IMOS
Integrated Marine Observing System

State and Trends of Australia's Oceans | Report

4.2 The impact on zooplankton of the 2011 heatwave off Western Australia

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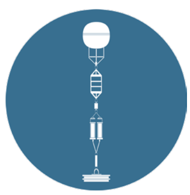
Summary

The 2011 WA marine heatwave led to a substantial decline in zooplankton biomass, abundance and size, and an increase in diversity at Rottnest Island. The poor food environment, which persisted for several months before resetting, could have caused poor feeding conditions and recruitment failures in higher trophic levels.

Key Data Streams



National Reference Stations

Western Australia Moorings

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Rationale

Extreme climate events such as heatwaves and floods can have pronounced ecosystem and evolutionary impacts because they provide little opportunity for organisms to acclimate or adapt. With climate change, extreme climate events are becoming more frequent and more intense (Herring et al., 2018). In early 2011, an extreme La Niña event caused an intense marine heatwave (MHW) in Western Australia, unprecedented in the 140-year local record (Wernberg et al., 2013). The Leeuwin Current accelerated, bringing warm oligotrophic water down the west coast of Australia. The MHW persisted for months along most of the west coast of Australia, with temperatures up to 5°C above average. This led to coral bleaching, death of kelp forests, mortality of seagrass meadows, fish kills, collapse of fisheries, and southwards shifts manta rays and whale sharks (Babcock et al., 2019; Wernberg et al., 2013). Despite the extensive work on the marine heatwave, its effect on plankton have not yet been studied. A better understanding of the impacts on plankton could potentially help to explain impacts of the heatwave on higher trophic levels.

Methods

As part of the Integrated Marine Observing System (IMOS) National Reference Station (NRS) facility, physical, chemical and biological samples have been collected monthly off Rottnest Island since 2009. To investigate the impact of the 2011 marine heatwave on zooplankton in the region, we ianalysed zooplankton biomass, abundance and diversity (AODN datasets: "IMOS National Reference Station (NRS) - Zooplankton Biomass" and "IMOS National Reference Station (NRS) - Zooplankton Abundance"). To place the 2011 marine heatwave in context, we used temperature data throughout the water column from the CTD (AODN dataset: "IMOS - Australian National Mooring Network (ANMN) - CTD Profiles") and chlorophyll-a data from (AODN dataset: "IMOS National Reference Station (NRS) - Phytoplankton HPLC Pigment Composition Analysis").

We tested the impact of the heatwave by using a linear model with the chlorophyll-a, zooplankton biomass, zooplankton abundance, the Shannon copepod diversity and the Pielou copepod evenness index as separate response variables. As predictors in each model, we used Condition, with two levels (Heatwave: Jan-Apr 2011) and non-heatwave (all other months) and a Month term to adjust for seasonality.

Finally, we compared the size spectrum of the zooplankton community during the heatwave and outside the heatwave. We estimated the size spectrum of the sample using ZooScan, a high-performance water-proof scanner (Gorsky et al., 2010). The size spectrum is a plot of the biovolume of all particles in a sample against size bins, from small to large particles.

Results and interpretation

The 2011 marine heatwave had a distinct temperature signal at Rottnest Island, compared with all other times. The extremely warm conditions extended throughout the water column (**Figure 1**). Water temperature was up to 24°C in the top 45 m.

The marine heatwave had a large impact on many aspects of the Rottnest Island ecosystem (**Figure 2**, **Figure 3**). The heatwave had significantly higher SOI values than usual. The high SOI values in the lead up to the heatwave are also clear. Surface temperature was significantly warmer than usual. There was no significant difference in Chl-a within the heatwave and outside that period.

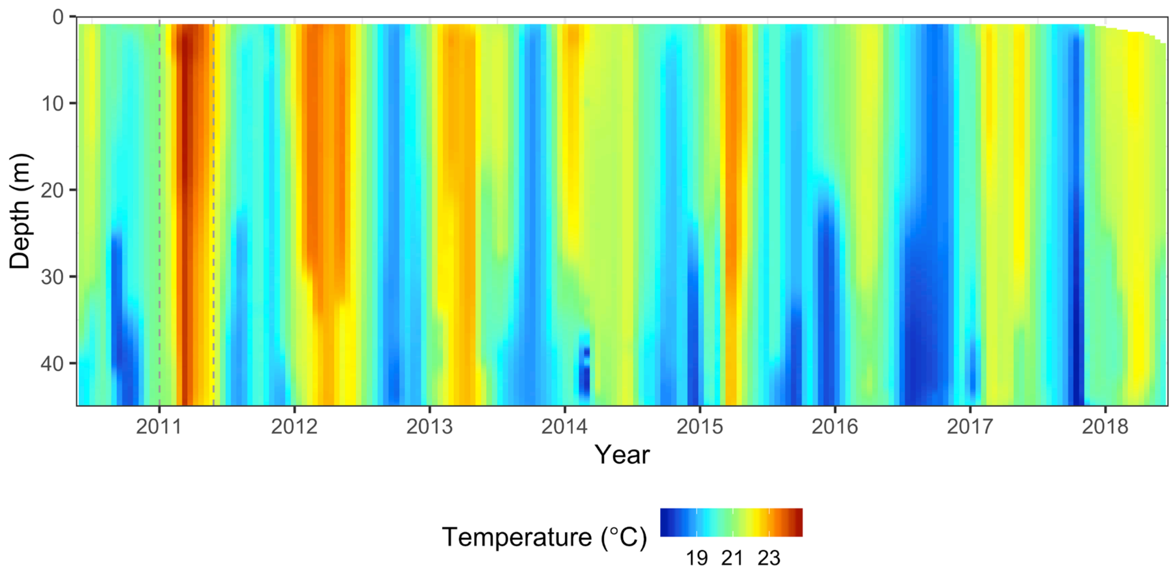

Figure 1. Contour plot of the temperature at Rottnest Island, Western Australia. The heatwave, from January 2011 to April 2011 is represented by the dashed lines.

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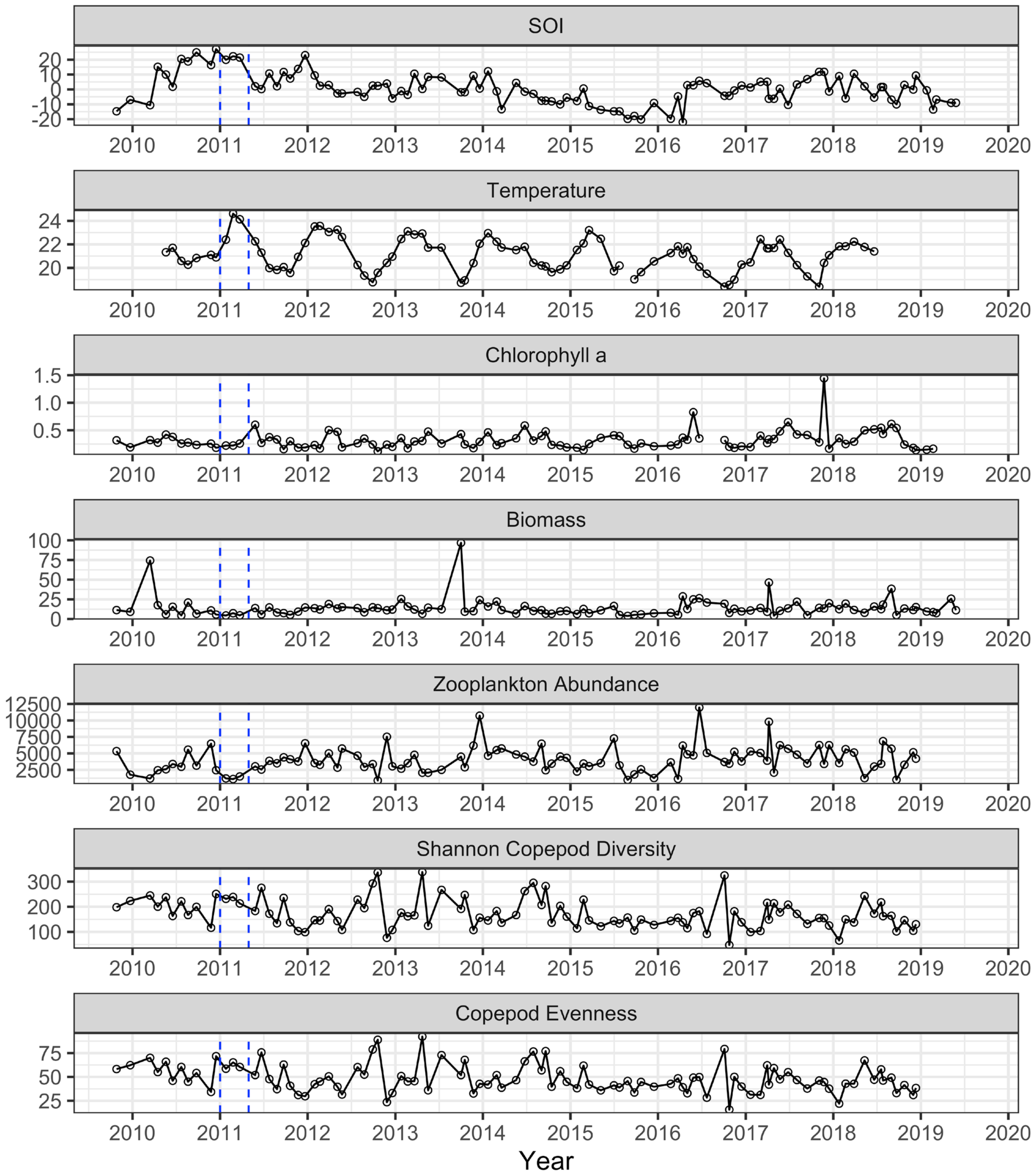

Figure 2. Time series of the Southern Oscillation Index, temperature (°C), surface chlorophyll-a (mg.m^{-3}), zooplankton biomass (mg.m^{-3}), zooplankton abundance (m^{-3}), copepod diversity, and evenness at Rottnest Island, Western Australia. The heatwave is represented by blue lines, from January 2011 to April 2011.

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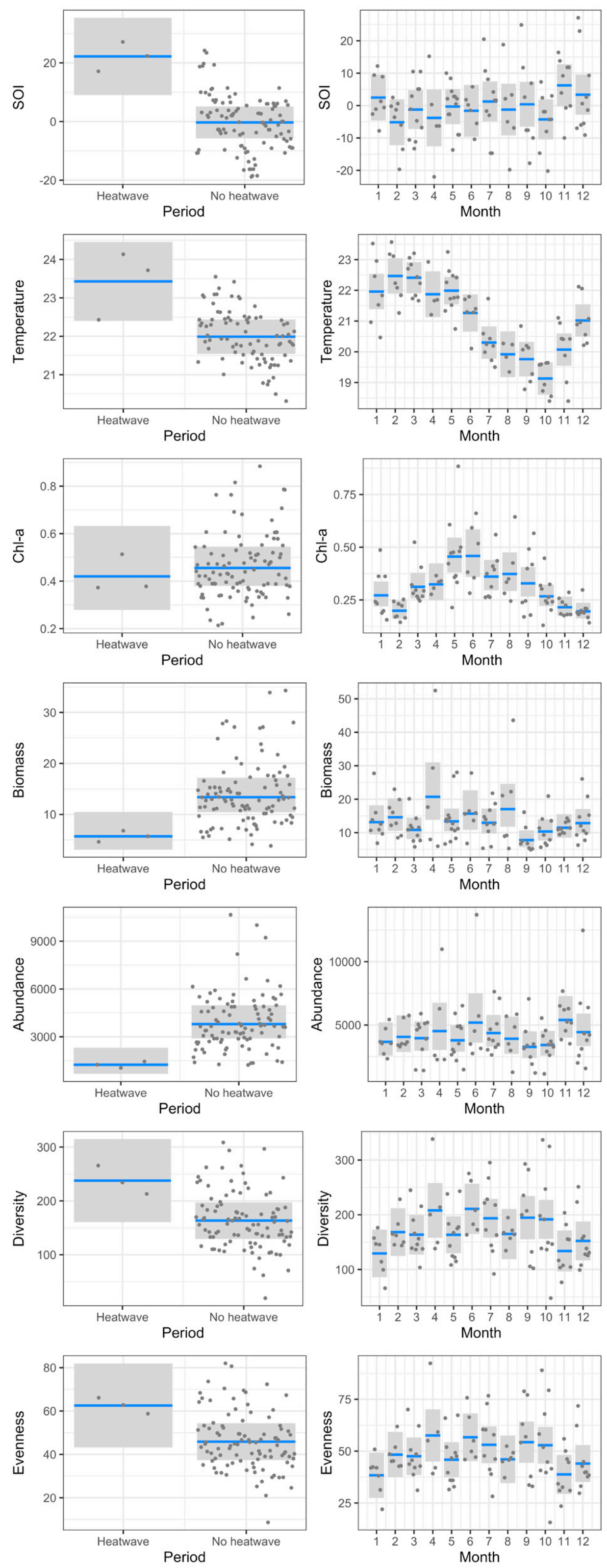

Figure 3. Linear models of different response variables, with predictors of Period (Heatwave, No heatwave) and Month.

By contrast, zooplankton biomass and abundance were significantly lower than usual. The copepod community had high significantly higher diversity during the heatwave, but similar evenness.

The size spectrum of zooplankton shifted lower during the marine heatwave (**Figure 4**). All zooplankton size classes declined, but particularly those in smaller size classes. Thus, the mean size of members of the zooplankton community declined.

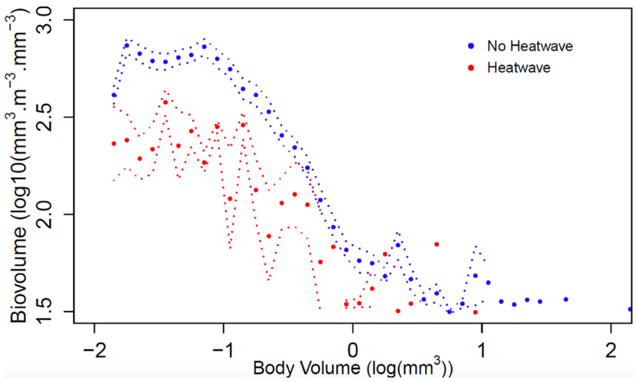

Figure 4. Biovolume for heatwave and non-heatwave samples. Dotted lines show standard error. Non-overlapping standard errors imply statistical significance.

Implications for people and ecosystems

We found that the 2011 marine heatwave had a major impact on the zooplankton at Rottnest Island. There was a substantial decline in zooplankton biomass, abundance and size, and an increase in diversity.

These responses are all consistent with our understanding of how zooplankton communities respond to warmer temperatures. The significant decrease in the biomass and abundance is most likely because the accelerating Leeuwin Current carried down fewer species in it, as plankton tends to be less abundant and smaller in the tropics (Daufresne, Lengfellner, & Sommer, 2009; Giani et al., 2012; Martin, Harris, & Irigoien, 2006). Similar results were found in another study in North West Australia, during the 1998-99 La Niña, where the greater influence of the Leeuwin Current resulted in a significant decrease in the abundance of copepods (McKinnon, Duggan, Carleton, & Bottger-Schnack, 2008). Further, tropical waters have higher diversity (Chaudhary, Saeedi, & Castello, 2016).

We also found that the zooplankton community bounced back quickly following the heatwave. Some of the impacts on higher trophic levels might not only be a consequence of the direct impacts of warm-water, but on the marked reduction in zooplankton productivity during the heatwave.

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Data Sources

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

IMOS Western Australia Moorings.
http://imos.org.au/facilities/nationalmooringnetwork/wamoorings/

References

Babcock, R. C., Bustamante, R. H., Fulton, E. A., Fulton, D. J., Haywood, M. D. E., Hobday, A. J., Vanderklift, M. A. (2019). Severe continental-scale impacts of climate change are happening now: extreme climate events impact marine habitat forming communities along 45% of Australia's coast. ***Frontiers in Marine Science, 6***(411). doi:10.3389/fmars.2019.00411

Chaudhary, C., Saeedi, H., & Castello, M. J. (2016). Bimodality of latitudinal gradients in marine species richness. ***Trends in Ecology & Evolution, 31***(9), 670-676. doi:10.1016/j.tree.2016.06.001

Daufresne, M., Lengfellner, K., & Sommer, U. (2009). Global warming benefits the small in aquatic ecosystems. ***Proceedings of the National Academy of Sciences of the United States of America, 106***(31), 12788-12793. doi:10.1073/pnas.0902080106

Giani, M., Djakovac, T., Degobbis, D., Cozzi, S., Solidoro, C., & Umani, S. F. (2012). Recent changes in the marine ecosystems of the northern Adriatic Sea. ***Estuarine Coastal and Shelf Science, 115***, 1-13. doi:10.1016/j.ecss.2012.08.023

Gorsky, G., Ohman, M. D., Picheral, M., Gasparini, S., Stemmann, L., Romagnan, J.-B., . . . Prejger, F. (2010). Digital zooplankton image analysis using the ZooScan integrated system. ***Journal of Plankton Research, 32***(3), 285-303. doi:10.1093/plankt/fbp124

Herring, S. C., Christidis, N., Hoell, A., Kossssin, J. P., Schreck, C. J., & Stott, P. A. (2018). Introduction to exlaining extreme events of 2016 from a climate perspective. ***Bulletin of the American Meteorological Society, 99***(1), S1-S6. doi:10.1175/bams-d-17-0284.1

Martin, E. S., Harris, R. P., & Irigoien, X. (2006). Latitudinal variation in plankton size spectra in the Atlantic Ocean. ***Deep-Sea Research Part Ii-Topical Studies in Oceanography, 53***(14-16), 1560-1572. doi:10.1016/j.dsr2.2006.05.006

McKinnon, A. D., Duggan, S., Carleton, J. H., & Bottger-Schnack, R. (2008). Summer planktonic copepod communities of Australia's North West Cape (Indian Ocean) during the 1997-99 El Nino/La Nina. ***Journal of Plankton Research, 30***(7), 839-855. doi:10.1093/plankt/fbn043

Wernberg, T., Smale, D. A., Tuya, F., Thomsen, M. S., Langlois, T. J., de Bettignies, T., . . . Rousseaux, C. S. (2013). An extreme climatic event alters marine ecosystem structure in a global biodiversity hotspot. ***Nature Climate Change, 3***(1), 78-82. doi:10.1038/nclimate1627