each of the families, and for subfamilies found in northern New Zealand, are summarised in *Diagnostic characters table – families and subfamilies*, and the characters used to separate the genera found in northern New Zealand are summarised in *Diagnostic characters table – Genera – Easy features* and *Diagnostic characters table – Genera – Complex features*. These tables are all in the TABLES & KEYS section of this guide. While some of these characters can be observed readily, using some simple procedures (see the chapter *In the lab* for details), it's important to note that many of these characters require specialist techniques and knowledge, usually requiring material to be embedded in resin, and thin sections cut and examined under a compound microscope.

All of the tables and keys in this identification guide are collected together, in the **TABLES & KEYS** section.

Molecular phylogeny

Molecular tools, and particularly DNA sequencing, are essential in modern taxonomy. In studying the coralline flora of northern New Zealand, we have used DNA sequence data in conjunction with morphological characters to understand the relationships between specimens. We can also use these tools to identify specimens that do not have the characters necessary for morphological identification, for instance specimens that are non-reproductive or damaged.

What do DNA sequence data tell us?
Sequence data are really just another suite of characters, and can be used in the same way as morphological characters. A species is understood as a group of organisms that share certain characteristics, and can interbreed. When we cannot test interbreeding directly, we infer membership by looking at the characters of the specimen. If it is grey, large, and has a trunk, it is probably an elephant, even if we cannot get it to produce a baby elephant. And if DNA sequence data from it are the same as or very similar to that from other elephants, we can also say "this is an elephant". This approach is not so useful for a whole elephant, perhaps, but it becomes useful if the source of the DNA is a bone, or a pile of dung.

For our study of the coralline algae, we have used sequence data from two particular genes from two cellular compartments – the ***psb*A** gene, which is located in the plastid and codes for the D1 protein of photosystem 2, and the **nSSU** gene, which codes for the small subunit ribosomal RNA and is located in the nucleus. We used these genes for our original study of the coralline flora of central New Zealand (Broom et al. 2008, Harvey et al. 2005). These two genes vary at different rates – *psb*A tends to be more variable while the nSSU changes only slowly. By using two loci we can check our results, and we can also take advantage of sequences already available in the international DNA sequence repository GenBank (http://www.ncbi.nlm.nih.gov/Genbank/index.html). At the time of writing, these are mostly nSSU sequences.

Because *psb*A is more variable, it is common for *psb*A sequences from different members of the same species to vary slightly. Where one specimen has a 'T', another might have a 'C'. This is less common for nSSU sequences, although not impossible. Changes in DNA sequences (natural mutations) can occur more or less at random, so logically there will be occasions on which two specimens have different DNA sequences at these loci even though one is the offspring of the other – but these events are rare.

How is it done?
Methods for extracting DNA from Corallinales taxa are now relatively straightforward (Broom et al. 2008 and others). Often the most difficult part is separating the alga from the substrate (we use a hammer and chisel if necessary!). The polymerase chain reaction (PCR) enables us to make millions of copies of the stretch of DNA we want to examine, which can then be sequenced.

Having obtained a sequence, we then compare it to sequences already obtained from New Zealand specimens using BLAST (Basic Local Alignment Search Tool, http://www.ncbi.nlm.nih.gov/blast/, Altschul et al. 1990). This tells us how similar the new sequence is to the existing most similar sequence. From this we have our first indication of whether or not we have sequenced a member of this species before. As more sequences are obtained, they are examined using phylogenetics programs to reconstruct relationships between them. This is an attempt to infer a 'family tree' of the sequences. These kinds of analyses are always an estimation procedure, since we have only a few sequences, and only sequences from members of taxa alive today, but they can be very informative about the evolutionary history of the group. Methods for phylogenetic reconstruction are changing and improving all the time. Sometimes firm answers are possible, and sometimes not. Support for a group is often indicated on a phylogenetic tree as a percentage value to the left of the group – 100 meaning confidence in the real existence of this group is very high, and support between 50 and 70 meaning the evidence is not strong, but it is worth considering the possibility that a real relationship exists.

Clarifying species boundaries
If sequences differ by more than 2 or 3 nucleotides (for nSSU) or more than 10 or so nucleotides (for *psb*A), experience has taught us that the specimens are probably not conspecific – that is, not from the same species. We know this through having compared sequences from specimens that we are sure are members of different species.

If variation is less than this, we need to look carefully at all the information available to make a decision about whether we are looking at one species or more. For instance, specimens of geniculate coralline algae belonging to the genus *Corallina* have almost identical *psb*A and nSSU sequences, but show several distinct morphologies. These seem to be a set of species that have diverged from one another relatively recently, and have not yet accumulated many differences in the *psb*A and nSSU genes. To distinguish taxa within this genus, we use an additional marker developed by us, the *psb*A-*trn*L spacer. This piece of DNA lies next to the *psb*A gene and is at least as variable as that gene. When we add sequence data from the spacer into the analysis, we can see that there are in fact several distinct sequence groups, which correlate with morphological groups. We consider that each of these is a separate species. This is a good example of how sequence analysis and morphological

analysis can be used together to understand what is really in front of us.

Some groups of taxa in the New Zealand flora remain unclear with the markers we have used. This is perhaps inevitable in a first study of this kind. A more variable marker or set of markers will be required to clarify taxonomic boundaries within the *Mesophyllum/Synarthrophyton/Phymatolithon* group, for instance.

Assigning names

A DNA sequence on its own cannot help us decide what species name to assign to a specimen. However once a sequence has been firmly anchored to a currently accepted name, we can be more confident about using sequence data to identify specimens. To do this we have obtained sequence data from specimens that conform to currently accepted species descriptions, and which are lodged in the Te Papa herbarium. It is essential that the actual specimens remain available for future researchers to access, so that if the understanding of that species changes, the specimen can be re-examined in the light of new knowledge.

Higher order relationships

Using both *psb*A and nSSU also has the advantage that we can look at relationships between families within the order. Our studies have shown that the three familes within Corallinales – Sporolithaceae, Hapalidiaceae, and Corallinaceae – are supported by an analysis using data from both *psb*A and nSSU combined. We have also identified a New Zealand specimen which does not fit into either of these three families; its relationships and identity are the subject of future work.

Results

Figure 10 shows the phylogenetic tree resulting from one analysis of the molecular data from this project. We've used this tree throughout the guide to illustrate phylogenetic relationships. For the technically inclined, this is a maximum likelihood phylogram showing support under 1000 bootstrap replicates. Numbers indicate percentage support for the group directly to the right of that number.

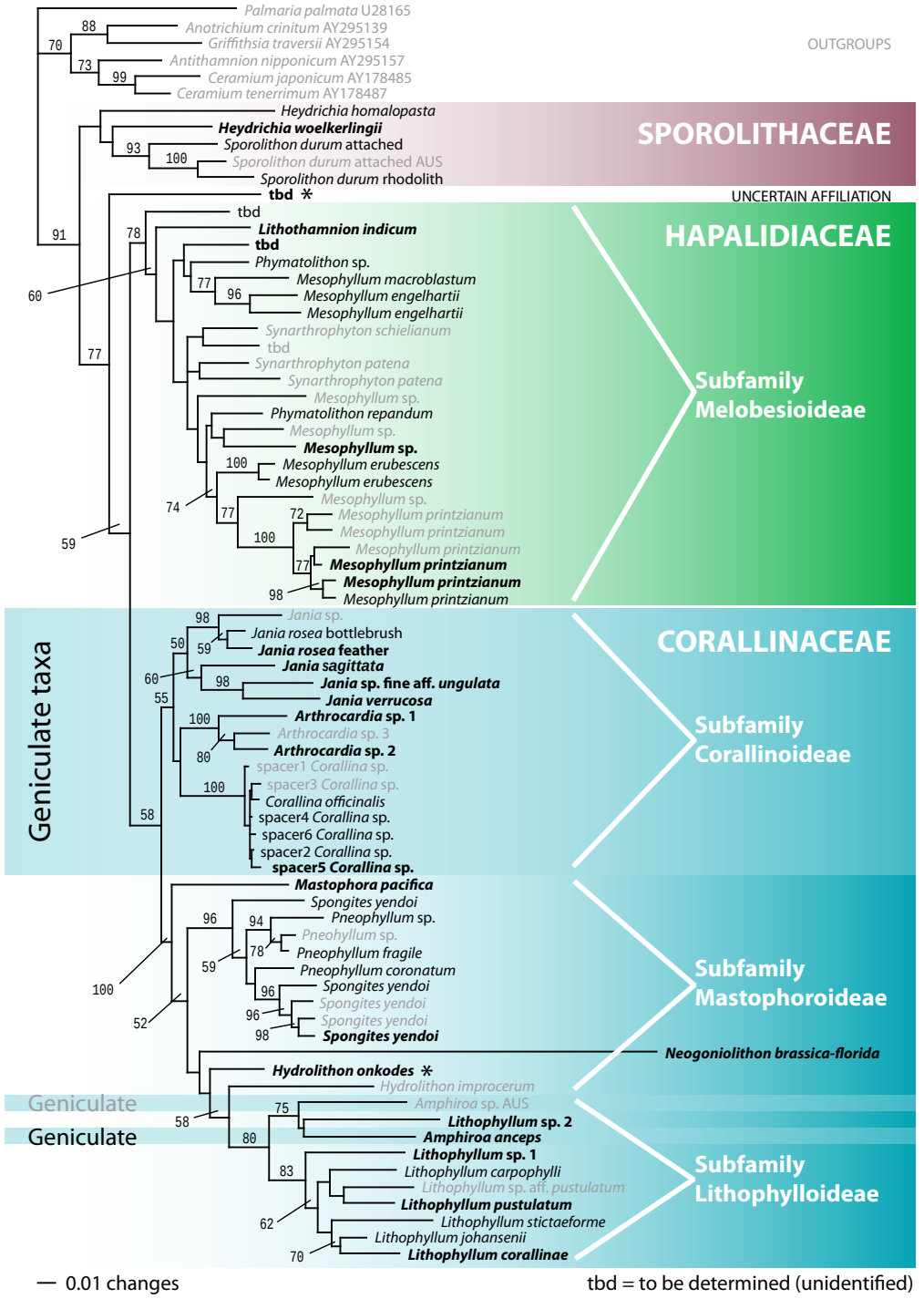

FIG. 10 *opposite*
Phylogenetic tree.

Where to from here?

Our studies have taken us a long way further in our understanding of the New Zealand flora, but have also raised a number of questions. It is clear that the New Zealand flora is rich, with many species, and also diverse, with species from all the currently recognised families in Corallinales. The application of names is not always clear. Relationships and species boundaries within *Mesophyllum/ Synarthrophyton*/*Phymatolithon* and within *Spongites* are at present unresolved, and additional, more variable markers are required to detect the genetic discontinuities that point to genus and species boundaries within this group.

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FELSENSTEIN J. (2004). Inferring Phylogenies. Sinauer Associates, Inc., Sunderland, Massachusetts.

HARRISON C.J.; LANGDALE J.A. (2000). A step by step guide to phylogeny reconstruction. *Plant Journal 45*: 561-572.

SWOFFORD D.; OLSEN G.; WADDELL P.; HILLIS D. (1996). Phylogenetic Inference. In: Hillis, D., Moritz, C., and Mable, B. (Eds.), Molecular Systematics. Sinauer, Sunderland, MA, pp. 407-514.

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HARVEY A.S.; WOELKERLING W.J.; MILLAR A.J.K. (2002). The Sporolithaceae (Corallinales, Rhodophyta) in south-eastern Australia: taxonomy and 18S rRNA phylogeny. *Phycologia 41*: 207–227.

VIDAL R.; MENESES I.; SMITH M. (2003). Molecular genetic identification of crustose representatives of the order Corallinales (Rhodophyta) in Chile. *Molecular Phylogenetics and Evolution 28*: 404-419.

In the field:
looking for & collecting corallines

At the shore

The first coralline species you will encounter as you walk down an intertidal rocky shore are geniculate corallines in high intertidal pools, forming a stiff grey/pink fringe around the edge, just under the water line. If you look more closely you will also see pink/grey crusts of non-geniculate species lining these pools.

As you go down to the mid and lower intertidal shore, there are a greater variety of habitats where corallines can be found. Coralline algae are rarely seen on open rock faces that will bake in the sun at low tide – they are much more likely to be in channels or shaded crevices, along rock walls or under overhanging surfaces, as well as being found under a curtain of attached fleshy seaweeds.

FIG. 11
Coralline algae on rock walls and in crevices, under a curtain of attached fleshy seaweeds.

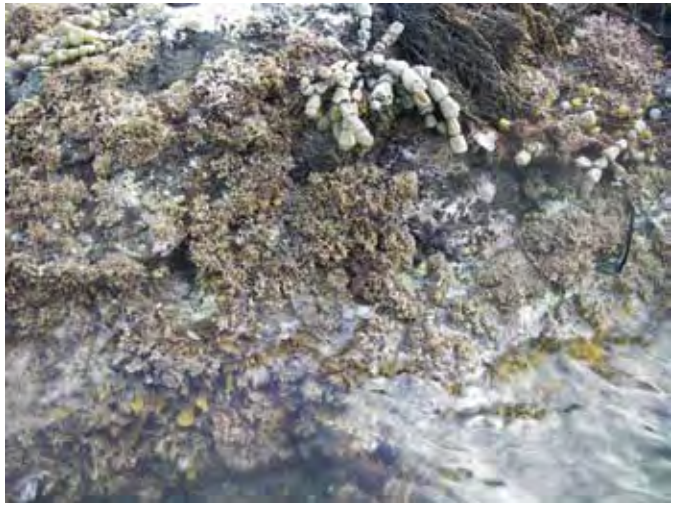
FIG. 12
Intertidal/upper subtidal shore in northern New Zealand, with abundant and diverse coralline algal flora.

FIG. 13
Non-geniculate coralline alga growing epiphytically on brown alga *Carpophyllum*. The coralline is a very thin, encrusting species, and appears as an almost luminescent coating on the brown alga.

FIG. 14 *Below*
Coralline algae growing epizoically on the shell of paua, *Haliotis iris*.

As well as growing on rock (epilithically) they are also found as epiphytes (on other seaweeds or seagrass) or epizoically (on animals, for example on gastropod shells). Sometimes these epiphytic and epizoic species are hard to see as they form just a very thin icing–like layer on the other species – but in most cases they are very obvious, growing as conspicuous lumpy layers or as erect branches. Most paua shells have coralline algae growing on them – which often makes a very effective camouflage and means they are hard to see against the coralline-covered rock faces.

FIG. 15
Geniculate corallines in short, dense turfs in the intertidal. The coralline turfs form a stiff, grey/ pink fringe to intertidal pools.



Some geniculate corallines grow in dense turfs, a few centimetres in height, with densely-branched stiff axes or stems. Sometimes these occur in pools, while other turfs are found in the mid to lower intertidal shoreline. These densely-branched coralline algae retain more moisture at low tide than neighbouring rock surfaces, providing a distinct microclimate for other intertidal dwellers. The many nooks and crannies created between the coralline branches provide a great array of habitats for small invertebrates, and the turfs also provide surfaces for both microalgae and small fleshy seaweeds to settle and grow.

FIG. 16
Three or more species of geniculate corallines growing together in the low intertidal.

In the subtidal zone both geniculate and non-geniculate species tend to have brighter and stronger colours, less bleached by sunlight. Geniculate corallines are often longer and less turf-like than in the intertidal. In some places non-geniculate coralline algae cover a very high percentage of the rock surfaces. Many other species may attach to or grow overhanging the corallines, but the primary cover on the surfaces is made up of a mosaic of crusts.

FIG. 17
A mosaic of non-geniculate and geniculate coralline algae growing subtidally, associated with bright orange sponge, and fleshy macroalgae.

Non-geniculate coralline algae used to be referred to as "pink paint" or *Lithothamnion* or *Lithophyllum* crusts. These terms lumped together a wide diversity of different crustose species, and ignored differing ecology and behaviour of different species. Areas with a high coverage of encrusting coralline algae have often been refered to as "barrens", a clear misnomer for what can include a high diversity of species of coralline algae.

Unfortunately, we still know very little about the ecology of individual species of coralline algae in New Zealand. It is clear that some species are more tolerant of wave exposure than others and will be found in areas that experience the full brunt of wind and wave action. Some species are found only subtidally, possibly because they are unable to cope with the high light conditions of intertidal shores, or possibly because they cannot tolerate even short periods of desiccation at low tide. Other species are able to grow in the widely varying conditions of the intertidal shore and are apparently able to compete with other species also colonizing these habitats.

In the profiles in this guide we have provided habitat notes about where we have found each species. These habitats

may not represent the full range of habitats possible for the species in question, but will at least give an indication of where they are confirmed to grow. We have also provided information about the characteristic morphology of the species based on measurements of the specimens we have found. There may be greater variation in size and growth form which will only be understood as more becomes known about the full range of habitats and geographical distribution. In particular, we have not yet studied the coralline algae of particular species of southern New Zealand.

How we collected coralline algae for this project

Preparing for a coralline algae field trip can seem more like preparing for a geology than a phycology field trip – the structure and growth of these organisms raises challenges in their collection, preservation, preparation, and storage compared with fleshy seaweeds, which can simply be pressed onto paper for archival preservation. We outline here our collecting process.

FIG. 18
Collecting coralline algae in the intertidal, using a hammer and chisel.

Let's assume that you want to discover the maximum diversity of species occurring at a particular field site. Decide on a collecting strategy to cover the diversity that is immediately apparent – e.g. working on the lowest tides each month (spring tides), you might follow the tide out, starting high on the shore, then working down to the upper subtidal. Collect from different habitats: rock pools and channels; high turfs; within and fringing pools. Collect loose pebbles and cobbles, as well as chiselling off epilithic species from rock walls and platforms. Collect the highest epilithic "pavement", which can be bleached to lilac or almost white in colour. Keep an eye out for epiphytes, as well as epizoic species.

It's likely that you will be able to see algal fertility – although not the details – with the naked eye, or a hand lens. Ideally, photograph each sample as you collect it, and link the photograph with the sample if possible. You may be able to see (and record) details of fertility using the macro function on your camera.

Ideally, collect each separate sample into a separate bag – although another approach is to collect all corallines into one collection bag, and sort them later, even after they have been in formalin for some time (for methods of preserving coralline algae, see the chapter *In the lab*). If you collect separately, you can link samples to field notes and photographs.

Each sample will be growing in a particular habitat and will have some feature – colour, growth form, branching, substrate, fertility – which seems to distinguish it from other coralline algae growing at the site. For example, on a single rock wall (same habitat) there might be a mosaic of encrusting corallines with clearly-defined edges, differing colours and textures, and different fertility. Each of these could be collected as a separate sample.

Or, you might collect a coralline which seems to be the same or a similar species, but is growing in two different habitats or zones at a site. You might collect "A" from high rock pools, and "B" from upper subtidal channels at a site, and determine later that they seem to be the same species. Confirming both collections from different habitats at a site though may have given you information about the abundance of the species, about the range of habitats it can grow in, and perhaps about subtle variation within colour or growth form.

Notes made in the field can be invaluable, but it can be some time before they are re-examined. Make field notes as descriptive as possible, link notes to samples wherever possible, and review your field notes as soon as possible after your field trip.

Samples should ideally be placed, loosely-packed to avoid physical damage, in a chilly bin with ice or chiller-packs for transport, and can generally be stored in a fridge or cold chilly bin for up to 24 hours before sorting and preserving. However, even with the best treatment, some samples will start to deteriorate. If your samples start to smell, or turn a bright/deep orange in colour, they are going off. The more quickly they are processed, the better, particularly to avoid deterioration of DNA, and we recommend processing into preservative within 6 hours from collection. For methods of preserving coralline algae, see the chapter *In the lab*.

As a less ideal alternative – for example, if at sea or travelling on land without access to space to sort, sample, and preserve specimens – samples can be preserved on the spot. Details are provided in the following chapter for preservation in either formalin or silica gel.

In the lab:
preserving & identifying corallines

Identifying samples using this guide

All of the tables and keys in this identification guide are collected together, in the **Tables & keys** section

Once you have collected a coralline alga, you can attempt to identify it using this identification guide. In this chapter, we provide a step-by-step guide to identifying coralline algae. We have collected all of the tables, keys, and information sheets that we refer to in this chapter into one section, Tables and Keys, for easy reference.

The basic workflow for identifying a coralline alga is much the same as it is for any collection of macroalgae, or indeed any organism. Follow the steps in WORKFLOW TABLE 1, over the page, to:

1. Split your collection to single species, where possible
2. Determine which FAMILY it belongs to
3. Determine which SUBFAMILY it belongs to
4. Determine which GENUS it belongs to
5. Determine which SPECIES it belongs to
6. Preserve and keep a voucher

It will not be possible to identify every collection you make to species, particularly when you're dealing with coralline algae. You can increase your chances of identifying material to species by collecting judiciously, and handling, processing, and preserving material appropriately. And as already stressed, you are unlikely to be able to identify non-geniculate coralline algae unless you have fertile material with good, intact reproductive features.

In our studies, we have used a combination of direct observation, complex lab techniques to determine anatomical characters (embedding samples in resin and cutting thin sections for examination under light microscope), and molecular analysis (DNA sequencing) to arrive at identifications for our collections. Even with this multi-pronged, expert approach, we still find that as much as 25% of collections made may be unidentifiable for one reason or another.

FIG. 19
Identifying coralline algae during a workshop. Tools of the trade include a good identification guide, dissecting microscope, forceps, razor blades, and microscope slides.

You should also be aware that if the coralline you have collected is not one of the species included in this guide, it won't key out correctly using the various tools we've provided here. That is, you may get an answer, but it won't be the right answer. Be aware too of forcing an identification to species when you don't have sufficient information. It may be that, with the material you have collected and the techniques available to you, you can only determine a collection to genus, or even only to subfamily or family.

We particularly urge you to retain vouchers of material you have collected, particularly if this has been identified for use in research or other publications. In this chapter, we give guidelines for storing and preserving coralline algae. If you retain a voucher specimen of material you have collected and used, it can always be referred back to for checking, confirmation or amendment of its identification. We recommend depositing voucher specimens in a registered herbarium.

Refer to the section *Sorting and preserving samples* at the end of this chapter for recommendations on sorting and preserving.

Workflow

We have provided the following **Workflow Tables** to guide you through the process of identifying your coralline algal samples. As you gain experience, you'll determine your own particular workflow, but we recommend you follow this guide initially.

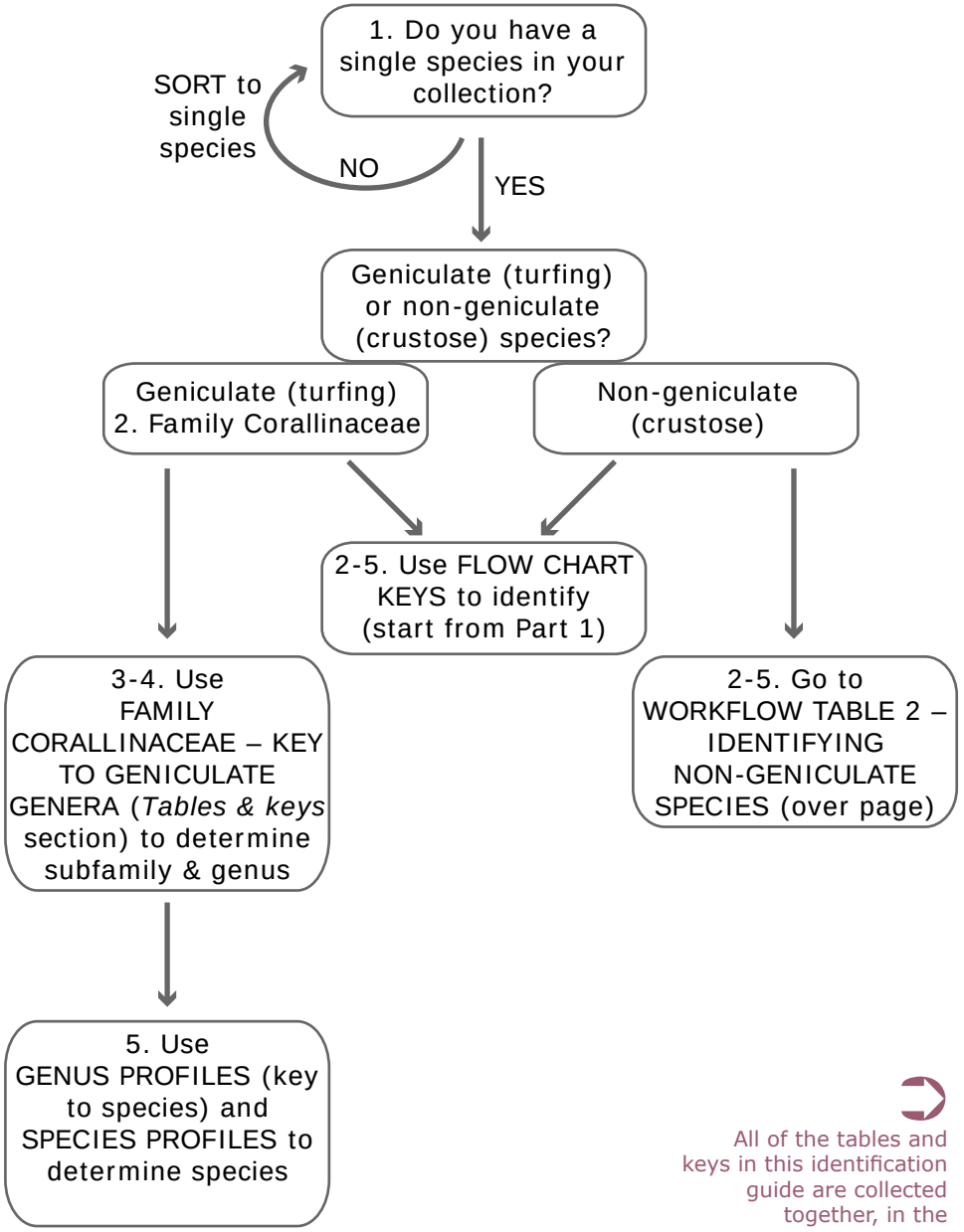
Workflow Table 1 (opposite) is your starting point. It directs you to one of two processes:

Systematic – go through a narrowing taxonomic progression from family and subfamily, down through genus, and finally to species. For geniculate samples, you're directed to tools in the TABLES AND KEYS section. For non-geniculate samples, you're directed to WORKFLOW TABLE 2, which directs you to a range of tools, including tabular, dichotomous and graphic keys. If this is a top-down approach, then the alternative is...

Bottom-up – by-pass the strictly systematic approach, and use our FLOW CHART KEYS for a more visual approach. The keys are designed to allow you to eliminate options, one character at a time, and they focus primarily on characters that are directly observable, or can be determined using simple lab methods.

Use whichever approach suits you. You may be limited by the facilities available to you, by time, or by your level of experience. Regardless, the variety of methods and approaches we give in this guide should enable you to go at least some way towards identifying the coralline algal samples you collect from northern New Zealand waters.

Workflow table 1



All of the tables and keys in this identification guide are collected together, in the **Tables & keys** section.

In order to:	Use these references/tools:	Section	Use this action/method:	Note:
1. Split collection to single species	Simplified taxonomic features – General & non-geniculate Simplified taxonomic features – Conceptacle details Growth form Life cycle	Tables & keys Tables & keys Introduction Introduction	Directly observe collection by eye or, preferably, using a hand lens or dissecting microscope.	Observe reproductive features (conceptacles, calcified compartments), growth form, substrate, etc.
2. Determine to FAMILY	Diagnostic characters – Families & subfamilies Families – Key to genera (contain key characters for family)	Tables & keys Tables & keys	Directly observe collection by eye, hand lens, or dissecting microscope. To determine contents of uniporate conceptacles, a simple squash may be sufficient (see *Simple lab methods for identification*, over page).	Reminder (tetrasporangia): Corallinoideae: zonate/uniporate Hapalidiaceae: zonate/multiporate Sporolithaceae: cruciate/calcified compartments **Note: uniporate conceptacles may not be tetrasporangial; they may be male or female.**
3. Determine to SUBFAMILY	Diagnostic characters – Families & subfamilies Families – Key to genera (contain key characters for family)	Tables & keys Tables & keys	To determine cell connections, contents of conceptacles, and other features, a simple squash may be sufficient (see *Simple lab methods for identification*, over page).	
4. Determine to GENUS	Families – Key to genera (dichotomous keys to genera) Diagnostic characters – Genera – Easy features (tabular) Diagnostic characters – Genera – Complex features (tabular)	Tables & keys Tables & keys Tables & keys	Directly observe collection by eye, hand lens, or dissecting microscope. Use simple lab methods (decalcify and squash, examine slide under light microscope) (see *Simple lab methods for identification*, over page). More complex methods may be required (embed in resin and cut thin sections; refer to Harvey et al. 2005) – or contact an expert.	Reminder: It may not be possible to identify your sample to genus.
5. Determine to SPECIES	Genus profiles – Keys to species (dichotomous & graphic) Species profiles – List characters and show images for each species	Species profiles Species profiles	As above.	Reminder: It may not be possible to identify your sample to species.
6. Keep a voucher	*Sorting and preserving samples*, end of this chapter	Introduction		It is critical to keep material you have identified so that it can be referred to in the future, and its identity checked, confirmed, or amended. Preferably, lodge vouchered herbarium specimens with a registered herbarium.

Simple lab methods for identification – decalcify & squash

A concise version of the simple lab methods described in Harvey et al. 2005 are provided here. This method uses an accessible range of chemicals, microscope slides, and a light microscope to prepare temporary slides of whole mounts of decalified, squashed coralline algae. It is then possible to observe vegetative and reproductive features which can't be determined by direct observation of the material.

Many features can be seen, with patience and experience, using these simple methods. But for some diagnostic features, and for some specimens, more complex lab methods are required. These involve embedding decalcified coralline material in resin, and cutting thin sections for microscopy. The method for this is detailed in Harvey et al. 2005, and is not included in this guide.

Chemicals and equipment

NOTE:
Take appropriate precautions when handling chemicals and equipment, and only use chemicals or equipment after appropriate training. Ask your lab manager or health and safety officer if you are unsure.

For picking samples to squash:
dissecting microscope or hand lens
light source
single-edge razor blades (or craft knife)
small glass or plastic vials
fine forceps
drip tray

For slides:
microscope slides and coverslips
pipettes or dispenser bottles
tissues or paper towels
compound (light) microscope

Decalcifying solution:
Dilute acid is required to decalcify coralline fragments before they can be squashed on a microscope slide.

Nitric acid decalcifying solution (0.6 M nitric acid)
Slowly add 27 ml of 70% nitric acid to 1 l of water. Gently swirl to mix. (**Note**: Concentrated [70%] nitric acid is extremely corrosive. It must be handled and stored safely, using personal protective equipment and a fume hood. The decalcifying solution, at 0.6 M, can be handled safely on the benchtop.)

Alternative decalcifying solution
For those without access to nitric acid, or to avoid handling extremely corrosive nitric acid stock, household vinegar (a dilute acid) may be used as a decalcifying solution. As acidity levels will vary, decalcification times may vary.

Staining solution:
Acid blue stain
Add 1 g of stain powder (either aniline blue water soluble [acid blue 22] or methyl blue [acid blue 93]) to 100 ml distilled water. Slightly warm the water and stir to help the stain dissolve.

Alternative stain
Green or blue food colouring works as an alternative to acid blue stains. As the amount and type of dye in food colourings vary, staining times and effects will also vary.

Method

1. Pick off samples.
- Pick pieces of coralline, usually 4–10 mm in size, with whole, intact conceptacles or calcified compartments. Place fragments in small labelled glass or acid-resistant plastic vials.

Thin epiphytes: cut off piece of host, with coralline attached, using razor blade or knife.

Corallines on rock or shell, thicker epiphytes: detach coralline from substrate using fingers, small chisel, or razor blades, as required.

2. Decalcify fragments.
- Add 1–2 ml of decalcifying solution, to generously cover each specimen. Bubbles will start to form and rise.
- Leave coralline in decalcifying solution until gas bubbles cease forming. This may take less than an hour for thin material, and 2 to 3 hours or more for thicker fragments.
- Change the decalfying solution every 1–3 hours, as required. A lack of gas bubbles can mean that the coralline has "used up" all of the acid available, so always replenish with fresh acid for a few minutes and confirm that no more bubbles form before assessing a sample as decalcified.
- Remove acid from the vial with a pipette or suction device, and rinse gently with water.

3. Make slide(s), and observe under microscope.
Some features can be seen easily without staining, while others may require staining. Be patient, observe carefully, and allow for variations in appearance – things won't always look exactly as they do in the images in this guide!

Whole mounts – show where and how many conceptacles
- Place whole specimen on a slide
- Add water and a coverslip
- View under microscope
- If staining required, add staining solution to fragment for 5–30 seconds or more, then prepare whole mount.

Squash – to observe contents of conceptacles

- Determine where conceptacles are either by preparing whole mount, or by directly observing under dissecting microscope.
- Place fragment with conceptacles on microscope slide
- Add water and coverslip
- View under microscope
- Find conceptacles on the slide and squash by pressing gently but firmly on the coverslip with forceps or a pencil – the blunt end of a pencil works best.
- Stain if required (as for Whole mount).

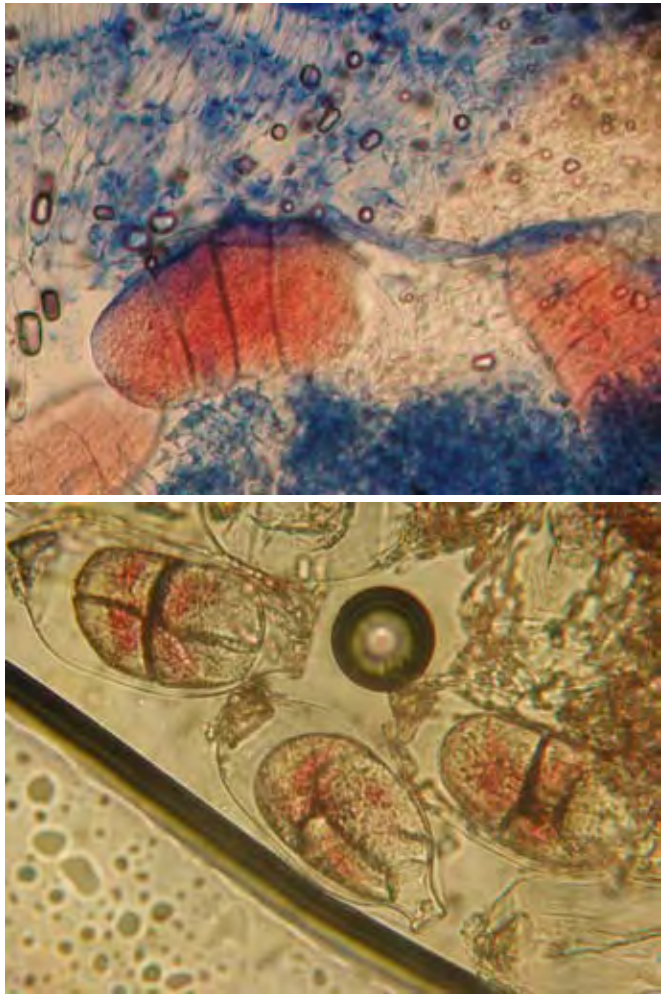


FIG. 20
Cell contents can be determined using simple lab methods. Zonate tetrasporangia (top) and cruciate tetrasporangia in calcified compartments (below), observed using squash method (methyl blue stain in top panel; no stain in lower panel).

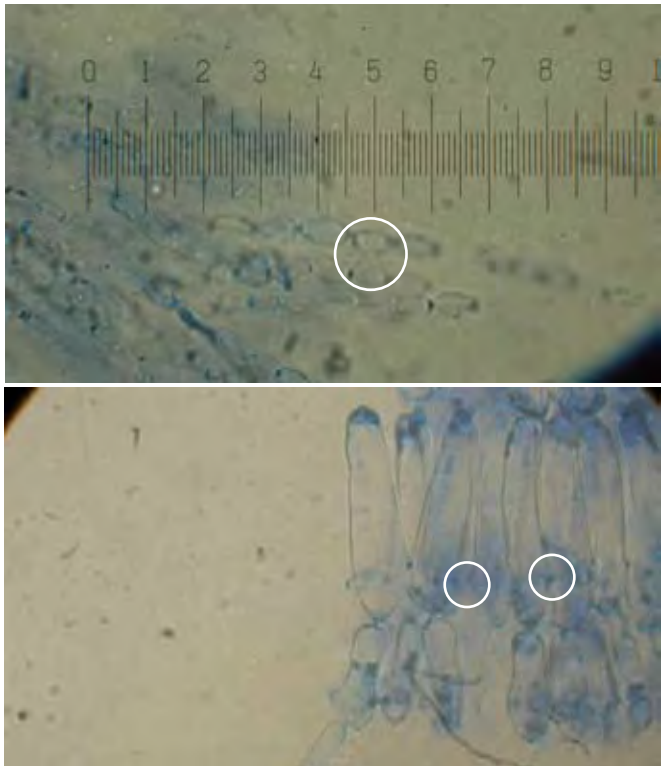


FIG. 21
Cell connections can be determined using simple lab methods. Cell fusions (top, circled) and secondary pit connections (below, circled), observed using squash method (methyl blue stain).

Squash – to observe cell connections

Cell connections are best viewed in side view (not surface view), and should be one cell thick for best results.

- Place specimen on a slide with water and a coverslip, and roll the thallus on its side as you squash it to one cell thick.

OR

- Make thin sections of the thallus first, using a razor blade and slicing along the thallus as thinly as you can, then place these sections on their side on a slide with water a coverslip, and squash to one cell thick.
- Stain if required.

Scrape thin corallines

Thin corallines growing on rock or macroalgae can be scraped directly off the substrate using a razor blade, the scrapings placed on a slide with water and a coverslip, and viewed under the microscope, with or without staining.

Sorting and preserving samples

This section is an overview of methods for sorting and preserving samples of coralline algae. Use this guide in conjunction with the previous section, *Identifying samples using this guide*.

Sort
Determine whether your sample seems to be all one species – for example, pebbles, cobbles and shells (even very small ones) are often covered with a mosaic of species. If your sample isn't completely (or mostly) made up of what appears to be one species, then it will need to be split into single-species specimens, or perhaps even discarded.

Observe & note
Ideally, take notes on each specimen as you observe it. Photographs are useful, and should always be linked in notes with the specimen they represent.

Examine each specimen for reproductive structures/fertility. This can be done using a hand lens and good lighting, but a dissecting microscope with a light source is preferable. Use the tools in this guide, including the TABLES AND KEYS and *Glossary* sections, for descriptions of features.

Subsample
Subsample reproductive regions for anatomy – if there are several types of fertility (multiporate and uniporate conceptacles, for example), sample both. A small (1 cm across) fragment of fertile material is sufficient for an experienced worker to process for sectioning for anatomical identification, but more (say 2–3 cm across) may be useful. Subsamples for anatomical work can be preserved in formalin for 1 day to several months, then rinsed and preserved long term in glycerol/ethanol storage solution. Alternatively, for immediate identification by simple lab procedures, place the specimen directly into decalcification solution.

If the specimen is to be sampled for molecular analysis, take a sample (where possible) from adjacent to the anatomy subsample, and place it immediately into a small square of Chux cloth or nappy liner, place in a tube or plastic bag, and add indicating silica gel beads to quickly dry the sample. Alternatively, samples for molecular analysis can be placed in 95% ethanol.

FIG. 22
Coralline algal collections being rinsed of formalin preservative, prior to storage in glycerol/ethanol storage solution. Each collection is labelled, and retained in a separate plastic basket for rinsing.

Method	Preserves anatomical features	Allows sampling for DNA	Toxicity (X) or safety (✓)	Disadvantages	Advantages
Formalin	✓✓✓	X	XXX	Corrosive; can't be sampled for molecular afterwards	Anatomical features preserved best
Silica gel	✓	✓✓✓	X	Anatomical features dry and may be hard to determine	Fast drying is best to allow sampling for molecular analysis
Ethanol	✓	✓✓✓	XX	Flammable; anatomical features dry and may be hard to determine	Dehydration is best to allow sampling for molecular analysis
Air dry	✓	✓	✓✓✓	Anatomical features dry and may be hard to determine; Slow drying may result in breakdown of DNA, so not ideal for molecular analysis	No chemicals or equipment required

Voucher
The remainder of the specimen should be retained as a voucher for the collection. The voucher can be preserved by:
(a) placing in formalin for 1 day to several months, then rinsing until formalin-free, and storing long-term in glycerol/ethanol storage solution (1:7:2 glycerol:ethanol:water); **OR**
(b) placing in a nappy liner in a bag with sufficient indicating silica gel beads to effect rapid drying; **OR**
(c) air drying, preferably out of direct sunlight (to better preserve colour).

Note that coralline algae can be preserved in any of these three ways at the time of collection, without subsampling for anatomical or molecular analysis, and even without any pre-sorting of samples for fertility or similarity. However, the disadvantages and advantages of each method of preservation are listed in the table above.

For long term storage, ideally samples should be stored in a cool, dry environment, out of direct sunlight, and with collection information (or at least a specimen identification number or code) clearly and permanently attached to the specimen.

References

HARVEY A.S.; WOELKERLING W.J.; FARR T.J.; NEILL K.F.; NELSON W.A. (2005). Coralline algae of central New Zealand: An identification guide to common 'crustose' species. NIWA Information Series No. 57.

For more information:

About preserving and identifying corallines

WOELKERLING W.J. (1988). The coralline red algae: an analysis of the genera and subfamilies of nongeniculate Corallinaceae. London and Oxford. British Museum (Natural History) and Oxford University Press. xi + 268 p.

Tables & keys

Tables & keys

Introduction to tables & keys

This section of the identification guide collects the various tables and keys you can use as tools and references to assist you as you examine and identify coralline algae using this guide.

We've organised this section of the guide so that you can follow it through the identification process. First, the **Workflow Tables** are repeated from the *In the lab* chapter. Then we've collected a range of **cartoons or schematics showing anatomical and morphological features** of coralline algae in three layouts.

Following this, tables and keys work systematically down from family and subfamily to genus level, with tables showing **diagnostic characters**, and layouts summarising **key characters** for families and presenting **dichotomous keys** to genera within them. You'll use these tables and keys if you utilise a 'top-down' or systematic approach to identifying coralline algae.

Finally, there is the four-part **Flow chart key**. You can use this for a 'bottom-up' approach to identifying coralline algae.

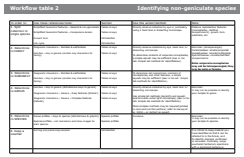
Over the page, you can find an index to the tables and keys in this section of the guide.

We recommend that you read the INTRODUCTON TO CORALLINE ALGAE section at the start of this guide before trying to use these tables and keys. In particular, you're likely to use this TABLES & KEYS section in conjunction with the section *In the lab: preserving and identifying corallines*. You might also find it useful as you work through the SPECIES PROFILES in the guide. Use the illustrated *Glossary* at the end of the guide to find definitions of terms used.

Index to Tables & keys

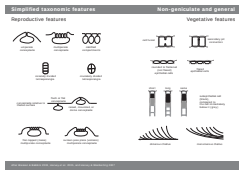
Workflow table 1

Workflow table 2

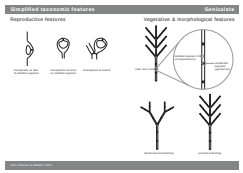


Simplified taxonomic features

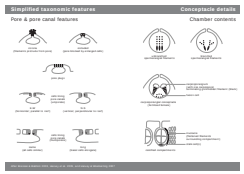
Non-geniculate & general



Geniculate



Conceptacle details

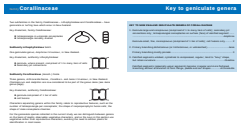


Diagnostic characters table

Families & subfamilies

Keys to genera within families

Corallinaceae (geniculate)



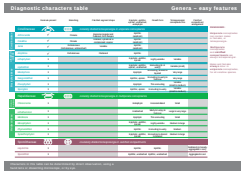
Corallinaceae (non-geniculate)

Hapalidiaceae (non-geniculate)

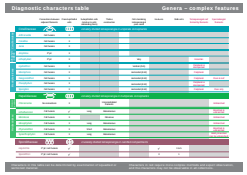
Sporolithaceae (non-geniculate)

Diagnostic characters tables – Genera

Easy features

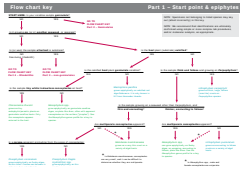


Complex features

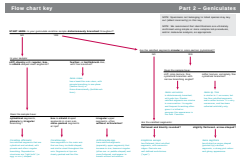


Flow chart keys

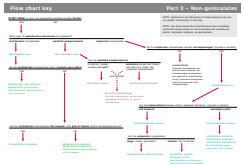
1. Start point & epiphytes



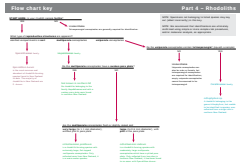
2. Geniculates



3. Non-geniculates



4. Rhodoliths



Workflow

We have provided the following **Workflow Tables** to guide you through the process of identifying your coralline algal samples. As you gain experience, you'll determine your own particular workflow, but we recommend you follow this guide initially.

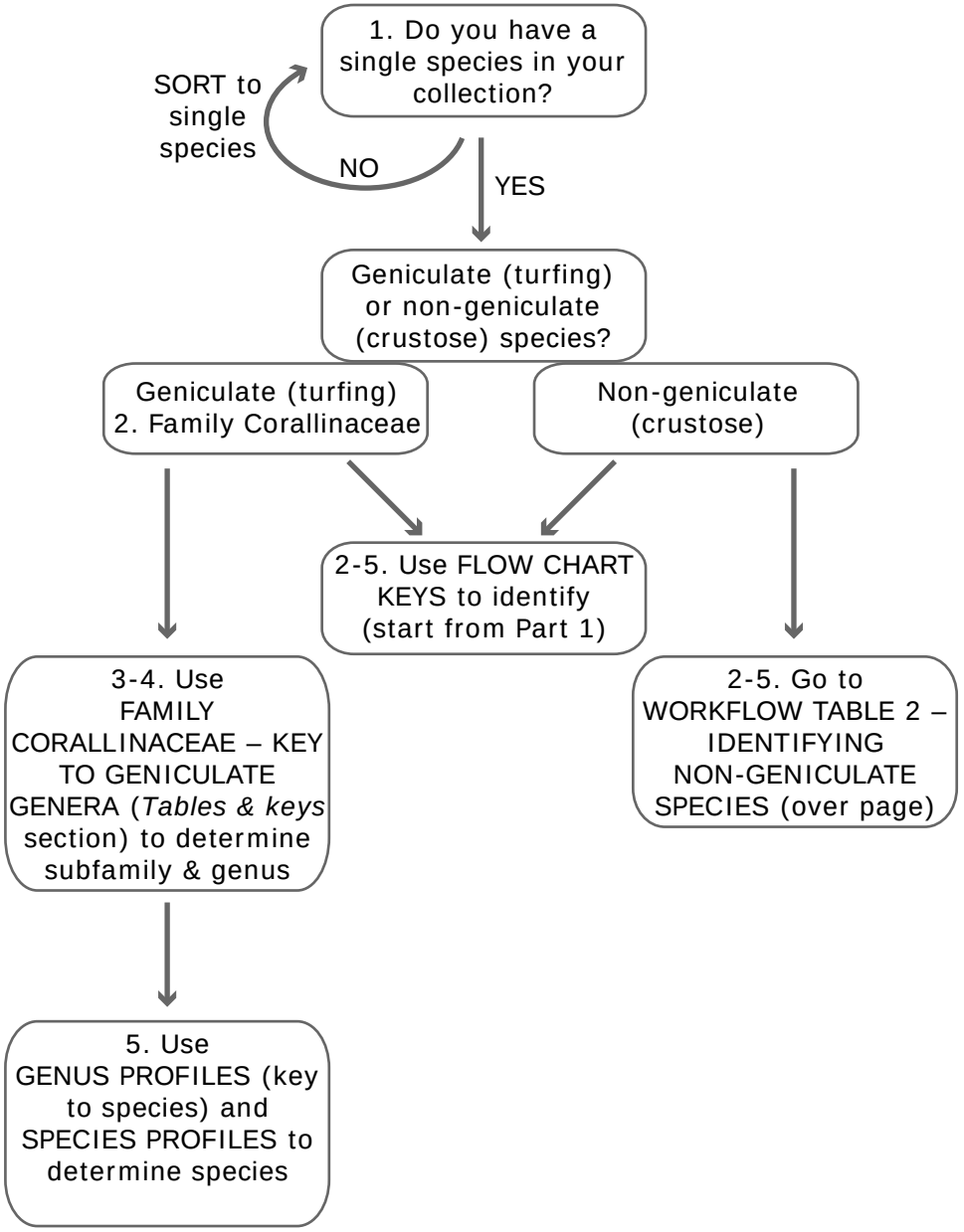
Workflow Table 1 (opposite) is your starting point. It directs you to one of two processes:

Systematic – go through a narrowing taxonomic progression from family and subfamily, down through genus, and finally to species. For geniculate samples, you're directed to tools in the TABLES AND KEYS section. For non-geniculate samples, you're directed to WORKFLOW TABLE 2, which directs you to a range of tools, including tabular, dichotomous and graphic keys. If this is a top-down approach, then the alternative is...

Bottom-up – by-pass the strictly systematic approach, and use our FLOW CHART KEYS for a more visual approach. The keys are designed to allow you to eliminate options, one character at a time, and they focus primarily on characters that are directly observable, or can be deterrmined using simple lab methods.

Use whichever approach suits you. You may be limited by the facilities available to you, by time, or by your level of experience. Regardless, the variety of methods and approaches we give in this guide should enable you to go at least some way towards identifying the coralline algal samples you collect from northern New Zealand waters.

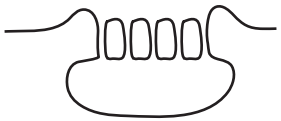
Workflow table 1



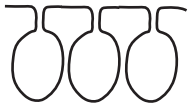
In order to:	Use these references/tools:	Section	Use this action/method:	Note:
1. Split collection to single species	Simplified taxonomic features – General & non-geniculate Simplified taxonomic features – Conceptacle details Growth form Life cycle	Tables & keys Tables & keys Introduction Introduction	Directly observe collection by eye or, preferably, using a hand lens or dissecting microscope.	Observe reproductive features (conceptacles, calcified compartments), growth form, substrate, etc.
2. Determine to FAMILY	Diagnostic characters – Families & subfamilies Families – Key to genera (contain key characters for family)	Tables & keys Tables & keys	Directly observe collection by eye, hand lens, or dissecting microscope. To determine contents of uniporate conceptacles, a simple squash may be sufficient (see *In the lab: Simple lab methods for identification*).	Reminder (tetrasporangia): Corallinoideae: zonate/uniporate Hapalidiaceae: zonate/multiporate Sporolithaceae: cruciate/calcified compartments **Note: uniporate conceptacles may not be tetrasporangial; they may be male or female.**
3. Determine to SUBFAMILY	Diagnostic characters – Families & subfamilies Families – Key to genera (contain key characters for family)	Tables & keys Tables & keys	To determine cell connections, contents of conceptacles, and other features, a simple squash may be sufficient (see *In the lab: Simple lab methods for identification*).	
4. Determine to GENUS	Families – Key to genera (dichotomous keys to genera) Diagnostic characters – Genera – Easy features (tabular) Diagnostic characters – Genera – Complex features (tabular)	Tables & keys Tables & keys Tables & keys	Directly observe collection by eye, hand lens, or dissecting microscope. Use simple lab methods (decalcify and squash, examine slide under light microscope) (see *In the lab: Simple lab methods for identification*). More complex methods may be required (embed in resin and cut thin sections; refer to Harvey et al. 2005) – or contact an expert.	Reminder: It may not be possible to identify your sample to genus.
5. Determine to SPECIES	Genus profiles – Keys to species (dichotomous & graphic) Species profiles – List characters and show images for each species	Species profiles Species profiles	As above.	Reminder: It may not be possible to identify your sample to species.
6. Keep a voucher	*Sorting and preserving samples*	Introduction		It is critical to keep material you have identified so that it can be referred to in the future, and its identity checked, confirmed, or amended. Preferably, lodge vouchered herbarium specimens with a registered herbarium.

Reproductive features

uniporate conceptacle



multiporate conceptacle

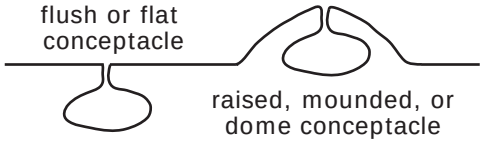


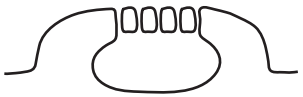
calcified compartments

zonately divided tetrasporangia

cruciately divided tetrasporangia

conceptacle relative to thallus surface



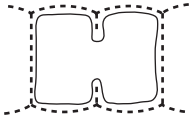


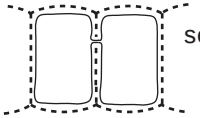
flat-topped (mesa) multiporate conceptacle

sunken pore plate (volcano) multiporate conceptacle

Vegetative features

cell fusion

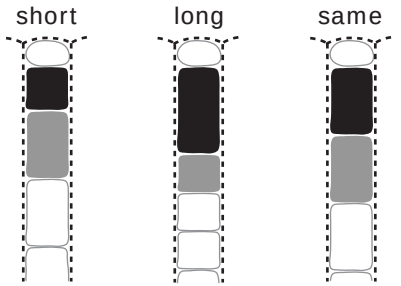




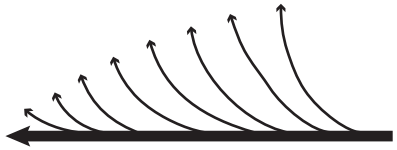
secondary pit connection

rounded to flattened (not flared) epithallial cells

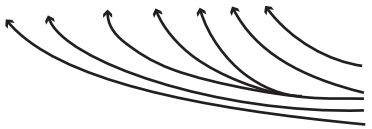
flared epithallial cells



subepithallial cell (black), compared to the cell immediately below it (grey)



dimerous thallus

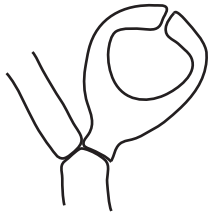


monomerous thallus

Reproductive features

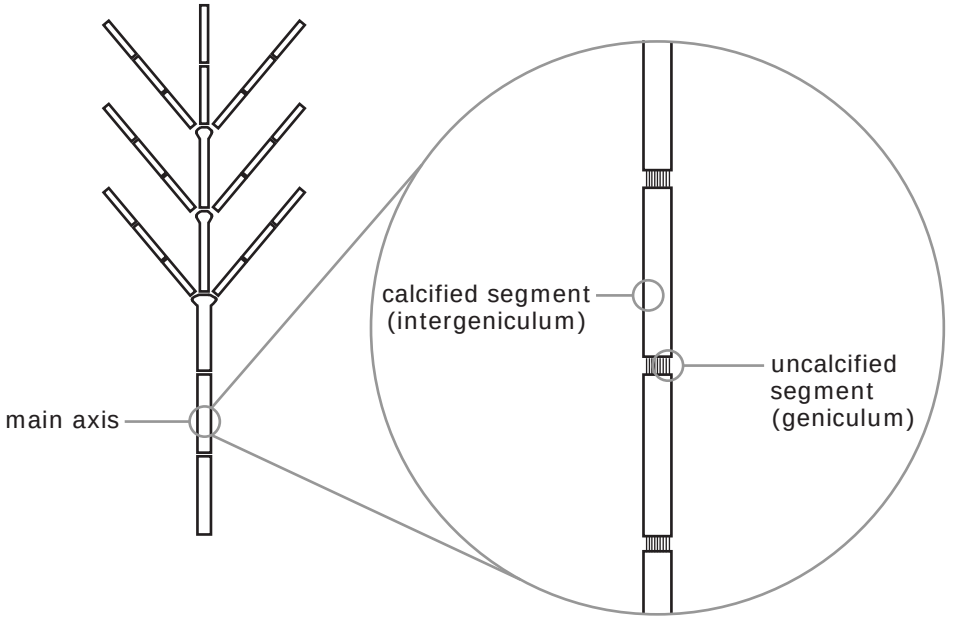
conceptacle on face of calcified segment

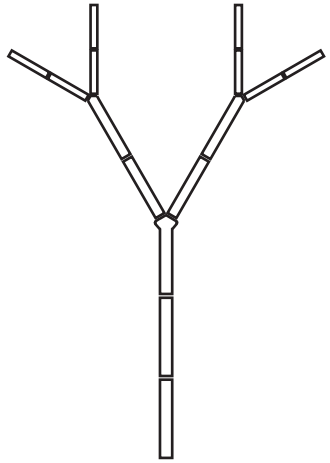
conceptacle terminal on calcified segment



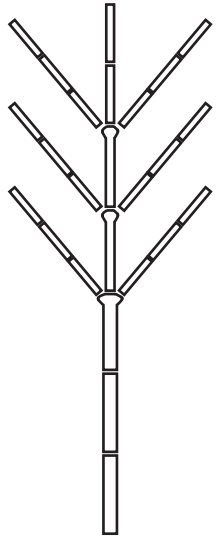
conceptacle at branch

Vegetative & morphological features





dichotomous branching



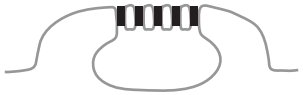
pinnate branching

Simplified taxonomic features

Pore & pore canal features

corona
(filaments protrude from pore)

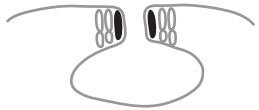
occluded
(pore blocked by enlarged cells)



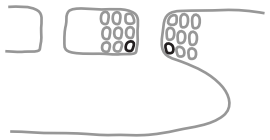
pore plugs

E-W
(horizontal; parallel to roof)

cells lining
pore canals
(uniporate)

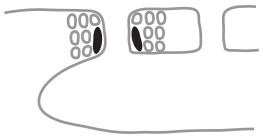


N-S
(vertical; perpendicular to roof)



same
(all cells similar)

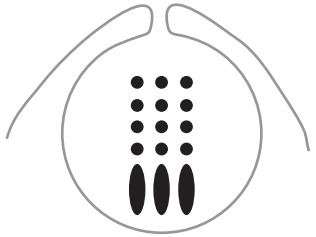
cells lining
pore canals
(multiporate)



long
(basal cells elongate)

Conceptacle details

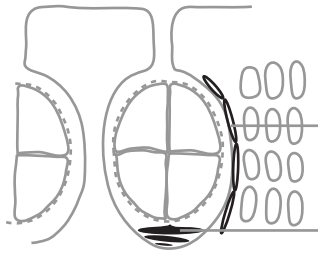
Chamber contents



unbranched
spermatangial filaments

branched
spermatangial filaments

carposporangial conceptacle
(fertilised female)



calcified compartments

Diagnostic characters table

Families & subfamilies

REMEMBER:

Uniporate conceptacles can contain males or females, or tetrasporangia.

Multiporate conceptacles and **calcified compartments** are *always* tetrasporangial.

Males and females **always** occur in **uniporate** conceptacles, for all coralline species.

Family

Subfamily (*genera* within subfamily)

Corallinaceae

Tetrasporangia in **uniporate** conceptacles

Tetrasporangia **zonately** divided

Apical plugs absent

Corallinoideae

Cells of adjacent filaments linked by cell fusions

Genicula composed of 1 tier of cells

Arthrocardia

Corallina

Jania

Lithophylloideae

Cells of adjacent filaments linked by secondary pit connections

Genicula (when present) composed of 1 or more tiers of cells

Amphiroa

Lithophyllum

Mastophoroideae

Cells of adjacent filaments linked by cell fusions

Genicula absent

Hydrolithon

Mastophora

Neogoniolithon

Pneophyllum

Spongites

Hapalidiaceae

Tetrasporangia in **multiporate** conceptacles

Tetrasporangia **zonately** divided

Apical plugs present

Choreonematoideae

Acellular multiporate conceptacle plate (appear uniporate but have hidden acellular multiporate plate beneath single outer opening)

Neither cell fusions nor secondary pit connections

Genicula absent

Choreonema

Melobesioideae

Multiporate conceptacle plate is multicellular

Cells of adjacent filaments linked by cell fusions

Genicula absent

Lithothamnion

Melobesia

Mesophyllum

Phymatolithon

Synarthrophyton

Sporolithaceae

Tetrasporangia in **calcified compartments**

Tetrasporangia **cruciately** divided

Apical plugs present

Not currently divided into subfamilies

Cells of adjacent filaments linked by either cell fusions or secondary pit connections or both

Heydrichia

Sporolithon

Family and subfamily classification follows Harvey et al. 2003a (see also Harvey et al. 2003b, Harvey et al. 2005).

This table includes only those families and subfamilies of living Corallinales containing geniculate or non-geniculate species confirmed to occur in New Zealand during the present study.

Key to geniculate genera

Two subfamilies in the family Corallinaceae – Lithophylloideae and Corallinoideae – have geniculate or turfing taxa which occur in New Zealand.

Key characters, family Corallinaceae:

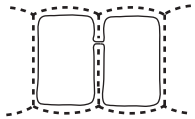
- tetrasporangia in uniporate conceptacles
- tetrasporangia zonately divided

Subfamily Lithophylloideae Setch.

One geniculate genus, *Amphiroa* J.V.Lamour., in New Zealand.

Key characters, subfamily Lithophylloideae:

- genicula, where present, comprised of 1 to many tiers of cells
- secondary pit connections

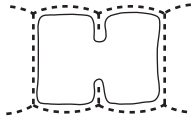


Subfamily Corallinoideae (Aresch.) Foslie

Three genera, *Arthrocardia* Decne., *Corallina* L. and *Jania* J.V.Lamour., in New Zealand. *Cheilosporum* and *Haliptilon* are now considered to be part of the genus *Jania* (see *Jania* genus page).

Key characters, subfamily Corallinoideae:

- genicula comprised of 1 tier of cells
- cell fusions



Characters separating genera within the family relate to reproductive features, such as the number of tetrasporangia per conceptacle; the shape of carposporophytic fusion cells; the shape of male conceptacle chamber.

For the geniculate species collected in the current study we can distinguish between genera on the basis of readily observable vegetative characters, and so the keys in this section use vegetative rather than reproductive characters, avoiding the need to section plants for identification in most cases.

KEY TO NEW ZEALAND GENICULATE GENERA OF CORALLINACEAE

1. Genicula large and conspicuous (comprised of 1 to many tiers of cells); secondary pit connections only; tetrasporangial conceptacles on surface (face) of calcified segment ..... *Amphiroa*

   Genicula small, fine, inconspicuous (comprised of 1 tier of cells); cell fusions only 2

2. Primary branching dichotomous (or trichotomous, or unbranched) ..... *Jania*

   Primary branching mostly pinnate 3

3. Calcified segments unlobed, cylindrical to compressed, regular; tend to “boxy” shape, but retain curvature ..... *Corallina*

   Calcified segments (especially upper segments) become irregular and more flattened, branching without articulation to form flange, paddle and oar shapes ..... *Arthrocardia*

Key to non-geniculate genera

Two subfamilies in the family Corallinaceae – Lithophylloideae and Mastophoroideae – have non-geniculate taxa which occur in New Zealand.

Key characters, family Corallinaceae:

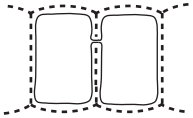
- tetrasporangia in uniporate conceptacles
- tetrasporangia zonately divided

Subfamily Lithophylloideae Setch.

One non-geniculate genus, *Lithophyllum* Phil., in New Zealand.

Key characters, subfamily Lithophylloideae:

- secondary pit connections

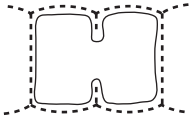


Subfamily Mastophoroideae Setch.

Five genera, *Hydrolithon* (Foslie) Foslie, *Mastophora* Decne., *Neogoniolithon* Setch. & L.R.Mason, *Pneophyllum* Kütz. and *Spongites* Kütz., in New Zealand.

Key characters, subfamily Mastophoroideae:

- cell fusions



KEY TO NEW ZEALAND NON-GENICULATE GENERA OF CORALLINACEAE

1. Secondary pit connections ..... *Lithophyllum*

   Cell fusions 2

2. Cells bordering tetrasporangial pore canal oriented more or less vertically (N-S) ..... *Hydrolithon*

   Cells bordering tetrasporangial pore canal oriented more or less horizontally (E-W) 3

3. Epiphytic 4

   Epilithic, epizoic, unattached 5

4. Lack a conspicuous layer of palisade cells in thallus; tetrasporangial conceptacle roof formed by filaments peripheral & interspersed amongst sporangial initials .... *Pneophyllum*

   Conspicuous layer of palisade cells in thallus; thallus 2-3 cells thick; central columella; tetrasporangial conceptacle roof formed by filaments peripheral to sporangial initials ..... *Mastophora*

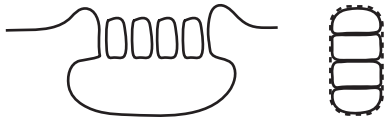
5. Spermatangia on floors and roofs of male conceptacles; tetrasporangial conceptacle roof formed by filaments peripheral & interspersed amongst sporangial initials..... *Neogoniolithon*

   Spermatangia on floors only of male conceptacles; tetrasporangial conceptacle roof formed by filaments peripheral to sporangial initials ..... *Spongites*

Two subfamilies recognised in the family Hapalidiaceae – Choreonematoideae and Melobesioideae – occur in New Zealand.

Key characters, family Hapalidiaceae:

- tetrasporangia in multiporate conceptacles
- tetrasporangia zonately divided



Subfamily Choreonematoideae Woelk.

The subfamily comprises a single monospecific genus, *Choreonema* F.Schmitz, which occurs in New Zealand.

Key characters, subfamily Choreonematoideae:

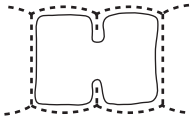
- cells not linked by secondary pit connections or cell fusions (unconsolidated thallus)
- tetrasporangial conceptacles with an acellular multiporate roof (look uniporate but have a hidden multiporate plate below a single outer opening)

Subfamily Melobesioideae Bizz.

Five genera in the subfamily Melobesioideae in New Zealand: *Lithothamnion* Heydr., *Melobesia* J.V.Lamour., *Mesophyllum* Me.Lemoine, *Phymatolithon* Foslie and *Synarthrophyton* R.A.Towns. No collections of *Synarthrophyton* species were confirmed from northern New Zealand in this study.

Key characters, subfamily Melobesioideae:

- cell fusions
- tetrasporangial conceptacles with a multicellular multiporate roof



KEY TO NORTHERN NEW ZEALAND GENERA OF HAPALIDIACEAE

1. Endophytic/parasitic on geniculate coralline algae; unconsolidated thallus (no connections); acellular multiporate tetrasporangial conceptacle..... *Choreonema*

   Not endophytic/parasitic; thallus connected by cell fusions; multicellular multiporate tetrasporangial conceptacles 2

2. Dimerous thallus; thin encrusting epiphyte..... *Melobesia*

   Monomerous thallus; epilithic, epizoic, thicker epiphyte, or unattached 3

3. Epithallial cells flared..... *Lithothamnion*

   Epithallial cells rounded or flattened but not flared 4

4. Subepithallial cells short; thin encrusting epilithic..... *Phymatolithon*

   Subepithallial cells long; epilithic, epizoic, epiphytic..... *Mesophyllum**

* *Synarthrophyton* also keys out here. *Synarthrophyton* was not confirmed from northern New Zealand collections, but does occur in central and lower North Island, South Island, Chatham Islands. The genera are separated on spermatangial branching in male conceptacles: unbranched only in *Mesophyllum*; mostly branched, but may be unbranched, in *Synarthrophyton*.

Two genera, *Sporolithon* Heydr. and *Heydrichia* R.A.Towns., Y.M.Chamb. & Keats, are recognised within the family Sporolithaceae, and both occur in New Zealand. No subfamilies are recognised within the family.

Key characters, family Sporolithaceae:

- flared epithallial cells
- tetrasporangia cruciately divided
- tetrasporangia in calcified compartments

KEY TO NEW ZEALAND GENERA OF SPOROLITHACEAE

1. Cruciate tetrasporangia in calcified compartments with single stalk cell, lacking an involucre, and aggregated in sori ..... *Sporolithon*

   Cruciate tetrasporangia in calcified compartments with 1-5 stalk cells, surrounded by an involucre, with compartments scattered on the thallus surface or loosely aggregated in sori ..... *Heydrichia*

Diagnostic characters table

Genera – easy features

		Genicula present	Branching	Calcified segment shape	Epiphytic, epilithic, epizoic, unattached, endophytic	Growth form	Tetrasporangial conceptacle size	Calcified compartment arrangement
	Corallinaceae			*zonately divided tetrasporangia in uniporate conceptacles*				
Corallinoideae	*Arthrocardia*	✓	Pinnate	Become irregular and flattened, form flanges	Epilithic (epiphytic)			
Corallinoideae	*Corallina*	✓	Pinnate	Unlobed, cylindrical to compressed, regular	Epilithic (epiphytic)			
Corallinoideae	*Jania*	✓	Dichotomous (trichotomous, unbranched)	Variable	Epilithic (epiphytic)			
Lithophyll--oideae	*Amphiroa*	✓	Dichotomous	Flattened	Epilithic			
Lithophyll--oideae	*Lithophyllum*	X			Epiphytic, epilithic, epizoic	Highly variable	Variable	
Mastophoroideae	*Hydrolithon*	X			Epiphytic, epilithic, epizoic, unattached	Encrusting (to sl. warty)	Variable (small)	
Mastophoroideae	*Mastophora*	X			Epiphytic	Encrusting, discoid to layered	Very large	
Mastophoroideae	*Neogoniolithon*	X			Epilithic, epizoic	Encrusting to warty to fruticose	Very large	
Mastophoroideae	*Pneophyllum*	X			Epiphytic	Thin encrusting	Variable (small to medium)	
Mastophoroideae	*Spongites*	X			Epilithic, epizoic	Encrusting to warty	Variable (small to medium)	
	Hapalidiaceae			*zonately divided tetrasporangia in multiporate conceptacles*				
Choreone--matoideae	*Choreonema*	X			Endophytic	Unconsolidated	Small	
Melobesioideae	*Lithothamnion*	X			Unattached	Warty to lumpy to fruticose	Large to very large	
Melobesioideae	*Melobesia*	X			Epiphytic	Thin encrusting	Small	
Melobesioideae	*Mesophyllum*	X			Epiphytic, epilithic, epizoic	Highly variable	Medium to large	
Melobesioideae	*Phymatolithon*	X			Epilithic	Encrusting to warty	Medium	
Melobesioideae	*Synarthrophyton*	X			Epiphytic, epilithic, epizoic	Encrusting to discoid to layered	Medium to large	
	Sporolithaceae			*cruciately divided tetrasporangia in calcified compartments*				
	Heydrichia	X			Epilithic	Epilithic		Scattered (or loosely aggregated in sori)
	Sporolithon	X			Epilithic, unattached	Epilithic, unattached		Aggregated in sori

REMEMBER:

Uniporate conceptacles can contain males or females, or tetrasporangia.

Multiporate conceptacles and **calcified compartments** are *always* tetrasporangial.

Males and females **always** occur in **uniporate** conceptacles, for all coralline species.

Characters in this table can be determined by direct observation, using a hand lens or dissecting microscope, or by eye.

		Connections between adjacent filaments	Flared epithallial cells	Subepithallial cells (relative to cells subtending them)	Thallus construction	Cells bordering tetrasporangial pore canal	Involucre	Stalk cells	Tetrasporangial roof formed by filaments	Spermatangial filaments
	Corallinaceae  	*zonately divided tetrasporangia in uniporate conceptacles*								
Corallinoideae	*Arthrocardia*	Cell fusions	X							
	Corallina	Cell fusions	X							
	Jania	Cell fusions	X							
Lithophyll-oideae	*Amphiroa*	2º pit	X							
	Lithophyllum	2º pit	X			Vary			Uncertain	
Mastophoroideae	*Hydrolithon*	Cell fusions	X			Vertical (N-S)			Peripheral & interspersed	
	Mastophora	Cell fusions	X			Horizontal (E-W)			Peripheral	
	Neogoniolithon	Cell fusions	X			Horizontal (E-W)			Peripheral	Floor & roof
	Pneophyllum	Cell fusions	X			Horizontal (E-W)			Peripheral & interspersed	
	Spongites	Cell fusions	X			Horizontal (E-W)			Peripheral	Floor only
	Hapalidiaceae  	*zonately divided tetrasporangia in multiporate conceptacles*								
Choreone-matoideae	*Choreonema*	No connections	X		Unconsolidated filaments					Unbranched
Melobesioideae	*Lithothamnion*	Cell fusions	✓	Long	Monomerous					Branched & unbranched
	Melobesia	Cell fusions	X		Dimerous					Unbranched
	Mesophyllum	Cell fusions	X	Long	Monomerous					Unbranched
	Phymatolithon	Cell fusions	X	Short	Monomerous					Branched & unbranched
	Synarthrophyton	Cell fusions	X	Long	Monomerous					Mostly branched (can be unbranched)
	Sporolithaceae  	*cruciately divided tetrasporangia in calcified compartments*								
	Heydrichia	2º pit / cell fusions	✓				✓	1 to 5		
	Sporolithon	2º pit / cell fusions	✓				X	1		

Characters in this table can be determined by examination of squashed or sectioned material.

Characters in red require more complex methods and expert observation, and the characters may not be observable in all collections.

Flow chart key

Part 1 – Start point & epiphytes

START HERE: Is your coralline sample **geniculate**?

NO

YES → **GO TO FLOW CHART KEY Part 2 – Geniculates**

Is it growing **on** (or in) **another seaweed**, or seagrass?

NO

YES

Is (or was) the sample **attached** to substrate?

NO free-living (rhodolith) → **GO TO FLOW CHART KEY Part 4 – Rhodoliths**

YES → **GO TO FLOW CHART KEY Part 3 – non-geniculates**

Is the **host** plant (substrate) **calcified**?

YES

Is the calcified **host** plant **geniculate** coralline?

YES

Is the sample **tiny white/colourless conceptacles** on host?

YES → *Choreonema thuretii* grows as tiny endophytic/parasitic plants on geniculate coralline hosts. Only the conceptacle appears external to the host.

NO → *Mesophyllum* spp. grow epiphytically on geniculate coralline algae, as plate-like discs, often with apparent conceptacles on the surface ("pimples"). See the *Mesophyllum* genus profile for a key to species.

NO → *Mastophora pacifica* grows epiphytically on calcified red alga *Galaxaura*. It is only known in NZ from Kermadec Islands.

NO

Is the sample **thick and foliose** and growing on ***Carpophyllum***?

YES → *Lithophyllum carpophylli* grows as thick, large, foliose (rose-like) crusts on *Carpophyllum* species.

NO

Is the sample growing on a seaweed other than *Carpophyllum*, and:

thin and encrusting?

Are **multiporate conceptacles** apparent?

NO

Is a **corona** apparent protruding from the pores of conceptacles:

YES → *Pneophyllum coronatum* grows epiphytically on fleshy algae, as thin crust. Corona can be seen in side view (use a hand lens).

NO → *Pneophyllum fragile* *Hydrolithon* spp. grow epiphytically as thin crusts.

YES → *Melobesia membranacea* grows as a very thin crust on a variety of algal hosts.

* In *Melobesia membranacea*, conceptacles are very small, and it can be difficult to determine whether they are multiporate.

thicker, encrusting to foliose?

Are **multiporate conceptacles** apparent?

YES → *Mesophyllum* spp. can grow epiphytically on fleshy algae, as wrapping, encrusting to foliose, plate-like discs. See the *Mesophyllum* genus profile for a key to species.

NO → *Lithophyllum pustulatum* grows as encrusting to foliose crusts on a variety of algal hosts.

* In *Mesophyllum* spp., male and female conceptacles are uniporate.

NOTE: Specimens not belonging to listed species may key out (albeit incorrectly) in this key.

NOTE: We recommend that identifications are ultimately confirmed using simple or more complex lab procedures, and/or molecular analysis, as appropriate.

NOTE: Specimens not belonging to listed species may key out (albeit incorrectly) in this key.

NOTE: We recommend that identifications are ultimately confirmed using simple or more complex lab procedures, and/or molecular analysis, as appropriate.

START HERE: Is your geniculate coralline sample **dichotomously branched** throughout?

NO

Is your sample:

stiff, chunky with **regular, box-** to **shield-**shaped main segments?

Does the sample have:

unlobed, cylindrical segments, **pinnate** and **regular** branching?

Corallina officinalis
has calcified segments that are unlobed and cylindrical, with pinnate and often regular branching. Reproductive structures are “light bulb” (or egg- or urn-) shaped.

box to **shield** shaped segments in main axis, **close-packed** segments at tips?

Corallina spp.
have segments in the main axis that are boxy to shield-shaped, and similar sized throughout the axis. Segments at tips are closely-packed and fan-like.

irregular upper segments, often **without articulation**?

Arthrocardia spp.
have calcified segments (especially upper segments) that increase in size, become irregular (often oar- or paddle-shaped) and more flattened, and appear to branch without articulation.

feather- or **bottlebrush-**like, with fine branches?

Jania rosea
has a bead-like main stem, with pinnate branching in one plane (feather form) or three-dimensionally (bottlebrush form).

YES

Are the calcified segments **circular** in cross-section (cylindrical)?

YES

Does the sample have:

stiff, crisp texture, fine cylindrical branches with narrow branching angles?

Jania verrucosa
is dichotomously branched, with pale tips. Slender calcified segments are circular in cross-section. Its regular and frequent branching often gives it a tufted or pompom-like appearance in the field. Common.

softer texture, extremely fine cylindrical branches?

Jania sp. fine
is similar to *J. verrucosa*, but has finer calcified segments, and a softer texture. It is very uncommon, and has been collected subtidally only.

NO

Are the calcified segments:

flattened and bluntly rounded?

Amphiroa anceps
has flattened, blunt calcified segments, with concentric ridges. Genicula are well-defined and obvious (”eyes”).

slightly flattened, arrow-shaped?

Jania sagittata
has distinctive arrow-shaped (pointed tip) calcified segments, a strong pink colour and glossy appearance.

Flow chart key

Part 3 – Non-geniculates

NOTE: Specimens not belonging to listed species may key out (albeit incorrectly) in this key.

NOTE: We recommend that identifications are ultimately confirmed using simple or more complex lab procedures, and/or molecular analysis, as appropriate.

START HERE: Is your non-geniculate coralline sample **fertile**?

YES

What type of **reproductive structures** are apparent?

multiporate conceptacles

Hapalidiaceae family

Do the **multiporate** conceptacles have a **sunken pore plate**?

YES

Mesophyllum macroblastum
Mesophyllum printzianum
See *Mesophyllum* genus profile for a key to species.

NO

Are the **multiporate** conceptacles **flat-topped**, with **pits in thallus** where conceptacles blown?

YES

Phymatolithon repandum

NO

Mesophyllum engelhartii
Mesophyllum erubescens
See *Mesophyllum* genus profile for a key to species.

NO

calcified compartments

Sporolithaceae family

Are the **calcified compartments**:

in distinct, raised, usually pale **sori**?

Sporolithon durum

intermediate

Heydrichia woelkerlingii
Calcified compartments can be loosely aggregated (sorus-like), or more or less scattered.

scattered across the thallus; look like very small, flat uniporate conceptacles?

Heydrichia homalopasta

NO

uniporate conceptacles

Do the **uniporate** conceptacles contain **tetrasporangia**? (squash a sample)

NO

Unidentifiable
Uniporate conceptacles can also be male or female, but tetrasporangial conceptacles are required for identification; empty uniporate conceptacles cannot be assumed to be tetrasporangial.

YES

Corallinaceae family

Are the **connections** between cells in adjacent filaments: (squash a sample)

cell fusions?

Mastophoroideae subfamily

Are the **uniporate** conceptacles:

large, raised, pustulate?

Neogoniolithon brassica-florida

smaller, flat to dome?

Hydrolithon species
Spongites yendoi
See *Hydrolithon* and *Spongites* genus profiles for keys to species.

secondary pits?

Lithophylloideae subfamily

Lithophyllum corallinae
Lithophyllum johansenii
Lithophyllum stictaeforme
See *Lithophyllum* genus profile for a key to species.

NOTE: Specimens not belonging to listed species may key out (albeit incorrectly) in this key.

NOTE: We recommend that identifications are ultimately confirmed using simple or more complex lab procedures, and/or molecular analysis, as appropriate.

START HERE: Is your rhodlith sample **fertile**?

YES

NO → Unidentifiable
Tetrasporangial conceptacles are generally required for identification.

What type of **reproductive structures** are apparent?

calcified compartments in **sori** → Sporolithaceae family → *Sporolithon durum*
is the most common and abundant of rhodolith-forming species found in New Zealand to date. The majority of rhodoliths in New Zealand are *S. durum*.

multiporate conceptacles → Hapalidiaceae family → Do the **multiporate** conceptacles have a **sunken pore plate**?

YES → Not known in northern NZ
No rhodoliths belonging to the family Hapalidiaceae and with a sunken pore plate were found in northern New Zealand.

NO → Are the **multiporate** conceptacles flush or slightly raised and:

very large (to 1.1 mm diameter), without pits in pore plate → *Lithothamnion proliferum*
is a rhodolith-forming species with extremely large, flat-topped multiporate conceptacles. Only collected once from New Zealand, it is a warm-water species.

large (to 0.6 mm diameter), with **pits** in the pore plate → *Lithothamnion indicum*
is a rhodolith-forming species with moderately large multiporate conceptacles which have a pitted pore plate. Only collected from two sites in northern New Zealand; it has been found to co-occur with *Sporolithon durum*.

uniporate conceptacles → Do the **uniporate** conceptacles contain **tetrasporangia**? (squash a sample)

NO → Unidentifiable
Uniporate conceptacles can also be male or female, but tetrasporangial conceptacles are required for identification; empty uniporate conceptacles cannot be assumed to be tetrasporangial.

YES → Corallinaceae family → *Lithophyllum* sp.
A rhodolith belonging to the genus Lithophyllum, but unable to be identified to species, was collected from a single site in northern New Zealand.

Species profiles

Species profiles

Introduction to species profiles

This section of the identification guide contains genus and species profiles for over 30 species of geniculate and non-geniculate coralline algae found in northern New Zealand.

We've organised this section of the guide more-or-less taxonomically. We've grouped all of the **Geniculate coralline species profiles** in the first section. This is followed by the **Non-geniculate species**, with a separate section for each family.

Within each of these sections, there is an introductory profile of the family, with key characters for the family, some notes on subfamilies, and a dichotomous key to genera. A profile for each genus (alphabetically within the family) is followed by the species profiles (alphabetically) for that genus.

Finally, there is a short section on **Rhodoliths**, with information on distribution and a guide to rhodolith-forming species in New Zealand.

Over the page, you can find a list of all the profiles in this section of the guide, in the order that they appear. Click to navigate to the section or profile you need.

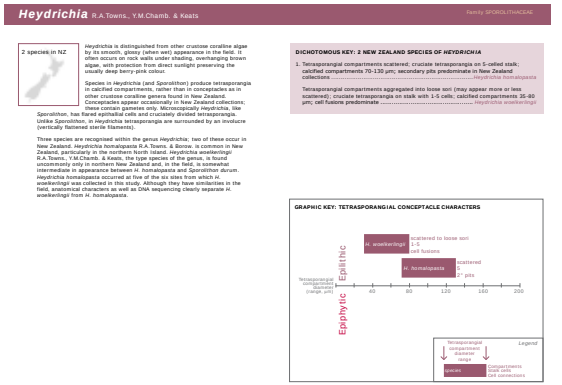
We recommend that you read the INTRODUCTON TO CORALLINE ALGAE section at the start of this guide before trying to use these species profiles. Refer to the TABLES & KEYS section of this guide to access any tools and references you may need while using the species profiles. Use the illustrated *Glossary* at the end of the guide to find definitions of terms used.

All profiles

The order, family and subfamily are given at the top right of the page.

Genus profiles

Each genus profile presents general information about the genus, a dichotomous key to species in New Zealand (where more than one species) at top right of the page, and a graphic key showing tetrasporangial conceptacle characters useful in distinguishing species (with legend to the graphic key at lower right of the page).



Species profiles

Each species profile includes a map (see note below), deatiled information about the species, and is illustrated with field and laboratory photographs of collections from northern New Zealand.

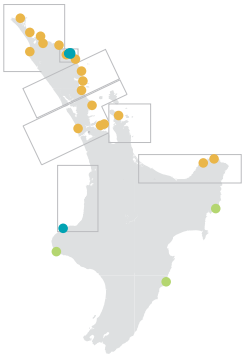
Each species profile has a shaded box (lower left) showing key characters for the species.

Species maps

In the upper left of each species profile is a map of the North Island, showing the sites of collections made in northern New Zealand during our current study.

orange indicates intertidal collection
blue indicates subtidal collection
green indicates previous collections (southern North Island)

Please note that these maps show identified collections only, and the actual distribution of a given species may be wider than is indicated by the dots on the map.



Index to species profiles

Geniculate (articulated, turfing) corallines

Non-geniculate (encrusting, crustose) corallines

Corallinaceae

Hapalidiaceae

Sporolithaceae

Rhodoliths

Corallinaceae

Geniculate species

Species profiles

Geniculate (articulated, turfing) coralline algae are branched, and have alternating segments that are calcified and uncalcified. The uncalcified segments – the gaps or joints between calcified segments – are called *genicula* (single *geniculum*), and the calcified segments are known as *intergenicula*.

Two subfamilies in the family Corallinaceae – Lithophylloideae and Corallinoideae – have geniculate taxa which occur in New Zealand.

Key characters, family Corallinaceae:

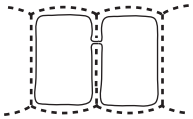
- tetrasporangia in uniporate conceptacles
- tetrasporangia zonately divided

Molecular analysis (see Figure 10) shows that the family Corallinaceae is supported as a monophyletic clade. The subfamily Corallinoideae is supported as a monophyletic clade, while the Lithophylloideae is nested in a clade with the Mastophoroideae.

Subfamily Lithophylloideae Setch.

One geniculate genus, *Amphiroa* J.V.Lamour., in New Zealand.

Key characters, subfamily Lithophylloideae:

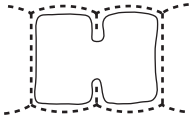


- genicula, where present, comprised of 1 to many tiers of cells
- secondary pit connections

Subfamily Corallinoideae (Aresch.) Foslie

Three genera, *Arthrocardia* Decne., *Corallina* L. and *Jania* J.V.Lamour., in New Zealand. *Cheilosporum* and *Haliptilon* are now considered to be part of the genus *Jania* (see *Jania* genus page).

Key characters, subfamily Corallinoideae:



- genicula comprised of 1 tier of cells
- cell fusions

Characters separating genera within the family relate to reproductive features, such as the number of tetrasporangia per conceptacle; the shape of carposporophytic fusion cells; the shape of male conceptacle chamber.

For the geniculate species collected in the current study we can distinguish between genera on the basis of readily observable vegetative characters, and so the keys in this section use vegetative rather than reproductive characters, avoiding the need to section plants for identification in most cases.

KEY TO NEW ZEALAND GENICULATE GENERA OF CORALLINACEAE

1. Genicula large and conspicuous (comprised of 1 to many tiers of cells); secondary pit connections only; tetrasporangial conceptacles on surface (face) of calcified segment ..... *Amphiroa*

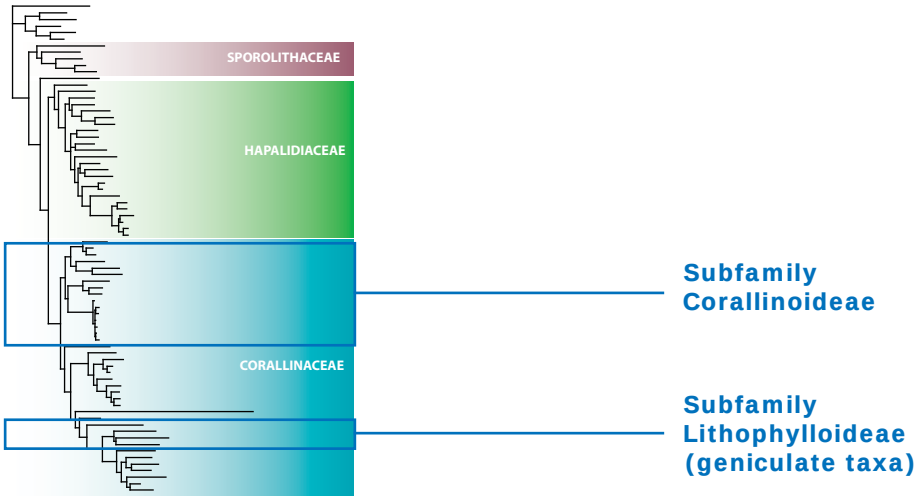
   Genicula small, fine, inconspicuous (comprised of 1 tier of cells); cell fusions only 2

2. Primary branching dichotomous (or trichotomous, or unbranched) ..... *Jania*

   Primary branching mostly pinnate 3

3. Calcified segments unlobed, cylindrical to compressed, regular; tend to “boxy” shape, but retain curvature ..... *Corallina*

   Calcified segments (especially upper segments) become irregular and more flattened, branching without articulation to form flange, paddle and oar shapes ..... *Arthrocardia*



For details of molecular analysis, see Figure 10, and the chapter *Coralline algal taxonomy*.

Amphiroa J.V.Lamour.

1 species in NZ

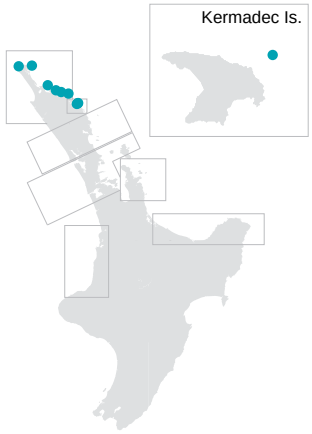
Species in *Amphiroa* have relatively large, obvious genicula – the "gaps" between calcified segments – which are comprised of 1 to many tiers of cells. *Amphiroa* species produce both tetrasporangia and gametes in uniporate conceptacles. Microscopically, the cells of adjacent filaments in the thallus are connected by secondary pit connections.

Around 50 species names are currently recognised worldwide within the genus *Amphiroa*. A single species, *Amphiroa anceps* (Lam.) Decne., is known from New Zealand collections.

Molecular analysis (see Figure 10) shows that *Amphiroa anceps* from New Zealand is closely related to, but distinct from, *Amphiroa anceps* from Australia. Additionally, there is a currently undescribed non-geniculate species, *Lithophyllum* sp. 2, which is most closely related genetically in our analysis to *Amphiroa* collections from Australia and New Zealand. The clade containing *Amphiroa* from Australia and New Zealand is a sister clade to that containing New Zealand Lithophylloideae, and is distinct and separate from the Corallinoideae clade, containing the other geniculate taxa from New Zealand.

Amphiroa anceps (Lam.) Decne.

Family CORALLINACEAE
Subfamily LITHOPHYLLOIDEAE



Amphiroa anceps is a geniculate coralline alga with dichotomously branched upright axes, purple to dull pink/grey, 2-10 cm in height, with a crustose holdfast. Calcified segments are compressed to flat in upper axes, but cylindrical to compressed at the base of the plant, with the plant lying in one plane. Concentric ridges can be seen on upper segments; branching occurs at every segment. Segment length is variable: 2-8 mm long and 0.75-2.5 mm wide. Apical tips are rounded, white to very pale pink. Genicula – the "gaps" between calcified segments – are relatively large and obvious, being comprised of many tiers of cells.

Habitat: Epilithic and subtidal to at least 20 m.

Anatomy & reproduction: Cells of adjacent filaments are connected by secondary pit connections. Conceptacles are found opening on the broad faces of calcified segments.

Distribution (NZ): Kermadec Islands. North Island: Far North, Bay of Islands. Not known from central and southern North Island, South Island, or Chatham Islands [although a single record from Fiordland (south west South I.) needs to be re-examined]. Collected from 9 of 86 northern study sites (11%), and from 1 of 5 Kermadec Islands sites (total 10 localities).

Distribution (elsewhere): Australia (except Tas.); widespread in Indo-Pacific.

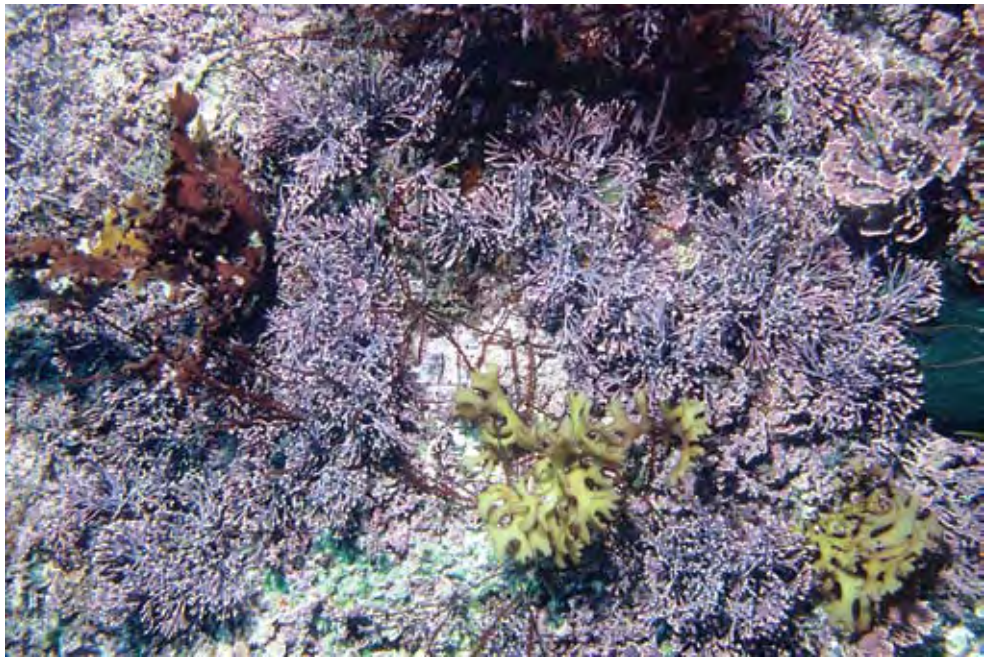
Etymology: *anceps* (Latin) = two headed.

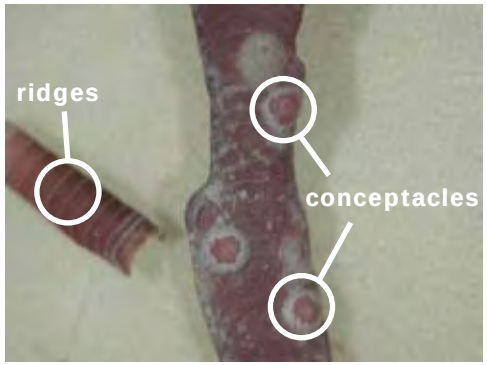
Type locality: "les mers australes ou de la Nouv. Holl", i.e. southern seas or Australia.

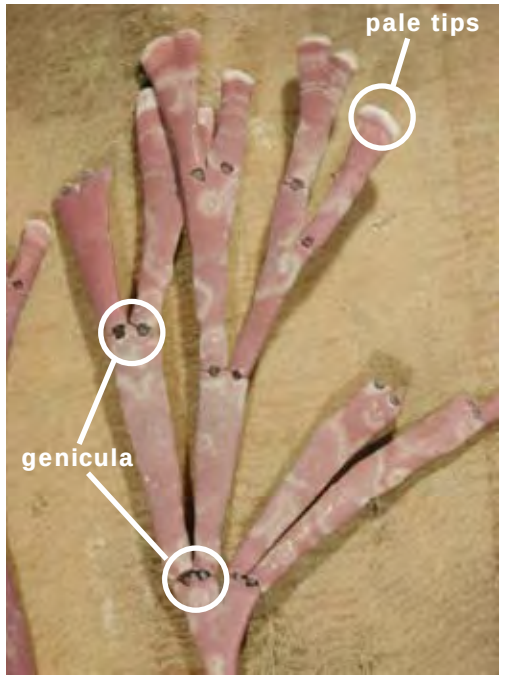
Reference: Decaisne 1842.

KEY CHARACTERS

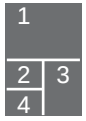
1. Dichotomous branching, flattened appearance.
2. Obvious genicula ("gaps" or "eyes" between calcified segments).
3. Broad, long calcified segments with pale (white) tips.
4. Conceptacles on the flattened, broad surfaces of the segments.
5. Grows subtidally in northern New Zealand, including Kermadec Islands.







Amphiroa anceps: 1, 2, growing subtidally, showing pale pink to white tips; 3, obvious genicula ("gaps" or "eyes" between calcified segments), concentric ridges on calcified segments, and pale pink to white tips; 4, close-up showing concentric ridges, and conceptacles on faces of segments.



Arthrocardia Decne. & *Corallina* L.

3+ species in NZ

Species in *Arthrocardia* and *Corallina* have relatively small, inconspicuous genicula – the "gaps" between calcified segments – which are comprised of a single tier of cells. Both species produce both tetrasporangia and gametes in uniporate conceptacles. Microscopically, the cells of the thallus are connected by cell fusions.

The two genera can be separated on the basis of the number of rows of medullary cells in their calcified segments. These can be observed as curved lines, rather like the growth rings in trees, on the calcified segment. In *Arthrocardia*, the calcified segments are made up of 20-50 tiers of medullary cells; in *Corallina*, there are fewer, usually 10-20 (up to 25).

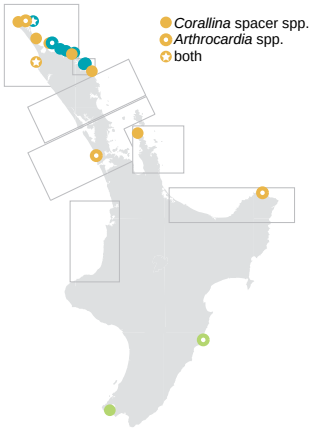
A predominant distinction between *Arthrocardia* and *Corallina* in the present study is the shape of the calcified segments. In *Corallina*, the lower segments are cylindrical, and the upper segments retain a degree of curvature; overall, they are quite regular, and often "boxy" in shape. In *Arthrocardia*, the lower segments are also cylindrical, and often bead-like; upper segments though tend to be irregular, to branch without articulation, and to form side flange, paddle or oar shapes.

Molecular analysis (see Figure 10) shows that *Arthrocardia* and *Corallina* together form a monophyletic clade within the Corallinoideae, a sister clade to that containing *Jania* sequences. However, during the current study we found that collections which we tentatively placed in *Arthrocardia* from initial field observations gave differing molecular data which placed them either as *Arthrocardia* or within *Corallina* (but distinct from *C. officinalis* L.). Subsequent anatomical observations and measurements, using the molecular data to group collections to taxon, have teased out differences between the taxa (see shape of calcified segments, above). Further analysis and continuing research will determine whether these are novel species and define their relationships to other *Arthrocardia* and *Corallina* species worldwide.

Eleven species names are currently recognised worldwide within the genus *Arthrocardia*. Two names, *A. corymbosa* (Lam.) Decne. and *A. wardii* (Harv.) Aresch., have been used for *Arthrocardia* in New Zealand; both are southern hemisphere species, described from South African and Australian material respectively. Doubt has been raised "about the correct placement of the species of *Arthrocardia* reported for New Zealand. Careful examination of the local plants may reveal that they differ from both the...southern African or Australian species" (Adams 1994, p. 159). Work is still in progress to determine the identity and relationships of species of *Arthrocardia* collected from New Zealand.

Seventeen species names are currently recognised worldwide within the genus *Corallina*. A single named species, *Corallina officinalis*, is widespread in New Zealand. The species *Corallina armata* Hook.f. & Harv., described from a New Zealand type, has not been investigated in a modern context, and its status as a distinct species is uncertain. Collections corresponding to *C. armata* were not found in the present study.

Arthrocardia spp. & *Corallina* spp.



During the current study we found that collections, which we tentatively placed in *Arthrocardia* from initial field observations, gave molecular data which placed them either as *Arthrocardia* or within *Corallina* (but distinct from *C. officinalis*). Subsequent anatomical observations and measurements, using the molecular data to group collections to taxon, have teased out differences between the taxa. Further analysis and continuing research will determine whether these are novel species and define their relationships to other *Arthrocardia* and *Corallina* species worldwide.

Arthrocardia species

We have found two distinct species of *Arthrocardia* (*Arthrocardia* sp. 1 and sp. 2) in this study of the northern region of New Zealand. As yet we do not have sufficient material to fully understand the distinguishing characters of these taxa, and how they differ from each other and other species described in the genus.

Arthrocardia species have calcified segments (intergenicula), particularly in the upper third of the plant, that appear to have branched without any articulation developing. Some of these segments have very irregular outlines, sometimes deeply incised or with odd shaped processes extending from the edges. The upper segments are flattened, and some of the branchlets and apical segments have a paddle or oar-like outline.

One feature of the *Arthrocardia* species and a feature which helps to distinguish them from the *Corallina* species is the appearance of the main axis. In *Arthrocardia* the lower axial segments are almost terete (cylindrical) and have a beaded appearance but further up the stem the segments become irregular in outline, often with flanges or processes extending beyond the upper edge of the joint with the geniculum ("gap" between segments).

During the current study, it became apparent that there was conflict in the literature over the features and characters defining species within the genus, and in the ways these have been applied by different workers. Pending further – and global – analysis, we have chosen not to present any species of *Arthrocardia* in detail.

Corallina species

Using *psb*A-*trn*L spacer sequence (which drills into differences between closely-related taxa) from a number of collections, we were able to distinguish six "spacer" taxa, four of which occur in northern New Zealand. These taxa are genetically clearly situated within the genus *Corallina*, but distinct from *C. officinalis*.

Although lower calcified segments may be nearly terete in the main axis in *Corallina* "spacer" species, the overall appearance of these species is more regular than in *Arthrocardia* species. Segments in the main "stem" have a pronounced "boxy" appearance, with very regular segments extending well up the main axis. These vary in appearance, sometimes having a shield-like shape, and some have sharply pointed edges or upper shoulders, but they all tend to extend in width at the upper edge rather than in height, and in general are broader than tall.

The upper segments of the *Corallina* "spacer" species may be strongly compressed but retain a degree of curvature. The apical segments tend to be highly ordered and tightly packed.

***Arthrocardia* spp.** ***Corallina* spp.**

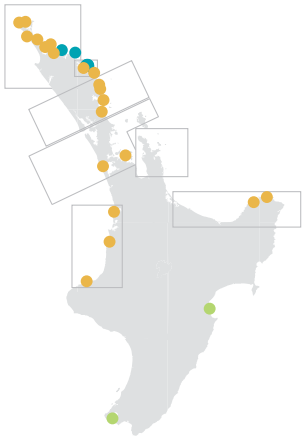
Details of upper segments of plants

1-3, *Arthrocardia* spp.: 1, *Arthrocardia* sp. 2; 2-3, *Arthrocardia* sp. 1.
Note side processes (oar, flange and paddle shapes), broad flattened upper segments lacking genicula.

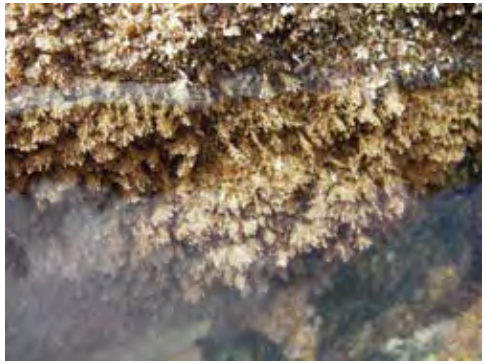
4-6, *Corallina* spp.: 4, *Corallina officinalis*; 5, *Corallina* sp. "spacer2"; 6, *Corallina* sp. "spacer2".
Note more regular appearance; strongly compressed but retaining curvature.

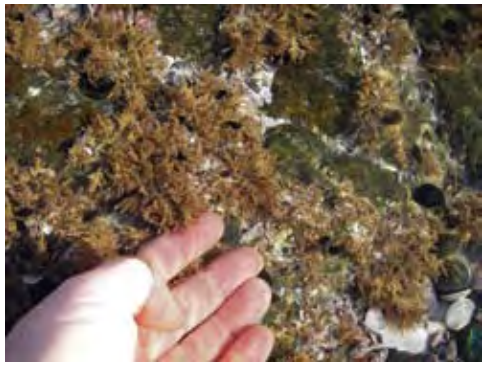
1	4
2	5
3	6

Corallina officinalis L.



Corallina officinalis is a geniculate coralline alga with branched stiff erect fronds up to 70 mm in height growing from a crust. The branching is pinnate and three dimensional. The calcified segments (intergenicula) are unlobed and 1-4 mm long and 0.5-1.5 mm wide, tending to be longer than broad, and mainly cylindrical, although may be slightly compressed in wide axes. Plants may be long and lush; or, particularly in the high intertidal, short and eroded, perhaps aggregated with sand.
Habitat: Common on rock in the intertidal; grows in high intertidal through to subtidal zone, to at least 18 m.
Anatomy & reproduction: Cells in adjacent filaments are connected by cell fusions. Uniporate conceptacles are egg- or urn-shaped ("light bulbs"), produced from the main stem, terminating side branchlets or occasionally (female and tetrasporangial) themselves bearing short slender branchlets.
Distribution (NZ): Widespread and common. North Island: Far North, Bay of Islands, Whangarei, Auckland, Bay of Plenty/East Cape, northern Taranaki, central and lower North Island. South Island; Chatham Islands. Collected from 27 of 86 northern study sites (31%).
Distribution (elsewhere): Widespread globally.
Etymology: *officinalis* (Latin) = of medicinal use.
Type locality: "Hab. O. Eur." [European Seas].
Reference: Linnaeus 1758.



KEY CHARACTERS

1. Pinnate, three-dimensional branching.
2. Calcified segments unlobed and mainly cylindrical.
3. "Light bulb" conceptacles from the main stem, terminating side branchlets.
4. Variable in field: long, lush plants, or short eroded turfs.
5. Common and widespread throughout New Zealand, especially intertidally.

Corallina officinalis: 1-4, field; 1, plants fringing intertidal pool; 2, 4, very short, turfing growth in intertidal; 3, subtidal plants, long and lush; 5, upper segments, showing pinnate branching, mainly cylindrical segments, "light bulb" conceptacles; 6, uniporate conceptacles.

1	2
3	4
5	6

In the past, the three genera *Cheilosporum*, *Haliptilon* and *Jania* have been distinguished from each other mainly on the basis of their branching patterns, with *Jania* species dichotomously branched, *Haliptilon* regarded to have primary dichotomous branching and secondary pinnate branching (although the pinnate branching is more conspicuous). *Cheilosporum* has been treated as a separate genus on the basis of the position of reproductive structures (conceptacles marginal rather than axial in position), and because species possess distinctive arrow-shaped calcified segments.

However, recent phylogenetic studies using both molecular and anatomical data have concluded that only a single genus should be recognised, and so species formerly placed in *Cheilosporum* and *Haliptilon* are now species of *Jania*.

These studies (Kim et al. 2007) concluded that reproductive rather than vegetative characters are phylogenetically important in the delimitation of genera in the Corallinoideae.

The genus *Jania* is now delineated by three reproductive features:

- thick and compact carposporophytic fusion cells
- a narrow male conceptacle chamber with short canal
- less than 15 tetrasporangia per conceptacle

More than 30 species species are currently recognised worldwide within the genus *Jania*. At least three species – *J. sagittata* (J.V.Lamour.) Blainv., *J. verrucosa* J.V.Lamour. and *J. rosea* (Lam.) Decne. – are currently recognised from New Zealand collections, and here we discuss additional forms which we can distinguish by anatomical, morphological and molecular analysis to be distinct taxa.

Molecular analysis (see Figure 10) shows that *Jania* species form a monophyletic clade in our analysis, a sister clade to the *Arthrocardia* and *Corallina* clade within the Corallinoideae. The analysis shows the two distinct but closely-related forms of *Jania rosea* (feather and bottlebrush); and the uncommon, fine *Jania* with affinities to *J. ungulata* (Yendo) Yendo.

DICHOTOMOUS KEY: 5 NEW ZEALAND SPECIES OF *JANIA*

1. Calcified segment (intergenicula) flattened, arrow-shaped ..... *Jania sagittata*

   Calcified segment (intergenicula) cylindrical 2

2. Feathery outline; main stem has regular beaded appearance; cylindrical curving stolons from lower segments 3

   Densely tufted plants, fine branches, narrow branching angle 4

3. Plant branches in one plane (“feather” appearance); mainly intertidal ..... *Jania rosea* feather

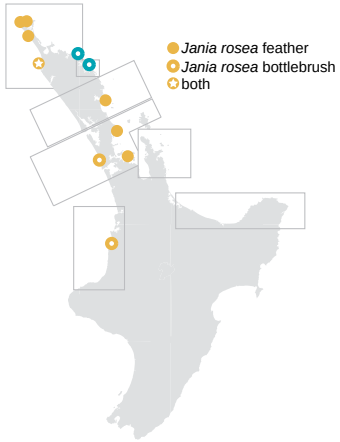
   Plant branches 3-dimensionally (“bottlebrush” appearance); low intertidal to subtidal ..... *Jania rosea* bottlebrush

4. Plants have stiff texture, grow to 5 cm height; segments 0.2-0.4 mm wide ..... *Jania verrucosa*

   Plants softer texture, smaller (1-2 cm height), with extremely fine segments (0.06-0.1 mm wide) ..... *Jania* sp. fine

Jania rosea (Lam.) Decne.

Family CORALLINACEAE
Subfamily CORALLINOIDEAE



Plants are upright and densely branched, 5-12 cm high, with a fine feathery outline. The stem has a regular, beaded appearance. Plants are bright rosy pink to grey pink, paler at the tips. As well as a crustose holdfast, stolons curve from the lower segments. Calcified segments in the lower plant and stolons are cylindrical, becoming flattened in the upper parts of the plant. On the shoulders of each segment lateral branchlets develop, which are unbranched or di- or trichotomously branched. In some specimens additional pinnately branched side branches develop. Side branchlets are often lost from lower parts; in older specimens the lower 1-2 cm of the stem may be bare.
Habitat: On rock; occasionally epiphytic. Feathery form found in intertidal, whereas bottlebrush form occurs to depths of 5 m.
Anatomy & reproduction: Cells in adjacent filaments are connected by cell fusions. Conceptacles occur on the stem (axial) at the tips of calcified segments, produced in lateral branchlets.
Distribution (NZ): North Island: Far North, Bay of Islands, Whangarei, Auckland, northern Taranaki. Collected from 11 of 86 northern study sites (13%). Known outside this study from Kermadec Islands, lower North Island, South Island, Chatham Islands, Stewart Island, and subantarctic islands.
Distribution (elsewhere): Australia (north-west & southern Australia, Tas, Qld); Europe/Asia (Turkey); South America; Africa.
Etymology: *rosea* (Latin) = rose-coloured.
Type locality: "Les mers Australes", probably from SW Australia or SW Tasmania.
Reference: Decaisne 1842.

Notes:
"*Haliptilon*": Until recently the species treated here was known as *Haliptilon roseum*. It is now understood to be more correctly placed in the genus *Jania* (see Kim et al. 2007).
Two growth forms: In the course of our study we have recognised two growth forms in the field – a feathery form which mainly lies in one plane and a more "bottlebrush" shaped form which tends to branch three-dimensionally. These two growth forms also correspond to two genetically distinct entities on the basis of molecular sequencing data.

Before a new species can be described it is necessary to fully explore the names that have been used previously for "*Haliptilon*" in New Zealand and elsewhere, including clarifying the use of the species name "*rosea*". We have treated this as a single species here – but wish to make it clear that further work is required and additional species are likely to be recognised in the future.

KEY CHARACTERS
1. Feathery outline; main stem has a beaded appearance.
2. Cylindrical curving stolons from lower segments.
3. Two forms – feather (one plane) and bottlebrush (3-dimensional) – likely represent distinct species.
4. Distinctive in the field – feathery outline, beaded main stem.
5. Occurs throughout New Zealand, in intertidal to upper subtidal.

Jania rosea: 1, 3, 5, 7, feather; 2, 4, 6, bottlebrush; 1, feather form in field; 2, bottlebrush form in field; 3, 5, feather form, showing single plane, bead-like main stem; 4, bottlebrush form, showing branching in three dimensions; 6, stolons curving from lower segments, below bead-like main stem, 5, 7, uniporate conceptacles.

1	2
3	4
5	6
	7

Jania sagittata (J.V.Lamour.) Blainv.

Family CORALLINACEAE
Subfamily CORALLINOIDEAE

Jania sagittata is a geniculate coralline alga which grows upright and dichotomously branched, 2.5-10 cm high, flattened, fan-like (in one plane) and spreading. Each calcified segment (intergeniculum) resembles a downward-pointing arrowhead with two opposite flattened upward-pointing lobes. The lobes of each segment extend from halfway to the full length of the next segment above. The topmost segments are rounded, with or without developing lobes, often pale in colour. Segments are 0.7-1.4 mm high below the lobes and 0.3-0.5 mm wide below the lobes. This species is rosy pink to pink-grey, sometimes with a glossy sheen.

Habitat: Epilithic, low intertidal to subtidal to at least 20 m.

Anatomy & reproduction: Cells in adjacent filaments are connected by cell fusions. Tetrasporangial conceptacles are swollen and occur on the inside of the lobes (closest to the "stem"). The pore is also on the inner side of the conceptacle and usually just below the tip. The tetrasporangia are zonately divided.

Distribution (NZ): Kermadec Islands. North Island: Far North, Bay of Islands, north Taranaki. Northern South Island. Collected from 8 of 86 northern study sites (9%), and from 1 of 5 Kermadec Islands sites (total 19 localities).

Distribution (elsewhere): Australia (WA, northern Vic, NSW); Kenya, Somalia, South Africa, Mauritius, Philippines, Indonesia, Brazil.

Etymology: after the French biologist Jean Vincent Félix Lamouroux (1779-1825) who erected the genus *Jania*.

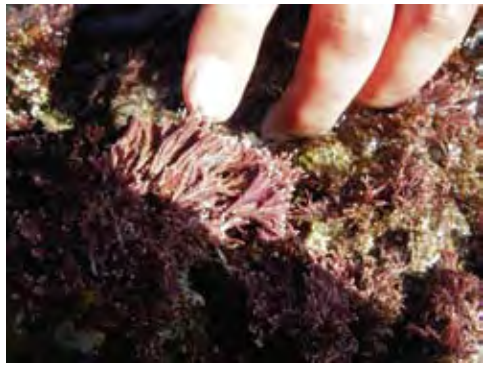
Type locality: Cape of Good Hope, South Africa.

Reference: Decaisne 1842.

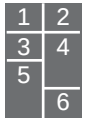
Note:
This species was previously known as *Cheilosporum sagittatum* (named for the distinctive, arrow-shaped [sagittate] segments). It has recently been transferred to the genus *Jania*, necessitating a transfer to *J. sagittata* (Kim et al. 2007, Woelkerling & Riviers 2008).

KEY CHARACTERS

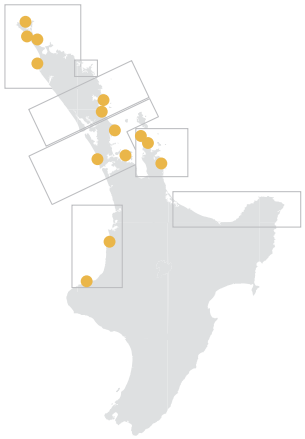
1. Dichotomously branched, regular, slender, fan-like thallus.
2. Arrow-shaped (sagittate) calcified segments.
3. Tetrasporangial conceptacles swollen, on inside of lobes.
4. Distinctive in the field; long flat plants, rosy pink colour, arrow-shaped segments.
5. Occurs occasionally in northern New Zealand, including Kermadec Islands, particularly in subtidal.



Jania sagittata: 1, growing intertidally; 2, 3, 5, dried plants from subtidal collections (deep pink colour); 3-5, arrow-shaped (sagittate) segments; 6, tetrasporangial conceptacles.



Jania verrucosa J.V.Lamour.



Jania verrucosa is a geniculate coralline alga which grows to 5 cm in height, with stiff and densely tufted axes; tips are often pale. The plants show dichotomous branching, with cyclindrical calcified segments (intergenicula) of variable lengths (0.5-1.3 (-3.5) mm), and 0.2-0.4 mm in width. Calcified segments are shorter in the lower third of the plant and slightly tapered at base of each segment. Branching angles are quite narrow and 1-5 (10) unbranched segments separate dichotomies.

Habitat: On rock in intertidal to upper subtidal.

Anatomy & reproduction: Cells in adjacent filaments are connected by cell fusions. Conceptacles occur on the stem (axial) or the tip (terminal), but collections from New Zealand are seldom fertile.

Distribution (NZ): North Island: Far North, Bay of Islands, Whangarei, Auckland, Coromandel, northern Taranaki. Collected from 14 of 86 northern study sites (16%).

Distribution (elsewhere): Widespread; Atlantic; Africa; Sri Lanka; Singapore; Australia (NSW, Qld, SA, WA, Vic); Hawaiian Islands; Mexico.

Etymology: *verrucosa* (Latin) = warty.

Type locality: "Amérique Méridionale" (central America).

Reference: Lamouroux 1816.

Note:

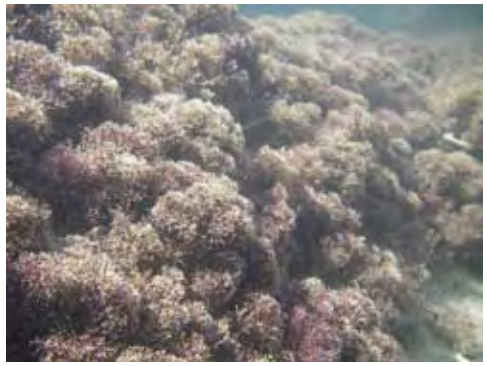
Two other names have been used for *Jania* (sensu *J. verrucosa*) in New Zealand (see Adams 1994):

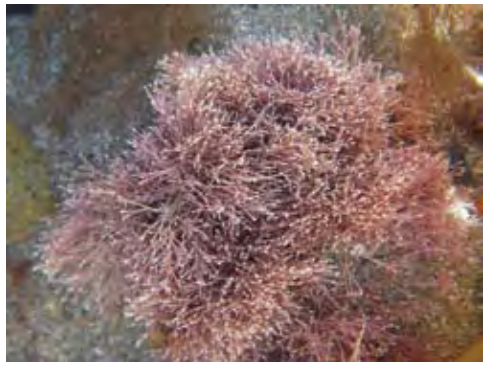
crassa (type locality Fiordland) has been synonymised by Womersley & Johansen in Womersley (1996) with *verrucosa*.

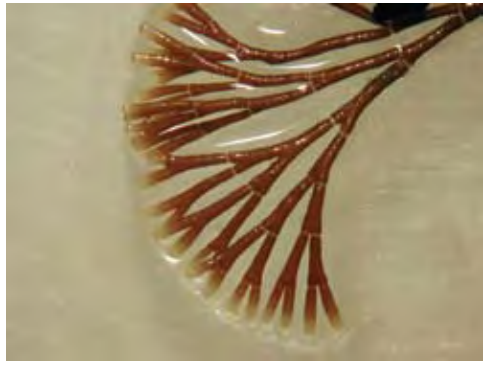
novae-zelandiae – collections from Banks Peninsula and East Coast are cited in the description (Harvey 1855: 237). A variety *longiarticulata* is also described. It is not clear where types are from; the status of these species is uncertain (Woelkerling & Nelson 2004).

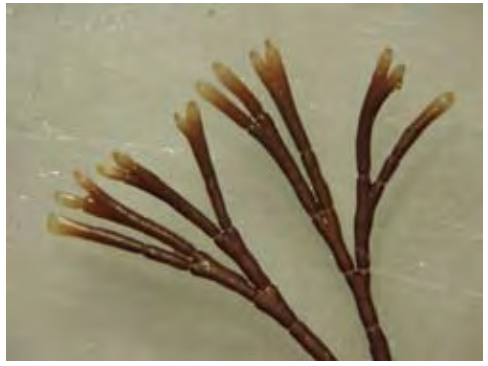
KEY CHARACTERS

1. Stiff, densely tufted plants, dichotomously branched, narrow angle between branches.
2. Cylindrical calcified segments of variable lengths.
3. Conceptacles on stem or tip.
4. Distinctive in the field – densely tufted, stiff texture, narrow segments, pale tips.
5. Occurs frequently in central and northern New Zealand, in intertidal to upper subtidal.



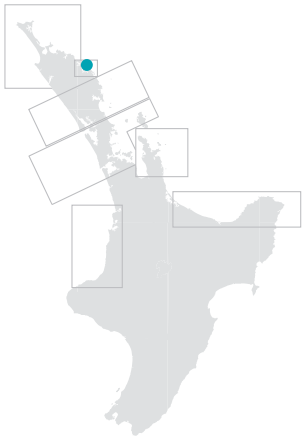






Jania verrucosa: 1-4, field shots show plants stiff and densely tufted, pale tips, fine branches; 5-7, narrow branching angles, dichotomous branching, pale tips.

Jania sp. fine



Known from a single collection in this study, from the Bay of Islands, collected from 1-5 m depth. This species grows as small plants (1-2 cm in circumference), densely dichotomously branched, pale pink/grey, with extremely fine stems (width 0.06-0.1 mm). Calcified segments (intergenicula) are 0.28-0.84 mm long. Segments at the tips of the plant are 0.2 mm long with a wide, flattened leading edge (0.175mm) and a narrow insertion (0.055 mm) to the lower part of the segment, giving an ungulate (clawed) appearance.
Habitat: Subtidal (to at least 5 m).
Distribution (NZ): North Island: Bay of Islands. Collected from 1 of 86 study sites, (1%).

Note:
This specimen has a number of features in common with *Jania ungulata* (Yendo) Yendo, and in the molecular study groups most closely with a sample named as *J. ungulata* from Korea. Confirmation of the identify of this species requires additional collections from New Zealand and comparison with material from the type region (Japan). *Jania ungulata* is reported from tropical and subtropical Pacific waters, Australia (Queensland), and the Indian Ocean.

KEY CHARACTERS
1. Small (1-2 cm) plants, densely dichotomously branched.
2. Extremely fine cylindrical calcified segments distinguish it from *J. verrucosa*.
3. Short segments on the tips with wide, flattened edge and claw-like appearance.
4. Uncommon; upper subtidal.

Corallinaceae

Non-geniculate species

Species profiles

Non-geniculate coralline algae are completely calcified. They are sometimes known as crustose or encrusting corallines, because of the growth form of many species.

Two subfamilies in the family Corallinaceae – Lithophylloideae and Mastophoroideae – have non-geniculate taxa which occur in New Zealand.

Key characters, family Corallinaceae:

- tetrasporangia in uniporate conceptacles
- tetrasporangia zonately divided

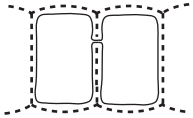
Molecular analysis (see Figure 10) shows that, while the family Corallinaceae is supported as a monophyletic clade, the relationships of the subfamilies within the Corallinaceae are less clear-cut.

Subfamily Lithophylloideae Setch.

One non-geniculate genus, *Lithophyllum* Phil., in New Zealand.

Key characters, subfamily Lithophylloideae:

- secondary pit connections



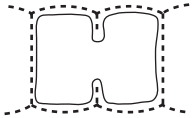
Characters separating species within the genus *Lithophyllum* include the diameter (range) of the tetrasporangial conceptacle; the number of layers of cells from floor of tetrasporangial conceptacle to the thallus surface; the number of cell layers in the conceptacle roof; and features of the tetrasporangial conceptacle pore.

Subfamily Mastophoroideae Setch.

Five genera, *Hydrolithon* (Foslie) Foslie, *Mastophora* Decne., *Neogoniolithon* Setch. & L.R.Mason, *Pneophyllum* Kütz. and *Spongites* Kütz., in New Zealand.

Key characters, subfamily Mastophoroideae:

- cell fusions



Characters separating genera within the family relate to the orientation of cells bordering the tetrasporangial conceptacle pore canals; and the arrangement of filaments forming the tetrasporangial conceptacle roof. As this latter developmental stage is often not observed, ancillary characters – such as *Pneophyllum* = epiphytic, *Spongites* = epilithic – are used.

KEY TO NEW ZEALAND NON-GENICULATE GENERA OF CORALLINACEAE

1. Secondary pit connections ..... *Lithophyllum*

   Cell fusions 2

2. Cells bordering tetrasporangial pore canal oriented more or less vertically (N-S) ..... *Hydrolithon*

   Cells bordering tetrasporangial pore canal oriented more or less horizontally (E-W) 3

3. Epiphytic 4

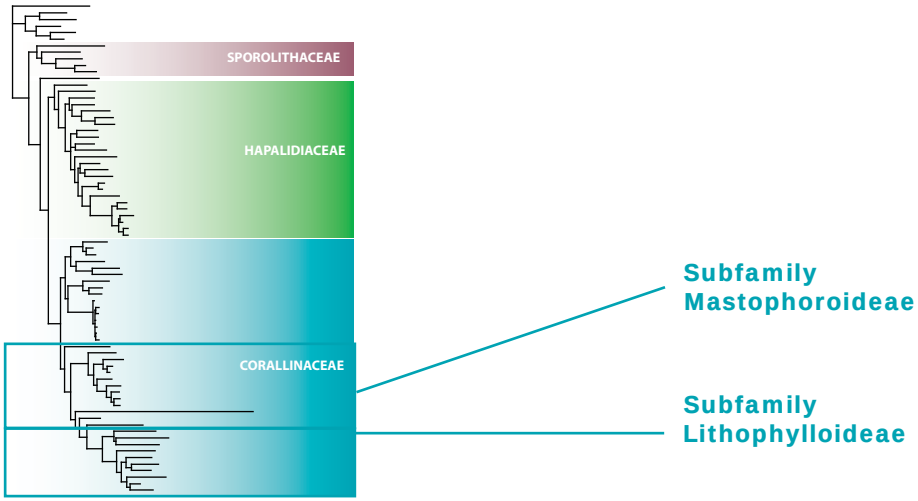
   Epilithic, epizoic, unattached 5

4. Lack a conspicuous layer of palisade cells in thallus; tetrasporangial conceptacle roof formed by filaments peripheral & interspersed amongst sporangial initials .... *Pneophyllum*

   Conspicuous layer of palisade cells in thallus; thallus 2-3 cells thick; central columella; tetrasporangial conceptacle roof formed by filaments peripheral to sporangial initials ..... *Mastophora*

5. Spermatangia on floors and roofs of male conceptacles; tetrasporangial conceptacle roof formed by filaments peripheral & interspersed amongst sporangial initials..... *Neogoniolithon*

   Spermatangia on floors only of male conceptacles; tetrasporangial conceptacle roof formed by filaments peripheral to sporangial initials ..... *Spongites*



For details of molecular analysis, see Figure 10, and the chapter *Coralline algal taxonomy*.

Hydrolithon (Foslie) Foslie

Family CORALLINACEAE
Subfamily MASTOPHOROIDEAE

3 species in NZ

Like all members of the subfamily Mastophoroideae (Corallinaceae, Corallinales), species in *Hydrolithon* produce both tetrasporangia and gametes in uniporate conceptacles, and have zonately divided tetrasporangia. The cells of the thallus are connected by cell fusions, with epithallial cells which are round or flattened but not flared. The genus *Hydrolithon* differs from other genera in the Mastophoroideae by having cells bordering the tetrasporangial pore canal oriented more or less vertically (having a "north-south" orientation).

More than 25 species are currently recognised worldwide within the genus *Hydrolithon*. Three species were found from northern New Zealand collections.

Characters separating species within the genus *Hydrolithon* include substrate, number of layers of cells in thallus, size and shape (flush or protruding above thallus surface) of tetrasporangial conceptacles, presence or absence of columella, and presence and placement of trichocytes.

DICHOTOMOUS KEY: 3 NEW ZEALAND SPECIES OF *HYDROLITHON*

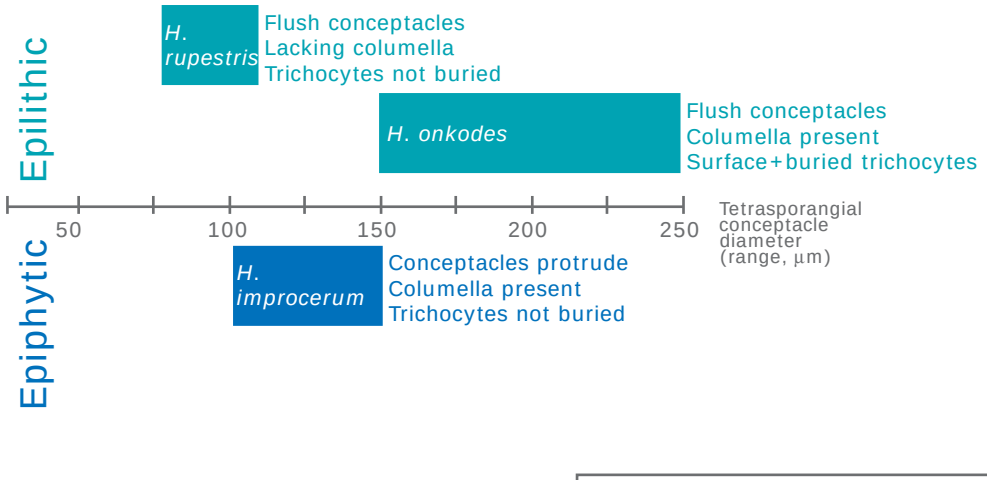
1. Epiphytic; thallus of applanate branches that overgrow one another, conceptacles protrude above surface ..... *Hydrolithon improcerum*

   Epilithic or epizoic, thallus >10 cells high, flush conceptacles 2

2. Small (80-110 µm) tetrasporangial conceptacles, lacking columella; trichocytes common in rows or singly at surface, but not buried in thallus ..... *Hydrolithon rupestris*

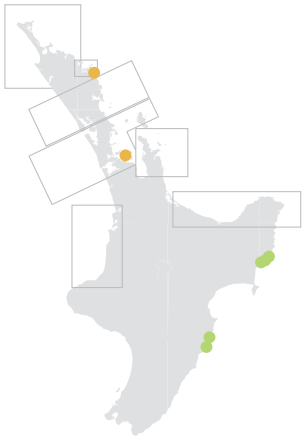
   Larger (150-250 µm) tetrasporangial conceptacles, tetrasporangia peripheral to central columella; trichocytes common in rows or singly at surface, and also commonly buried in thallus ..... *Hydrolithon onkodes*

GRAPHIC KEY: VEGETATIVE & TETRASPORANGIAL CONCEPTACLE CHARACTERS



Hydrolithon improcerum (Foslie & M.Howe) Foslie

Family CORALLINACEAE
Subfamily MASTOPHOROIDEAE



Hydrolithon improcerum grows as small, thin, encrusting non-geniculate coralline alga epiphytic on the brown algae *Cystophora retroflexa* and *C. torulosa*.

Habitat: Intertidal and upper subtidal. Adherent to substrate, crumbles away from substrate on drying. Grows in New Zealand on species of *Cystophora* (*C. retroflexa*, *C. torulosa*); known to occur on red and other brown algae, and on rock, in southern Australia.

Anatomy & reproduction: Tetrasporangia are zonately divided and produced in uniporate conceptacles (diameter 100-150 µm) which protrude above the thallus surface; cells in the pore canals of tetrasporangial conceptacles are oriented more or less vertically ("north-south" orientation). Cells are connected by cell fusions only; thalli are composed of a number of overlapping layers, each commonly 2 cells thick.

Distribution (NZ): North Island: Bay of Islands, Auckland, Gisborne, northern Wairarapa. Collections from east coast, North Island only; not confirmed from lower North Island, South Island, or Chatham Islands. Collected from 2 of 86 northern study sites (2.3%).

Distribution (elsewhere): Australia (SA, Tas); Bahamas; Caribbean; Jamaica.

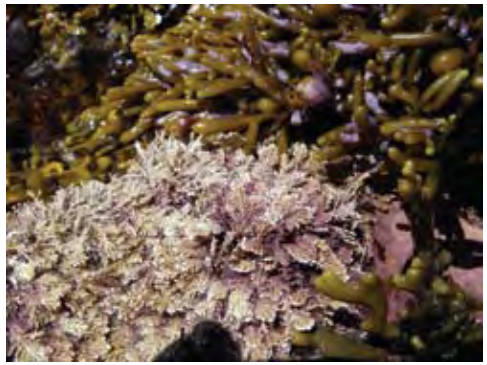
Etymology: *im-* (Latin) = not, *procer-* (Latin) = tall, high.

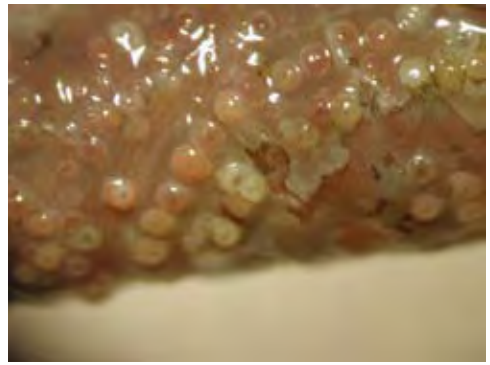
Type locality: Montego Bay, Jamaica.

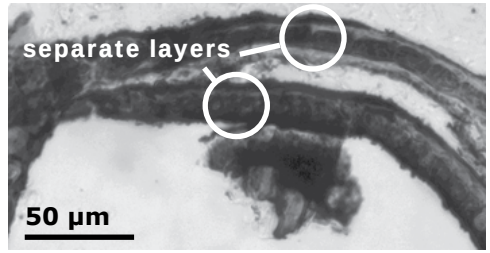
Reference: Foslie 1909.

KEY CHARACTERS

1. Small, thin, encrusting coralline alga growing epiphytically on *Cystophora*.
2. Zonate tetrasporangia produced in uniporate conceptacles.
3. Distinguished from other thin, encrusting, uniporate epiphytes (such as *Pneophyllum* spp.) by having cell fusions, thallus in overlapping layers, and cells in pore canal oriented N-S.
4. Apparently limited distribution (east coast of North Island only), despite widespread distribution of host brown algae.





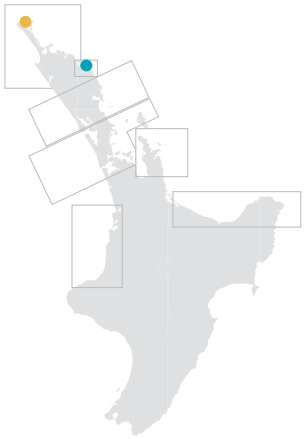


Hydrolithon improcerum: 1-2, field shots show thin encrusting purple-ish crust on *Cystophora*; 3, rounded (dome) and flatter uniporate conceptacles; 4, tetrasporangial conceptacle; 5, thallus in thin, overlapping layers.

1
2 3
4 5

Hydrolithon onkodes (Heydr.) Penrose & Woelk.

Family CORALLINACEAE
Subfamily MASTOPHOROIDEAE



Hydrolithon onkodes is a smooth, encrusting to slightly warty non-geniculate coralline alga, pale pink in colour, growing on rock. Essentially a tropical/subtropical species, it is uncommon, and restricted to the north (Far North, Bay of Islands), in New Zealand collections.

Habitat: Intertidal to upper subtidal (to 5 m). Collections in New Zealand are all growing on rock; *H. onkodes* is known to grow elsewhere on shells.

Anatomy & reproduction: Tetrasporangia are zonately divided and produced in uniporate conceptacles (diameter 160-250 µm) with a central columella, and which are flush with the surface of the thallus; cells in the pore canals of tetrasporangial conceptacles are oriented more or less vertically ("north-south" orientation). Cells are connected by cell fusions only. Trichocytes occur in rows or singly at the thallus surface as well as buried within the thallus.

Distribution (NZ): North Island: Far North, Bay of Islands. Uncommon. Collected from 2 of 86 northern study sites (2.3%). Not recorded from central and lower North Island, South Island, Chatham Islands. Not previously recorded from New Zealand.

Distribution (elsewhere): Subtropical and tropical localities including New Guinea; Australia (northern; subtropical and tropical WA); uncommon in southern Australia.

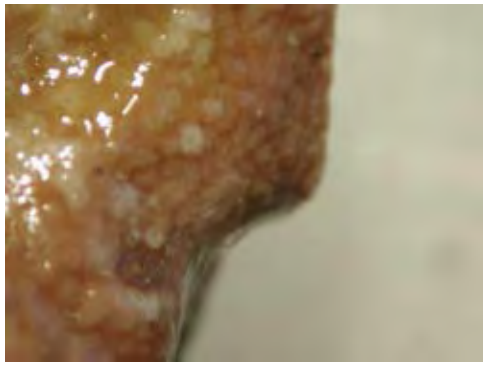
Etymology: *onco*, *-us-* (Greek) = a mass, tubercle, swelling.

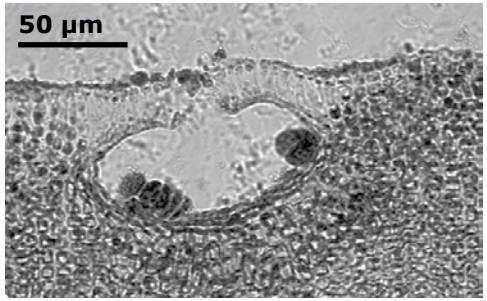
Type locality: Papua New Guinea.

Reference: Penrose & Woelkerling 1992.

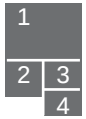
KEY CHARACTERS

1. Encrusting coralline alga growing on rocks in intertidal to upper subtidal.
2. Zonate tetrasporangia produced in uniporate conceptacles which are flush with the thallus surface.
3. Distinguished from other encrusting, uniporate epilithic species by having cell fusions, cells in pore canal oriented N-S, trichocytes in rows and singly at surface and buried.
4. Uncommon; restricted to north (Far North, Bay of Islands) in New Zealand.



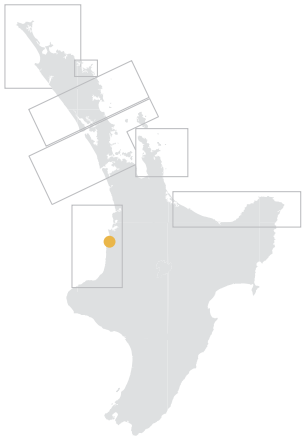


Hydrolithon onkodes: 1, 2, encrusting to slightly warty, growing on rock; 3, flat uniporate conceptacles; 4, tetrasporangial conceptacle flush with thallus surface.



Hydrolithon rupestris (Foslie) Penrose

Family CORALLINACEAE
Subfamily MASTOPHOROIDEAE



Hydrolithon rupestris grows as an encrusting non-geniculate coralline alga on rock in the intertidal. It is uncommon in New Zealand collections, and represented by a single collection in this study.

Habitat: Intertidal. Adherent to substrate. Grows in New Zealand on rock; known to occur on rock and shells in southern Australia.

Anatomy & reproduction: Tetrasporangia are zonately divided and produced in small (80-110 µm) uniporate conceptacles without a central columella, and which are flush with the surface of the thallus; cells in the pore canals of tetrasporangial conceptacles are oriented more or less vertically ("north-south" orientation). Cells are connected by cell fusions only. Trichocytes occur in fields or singly at the thallus surface, but not buried within the thallus.

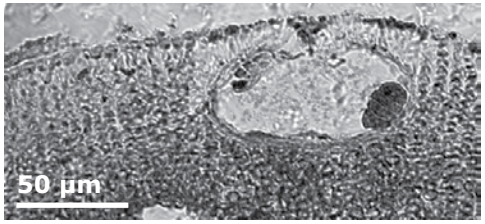
Distribution (NZ): North Island: North Taranaki. Known from only one collection in northern New Zealand (1/86 = 1%). Not previously recorded from New Zealand.

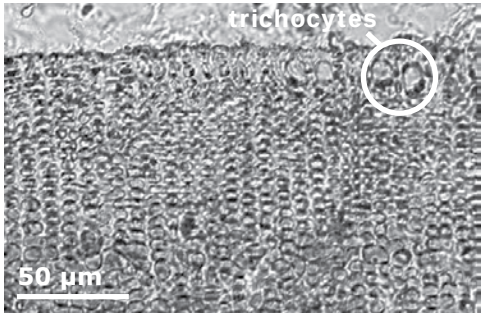
Distribution (elsewhere): Australia (NSW, SA, Vic, WA). Not known from outside Australasia.

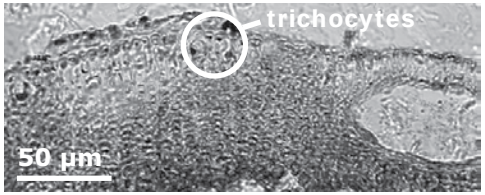
Etymology: *rupestri* (Latin) = rock; rocky, rock-dwelling.

Type locality: Victoria, Australia.

Reference: Penrose 1996.







KEY CHARACTERS

1. Encrusting coralline alga growing on rocks in intertidal.
2. Zonate tetrasporangia produced in uniporate conceptacles which are flush with the thallus surface.
3. Distinguished from other encrusting, uniporate epilithic species by having cell fusions, cells in pore canal oriented N-S, small conceptacles, trichocytes scattered at surface and not buried.
4. Uncommon in northern New Zealand.

Hydrolithon rupestris: 1, small, flat, uniporate conceptacles on crust growing on rock; 2, 4, trichocytes at surface of thallus; 3, small, flat, flush uniporate tetrasporangial conceptacle.

1	2
3	4

Lithophyllum Phil.

5+ species in NZ

Species in *Lithophyllum* produce both tetrasporangia and gametes in uniporate conceptacles. Microscopically, *Lithophyllum* has epithallial cells which are round or flattened but not flared, and zonately divided tetrasporangia. The cells of adjacent filaments in the thallus are connected by secondary pit connections.

More than 100 species are currently recognised worldwide within the genus *Lithophyllum*. Five species are currently recognised from New Zealand collections.

Molecular analysis (see Figure 10) shows additional distinct taxa from northern New Zealand related to *Lithophyllum*: one clade (sp. 1) clearly situated within the genus *Lithophyllum*, and the other (sp. 2) – a new species currently being described from material in Australia (pers. comm.) – most closely related genetically in our analysis to *Amphiroa* collections from Australia and New Zealand. A further epiphytic species (sp. aff. *pustulatum*) is known from central New Zealand collections. Work is in progress to understand the distinguishing characters of these taxa, and to establish their relationships with other species in the Lithophylloideae. They are not treated here.

Characters separating species within the genus *Lithophyllum* include the diameter (range) of the tetrasporangial conceptacle; the number of layers of cells from floor of tetrasporangial conceptacle to the thallus surface; the number of cell layers in the conceptacle roof; and features of the tetrasporangial conceptacle pore.

DICHOTOMOUS KEY: 5 NEW ZEALAND SPECIES OF *LITHOPHYLLUM*

1. Epiphytic 2

   Epilithic 3

2. Epiphytic on *Carpophyllum* spp., foliose growth form ..... *Lithophyllum carpophylli*

   Epiphytic on host other than *Carpophyllum* spp., thin encrusting to foliose..... .....*Lithophyllum pustulatum*

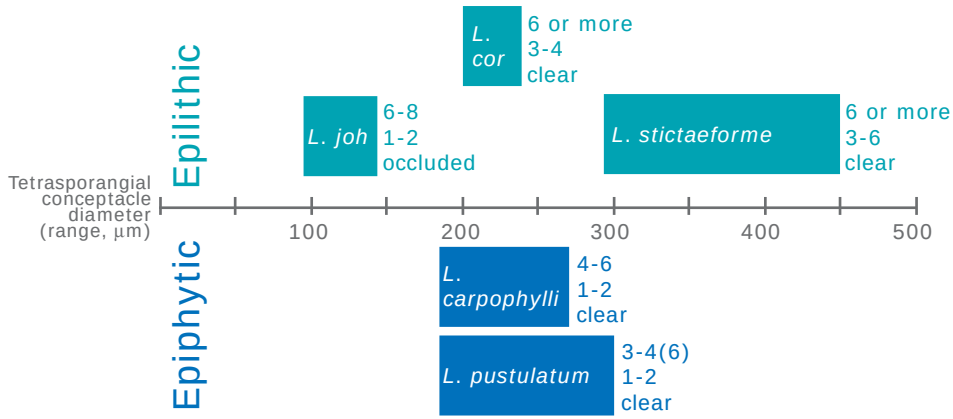
3. Small (95-145 µm) tetrasporangial conceptacles, occluded pore, 1-2 cell layers in conceptacle roof ..... *Lithophyllum johansenii*

   Tetrasporangial conceptacle diameter 180 µm or greater, pore not occluded, three or more cell layers in conceptacle roof..... 4

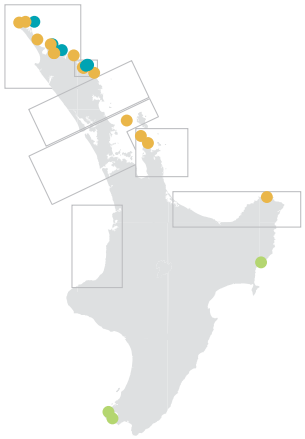
4. Tetrasporangial conceptacles 200-240 µm diameter, 3-4 cell layers in conceptacle roof.... .....*Lithophyllum corallinae*

   Large tetrasporangial conceptacles (290-450 µm diameter), 3-6 layers in conceptacle roof ..... *Lithophyllum stictaeforme*

GRAPHIC KEY: TETRASPORANGIAL CONCEPTACLE CHARACTERS



Lithophyllum carpophylli Heydr. (Heydr.)



Lithophyllum carpophylli is an endemic New Zealand coralline alga which grows on various species of the endemic brown algal genus *Carpophyllum*. Plants are irregular in outline, foliose (with upright ridge-like branches as sinuous ridges arising from encrusting base) and relatively thick, large (to 65 mm across), and rose pink, bleaching to pale pink to chalky white.
Habitat: Intertidal and subtidal to at least 18 m. Firmly adherent, epiphytic on species of *Carpophyllum*. Parts of the plant may encircle the host stem.
Anatomy & reproduction: Tetrasporangia are zonately divided and produced in uniporate conceptacles. It is distinguished from other *Lithophyllum* species by the number of cell layers (4-6) from floor of conceptacle to thallus surface; thickness of conceptacle roof (1-2 cell layers); tetrasporangial conceptacle diameter (185-270 µm); and the absence of enlarged cells blocking the conceptacle pore. Epithallial cells are round or flattened but not flared, and cells in adjacent filaments are connected by secondary pits only.

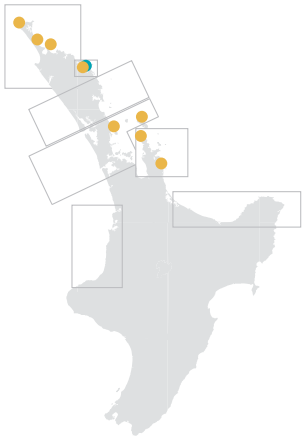
Distribution (NZ): North Island: common in Far North and Bay of Islands; occurs in Auckland, Coromandel, Bay of Plenty, and lower North Island (Wellington, Makara, Pukerua Bay); no collections from west coast of North Island (north of Pukerua Bay). South Island: collections from Nelson region only. Chatham Islands: Port Hutt. Collected from 20 of 86 northern study sites (23%).
Distribution (elsewhere): A New Zealand endemic.
Etymology: *carpophylli*, from its growth on host macroalga *Carpophyllum* spp.
Type locality: Bay of Islands, New Zealand.
Reference: Heydrich 1897a.

Notes:
1. The type of *Lithophyllum carpophylli* has not been examined in a modern context, and requires proper treatment. Often identified as *Tenarea carpophylli* (e.g., Adams 1994), placement in *Lithophyllum* is supported by vegetative characters (Harvey et al. 2005) and molecular sequencing (see Figure 10).
2. Note also confirmed one record growing on *Lessonia* stipe – otherwise considered host-specific (to species of *Carpophyllum*).

KEY CHARACTERS
1. Thick, large, rigid, foliose coralline alga growing epiphytically on *Carpophyllum* species.
2. Zonate tetrasporangia produced in uniporate conceptacles.
3. Distinguished from other uniporate epiphytes by thick, foliose growth form, secondary pit connections, growth on *Carpophyllum* host.
4. Common in Far North, Bay of Islands.

Lithophyllum carpophylli: 1-3, dried plants, showing foliose growth form; 3, 4, uniporate conceptacles can be seen on the surface; 5, fractured plant shows uniporate conceptacles at both thallus surfaces, and buried below thallus surface.

Lithophyllum corallinae (P.Crouan & H.Crouan) Heydr.

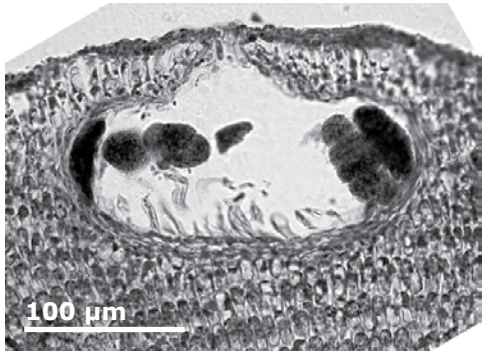


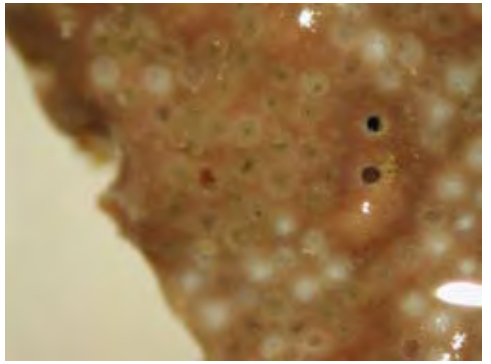
Lithophyllum corallinae grows as fruticose (occasionally encrusting to foliose) plants, pale pink to peach in colour, to 40 mm or more across, on rock. The plant surface is characterised by fruticose growth form (cylindrical to compressed knobbly branches), with branches more or less eroded.
Habitat: Intertidal and subtidal to at least 5 m. Firmly adherent, on rock.
Anatomy & reproduction: Tetrasporangia are zonately divided and produced in uniporate conceptacles. It is distinguished from other *Lithophyllum* species by the number of cell layers (6 or more) from floor of conceptacle to thallus surface; thickness of conceptacle roof (3-4 cell layers); tetrasporangial conceptacle diameter (200-240 µm); and the absence of enlarged cells blocking the conceptacle pore. Epithallial cells round or flattened but not flared, and cells are connected by secondary pits only.
Distribution (NZ): North Island: Far North, Bay of Islands, Auckland, Coromandel. Not confirmed from central and lower North Island, South Island, or Chatham Islands. Collected from 9 of 86 northern study sites (10.5%).
Distribution (elsewhere): Widespread, probably cosmopolitan (Woelkerling & Nelson 2004).

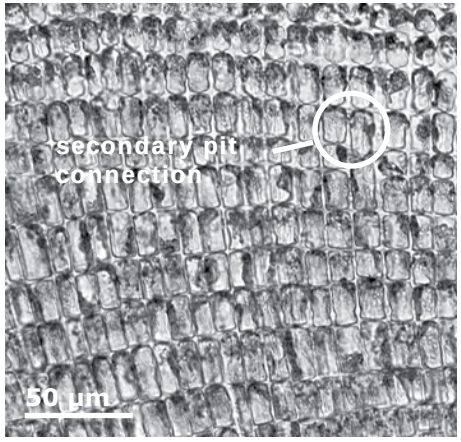
Etymology: *corallinae* – of or on corallines.
Type locality: Brest, France.
Reference: Heydrich 1897b.

Note:
In Australia and New Zealand, this species forms a species complex with *L. stictaeforme* – they are distinguished from one another on differences in tetrasporangial conceptacle chamber diameter and roof anatomy. *Lithophyllum stictaeforme* is apparently more common in New Zealand than is *L. corallinae* but, with intermediate collections not able to be confirmed to either species, *L. corallinae* may be more widely distributed than confirmed records indicate.

KEY CHARACTERS
1. Fruticose (occasionally encrusting to foliose) non-geniculate coralline alga growing on rock.
2. Zonate tetrasporangia produced in uniporate conceptacles.
3. Secondary pit connections only; absence of enlarged cells blocking tetrasporangial conceptacle pore.



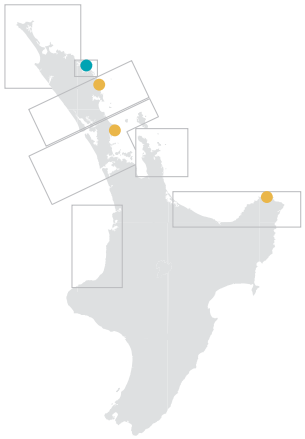




Lithophyllum corallinae: 1-3, in the field; 4, side view shows fruticse growth form; 5, uniporate conceptacles; 6, tetrasporangial conceptacles; 7, vegetative thallus showing secondary pit connections.

1	2
3	
4	5
6	7

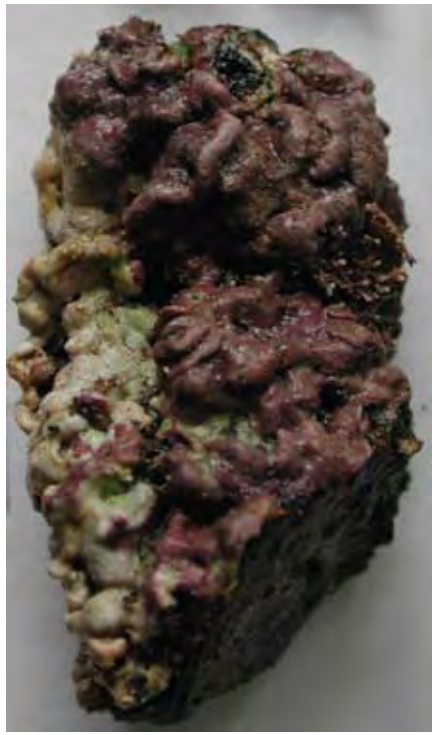
Lithophyllum johansenii Woelk. & S.J.Campb.

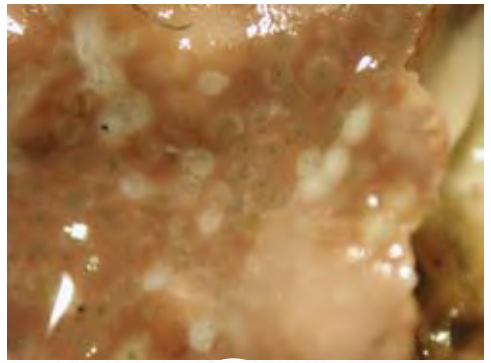


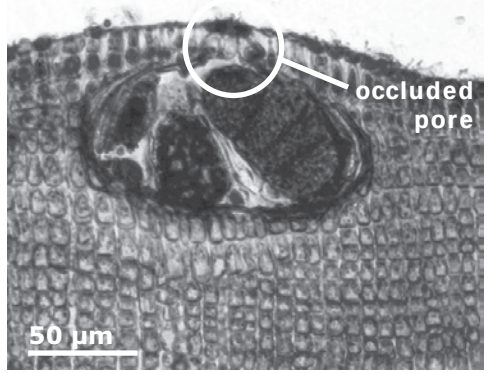
Lithophyllum johansenii grows as encrusting to warty to lumpy plants, to 90 mm across, on rock.
Habitat: Intertidal and subtidal to at least 8 m. Firmly adherent, on rock.
Anatomy & reproduction: Tetrasporangia or bisporangia are zonately divided and produced in uniporate conceptacles with pore canals which are completely blocked by 2 to 4 enlarged cells. It is distinguished from other *Lithophyllum* species by the number of cell layers (6-8) from floor of conceptacle to thallus surface; thickness of conceptacle roof (1-2 cell layers); small tetrasporangial conceptacle diameter (95-145 µm); and the presence of enlarged cells blocking the conceptacle pore. Epithallial cells are round or flattened but not flared, and cells of adjacent filaments are connected by secondary pits only.
Distribution (NZ): North Island: Bay of Islands, Whangarei, Auckland, Bay of Plenty/East Cape. Not known from lower to central North Island. South Island: Kaikoura; Westport. Chatham Islands. Collected from 4 of 86 northern study sites (5%).
Distribution (elsewhere): Australia (SA, southern Vic, Tas). Not known from outside Australasia.
Etymology: honouring coralline algal research specialist H.W. Johansen.
Type locality: Port Fairy, Victoria, Australia.
Reference: Woelkerling & Campbell 1992.

Note:
In central New Zealand, collections of *L. johansenii* were observed to have only bisporangia (Harvey et al. 2005). At least one collection from northern New Zealand has tetrasporangia. Collections from Australia have tetrasporangia or bisporangia.

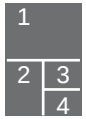
KEY CHARACTERS
1. Encrusting to warty to lumpy non-geniculate coralline alga growing on rock.
2. Zonate tetrasporangia or bisporangia produced in small uniporate conceptacles, with conceptacle pores blocked by enlarged cells.
3. Secondary pit connections only.





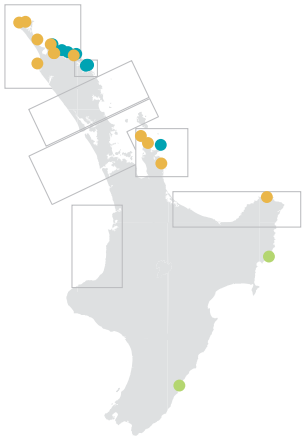


Lithophyllum johansenii: 1, field shot; 2, collected plant; 3, uniporate conceptacles on surface; 4, tetrasporangial conceptacle, showing occluded pore.



Lithophyllum pustulatum (J.V.Lamour.) Foslie

Family CORALLINACEAE
Subfamily LITHOPHYLLOIDEAE



Lithophyllum pustulatum is a coralline alga which in New Zealand grows epiphytically on various species of algae. Plants are encrusting to foliose, small (to 20 mm across), thin relative to *Lithophyllum carpophylli*, and rose pink, bleaching to pale pink to chalky white.

Habitat: Intertidal and subtidal to at least 18 m. Firmly adherent to substrate. Substrate in northern New Zealand is almost exclusively red alga *Pterocladia*. Known to occur on other algae (e.g. *Xiphophora*, *Gymnogongrus*, *Cladophora*) in central New Zealand, and on rock, sponges, shells in southern Australia.

Anatomy & reproduction: Tetrasporangia are zonately divided and produced in uniporate conceptacles. In Australia and elsewhere, *L. pustulatum* can grow on substrate other than macroalgae; in these cases it is distinguished from other *Lithophyllum* species by the number of cell layers (3-4 (6)) from floor of conceptacle to thallus surface; thickness of conceptacle roof (1-2 cell layers); tetrasporangial conceptacle diameter (185-300 µm); and the absence of enlarged cells blocking the conceptacle pore. Epithallial cells round or flattened but not flared, and cells in adjacent filaments are connected by secondary pits only.

Distribution (NZ): North Island: common in Far North, Bay of Islands and Coromandel; occurs in Bay of Plenty/East Cape, and eastern central/lower North Island (Gisborne, Wairarapa); no collections from west coast of North Island (south of Ahipara). Occurs in South Island, Chatham Islands. Collected from 21 of 86 northern study sites (25%).

Distribution (elsewhere): Widespread globally; however, Woelkerling (in Womersley 1996) cautions that many published records involve misidentifications.

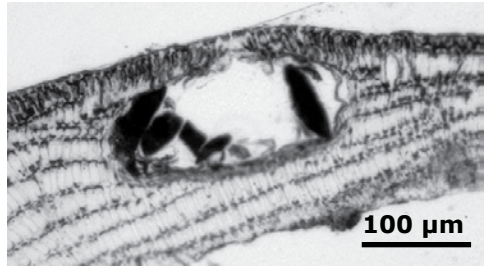
Etymology: *pustulatum*: pustulate tetrasporangial and gametangial conceptacles give plants the appearance of being covered in pustules or blisters.

Type locality: France.

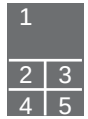
Reference: Foslie 1904.

KEY CHARACTERS

1. Encrusting to foliose coralline alga growing epiphytically on various species of macroalgae (predominantly *Pterocladia* in northern New Zealand).
2. Zonate tetrasporangia produced in uniporate conceptacles.
3. Distinguished from other uniporate epiphytes by secondary pit connections, growth on host other than *Carpophyllum*, growth form less thick and less foliose than *Lithopohyllum carpophylli*.
4. Common in intertidal and subtidal.

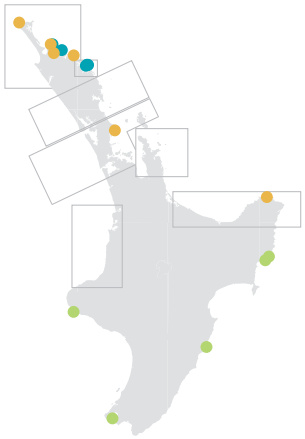


Lithophyllum pustulatum: 1, plants in the field, and 3, collected, growing on host red alga; 2, pointed and 4, flat uniporate conceptacles; 5, tetrasporangial conceptacle, thin section.



Lithophyllum stictaeforme (Aresch.) Hauck

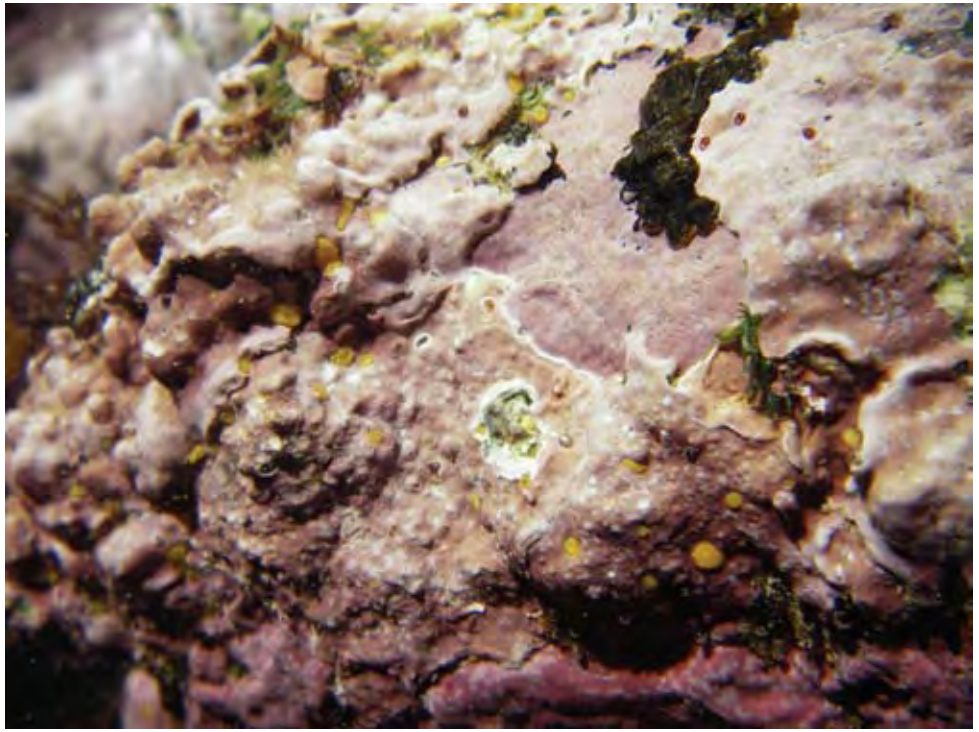
Family CORALLINACEAE
Subfamily LITHOPHYLLOIDEAE

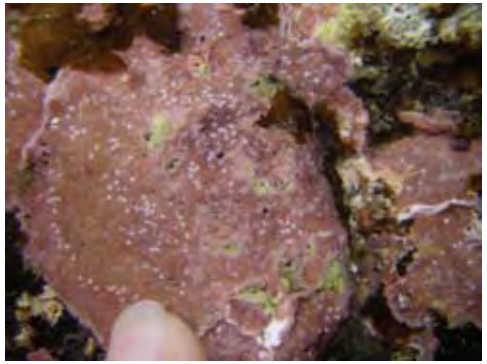


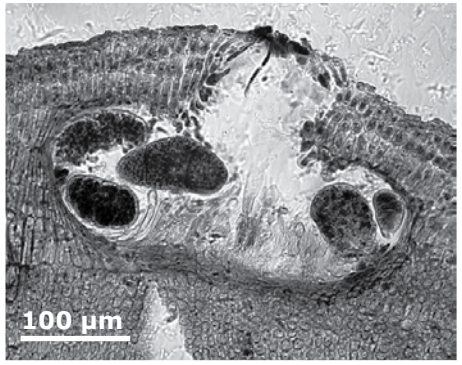
Lithophyllum stictaeforme grows as encrusting to lumpy or fruticose plants on a variety of substrates.
Habitat: Intertidal and subtidal to at least 18 m. Firmly adherent, on rock, shells (e.g. mussels, paua), other algae (e.g. bases of *Carpophyllum*).
Anatomy & reproduction: Tetrasporangia are zonately divided and produced in uniporate conceptacles. It is distinguished from other *Lithophyllum* species by the number of cell layers (6 or more) from floor of conceptacle to thallus surface; thickness of conceptacle roof (3-6 cell layers); large tetrasporangial conceptacle diameter (290-450 µm); and the absence of enlarged cells blocking the conceptacle pore. Epithallial cells are round or flattened but not flared, and cells in adjacent filaments are connected by secondary pits only.
Distribution (NZ): North Island: Far North, Bay of Islands, Auckland, Bay of Plenty; central and lower North Island (Taranaki, Wellington, Wairarapa, Gisborne). South Island. Chatham Islands. Collected from 12 of 86 northern study sites (14%).
Distribution (elsewhere): Widespread, cosmopolitan.
Etymology: *stict-* (Greek) = punctured, dappled.
Type locality: Mediterranean Sea.
Reference: Hauck 1877.

Note:
In Australia and New Zealand, this species forms a species complex with *L. corallinae* – they are distinguished from one another on differences in tetrasporangial conceptacle chamber diameter and roof anatomy. *Lithophyllum stictaeforme* is apparently more common in New Zealand than is *L. corallinae* but, with intermediate collections not able to be confirmed to either species, *L. corallinae* may be more widely distributed than confirmed records indicate.

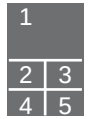
KEY CHARACTERS
1. Encrusting to lumpy or fruticose non-geniculate coralline alga growing on rock, shells, or the holdfasts of other macroalgae.
2. Zonate tetrasporangia produced in uniporate conceptacles.
3. Secondary pit connections only; large tetrasporangial conceptacles; absence of enlarged cells blocking tetrasporangial conceptacle pore.
4. Occasional, in intertidal and subtidal.







Lithophyllum stictaeforme: 1-3, field shots show range of growth forms; 4, domed uniporate conceptacles; 5, tetrasporangial conceptacle.



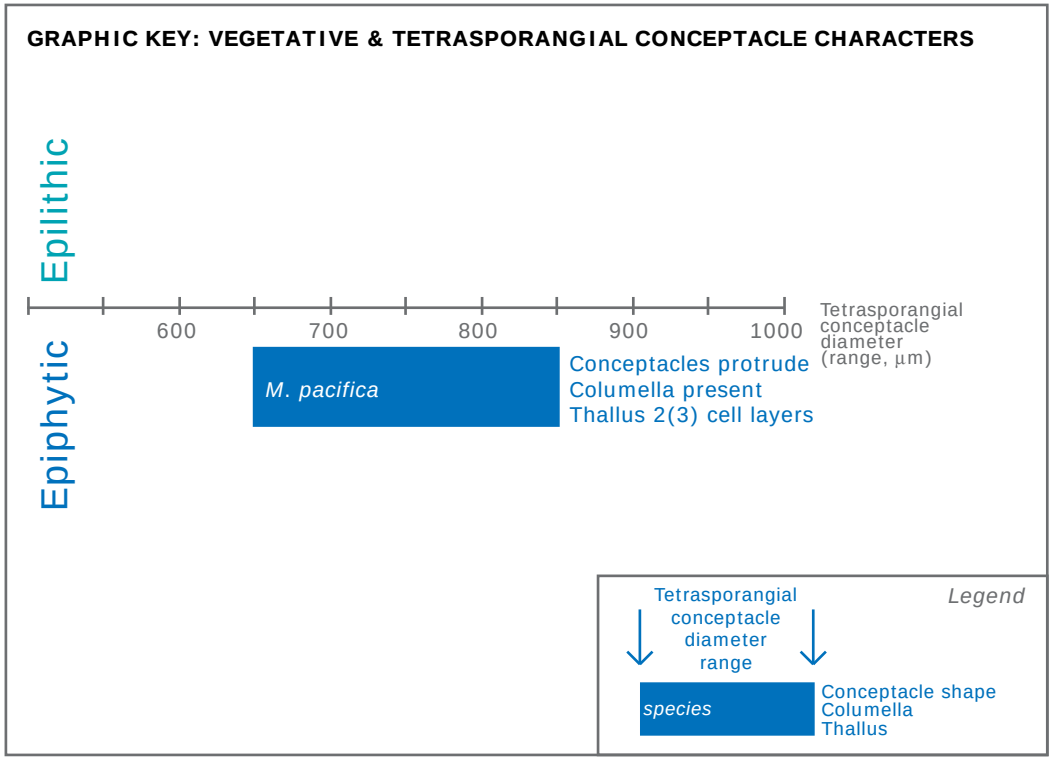
Mastophora Decne.

1 species in NZ

Like all members of the subfamily Mastophoroideae (Corallinaceae, Corallinales), species in *Mastophora* produce both tetrasporangia and gametes in uniporate conceptacles, have zonately-divided tetrasporangia; the cells of the thallus are connected by cell fusions, with epithallial cells which are round or flattened but not flared. The genus *Mastophora* differs from other genera in the Mastophoroideae by having cells bordering the tetrasporangial pore canal oriented more or less horizontally (having an “east-west” orientation); a conspicuous layer of palisade cells in thallus 2 to 3 cells thick; and a central columella.

Three species are currently recognised worldwide within the genus *Mastophora*. Only one species, *Mastophora pacifica*, has been found in New Zealand, and only from collections made in the tropical Kermadec Islands. *Mastophora* was not found from North Island collections.

In our molecular analysis, *Mastophora pacifica* is basal within a clade containing New Zealand members of the subfamilies Mastophoroideae, Lithophylloideae and Amphiroideae.



Mastophora pacifica (Heydr.) Foslie

Mastophora pacifica is an encrusting, discoid to layered non-geniculate coralline alga, dense in texture and dusty pink in colour, growing epiphytically on *Galaxaura* species. Very large (externally to 1 mm across) uniporate conceptacles on a thin crust are distinctive in the field. Essentially a tropical species, it is uncommon, and restricted to the Kermadec Islands in New Zealand collections.

Habitat: Subtidal (11-14 m). Collections in New Zealand are all growing on the red alga *Galaxaura* sp.; elsewhere, *Mastophora pacifica* grows attached to various substrates (including red algae, sponge, shells).

Anatomy & reproduction: Thallus 2(3) cells thick, with conspicuous layer of palisade cells. Cells are connected by cell fusions only. Tetrasporangia are zonately divided and peripheral to a central columella, produced in large uniporate conceptacles (diameter 650-850 µm) which protrude above the surrounding thallus; cells in the pore canals of tetrasporangial conceptacles are oriented more or less horizontally ("east-west" orientation).

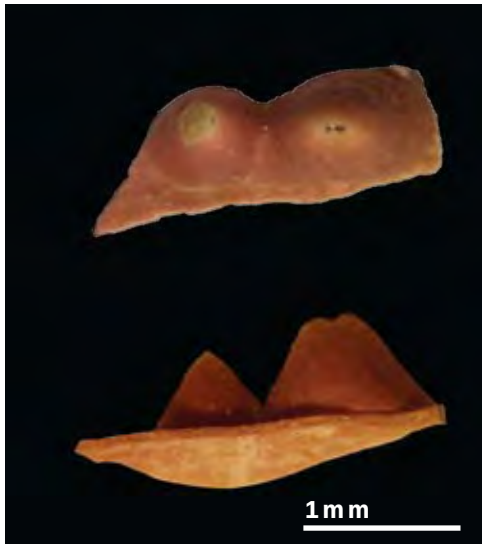
Distribution (NZ): Kermadec Islands only. Not recorded from North Island, South Island, Chatham Islands. Not previously recorded from New Zealand. Collected from 2 of 5 Kermadec Island region study sites (40%); from 0 of 86 northern North Island study sites.

Distribution (elsewhere): China, Vietnam, Indonesia, Guam, Hawaiian Islands; Australia (WA, Vic).

Etymology: *pacifica* (Latin) = pertaining to the Pacific Ocean.

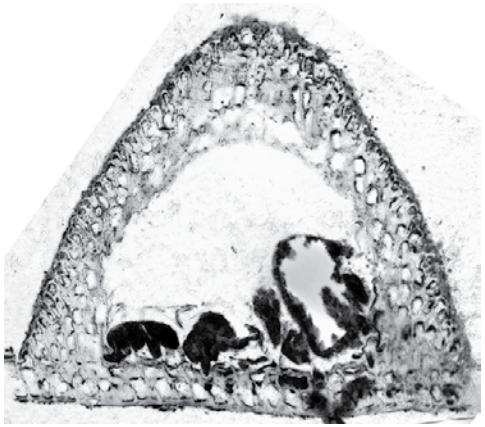
Type locality: Hawaiian Islands.

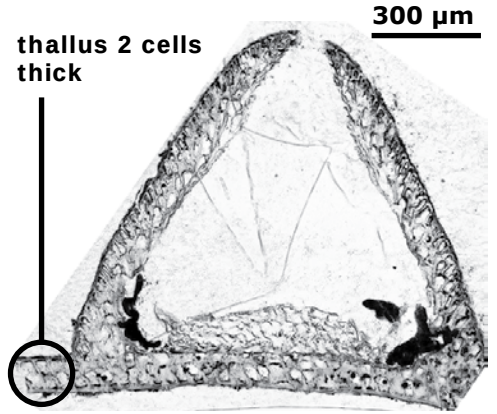
Reference: Foslie 1903.



KEY CHARACTERS

1. Encrusting, discoid to layered coralline alga growing epiphytically on red alga *Galaxaura* sp.; subtidal.
2. Zonate tetrasporangia produced in large uniporate conceptacles which protrude above the surrounding thallus.
3. Distinguished from other encrusting, uniporate epiphytic species by having thallus 2(3) cells thick with layer of palisade cells, cell fusions, cells in pore canal oriented E-W.
4. Restricted to Kermadec Islands in New Zealand.





Mastophora pacifica: 1, 2, epiphyte on *Galaxaura* host, large uniporate conceptacles apparent (white colouration due to formalin preservation); 3, 4, dried sample shows pink colour, large uniporate conceptacles on thin thallus; 5, 6, very large uniporate tetrasporangial conceptacles; 5, zonate tetrasporangia; 6, pore; thallus 2 cells thick.

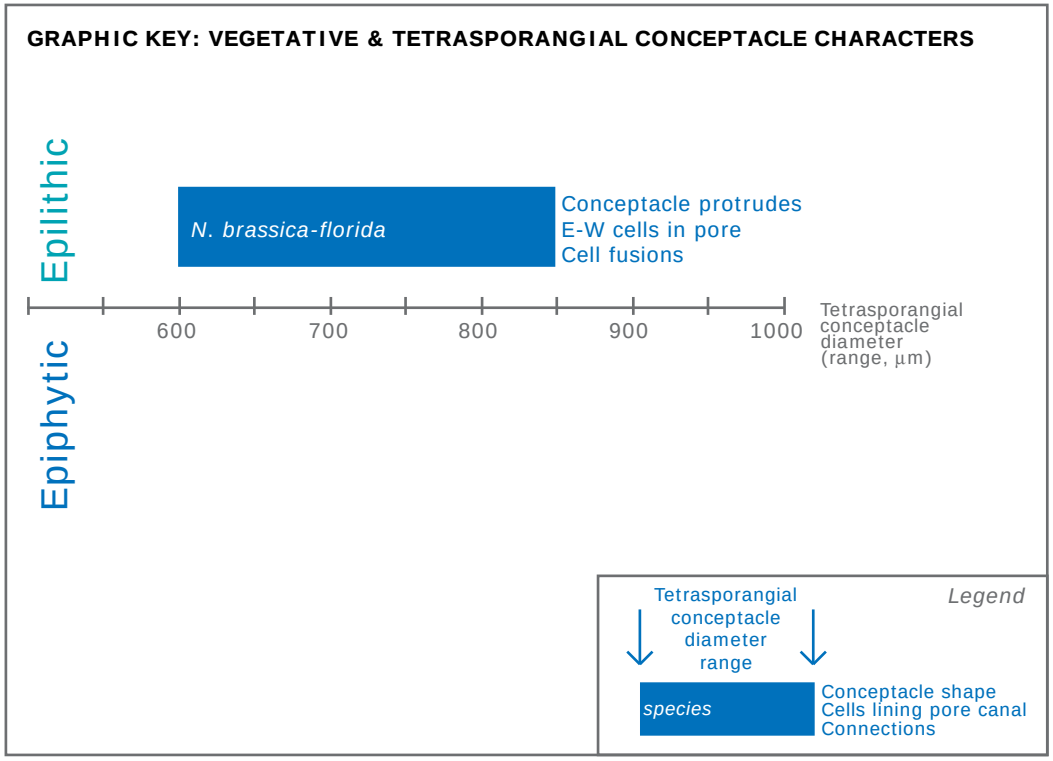
Neogoniolithon Setch. & L.R.Mason

1 species in NZ

Like all members of the subfamily Mastophoroideae (Corallinaceae, Corallinales), species in *Neogoniolithon* produce both tetrasporangia and gametes in uniporate conceptacles, and have zonately divided tetrasporangia. The cells of adjacent filaments in the thallus are connected by cell fusions, with epithallial cells which are round or flattened but not flared. The genus *Neogoniolithon* differs from other genera in the Mastophoroideae by not growing epiphytically, and by having: cells bordering the tetrasporangial pore canal oriented more or less horizontally (having an “east-west” orientation); spermatangia on floors and roofs of male conceptacles; and tetrasporangial roof formed by filaments peripheral and interspersed amongst sporangial initials.

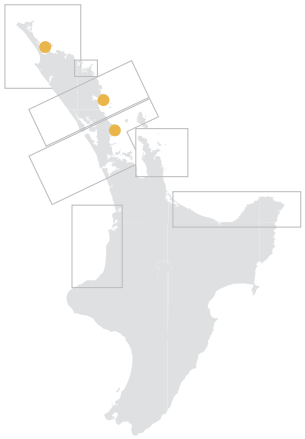
More than thirty species are currently recognised worldwide within the genus *Neogoniolithon*. Only 1 species, *Neogoniolithon brassica-florida*, was found in New Zealand.

In our molecular analysis (see Figure 10), *Neogoniolithon brassica-florida* is on a very long branch – indicating its genetic distinctiveness – within a clade containing New Zealand members of the subfamilies Mastophoroideae and Lithophylloideae.



Neogoniolithon brassica-florida (Harv.) Setch. & L.R.Mason

Family CORALLINACEAE
Subfamily MASTOPHOROIDEAE



Neogoniolithon brassica-florida is an encrusting to warty to fruticose non-geniculate coralline alga, 1mm to several cm thick, growing on rock in the intertidal. While collected at only 3% of sites in northern New Zealand, it is abundant at sites where it occurs. Large, protruding conceptacles make this species distinctive in the field.

Habitat: Intertidal, especially high intertidal; abundant where it occurs. Collections in New Zealand are all growing on rock (rock faces, high intertidal reef pools, cobbles); elsewhere, *Neogoniolithon brassica-florida* grows epilithically, epizoically, or unattached and free-living.

Anatomy & reproduction: Cells are connected by cell fusions only. Tetrasporangia and bisporangia are zonately divided and scattered across the conceptacle floor. Large uniporate tetrasporangial conceptacles (diameter 650-850 µm) protrude above the surrounding thallus. Cells in the pore canals of tetrasporangial conceptacles are oriented more or less horizontally ("east-west" orientation). Tetrasporangial conceptacle roof is formed by filaments peripheral and interspersed amongst sporangial initials, spermatangia are arranged on floor and roof of male conceptacles.

Distribution (NZ): North Island: Far North, Whangarei, Auckland. Only recorded from east coast sites. Not recorded from central and lower North Island, South Island, Chatham Islands. Not previously recorded from New Zealand. Collected from 3 of 86 (3.5%) North Island study sites.

Distribution (elsewhere): Widespread: Europe, Africa, Asia, South America, Australia; Indian Ocean, Pacific Ocean, Red Sea. In Australia, tropical WA and Qld; common in southern Australia, from Rottnest (WA) to Walkerville (Vic).

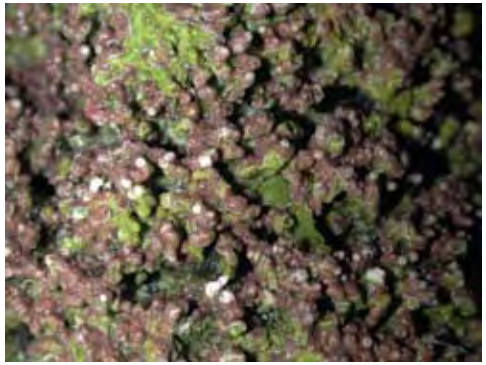
Etymology: *brassica* (Latin) = cabbage; *florida* (Latin)= flowering.

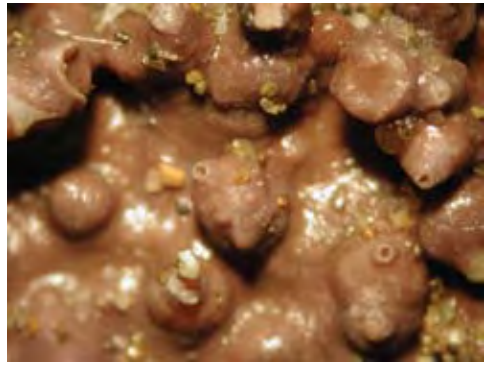
Type locality: Cape Province, South Africa.

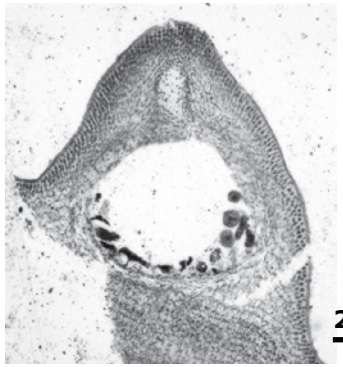
Reference: Setchell & Mason 1943.

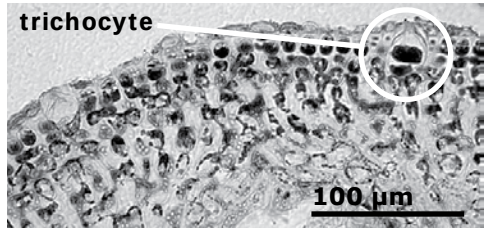
KEY CHARACTERS

1. Encrusting to warty to fruticose coralline alga growing on rock in intertidal.
2. Zonate tetrasporangia produced in large uniporate conceptacles which protrude above the surrounding thallus.
3. Distinguished from other encrusting, uniporate epilithic species by having cell fusions, cells in pore canal oriented E-W, spermatangia on floor and roof of male conceptacles.

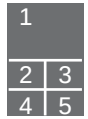








Neogoniolithon brassica-florida: 1, 2, field shots (greenish yellow colouration in patches in Fig. 2 may be disease); 3, large uniporate conceptacles; 4, tetrasporangial conceptacle, with many small tetrasporangia scattered across floor (note section not through centre of pore); 5, trichocytes at surface.



Pneophyllum Kütz. & *Spongites* Kütz.

3+ species in NZ

Like all members of the subfamily Mastophoroideae (Corallinaceae, Corallinales), species in *Pneophyllum* and *Spongites* produce both tetrasporangia and gametes in uniporate conceptacles, and have zonately divided tetrasporangia. The cells of adjacent filaments of the thallus are connected by cell fusions, with epithallial cells which are round or flattened but not flared. Both genera have cells bordering the tetrasporangial pore canal oriented more or less horizontally (having an "east-west" orientation).

Eighteen species are currently recognised worldwide within the genus *Pneophyllum*, and 11 within *Spongites*.

The genera *Pneophyllum* and *Spongites* are distinguished by mode of conceptacle development (see key, Corallinaceae family page). As this requires developmental stages that are often missing in collections, an ancillary character has been used to help identify plants of these genera in New Zealand (and southern Australia – see Woelkerling 1996): epiphytic plants are considered to belong to *Pneophyllum*, and epilithic, epizoic or unattached plants to *Spongites*. However, *Pneophyllum coronatum* (Rozanov) Penrose has been reported to occur on rock, glass, shells and other algae in the British Isles (Chamberlain 1994, as *P. caulerpae*).

Further, molecular analysis (see Figure 10) of northern New Zealand collections of *Pneophyllum* and *Spongites* indicate that relationships and species boundaries within the complex are at present unclear. While *Pneophyllum* and *Spongites* collections all form a distinct clade within the Mastophoroideae, there appear to be several distinct epilithic/epizoic taxa which fall within the current concept of *Spongites yendoi* (Foslie) Y.M.Chamb., and epiphytic collections which differ at the molecular level from *P. coronatum* or *P. fragile* Kütz. Additional more variable markers are required to detect the genetic discontinuities that point to species boundaries within these genera.

Work is in progress to determine whether anatomical and morphological characters can be mapped to the taxa apparent from molecular analysis, and whether these taxa represent currently named taxa within the *Spongites*/*Pneophyllum* complex, or are new to science. Until such work is complete, epilithic and epizoic collections from northern New Zealand can be considered to fall within *Spongites yendoi*, and epiphytic collections within *Pneophyllum*. [See also *Neogoniolithon*.]

DICHOTOMOUS KEY: 3 NEW ZEALAND SPECIES OF *PNEOPHYLLUM* AND *SPONGITES*

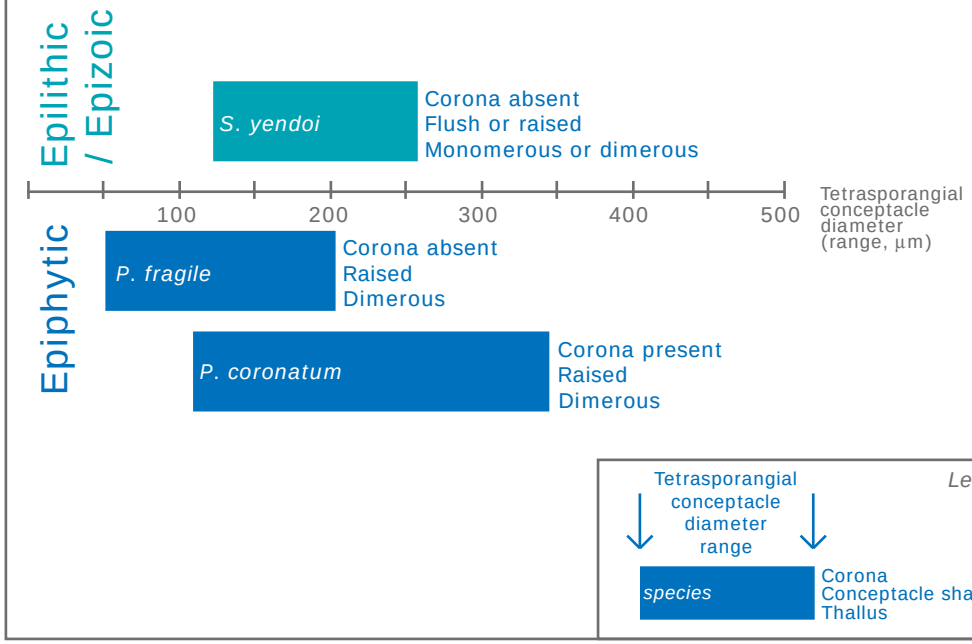
1. Epilithic or epizoic; monomerous or dimerous thallus construction; tetrasporangial conceptacles raised or flush to thallus surface, and lacking corona..... *Spongites yendoi*

   Epiphytic 2

2. Tetrasporangial conceptacles have corona protruding from pore; dimerous thallus construction; tetrasporangial conceptacles raised above thallus surface..... .....*Pneophyllum coronatum*

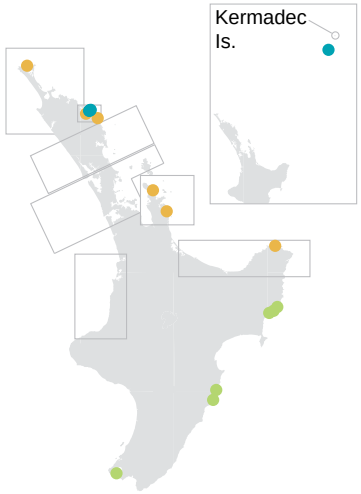
   Tetrasporangial conceptacle lack corona; dimerous thallus construction; tetrasporangial conceptacles raised above thallus surface..... .....*Pneophyllum fragile*

GRAPHIC KEY: VEGETATIVE & TETRASPORANGIAL CONCEPTACLE CHARACTERS



Pneophyllum coronatum (Rozanov) Penrose

Family CORALLINACEAE
Subfamily MASTOPHOROIDEAE



Pneophyllum coronatum is found as small, thin, encrusting layers on various red, green and brown algae. The distinctive corona that protrudes from the pore of tetrasporangial and female conceptacles may be visible using a hand lens or dissecting microscope (see Fig. 4 this page).

Habitat: Intertidal and subtidal to at least 18 m. Adherent to substrate, crumbles away from substrate on drying. Grows in New Zealand on red, green, and brown macroalgae (e.g. *Plocamium*, *Caulerpa*, *Zonaria*); most commonly on *Zonaria* in northern New Zealand. Reported to occur on rock, glass, shells, and other algae in the British Isles (Chamberlain 1994) as *P. caulerpae*).

Anatomy & reproduction: Tetrasporangia are zonately divided and produced in uniporate conceptacles; cells within the pore canal of tetrasporangial conceptacles are oriented more or less horizontally to the roof surface (E-W). These pore cells elongate and protrude from the pore, forming a corona. Gametes also occur in uniporate conceptacles (female conceptacles have corona; males lack a corona). Cells in adjacent filaments of the thallus are connected by cell fusions only.

Distribution (NZ): Kermadec Islands. North Island: Far North; Bay of Islands; Coromandel; Bay of Plenty/East Cape; central and lower North Island. Occurs on South Island and Chatham Islands. Collected from 11 of 86 northern study sites (13%), as well as 1 of 5 sites in the Kermadec Islands.

Distribution (elsewhere): Malay Archipelago; Australia (tropical WA, SA, southern Vic, Tas). As *P. caulerpae*: Europe; Africa; Sri Lanka.

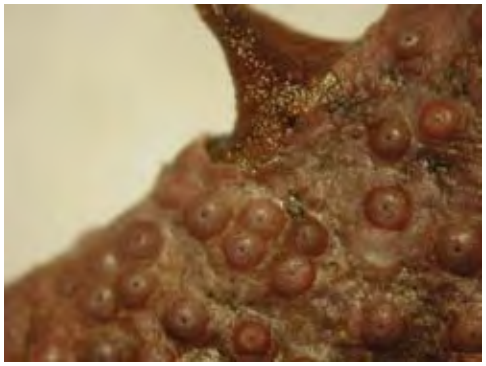
Etymology: *coronatum* – tetrasporangial conceptacles possess a corona.

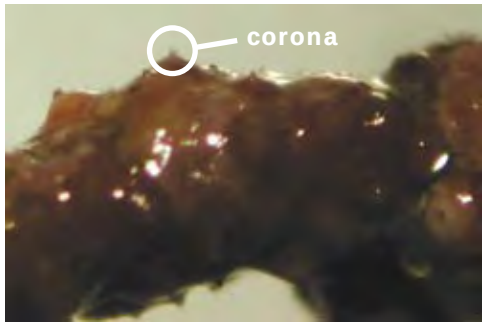
Type locality: Australia (Port Phillip Bay), Victoria.

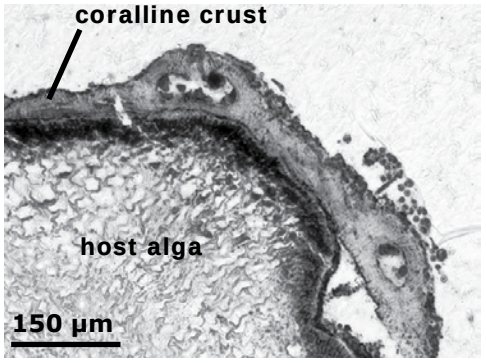
Reference: Chamberlain 1994.

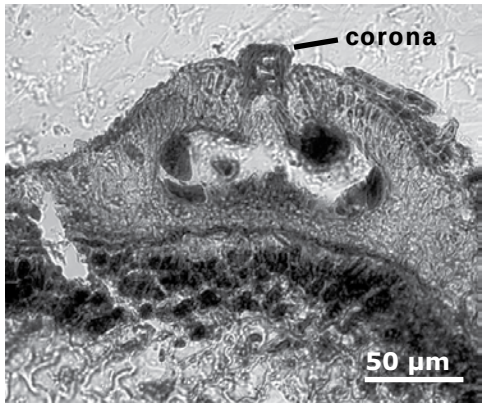
KEY CHARACTERS

1. Small, thin, encrusting coralline alga growing epiphytically on red, green and brown algae (e.g. *Plocamium*, *Caulerpa*, *Zonaria*); commonly on *Zonaria*.
2. Zonate tetrasporangia produced in uniporate conceptacles, with corona.
3. Distinguished from other thin, encrusting, uniporate epiphytes by having cell fusions, cells within pore canal oriented E-W, and corona.





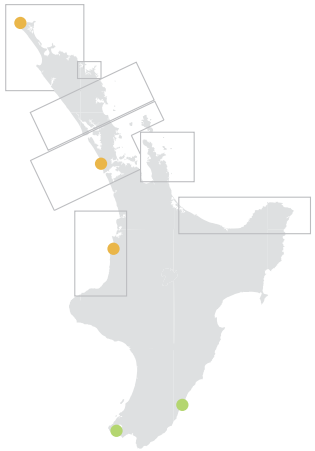




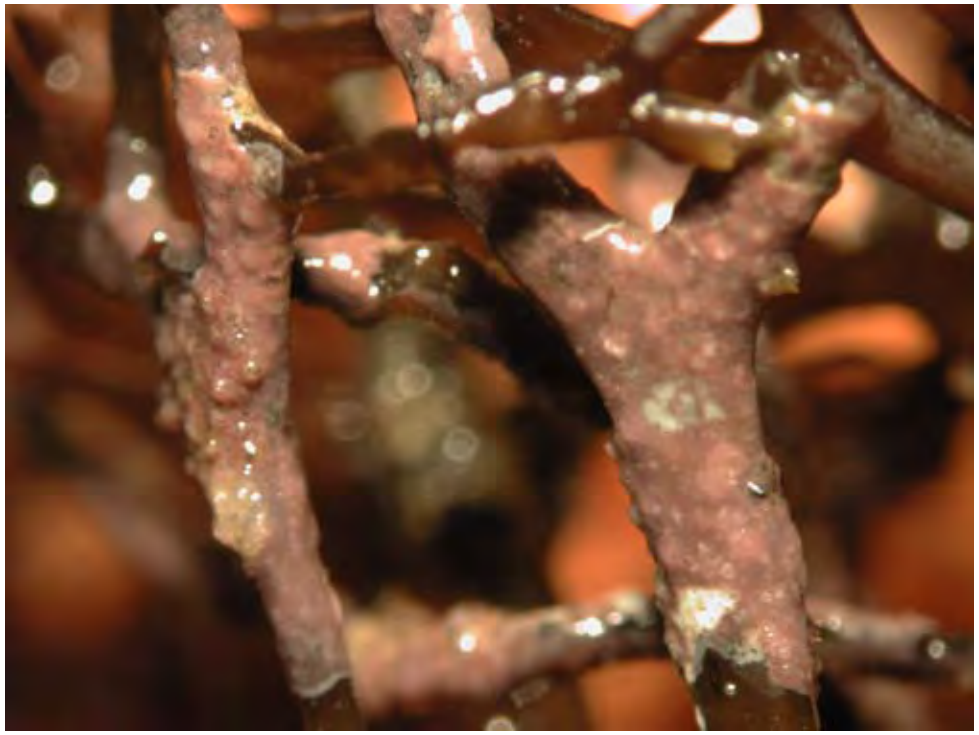
Pneophyllum coronatum: 1, larger and smaller uniporate conceptacles on host alga; 2, thin encrusting layers on host *Carpophyllum*; 3, dome uniporate conceptacles; 4, corona visible in side view of uniporate conceptacles; 5, 6, tetrasporangial conceptacles on surface of host alga, showing corona.

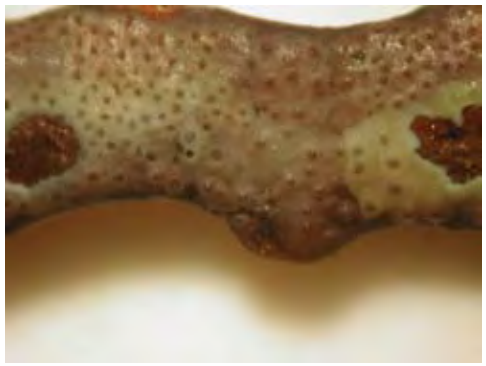
1	2
3	4
5	6

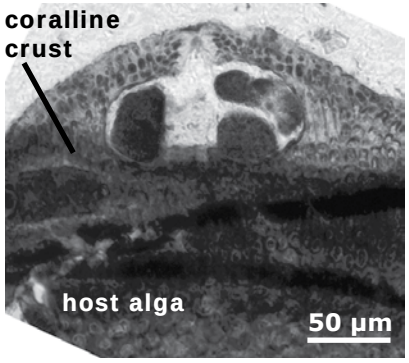
Pneophyllum fragile Kütz.



Pneophyllum fragile is a small, thin, encrusting non-geniculate coralline alga growing on various macroalgae.
Habitat: Intertidal and upper subtidal. Adherent to substrate, crumbles away from substrate on drying. Grows in northern New Zealand on red macroalgae (e.g. *Gymnogongrus*, *Osmundaria*). Elsewhere in New Zealand, known from subtidal (to at least 12 m), and on various red and brown macroalgae. Plants often become confluent and form extensive coverings on the algal host.
Anatomy & reproduction: Tetrasporangia are zonately divided and produced in uniporate conceptacles; cells within the pore canal of tetrasporangial conceptacles are oriented more or less horizontally (E-W). Corona are not present in pore canals. Cells of adjacent filaments in the thallus are connected by cell fusions only.
Distribution (NZ): North Island: Far North, Auckland; North Taranaki; lower North Island. Occurs on South Island and Chatham Islands. Collected from 3 of 86 northern study sites (3.5%).
Distribution (elsewhere): Widespread globally.
Etymology: *frag-* (Latin) = break, in reference to size and crumbling texture.
Type locality: Mediterranean Sea.
Reference: Kützing 1843.

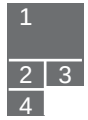






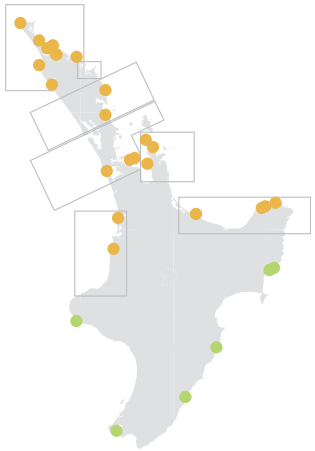
KEY CHARACTERS
1. Small, thin, encrusting coralline alga growing epiphytically on macroalgae (e.g. *Gymnogongrus*, *Osmundaria*).
2. Zonate tetrasporangia produced in uniporate conceptacles, without corona.
3. Distinguished from other thin, encrusting, uniporate epiphytes by having cell fusions, cells within pore canal oriented E-W, and lacking corona.

Pneophyllum fragile: 1-3, uniporate conceptacles, thin encrusting coralline, on host alga; 4, tetrasporangial conceptacle, thin encrusting coralline on algal host.



Spongites yendoi (Foslie) Y.M.Chamb.

Family CORALLINACEAE
Subfamily MASTOPHOROIDEAE



Spongites yendoi is an encrusting to warty non-geniculate coralline alga, firmly adhering to rock or shell substrate. Can grow as pavement, or as small, thin plants, giving distinctive "splattered paint" appearance (see Fig. 2 this page). Colour tends to range from lilac to apricot.

Habitat: Intertidal to upper subtidal in northern New Zealand (elsewhere in New Zealand, subtidal to at least 15m). Firmly adherent to substrate; in northern New Zealand, grows predominantly on rock, occasionally on shell (e.g. oyster).

Anatomy & reproduction: Tetrasporangia are zonately divided and produced in uniporate conceptacles; cells in the pore canal of tetrasporangial conceptacles are oriented more or less horizontally (E-W). A corona is not present in the pore canal. Conceptacles may be flush or raised above the thallus surface. Thallus construction may be monomerous or dimerous. Cells of adjacent filaments in the thallus are connected by cell fusions only.

Distribution (NZ): North Island: Far North; Bay of Islands; Whangarei; Auckland; Coromandel; Bay of Plenty/East Cape; North Taranaki; central and lower North Island. Occurs on South Island and Chatham Islands. Collected from 25 of 86 northern study sites (29%).

Distribution (elsewhere): Japan; South Africa; Australia (Vic); South-East Asia.

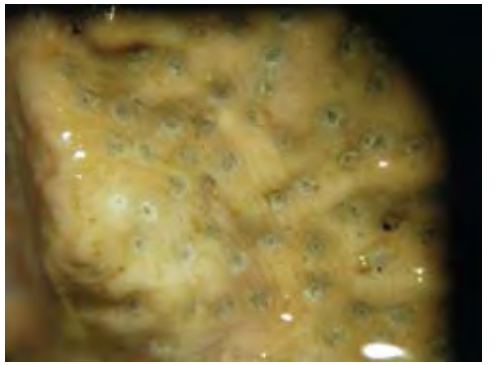
Etymology: *yendoi* – honouring Japanese coralline specialist Yendo.

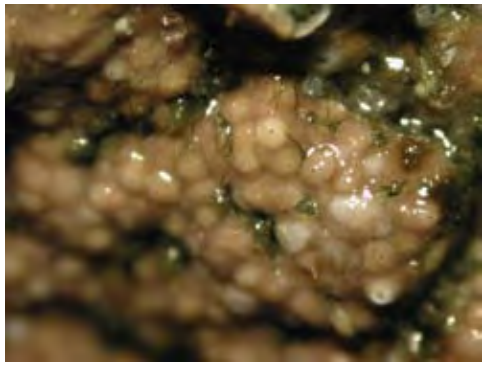
Type locality: Lectotype locality: Shimoda, Shizuoka Prefecture, Japan.

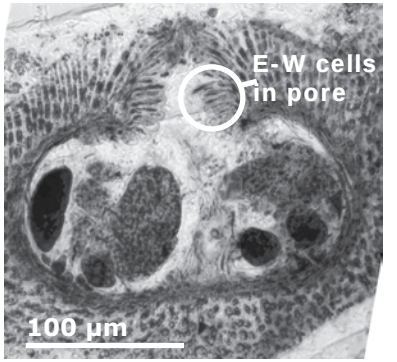
Reference: Chamberlain 1993.

KEY CHARACTERS

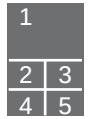
1. Encrusting to warty non-geniculate coralline alga growing commonly on rock, occasionally on shell.
2. Zonate tetrasporangia produced in uniporate conceptacles.
3. Distinguished from other encrusting uniporate epilithic species by having cell fusions only, with tetrasporangial conceptacle pore cells in E-W orientation and lacking corona.
4. Common in intertidal to upper subtidal; lilac to apricot; pavement or thinner "splattered paint" growth.







Spongites yendoi: 1, pavement in upper subtidal; 2, small, thin plants give "splattered paint" look; 3, flush uniporate conceptacles (note grazing lines across thallus surface); 4, raised/mounded uniporate conceptacles; 5; tetrasporangial conceptacle, E-W cells in pore.



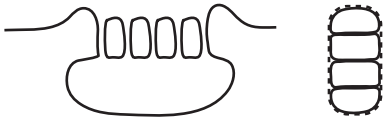
Hapalidiaceae

Non-geniculate species

Species profiles

Two subfamilies recognised in the family Hapalidiaceae – Choreonematoideae and Melobesioideae – occur in New Zealand.

Key characters, family Hapalidiaceae:



- tetrasporangia in multiporate conceptacles
- tetrasporangia zonately divided

Molecular analysis (see Figure 10) shows that, while the subfamily Melobesioideae is supported as a monophyletic clade, the relationships of the genera within the subfamily are less clear-cut. Material from the subfamily Choreonematoideae was not available for molecular analysis.

Subfamily Choreonematoideae Woelk.

The subfamily comprises a single monospecific genus, *Choreonema* F.Schmitz, which occurs in New Zealand.

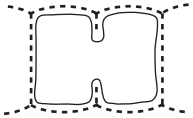
Key characters, subfamily Choreonematoideae:

- cells not linked by secondary pit connections or cell fusions (unconsolidated thallus)
- tetrasporangial conceptacles with an acellular multiporate roof (look uniporate but have a hidden multiporate plate below a single outer opening)

Subfamily Melobesioideae Bizz.

Five genera in the subfamily Melobesioideae in New Zealand: *Lithothamnion* Heydr., *Melobesia* J.V.Lamour., *Mesophyllum* Me.Lemoine, *Phymatolithon* Foslie and *Synarthrophyton* R.A.Towns. No collections of *Synarthrophyton* species were confirmed from northern New Zealand in this study.

Key characters, subfamily Melobesioideae:



- cell fusions
- tetrasporangial conceptacles with a multicellular multiporate roof

Characters separating genera within the family include: thallus construction; epithallial cell shape; length of subepithallial initials relative to cells subtending them; and branching of spermatangial filaments.

KEY TO NORTHERN NEW ZEALAND GENERA OF HAPALIDIACEAE

1. Endophytic/parasitic on geniculate coralline algae; unconsolidated thallus (no connections); acellular multiporate tetrasporangial conceptacle..... *Choreonema*

   Not endophytic/parasitic; thallus connected by cell fusions; multicellular multiporate tetrasporangial conceptacles 2

2. Dimerous thallus; thin encrusting epiphyte..... *Melobesia*

   Monomerous thallus; epilithic, epizoic, thicker epiphyte, or unattached 3

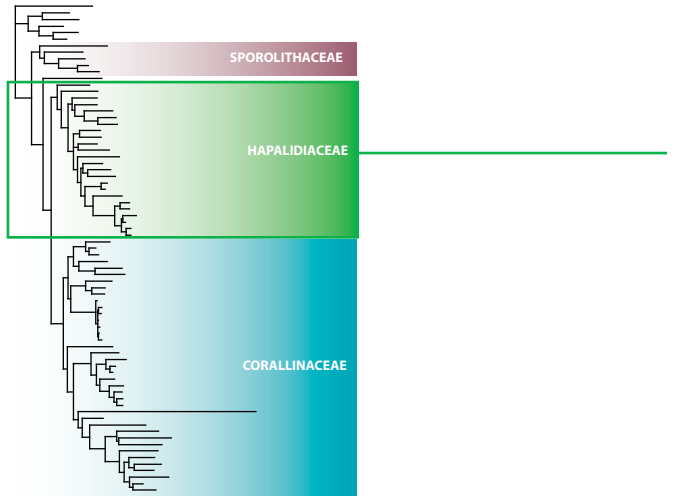
3. Epithallial cells flared..... *Lithothamnion*

   Epithallial cells rounded or flattened but not flared 4

4. Subepithallial cells short; thin encrusting epilithic..... *Phymatolithon*

   Subepithallial cells long; epilithic, epizoic, epiphytic..... *Mesophyllum**

* *Synarthrophyton* also keys out here. *Synarthrophyton* was not confirmed from northern New Zealand collections, but does occur in central and lower North Island, South Island, Chatham Islands. The genera are separated on spermatangial branching in male conceptacles: unbranched only in *Mesophyllum*; mostly branched, but may be unbranched, in *Synarthrophyton*.



For details of molecular analysis, see Figure 10, and the chapter *Coralline algal taxonomy*.

Choreonema F.Schmitz

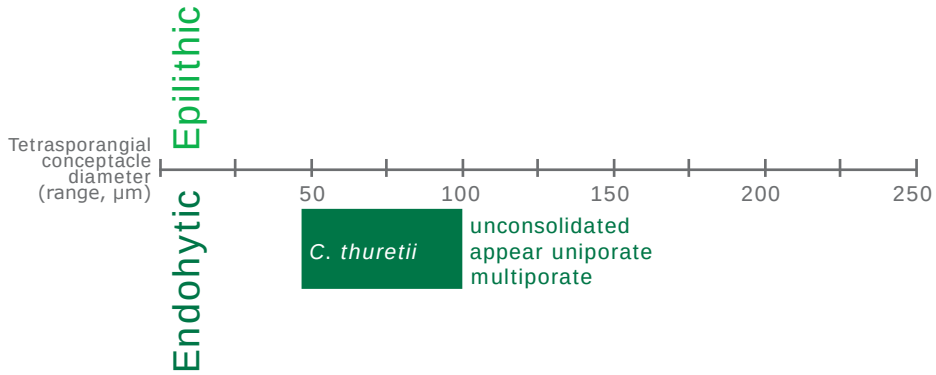
1 species in NZ

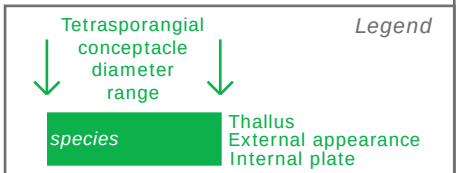
Choreonema grows parasitically on geniculate coralline algae: the unconsolidated thallus of *Choreonema* is endophytic, while the reproductive conceptacles are external to the host. Plants in *Choreonema* produce zonately divided tetrasporangia in acellular multiporate conceptacles – these appear uniporate, but comprise a multiporate plate beneath a single external opening. Gametes are produced in uniporate conceptacles.

A single species, *Choreonema thuretii* (Bornet) F.Scmitz, is recognised within the genus.

Molecular analysis was not carried out on *Choreonema* in this study, although other authors (Harvey et al. 2003a) have shown it to be contained within a monophyletic Hapalidiaceae.

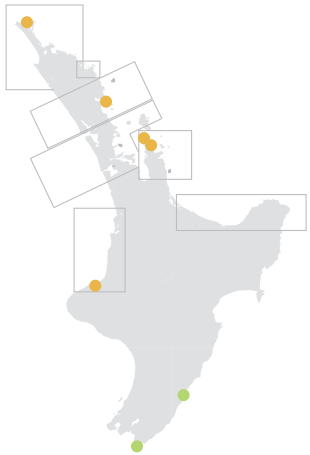
GRAPHIC KEY: TETRASPORANGIAL CONCEPTACLE CHARACTERS





Choreonema thuretii (Bornet) F.Schmitz

Family HAPALIDIACEAE
Subfamily CHOREONEMATOIDEAE



Choreonema thuretii is a tiny, non-geniculate alga, parasitic on geniculate coralline algae. Its vegetative thallus is unconsolidated, and entirely endophytic (growing within the host), while the reproductive conceptacles are external and colourless.

Habitat: Intertidal and subtidal; parasitic (semi-endophytic) on geniculate coralline algae (*Jania verrucosa* and *J. rosea* in this study; known from *Corallina* elsewhere in New Zealand).

Anatomy & reproduction: Conceptacles are colourless, to 95 µm across. Tetrasporangia are zonately divided, and produced in apparently uniporate conceptacles, which comprise an acellular multiporate plate sunken beneath a single outer opening; gametes also occur in uniporate conceptacles.

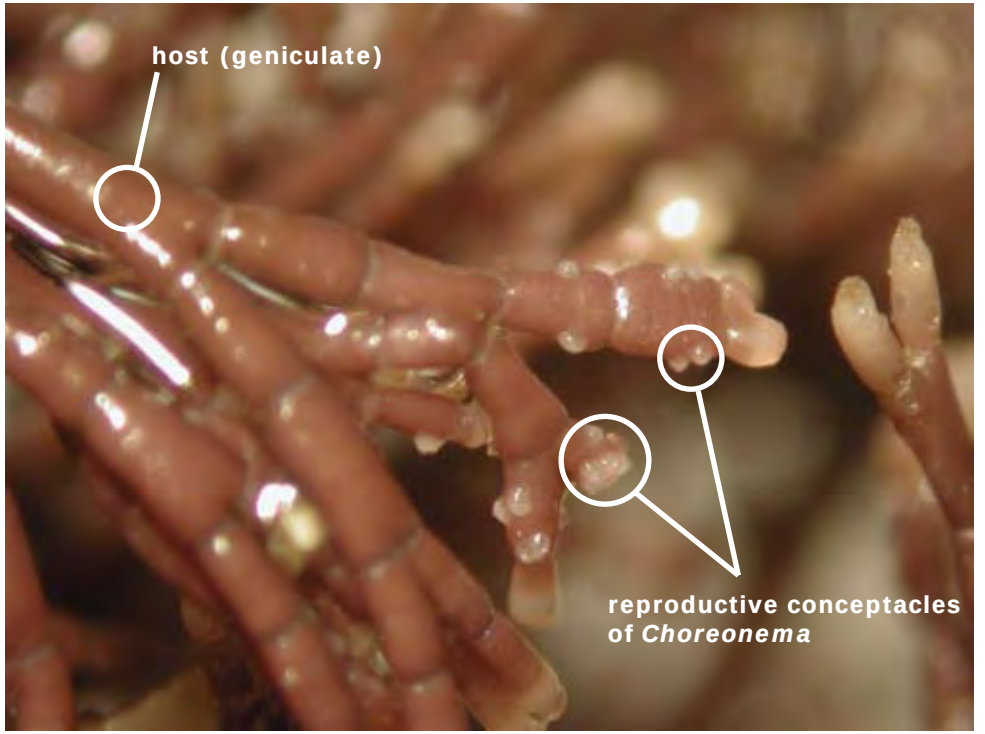
Distribution (NZ): North Island: Far North, Whangarei, Coromandel, North Taranaki, Wairarapa. South Island: Kaikoura. Not known from Chatham Islands. Collected from 5 of 86 northern study sites (6%).

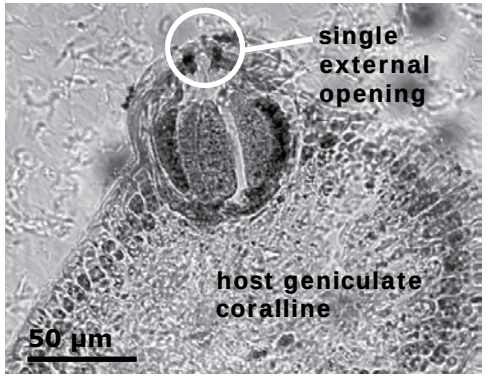
Distribution (elsewhere): Widespread globally.

Etymology: honouring Gustave Adolphe Thuret, 19th century French phycologist.

Type locality: Atlantic France.

Reference: Schmitz 1889.





KEY CHARACTERS

1. Parasitic on geniculate coralline algae.
2. Colourless, apparently uniporate conceptacles.

Choreonema thuretii: 1, 2, growing endophytically on host geniculate coralline; 3, tetrasporangial conceptacle with single external opening over multiporate plate.

Lithothamnion Heydr.

Species in *Lithothamnion* produce zonately divided tetrasporangia in multiporate conceptacles, and gametes in uniporate conceptacles. Microscopically, *Lithothamnium* has epithallial cells which are flared, distinguishing it from other multiporate genera. The cells of adjacent filaments in the thallus are connected by cell fusions.

More than 80 species are currently recognised worldwide within the genus *Lithothamnion*. Two species are currently confirmed from New Zealand collections. All *Lithothamnion* collections from New Zealand were found growing unattached, as rhodoliths; elsewhere, some species grow attached to substrate.

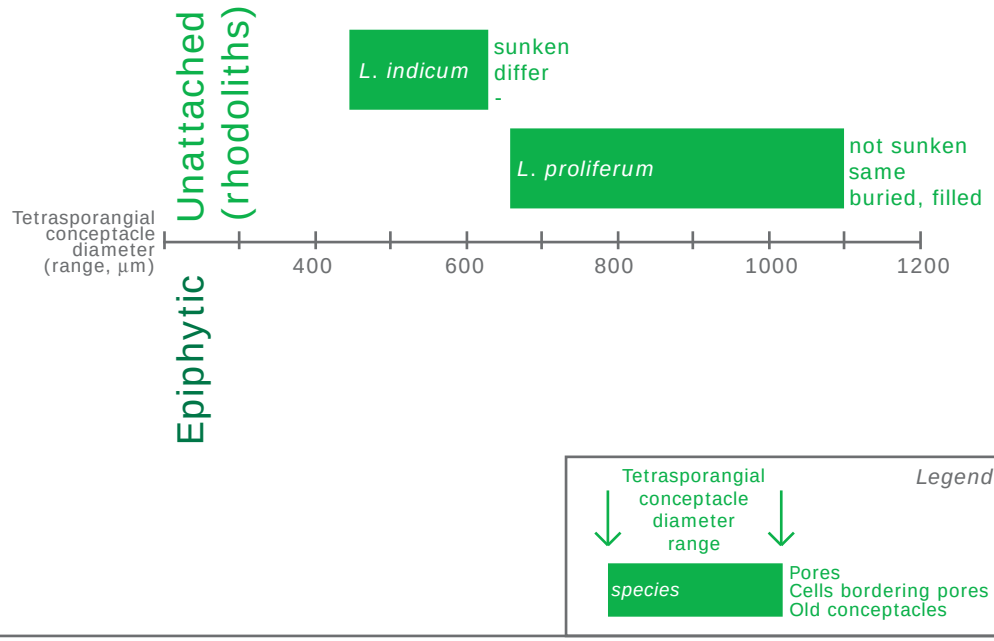
Characters separating species within the genus *Lithothamnion* include the diameter (range) of the tetrasporangial conceptacle; and features of the tetrasporangial conceptacle roof.

DICHOTOMOUS KEY: 2 NEW ZEALAND SPECIES OF *LITHOTHAMNION*

1. Large multiporate conceptacles (450-600 µm diameter) flush or slightly raised, with cells bordering pores that differ in size and shape from other roof cells, and depressions in roof overlaying pores (sunken pores) ..... *Lithothamnion indicum*

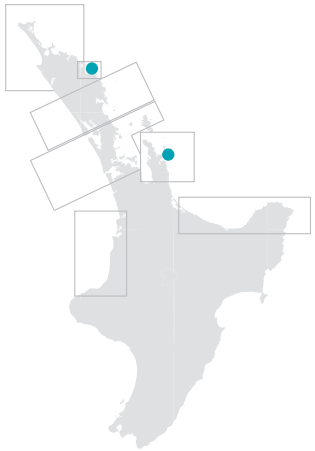
   Very large multiporate conceptacles (660-1100 µm diameter) flush or slightly raised, with cells bordering pores that do not differ in size and shape from other roof cells, and pores not sunken; old conceptacles become buried and filled with calcified cells..... ..... *Lithothamnion proliferum*

GRAPHIC KEY: TETRASPORANGIAL CONCEPTACLE CHARACTERS



Lithothamnion indicum Foslie

Family HAPALIDIACEAE
Subfamily MELOBESIOIDEAE



Lithothamnion indicum is a non-geniculate coralline alga that is warty to lumpy to fruticose in growth form, growing unattached and forming rhodoliths from 15 to 40 mm across, generally with short branches. Large multiporate conceptacles appear macroscopically flat-topped and are flush or raised above the surrounding thallus; they may be mistaken in the field for small sori.

Habitat: Subtidal to at least 22 m. Grows unattached, free-living, as rhodoliths.

Anatomy & reproduction: Epithallial cells are flared; cells in adjacent filaments connect by cell fusions only within a monomerous thallus. Zonately divided tetrasporangia are produced in large (450-600 µm) multiporate conceptacles flush with or raised above the surrounding thallus; tetrasporangial conceptacle pores are bordered by cells that differ in size and shape from other roof cells. Roof of mature tetrasporangial conceptacle pitted with depressions each of which overlies a pore, so that pores are sunken with respect to pore plate.

Distribution (NZ): North Island: Bay of Islands, Coromandel. Not known from central and lower North Island, South Island or Chatham Islands. Collected from 2 of 86 northern study sites (2%). Not previously recorded from New Zealand.

Distribution (elsewhere): Australia (Vic); reports from elsewhere (Central America; Africa; South-East Asia) require confirmation (Womersley 1996) as species relationships within *Lithothamnion* are reviewed.

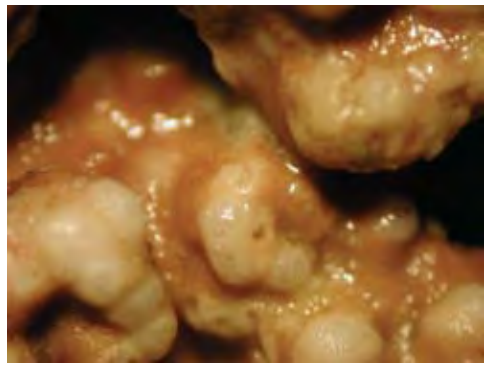
Etymology: *indicum* (Latin) = that which points out.

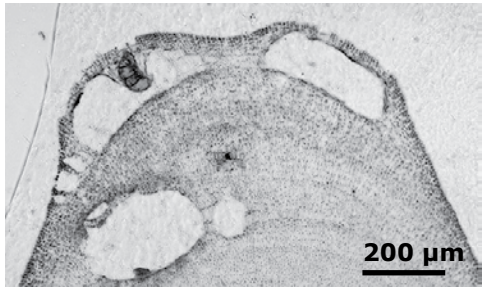
Type locality: Victoria, Australia.

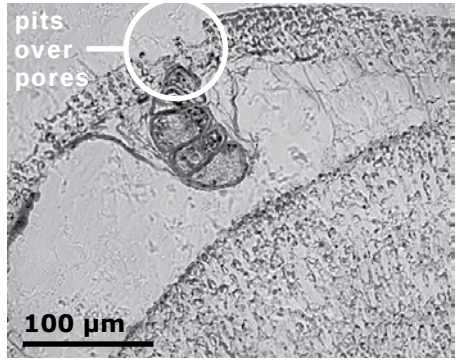
Reference: Foslie 1907.

KEY CHARACTERS

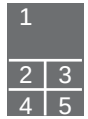
1. Warty to lumpy to fruticose non-geniculate coralline alga, growing unattached as rhodolith.
2. Large multiporate conceptacles, flat-topped, flush with or raised above thallus.
3. Epithallial cells flared; cells lining pore canal differ from other roof cells; tetrasporangial conceptacle roof pitted with depressions (pores sunken with respect to pore plate).
4. Uncommon in collections of New Zealand rhodoliths.



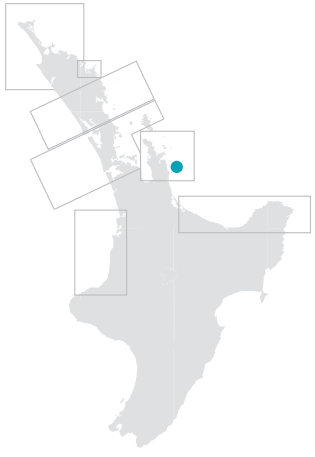




Lithothamnion indicum: 1, 2, rhodoliths (multiporate conceptacles are visible on tips of some branches); 3, multiporate conceptacles are large, pale, raised, flat-topped, and can be mistaken for sori; 4, 5, tetrasporangial conceptacles; note depressions in pore plate at each pore.



Lithothamnion proliferum Foslie



Lithothamnion proliferum is a non-geniculate coralline alga that is lumpy to fruticose in growth form, growing unattached and forming rhodoliths to at least 100 mm across, with short branches. Large, flat-topped multiporate conceptacles are flush or slightly raised above the surrounding thallus; these can be mistaken in the field for sori. Large uniporate conceptacles (female) also occur. Thallus is characteristically smooth, glossy and velvety in field.

Habitat: Subtidal to at least 30 m. Grows unattached, free-living, as rhodolith. Elsewhere grows epilithically (with growth as rhodolith reported only from Kiribati).

Anatomy & reproduction: Epithallial cells are flared; cells connect by cell fusions only within a monomerous thallus. Zonately divided tetrasporangia are produced in large (660-1100 µm) multiporate conceptacles, flat-topped and flush or only slightly raised above the surrounding thallus; tetrasporangial conceptacle pores are bordered by cells that do not differ in size and shape from other roof cells. Old conceptacles persist and become buried in the thallus, becoming filled in by irregularly-arranged calcified cells.

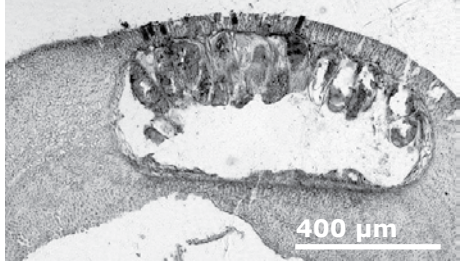
Distribution (NZ): North Island: Coromandel. Not known from central and lower North Island, South Island, Chatham Islands. Collected from 1 of 86 northern study sites (1%) – known from a single rhodolith collected from 30 m depth. Not previously recorded from New Zealand.

Distribution (elsewhere): Australia (Qld); Pacific Islands (Kiribati); southern Asia (India, Indonesia); Africa (Madagascar). Considered a tropical/subtropical Indo-Pacific species.

Etymology: *proliferum* (Latin) = producing offsets, bearing progeny as offshoots.

Type locality: Indonesia.

Reference: Foslie 1904.



KEY CHARACTERS

1. Lumpy to fruticose non-geniculate coralline alga, growing unattached as rhodolith.
2. Large multiporate conceptacles, flat-topped, flush or slightly raised above thallus.
3. Epithallial cells flared; cells lining pore canal do not differ from other roof cells; old conceptacles become buried and filled with calcified cells.
4. Characteristic smooth, glossy, velvety texture and appearance in field.
5. Considered a (sub)tropical species; uncommon, known from a single rhodolith collection in New Zealand.

Lithothamnion proliferum: 1, whole rhodolith, diameter 100 mm; 2, flat-topped multiporate conceptacles; 3, uniporate conceptacles; 4, tetrasporangial conceptacle.

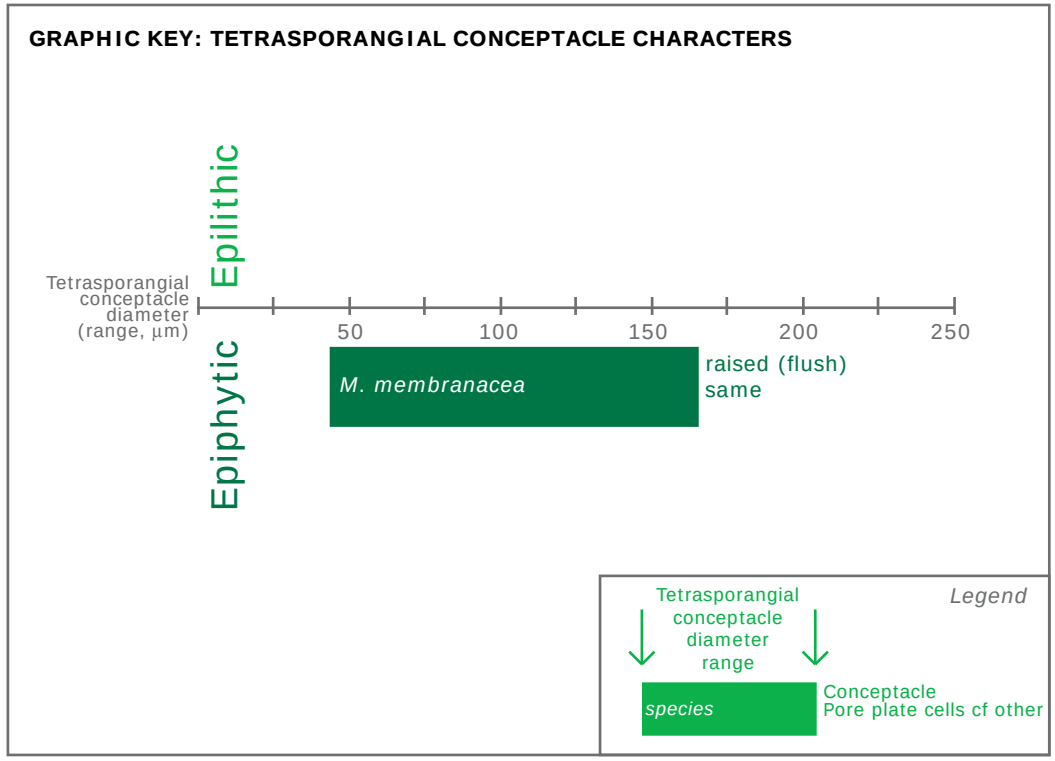
Melobesia J.V.Lamour.

New Zealand species of *Melobesia* are thin, encrusting and epiphytic. They produce zonately divided tetrasporangia in multiporate conceptacles, and gametes in uniporate conceptacles. Microscopically, *Melobesia* has epithallial cells which are rounded or flattened, but not flared. The cells of adjacent filaments of the thallus are connected by cell fusions.

Eighteen species are currently recognised worldwide within the genus *Melobesia*, although many more have been recognised in the past. One species of *Melobesia* was confirmed from northern New Zealand collections.

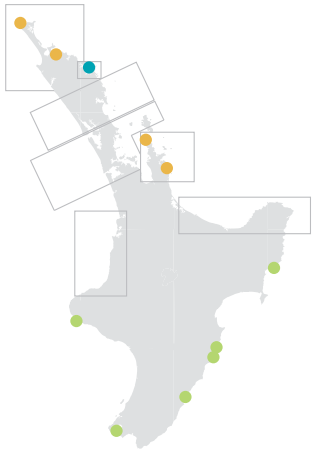
Molecular analysis was not carried out on *Melobesia* in this study.

Characters separating species within the genus *Melobesia* include whether the tetrasporangial conceptacle is raised or sunken relative to the thallus surface; whether cells in the tetrasporangial conceptacle pore plate are similar to or differ from other roof cells; and features of the vegetative thallus.



Melobesia membranacea (Esper) J.V.Lamour.

Family HAPALIDIACEAE
Subfamily MELOBESIOIDEAE



Melobesia membranacea is a thin, small (to 35 mm across), pink to pale, encrusting coralline alga, epiphytic on various red and brown macroalgae. The only thin encrusting epiphyte confirmed from New Zealand collections that has multiporate conceptacles, these often appear dark or "jelly-like" against a paler encrusting thallus.

Habitat: Intertidal and subtidal to at least 8 m. Grows in New Zealand on brown and red macroalgae (e.g. *Carpophyllum*, *Pterocladiella*, *Vidalia*).

Anatomy & reproduction: Tetrasporangia are zonately divided, and produced in small (40-165 µm) multiporate conceptacles. Epithallial cells are round or flattened but not flared; cells of adjacent filaments in the thallus are connected by cell fusions only.

Distribution (NZ): North Island: Far North, Bay of Islands, Coromandel, central and lower North Island. South Island. Chatham Islands. Collected from 5 of 86 northern study sites (6%).

Distribution (elsewhere): Widespread, but many records require confirmation (see also Wilks & Woelkerling, 1991: 524; Chamberlain & Irvine, 1994c: 199) (Woelkerling 1996).

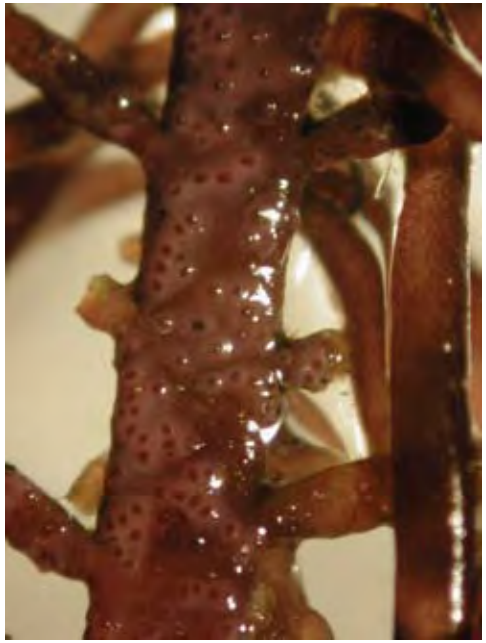
Etymology: *membranacea* (Latin) = membranous.

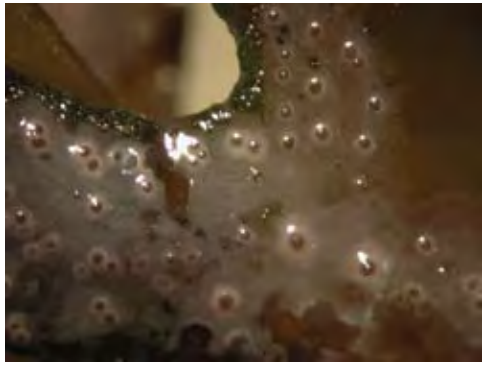
Type locality: France (west coast).

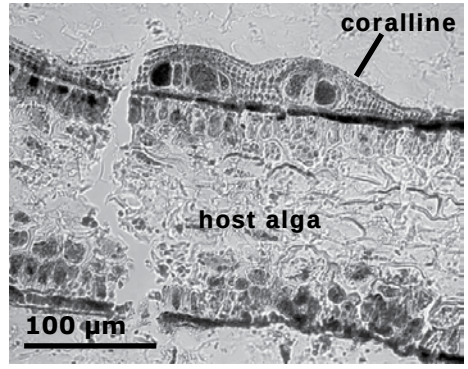
Reference: Lamouroux 1812.

KEY CHARACTERS

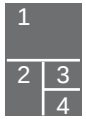
1. Thin, small, encrusting coralline alga, epiphytic on various red or brown macroalgae.
2. Small, flat-topped multiporate conceptacles, often appearing dark or "jelly-like" against a paler thallus.
3. The only thin, small, encrusting epiphytic coralline algae known from New Zealand collections that has multiporate conceptacles.







Melobesia membranacea: 1, in the field, the thin epiphyte can be hard to see – look for a thin crust or sheen on host plants; 2, 3, small "jelly-like" conceptacles on a thin crust; 4, tetrasporangial conceptacles, very thin coralline crust on host alga.



Mesophyllum Me.Lemoine

Species in *Mesophyllum* produce zonately divided tetrasporangia in multiporate conceptacles, and gametes in uniporate conceptacles. Microscopically, *Mesophyllum* has epithallial cells which are rounded or flattened, but not flared. The cells of adjacent filaments in the thallus are connected by cell fusions.

More than 40 species are currently recognised worldwide within the genus *Mesophyllum*. Four species are confirmed from New Zealand collections.

Molecular analysis (see Figure 10) shows that, while the Melobesioid taxa analysed form a monophyletic clade, generic and species relationships are complex. Analysis also shows additional distinct taxa from northern New Zealand relating to *Mesophyllum*, indicated by the *Mesophyllum* sp. (not confirmed to species) and unidentified taxa. These unassigned taxa are not treated here. Work is in progress to understand the distinguishing characters and relationships of all taxa in the Melobesioideae.

Characters separating species within the genus *Mesophyllum* include the diameter (range) and shape (flat-topped or sunken pore plate) of the tetrasporangial conceptacle; and whether cells lining the pore canal are long or similar when compared with other roof cells.

DICHOTOMOUS KEY: 4 NEW ZEALAND SPECIES OF *MESOPHYLLUM*

1. Tetrasporangial conceptacles have sunken pore plate, with distinctive rim 2

   Tetrasporangial conceptacles flat-topped 3

2. Cells bordering tetrasporangial conceptacle pores are longer than other cells in conceptacle roof ..... *Mesophyllum printzianum**

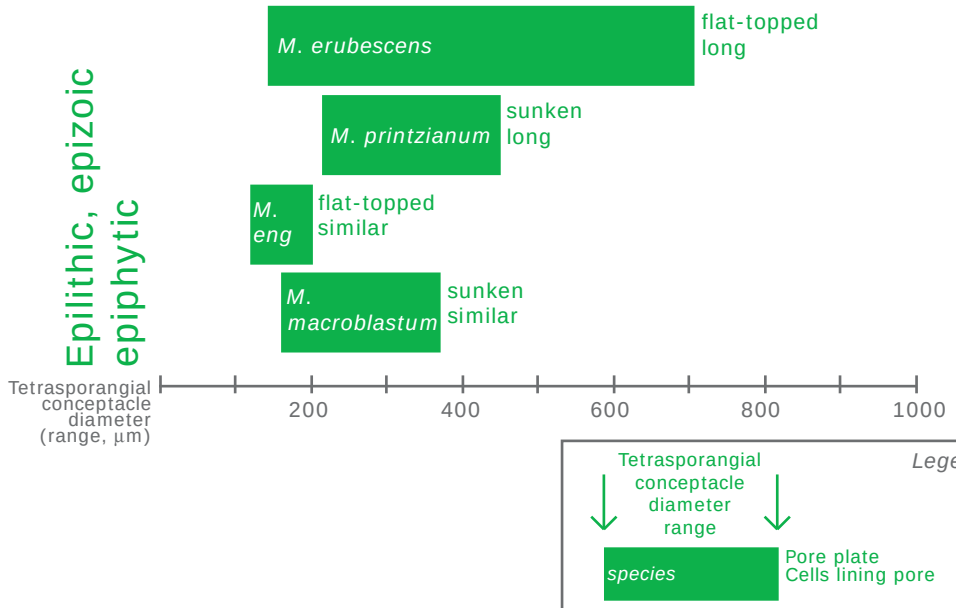
   Cells bordering tetrasporangial conceptacle pores are similar to other cells in conceptacle roof ..... *Mesophyllum macroblastum*

3. Cells bordering tetrasporangial conceptacle pores are longer than other cells in conceptacle roof ..... *Mesophyllum erubescens**

   Cells bordering tetrasporangial conceptacle pores are similar to other cells in conceptacle roof ..... *Mesophyllum engelhartii*

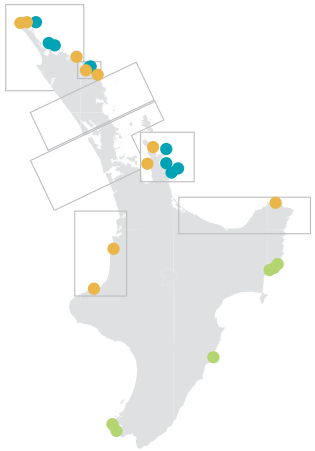
* Some collections with elongate cells lining the pore canal have tetrasporangial conceptacle shape intermediate between the flat top of *M. erubescens* and the sunken pore plate of *M. printzianum*. Molecular analysis may help resolve identification of such collections; in this study, we found that they tended to group with *M. printzianum*.

GRAPHIC KEY: TETRASPORANGIAL CONCEPTACLE CHARACTERS



Mesophyllum engelhartii (Foslie) W.H.Adey

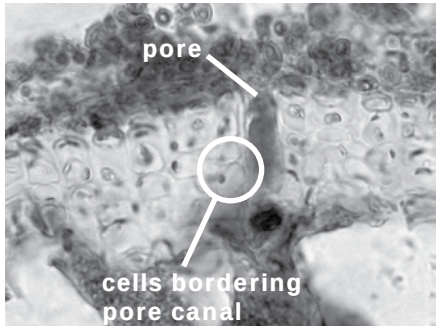
Family HAPALIDIACEAE
Subfamily MELOBESIOIDEAE

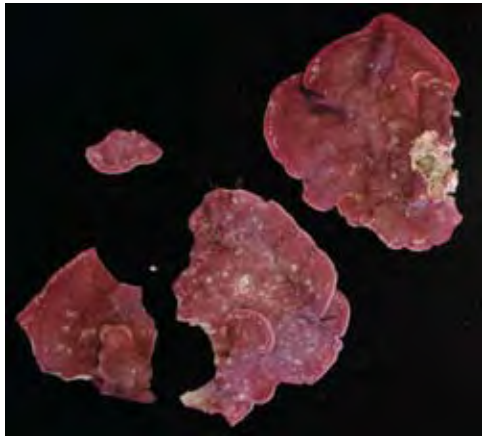


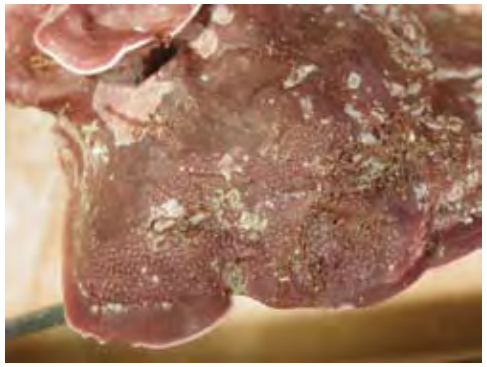
Mesophyllum engelhartii is an encrusting to warty to layered to foliose non-geniculate coralline alga. Plants grow to 45 mm across and may be readily removed from substrate, often forming flat or wrapping discs or plates ("pappadums").
Habitat: Predominantly subtidal (occasional collections from very low intertidal/upper subtidal) to at least 24 m, on rock, sponge, shell, and other macroalgae (*Pterocladia*; *Carpophyllum* and *Ecklonia* holdfasts).
Anatomy & reproduction: Epithallial cells round or flattened (not flared), subepithallial cells long, cells in adjacent filaments connect by cell fusions only, thallus monomerous. Tetrasporangia zonately divided, in flat-topped multiporate conceptacles (125-200 µm diameter); tetrasporangial conceptacle pores bordered by cells similar in size and shape to other roof cells. Spermatangial filaments unbranched.
Distribution (NZ): North Island: Far North, Bay of Islands, Whangarei, Auckland, Coromandel, Bay of Plenty/East Cape, north Taranaki, central and lower North Island. South Island; Chatham Islands; Auckland Islands. Collected from 20 of 86 northern study sites (23%).
Distribution (elsewhere): Australia (WA, SA, Vic, Tas); South Africa, Namibia.
Etymology: named after a medical doctor in South Australia (A.F.G. Engelhart) who collected and sent specimens to Foslie.
Type locality: Cape Jaffa, South Australia, Australia.
Reference: Adey 1970.

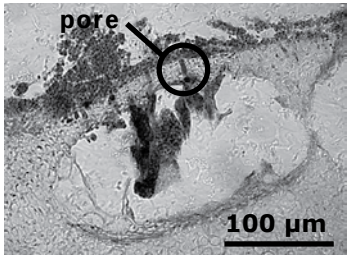
Notes:
1. *Mesophyllum engelhartii* and *Synarthrophyton patena* are distinguished by spermatangial filament branching in male conceptacles (unbranched only in *M. engelhartii*; both branched and unbranched in *S. patena*). Where male conceptacles were available in this study, only unbranched spermatangial filaments were observed.
2. Collections in this study were placed in *M. engelhartii* rather than *S. patena* based on molecular data. Collections with "*patena*/*engelhartii*" morphology fell within two closely-related clades matching DNA sequence from *M. engelhartii* collections from central New Zealand. No collections from northern New Zealand study area fell within the clades representing *Synarthrophyton* species.

KEY CHARACTERS
1. Encrusting to warty to layered to foliose coralline alga on rock, sponge, shell, algae, often forming flat or wrapping discs or plates.
2. Flat-topped multiporate conceptacles.
3. Distinguished from other multiporate non-geniculate coralline algae by flat-topped conceptacles, epithallial cells not flared, subepithallial cells long, canals lining pore canal same.
4. Can only be distinguished from *Synarthrophyton patena* by spermatangial filament branching and molecular data (see notes).







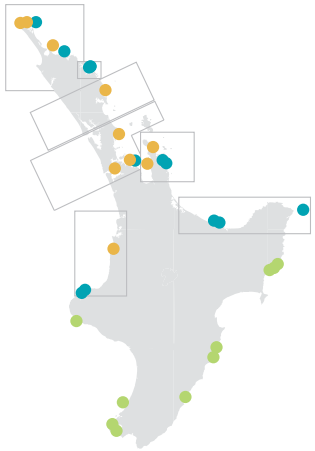


Mesophyllum engelhartii: 1-3, range of growth forms; 1, encrusting to warty; 2, "pappadum"; 3, foliose; 4, conceptacles clearly visible on plate; 5, flat-topped multiporate conceptacles; 6, domed uniporate conceptacles; 7, tetrasporangial conceptacle pores bordered by cells similar to other roof cells; 8, tetrasporangial conceptacles, flat-topped.

1	2
3	4
5	6
7	8

Mesophyllum erubescens (Foslie) Me.Lemoine

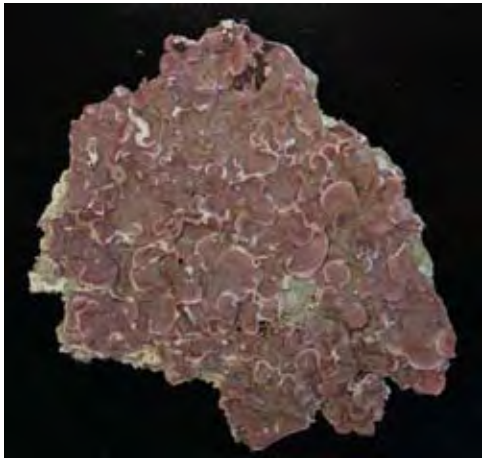
Family HAPALIDIACEAE
Subfamily MELOBESIOIDEAE

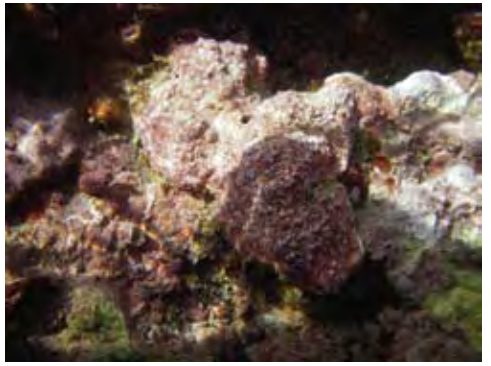


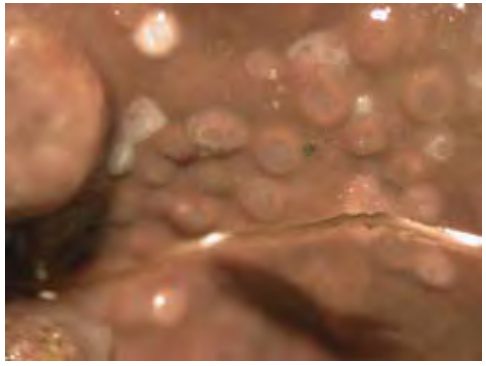
Mesophyllum erubescens is a non-geniculate coralline alga that is highly variable in growth form (encrusting to warty to lumpy to fruticose or discoid to layered to foliose); plants grow to 115 mm across, and may be partially to completely adherent to the substrate (rock, shells or other macroalgae).
Habitat: Intertidal and subtidal to at least 25 m. Grows on rock or epizoically (worm tubes, sponges, shells) in northern New Zealand; sponge was the most common animal substrate in this study. Elsewhere in New Zealand, also grows epiphytically on other macroalgae (e.g. geniculate coralline algae, *Carpophyllum* holdfasts).
Anatomy & reproduction: Epithallial cells round or flattened (not flared), subepithallial cells long, cell fusions only, thallus monomerous. Tetrasporangia zonately divided, in flat-topped multiporate conceptacles (140-700 µm diameter); tetrasporangial conceptacle pores bordered by cells more elongate, especially near base of pore, than other roof cells. Spermatangial filaments unbranched.
Distribution (NZ): North Island: Far North, Bay of Islands, Whangarei, Auckland, Coromandel, Bay of Plenty/East Cape, north Taranaki, central and lower North Island. South Island; Chatham Islands; Auckland Islands; Campbell Island; Snares Islands. Collected from 23 of 86 northern study sites (27%).
Distribution (elsewhere): Australia (WA, SA, Vic, Tas, NSW, Qld). South America; Africa; Asia; Pacific; Caribbean.
Etymology: *erubescens* (Latin) = blushing, reddening, rose.
Type locality: Brazil.
Reference: Verheij & Prud'homme van Reine 1993.

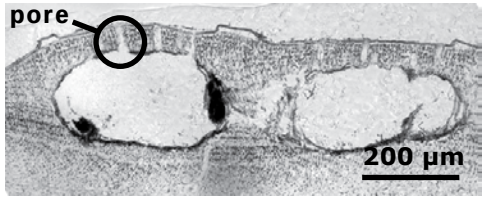
Note:
Both *M. erubescens* and *M. printzianum* have long cells lining pore canals of tetrasporangial conceptacles. Specimens may have tetrasporangial conceptacles intermediate between the two taxa (flat-topped for *M. erubescens* vs sunken pore plate for *M. printzianum*). Further taxonomic work, including molecular analysis, is required.

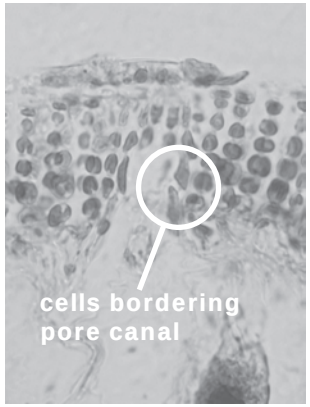
KEY CHARACTERS
1. Extremely variable in growth form – encrusting to warty to lumpy to fruticose, or discoid to layered to foliose.
2. Substrate may be rock, sponge or shell.
3. Flat-topped multiporate conceptacles.
4. Common throughout New Zealand.
5. Distinguished from other multiporate non-geniculate coralline algae by flat-topped conceptacles, epithallial cells not flared, subepithallial cells long, cells lining pore canals long.

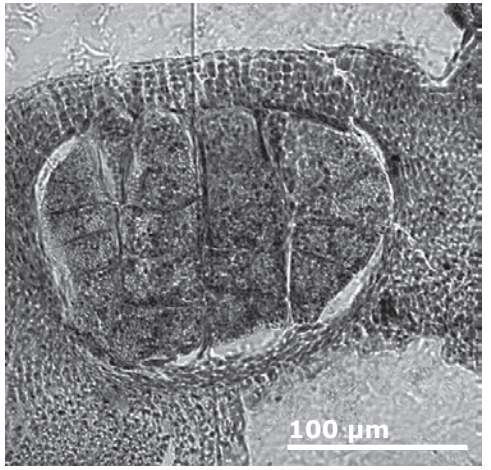












Mesophyllum erubescens: 1-2, plants in field; 3, multiporate concetptacles; 4, uniporate conceptacles; 5, 6, multiporate conceptacles, flat-topped; 7, long cells line pore canal.

1	2
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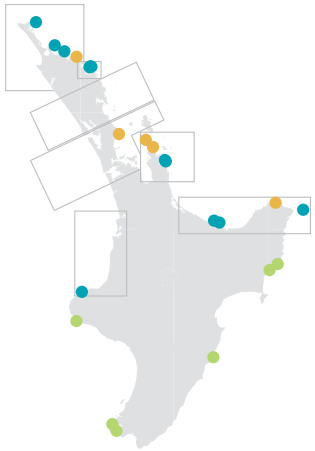
Mesophyllum macroblastum (Foslie) W.H.Adey

Family HAPALIDIACEAE
Subfamily MELOBESIOIDEAE



Mesophyllum macroblastum is a non-geniculate coralline alga that is highly variable in growth form (encrusting to warty or layered or lumpy); plants grow to 105 mm across, and may be partially to completely adherent to the substrate (rock, shells, sponges, or other macroalgae, e.g. *Ecklonia* holdfasts). Large multiporate conceptacles with sunken pore plates are distinctive in the field.

Habitat: Intertidal and subtidal to at least 18 m. Common throughout New Zealand in intertidal and subtidal; in northern New Zealand, two-thirds of collections were subtidal. Partially to completely adherent to substrate (rock, shells, animals or other macroalgae).

Anatomy & reproduction: Epithallial cells round or flattened (not flared), subepithallial cells long, cell fusions only, thallus monomerous. Tetrasporangia zonately divided, in large (160-360 µm) multiporate conceptacles with a distinct rim surrounding a sunken pore plate; tetrasporangial conceptacle pores bordered by cells similar in size and shape to other roof cells. Spermatangial filaments unbranched.

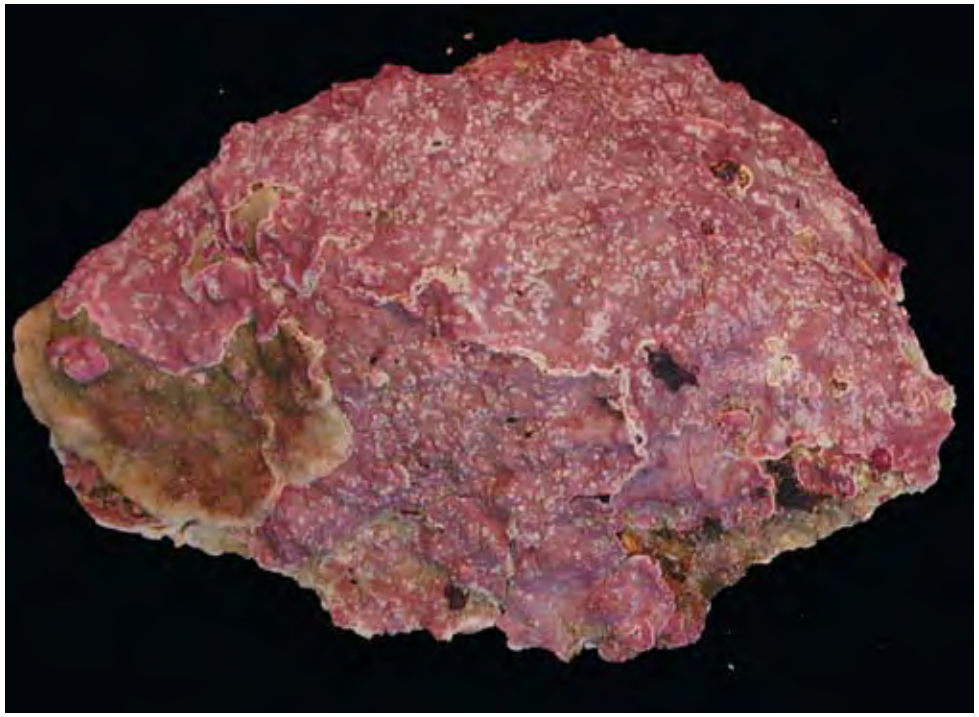
Distribution (NZ): North Island: Far North, Bay of Islands, Auckland, Coromandel, north Taranaki, central and lower North Island. South Island. Chatham Islands. Collected from 18 of 86 northern study sites (21%).

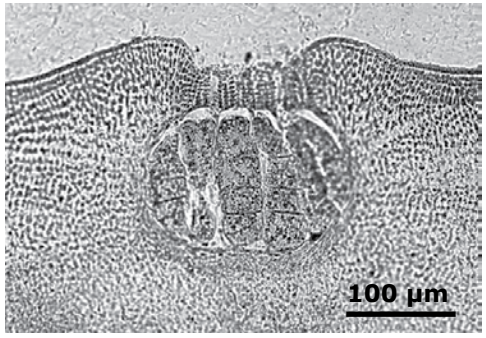
Distribution (elsewhere): Australia (Tas, SA, Vic, NSW). Mediterranean Europe (France, Italy).

Etymology: *macroblastum* refers to large conceptacle size.

Type locality: Cape Gulf of Naples, Italy.

Reference: Adey 1970.





KEY CHARACTERS

1. Encrusting to warty (or layered or lumpy) coralline alga on rock, shell, sponge, ascidian, macroalgae (e.g. *Ecklonia* holdfasts).
2. Large multiporate conceptacles with sunken pore plates and distinct rim.
3. Common throughout New Zealand; in northern New Zealand, two-thirds of collections were subtidal.
5. Distinguished from other multiporate non-geniculate coralline algae by large conceptacles, sunken pore plate, epithallial cells not flared, subepithallial cells long, canals lining pore canal same.

Mesophyllum macroblastum: 1, on sponge; 2, multiporate conceptacles with sunken pore plate (small bladed red alga is growing on the coralline); 3, uniporate conceptacles; 4, tetrasporangial conceptacle with sunken pore plate, cells lining pore similar to other roof cells.

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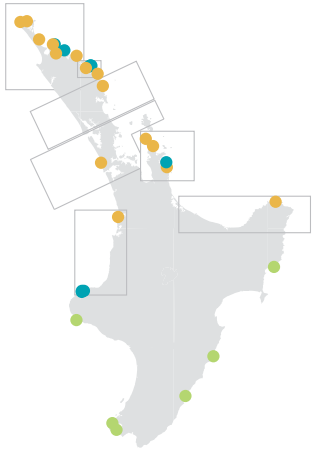
Mesophyllum printzianum Woelk. & A.Harv.



Mesophyllum printzianum is a common non-geniculate coralline alga that is highly-variable in growth form (encrusting to warty to lumpy to fruticose); plants grow to 145 mm across, partially to completely adherent to a range of substrates (rock, shells, sponges, other macroalgae). Large multiporate conceptacles with sunken pore plates are distinctive in the field.

Habitat: Intertidal and subtidal to at least 25 m. Common throughout New Zealand in intertidal and subtidal; in northern New Zealand, two-thirds of collections were intertidal. Grows on rock, epizoically (shells, e.g. barnacles, paua, *Turbo* sp.; sponges), or epiphytically on other macroalgae (e.g. *Lessonia* and *Ecklonia* holdfasts).

Anatomy & reproduction: Epithallial cells round or flattened (not flared), subepithallial cells long, cell fusions only, thallus monomerous. Zonately divided tetrasporangia in large (220-450 µm) multiporate conceptacles with a distinct rim surrounding a sunken pore plate; tetrasporangial conceptacle pores bordered by cells more elongate, especially near base of pore, than other roof cells. Spermatangial filaments unbranched.

Distribution (NZ): North Island: Far North, Bay of Islands, Whangarei, Auckland, Coromandel, Bay of Plenty/East Cape, north Taranaki, central and lower North Island. South Island. Chatham Islands. Collected from 25 of 86 northern study sites (29%).

Distribution (elsewhere): Australia (SA, Vic, NSW, Tas). Not known from outside Australasia.

Etymology: *printzianum* – honouring phycologist K.H.O. Printz (1888-1978).

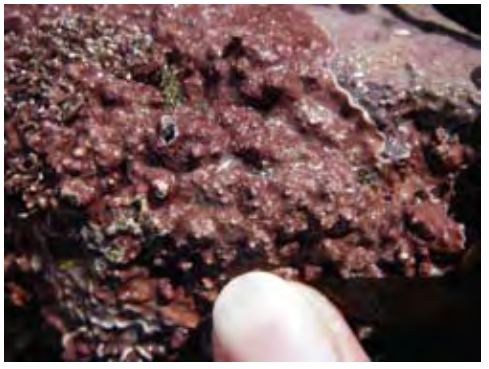
Type locality: Blanket Bay, Otway National Park, Victoria, Australia.

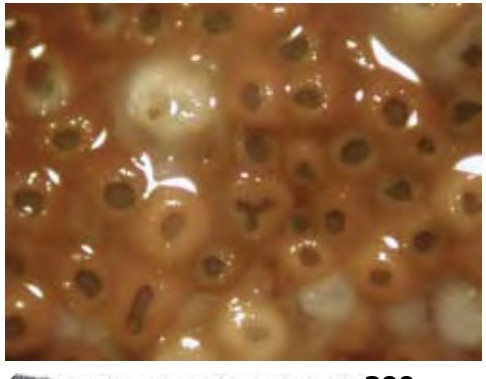
Reference: Woelkerling & Harvey 1993.

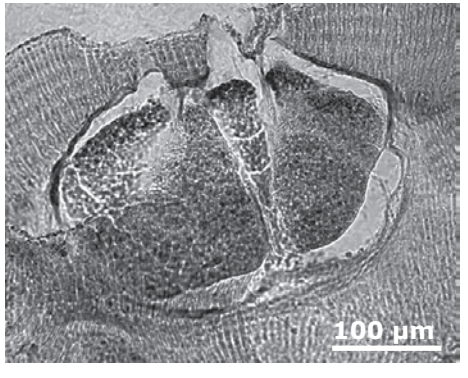
Note:
Both *M. erubescens* and *M. printzianum* have long cells lining pore canals of tetrasporangial conceptacles. Specimens may have tetrasporangial conceptacles intermediate between the two taxa (flat-topped for *M. erubescens* vs sunken pore plate for *M. printzianum*). Further taxonomic work, including molecular analysis, is required.

KEY CHARACTERS

1. Highly variable in growth form – encrusting to warty to lumpy to fruticose – and substrate.
2. Large multiporate conceptacles, sunken pore plates with rim.
4. Common throughout New Zealand; in northern New Zealand, two-thirds of collections were intertidal.
5. Distinguished from other multiporate non-geniculate coralline algae by large conceptacles, sunken pore plate, epithallial cells not flared, subepithallial cells long, canals lining pore canal long.







Mesophyllum printzianum: 1-4, range of growth forms; 5, multiporate conceptacles with sunken pore plate; 6, uniporate conceptacles; 7, 8, tetrasporangial conceptacles, sunken pore plate, long cells lining pore canal.

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Phymatolithon Foslie

1+ species in NZ

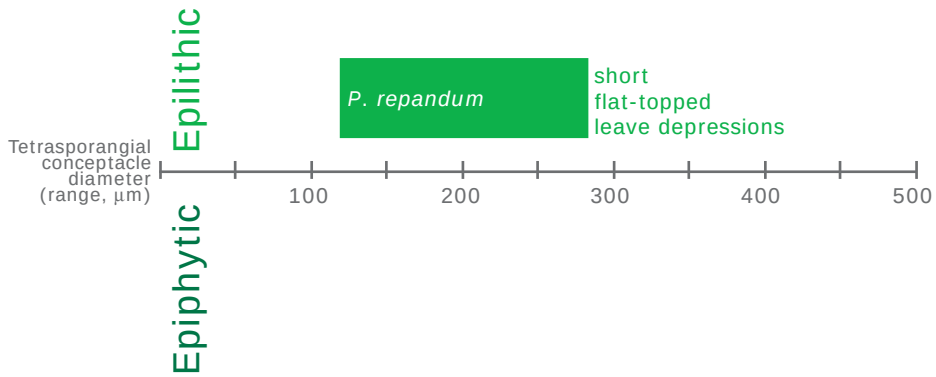
Species in *Phymatolithon* produce zonately divided tetrasporangia in multiporate conceptacles, and gametes in uniporate conceptacles. Microscopically, *Phymatolithon* has epithallial cells which are rounded or flattened, but not flared. The cells of adjacent filaments in the thallus are connected by cell fusions.

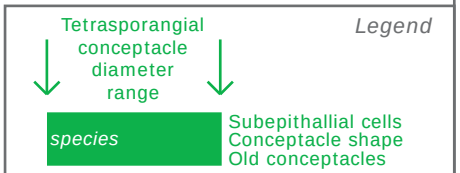
Eleven species are currently recognised worldwide within the genus *Phymatoliton*. One species is currently recognised from New Zealand collections.

Molecular analysis (see Figure 10) shows an additional distinct taxon from New Zealand relating to *Phymatolithon*: one clade (*Phymatolithon* sp.) clearly situated within the subfamily, but quite distinct and separate from the *Phymatolithon repandum* clade. Work is in progress to tease out and understand the distinguishing characters of both taxa, and to establish their relationships with other species in the Melobesioideae; current species concepts place collections from both clades in *P. repandum*.

Phymatolithon is distinguished from *Mesophyllum* and *Synarthrophyton* by having subepithallial cells which are as short as or shorter than the cells immediately below them.

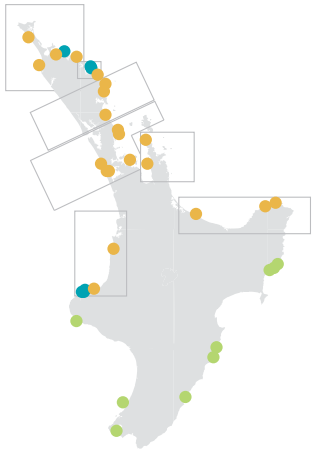
GRAPHIC KEY: TETRASPORANGIAL CONCEPTACLE CHARACTERS





Phymatolithon repandum (Foslie) Wilks & Woelk.

Family HAPALIDIACEAE
Subfamily MELOBESIOIDEAE

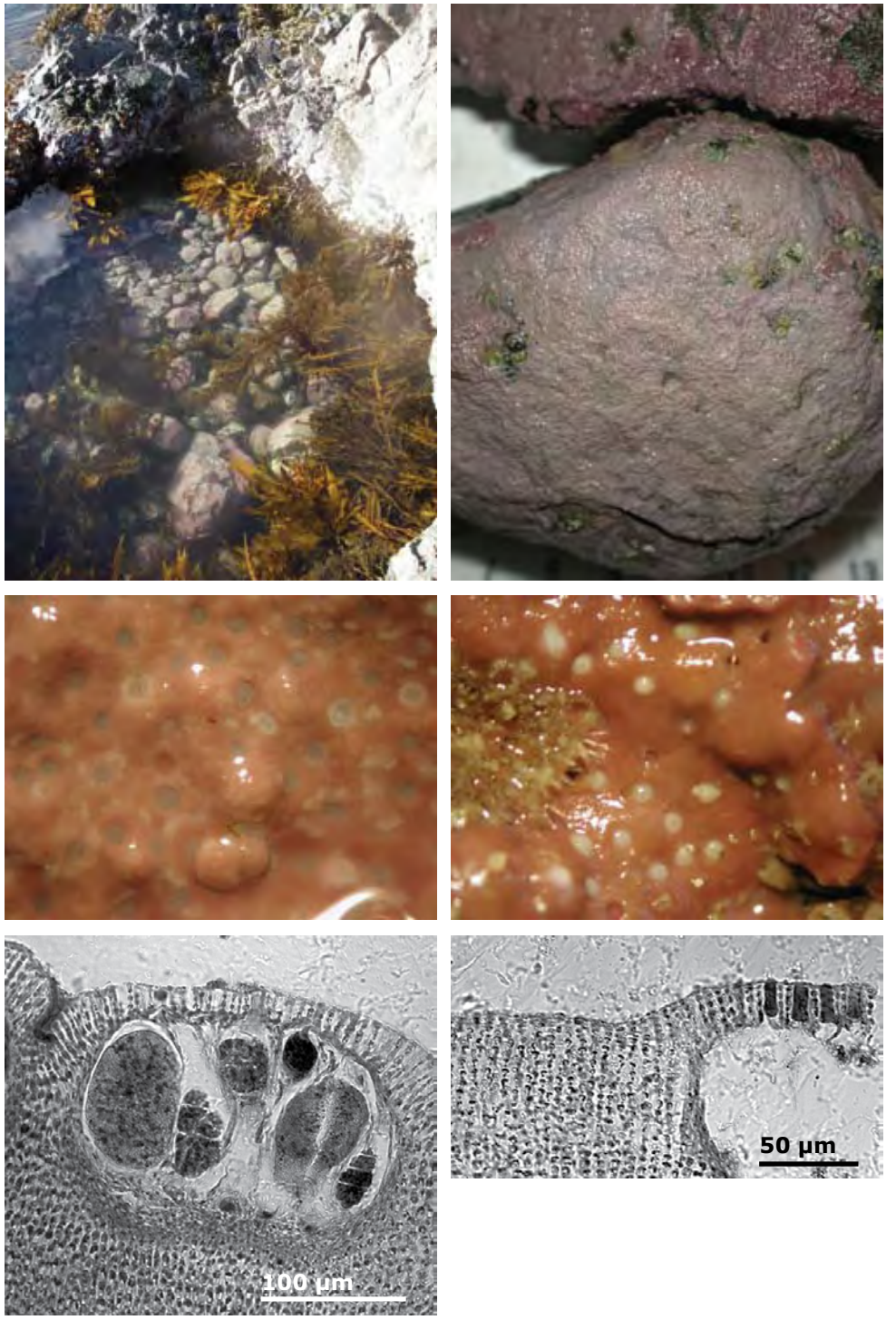


Phymatolithon repandum is an encrusting to warty non-geniculate coralline alga growing on rocks, cobbles and pebbles; occasionally growing on old shells. Plants grow to 120 mm, and are firmly adherent to substrate. Common in New Zealand, notably on cobbles in intertidal pools, with distinctive pits or depressions often apparent in the plant surface.
Habitat: Intertidal and subtidal to at least 18 m, on rocks, cobbles and pebbles.
Anatomy & reproduction: Epithallial cells are round or flattened but not flared, subepithallial cells short, and cells connect by cell fusions only within a monomerous thallus. Zonately divided tetrasporangia produced in flat-topped multiporate conceptacles (120-280 µm), which may have roofs slightly below the thallus surface; tetrasporangial conceptacle pores bordered by cells that are similar in size and shape to other cells in the conceptacle roof. Plant surface often has pits or depressions where conceptacle roofs have broken away.
Distribution (NZ): North Island: Far North, Bay of Islands, Whangarei, Auckland, Coromandel, Bay of Plenty/East Cape, north Taranaki, central and lower North Island. South Island; Chatham Islands.
Distribution (elsewhere): Australia (WA, Tas, SA, Vic, NSW, Qld). Harvey et al. (2003b) state that this species has not been reported from outside Australasia, however Algaebase (June 2007) reports it from Africa, Seychelles, Korea, Micronesia, and Australia.
Etymology: *repandum* (Latin) = with a wavy margin.
Type locality: Port Phillip Bay, Victoria, Australia.
Reference: Wilks & Woelkerling 1994.

Note:
Where molecular data are available from collections of *P. repandum* in this study, they fall into two distinct clades within the larger Hapalidiaceae clade. Collections in both clades fall within the current concept of *Phymatolithon repandum*; work is in progress to map distinct anatomical and morphological characters to each of the clades, and these may yet be shown to represent two distinct taxa.

KEY CHARACTERS

1. Encrusting to warty coralline algae, growing on rocks, cobbles and pebbles.
2. Flat-topped multiporate conceptacles may be raised, flush with, or slightly below thallus surface.
3. Plant surface often has pits or depressions where conceptacle roofs have broken away.
4. Common in New Zealand, esp. on cobbles in intertidal pools.
5. Distinguished from other multiporate non-geniculate coralline algae by flat-topped conceptacles, epithallial cells not flared, subepithallial cells short, cells lining pore canal similar.



Phymatolithon repandum: 1, cobbles covered with P. repandum in an intertidal pool; 2, cobble showing characteristic thin encrusting coralline with pits or depressions in the plant surface; 3, flat multiporate conceptacles (some pits apparent); flat to domed uniporate conceptacles; 5, 6, tetrasporangial conceptacle, flat-topped; 6, short subepithallial cells.

1	2
3	4
5	6

Why aren't any species of *Synarthrophyton* included here?

Synarthrophyton was not confirmed from northern New Zealand collections, but does occur in the lower North Island, South Island, Chatham Islands, Stewart Islands and subantartic islands.

Species in *Synarthrophyton*, like those in *Mesophyllum* and *Phymatolithon*, produce zonately divided tetrasporangia in multiporate conceptacles, and gametes in uniporate conceptacles. Epithallial cells are rounded or flattened, but not flared. The thallus is monomerous, with cells in adjacent filaments connected by cell fusions.

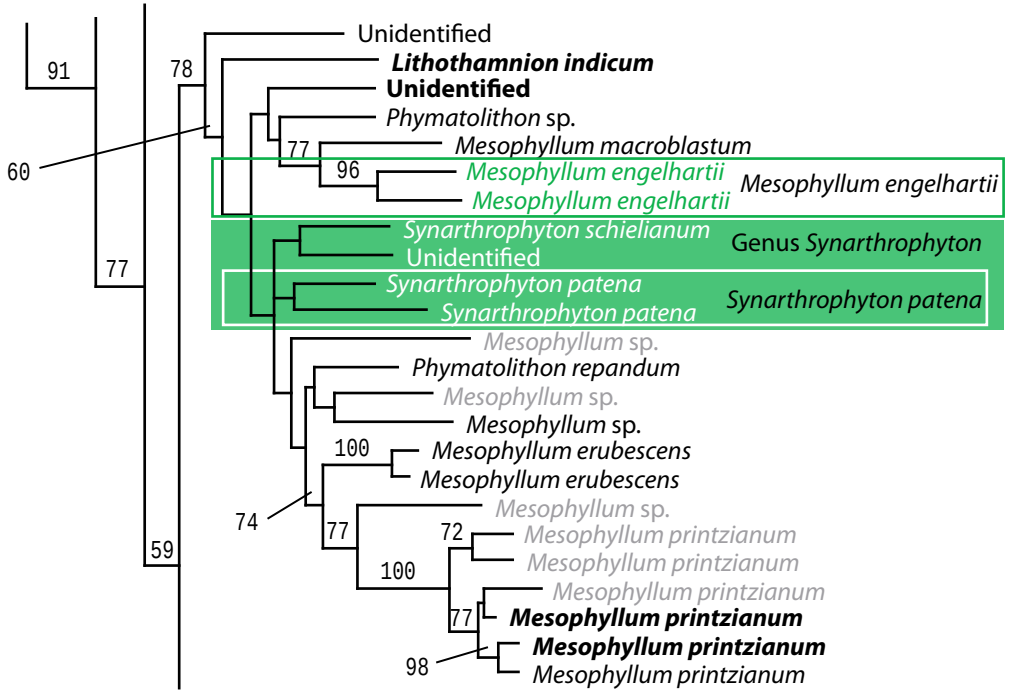
Like *Mesophyllum* (but not *Phymatolithon*), in *Synarthrophyton* subepithallial cells are long relative to the cells below them. The two genera are separated on spermatangial branching in male conceptacles: unbranched only in *Mesophyllum*; mostly branched, but may be unbranched, in *Synarthrophyton*.

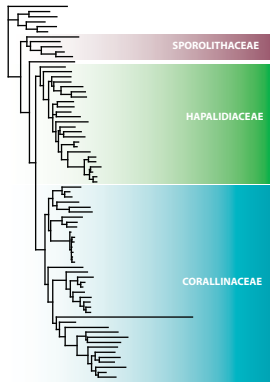
Eight species are currently recognised worldwide within the genus *Synarthrophyton*. Two species occur in central and southern New Zealand, but *Synarthrophyton* was not confirmed from northern New Zealand collections in this study.

One species, *S. schielianum*, is endemic to New Zealand, and while found in Wellington (Cook Strait, lower North Island), is otherwise restricted to the South Island, Chatham Islands, and subantarctic islands. This species, which is covered in our guide to central New Zealand corallines (Harvey et al. 2005), is distinctive, with elaborate struts as part of the vegetative thallus. It was not found in northern collections.

In northern New Zealand, collections were found which fell by anatomical and morphological analysis into either *Mesophyllum engelhartii* or *Synarthrophyton patena*. These two species are distinguished by spermatangial filament branching in male conceptacles (unbranched only in *M. engelhartii*; both branched and unbranched in *S. patena*). Where male conceptacles were available in this study, only unbranched spermatangial filaments were observed, so the specimens could belong to either species.

However, these collections were able to be placed in *M. engelhartii* rather than *S. patena* based on molecular data. Collections with "*patena*/*engelhartii*" morphology fell within two closely-related clades (see Figure 10, and extract from Figure 10, opposite) matching DNA sequence from *M. engelhartii* collections from central New Zealand. No collections from the northern New Zealand study area fell within the clades representing *Synarthrophyton* species.





For details of molecular analysis, see Figure 10, and the chapter *Coralline algal taxonomy*.

Sporolithaceae

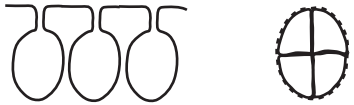
Non-geniculate species

Species profiles

Two genera, *Sporolithon* Heydr. and *Heydrichia* R.A.Towns., Y.M.Chamb. & Keats, are recognised within the family Sporolithaceae, and both occur in New Zealand. No subfamilies are recognised within the family.

Key characters, family Sporolithaceae:

- flared epithallial cells
- tetrasporangia cruciately divided
- tetrasporangia in calcified compartments

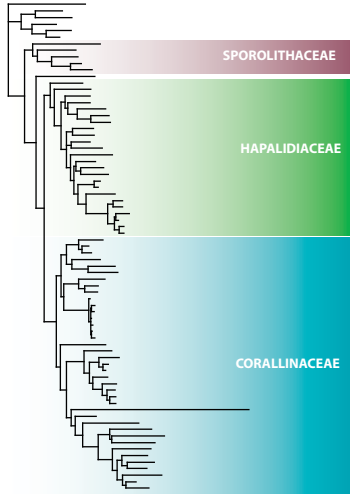


Molecular analysis (see Figure 10) shows that the Sporolithaceae is supported as a monophyletic clade, basal to other families within the order Corallinales. In our analysis, *Heydrichia* species are paraphyletic within the Sporolithaceae clade, with *Heydrichia woelkerlingii* grouping with the monophyletic *Sporolithon* clade.

KEY TO GENERA OF SPOROLITHACEAE IN NORTHERN NEW ZEALAND

1. Cruciate tetrasporangia in calcified compartments with single stalk cell, lacking an involucre, and aggregated in sori ..... *Sporolithon*

   Cruciate tetrasporangia in calcified compartments with 1-5 stalk cells, surrounded by an involucre, with compartments scattered on the thallus surface or loosely aggregated in sori ..... *Heydrichia*



For details of molecular analysis, see Figure 10, and the chapter *Coralline algal taxonomy*.

2 species in NZ

Heydrichia is distinguished from other crustose coralline algae by its smooth, glossy (when wet) appearance in the field. It often occurs on rock walls under shading, overhanging brown algae, with protection from direct sunlight preserving the usually deep berry-pink colour.

Species in *Heydrichia* (and *Sporolithon*) produce tetrasporangia in calcified compartments, rather than in conceptacles as in other crustose coralline genera found in New Zealand. Conceptacles appear occasionally in New Zealand collections; these contain gametes only. Microscopically *Heydrichia*, like *Sporolithon*, has flared epithallial cells and cruciately divided tetrasporangia. Unlike *Sporolithon*, in *Heydrichia* tetrasporangia are surrounded by an involucre (vertically flattened sterile filaments).

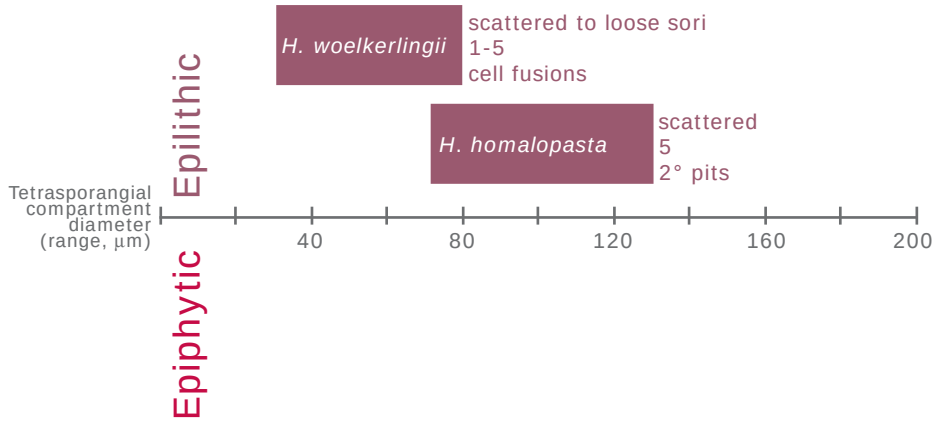
Three species are recognised within the genus *Heydrichia*; two of these occur in New Zealand. *Heydrichia homalopasta* R.A.Towns. & Borow. is common in New Zealand, particularly in the northern North Island. *Heydrichia woelkerlingii* R.A.Towns., Y.M.Chamb. & Keats, the type species of the genus, is found uncommonly only in northern New Zealand and, in the field, is somewhat intermediate in appearance between *H. homalopasta* and *Sporolithon durum*. *Heydrichia homalopasta* occurred at five of the six sites from which *H. woelkerlingii* was collected in this study. Although they have similarities in the field, anatomical characters as well as DNA sequencing clearly separate *H. woelkerlingii* from *H. homalopasta*.

DICHOTOMOUS KEY: 2 NEW ZEALAND SPECIES OF *HEYDRICHIA*

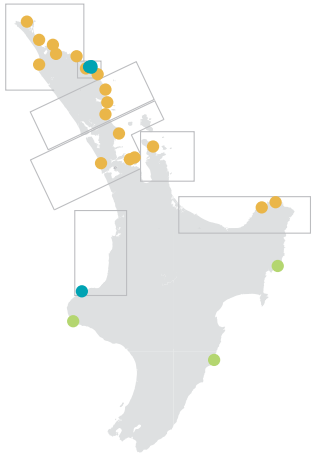
1. Tetrasporangial compartments scattered; cruciate tetrasporangia on 5-celled stalk; calcified compartments 70-130 µm; secondary pits predominate in New Zealand collections ..... *Heydrichia homalopasta*

   Tetrasporangial compartments aggregated into loose sori (may appear more or less scattered); cruciate tetrasporangia on stalk with 1-5 cells; calcified compartments 35-80 µm; cell fusions predominate ..... *Heydrichia woelkerlingii*

GRAPHIC KEY: TETRASPORANGIAL CONCEPTACLE CHARACTERS



Heydrichia homalopasta R.A.Towns. & Borow.



Smooth, encrusting non-geniculate coralline alga growing on rocks and cobbles. Plants are dark purple to deep pink where shaded, bleaching to paler pink where exposed to sunlight. The crusts are thin (0.5 mm), can grow to 170 mm across, and have a glossy appearance when wet.

Habitat: Intertidal and subtidal to at least 18 m; common under shading browns in upper subtidal. Often abundant at sites where it occurs.

Anatomy & reproduction: Flared epithallial cells; in New Zealand collections cells in adjacent filaments are usually connected by secondary pits. Tetrasporangia are cruciately divided and produced in calcified compartments scattered throughout the thallus; these appear as inconspicuous holes scattered over the surface of the fertile plant. Tetrasporangial compartments 70-130 µm in diameter. Tetrasporangia surrounded by vertically flattened sterile filaments (involucre); cruciate tetrasporangia on stalk with 5 cells. Sori/compartments become buried within thallus.

Distribution (NZ): North Island: Far North, Bay of Islands, Whangarei, Auckland, Coromandel, Bay of Plenty/East Cape, north Taranaki, northern Wairarapa; not known from Wellington/Cook Strait, southern Wairarapa, nor Kapiti Coast. South Island: Collections from Nelson region only. Chatham Islands: Port Hutt. Collected from 23 of 86 northern study sites (27%).

Distribution (elsewhere): Australia (NSW). Not reported from outside Australasia.

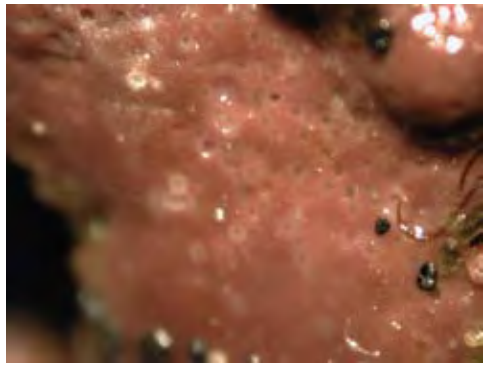
Etymology: *homalos* (Greek) = even; *pastos* (Greek) = sprinkled; in reference to the sporangial complexes sprinkled across the tetrasporangial thallus.

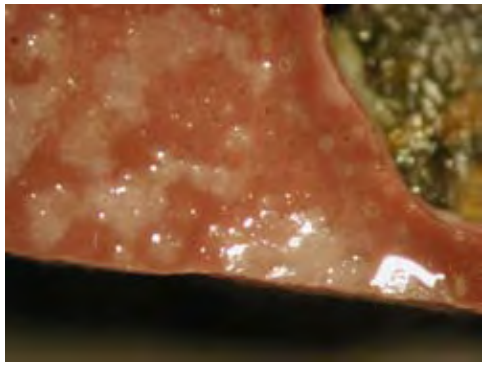
Type locality: Bongin Bongin Bay, New South Wales, Australia.

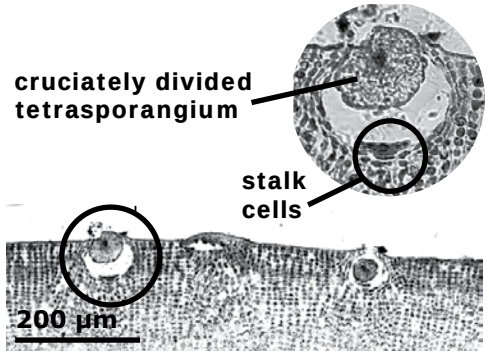
Reference: Townsend & Borowitzka 2001.

KEY CHARACTERS

1. Smooth encrusting crustose coralline on rock.
2. Dark purple/deep pink where shaded.
3. Common in North Island under shading browns in upper subtidal/low intertidal.
4. Cruciate tetrasporangia in calcified compartments scattered throughout the thallus.
5. Tetrasporangial conceptacles larger cf *H. woelkerlingii*; compartments have 5 stalk cells; epithallial cells flared.







Heydrichia homalopasta: 1, 2, pink to deep purple plants under shading browns; 3, 4, inconspicous pinpricks on thallus surface are pores of calcified compartments; 5 (with compartment magnified), scattered calcified compartments, cruciately divided tetraspores, five stalk cells.

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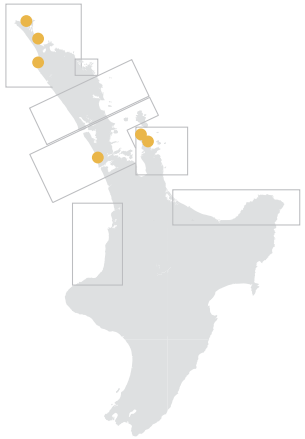
4 5

Heydrichia woelkerlingii R.A.Towns., Y.M.Chamb. & Keats

Family SPOROLITHACEAE



Smooth, encrusting non-geniculate coralline alga growing on rocks and cobbles. Plants are dark purple to deep pink where shaded. Crusts are 0.5 cm to several cm thick, and can grow to at least 100 mm across.

Habitat: Intertidal; found under shading browns in intertidal (to upper subtidal).

Anatomy & reproduction: Flared epithallial cells; cells in adjacent filaments are usually connected by cell fusions. Tetrasporangia are cruciately divided and produced in calcified compartments; tetrasporangial compartments aggregated into loose sori (may appear more-or-less scattered). Tetrasporangial compartments 35-80 µm diameter, and smaller than compartments of *Heydrichia homalopasta*. Tetrasporangia are surrounded by vertically flattened sterile filaments (involucre); cruciate tetrasporangia occur on a stalk with 1-5 cells. Sori/compartments do not become buried within thallus.

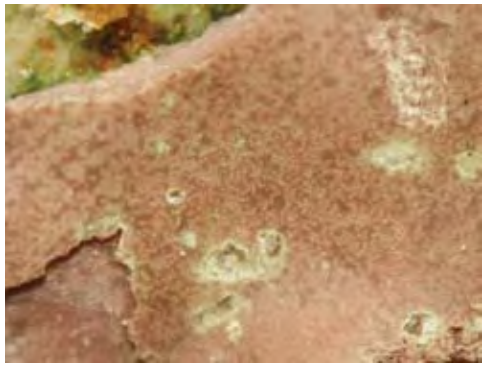
Distribution (NZ): North Island: Far North, Auckland, Coromandel; not known from south of Auckland/Coromandel. No collections from South Island or Chatham Islands. Collected from 6 of 86 northern study sites (7%). At 5 of 6 collection sites, co-occurred with *Heydrichia homalopasta*. Not previously recorded from New Zealand.

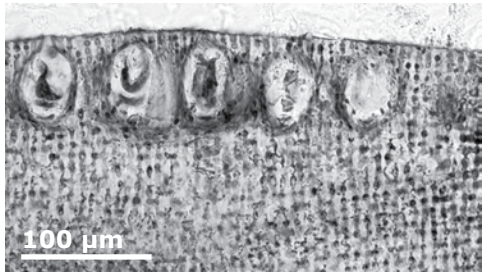
Distribution (elsewhere): Only known previously from South Africa. Not reported from Australia.

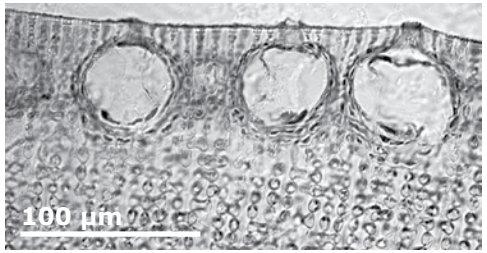
Etymology: The species name honours coralline algal taxonomist W.J. Woelkerling.

Type locality: Oudekraal, Cape Province, South Africa.

Reference: Townsend et al. 1994.



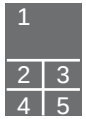




KEY CHARACTERS

1. Smooth encrusting crustose coralline on rock.
2. Dark purple/deep pink where shaded; intertidal.
3. Restricted to northern North Island; uncommon. Usually co-occurs with more common species *H. homalopasta*.
4. Cruciate tetrasporangia in calcified compartments aggregated into loose sori or scattered on surface.
5. Tetrasporangial conceptacles smaller cf *H. homalopasta*; compartments have 1-5 stalk cells, epithallial cells flared.

Heydrichia woelkerlingii: 1, pink to deep purple plants under shading browns; 2, calcified compartments in sorus; 3, calcified compartments more or less scattered across thallus; 4, 5, calcified compartments arranged in loose sorus, cruciately divided tetraspores, 1-5 stalk cells.



1 species in NZ

(2 forms – rhodolith & attached)

Species in *Sporolithon* (and *Heydrichia*) produce tetrasporangia in calcified compartments, rather than in conceptacles as in other crustose coralline genera found in New Zealand. Conceptacles appear occasionally in New Zealand collections; these contain gametes only. Microscopically, *Sporolithon*, like *Heydrichia*, has flared epithallial cells, and cruciately divided tetrasporangia. Unlike *Heydrichia*, in *Sporolithon* tetrasporangia are not surrounded by an involucre (vertically flattened sterile filaments).

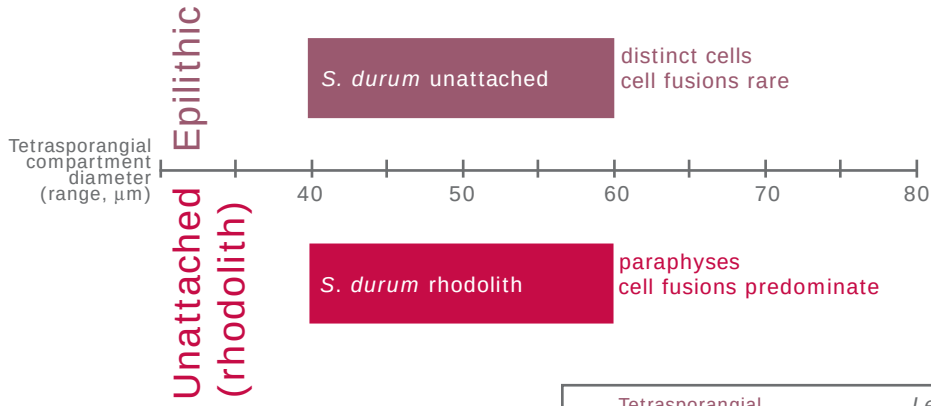
Twenty species are currently recognised worldwide within the genus *Sporolithon*. Only one species, *Sporolithon durum* (Foslie) R.A.Towns. & Woelk., is currently recognised from New Zealand collections. However, molecular analysis (see Figure 10) shows very clearly that there are two distinct and separate taxa from New Zealand: one clade contains only rhodolith collections, and the other contains only collections growing attached to rock walls and faces. Apart from their differences in habit and molecular characters, collections from both taxa fall within the parameters of *Sporolithon durum* as currently understood. Work is in progress to understand the distinguishing characters of these taxa, to define how they differ from each other, and to establish their relationships with other material described as *Sporolithon durum*.

DICHOTOMOUS KEY: 2 NEW ZEALAND SPECIES (FORMS) OF *SPOROLITHON*

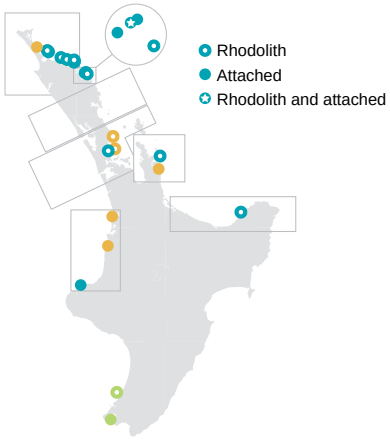
1. Rhodolith (free-living coralline alga) with sori apparent ..... *Sporolithon durum* rhodolith

   Epilithic alga with sori apparent ..... *Sporolithon durum* attached

GRAPHIC KEY: TETRASPORANGIAL COMPARTMENT CHARACTERS



Sporolithon durum (Foslie) R.A.Towns. & Woelk.



Sporolithon durum is an encrusting to warty non-geniculate coralline alga that grows firmly attached to rocks and cobbles, with plants up to 120 mm across. *Sporolithon durum* also occurs as rhodoliths – lumpy to fruticose, free-living plants, not attached to substrate. Rhodoliths range in shape/form from spherical with short, lumpy branches, to a more open structure with sparse, twiggy branches; rhodoliths can grow to 130 mm across. In colour, *S. durum* can be deep rose purple pink, bleaching to pale pink. Reproductive sori, are generally clearly visible on the surface of the fertile plant, and appear as irregularly-shaped, slightly raised, pink or white patches, dotted with pinpricks (compartment pores).

Habitat: Intertidal and subtidal to at least 34 m. *Sporolithon durum* occurs in New Zealand growing attached to rock or cobble substrate, or free-living, as unattached rhodoliths.

Anatomy & reproduction: Flared epithallial cells; cells in adjacent filaments are connected by cell fusions only, or by cell fusions and secondary pits. Tetrasporangia are cruciately divided and produced in calcified compartments arranged in sori. Tetrasporangial compartments are 40-60 µm diameter (W), with H>W. Tetrasporangia are not surrounded by an involucre; cruciate tetrasporangia occur on a stalk with single stalk cell.

Distribution (NZ): North Island: Far North, Bay of Islands, Auckland, Coromandel, Bay of Plenty, North Taranaki, Wellington, Kapiti. South Island: Whararíki Beach, Nelson, Greymouth. No records from east coast south of East Cape, on either North or South Island, nor Chatham Islands. Collected from 21 of 86 northern study sites (24%); rhodoliths collected from 14 sites (16%); attached plants collected from 8 sites (9%); at 1 site, both rhodoliths and attached plants collected.

Distribution (elsewhere): Southern Australia (WA, SA, NSW). Not reported from outside Australasia (Harvey et al. 2002).

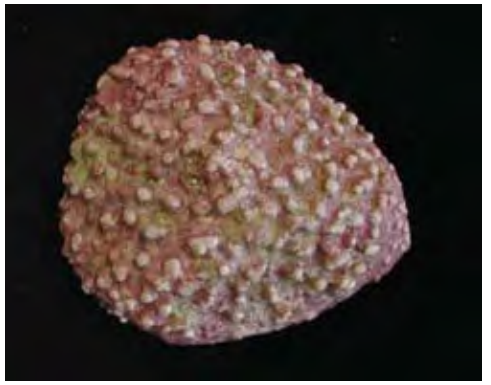
Etymology: *durum* (Latin) = hard.

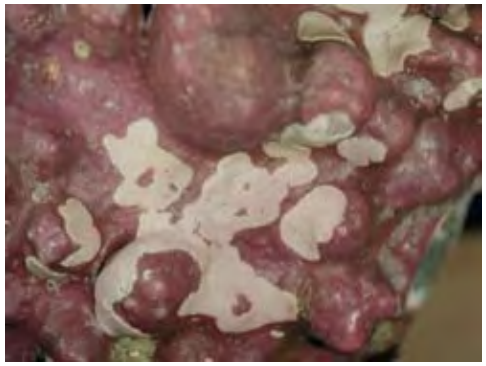
Type locality: Cape Jaffa, South Australia, Australia.

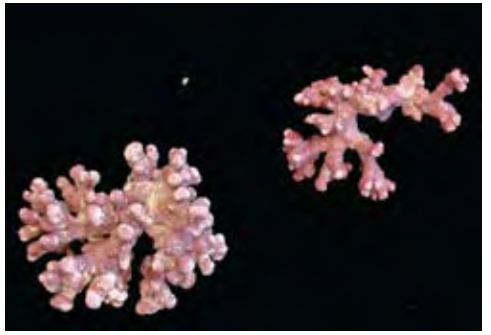
Reference: Townsend et al. 1995.

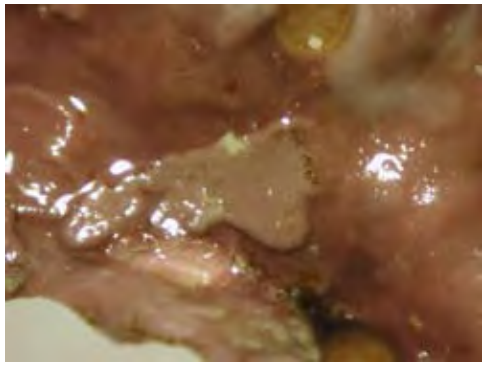
KEY CHARACTERS

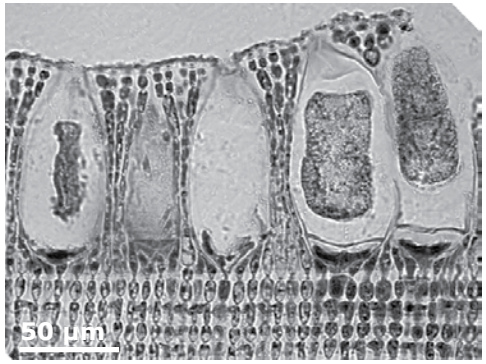
1. Encrusting to warty crustose coralline on rock; or lumpy to fruticose rhodolith.
2. Irregularly-shaped, raised patches (sori) contain cruciate tetrasporangia in calcified compartments (H>W); single stalk cell.
3. Flared epithallial cells.
4. No records from east coast south of East Cape, on either North or South Island, nor Chatham Islands.

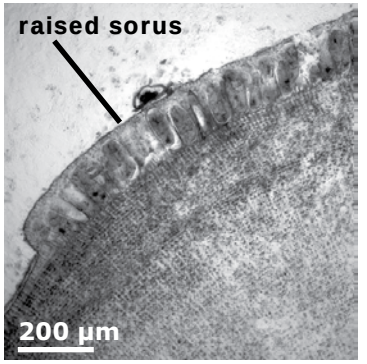












Sporolithon durum; 1, epilithic (attached), encrusting to warty plants; 2, rhodolith with short lumpy branches; 3, raised, pale sori on rhodolith; 4, small rhodoliths, fruticose, twiggy branches; 5, pale pink sorus, slightly raised; 6, bright white sorus, distinct and raised; 7, 8, calcified compartments tightly packed in sorus.

1	2
3	4
5	6
7	8

Rhodoliths

free-living, unattached,
non-geniculate coralline algae

Rhodoliths – an introduction

Free-living non-geniculate coralline algae are known as rhodoliths (or maerl – a term used mainly in Europe). These are not attached to any fixed surface but rather are able to be rolled on the sea floor by the action of water motion and currents. The free-living rhodoliths are found subtidally in areas where there are no reefs but rather coarse sand, gravel or shell debris, often in areas with strong currents.

Aggregations of rhodoliths are known as rhodolith beds. These provide three dimensional structures which are a complex, intricate and often stable habitat for invertebrates, fishes and other algae. International studies have reported these beds to be biodiversity hotspots as they have been found to harbour rare and unusual species, as well as serving as nursery areas for some commercially important species of fish and also scallops. Action to protect rhodolith beds from human-induced changes has occurred relatively recently in European waters, although it is non-existent in most regions of the world.

A structure is considered to be a rhodolith when more than 50% of it is made up of coralline algal material. Individual rhodoliths can form around shell, rock, or other material, or be comprised entirely of coralline algal material. An individual rhodolith may contain more than one coralline species. This can occur when a rhodolith forms around a core of dead coralline algae; or, more than one rhodolith-forming species might make up an individual rhodolith.

Eight non-geniculate coralline algal genera are known to contain species that form rhodoliths (Harvey & Woelkerling 2007):

Family Corallinaceae:
- ***Lithophyllum***
- *Neogoniolithon*
- *Hydrolithon*
- *Spongites*

Family Hapalidiaceae
- *Phymatolithon*
- *Mesophyllum*
- ***Lithothamnion***

Family Sporolithaceae
- ***Sporolithon***

In our study, rhodoliths were confirmed from four species in three of these genera, *Lithophyllum*, *Lithothamnion* and *Sporolithon* (see *Key to species* opposite, and *Rhodolith-forming species* profile over page). The two species of Lithothamnion rhodoliths represents new records for New Zealand. The single rhodolith sample identified as *Lithophyllum* sp. cannot be identified to species, and awaits further work.

Despite their importance, rhodoliths have been little studied in New Zealand to date. A critical first step in understanding the ecological roles played by these organisms is to determine which species are present in rhodolith beds in New Zealand.

DICHOTOMOUS KEY: 4 NEW ZEALAND SPECIES FORMING RHODOLITHS

1. Rhodolith with calcified compartments in sori ..... *Sporolithon durum*

   Rhodolith with uniporate or multiporate tetrasporangial conceptacles 2

2. Rhodolith with uniporate tetrasporangial conceptacles ..... *Lithophyllum* sp.

   Rhodolith with multiporate conceptacles 3

3. Large multiporate conceptacles (450-600 µm diameter) flush or slightly raised, with cells bordering pores that differ in size and shape from other roof cells, and depressions in roof overlaying pores (sunken pores) ..... *Lithothamnion indicum*

   Very large multiporate conceptacles (660-1100 µm diameter) flush or slightly raised, with cells bordering pores that do not differ in size and shape from other roof cells, and pores not sunken; old conceptacles become buried and filled with calcified cells..... ..... *Lithothamnion proliferum*

Reference

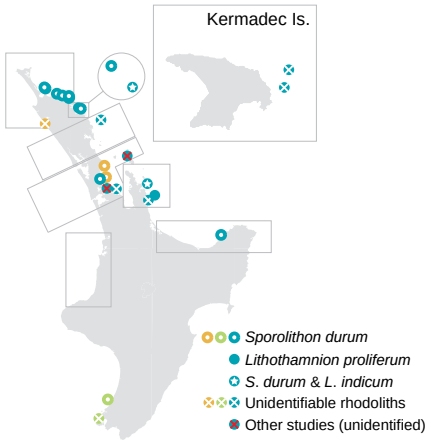
HARVEY A.S.; WOELKERLING W.J. (2007). A guide to nongeniculate coralline red algal (Corallinales, Rhodophyta) rhodolith identification. *Ciencias Marinas* 33: 411-426.

For more information

About rhodoliths

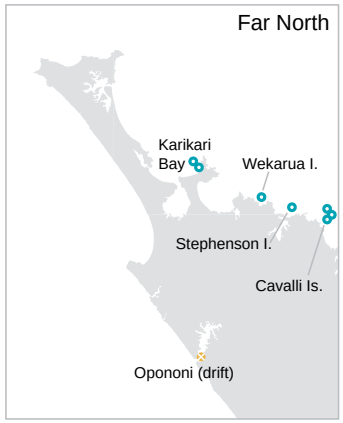
BASSO D.; NALIN R.; NELSON C.S. (2009). Shallow-water *Sporolithon* rhodoliths from North Island (New Zealand). *Palaios* 24: 92-103.
BIRKETT D.A.; MAGGS C.A.; DRING M.J. (1998). MAERL: An overview of dynamics and sensitivity characteristics for conservation management of marine SACs. Scottish Association of Marine Science (SAMS). 117 p.
FOSTER M.S. (2001). Rhodoliths: between rocks and soft places. *Journal of Phycology* 37: 659–667.
HARVEY A.S.; BIRD F.L. (2008). Community structure of a rhodolith bed from cold-temperate waters (southern Australia). *Australian Journal of Botany* 56: 437-450.

Rhodolith-forming species from northern New Zealand



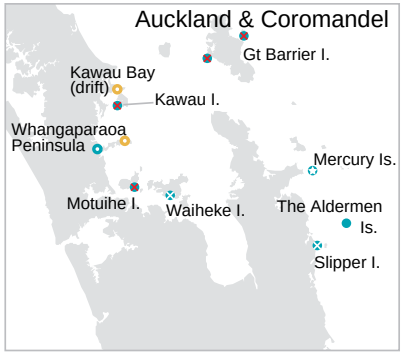
Rhodoliths were collected from a total of 20 sites in this study: from 18 of 86 North Island study sites (21%), and from 2 of 5 Kermadec Island study sites. Rhodoliths from both Kermadec sites, and from 3 of the North Island sites, were unable to be identified. Rhodoliths from 15 sites from the North Island were identified to species. Of the rhodoliths unable to be identified, most were infertile and failed to give useful DNA sequence. One collection – from the single site in the Whangarei region on the map at left – contained a mixture of unidentifiable rhodolith species, including fertile material which we have tentatively identified as *Lithophyllum* sp., but which we are currently unable to assign to species. Work is continuing on this collection.

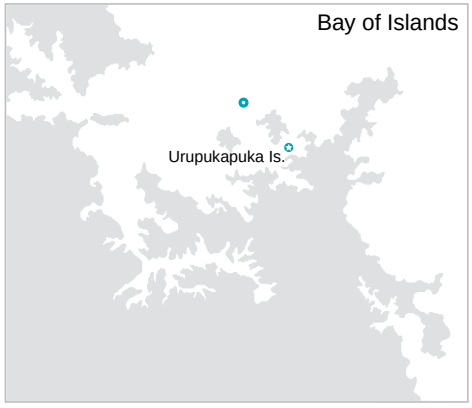
The most common species growing as a rhodolith in New Zealand is *Sporolithon durum*. Rhodoliths identified as *S. durum* were collected from 14 of 86 study sites (16%) in northern New Zealand. *Sporolithon durum* rhodoliths, when fertile, have tetrasporangia in calcified compartments grouped in raised, often pale to white sori. Epithallial cells are flared. Rhodoliths of *S. durum* can be "twiggy" and sparsely branched, or "golfball-like", more spherical with short lumpy branches (see figures opposite).



Rhodoliths belonging to the genus *Lithothamnion* were identified from 3 collection sites. *Lithothamnion indicum* rhodoliths were collected at 2 of 86 study sites (2.3%), at both of which they co-occurred with *Sporolithon durum* rhodoliths. In this study, *Lithothamnion proliferum* was collected from a single site (1.1% of North Island study sites) at which no other rhodolith species were collected.

Lithothamnion species form spherical rhodoliths with short lumpy branches, and large multiporate conceptacles (see figures opposite). Epithallial cells are flared. See the *Lithothamnion* genus and species profiles for a key to and details of species.

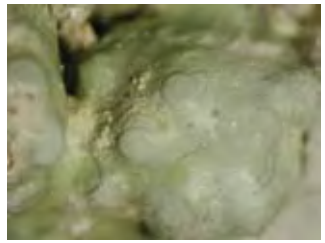




Sporolithon durum rhodoliths (right), and close-up of sorus (below)

Lithothamnion indicum rhodolith (right), and close-up of multiporate conceptacles (below)

Lithothamnion proliferum rhodolith (right), and close-up of multiporate conceptacles (below)



Acknowledgments

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Malcolm Francis, Erika MacKay (NIWA) and Debbie Freeman (Department of Conservation) are thanked for assistance with images and illustrations, Michelle Carter (NIWA) for assistance with databasing and specimen processing, and Spencer Stevens for assistance with editing.

Image credits

T. Farr, A. Harvey & K. Neill: growth form photos, Figure 6.

M. Francis: Figures 1 and 2, *Amphiroa anceps* species profile.

D. Freeman: Figures 3, 5, 17, Introduction; Figures 1, 3, *Jania verrucosa* species profile; Rhodolith section cover page.

A. Harvey: Figure 7, *Mesophyllum engelhartii* species profile; Figure 7, *Mesophyllum erubescens* species profile.

E. Mackay: artwork and layout, simplified sexual cycle.

Unless otherwise stated above, photos are by Tracy Farr and Kate Neill, and drawings by Tracy Farr.

Collectors

We would like to thank the many people who assisted with field collections: Jeff Forman, Svenja Heesch, and Sheryl Miller (NIWA); Debbie Freeman, Sean Cooper, Clinton Duffy, Paul Buisson, (Department of Conservation); Nick Shears, Franz Smith, and Mike Wilcox.

Glossary

The glossary of terms used in this guide is adapted primarily from Harvey et al 2005. An excellent glossary of algal terminology can be found online at AlgaeBase http://www.algaebase.org/search/glossary/

Acute: with a pointed apex or a narrow axil

Apex/apical: tip of a thallus or branch

Apical plug: a hard, mucilage-like plug produced at the tip of a tetrasporangium in species of Hapalidiaceae and Sporolithaceae but not found in the Corallinaceae

Applanate: flattened horizontally

Articulated: having flexible joints between hard parts as in the geniculate coralline algae

Axis: a stem-like stalk

Bispore: sometimes formed instead of a **tetraspore** in some species of corallines.

Calcified compartment: a structure containing a tetrasporangium in genera of Sporolithaceae

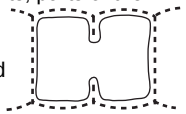
Carpogonium (carpogonia): a haploid female reproductive cell. Carpogonia are terminal on filaments in female conceptacles

Carposporangium (carposporangia): a structure that contains a carpospore

Carpospore: a diploid spore that is produced by a carposporophyte and that gives rise to a diploid tetrasporophyte

Carposporophyte: a small (usually microscopic) diploid, parasitic plant that develops from a fertilised carpogonium, remains attached to the old female haploid parent, and produces carpospores (see *Life cycle figure*). The carposporophyte is one of three distinct morphological phases in the sexual cycle of corallines; the other two are the haploid gametophyte and the diploid tetrasporophyte

Cell fusion: cell connection between two adjacent vegetative filaments; parts of the cell walls break down and the protoplasts then seem to fuse (Not to be confused with **fusion-cell**)

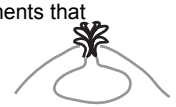


Collection: For coralline algae, a single 'collection' of a small species may contain thousands of individuals growing on a single host alga or stone, while for some larger species, only part of a single individual may make up a 'collection'

Columella: a structure made up of sterile cells; arises centrally from the floor of a tetrasporangial or bisporangial conceptacle in some species of corallines

Conceptacle: a structure that contains a chamber that holds reproductive bodies. A conceptacle may contain a single pore (uniporate) or a number of pores (multiporate) through which spores or gametes are released

Corona: a ring of cells/filaments that surrounds and protrudes above the surface of a pore in conceptacles of some species of Corallinaceae



Cortex: outer cell layers

Cruciate: the arrangement of spores lying side by side in two rows in a tetrasporangium (cross-shaped, "hot cross buns"). In corallines, cruciate sporangia characteristically occur only in the Sporolithaceae

Diagnostic character: any character(s) that unambiguously separates one species from other species in the same genus

Dichotomous: with two equal branches at each fork; or forked into two similar parts as a result of the equal division of the apex

Dimerous: thallus construction in nongeniculate corallines where two distinct groups of filaments are produced successively and are more or less at right angles to one another

Diploid: a nucleus with two representatives of each chromosome; an organism with diploid nuclei. Compare with Haploid

Discoid: in nongeniculate corallines, growth-form composed of an unbranched, largely unattached, flattened, disc-like plant of varying shape

Encrusting: in nongeniculate corallines, growth-form that is unbranched, largely attached, crustose, and flattened or sleeve-like

Endophytic: growing within another plant

Epilithic: growing on rock

Epiphytic: growing on another plant

Epithallial cell: in corallines, the terminal cell or cells of a filament at the surface of a plant. Epithallial cells are formed outwardly from the division of a vegetative cell just below the tip of a filament. In some species, more than one epithallial cell may occur at the tip of a filament

Epizoic: growing on an animal

Filament: in corallines, a row of cells, linked by primary pit-connections

Flat-topped: multiporate conceptacles with a flat roof (lacking a distinct rim and central sunken pore-plate); conceptacles may be either mound-like ("mesa") or more-or-less level with the thallus surface ("flat" or "flush").

Flared: spread out or broadened above the base; used to describe epithallial cells of some corallines

Foliose: leaf-like, flattened and leafy; in nongeniculate corallines, growth-form with flattened, plate-like branches at various angles to one another

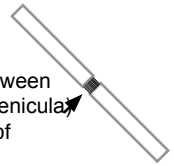
Frond: a term sometimes used to describe a leaf-like part of a plant

Fruticose: shrubby; in nongeniculate corallines, growth-form composed mainly of cylindrical to compressed or knobby branches that are over 3 mm long

Fusion cell: an enlarged, often irregular, cell formed from the zygote by fusion with other adjacent cells

Gamete: either of two haploid cells involved in zygote formation; in corallines the female gamete is the carpogonium and the male gamete is the spermatium

Geniculum (geniculum): the uncalcified segment found between two calcified segments (intergenicula) in branches of some species of Corallinaceae



Geniculate: possessing genicula; geniculate coralline algae are also known as turfing, jointed, or articulated

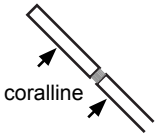
Gonimoblast filament: in carposporophytes, a name for a filament that ultimately produces carposporangia

Haploid: a nucleus with one representative of each chromosome; an organism with haploid nuclei. Compare with **Diploid**

Holdfast: a small, basal attachment structure that anchors a plant to a substrate

Initial: see **Subepithallial initial**

Intergeniculum (intergenicula): calcified segments between the non-calcified joints (genicula) of a coralline alga



Intertidal: seashore exposed at low tide

Involucre: In the Sporolithaceae, applies to the vertically flattened sterile filaments surrounding the tetrasporangial compartment

Layered: in nongeniculate corallines, growth-form composed of several to many plate-like branches arranged in horizontally orientated layers

Lumpy: in nongeniculate corallines, growth-form composed of short, swollen protuberances that are usually unbranched and are often crowded or contiguous

Maerl: rhodoliths; the sediment composed mainly of irregularly branched, unattached, non-geniculate coralline algae

Medulla: inner core of tissue, central region internal to cortex

Meiosis: a specialised nuclear division sequence in which the chromosome number is reduced from 2N to N and genetic segregation occurs

Monomerous: thallus construction in nongeniculate corallines; a single system of repeatedly branched filaments form a core of filaments orientated more or less parallel to the thallus surface, and a peripheral region where a portion of filaments become orientated more or less perpendicular to the thallus surface

Multiporate: in corallines, a conceptacle whose roof has multiple pores

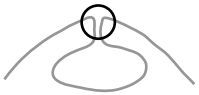
Non-geniculate: lacking genicula; completely calcified coralline algae; non-geniculate coralline algae are also known as “crustose” or “encrusting” corallines

Pinnate: with branches in two opposite rows along an axis; paired or alternate; feather-like

Pit connection: a link between two cells in which a pit plug occurs in an opening in the contiguous cell walls

Pit plug: a distinct, lens-shaped structure that is part of a primary or secondary pit connection

Pore canal (or **pore):** in coralline conceptacles, an opening in the roof through which spores or gametes can pass

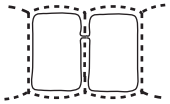


Primary pit connection: a pit connection between adjacent cells of the same filament

Protuberance: in nongeniculate corallines, a cylindrical to compressed or irregularly shaped outgrowth or branch of a plant

Rhodolith: an unattached coralline plant; may develop around a core of loose stone, shell or other object

Secondary pit connection: a pit connection between cells of two adjacent filaments (also termed secondary pits or 2° pits)



Semi-endophytic: growing partly within another plant, as for example, the thallus of *Choreonema*

Sorus (sori): in the Sporolithaceae, a cluster of calcified compartments (each containing one sporangium) occurring as a surface patch or slightly raised group

Spermatium (spermatia): non-motile male gamete in the red algae; male gamete

Spermatangium (spermatangia): a structure that contains spermatia

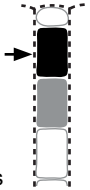
Sporangium (sporangia): spore-producing cells or structures

Spore: a reproductive cell derived by mitosis (mitospore) or meiosis (meiospore) and capable of growth directly into another plant

Stipe: a stalk, stem or trunk

Stolon: creeping (mostly cylindrical) structure from which upright branches arise

Subepithallial initial: in corallines, the cell (arrowed black, at right) situated beneath an epithallial cell in a filament. Subepithallial initials divide to give rise to new epithallial cells outwardly and new ordinary vegetative cells inwardly



Subtending: immediately below, as for example the cells (shaded grey, at right) beneath a subepithallial initial in a vegetative filament

Subtidal: at a depth below the lowest level of low tide

Taxon (taxa): a group of organisms of any taxonomic rank e.g., family, genus or species Terete: cylindrical; more or less circular in cross section

Tetrasporangium (tetrasporangia): a sporangium containing four spores, usually in a distinctive arrangement

Tetraspore: any one of the four spores formed in a tetrasporangium. Tetraspores are generally presumed to be formed as a result of meiosis

Thallus (thalli): the plant body of a macroalga

Trichocyte: a specialised cell that may bear hairs, usually longer, with thicker walls, or more intensely staining than other vegetative cells

Type locality: the geographical site at which the type material (the material from which a species was first described) of a species was collected

Unconsolidated: in nongeniculate corallines, growth-form where filaments do not group together to form a distinct thallus (for example *Choreonema*)

Uniporate: in corallines, a conceptacle with a single pore

Volcano-like: multiporate conceptacles that have a distinct raised rim with a central sunken pore-plate

Warty: in nongeniculate corallines, growth-form with wart-like protuberances

Zonate: the arrangement of four spores lying in a single row within a tetrasporangium. In corallines, zonate tetrasporangia characteristically occur in the Corallinaceae and Hapalidiaceae

Zygote: the diploid cell resulting from fusion of two haploid gametes.

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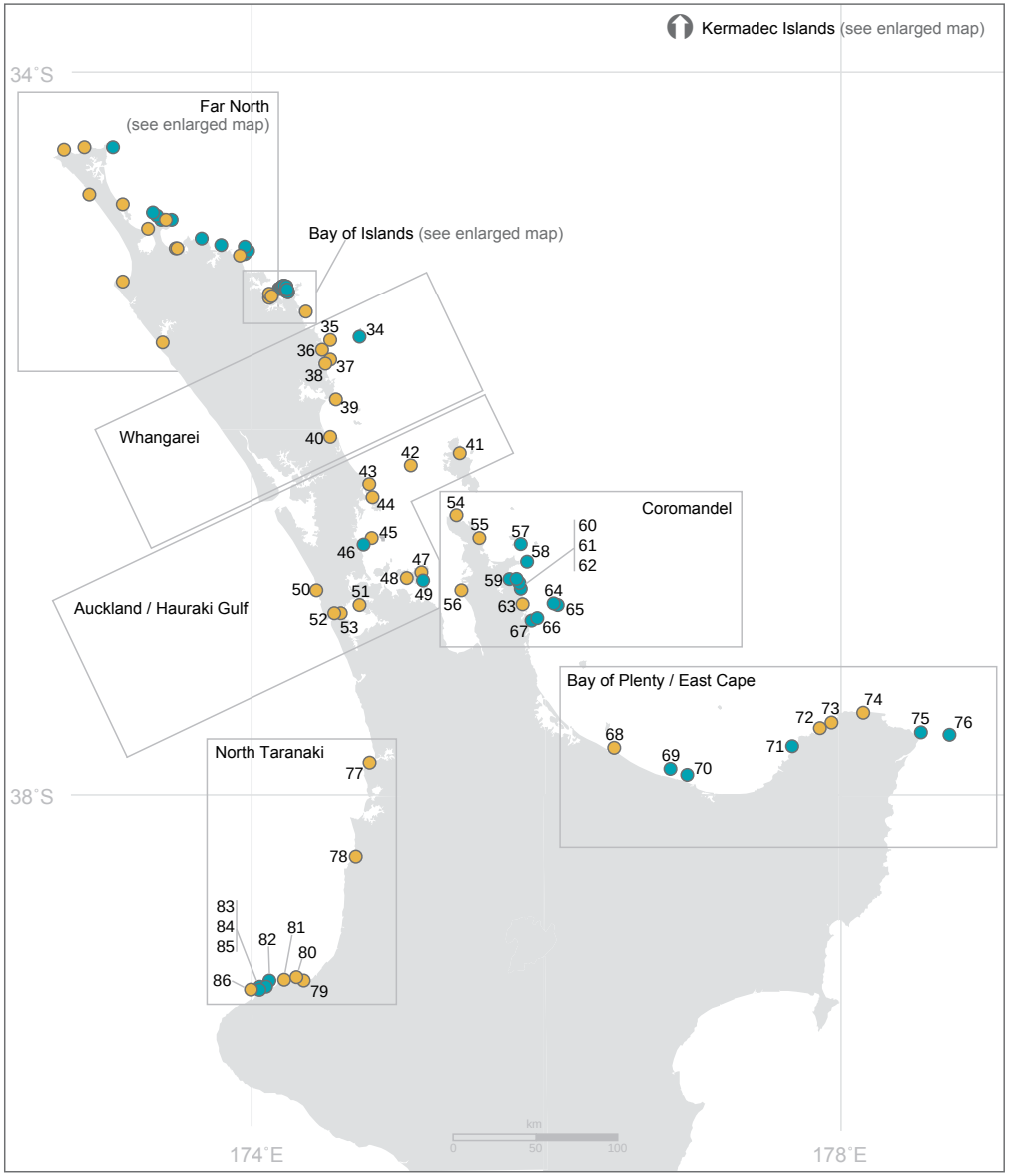
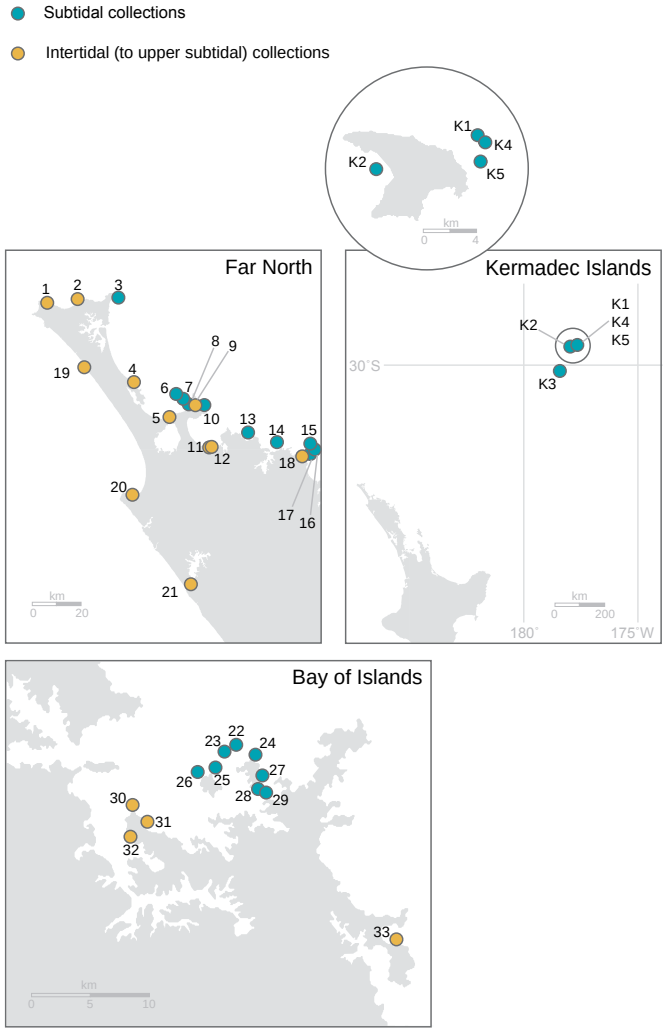
Appendix 1

Map of collection sites





Collection sites for this identification guide. Intertidal sites (orange) and subtidal sites (blue) are indicated. Intertidal sites were collected at extreme low tides, and represent intertidal to upper subtidal (to 1-2 m depth) collections.

Family		Corallinaceae							Corallinaceae					Corallinaceae												Hapalidiaceae									Sporolithaceae			Other
Geniculate / non-geniculate		Geniculate							Non-geniculate					Non-geniculate																								
Subfamily		Corallinoideae						Lith-ophyl-loideae	Lithophylloideae					Mastophoroideae											Chore-onema-toideae	Melobesioideae								n/a			n/a
Locality number	Locality name	*Arthrocardia & Corallina* spp.	*Corallina officinalis*	*Janiа sagittata*	*J. rosea*	*J. verrucosa*	*J.* sp. aff. *ungulata*	*Amphiroa anceps*	*Lithophyllum carpophylli*	*L. corallinae*	*L. johansenii*	*L. pustulatum*	*L. stictaeforme*	*Hydrolithon improcerum*	*H. onkodes*	*H. rupestris*	*Mastophora pacifica*	*Neogoniolithon brassica-florida*	*Pneophyllum coronatum*	*P. fragile*	*Spongites yendoi*	*Choreonema thuretii*	*Lithothamnion indicum*	*L. proliferum*	*Melobesia membranaceae*	*Mesophyllum engelhartii*	*M. erubescens*	*M. macroblastum*	*M. printzianum*	*Phymatolithon repandum*	*Heydrichia homalopasta*	*H. woelkerlingii*	*Sporolithon durum*	Unidentified Rhodoliths
Kermadec Islands																																				
K1	Boat Harbour							•									•																			
K2	Denham Bay																•																			
K3	Denham Bay			•															•																	
K4	Kermadec Ridge 1																																			•
K5	Kermadec Ridge 2																																			•
Far North																																				
1	Tapotupotu Bay	2	•	•	F			•	•	•		•	•		•					•	•				•	•	•		•							
2	Kapowairua	•	•	•	F	•			•			•			•				•		•	•				•	•		•		•	•				
3	North Cape	2		•				•	•												•					•	•	•	•*							
4	Henderson Point	•	•			•			•	•		•									•								•		•	•	E		
5	Rangiputa		•															•			•														
6	Staffa Rock																							•												
7	Karikari Bay 2																																R			
8	Karikari Bay 1																																R			
9	Matai Bay	•	•						•	•		•	•								•					•		•		•						
10	Pihakoa Point	•						•	•			•	•												•	•*	•	•							
11	Cable Bay		•						•			•	•								•			•				•	•	•					
12	Chucks Cove								•			•									•														
13	Wekarua Island	•	•	•				•	•			•	•														•	•	•	•			R		
14	Stephenson Island	•						•				•																					R		
15	Haraweka Island		•																														R		
16	Motuharakeke	•		•	B			•				•																					R		
17	Cavalli Passage																																R			•
18	Matauri Bay	•							•			•	•								•				•		•	•	•	•					
19	The Bluff		•		F	•																							•						
20	Ahipara	3			FB	•															•								•	•	•				
21	Opononi																				•														

Family		Corallinaceae							Corallinaceae					Corallinaceae										Hapalidiaceae									Sporolithaceae			Other
Geniculate / non-geniculate		Geniculate							Non-geniculate					Non-geniculate																						
Subfamily		Corallinoideae						Lith-ophyl-loideae	Lithophylloideae					Mastophoroideae										Chore-onema-toideae	Melobesioideae								n/a			n/a
Locality number	Locality name	*Arthrocardia & Corallina* spp.	*Corallina officinalis*	*Jania sagittata*	*J. rosea*	*J. verrucosa*	*J.* sp. aff. *ungulata*	*Amphiroa anceps*	*Lithophyllum carpophylli*	*L. corallinae*	*L. johansenii*	*L. pustulatum*	*L. stictaeforme*	*Hydrolithon improcerum*	*H. onkodes*	*H. rupestris*	*Mastophora pacifica*	*Neogoniolithon brassica-florida*	*Pneophyllum coronatum*	*P. fragile*	*Spongites yendoi*	*Choreonema thuretii*	*Lithothamnion indicum*	*L. proliferum*	*Melobesia membranaceae*	*Mesophyllum engelhartii*	*M. erubescens*	*M. macroblastum*	*M. printzianum*	*Phymatolithon repandum*	*Heydrichia homalopasta*	*H. woelkerlingii*	*Sporolithon durum*	Unidentified Rhodoliths
Bay of Islands																																			
22	Okahu Channel	2	•		B			•	•			•	•						•							•	•	•	•	•			E	
23	Okahu Island		•				•	•				•	•						•								•	•	•				RE	
24	Urupukapuka	•	•	•					•			•	•															•	•	•		•			
25	Moturoa		•								•				•				•							•			•			•			
26	Rangiatea	•	•	•				•	•	•		•	•						•						•	•	•			•		•		E	
27	Urupukapuka Bay		•																																
28	Round Island																													•		•			
29	Whau Point																					•												R	
30	Tapeka Beach								•	•																				•					
31	Waitata Rocks		•						•																										
32	Russell																		•						•										
33	Bland Bay	•	•						•					•					•						•			•	•	•					
Whangarei																																			
34	Poor Knights Is.																																		•
35	Urquhart's Bay																												•						
36	Sandy Bay		•								•																	•						
37	Tutukaka Marina																				•					•				•				
38	Ngunguru Harbour		•																										•					
39	Ocean Beach		•		F	•												•			•									•				
40	Lang's Beach		•			•														•									•	•				

N = N species

B = Bottlebrush form
F = Feather form

●* = intermediate between *L. corallinae* & *L. stictaeforme*

●* = intermediate between *L. corallinae* & *L. stictaeforme*

●* = intermediate between *M. erubescens* & *M. printzianum*

●* = intermediate between *M. erubescens* & *M. printzianum*

R = Rhodolith (unattached)
E = Epilithic (attached)

Family		Corallinaceae							Corallinaceae					Corallinaceae											Hapalidiaceae									Sporolithaceae			Other
Geniculate / non-geniculate		Geniculate							Non-geniculate					Non-geniculate																							
Subfamily		Corallinoideae						Lith-ophyl-loideae	Lithophylloideae					Mastophoroideae											Chore-onema-toideae	Melobesioideae								n/a			n/a
Locality number	Locality name	*Arthrocardia & Corallina* spp.	*Corallina officinalis*	*Jania sagittata*	*J. rosea*	*J. verrucosa*	*J.* sp. aff. *ungulata*	*Amphiroa anceps*	*Lithophyllum carpophylli*	*L. corallinae*	*L. johansenii*	*L. pustulatum*	*L. stictaeforme*	*Hydrolithon improcerum*	*H. onkodes*	*H. rupestris*	*Mastophora pacifica*	*Neogoniolithon brassica-florida*	*Pneophyllum coronatum*	*P. fragile*	*Spongites yendoi*	*Choreonema thuretii*	*Lithothamnion indicum*	*L. proliferum*	*Melobesia membranaceae*	*Mesophyllum engelhartii*	*M. erubescens*	*M. macroblastum*	*M. printzianum*	*Phymatolithon repandum*	*Heydrichia homalopasta*	*H. woelkerlingii*	*Sporolithon durum*	Unidentified Rhodoliths
Auckland / Hauraki Gulf																																				
41	Whangapoua									•																										
42	Little Barrier I.								•																											
43	Matheson Bay									•																				•						
44	Jones Bay				F	•					•		•					•								•	•		•	•		R		
45	Army Bay																															R			
46	Little Manly Beach																															R			
47	Man-o-war Bay																				•									•					
48	Rocky Bay		•		F	•								•							•					•			•	•				
49	Waiheke Channel																									•									•
50	Te Henga	•			B	•														•									•	•	•			
51	Mangere I.																									•									
52	Little Huia		•																		•								•					
53	Cornwallis Wharf																												•						
Coromandel																																				
54	Fletcher Bay	•				•			•	•		•									•			•			•	•	•		•			
55	Waikawau					•			•			•							•		•				•	•	•	•		•	•			
56	Wilson Bay																				•				•	•			•					
57	Great Mercury Island											•													•										
58	Flat Island, Mercury Is.																					•										R			
59	Cooks Bluff																									•									
60	Kingfish Rock																										•								
61	Hapuka Rock																										•								
62	Hahei																					•			•	•		•							
63	Sailors Grave					•				•		•							•					•				•				E		
64	Flat Island, Aldermen Is.																						•												
65	Aldermen Is.																								•										
66	Slipper I.																								•										
67	Slipper I.																																		•

Family	Corallinaceae							Corallinaceae					Corallinaceae										Hapalidiaceae									Sporolithaceae			Other
Geniculate / non-geniculate	Geniculate							Non-geniculate					Non-geniculate																							
Subfamily	Corallinoideae						Lith-ophyl-loideae	Lithophylloideae					Mastophoroideae										Chore-onema-toideae	Melobesioideae									n/a			n/a
Locality number / Locality name	*Arthrocardia & Corallina* spp.	*Corallina officinalis*	*Jania sagittata*	*J. rosea*	*J. verrucosa*	*J.* sp. aff. *ungulata*	*Amphiroa anceps*	*Lithophyllum carpophylli*	*L. corallinae*	*L. johansenii*	*L. pustulatum*	*L. stictaeforme*	*Hydrolithon improcerum*	*H. onkodes*	*H. rupestris*	*Mastophora pacifica*	*Neogoniolithon brassica-florida*	*Pneophyllum coronatum*	*P. fragile*	*Spongites yendoi*	*Choreonema thuretii*	*Lithothamnion indicum*	*L. proliferum*	*Melobesia membranaceae*	*Mesophyllum engelhartii*	*M. erubescens*	*M. macroblastum*	*M. printzianum*	*Phymatolithon repandum*	*Heydrichia homalopasta*	*H. woelkerlingii*	*Sporolithon durum*	Unidentified Rhodoliths
Bay of Plenty / East Cape																																		
68 Maketu																			•									•					
69 Rarimu Islands																									•	•							
70 Whale Island																									•	•	•*						
71 Te Kaha																															R		
72 Raukokere																			•										•				
73 Te Rangiharu Bay																			•									•					
74 Lottin Point	•	•						•		•	•	•						•	•					•		•	•	•	•				
75 Plate Island																								•									
76 Waikawa Rock																									•	•							
North Taranaki																																		
77 Whale Bay		•																	•								•				E		
78 Kiritehere Beach		•	•	B	•										•			•	•					•	•		•*				E		
79 Onaero																				•													
80 Parahaki Stream Reef																			•					•									
81 Waitara		•			•																							•					
82 Radio Mast Boulders																									•			•			E		
83 Waiwhakaiho Reef																											•	•					
84 Sugar Loaf Islands									•*			•*														•	•	•	•				
85 Kawaroa Reef/Hapuka Rock									•*			•*													•		•						
86 Belt Rd Reef/Pt Taranaki																			•														

N = N species

B = Bottlebrush form
F = Feather form

•* = intermediate between *L. corallinae* & *L. stictaeforme*

•* = intermediate between *L. corallinae* & *L. stictaeforme*

•* = intermediate between *M. erubescens* & *M. printzianum*

•* = intermediate between *M. erubescens* & *M. printzianum*

R = Rhodolith (unattached)
E = Epilithic (attached)

Appendix 3 GenBank accession numbers

GenBank http://www.ncbi.nlm.nih.gov/Genbank/index.html accession numbers are listed only for sequences included in the phylogenetic analysis. List is in order, reading down from the top of the tree (Figure 10). Where applicable, WELT numbers (accession numbers for the herbarium at Museum of New Zealand Te Papa Tongarewa) are given.

Species	Genbank Acc. No.	WELT No.
Ceramium japonicum	AY178485	
Ceramium tenerrimum	AY178487	
Antithamnion nipponicum	AY295157	
Anotrichium crinitum	AY295139	
Griffithsia traversii	AY295154	
Palmaria palmata	U28165	
Heydrichia homalopasta	FJ361383	A029111
Heydrichia woelkerlingii	FJ361382	A029119
Sporolithon durum attached	FJ361509	A029451
Sporolithon durum rhodolith	FJ361583	A029434
Unidentified	FJ361419	
Lithothamnion indicum	FJ361502	A029241
Phymatolithon sp.	FJ361381	A029375
Mesophyllum macroblastum	FJ361519	A029300
Mesophyllum engelhartii	FJ361517	A029456
Synarthrophyton schielianum	DQ168016	
Synarthrophyton patena	DQ168000	
Phymatolithon repandum	FJ361683	A029357
Mesophyllum erubescens	FJ361551	A029254
Mesophyllum erubescens	FJ361750	A029275
Mesophyllum printzianum	DQ167985	
Mesophyllum printzianum	DQ167919	
Mesophyllum printzianum	FJ361605	A029283
Mesophyllum printzianum	FJ361577	A029332
Mesophyllum printzianum	FJ361436	A029327
Jania sp.	FJ755792	
Jania rosea bottlebrush	FJ361425	A029080
Jania rosea feather	FJ361713	A029088

Species	Genbank Acc. No.	WELT No.
Jania sagittata	FJ361571	A029013
Jania sp. fine	FJ361501	A029128
Jania verrucosa	FJ361686	A029132
Arthrocardia sp. 1	FJ361708	A029003
Arthrocardia sp. 2	FJ361719	A029006
Arthrocardia sp. 3	DQ168012	
Corallina officinalis	FJ361705	A029033
Corallina sp. spacer3	FJ755793	
Corallina sp. spacer6	FJ361738	A029074
Corallina sp. spacer2	FJ361418	A029062
Corallina sp. spacer5	EF628246	
Corallina sp. spacer4	FJ361494	A029072
Corallina sp. spacer1	DQ167938	
Mastophora pacifica	FJ361461	A029244
Neogoniolithon brassica-florida	FJ361443	A029356
Spongites yendoi	FJ361378	A029408
Pneophyllum sp.	FJ361545	
Pneophyllum sp.	FJ361387	
Pneophyllum coronatum	FJ361739	A029393
Spongites yendoi	FJ361459	A029414
Spongites yendoi	DQ167869	
Spongites yendoi	FJ361440	A029419
Spongites yendoi	DQ167944	
Hydrolithon onkodes	FJ361689	A029125
Hydrolithon improcerum	DQ168005	
Lithophyllum sp. 2	FJ361615	A029213
Amphiroa anceps	FJ361601	A028993
Lithophyllum sp. 1	FJ361730	A029216
Lithophyllum carpophylli	FJ361554	A029153
Lithophyllum pustulatum	FJ361746	A029193
Lithophyllum stictaeforme	FJ361446	A029229
Lithophyllum johansenii	FJ361549	A029184
Lithophyllum corallinae	FJ361544	A029176

Reference specimens for each species have been lodged at WELT (the herbarium at the Museum of New Zealand Te Papa Tongarewa), as part of the National Coralline Algal Reference Collection. Additional specimens (not listed here) have also been lodged at WELT. For each species listed, the number of specimens examined (and with confirmed identification) in the current study is recorded.

Species	WELT No.
Corallinaceae (geniculate)	
Amphiroa anceps 10 specimens examined	A028991 A028995 A028994 A029000
Arthrocardia spp. 9 specimens examined	A029001 A029003
Corallina spp. spacers 17 specimens examined	A029062 A029064 A029066 A029070 A029067
Corallina officinalis 30 specimens examined	A029038 A029034 A029028 A029056
Jania sagittata 12 specimens examined	A029012 A029019 A029020 A029011
Jania rosea feather 8 specimens examined	A029084 A029081
Jania rosea bottlebrush 5 specimens examined	A029080
Jania verrucosa 15 specimens examined	A029143 A029141
Jania sp. fine 1 specimen examined	A029128

Species	WELT No.
Corallinaceae (non-geniculate)	
Hydrolithon improcerum 2 specimens examined	A029123
Hydrolithon onkodes 2 specimens examined	A029124 A029125
Hydrolithon rupestris 1 specimen examined	A029127
Lithophyllum carpophylli 23 specimens examined	A029145
Lithophyllum corallinae 14 specimens examined	A029170 A029176
Lithophyllum johansenii 6 specimens examined	A029183
Lithophyllum pustulatum 26 specimens examined	A029195 A029207
Lithophyllum stictaeforme 16 specimens examined	A029230 A029235 A029227
Mastophora pacifica 2 specimens examined	A029244 A029243
Neogoniolithon brassica-florida 3 specimens examined	A029354 A029355 A029356
Pneophyllum coronatum 13 specimens examined	A029383 A029391
Pneophyllum fragile 3 specimens examined	A029398 A029397
Spongites yendoi 29 specimens examined	A029412 A029420 A029402 A029407 A029416 A029417 A029425 A029427

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Species	WELT No.
Hapalidiaceae	
Choreonema thuretii 6 specimens examined	A029024 A029025 A029023
Lithothamnion indicum 2 specimens examined	A029241
Lithothamnion proliferum 1 specimen examined	A029242
Melobesia membranacea 5 specimens examined	A029245 A029247
Mesophyllum engelhartii 23 specimens examined	A029462 A029475 A029476 A029477 A029474
Mesophyllum erubescens 31 specimens examined	A029268 A029255 A029260 A029277 A029281 A029270 A029278 A029252
Mesophyllum macroblastum 27 specimens examined	A029308 A029302 A029292 A029305
Mesophyllum printzianum 41 specimens examined	A029343 A029331
Phymatolithon repandum 26 specimens examined	A029359 A029380

Species	WELT No.
Sporolithaceae	
Heydrichia homalopasta 26 specimens examined	A029109
Heydrichia woelkerlingii 6 specimens examined	A029119 A029118
Sporolithon durum attached 13 specimens examined	A029452 A029438
Sporolithon durum rhodolith 14 specimens examined	A029445 A029454 A029448