

2.6 | Picophytoplankton: harbingers of change in our coastal oceans

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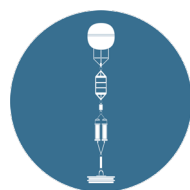
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Summary

Strengthening boundary currents and episodic marine heatwaves are carrying tropical and subtropical picophytoplankton species such as *Prochlorococcus* and *Synechococcus* far into temperate southern waters around Tasmania and South West Australia, with implications for both people and ecosystems. As biomarkers for warmer currents, the picophytoplankton are sensitive indicators of tropical/subtropical microbial communities and thus may 1) afford us a glimpse of future microbial communities in our warming southern oceans and 2), help us model the spread of viral diseases, pathogens and other microbes along our coastlines. Using sensitive biomarkers such as the picophytoplankton will help us understand changes in marine microbial communities at the base of the marine food chain and subsequent impacts on the environment and marine industry such as aquaculture.

Key Data Streams



National Reference
Stations

Rationale

Australia's coastal oceans are changing. Our major boundary currents, the southward-flowing East Australian Current off the east coast and the Leeuwin Current off the west coast are changing and are penetrating warm tropical water further south, sometimes resulting in devastating marine heatwaves (Oliver et al., 2017). These changes have led to the 'tropicalisation' of Australia's southern coastlines and are responsible for the loss of seagrass meadows, kelp forests, species translocations, and impacts on fisheries and aquaculture (Babcock et al., 2019, Oliver et al., 2018, Wernberg et al., 2016). However, little is known of the changes within the less visible, marine microbial communities that form the base of the marine food web. Here we show that the smallest size class of the phytoplankton, the picophytoplankton, are being carried southwards. As sensitive biomarkers of change, their appearance in southern waters may be indicative of future marine microbial communities, with implications for our blue economy.

The picophytoplankton, *Prochlorococcus* and *Synechococcus*, are small (< 2µm diameter) photosynthetic, cyanobacterial cells that contribute most of the primary productivity to the world's open oceans (Worden et al., 2004). Both genera inhabit specific niches. *Prochlorococcus* flourishes in warm, tropical waters with few nutrients and abundant light, and tends to be intolerant of coastal waters. By contrast, *Synechococcus* is distributed further into subtropical zones and is most abundant in upwelling areas or coastal regions where waters are nutrient replete and more turbid. Being so small, picophytoplankton have a large surface area to volume ratio, which places them in intimate contact with surrounding seawater. This results in the cells being able to rapidly access nutrients, allowing them to respond quickly to changing environmental conditions. Picophytoplankton are also light and buoyant, rendering them capable of being carried long distances by ocean currents. Picophytoplankton are thus sensitive indicators of change in our coastal oceans.

Methods

We used samples from the Integrated Marine Observing System (IMOS) National Reference Stations (NRS) at Yongala, Maria Island and Rottneest Island to analyse the abundance of picophytoplankton between 2009 and 2018. These sites were chosen as they represented regions that were strongly influenced by Australia's boundary currents. Triplicate 1 ml seawater samples for the picophytoplankton were collected monthly from pooled water samples over several depths, fixed to a final concentration of 0.5% glutaraldehyde, and frozen in liquid nitrogen until analysis. Picophytoplankton abundance was analysed by standard flow cytometric methods where populations of *Prochlorococcus* and *Synechococcus* were discriminated based on their relative autofluorescence of

chlorophyll-a (red) and phycoerythrin (orange) pigments (Marie et al., 2005). A Beckton Dickinson FacsCanto flow cytometer analysed samples from 2009, but a CytoSense cytometer was used from September 2015. Counts between the two instruments were calibrated by determining the relationship between replicate samples taken over a four-year period from 2013 to 2017, and calculating a corresponding conversion factor (Frampton et al., 2019). We used the accessory pigment divinyl chlorophyll-a (a marker for *Prochlorococcus*) from simultaneous water samples to help correct for false detections. Where divinyl chlorophyll-a was not detected, we removed counts resulting from particle and electronic noise. We matched picophytoplankton abundances to seawater temperature and salinity time series from the IMOS NRS stations and known events impacting the station such as cyclones, monsoonal rainfall and marine heatwaves.

Results and interpretation

Yongala, North Queensland

At the Yongala NRS, seasonal patterns of seawater temperature, salinity and picophytoplankton abundance illustrate the preferential niche of the picophytoplankton (**Figure 1**). *Prochlorococcus* is generally most abundant during spring and summer, when seawater temperatures are rising under the influence of the warm, clear Pacific waters feeding the source of the EAC.

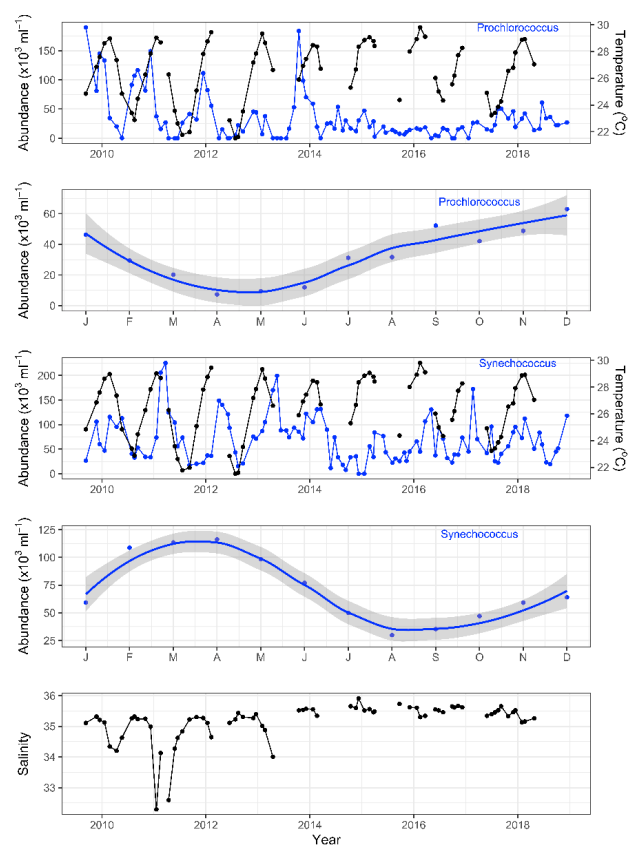


Figure 1. Picophytoplankton abundances and seasonal cycles at the IMOS Yongala National Reference Station. Also shown are temperature and salinity time series from the mooring. Note that there are missing data when the mooring has been damaged.

Prochlorococcus abundance, however, declines abruptly early in the year, with relatively large decreases in seawater salinity caused by either rainfall from cyclones (e.g., Tropical Cyclone Yasi in 2011) or the monsoon season between December to March. Cyclones and high rainfall also result in mixing and sediment runoff, which increase both nutrient concentrations and turbidity (data not shown), conditions not favourable for *Prochlorococcus*. Conversely, *Synechococcus* abundances increase from late summer through to autumn, before declining with cooler temperatures into winter, confirming their preference for warm, turbid and nutrient-rich seawater. Over the longer term, patterns of picophytoplankton abundance appear to be influenced by the El Niño–Southern Oscillation (ENSO), where abundances can be higher during La Niña or neutral years (2009 – 2014) than in El Niño years (2015 onwards).

Rottnest Island, Western Australia

At the Rottnest Island NRS, seawater temperatures ranged between 18°C to 23°C between 2009 and 2018, with the exception of periods in 2011 and 2012 when temperatures reached 25°C (Figure 2). Elevated temperatures beginning in February 2011 were a result of a record strength Leeuwin Current and a severe marine heatwave, which persisted into 2012 (Feng et al., 2013). This is confirmed by the lower salinity seawater (a marker of the Leeuwin Current water) evident into 2012.

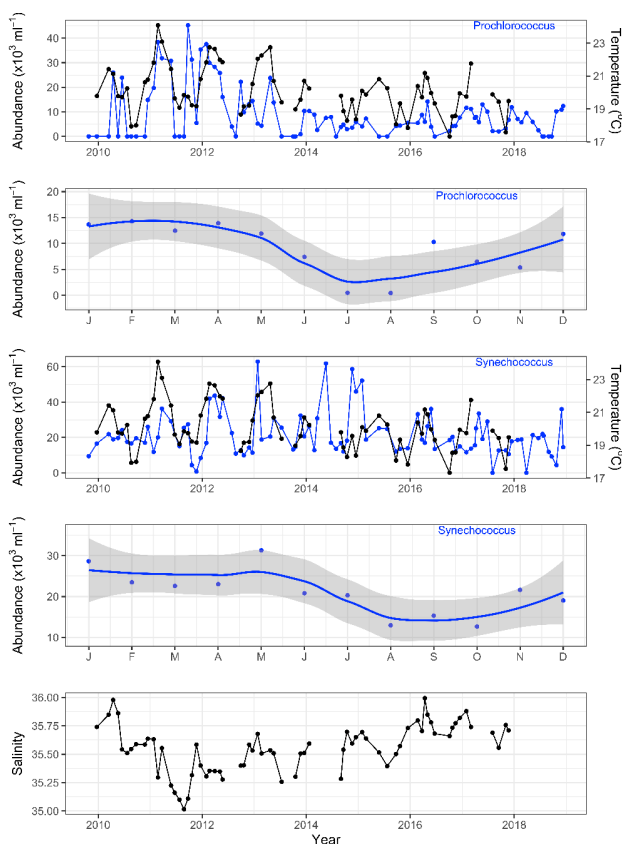


Figure 2. Picophytoplankton abundances and seasonal cycles at the IMOS Rottnest Island National Reference Station. Also shown are temperature and salinity time series from the mooring. Note that there are missing data when the mooring has been damaged.

An immediate effect of the heatwave was the unseasonal appearance of the tropical *Prochlorococcus* at the Rottnest Island NRS, at abundances at least twice the values observed outside the heatwave conditions. Further, *Prochlorococcus* abundance remained elevated throughout 2011 and into 2012, carried by the persistent Leeuwin Current. At this site, *Synechococcus* abundances correlated poorly with the marine heatwave conditions and appeared influenced more by coastal upwelling water of the inshore northward flowing Capes Current.

Maria Island, Tasmania

At the Maria Island NRS, seawater temperature has distinct seasonal cycles and peaks in late summer each year (Figure 3).

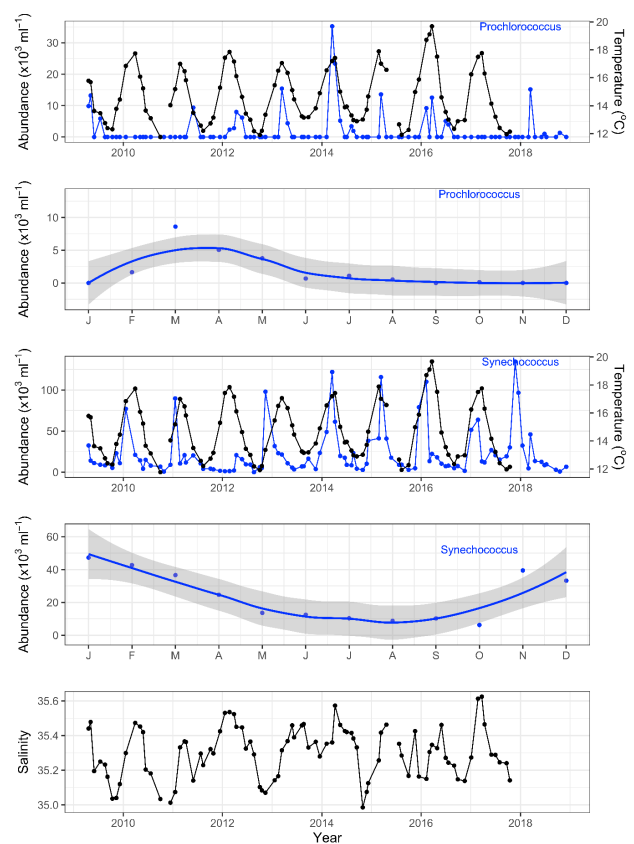


Figure 3. Picophytoplankton abundances and seasonal cycles at the IMOS Maria Island National Reference Station. Also shown are temperature and salinity time series from the mooring. Note that there are missing data when the mooring has been damaged.

Since 2009 at this temperate site, there have been small peaks in abundance of the tropical *Prochlorococcus* of up to 40 000 cells ml^{-1} most summers. The subtropical *Synechococcus* was also recorded most summers and appears to increase in abundance to 2014, before remaining at stable but elevated concentrations through to the most recent observations. Further, peaks in *Synechococcus* abundance were only found in a single month prior to 2014, but were found over at least two successive months from 2014, indicating prolonged exposure to tropical waters. A warming trend has been recorded at the Maria Island NRS over the past 50 years

(Ridgway, 2007, Kelly et al., 2015, Kelly et al., 2016), and the east coast of Tasmania has experienced marine heatwaves since 2015 until present day (Oliver et al., 2018). Both the gradual warming and the marine heatwaves have been attributed to the increasing strength of the EAC extension to 2014 and the impact of its' eddies that have intensified from 2015. Thus, the appearance of the tropical and subtropical picophytoplankton appear to be a direct result of transport by the EAC southwards along the Tasmanian coast.

Implications for people and ecosystems

Data from the IMOS NRS show that picophytoplankton are sensitive biomarkers of environmental conditions. Picophytoplankton have specific environmental niches and respond quickly to changing conditions, such as decreasing salinity resulting from rainfall and the passage of cyclones. We have provided evidence that tropical and subtropical picophytoplankton are increasing in abundance in southern Australian waters, either as a result of episodic marine heatwaves and/or through strengthening boundary currents. These increases in abundance represent an immediate ecological impact and are consistent with other impacts of warming along our southern coastlines, such as abalone mortality, fish kills, species translocations and the loss of kelp forests (Oliver et al., 2017, Wernberg et al., 2016, Pearce and Feng, 2013).

What is the significance of the picophytoplankton? As biomarkers for warmer currents, these light and buoyant cells can be used as proxies for understanding the spread of viral diseases, pathogens and other microbes along our coastlines, as well as impacts of marine heatwaves. For example, oyster aquaculture in Tasmania was severely impacted for the first time by the Pacific Oyster Mortality Syndrome (POMS) in 2015. Previously POMS was only known in NSW (Green et al., 2014). Was this virus spread to Tasmanian waters by the EAC? The transport of the picophytoplankton southwards makes this and the translocation of other pathogens a possibility. Further, as picophytoplankton are biomarkers for tropical seawater, it is likely they are markers for tropical microbial communities, possibly of a different size class, species composition and nutritional quality than found locally. While the stress of hotter temperatures during marine heatwaves can impact wild shellfish (including fished species) and aquaculture shellfish such as farmed oysters, it is likely that a change in the underlying microbial community is responsible for additional, chronic stress to higher trophic levels. Finally, like our southern coastlines undergoing tropicalisation, the picophytoplankton biomarkers may also be giving us a glimpse of future microbial communities in our warming southern oceans.

Acknowledgements

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Data Sources

IMOS National Reference Stations.

<http://imos.org.au/facilities/nationalmooringnetwork/nrs/>

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