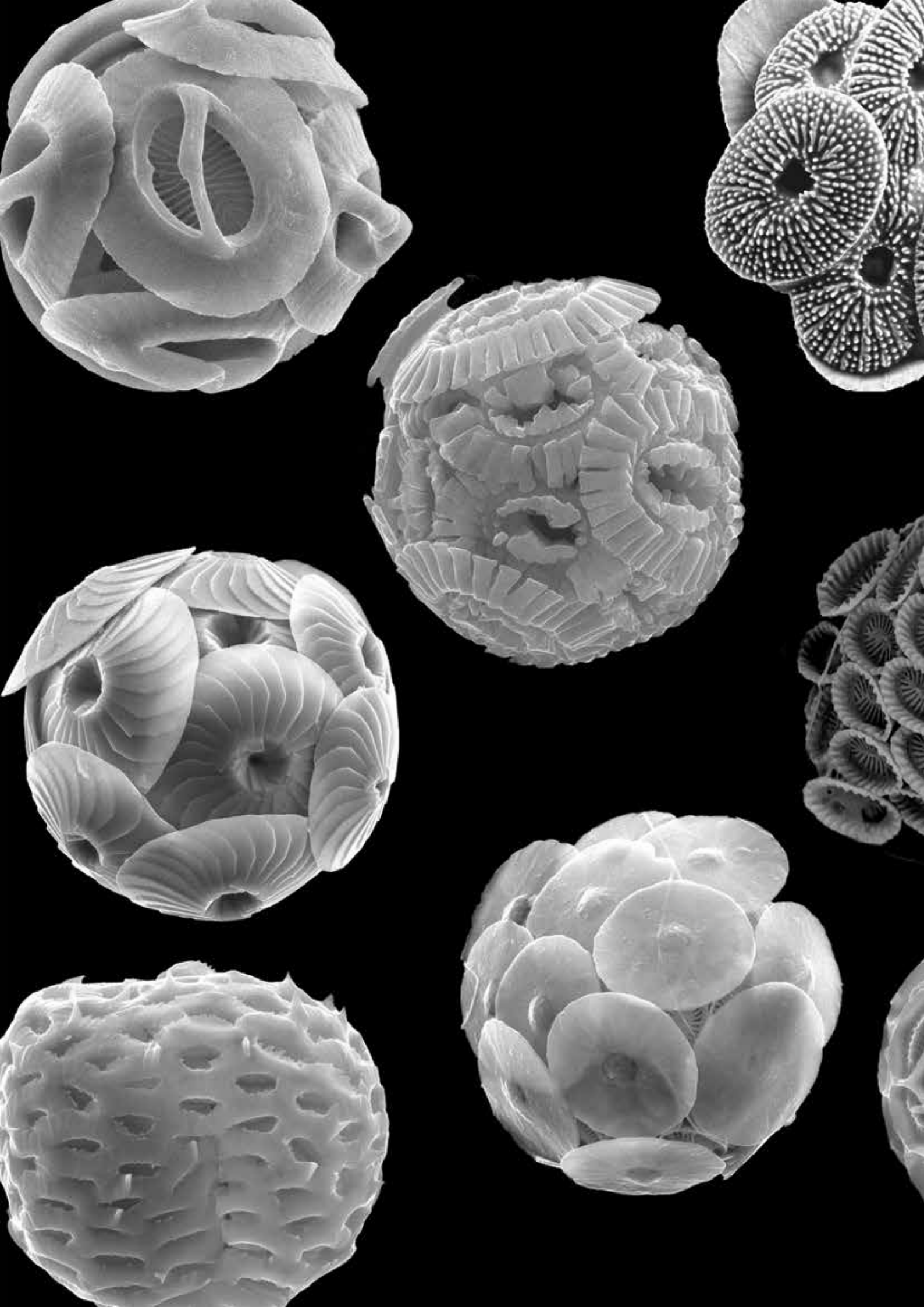
the Marine Biota of New Zealand

Catalogue and description of the coccolithophores (Haptophyta, Coccolithophyceae), calcareous, scale-bearing microalgae, in New Zealand waters

F. Hoe Chang

NIWA Biodiversity Memoir 131 2019

NIWA Taihoro Nukurangi



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Cover image

A spectacular oceanic bloom in spring 2009 – detected by the MODIS sensor on NASA's Aqua satellite off the central east coast of New Zealand (NASA Earth Observatory 2009). This highly reflective, chalky-blue, surface water was confirmed by ground-truthing to be caused by an almost monospecific bloom of *Emiliania huxleyi* (Lohmann) Hay & Mohler. The massive accumulation of coccoliths shed from cells of *E. huxleyi*, was found to contribute to this surface discolouration.

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Foreword

This is the first volume in the NIWA Biodiversity Memoir (NBM) series that addresses photosynthetic organisms, cataloguing the wonderful diversity of coccolithophores in New Zealand waters. This is a departure from previous volumes: until now the Memoirs have comprised technical works that describe New Zealand's invertebrate marine life – sponges, corals, hydroids, worms, molluscs, crustaceans, sea stars, and lesser-known groups – documenting the fauna of the region, providing monographic treatments, and including revisionary work that is relevant globally.

Over the past four decades Hoe Chang has made significant discoveries and contributions to understanding the physiology, ecology, anatomy and life history of New Zealand marine phytoplankton. NIWA has been very fortunate to have had Hoe as a staff member, and has benefitted greatly from his expertise and skills and their application to diverse research questions. Hoe recently retired and now holds an emeritus role at NIWA. His work on coccolithophores, presented here, is the culmination of many years of study on these exceptionally beautiful and ecologically important scale-bearing microalgae.

This Memoir will be an indispensable reference for academic researchers and postgraduate students interested in coccolithophores and the diversity present in the New Zealand region, and will also be of relevance to international researchers working on this key group of marine phytoplankton.

Wendy Nelson, PhD, MNZM, FRSNZ
Programme Leader,
Coasts and Oceans – Marine Biological Resources,
Marine Taxonomy Programme;
Professor, School of Biological Sciences,
University of Auckland.

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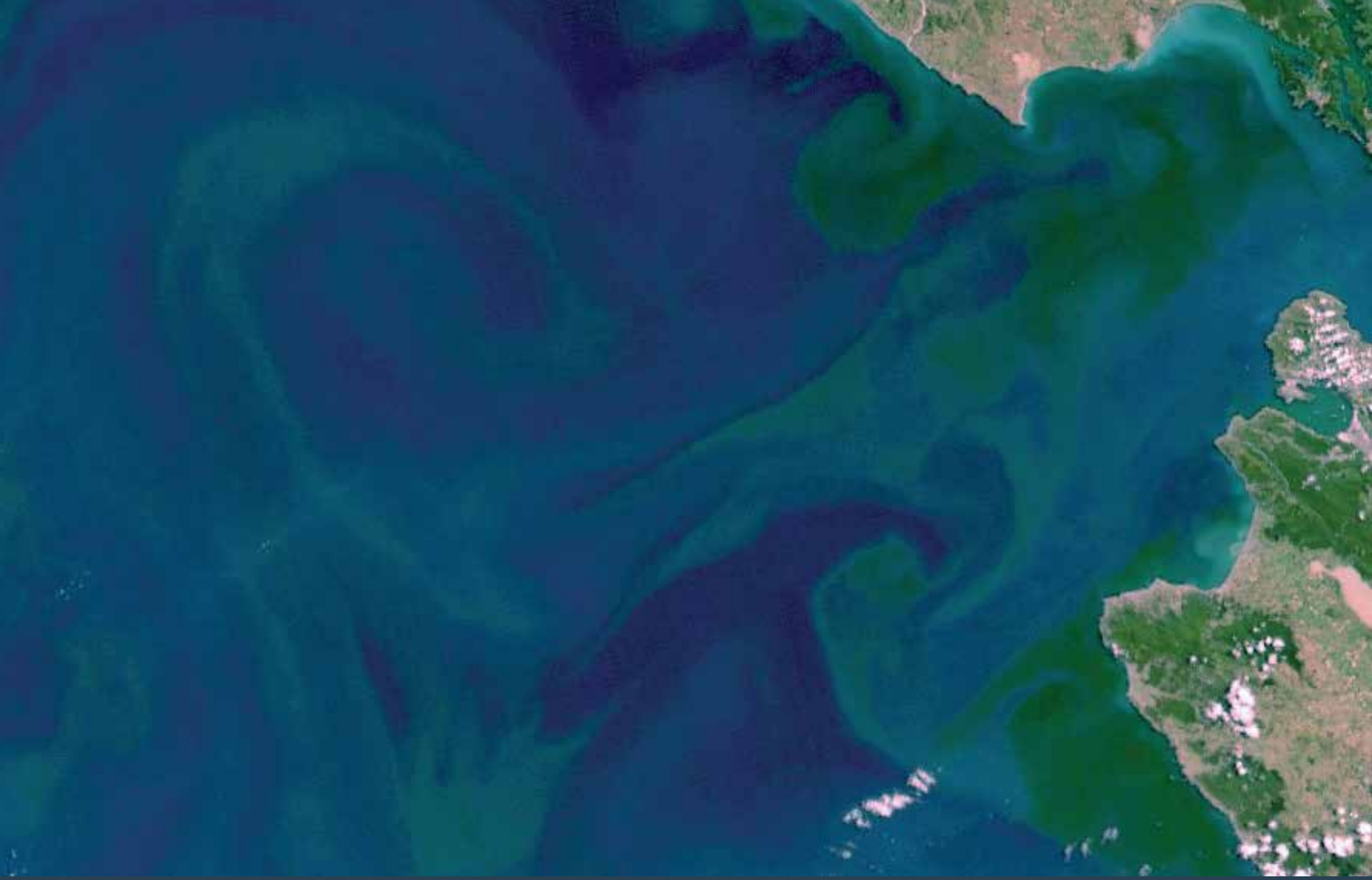
TAXONOMY & SYSTEMATICS

In contrast with spring 2009 and autumn 2011 coccolithophore blooms, which typically displayed a chalky-blue, surface discolouration, the summer 2011 oceanic bloom detected by the NASA's Aqua satellite off the central east coast of New Zealand (NASA Earth Observatory 2011) was made up of bands of turquoise waters intermingling with relatively weak, chalky-blue waters. Samples collected within this bloom showed a massive build-up of diatoms (dominated by *Fragilariopsis, Chaetoceros,* and *Rhizosolenia* spp., Chang unpublished results) and coccolithophores (dominated by *E. huxleyi,* see Appendix VII).



PREFACE

Catalogue and description of the coccolithophores (Haptophyta, Coccolithophyceae), calcareous, scale-bearing microalgae, in New Zealand waters

F. HOE CHANG

Coasts and Oceans National Centre
National Institute of Water & Atmospheric Research
Private Bag 14–021, Kilbirnie, Wellington 6021
hoe.chang@niwa.co.nz

&

School of Science & Technology
The Open University of Hong Kong
Hong Kong Special Administrative Region, China

Abstract

A checklist is presented of coccolithophores previously recorded from the New Zealand region; it contains 80 species, plus three different life-cycle forms of two of these species. Studies of extant coccolithophores, based on 160 samples collected from 10 oceanographic surveys, between January 2009 and February 2012, revealed a total of 50 taxa, with two taxa as first records for the region (*Cyrtosphaera lecaliae* Kleijne, 1992 and *Syracosphaera azureaplaneta* Young *et al*., 2018, recorded here for the first time). The 50 taxa recorded in this study are illustrated with 157 scanning electron micrographs in 29 plates. Of the 50 taxa, 45 were robust heterococcolithophores, with two having both holo– and heterococcolith-bearing forms, and the remaining three were holococcolithophores. Forty-two taxa in the heterococcolith-bearing group were placed in seven families in the four orders: Coccolithales, Isochrysidales, Syracosphaerales and Zygodiscales. Five taxa were *incertae sedis* (four families). Three holococcolithophore taxa were placed in the family Calyptrosphaeraceae. *Emiliania huxleyi* (Lohmann, 1902) Hay & Mohler in Hay *et al*., 1967 was the most plentiful and widespread taxon. On three occasions, in spring 2009 and two consecutive summers in 2011 and 2012, this species formed massive blooms off the central east coast of New Zealand, two of which (spring 2009 and summer 2011) were visible in NASA's satellite observations. Seven other relatively widespread species recorded here were: *Reticulofenestra parvula* (Okada & McIntyre, 1977) Biekart, 1989, *Umbellosphaera tenuis* type II (Kamptner, 1937) Paasche, 1955, *Syracosphaera molischii* Schiller, 1925, *Syracosphaera anthos* (Lohmann, 1912) Janin, 1987, *Gephyrocapsa ericsonii* McIntyre & Bé, 1967, *Syracosphaera mediterranea* (Lohmann, 1902) Triantaphyllou

et al., 2015, and *Calcidiscus leptoporus* (Murray & Blackman, 1898) Loeblich & Tappan, 1978. *Reticulofenestra parvula* was the second species in spring 2009 to be found in bloom proportion (up to 571,000 cells l^{-1}), but the bloom was limited to Kaikoura on the east coast of New Zealand. In this study *Syracosphaera* spp. were the most speciose genus, with 17 species, and one life-cycle form of one of these species, which made up about 36% of all extant coccolithophores identified. Most of the other genera, however, had few species which occurred only at a few stations. This monograph provides a diagnostic description of all 50 extant coccolithophores identified in New Zealand waters, using scanning electron microscopy (SEM), and gives information on cell abundances and distribution in the New Zealand region.

Non-technical summary

A checklist is presented of living, calcareous, scale-bearing microalgae previously recorded from the New Zealand region; it contains 80 species, plus three different life-cycle forms of two of these species. Studies of this group of microalgae, based on 160 samples collected from 10 ocean-going surveys between January 2009 and February 2012, revealed a total of 50 named individual groups of microalgae (taxa), with two taxa as first records for the region (*Cyrtosphaera lecaliae* Kleijne, 1992, and *Syracosphaera azureaplaneta* Young *et al*., 2018, both recorded here for the first time). The 50 taxa recorded in this study are illustrated with 157 scanning electron micrographs in 29 plates. Of the 50 taxa presented in this monograph, 45 were placed in a group characterised by having calcareous scales of variable shape and size that are formed inside the cell (heterococcolithophores), while three taxa (with one being transferred to to the family Syracosphaeraceae) were placed in another group characterised by having numerous minute crystallite scales that appear to be calcified outside the cell (holococcolithophores). Two of the first group also had forms showing characteristics of both groups. Forty-two taxa from the first group were placed in seven families in the four orders: Coccolithales, Isochrysidales, Syracosphaerales and Zygodiscales, and five taxa in four families of uncertain taxonomic position. Three holococcolithophore taxa were placed in the family Calyptrosphaeraceae. *Emiliania huxleyi* was the most plentiful and widespread taxon. On three occasions, in spring 2009 and two consecutive summers in 2011 and 2012, this species formed massive blooms off the central east coast of New Zealand, two of which (spring 2009 and summer 2011) were visible in NASA's satellite observations. Seven other relatively widespread species recorded here were: *Reticulofenestra parvula, Umbellosphaera tenuis* type II, *Syracosphaera molischii, Syracosphaera anthos, Gephyrocapsa ericsonii, Syracosphaera mediterranea*, and *Calcidiscus leptoporus*. In spring 2009 *Reticulofenestra parvula* was the second species found in bloom proportion (up to 571,000 cells l^{-1}), but the bloom was limited to Kaikoura on the east coast of New Zealand. In this study the genus *Syracosphaera* was the largest group, with 17 species and one life-cycle form of one of these species, which made up about 36% of all living coccolithophores identified. Most of the other genera, however, did not have many species and occurred in very limited areas. This work provides a diagnostic description of all 50 living coccolithophores identified in New Zealand waters, using scanning electron microscopy (SEM), and gives information on cell abundances and distribution in the New Zealand region.

Keywords

Extant coccolithophores, heterococcoliths, holococcoliths, cell abundances, new records, New Zealand, recently described species, Southwest Pacific, taxonomy, biogeography

Introduction

Coccolithophores (or coccolithophorids) are a small group of calcareous, golden–brown microalgae. Most of them occur as unicellular non-motile or motile forms, with a few that form colonies (Eikrem *et al*. 2016). They are mostly marine, with a few freshwater (Stoermer & Sicko-Goad 1977). In total over 200 species have been recorded worldwide (Jordan *et al*. 2004). This group is one of the most abundant primary producers in the ocean. They are characterised by the production of very small, calcium carbonate-scales, called coccoliths (e.g., Cros & Fortuño 2002; Young *et al*. 2003). These coccoliths are primarily formed of calcite. They have been the main source of calcite in the open ocean since the late Jurassic and are important microfossils (Hay 2004). These algae have gained increased attention as they play an important role in the global carbon cycle and are possibly also susceptible to ocean acidification (e.g., Hiramatsu & De Deckker 1997; Doney *et al*. 2009; Beaufort *et al*. 2011).

Coccolithophores are currently placed in the phylum Haptophyta, class Coccolithophyceae (= Prymnesiophyceae) (Rothmaler 1951; Ruggiero *et al*. 2015; Eikrem *et al*. 2016). This class is divided into four orders: Coccolithales, Isochrysidales, Syracospharales, Zygodiscales, and a group of unassigned genera/ families (incertae sedis) (Young *et al*. 2003; Jordan *et al*. 2004). Two other orders which belong to the same class as coccolithophores are Phaeocystales and Prymnesiales (Jordan *et al*. 2004). Both these orders contain harmful species, e.g., *Phaeocystis* Lagerheim, 1893, *Prymnesium* Massart, 1920 ex Conrad, 1926, *Chrysochromulina* Lackey, 1939 (e.g., Chang & Ryan 1985; Moestrup 2016). Even though most of coccolithophores are not known to be harmful, a few species of *Pleurochrysis* Pringsheim, 1955, and *Jomonlithus* Inouye & Chihara, 1983, have been tested toxic to brine shrimps (Houdan *et al*. 2004). The former are members of the order Coccolithales while the latter is a member of the Hymenomonaceae (Probert *et al*. 2014). No harmful outbreaks attributed to any of these species have so far been reported in New Zealand.

The identification of coccolithophores is primarily based on the morphology of the exquisite coccoliths. These may be either the heterococcoliths or holococcoliths. Heterococcoliths are formed by crystal units of variable shape and size, and their biomineralisation occurs intracellularly (Manton & Leedale 1969), while holococcoliths are formed of numerous minute crystallites that appear to be calcified extracellularly (Rowson *et al*. 1986). A third group of calcareous scales, which does not clearly conform to either the heterococcolith or holococcolith form, are referred to as nannoliths (e.g., Young *et al*. 1999; Young *et al*. 2003; Jordan *et al*. 2004). The three forms appear to be related to different life-cycle stages with three patterns occurring: 1) diploid phase heterococcolith-bearing, haploid phase naked (non-calcifying); 2) diploid phase heterococcolith-bearing, haploid phase holococcolith-bearing, and 3) diploid? phase heterococcolith-bearing, haploid? phase nannolith-bearing (e.g., Thomsen *et al*. 1991; Kleijne 1991; Cros & Fortuño 2002, Geisen 2002; Young *et al*. 2003).

In New Zealand, initial studies of coccolithophores were limited to coccoliths collected from sediment samples (Murray & Renard 1891; Edwards 1968, 1982; McIntyre *et al*. 1970; Burns 1973, 1975). Studies of extant coccolithophores started in the early 1960s and continued until the 2000s (Norris 1961; Cassie 1961; Burns 1977, Rhodes *et al*. 1993, 1995; Pellitero *et al*. 2014). Most of these studies, however, were limited to coastal areas around New Zealand. Norris (1961) was the first to examine living coccolithophore samples collected from a much larger region that extended from the northeast of New Zealand to Tonga. In his study, a total of 30 extant coccolithophore species were recorded (Norris 1961; Appendix 2, Table 2.1). However, only 24 of these species are included in the checklist of this monograph (Appendix 2, Table 2.1), because five of these species, *Calyptrosphaera insignis* Schiller, 1913, *Corisphaera gagei* Bernard, 1939, *Lohmannosphaera paucoscyphos* Schiller, 1925, *Pontosphaera caelamensis* Lecal-Schlauder, 1951, and *P. granii* Gaarder, 1954, are not able to be related to any species in modern taxonomy and it is not possible to guess what species might have been observed (Young pers. comm.), plus another species, *Thoracosphaera heimi* (Lohmann, 1919) Kamptner 1944, is a dinoflagellate. . Rhodes *et al*. (2012), added 21 species to this checklist. Studies undertaken by Saavedra–Pellitero *et al*. (2014), at three sites on the east coast of New Zealand, added another ten taxa to the New Zealand flora (Appendix 2, Table 2.2). Additionally, a further 26 new records were added for the New Zealand region by Chang (2013) and Chang & Northcote (2016). This work is based on the earlier studies of Chang & Northcote (2016). In this monograph, two additional

first–time records, *Cyrtosphaera lecaliae* Kleijne, 1992 and *Syracosphaera azureaplaneta* Young *et al*., 2018, were subsequently identified in the samples previously studied, and are added to the list of 26 new records in Chang & Northcote (2016) (see Checklist).

Prior to this study, a large proportion of living coccolithophore species, were identified using light microscopy and were not illustrated (e.g., Cassie 1961; Norris 1961), so the intent of this monograph is to provide brief descriptions of all 50 taxa found from 2009 to 2012 and illustrate these with SEM images. No attempt, however, has been made to give detailed descriptions of all these taxa as these are readily available in the primary literature and on the Nannotax3 website (Young *et al*. 2019). As very little is known about the distribution and cell density of living coccolithophores around New Zealand, additional information on biogeography and abundances of each taxon are also presented here (see figures and appendices).

Methods and materials

Cruises and sampling sites

A total of ten surveys were conducted aboard RV *Tangaroa* and RV *Kaharoa* from January 2009 to February 2012 in the Southwest Pacific near New Zealand. However, the main sampling sites were confined to the east of New Zealand. Seven surveys were conducted over Chatham Rise and Kaikoura coast, with the remaining three spreading across from the west (Tasman Sea), to both the south and northeast of New Zealand (Table 1, Figure 1). Out of these ten surveys, a total of five were conducted in summer, three in spring, and two in autumn. The RV *Tangaroa* cruise/stations are cited under the sections entitled 'Occurrence records' in each description, as NIWA Stn TANXXXX/XXX, and the RV *Kaharoa* cruise/stations as NIWA Stn KAHXXXX/XXX. Species previously recorded around New Zealand and other regions globally are including in the section entitled 'Previous records' in each description.

Sample collection

On each survey, discrete water samples were collected mainly from the upper 10 m using 10–litre Niskin bottles mounted on the CTD rosette system. Immediately, 1.5 to 3 L of water were filtered through a 47mm diameter 0.8 μm Nuclepore Polycarbonate Track–Etch Membrane filter (Whatman 111109). To minimise mechanical disruption of coccospheres, a vacuum of less than 100 mm Hg (low pressure) was applied below the filter with an electrical vacuum pump. These filters were individually placed in a labelled plastic Millipore petri dish (PF10266, 47 mm diameter) and air dried. The filters were then stored in a sealed plastic storage container with desiccant until analysis.

Scanning electron microscopy

Using a cork borer (10 mm in diameter) a small circular piece was cut out of the 47 mm Nuclepore Polycarbonate membrane filter. Cells retained on each of these filters were mounted on JEOL 15×10 mm aluminium stub using double-sided adhesive tape. These were then sputter-coated with either platinum or carbon (15 nm thick) and examined with either a JEOL JSM–5300LV (Tokyo, Japan) or Quanta 450 (Oregon, USA) SEM (20 kV) as described in Chang (2013). High-resolution images were also taken using a JEOL JSM6500F FEG–SEM (10 kV).

Table 1. Location, seasonality, date and number of stations where water samples were collected from each voyage during the period from January 2009 to February 2012, around New Zealand.

Voyage	Location	Season	Date	No.
TAN0902	Chatham Rise	summer	28 Jan to 03 Feb 2009	15
TAN0904	Kaikoura	autumn	21 Apr to 30 Apr 2009	21
TAN0908	Kaikoura	summer	01 Oct to 21 Oct 2009	04
TAN0909	Chatham Rise	spring	16 Oct to 30 Oct 2009	19
KAH0907	Bay of Plenty	spring	20 Aug to 22 Aug 2009	03
PINTS	Tasman Sea	summer	31 Jan to 15 Feb 2010	36
TAN1102	Chatham Rise	summer	06 Feb to 11 Feb 2011	16
TAN1106	Southern NZ	autumn	28 Sep to 01 Oct 2011	09
TAN1107	Chatham Rise	autumn	04 May to 10 May 2011	08
TAN1203	Chatham Rise	summer	05 Feb to 28 Feb 2012	25

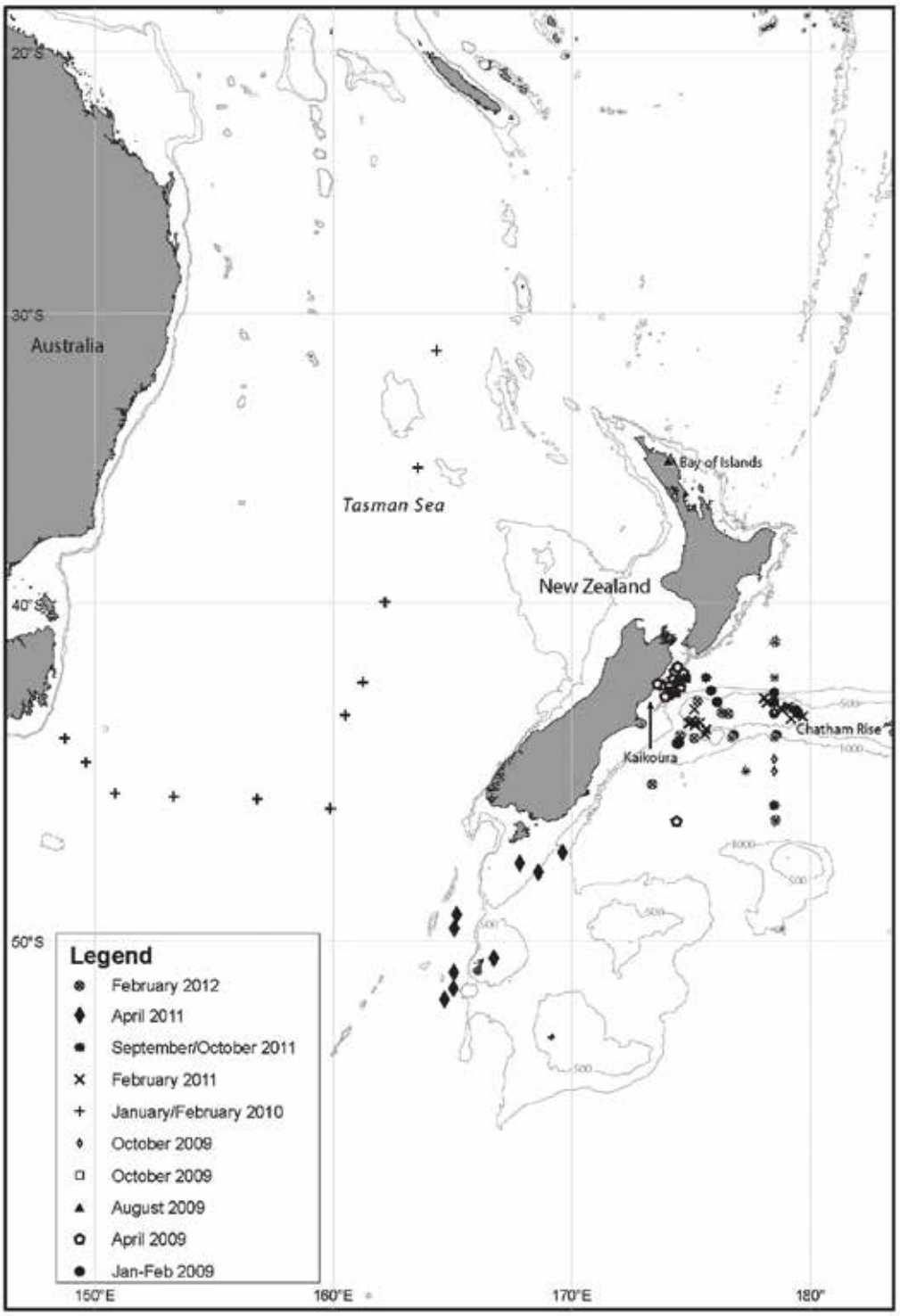


Figure 1. Map of the study area showing sampling stations around New Zealand (reproduced with permission from Chang & Northcote 2016).

Species identification and cell enumeration

Taxonomic identification relied on the work of Okada & McIntyre (1977), Hallegraeff (1984, 2010), Kleijne (1992, 1993), Winter & Siesser (1994), Cros & Fortuño (2002), Young *et al.* (2003), Kleijne & Cros (2009), Frada *et al.* (2010) and Young *et al.* (2019) (Nannotax3). The recent classification system of Jordan & Kleijne (1994), Young *et al.* (2003) and Jordan *et al.* (2004) was used, which includes 12 families of living heterococcolithophores and others in *incertae sedis* containing holococcolithophore species.

For cell enumeration, a minimum of 200 intact coccospheres (up to 800) were counted at ×1,000 magnification using a SEM. For rare species, where possible, at least 10 specimens per species were counted as described in Chang *et al.* (2013). Cell abundance (number of cells per litre) was determined by estimating the total number of cells per surface area of the filter and

dividing it by the total volume of water filtered.

Registration of types and type species references

The only holotype specimen of a species, *Syracosphaera pemmadiscus* Chang, 2013, listed in this monograph (Chang 2013), is deposited in the NIWA Invertebrate Collection (NIC) at the National Institute of Water and Atmospheric Research (NIWA) (formerly New Zealand Oceanographic Institute; NZOI), Greta Point, Wellington, using the prefix NIWA–). For the remaining species described in this monograph, the holotypes and type localities are mostly based on the Farinacci Catalog edited by Farinacci (1969–1989) and Howe (2000–2017), which is the key part of the Nannotax3 website (see Young *et al.* 2019), the primary literature, and the Algaebase website (see www.algaebase.org).

Environmental metadata

Environmental metadata (including chlorophyll *a* in some surveys), which provide supporting information on distribution and cell density of coccolithophores in this study are presented in Appendix 3 (from Tables 3.1 to 3.8). This set of data was compiled from discrete water samples collected mostly from 0 to 30 m, using 5- and 10-litre Niskin bottles mounted on a CTD rosette, during eight research voyages across New Zealand waters and the South West Pacific. Data were also collected continuously from 6 m depth in underway mode on one voyage in the Chatham Rise region (TAN1102). Temperature and salinity were measured using a Seabird Electronics SBE 21 thermosalinograph (Chang *et al.* 2013). All dissolved inorganic nutrients, e.g., silicate, nitrate, ammonium, and phosphate were analysed according to methods described in Pickmere (1998). Chlorophyll *a* values were determined in 90% acetone extracts by the fluorometric technique (Strickland & Parsons 1972) using a Turner Designs fluorometer.

Terminology

The most comprehensive glossary of coccolithophore morphology available is from Jordan *et al.* (1995), Cros & Fortuño (2002), Young *et al.* (2003) and on the International Nannoplankton Association (Nannotax3) website (Young *et al.* 1997). Terminology most frequently used in this monograph is given below:

body coccoliths – coccoliths covering most of the coccosphere to form the endotheca (Fig. 2 A, B)

calytroplith – basket-shaped holococcolith with opening near the base

caneolith – a heterococcolith having a central area with laths, a simple or complex wall, and petaloid upper or lower rims

circum-flagellar coccoliths (CFC) – specialised endothecal coccoliths that occur around the flagellar opening in some species and are morphologically differentiated from body coccoliths. They usually possess central spines or longer spines than those of the body coccoliths (Fig. 2 A)

coccospheres – a complete cover of coccoliths around the cell (or cells) (Fig. 2 A, B)

endotheca – internal layer of coccoliths formed by one (monomorphic), two (dimorphic) or more (polymorphic) different endothecal coccoliths (Fig. 2B)

exotheca – external layer of coccoliths (Fig. 2B)

helicolith – a placolith with a spiral margin

helladolith – tube-shaped holococcolith with bridge developed into leaf-like process

heterococcolith – presumed to be the diploid phase of life cycle (Young *et al.* 2003); coccoliths are formed by a complex arrays of crystal units typically arranged in rings. Three major, morphologically different heterococcolith types are recognised: planoliths, placoliths and muroliths (Young *et al.* 1997). Heterococcoliths have two morphologically differentiated parts: the central area and the rim

heterococcolithophore – cell bearing coccospheres of heterococcoliths

holococcolith – presumed to be the haploid phase of the life cycle (Young *et al.* 2003); coccoliths are composed of numerous minute euhedral crystallites, with a high degree of morphological diversity (Kleijne 1991)

holococcolithophore – cell bearing coccospheres of holococcoliths

lopadolith – large, vase-shaped coccoliths

mono– and dithecate – most coccospheres are made up of coccoliths of different sizes and shapes. Each coccosphere produces two distinct layers (outer and inner) (dithecate) of coccoliths. Some species have only a single layer of coccoliths (monothecate) (Fig. 2 A, B)

murolith – bowl-shaped coccolith with sub-vertical wall (tube) (Fig. 2 E)

pappolith – coccolith with a central spine supporting a calyx of four plates and attached to a crown-like basal part (see Heimdal 1997: 737, fig. 5J)

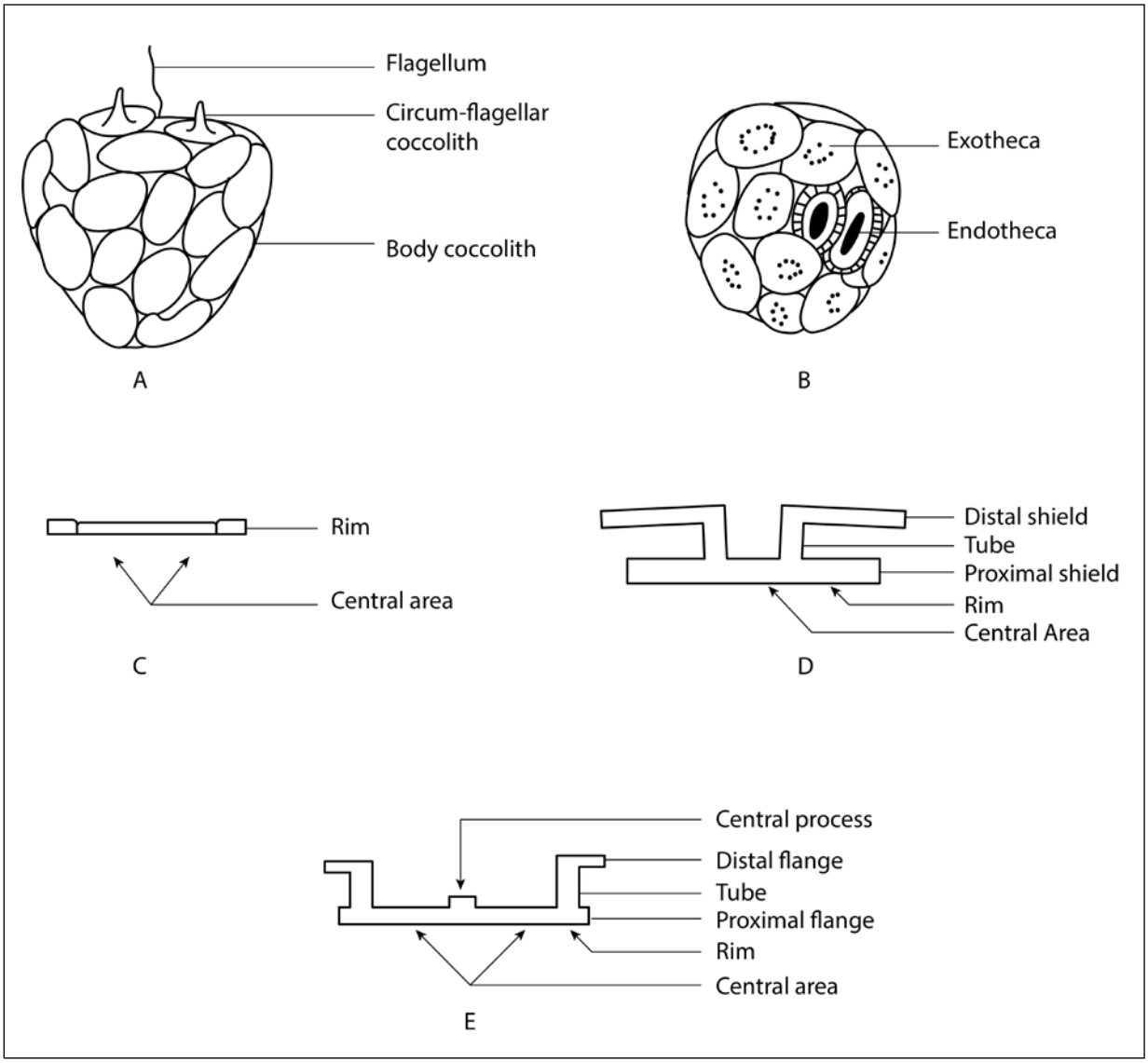


Figure 2. Coccosphere terminology: **A**. monothecate coccosphere; **B**. dithecate coccosphere – endotheca and exotheca each with one coccolith type. Types of heterococcolith based on shapes (vertical sections): **C**. disc-shaped planolith with low rim; **D**. placolith – rim with two shields and a tube in the middle; **E**. bowl-shaped murolith – rim with subvertical wall (tube), distal and proximal flanges (based on Cros & Fortuño 2002 and Young *et al*. 2003).

pentalith – pentagonal-shaped coccolith consisting of five segments, each of which behaves like a discrete crystal unit

placolith – coccolith with rim and two shields separated by a tube (Fig. 2 D)

planolith – disc-shaped coccolith with low rim (Fig. 2 C)

rhabdolith – taxonomic descriptive term for all coccoliths of the Rhabdosphaeraceae. They consist of a sub-horizontal rim of two circles of elements, and central area of one to three circles of elements, arranged in dissimilar patterns. A central area protrusion or process may be present

sacculiform – shaped like a small sac

scapholith – rhomboidal coccolith found in species of *Calciosolenia*

zygolith – elliptical holococcolith with arch

Abbreviations

CTD	Conductivity Temperature Depth probe (an oceanographic instrument used to measure the conductivity, temperature, and pressure of seawater)
DCM	deep chlorophyll maximum
Hg	chemical symbol for mercury
JEOL	Nihon Denshi Kabushiki-gaisha (a major manufacturer of electron microscopes in Japan)
KAH	NIWA research vessel RV *Kaharoa*
NASA	National Aeronautics and Space Administration
NIWA	National Institute of Water & Atmospheric Research, 301 Evans Bay Parade, Hataitai, Wellington 6021
NZOI	New Zealand Oceanographic Institute
PINTS	'Primary productivity induced by Iron and

	Nitrogen in the Tasman Sea' research voyage conducted on the Australian RV *Southern Surveyor*
SA	Subantarctic
SEM	Scanning Electron Microscope
SOAP	'Surface Ocean Aerosol Production' research voyage conducted on the NIWA RV *Tangaroa*
ST	Subtropical
STF	Subtropical Front
TAN	NIWA research vessel RV *Tangaroa*

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Another extensive coccolithophore bloom - showing strong, chalky-blue surface discolouration detected by the MODIS sensor on NASA's Aqua satellite in April 2011, in central New Zealand (NASA Earth Observatory 2011).

TAXONOMY & SYSTEMATICS

Checklist of extant species known from the New Zealand EEZ and Tasman Sea

A total of 50 extant coccolithophore taxa were identified from samples collected between January 2009 and February 2012, in ten oceanographic surveys (Chang 2013; Chang & Northcote 2016). Of the 50 taxa recorded, 45 were robust heterococcolithophores (including two species with both hetero- and holococcolith-bearing forms), and three were holococcolithophores. The classification of these coccolithophores is based on that of Young & Bown (1997a, b) emend. Young *et al*. (2003), the Nannotax3 website provided by Young *et al*. (2019) (http://www.mikrotax.org/Nannotax3/), and Jordan *et al*. (2004), which includes the use of a three-level, order–family–genus, classification.

In this monograph, 42 of the heterococcolithophore taxa are placed in seven families of the four orders, Coccolithales, Isochrysidales, Zygodiscales, and Syracosphaerales, four in three heterococcolith-bearing families *incertae sedis*, and one in a nannolith-bearing family *incertae sedis*. The two holococcolith-bearing forms (life-cycle phase), *Helicosphaera carteri* HOL (= *Syracolithus catilliferus* (Kamptner, 1937) Deflandre, 1952) and *Syracosphaera mediterranea* HOL *hellenica*-type (= *Zygosphaera hellenica* Kamptner, 1937), are included in the orders Zygodiscales and Syracosphaerales, respectively, with the two corresponding heterococcolith-bearing forms. Three holococcolithophore species are placed in the family Calyptrosphaeraceae, with *Homozygosphaera arethusae* (Kamptner, 1941) Kleijne 1991, which was previously placed in the family Calytrosphaeraceae by Chang & Northcote (2016), now transferred to the family Syracosphaeraceae, as *Syracosphaera arethusae* HOL (Kamptner, 1941) Triantaphyllou *et al*. 2015, in the Checklist.

In total, 55 extant coccolithophore species were previously recorded in the New Zealand region (Norris 1961; Dawson 1992; Rhodes 1994; Rhodes *et al*. 2012; Saavedra-Pellitero *et al*. 2014). Twenty-two taxa were observed again during the 2009 to 2012 surveys (Chang & Northcote 2016). These are noted with a double asterisk (**). The remaining 33 previously recorded species are noted with a single asterisk (*). In this monograph, 26 of 50 taxa were added to the flora by Chang (2013) and Chang & Northcote (2016). These species are noted with a single § sign. Two first records for the New Zealand region, added in this monograph, are noted with a double §§ sign.

Phylum HAPTOPHYTA Cavalier–Smith, 1986

Class COCCOLITHOPHYCEAE Rothmaler, 1951, emend. Ruggiero *et al*., 2015

Order COCCOLITHALES Schwarz, 1932; emend. Young & Bown, 1997, Edvardsen & Eikrem in Edvardsen *et al*., 2000

Family CALCIDISCACEAE Young & Bown, 1997

Genus ***Calcidiscus*** Kamptner, 1950

Calcidiscus leptoporus (Murray & Blackman, 1898) Loeblich & Tappan, 1978**

Genus ***Oolithus*** Reinhardt in Cohen & Reinhardt, 1968

Oolithus antillarum (Cohen, 1964) Reinhardt, in Cohen & Reinhardt, 1968*

Genus ***Umbilicosphaera*** Lohmann, 1902

Umbilicosphaera foliosa (Kamptner, 1963, ex Kleijne, 1993) Geisen in Sáez *et al*., 2003*

Umbilicosphaera sibogae (Weber-van Bosse, 1901) Gaarder, 1901) Gaarder, 1970*

Umbilicosphaera hulburtiana Gaarder, 1970**

Family COCCOLITHACEAE Poche, 1913; emend. Young & Bown, 1997

Genus ***Coccolithus*** Schwarz, 1894

Coccolithus pelagicus (Wallich, 1877) Schiller, 1930*

Family HYMENOMONACEAE Senn, 1900

Genus ***Hymenomonas*** Stein, 1878

Hymenomonas globosa (Magne, 1954) Gaynal & Fresnel, 1976*

Family PLEUROCHRYSIDACEAE Fresnel & Billard, 1991

Genus ***Pleurochrysis*** Pringheim, 1955 (= *Cricosphaera* Braarud, 1960)

Pleurochrysis sp.*

Order ISOCHRYSIDALES Pascher, 1910

Family NOËLAERHABDACEAE Jerkovic, 1970; emend. Young & Bown, 1997
Genus ***Emiliania*** Hay & Mohler in Hay *et al*., 1967
Emiliania huxleyi (Lohmann, 1902) Hay & Mohler in Hay *et al*., 1967 **
Genus ***Gephyrocapsa*** Kamptner, 1943
Gephyrocapsa ericsonii McIntyre & Bé, 1967 **
Gephyrocapsa mullerae Bréhéret, 1978 §
Gephyrocapsa oceanica Kamptner, 1943 **
Gephyrocapsa sp. §
Genus ***Reticulofenestra*** Hay, Mohler & Wade, 1966
Reticulofenestra parvula (Okada & McIntyre, 1977) Biekart, 1989 §
Reticulofenestra parvula var. *tecticentrum* (Okada & McIntyre, 1977) Jordan & Young, 1990§

Order SYRACOSPHAERALES Hay, 1997; emend. Young *et al*., 2003

Family CALCIOSOLENIACEAE Kamptner, 1927
Genus ***Calciosolenia*** Gran, 1912; emend. Young *et al*., 2003
Calciosolenia brasiliensis (Lohmann, 1919) Young *et al*., 2003 **
Calciosolenia murrayi Gran, 1912 **

Family RHABDOSPHAERACEAE Haeckel, 1894
Genus ***Acanthoica*** Lohmann, 1903; emend. Schiller, 1913; Kleijne, 1992.
Acanthoica acanthifera Lohmann, 1902 *
[a]*Acanthoica acanthos* Schiller, 1925 §
Acanthoica quattrospina Lohmann, 1903 **
Genus ***Algirosphaera*** Schlauder, 1945; emend. Norris, 1984
Algirosphaera cucullata (Lecal-Schlauder, 1951) Young *et al*., 2003 *
Algirosphaera robusta (Lohmann, 1902) Norris, 1984 **
Genus ***Cyrtosphaera*** Kleijne, 1992
Cyrtosphaera aculeata (Kamptner, 1941) Kleijne, 1992 §
Cyrtosphaera lecaliae Kleijne, 1992 §§
Genus ***Discosphaera*** Haeckel, 1894
Discosphaera tubifera (Murray & Blackman, 1898) Ostenfeld, 1900 **
Genus ***Palusphaera*** Lecal, 1965; emend. Norris, 1984
Palusphaera vandelii Lecal, 1965; emend. Norris, 1984 §
Genus ***Rhabdosphaera*** Haeckel, 1894
Rhabdosphaera claviger Murray & Blackman, 1898 *
Rhabdosphaera stylifer Lohmann, 1902 *
Rhabdosphaera xiphos (Deflandre & Fert, 1954) Norris, 1984 §

Family SYRACOSPHAERACEAE (Lohmann, 1902) Lemmermann, 1903
Genus ***Michaelsarsia*** Gran, 1912
Michaelsarsia elegans Gran, 1912 (= *Michaelsarsia splendens* Lohmann, 1912) *
Genus ***Ophiaster*** Gran, 1912
Ophiaster hydroideus Lohmann, 1913 *

Note

[a]*Anacanthoica acanthos* previously reported in Chang & Northcote (2016) is now placed in the genus *Acanthoica* as *A. acanthos* (*see* Young *et al*. 2019: Nannotax3 website).

Genus ***Syracosphaera*** Lohmann, 1902

Syracosphaera anthos (Lohmann, 1912) Janin, 1987 §

[b]*Syracosphaera arethusae* HOL (Kamptner, 1941) Triantaphyllou *et al*., 2015 [= *Homozygosphaera arethusae* (Kamptner, 1941) Kleijne, 1991] §

[c]*Syracosphaera azureaplaneta* Young *et al*., 2018 §§

Syracosphaera bannockii (Borsetti & Cati, 1976) Cros *et al*., 2000 §

Syracosphaera binodata Kamptner, 1941 *

Syracosphaera borealis Okada & McIntyre, 1977 *

Syracosphaera castellata Kleijne & Cros, 1993 *

Syracosphaera corii Schiller, 1925 *

Syracosphaera corolla Lecal, 1966 *

Syracosphaera corrugis Okada & McIntyre, 1977*

Syracosphaera dalmatica Kamptner, 1927 *

Syracosphaera dilatata Jordan *et al*., 1993 *

Syracosphaera florida Sánchez-Suáreq, 1990 (= *S.* sp. type F of Kleijne, 1993) *

Syracosphaera halldalii Gaarder in Gaarder & Hasle, 1971 ex Jordan & Green, 1994*

Syracosphaera histrica Kamptner, 1941 *

Syracosphaera cf. *lamina**

Syracosphaera leptolepis Kleijne & Cros, 2009 §

Syracosphaera mediterranea (Lohmann, 1902) Triantaphyllou *et al*., 2015**

Syracosphaera mediterranea HOL *hellenica*-type (= *Zygosphaera hellenica* Kamptner, 1937; Kleijne, 1991) Triantaphyllou *et al*., 2015 §

Syracosphaera mediterranea HOL *wettsteinii*-type (= *Coronosphaera mediterranea* HOL *wettsteinii*-type Young *et al*., 2003) *

Syracosphaera molischii Schiller, 1925 **

Syracosphaera nana (Kamptner, 1941) Okada & McIntyre, 1977 **

Syracosphaera nodosa Kamptner, 1941 §

Syracosphaera sp. aff. *S. nodosa* type 2 §

Syracosphaera orbiculus Okada & McIntyre, 1977 **

Syracosphaera cf. *orbiculus* §

Syracosphaera ossa (Lecal, 1966) Loeblich & Tappan, 1968 **

Syracosphaera pemmadiscus Chang, 2013 §

[d]*Syracosphaera prolongata* Gran, 1912 ex Lohmann, 1913 *

Syracosphaera pulchra Lohmann, 1902 **

Syracosphaera serrata Kleijne & Cros, 2009 §

Syracosphaera tumularis Sánchez-Suárez, 1990 **

Families with possible affinities to the Order SYRACOSPHAERALES

Family ALISPHAERACEAE Young *et al*., 2003

Genus ***Alisphaera*** Heimdal, 1973; emend. Schiller, 1913.

Alisphaera pinnigera Kleijne *et al*., 2002 §

Alisphaera unicornis Kleijne *et al*., 2002*

Notes

[b]*Homozygosphaera arethusae* is a holococcolith-bearing stage of *Syracosphaera arethusae* and is now referred to as *Syracosphaera arethusae* HOL (*see* Triantaphyllou *et al*. 2015 and Young *et al*. 2019) and placed in the family Syracosphaeraceae.

[c]One variant of *Syracosphaera corolla* was described as *Syracosphaera azureaplaneta* by Young *et al*. (2018).

[d]*Syracosphaera pirus* is a synonym of *S. prolongata* (*see* Young *et al*. 2019) and so *S. pirus* is removed from the Checklist

Genus ***Polycrater*** Manton & Oates, 1980
Polycrater galapagensis Manton & Oates, 1980 §
Family PAPPOSPHAERACEAE Jordan & Young, 1990
Genus ***Papposphaera*** Tangen, 1972
Papposphaera lepida Tangen, 1972 §
Family UMBELLOSPHAERACEAE Young *et al*., 2003
Genus ***Umbellosphaera*** Paasche in Markali & Paasche, 1955; emend. Gaarder, 1981 in Heimdal & Gaarder, 1981
Umbellosphaera sibogae (Weber-van Bosse, 1901) Gaarder, 1970 *
Umbellosphaera tenuis Type II (Kamptner, 1937) Paasche in Markali & Paasche, 1955 **
Umbellosphaera irregularis Paasche in Markali & Paasche, 1955 *

Order ZYGODISCALES Young & Bown, 1997

Family HELICOSPHAERACEAE Black, 1971; emend. Jafar & Martini, 1975
Genus ***Helicosphaera*** Kamptner, 1954
Helicosphaera carteri (Wallich, 1877) Kamptner, 1954 **
Helicosphaera carteri HOL *catilliferus*-type (= *Syracolithus catilliferus* (Kamptner, 1937) Deflandre, 1952) §
Helicosphaera hyalina Gaarder, 1970 §
Helicosphaera wallichii (Lohmann, 1902) Okada & McIntyre, 1977 §
Family PONTOSPHAERACEAE Lemmermann, 1908
Genus ***Pontosphaera*** Lohmann, 1902
Pontosphaera japonica (Takayama, 1967) Nishida, 1971*
Genus ***Scyphosphaera*** Lohmann, 1902
Scyphosphaera apsteinii Lohmann, 1902 **

Holococcolith-bearing taxa formerly belonging to the family Calyptrosphaeraceae
Family CALYPTROSPHAERACEAE Boudreaux & Hay, 1969
Genus ***Calyptrosphaera*** Lohmann, 1902
Calyptrosphaera oblonga Lohmann, 1902*
Genus ***Corisphaera*** Kamptner, 1937
Corisphaera gracilis Kamptner, 1937 §
Genus ***Helladosphaera*** Kamptner, 1937
Helladosphaera vavilovii (Borsetti & Cati, 1976) Young & Kleijne in Young *et al*., 2003 *
Genus ***Holococcolithophora*** (Schiller, 1913) Jordan *et al*., 2004
Holococcolithophora sphaeroidea (Schiller, 1913) Jordan *et al*., 2004 §
Genus ***Poricalyptra*** Kleijne, 1991
Poricalyptra aurisinae (Kamptner, 1941) Kleijne, 1991 §
Genus ***Sphaerocalyptra*** Deflandre, 1952
Sphaerocalyptra quadridentata (Schiller, 1913) Deflandre, 1952*

Nannolith-bearing family *incertae sedis*
Family BRAARUDOSPHAERACEAE Deflandre, 1947
Genus ***Braarudosphaera*** Deflandre, 1947
Braarudosphaera bigelowii (Gran & Braarud, 1935) Deflandre, 1947 **

Systematics

The classification system of extant coccolithophores at higher levels follows Cavalier–Smith (1981, 1998) and Ruggiero *et al.* (2015):

Kingdom **Chromista**

Subkingdom **Hacrobia**

Phylum **Haptophyta**

Class **Coccolithophyceae** (= Prymnesiophyceae)

The classification at class level follows Rothmaler 1951, Ruggiero *et al.* (2015) and Eikrem *et al.* (2016), while at order, family and lower rank levels, it follows the emended scheme of Young *et al.* (2003) and Jordon *et al.* (2004). As multiple extended descriptions of coccolithophores can be found in the primary literature, abridged descriptions of the observed coccolithophore taxa are presented here. The descriptions of coccolithophore taxa at order, family and species levels are arranged in alphabetical order.

Phylum **Haptophyta** Cavalier-Smith, 1986: 342

Class **Coccolithophyceae** Rothmaler, 1951; emend. Ruggiero *et al.*, 2015; Eikrem *et al.*, 2016 (= Class Prymnesiophyceae Hibberd, 1980: 273)

Description. Mostly unicellular, with one or two chloroplasts. Nearly all have a characteristic filiform appendage, the haptonema, arising between two, either equal or subequal, flagella. Many with one or more layers of calcified scales (coccoliths), while others with non–calcified scales (organic) (Throndsen 1972; Heimdal 1997; Eikrem *et al.* 2016).

Order **Coccolithales** Schwarz, 1932; emend. Young & Bown, 1997; Edvardsen & Eikrem in Edvardsen, *et al.*, 2000

Description. Coccosphere monomorphic; forming placolith coccoliths, with rim and distal shield separated by a tube in the centre (Cros & Fortuño 2002; Young *et al.* 2003).

Family **Calcidiscaceae** Young & Bown, 1997 = Family **Coccolithaceae** Poche, 1913; emend. Young & Bown, 1997

Description. Placoliths with similar rim structure to that of *Calcidicus*. Large distal shields with sutures that typically exhibit levogyral curvature (Kleijne 1991; Cros & Fortuño 2002; Young *et al.* 2003).

Genus ***Calcidiscus*** Kamptner, 1950

Coccosphaera Murray & Blackman, 1898: 430–432, pl. 15, figs 1–7.
Crepidolithus Bartolini & Pirini, 1969: 82, pl. 1, figs 3–4, pl. 2, figs 1–2.
Cyclococcolithus Kamptner, 1963: 163, pl. 2, fig. 8, text fig 20 a, b.

Description. Spherical to sub-spherical coccosphere with tightly interlocked placoliths. Central area of placolith either closed or with narrow opening; distal shield with laevogyral sutures (Cros & Fortuño 2002; Young *et al.* 2003).

Type species. *Calcidiscus quadriforatus* Kamptner, 1950

Calcidiscus leptoporus (Murray & Blackman, 1898) Loeblich & Tappan, 1978

(Fig. 3 A–C)

Murray & Blackman, 1898: 430, pl.15, figs 1–7; Gaarder & Hasle, 1971: fig. 7; Hallegraeff, 1984: 233, fig. 6; Kleijne, 1993: 185–189, pl. 1, figs 1–6; Cros & Fortuño, 2002: 47, figs 62A, B; Young *et al.* 2003: 18, pl. 6, figs 1–9.

Basionym: *Coccosphaera leptopora* Murray & Blackman, 1898: 430, pl. 15, figs 1–7.

Synonyms: *Calcidiscus leptoporus* f. *rigidus* (Gaarder) stat. nov. Kleijne, 1991: 17, 19, 21, pl. IV, figs 4–6.
Calcidiscus medusoides Kamptner, 1950: 153, 155.
Calcidiscus quadriforatus Kamptner, 1950: 153, 155, Fig. 11a. b.
Coccolithus leptoporus (Murray & Blackman, 1898) Schiller in Schiller, 1930: 100, 101, 245, figs 9 a, b, 10, 121, 122; Kamptner, 1941: 94, pl. 13, figs 137–139.
Coccolithophora leptopora (Murray & Blackman, 1898) Lohmann in Lohmann 1902: 137, pl. 5 figs 52, 61–64.
Crystallolithus rigidus Gaarder in Heimdal & Gaarder, 1980: 6–7, pl. 2, figs 10–12.
Cyclococcolithus leptoporus (Murray & Blackman, 1898) Kamptner in Kamptner,1954: 23, fig. 20; Hasle 1960, pl. 1, figs 3–4, pl. 3, figs 1–2.

Occurrence records. *Kaikoura*: NIWA Stn TAN0904/S07, 42.162° S, 174.320° E, Apr 2009; NIWA Stn TAN0904/13, 46.670° S 174.409° E, Apr 2009; NIWA Stn TAN0904/S71, 42.531° S, 174.349° E, Apr 2009

Chatham Rise: NIWA Stn TAN0909/PM26, 41.202° S, 178.554° E, Oct 2009; NIWA Stn TAN1107/T4, 45.204° S, 177.307° E, May 2011; NIWA Stn TAN1107/T6, 44.198° S, 178.494° E, May 2011; NIWA Stn TAN1107/SBM, 46.656° S, 178.556° E, May 2011.

Tasman Sea: PINTS Stn CO2, 31.360° S, 164.338° E, Jan 2010; PINTS Stn C47, 44.930° S, 149.637° E, Jan 2010.

South of New Zealand: NIWA Stn TAN1106/S21,

49.675° S, 165.078° E, Apr 2011; NIWA Stn TAN1106/S27, 51.288° S, 165.041° E, Apr 2011; NIWA Stn TAN1106/55, 47.563° S, 169.632° E, Apr 2011.

Holotype. Type is possibly held at the Natural History Museum, London, UK. (*see* Young *et al.* 2019).

Type locality. Atlantic Ocean.

Description. Large, spherical coccosphere (up to 20 µm) (Fig. 3A). Placoliths (6–7 µm), with a central tube consisting of curved distal shield sutures usually angular with 22–24 elements (Fig. 3B–C).

Distribution and cell abundance. *Calcidiscus leptoporus* is widely distributed in extensive areas ranging from the Kaikoura coast and the vicinity of Chatham Rise to the east, Subantartic (SA) water to the south, and Subtropical (ST) and SA waters (Tasman Sea) to the west of New Zealand (Fig. 4). During the three years of surveys, *C. leptoporus* was more widespread in autumns of 2009 and 2011, off Kaikoura coast and at Chatham Rise and South of New Zealand (3 sites each) (Appendix 1, Table 1.2, 1.8, 1.9) than in spring 2009 and summer 2010 at Chatham Rise and in the Tasman Sea respectively (Appendix 1, Table 1.5, 1.6). Cell concentrations recorded at all sites were generally moderate, ranging from 500 to 7,000 cells l^{-1}. One site in SA water of the Tasman Sea was the only exception, with 27,000 cells l^{-1} recorded.

Previous records. *Calcidiscus leptoporus* was previously recorded from samples collected at five sites, NZOI stations B65, B67, B69, B71 and B77, along a transect from northeast New Zealand to Tonga (Norris 1961; Appendix 2, Table 2.1). This species has also been recorded at several sites around New Zealand by Chang & Northcote (2016).

Elsewhere, this species is very widely distributed. It was recorded from samples collected, e.g., in the equatorial and subequatorial Pacific Ocean (Hagino & Okada 2004), in the tropical and subtropical waters of the South China Sea (Lee Chen *et al.* 2007), in the southwest Pacific around the East Australian Current, Bass Strait and the Coral Sea (Hallegraeff 2010), in the eastern Pacific sector of the Southern Ocean (Bellingshausen and Amundsen Seas) (Gravalosa *et al.* 2008), in the subtropical and subantarctic zones of the Southern Ocean (Saavedra-Pellitero *et al.* 2014), in the Southern Ocean south of the Polar Front (Australian sector) (Findlay & Giraudeau 2000; Findlay *et al.* 2005), along a temperate to polar gradient in the West Pacific sector of the Southern Ocean (Malinverno *et al.* 2015), in the western subartic Pacific and Bering Sea (Hattori *et al.* 2004), in the subtropical South Atlantic Ocean (Baumann *et al.* 2008), off Terceira Island, Azores, in the central North Atlantic Ocean (Narciso *et al.* 2016), in the subtropical and temperate northeast Atlantic Ocean (Broerse *et al.* 2000a; Poulton *et al.* 2017), in the northwestern Mediterranean Sea (Silva *et al.* 2009; Cros & Fortuño, 2002), in the middle, eastern and northern Adriatic Sea (Mediterranean) (Šupraha *et al.* 2016; Skejić *et al.* 2018; Godrijan *et al.* 2018), in the Java upwelling region of the tropical Indian Ocean (Andruleit 2007), in the Bay of Bengal, Indian Ocean (Mergulhao *et al.* 2013), in an upwelling region off Somalia (NW Indian Ocean) (Broerse *et al.* 2000b), and in the Indian sector of the Southern Ocean (Patil *et al.* 2017).

Genus ***Umbilicosphaera*** Lohmann, 1902

Description. Placolith circular or elliptical, with large central opening; distal shields showing complex kinked sutures (e.g., Cros & Fortuño 2002; Young *et al.* 2003).

Type species. *Umbilicosphaera mirabilis* Lohmann, 1902: 187, text–fig. 36a, b.

Umbilicosphaera hulburtiana Gaarder, 1970 (Fig. 3 D–F)

Gaarder, 1970: 121, figs 7a–d, 9a, b; Kleijne, 1993: 211, pl. 3, figs 5–6; Cros & Fortuño, 2002: 48, figs 63c, d; Young e*t al.* 2003: 20, pl. 7, figs 13–15.

Occurrence records. *Chatham Rise*: NIWA Stn TAN1107/NBM, 41.229° S, 178.512° E, May 2011; NIWA Stn TAN1107/T8, 42.340° S, 178.504° E, May 2011.

Holotype. W1008 and 1009, deposited at the University of Oslo, Norway.

Type locality. Atlantic Ocean, Gulf of Mexico.

Description. Coccospheres spherical or subspherical (6–8 µm) (Fig. 3D). Elliptical placoliths (*c.* 4 µm) have a central elliptical opening with a conspicuous ring of nodules around the distal end of the opening (Figs 3E–F).

Distribution and cell abundance. *Umbilicosphaera hulburtiana* was found at two sites in ST waters to the east of New Zealand (Fig. 4). This species was recorded only in autumn 2011, with < 1,000 cells l^{-1} (Appendix 1, Table 1.9).

Previous records. Extant *Umbilicosphaera hulburtiana* was previously reported as a first-time record for New Zealand by Chang & Northcote (2016). Elsewhere, this species is widely distributed, e.g., in the equatorial and subequatorial Pacific Ocean (Hagino & Okada 2004), in the tropical and subtropical waters

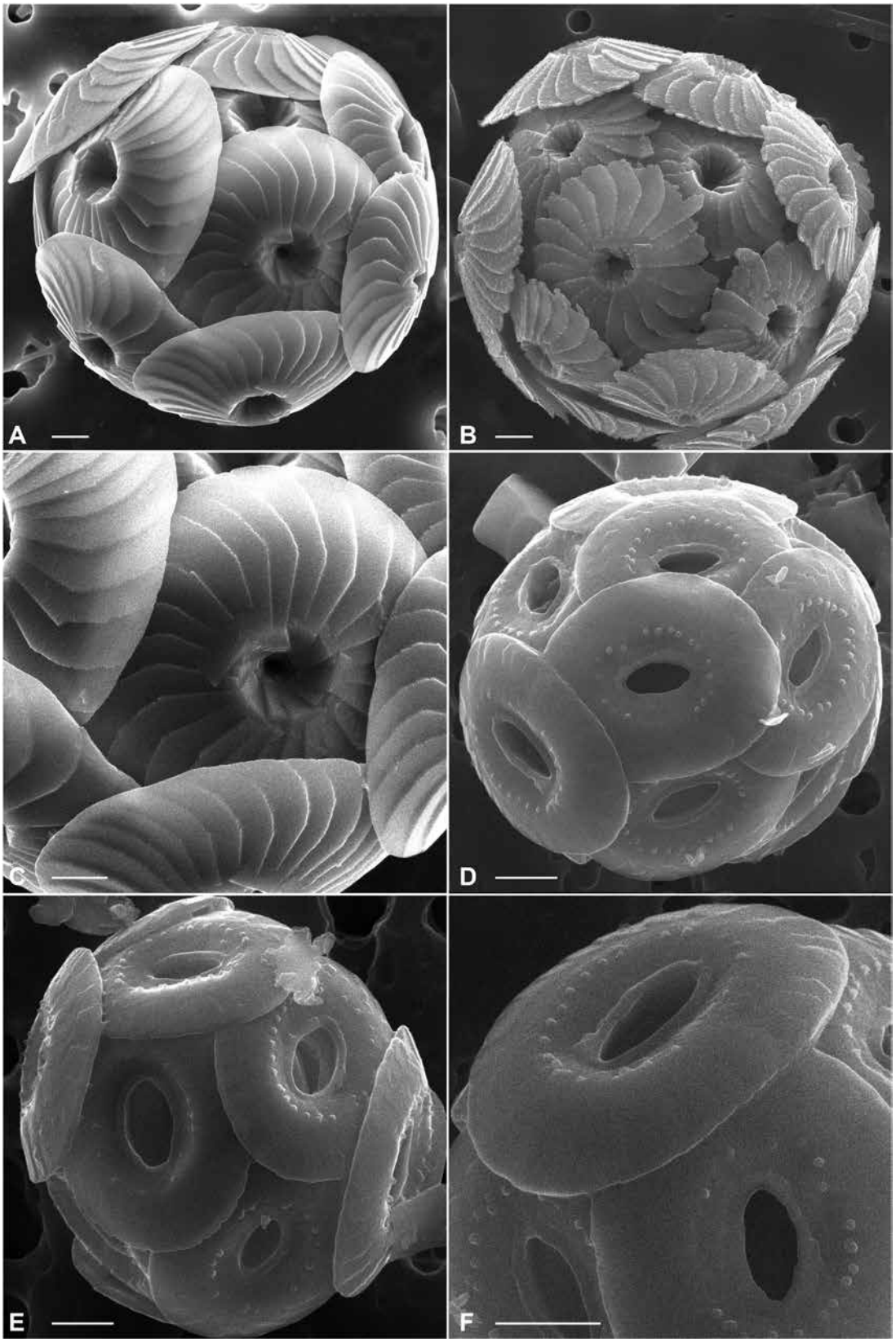

Figure 3. Coccolithophore morphology: **A–C.** cells of *Calcidiscus leptoporus* Murray & Blackman, 1898) Loeblich & Tappan, 1978; **D–F.** cells of *Umbilicosphaera hulburtiana* Gaarder, 1970. Scale bars A–F, 1 m.

of South China Sea (Lee Chen *et al*. 2007), in the East Australian Current, the Great Australian Bight, Bass Strait, the Coral Sea, northwestern Australia, and the Gulf of Carpentaria (Hallegraeff 2010), in the western subarctic Pacific and Bering Sea (Hattori *et al*. 2004), in the subtropical and temperate northeast Atlantic (Broerse *et al*. 2000a), in the northwestern Mediterranean Sea (Cros & Fortuño, 2002), in the Java upwelling region of the tropical Indian Ocean (Andruleit 2007), and in the Indian sector of the Southern Ocean (Patil *et al*. 2017).

Order **Isochrysidales** Pascher, 1910
= Order Prinsiales Young & Bown, 1997

Description. Coccosphere monomorphic. Placoliths usually have grill-like structures in the central area with straight and non-imbricate shield elements (Young & Bown 1997; Young *et al.* 2003).

Family **Noëlaerhabdaceae** Jerkovic, 1970; emend. Young & Bown, 1997
= Family Gephyrocapsaceae Black, 1971

Description. Placoliths of *Emiliania*-type structure: grills in central area, anti-clockwise imbrication of inner tube elements, and monocyclic proximal shield. Placoliths of *Reticulofenestra*-type: distal and proximal

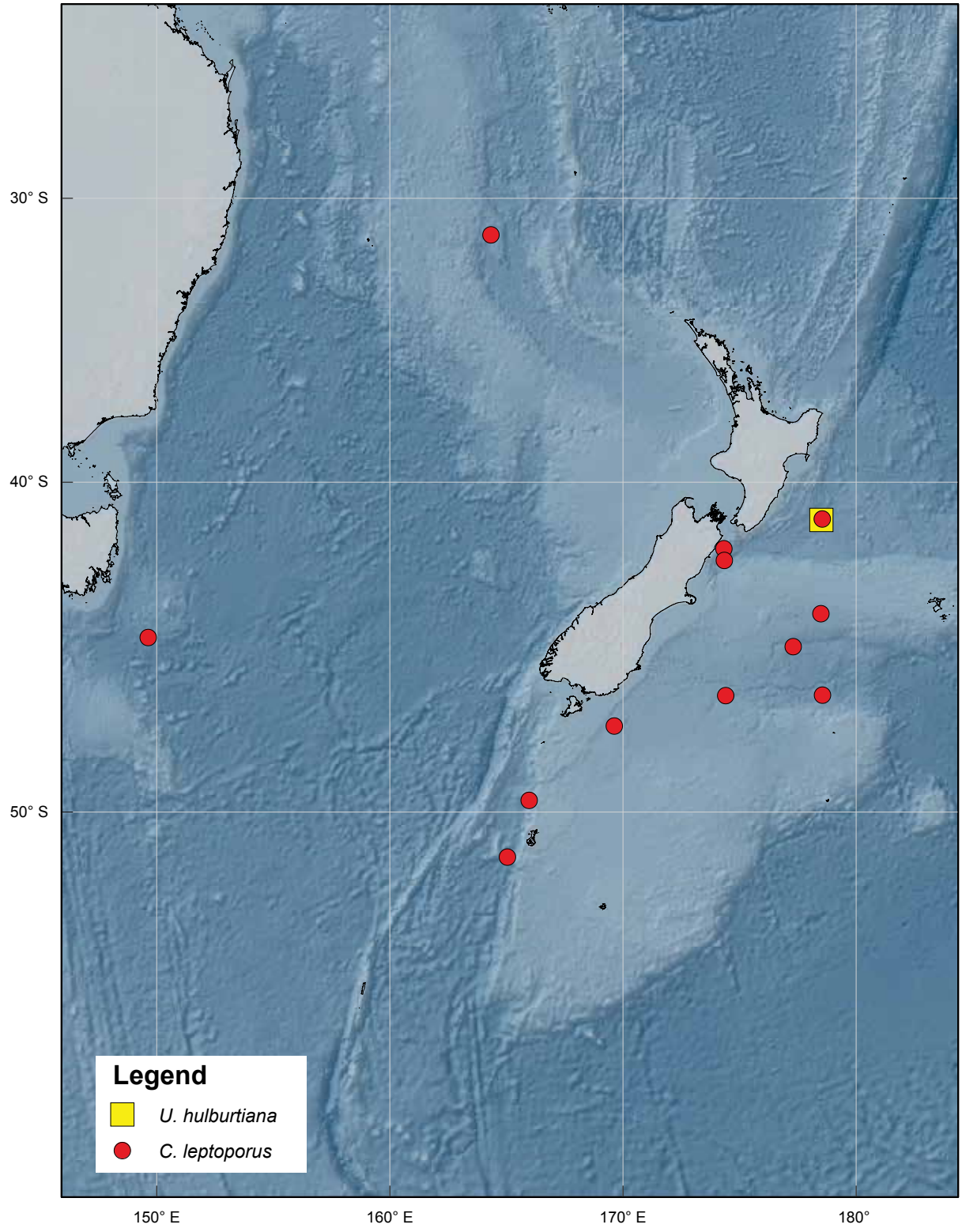

Figure 4. Distribution of *Calcidiscus leptoporus* (Murray & Blackman, 1898) Loeblich & Tappan, 1978 and *Umbilicosphaera hulburtiana* Gaarder, 1970 around New Zealand.

shields, two tube element cycles with opposite senses of imbrication and usually a central area structure (Young 1989; Cros & Fortuño 2002; Young *et al*. 2003).

Genus ***Emiliania*** Hay & Mohler in Hay *et al*., 1967

Coccolithus Kamptner, 1943: 45.
Pontosphaera Lohmann, 1902: 130, pl. 4, figs 1–9.

Description. Placoliths with slits between all distal shields; elements between slits are T-shaped with interlocking ends at the margin (Cros & Fortuño 2002; Young *et al*. 2003).

Type species. *Emiliania huxleyi* (Lohmann, 1902) Hay & Mohler in Hay *et al*., 1967: 447.

Emiliania huxleyi (Lohmann, 1902) Hay & Mohler in Hay et al., 1967

Figs 5 A–F; 6 A–F

(Lohmann, 1902) Hay & Mohler in Hay *et al*., 1967: 447; Kamptner, 1943: 43; McIntyre & Bé, 1967: 568–569, pls. 6, 7; Borsetti & Cati, 1972: 405, pl. 51, fig. 2; Okada & Honjo, 1973: pl.1, figs 1–3; Hallegraeff, 1984: 234, figs 8–12; Cros & Fortuño, 2002: 121, fig. 59A–D; Young *et al*. 2003: 9, pl. 1, figs 1–15.

Basionym: *Pontosphaera huxleyi* Lohmann, 1902: 129–130, pl. 4, figs 1–9.

Synonyms: *Coccolithus cordus* Kamptner, 1943: 45.
Coccolithus cucullus Lecal & Bernheim, 1960: fig. 25.
Coccolithus huxleyi Kamptner, 1943: 43; McIntyre & Bé, 1967: 568–569, pl. 5 fig. D, pl. 6.
Gephyrocapsa huxleyi, (Lohmann, 1902) Reinhardt, 1972: 89.
Hymenomonas huxleyi (Lohmann, 1902) Kamptner, 1930: 155, 159.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS2, 42.747° S, 175.841° E, Jan–Feb 2009; NIWA Stn TAN0902/YS3, 43.101° S, 176.095° E, Jan–Feb 2009; NIWA Stn TAN0902/4, 43.432° S, 176.301° E, Jan–Feb 2009; NIWA Stn TAN0902/YS7, 44.108° S, 176.798° E, Jan–Feb 2009; NIWA Stn TAN0902/YS8, 44.108° S, 176.798° E, Jan–Feb 2009; NIWA Stn TAN0902/YS29, 46.636° S, 178.556° E, Jan–Feb 2009; NIWA Stn TAN0902/YS30, 46.638° S, 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS31, 41.107° S, 178.590° E, Jan–Feb 2009; NIWA Stn TAN0902/YS32, 46.633° S 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS33, 46.633° S, 178.112° E, Jan–Feb 2009; NIWA Stn TAN0902/YS36, 43.446° S, 178.488° E, Jan–Feb 2009; NIWA Stn TAN0902/YS38, 43.102° S, 178.489° E, Jan–Feb 2009; NIWA Stn TAN0902/YS39, 42.820° S, 178.495° E, Jan–Feb 2009; NIWA Stn TAN0902/YS56, 41.235° S, 178.522° E, Jan–Feb 2009; NIWA Stn TAN0902/YS59, 41.228° S, 178.522° E, Jan–Feb 2009; NIWA Stn TAN0909/PM6, 42.350° S, 175.651° E, Oct 2009; NIWA Stn TAN0909/PM7, 43.388° S, 176.250° E, Oct 2009; NIWA Stn TAN0909/PM8, 43.400° S, 176.250° E, Oct 2009; NIWA Stn TAN0909/PM9, 44.199° S, 176.698° E, Oct 2009; NIWA Stn TAN0909/PM10, 44.200° S, 176.698° E, Oct 2009; NIWA Stn TAN0909/PM12, 45.173° S, 177.289° E, Oct 2009; NIWA Stn TAN0909/PM13, 46.397° S, 178.300° E, Oct 2009; NIWA Stn TAN0909/PM14, 46.639° S, 178.536° E, Oct 2009; NIWA Stn TAN0909/PM16, 44.501° S, 178.300° E, Oct 2009; NIWA Stn TAN0909/PM17, 45.200° S, 178.501° E, Oct 2009; NIWA Stn TAN0909/PM19, 44.109° S, 178.504° E, Oct 2009; NIWA Stn TAN0909/PM21, 43.410° S, 178.504° E, Oct 2009; NIWA Stn TAN0909/PM23, 43.410° S, 178.502° E, Oct 2009; NIWA Stn TAN0909/PM119, 43.410° S, 178.504° E, Oct 2009; NIWA Stn TAN1102/NH7, 43.805° S, 175.375° E, Feb 2011; NIWA Stn TAN1102/NH16, 43.341° S, 175.155° E, Feb 2011; NIWA Stn TAN1102/NH18, 43.805° S, 175.175° E, Feb 2011; NIWA Stn TAN1102/NH43, 43.733° S, 174.984° E, Feb 2011; NIWA Stn TAN1102/NH49, 43.753° S, 174.903° E, Feb 2011; NIWA Stn TAN1102/NH54, 43.674° S, 175.049° E, Feb 2011; NIWA Stn TAN1102/NH60, 43.731° S, 175.387° E, Feb 2011; NIWA Stn TAN1102/NH 89, 43.727° S, 175.188° E, Feb 2011; NIWA Stn TAN1102/NH109, 42.994° S, 178.093° W; NIWA Stn TAN1102/NH111, 42.994° S, 178.295° W, Feb 2011; NIWA Stn TAN1102/NH118, 43.994° S, 178.063° W, Feb 2011; NIWA Stn NH147, 43.298° S, 178.749° E, Feb 2011; NIWA Stn TAN1102/NH149, 43.298° S, 178. 658° E, Feb 2011; NIWA Stn NH162, 43.616° S, 179.205° E, Feb 2011; NIWA Stn NH175, 43.556° S, 179.699° E, Feb 2011; NIWA Stn TAN1107/T1, 42.351° S, 175.651° E, May 2011; NIWA Stn TAN1107/T2, 43.411° S, 176.250° E, May 2011; NIWA Stn TAN1107/T3, 44.206° S, 176.701° E, May 2011; NIWA Stn TAN1107/T4, 45.204° S, 177.307° E, May 2011; NIWA Stn TAN1107/SBM, 46.656° S, 178.556° E, May 2011; NIWA Stn TAN1107/T5, 46.202° S, 178.500° E, May 2011; NIWA Stn TAN1107/T6, 44.198° S, 178.494° E, May 2011; NIWA Stn TAN1107/T8, 42.340° S, 178.504° E; NIWA Stn TAN1107/NBM, 41.229° S, 178.512° E, May 2011; NIWA Stn TAN1203/DA6, 43.365° S, 174.464° E, Feb 2012; NIWA Stn TAN1203/DA11, 44.350° S, 174.419° E, Feb 2012; NIWA Stn TAN1203/DA27, 44.201° S, 175.148° E, Feb 2012; NIWA Stn TAN1203/DA31, 45.576° S, 173.387° E, Feb 2012; NIWA Stn TAN1203/DA35, 43.445° S, 176.579° E, Feb 2012; NIWA Stn TAN1203/DA39, 43.289° S, 179.068° E, Feb 2012; NIWA Stn TAN1203/43, 43.430° S 179.506° E, Feb 2012; NIWA

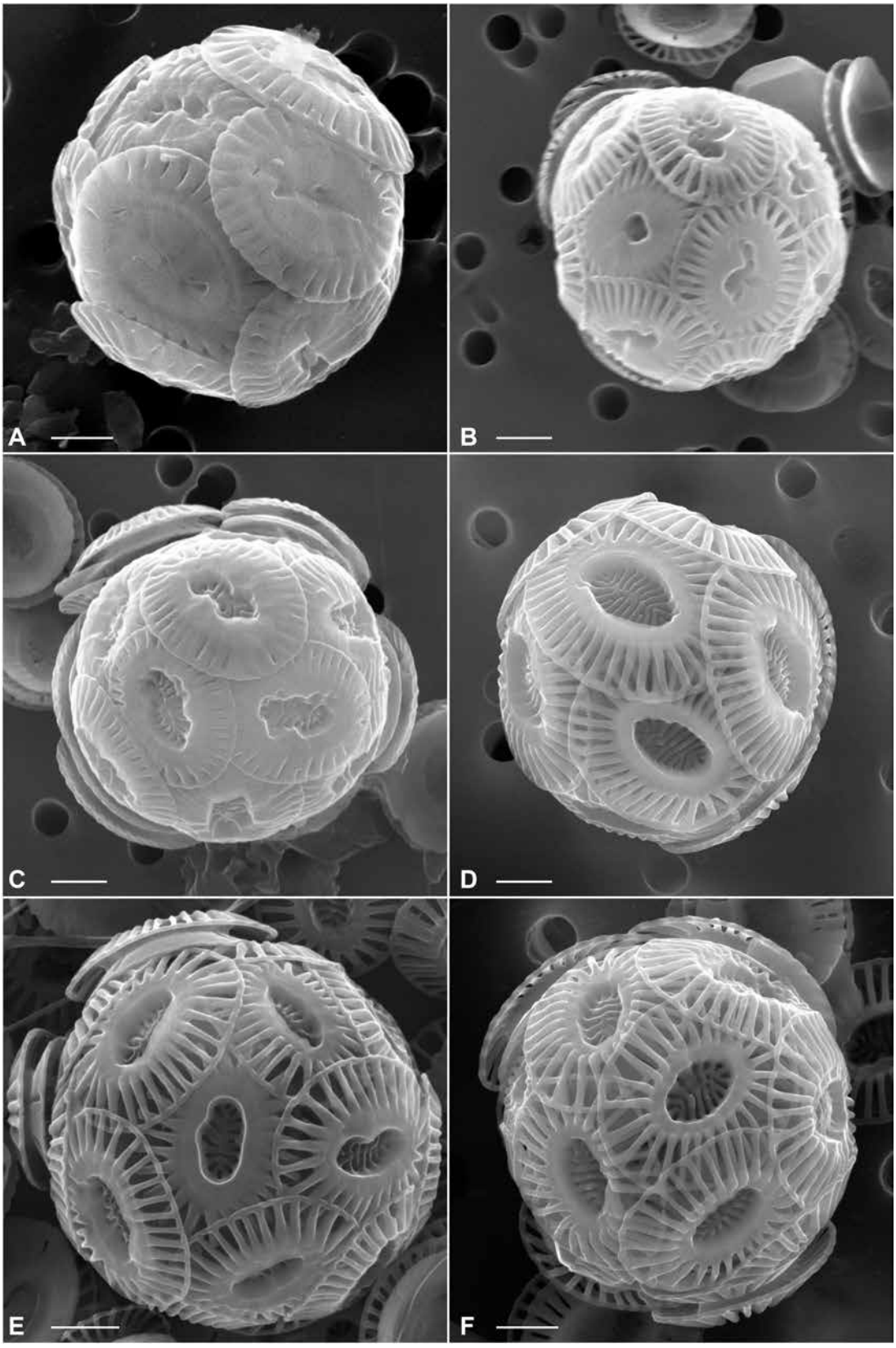

Figure 5. Four different morphotypes of *Emiliania huxleyi* (Lohmann, 1902) Hay & Mohler in Hay *et al.* 1967: **A.** super-calcified; **B–C.** type A over-calcified; **D–E.** type A; **F.** type B. Scale bars A–F, 1 µm.

Stn TAN1203/DA48, 43.426° S, 179.457° E, Feb 2012; NIWA Stn TAN1203/DA52, 43.420° S, 179.463° E, Feb 2012; NIWA Stn TAN1203/DA59, 43.386° S, 179.452° E, Feb 2012; NIWA Stn TAN1203/DA71, 43.334° S, 179.411° E, Feb 2012; NIWA Stn TAN1203/DA75, 43.378° S, 179.444° E, Feb 2012; NIWA Stn TAN1203/DA82, 43.067° S, 175.285° E, Feb 2012; NIWA Stn TAN1203/DA87, 44.295° S, 174.509° E, Feb 2012; NIWA Stn TAN1203/DA90, 44.325° S, 174.524° E, Feb 2012; NIWA Stn TAN1203/DA98, 44.114° S, 174.555° E, Feb 2012; NIWA Stn TAN1203/101, 44.114° S, 174.445° E, Feb 2012, NIWA Stn TAN1203/DA102, 44.183° S,

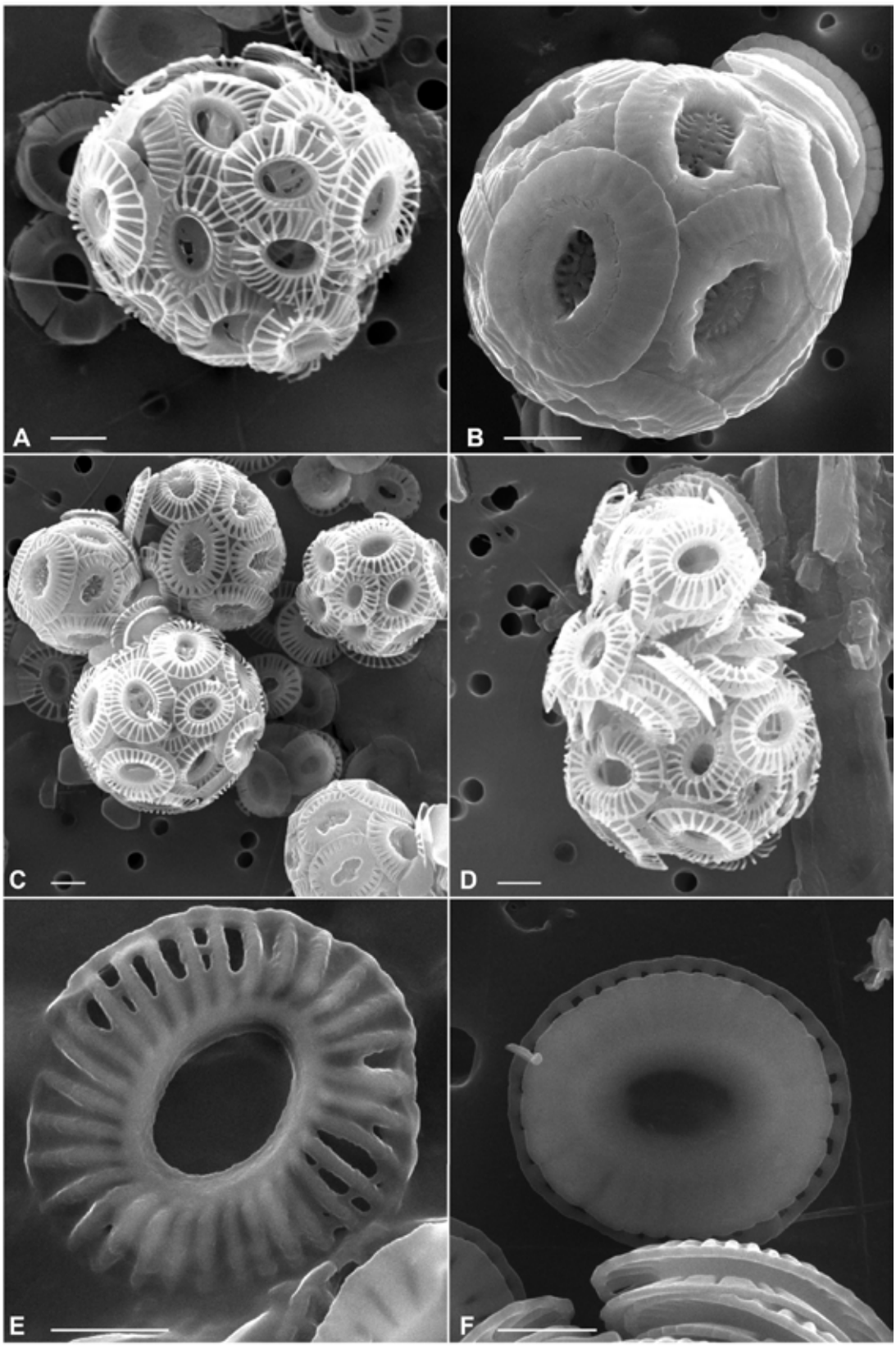

Figure 6. Additional two morphotypes of *Emiliania huxleyi* (Lohmann, 1902) Hay & Mohler *in* Hay *et al.* 1967 (continued): **A.** type C; **B.** type R; **C.** a mixture of cells with different sizes and degree of calcification; **D.** two different sizes of type C cells; **E–F.** coccoliths of *E. huxleyi*. Scale bars A–F, 1 μm.

174.933° E, Feb 2012; NIWA Stn TAN1203/104, 44.758° S, 174.633° E, Feb 2012; NIWA Stn TAN1203/DA110, 44.233° S, 174.517° E, Feb 2012.

Kaikoura: NIWA Stn TAN0904/S7, 42.162° S, 174.328° E, Apr 2009; NIWA Stn TAN0904/S13 46.670° S, 174.409 E, Apr 2009; NIWA Stn TAN0904/S21, 42.401° S, 174.264° E, Apr 2009; NIWA Stn TAN0904/33, 42.900° S, 174.135° E, Apr 2009; NIWA Stn TAN0904/S35, 42.576° S, 173.787° E, Apr 2009; NIWA Stn TAN0904/S45, 42.941° S, 173.926° E, Apr 2009;

NIWA Stn TAN0904/S55, 42.207° S, 174.702° E, Apr 2009; NIWA Stn TAN0904/S63, 42.008° S, 174.443° E, Apr 2009; NIWA Stn TAN0904/S67, 42.642° S, 174.584° E, Apr 2009; NIWA Stn TAN0904/S71, 42.642° S, 174.584° E, Apr 2009; NIWA Stn TAN0904/S85, 42.614° S, 174.097° E, Apr 2009; NIWA Stn TAN0904/S91, 42.703° S, 173.886° E, Apr 2009; NIWA Stn TAN0904/S95, 42.535° S, 173.607° E, Apr 2009; NIWA Stn TAN0908/R3, 42.372° S, 174.802° E, Oct 2009; NIWA Stn TAN0908/R6, 42.748° S, 174.176° E; NIWA Stn TAN0908/R9, 42.478° S, 174.491° E, Oct 2009; NIWA Stn TAN0908/R29, 42.748° S, 174.176° E, Oct 2009.

Bay of Plenty: NIWA Stn KAH0907/S13, 35.195° S, 174.157° E, Sept 2009; NIWA Stn KAH0907/S17, 35.240° S, 174.206° E, Sept 2009; NIWA Stn KAH0907/S18, 35.224° S, 174.093° E, Sept 2009.

Tasman Sea: PINTS Stn C5, 39.960° S,162.185° E, Jan 2010; PINTS Stn C14, 46.302° S, 159.883° E, Jan 2010; PINTS Stn C17, 39.996° S, 162.177° E, Jan 2010; PINTS Stn C18, 39.966° S, 162.177° E, Jan 2010; PINTS Stn C20, 39.945° S, 162.276° E, Jan 2010; PINTS Stn C23A, 46.300° S, 159.872° E, Jan 2010; PINTS Stn C23B, 46.300° S, 159.872° E, Jan 2010; PINTS Stn C24, 46.022° S, 156.822° E, Jan 2010; PINTS Stn C33, 45.956° S, 153.323° E, Jan 2010; PINTS Stn C45, 45.854° S, 150.881° S, Jan 2010; PINTS Stn C46, 45.854° S, 150.872° E, Jan 2010; PINTS Stn C47, 44.930° S, 149.637° E, Jan 2010; PINTS Stn C48, 44.928° S, 149.650° E, Jan 2010; PINTS Stn C49, 44.219° S, 148.748° E, Jan 2010; PINTS Stn C50, 44.220° S, 148.750° E, Jan 2010; PINTS Stn C52, 46.300° S, 159.872° E, Jan 2010.

South of New Zealand: NIWA Stn TAN1106/S21, 49.675° S, 165.076° E, Apr 2011; NIWA Stn TAN1106/S27, 51.228° S, 165.041° E, Apr 2011; NIWA Stn TAN1106/42, 50.474° S, 166.829° E, Apr 2011; NIWA Stn TAN1106/47, 47.865° S, 167.829° E, Apr 2011; NIWA Stn TAN1106/55, 46.563° S, 169.632° E, Apr 2011.

Holotype. Negative ON–1, deposited at Lamont–Doherty Geological Observatory of Columbia University, USA.

Type locality. Pacific Ocean (35.000° N, 154.950° W).

Description. Small spherical to subspherical coccosphere with considerable size variation (3–10 µm in diameter) (Figs 5A–F; 6A–D). The disc-like coccoliths (placoliths) are made up of T-shaped elements (Fig. 6E). Young & Westbrock (1991) recognised three morphotypes based on heterococcolith morphology. Six morphotypes, however, have been observed in the New Zealand region: supercalcified (Figs 5A), type A over–calcified (Fig. 5B, C), type A (Fig. 5D, E), type B (Fig. 5F), type C (Fig. 6A) and type R (Fig. 6B) (*see* also Young *et al*. 2003 and Fig. 58C, D). The first five morphotypes were observed in massive *E. huxleyi* blooms off the central east coast of New Zealand, while the *E. huxleyi* type R was observed in both autumn and summer of 2009 mainly off the Kaikoura coast.

Distribution and cell abundance. Over three years from January 2009 to February 2012, *Emiliania huxleyi* was ubiquitous, found at virtually all sampling sites around New Zealand (Fig. 7). In spring 2009 and summers of 2011 and 2012, this species formed massive blooms off the central east coast of New Zealand (with five morphotypes being observed) (Figs 5–6). On both occasions, in spring 2009 and summer 2011, the very widespread *E. huxleyi* blooms corresponded well with visual observations made by the NASA Earth Observatory (2009, 2011). In spring 2009, intact *E. huxleyi* coccospheres (virtually monospecific) and massive numbers of their shed coccoliths, made up the bulk of the bloom (see cover page). In some samples freely detached coccoliths were found to be numerically greater (up to 99 billion l^{-1}) than intact coccospheres (24,000 cells l^{-1}) (see Fig. 58A, B; Appendix 1, Table 1.5). The highly reflective, chalky-blue surface water observed by the NASA Earth Observatory in the spring bloom of 2009, coincided with the presence of the massive aggregation of calcite coccoliths, which apparently represented the tail-end of an *E. huxleyi* bloom. Except for station PM6, cell concentrations of most other stations during this bloom were < 79,000 cells l^{-1} (Appendix 1, Table 1.5). Concentrations of chlorophyll *a* measured at this point during the bloom were also quite low (< 0.5 µg l^{-1}) (Appendix 3, Table 3.4), consistent with observations made elsewhere that *E. huxleyi* blooms are usually associated with low rather than high chlorophyll *a* (Tyrrell & Merico 2004). In the summer of 2011, however, a mixture of surface dull yellowish green (turquoise) and a tint of chalky-blue discolouration was observed by the NASA Earth Observatory (2011) (see image on Preface divider). A massive build-up of diatoms and coccolithophores, recorded from water samples collected from ground-truthing, confirmed a mixed diatom and coccolithophore bloom. In this summer bloom, *E. huxleyi* (up to 3.5 million cells l^{-1}) was dominant among the coccolithophore taxa (Appendix 1, Table 1.7). Chlorophyll *a* (up to 5.23 µg l^{-1}) measured during the summer 2011 mixed diatom/coccolithophore bloom (Appendix 3, Table 3.6) was much greater than the spring 2009 *E. huxleyi* bloom.

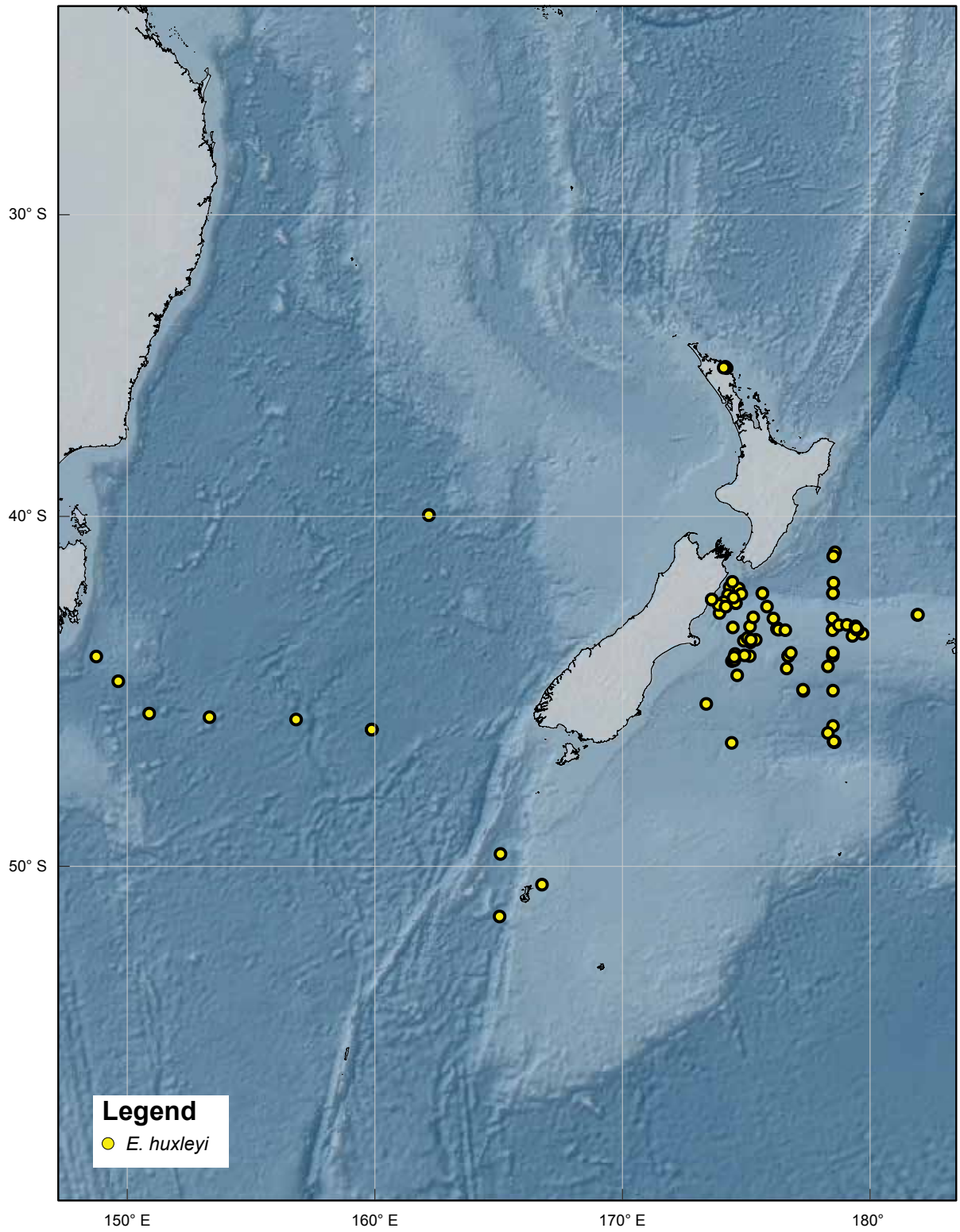

Figure 7. Distribution of *Emiliania huxleyi* (Lohmann, 1902) Hay & Mohler in Hay *et al.* 1967 around New Zealand.

In the summer of 2012, there was also another massive build-up of *E. huxleyi* (up to 2.1 million cells l^{-1}) over the Chatham Rise (Appendix 1, Table 1.10). Chlorophyll *a* values measured in this summer were moderate, ranging from 0.32 to 1.43 µg l^{-1} (Appendix 3, Table 3.8).

In non-bloom conditions, e.g., in spring 2009, coccosphere concentrations of *E. huxleyi* recorded off Kaikoura coast and Bay of Plenty, ranged from moderate (6,000–15,000 cells l^{-1}) to high (4,000 to 121,000 cells l^{-1}) (Appendix 1, Tables 1.3, 1.4). In the summers of 2009 and 2011, coccospheres recorded in the Tasman Sea and over the Chatham Rise, ranged from low to moderate (up to 2,000 cells l^{-1}) and from moderate to high (up to 201,000 cells l^{-1}) respectively (Appendix 1, Table 1.1,

1.6, 1.10). In other non-bloom conditions, e.g., in the autumns of 2009 and 2011, coccosphere concentrations of *E. huxlei* recorded off Kaikoura and south of New Zealand, were very low, while in autumn of 2011, at Chatham Rise, moderate to high (Appendix 1, Tables 1.2, 1.8, 1.9).

Previous records. *Emiliania huxleyi* was previously recorded at three NZOI stations, B67, B69, B71, along a transect between northeast New Zealand and Tonga (Norris 1961; Appendix 2, Table 2.1). This species had also been detected in Wellington Harbour (Norris 1964; Chang unpublished results; Law pers. comm.), Tasman Bay (MacKenzie & Gillespie 1986) and in a 1992 *Gephyrocapsa oceanica* bloom on the northeast coast of New Zealand (Rhodes *et al.* 1993). A very extensive *E. huxleyi* bloom (up to 9.6 million cells l^{-1}) was also reported in Big Glory Bay (Rhodes *et al.* 1995). In STF/SA waters, between 44.8° S and 68.7° S near New Zealand, over 536,000 cells l^{-1} of several morphotypes of *E. huxleyi* were reported by Saavedra-Pellitero *et al.* (2014) (Appendix 2, Table 2.2). *E. huxleyi* has also been reported by Chang & Northcote (2016) as a widely distributed species around New Zealand.

On a global scale, *Emiliania huxleyi* is known to be numerically most abundant and is an extremely cosmopolitan species. It forms massive blooms (sometimes almost monospecific), which can cover a surface area of >100,000 km^2 in many parts of the world, e.g., in the Gulf of Maine (Townsend *et al.* 1994), in the northeast Atlantic Ocean, south of Iceland and the region between Iceland and Scotland (Holligan *et al.* 1993), in the North Sea (Maraňón & González 1997), along the Patagonian Self in the southwest Atlantic Ocean (Poulton *et al.* 2013), and in the Black Sea (Cokacar *et al.* 2001). This species can be found from the tropics to high latitude subarctic and subantarctic regions, e.g., in the equatorial and subequatorial Pacific Ocean (Hagino & Okada 2004), in the tropical and subtropical waters of South China Sea (Lee Chen *et al.* 2007), in the Yellow and East China Seas (Wang *et al.* 2012), in surrounding waters of South Australia, Victoria, New South Wales, Tasmania, and in the Tasman Sea (Hallegraeff 2010), in the Australian sector of the Southern Ocean (Findlay & Giraudeau 2000), in the Southern Ocean south of the Polar Front (Findlay *et al.* 2005; Saavedra-Pellitero *et al.* 2014; Malinverno *et al.* 2015), in the eastern Pacific sector of the Southern Ocean (Bellingshausen and Amundsen Seas) (Gravalosa *et al.* 2008), in the western subarctic Pacific and Bering Sea (Hattori *et al.* 2004), off Terceira Island, Azores, in the central North Atlantic Ocean (Narciso *et al.* 2016), in the subtropical South Atlantic (Baumann *et al.* 2008; Poulton *et al.* 2017), in the subtropical and temperate northeast Atlantic Ocean (Broerse *et al.* 2000a), in the eastern Mediterranean Sea (Knappertsbusch 1993), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in a coastal upwelling region of Lisbon Bay, Portugal, in the Mediterranean (Silva *et al.* 2009), in the Aegean Sea in NE Mediterranean (Dimiza *et al.* 2015), in the middle and northern Adriatic Sea (Mediterranean) (Skejić *et al.* 2018; Godrijan *et al.* 2018), in the Java upwelling region of the tropical Indian Ocean (Andruleit (2007), in the Bay of Bengal of the Indian Ocean (Mergulhao *et al.* 2013), off Somalia in the northwestern Indian Ocean (Broerse *et al.* 2000b), and in the Indian sector of the Southern Ocean (Patil *et al.* 2017).

Genus ***Gephyrocapsa*** Kamptner, 1943

Description. Shields of placoliths usually solid; in the central area a bridge is made up of two diametrically opposite extensions of inner tube elements (Samtleben 1980; Cros & Fortuňo 2002; Young *et al.* 2003).

Type species. *Gephyrocapsa oceanica* Kamptner, 1943: 43–49.

Gephyrocapsa ericsonii McIntyre & Bé, 1967

Fig. 8 A–D

McIntyre & Bé, 1967: 571, pl. 10, Figs 12b; Borsetti & Cati, 1979: 158, pl. 14, figs 1–2; Kleijne, 1993: 230, plate 2, figs 1–2; Cros & Fortuňo, 2002: 46, fig. 60A–D; Young *et al.* 2003: 11, pl. 2, figs 10–12.

Basionym: *Gephyrocapsa ericsonii* McIntyre & Bé, 1967: 571, pl. 10.

Synonyms: G*ephyrocapsa protohuxleyi* McIntyre, in Winter *et al.* 1978: 295–297, pl. 1.

Gephyrocapsa aff. *protohuxleyi* McIntyre *et al.*, 1970: 158, pl. 14, fig. 4.

Gephyrocapsa undulatus Lecal, 1967: 305.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS03, 43.101° S, 175.095° E, Jan–Feb 2009; NIWA Stn TAN0902/YS30, 46.638° S, 178.541° E, Jan–Feb 2009; NIWA Stn TAN0902/YS36, 46.633° S, 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS38, 43.102° S, 178.489° E, Jan–Feb 2009; NIWA Stn TAN0909/PM9, 44.199° S, 176.698° E, Oct 2009; NIWA Stn TAN1102/NH162, 43.616° S, 179.205° E, Feb 2011; NIWA Stn TAN1107/T1, 42.351° S, 175.651° E, May 2011; NIWA Stn TAN1107/T2, 43.411° S, 176.250° E, May 2011; NIWA Stn TAN1107/T3, 44.206° S, 176.701° E, May 2011; NIWA Stn TAN1107/T5, 46.202° S, 178.500° E,

May 2011; NIWA Stn TAN1107/SBM, 46.656° S, 178.556° E, May 2011; NIWA Stn TAN1107/NBM, 41.229° S, 178.512° E, May 2011; NIWA Stn TAN1203/DA59, 43.386° S, 179.452° E, Feb 2012.

Kaikoura: NIWA Stn TAN0904/S09, 42.162° S, 174.328° E, Apr 2009; NIWA Stn TAN0904/S13, 46.670° S, 174.409° E, Apr 2009; NIWA Stn TAN0904/S21, 46.620° S, 174.094° E, Apr 2009; NIWA Stn TAN0904/S33, 42.898° S, 174.135° E, Apr 2009; NIWA Stn TAN0904/S35, 42.576° S, 173.787° E; NIWA Stn TAN0904/S45, 42.907° S, 173.926° E, Apr 2009; NIWA Stn TAN0904/S55, 42.207° S, 174.702° E, Apr 2009; NIWA Stn TAN0904/S63, 42.008° S, 174.443° E, Apr 2009; NIWA Stn TAN0904/S71, 42.531° S, 174.349° E, Apr 2009; NIWA Stn TAN0908/R29, 42.748° S, 174.176° E, Oct 2009.

Bay of Plenty: NIWA Stn KAH0907/S13, 35.195° S, 176.698° E, Aug 2009.

Tasman Sea: PINTS Stn C47, 44.930° S, 149.637° E, Jan 2010; PINTS Stn C49, 44.219° S, 148.748° E, Jan 2010; PINTS Stn C50, 44.224° S, 148.748° E, Jan 2010.

Holotype. Plate L, G, O, 2CA; held at the Electronmicroscope Laboratory at Lamont Geological Observatory, Palisades, New York, USA.

Type locality. Atlantic Ocean.

Description. Coccosphere generally very small, spherical to subspherical (diameter 3–5 µm) (Fig. 8A, C); elliptical placoliths 1.5–2.2 µm long, with low to intermediate angle bridge to the long axis, with or without slits between distal shield elements (Fig. 8B, D). Distal shields of most specimens collected in New Zealand waters have no slits between distal shield elements. This morphotype has sometimes been referred to as *Gephyrocapsa ericsonii* var. *ericsonii*. Both high and low, thin, arched bridges have been observed (Fig. 8C, D).

Distribution and abundance. *Gephyrocapsa ericsonii* is most widely distributed close to the Kaikoura coast (Fig. 9). Greatest cell concentrations (4000–11,000 cells l^{-1}) were recorded in the summer of 2009, particularly in the STF over Chatham Rise, east of New Zealand (Appendix 1, Table 1.1). Moderate coccosphere concentrations (up to 2,000 cells l^{-1}), however, were recorded in summers, from 2010 to 2012, at a limited number of sites, either over Chatham Rise or in the Tasman Sea (Appendix 1, Tables 1.6, 1.7, 1.10). Off the Kaikoura coast in autumn 2009, generally low cell concentrations (20–500 cells l^{-1}) were recorded over a large area, with moderate to high, at two sites (2,100 and 13,000 cells l^{-1}) (Appendix 1, Table 1.2). Over Chatham Rise in autumn 2011, low to moderate cell concentrations (300–7,000 cells l^{-1}) were recorded, while around southwest of New Zealand, they were absent (Appendix 1, Tables 1.8, 1.10). In the spring of 2009, low to moderate numbers of coccospheres were recorded in a very limited number of sites in Bay of Plenty, off the Kaikoura coast and in the vicinity of Chatham Rise (Appendix 1, Tables 1.3–1.5).

Previous records. Extant *Gephyrocapsa ericsonii* was previously reported as a first-time record for New Zealand by Chang & Northcote (2016). Elsewhere, *Gephyrocapsa ericsonii* is widely distributed. It was recorded from samples collected, e.g., in the tropical and subtropical waters of South China Sea (Lee Chen *et al.* 2007), in the East China Sea (Wang *et al.* 2012), in the East Australian Current, and in Bass Strait (Hallegraeff 2010), in the Australian sector of the Southern Ocean (Findlay & Giraudeau 2000), in the Southern Ocean south of the Polar Front (Findlay *et al.* 2005), along a temperate to polar gradient in the West Pacific sector of the Southern Ocean (Malinverno *et al.* 2015), in the subtropical South Atlantic (Baumann *et al.* 2008), off Terceira Island, Azores, in the Central North Atlantic (Narciso *et al.* 2016), in the tropical and subtropical Atlantic Ocean (Broerse *et al.* 2000a; Poulton *et al.* 2017), in a coastal upwelling region of Lisbon, Portugal, in the Mediterranean (Silva *et al.* 2009), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in an upwelling region off Somalia (NW Indian Ocean) (Broerse *et al.* 2000b), and in the Java upwelling region of the tropical Indian Ocean (Andruleit 2007).

Gephyrocapsa muellerae Bréhéret, 1978

Fig. 8 E, F

Bréhéret, 1978, pl. 2, figs 3–4; Kleijne, 1993: 230, pl. 2, fig. 4; Cros & Fortuño, 2002: 123, fig. 61A; Young *et al.* 2003: 11, pl. 2, figs 7–9.

Synonym: *Gephyrocapsa oceanica* var. *californiensis* Kamptner, 1956 (*see* Nannotax3 website: www.mikrotax.org).

Occurrence records. *Kaikoura*: NIWA Stn TAN0904/S33, 42.900° S, 174.135° E, Apr 2009.

Chatham Rise: NIWA Stn TAN1107/T5, 46.202° S, 178.500° E, May 2011; NIWA Stn TAN1203/DA59, 43.386° S, 179.452° E, Feb 2012.

Holotype. Type is held in France.

Type locality. North Atlantic (NE of Azores).

Description. Coccosphere of intermediate size (5–9 µm), spherical to subspherical; elliptical placoliths 3–4 µm long (Fig. 8E, F). Elliptical placoliths are similar in construction to those of *Gephyrocapsa oceanica*, with a large bridge at a low angle to the axis (Fig. 8F).

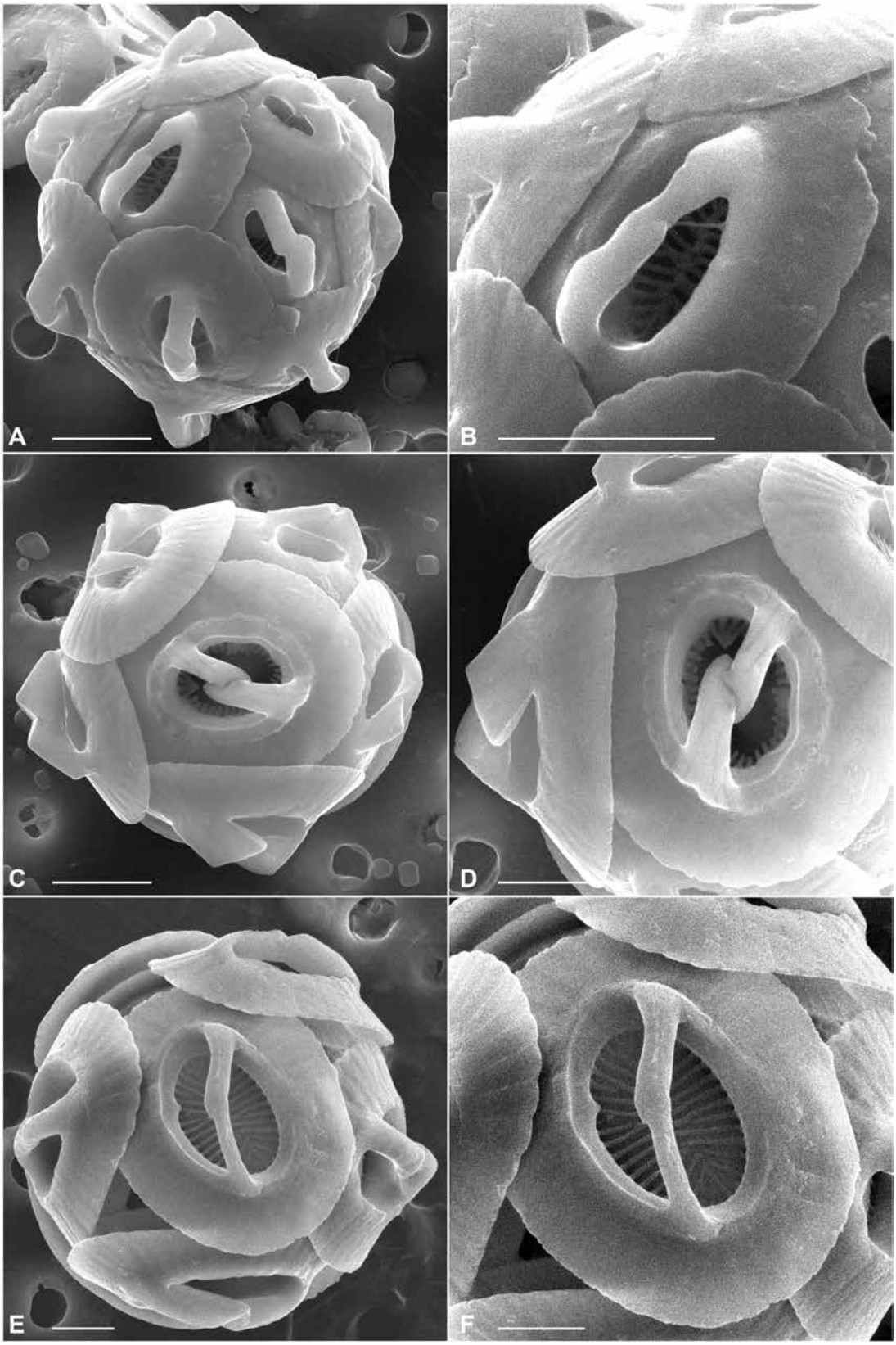

Figure 8. Coccolithophore morphology: **A, C.** cells of *Gephyrocapsa ericsonii* McIntyre & Bé, 1967; **B, D.** coccoliths of *G. ericsonii*; **E.** cell of *G. muellerae* Bréhéret, 1978; **F.** coccoliths of *G. muellerae*. Scale bars A–F, 1 μm.

Distribution and cell abundance. *Gephyrocapsa muellerae* was found at one site off the Kaikoura coast and at two sites close to Chatham Rise, east of New Zealand (Fig. 9)**.** Cell concentrations of this species were recorded on three separate occasions: autumn of 2009 and 2011, and summer of 2012, concentrations of which ranged from low (300–500 cells l^{-1}) to moderate (1,100 cells l^{-1}) (Appendix 1, Tables 1.2, 1.9, 1.10**)**.

Previous records. Extant *Gephyrocapsa muellerae* was previously recorded at three sites in STF/SA waters

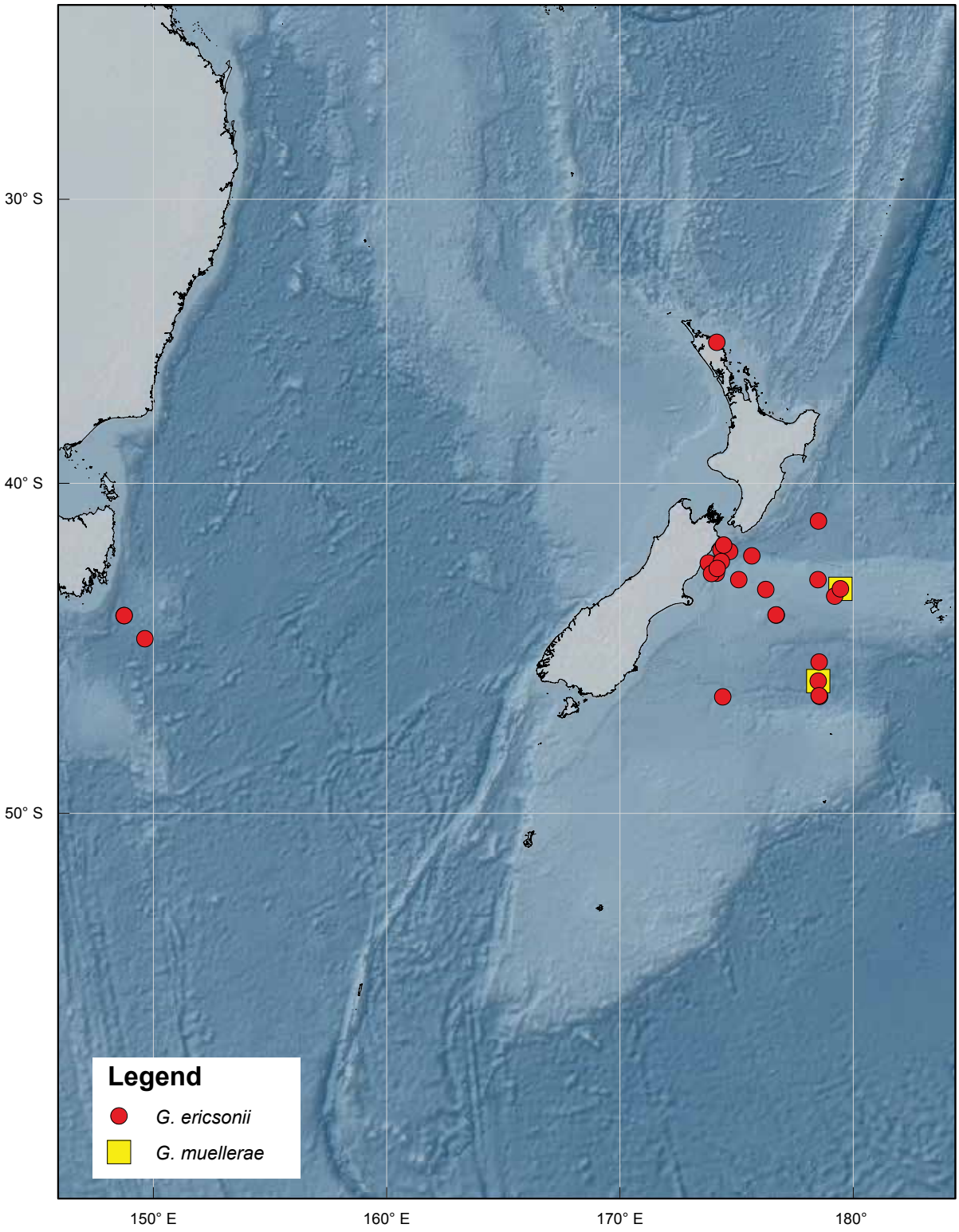

Figure 9. Distribution of *Gephyrocapsa ericsonii* McIntyre & Bé, 1967 and *G. muellerae* Bréhéret, 1978 around New Zealand.

to the east of New Zealand (Saavedra-Pellitero *et al.* 2014; Appendix 2, Table 2.2), and at a limited number of sites over Chatham Rise (Chang & Northcote 2016). Elsewhere, this species is quite well distributed and was recorded from samples collected, e.g., in the Australian sector of the Southern Ocean (Findlay & Giraudeau 2000), off Terceira Island, in the western subarctic Pacific and Bering Sea (Hattori *et al.* 2004), off Azores, in the Central North Atlantic (Narciso *et al.* 2016), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in a coastal upwelling region of Lisbon, Portugal, in the Mediterranean (Silva *et al.* 2009), in the tropical and subtropical Atlantic Ocean (Poulton *et al.* 2017), and in the subtropical and temperate northeast Atlantic (Broerse *et al.* 2000a).

Remarks. In older literature, this species is often called *Gephyrocapsa caribbeanica* Boudreaux & Hay (Hay *et al*. 1967).

Gephyrocapsa oceanica Kamptner, 1943

Fig. 10 A, B

Okada & McIntyre, 1977: 10–11, pl. 3, figs 3–9; Nishida, 1979, pl. 2, fig. 1; Kleijne, 1993: 230, pl. 2, fig. 5; Cros & Fortuño, 2002: 123, fig. 61B; Young *et al*. 2003: 11, pl. 2, figs 1–5.

Synonyms: *Gephyrocapsa dentata* Halldal & Markali, 1955: 18, pl. 24, fig. 3.

Gephyrocapsa gracillima Lecal & Bernheim, 1960: 290, pl. 18, photo. 31, pl. 19, photo. 32.

Occurrence records. *Kaikoura*: NIWA Stn TAN0904/S13, 46.670° S, 174.409° E, Apr 2009; NIWA Stn TAN0904/S21, 42.401° S, 174.264° E, Apr 2009; NIWA Stn TAN0904/S35, 42.576° S, 173.787° E, Apr 2009; NIWA Stn TAN0904/S71, 42.531° S, 174.349° E, Apr 2009; NIWA Stn TAN0908/R6, 42.350° S, 174.802° E, Oct 2009; NIWA Stn TAN0908/R29, 42.748° S, 174.176° E, Oct 2009.

Bay of Plenty: NIWA Stn KAH0907/S13, 35.195° S, 174.157° E, Sept 2009; NIWA Stn KAH0907/S18, 35.224° S, 174.093° E, Sept 2009.

Chatham Rise: NIWA Stn TAN1102/NH162, 43.616° S, 179.205° E, Feb 2011; NIWA Stn TAN1102/NH175, 43.556° S, 179.699° E, Feb 2011; NIWA Stn TAN1107/T1, 42.351° S, 175.651° E, May 2011; NIWA Stn TAN1107/T2, 43.411° S, 176.250° E, May 2011; NIWA Stn TAN1107/T3, 44.206° S, 176.701° E, May 2011; NIWA Stn TAN1107/T8, 42.340° S, 174.093° E, May 2011.

Holotype. Type is held at the Natural History Museum Vienna, Austria.

Type locality. Pacific Ocean, off California, USA.

Description. Relatively large coccosphere (5–10 µm), with elliptical placoliths 3.5–6 µm long (Fig. 10A, B). The bridge is oriented at approximately a right angle to the long axis of the placoliths (Fig. 10B). Inner tube of the placolith protrudes to form a collar around the central area.

Distribution and cell abundance. *Gephyrocapsa oceanica* was mainly found in coastal waters off Kaikoura and over Chatham Rise, east of New Zealand (Fig. 11). This species has also been detected in the Bay of Plenty, northeast New Zealand. Cell concentrations ranged from low to moderate in autumn of 2009 and 2011, at four sites off the Kaikoura coast (20–5,000 cells l^{-1}) (Appendix 1, Table 1.2) and in open waters over Chatham Rise (300–3,000 cells l^{-1}) (Appendix 1, Table 1.9). In spring 2009, this species was recorded in coastal sites, in the Bay of Plenty and Kaikoura, and at one site over Chatham Rise (Appendix 1, Table 1.3–1.5). Fewest cells, however, were found in summer; the only site where this species was recorded at that time was over Chatham Rise, east of New Zealand (Appendix 1, Table 1.7).

Previous records. *Gephyrocapsa oceanica* was previously recorded at two NZOI stations, B67 and B71, on a transect between northeast New Zealand and Tonga (Norris 1961; Appendix 2, Table 2.1). In November 1992, a bloom attributed to this species was reported off northeast New Zealand (Rhodes *et al*. 1993). From September to February 1992/1993 and in March 1993, it was also detected in Queen Charlotte Sound and Northland (Rhodes *et al*. 1995), and off the central east coast of New Zealand (Chang & Northcote 2016).

Elsewhere, *Gephyrocapsa oceanica* is also known to form massive blooms, e.g., in Jervis Bay, Australia, 1992 (Blackburn & Cresswell 1993), in Tokyo Bay, Japan, 1995 (Ogura & Sato 2001), and in Mikawa Bay, Japan, 1996 (Kai *et al*. 1999). This species is very widely distributed, e.g., in the tropical and subtropical waters of the South China Sea (Lee Chen *et al*. 2007), in the Yellow and East China Seas (Wang *et al*. 2012), in the equatorial and subequatorial Pacific Ocean (Hagino & Okada 2004), in surrounding waters of South Australia, Victoria, New South Wales, Tasmania, northwestern Australia, Gulf of Carpentaria and the Coral Sea (Hallegraeff 2010), in the Southern Ocean south of the Polar Front (Findlay *et al*. 2005), along a temperate to polar gradient in the West Pacific sector of the Southern Ocean (Malinverno *et al*. 2015), in the tropical and subtropical Atlantic Ocean (Poulton *et al*. 2017), in the subtropical and temperate northeast Atlantic (Broerse *et al*. 2000a), off Terceira Island, Azores, in the Central North Atlantic (Narciso *et al*. 2016), in the subtropical water of the South Atlantic (Baumann *et al*. 2008), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the eastern Mediterranean Sea (Knappertsbusch 1993), in a coastal upwelling region of Lisbon Bay, Portugal, in the Mediterranean (Silva *et al*. 2009), in the Aegean Sea (NE Mediterranean) (Dimiza *et al*. 2015), in the Java upwelling region of the tropical Indian Ocean (Andruleit (2007), in an upwelling region off Somalia (NW Indian Ocean) (Broerse *et al*. 2000), in the Bay of Bengal of the Indian Ocean (Mergulhao *et al*. 2013), and in the Indian sector of the Southern Ocean (Patil *et al*. 2017).

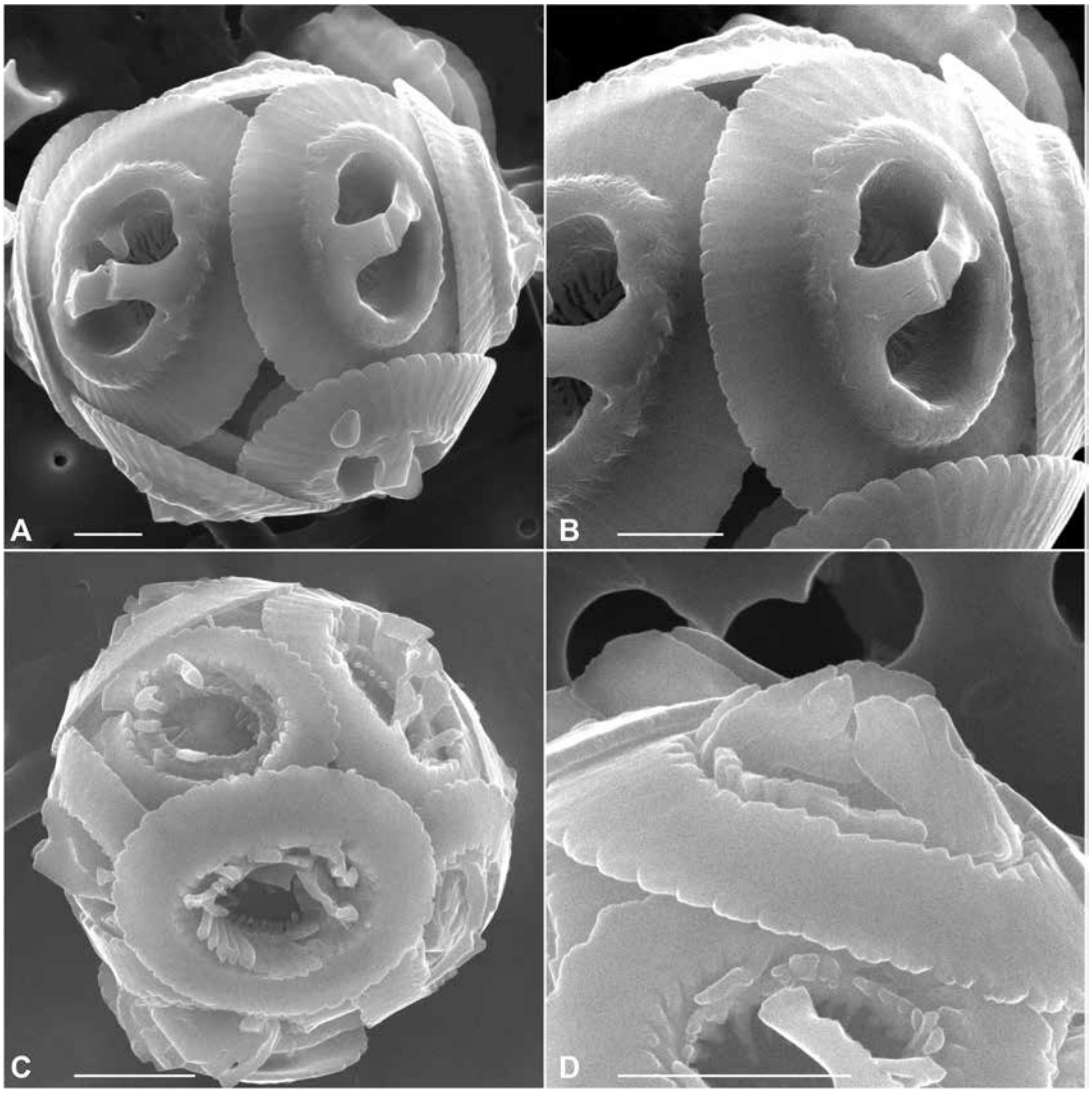

Figure 10. Coccolithophore morphology: **A.** cell of *Gephyrocapsa oceanica* Kamptner, 1943; **B.** coccoliths of *G. oceanica*; **C.** cell of *Gephyrocapsa* sp.; **D.** coccoliths of *Gephyrocapsa* sp. Scale bars A–D, 1 µm.

Gephyrocapsa sp.

Fig. 10 C, D

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS02, 42.747° S, 175.841° E, Jan–Feb 2009.

Kaikoura: NIWA Stn TAN0904/S13, 46.670° S, 174.409° E, Apr 2009; NIWA Stn TAN0904/S21, 42.401° S, 174.264° E, Apr 2009.

Description. Coccosphere spherical (4–6 µm) (Fig. 10C). Elliptical placoliths similar to those of *Gephyrocapsa ericsonii* but with a much larger/higher bridge formed from two diametrically opposite thin and expanded plates, and with a conspicuous ring of short processes around the central area (Fig. 10D). The bridge is at a low angle to the long axis.

Distribution and cell abundance. This species was found only in ST and SA waters to the east of New Zealand (Fig. 11). Cell concentrations recorded at two sites off Kaikoura and in STF and SA waters, east of New Zealand, ranging from low to moderate (100 to 1,000 cells l^{-1}) (Appendix 1, Tables 1.1, 1.2).

Remarks. *Gephyrocapsa* sp. was previously reported as *Gephyrocapsa ornata* on the east coast of New Zealand (Chang & Northcote 2016). Because *G.* sp. lacks a conspicuous ring of relatively long spines around the central area of placolith like those of *G. ornata*, it is not considered to be the same species.

Genus ***Reticulofenestra*** Hay, Mohler & Wade, 1966

Crenalithus Roth, 1973: 731.
Gephyrocapsa Okada & McIntyre, 1977: 10, pl. 2, figs 5–6.

Description. Placoliths without slits in the distal shields and without a bridge in the central area. Central area may be partially closed by extensions of the inner tube-elements (Okada & McIntyre 1977; Cros & Fortuño 2002; Young *et al.* 2003).

Type species. *Reticulofenestra caucasica* Hay *et al*., 1966.

Reticulofenestra parvula (Okada & McIntyre, 1977) Biekart, 1989

Fig. 12 A–C

Okada & McIntyre, 1977: 6–7, pl. 2, figs 1–2; Heimdal & Gaarder, 1981: 48, pl. 4, fig. 17; Cros & Fortuño, 2002: 123, fig. 61D; Young *et al*. 2003: 13, pl. 3, figs 4–6.
Basionym: *Crenalithus parvulus* Okada & McIntyre, 1977: 6–7, pl. 2.
Synonym: *Gephyrocapsa parvula* Okada & McIntyre, 1977: 6–7.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS31, 44.107° S, 178.590° E, Jan–Feb 2009; NIWA Stn TAN0902/YS38, 43.102° S, 178.489° E, Jan–Feb 2009; NIWA Stn TAN1107/T1, 42.351° S, 175.651° E, May 2011; NIWA Stn TAN1107/T2, 43.411° S, 176.250° E, May 2011; NIWA Stn TAN1107/T3, 44.206° S, 176.701° E, May 2011; NIWA Stn TAN1107/T4, 45.204° S, 177.307° E, May 2011; NIWA Stn TAN1107/SBM, 46.656° S, 178.556° E, May 2011; NIWA Stn TAN1107/T5, 46.202° S, 178.500° E, May 2011; NIWA Stn TAN1107/T6, 44.198° S, 178.494° E, May 2011; NIWA Stn TAN1107/T8, 42.340° S, 178.504° E, May 2011; NIWA Stn TAN1107/NBM, 41.229° S, 178.512° E, May 2011.

Kaikoura: NIWA Stn TAN0904/S09, 42.162° S, 174.328° E, Apr 2009; NIWA Stn TAN0904/S13, 46.670° S, 174.409° E, Apr 2009; NIWA Stn TAN0904/S21, 42.401° S, 174.264° E, Apr 2009; NIWA Stn TAN0904/S35, 42.576° S, 173.787° E, Apr 2009; NIWA Stn TAN0904/S39, 42.576° S, 173.787° E, Apr 2009; NIWA Stn TAN0904/S43, 42.941° S, 173.926° E, Apr 2009; NIWA Stn TAN0904/S55, 42.207° S, 174.702° E, Apr 2009; NIWA Stn TAN0904/S63, 42.008° S, 174.443° E, Apr 2009; NIWA Stn TAN0904/S71, 42.642° S, 174.584° E, Apr 2009; NIWA Stn TAN0904/S81, 42.614° S, 174.097° E, Apr 2009; NIWA Stn TAN0904/S95, 42.535° S, 173.607° E, Apr 2009; NIWA Stn TAN0908/R3, 42.372° S, 174.802° E, Oct 2009; NIWA Stn TAN0908/R6, 42.748° S, 174.176° E, Oct 2009; NIWA Stn TAN0908/R9, 42.478° S, 174.491° E, Oct 2009; NIWA Stn TAN0908/R29, 42.748° S, 174.176° E, Oct 2009.

Holotype. Negative ON-3, held at the Lamont–Doherty Geological Observatory of Columbia University, USA.

Type locality. Pacific Ocean, 10° N, 155.083° W.

Description. Coccosphere spherical and very small (3–5 µm), like *Gephyrocapsa ericsonii* (Fig. 12A, C). Placoliths with the central area filled by a reticulate grid and distal shield differs from that of *Emiliania huxleyi* in not having slits between elements (Fig. 12B). Inner tube of placolith with a conspicuous ring of very small structures.

Distribution and cell abundance. *Reticulofenestra parvula* was found off the Kaikorua coast and in offshore ST, STF and SA waters, east of New Zealand (Fig. 13). This species was recorded on four occasions – spring and autumn 2009, off the Kaikoura coast (Appendix 1, Tables 1.2, 1.4), in summer 2009 and autumn 2011, and in ST, STF and SA waters, over Chatham Rise (Appendix 1, Tables 1.1, 1.9). Off Kaikoura in spring 2009, *R. parvul*a was found in bloom proportion of 571,000 cells l^{-1} (Appendix 1, Table 1.4). On other occasions, cell concentrations of this species varied from a few hundreds to tens of thousands, e.g., off Kaikoura in autumn 2009 (Appendix 1, Table 1.2) and over Chatham Rise in summer 2009 and autumn 2011, respectively (Appendix 1, Tables 1.1, 1.9).

Previous records. Extant *Reticulofenestra parvula* was previously reported by Chang & Northcote (2016) off the east coast of New Zealand. Elsewhere, this species was recorded, e.g., in the tropical and subtropical Atlantic Ocean (Poulton *et al*. 2017), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the subtropical northeast Atlantic (Broerse *et al*. 2000a), in an upwelling region off Somalia (NW Indian Ocean) (Broerse *et al*. 2000b), and in an upwelling region of Java in the tropical Indian Ocean (Andruleit 2007).

Reticulofenestra parvula **var.** ***tecticentrum*** (Okada & McIntyre, 1977) Jordan & Young, 1990

Fig. 12 D–F

Jordan & Young, 1990: 15–18; Young *et al*. 2003: 13, pl. 3, figs 7–9.
Basionym: *Crenalithus parvulus* subsp. *tecticentrum* Okada & McIntyre 1977: 7, pl. 2, figs 3, 4, 7.

Occurrence records. *Kaikoura*: NIWA Stn TAN0904/S13, 46.670° S, 174.409° E, Apr 2009; NIWA Stn TAN0904/S45, 42.941° S, 173.926° E, Apr 2009; NIWA Stn TAN0908/R3, 42.372° S, 174.802° E, Oct 2009; NIWA Stn TAN0908/R6, 42.748° S, 174.176° E, Oct 2009; NIWA Stn TAN0908/R9, 42.478° S, 174.491° E, Oct 2009; NIWA Stn TAN0908/ R29, 42.748° S, 174.176° E, Oct 2009.

Chatham Rise (*TAN1107*, *November 2011*): NIWA Stn TAN1107/T3, 44.206° S, 176.701° E, May 2011; NIWA Stn TAN1107/SBM, 46.656° S, 178.500° E, May 2011.

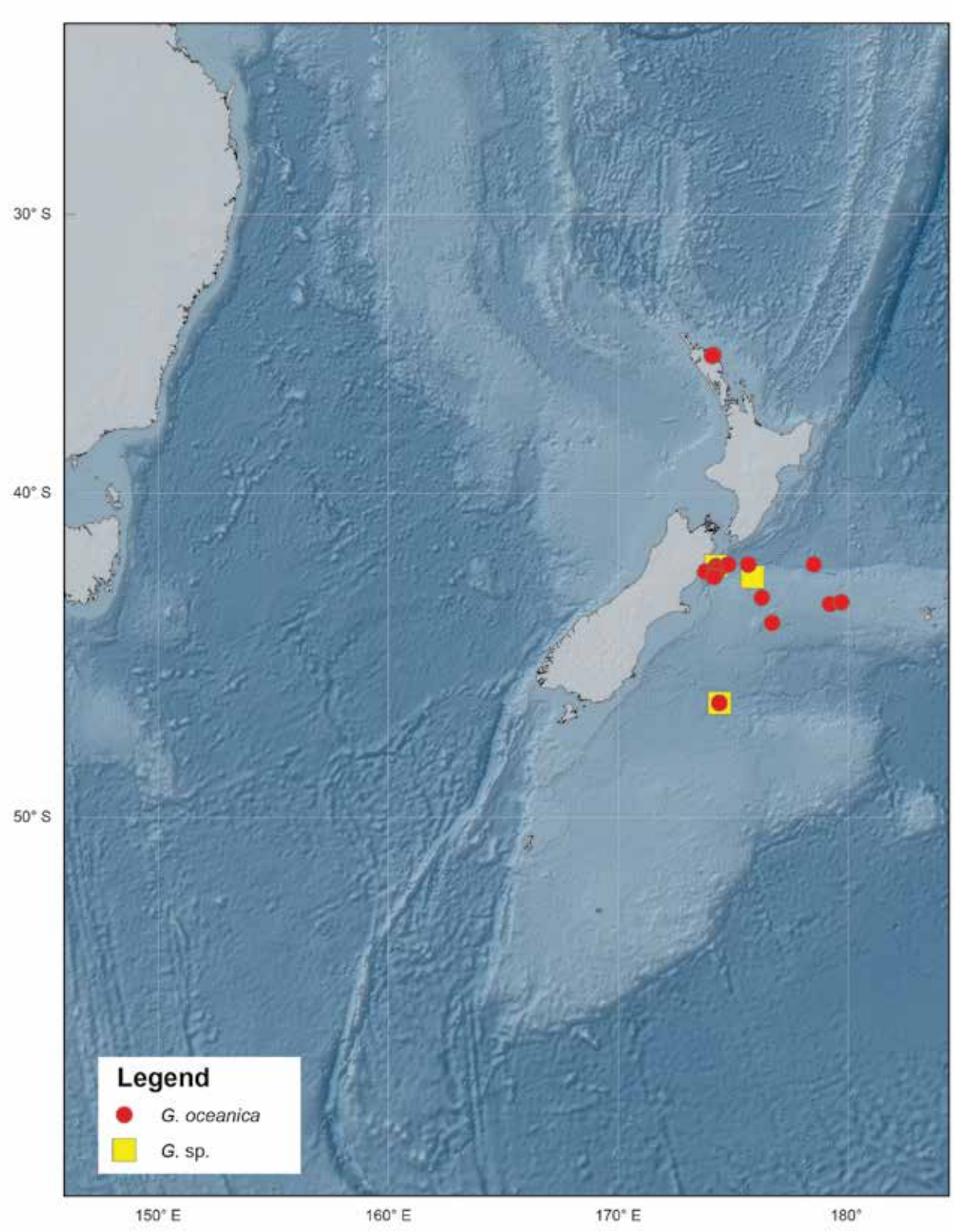

Figure 11. Distribution of *Gephyrocapsa oceanica* Kamptner, 1943 and *Gephyrocapsa* sp. around New Zealand.

Holotype. Negative ON-4, held at the Lamont–Doherty Geological Observatory of Columbia University, USA.

Type locality. Pacific Ocean, 10° N, 155.083° W.

Description. Coccosphere spherical and small (3–5 µm) (Fig. 12D). Placoliths heavily calcified, with either the central area closed or partly filled by extensions from the calcified inner tube-cycle (Fig. 12E, F). This is a variant of *R. parvula*.

Distribution and cell abundance. *Reticulofenestra parvula* var. *tecticentrum* occurred in almost the same areas as *R. parvula* – off the Kaikoura coast and in the vicinity of Chatham Rise – but it was not as widely distributed as the latter (Fig. 13). Cell concentrations

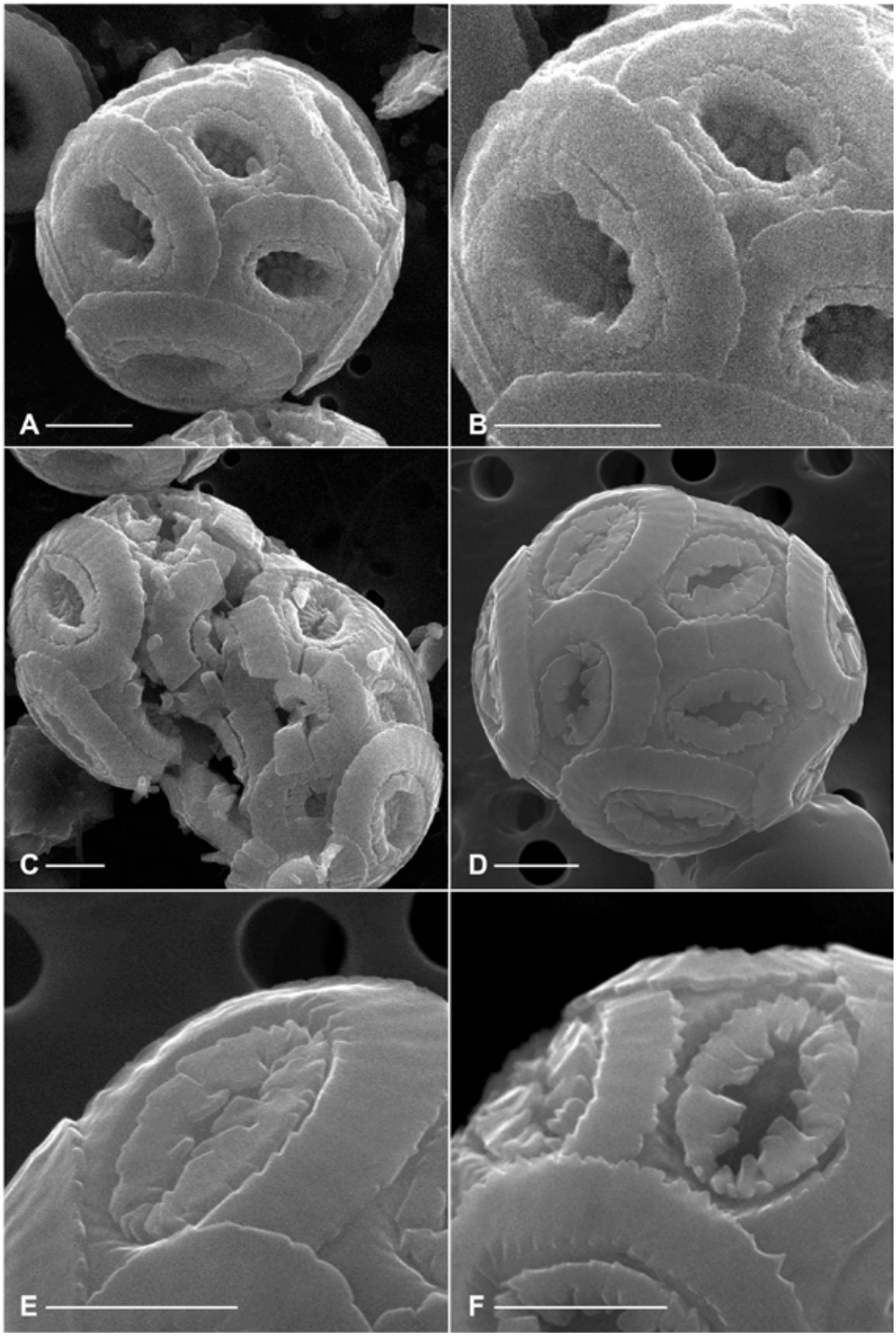

Figure 12. Coccolithophore morphology: **A.** cell of *Reticulofenestra parvula* (Okada & McIntyre, 1977) Biekart 1989; **B.** coccoliths of *R. parvula*; **C.** two dividing cells of *R. parvula*; **D.** cell of *R. parvula* var. *tecticentrum* (Okada & McIntyre, 1977) Jordan & Young 1990; **E–F.** coccoliths of *R. parvula* var. *tecticentrum*. Scale bars A–F, 1 μm.

of this species were generally much lower than those of *R. parvula*. It was recorded only on three occasions, off Kaikoura in spring (100–7,000 cells l^{-1}) and autumn 2009 (< 20–500 cells l^{-1}), and over Chatham Rise in autumn 2011 (100–300 cells l^{-1}) (Appendix 1, Tables 1.1, 1.4, 1.9).

Previous records. Extant *Reticulofenestra parvula* var. *tecticentrum* was previously reported off the east coast of New Zealand by Chang & Northcote (2016). Elsewhere, *R. parvula* var. *tecticentrum* was recorded in the type locality of the Pacific Ocean (*see* Okada & McIntyre 1977) and in the northwestern Mediterranean Sea (Cros & Fortuño 2002).

Order **Syracosphaerales** Hay, 1977; emend. Young *et al*., 2003

Description. Coccoliths of members of this group have more than one coccolith type – muroliths, planoliths or both. Coccospheres can show different kinds of coccoliths in only one theca or in different theca. A common feature of body coccoliths in *Syracosphaera* is the exhibition of a distinct radial lath cycle (e.g., Cros & Fortuño 2002; Young *et al*. 2003).

Family **Calciosoleniaceae** Kamptner, 1927

Previously in Order Stephanolithiales Bown & Young, 1997 (*see* Cros & Fortuño, 2002: 20).

Description. Coccospheres monothecate and elongate fusiform in shape. Scapholiths are rhomboidal muroliths without flanges; central area has laths with a perpendicular disposition (*see* Manton & Oates 1985; Cros & Fortuño 2002; Young *et al*. 2003).

Genus ***Calciosolenia*** Gran, 1912; emend. Young et al., 2003

Acanthosolenia Bernard, 1939: 40.
Anoplosolenia Deflandre, 1952: 458; Norris, 1961: 174; Cros & Fortuño, 2002: 20.
Scapholithus Deflandre & Fert, 1954: 165, pl. 8, figs 12, 16, 17.

Description. Large coccosphere with tapering ends. Rhomboid scapholiths either monomorphic or dimorphic; polar scapholiths with or without long spines (Cros & Fortuño 2002; Young *et al*. 2003).

Type species. *Calciosolenia murrayi* Gran, 1912: 332, fig. 239(5).

Calciosolenia brasiliensis (Lohmann, 1920) Young, in Young *et al.*, 2003

Fig. 14 A–C

Deflandre, 1952: 458, figs 356D, E; Gaarder & Hasle, 1971: 523, figs 3a–c; Kleijne, 1993: 232–232, pl. 1, figs 1–2, Cros & Fortuño, 2002: 76, figs 14a–C; Young *et al.* 2003: 55, pl. 24, figs 1–4.

Basionym: *Cylindrotheca brasilensis* Lohmann, 1920: 187.

Synonyms: *Anoplosolenia brasiliensis* (Lohmann) Deflandre, 1952: 458, figs 356 D, E; Norris 1961: 174; Cros & Fortuño, 2002: 20.
Calciosolenia grani closterium Schiller, 1925: 28, pl. 2, fig. 21.
Calciosolenia grani cylindrothecaeformis Schiller, 1925: 28, pl. 2.
Calciosolenia tenuis Bernard & Lecal, 1960: 21, fig. 9.
Scapholithus ganoretus Kamptner, 1967: 147, pl. 8, fig. 62.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS32, 42.633° S, 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS39, 42.820° S, 178.495° E, Jan–Feb 2009.

Holotype. Not recorded.

Type locality. Atlantic Ocean.

Description. Coccosphere (40–50 µm long), monomorphic, elongated, tapering at both ends into long horns (Fig. 14A, B). Scapholiths (coccoliths) (2–3 µm long) are spindle–shaped (elongate) (Fig. 14C).

Distribution and cell abundance. *Calciosolenia brasiliensis* was found only at two sites in STF waters over Chatham Rise (Fig. 15). Cell concentrations recorded at both sites in summer 2009 were 100–200 cells l^{-1} (Appendix 1, Table 1.1).

Previous records. *Calciosolenia brasiliensis* was previously recorded as *Anoplosolenia brasiliensis* (Lohman) Deflandre, 1952 by Norris (1961), at one NZOI station (B67) along a transect from northeast New Zealand to Tonga (Appendix 2, Table 2.1). This species was also reported off the east coast of New Zealand (Chang & Northcote 2016).

Elsewhere, this species is widely distributed, e.g., in the equatorial and subequatorial Pacific Ocean (Hagino & Okada 2004), in the East China Sea (Wang *et al*. 2012), in the tropical water of Australia (Hallegraeff 1984), along a temperate to polar gradient in the West Pacific sector of the Southern Ocean (Malinverno *et al*. 2015), in the tropical and subtropical Atlantic Ocean (Poulton *et al*. 2017), in the subtropical South Atlantic (Baumann *et al*. 2008), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the middle and northern Adriatic Sea (Mediterranean) (Skejić *et al*. 2018; Godrijan *et al*. 2018), in an upwelling region off Somalia (NW Indian Ocean) (Broerse *et al*. 2000b), in the Java upwelling region of the tropical Indian Ocean (Andruleit (2007), and in the Indian sector of the Southern Ocean (Patil *et al*. 2017).

Calciosolenia murrayi Gran, 1912

Fig. 14 D–F

Gaarder & Hasle, 1971: 529, fig. 3 d, e; Manton & Oates, 1985: 469–471, pl. 4, figs 13–18; Kleijne, 1993: 232, pl. 1, figs 4–5; Cros & Fortuño, 2002: 77, figs 15A–D; Young *et al.* 2003: 55, pl. 24, figs 5–8.

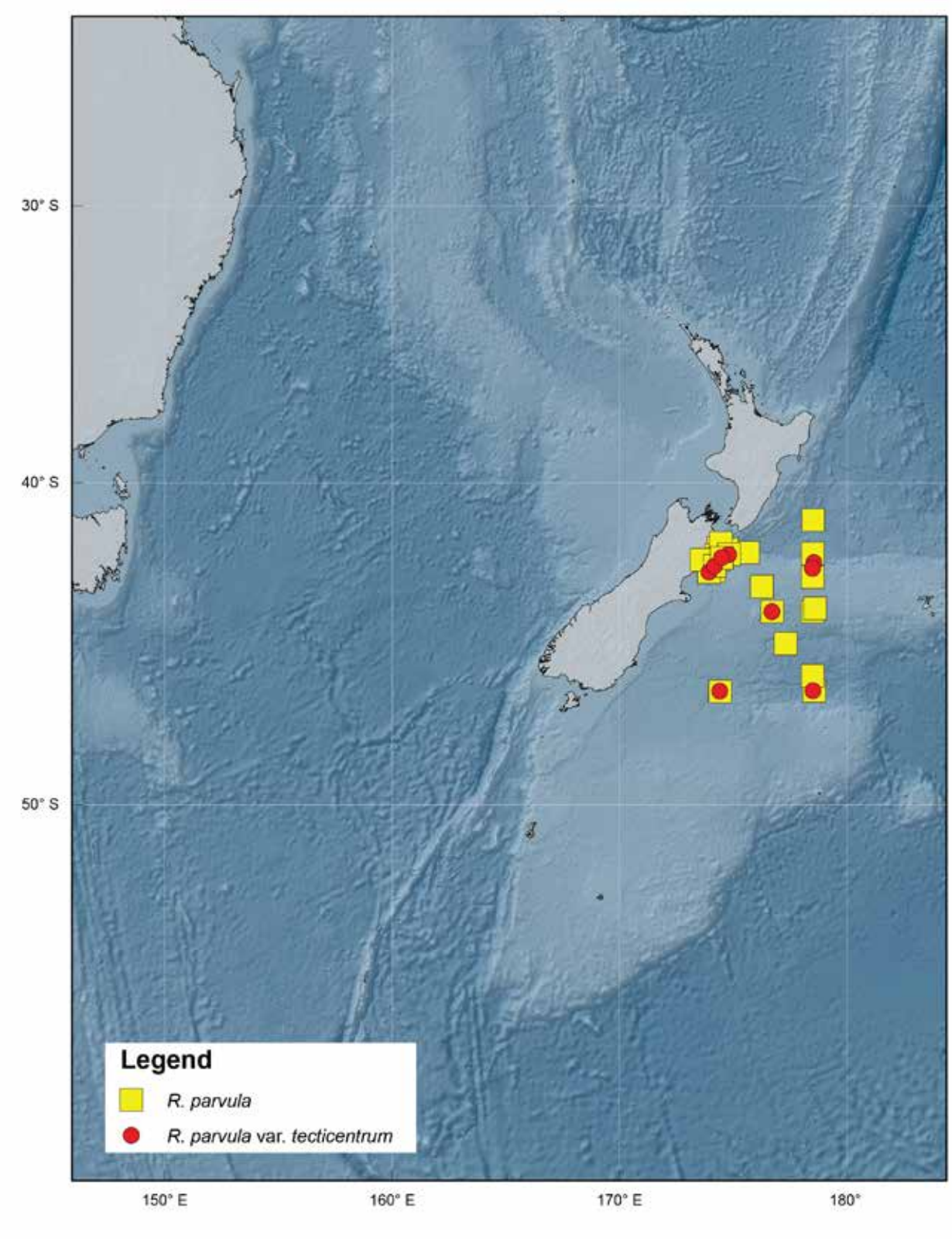

Figure 13. Distribution of *Reticulofenestra parvula* (Okada & McIntyre, 1977) Biekart 1989 and *R. parvula* var. *tecticentrum* (Okada & McIntyre, 1977) Jordan & Young 1990 around New Zealand.

Synonyms: *Acanthosolenia mediterranea* Bernard, 1939: 41, fig. 2e.
Calciosolenia sinuosa Schlauder in Halldal & Markali, 1955: 15. pl. 17.
Calciosolenia compacta Martini, 1981: 559, pl. 4, fig. 8, pl. 5, fig. 1.

Occurrence records. *Chatham Rise* (*TAN0902*, *January–February 2009*): NIWA Stn TAN0902/YS3, 43.101° S, 176.095° E, Jan–Feb 2009; NIWA Stn TAN0902/YS32, 42.633° S, 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS39, 42.820° S, 178.495° E, Jan–Feb 2009; NIWA Stn TAN1107/T1, 42.351° S, 1765.651° E, May 2011; NIWA Stn TAN1107/T2, 43.411° S, 176.250° E, May 2011; NIWA Stn TAN1107/T6, 44.198° S, 178.494° E, May 2011.

Kaikoura: NIWA Stn TAN0904/ S09, 42.162° S, 174.328° E, Apr 2009; NIWA Stn TAN0904/S21, 42.401° S, 174.264° E, Apr 2009; NIWA Stn TAN0904/

S45, 42.941° S, 173.926° E, Apr 2009; NIWA Stn TAN0904/55, 42.207° S, 174.702° E, Apr 2009, NIWA Stn TAN0904/S71, 42.531° S, 174.349° E, Apr 2009; NIWA Stn TAN0904/S91, 42.703° S, 173.886° E, Apr 2009; NIWA Stn TAN0904/S95, 42.535° S, 173.607° E, Apr 2009.

Holotype. Type held at Oslo University, Botany Department, Norway (this is where Gran was based).

Type locality. Atlantic Ocean.

Description. Coccosphere (35–45 µm long), dimorphic, broad in the middle and tapering at both ends, with spine–bearing polar coccoliths (up to 30 µm long) (Fig. 14D, E). Rhomboidal coccoliths (scapholiths) (3–4 µm long) are larger than those of *Calciosolenia brasiliensis* (Fig. 14F).

Distribution and cell abundance. *Calciosolenia murrayi* was a common species found off the Kaikoura coast and in offshore ST, STF and SA waters, east of New Zealand (Fig. 15). This species was recorded on three occasions – summer 2009 and autumns of 2009 and 2011 – near Kaikoura and over Chatham Rise (Appendix 1, Tables 1.1, 1.2, 1.9). Off Kaikoura in autumn 2009, *C. murrayi* was widespread with cell concentrations ranging from 300 to 4,800 cells l^{-1} (Appendix 1, Table 1.2), while over Chatham Rise in autumn 2011, cell concentrations at a limited number of sites were moderate (2000–4000 cells l^{-1}) (Appendix 1, Table 1.9). The greatest cell concentration (up to 33,500 cells l^{-1}), however, was recorded in summer 2009, at a STF site over Chatham Rise (*see* Fig. 14 D; Appendix 1, Table 1.1).

Previous records. *Calciosolenia murrayi* was previously recorded as *Acanthosolenia mediterranea* Bernard, 1939 by Norris (1961), at a NZOI station, B67, along a transect between northeast New Zealand and Tonga (Appendix 2, Table 2.1), and at several sites off the central east coast of New Zealand (Chang & Northcote 2016).

Elsewhere, this species was widely distributed, e.g., in the tropical and subtropical waters of the South China Sea (Lee Chen *et al.* 2007), in the East China Sea (Wang *et al.* 2012), in the East Australian Current, Bass Strait, the Coral Sea and northwestern Australia (Hallegraeff 2010), in the Australian sector of the Southern Ocean (Findlay & Giraudeau 2000), in the tropical and subtropical Atlantic Ocean (Poulton *et al.* 2017), in the subtropical and temperate northeast Atlantic Ocean (Broerse *et al.* 2000a), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the middle and northern Adriatic Sea (Mediterranean) (Skejić *et al.* 2018; Godrijan *et al.* 2018), in the Java upwelling region of the tropical Indian Ocean (Andruleit (2007), in an upwelling region off Somalia (NW Indian Ocean) (Broerse *et al.* 2000b), and in the Indian sector of the Southern Ocean (Patil *et al.* 2017).

Family **Rhabdosphaeraceae** Haeckel, 1894

Description. Coccospheres monomorphic, dimorphic, polymorphic and varimorphic. Rhabdoliths having rims formed of two rings of elements and a central area consisting of one to several rings of different types of elements. Central area either in conical or sacculiform shape or has a robust spine (Norris 1984; Cros & Fortuño 2002; Young *et al.* 2003).

Genus ***Acanthoica*** Lohmann, 1903; emend. Schiller, 1913; Kleijne, 1992

Description. Coccospheres monothecate with polymorphic coccoliths. Three different types of rhabdoliths: body coccoliths, with well-developed radial ring, lamellar ring forms low solid cone or hollow protrusion; circum-flagellar coccoliths, with spine formed by lamellar rings; antapical coccoliths, with very long spine, basal disk folded with broad rim but no radial ring (Cros & Fortuño 2002; Young *et al.* 2003).

Type species. *Acanthoica coronata* Lohmann, 1903: 68, pl. 2, figs 21–22.

Acanthoica acanthos Schiller, 1925

Fig. 16 A–B

Schiller, 1925: 34, pl. 3, figs 32, 32a; (Schiller) Deflandre, 1952: 452, fig. 350 d; Kleijne, 1992: 31–32, pl. 7, fig. 1; Cros & Fortuño, 2002: 78, figs 16C, D; Young *et al.* 2003: 59, pl. 26, figs 10, 13.

Synonym: *Anacanthoica acanthos* (Schiller 1925) Deflandre, 1952: 452, figs 16C, D.

Basionym: *Acanthoica acanthos* Schiller, 1925:34, pl. 3, figs 32, 32a.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/4, 43.432° S, 176.301° E, Jan–Feb 2009; NIWA Stn TAN1107/NBM, 41.229° S, 178.512° E, May 2011.

Kaikoura: NIWA Stn TAN0904/S45, 42.941° S, 173.926° E, Apr 2009.

Holotype. Type is possibly held at Vienna University, Botany Department, Austria (this is where Schiller was based).

Type locality. Adriatic Sea.

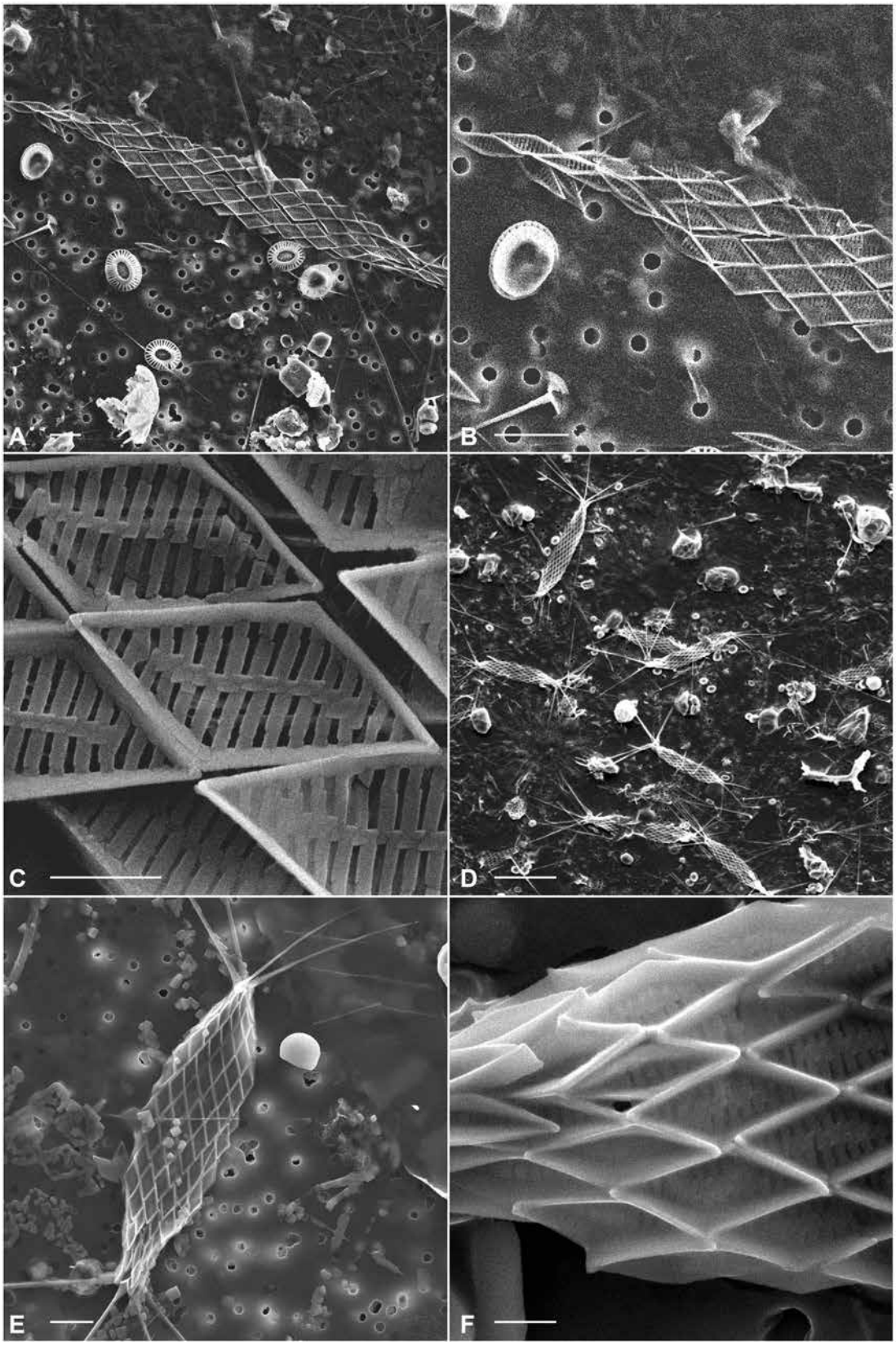

Figure 14. Coccolithophore morphology: **A–B.** cells of *Calciosolenia brasilensis* (Lohmann, 1920) Young *et al*., 2003; **C.** coccoliths of *C. brasilensis*; **D–E.** cells of *Calciosolenia murrayi* Gran, 1912; **F.** coccoliths of *C. murrayi*. Scale bars A–B, 5 µm; C, 1 µm; D–E, 5 µm; F, 1 µm.

Description. Coccosphere ovoid (7–8 µm long), monothecate and monomorphic, without spine (otherwise similar to *Acanthoica*) (Fig. 16A, B). Rhabdoliths elliptical with a relatively wide rim and a ring of flat radial laths with openings between them, and also a central, low, blunt conical protrusion.

Distribution and cell abundance. *Acanthoica acanthos* was recorded from samples collected off Kaikoura and in offshore ST and SA waters, east of New Zealand (Fig. 17). This species was found on three

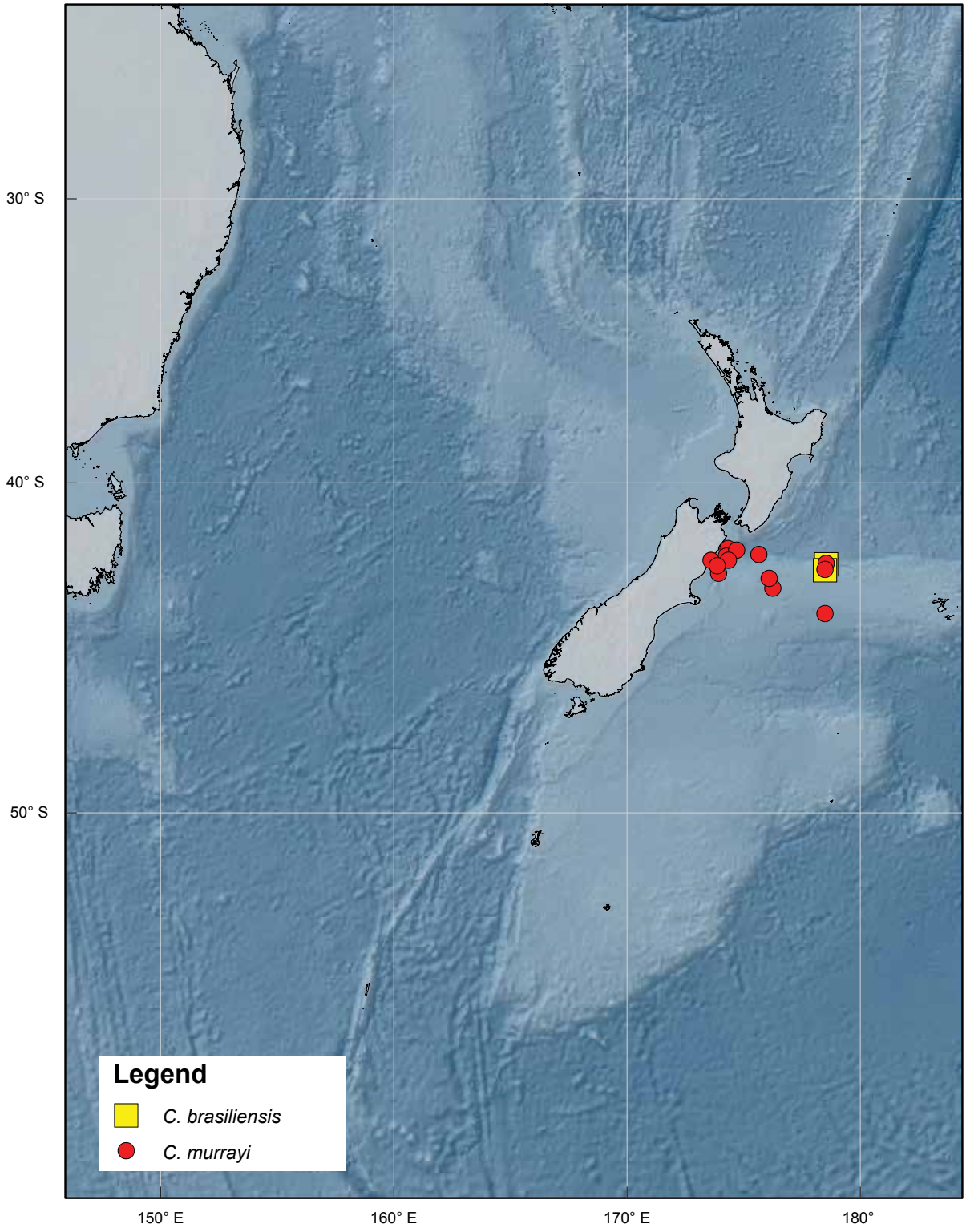

Figure 15. Distribution of *Calciosolenia brasiliensis* (Lohmann, 1920) Young *et al.*, 2003 and *C. murrayi* Gran, 1912 around New Zealand.

occasions – summer 2009 and autumn of 2009 and 2011, east of New Zealand (Appendix 1, Tables 1.1, 1.2, 1.9). Cell concentrations were generally very low (up to 300 cells l^{-1}) (Appendix 1, Tables 1.1, 1.9).

Previous records. Extant *Acanthoica acanthos* was previously reported as a first–time record of New Zealand (Chang & Northcote 2016). Elsewhere, this species was recorded in several areas around the world, e.g., the subtropical and subantarctic zones of the Southern Ocean (Saavedra-Pellitero *et al.* 2014), in central north Atlantic Ocean (Kleijne 1992), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), and in the Indian sector of the Southern Ocean (Patil *et al.* 2017).

Acanthoica quattrospina Lohmann, 1903

Fig. 16 C–E

Lohmann, 1903: 68, pl. 2, figs 23–24; Nishida, 1979, pl. 13, fig. 1; Winter & Siesser, 1994: 128, fig. 72; Cros & Fortuño, 2002: 79–80, figs 17–18; Young *et al*. 2003: 59, pl. 26, figs 1–4.

Synonym: *Acanthoica brevispina* Schiller, 1913: 610.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/4, 43.432° S, 176.301° E, Jan–Feb 2009; NIWA Stn TAN0902/YS7, 44.108° S, 176.798° E, Jan–Feb 2009; NIWA Stn TAN0902/YS30, 46.638° S, 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS38, 43.102° S, 178.489° E, Jan–Feb 2009; NIWA Stn TAN0902/YS39, 42.820° S, 178.495° E, Jan–Feb 2009; NIWA Stn TAN1107/T3, 44.206° S, 176.701° E, May 2011; NIWA Stn TAN1107/NBM, 41.229° S, 178.512° E.

Kaikoura: NIWA Stn TAN0904/33, 42.900° S, 174.135° E, Apr 2009; NIWA Stn TAN0904/S45, 42.941° S, 173.926° E, Apr 2009; NIWA Stn TAN0904/S91, 42.703 S, 173.886 E, Apr 2009.

Holotype. Type is possibly held in Kiel, Germany.

Type locality. Mediterranean Sea.

Description. Coccosphere ovoid (7–8 µm long) and dimorphic (Fig. 16C–D). Circum-flagellar coccoliths with polar spines – one long and three short at one end and 1 to 2 long at the opposite end (long spine up to 9 µm long) (Fig. 16C–E). Body rhabdoliths vary from subcircular to elliptical with well-developed radial ring elements of 32 somewhat tilted laths with openings between them (Fig. 16E); lamellar rings form a low solid cone or hollow protrusion.

Distribution and cell abundance. *Acanthoica quattrospina* was found mainly off Kaikoura and near Chatham Rise (Fig. 17). This species was recorded in samples collected on three occasions – summer 2009 and autumn of 2009 and 2011 (Appendix 1, Tables 1.1, 1.2, 1.9). Cell concentrations recorded on all three occasions were quite low, ranging from 200 to 700 cells l^{-1}. At one site in summer 2009, about 3000 cells l^{-1} were recorded in the SA water near Chatham Rise (Appendix 1. Table 1.1).

Previous records. *Acanthoica quattrospina* was previously recorded by Norris (1961), at a NZOI station (B67) along a transect between northeast New Zealand and Tonga (Appendix 2, Table 2.1). This species had also been recorded at three stations in STF/SA waters (Saavedra-Pellitero *et al*. 2014; Appendix 2, Table 2.2) and at several sites on the central east coast of New Zealand (Chang & Northcote 2016).

Elsewhere, this species is widely distributed, e.g., in both the Yellow and East China Seas (Wang *et al*. 2012), in the east Australian Current and Bass Strait (Hallegraeff 2010), in the Australian Sector of the Southern Ocean (Findlay & Giraudeau 2000), along a temperate to polar gradient in the West Pacific sector of the Southern Ocean (Malinverno *et al*. 2015), in the tropical and subtropical Atlantic Ocean (Poulton *et al*. 2017), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the middle, eastern and northern Adriatic Sea (Mediterranean) (Šupraha *et al*. 2016; Skejić *et al*. 2018; Godrijan *et al*. 2018), in the Mediterranean Sea, eastern and western Arabian Sea, Gulf of Aden, Red Sea, and the south and northeastern Indian Ocean (Kleijne 1992), in a Java upwelling region of the tropical Indian Ocean (Andruleit 2007), and in the Indian sector of the Southern Ocean (Patil *et al*. 2017).

Genus ***Algirosphaera*** Schlauder, 1945; emend. Norris, 1984

Anthosphaera (Lohmann) Kamptner, 1941
Syracosphaera Lohmann, 1902

Description. Coccospheres monothecate and dimorphic; coccoliths with a large sacculiform protrusion, rim and radial cycle normal (Kleijne 1992; Cros & Fortuňo 2002; Young *et al*. 2003).

Type species. *Algirosphaera oryza* Schlauder, 1945: 23.

Algirosphaera robusta (Lohmann, 1902) Norris, 1984

Fig. 16 F

(Lohmann 1902) Norris, 1984: 38, figs 14–16; Kleijne, 1992: 28–31, pl. 6, figs 1–7; Cros & Fortuño, 2002: 81, figs 19 A–D; Young *et al*. 2003: 61, pl. 27, figs 1, 2.

Basionym: *Syracosphaera robusta* Lohmann, 1902: 133.

Synonyms: *Syracosphaera quadricorn* Schiller, 1914: 6, pl. 2, fig. 19.
Syracosphaera robusta Lohmann, 1902: 135, pl. 4, figs 34, 35.
Anthosphaera robusta (Lohmann 1902) Kamptner, 1941: 54.
Algirosphaera oryza Schlauder, 1945: 23, pl. 5, figs 19 a–c.

Occurrence records. *Chatham Rise*: NIWA Stn TAN1107/T2, 43.411° S, 176.250° E, May 2011.

Holotype. Type is possibly held in Kiel, Germany.

Type locality. Mediterranean Sea.

Description. Coccosphere spherical to ellipsoidal, monothecate and dimorphic (Fig. 16F). Body rhabdoliths sacculiform with a low, bulging protrusion. In distal view, the elongate central cavity of the body rhabdolith is visible as a dark line.

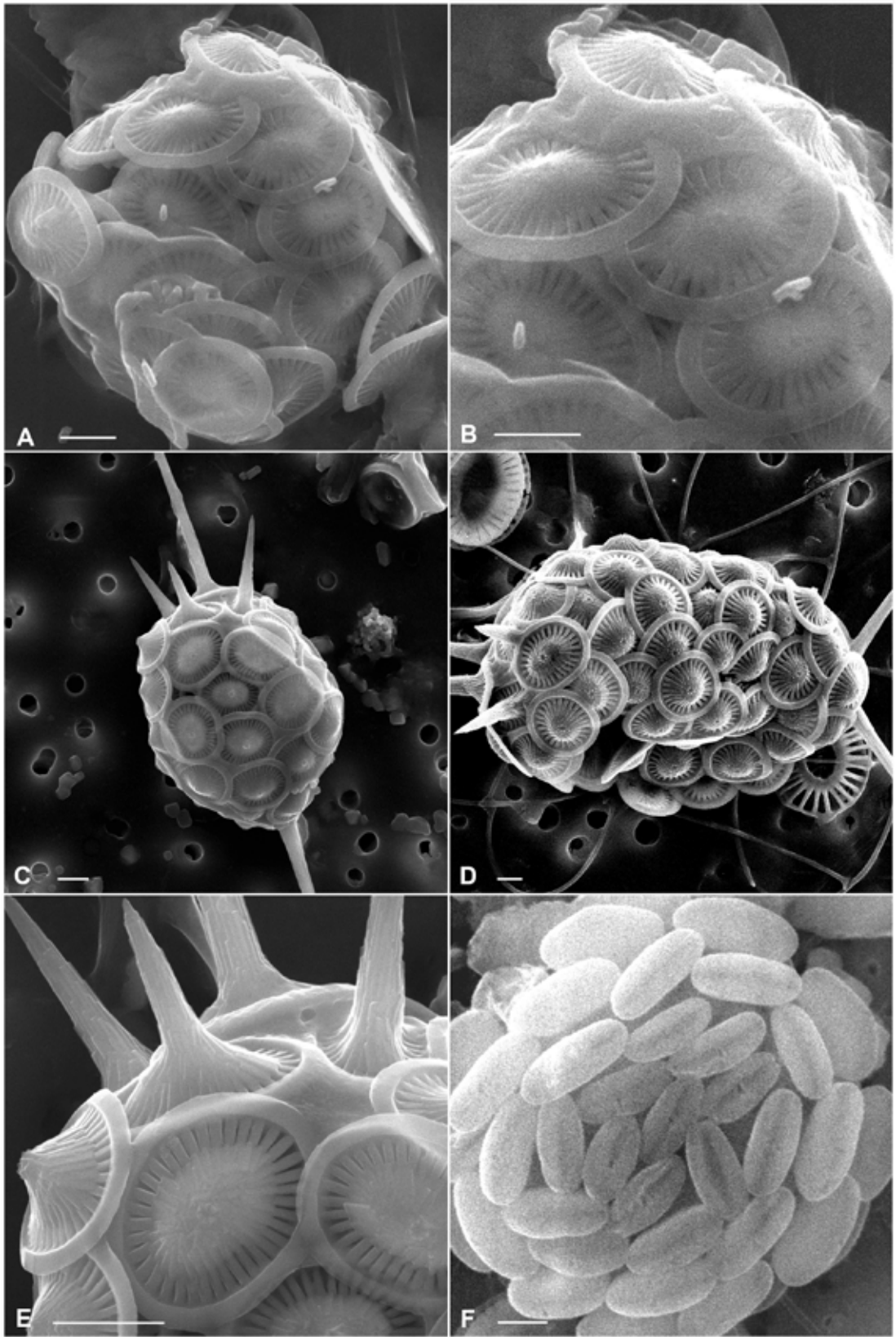

Figure 16. Coccolithophore morphology: **A.** cell of *Acanthoica acanthos* Schiller, 1925; **B.** coccoliths of *A. acanthos*; **C.** cell of *Acanthoica quattrospina* Lohmann, 1903 with long spines at each end; **D.** two dividing cells of *A. quattrospina*; **E.** circum-flagellar coccoliths of *A. quattrospina* with spines; **F.** cell of *Algirosphaera robusta* (Lohmann, 1902) Norris 1984. Scale bars A–F, 1 μm.

Distribution and cell abundance. This is quite a rare species and was found only in summer 2009 at a site over STF water of Chatham Rise (< 20 cells l^{-1}) (Fig. 17, Appendix 1, Table 1.1).

Previous records. *Algirosphaera robusta* was previously recorded by Norris (1961), at a NZOI station (B67) along a transect between northeast New Zealand and Tonga (Appendix 2, Table 2.1), and at one site off the

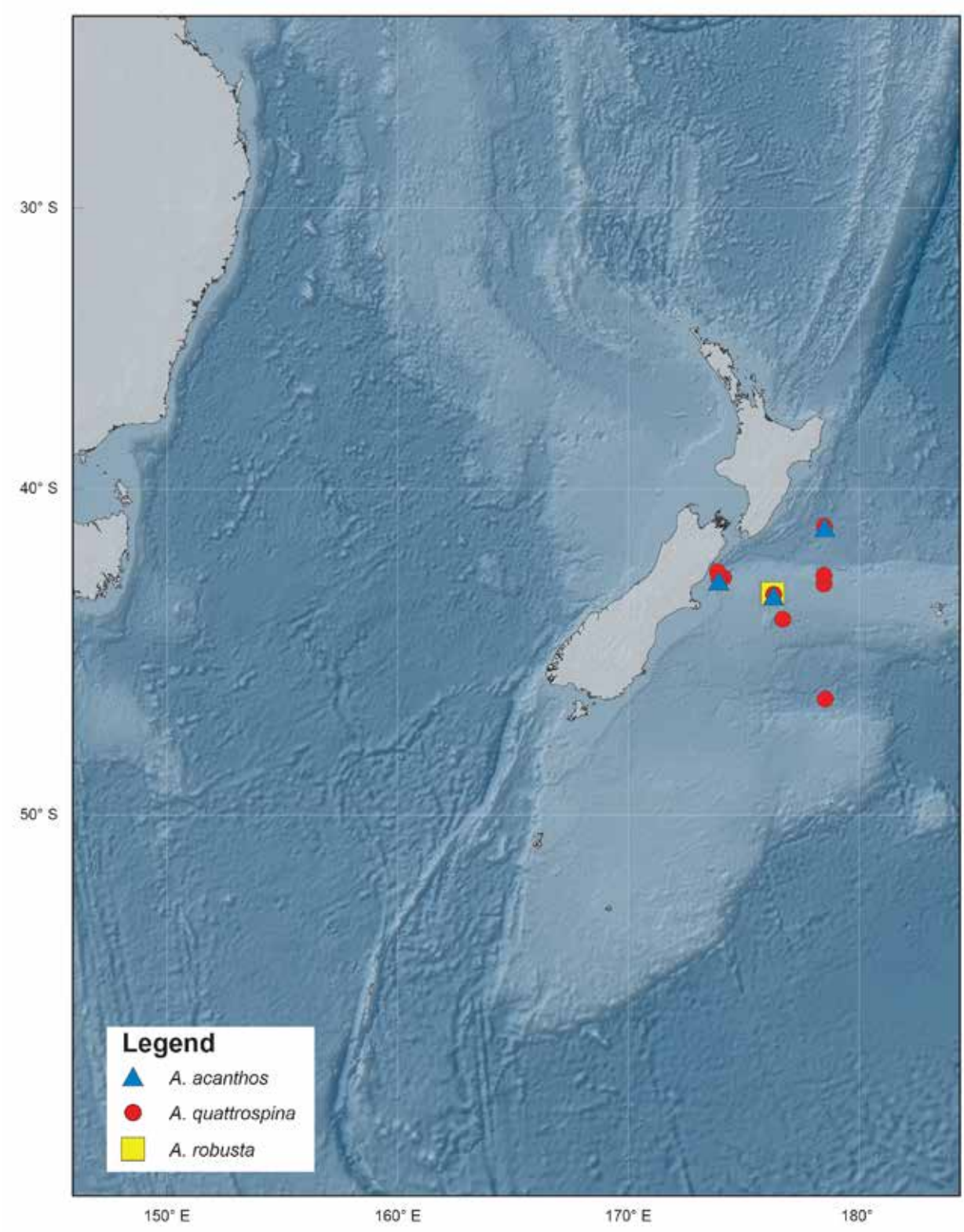

Figure 17. Distribution of *Acanthoica acanthos* Schiller, 1925; *Acanthoica quattrospina* Lohmann, 1903 and *Algirosphaera robusta* (Lohmann, 1902) Norris 1984 around New Zealand.

east coast of New Zealand (Chang & Northcote 2016).

Elsewhere, this species was widely recorded, e.g., in the tropical and subtropical waters of the South China Sea (Lee Chen *et al.* 2007), in the east Australian Current and Bass Strait, the Coral Sea, and northwestern Australia (Hallegraeff 2010), in the tropical and subtropical Atlantic Ocean (Poulton *et al.* 2017), in the subtropical northeast Atlantic (Broerse *et al.* 2000a), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the middle, eastern and northern Adriatic Sea (Mediterranean) (Šupraha *et al.* 2016; Skejić *et al.* 2018; Godrijan *et al.* 2018), in the western and eastern Arabian Sea, in the south and northeastern Indian Ocean (Kleijne 1992), in the Java upwelling region of the tropical Indian Ocean (Andruleit 2007), in the Bay of Bengal of the Indian Ocean (Mergulhao *et al.* 2013), in an upwelling

region off Somalia (NW Indian Ocean) (Broerse *et al.* 2000b), and in the Indian sector of the Southern Ocean (Patil *et al.* 2017).

Genus ***Cyrtosphaera*** Kleijne, 1992

Description. Coccospheres monothecate and varimorphic; rhabdolith with a rim, radial laths and a conical or sacculiform protrusion; protrusion (spine) increases in length towards one pole of the coccosphere (Cros & Fortuño 2002; Young *et al.* 2003).

Type species. *Cyrtosphaera aculeata* (Kamptner, 1941) Kleijne, 1992.

Cyrtosphaera aculeata (Kamptner, 1941) Kleijne, 1992

Fig. 18 A–B

(Kamptner) Kleijne, 1992: 34–36, pl. 1, figs 1–3; Cros & Fortuño, 2002: 80, figs 20A, B; Young *et al.* 2003: 59, pl. 26, figs 11, 14.

Basionym: *Acanthoica aculeata* Kamptner, 1941: 76, 79, pl. 1, figs 1, 3.

Synonyms: *Acanthoica aculeata* Kamptner, 1941: 76, 79, pl. 1, figs 1, 3; Gaarder & Hasle, 1971: 523, fig.2.; Borsetti & Cati, 1976: 209, pl. 12, fig.1; Nishida, 1979: pl. 13, fig. 3.

Syracorhabdus lactaria Lecal, 1965 (invalid, cited by Kleijne 1992 in synonymy of *C. lecaliae*).

Occurrence records. *Chatham Rise*: NIWA Stn TAN1107/NBM, 41.229° S, 178.512° E, May 2011.

Holotype. Type is held at the Natural History Museum Vienna, Austria.

Type locality. Southwest coast of Istria, Croatia.

Description. Coccosphere subspherical to elongate (8–12 µm long), monothecate (Fig. 18A, B). Rhabdolith varimorphic, with the rim turning upwards; a ring of radial laths in the central area with opening between them; conical inner central area with a protrusion ending in a papilla (Fig. 18B). Protrusions of some apical coccoliths modified into a spine.

Distribution and cell abundance. *Cyrtosphaera aculeata* was found only at one site in ST water north of Chatham Rise (Fig. 19). Cell concentration recorded at this site in the autumn of 2011 was low (300 cells l^{-1}) (Appendix 1, Table 1.9).

Previous records. Extant *Cyrtosphaera aculeata* was previously reported as a first–time record of New Zealand (Chang & Northcote 2016). Elsewhere, this species was recorded, e.g., in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the northern Adriatic Sea (Mediterranean) (Godrijan *et al.* 2018), in the northeastern Indian Ocean and Red Sea (Kleijne 1992), in the Java upwelling region of the tropical Indian Ocean (Andruleit (2007), and in the Indian sector of the Southern Ocean (Patil *et al.* 2017).

Cyrtosphaera lecaliae Kleijne, 1992

Fig. 18 C–D

Kleijne, 1992: 34–35, pl. 1, fig. 4; Cros & Fortuño, 2002: 82, figs 20C, D; Young *et al.* 2003: 59, pl. 26, figs 12, 15.

Synonyms: *Syracohabdus lactaria* Lecal, 1965: 65, text tig, fig.2; Lecal, 1965: 256–257, pl. 6, figs 18–21.

Acanthoica aculeata Kamptner *in* Borsetti & Cati, 1976: 209–210, pl. 12, fig. 1.

Occurrence records. *Chatham Rise*: NIWA Stn TAN1107/NBM, 41.229° S, 178.512° E, May 2011.

Holotype. Specimen illustrated by Kleijne (1992) on Plate 1, fig.4.

Type locality. Station T86-51-C-A, 34°19.9'N, 34°23.8'W, Central North Atlantic, depth 0–5m, 31 Aug 1986.

Description. Like *Cyrtosphaera aculeata*, coccosphere of this species subspherical to elongate (8–12 µm long), but with larger rhabdoliths than the latter (Fig. 18C). The central protrusion of the body coccolith (spine) is prominent and is much longer and more steeply sloping than that of *C. aculeata* (Fig. 18D).

Distribution and cell abundance. *Cyrtosphaera lecaliae* was found at only one site in ST water in autumn 2011 north of Chatham Rise (Fig. 19), where cell concentration was < 20 cell l^{-1} (Appendix 1, Table 1.9).

Previous records. This is a first record for New Zealand. Elsewhere, this species was also recorded, e.g., in the Yellow Sea (Wang *et al.* 2012), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the northern Adriatic Sea (Mediterranean) (Godrijan *et al.* 2018), in the Java upwelling region of the tropical Indian Ocean (Andruleit (2007), and in the Indian sector of the Southern Ocean (Patil *et al.* 2017).

Genus ***Discosphaera*** Haeckel, 1894

Description. Coccosphere monothecate with trumpet–like spines. Coccolith bases broadly elliptical, with normal rim, radial and lamellar cycles (Cros & Fortuño 2002; Young *et al.* 2003).

Type species. *Discosphaera thomsonii* Ostenfeld, 1899.

Discosphaera tubifera (Murray & Blackman, 1898) Ostenfeld, 1900

Fig. 20 A, B

(Murray & Blackman) Lohmann 1902: 141, pl. 5, figs 47, 48, 48a, 50; Halldal & Markali, 1955: 17, pl. 22, figs 1–3; McIntyre & Bé, 1967: 566, pl. 1; Norris, 1984: 35, figs 11-12; Gaarder & Hasle, 1971, fig. 8; Hallegraeff, 1984: 238, figs 34–36; Kleijne, 1992, pl. 7, figs 5–7; Cros & Fortuño, 2002: 83, figs 21 C, D; Young *et al*. 2003: 57, pl. 25, figs 12–15.

Basionym: *Rhabdosphaera tubifera* Murray & Blackman, 1898: 27.

Synonym: *Discosphaera thomsoni* Ostenfeld, 1899: 436.

Occurrence records. *Tasman Sea*: PINTS Stn C4, 39.960° S, 163.185° E.

Chatham Rise: NIWA Stn TAN1107/NBM, 41.229° S, 178.512° E, May 2011.

Holotype. Held at Kiel, Germany.

Type locality. Near Syracuse, Sicily, Italy.

Description. Coccosphere subspherical (13–15 µm), monothecate and monomorphic. Body coccolith (rhabdolith) made up of a distal trumpet-like structure linked to a proximal disc (Fig. 20A, B). The proximal disc with a well-developed rim, a radial ring of laths, and a lamellar ring surrounding a pore.

Distribution and cell abundance. *Discosphaera tubifera* was found only at one site each in ST water north of Chatham Rise and the Tasman Sea (Fig. 21). Cell concentrations in autumn 2011 were < 100 cells l^{-1} (Appendix 1, Table 1.9).

Previous records. *Discosphaera tubifera* was previously recorded by Norris (1961), at four NZOI stations, B67, B77, B80 and B85, along a transect between northeast New Zealand and Tonga (Appendix 2, Table 2.1), and at one site each on both the east and west coast of New Zealand (Chang & Northcote 2016).

Elsewhere, this species is very widely distributed, e.g., in the equatorial and subequatorial Pacific Ocean (Hagino & Okada 2004), in the tropical and subtropical waters of South China Sea (Lee Chen *et al*. 2007), in the East Australian Current, Bass Strait, the Great

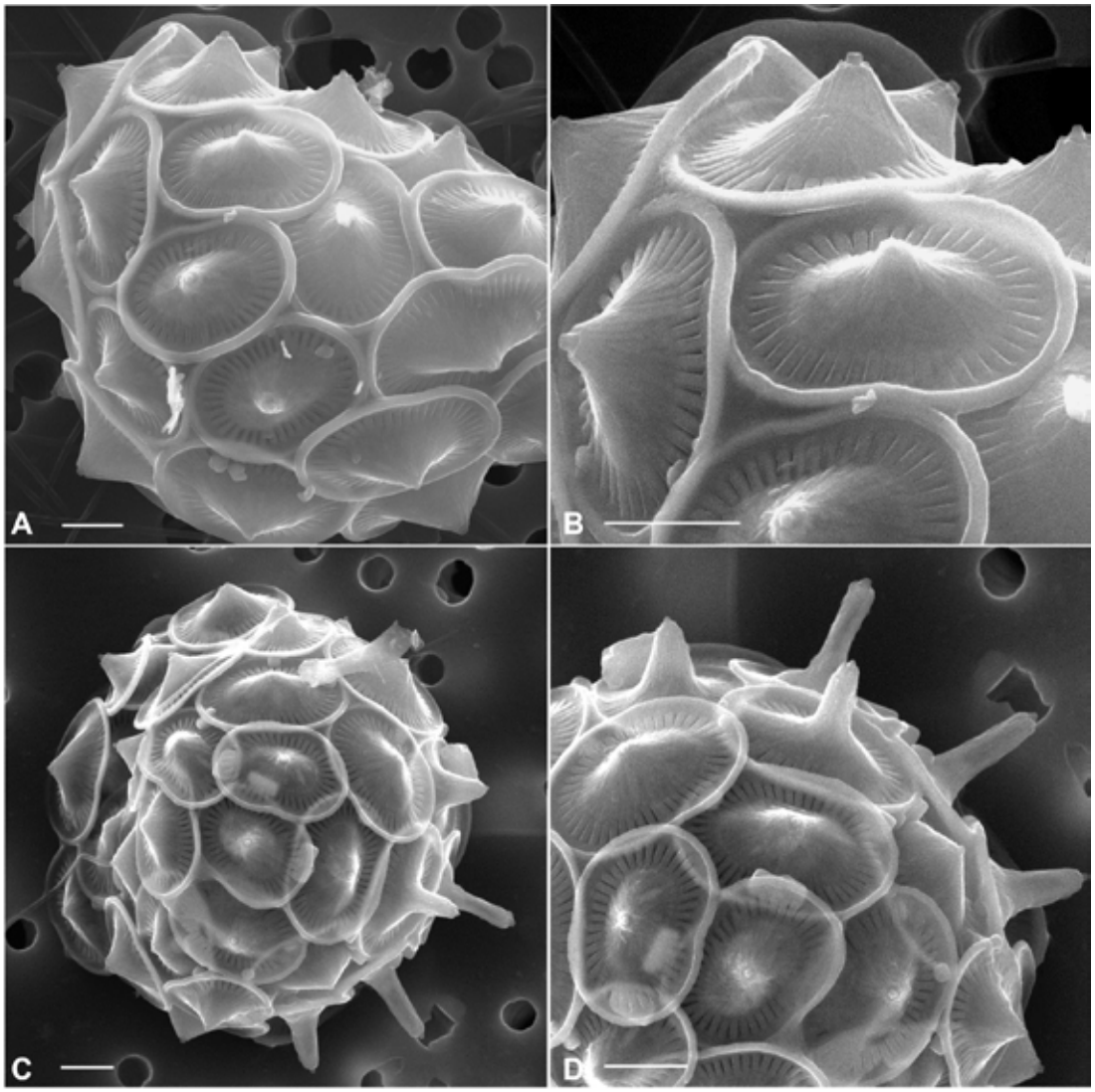

Figure 18. Coccolithophore morphology: **A.** cell of *Cyrtosphaera aculeata* (Kamptner, 1941) Kleijne 1992; **B.** detail of some coccoliths of *C. aculeata* with prominent protrusion ending in a papilla on each coccolith; **C.** cell of *Cyrtosphaera lecaliae* Kleijne, 1992; **D.** detail of some coccoliths of *C. lecaliae*, with well-developed spines on circum-flagella coccoliths and less prominent papillae on body coccoliths. Scale bars A–D, 1 µm.

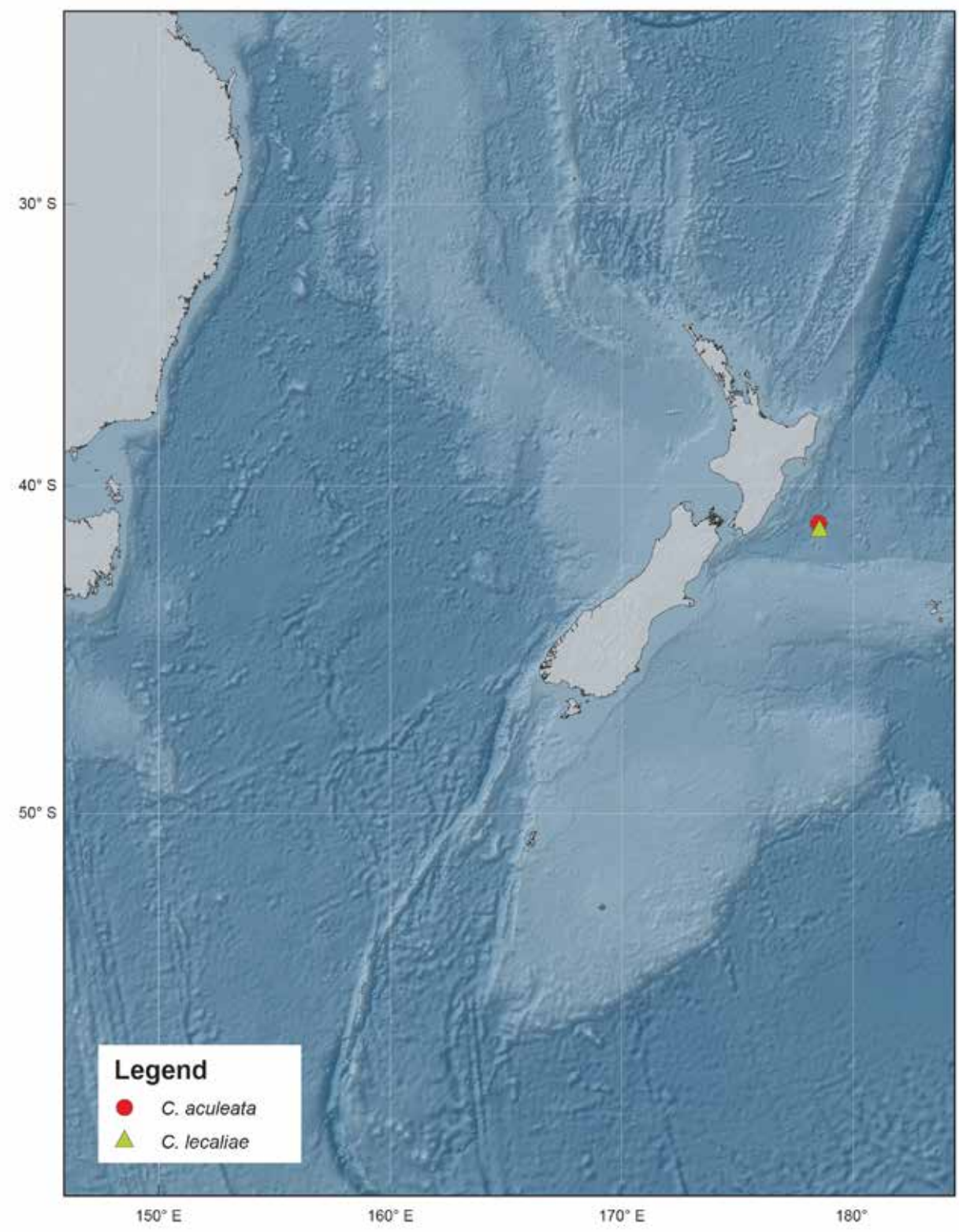

Figure 19. Distribution of *Cyrtosphaera aculeata* (Kamptner, 1941) Kleijne 1992 and *C. lecaliae* Kleijne, 1992 around New Zealand.

Barrier Reef, the Gulf of Carpentaria and northwestern Australia (Hallegraeff 2010), in the Australian sector of the Southern Ocean (Findlay & Giraudeau 2000), along a temperate to polar gradient in the West Pacific sector of the Southern Ocean (Malinverno *et al.* 2015), in the subtropical South Atlantic (Baumann *et al.* 2008), in the tropical and subtropical Atlantic Ocean (Poulton *et al.* 2017), in the subtropical and temperate northeast Atlantic Ocean (Broerse *et al.* 2000a), off Terceira Island, Azores, in the Central North Atlantic (Narciso *et al.* 2016), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the middle Adriatic Sea (northern Mediterranean) (Skejić *et al.* 2018), in the eastern North Atlantic Ocean, Mediterranean Sea, eastern and western Arabian Sea, Gulf of Aden, Red Sea, and northeastern Indian Ocean (Kleijne 1992), in the Java upwelling region of the tropical Indian Ocean (Andruleit 2007), in the Bay of Bengal of the Indian Ocean (Mergulhao *et al.*

2013), in an upwelling region off Somalia (NW Indian Ocean) (Broerse *et al*. 2000b), and in the Indian sector of the Southern Ocean (Patil *et al*. 2017).

Genus ***Palusphaera*** Lecal, 1965; emend. Norris, 1984

Description. Coccospheres monothecate; one type of coccolith, with a long styliform central structure (Cros & Fortuño 2002; Young *et al*. 2003).

Type species. *Palusphaera vandelii* Lecal, 1965

Palusphaera vandelii Lecal, 1965; emend. Norris, 1984

Fig. 20 C, D

Lecal, 1965b: 68–69, text–fig. k, pl. 2, fig. 9; Norris, 1984: 35, figs 1f, 9, 10; Kleijne, 1992: 38–39, pl. 8, fig. 1; Giraudeau & Bailey, 1995, pl. 3, fig. 3; Cros & Fortuño, 2002: 84, figs 22 A, B; Young *et al*. 2003: 57, pl. 25, figs 8–9.

Synonym: *Rhabdosphaera longistylis* Schiller, 1925: 40, pl. 4, fig. 41.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS2, 42.747° S, 175.841° E, Jan–Feb 2009; NIWA Stn TAN0902/YS3, 43.101° S, 176.095° E, Jan–Feb 2009; NIWA Stn TAN0902/YS29, 46.636° S, 178.556° E, Jan–Feb 2009; NIWA Stn TAN0902/YS30, 46.638° S, 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS32, 46.633° S 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS36, 43.446° S, 178.488° E, Jan–Feb 2009; NIWA Stn TAN0902/YS38, 43.102° S, 178.489° E, Jan–Feb 2009; NIWA Stn TAN0902/YS39, 42.820° S, 178.495° E, Jan–Feb 2009; NIWA Stn C4, 39.960° S, 162.185° E, Jan-Feb 2010; NIWA Stn TAN1107/SBM, 46.656° S, 178.556° E, May 2011; NIWA Stn TAN1107/T8, 42.340° S, 178.504° E, May 2011.

Holotype. Type is possibly held at University of Natal, Department of Botany, Durban, South Africa (which was where Norris was based).

Type locality. Indian Ocean (R/V *Anton Bruun*, International Indian Ocean Expedition 1963).

Description. Coccosphere subspherical (without spines, 5–6 µm), monothecate and monomorphic. Rhabdoliths with relatively long, distal spines (9–12 µm long) and an almost flat, circular proximal disc (Fig. 20C). A rather wide, slightly raised rim on the upper face of the proximal disc with smooth central area towards the base of spine (Fig. 20D).

Distribution and cell abundance. *Palusphaera vandelii* was mainly found in ST and SA waters over Chatham Rise, and at only one other site in ST water in the Tasman Sea, to the west of New Zealand (Fig. 21). This species was recorded on three occasions – summer of 2009 and 2010, and autumn 2011 (Appendix 1, Tables 1.1, 1.6, 1.9). It was most widely distributed in summer 2009 – at up to 8 sites in ST, STF and SA waters, in the vicinity of Chatham Rise (Appendix 1, Table 1.1), and in the Tasman Sea (Appendix 1, Table 1.6). Cell concentrations generally ranged from hundreds to thousands per litre, and with only two exceptions, over tens of thousands (up 31,000 cells l^{-1}) in summer 2009, to the east of New Zealand (Appendix 1, Table 1.1).

Previous records. Extant *Palusphaera vandelii* was previously reported as a first-time record for New Zealand by Chang & Northcote (2016). Elsewhere, *Palusphaera vandelii* is widely distributed, e.g., in the tropical and subtropical waters of the South China Sea (Lee Chen *et al*. 2007), in both the Yellow Sea and East China Seas (Wang *et al*. 2012), in the eastern Pacific sector of the Southern Ocean (Bellingshausen and Amundsen Seas) (Gravalosa *et al*. 2008), along a temperate to polar gradient in the West Pacific sector of the Southern Ocean (Malinverno *et al*. 2015), in the tropical and subtropical Atlantic Ocean (Poulton *et al*. 2017), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the middle and northern Adriatic Sea (Mediterranean) (Skejić *et al*. 2018; Godrijan *et al*. 2018), in the Mediterranean, eastern and western Arabian Sea, Gulf of Aden, Red Sea, and the south and northeastern Indian Ocean (Kleijne 1992), in the Java upwelling region of the tropical Indian Ocean (Andruleit (2007), and in the Indian sector of the Southern Ocean (Patil *et al*. 2017).

Genus ***Rhabdosphaera*** Haeckel, 1894

Description. Coccospheres dithecate and dimorphic. Two different types of coccoliths, inner spine-bearing and outer non-spine-bearing coccoliths, distributed around coccosphere, radial cycle absent, lamellar cycle filling central area and forming a spine (Cros & Fortuño 2002; Young *et al*. 2003).

Type species. *Rhabdosphaera clavigera* Murray & Blackman, 1898.

Rhabdosphaera xiphos (Deflandre & Fert, 1954) Norris, 1984

Fig. 20 E, F

Deflandre & Fert, 1954: 42, pl. 8, figs 1–3; Norris, 1984: 33, figs 1d, e, 6–8; Kleijne, 1992: 41–42, pl. 8, figs 2, 5; Cros & Fortuño, 2002: 85, figs 23C, D; Young *et al*. 2003: 57, pl. 25, figs 5–7.

Basionym: *Rhabdolithus xiphos* Deflandre & Fert, 1954: 42, pl. 8, figs

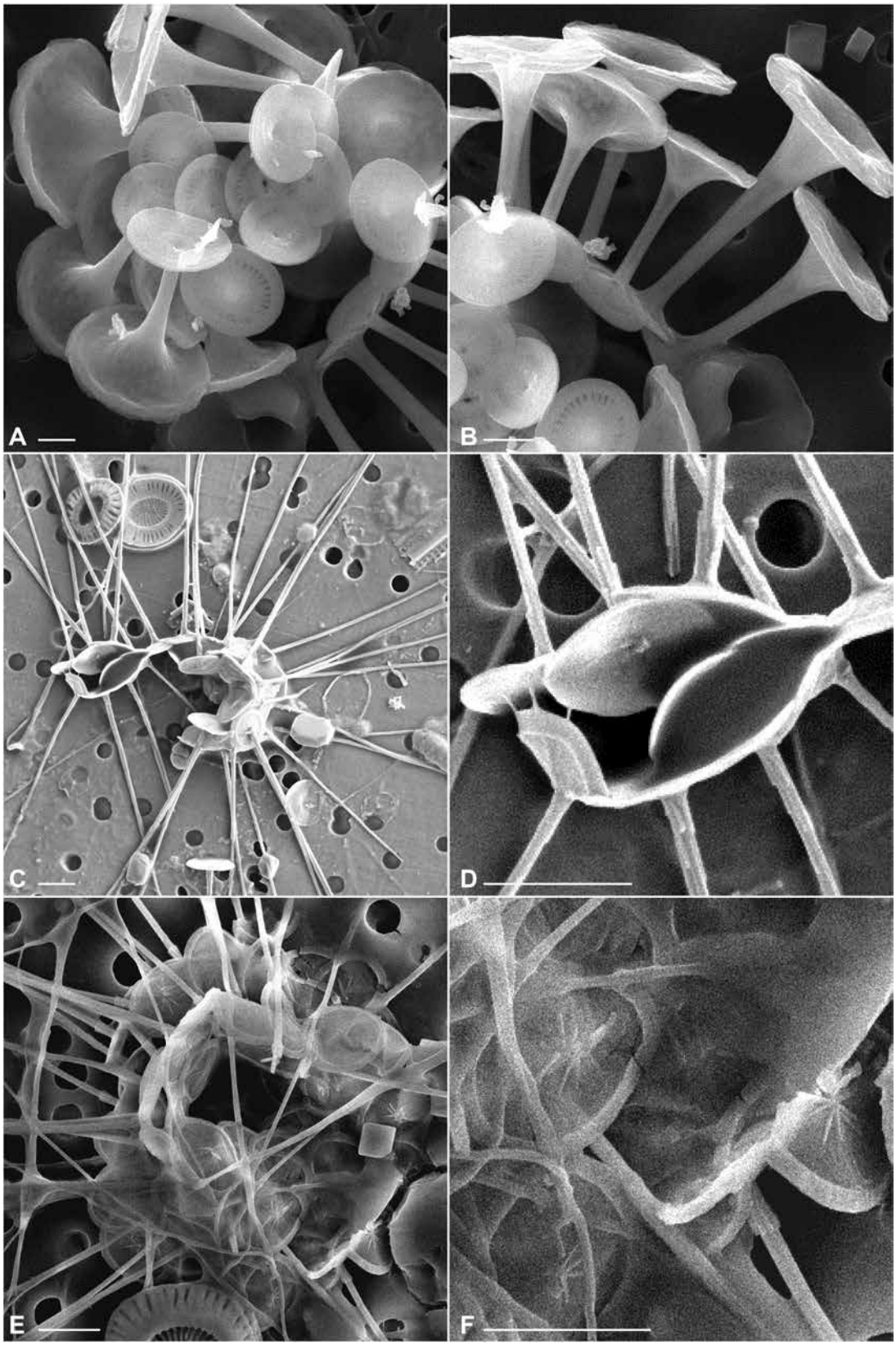

Figure 20. Coccolithophore morphology: **A.** cell of *Discophaera tubifera* (Murray & Blackman, 1898) Ostenfeld 1900; **B.** coccoliths of *D. tubifera*; **C–D.** coccoliths of *Palusphaera vandelii* Lecal, 1965, emend. Norris 1984; **E.** a broken cell of *Rhabdosphaera xiphos* (Deflandre & Fert, 1954) Norris 1984; **F.** coccoliths of *R. xiphos*, showing distinctive star pattern on the distal surface. Scale bars A–B, 1 μm; C, 3 μm; D–F 1 μm.

1–3.

Synonym: *Rhabdosphaera longistylis* (Schiller) Okada & McIntyre, 1977: 17, pl. 5, fig. 6.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS2, 42.747° S, 175.841° E, Jan–Feb 2009; NIWA Stn TAN0902/YS30, 46.638° S, 178.542° E,

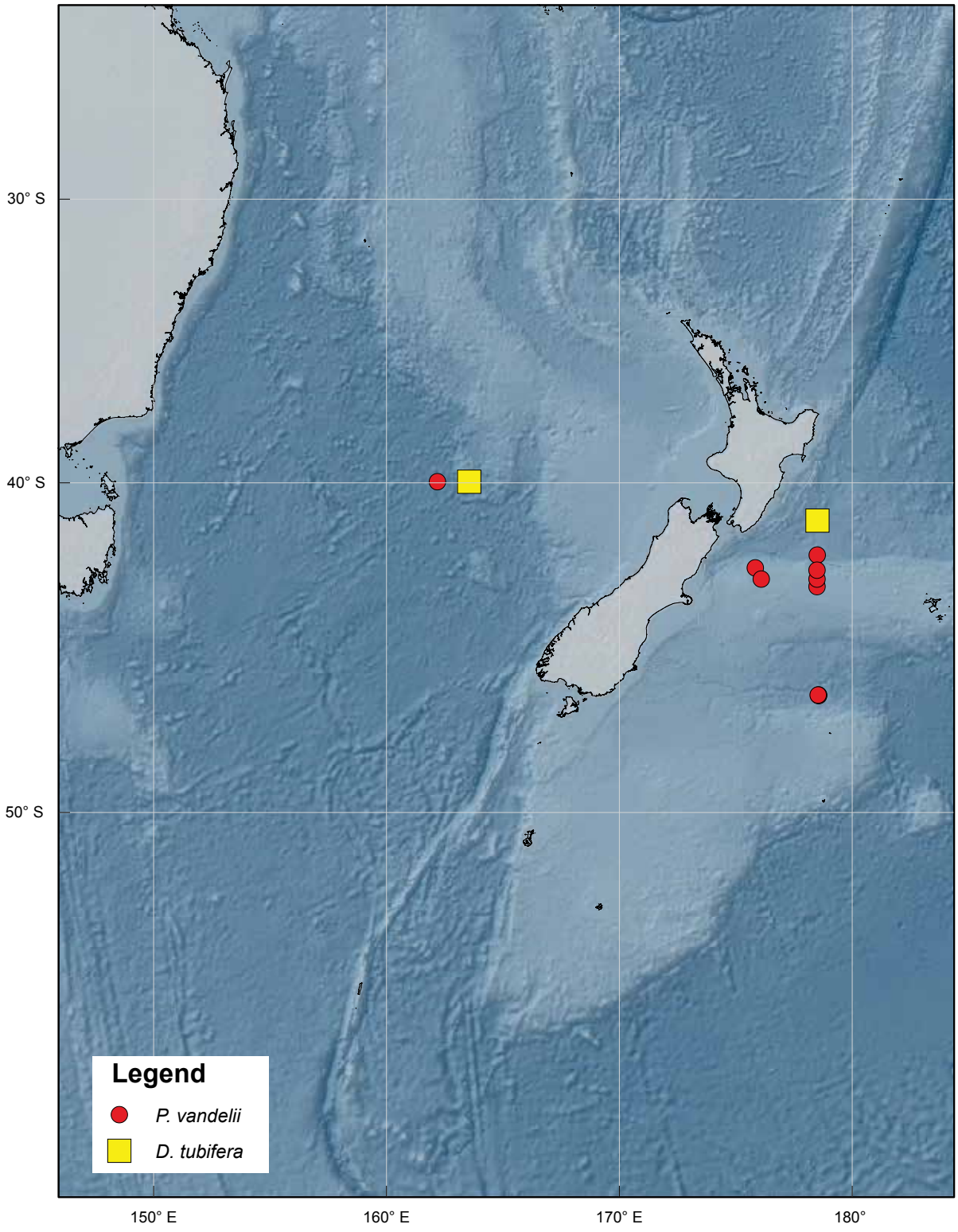

Figure 21. Distribution of *Discosphaera tubifera* (Murray & Blackman, 1898) Ostenfeld 1900 and *Palusphaera vandelii* Lecal, 1965; emend. Norris 1984 around New Zealand.

Jan–Feb 2009; NIWA Stn TAN0902/YS32, 46.633° S 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS38, 43.102° S, 178.489° E, Jan–Feb 2009; NIWA Stn TAN0902/YS39, 42.820° S, 178.495° E, Jan–Feb 2009.

Holotype. Type is held at Paris, Laboratoire de Micropaléontologie–probably now at Muséum national d'Histoire naturelle, Paris, France.

Type locality. Monaco, Mediterranean Sea.

Description. Coccosphere subspherical (6–8 µm) and dimorphic. On the distal face of the circular endothecal rhabdolith, there is a delicate spine with a short collar at its base. The broad elliptical exothecal coccoliths are larger than the endothecal coccoliths and are spineless (Fig. 20E); with a slightly raised rim and a characteristic star-like central structure on the distal face (Fig. 20F).

Distribution and cell abundance. *Rhabdosphaera xiphos* was found only in summer 2009, in ST, STF waters over, and SA water to the south of Chatham Rise (Fig. 22). Cell concentrations were generally low, ranging from 100 to 500 cells l^{-1} (Appendix 1, Table 1.1). The only exception was at a site in STF water, where up to 5,000 cells l^{-1} was recorded.

Previous records. This extant species was previously reported around New Zealand (Chang & Northcote 2016). Elsewhere, this species was widely recorded, e.g., in the western subarctic Pacific and Bering Sea (Hattori *et al*. 2004), in the subtropical South Atlantic Ocean (Baumann *et al*. 2008), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the middle, eastern and northern Adriatic Sea (Mediterranean) (Šupraha *et al*. 2016; Skejić *et al*. 2018; Godrijan *et al*. 2018), in the Mediterranean Sea, Red Sea, and the eastern north Atlantic (Kleijne 1992), and in the Indian sector of the Southern Ocean (Patil *et al*. 2017).

Family **Syracosphaeraceae** (Lohmann, 1902) Lemmermann, 1903

Description. Coccospheres mostly dithecate. Endothecal coccoliths (inner layer) typically are muroliths with a well-developed central-area lath-ring and variable inner central-area, while exothecal coccoliths (outer layer) are more variable, could be planolith, muroliths and dome-shaped forms (Kleijne 1993; Cros & Fortuño 2002; Young *et al*. 2003).

Genus ***Syracosphaera*** Lohmann, 1902

Syracosphaera Lohmann, 1902: 33.

Caneosphaera Gaarder in Gaarder & Heimdal, 1977: 58; *Deutschlandia* Lohmann 1912: 156.

Description. Coccospheres usually dithecate. Endothecal coccoliths are muroliths with one, two or three flanges; dimorphism is frequent, with apical spine–bearing, circum–flagellar coccoliths, and antapical coccoliths. Exothecal coccoliths highly variable, can be planoliths, mucroliths or dome–shaped (Cros & Fortuño 2002; Young *et al*. 2003).

Type species. *Syracosphaera pulchra* Lohman, 1902

Syracosphaera anthos (Lohmann, 1912) Janin, 1987

Fig. 23 A–F

Janin, 1987: 112–113; Kleijne, 1993: 236, pl. 6 fig. 10; Giraudeau & Bailey, 1995, pl. 3, figs 11–13; Cros 2000, pl. 1, figs 3–4; Cros & Fortuño, 2002: 96–97, figs 34–35; Young *et al.* 2003: 39, pl. 16, figs 1–4.

Basionyms: *Deutschlandia anthos* Lohmann, 1912: 156, pl. 2, figs 5–6, Heimdal & Gaarder, 1981: 48–50, pl. 5, figs 23–26.

Syracosphaera variabilis (Halldal & Markali) Okada & McIntyre, 1977: 27, pl. 9, figs 7–8; Nishida, 1979, pl. 8, figs 1 a, b.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS2, 42.747° S, 175.841° E, Jan–Feb 2009; NIWA Stn TAN0902/YS32, 46.633° S 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS56, 41.235° S, 178.522° E, Jan–Feb 2009; NIWA Stn TAN1102/NH175, 43.556° S, 179.699° E, Feb 2011; NIWA Stn TAN1107/T1, 42.351° S, 175.651° E, May 2011; NIWA Stn TAN1107/T2, 43.411° S, 176.250° E, May 2011; NIWA Stn TAN1107/SBM, 46.656° S, 178.556° E, May 2011; NIWA Stn TAN1107/T8, 42.340° S, 178.504° E, May 2011.

Kaikoura: NIWA Stn TAN0904/S13 46.670° S, 174.409° E, Apr 2009; NIWA Stn TAN0904/S21, 42.401° S, 174.264° E; NIWA Stn TAN0904/33, 42.900° S, 174.135° E, Apr 2009; NIWA Stn TAN0904/S45, 42.941° S, 173.926° E, Apr 2009; NIWA Stn TAN0904/S55, 42.207° S, 174.702° E, Apr 2009; NIWA Stn TAN0904/S71, 42.642° S, 174.584° E, Apr 2009; NIWA Stn TAN0904/S85, 42.614° S, 174.097° E, Apr 2009; NIWA Stn TAN0904/S95, 42.535° S, 173.607° E, Apr 2009.

Tasman Sea: PINTS Stn C10, 43.514° S, 160.515° E, Jan 2010; PINTS Stn C16, 46.302° S, 159.883° E, Jan 2010; PINTS Stn C20, 39.945° S, 162.276° E, Jan 2010; PINTS Stn C21, 39.966° S, 162.177° E, Jan 2010; PINTS Stn C24, 46.022° S, 156.822° E, Jan 2010; PINTS Stn C33, 45.956° S, 153.323° E, Jan 2010; PINTS Stn C34, 39.396° S, 162.170° E, Jan 2010; PINTS Stn C35, 29.956° S, 162.170° E, Jan 2010; PINTS Stn C46, 45.854° S, 150.872° E, Jan 2010; PINTS Stn C50, 44.220° S, 148.750° E, Jan 2010.

Holotype. Not recorded.

Type locality. Atlantic Ocean, east of Sargasso Sea.

Description. Coccosphere subspherical (11–14 µm) and dithecate with dimorphic endothecal coccoliths (Fig. 23A, B). Exothecal coccolith is a circular disc (planoliths) (4–6 µm wide) with a very broad rim, slightly raised with curved sutures; the central structure is a small dome with either a smooth or a rough surface (Fig. 23C–F). Endothecal coccoliths (2.2–2.4 µm long) are elliptical with a slightly raised rim (Fig. 23C, D); the central area is vaulted, and the laths are curved near the rim. Circum-flagellar coccolith has a prominent spine.

Distribution and cell abundance. *Syracosphaera anthos* was widespread in distribution. It was recorded both off Kaikoura and in ST, STF and SA waters over Chatham Rise, to the east, and in the open waters of the

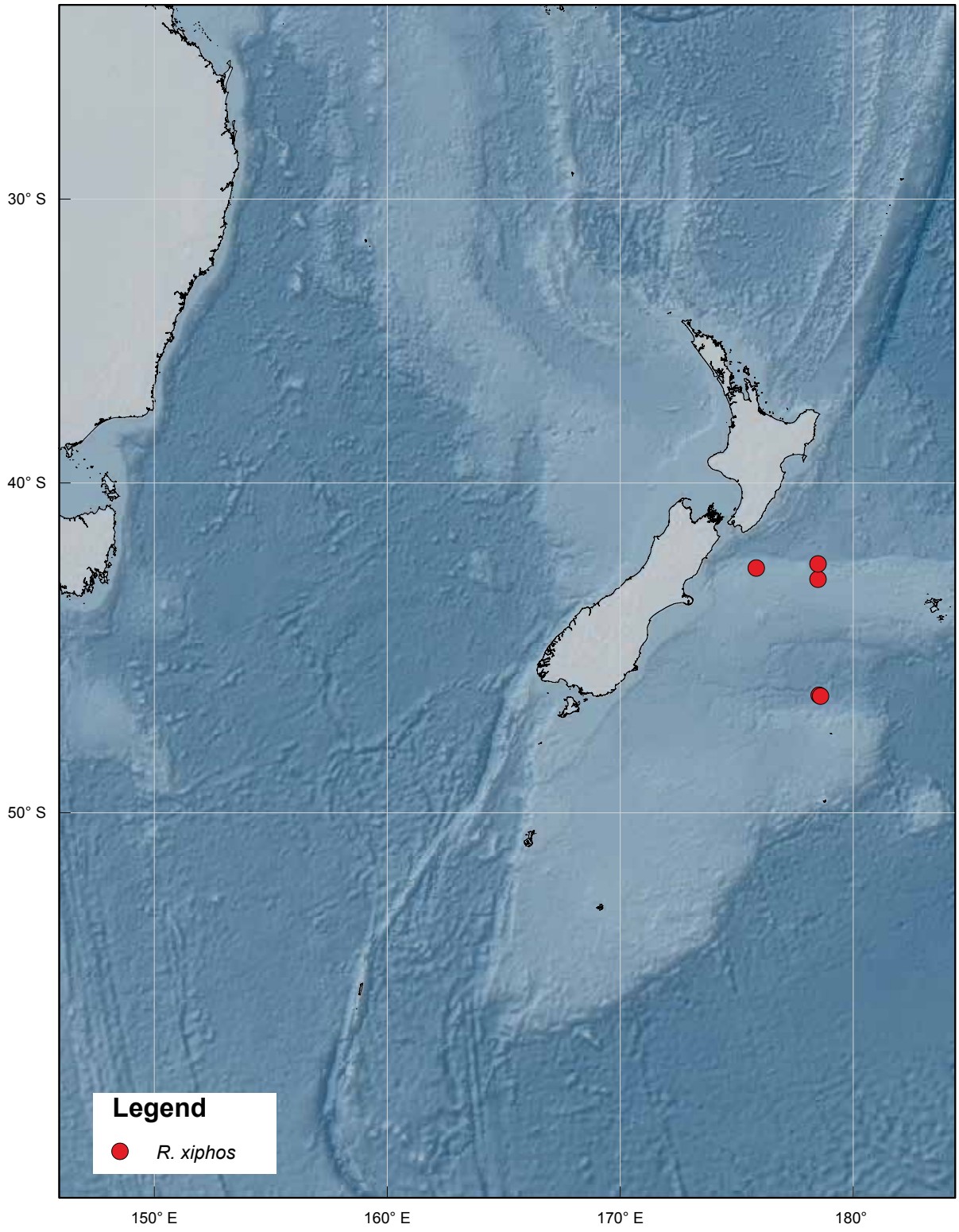

Figure 22. Distribution of *Rhabdosphaera xiphos* (Deflandre & Fert, 1954) Norris 1984 around New Zealand.

Tasman Sea, to the west of New Zealand (Fig. 24). In this study *S. anthos* was recorded in all four summers from 2009 to 2012 (Appendix 1, Tables 1.1, 1.6, 1.7, 1.10) and autumn of 2009 to 2011 (Appendix 1, Table 1.2, 1.9). Cell concentrations ranged from low to moderate, with an exception of one site in STF water over Chatham Rise, in the summer of 2009, where up to 101,000 cells l^{-1} were recorded (Appendix 1, Tables 1.1, 1.6, 1.7). Off Kaikoura in autumn 2009, cell concentrations generally ranged from very low to moderate, with up to 12,000 cells l^{-1} recorded at one site (Appendix 1, Table 1.2). Cell concentrations recorded in autumn 2011, over Chatham Rise, however, were < 2,000 cells l^{-1} (Appendix 1, Table 1.10).

Previous records. This extant species was previously reported as a first-time record by Chang & Northcote

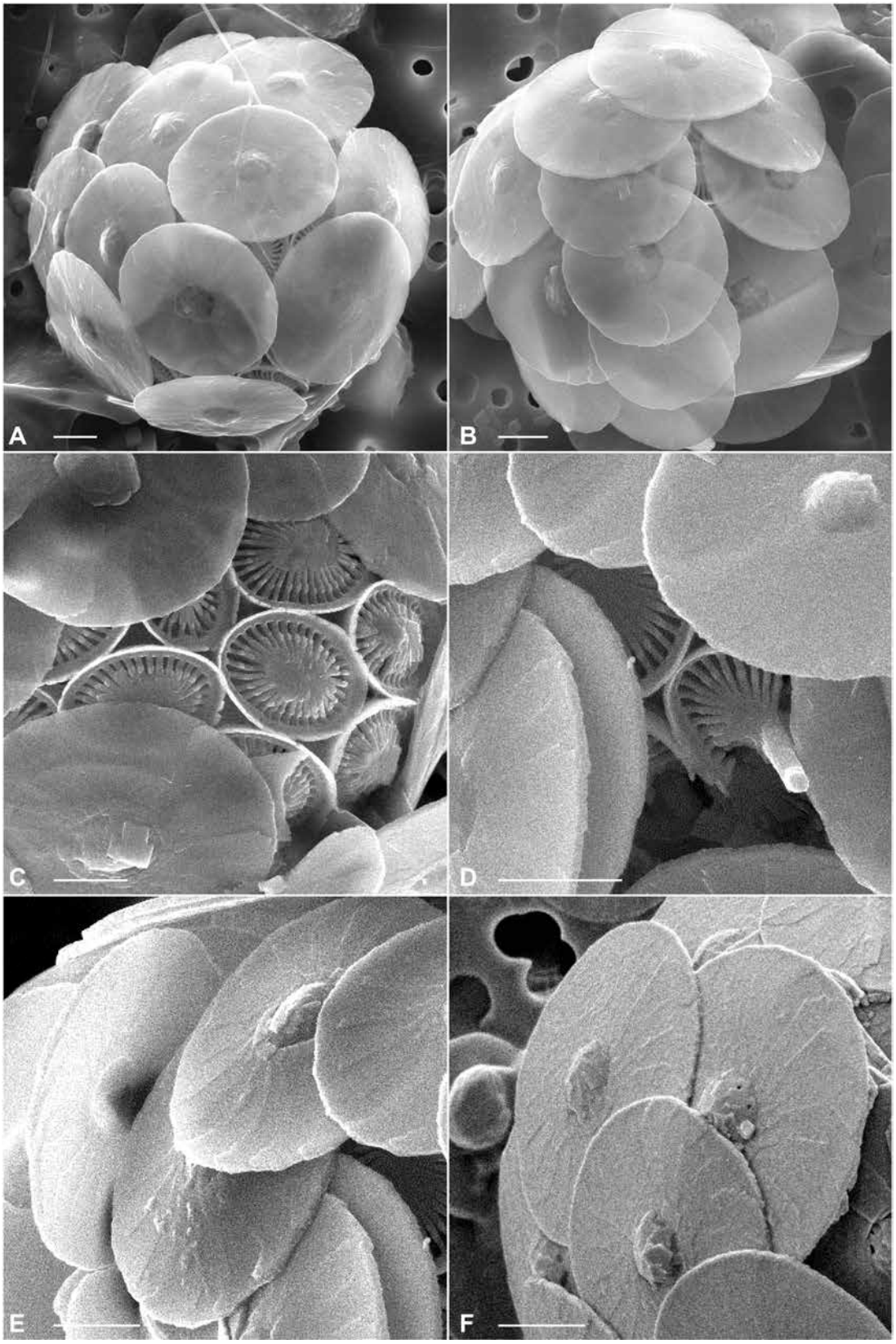

Figure 23. Coccolithophore morphology: **A–B.** cells of *Syracosphaera anthos* (Lohmann, 1912) Janin 1987; **C–D.** dimorphic coccoliths of *S. anthos*; **E–F.** exothecal coccoliths of *S. anthos*. Scale bars A–F, 1 μm.

(2016). Elsewhere, this species has been recorded in many parts of the world, e.g., in the Australian sector of the Southern Ocean (Findlay & Giraudeau 2000), in the tropical and subtropical Atlantic Ocean (Poulton *et al*. 2017), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the eastern Mediterranean Sea (Dimiza *et al*. 2016), in the middle and eastern Adriatic Sea (northern Mediterranean) (Šupraha *et al*. 2016; Skejić *et al*. 2018), in the Arabian Sea (Schiebel *et al*. 2004), in the Java upwelling region of the tropical Indian

Ocean (Andruleit 2007), and in the Indian sector of the Southern Ocean (Patil *et al.* 2017).

Syracosphaera arethusae **HOL** (Kamptner, 1941) Kleijne, 1991; Triantaphyllou et al., 2015

Fig. 25 A-D

Kleijne, 1991: 31, pl. 5, figs 3–4; Winter & Siesser, 1994: 145, fig. 151; Cros & Fortuño, 2002: 159, figs 99 A, B; Young *et al.* 2003: 103, pl. 48, fig. 7; Triantaphyllou *et al.* 2015: 466, pl. 4., figs 1-6.

Basionym: *Corisphaera arethusae* Kamptner *in* Borsetti & Cati, 1972: 403, pl. 48, fig. 3 a, b.

Syracosphaera sp. type D Kleijne, 1993: 242.

Synonym: *Homozogosphaera arethusae* (Kamptner, 1941) Kleijne, 1991: 31, pl. 5, fig. 3, 4; Winter & Siesser, 1994: 145, fig. 151.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS2, 42.747° S, 175.841° E, Jan–Feb 2009;

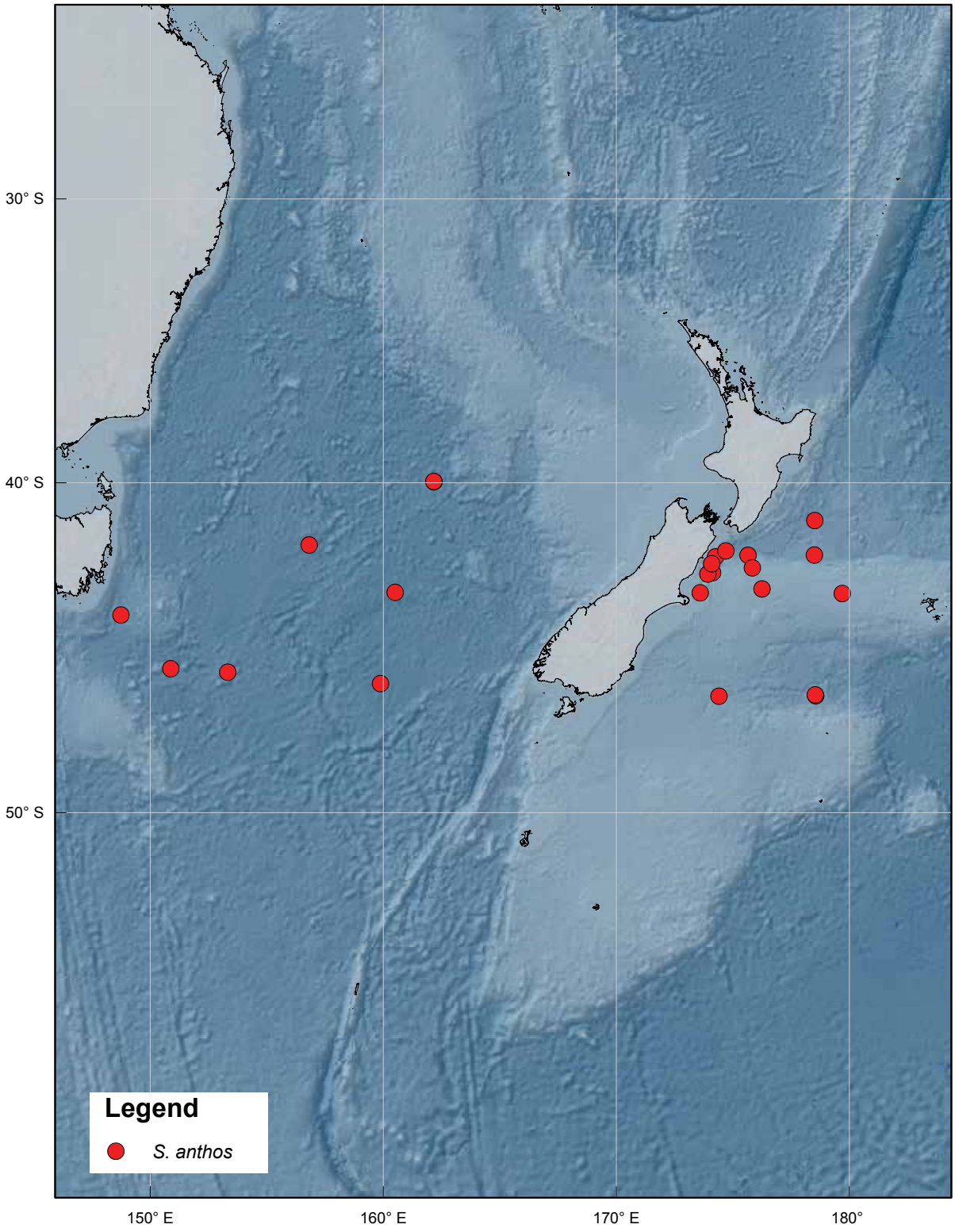

Figure 24. Distribution of *Syracosphaera anthos* (Lohmann, 1912) Janin 1987 around New Zealand.

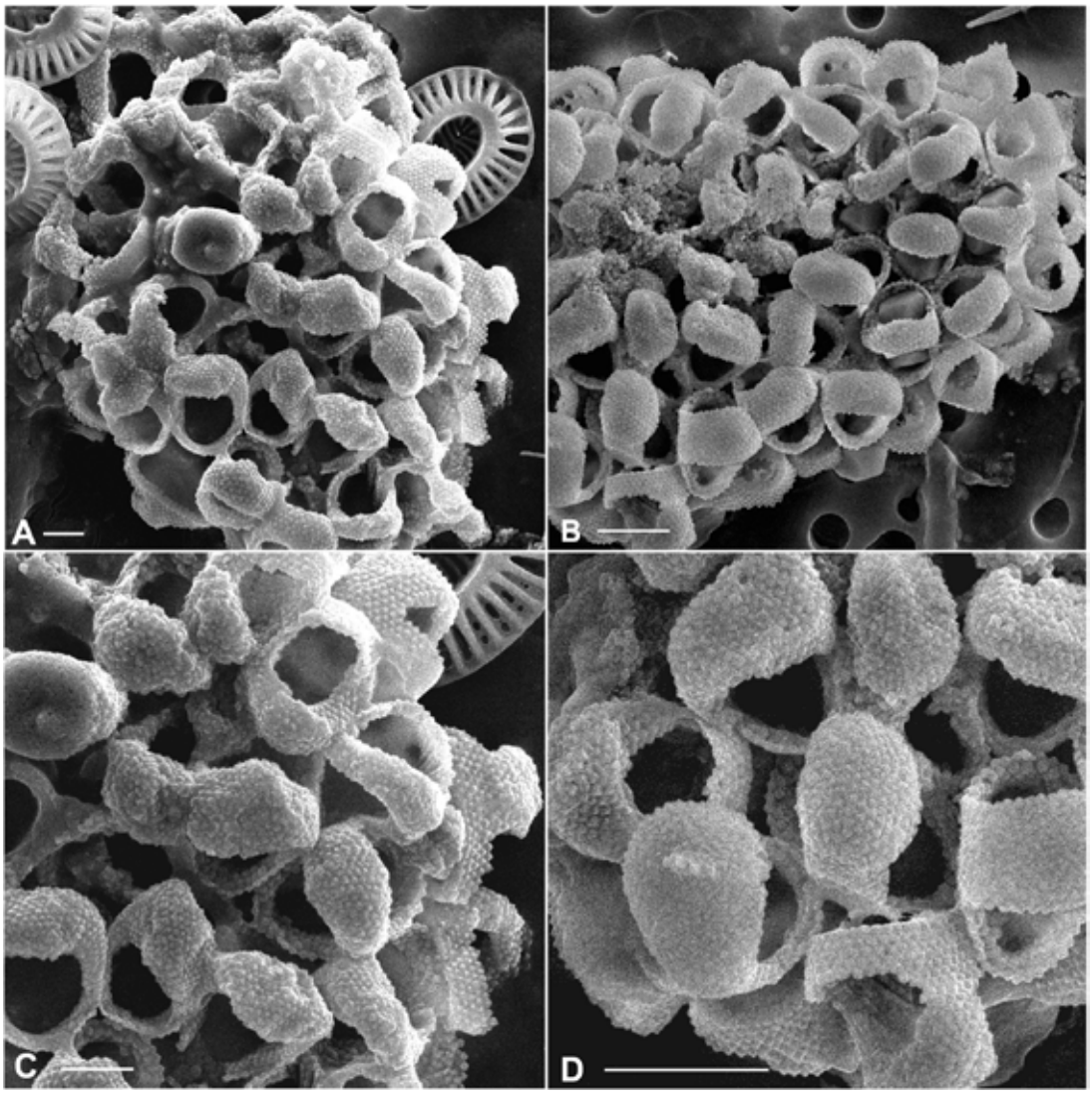

Figure 25. Coccolithophore morphology: **A–B.** cells of holococcolith-bearing form of *Syracosphaera arethusae* HOL (Kamptner, 1941) Triantaphyllou *et al*., 2015; **C–D.** coccoliths of *S. arethusae* HOL. Scale bars A–D, 1 µm.

NIWA Stn TAN0902/YS30, 46.638° S, 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS36, 43.446° S, 178.488° E, Jan–Feb 2009; NIWA Stn TAN0902/YS38, 43.102° S, 178.489° E; NIWA Stn TAN0902/YS39, 42.820° S, 178.495° E, Jan–Feb 2009.

Holotype. Type is held at Vienna, Natural History Museum, Austria.

Type locality. Southwest coast of Istria, Croatia.

Description. Coccosphere of this holococcolith-bearing form ovoid (9–13 µm long) (Fig. 25A, B). Coccolith length 1.6–1.8 µm. Body coccoliths have a proximal tube, with wide, broad arch, and a distal, robust bridge which is sometimes very broad (Fig. 25C, D).

Distribution and cell abundance. *Syracosphaera arethusae* HOL was recorded only in summer 2009, at five sites over and to the south of Chatham Rise (Fig. 26). Cell concen-trations varied from 300 to 1,000 cells l^{-1} (Appendix 1, Table 1.1).

Previous records. This life-cycle phase (holococcolith-bearing form) was previously reported by Chang & Northcote (2016) off the east coast of New Zealand. Elsewhere, this species was also recorded, e.g., in the northeastern Atlantic (Kleijne 1991), as *Homozogosphaera arethusae* in the tropical and subtropical Atlantic Ocean (Poulton *et al.* 2017), in the Mediterranean Sea (Cros & Fortuño 2002; Kleijne 1991), in the Aegean Sea (NE Mediterranean) (Dimiza *et al.* 2015), in the middle, eastern and northern Adriatic Sea (Mediterranean) (Šupraha *et al.* 2016; Skejić *et al.* 2018; Godrijan *et al.* 2018), and in the tropical Indian Ocean (Kleijne 1991).

Remarks. *Syracosphaera arethusae* HOL was previously recorded as *Homozogosphaera arethusae*, a holococcolithophore, by Chang & Northcote (2016). The holococcolith-bearing form is an alternate life cycle phase.

Syracosphaera azureaplaneta Young et al., 2018
Fig. 27 A–D

Young *et al*., 2018, fig. 1, figs 1-4

Synonyms: *Syracosphaera corolla* Lecal, 1965a: 252–253, pl. 1, figs 1–4; Okada & McIntyre, 1977, pl. 6, figs 1-2; Nishida, 1979, pl. 6, fig. 4; Winter & Siesser, 1994, fig. 107; Young *et al*. 2003: 45, pl. 19, figs 13–15; Malinverno *et al*. 2008, fig. 76.

Gaarderia corolla (Lecal 1966) Kleijne, 1993: 200–201, pl. 6, figs 3–6; Cros & Fortuño, 2002: 91, figs 29A–D.

Umbellosphaera corolla (Lecal,1966) Kleijne, 1993, pl. 6, fig. 3-5; Cros & Fortuño: 251–270.

Occurrence records. *Chatham Rise*: NIWA Stn TAN1107/T3, 44.206° S, 176.701° E, May 2011; NIWA Stn TAN1107/T5, 46.202° S, 178.500° E, May 2011; NIWA Stn TAN1107/NBM, 41.229° S, 178.512° E, May 2011.

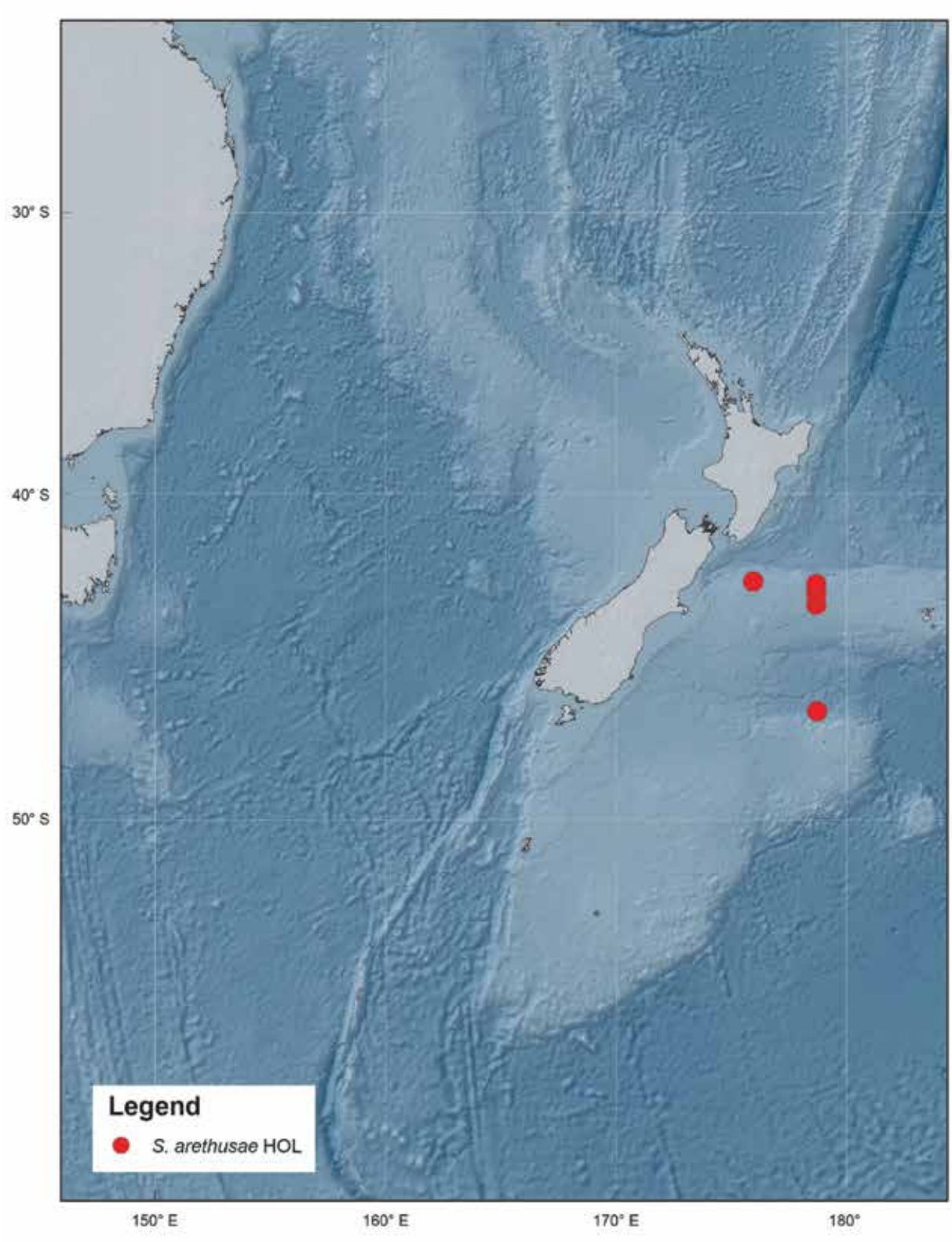

Figure 26. Distribution of *Syracosphaera arethusae* HOL (Kamptner, 1941) Triantaphyllou *et al*., 2015 around New Zealand.

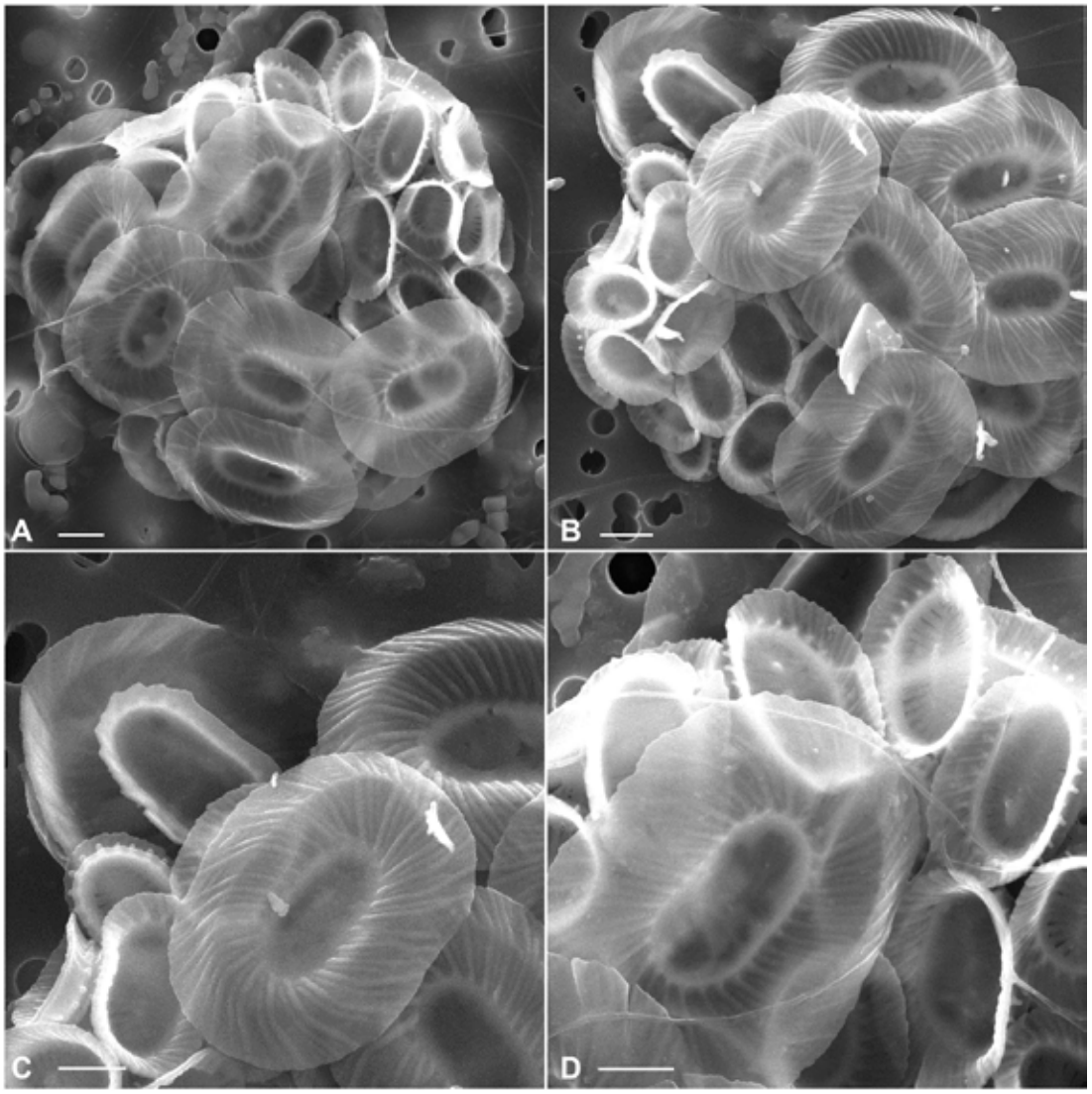

Figure 27. Coccolithophore morphology: **A–B.** cells of *Syracosphaera azureaplaneta* Young *et al*., 2018; **C–D.** dimorphic muroliths of *S. azureaplaneta*. Scale bars A–D, 1 µm.

Holotype. Specimen illustrated by Young *et al*. 2018 on Plate 1, fig.1.

Type locality. South Atlantic, research cruise of the RRS *James Clark Ross*. Sample AMT18-CTD8948m, 32.18° S; 29.83° W, 2 Nov 2008.

Description. Coccosphere ovoid (12–14 µm) and dithecate (Fig. 27A, B). Exothecal muroliths (4.9–5.6 µm long) similar to the body coccoliths, but with much broader distal flange and relatively wide central area, have slightly raised, curved bands on the surface of its broad petaloid distal flange and are larger than endothecal coccoliths (2.3–2.8 µm long) (Fig. 27C, D). Endothecal coccoliths irregularly-elliptical, have tube–like structure but no clear distal flange.

Distribution and cell abundance. *Syracosphaera azureaplaneta* was found on only one occasion, in the autumn of 2011, at three sites, in ST and SA waters over Chatham Rise (Fig. 29). Cell concentrations recorded at these sites, ranged from 300 to 2000 cells l^{-1} (Appendix 1, Table 1.9).

Previous records. This extant species is a first record for New Zealand. Previously this species was reported as *S. corolla*, over Chatham Rise, by Chang & Northcote (2016). Globally, *Syracosphaera azureaplaneta* has a very broad distribution, occurring from tropics to the subarctic and in all the major oceans (Young *et al*. 2018).

Remarks. Another closely related species illustrated in Plate II (g) of Saavedra-Pellitero *et al*. (2014), recorded in STF/SA waters on the east coast of New Zealand, shows narrow central-areas in exothecal coccoliths, and hence fits the description of *S. corolla*, which is distinct from *S. azureaplaneta* described by Young *et al*. (2018) (Appendix 2, Table 2.2).

Syracosphaera bannockii (Borsetti & Cati, 1976) Cros *et al*., 2000

Fig. 28 A–B

Cros, 2000, pl. 3, figs 3–4; Cros *et al*. 2000, pl. VII, fig. 1, Cros & Fortuño, 2002: 101–102, figs 39–40; Young *et al*. 2003: 41, pl. 17, figs 1–4; Skejić *et al*. 2018: 40, fig. 7d.

Basionym: *Sphaerocalyptra bannockii* Borsetti & Cati, 1976.

Synonyms: *Syracosphaera nana* Kamptner in Nishida, 1979, pl. 7, fig. 4.

Syracosphaera orbiculus in Samtleben *et al.* 1995: pl. II, fig. 4.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS30, 46.638° S, 178.542° E, Jan–Feb 2009.

Kaikoura: NIWA Stn TAN0904/S13, 46.670° S, 174.409° E, Apr 2009.

Holotype. Figs 4, 6: (Silva 1996-to date), held at Bologna, Marine Geology Laboratory, Italy.

Type locality. Tyrrhenian Sea, Mediterranean Sea off the western coast of Italy: Stn 61, 40.380° N, 13.680° E.

Description. Coccosphere ovoid (long axis 5–7 µm) and dithecate (Fig. 28A–B). Disc-like exothecal coccolith (2.3–2.5 µm long) is narrowly elliptical. Endothecal coccoliths (muroliths), elliptical (1.5–1.7 µm long) with low and thick wall and neither mid-wall nor distal flange; central structure from slightly elongated mound to nearly flat (Cros & Fortuño 2002). Circum-flagellar coccoliths with a pointed spine, sometimes slightly curved at the tip.

Distribution and cell abundance. A small number of *Syracosphaera bannockii* was found in SA water south of Chatham Rise (Fig. 29). Cell concentrations recorded in summer 2009, at 2 sites in SA water, were < 500 cells l^{-1} (Appendix 1, Table 1.1).

Previous records. Extant *Syracosphaera bannockii* was previously reported as a first–time record by Chang & Northcote (2016). Elsewhere, this species has been recorded in several regions globally, e.g., in the northwest Mediterannean (Cros & Fortuño 2002), in the middle and northern Adriatic Sea (Mediterranean) (Skejić *et al.* 2018; Godrijan *et al.* 2018), in the Bay of Biscay in the eastern Atlantic Ocean (Daniels *et al.* 2014), and in the Java upwelling region of the Indian Ocean (Andruleit 2007).

Syracosphaera leptolepis Kleijne & Cros, 2009

Fig. 28 C–F

Kleijne & Cros, 2009: 443, pl. 6, figs 1–6.

Synonyms: *Syracosphaera* sp. type L of Klejne, 1993: 245, pl. 5, figs 1–2; Cros, 2000: 42, pl. 2 figs 5, 7; Cros, 2002: 55–56, pl. 29, figs 5–6; Cros & Fortuño, 2002: 38, figs 43C, D; Young *et al.* 2003: 36: pl. 15, figs 7–9.

Syracosphaera nodosa (Kamptner) Okada & McIntyre, 1977: 25, pl. 9, figs 1, 3, fig. 2.

Syracosphaera nana auct. non (Kamptner) Winter & Siesser, 1994: fig. 116.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS39, 42.820° S, 178.495° E, Jan–Feb 2009; NIWA Stn TAN1107/T1, 42.351° S, 175.651° E, May 2011; NIWA Stn TAN1107/T2, 43.411° S, 176.250° E, May 2011.

Holotype. Negative A77/3 (pl. 6, fig. 1), held at the National Herbarium Nederland, Universiteit Leiden branch (L), Netherlands.

Type locality. North Atlantic: 50.318° N, 27.052° W, 0–5 m, 21 Aug 1986 (Cruise APNAP–1, Stn T86–19C).

Description. Coccosphere subspherical (6–8 µm long) and dithecate (Fig. 28C). Circular exothecal coccoliths (planoliths) (1.5–2.0 µm diameter) are flat with a plate-like structure; the central part consists of dextrally oblique elements and is surrounded by a rim of plate-like elements (Fig. 28D). Endothecal coccoliths are broadly elliptical muroliths (1.2–2.5 µm long); the central area slightly vaulted with a slightly raised, inner central structure (Fig. 28E, F).

Distribution and cell abundance. *Syracosphaera leptolepis* was found at one site in ST water (Appendix 1, Table 1.1) and at two sites in both ST and SA water (Appendix 1, Table 1.2) over Chatham Rise, in summer 2009, and autumn 2011 respectively (Fig. 29). Cell concentrations recorded at these sites varied from 200 to 300 cells l^{-1}.

Previous records. This extant species was previously reported as a new record off the east coast of New Zealand (Chang & Northcote 2016). Elsewhere, a low concentration of *S. leptolepis* cells was reported in the North Atlantic (Kleijne & Cros 2009).

Syracosphaera mediterranea (Lohmann, 1902) Triantaphyllou *et al.*, 2015

Fig. 30 A–F

Lohmann, 1902: 133, pl. 4, figs 31, 32; Okada & McIntyre, 1997: 23, pl.10, figs 4-5; Triantaphyllou *et al.* 2015: 460, pl. 1, figs 1-6.

Synonyms: *Coronosphaera mediterranea* (Lohmann) Gaarder *in* Gaarder & Heimdal, 1977: 62, pl. 4; Nishida, 1979, pl. 6, figs 1a-b, Cros *et al.* 2000: 29, pl. IV, figs 2, 3; Cros & Fortuño, 2002: 28, figs 27D, 28; Geisen *et al.* 2002: 546, fig. 35; Young *et al.* 2003: 52, pl. 23, figs 1-3; Jordan *et al.* 2004: 59; Malinverno *et al.* 2008: 112, 113, fig. 84.

Syracosphaera pulchroides Halldal & Markali, 1955:10-11; Heimdal, 1973 [*see* Nannotax3 website].

Syracosphaera tuberculata Kamptner, 1937: 302-303, pl. 15, figs 17-19; Kamptner, 1941: 86, 106, pl. 8, figs 85-87, pl. 9, fig. 88; Halldal & Markali, 1955: 10, pl. 7; Borsetti & Cati, 1972: 402, pl. 47, fig. 2.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS4, 43.432° S, 176.301° E, Jan–Feb 2009; NIWA Stn TAN0902/YS8, 44.108° S, 176.798° E, Jan–Feb 2009; NIWA Stn TAN0902/YS30, 46.638° S, 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS31, 41.107° S,

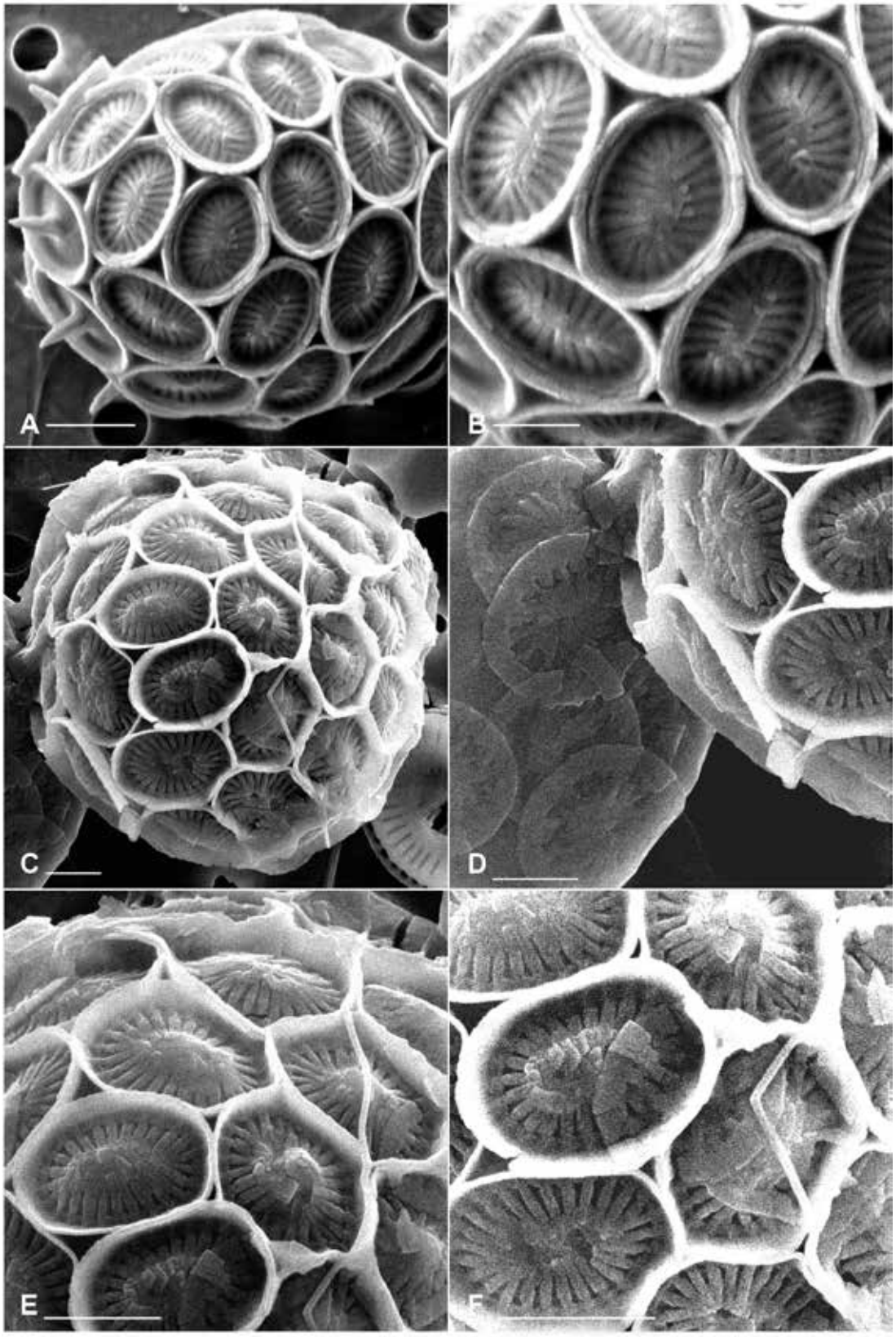

Figure 28. Coccolithophore morphology: **A.** cell of *Syracosphaera bannockii* (Borsetti & Cati, 1976) Cros *et al*., 2000; **B.** muroliths of *S. bannockii*; **C.** cell of *Syracosphaera leptolepis* Kleijne & Cros, 2009; **D.** exothecal coccoliths of *S. leptolepis*; **E–F.** muroliths of *S. leptolepis*. Scale bars A–F, 1 µm.

178.590° E, Jan–Feb 2009; NIWA Stn TAN0902/YS32, 46.633° S 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS39, 42.820° S, 178.495° E, Jan–Feb 2009; NIWA Stn TAN1107/T1, 42.351° S, 175.651° E, May 2011; NIWA Stn TAN1107/T2, 43.411° S, 176.250° E, May 2011; NIWA Stn TAN1107/T4, 45.204° S, 177.307° E, May 2011; NIWA Stn TAN1107/SBM, 46.656° S, 178.556° E, May 2011; NIWA Stn TAN1107/T5, 46.202° S, 178.500° E, May 2011.

Kaikoura: NIWA Stn TAN0904/S17, 46.670° S,

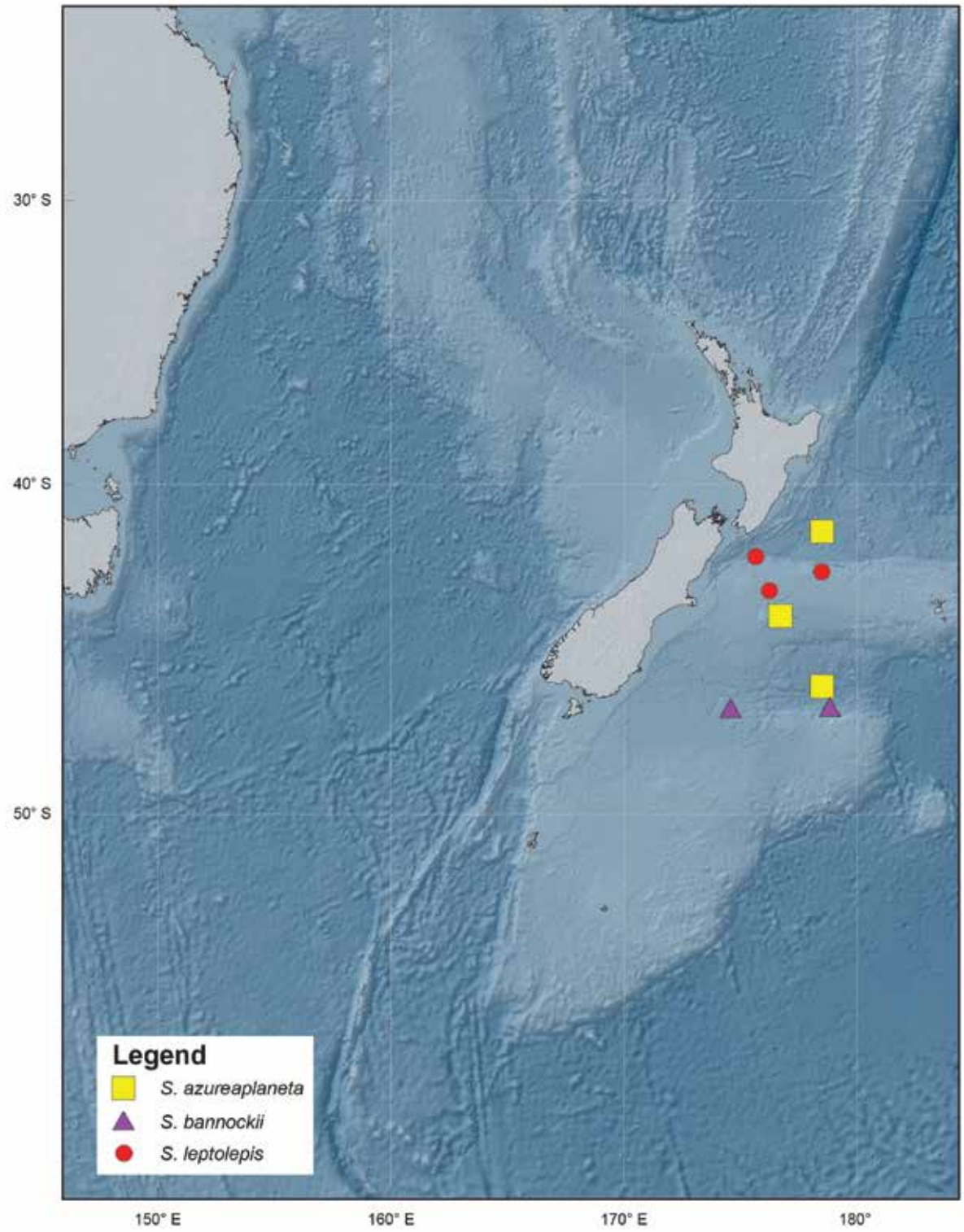

Figure 29. Distribution of *Syracosphaera azureaplaneta* Young *et al*., 2018, *S. bannockii* (Borsetti & Cati, 1976) Cros *et al*., 2000, and *S. leptolepis* Kleijne & Cros, 2009 around New Zealand.

174.709° E, Apr 2009; NIWA Stn TAN0904/S45, 42.941° S, 173.926° E, Apr 2009; NIWA Stn TAN0904/S55, 42.207° S, 174.702° E, Apr 2009; NIWA Stn TAN0904/S71, 42.642° S, 174.584° E, Apr 2009; NIWA Stn TAN0904/S81, 42.614° S, 174.097° E, Apr 2009; NIWA Stn TAN0904/S91, 42.703° S, 173.886° E, Apr 2009; NIWA Stn TAN0904/S95, 42.535° S, 173.607° E, Apr 2009.

Bay of Plenty: KAH0907/Stn S13, 35.195° S, 174.157° E, Sep 2009.

Tasman Sea: PINTS Stn C8, 42.501° S, 161.251° E, Jan 2010; PINTS Stn C9, 43.514° S, 160.515° E, Jan 2010; PINTS Stn C11, 46.295° S, 159.882° E, Jan 2010.

Holotype. Type is possibly held in Kiel, Germany.

Type locality. Near Syracuse, Sicily, Italy.

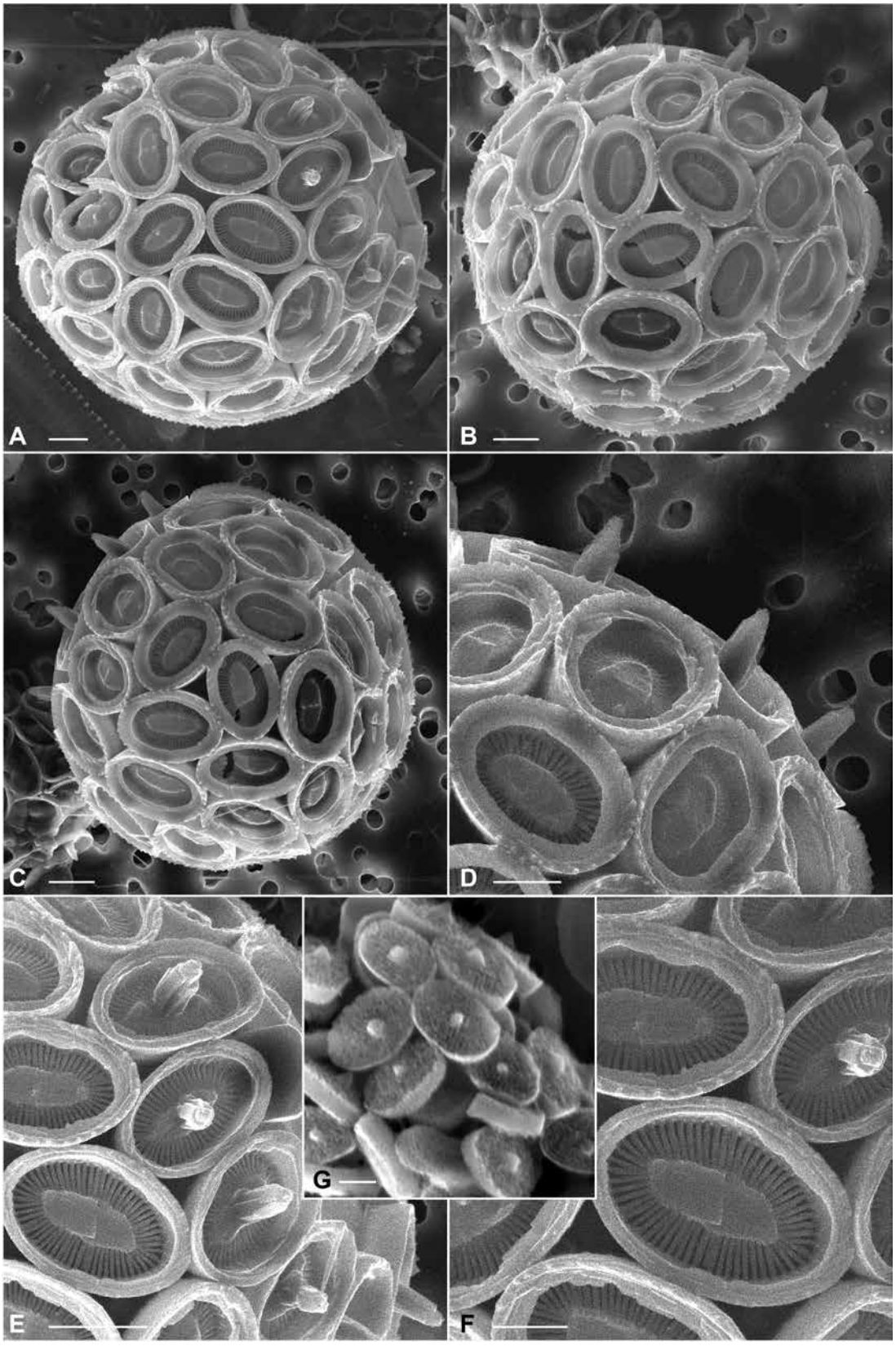

Figure 30. Coccolithophore morphology: **A–C.** cells of heterococcolith-bearing form of *Syracosphaera mediterranea* (Lohmann, 1902) Triantaphyllou *et al.*, 2015; **D–F.** circum-flagellar coccolith and coccoliths of *S. mediterranea*; **G.** coccoliths of holococcolith-bearing form of *S. mediterranea* HOL *hellenica*-type (Young *et al.*, 2003). Scale bars A–G 1 μm.

Description. Coccosphere of the heterococcolith-bearing form spherical or subspherical (11–16 μm) and monothecate (Fig. 30A–C). Body coccoliths elliptical; internal coccoliths are dish-like with a low central mound consisting of two flattened parts and two to six circum-flagellar coccoliths with spines (Fig. 30D–F).

Distribution and cell abundance. The heterococcolith form of *Syracosphaera mediterranea* was

widely distributed off the Kaikoura coast, over Chatham Rise, and in open waters of the Tasman Sea (Fig. 31). During surveys from 2009 to 2012, *S. mediterranea* was recorded at six sites over Chatham Rise and three sites in the Tasman Sea in the summers of 2009 and 2010 (Appendix 1, Tables 1.1, 1.6), at seven sites off Kaikoura and five sites over Chatham Rise, in the autumns of 2009 and 2011, respectively (Appendix 1, Tables 1.2, 1.9). Cell concentrations generally were from < 20 to thousands of cells l^{-1}. The greatest cell concentration (up to 8,000 cells l^{-1}) was recorded in the summer of 2009, in SA water over Chatham Rise (Appendix 1, Table 1.1).

Previous records. Extant *Syracosphaera mediterranea* was previously recorded by Norris (1961), at one NZOI station, B67, in a transect between northeast New Zealand and Tonga (Appendix 2, Table 2.1), and at many sites on both the east and west coasts of New Zealand (Chang & Northcote 2016).

Elsewhere, this species is very widely distributed, e.g., in the East Australian Current, Bass Strait, northwestern Australia and the Coral Sea (Hallegraeff 2010), in the Australian Sector of the Southern Ocean (Findlay & Giraudeau 2000), along a temperate to polar gradient in the West Pacific sector of the Southern Ocean (Malinverno *et al.* 2015), off Terceira Island, Azores, in the Central North Atlantic Ocean (Narciso *et al.* 2016), in the subtropical and temperate northeast Atlantic Ocean (Broerse *et al.* 2000a), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in Lisbon Bay, Portugal of the Mediterranean Sea (Silva *et al.* 2009), in the middle, eastern and northern Adriatic Sea (Mediterranean) (Šupraha *et al.* 2016; Skejić *et al.* 2018; Godrijan *et al.* 2018), in an upwelling region off Somalia (NW Indian Ocean) (Broerse *et al.* 2000b), in the Bay of Bengal in the Indian Ocean (Mergulhao *et al.* 2013), and in the Indian sector of the Southern Ocean (Patil *et al.* 2017).

Remarks. The heterococcolith-bearing form of *Syracosphaera mediterranea* was formerly placed in the genus *Coronosphaera* as *C. mediterranea*. It is proposed by Triantaphyllou *et al.* (2015) that the genus *Coronosphaera* be placed back to *Syracosphaera*, thus synonymising the former with the latter.

Syracosphaera mediterranea HOL *hellenica*-type

Fig. 30 G

Coronosphaera mediterranea HOL *hellenica*–type Young *et al.*, 2003: 106, pl. 50, figs 7–9; Triantaphyllou *et al.* 2015: 460, pl. 1, figs1-6.

Basionym: *Zygosphaera hellenica* Kamptner, 1937: 306, pl. 16, figs 27, 28a-c, 29a-d; Young *et al.* 2003: 106, pl. 6.

Synonym: *Laminolithus hellenicus* (Kamptner) Heimdal, *in* Heimdal & Gaarder, 1980: 1–14.

Occurrence records. *Tasman Sea*: PINTS Stn C52B, 46.300° S, 159.872° E, Jan 2010.

Description. Body coccoliths of this holococcolith-bearing form with concentric structure and central node; tube wall shows hexagonal crystallite fabric with row of perforations above base and a variable number of extra perforations (Fig. 30G).

Distribution and abundance. Only a very small number of this alternate life-history phase (< 20 cells l^{-1}) were found in the Tasman Sea (Fig. 31, Appendix 1, Table 1.6).

Previous records. The extant holococcolith-bearing form was previously reported as *Coronosphaera mediterranea* HOL *gracillima*-type in the Tasman Sea by Chang & Northcote (2016). Elsewhere, this life-cycle form also occurs in small numbers, e.g., in the tropical and subtropical Atlantic Ocean (Poulton *et al.* 2017), in the Aegean Sea (NE Mediterranean) (Dimiza *et al.* 2015), in the middle and eastern Adriatic Sea (northern Mediterranean) (Šupraha *et al.* 2016; Skejić *et al.* 2018), and as *Zygosphaera hellenica* in the Java upwelling region of the tropical Indian Ocean (Andruleit 2007).

Remarks. Geisen *et al.* (2002) reported that *Zygosphaera hellenica* is an alternate life-cycle phase of *Coronosphaera mediterranea* in culture and proposed the use of the informal name *C. mediterranea* HOL *hellenica*-type (see also Malinverno *et al.* 2008; Young *et al.* 2014). It is now proposed by Triantaphyllou *et al.* (2015) that this species be placed in the genus *Syracosphaera* as *S. mediterranea* HOL *hellenica*-type.

Syracosphaera molischii Schiller, 1925

Fig. 32 A–F

Schiller, 1925, Halldal & Markali, 1954: 332–333, fig. 5; Borsetti & Cati, 1972: 401, pl. 45, figs 2 a–b; Okada & McIntyre, 1977: 24, pl. 8, figs 4–5; Hallegraeff, 1984, figs 47 a, b; Samtleben & Schröder, 1992: 345, pl. 1, fig. 2; Kleijne, 1993: 238, pl. 3, figs 10–11; Winter & Siesser, 1994: 137, figs 115 A, B; Cros, 2000: 49, pl. 5, fig. 1; Cros & Fortuño, 2002: 93, figs 31 A, D; Young *et al.* 2003: 47, pl. 20, figs 1–4.

Basionym: *Syracosphaera molischi* Schiller, 1925: 21, text-figs Ka-b.

Synonyms: *Syracosphaera corrugis* Okada & McIntyre, 1977: 21, pl. 8, figs 3, 6.

Syracosphaera elatensis Winter in Winter *et al.*, 1979: 207, pl. 3, figs 11–15.

Caneosphaera molischii (Schiller) Gaarder in Gaarder & Heimdal, 1977: 66–68, pl, 7, fig. 49; Heimdal & Gaarder, 1981: 44–46, pl. 3; Halegraeff, 1984: 242, figs 47 a, b.

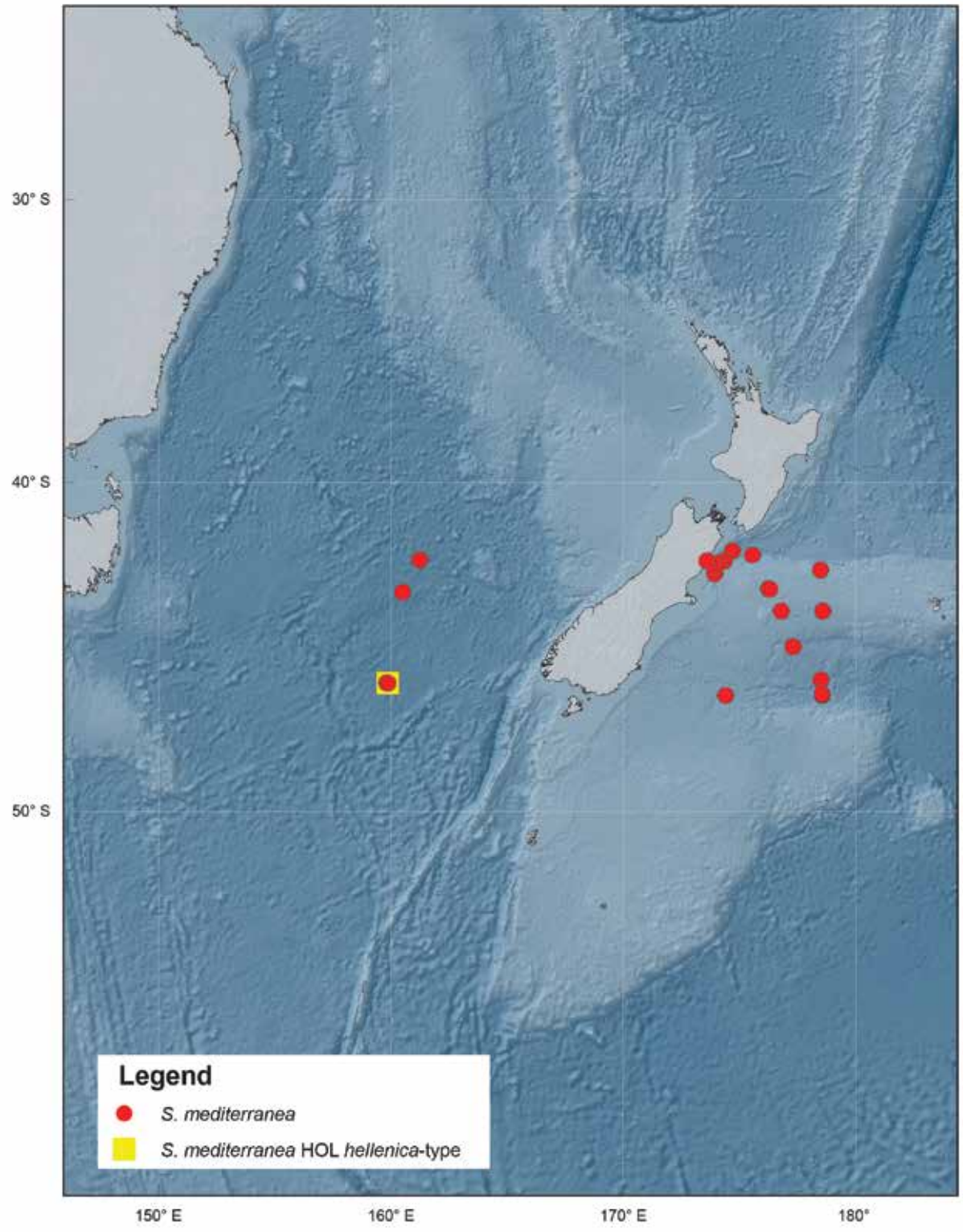

Figure 31. Distribution of the heterococcolith-bearing form of *Syracosphaera mediterranea* (Lohmann, 1902) Triantaphyllou et al., 2015 and holococcolith-bearing form of *S. mediterranea* HOL *hellenica*-type around New Zealand.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/4, 43.432° S, 176.301° E, Jan–Feb, 2009; NIWA Stn TAN0902/YS8, 44.108° S, 176.798° E, Jan–Feb, 2009; NIWA Stn TAN0902/YS29, 46.636° S, 178.556° E, Jan–Feb, 2009; NIWA Stn TAN0902/YS31, 41.107° S, 178.590° E, Jan–Feb, 2009; NIWA Stn TAN0902/YS32, 46.633° S 178.542° E, Jan–Feb, 2009; NIWA Stn TAN0902/YS36, 43.446° S, 178.488° E, Jan–Feb, 2009; NIWA Stn TAN0902/YS38, 43.102° S, 178.489° E, Jan–Feb, 2009; NIWA Stn TAN0902/YS39, 42.820° S, 178.495° E, Jan–Feb, 2009; NIWA Stn TAN0909/PM25, 42.349° S, 178.502° E, Oct 2009; NIWA Stn TAN1107/T1, 42.351° S, 175.651° E, May 2011; NIWA Stn TAN1107/T2, 43.411° S, 176.250° E, May 2011; NIWA

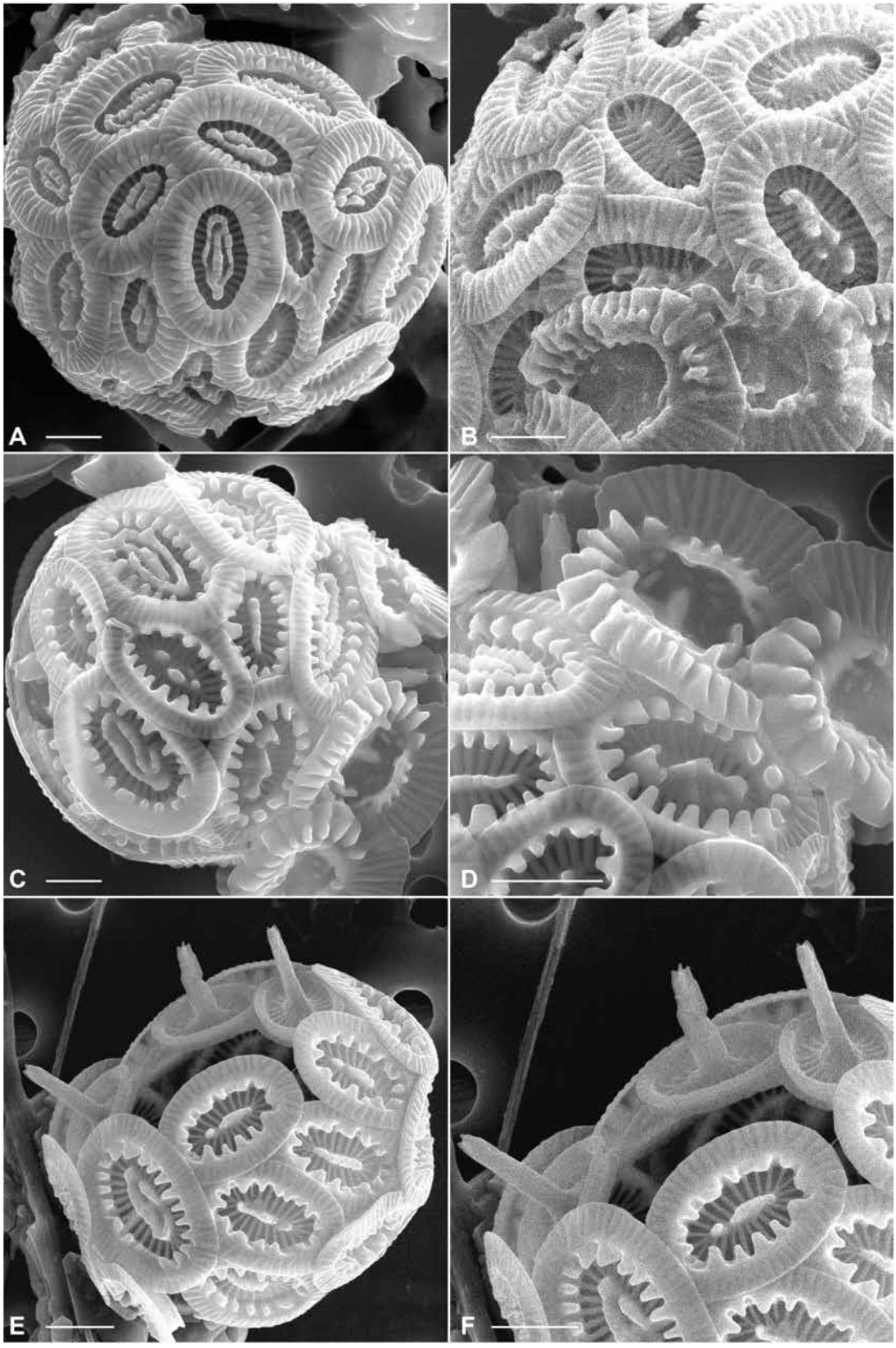

Figure 32. Coccolithophore morphology: **A.** cell of *Syracosphaera molischii* Schiller, 1925 type 1; **B.** muroliths of *S. molischii* type 1; **C.** cell of *S. molischii* type 2; **D.** muroliths of *S. molischii* type 2; **E.** cell of *S. molischii* type 2; **F.** circum-flagellar coccoliths of *S. molischii* type 2, showing processes tipped by four nodes. Scale bars A–F, 1 μm.

Stn TAN1203/DA11, 44.350° S, 174.419° E, Feb 2012; NIWA Stn TAN1203/DA31, 45.576° S, 173.387° E, Feb 2012; NIWA Stn TAN1203/DA59, 43.386° S, 179.450° E, Feb 2012; NIWA Stn TAN1203/DA104, 44.758° S, 174.633° E, Feb 2012.

Kaikoura: NIWA Stn TAN0904/S13, 46.670° S, 174.409° E, Apr 2009; NIWA Stn TAN0904/S45, 42.941° S, 173.926° E, Apr 2009; NIWA Stn TAN0904/

S55, 42.207° S, 174.702° E, Apr 2009; NIWA Stn TAN0904/S71, 42.642° S, 174.584° E, Apr 2009; NIWA Stn TAN0904/S85, 42.614° S, 174.097° E, Apr 2009; NIWA Stn TAN0904/S95, 42.535° S, 173.607° E, Apr 2009.

Tasman Sea: PINTS Stn C10, 43.514° S, 159.883° E, Jan 2010; PINTS Stn C24, 46.022° S, 156.822° E, Jan 2010; PINTS Stn C34, 39.956° S, 162.170° E, Jan 2010; PINTS Stn C46, 45.854° S, 150.872° E, Jan 2010.

Holotype. Type is possibly held at Vienna University, Botany Department, Austria (which is where Schiller was based).

Type locality. Geographic distribution: Adriatic Sea. Occurrence: 0–50 m.

Description. Coccosphere subspherical (6–9 µm long) and dithecate (Fig. 32A, C, E). Body coccoliths (endothecal coccoliths) (2.4–2.8 µm long) with broad distal flange, usually heavily ribbed, sometimes with fine protrusions directed towards the central area; central area usually an elongated, irregular ridge, and/or with a slightly raised ring formed around the ridge (Fig. 32A–D). Circum-flagellar coccoliths are generally smaller than the body coccoliths with a short spine (Fig. 32E, F).

Four different body coccolith ornamentations were recognised by Young *et al.* (2003): Type 1—the outer part of the distal flange with low ridges, and the inner part with fewer, high ridges; Type 2—the outer part of the distal flange with low ridges, and the inner part formed of tooth-like projections; Type 3—the outer part of the distal flange with low ridges, and the inner part is smooth; Type 4—the outer part of the flange smooth, and the inner part is formed of tooth-like projections. Only two types (1 and 2) were observed in this study (Fig. 32A–B, D–F); Type 1 is the dominant form. Type 2 ranged from less common to moderate in terms of cell concentrations.

Distribution and cell abundance. *Syracosphaera molischii* was very widespread and was recorded mainly off Kaikoura and in open waters both to the east (over Chatham Rise) and west (Tasman Sea) of New Zealand (Fig. 33). This species was found in three summers (2009, 2010, 2012), two autumns (2009, 2011) and one spring (2009) (Appendix 1, Tables 1.1, 1.2, 1.5, 1.6, 1.9, 1.10). Cell concentrations ranged from a low of hundreds of cells to a high of tens of thousands of cells per litre (Appendix 1, Tables 1.1, 1.2, 1.5, 1.6). The greatest cell concentration (up to 161,000 cells l^{-1}) was recorded in summer 2009, at one site in STF water over Chatham Rise (Appendix 1, Table 1.1).

Previous records. *Syracosphaera molischii* was previously recorded by Norris (1961), at two NZOI stations, B67 and B77, along a transect between northeast New Zealand and Tonga (Appendix 2, Table 2.1). This species has also been recorded in STF/SA waters, east of New Zealand (Saavedra-Pellitero *et al.* 2014) and several sites around New Zealand (Chang & Northcote 2016).

Elsewhere, this species is very widely distributed, e.g., in coastal waters of Sydney, Peterborough-Moggs Creek and Wilsons Promontory of Victoria, in Bass Strait and northwestern Australia (Hallegraeff 2010), in the subantarctic zone of the Southern Ocean (Saavedra-Pellitero *et al.* 2014), in the Australian sector of the Southern Ocean (Findlay & Giraudeau 2000), in the Southern Ocean south of the Polar Front (Findlay *et al.* 2005), in the subtropical and temperate northeast Atlantic (Broerse *et al.* 2000a), in the tropical and subtropical Atlantic Ocean (Poulton *et al.* 2017), in the Aegean Sea (NE Mediterranean) (Dimiza *et al.* 2015), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the middle and northern Adriatic Sea (Mediterranean) (Skejić *et al.* 2018; Godrijan *et al.* 2018), in the Java upwelling region of the tropical Indian Ocean (Andruleit 2007), and in the Indian sector of the Southern Ocean (Patil *et al.* 2017).

Syracosphaera nana (Kamptner, 1941) Okada & McIntyre, 1977

Fig. 34 A–C

(Kamptner, 1941) Okada & McIntyre, 1977: 24, pl. 8, figs 7-9; Cros, 2000: 46, plate 2, figs 6, 8; Cros & Fortuño, 2002: 98, figs 36–37; Young *et al.* 2003: 37, plate 15, figs 10–11.

Basionym: *Pontosphaera nana* Kamptner, 1941: 79, pl. 3, figs 31–33.

Synonyms: *Syracosphaera* sp. type A of Kleijne, 1991: 21, pl. 20, figs 5–6; Kleijne, 1993: 241, pl. 6, fig. 1.

Syracosphaera sp. 1 Borsetti & Cati, 1972: 402, pl. 47, fig. 4.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS38, 43.102° S, 178.489° E, Jan–Feb 2009; NIWA Stn TAN1107/T8, 42.340° S, 178.504° E, Sep-Oct 2011; NIWA Stn TAN1203/DA31, 45.576° S, 173.387° E, May 2012.

Holotype. Type is held at the Natural History Museum Vienna, Austria.

Type locality. Southwest coast of Istria, Italy.

Description. Coccosphere ovoid (6–8 µm long) (Fig. 34 A). No exothecal coccolith was observed. Outer wall of the long elliptical endothecal muroliths (1.3–1.5 µm long) short with no flaring; the central area with radial laths vaulted into whaleback-like ridge (Fig. 34 B, C). Circum-flagellar coccoliths with short spines.

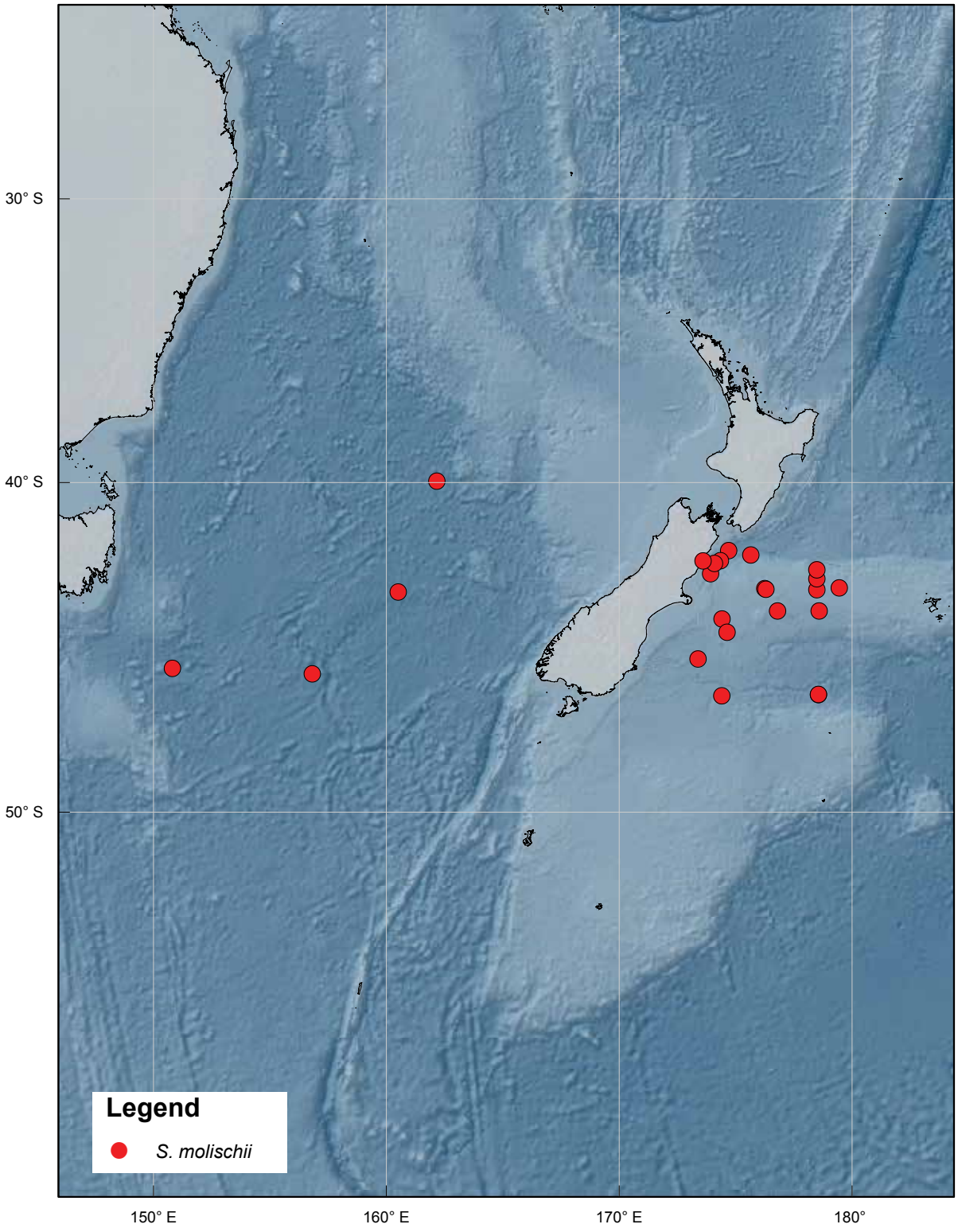

Figure 33. Distribution of *Syracosphaera molischii* Schiller, 1925 around New Zealand.

Distribution and cell abundance. Extant *Syracosphaera nana* was found at one site each in the summers of 2009 and 2012, and the autumn of 2011, over Chatham Rise (Fig. 35). Cell concentrations recorded at each site ranged from a few hundreds to several thousand cells l^{-1} (Appendix 1, Tables 1.1, 1.9, 1.10).

Previous records. *Syracosphaera nana* has previously been recorded in STF/SA waters by Saavedra-Pellitero *et al.* (2014) (Appendix 2, Table 2.2) and over Chatham Rise by Chang & Northcote (2016).

Elsewhere, *S. nana* was widely recorded, e.g., in the Bass Strait of Australia (Hallegraeff 2010), in the Australian sector of the Southern Ocean (Findlay & Giraudeau 2000), in the subtropical and subantarctic zones of the Southern Ocean (Saavedra-Pellitero *et al.* 2014), along a temperate to polar gradient in the West

Pacific sector of the Southern Ocean (Malinverno *et al*. 2015), in eastern North Atlantic Ocean, south Atlantic Ocean off Namibia (Kleijne & Cros 2009), in the subtropical and temperate northeast Atlantic Ocean (Broerse *et al*. 2000a), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the eastern Adriatic Sea (northern Mediterranean) (Šupraha *et al*. 2016), in the Java upwelling region in the tropical Indian Ocean (Andruleit 2007), and in the Indian section of the Southern Ocean (Patil *et al*. 2017).

Syracosphaera nodosa Kamptner, 1941

Fig. 34 D–F

Kamptner, 1941: 84–85, pl. 7, figs 73–76; Kamptner *in* Sánchez-Suárez, 1992: 117, figs 3D–E; Nishida, 1979, pl. 7, fig. 3; Winter & Siesser, 1994: 138, figs 117a, b; Cros, 2000: 46, pl. 2, fig. 3; Cros & Fortuño, 2002: 108, fig 46; Young *et al*. 2003: 37, pl. 15, fig. 4.

Synonym: *Pontosphaera variabilis* Halldal & Markali, 1955: 12, pl. 12.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS30, 46.638° S, 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS32, 46.633° S 178.542° E, Jan–Feb 2009; NIWA Stn TAN1107/T8, 42.340° S, 178.504° E, Sep-Oct 2011. NIWA Stn YS32, 46.397° S, 178.300° E, Oct 2009.

Kaikoura: NIWA Stn TAN/S13, 46.670° S, 174.409° E, Apr 2009.

Holotype. Type is held at the Natural History Museum Vienna, Austria.

Type locality. Southwest coast of Istria, Italy.

Description. Coccosphere ovoid (5.0–6.5 µm long) and dithecate (Fig. 34D). Endothecal muroliths (2.39–2.6 µm long) elliptical with relatively deep wall but without a distal flange and characteristic vertical ribs on the outer surface of the wall (Fig. 34E, F). Circumflagellar coccoliths have a strong spine, with a sheath-like structure covering about 80% of the bottom part of the spine.

Distribution and cell abundance. *Syracosphaera nodosa* was found only at two sites south of Chatham Rise (Fig. 35). In this study, coccospheres of this species were recorded only in summer 2009, autumn 2009 and spring 2011 (Appendix 1, Tables 1.1, 1.2, 1.9). Cell concentrations generally were quite low, ranging from 300 to 500 cells l^{-1}.

Previous records. This species was previously reported as a first-time record for New Zealand (Chang & Northcote 2016). Elsewhere, this species was widely recorded, e.g., in tropical and subtropical waters of the South China Sea (Lee Chen *et al*. 2007), in the East China Sea (only at one site) (Wang *et al*. 2012), in the Bass Strait of Australia (Hallegraeff 2010), in the Australian sector of the Southern Ocean (Findlay & Giraudeau 2000), along a temperate to polar gradient in the West Pacific sector of the Southern Ocean (Malinverno *et al*. 2015), in the western subarctic Pacific and Bering Sea (Hattori *et al*. 2004), in the tropical and subtropical Atlantic Ocean (Poulton *et al*. 2017), in the subtropical northeast Atlantic (Broerse *et al*. 2000a), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the northern Adriatic Sea (Mediterranean) (Godrijan *et al*. 2018), in the subtropical and temperate northeast Atlantic (Broerse *et al*. 2000b), in the Java upwelling region in the tropical Indian Ocean (Andruleit 2007), and in the Indian section of the Southern Ocean (Patil *et al*. 2017).

***Syracosphaera* sp. aff. *S. nodosa* type 2**

Fig. 36 A–C

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS38, 43.102° S, 178.489° E, Jan–Feb 2009; NIWA Stn TAN1107/T4, 45.204° S, 177.307° E, May 2011.

Description. Coccosphere spherical to subspherical (*c*. 10 µm) and dithecate (Fig. 36A). Endothecal muroliths (2.7–2.8 µm long) with a relatively thin and medium-high wall; central area with a slightly raised, central connecting structure (Fig. 36B, C). Exothecal planoliths (2.7–3.3 µm long) broad, thin, subspherical, with a central structure consisting of a thin, square plate (Fig. 36B). The smooth lamina-like, exothecal coccoliths, do not have the wheel-like structure of *Syracosphaera nodosa*.

Distribution and cell abundance. *Syracosphaera* sp. aff. *S. nodosa* was found at two sites, in STF and SA waters over Chatham Rise (Fig. 37). Cell concentrations of this form, recorded in the summer of 2009, were < 20 cells l^{-1} (Appendix 1, Table 1.1).

Previous records. This extant species was reported off the east coast of New Zealand by Chang & Northcote (2016). Elsewhere, this species was found in the northwestern Mediterranean Sea (Cros & Fortuño 2002).

Syracosphaera orbiculus Okada & McIntyre, 1977

Fig. 36 D–F

Okada & McIntyre, 1977: 25, pl. 9, figs 4-6; Cros, 2000, pl. 3, figs 3–4; Cros *et al*. 2000, pl. VII, fig. 1, Cros & Fortuño, 2002: 101–102, figs 39–40; Young *et al*. 2003: 41, pl. 17, figs 1–4.

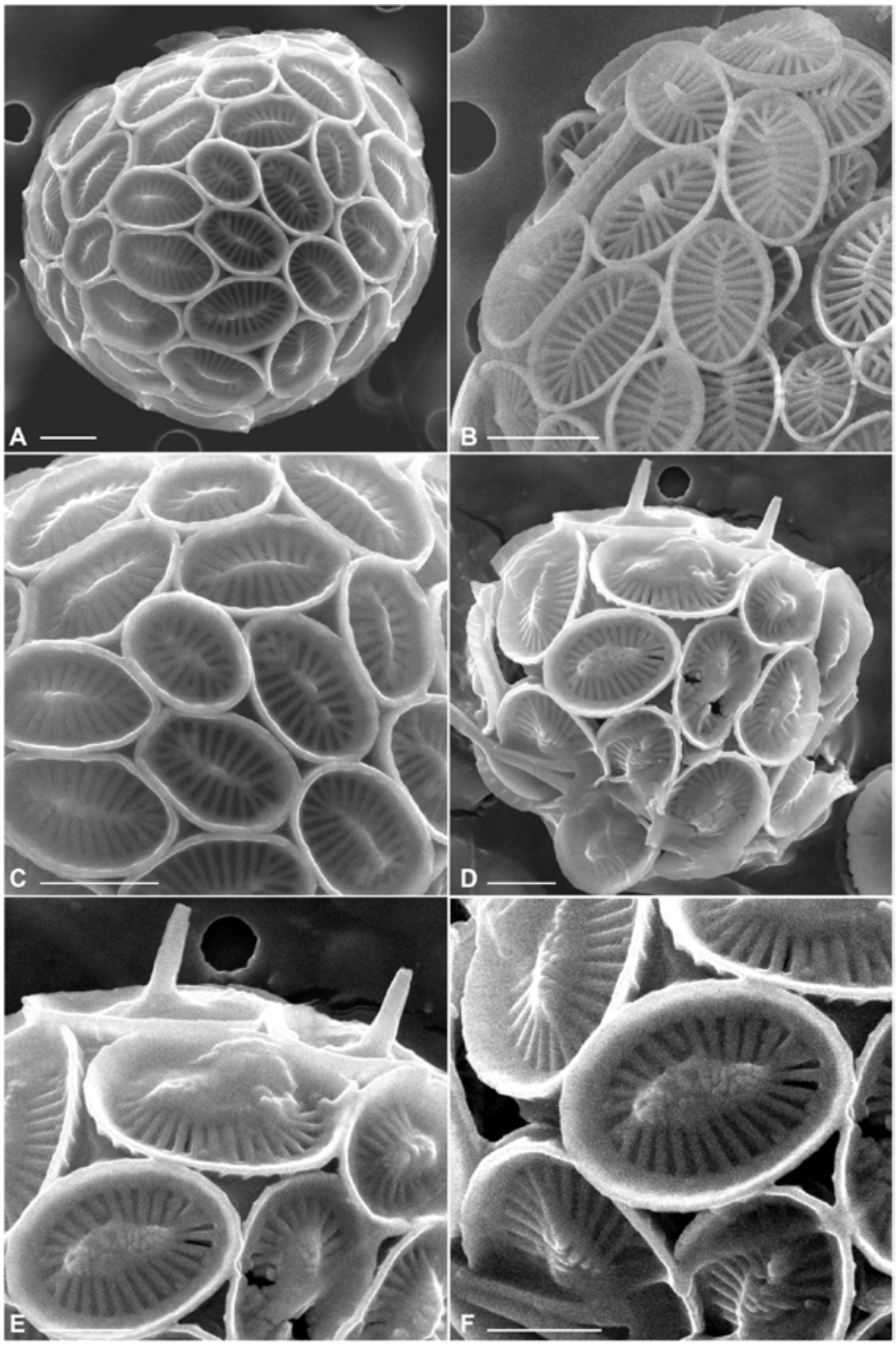

Figure 34. Coccolithophore morphology: **A.** cell of *Syracosphaera nana* (Kamptner, 1941) Okada & McIntyre 1977; **B–C.** caneoliths of *S. nana*; **D.** cell of *Syracosphaera nodosa* Kamptner, 1941; **E–F.** circum-flagellar caneoliths of *S. nodosa*. Scale bars A–F, 1 μm.

Basionym: *Sphaerocalyptra bannockii* Borsetti & Cati, 1976: 209.

Synonyms: *Syracosphaera nana* Kamptner in Nishida, 1979, pl. 7, fig. 4.

Syracosphaera orbiculus in Samtleben *et al.*, 1995: pl. II, fig. 4.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS30, 46.638° S, 178.542° E, Jan–Feb 2009.

Kaikoura: NIWA Stn TAN0904/S13, 46.670° S, 174.409° E, Apr 2009.

Holotype. Plate 9, figure 4. Negative ON-16, L-DGO.

Type locality. Atlantic Ocean, 38.05° N, 75.95° W.

Description. Coccosphere spherical or subspherical (7–12 μm) and dithecate (Fig. 36D, E). Endothecal

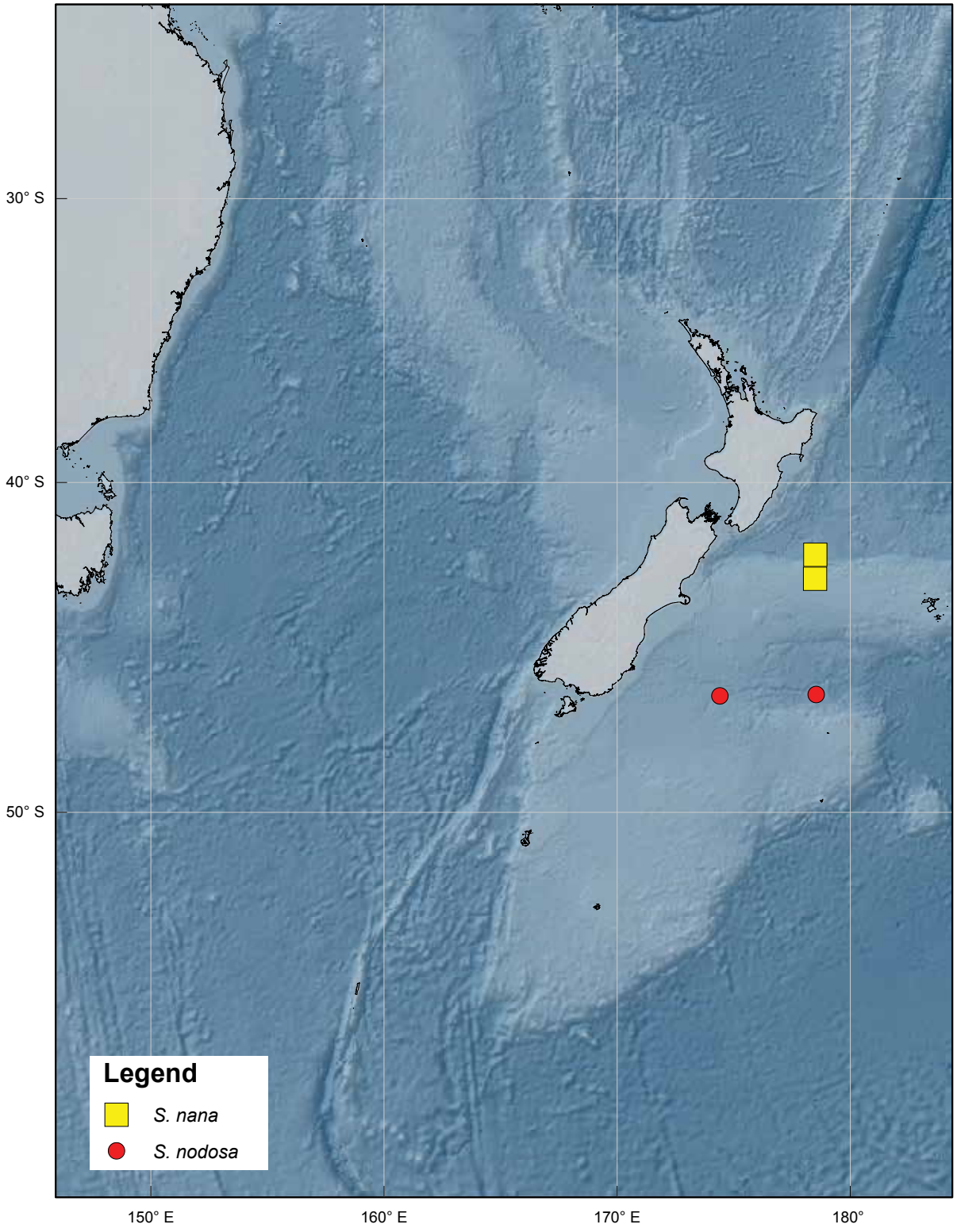

Figure 35. Distribution of *Syracosphaera nana* (Kamptner, 1941) Okada & McIntyre 1977 and *S. nodosa* Kamptner, 1941 around New Zealand (three sites with two virtually overlapped).

muroliths elliptical, 1.5–1.7 µm long; rim narrow, with low, delicate wall; central area formed of 26–28 radially arranged lamellar elements and a large, flat and smooth surface reminiscent of those of *S. orbiculus* (Okada & McIntyre, 1977: 25, pl. 9, fig.6). Circum-flagellar coccoliths with 4-5 small, slightly pointed spines (*c.* 0.9 µm long) (Fig. 36E, F).

Distribution and cell abundance. A small number of *Syracosphaera orbiculus* were found in SA water south of Chatham Rise (Fig. 37). Cell concentrations recorded in summer 2009, at two sites in SA water, were < 500 cells l^{-1} (Appendix 1, Table 1.1).

Previous records. *Syracosphaera orbiculus* was previously recorded on the southeast of New Zealand by

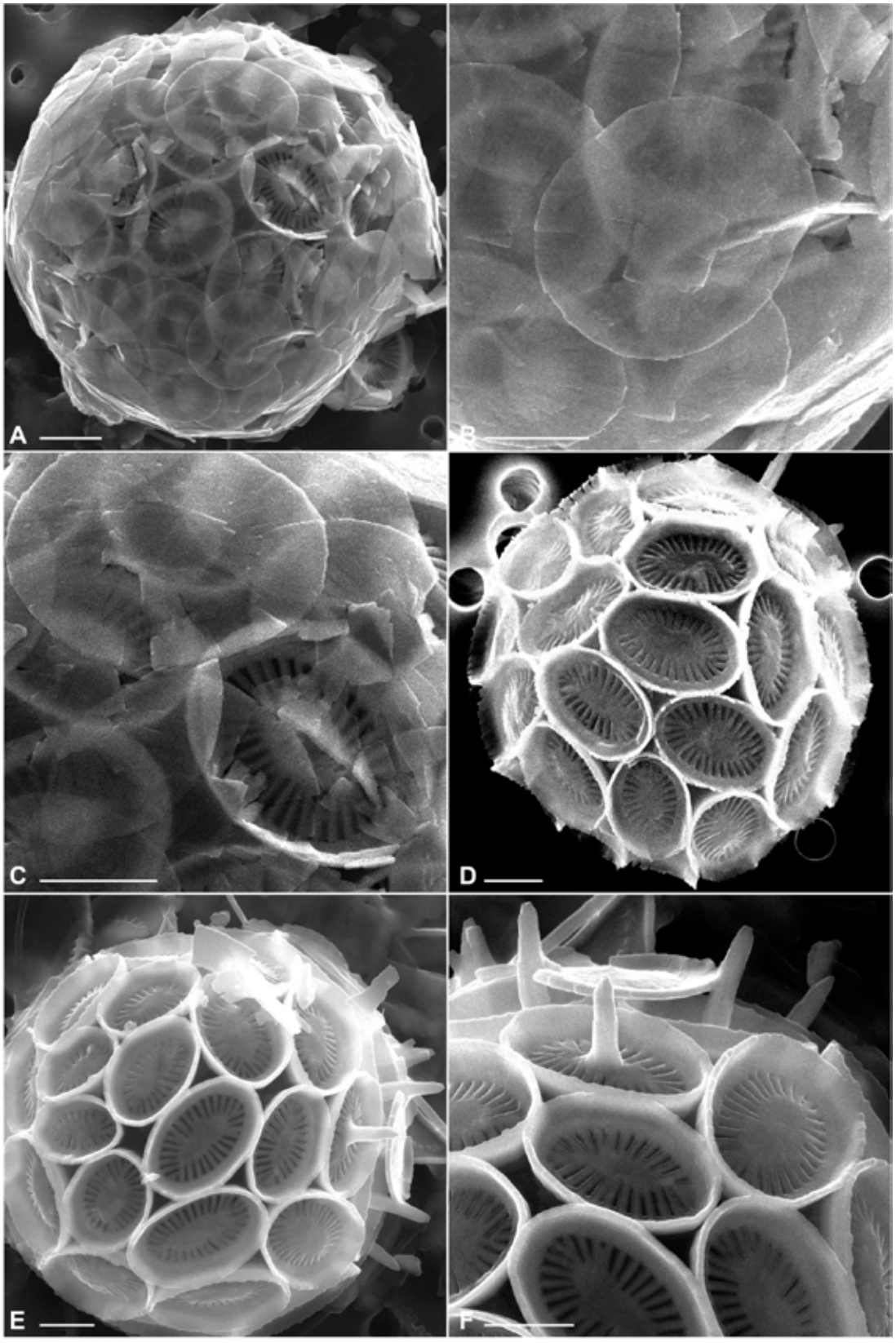

Figure 36. Coccolithophore morphology: **A.** cell of *Syracosphaera* sp. aff. *S. nodosa* type 2; **B.** exothecal coccoliths of *S.* sp. aff. *S. nodosa* type 2; **C.** exo- and endothecal muroliths of *S.* sp. aff. *S. nodosa*; **D–E.** cells of *Syracosphaera orbiculus* Okada & McIntyre, 1977; **F.** circum-flagellar coccoliths of *S. orbiculus* (one exothecal coccolith noted among spines). Scale bars A–F, 1 µm.

Saavedra-Pellitero et al. (2014). Elsewhere, this species appears to be quite limited in distribution. It has been recorded, e.g., in the western subarctic Pacific and Bering Sea (Hattori *et al*. 2004) and in the Java upwelling region of the tropical Indian Ocean (Andruleit 2007).

Remarks. Muroliths of *S. orbiculus* are similar to *S. bannockii*, but lack thick inner wall. Circum-flagellar coccoliths, are, however, like *S. bannockii*, with small spines (*see* Young *et al*. 2019, Nannotax3 website).

Syracosphaera* cf. *orbiculus

Fig. 38 A–D

Occurrence records. *Kaikoura*: NIWA Stn TAN0904/S13, 46.670° S, 174.409° E, Apr 2009.

Chatham Rise: NIWA Stn TAN1107/SBM, 46.656° S, 178.556° E, May 2011.

Description. Coccosphere ovoid (*c.*7 µm) (Fig. 38A). Endothecal muroliths (1.8–2.6 µm long) with a thin, smooth wall and without a distal flange; central area formed of 24–28 radially arranged lamellar elements, with a flat, slightly elongated, internal connecting structure (Fig. 38B). Three circum-flagellar coccoliths

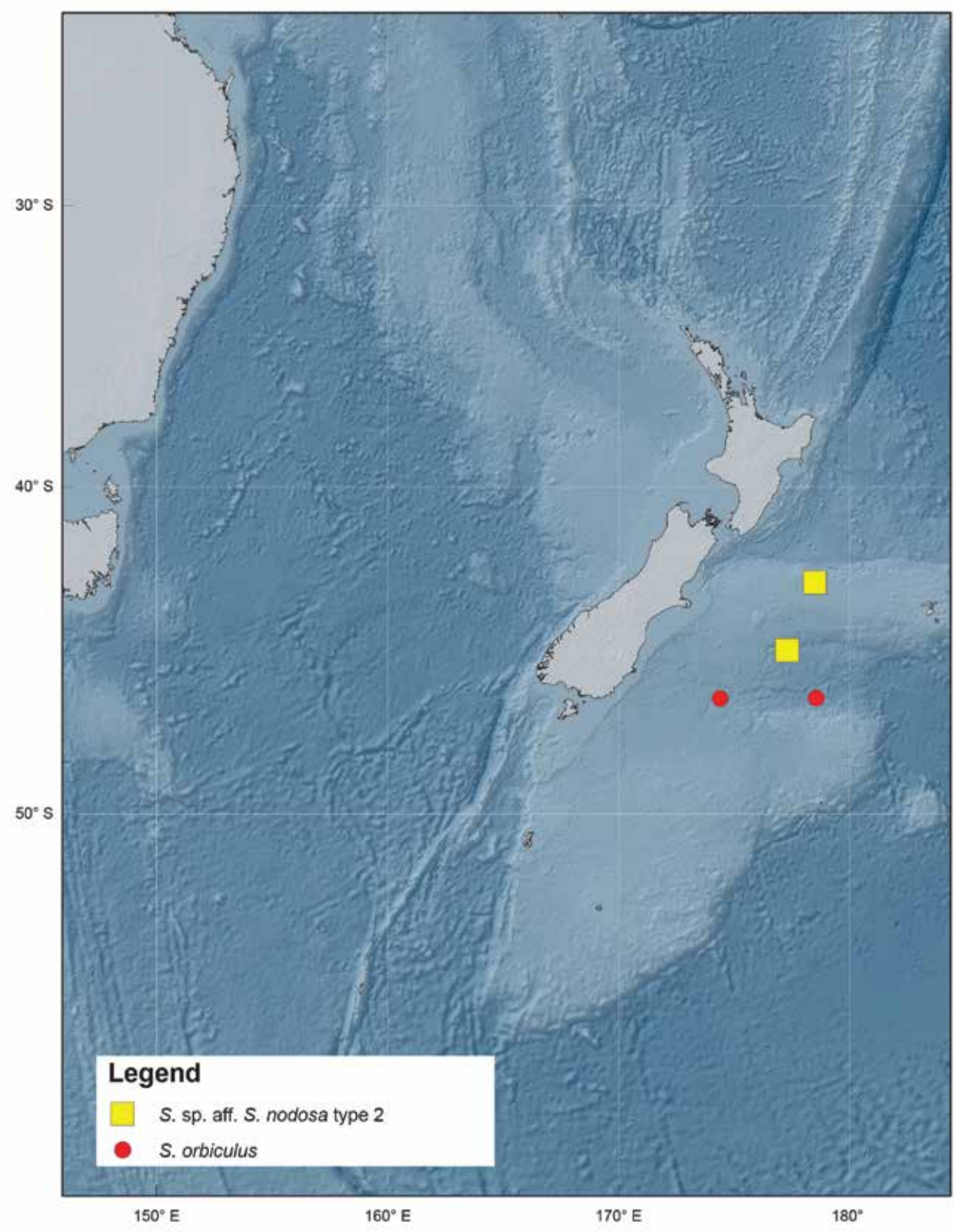

Figure 37. Distribution of *Syracosphaera* sp. aff. *S. nodosa* type 2 and *S. orbiculus* Okada & McIntyre, 1977 around New Zealand.

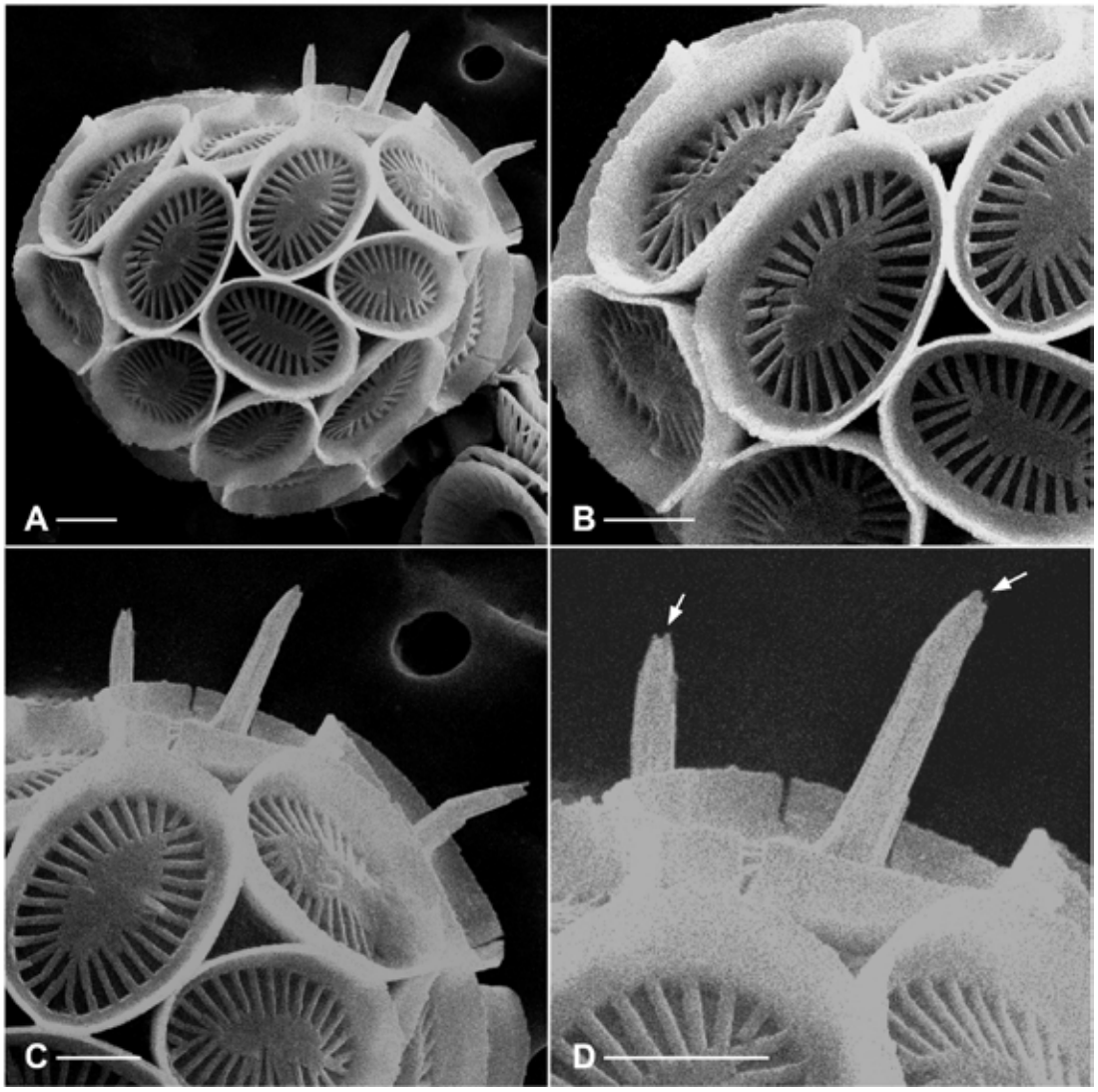

Figure 38. Coccolithophore morphology: **A.** cell of *Syracosphaera* cf. *orbiculus*; **B.** muroliths of *S.* cf. *orbiculus*; **C–D.** circum-flagellar coccoliths of *S.* cf. *orbiculus* (arrowheads in D. showing dichotomous tips). Scale bars A–D, 1 μm.

with relatively long (1.1–1.5 μm), somewhat bent spines, and each with a small 'dichotomous' tip (Fig. 38C, D). The three, long and somewhat bent spines observed here appear to be reminiscent of those of *Syracosphaera* cf. *orbiculus* as reported by Young *et al.* (2003) (*see* p. 41 and fig. 9).

Distribution and cell abundance. A small number of coccospheres of *Syracosphaera* cf. *orbiculus* were recorded at two sites in SA water south of Chatham Rise (Fig. 39). Cell concentrations recorded in autumns 2009 and 2011, ranged from 100–300 cells l^{-1} (Appendix 1, Tables 1.2, 1.9).

Previous records. This species was previously recorded as a first record for New Zealand (Chang & Northcote 2016).

Syracosphaera ossa (Lecal, 1966) Loeblich & Tappan, 1968

Fig. 40 A–D

Lecal, 1965a: 253–254, pl. 2, figs 5–8; (Lecal) Loeblich & Tappan, Okada & McIntyre, 1977: 25–26, pl. 10, figs 9–10; Kleijne, 1993: 240, pl. 5, figs 4–5; Winter & Siesser, 1994: 138, fig. 119; Cros & Fortuño, 2002: 94, figs 32A–D; Young *et al.* 2003: 49, pl. 21, figs 1, 4.

Basionym: *Syracolithus ossa* (Lecal) Loeblich & Tappan, 1968: 584–598.

Synonym: *Syracorhabdus ossa* Lecal, 1965: 253–254, pl. 2, figs 5–8.

Occurrence records. *Chatham Rise*: NIWA Stn TAN1107/T4, 45.204° S, 177.307° E, May 2011; NIWA Stn TAN1107/T5, 46.202° S, 178.500° E, May 2011; NIWA Stn TAN1203/DA59, 43.386° S, 179.452° E, Feb 2012.

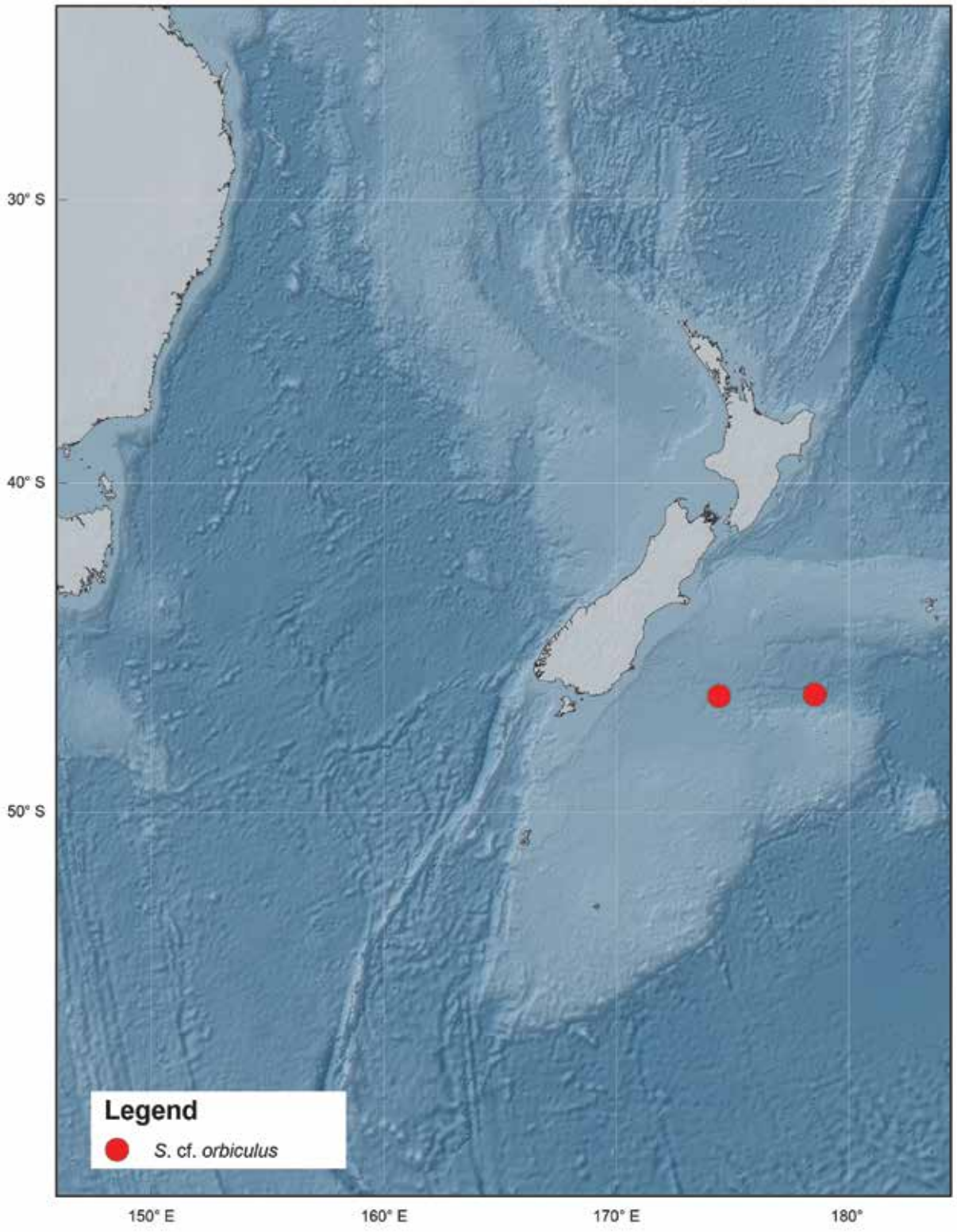

Figure 39. Distribution of *Syracosphaera* cf. *orbiculus* around New Zealand.

Holotype. Type is probably held at Toulouse Lab de Zoologie, France.

Type locality. Not recorded.

Description. Coccosphere ovoid (6–7 µm long) and dithecate (Fig. 40A). Exothecal coccoliths (*c.* 2.0 µm long) smooth and undulating with parenthesis–like openings bordering the ends of the slightly sunken central part (Fig. 40B). Body muroliths (1.7–2.6 µm long) elliptical with a broad, smooth distal flange and a central area consisting of thick radial laths and a smooth and sometimes a ridge-like central structure (Fig. 40C, D). Small circum-flagellar coccoliths (1.3–1.5 µm long) with a relatively narrow rim and a robust spine with an irregular but almost four-sided flat tip (Fig. 40C).

Distribution and cell abundance. *Syracosphaera ossa* was found at three sites in STF and SA waters over

Chatham Rise (Fig. 41). Cell concentrations recorded in autumn 2011, were 300–1,000 cells l^{-1} (Appendix 1, Table 1.9), and in summer 2012, were 4,200 cells l^{-1} (Appendix 1, Table 1.10).

Previous records. *Syracosphaera ossa* was previously recorded in STF/SA waters by Saavedra-Pellitero *et al.* (2014) and in the vicinity of the Chatham Rise by Chang & Northcote (2016). Elsewhere, this species is widely distributed, e.g., in the East China Sea (Wang *et al.* 2012), in the subtropical and subantarctic zones of the Southern Ocean (Saavedra-Pellitero *et al.* 2014), in the Australian sector of the Southern Ocean (Findlay & Giraudeau 2000), along a temperate to polar gradient in the West Pacific sector of the Southern Ocean (Malinverno *et al.* 2015), in the tropical and subtropical Atlantic Ocean (Poulton *et al.* 2017), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the Aegean Sea (NE Mediterranean) (Dimiza *et al.* 2015), in the middle and northern Adriatic Sea (Mediterranean) (Skejić *et al.* 2018; Godrijan *et al.* 2018), in the Java upwelling region of the tropical Indian Ocean (Andruleit 2007), and in the Indian sector of the Southern Ocean (Patil *et al.* 2017).

Syracosphaera pemmadiscus Chang, 2013

Fig. 42 A–F

Chang, 2013: 619–620, figs 1–7.

Occurrence records. *Chatham Rise*: Holotype—NIWA 88900, SEM stub, NIWA Stn TAN0902/YS39, 46.636° S, 178.566° E, Jan–Feb 2009; NIWA Stn TAN1107/T6, 44.198° S, 178.494° E, May 2011.

Holotype. SEM stub NIWA 88900, deposited at NIWA, Wellington, New Zealand.

Type locality. Subantarctic water in the vicinity of Chatham Rise, off the east coast of New Zealand (46.636° S, 178.566° E).

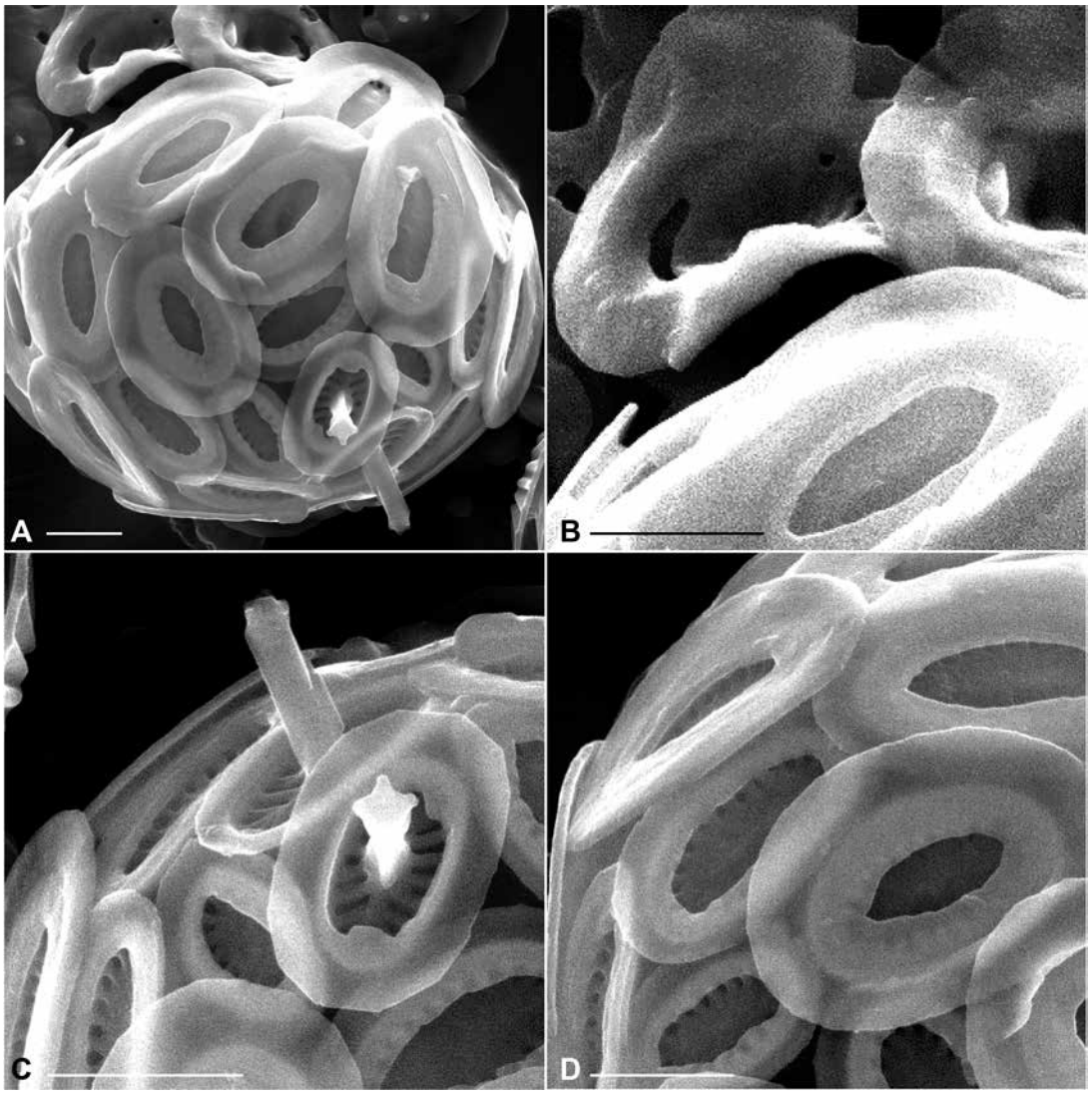

Figure 40. Coccolithophore morphology: **A.** cell of *Syracosphaera ossa* (Lecal, 1966) Loeblich & Tappan 1968; **B.** exothecal (top) and endothecal muroliths (bottom) of *S. ossa*; **C.** endothecal and circumflagellar coccoliths of *S. ossa*. **D.** body coccoliths of *S. ossa*. Scale bars A–D, 1 µm.

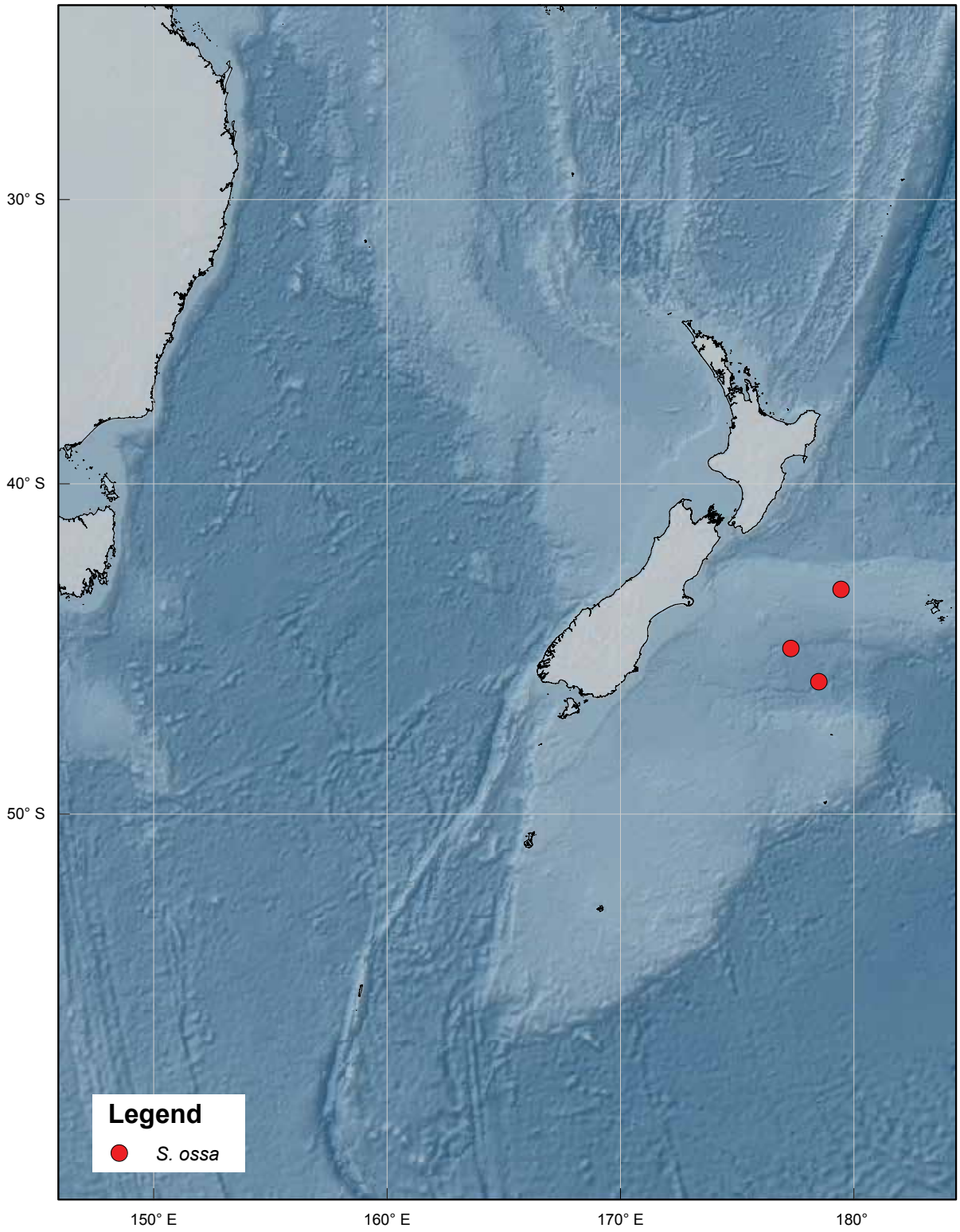

Figure 41. Distribution of *Syracosphaera ossa* (Lecal, 1966) Loeblich & Tappan 1968 around New Zealand.

Description. Coccosphere spherical to subspherical (7–8 µm long) and dithecate (Fig. 42A). Exothecal coccoliths (*c.* 1.6 µm long) range from disc-like to saddle-shaped planoliths (Fig. 42B, C). Endothecal muroliths (1.5–1.9 µm long) are elliptical and fluted on the inner wall like a cup-cake baking cup; the upper wall is flared prominently outward into the distal flange (Fig. 42D–F). The central area consisting of radial laths and the inner central structure varies from a low, longitudinal ridge to one or two short central processes (spines) (Fig. 42F).

Distribution and cell abundance. This species was found only on two occasions, summer 2009 and autumn 2011 in STF and SA waters, south of Chatham Rise (Fig. 43). Cell concentrations recorded are < 20 cells l^{-1} (Appendix 1, Tables 1.1, 1.9).

Previous records. Extant *Syracosphaera pemmadiscus* was previously described by Chang (2013) from New Zealand. Elsewhere, this species has been

recorded from samples collected along a temperate to polar gradient in the West Pacific sector of the Southern Ocean (Malinverno *et al*. 2015).

Syracosphaera pulchra Lohmann, 1902

Fig. 44 A–C

Lohmann, 1902: 134, pl. 4, figs 33, 36, 37; Kamptner, 1941: 85–86, 105–106, pl. 7, figs 77–78, pl. 8, figs 79–84; Lecal-Schlauder, 1951: 286, fig. 22, pl. 9, figs 1–5, 8–9; Loeblich & Tappan, 1963:

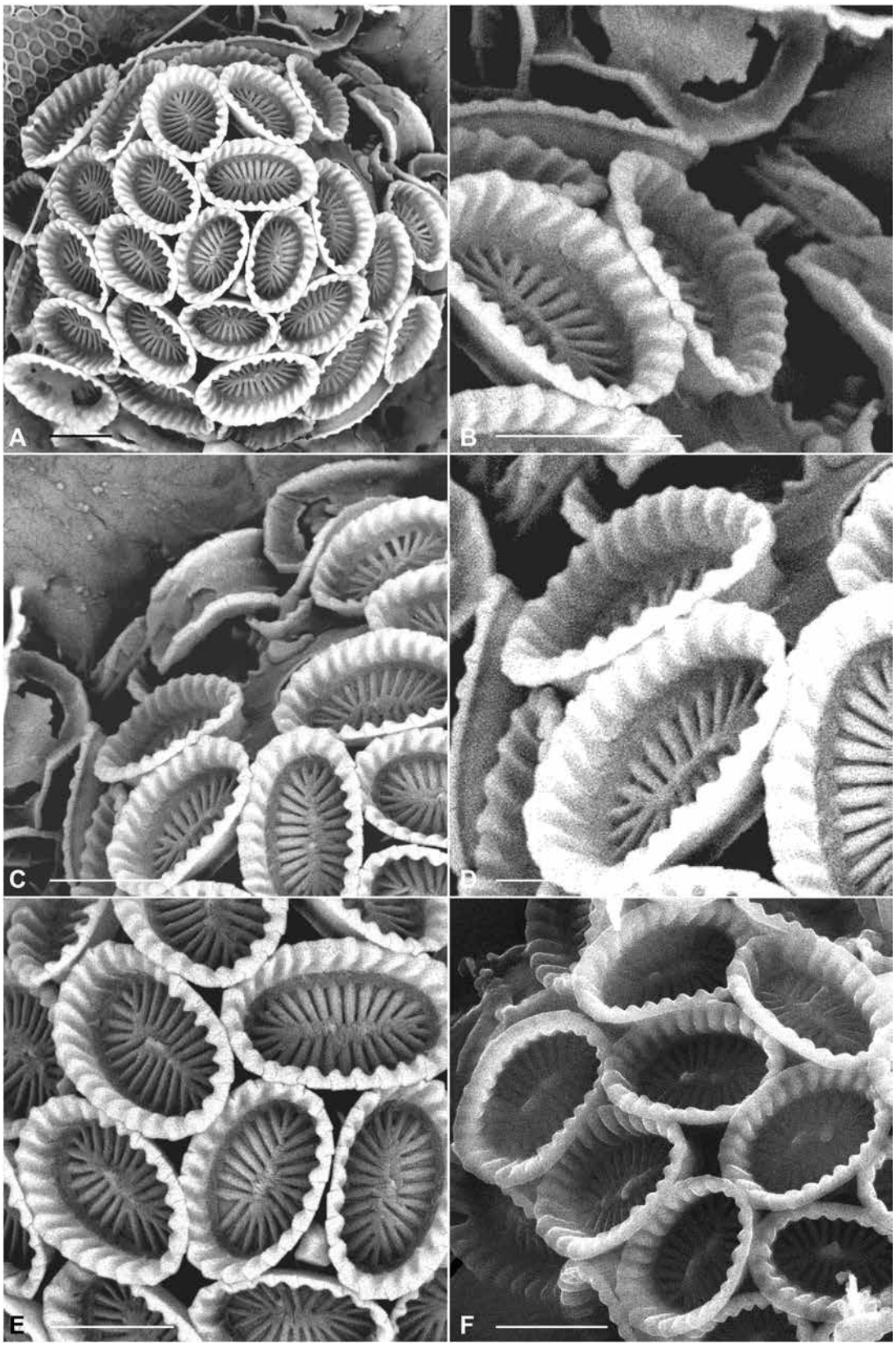

Figure 42. Coccolithophore morphology: **A.** cell of *Syracosphaera pemmadiscus* Chang, 2013; **B.** exothecal (top) and endothecal muroliths (bottom) of *S. pemmadiscus*; **C–F.** endothecal muroliths of *S. pemmadiscus*. Scale bars A–F, 1 μm.

193; Okada & McIntyre, 1977: 27, pl. 10, figs 11–12; Gaarder & Heimdal, 1977: 55, pl. 1, figs 1–8; Borsetti & Cati, 1972: 402, pl. 46, figs 2 a, b; Nishida, 1979: pl. 6, fig. 3; Hallegraeff, 1984: 239, figs 46 a, b; Inouye & Pienaar, 1988: 207–216, figs 1–15; Delgado & Fortuño, 1991: 21, pl. 79, fig. d, pl. 80, figs a–d, pl. 81, fig. a; Heimdal, 1973: 227–228, pl. 7, figs a–b; Kleijne, 1993: 241, pl. 5, fig. 10; Winter & Siesser, 1994: 139, fig. 122; Cros & Fortuño, 2002: 112–113, figs 50–51; Young *et al.* 2002: 43, pl. 18, figs 1–3.

Synonyms: *Syracorhabdus pulchra* (Lohmann) Lecal, 1966: 257–258, pl. 4, figs 11–13; Lecal, 1967: 315–316, text–fig. 11, fig. 15.
Syracosphaera decussata Hay & Beaudry, 1973: pl. 2, Figs 17–18.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS30, 46.638° S, 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS39, 42.820° S, 178.495° E, Jan–Feb 2009; NIWA Stn TAN0909/PM23, 42.349° S, 178.502° E, Oct 2009; NIWA Stn TAN0909/PM25, 42.392° S, 178.502° E, Oct 2009; NIWA Stn TAN1107/T1, 42.351° S, 175.651° E, May 2011; NIWA Stn TAN1203/DA16, 44.350° S, 174.419° E, Feb 2012; NIWA Stn TAN1203/DA31, 45.576° S, 173.387° E, Feb 2012.

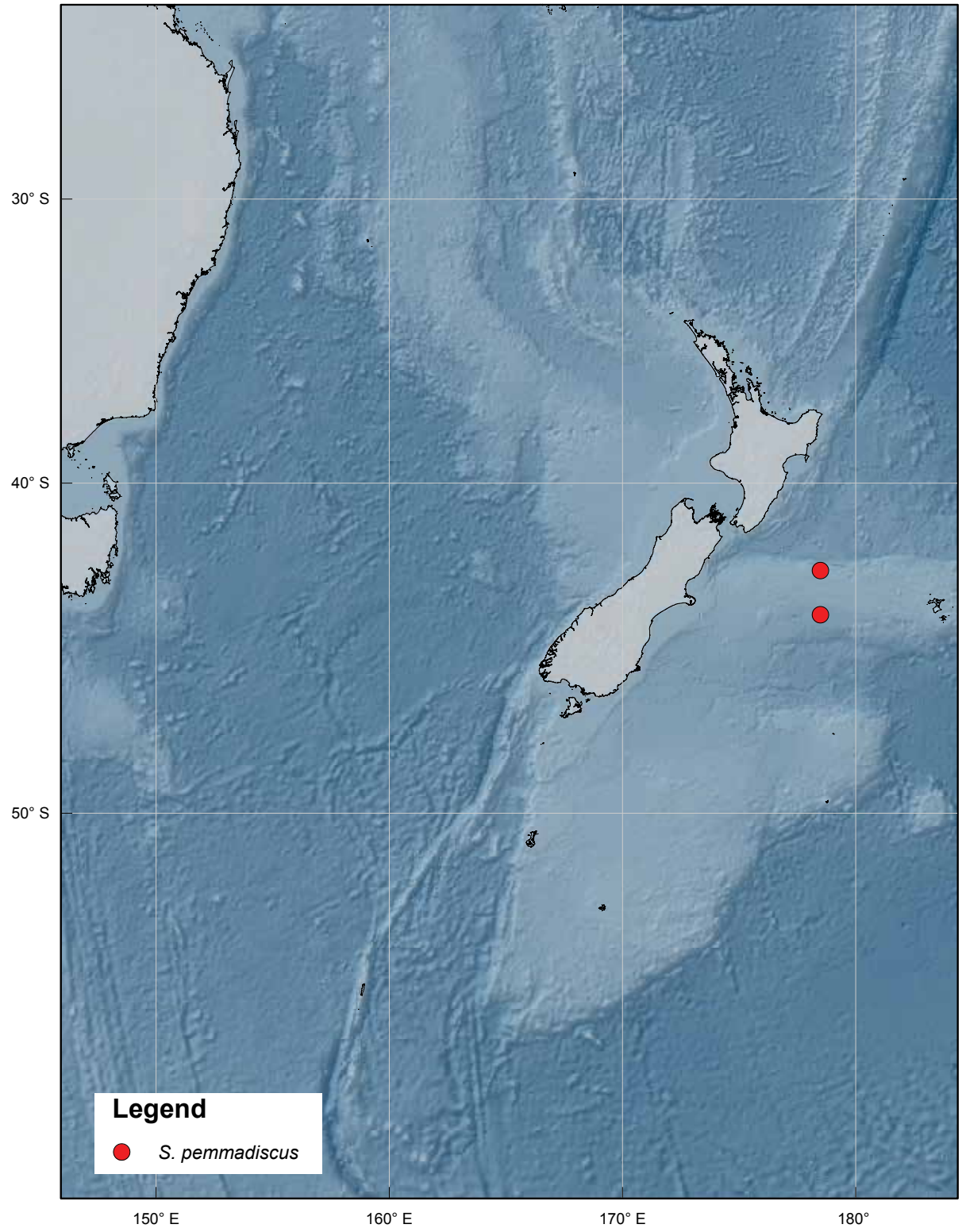

Figure 43. Distribution of *Syracosphaera pemmadiscus* Chang, 2013 around New Zealand.

Kaikoura: NIWA Stn TAN0904/S13, 46.670° S, 174.409° E, Apr 2009; NIWA Stn TAN0904/S45, 42.941° S, 173.926° E, Apr 2009; NIWA Stn TAN0904/S55, 42.207° S, 174.702° E, Apr 2009; NIWA Stn TAN0904/S71, 42.642° S, 174.584° E, Apr 2009; NIWA Stn TAN0904/S85, 42.614° S, 174.097° E, Apr 2009; NIWA Stn TAN0904/S95, 42.535° S, 173.607° E, Apr 2009.

Tasman Sea: PINTS Stn C34, 39.956° S, 162.170° E, Jan 2010.

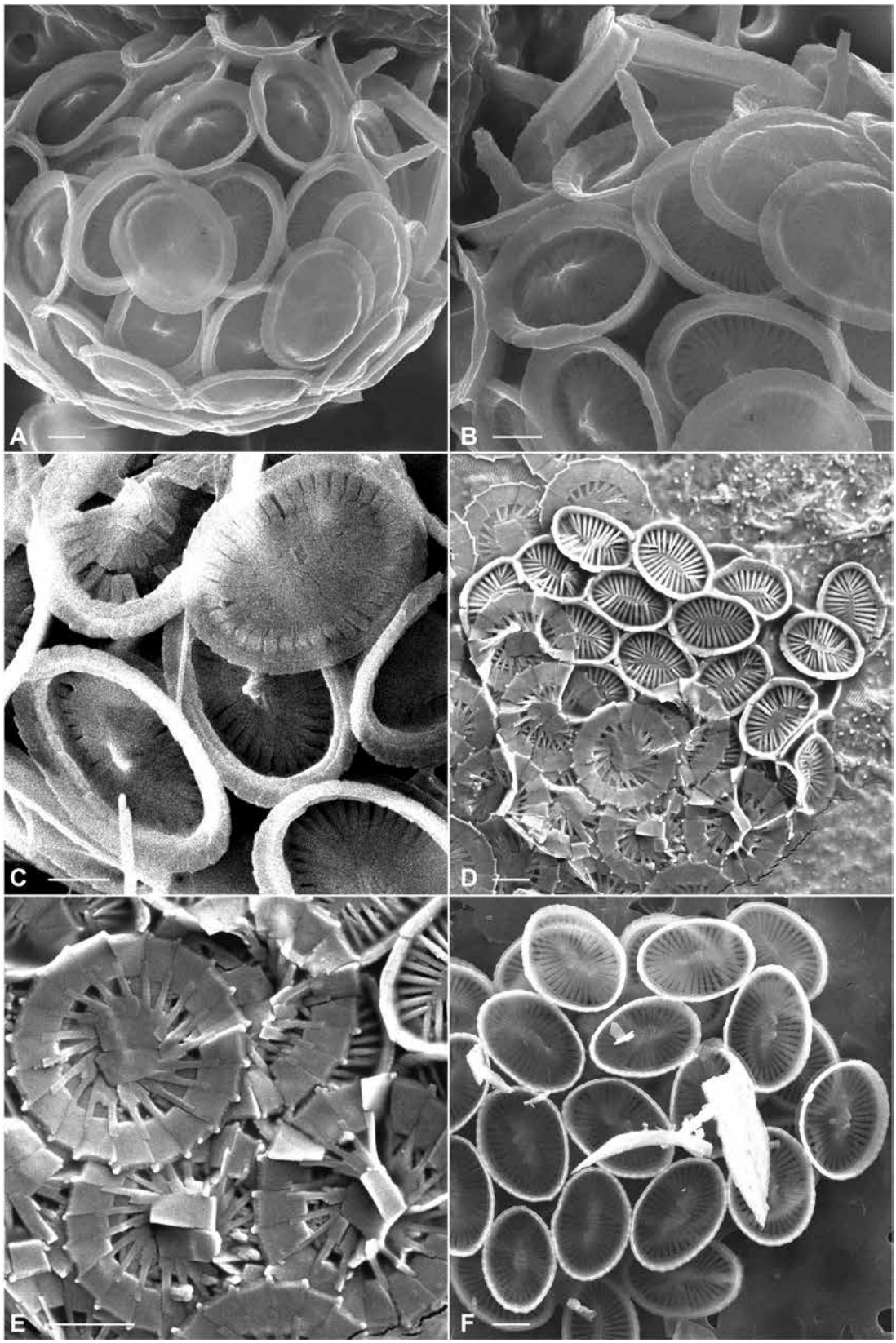

Figure 44. Coccolithophore morphology: **A.** cell of *Syracosphaera pulchra* Lohmann, 1902; **B–C.** circum-flagellar and endothecal coccoliths of *S. pulchra*; **D.** collapsed cell of *Syracosphaera serrata* Kleijne & Cros, 2009; **E.** wheel-like exothecal coccoliths of *S. serrata*; **F.** endothecal coccoliths of *Syracosphaera tumularis* Sánchez-Suárez, 1990. Scale bars A–F, 1 μm.

Holotype. Type is probably held in Kiel, Germany.

Type locality. Near Syracuse, Sicily, Italy.

Description. Coccosphere ovoid (10–12 µm long) and dithecate (Fig. 44A). Endothecal muroliths (3.8–4.2 µm long) elliptical with mid-wall flanges; the central area filled by numerous narrow, short laths and sometimes with a very short central process (spine) (Fig. 44B, C). Circum-flagellar coccoliths with robust spines (Fig. 44B).

Distribution and cell abundance. *Syracosphaera pulchra* was widely distributed off the Kaikoura coast and in the vicinity of Chatham Rise, and at one site in the Tasman Sea (Fig. 45). In this study coccospheres of *S. pulchra* were found in three summers (2009, 2010, 2012), two autumns (2009, 2011) and one spring (2009), with cell concentrations ranging from hundreds to thousands of cells per litre (Appendix 1, Tables 1.1, 1.2, 1.6, 1.9, 1.10). The greatest cell concentration (up to 11,000 cells l^{-1}) was recorded at one site off the Kaikoura coast, in autumn 2009 (Appendix 1, Table 1.2).

Previous records. *Syracosphaera pulchra* was previously recorded by Norris (1961), at three NZOI stations, B67, B80, and B85, along a transect between northeast New Zealand and Tonga (Appendix 2, Table 2.1), and at several sites on both the east and west coasts of New Zealand (Chang & Northcote 2016).

Elsewhere, this species has exhibited a very broad distribution. It has been recorded, e.g., in tropical and subtropical waters of the South China Sea (Lee Chen *et al.* 2007), in the East China Sea (only one site) (Wang *et al.* 2012), in the East Australian Current, the Coral Sea, northwestern Australia, Bass Strait, and southern Tasmanian waters (Hallegraeff 2010), in the Australian sector of the Southern Ocean (Findlay & Giraudeau 2000), in the Southern Ocean south of the Polar Front (Findlay *et al.* 2005), along a temperate to polar gradient in the West Pacific sector of the Southern Ocean (Malinverno *et al.* 2015), in the western subarctic Pacific and Bering Sea (Hattori *et al.* 2004), in the subtropical South Atlantic Ocean (Baumann *et al.* 2008), in the subtropical and temperate northeast Atlantic (Broerse *et al.* 2000a), in the tropical and subtropical Atlantic Ocean (Poulton *et al.* 2017), in a coastal upwelling region of Lisbon, Portugal, in the Mediterranean (Silva *et al.* 2009), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the Aegean Sea in the NE Mediterranean (Dimiza *et al.* 2015), in the middle and northern Adriatic Sea (Mediterranean) (Skejić *et al.* 2018; Godrijan *et al.* 2018), in the Bay of Bengal (Mergulhao *et al.* 2013), in an upwelling region off Somalia (NW Indian Ocean) (Broerse *et al.* 2000b), in the Java upwelling region in the tropical Indian Ocean (Andruleit 2007), and in the Indian sector of the Southern Ocean (Patil *et al.* 2017).

Syracosphaera serrata Kleijne & Cros, 2009

Fig. 44 D, E

Kleijne & Cros, 2009: 449–449, pl. 9, figs 1–6.

Synonyms: *Syracosphaera* sp. type B of Kleijne, 1993: 241, pl. 6, figs 2–3.

Syracosphaera nodosa type B of Young *et al.*, 2003: 36, pl. 15, fig. 6.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS30, 46.638° S, 178.542° E, Jan–Feb 2009.

Holotype. A15/98 (pl. 9, fig. 1), deposited at the National Herbarium Nederland, Universiteit Leiden branch (L), Netherlands.

Type locality. Snellius–II Expedition, Stn Go–98, Southern Red Sea, 13.852°N, 42.868°E, 0–5 m, 13 Jun 1998.

Description. Coccosphere dithecate (Fig. 44D). The almost circular exothecal coccoliths (*c.* 2.8 µm diameter) are a wheel-like disc with a relatively wide rim and a serrated margin (Fig. 44E). Endothecal muroliths (2.1–2.4 µm long) broadly elliptical with an irregular outline and a low, thin flaring wall; the central area is made up of radial laths and a flat inner centre.

Distribution and cell abundance. *Syracosphaera serrata* was found only at one site in SA water, south of Chatham Rise (Fig. 45). A very small number (< 20 cells l^{-1}) of this species was recorded in SA water in summer 2009 (Appendix 1, Table 1.1).

Previous records. *Syracosphaera serrata* was previously reported as a first record off the east coast of New Zealand (Chang & Northcote 2016). This species is widely distributed and has been recorded in many parts of the world, e.g., the Southern Red Sea, northeastern Indian Ocean, Gulf of Aden and Canary Islands (Kleijne & Cros 2009).

Syracosphaera tumularis Sánchez-Suárez, 1990

Fig. 44 F

Sánchez-Suárez, 1990: 157–158, figs 4A–F; Cros & Fortuño, 2002: 107, fig. 45; Young *et al.* 2002: 39, pl. 16, figs 7–12.

Synonyms: *Syracosphaera* sp. type C of Kleijne, 1993: 242, pl. 5, figs 11–12. Heimdal & Gaarder, 1981, pl. 10, figs 51a, b.

Syracosphaera sp. (Kamptner) Borsetti & Cati, 1972: 402, pl. 47, fig. 3; Hallegraeff, 1984: 239, fig. 44.

Syracosphaera lamina auct. *non* Lecal-Schlauder in Nishida, 1979, pl. 8, fig. 3; Winter & Siesser, 1994: 137, fig. 114.

Pontosphaera cf. *variabilis* Halldal & Markali in Reid, 1980: 156, pl. 3, figs 1–3.

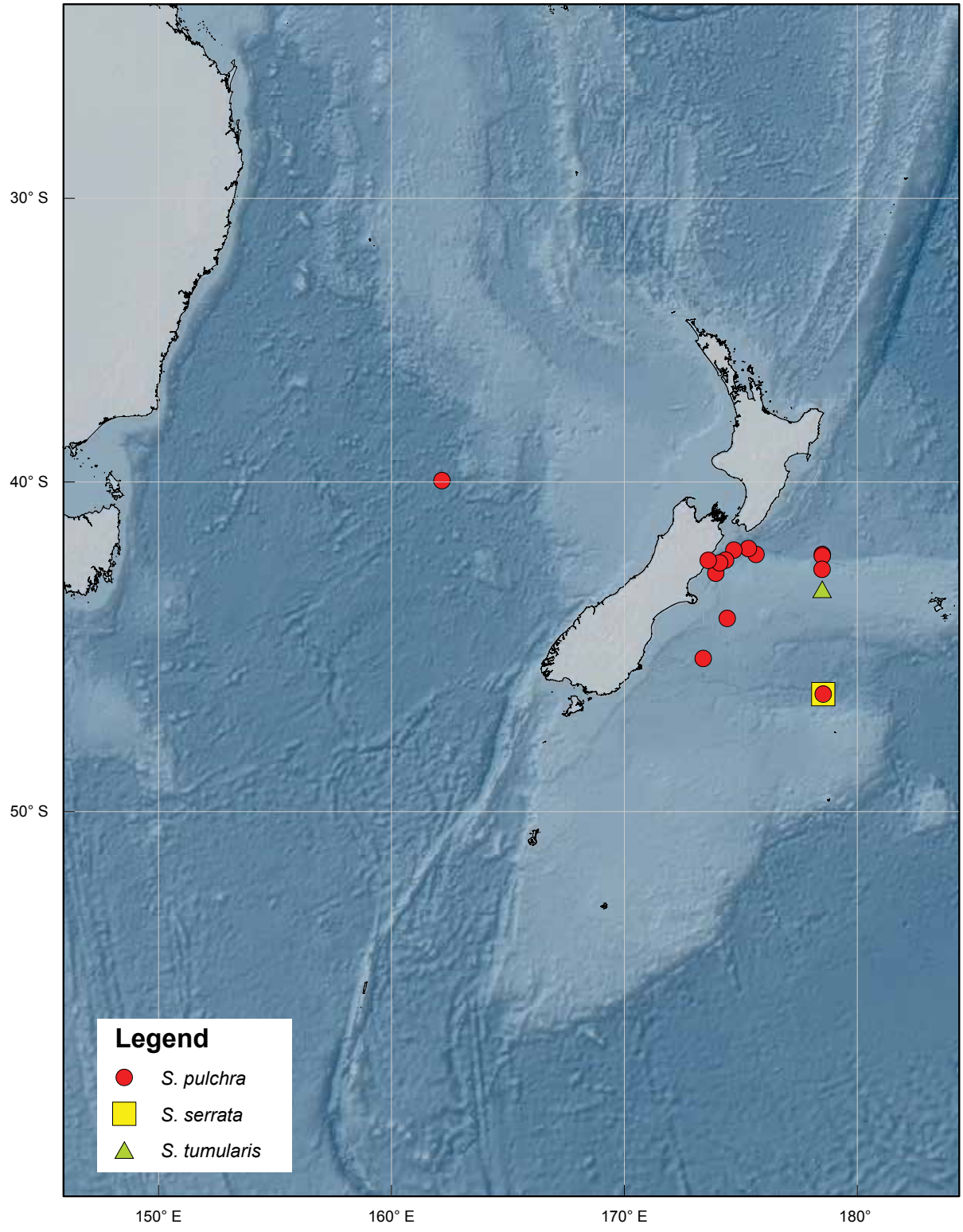

Figure 45. Distribution of *Syracosphaera pulchra* Lohmann, 1902, *S. serrata* Kleijne & Cros, 2009 and *S. tumularis* Sánchez-Suárez, 1990 around New Zealand.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS36, 43.446° S, 178.488° E, Jan–Feb 2009.

Holotype. Not recorded.

Type locality. Caribbean.

Description. Coccosphere dithecate but only broadly elliptical endothecal coccoliths were observed. The muroliths (3.0–3.3 µm long) have a relatively high, thin wall; the central area consists of radial laths with an elongated inner central mound constructed from irregular transverse elements (Fig. 44F).

Distribution and cell abundance. *Syracosphaera tumularis* has so far been found at one site over Chatham Rise (Fig. 45). Cell concentration recorded in summer 2009 was < 20 cells l^{-1} (Appendix 1, Table 1.1).

Previous records. The extant *Syracosphaera tumularis* was previously recorded in STF/SA waters

by Saavedra-Pellitero *et al.* 2014) (Appendix 2, Table 2.2) and at one site over Chatham Rise by Chang & Northcote (2016). Elsewhere, this species was recorded, e.g., in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the middle Adriatic Sea (northern Mediterranean) (Skejić *et al.* 2018), in the Java upwelling region of the tropical Indian Ocean (Andruleit 2007), and in the Indian sector of the Southern Ocean (Patil *et al.* 2017).

Families with possible affinities to the Order Syracosphaerales

Family **Alisphaeraceae** Young *et al.*, 2003

Description. Heterococcoliths arranged in meridional rows. Coccoliths asymmetrical with edge directed toward flagellar opening extended into a flange or protrusion (Kleijne 2002; Cros & Fortuño 2002; Young *et al.* 2003).

Type genus. *Alisphaera* Heimdal, 1973; emend. Kleijne *et al.*, 2002

Genus ***Alisphaera*** Heimdal, 1973; emend. Kleijne *et al.*, 2002

Heimdal 1973: 34; emend. Kleijne *et al.*, 2002: 587.

Description. Coccospheres ellipsoidal and monothecate. Placolith-like cocccoliths elliptical with a short tube, a proximal flange and an asymmetrical distal flange; central area usually with a longitudinal, slightly S-shaped fissure and nodules along the inner periphery of the distal flange, especially on the narrow side (Kleijne 2002; Cros & Fortuño 2002; Young *et al.* 2003).

Type species. *Alisphaera ordinata* (Kamptner) Heimdal, 1973.

Alisphaera pinnigera Kleijne *et al.,* 2002

Fig. 46 A, B

Kleijne *et al.*, 2002: 594, figs 40–45; Cros & Fortuño, 2002: 237, figs 75A, B; Young *et al.* 2003: 65, pl. 29, figs 4–6.

Synonym: *Alisphaera* sp. cf. *Alisphaera unicornis* (Okada & McIntyre) Giraudeau & Bailey, 1995, pl. 3, fig. 6.

Occurrence records. *Kaikoura*: NIWA Stn TAN0908/R13, 42.478° S, 174.491° E, Oct 2009.

Holotype. Type is held at Leiden, National Herbarium, Netherlands.

Type locality. Indian Ocean.

Description. Coccosphere (*c.* 7 µm long) dimorphic (Fig. 46A). The central area of the coccolith has a horizontal fissure. Some coccoliths have either a sharp, tooth-like spike or a flat, triangular protrusion along their inner margin (Fig. 46B).

Distribution and abundance. *Alisphaera pinnigera* was found on only one occasion, in spring 2009, off Kaikoura, on the east coast of New Zealand (Fig. 47). Coccospheres were recorded at this site at < 20 cells l^{-1} (Appendix 1, Table 1.2).

Previous records. The extant *Alisphaera pinnigera* was previously reported as a first-time record by Chang & Northcote (2016), off the east coast of New Zealand. This species was also recorded elsewhere, e.g., in the tropical and subtropical Atlantic Ocean (Poulton *et al.* 2017), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), and in the Java upwelling region in the tropical Indian Ocean (Andruleit 2007).

Genus ***Polycrater*** Manton & Oates, 1980

Description. Coccospheres with a closely packed layer of delicate, bowl-shaped, aragonitic coccoliths arranged with the concavities directed outwards; quadrate in plan view, and hour-glass shape in profile, with sepal-like proximal and petal-like distal structures (Manton & Oates 1980; Cros & Fortuño 2002; Young *et al.* 2003).

Type species. *Polycrater galapagensis* Manton & Oates, 1980

Polycrater galapagensis Manton & Oates, 1980

Fig. 46 C, D

Manton & Oates, 1980: 102, figs 1, 3–6; Thomsen *et al.* 1994, figs 10.6, 10.7; Cros & Fortuño, 2002: 142, figs 80A, B; Young *et al.* 2003: 67, pl. 30, fig. 7.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS2, 42.747° S, 175.841° E, Jan-Feb 2009; NIWA Stn TAN0902/YS39, 42.820° S, 178.495° E, Jan–Feb 2009.

Holotype. Type specimen illustrated in figs 1–6 of Manton & Oates (1980).

Type locality. Academy Bay, Galapagos Islands, 10 m.

Description. Coccosphere (*c.* 10 µm wide) with numerous very small coccoliths (0.5–0.6 µm) (Fig. 46C). They are quadrate in plan-view and an upside-down triangle in lateral view (Fig. 46D). Coccoliths are aragonite (Manton & Oates 1980).

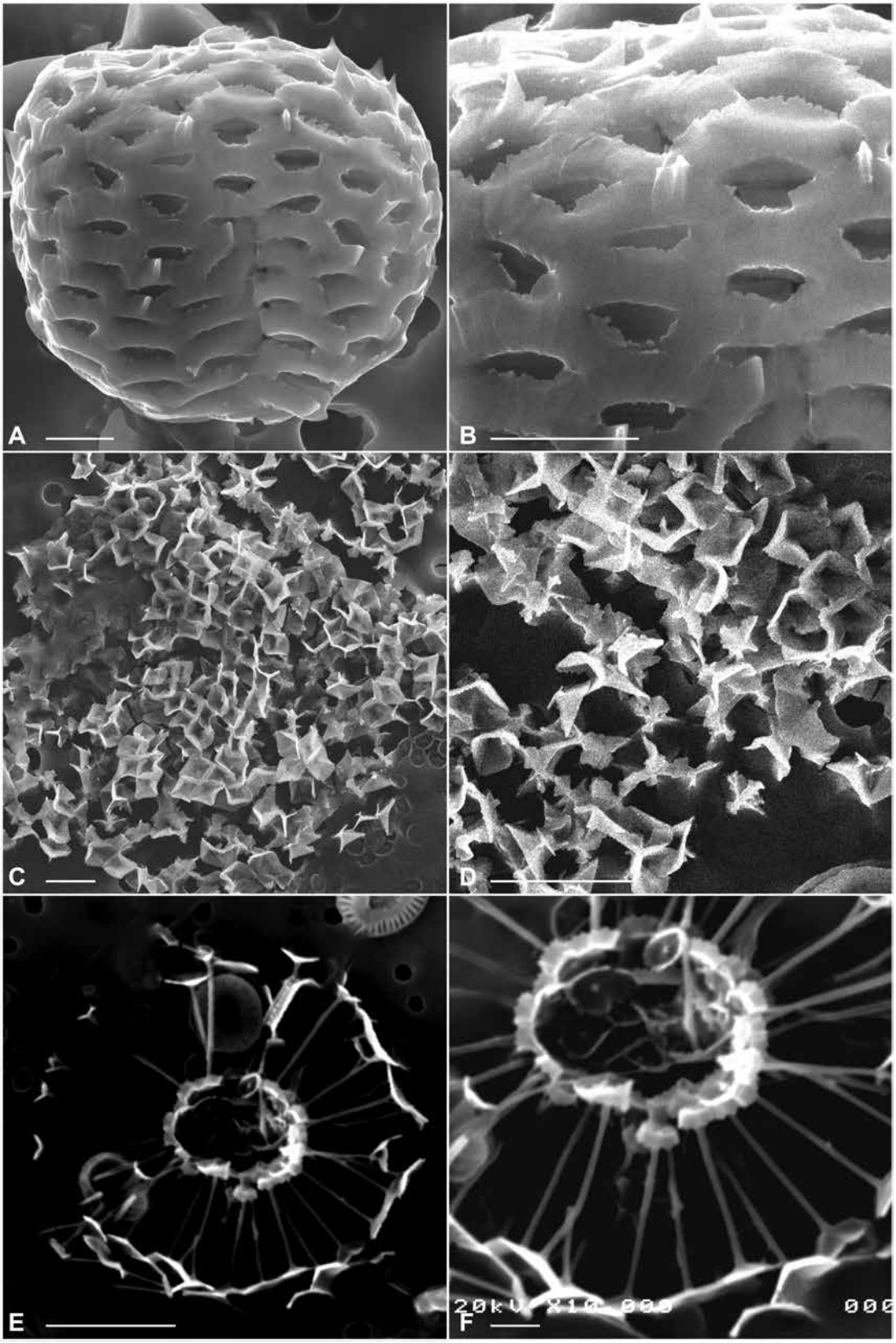

Figure 46. Coccolithophore morphology: **A.** cell of *Alisphaera pinnigera* Kleijne *et al*., 2002; **B.** coccoliths of *A. pinnigera*; **C.** cell of *Polycrater galapagensis* Manton & Oates, 1980; **D.** coccoliths of *P. galapagensis*; **E.** *Papposphaera lepida* Tangen, 1972; **F.** coccoliths of *P. lepida*. Scale bars A–D, 1 µm; E, 5 µm; F, 1 µm.

Distribution and cell abundance. *Polycrater galapagensis* was found at two sites over Chatham Rise (Fig. 47). Coccospheres were recorded only in summer 2009, with < 300 cells l^{-1} at two sites (Appendix 1, Table 1.1).

Previous records. *Polycrater galapagensis* was previously reported by Chang & Northcote (2016), off the east coast of New Zealand. Elsewhere, this species was widely recorded, e.g., in the Australian sector of the Southern Ocean (Findlay & Giraudeau 2000),

in the eastern Pacific sector of the Southern Ocean (Bellingshausen and Amundsen Seas) (Gravalosa *et al.* 2008), in the tropical and subtropical Atlantic Ocean (Poulton *et al.* 2017), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the middle Adriatic Sea (northern Mediterranean) (Skejić *et al.* 2018), in the Java upwelling region of the tropical Indian Ocean (Andruleit 2007), and in the Indian sector of the Southern Ocean (Patil *et al.* 2017).

Family **Pappospheraceae** Jordan & Young, 1990

Jordan & Young 1990: 15–18.

Description. Small, lightly calcified coccospheres. Pappoliths with a narrow murolith rim of non–overlapping elements, which may have a central spine supporting a calyx of four plates (Thomsen & Buck 1998; Young *et al.* 2003).

Remarks. This group is mainly recorded from high latitudes (Arctic and Antarctic), but many low-latitude species have also been recorded (Thomsen & Buck 1998; Cros & Fortuño 2002; Young *et al.* 2003).

Genus ***Papposphaera*** Tangen, 1972

Description. Coccospheres monomorphic or varimorphic. Pappoliths with processes and with pentagonal plates that form the rim. The shape of the process and the morphology of the base plate are used to separate the different species (Tangen 1972).

Type species. *Papposphaera lepida* Tangen, 1972.

Papposphaera lepida Tangen, 1972

Fig. 46 E, F

Tangen, 1972: 172, 175–177, figs 1–13, Tangen *in* Manton & Oates, 1975: 94, 96, figs 3–4; Thomsen & Buck, 1998: 32–33, figs 2–8; Cros & Fortuño, 2002: 127, fig. 65; Young *et al.* 2003: 75, pl. 34, figs 1–3.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS39, 42.820° S, 178.495° E, Jan–Feb 2009.

Holotype. Type is held at Oslo University, Institute of Marine Biology, Norway.

Type locality. Norwegian Sea.

Description. Coccosphere spherical (*c.* 6 µm) (Fig. 46E). The base of coccolith is subcircular to elliptical; the slightly raised rim is made up of a distally pointed crown. The central area is a long process (stem-like); at the top is a wide structure called a calyx (Fig. 46F).

Distribution and cell abundance. *Papposphaera lepida* was found only at one site in STF water over Chatham Rise (Fig. 47), in summer 2009, with a concentration of 300 cells l^{-1} (Appendix 1, Table 1.1).

Previous records. This extant species was previously reported by Chang & Northcote (2016), off the east coast of New Zealand. Elsewhere, *P. lepida* is found to be widely distributed, e.g., in the Australian sector of the Southern Ocean (Findlay & Giraudeau 2000), in the tropical and subtropical Atlantic Ocean (Poulton *et al.* 2017), in the Norwegian Sea (Tangen 1972), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the middle Adriatic Sea (northern Mediterranean) (Skejić *et al.* 2018), and in the Java upwelling region of the tropical Indian Ocean (Andruleit 2007).

Family **Umbellosphaeraceae** Young *et al.*, 2003

Description. Coccosphere dimorphic. Coccoliths variable in size, with a funnel-shaped distal part on a flat base. The funnel elements are continuous with the basal plate elements of the central area; a flange may be present around the basal plate (Young *et al.* 2003).

Genus ***Umbellosphaera*** Paasche in Markali & Paasche, 1955; emend. Gaarder, 1981 in Heimdal & Gaarder, 1981

Heimdal & Gaarder, 1981: 62–63, pl. 11, figs 59 a, b.

Description. Coccospheres sub-spherical without obvious flagellar opening. Coccoliths are placolith–like, with distal shield greatly extended (Cros & Fortuño 2002; Young *et al.* 2003).

Type species. *Umbellosphaera tenuis* (Kamptner, 1937) Paasche in Markali & Paasche, 1955.

Umbellosphaera tenuis (Kamptner, 1937) Paasche in Markali & Paasche, 1955

Fig. 48 A–F

(Kamptner) Paasche *in* Markali & Paasche, 1955: 96–97, pl. 1–2; McIntyre & Bé, 1967: 566–567, pl. 3; Borsetti & Cati, 1972: 406–407, pl. 53, fig. 3, pl. 54, figs 1–2; Heimdal & Gaarder, 1981: 62–63, pl. 11, figs 59a, b; Hallegraeff, 1984: 237, fig. 30; Samtleben & Schröder, 1990: pl. 4, fig. 1; Kleijne, 1993: 221, pl.8, figs 1–2; Cros & Fortuño, 2002: 145, figs 83A, B; Young *et al.* 2003: 69, pl. 31, fig. 9.

Basionym: *Coccolithus tenuis* Kamptner, 193: 311–312, pl. 17, figs 41–427.

Synonyms: *Ellipsodiscoaster lidzii* Boudreaux & Hay, 1969: 249.
Discoaster murrayi Black & Barnes, 1961: 137.
Umbilicosphaera rosaceus Lecal, 1967: 305.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS2, 42.747° S, 175.841° E, Jan–Feb 2009;

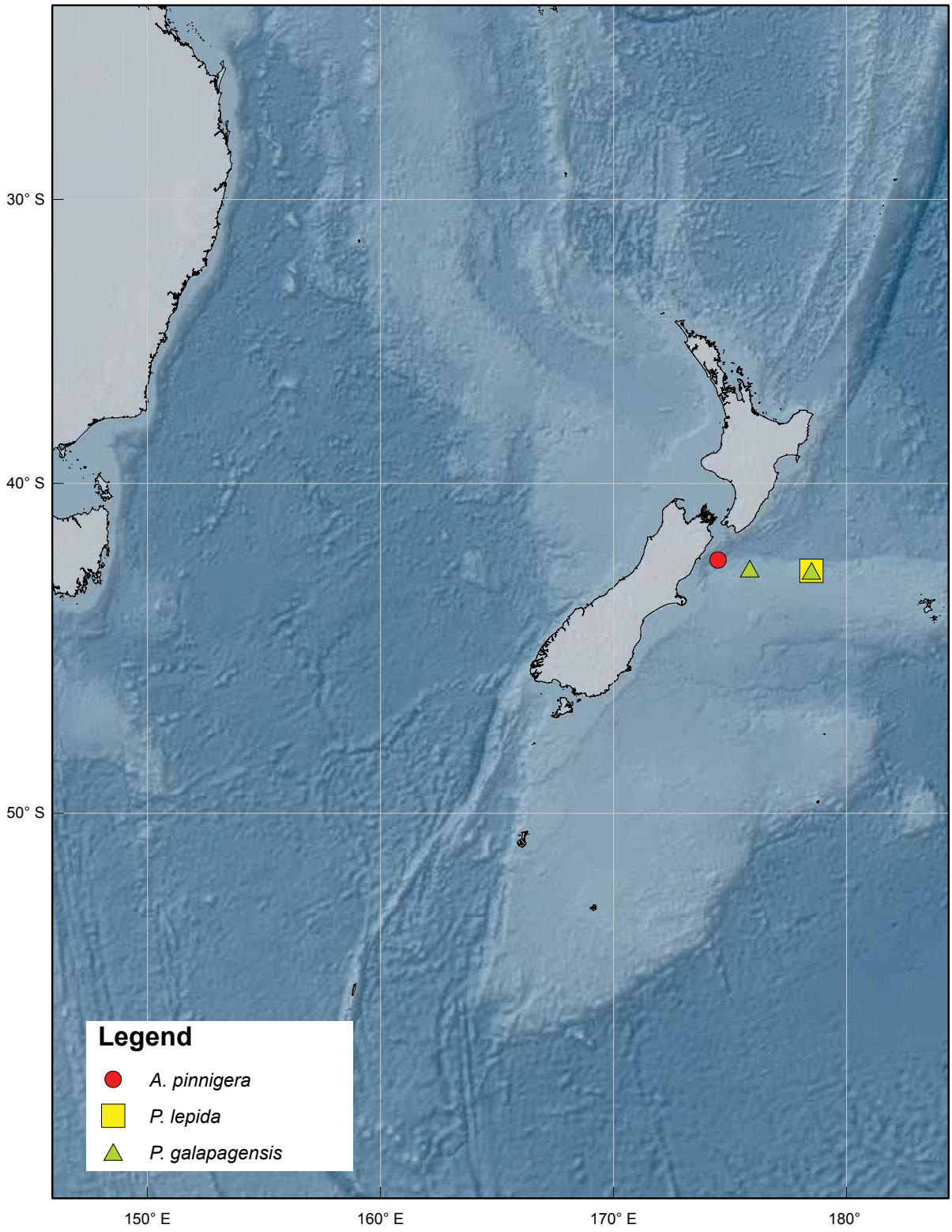

Figure 47. Distribution of *Alisphaera pinnigera* Kleijne *et al*., 2002, *Polycrater galapagensis* Manton & Oates, 1980 and *Papposphaera lepida* Tangen, 1972 around New Zealand.

NIWA Stn TAN0902/YS29, 46.636° S, 178.556° E, Jan–Feb 2009; NIWA Stn TAN0902/YS30, 46.638° S, 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS31, 41.107° S, 178.590° E, Jan–Feb 2009; NIWA Stn TAN0902/YS59, 41.228° S, 178.522° E, Jan–Feb 2009; NIWA Stn TAN0909/PM16, 44.501° S, 178.300° E, Oct 2009; NIWA Stn TAN0909/PM19, 44.109° S, 178.504° E, Oct 2009; NIWA Stn TAN1102/NH89, 43.727° S, 175.188° E, Feb 2011; NIWA Stn TAN1107/T3, 44.206° S, 176.701° E, May 2011; NIWA Stn TAN1107/SBM, 46.656° S, 178.556° E, May 2011; NIWA Stn TAN1107/T5, 46.202° S, 178.500° E, May 2011; NIWA Stn TAN1107/T6, 44.198° S, 178.494° E, May 2011; NIWA Stn TAN1203/DA6, 43.365° S, 174.464° E, Feb 2012; NIWA Stn TAN1203/DA11, 44.350° S, 174.419° E, Feb 2012; NIWA Stn TAN1203/DA27, 44.201° S, 175.148° E,

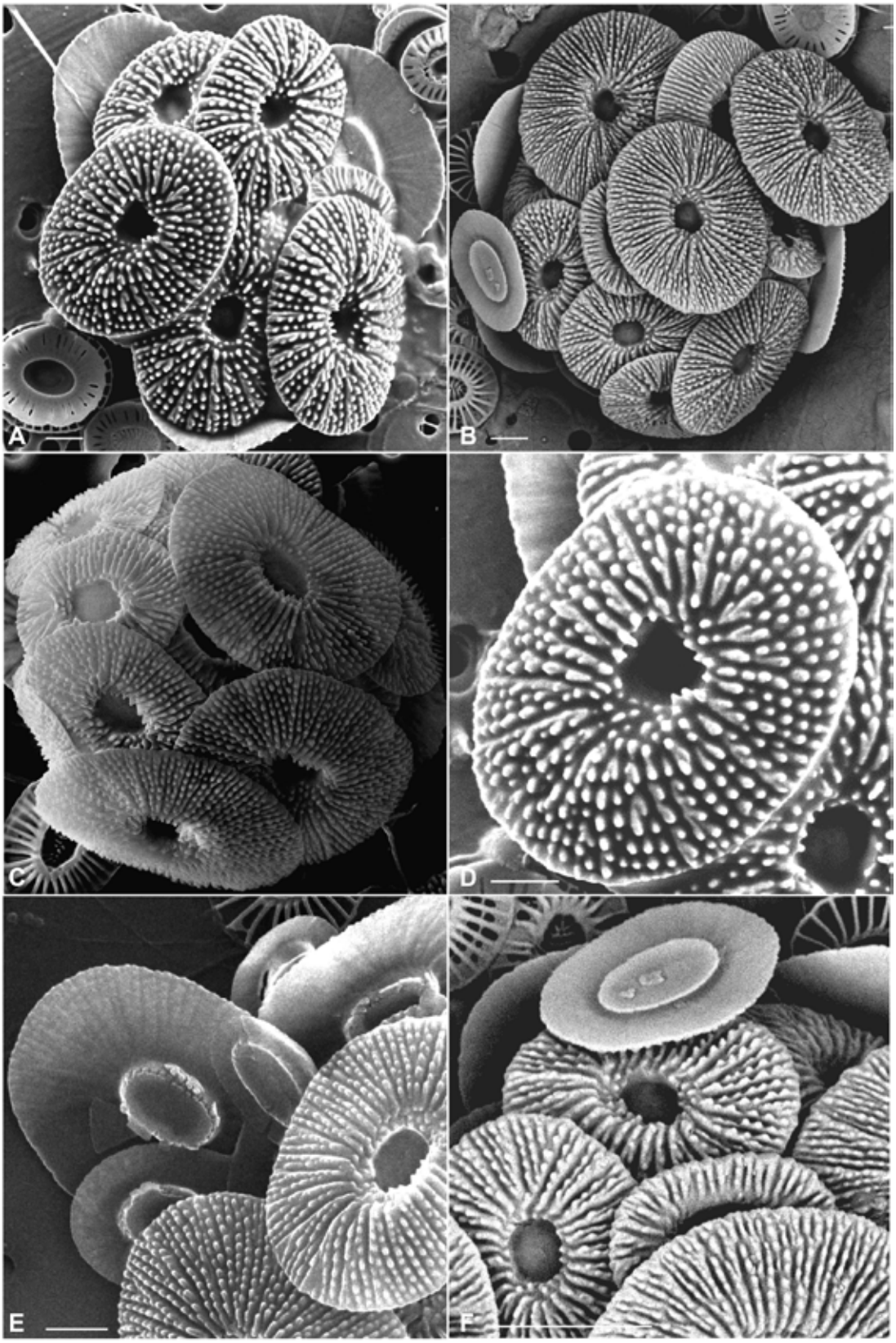

Figure 48. Coccolithophore morphology: **A–C.** cells of *Umbellosphaera tenuis* type II (Kamptner, 1937) Paasche in Markali & Paasche 1955; **D.** macrococcolith of *U. tenuis* type II; **E–F.** micro- and macrococcoliths of *U. tenuis* type II. Scale bars A–F, 1 μm.

Feb 2012; NIWA Stn TAN1203/DA31, 45.576° S, 173.387° E, Feb 2012; NIWA Stn TAN1203/DA35, 43.445° S, 176.579° E, Feb 2012; NIWA Stn TAN1203/DA48, 43.426° S, 179.457° E, Feb 2012; NIWA Stn TAN1203/DA82, 43.067° S, 175.285° E, Feb 2012; NIWA Stn TAN1203/104, 44.758° S, 174.633° E, Feb 2012.

Tasman Sea: PINTS Stn C2, 31.360° S, 162.338° E, Jan 2010; PINTS Stn C5, 39.960° S, 162.185° E, Jan 2010; PINTS Stn C6, 39.996° S, 162.177° E, Jan 2010; PINTS Stn C7, 42.501° S, 161.251° E, Jan 2010; PINTS

Stn C9, 43.514° S, 160.515° E, Jan 2010; PINTS Stn C11, 46.295° S, 159.882° E, Jan 2010; PINTS Stn C14, 46.302° S, 159.883° E, Jan 2010; PINTS Stn C19, 39.966° S, 162.117° E, Jan 2010; PINTS Stn C23A, 46.300° S, 159.872° E, Jan 2010; PINTS Stn C23B, 46.300° S, 159.872° E, Jan 2010; PINTS Stn C24, 46.022° S, 156.822° E, Jan 2010; PINTS Stn C46, 45.854° S, 150.872° E, Jan 2010; PINTS Stn C47, 44.930° S, 149.637° E, Jan 2010; PINTS Stn C50, 44.220° S, 148.750° E, Jan 2010.

Holotype. Type is probably held at Natural History Museum Vienna, Austria.

Type locality. Mediterranean Sea, Stns 14, 15 (14: half way between Psará and Andros Islands, 38.333° N, 28.183° E; 15: south of Canal du Oro, 30.833° N, 24.583° E).

Description. Coccosphere subspherical (8–12 µm long) with coccoliths of different sizes – small micrococcoliths (2.0–3.0 µm long) and large macrococcoliths (4.0–6.0 µm long) (Fig. 48A–F). Both have subcircular to elliptical central areas. Coccoliths slightly convex; distal surface with pattern of ridges (Fig. 48D). The morphology is very variable, with different patterns of ridges (Young *et al.* 2003). The only form recorded around New Zealand is *U. tenuis* type II, characterised by the presence of papillae (nodes) on ridges of coccolith (Fig. 48D).

Distribution and cell abundance. *Umbellophaera tenuis* type II was most widely distributed in open waters over Chatham Rise to the east, the Tasman Sea to the west, and at one site to the south of New Zealand (Fig. 49). In terms of seasonality, most coccospheres of *U. tenuis* type II were found in summer (virtually in all four summers from January 2009 to February 2012) (Appendix 1, Tables 1.1, 1.6, 1.7, 1.10). Fewer were recorded in the autumn of 2011 (Apps. VIII, IX), and the fewest in the spring of 2009 (Appendix 1, Table 1.5). This species was most widely distributed in the Tasman Sea (20 out of 29 sites), with cell concentrations ranging from 300 to 6,000 cells l^{-1} (Appendix 1, Table 1.6). Coccospheres of this species were found to be the most abundant over Chatham Rise on two occasions – in the summer of 2009 (up to 224,000 cells l^{-1}) and the summer of 2012 (18,000 cells l^{-1}) (Appendix 1, Tables 1.1, 1.10). This species was absent from the coastal waters off Kaikoura, in both the spring or autumn of 2009 (Appendix 1, Tables 1.2, 1.4), or in the Bay of Plenty, in the spring of 2009 (Appendix 1, Table 1.3).

Previous records. This extant species was previously reported in STF/SA waters to the east (Saavedra-Pellitero *et al.* 2014; Appendix 2, Table 2.2) and in many other sites around New Zealand (Chang & Northcote 2016).

Elsewhere, *U. tenuis* has a very broad distribution. It was recorded, e.g., in the equatorial and subequatorial Pacific Ocean (Hagino & Okada 2004), in tropical and subtropical waters of the South China Sea (Lee Chen *et al.* 2007), in the East China Sea (Wang *et al.* 2012), in the East Australian Current (Hallegraeff 2010), in the Australian sector of the Southern Ocean (Findlay & Giraudeau 2000), along a temperate to polar gradient in the West Pacific sector of the Southern Ocean (Malinverno *et al.* 2015), in the western subarctic Pacific and Bering Sea (Hattori *et al.* 2004), in the subtropical South Atlantic Ocean (Baumann *et al.* 2008), off Terceira Island, Azores, in the central North Atlantic Ocean (Narciso *et al.* 2016), in the subtropical and temperate northeast Atlantic (Broerse *et al.* 2000a), in the tropical and subtropical Atlantic Ocean (Poulton *et al.* 2017), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the Aegean Sea (NE Mediterranean) (Dimiza *et al.* 2015), in the Java upwelling region of the tropical Indian Ocean (Andruleit 2007), in an upwelling region off Somalia (NW Indian Ocean) (Broerse *et al.* 2000b), in the Bay of Bengal in the Indian Ocean (Mergulhao *et al.* 2013), and in the Indian sector of the Southern Ocean (Patil *et al.* 2017).

Order **Zygodiscales** Young & Bown, 1997

Description. Coccospheres with monomorphic or dimorphic coccoliths. Heterococcoliths are muroliths and modified derivatives; outer rim with clockwise imbrication (Cros & Fortuño 2002; Young *et al.* 2003).

Family **Helicosphaeraceae** Black, 1971; emend. Jafar & Martini, 1975

Description. Coccospheres ellipsoidal with a prominent flagellar opening. Coccoliths spirally arranged round the coccosphere; outer rim modified into a helical flange, ending in a wing or spike (Jordan & Green 1994; Cros & Fortuño 2002; Young *et al.* 2003).

Genus ***Helicosphaera*** Kamptner, 1954

Helicopontosphaera Hay & Mohler, 1967

Description. Ellipsoidal coccospheres. Helicoliths with a characteristic helical flange (Cros & Fortuño 2002; Young *et al.* 2003).

Type species. *Helicosphaera carteri* (Wallich) Kamptner, 1954.

Helicosphaera carteri (Wallich, 1877) Kamptner, 1954

Fig. 50 A–D

Helicosphaera carteri (Wallich) nov. comb. Kamptner, 1954: 21, 23, figs 17–1.9; Gaarder & Hasle, 1971: fig. 9; Hallegraeff, 1984: 235, figs 19–20; Kleijne, 1993: plate 1, fig. 8; Cros & Fortuño, 2002: 71, figs 9A–C; Young *et al.* 2003: 27, pl. 10, figs 1–6.

Basionym: *Coccosphaera carteri* Wallich, 1877: 342.

Synonyms: *Coccolithus carteri* (Wallich) Kamptner *in* Kamptner, 1941: 93–94, 111–112, pl. 12, fig. 134, pl. 13, figs 135–136.

Coccolithus pelagicus forme *diademata* Gardet, 1955: 511, pl. 5, figs 46–47.

Discolithus cristatus Gardet, 1955: 501, pl. 2, figs 18 a, b.

Discolithus margaritiferus Gardet, 1955: 507, pl. 4, figs 37 a–f.

Helicopontosphaera Kamptner, Hay & Mohler in Hay *et al.*, 1967, pl. 10–11, fig. 5; Perch–Nielsen, 1985, figs 43, 45.

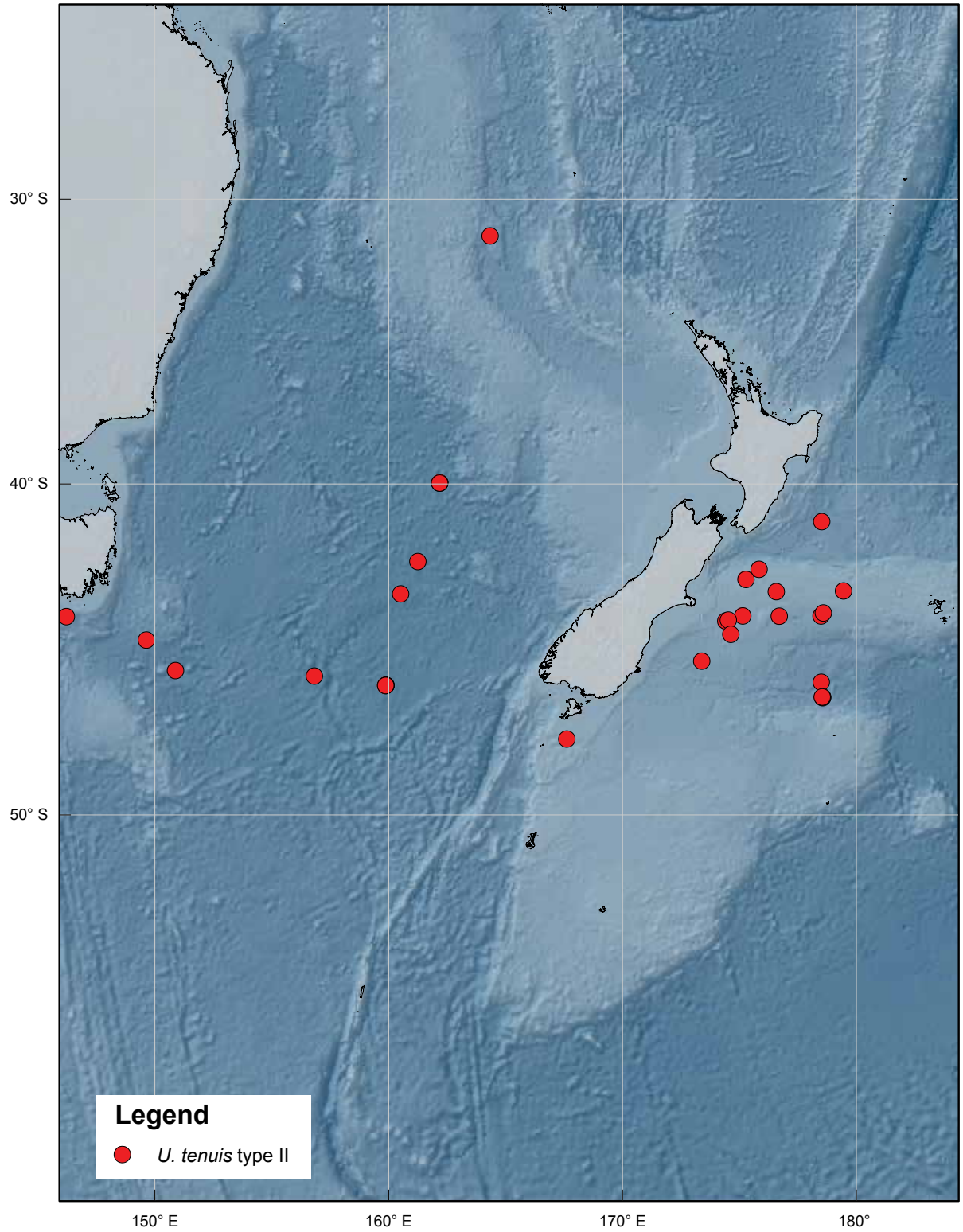

Figure 49. Distribution of *Umbellosphaera tenuis* type II (Kamptner, 1937) Paasche in Markali & Paasche 1955 around New Zealand.

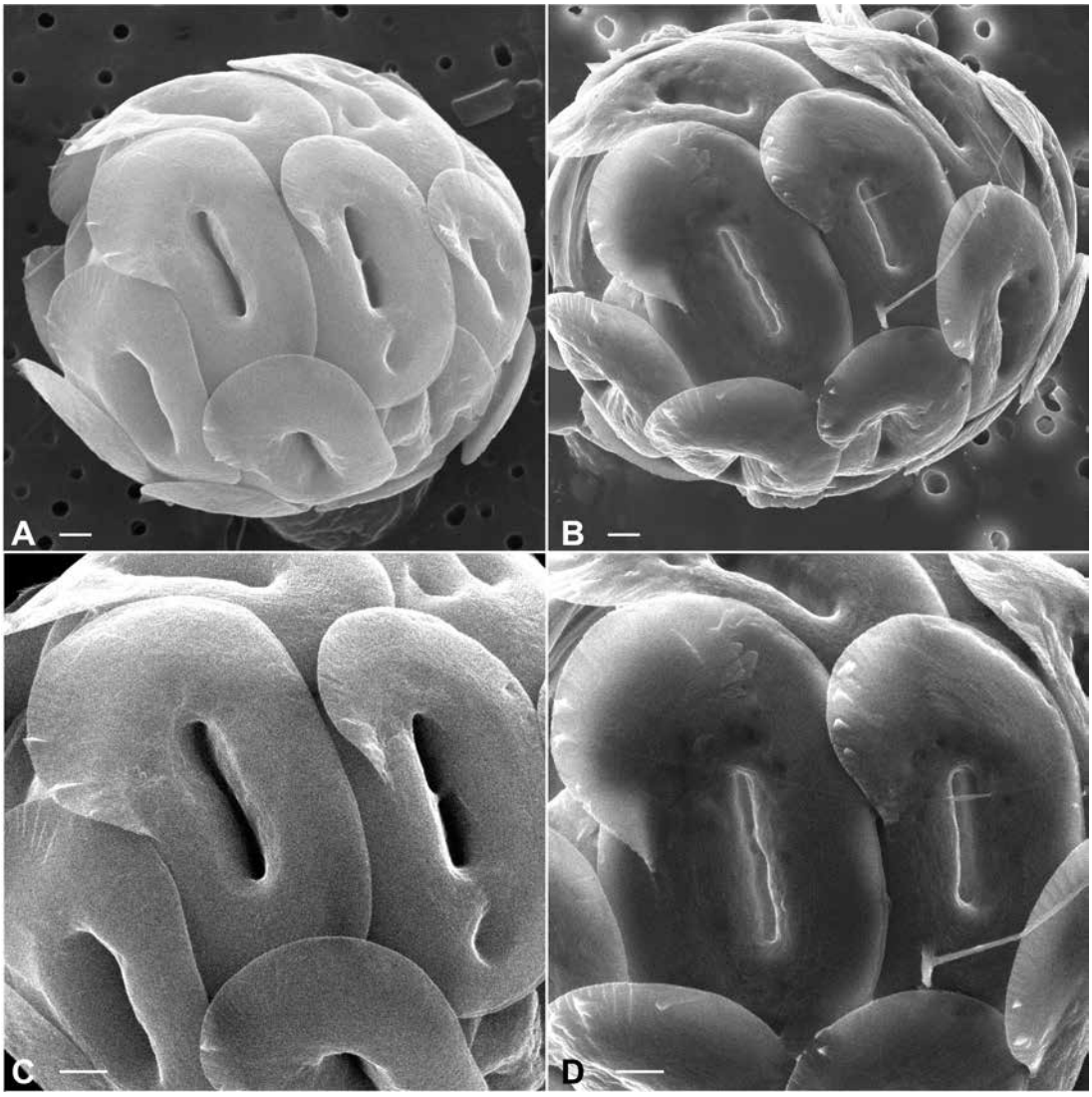

Figure 50. Coccolithophore morphology: **A–B.** cells of *Helicosphaera carteri* (Wallich, 1877) Kamptner, 1954; **C–D.** coccoliths of *H. carteri*. Scale bars A–D, 1 μm.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS2, 42.747° S, 175.841° E, Jan–Feb 2009; NIWA Stn TAN0902/YS3, 43.101° S, 176.095° E, Jan–Feb 2009; NIWA Stn TAN0902/YS30, 46.638° S, 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS36, 43.446° S, 178.488° E, Jan–Feb 2009; NIWA Stn TAN0902/YS39, 42.820° S, 178.495° E, Jan–Feb 2009; NIWA Stn TAN0902/YS59, 41.228° S, 178.522° E, Jan–Feb 2009; NIWA Stn TAN1203/DA11, 44.350° S, 174.419° E, Feb 2012; NIWA Stn TAN1203/DA43, 43.430° S, 179.506° E, Feb 2012; NIWA Stn TAN1203/DA48, 43.426° S, !79.457° E, Feb 2012.

Kaikoura: NIWA Stn TAN0904/S13, 46.670° S, 174.409° E, Apr 2009; NIWA Stn TAN0904/S21, 42.401° S, 174.264° E, Apr 2009; NIWA Stn TAN0904/S45, 42.941° S, 173.926° E, Apr 2009; NIWA Stn TAN0904/S67, 42.642° S, 174.584° E, Apr 2009; NIWA Stn TAN0904/S71, 42.642° S, 174.584° E, Apr 2009.

Holotype. Netherlands.

Type locality. Not recorded.

Description. Coccosphere of heterococcolith phase ellipsoidal (15–17 μm long) (Fig. 50A, B). Body coccoliths up to 10 μm long, wedged into one another by the winged flanges; two in-line slits or sometimes a single long slit was observed in the central area (Fig. 50C, D).

Distribution and cell abundance. Extant *H. carteri* was mainly found off the Kaikoura coast and in ST, STF and SA waters of Chatham Rise (Fig. 52). This species was detected on three occasions – at six sites over Chatham Rise in summer 2009, three sites in the same region in summer 2012, and another six sites off the Kaikoura coast in autumn 2009 (Appendix 1, Tables 1.1, 1.2, 1.10). Cell concentrations were tens of cells to thousands l^{-1}. The greatest cell concentration recorded on one occasion in STF water over Chatham Rise was up to 21,000 cells l^{-1} (Appendix 1, Table 1.1).

Previous records. *Helicosphaera carteri* was previously recorded at only one NZOI station, B67, in a transect between northeast New Zealand and Tonga

(Norris 1961; Appendix 2, Table 2.1). This species had also been recorded in STF/SA waters to the east (Saavedra-Pellitero *et al*. 2014; Appendix 2, Table 2.2) and at several sites around the central east coast of New Zealand (Chang & Northcote 2016).

Elsewhere, *H. carteri* is found to be a cosmopolitan species. It has been recorded, e.g., in tropical and subtropical waters of the South China Sea (Lee Chen *et al*. 2007), in the East China Sea (Wang *et al*. 2012), in the East Australian Current, Bass Strait, the Coral Sea, and the Gulf of Carpentaria (Hallegraeff 2010), in the Southern Ocean south of the Polar Front (Findlay *et al*. 2005), in the Australian sector of the Southern Ocean (Findlay & Giraudeau 2000), along a temperate to polar gradient in the West Pacific sector of the Southern Ocean (Malinverno *et al*. 2015), in the tropical and subtropical Atlantic Ocean (Poulton *et al*. 2017), in the subtropical northeast and temperate Atlantic Ocean (Broerse *et al*. 2000a), off Terceira Island, Azores, in the Central North Atlantic Ocean (Narciso *et al*. 2016), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the Aegean Sea (NE Mediterranean) (Dimiza *et al*. 2015), in the middle and eastern Adriatic Sea (northern Mediterranean) (Šupraha *et al*. 2016; Skejić *et al*. 2018), in the Bay of Bengal in the Indian Ocean (Mergulhao *et al*. 2013), in an upwelling region off Somalia (NW Indian Ocean) (Broerse *et al*. 2000b), in the Java upwelling region in the tropical Indian Ocean (Andruleit 2007), and in the Indian sector of the Southern Ocean (Patil *et al*. 2017).

Helicosphaera carteri **HOL *catilliferus*-type** (= *Syracolithus catilliferus* (Kamptner, 1937) Deflandre, 1952 [*Syracosphaera*])

Fig. 51 A–C

Kamptner, 1941, pl. 4, figs 43–45; Cros & Fortuño, 2002: 72–72, figs 10 C, D and 11; Young *et al*. 2003: 107, pl. 52, figs 7–9.

Basionym: *Syracosphaera catillifera* Kamptner 1941: 81, 103, pl. 4, figs 43–45.

Synonyms: *Calyptrosphaera catillifera* (Kamptner) Gaarder 1962: pl. 17, figs 3a, b.
Calyptrolithophora catillifera (Kamptner) Norris 1985: 625, fig. 33.
Syracosphaera catillifera Kamptner, 1937: 279.
Syracosphaera cornus Kamptner 1941: 81, 103, pl. 4, figs 43–45.
Syracolithus catilliferus (Kamptner, 1937) Deflandre 1952: 453, figs 351c, d; Kleijne 1991: 34, pl. 6, fig. 12.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS39, 42.820° S, 178.495° E, Jan–Feb 2009.

Description. Coccosphere of holococcolith form (alternate phase) subspherical (12–14 µm) (Fig. 51A). Body coccolith (2–3 µm long) elliptical with a central pyramidal spine near centre; the rim one crystallite wide and 5–6 crystallites high (Fig. 51B, C).

Distribution and cell abundance. This holococcolith phase was recorded only at one site (< 20 cells l^{-1}) in the summer of 2009 (Appendix 1, Table 1.1), to the east of New Zealand (Fig. 52).

Previous records. *Helicosphaera carteri* HOL *catilliferus*-type was previously reported as a first-time record of New Zealand by Chang & Northcote (2016). Elsewhere, this alternate life cycle phase was quite widely distributed. It was reported, e.g., in the Southern Ocean south of the Polar Front (Findlay *et al*. 2005), in the tropical and subtropical Atlantic Ocean (Poulton *et al*. 2017), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the Aegean Sea (NE Mediterranean) (Dimiza *et al*. 2015), and as *Syracolithus catilliferus* in the Java upwelling region of the tropical Indian Ocean (Andruleit 2007).

Helicosphaera hyalina Gaarder, 1970

Fig. 51 D

Gaarder, 1970: 113–119, figs 1a–g, 2a–d, 3a; Borsetti & Cati, 1972: 406, pl. 52, figs 3–4; Nishida, 1979: pl. 9, fig. 1; Heimdal, 1973: 215, pl. 5; Cros & Fortuño, 2002: 74, figs 12 A–D; Young *et al*. 2003: 27, pl. 10, figs 7–9.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS30, 46.638° S, 178.542° E, Jan–Feb 2009.

Holotype. SEM 1, IMBB. Held at University of Oslo, Norway.

Type locality. Gulf of Mexico.

Description. Coccosphere is like that of *Helicosphaera carteri*, but coccoliths with closed central area (no slits) (Fig. 51D) and are usually smaller than those of *H. carteri*.

Distribution and cell abundance. *Helicosphaera hyalina* was found at one site, to the east of New Zealand (Fig. 53). This was a rare species, with < 20 cells l^{-1} recorded in summer 2009 (Appendix 1, Table 1.1).

Previous records. Extant *H. hyalina* was previously reported as a first-time record of New Zealand (Chang & Northcote 2016). Elsewhere, a small number of this species was recorded, e.g., in the western subarctic Pacific and Bering Sea (Hattori *et al*. 2004), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the middle Adriatic Sea (northern Mediterranean) (Skejić *et al*. 2018), and in the Java upwelling region of the tropical Indian Ocean (Andruleit 2007).

Helicosphaera wallichii (Lohmann, 1902) Okada & McIntyre, 1977

Fig. 51 E

Lohmann, 1902: 138, pl. 5, figs 58, 58b; Lohmann in Boudreaux & Hay, 1969: 272–273, pl. 6, fig. 9; Okada & McIntyre, 1977: 14, pl. 4, fig. 8; Hallegraeff, 1984: 235, fig. 21; Delgado & Fortuña, 1991: pl. 86, fig. d; Young *et al*. 2003: 27, pl. 10, figs10–12.

Basionym: *Coccolithophora wallichi* Lohmann, 1902: 138, pl. 5, fig. 58.

Synonyms: *Coccolithus wallichi* Lohmann in Schiller, 1930: 247–248, text-fig. 124c.

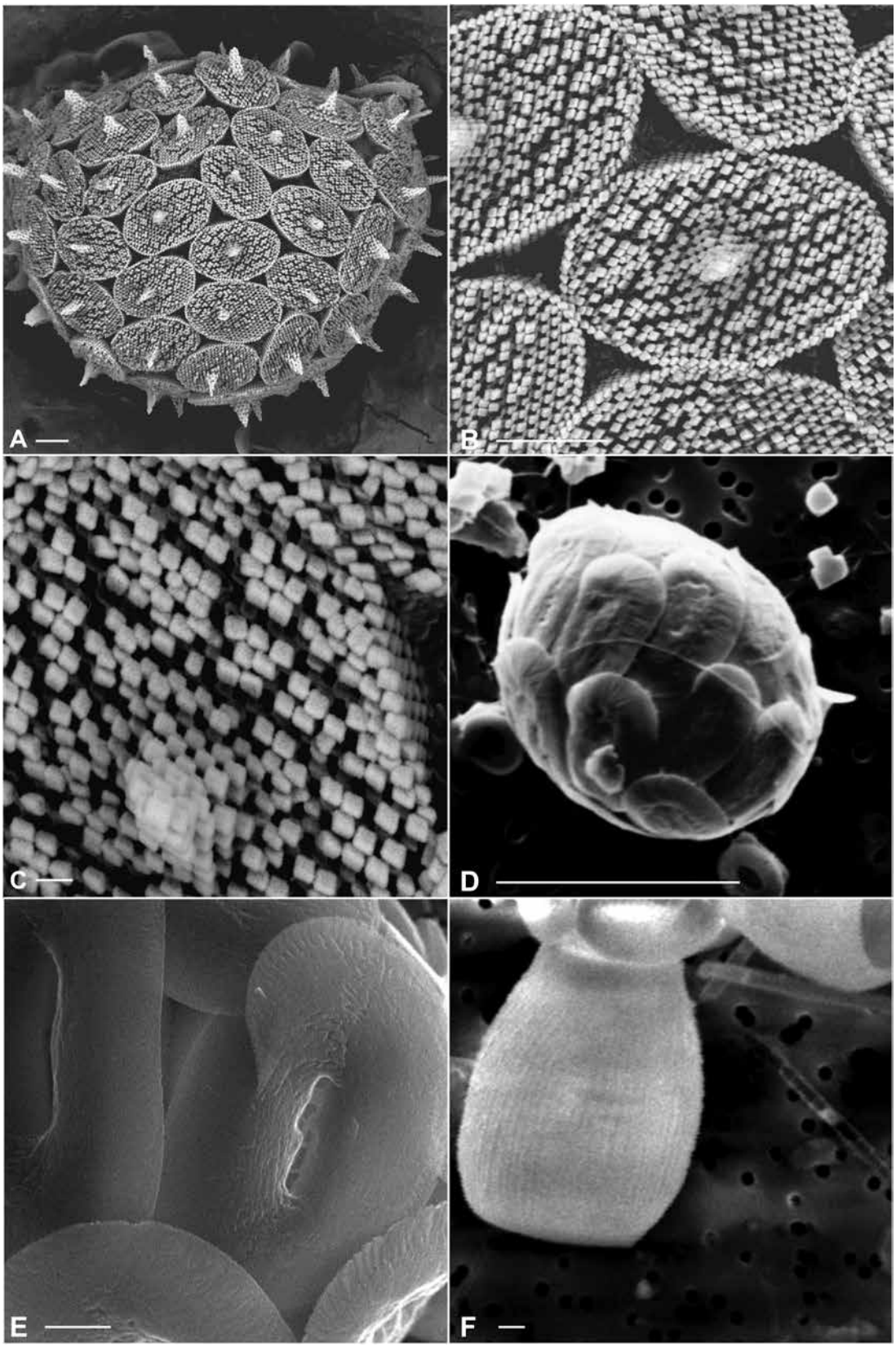

Figure 51. Coccolithophore morphology: **A.** cell of *Helicosphaera carteri* HOL *catilliferus*-type; **B–C.** coccoliths of *H. carteri* HOL showing layers of rhomboidal-shaped crystallites with a pointed pyramid in the centre; **D.** cell of *Helicosphaera hyalina* Gaarder, 1970; **E.** coccoliths of *Helicosphaera wallichii* (Lohmann, 1902) Okada & McIntyre 1977; **F.** elevated coccolith–lopadolith of *Scyphosphaera apsteinii* Lohmann, 1902. Scale bars A–F, 1 µm.

Helicopontosphaera wallichi Lohmann in Boudreaux & Hay, 1969: 272–273, pl. 6, fig. 9.

Occurrence records. *Kaikoura*: NIWA Stn TAN0904/S63, 42.008° S, 174.443° E, Apr 2009.

Holotype. Type is possibly held in Kiel, Germany.

Type locality. Near Syracuse, Sicily, Italy.

Description. As with coccosphere of *Helicosphaera carteri*, but central area of coccolith with oblique slits, rather than two in-line slits (Fig. 51E).

Distribution and cell abundance. Cell concentrations of this species were very low (< 20 cells l^{-1}) (Appendix 1, Table 1.2) and it was found only on one occasion, in autumn 2009, off the Kaikoura coast (Fig. 53).

Previous records. *Helicosphaera wallichii* was previously reported by Chang & Northcote (2016) as

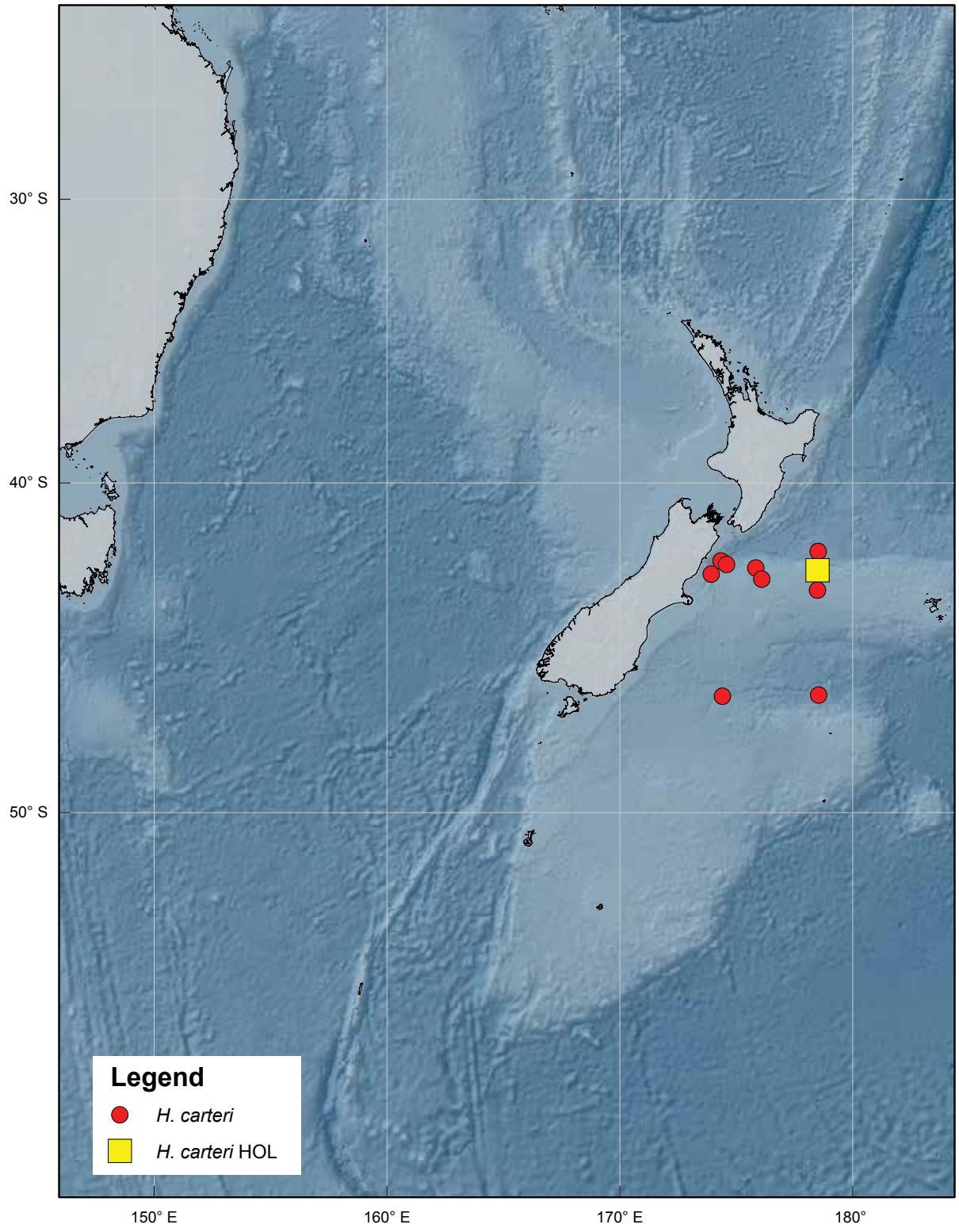

Figure 52. Distribution of *Helicosphaera carteri* (Wallich, 1877) Kamptner, 1954 and *H. carteri* HOL *catilliferus*-type around New Zealand.

a first-time record of New Zealand. Elsewhere, this species was recorded, e.g., in the East Australian Current and the Southern Ocean (Hallegraeff 2010), in the East China Sea (Wang *et al.* 2012), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), and in the Java upwelling region of the tropical Indian Ocean (Andruleit 2007).

Family **Pontosphaeraceae** Lemmermann, 1908

Description. Coccospheres sub-spherical, monomorphic (*Pontosphaera*) or dimorphic with strongly-modified equatorial coccoliths (*Scyphosphaera*). Muroliths have an outer rim with a clear anticlockwise imbrication; central area with variable number of perforations (Cros & Fortuño 2002; Young *et al.* 2003).

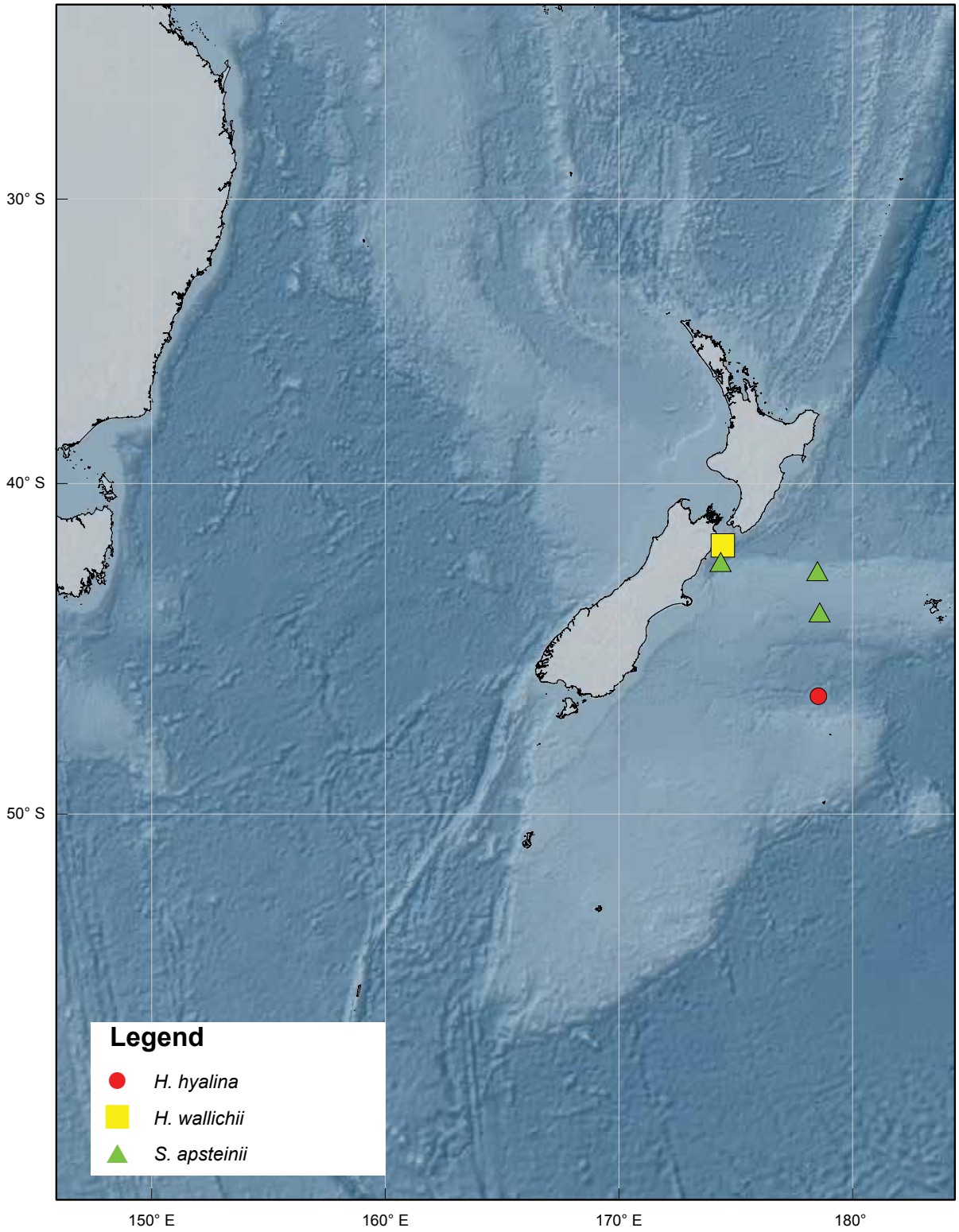

Figure 53. Distribution of *Helicosphaera hyalina* Gaarder, 1970; *H. wallichii* (Lohmann, 1902) Okada & McIntyre, 1977, and *Scyphosphaera apsteinii* Lohmann, 1902 around New Zealand.

Genus ***Scyphosphaera*** Lohmann, 1902

Description. Dimorphic coccospheres; coccoliths with central area solid or with a variable number of pores, and also with elevated equatorial lopadoliths (Siesser 1998; Cros & Fortuño 2002; Young *et al*. 2003).

Type species. *Scyphosphaera apsteinii* Lohmann, 1902.

Scyphosphaera apsteinii Lohmann, 1902

Fig. 51 F

Lohmann, 1902: 132, pl. 4, figs 26–30; Boudreaux & Hay, 1969: 274–275, pl. 4, figs 16–18; Borsetti & Cati, 1972: 339, pl. 41, fig. 3, pl. 42, figs 1–2; Heimdal 1993, pl. 6; Hallegraeff 1984: 235, figs 24 a, b; Cros & Fortuño, 2002: 75, figs 13A–C; Young *et al*. 2003: 29, pl. 11, figs10–15.

Basionym: *Scyphosphaera apsteini* f. *dilatata* Gaarder, 1970: 119, figs 4–6.

Synonyms: *Scyphosphaera cohenii* Boudreaux & Hay, 1969, *in* Siesser, 1998: 359–360, pl. 2 fig. 2a.

Pontosphaera scutellum Kamptner, 1952: 378, fig. 1 a–b.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS38, 43.102° S, 178.489° E; NIWA Stn TAN0902/YS39, 42.820° S, 178.495° E, Jan–Feb 2009.

Kaikoura: NIWA Stn TAN0904/S71, 42.642° S, 174.584° E, Apr 2009.

Holotype. SEM 2, IMBB, deposited at University of Oslo, Norway.

Type locality. Near Syracuse, Sicily, Italy.

Description. Dimorphic coccosphere made up of small coccoliths (muroliths) as well as large, vase-shaped coccoliths (lopadoliths) (Fig. 51F).

Distribution and cell abundance. A small number of *Scyphosphaera apsteinii* coccospheres (< 20 to 300 cells l^{-1}) (Appendix 1, Tables 1.1, 1.2) were found on two occasions, summer 2009, over Charham Rise and off Kaikoura, east of New Zealand (Fig. 53).

Previous records. Extant *Scyphosphaera apsteinii* was previously recorded by Norris (1961), at two NZOI stations, B67 and B80, along a transect between northeast New Zealand and Tonga (Appendix 2, Table 2.1). Chang & Northcote (2016) also reported the presence of this species in New Zealand waters.

Elsewhere, this species is widely distributed, e.g., in the East Australian Current and Leeuwin Current, the Tasman Sea and the Great Australian Bight (Hallegraeff 2010), along a temperate to polar gradient in the West Pacific sector of the Southern Ocean (Malinverno *et al*. 2015), in the subtropical and temperate northeast Atlantic Ocean (Broerse *et al*. 2000a), off Terceira Island, Azores, in the Central North Atlantic Ocean (Narciso *et al*. 2016), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), and in an upwelling region off Somalia (NW Indian Ocean) (Broerse *et al*. 2000b).

Holococcolith-bearing taxa formerly belonging to the family Calyptrosphaeraceae

Family **Calyptrosphaeraceae** Boudreaux & Hay, 1969

Boudreaux & Hay, 1969: 249.

Description. Holococcoliths made up of numerous, minute, rhombohedral microcrystals arranged in an orderly manner (Cros & Fortuño 2002; Young *et al*. 2003).

Remarks. This family embraces virtually all the holococcolithophores, which thus far, have only the holococcolith-bearing form known in their life cycle (Cros & Fortuño 2002 [p. 58]).

Genus ***Corisphaera*** Kamptner, 1937

Description. Coccospheres weakly dimorphic. Body zygoliths with tube spanned by bridge; circum-flagellar zygoliths with taller and expanded bridges (Kleijne 1991; Cros & Fortuño 2002; Young *et al*. 2003).

Type species. *Corisphaera gracilis* Kamptner, 1937

Corisphaera gracilis Kamptner, 1937

Fig. 54 A–D

Kamptner, 1937: 307–308, pl. 16, figs 33–35; Kamptner, 1941: 90, 107–108, p.11, figs 113–116; Heimdal & Gaarder, 1980: 3, pl. 1, figs 6a, b; Kleijne, 1991: 52, pl. 12, figs 3–5; Cros & Fortuño, 2002: 158, fig. 96A; Young *et al*. 2003: 105, pl. 49, figs 1, 4.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS3, 43.101° S, 176.095° E, Jan–Feb 2009; NIWA Stn TAN1107/NBM, 41.229° S, 178.512° E, May 2011.

Holotype. Type is held at Natural History Museum Vienna, Austria.

Type locality. Mediterranean Sea: Stn 1: off Patras (38.250° N, 21.667° E); Stn 2: Gulf of Lepanto (38.167° N, 22.500° E); Stn 3: off Kéos (37.500° N, 24.167° E).

Description. Coccosphere subspherical (*c.* 5–6 µm) (Fig. 54A). Coccoliths with a low wall and a tranverse, arched bridge across the open distal end. Proximal end appears to be sealed by a thin layer of crystallites (Fig. 54B–D).

Distribution and cell abundance. Extant *Corisphaera gracilis* was found on only two occasions, summer 2009 and autumn 2011, in ST water over Chatham Rise (Fig. 55). Cell concentrations recorded

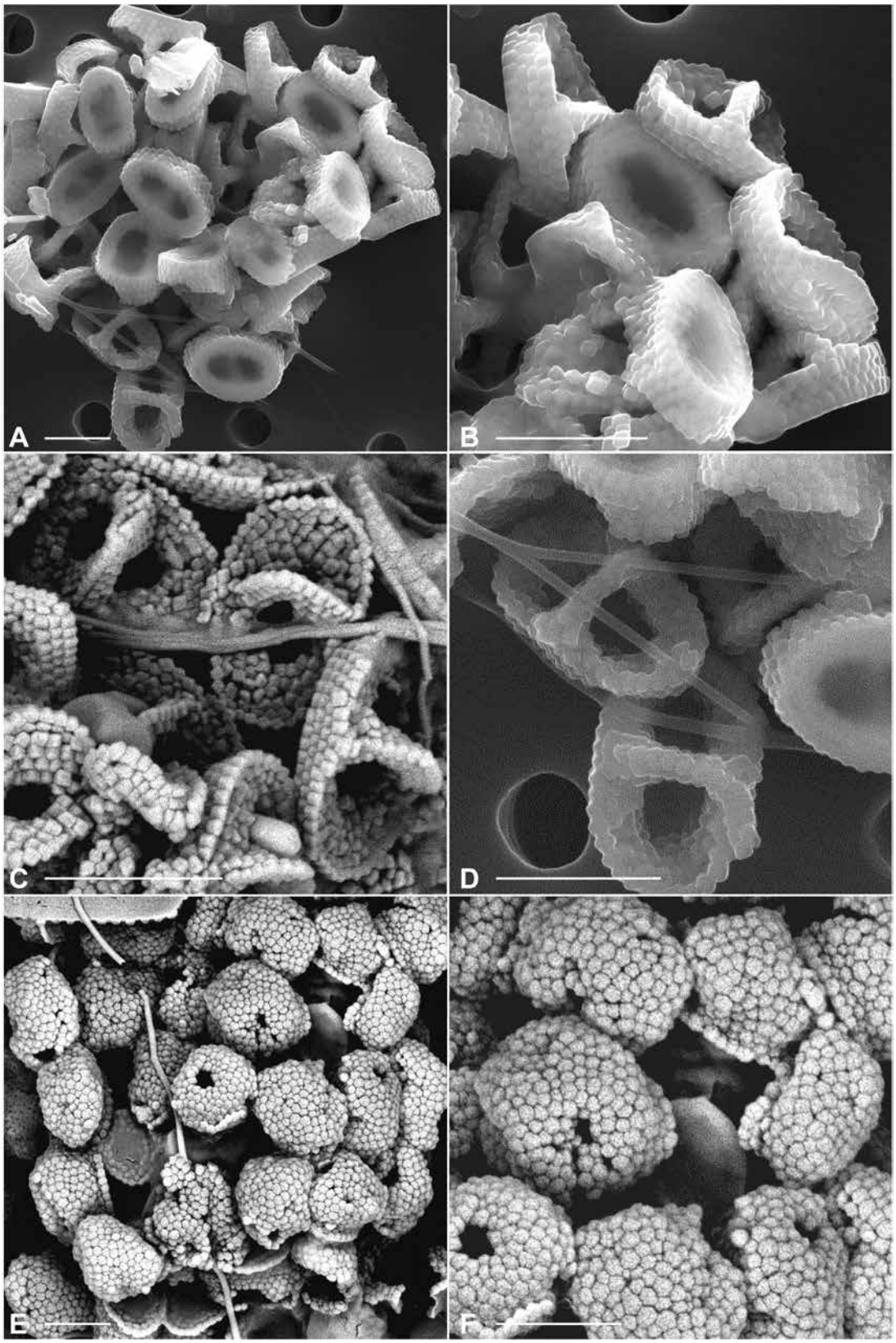

Figure 54. Coccolithophore morphology: **A.** cell of *Corisphaera gracilis* Kamptner, 1937; **B–D.** coccoliths of *C. gracilis*; **E.** part of cell of *Holococcolithophora sphaeroidea* (Schiller, 1913) Jordan *et al*., 2004; **F.** coccoliths of *H. sphaeroidea*. Scale bars A–F, 1 µm.

on both occasions, were 300 cells l^{-1} and 100 cells l^{-1}, respectively (Appendix 1, Tables 1.1, 1.9).

Previous records. *Corisphaera gracilis* was previously reported by Chang & Northcote (2016) off the east coast of New Zealand. Elsewhere, this species is reasonably well distributed, e.g., in the Australian sector of the Southern Ocean (Findlay & Giraudeau 2000), in the North Atlantic Ocean (Kleijne 1991), in the subtropical northeast Atlantic Ocean (Broerse *et al*. 2000a), in the Mediterranean Sea (Kleijne 1991; Cros

& Fortuño 2002), in the middle Adriatic Sea (northern Mediterranean) (Skejić et al. 2018), in the Red Sea and tropical Indian Ocean (Kleijne 1991), and in the Indian sector of the Southern Ocean (Patil *et al.* 2017).

Genus ***Holococcolithophora*** (Schiller, 1913) Jordan *et al.*, 2004

(Schiller) Jordan *et al.*, 2004: 66.

Description. Monomorphic coccosphere with holococcoliths; both body and circum–flagellar coccoliths are calyptroliths (Young *et al.* 2003; Jordan *et al.* 2004).

Type species. *Holococcolithophora sphaeroidea* (Schiller, 1913) Jordan *et al.*, 2004.

Holococcolithophora sphaeroidea (Schiller, 1913) Jordan *et al.*, 2004

Fig. 54 E, F

(Schiller) Jordan *et al.*, 2004: 60.

Basionym: *Calyptrosphaera sphaeroidea* Schiller 1913: 606, pl. 3, figs 18 a, b.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS2, 42.747° S, 175.841° E, Jan–Feb 2009; NIWA Stn TAN0902/YS30, 46.638° S, 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS36, 43.446° S, 178.488° E, Jan–Feb 2009; NIWA Stn TAN0902/YS38, 43.102° S, 178.489° E, Jan–Feb 2009.

Holotype. Type is possibly held at Vienna University, Botany Department, Austria (which is where Schiller was based).

Type locality. Adriatic Sea.

Description. Coccosphere ovoid (*c.*10–12 µm long) (Fig. 54E). Coccoliths vary from coccoid- to dome-shaped with a pore at the distal end and are one crystallite thick (Fig. 54F); crystallites at surface irregularly arranged.

Distribution and cell abundance. Coccospheres of *Holococcolithophora sphaeroidea* were found only in summer 2009, at three sites, in the vicinity of Chatham Rise (Fig. 55). Cell concentrations were generally low (< 20 to 100 cells l^{-1}) (Appendix 1, Table 1.1).

Previous records. Extant *Holococcolithophora sphaeroidea* was previously reported by Chang & Northcote (2016) off the east coast of New Zealand. Elsewhere, this species appears to be less well distributed, e.g., in the North Atlantic Ocean and Mediterranean Sea (Kleijne 1991), and in the northern Adriatic Sea (Mediterranean) (Godrijan *et al.* 2018).

Genus ***Poricalyptra*** Kleijne, 1991

Description. Coccosphere with dimorphic coccoliths; body calyptroliths with a perforated tube wall and a flat distal surface with slits or pores and a prominent rim. Circum–flagellar helladoliths with prominent, extended leaf, no openings in tube (Cros & Fortuño 2002; Young *et al.* 2003).

Type species. *Poricalyptra aurisinae* (Kamptner, 1941) Kleijne, 1991: 1–76.

Poricalyptra aurisinae (Kamptner, 1941) Kleijne, 1991

Fig. 56 A, B

Winter & Siesser 1994: 7, fig. 179; Cros & Fortuño 2002: 162, figs 100A, B; Young *et al.* 2003:109, pl. 51, figs 8–9.

Basionym: *Helladosphaera aurisinae* Kamptner, 1941: 91, pl. 11, figs 121–124.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS38, 43.102° S, 178.489° E, Jan–Feb 2009.

Holotype. Type is held at the Natural History Museum Vienna, Austria.

Type locality. Southwest coast of Istria, Croatia.

Description. Coccosphere ovoid (*c.* 8 µm long) (Fig. 56A). Coccoliths 2.3–2.4 µm long, elliptical with four oblong openings and a transverse, virtually one-layer ridge on the distal surface (Fig. 56B).

Distribution and cell abundance. *Poricalyptra aurisinae* was found at one site in STF water over Chatham Rise (Fig. 57). Cell concentration recorded on one occasion in summer 2009 was 100 cells l^{-1} (Appendix 1, Table 1.1).

Previous records. Extant *P. aurisinae* was previously reported by Chang & Northcote (2016) off the east coast of New Zealand. Elsewhere this species was recorded, e.g., in the tropical and subtropical Atlantic Ocean (Poulton *et al.* 2017), in the subtropical northeast Atlantic Ocean (Broerse *et al.* 2000a), in the northwestern Mediterranean Sea (Cros & Fortuño 2002), in the middle Adriatic Sea (northern Mediterranean) (Skejić *et al.* 2018), in the Java upwelling region of the tropical Indian Ocean (Andruleit 2007), and in the Indian sector of the Southern Ocean (Patil *et al.* 2017).

Nannolith-bearing family *incertae sedis*

Family **Braarudosphaeraceae** Deflandre, 1947

Description. Dodecahedron coccospheres making up of 12 pentagonal shape exotheca plates. Pentaliths consisting of five segments, each of which behaves as a discrete crystal–unit (Young *et al.* 2003).

Genus ***Braarudosphaera*** Deflandre, 1947

Deflandre 1947: 439, figs 1–5.

Description. Pentagonal shape pentaliths with sutures which go to the edges of pentagon (Young *et al.* 2003).

Type species. *Braarudosphaera bigelowii* (Gran & Braarud, 1935) Deflandre, 1947

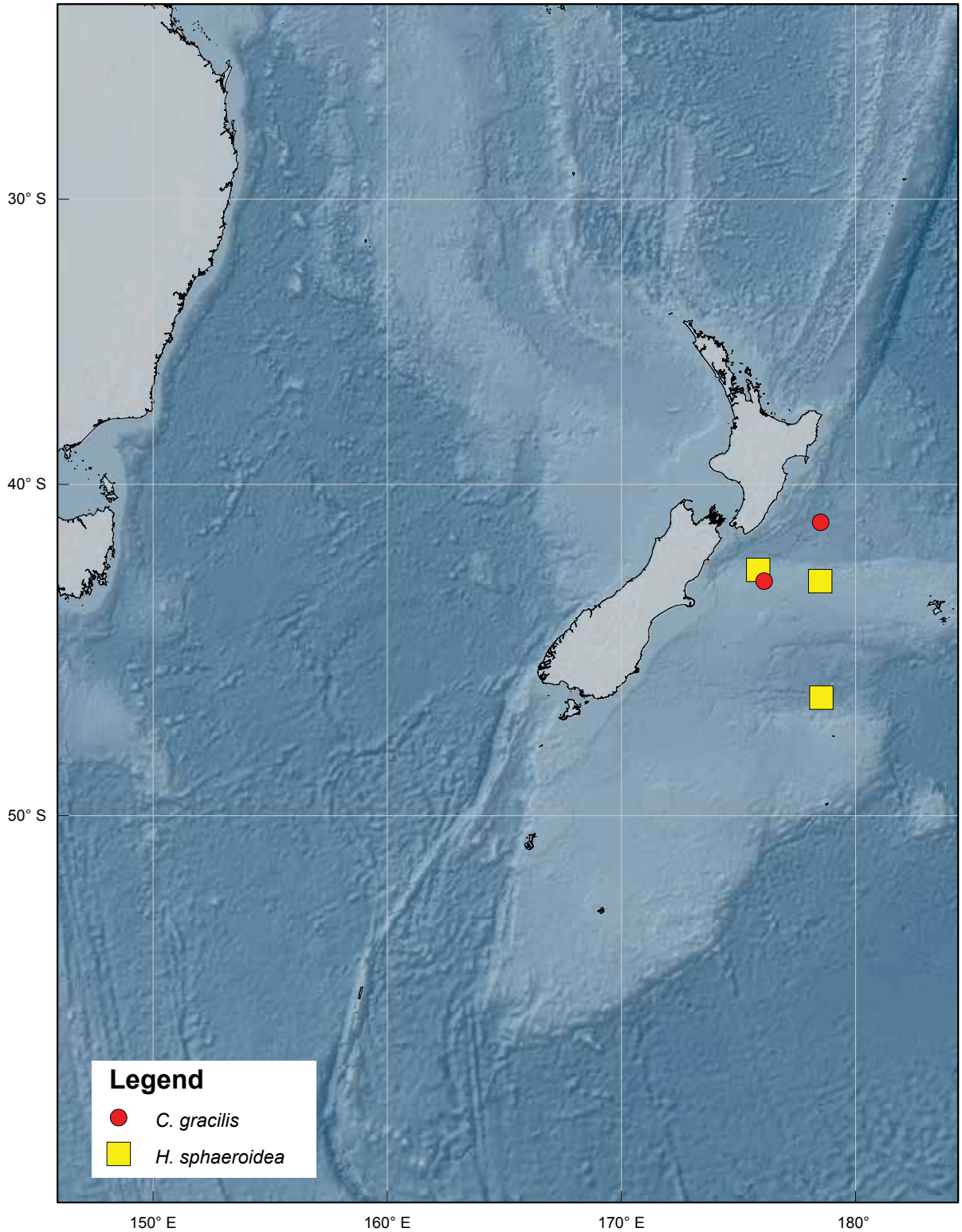

Figure 55. Distribution of *Corisphaera gracilis* Kamptner, 1937 and *Holococcolithophora sphaeroidea* (Schiller, 1913) Jordan *et al.*, 2004 around New Zealand.

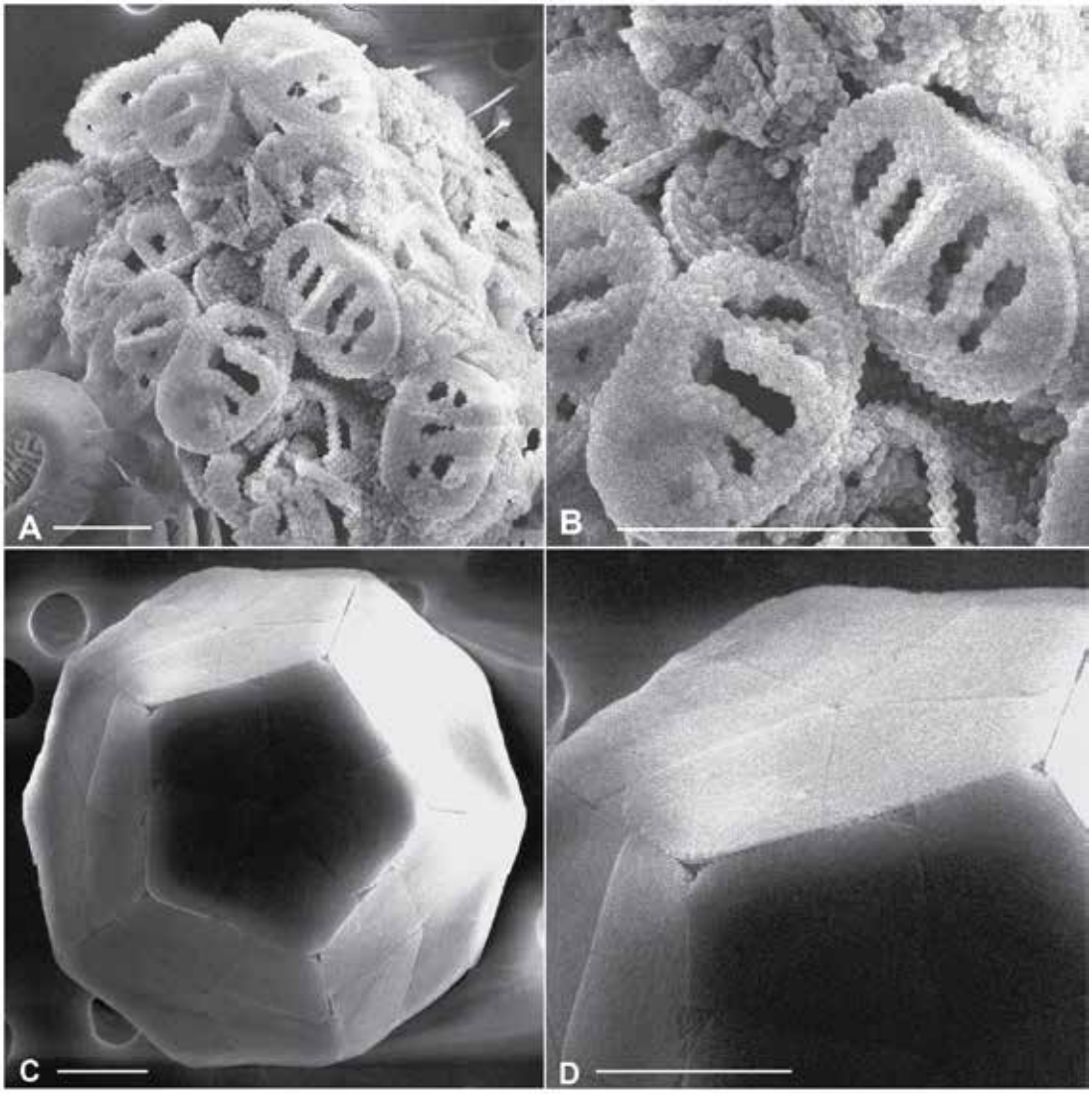

Figure 56. Coccolithophore morphology: **A.** cell of *Polycalyptra aurisinae* (Kamptner, 1941) Kleijne 1991; **B.** coccoliths of *P. aurisinae*; **C.** cell of *Braarudosphaera bigelowii* (Gran & Braarud, 1935) Deflandre 1947; **D.** coccoliths of *B. bigelowii*. Scale bars A–D, 1 μm.

Braarudosphaera bigelowii (Gran & Braarud, 1935) Deflandre, 1947

Fig. 56 C, D

(Gran & Braarud) Deflandre, 1947: 439, figs 1–5; Borsetti & Cati, 1972: 410, pl. 57; Nishida, 1979, pl.16, fig. 1; Young *et al.* 2003: 81, pl. 37, figs 1–6.

Basionym: *Pontosphaera bigelowii* Gran & Braarud, 1935: 67.

Synonyms: *Eodiscoaster danicus* Martini, 1961: 1–32 (cf. Martini 1971: 115).

Braarudosphaera deflandrei Lecal–Schlauder, 1949: 160.

Discoaster murrayi Black & Barnes, 1961: 145.

Occurrence records. *Chatham Rise*: NIWA Stn TAN0902/YS3, 43.101° S, 176.095° E, Jan–Feb 2009; NIWA Stn TAN0902/YS30, 46.638° S, 178.542° E, Jan–Feb 2009; NIWA Stn TAN0902/YS38, 43.102° S, 178.489° E, Jan–Feb 2009.

Holotype. Type is possibly held at Oslo University, Botany Department, Norway (which is where Gran was based).

Type locality. Atlantic Ocean.

Description. Coccosphere (*c.* 5–6 μm) is a regular pentagonal dodecahedron (Fig. 56C). Coccoliths of *c.* 3.0 μm, pentagonal-shaped, and are divided further by five pentagonal substructures on a flat and smooth surface (Fig. 56D).

Distribution and cell abundance. A small number of coccospheres of *Braarudosphaera bigelowii* was found only in summer 2009, at three sites over and to the south of Chatham Rise (Fig. 57). Cell concentrations were generally low (100–300 cells l^{-1}) (Appendix 1, Table 1.1).

Previous records. Extant *B. bigelowii* was previously reported by Chang & Northcote (2016), off the east coast of New Zealand. Elsewhere this species was recorded, e.g., in the Bass Strait of Australia (Callaghan, 1992; Hallegraeff 2010), in the subtropical northeast Atlantic (Broerse *et al.* 2000a), and off Terceira Island, Azores, and in the central North Atlantic Ocean (Narciso *et al.* 2016).

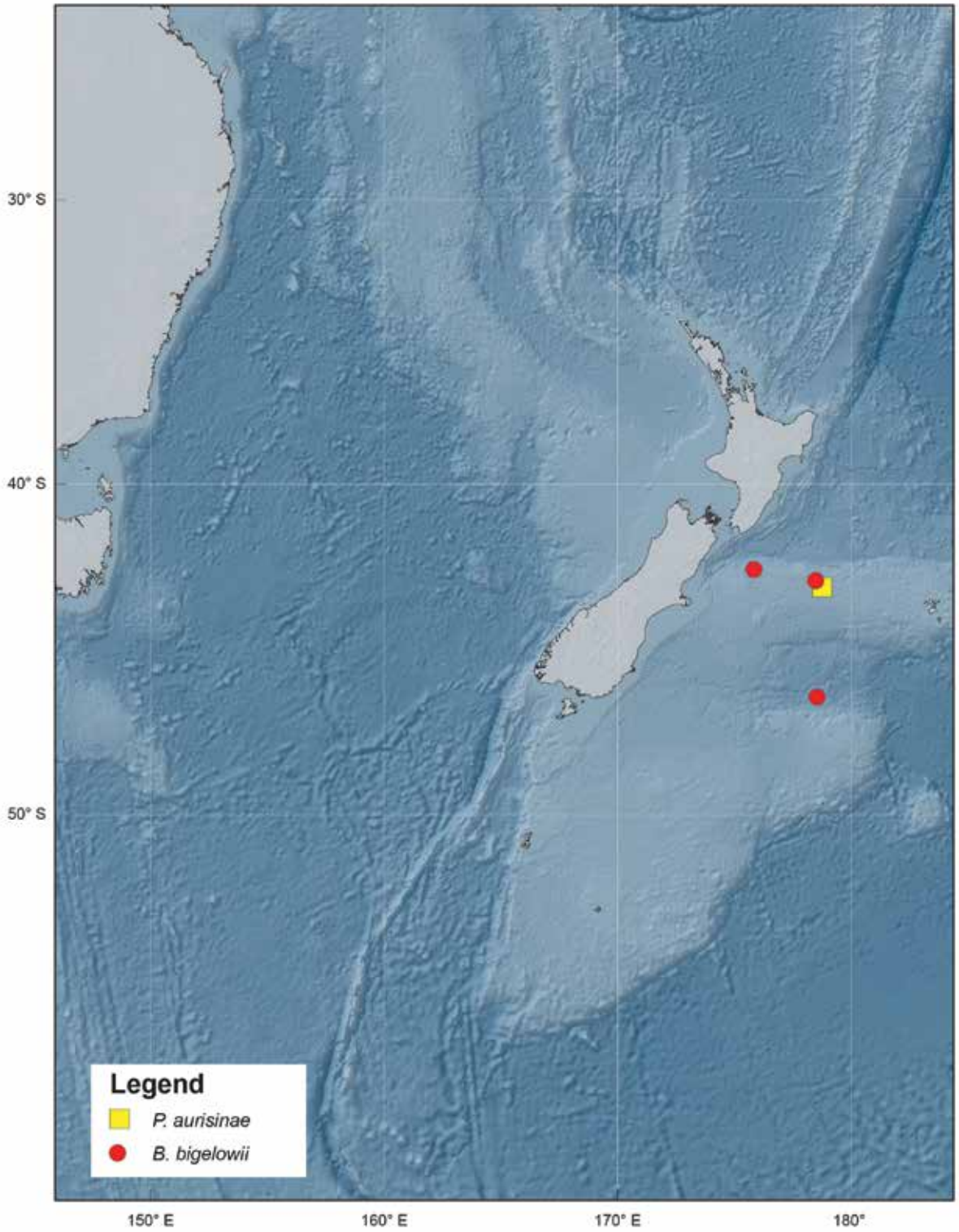

Figure 57. Distribution of *Polycalyptra aurisinae* (Kamptner, 1941) Kleijne 1991 and *Braarudosphaera bigelowii* (Gran & Braarud, 1935) Deflandre 1947 around New Zealand.

Remarks. Currently *B. bigelowii* is placed in the family Braarudosphaeraceae [*see* Young *et al.* 2003; Jordan *et al.* 2004; Nannotax3 website: www.mikrotax.org/Nannotax3]. However, a recent molecular phylogenetic study undertaken by Hagino *et al.* (2013) revealed that one of the non-motile nannolith-bearing forms, *B. bigelowii* (Gran & Braarud, 1935) Deflandre, 1947, is the alternate life-cycle phase of *Chrysochromulina parkeae* Green & Leadbeater, 1972, motile phase. Typically, *B. bigelowii* is characterised by bearing calcareous scales called pentaliths, while *C. parkeae* bears organic scales. Even though it was assumed by analogy with another coccolithophore species, *Emiliania huxleyi* (Lohmann, 1902) Hay & Mohler in Hay *et al.*, 1967, that the calcifying (*B. bigelowii*) phase is diploid and the non-calcifying (*C. parkeae*) is haploid, this has not been

confirmed by culture studies of either species (Hagino *et al*. 2013). Moreover, the name *B. bigelowii* has priority over *C. parkeae*. Until the life histories of both species have been resolved, the non-motile nannolith-bearing form of this species is included here in the family Braarudosphaeraceae.

Discussion

Previously, 55 coccolithophore taxa have been recorded in the New Zealand region (Norris 1961; Dawson 1992; Rhodes *et al*. 2012; Saavedra-Pellitero *et al*. 2014). A further 26 taxa were added to the flora by Chang (2013) and Chang & Northcote (2016). Adding two first–time records identified in this monograph to the 81 previously documented taxa in the New Zealand region, the total number of extant coccolithophores is now 83 taxa (80 species, plus three different life-cycle forms of two of these species). Compared with other regions around the globe, this number recorded in New Zealand waters is greater than the 45 species recognised in subtropical and temperate waters of Australia (Conley 1979; Hallegraeff 1984; Callaghan 1992), and the 70 species reported in the Yellow and East China Seas (Wang *et al*. 2012), but is less than the 150 plus species/forms reported in northwestern Mediterranean Sea (Cros and Fortuño 2002), and the 125 species recorded in tropical waters of Hawaii (Cortés *et al*. 2001).

In this study a total of ten surveys were conducted over the three-year period. Seven of these were located near Kaikoura and in the vicinity of Chatham Rise, east of New Zealand. It is noteworthy that all 50 coccolithophore taxa identified in these surveys were from samples collected in this region alone. The diversity of coccolithophores off the central east coast was thus greater than those recorded in other areas around New Zealand, e.g., along two transects in the Tasman Sea (15 taxa), south of the South Island (3), and in the Bay of Plenty, northeast New Zealand (4). Over the three-year sampling period, three *Emiliania huxleyi* blooms, in spring 2009 (cover image, Fig. 58) and the summers of 2011 and 2012, were recorded off the central east coast of New Zealand. Both the massive 2009 spring and 2011 summer blooms were confirmed by NASA's Aqua satellite (NASA Earth Observatory 2009, 2011). However, during the same period no such very extensive event, was detected by satellite observation in other areas around New Zealand.

The STF over Chatham Rise near 43°S, east of New Zealand, has important oceanographic characteristics. This is a region where warm, macronutrient-poor, relatively iron-rich, ST water in the north, and cool, fresher, macronutrient rich, iron-poor, SA water in the south, converge (e.g., Heath 1985, Chang & Gall 1998; Butler *et al*. 1992; Boyd *et al*. 1999). In addition to the increased availability of nutrients in the STF, there is also an increase in the stability of the surface mixed layer, which enhances biological productivity (Murphy *et al*. 2001). An analysis of hydrographic and nutrient conditions carried out by Law *et al*. (2015) around Chatham Rise revealed that there is a positive correlation between *E. huxleyi* and temperature and a negative correlation with silicate and the N/P ratio, suggesting that seasonally shallow mixed layers, high solar irradiance, high temperature, low silicate and low N/P ratio, favour *E. huxleyi* blooms. Therefore, all three *E. huxleyi* blooms and possibly elevated numbers of coccolithophores, observed in the vicinity of Chatham Rise, reflect the special physico-chemical conditions that favoured coccolithophores.

Out of the 50 taxa recorded, eight were found to be widespread in the present study: *Emiliania huxleyi*, *Reticulofenestra parvula*, *Umbellosphaera tenuis* type II, *Syracosphaera molischii*, *S. anthos*, *S. mediterranea*, *Gephyrocapsa ericsonii*, and *Calcidiscus leptoporus*. *Emiliania huxleyi* is clearly the most plentiful and ubiquitous taxon, in both bloom and non–bloom conditions. This is consistent with observations made by, e.g., Birkenes & Braarud (1952) in Oslo Fjord, Okada & Honjo (1975) in the North Pacific Ocean, Holligan *et al*. (1993) in the North Atlantic, Cokacar *et al*. (2001) in the Black Sea, Wang *et al*. (2012) in the East China Sea, and Saavedra-Pellitero *et al*. (2014) in the Pacific Sector of the Southern Ocean.

Even though *Reticulofenestra parvula* is not as widely distributed as the other seven species and was limited mainly to the Kaikoura coast, it is the second most plentiful taxon. In spring 2009, *R. parvula* dominated the coccolithophore assemblage, with concentrations as high as 571,000 cells l^{-1} recorded off Kaikoura (Appendix 1, Table 1.4). Previously, *R. parvula* was reported to be dominant only in surface sediments of the Eastern Mediterranean Sea (Ziveri *et al*. 2000). Cell concentrations of other relatively widespread species, however, were generally low. Only occasionally did their numbers increase, e.g., *U. tenuis* type II (up to 224,000 cells l^{-1}), *S. molischii* (up to 161,000 cells l^{-1}), *S. anthos*

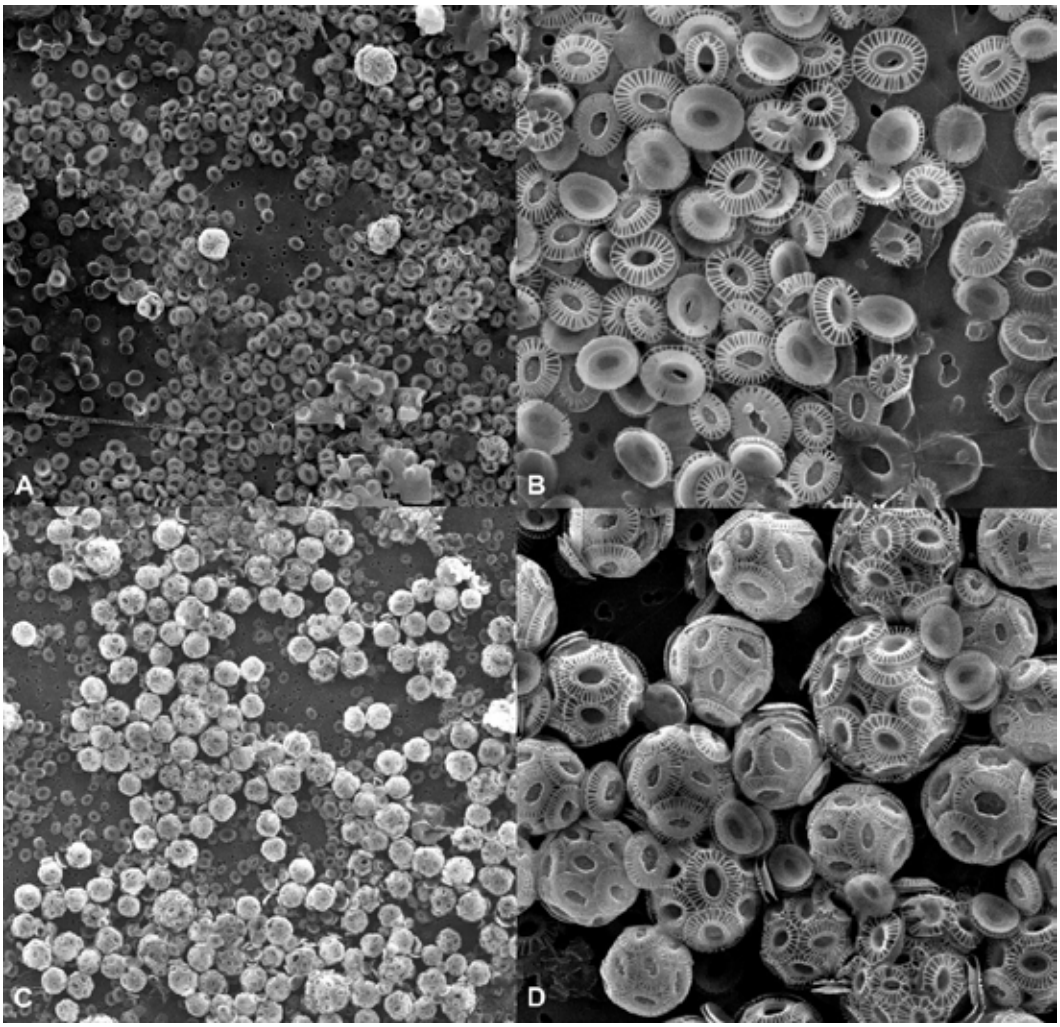

Figure 58. A. typically within the highly reflective, chalky-blue water of the spring 2009 bloom, a few intact coccospheres of *Emiliania huxleyi* were observed among the massive numbers of very small, calcite scales (coccoliths) (up to 99 billion per litre) in samples collected from many sites within the bloom; **B.** enlarged calcite coccoliths taken from A; **C.** at some sites within the massive bloom, a large number of intact *E. huxleyi* coccospheres (up to 5,000,000 cells per litre) were also observed among the free, calcite coccoliths, in the background; **D.** four different morphotypes – types A, B and C of *E. huxleyi* were found in samples collected from this bloom (for details please refer to: Figs 5–6).

(up to 101,000 cells l^{-1}), *G. ericsonii* (up to 13,000 cells l^{-1}), *S. mediterranea* (up to 8,000 cells l^{-1}), and *Calcidiscus leptoporus* (up to 8,000 cells l^{-1}). With the exception of *U. tenuis* type II, which dominated on one occasion, in summer 2009 (Appendix 1, Table 1.1), the remaining species were not plentiful on any sampling occasion.

In this study, a total of 17 *Syracosphaera* spp. plus one life-cycle form (about 36%) were recorded, with one species as a first record for the region. Adding *S. azureaplaneta* to the previously recorded species, plus two life-cycle forms documented in the New Zealand region, a total of 32 extant *Syracosphaera* taxa are recorded in New Zealand (*see* Checklist). This is greater than the total number of *Syracosphaera* spp. reported in Australia (8) (Hallegraeff 1984, 2010), the Australian Sector of the Southern Ocean (9) (Findlay & Giraudeau 2000), Yellow and East China Seas (7) (Wang *et al*. 2012), and those recorded in the northwestern Mediterranean Sea (26) (Cross & Fortuño 2002). Except for three species, *S. anthos*, *S. molischii* and *S. mediterranea*, the other 14 *Syracosphaera* spp. occurred less frequently and were generally in low coccosphere concentrations. This is consistent with observations made on this group around the globe (e.g., Kleijne 1993; Jordan & Kleijne 1994; Kleijne *et al*. 2002; Cross & Fortuño 2002). Overall the New Zealand region fits into a worldwide pattern of coccolithophore *E. huxleyi* being, in terms of cell density and biogeography, the most important component, and *Syracosphaera* spp., as the most diverse group.

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Appendices

Appendix 1. Cell concentrations of coccolithophores recorded in samples collected from ten voyages in the New Zealand region.

Table 1.1. Cell concentrations of coccolithophores over Chatham Rise, east of New Zealand, in summer 2009 (TAN0902) (0 = absent; '+' = < 20 cells l^{-1}).

	Chatham Rise (cell concentrations × 10^4 per litre)														
Taxa	YS2	YS3	YS4	YS7	YS8	YS29	YS30*	YS31	YS32	YS33	YS36	YS38	YS39	YS56	Y59
Acanthoica quattrospina	0	0	0.3	0	0	0	0.11	0	0	0	0	0.1	0.2	0	0
Acanthoica acanthos	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0
Algirosphaera robusta	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0
Braarudosphaera bigelowii	0	0.01	0	0	0	0	0.03	0	0	0	0	0.03	0	0	0
Calciosolenia brasiliensis	0	0	0	0	0	0	0	0	0.01	0	0	0	0.02	0	0
C. murrayi	0	0.4	0	0	0	0	0	0	33.5	0	0	0	0.1	0	0
Corisphaera gracilis	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0
Emiliania huxleyi	4.9	7.5	6.3	0	20.1	12.2	9.3	12.9	8.1	10.3	10.1	16.1	1.1	2.0	8.9
Gephyrocapsa ericsonii	0	0.1	0	0	0	0	0.2	0	0	0	0.4	1.1	0	0	0
G. oceanica	0.2	0	0	0	0	0	0.1	0	0	0	0.4	0.03	0	0	0
G. sp.	0.1	0	0	0	0	0	0	0	0	0	0	0.03	0	0	0
Helicosphaera carteri	0.3	0.05	0	0	0	0	0.8	0	0	0	0.4	0	2.1	0	0.3
Helicosphaera carteri HOL	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0
Helicosphaera hyalina	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0
Holococcolithophora sphaeroidea	0	0	+	0	0	0	0.01	0	0	0	+	0	0	0	0
Palusphaera vandelii	1.04	0.1	0	0	0	0.4	3.1	0	1.3	0	0.4	0.21	0.01	0	0
Papposphaera lepida	0	0	0	0	0	0	0	0	0	0	0	0	0.03	0	0
Polycrater galapagensis	0.03	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0
Poricalyptra aurisinae	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0
Rhabdosphaera xiphos	0.03	0	0	0	0	0	0.1	0	0.2	0	0	0.05	0.01	0	0
Reticulofenestra parvula	0	0	0	0	0	0	0	0.1	0	0	0	0.4	0	0	0
Scyphosphaera apsteinii	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0
Sphaerocalyptra quadridentata	0.03	0	0	0	0	0	0.05	0	0	0	0.4	0.12	0	0	0
Syracosphaera anthos	0.02	0	1.9	0	0	0	0	0	10.1	0	0	0	0	0.05	0
S. arethusae HOL	0.03	0	0	0	0	0	0.05	0	0	0	0.1	0.03	0.03	0	0
S. bannockii	0	0	0	0	0	0	0.03	0	0	0	0	0.05	0	0	0
S. leptolepis	0	0	0	0	0	0	0	0	0	0	0	0	0.03	0	0
S. mediterranea	0	0	0.6	0	0.3	0	0.5	0.8	0.2	0	0	0	0.03	0	0
S. mediterranea HOL	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0
S. molischii	0	0	16.1	0	0.4	0.4	0	0.1	0.43	0	0.3	0.2	0.13	0	0
S. nana	0	0	0	0	0	0	0	0	0	0	0	0.05	0	0	0
S. nodosa	0	0	0	0	0	0	0.03	0	0.03	0	0	0	0	0	0
S. orbiculus	0	0	0	0	0	0	0.02	0	0.01	0	0	0	0	0	0
S. pemmadiscus	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0
S. pulchra	0	0	0	0	0	0	0.3	0	0	0	0	0	0.2	0	0.03
S. serrata	0	0	0	0	0	0	0.05	0	0	0	0	0	0	0	0
S. sp. aff. *S. nodosa* type 2	0	0	0	0	0	0	0	+	0	0	0	0	+	0	0
S. tumularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+
Umbellosphaera tenuis type II	0.3	0	0	0	0	22.4	12.6	7.7	0	0	0	0	0	0	20.1

Stations YS30, YS6, YS31 = Subantarctic waters (SA); YS2, YS38, YS39, YS56, YS59 = Subtropical waters (ST); YS32. YS33, YS36, YS38, YS39 = Subtropical Front (STF).

Table 1.2. Cell concentrations of coccolithophores off Kaikoura Coast, in autumn 2009 (TAN0904) (0 = absent; '+' = < 20 cells l^{-1}).

	Kaikoura Coast(cell concentrations × 10^4 per litre)														
Taxa	S09	S07	S13	S17	S25	S35	S33	S41	S21	S45	S55	S63	S71	S85	95
Acanthoica quattrospina	0	0	0	0	0	0	0.02	0	0	0.07	0	0	0	0	0
Acanthoica acanthos	0	0	0	0	0	0	0	0	0	0.03	0	0	0	0	0
Alisphaera pinnigera	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0
Calcidiscus leptoporus	0	0.7	0.06	0	0	0	0	0	0	0	0	0	0.08	0	0
Calciosolenia murrayi	0.03	0	0	0	0	0	0	0.48	0.07	0.06	0	0.1	0	0.12	0
Emiliania huxleyi	0	0.7	1.5	0.06	0.13	0.8	0.16	0	0.8	1.4	1.8	0.23	2.1	1.6	0.1
Gephyrocapsa ericsonii	0	0.03	+	0.03	0.03	0.21	0.02	0	1.3	0.03	0	0.03	0.05	0	0
G. oceanica	0	0	+	0	0	0.16	0	0	0.5	0	0	0	0.03	0	0
G. muellerae	0	0	0	0	0	0	0.11	0	0	0	0	0	0	0	0
G. sp.	0	0.07	0.01	0	0	0	0	0	0	0	0	0	0	0	0
Helicosphaera carteri	0	0	+	0	0	0	0	0	0	0.07	0	0.48	0.13	0	0
Helicosphaera wallichii	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0
Reticulofenestra parvula	0	2.2	3.6	0.39	0.2	3.1	0.4	0	1.5	3.1	3.4	0.73	2.8	3.1	0.16
R. parvula var. *tecticentrum*	0	0	0	0.03	0	0	0	0	0	0.05	0	0	0	0	0
Scyphosphaera apsteinii	0	0	0	0	0	0	0	0	0	0	0	0	0.03	0	0
Syracosphaera anthos	0	0	0.9	0	0	0	0.02	0	0.48	1.2	0.91	0	0.9	0.7	0.21
S. mediterranea	0	0	0.04	0	0	0	0	0	0.1	0.06	0	0	0	0	0
S. molischii	0	0	1.80	0	0	0	0	0.7	0.6	0.03	0.21	0.28	0.2	0	0.04
S. nodosa	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0	0
S. cf. *orbiculus*	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0
S. pulchra	0	0	1.1	0	0	0	0	0	0	0.6	0.18	0	0.17	0.12	0.1

Table 1.2 (*continued*). Cell concentrations of coccolithophores off Kaikoura Coast, in autumn 2009 (TAN0904) (0 = absent; '+' = < 20 cells l^{-1}).

	Kaikoura Coast(cell concentrations × 10^4 per litre)				
Taxa	S67	S71	S81	S91	S95
Acanthoica quattrospina	0	0	0	0.02	0
Acanthoica acanthos	0	0	0	0	0
Alisphaera pinnigera	0	0	0	0	0
Calcidiscus leptoporus	0	0	0	0	0
Calciosolenia murrayi	0	0	0	+	0
Emiliania huxleyi	+	+	+	+	0.26
Gephyrocapsa ericsonii	0	0	0	0	+
G. oceanica	0	0	0	0	0
G. muellerae	0	0	0	0	0
G. sp.	0	0	0	0	0
Helicosphaera carteri	0	+	0	0	+
H. wallichii	0	0	0	0	0
H. hyalina	0	0	0	0	0
Reticulofenestra parvula	+	0	0	0	0
R. parvula var. *tecticentrum*	+	0	0	0	0
Scyphosphaera apsteinii	0	0	0	0	0
Syracosphaera anthos	+	+	+	+	0.51
S. mediterranea	+	+	+	+	0
S. molischii	0	0	0	0	0
S. nodosa	0	0	0	0	0
S. cf. *orbiculus*	0	0	0	0	0
S. pulchra	0	0	0	0	0

Table 1.3. Cell concentrations of coccolithophores in the Bay of Plenty, northeast New Zealand, in spring 2009 (KAH0907).

Bay of Plenty (cell concentrations × 10^3 per litre)			
Taxa	S13	S17	S18
Emiliania huxleyi	0.8	1.5	0.6
Gephyrocapsa ericsonii	0.2	0	0
G. oceanica	0.1	0	0.4
Syracosphaera mediterranea	0.03	0	0

Table 1.4. Cell concentrations of coccolithophores off Kaikoura Coast, east of New Zealand, in spring 2009 (TAN0908)

Kaikoura Coast (cell concentrations × 10^4 per litre)				
Taxa	R3	R6	R9	R29
Emiliania huxleyi	12.1	0.4	10.8	1.1
Gephyrocapsa ericsonii	0	0	0	0.08
G. oceanica	0	0.05	0	0.12
Reticulofenestra parvula	57.1	0.2	34.4	3.1
R. parvula var. *tecticentrum*	0.7	0.01	0.5	0.03

Table 1.5. Cell concentrations of coccolithophores over Chatham Rise, east of New Zealand, in spring 2009 (TAN0909) (0 = absent; '+' = < 20 cells l^{-1}).

Chatham Rise (cell concentrations × 10^4 per litre)														
Taxa	[a]PM2	PM7	PM9	PM13	PM14	PM16	PM17	[b]PM19	PM20	PM21	PM23	PM25	PM26	PM119
Calcidiscus leptoporus	0	0	0	+	0	0	0	0	0	0	0	0	0.2	0
Emiliania huxleyi	94.6	2.9	7.9	2.9	3.5	0.92	3.1	2.4	1.83	2.2	1.2	1.4	2.9	3.3
Gephyrocapsa ericsonii	0	0	0.12	0	0	0	0	0	0	0	0	0	0	0
G. oceanica	0	0	0.08	0	0	0	0	0	0	0	0	0	0	0
Syracosphaera molischii	0	0	0	0	0	0	0	0	0	0	0	0.23	0	0
S. pulchra	0	0	0	0	0	0	0	0	0	0	0.2	0.18	0	0
Umbellosphaera tenuis type II	0	0	0	0	0	0.6	0.2	0	0	0	0	0	0	0

Note: [a]Stn PM2: *Emiliania huxleyi* coccolith concentration = 1.8 × 10^6 per litre; [b]Stn PM19: *Emiliania huxleyi* coccolith concentration = 9.9 × 10^9 per litre.

Table 1.5 (*continued*). Cell concentrations of coccolithophores over Chatham Rise, east of New Zealand, in spring 2009 (TAN0909) ('+' = < 20 cells l^{-1})

	Chatham Rise (cell concentrations × 10^4 per litre)				
Taxa	PM6	PM8	PM27	PM10	PM12
Calcidiscus leptoporus	0	0	0	0	0
Emiliania huxleyi	248	3.17	82.3	2.7	0.57
Gephyrocapsa ericsonii	0	0	0	0	0
G. oceanica	0	0	0	0	0
Syracosphaera molischii	0	0	0	0	0
S. pulchra	0	0	0	0	0
Umbellosphaera tenuis type II	0	0	0	0	0

Table 1.6. Cell concentrations of coccolithophores in the Tasman Sea, west of New Zealand, in summer 2010 (PINTS) (0 = absence).

	Tasman Sea (Cell concentrations × 10^4 per litre)														
Taxa	CO1	CO2	CO4	CO5	CO6	CO7	CO8	CO9	CO10	CO11	CO14	CO15	CO16	CO19	CO20
Calcidiscus leptoporus	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0
Emiliania huxleyi	0.03	0	0.1	0.05	0.05	0.03	0	0.03	0.2	0.09	0.2	0.2	0.6	0.05	0.2
Gephyrocapsa ericsonii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Palusphaera vandelii	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0
Syracosphaera anthos	0	0	0	0	0	0	0	0	0.07	0	0	0	0.05	0	0.03
S. mediterranea	0	0	0	0	0	0	0.03	0.03	0	0.04	0	0	0	0	0
S. molischii	0	0	0	0	0	0	0	0	0.08	0	0	0	0	0	0
S. pulchra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Umbellosphaera tenuis type II	0	0.03	0.03	0.03	0.05	0.05	0.03	0.2	0.05	0.03	0.6	0.6	0.1	0.05	0

Table 1.6 (*continued*). Cell concentrations of coccolithophores in the Tasman Sea, west of New Zealand, in summer 2010 (PINTS).

	Tasman Sea (Cell concentrations × 10^4 per litre)													
Taxa	C020	CO21	CO23	CO24	CO25	CO32	CO33	CO34	CO35	CO45	C047	CO48	CO49	CO50
Calcidiscus leptoporus	0	0	0	0	0	0	0	0	0	0	2.2	0	0	0
Emiliania huxleyi	0.05	0.2	0.04	0.6	0.3	0	0.3	0	0	0.3	0.9	0.1	0.1	0.2
Gephyrocapsa ericsonii	0	0	0	0	0	0	0	0	0	0	0.2	0	0.03	0.03
Palusphaera vandelii	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Syracosphaera anthos	0	0.03	0	0.02	0	0	0.05	2.5	0.8	0	0	0	0	0.03
S. mediterranea	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S. molischii	0	0	0	0.02	0	0	0	0.8	0.9	0	0	0	0	0
S. pulchra	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0
Umbellosphaera tenuis type II	0.05	0	0.2	0.3	0.03	0	0	0	0	0.9	0.3	0.06	0.06	0.06

Table 1.7. Cell concentrations of coccolithophores over Chatham Rise, east of New Zealand, in summer 2011 (PreSOAP–TAN1102).

	Chatham Rise (cell concentrations × 10^4 per litre)												
Taxa	NH5	NH16	NH18	NH7	NH43	NH49	NH54	NH60	NH89	NH109	NH111	NH118	NH147
Emiliania huxleyi	0	7.9	0.7	7.7	0.6	8.8	1.3	5.3	4.9	227	181	350	0
Gephyrocapsa ericsonii	0	0	0	0	0	0	0	0	0	0	0	0	0
G. oceanica	0	0	0	0	0	0	0	0	0	0	0	0	0
Syracosphaera anthos	0	0	0	0	0	0	0	0	0	0	0	0	0
Umbellosphaera tenuis type II	0	0	0	0	0	0	0	0	0.5	0	0	0	0

Table 1.7 (*continued*). Cell concentrations of coccolithophores over Chatham Rise, east of New Zealand, in summer 2011 (PreSOAP–TAN1102).

	Chatham Rise (cell concentrations × 10^4 per litre)		
Taxa	NH149	NH162	NH175
Emiliania huxleyi	3.1	0.7	6.02
Gephyrocapsa ericsonii	0	0.2	0
G. oceanica	0	0.5	1.20
Syracosphaera anthos	0	0	1.2
Umbellosphaera tenuis type II	0	0	0

Table 1.8. Cell concentrations of coccolithophores to the south of New Zealand, in autumn 2011 (TAN1106).

	South of New Zealand (cell concentrations × 10^3 per litre)							
Taxa	S17	S21	S21	S27	S29	S42	S47	S55
Calcidiscus leptoporus	0	0	0.06	0.03	0	0	0	0.06
Emiliania huxleyi	0	0	0.21	0.3	0	0.2	0.05	0.39
Umbellosphaera tenuis type II	0	0	0	0	0	0	0.06	0

Table 1.9. Cell concentrations of coccolithophores over Chatham Rise, east of New Zealand, in autumn 2011 (TAN 1107, Biophysical Moorings) ('+' = < 20 cells l^{-1}).

	Chatham Rise (cell concentrations × 10^4 per litre)								
Taxa	T1	T2	T3	T4	SBM	T5	T6	T8	NBM
Acanthoica quattrospina	0.1	0	0.3	0	0	0	0	0	0.03
Acanthoica acanthos	0	0	0	0	0	0	0	0	0.03
Calcidiscus leptoporus	0	0	0	0.6	0.05	0	0.4	0	0
C. murrayi	0.3	0.2	0	0	0	0	0.4	0	0
Corisphaera gracilis	0	0	0	0	0	0	0	0	0.01
Cyrtosphaera aculeata	0	0	0	0	0.03	0	0	0	0
Cyrtosphaera lecaliae	0	0	0	0	0.01	0	0	0	0
Discosphaera tubifera	0	0	0	0	0	0	0	0	0.01
Emiliania huxleyi	1.86	0.17	2.3	0.8	0.8	0.2	1.4	0.8	0.4
Gephyrocapsa ericsonii	0.3	0.1	0.7	0	0.03	0.1	0	0	0.3
G. oceanica	0.04	0.03	0.3	0	0	0	0	0	0.03
G. muellerae	0	0	0	0	0	0.03	0	0	0
Palusphaera vandelii	0	0	0	0	0.03	0	0	0.03	0
Reticulofenestra parvula	3.7	0.8	0.7	3.2	2.3	1.1	2.9	1.2	0.3
R. parvula var. *tecticentrum*	0	0	0.01	0	0.03	0	0	0	0
Syracosphaera anthos	0.03	0.2	0	0	0.05	0	0	0.1	0
S. azureaplaneta	0	0	0.3	0	0	0.03	0	0	0.2
S. leptolepis	0.03	0.02	0	0	0	0	0	0	0
S. mediterranea	0.04	0.2	0	0.3	0.1	0.6	0	0	0
S. molischii	0.08	0.03	0	0	0	0	0	0	0
S. nana	0	0	0	0	0	0	0	0.7	0
S. nodosa	0	0	0	0.03	0	0	0	0	0
S. ossa	0	0	0	0.1	0	0.03	0	0	0
S. cf. *orbiculus*	0	0	0	0	0.01	0	0	0	0
S. pemmadiscus	0	0	0	0	0	0	+	0	0
S. pulchra	0.03	0	0	0	0	0	0	0	0
Umbellosphaera tenuis type II	0	0	0.3	0	0.4	0.3	0.4	0	0
Umbilicosphaera hulburtiana	0	0	0	0	0	0	0	0.1	0.03

Table 1.10. Cell concentrations of coccolithophores over Chatham Rise, east of New Zealand, in summer 2012 (TAN1203, SOAP).

	Chatham Rise (cell concentrations × 10^4 per litre)														
Taxa	DA6	DA11	DA16	DA27	DA31	DA35	DA39	DA43	DA48	DA52	DA59	DA62	DA66	DA71	DA75
Emiliania huxleyi	10.1	19.3	94	17.1	50.2	88.4	55.1	127	76.9	123.0	103.3	58.0	45.7	53	63.4
Gephyrocapsa ericsonii	0	0	0	0	0	0	0	0	0	0	0.06	0	0	0	0
G. muellerae	0	0	0	0	0	0	0	0	0	0	0.05	0	0	0	0
Helicosphaera carteri	0	0.49	0	0	0	0	0	0.06	0.57	0	0	0	0	0	0
Syracosphaera anthos	0	0	0.21	0	0.61	0	0	0	0	0	0	0	0	0	0
S. dilatata	0	0	0	0	0	0	0	0	0	0	0.16	0	0	0	0
S. nana	0	0	0	0	0.06	0	0	0	0	0	0	0	0	0	0
S. molischii	0	0.06	0.19	0	0.32	0	0	0	0	0	0.58	0	0	0	0
S. ossa	0	0	0	0	0	0	0	0	0	0	0.42	0	0	0	0
S. pulchra	0	0	0.03	0	0.15	0	0	0	0	0	0	0	0	0	0
Umbellosphaera tenuis type II	1.8	0.58	0	0.58	0.58	0.6	0	0	1.68	0	0	0	0	0	0

Table 1.10 (*continued*)**.** Cell concentrations of coccolithophores over Chatham Rise, east of New Zealand, in summer 2012 (TAN1203, SOAP).

	Chatham Rise (cell concentrations × 10^4 per litre)												
Taxa	DA82	DA87	DA90/ 10M	DA90/ 30M	DA93	DA95	DA98	DA98	DA101	DA102	DA104	DA105	DA110
Emiliania huxleyi	210.7	104.1	45.6	31.0	50.1	95.1	2.1	39	142	136.6	23.0	19.3	203
Gephyrocapsa ericsonii	0	0	0	0	0	0	0	0	0	0	0	0	0
G. muellerae	0	0	0	0	0	0	0	0	0	0	0	0	0
Helicosphaera carteri	0	0	0	0	0	0	0	0	0	0	0	0	0
Syracosphaera anthos	0	0	0	0	0	0	0	0	0	0	0	0	0
S. nana	0	0	0	0	0	0	0		0	0	0	0	0
S. molischii	0	0	0	0	0	0	0	0	0	0	2.6	0	0
S. ossa	0	0	0	0	0	0	0	0	0	0	0	0	0
S. pulchra	0	0	0	0	0	0	0	0	0	0	0	0	0
Umbellosphaera tenuis type II	0.58	0	1.20	0	0	0	0	0	0	0	0.40	0	0

Appendix 2. Records of extant coccolithophore species previously recorded from the New Zealand region.

Table 2.1. A list of extant coccolithophore species recorded at eight stations along a transect from northeast New Zealand to Tonga (Norris 1960), with updated species names; '+' = present, '0' = absent.

	NZOI Stations							
Taxa	B65	B67	B69	B71	B77	B80	B85	B91
Acanthoica acanthifera Lohmann, 1902	+	+	0	0	0	0	0	0
Acanthoica quattrospina Lohmann, 1903	0	+	0	0	0	0	0	0
Algirosphaera robusta (Lohmann) Norris, 1984 (= *Anthosphaera robusta* (Lohmann) Kamptner, 1941)	0	+	0	0	0	0	0	0
Calcidiscus leptoporus (Murray & Blackman) Loeblich & Tappan, 1978 (= *Cyclococcolithus leptoporus* (Murray & Blackman) Kamptner, 1954)	+	+	+	+	+	0	0	0
Calcidiscus leptoporus (= *Cyclococcolithus leptoporus* (Murray & Blackman) Kamptner, 1954)	0	0	0	0	+	0	0	0
Calciosolenia murrayi Gran, 1912 (= *Acanthosolenia mediterranea* Bernard, 1939)	0	+	0	0	0	0	0	0
Calciosolenia brasiliensis (Lohmann) Young *in* Young *et al*. (2003) (= *Anoplosolenia brasiliensis* (Lohmann) Deflandre, 1952)	0	0	+	0	0	0	0	0
[a]*Calyptrosphaera insignis* Schiller, 1913	0	0	0	0	0	+	0	0
[b]*Corisphaera fagei* Bernard, 1939	0	0	+	0	0	0	0	0
Discosphaera tubifera (Murray & Blackman) Ostenfield, 1900	0	+	0	0	+	+	+	0
Emiliania huxleyi (Lohmann) Hay & Mohler in Hay *et al*. (1967) (= *Coccolithus huxleyi* (Lohmann) Kampter, 1943)	0	+	+	0	+	0	0	0
Gephyrocapsa oceanica Kamptner, 1943	0	+	0	+	0	0	0	0
Helicosphaera carteri (Wallich) Kamptner, 1954	0	+	0	0	0	0	0	0
[c]*Lohmannosphaera paucoscyphos* Schiller, 1925	0	+	0	0	0	0	0	0
Michaelsarsia elegans Gran, 1912 (= *Michaelsarsia splendens* Lohmann, 1912)	0	+	0	0	0	0	0	0
Ophiaster hydroideus Lohmann, 1913	+	+	0	0	0	+	0	+
[d]*Pontosphaera caelamensis* Lecal-Schlauder, 1951	0	+	0	0	0	0	0	0
[e]*Pontosphaera granii* Gaarder, 1954	0	0	0	0	+	0	0	0
Rhabdosphaera clavigera Murray & Blackman, 1898	0	+	0	0	+	+	0	+
Rhabdosphaera stylifer Lohmann, 1902	0	+	+	0	+	+	0	0
Scyphosphaera apsteinii Lohmann, 1902	0	+	0	0	0	+	0	0
Syracosphaera binodata Kamptner, 1941	0	+	0	0	0	0	0	0
Syracosphaera corii Schiller, 1925	0	+	0	0	0	0	0	0
Syracosphaera dalmatica Kamptner, 1927	0	+	0	0	0	0	0	0
Syracosphaera histrica Kamptner, 1941	0	+	0	0	0	0	0	0
Syracosphaera mediterranea Lohmann, 1902 (= *Coronosphaera mediterranea* (Lohmann, 1902) Gaarder in Gaarder & Heimdal, 1977)	0	+	0	0	0	0	0	0
Syracosphaera molischii Schiller, 1925	0	+	0	0	0	+	+	0
Syracosphaera pulchra Lohmann, 1920	0	+	0	0	0	0	+	0
[f]*Thoracosphaera heimii* (Lohmann) Kamptner, 1944	0	+	0	0	0	0	+	0
Umbellosphaera irregularis Paasche *in* Markali & Paasche (1955)	0	0	0	0	0	0	+	0

Notes: [a]The name *Calyptrosphaera insignis* is not used in modern taxonomy and it is impossible to guess what species might have been observed by Norris (Young pers. comm.), hence is not included in the checklist. [b]*Corisphaera fagei* is now recognised as *Syracosphaera mediterranea* (Young pers. comm.), which is included in the checklist. [c]*Lohmannosphaera paucoscyphos* is not used in modern taxonomy and it is impossible to guess what species might have been observed by Norris (Young pers. comm.), hence it is not included in the checklist. The names of both [d]*Pontosphaera caelamensis* and [e]*P. granii* are not used in modern taxonomy and it is not possible to guess what species might have been observed by Norris (Young pers. comm.), hence they are not included in the checklist. [f]*Thoracosphaera heimii* is a dinoflagellate and is not included in the checklist.

Latitude and longitude in Norris (1960) stations:

Stn B64: 34.90° S, 177.08° E
Stn B65: 32.84° S, 179.17° E
Stn B67: 30.58° S, 179.27° W
Stn B69: 23.45° S, 171.45° W
Stn B71: 21.98° S, 174.17° W
Stn B77: 21.03° S, 172.97° W
Stn B80: 18.47° S, 172.73° W
Stn B85: 17.75° S, 178.12° W
Stn B91: 26.25° S, 174.78° E

Table 2.2. A list of extant coccolithophore species recorded at three STF (subtropical front)/ SA (subantarctic) stations*, southeast New Zealand (Saavedra-Pellitero *et al.* 2014).

Coccolithophore species	STF/SA waters
Acanthoica quattrospina	+
Algirosphaera cucullata	+
Calcidiscus leptoporus	+
Calciopappus caudatus	+
Coccolithus pelagicus (*sensu lato*) HOL *Calyptrolithopora* aff. *C. papillifera*	+
Emiliania huxleyi type A, B, B/C, C	+
Gephyrocapsa muellerae	+
Helicosphaera carteri	+
Michaelsarsia spp.	+
Ophiaster spp.	+
Palusphaera spp.	+
Pappomonas spp.	+
Papposphaera spp.	+
Syracosphaera borealis	+
Syracosphaera castellata	+
[a]*Syracosphaera corolla*	+
Syracosphaera dilatata	+
Syracosphaera florida	+
Syracosphaera halldalii	+
Syracosphaera histrica	+
Syracosphaera molischii	+
Syracosphaera nana	+
[b]*Syracosphaera orbiculus*	+
Syracosphaera ossa	+
[c]*Syracosphaera prolongata*	+
Syracosphaera tumularis	+
Syracosphaera type J	+
Umbellosphaera tenuis	+
Umbilicosphaera sibogae	+

Notes: [a]*Syracosphaera corolla* illustrated in Plate II (g) of Saavedra-Pellitero *et al.* (2014) shows narrow central areas in exothecal coccoliths and hence fits the revised description of *S. corolla* by Young *et al.* (2018). [b]*Syracosphaera delicata* is a synonym of *Syracosphaera orbiculus* (see Nannotax3 website) and is thus replaced by *S. orbiculus* in the Checklist. [c]*Syracosphaera prolongata* is a synonym of *S. pirus* (see Nannotax3 website) and is replaced by *S. pirus* in the Checklist.

***Latitude and longitude of Saavedra-Pellitero *et al.* (2014) stations:**

Stn PS75/099-5: 48.26° S, 177.27° E;

Stn PS75/100-5: 45.76° S, 177.15° E;

Stn PS75/104-3: 44.77° S, 174.53° E.

Appendix 3. Additional environmental metadata (including chlorophll a) for the NIWA stations from which coccolithophores were examined (depth range 0–70 m).

Table 3.1. Discrete environmental metadata for coccolithophores collected on NIWA voyage TAN0902 (Biophysical Moorings 17), Chatham Rise, January 2009.

Parameter	Unit						
Station name		YS2	YS3	YS4	YS8	YS29	YS30
CTD no.		U5801	U5802	U5803	U5805	U5815	U5815
Depth	m	42	10	10	10	40	10
Date, 2009		28/01	28/01	28/01	28/01	31/01	31/01
Lat	degrees/decimal minutes	–42.747	–43.101	–43.432	–44.108	–46.636	–46.636
Long	degrees/decimal minutes	175.841	176.095	176.301	176.798	178.556	178.556
Temp	degrees C	14.65	16.90	16.66	15.40	15.06	15.08
Salinity	psu	34.95	34.93	34.87	34.47	34.21	34.21
Silicate	µmol/l	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Ammonium	µmol/l	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Nitrate	µmol/l	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Phosphate	µmol/l	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

Table 3.1 (*continued*). Discrete environmental metadata for coccolithophores collected on NIWA voyage TAN0902 (Biophysical Moorings 17), Chatham Rise, January 2009.

Parameter	Unit								
Station name		YS31	YS32	YS33	YS36	YS38	YS39	YS56	YS59
CTD no.		U5817	U5818	U5818	U5819	U5820	U5821	U5833	U5834
Depth	m	10	40	10	10	10	10	50	10
Date, 2009		1/02	1/02	1/02	1/02	1/02	1/02	3/02	3/02
Lat	degrees/decimal minutes	–44.107	–43.758	–43.758	–43.446	–43.102	–42.820	–41.235	–41.228
Long	degrees/decimal minutes	178.590	–178.507	–178.507	–178.488	–178.489	–178.495	–178.521	–178.522
Temp	degrees C	15.67	13.38	16.57	17.03	17.35	17.40	15.60	17.09
Salinity	psu	34.35	34.68	34.61	34.86	34.89	34.89	34.98	35.17
Silicate	µmol/l	0.12	#N/A	0.13	0.57	0.40	0.45	0.46	0.61
Ammonium	µmol/l	5.15	#N/A	0.59	0.00	0.07	0.00	0.01	0.08
Nitrate	µmol/l	0.00	#N/A	0.00	0.02	0.00	0.00	0.47	0.34
Phosphate	µmol/l	0.45	#N/A	0.18	0.62	0.10	0.11	0.12	0.05

Table 3.2. Discrete environmental metadata for coccolithophores collected on NIWA voyage TAN0904 (Kaikoura I), Kaikoura, April 2009.

Parameter	Unit								
Station name		S09	S07	S13	S17	S25	S35	S33	S41
CTD no.		9	7	13	17	25	35	33	41
Depth	m	10	10	10	10	10	10	10	10
Date, 2009		21/04	21/04	22/04	22/04	23/04	24/04	24/04	24/04
Lat	degrees/decimal minutes	–42.27	–42.04	–42.78	–42.18	–42.56	–42.56	–42.90	–42.80
Long	degrees/decimal minutes	–174.55	–174.60	–174.68	–174.30	–174.23	–173.97	–174.13	–173.95
Temp	degrees C	14.16	12.95	13.61	14.27	13.52	13.44	13.98	14.14
Salinity	psu	34.75	34.51	34.61	34.80	34.64	34.63	34.74	34.78
Silicate	µmol/l	0.89	0.91	0.37	1.92	2.18	0.48	1.23	0.78
Ammonium	µmol/l	0.37	-	-	-	-	-	0.10	-
Nitrate	µmol/l	1.09	2.10	0.91	1.94	1.51	0.96	5.61	2.33
Phosphate	µmol/l	0.17	0.15	0.09	0.15	0.10	0.11	0.57	0.13
N:P		6.40	13.98	10.06	12.82	15.08	8.79	9.81	18.47

Table 3.2 (*continued*). Discrete environmental metadata for coccolithophores collected on NIWA voyage TAN0904 (Kaikoura I), Kaikoura, April 2009.

Parameter	Unit							
Station name		S21	S45	S55	S63	S71	S85	S91	S95
CTD no.		21	45	55	63	71	85	91	95
Depth	m	10	10	10	10	10	10	10	10
Date, 2009		22/04	25/04	26/04	27/04	28/04	30/04	30/04	30/04
Latdegrees/decimal minutes		–42.67	–42.72	–42.20	–42.12	–42.53	–42.54	–42.71	–42.53
Long	degrees/decimal minutes	–174.43	–173.79	–174.70	–174.44	–174.34	–173.91	–173.89	–173.61
Temp	degrees C	13.77	11.75	12.18	12.80	13.43	11.78	12.11	13.32
Salinity	psu	34.70	34.45	34.46	34.46	34.63	34.52	34.56	34.29
Silicate	µmol/l	0.54	0.82	0.39	0.73	0.45	0.81	0.96	2.98
Ammonium	µmol/l	0.44	-	0.16	0.14	0.08	0.07	0.27	0.54
Nitrate	µmol/l	1.66	5.67	4.85	3.01	2.78	4.10	6.36	3.18
Phosphate	µmol/l	0.13	0.31	0.28	0.35	0.20	0.40	0.50	0.18
N:P		12.83	18.55	17.13	8.65	14.15	10.27	12.72	17.90

Table 3.3. Discrete environmental metadata for coccolithophores collected on NIWA voyage TAN0908 (Kaikoura II), Kaikoura, September 2009.

Parameter	Unit				
Station name		R3	R6	R9	R29
CTD no.		U6203	U6209	U6219	U6229
Depth	m	13	10	10	10
Date		10/10	11/10	12/10	13/10
Lat	degrees/decimal minutes	–42.3683	–42.582	–42.672	–42.747
Long	degrees/decimal minutes	–174.8	–174.74	–174.438	–174.177
Temp	degrees C	10.27	10.49	11.72	11.17
Salinity	psu	34.60	34.68	34.93	34.77
Silicate	µmol/l	2.58	#N/A	2.47	1.09
Ammonium	µmol/l	0.56	0.00	0.00	0.44
Nitrate	µmol/l	3.93	35.82	5.12	5.30
Phosphate	µmol/l	0.39	2.36	0.38	0.44
N:P		10.08	15.20	13.47	11.97

Table 3.4. Discrete environmental metadata for coccolithophores collected on NIWA voyage TAN0909 (Biophysical Moorings 19), Chatham Rise, October 2009. DCM = deep chlorophyll maximum.

Parameter	Unit							
Station name		PM9	PM13	PM14	PM17	PM19	PM25	PM26
CTD no.		U6365	U6377	U6385	U6404	U6408	U6425	U6431
Depth	m	60	75 DCM	10	10	50	75 DCM	10
Date, 2009		26/10	27/10	27/10	29/10	29/10	30/10	30/10
Lat	degrees/decimal minutes	–44.199	–46.662	–46.639	–45.200	–44.109	–41.227	–41.203
Long	degrees/decimal minutes	176.698	–178.506	178.536	178.501	178.595	178.481	178.554
Temp	degrees C	8.57	7.75	9.09	9.18	9.10	13.13	13.14
Salinity	psu	34.43	34.20	34.20	34.22	34.47	35.23	35.23
Silicate	µmol/l	2.46	1.95	1.78	2.50	1.55	1.91	#N/A
Ammonium	µmol/l	0.50	0.00	0.00	0.00	0.41	0.15	#N/A
Nitrate	µmol/l	12.85	15.25	14.65	15.51	11.79	4.59	#N/A
Phosphate	µmol/l	0.97	1.13	1.09	1.02	0.76	0.40	#N/A
N:P		13.25	13.49	13.45	15.26	15.46	11.50	#N/A
Chlorophyll a	µg/l	0.327	0.1655	0.1885	0.0545	0.2585	0.3295	#N/A

Table 3.4 (*continued*). Discrete environmental metadata for coccolithophores collected on NIWA voyage TAN0909 (Biophysical Moorings 19), Chatham Rise, October 2009.

Parameter	Unit			
Station name		PM6	PM27	PM12
CTD no.		U6363		U6368
Depth	m	10	0	10
Date, 2009		26/10	1/11	26/10
Lat	degrees/decimal minutes	–42.350	–41.60	–45.173
Long	degrees/decimal minutes	175.651	–175.69	177.289
Temp	degrees C	12.06		#N/A
Salinity	psu	34.85		#N/A
Silicate	µmol/l	2.79	#N/A	2.51
Ammonium	µmol/l	0.25	#N/A	0.00
Nitrate	µmol/l	3.44	#N/A	14.46
Phosphate	µmol/l	0.37	#N/A	1.08
N:P		9.31	#N/A	13.44
Chlorophyll a	µg/l	2.416	#N/A	0.0585

Table 3.5. Discrete environmental metadata for coccolithophores collected on Southern Surveyor voyage SS01, PINTS, Tasman Sea, January–February 2010.

	Unit						
CTD No.		Cast 25	Cast 37	P3/42	P3/42	Cast 24	Cast 25
Depth	m	2	10	15	16	24	25
Lat	degrees/decimal minutes	31 36.04 S	43 51.40 S	46 18.10 S	46 18.10 S	29 59.86 S	31 36.04 S
Long	degrees/decimal minutes	164 33.78 E	160 51.48 E	159 53.00 E	159 53.00 E	165 00.25 E	164 33.78 E

Table 3.5 (*continued*). Discrete environmental metadata for coccolithophores collected on Southern Surveyor voyage SS01, PINTS, Tasman Sea, January–February 2010.

	Unit						
CTD No.		Cast 50	Cast 33	Cast 34	Cast 35	Cast 45	Cast 47
Depth	m	32	33	34	35	45	47
Lat	degrees/decimal minutes	45 57.38 S	39 57.76 S	39 57.36 S	39 57.95 S	46 18.01 S	46 01.32 S
Long	degrees/decimal minutes	153 19.36 E	162 11.62 E	162 10.22 E	162 10.62 E	159 52.30 E	156 49.29 E

Table 3.5 (*continued*). Discrete environmental metadata for coccolithophores collected on Southern Surveyor voyage SS01, PINTS, Tasman Sea, January–February 2010.

	Unit			
CTD No.		Cast 49	Cast 50	Cast 50
Depth	m	49	32	50
Lat	degrees/decimal minutes	45 57.41 S	39 57.92 S	45 57.38 S
Long	degrees/decimal minutes	153 19.71 E	162 11.99 E	153 19.36 E

Table 3.6. Discrete environmental metadata for coccolithophores collected on NIWA voyage TAN1102 (PreSOAP), Chatham Rise, February 2011.

Parameter	Unit						
Station name		NH5	NH16	NH18	NH7	NH43	NH49
CTD no.		uway	U6802	U6802	uway	U6804	uway
Depth	m	5	0	30	5	0	5
Date, 2011/Time		1/02 21:54	2/02	2/02	2/02 1:04	4/02	4/02 12:37
Lat	degrees/decimal minutes	–43.341	–43.805	–43.805	–43.909	–43.733	–43.753
Long	degrees/decimal minutes	175.155	175.175	175.175	175.174	174.984	174.903
Temp	degrees C		14.42	14.08		13.85	
Salinity	psu		34.44	34.43		34.50	
Silicate	µmol/l		0.47	0.52		0.37	
Ammonium	µmol/l		0.20	0.23		0.52	
Nitrate	µmol/l		2.76	2.99		2.37	
Phosphate	µmol/l		0.27	0.25		0.21	
N:P			10.08	12.00		11.38	
Chlorophyll a	µg/l	0.30	1.05	1.22	0.55	5.23	0.76

Table 3.6 (*continued*). Discrete environmental metadata for coccolithophores collected on NIWA voyage TAN1102 (Pre-SOAP), Chatham Rise, February 2011.

Parameter	Unit							
Station name		NH54	NH60	NH89	NH109	NH111	NH118	NH175
CTD no.		U6805	U6806	U6809	U6810	U6810	U6811	U6817
Depth	m	0	0	0	10	50	0	50
Date, 2011		4/02	5/02	6/02	7/02	7/02	8/02	11/02
Lat	degrees/decimal minutes	–43.674	–43.731	–43.727	–42.994	–42.994	–42.992	–43.556
Long	degrees/decimal minutes	175.045	175.387	175.188	181.907	181.907	181.937	179.699
Temp	degrees C	15.47	14.99	15.59	15.64	15.02	15.68	15.38
Salinity	psu	34.60	34.58	34.66	34.88	34.85	34.86	34.76
Silicate	µmol/l	0.48	0.64	0.60	0.33	0.82	0.40	0.48
Ammonium	µmol/l	0.40	0.43	0.38	0.30	0.74	0.18	0.45
Nitrate	µmol/l	1.24	1.68	0.54	0.10	0.73	0.02	0.47
Phosphate	µmol/l	0.19	0.31	0.19	0.15	0.20	0.17	0.14
N:P		6.63	5.40	2.86	0.69	3.67	0.14	3.35
Chlorophyll a	µg/l	2.16	0.59	0.84	1.08	0.48	0.91	0.54

Table 3.6 (*continued*). Discrete environmental metadata for coccolithophores collected on NIWA voyage TAN1102 (PreSOAP), Chatham Rise, February 2011.

Parameter	Unit		
Station name		NH149	NH162
CTD no.		U6814	uway
Depth	m	30	5
Date, 2011/Time		10/02	11/02 0:10
Lat	degrees/decimal minutes	-43.298	-43.616
Long	degrees/decimal minutes	178.749	179.205
Temp	degrees C	15.29	
Salinity	psu	34.60	
Silicate	µmol/l	0.95	
Ammonium	µmol/l	0.27	
Nitrate	µmol/l	0.04	
Phosphate	µmol/l	0.14	
N:P		0.30	
Chlorophyll a	µg/l	1.75	1.08

Table 3.7. Discrete environmental metadata for coccolithophores collected on NIWA voyage TAN1113 (Biophysical Moorings 22), Chatham Rise, September–October 2011.

Parameter	Unit						
Station name		T1	T2	T3	T4	SBM	T5
CTD no.		U7403	U7404	U7405	U7406	U7408	U7413
Depth	m	0	0	0	0	10	0
Date, 2011		27/09	28/09	28/09	27/09	29/09	30/09
Lat	degrees/decimal minutes	–42.35	–43.41	–44.21	–45.20	–46.63	–46.20
Long	degrees/decimal minutes	–175.65	–176.25	–176.70	–177.31	178.58	–178.49
Temp	degrees C	11.5132	10.8011	8.8301	8.6829	8.4546	8.6646
Salinity	psu	34.753	34.713	34.5	34.333	34.34	34.309
Silicate	µmol/l	2.15	0.93	1.55	2.05	2.62	2.13
Ammonium	µmol/l	4.32	6.01	12.44	13.54	14.06	12.90
Nitrate	µmol/l	0.08	0.22	0.00	0.10	0.00	0.21
Phosphate	µmol/l	0.63	0.32	0.67	0.74	0.87	0.78
N:P		6.91	19.07	18.44	18.20	16.16	16.53

Table 3.7 (***continued***). Discrete environmental metadata for coccolithophores collected on NIWA voyage TAN1113 (Biophysical Moorings 22), Chatham Rise, September–October 2011.

Parameter	Unit		
Station name		T6	T8
CTD no.		U7414	U7420
Depth	m	0	0
Date, 2011		30/09	1/10
Lat	degrees/decimal minutes	-44.20	-42.35
Long	degrees/decimal minutes	-178.50	-178.50
Temp	degrees C	9.0855	12.4543
Salinity	psu	34.275	34.994
Silicate	µmol/l	2.16	1.49
Ammonium	µmol/l	12.88	4.13
Nitrate	µmol/l	0.00	0.16
Phosphate	µmol/l	0.76	0.14
N:P		17.03	28.83

Table 3.8. Discrete environmental metadata for coccolithophores collected on NIWA voyage TAN1203 (SOAP), Chatham Rise, February 2012.

Parameter	Unit							
Station name		DA6	DA11	DA16	DA27	DA31	DA35	DA39
CTD no.		U7502	U7503	U7504	U7506	U7507	U7508	U7509
Depth	m	2	2	2	2	2	2	2
Date, 2012		15/02	16/02	17/02	19/02	20/02	21/02	21/02
Lat	degrees/decimal minutes	–44.608	–44.583	–44.550	–44.336	–45.960	–43.741	–43.483
Long	degrees/decimal minutes	174.773	174.700	174.712	175.243	173.645	176.965	179.114
Temp	degrees C	13.92	14.46	14.99	14.67	13.58	15.12	15.88
Salinity	psu	34.43	34.49	34.56	34.44	34.40	34.61	34.79
Silicate	µmol/l	0.21	0.36	0.47	0.34	0.24	0.10	0.17
Ammonium	µmol/l	0.30	0.39	0.21	0.36	0.20	0.61	0.13
Nitrate	µmol/l	5.91	5.56	4.02	5.86	3.77	1.26	0.00
Phosphate	µmol/l	0.58	0.56	0.41	0.51	0.64	0.25	0.12
N:P		10.12	10.02	9.88	11.56	5.90	5.12	0.03
Chlorophyll a	µg/l	1.035	0.835	1.43	0.905	0.88	0.665	0.315

Table 3.8 (*continued*). Discrete environmental metadata for coccolithophores collected on NIWA voyage TAN1203 (SOAP), Chatham Rise, February 2012.

Parameter	Unit							
Station name		DA43	DA48	DA52	DA59	DA62	DA66	DA71
CTD no.		U7510	U7513	U7514	U7516	U7517	U7518	U7519
Depth	m	2	2	2	2	2	2	2
Date, 2012		22/02	23/02	23/02	23/02	24/02	24/02	25/02
Lat	degrees/decimal minutes	–43.717	–43.710	–43.699	–43.641	–43.667	–43.601	–43.557
Long	degrees/decimal minutes	180.157	180.238	180.228	180.247	180.236	180.235	180.316
Temp	degrees C	15.88	15.72	15.65	15.52	15.56	15.72	15.44
Salinity	psu	34.65	34.56	34.52	34.60	34.58	34.65	34.56
Silicate	µmol/l	0.25	0.21	0.11	0.30	0.26	0.40	0.29
Ammonium	µmol/l	0.38	0.24	0.35	1.28	1.14	0.33	0.53
Nitrate	µmol/l	0.08	2.62	2.50	1.56	1.32	1.15	2.86
Phosphate	µmol/l	0.14	0.30	0.30	0.29	0.26	0.24	0.35
N:P		0.55	8.63	8.41	5.36	5.11	4.75	8.11
Chlorophyll a	µg/l	1.515	0.57	0.54	0.525	0.67	0.42	0.61

Table 3.8 (*continued*). Discrete environmental metadata for coccolithophores collected on NIWA voyage TAN1203 (SOAP), Chatham Rise, February 2012.

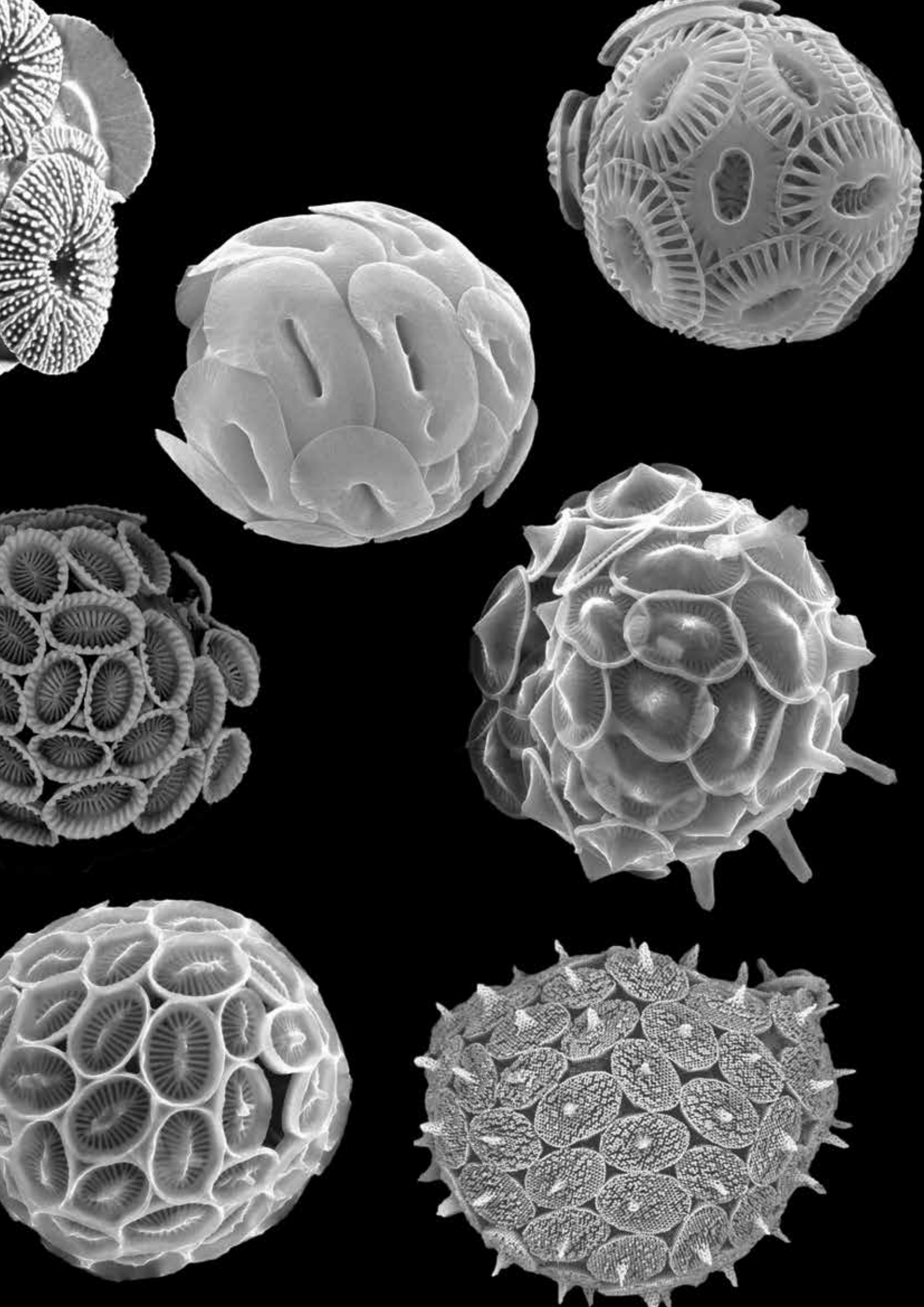
Parameter	Unit							
Station name		DA75	DA82	DA87	DA90	DA93	DA95	DA98
CTD no.		U7520	U7522	U7523	U7524	U7525	U7525	U7527
Depth	m	10	2	10	10	2	30	10
Date, 2012		25/02	27/02	28/02	28/02	29/02	29/02	2/03
Lat	degrees/decimal minutes	–43.630	–44.112	–44.491	–44.542	–44.607	–44.607	–44.191
Long	degrees/decimal minutes	180.260	175.475	174.850	174.873	174.870	174.870	174.925
Temp	degrees C	15.59	14.71	14.24	14.36	14.19	12.66	13.62
Salinity	psu	34.55	34.51	34.53	34.49	34.49	34.49	34.52
Silicate	µmol/l	1.18	0.19	0.22	0.23	0.30	0.43	0.58
Ammonium	µmol/l	0.70	0.54	0.76	0.81	1.19	1.58	1.09
Nitrate	µmol/l	2.92	3.93	2.21	4.40	4.42	3.83	5.28
Phosphate	µmol/l	0.34	0.32	0.26	0.35	0.35	0.36	0.41
N:P		8.53	12.43	8.46	12.73	12.67	10.70	12.77
Chlorophyll a	µg/l	0.63	0.52	0.39	0.285	0.365	#N/A	0.415

Table 3.8 (*continued*). Discrete environmental metadata for coccolithophores collected on NIWA voyage TAN1203 (SOAP), Chatham Rise, February 2012.

Parameter	Unit					
Station name		DA101	DA102	DA104	DA105	DA110
CTD no.		U7528	U7528	U7529	U7529	U7531
Depth	m	10	30	10	30	10
Date, 2012		2/03	2/03	3/03	3/03	4/03
Lat	degrees/decimal minutes	–44.192	–44.192	–44.759	–44.759	–44.243
Long	degrees/decimal minutes	174.927	174.927	174.640	174.640	174.523
Temp	degrees C	13.70	13.68	13.27	11.62	12.88
Salinity	psu	34.54	34.54	34.38	34.47	34.50
Silicate	µmol/l	0.52	0.56	0.43	0.54	0.47
Ammonium	µmol/l	0.70	0.61	0.69	1.43	0.56
Nitrate	µmol/l	2.93	3.10	5.33	8.57	3.86
Phosphate	µmol/l	0.31	0.29	0.49	0.72	0.36
N:P		9.44	10.55	10.94	11.85	10.88
Chlorophyll a	µg/l	0.445	#N/A	0.605	#N/A	0.74

Taxonomic index

Principal taxonomic account is in bold font; species illustrations in bold italic.



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