

## 2.3 | Contrasting trends of Australia's plankton communities

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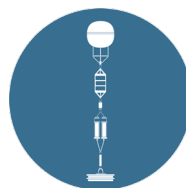
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### Summary

We show that around Australia, phytoplankton are, on average, decreasing in their abundance, a trend consistent with other observations including both chlorophyll a and primary production. Despite this trend in phytoplankton, zooplankton have generally been increasing in their abundance and biomass, with implications for the fish communities they can potentially support.

### Key Data Streams



National Reference  
Stations

## Rationale

The magnitude and distribution of fish caught in the ocean depends on the biomass of phytoplankton (microscopic photosynthetic “plants”) and zooplankton (animal drifters) at the base of the food web (Chassot et al., 2010; Irigoien et al., 2014). Changes in phytoplankton biomass will constrain future fish biomass (Lam, Cheung, Reygondeau, & Sumaila, 2016). Under climate change, global models show an overall decline in global phytoplankton biomass (C. A. Stock, Dunne, & John, 2014; Woodworth-Jefcoats, Polovina, & Drazen, 2017), but with increases in some regions and declines in others. However, the idea that reduced phytoplankton biomass directly translates to reduced fish biomass ignores the complex phytoplankton-zooplankton role. As the intermediate trophic link in the ocean, zooplankton graze on phytoplankton, heterotrophic microbes, and each other, and are eaten by fish, seabirds and marine mammals. They are thus pivotal in the transfer of energy to higher trophic levels.

## Methods

Here we present 10 years (2009-2019) of phytoplankton and zooplankton abundance and biomass data from the seven Integrated Marine Observing System (IMOS) National Reference Stations (NRS) to investigate long-term changes in the two lowest trophic levels in the ocean. We use multiple lines of evidence to investigate changes in phytoplankton. We use two measures to represent change in the phytoplankton: changes in biovolume of phytoplankton and changes in abundance. These measures are based on phytoplankton samples collected by Niskin bottles at several depths, mixed into a single sample, and counted in the laboratory (Eriksen et al., 2019). We also use two measures to represent change in the zooplankton: changes in biomass and changes in the abundance. These measures are based on zooplankton samples collected with a 100  $\mu\text{m}$  mesh drop net and counted (for abundance) or dried and weighed (biomass) in the laboratory.

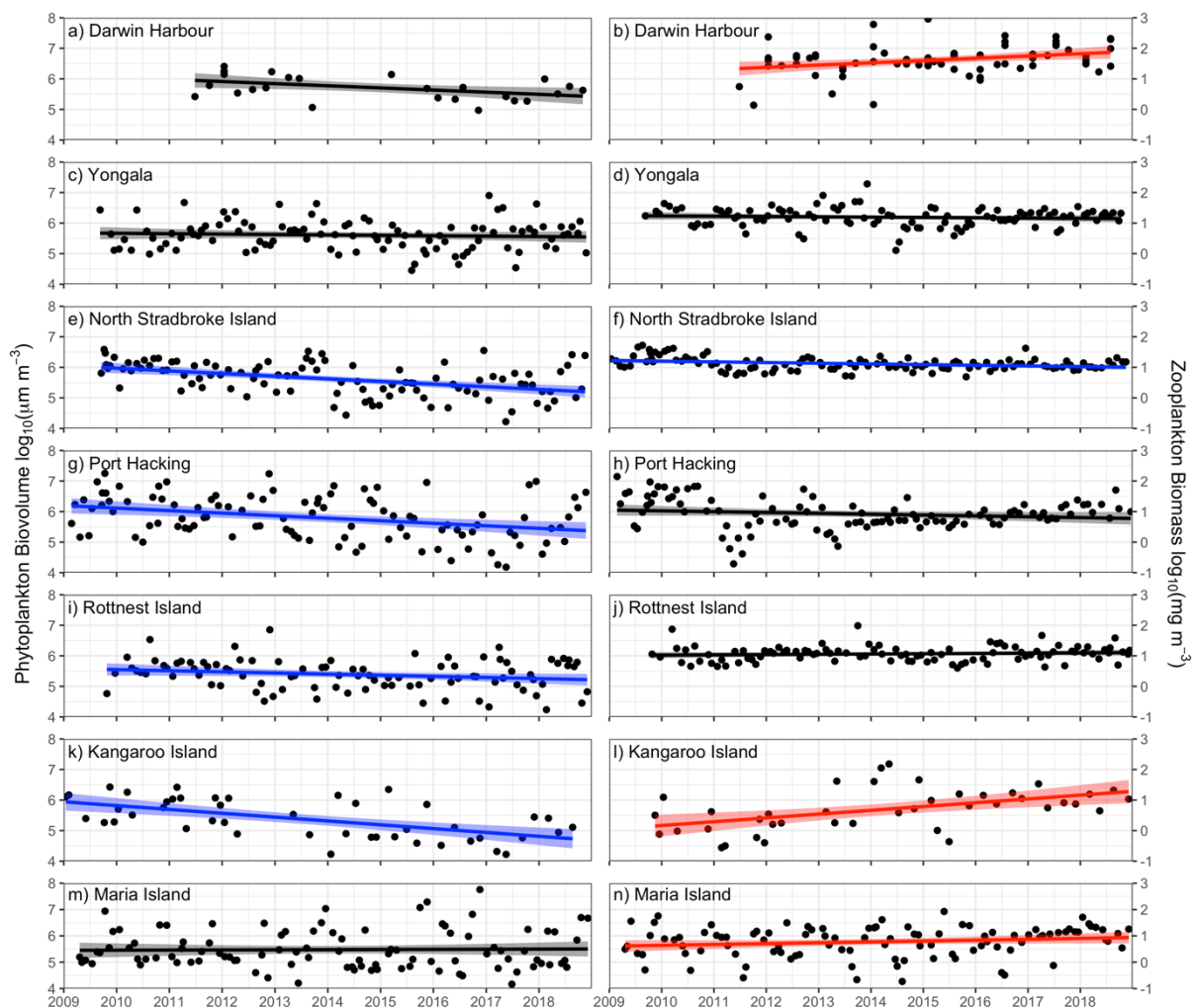


Figure 1. Phytoplankton biovolume ( $\log_{10} \mu\text{m}^3 \text{m}^{-3}$ ; left column) and Zooplankton Biomass ( $\log_{10} \text{mg m}^{-3}$ ; right column). Data are plotted with blue (decreasing) and red (increasing) trendlines indicating a significant change. Black trendlines indicate no statistically significant change.

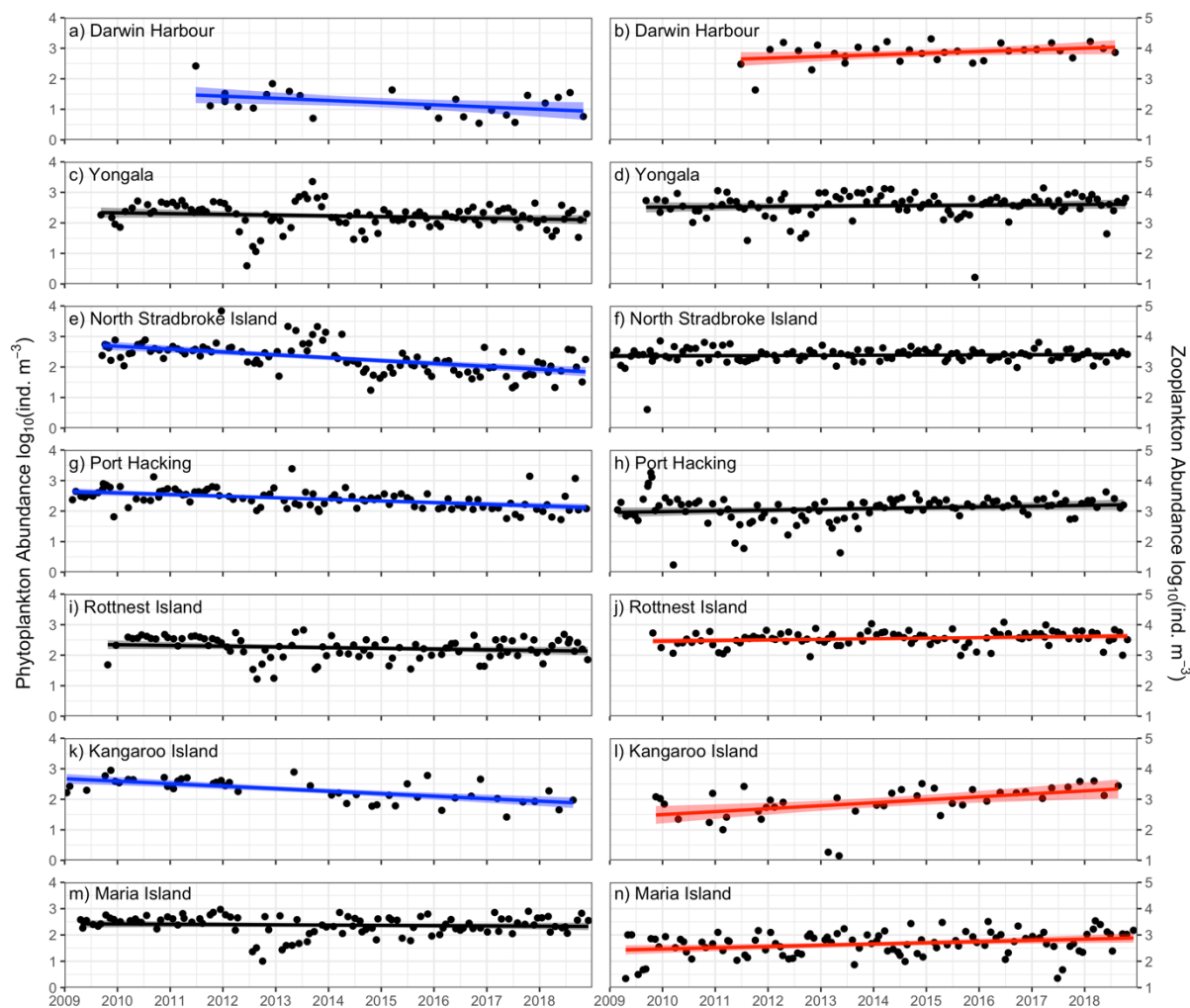


Figure 2. Phytoplankton (left column) and zooplankton (right column) abundance ( $\log_{10}$  counts  $\text{m}^{-3}$ ) at each NRS. Data are plotted with blue (decreasing) and red (increasing) trendlines indicating a significant change. Black trendlines indicate no statistically significant change.

Data were analysed using a linear model with the response variable being either Abundance or Biomass/Biovolume, and predictors being Date (continuous) and Month (a fixed factor). Including Month in the model adjusts for the temporal autocorrelation. Based on visual inspection of the diagnostic plots, a  $\log_{10}$  transformation of the response improved the normality and homogeneity of variance assumptions.

All data were sourced from the IMOS Australian Ocean Data Network (AODN) (<https://portal.aodn.org.au/>; see the datasets IMOS National Reference Station (NRS) - Phytoplankton Abundance and Biovolume", "IMOS National Reference Station (NRS) - Zooplankton Abundance", "IMOS National Reference and "IMOS National Reference Station (NRS) - Zooplankton Biomass")

## Results and Interpretation

Both phytoplankton biovolume (**Figure 1, column 1**) and abundance (**Figure 2, column 1**) are declining significantly at North Stradbroke Island, Port Hacking and Kangaroo Island NRS. Phytoplankton biovolume is also declining at Rottnest Island, and abundance is declining at Darwin. Kangaroo Island

had the largest relative decline in biovolume ( $-96\%$  decade $^{-1}$ ,  $-579,271 \mu\text{m}^3 \text{m}^{-3} \text{decade}^{-1}$ ) and a  $76\%$  decade $^{-1}$  decline in abundance ( $-267 \text{ cells m}^{-3} \text{decade}^{-1}$ ). North Stradbroke Island had a  $93\%$  decade $^{-1}$  decline in abundance ( $-389 \text{ cells m}^{-3} \text{decade}^{-1}$ ) and Port Hacking had a significant decline in both abundance ( $54\%$  decade $^{-1}$ ,  $-209 \text{ cells m}^{-3} \text{decade}^{-1}$ ) and biovolume ( $-80\%$  decade $^{-1}$ ,  $-717,364 \mu\text{m}^3 \text{m}^{-3} \text{decade}^{-1}$ )

By contrast, zooplankton abundance (**Figure 1, column 2**) and biomass (**Figure 2, column 2**) are increasing at Darwin ( $174 \text{ mg m}^{-3} \text{decade}^{-1}$ ;  $9372 \text{ individuals m}^{-3} \text{decade}^{-1}$ ), Kangaroo Island ( $25 \text{ mg m}^{-3} \text{decade}^{-1}$ ;  $2630 \text{ individuals m}^{-3} \text{decade}^{-1}$ ) and Maria Island ( $19 \text{ mg m}^{-3} \text{decade}^{-1}$ ;  $359 \text{ individuals m}^{-3} \text{decade}^{-1}$ ). Zooplankton abundance, but not biomass, is increasing at Rottnest Island ( $1277 \text{ individuals m}^{-3} \text{decade}^{-1}$ ). The biomass of zooplankton is declining at North Stradbroke Island ( $-5 \text{ mg m}^{-3} \text{decade}^{-1}$ ), making it the only station that shows a consistent pattern (decline or increase) between phytoplankton and zooplankton, and the only station that has a declining zooplankton biomass (albeit only a small decline).

## Implications for people and ecosystems

Around Australia, we found that phytoplankton are generally decreasing in abundance. This is consistent with observed declines in chlorophyll-a (see State and Trends of Australia's Ocean Report 2.1: Spatial and seasonal trends in Chlorophyll a and primary production).

Somewhat surprisingly, therefore, we found that zooplankton are not decreasing in response to the phytoplankton decline, but are generally increasing. Over large time and space scales, zooplankton abundance and biomass typically follow changes in phytoplankton, their primary food source (Richardson & Schoeman, 2004). Recent work has shown that differences in fish catch across the ocean far exceed differences in phytoplankton production, indicating that zooplankton is playing a major role (Stock et al., 2017). The increase in zooplankton despite the decline in phytoplankton could be because of increases in microzooplankton (not measured in this analysis), which are grazed upon by larger omnivorous zooplankton. An alternative theory is that there is a relaxation of top-down control of zooplankton. For instance, fewer planktivorous fish (small fish species that eat zooplankton such as mado, yakka and anchovy) could reduce the predation pressure on zooplankton and lead to them increasing in abundance. Despite being more common on coastal reefs (Bellwood et al., 2018), we know little about planktivorous fish in most coastal regions of Australia.

An outstanding question is whether these substantial changes in lower trophic levels are impacting coastal fish communities. Typically, higher zooplankton biomass supports higher fish biomass (Chassot et al., 2010; Ware & Thomson, 2005). Whether these trends in phytoplankton and zooplankton continue is an outstanding question, and one that IMOS is well placed to answer in the future.

## Acknowledgements

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## Data Sources

IMOS National Reference Stations.  
<http://imos.org.au/facilities/nationalmooringnetwork/nrs/>

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