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Extended abstract

Big things come in small packages. Biomass contribution of the krill *Thysanoessa macrura* to the marine ecosystem in the Kerguelen Plateau region

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Southern Ocean krill (*Thysanoessa macrura*) are a small and abundant species of krill in the Southern Ocean. It is considered the second most abundant krill species, with Antarctic krill (*Euphausia superba*) the biomass dominant species in Antarctic waters (Makarov, 1979; Hosie, 1991; Nordhausen, 1992). *Euphausia superba* is generally found south of the Polar Front, while *T. macrura* has a range that extends from the Antarctic coast to north of the sub-Antarctic front (Kirkwood, 1982; Cuzin-Roudy, et al. 2014). Consequently, *T. macrura* is likely the second most abundant euphausiid in the Antarctic, however estimates of its abundance in the Southern Ocean are largely lacking. *Thysanoessa macrura* play a vital role in the diet of many flying seabirds, fish and penguins. In the sub-Antarctic, the dietary contribution of *T. macrura* outweighs the contribution of other krill species and forms up to 80% of the diet of some sub-Antarctic bird species (Raymond et al., 2011).

Thysanoessa macrura are thought to be omnivorous. Microscopic analysis of gut contents, primarily in the high Antarctic, have highlighted the plastic diet of adult *T. macrura*, with analysis identifying dominant diatom and dinoflagellate groups, protozoans and copepods as primary prey sources (Hopkins, 1987; Raymond et al., 2011). Biochemical analyses, stable isotopes and fatty acid and alcohol analyses both provide insights into long-term feeding trends that compliment ‘snapshot’ information of diets provided by examining gut contents. Fatty acid and alcohol analyses indicate a large wax-ester component of total lipids and a fatty alcohol signature that reflects carnivorous feeding. A review of lipid biosynthetic pathways for *T. macrura* indicates feeding on a dominant Southern Ocean copepod, *Calanoides acutus* (Falk-Petersen et al., 2000). Similarly, stable isotope analysis of Antarctic meso- and macrozooplankton identify a high d^{15}N for *T. macrura*, when compared to *E. superba*, indicating a higher trophic position and thus supporting an omnivorous diet (Rau et al., 1991).

A late-winter reproductive period adds to the ecological complexity of *T. macrura*. The use of wax-esters as a dominant lipid store, possibly derived from *C. acutus* and a total lipid content of more than 50% of dry weight during autumn and winter facilitates the earliest spawning season of all Southern Ocean euphausiids (Hagen and Kattner, 1998; Wallis et al., 2018). *Thysanoessa macrura* store their lipids as a mass within the free space of the carapace (Wallis et al. 2018). This mass, acting like the fat body found in *E. superba*, fuels gonadal development and enables reproduction to be decoupled from phytoplankton blooms, making *T. macrura* a good example of a capital breeder (Murphy et al., 2017). This use of lipids facilitates reproduction in late-winter and thus allows early larval stages to reach surface waters at the beginning of periods of phytoplankton growth (Wallis et al., 2017).

Understanding the role of *T. macrura* in the Southern Ocean ecosystem is important for addressing

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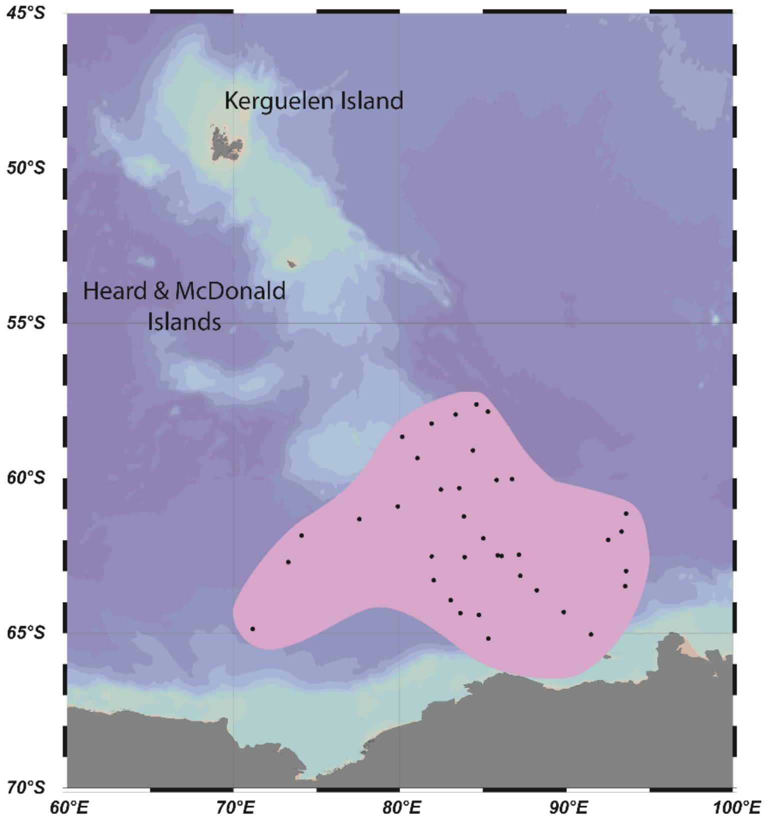

Figure 1: Map of the study region on the southern extent of the Kerguelen Plateau. Black dots indicate sites where *Thysanoessa macrura* were collected and the pink-shaded area indicates the extent of modelled data.

key questions regarding the stability of higher-latitude ecosystems in the face of a changing climate, especially with the uncertainty around responses that might be shown by *E. superba*. *Thysanoessa macrura* represent a pivotal link in the Southern Ocean food web that is currently unquantified. This study aims to provide the first estimates of *T. macrura* biomass in the sub-Antarctic centred on the southern extent of the Kerguelen Plateau.

Thysanoessa macrura were collected during the Kerguelen Axis research voyage by the RV *Aurora Australis* in the southern Kerguelen Plateau region during January and February 2016 (Figure 1). Krill were collected using RMT1+8 double oblique trawls from the surface to 200 m and krill were frozen upon collection. Allometric relationships were established for both wet weight and dry weight for *T. macrura* within the study area. By combining data for calyptopis, furcilia and adult stages, comprehensive relationships were established for both wet weight and dry weight based upon length. Using the established allometric relationships and the average size of calyptopis, furcilia and adult stages, the wet weight biomass of these developmental groups was estimated for the study region. Their relative contribution to the carbon pool was then estimated by first applying the total length – dry weight relationship based upon mean size of each developmental group and an assumed 50% carbon content of dry weight (Froneman et al., 1996). Ocean Data View (ODV, version 5.0) was then used to estimate the total wet weight and carbon biomass of each of the developmental groups using 25 km^2 gridded data-interpolating variational analysis in ODV.

An estimated 1.4 million tonnes of adult *T. macrura* in the upper 200 m of the water column are present in the 557 158 km^2 surveyed region of the Kerguelen Plateau, with 300 000 and 20 000 tonnes of furcilia and calyptopis respectively (wet weight) (Figure 2). Due to the large lipid content of *T. macrura* and the subsequent carbon content (50% of dry weight), the combined contribution of *T. macrura* and its developmental groups in the southern Kerguelen Plateau region was estimated to be 232 200 tonnes of biogenic carbon, with adults contributing over 77% of this total due to their large size compared to the larval developmental groups (Figure 2).

Thysanoessa macrura make a large contribution to the biogenic carbon pool within the southern extent of the Kerguelen Plateau with an average carbon biomass of 0.42 g C m^{-2}. As a single species, this value is high when compared to total zooplankton biomass estimates (up to 2 mm) in the Kerguelen region, which range

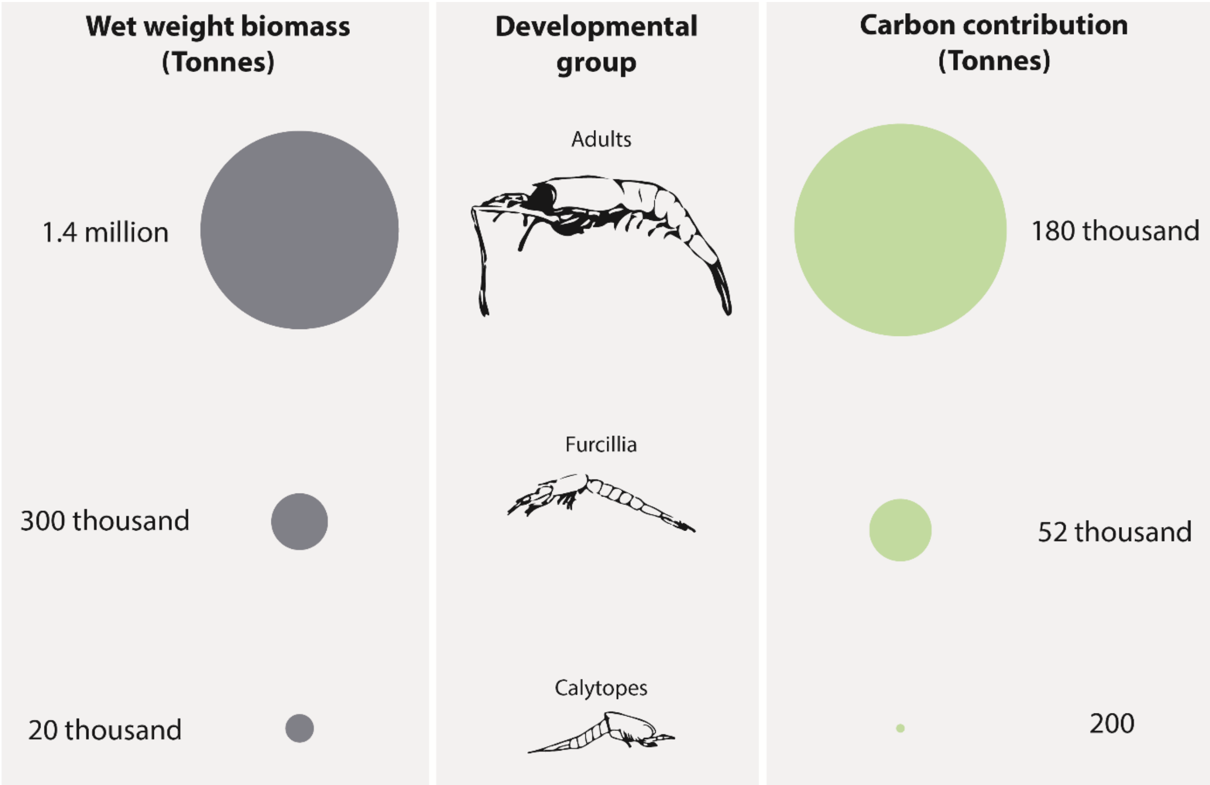

Figure 2: The total contribution of key developmental phases of *Thysanoessa macrura* to both wet weight and carbon biomass in the southern Kerguelen Plateau region.

from 4 to 15 g C m^{-2} in shelf waters and from 1.2 to 4 g C m^{-2} in oceanic waters (Carlotti et al., 2015). A direct comparison of the biomass of *T. macrura* and *E. superba* in the surveyed region would be misleading due to the low numbers of *E. superba* caught in routine trawls. *Thysanoessa macrura* was estimated to have an average density of 3.1 g m^{-2} by wet weight in the surveyed region. A comparison with *E. superba* in the waters south of the Kerguelen Plateau, surveyed during the BROKE (Baseline Research on Oceanography, Krill and the Environment) voyage in 1996, however, indicates mean *E. superba* densities of 5.54 g m^{-2} derived from bioacoustics and an average of 0.4 g m^{-2} from net haul data (Nicol et al. 2000; Pauley et al. 2000). Whilst these estimates of *E. superba* are considered to be low compared to other regions, the similarity in estimates calculated for *T. macrura* in the general region highlights the importance of *T. macrura* in the Southern Ocean ecosystem.

Considerable work still needs to be undertaken to fully realise the importance of *T. macrura* within the Southern Ocean. The results of this study however indicate that despite being a small euphausiid species, the abundance and biomass of *T. macrura* make them a key player in the Southern Ocean ecosystem that is currently underappreciated.

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References

Carlotti, F., M.-P. Jouandet, A. Nowaczyk, M. Harmelin-Vivien, D. Lefèvre, P. Richard, Y. Zhu and M. Zhou. 2015. Measozooplankton structure and functioning during the onset of the Kerguelen phytoplankton bloom during KEOPS2 survey. *Biogeosciences*., 12: 4543–4563.

Cuzin-Roudy, J., J.O. Irisson, F. Penot, S. Kawaguchi and C. Vallet. 2014. Southern Ocean Euphausiids In: De Broyer C., P. Koubbi, H.J. Griffiths, B. Raymond and C. Udekem d'Acoz (Eds). *The Biogeographic Atlas of the Southern Ocean*. Scientific Committee on Antarctic Research, Cambridge: 2–9.

Falk-Petersen, S., W. Hagen, G. Kattner, A. Clarke and J. Sargent. 2000. Lipids, trophic relationships, and biodiversity in Arctic and Antarctic krill. *Can. J. Fish. Aquat. Sci*., 57: 178–191.

Froneman, P.W., E.A. Pakhomov, R. Pressinotto and C.D. McQuaid. 1996. Role of microzooplankton in the diet and daily ration of Antarctic zooplankton species during austral summer. *Mar. Ecol. Prog. Ser*., 143: 15–23.

Hagen, W. and G. Kattner. 1998. Lipid metabolism of the Antarctic euphausiid *Thysanoessa macrura* and its ecological implications. *Limnol. Oceanogr*., 43: 1894–1901.

Hopkins, T.L. 1987. Midwater food web in McMurdo Sounds, Ross Sea, Antarctica. *Mar. Biol*., 96: 93–106.

Hosie, G.W. 1991. Distribution and abundance of euphausiid larvae in the Prydz Bay region, Antarctica. *Ant. Sci*., 3: 167–180.

Kirkwood, J.M. 1982. A guide to the Euphausiacea of the Southern Ocean. *ANARE Research Notes 1*: 1–45.

Makarov, R.R. 1979. Larval distribution and reproductive ecology of *Thysanoessa macrura* (Crustacea: Euphausiacea) in the Scotia Sea. *Mar. Biol*., 52: 377–386.

Murphy, E.J., R.D. Cavanagh, K.F. Drinkwater, S.M. Grant, J.J. Heymans, E.E. Hofmann, G.L. Hunt Jr and N.M. Johnston. 2017. Understanding the structure and function of polar pelagic ecosystems to predict the impacts of change. *Proc. Royal Soc. B*., 283: 20161646.

Nicol, S., J. Kitchener, R. King, G. Hosie and W.K. de la Mare. 2000. Population structure of Antarctic krill (*Euphausia* superba) off East Antarctica (80–150°E) during the Austral summer of 1995/1996. *Deep-Sea Res. II*., 47: 2489–2517.

Nordhausen, W. 1992. Distribution and growth of larval and adult *Thysanoessa macrura* (Euphausiacea) in the Bransfield Strait region, Antarctica. *Mar. Ecol. Prog. Ser*., 83: 185–196.

Pauly, T., S. Nicol, I. Higginbottom, G. Hosie and J. Kitchener. 2000. Distribution and abundance of Antarctic krill (*Euphausia superba*) off East Antarctica (80–150°E) during the Austral summer of 1995/1996. *Deep Sea Res. II*., 47: 2465–2488.

Raymond, B., M. Marshall, G. Nevitt, C. Gillies, J. van den Hoff, J.S. Stark, M. Losekoot, E.J. Woehler and A.J Constable. 2011. A Southern Ocean dietary database. *Ecology*., 92: 1188.

Rau, G.H., T.L. Hopkins and J.J. Torres. 1991. $^{15}N/^{14}N$ and $^{13}C/^{14}C$ in Weddell Sea invertebrates: implications for feeding diversity. *Mar. Ecol. Prog. Ser*., 77: 1–6.

Wallis, J.R., S. Kawaguchi and K.M. Swadling. 2018. Sexual differentiation, gonad maturation, and reproduction of the Southern Ocean euphausiid Thysanoessa macrura (Sars, 1883) (Crustacea: Euphausiacea). *J. Crustacean Biol*., 38: 107–118.