Oceanologia (2015) 57, 251—262

Available online at www.sciencedirect.com

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journal homepage: www.elsevier.com/locate/oceano

ORIGINAL RESEARCH ARTICLE

Seasonal changes in phytoplankton on the north-eastern shelf of Kangaroo Island (South Australia) in 2012 and 2013☆

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Received 4 June 2014; accepted 20 April 2015
Available online 2 May 2015

KEYWORDS
Bacteria;
Picoplankton;
Phytoplankton;
Oligotrophic conditions;
Penneshaw desalination plant

Summary This work investigates for the first time the seasonal changes in phytoplankton, bacteria, and photosynthetic picoplankton as well as nutrient concentrations on the North-western shelf of Kangaroo Island, South Australia. Seawater samples were collected off Penneshaw desalination plant, where waters from the Investigator Straight, Gulf Saint Vincent and Backstairs Passage meet. Low nutrient values were measured throughout the period of study (July 2012—July 2013) suggesting the occurrence of oligotrophic conditions on the region. The phytoplankton community was dominated by Bacillariophyceae, Dinoflagellata and Cryptophyta. *Prochlorococcus* Cyanobacteria prevailed among picophytoplankton during most of the period of study (July 2012—July 2013). Previous studies indicate that oligotrophic environments are indeed typically dominated by *Prochlorococcus*. The dominant species found here seem either adapted to grow under low nutrient concentrations, possessing high surface/volume ratios, or have a mixotrophic behaviour allowing them to complement photosynthesis with predation. This study provides base knowledge on the microbial communities north of Kangaroo Island that is needed to sustain the ecosystem and associated economic activities in the future.

☆ The authors acknowledge the financial support of the National Centre of Excellence in Desalination Australia (NCEDA) (Project code: 08313) which is funded by the Australian Government through the *Water for the Future* initiative.
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Peer review under the responsibility of Institute of Oceanology of the Polish Academy of Sciences.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.oceano.2015.04.003

1. Introduction

The South Australian coastal marine ecosystem is one of the most diverse in the world, with a unique endemism rate (O'Hara, 2002). This region supports significant economic activities, notably through aquaculture and most importantly tuna breeding (Prince, 2001). The state of the coastal marine ecosystem in South Australia is then paramount to the sustainability of these economic activities.

Phytoplankton communities, at the bottom of the marine food web, are necessary to the survival of all upper trophic level species (Huertas et al., 2011). Phytoplankton composition fluctuates depending on hydrochemical conditions, such as light, temperature, salinity, nutrients and turbulence (Cloern, 1987; Fisher et al., 1988; Head and Pepin, 2010; Leterme et al., 2005; Sverdrup, 1953). Moreover, the structure of phytoplankton communities is influenced by predation from zooplankton (Landry and Hassett, 1982) and from heterotrophic flagellates (Weisse, 1989), as well as by interactions with bacteria (Azam et al., 1983; Bird and Kalff, 1984) and viruses (Larsen et al., 2001).

Phytoplankton spans across a broad size range, but its smallest fraction, picophytoplankton (<2 μm), accounts for a significant fraction of primary production in seawater, especially in oligotrophic environments (Agawin et al., 2000; Maranon et al., 2001). The prokaryotic component of picophytoplankton mostly includes two cyanobacterial genera, *Prochlorococcus* and *Synechococcus* (Partensky et al., 1999), worldwide. In contrast picoeukaryotes are highly diversified (Vaulot et al., 2008). Oligotrophic environments are typically dominated by *Prochlorococcus* whereas *Synechococcus* and larger sized phytoplankton tend to be more abundant under mesotrophic conditions while picoeukaryotes follow a more complex pattern (Campbell and Vaulot, 1993; Partensky et al., 1996, 1999; Zubkov et al., 2000).

The larger fraction of phytoplankton (>2 μm), which includes nanoplankton (2–20 μm) and microplankton (>20 μm) is also highly diversified, with Bacillariophyceae and dinoflagellates often being the dominant taxa (Tomas, 1997). Within nanoplankton and microplankton, Haptophyta are more adapted to oligotrophic conditions and Bacillariophyceae tend to dominate under high nutrient concentrations, whereas dinoflagellates and green algae occur mostly under intermediate trophic conditions (Cavender-Bares et al., 2001; Iglesias-Rodriguez et al., 2002; Litchman et al., 2007; Schiebel et al., 2004). However, both cell size and shape are highly variable within each taxonomic group, leading to a variability in the surface/volume ratio of the cells and therefore to different nutrient uptake rates and nutrient requirements for each species. This implies a direct relationship between phytoplankton morphology and nutrient composition of seawater (Alves-de-Souza et al., 2008; Hillebrand et al., 1999; Lewis, 1976; Margalef, 1978).

In coastal ecosystems, the capacity for phytoplankton populations and biomass to fluctuate in response to changing environmental conditions is often highly amplified when compared to the open ocean (Carter et al., 2005; Cloern, 1996). These changes range from temperature and light availability, over naturally occurring nutrient fluctuations caused by upwelling/downwelling-favourable conditions, to biochemical input from natural and anthropogenic land run-off (Justic et al., 1995).

Previous studies on the Great Australian Bight highlighted the occurrence of a summer upwelling bringing deep waters to the surface (Kampf et al., 2004). This upwelling occurs on the south western shelf of Kangaroo Island and the upwelled water then circulates to the surrounding areas of the Great Australian Bight (McClatchie et al., 2006). However, upwelled waters are not always enriched in nutrients because of an interannual variability of the depth at which upwelling starts (Middleton et al., 2007). This involves an interannual variability in surface picophytoplankton composition, with *Prochlorococcus* dominating under low nutrient concentrations and *Synechococcus* and picoeukaryotes being more abundant under mesotrophic conditions (van Dongen-Vogels et al., 2012). The composition of picophytoplankton has been investigated in detail, both seasonally (Van Dongen-Vogels et al., 2011) and interannually (van Dongen-Vogels et al., 2012) in the Great Australian Bight, whereas the distribution of large phytoplankton (>2 μm) has been assessed in the Gulf Saint Vincent (Leterme et al., 2014). However, despite the importance of phytoplankton to marine ecosystems, no previous study has combined the concentration of nutrients with the abundance and the composition of both picophytoplankton and large phytoplankton during different seasons for South Australian seawater.

The present study investigates the seasonal fluctuations of the phytoplankton communities of the north-eastern shelf of Kangaroo Island, South Australia. Biological and chemical properties of the ecosystem were monitored from July 2012–July 2013 to assess and explain changes in species composition in relation to environmental conditions. This is the first study simultaneously investigating the phytoplankton communities and their environment in this area and is essential to set up the baseline of future studies. This information will indeed allow evaluating the impact of future changes in temperature and seawater pH to the phytoplankton communities in South Australia.

2. Material and methods

Seawater samples were collected from a DN280 PE280 intake pipe with a nominal diameter of 0.8 m (Leterme et al., 2014), at Penneshaw desalination plant, located on the north-eastern coast Kangaroo Island, South Australia, where waters from the Investigator Straight, Gulf Saint Vincent and Backstairs Passage meet (Fig. 1). The intake pipe pumps seawater at about 190 m off the north-eastern coast of Kangaroo Island, at a depth of 6 m. The high (typically 8.4 L s^{-1}) and uninterrupted flow of seawater within the pre-treatment system implies a very short residence time of seawater within the intake pipe, preventing particle settling. Seawater from the intake pipe thus reflects the environmental conditions occurring in sub-surface seawater off Kangaroo Island during the sampling period. This method of sampling has been tested previously by Manes et al. (2011) for bacteria and by Sewell and Jury (2011) for phytoplankton and meroplankton and was shown not to cause any bias in observations. Seawater was collected using 1 L polyethylene terephthalate (PET) bottles and samples were stored on ice and transported to the laboratory for immediate processing. For phytoplankton