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## Revealing long-term changes in the marine environment and ecosystems of the Southern Ocean

Large-scale multidisciplinary ecological survey reveals long-term changes in the eastern Indian sector of the Southern Ocean

### Summary

- A large-scale multidisciplinary ecosystem survey in the eastern Indian sector (80–150°E) of the Southern Ocean was conducted by the Japanese research vessel, *Kaiyo-maru*, during the 2018–2019 austral summer (KY1804 survey).
- This was the first time such a large-scale survey was conducted in the area since 1996.
- The biomass estimates of Antarctic krill between this survey and the survey in 1996 were comparable, although there are some caveats in the interpretation.
- The Commission for the Conservation of Marine Living Resources (CCAMLR) regards the estimated biomass of Antarctic krill from this survey as the best available estimate to date.
- Compared to 1996, the southern boundary of the Antarctic Circumpolar Current (SB) in the eastern part of the study area (112–150°E) has shifted 50–120 km southward, and water temperature has increased.
- In the eastern part of the research area, the dominant large zooplankton changed from salps to amphipods, which could be linked to oceanographic changes.
- This first large-scale multidisciplinary ecosystem survey conducted in about 20 years has revealed significant changes in the marine environment and distribution of organisms in this area.
- The findings from this survey are expected to be used for academic research on climate and marine ecosystem changes, and for various purposes by international organizations such as CCAMLR.
- Prof. Hiroto Murase (Department of Ocean Sciences, Tokyo University of Marine Science and Technology; the senior researcher at Japan Fisheries Research and Education Agency at the time of the survey) took the lead in compiling the research results into an online special issue.

The results are compiled in an online special issue of “Progress in Oceanography,” published on March 10, 2025.

<https://www.sciencedirect.com/special-issue/10LJ8PLCQ72>

## Background

Krill is considered to be the largest animal biomass in the wild on Earth and is an important prey species for baleen whales and seabirds, making it a key species in the Antarctic marine ecosystem. Fishing for Antarctic krill began in the Indian Ocean sector in the 1970s and it has become an important target species in the Southern Ocean. Since the 1990s, the main fishery has been in the Atlantic Ocean sector, and research and surveys of Antarctic krill have been concentrated in this sector. Large-scale surveys for Antarctic krill in the eastern Indian Ocean sector, south of the Australian continent (80–150°E) have not been conducted since the 1996 Australian BROKE survey (Baseline Research on Oceanography, Krill and the Environment). In recent years, the demand for krill oil as a health food ingredient has increased, and the catch limits have regularly been reached in the main krill fishing ground in the Atlantic. This has led to a trend toward expansion of the Antarctic krill fishery, which now includes limited operations in the Indian Ocean sector. The populations of humpback whales that feed on Antarctic krill was reduced to the verge of extinction due to commercial whaling, but since the International Whaling Commission (IWC) banned the whaling in 1966, the population has recovered in 2015, the population in the Indian sector recovered to the level before commercial whaling began.

The BROKE survey also included oceanographic observations using CTD (conductivity (salinity), temperature and bathymetry) sensors. Since then, changes in bottom water characteristics have become apparent, and detailed, wide-area oceanographic observations were necessary to elucidate the causes and understand trends.

Against this background, a large-scale multidisciplinary ecosystem survey was conducted in the eastern Indian sector of the Southern Ocean (80–150°E) by the Japanese research vessel, *Kaiyo-maru* (Fisheries Agency of Japan, Figure 1), during the 2018-2019 austral summer (KY1804 survey, an acronym for the fourth survey of the vessel in the Japanese fiscal year 2018).



Figure 1: *Kaiyo-maru* (belonging to Fisheries Agency of Japan)

## Methods

The KY1804 survey was conducted by researchers from more than 20 research institutes and universities in five countries, including the Tokyo University of Marine Science and Technology (TUMSAT), Hokkaido University, the National Institute of Polar Research (NIPR), the Japan Fisheries Research and Education Agency (FRA), the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO, Australia), Shanghai Ocean University (China), Wageningen Marine Research (WMR, the Netherlands), the Scripps Institution of Oceanography (USA), and the Southwest Fisheries Science Center (SWFSC, USA). The research was conducted with two main objectives: (1) estimation of standing stock (biomass) of Antarctic krill in the survey area and (2) oceanographic observations in the area to detect any long-term changes.

Along with these main objectives, as with BROKE, we attempted to detect changes in the marine ecosystem between 1996 and 2018–2019 by conducting a survey covering from primary producers to top predators.

The research vessel departed Tokyo on 16 November 2018 and returned after 127 days on 22 March 2019. The vessel called at Fremantle, Melbourne, and Sydney (all in Australia) for resupply. The research area is south of 60°S and between 80°E and 150°E. This is one of CCAMLR's management areas, Division 58.4.1.

Eighteen survey tracklines were placed in the research area (Figure 2), and data from the quantitative echosounder, which were necessary for estimating the biomass of Antarctic krill, were recorded along these lines. Several types of nets were also towed to collect data on zooplankton distributed in the area. A CTD equipped with water samplers collected biological and oceanographic data from the sea surface to depths of up to 3,000 m or more.

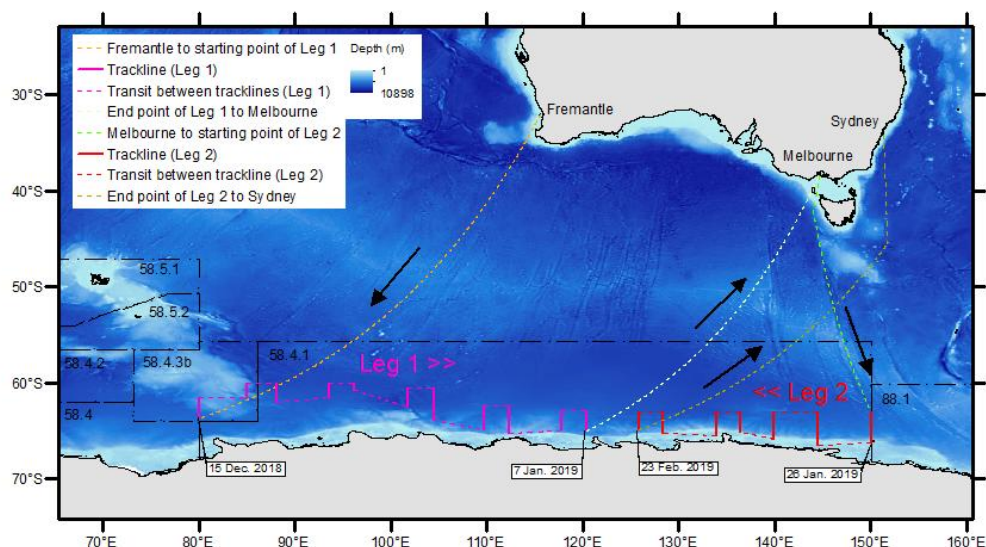


Figure 2. Schematic map showing the research area. The survey was conducted in the first and second legs, with a stopover in Australia *en route* for resupply. The black dotted line is the boundary of the management areas of the Commission for the Conservation of Marine Living Resources (CCAMLR).

## Results

The biomass estimate of Antarctic krill from this survey was regarded as the best available estimate in this area by CCAMLR in 2021. The biomass estimates of Antarctic krill from this survey and BROKE in 1996 were comparable, although there are some caveats in the interpretation as the timing of the survey and estimation methods differed.

Compared to 1996, the southern boundary of the Antarctic Circumpolar Current (SB) has shifted 50–120 km southward in the eastern part of the study area (112–150°E), and water temperature has increased. The freshening trend of the Antarctic Bottom Water (AABW) in the Australian–Antarctic Basin was reversed during the 2010s. This may be due to the slowdown of the melting of ice shelves around the Amundsen Sea, which is the upper reaches of the Antarctic Coastal Current, and as a result, the supply of freshwater may have been reduced.

In the eastern part of the study area, the dominant macrozooplankton were salps in 1996, but this changed to amphipods in 2018–2019. This change may be related to the southward shift of the southern boundary of the Antarctic Circumpolar Current, although it could also be due to the difference in the timing of the surveys. In addition, we collected sea surface organisms using a sea surface net, which is not commonly done in the surveys in the Southern Ocean. It was found that Antarctic krill were abundant near the sea surface.

Other studies included investigation on vertical and horizontal mixing of sea waters, biogeochemical studies of floating ice and seawater, studies of primary production, and abundance and prey consumption estimates for seabirds and cetaceans.

The results of these studies were reported in 14 scientific papers and published as an online special issue of the peer-reviewed journal "Progress in Oceanography" on 10 March 2025. In addition to this special issue, 12 other scientific papers have been published to date. A list of these papers is provided later in this press release.

URL of the online special issue

<https://www.sciencedirect.com/special-issue/10LJ8PLCQ72>

## Future Perspective

Through this survey and research, we were able to obtain knowledge on the current status of the ecosystem in the eastern Indian sector of the Southern Ocean, where few large-scale ecosystem surveys have been conducted. The findings from this research are expected to be utilized in academic studies such as monitoring of climate and marine ecosystem changes, as well as in various considerations by international organizations such as CCAMLR.

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## List of papers published in Progress in Oceanography

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### **List of papers published in other peer-reviewed journals**

- Aoki, S., Yamazaki, K., Hirano, D., Katsumata, K., Shimada, K., Kitade, Y., Sasaki, H., Murase, H., 2020. Reversal of freshening trend of Antarctic Bottom Water in the Australian-Antarctic Basin during 2010s. *Scientific Reports* 10, 14415. <https://doi.org/10.1038/s41598-020-71290-6>
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