



Zooplankton monitoring using a twin NORPAC net during the 63rd Japanese Antarctic Research Expedition in austral summer 2021–2022

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Abstract: As a part of the monitoring programs of the Japanese Antarctic Research Expedition (JARE), zooplankton sampling using a NORPAC (NORth PACific) standard net has been routinely carried out since JARE-14 (1972/73 season) to estimate the long-term trends of abundance, species composition and their temporal/spatial variation in the uppermost 150 m of the Indian Ocean sector of the Southern Ocean. The icebreaker *Shirase* has a fixed schedule and route, traveling down longitude 110°E each December. Data collected on fixed schedules seems to be ideal for long-term monitoring work, and can be used as time series and/or seasonal analysis. This report provides the latest zooplankton data collected during the *Shirase* cruise in the 2021/22 seasons, and is the fifth report for the zooplankton monitoring on board *Shirase* since the first report of the 2016/17 season in this journal.

1. Background & Summary

The need to conduct monitoring of zooplankton in the Southern Ocean has long been recognized. Since zooplankton have short life spans and faster population turnover than vertebrate predators, zooplankton communities tend to change rapidly reflecting ambient environmental conditions¹. They are closer to the base of the marine food web, and they form extremely important links between phytoplankton and higher predators. Therefore, zooplankton community structure is a useful indicator of environmental variability in the Southern Ocean^{1,2}. Moreover, long-term monitoring of zooplankton communities provide a valuable early warning of any changes in the

Southern Ocean and Antarctic ecosystem^{2,3,4}. Numerous intensive surveys have been conducted around Antarctica and its surrounding waters to define zooplankton composition, abundance, and community structures. However, longer-term monitoring is difficult in the remote Southern Ocean, because research opportunities are limited in both time and space.

The Japanese Antarctic Research Expedition (JARE) has been carrying out routine zooplankton monitoring in the Indian Ocean sector of the Southern Ocean every austral summer (December–March) since 1972 (JARE-14). This monitoring program is conducted from an icebreaker, which travels along much the same cruise track at approximately the same time each year. This routine sampling is ideal for long-term monitoring of this region. Although several kinds of plankton nets have been deployed from the icebreakers, vertical hauls using a NORPAC (NORth PACific) standard net have been routinely and frequently carried out to estimate the long-term trends of abundance and species composition of surface zooplankton and its spatiotemporal variability in the upper layers of the Indian Ocean sector of the Southern Ocean. Sampling was conducted from the icebreaker *Fuji* during JARE-14 until JARE-24 (1972–1983)^{5,6}, from the icebreaker *Shirase* during JARE-25 until JARE-49 (1983–2008)^{7,8,9}, from RSV *Aurora Australis* during JARE-50 (2009)¹⁰, and from the new icebreaker *Shirase* during JARE-51 to JARE-61 (2009–2020)^{10,11,12,13,14,15,16,17}. The JARE NORPAC monitoring is the longest ongoing zooplankton study within the Antarctic regions; it has been carried out for the last 50 years. In addition, zooplankton monitoring has also been carried out by the T/V *Umitaka-maru* of Tokyo University of Marine Science and Technology, since the 2013/2014 season (JARE-55) as a part of the JARE monitoring programs^{11,12,13,14,15,16}.

Due to the influence of COVID-19, monitoring program of JARE-62 (2020–2021) was cancelled, and the sampling plan on JARE-63 (2021–2022) was reduced. This report, which is the fifth report for the zooplankton monitoring on board *Shirase* in this journal, presents the data obtained from the NORPAC standard net at two sites during JARE-63 (December 2021).

2. Sampling Location

From JARE-14 to JARE-28 (1986/1987), NORPAC standard net sampling sites were mainly within the western part of the Indian Ocean Sector. Thereafter, sampling stations were shifted to the east where the cruise tracks of the icebreaker *Shirase* remained along the same cruise track each season, beginning with JARE-29 (1987/1988). Regular sampling has been conducted from the icebreaker *Shirase* at five stations along longitude 110°E, ranging from 40°S to 60°S in December. Typically, routine sampling stations are located at intervals of 5 degrees of latitude. In JARE-63, sampling station L01 (40°S, 110°E), L02 (45°S, 110°E), and L03 (50°S, 110°E) were omitted because of rough seas. The location of sampling stations is shown in [Figure 1](#).

3. Methods

The NORPAC standard net was established as a standard method for collecting zooplankton in international cooperative surveys at an international meeting held in Honolulu in February 1956¹⁸. A twin NORPAC standard net made of nylon bolting cloth (NGG 54, mesh size 315 μm ; NXX 13, mesh size 100 μm) was used at all sampling stations (Fig. 2). The net was hauled vertically at a speed of about 1 m/s from a depth of approximately 150 m. The maximum depth reached was estimated from the wire angle and length of the wire paid out. All samples obtained were immediately preserved on board in seawater containing 5%–10% buffered formalin. The volume of water filtered by each net haul was estimated using a flow-meter (Rigo Co., Ltd., Saitama, Japan) mounted at the center of the mouth ring of the net. Sampling was conducted during the daytime at two stations, reducing the contribution of diel vertically migrating zooplankton to the biomass.

4. Data Records

Zooplankton monitoring datasets are presented in three data sheets, species/taxa list, abundance data, and wet weight data. The fields in the dataset are:

JARE number – the JARE number of this sampling season

Ship name – the name of the ship on which the sampling was conducted

Station number – the name of the station on which the sampling was conducted

Latitude – the decimal latitude of the sampling station (negative value for South)

Longitude – the decimal longitude of the sampling station (positive value for East)

Sampling season – two-year Antarctic season based around the austral summer, e.g., “2021-2022” runs from December 2021 to March 2022

Sampling year – the sampling date year

Sampling month – the sampling date month

Sampling day – the sampling date day

Sampling time – the sampling date time (UTC)

Sampling depth – the depth of sampling tow

Mesh size – the mesh size of plankton net

Estimated volume of water filtered – the estimated volume of water filtered using a flow-meter

Abundance – the abundance of each species/taxa

Total abundance – total abundance of all zooplankton in a sample

Number of species/taxa – the number of species/taxa in a sample

Wet weight – the wet weight of each category

Total wet weight - total wet weight of all zooplankton in a sample

5. Technical Validation

5.1. Zooplankton identification

Zooplankton were identified to the lowest practical taxonomic level, generally to species or genus, using a stereo-microscope (SMZ1500, Nikon, Japan). Copepodite stages of copepod species, calyptopis stages and furcilia stages of euphausiid species were subdivided from the adults. The nauplius stages of *Rhincalanus gigas* (Copepoda: Calanoida) were distinguished from other calanoid nauplii by their large size and morphological characteristics. Zooplankton abundance was converted to individuals per cubic meter of water filtered.

The species list for this dataset was checked using the Taxon Match of the World Register of Marine Species (WoRMS: <http://www.marinespecies.org/index.php>) name validation tool. WoRMS is an open-access inventory of all marine species, being >90% complete¹⁹. The tool performs a cross-check of the spelling and taxonomic status of species against the WoRMS database; it returns standard taxonomic information with valid names.

5.2. Wet weight measurement

Processing of samples was carried out according to the four-step procedure outlined below and shown in [Fig. 3](#).

Step 1: the large-sized zooplankton (more than 10 mm in size) were sorted for the whole sample in the laboratory. Zooplankton were classified into five categories, and counting number of individuals and measured the wet weight each category using an electronic balance (Sartorius Quintix124-1SJP, readability 0.1 mg).

Step 2: after removing the larger-sized zooplankton in the step 1, all other species (<10 mm in size) were counted from 1/2 to 1/32 aliquots of the whole sample, and identified to the lowest taxonomic level, generally species or genus, level, using a stereo-microscope. We used a Motoda box-type plankton sample splitter to subdivide a sample. While sorting and counting this size fraction, the wet weight of zooplankton typically reached more than 10 mg per aliquot.

Step 3: given that the wet weight of zooplankton of 1 mm size or less were hard to sort, this fraction was offered to count the individual numbers then the wet weight was estimated by using conversion factors listed in [Table 1](#). The lengths of body parts for calculation were measured using a stereo-microscope (SMZ1500, Nikon, Japan).

Step 4: the weights obtained in steps 1–3 were summed to give a total wet weight per each sample.

Zooplankton abundance per haul was converted to mg m^{-3} . For a detailed description of zooplankton processing for wet-weight measurements, see Ukai *et al.* (2014)²⁸.

6. Figures

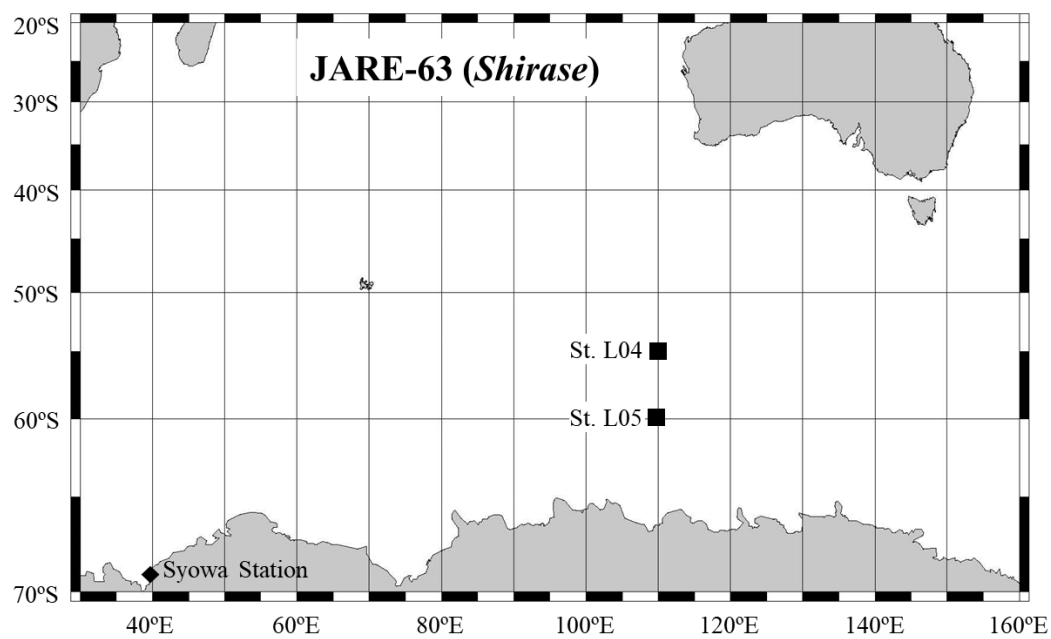


Fig. 1. Locations of the icebreaker *Shirase* sampling stations during JARE-63 in 2021/2022. Stations L01, L02, and L03 were omitted because of rough sea conditions.



Fig. 2. The twin NORPAC standard net. Flow-meter is attached at each mouth ring of net.

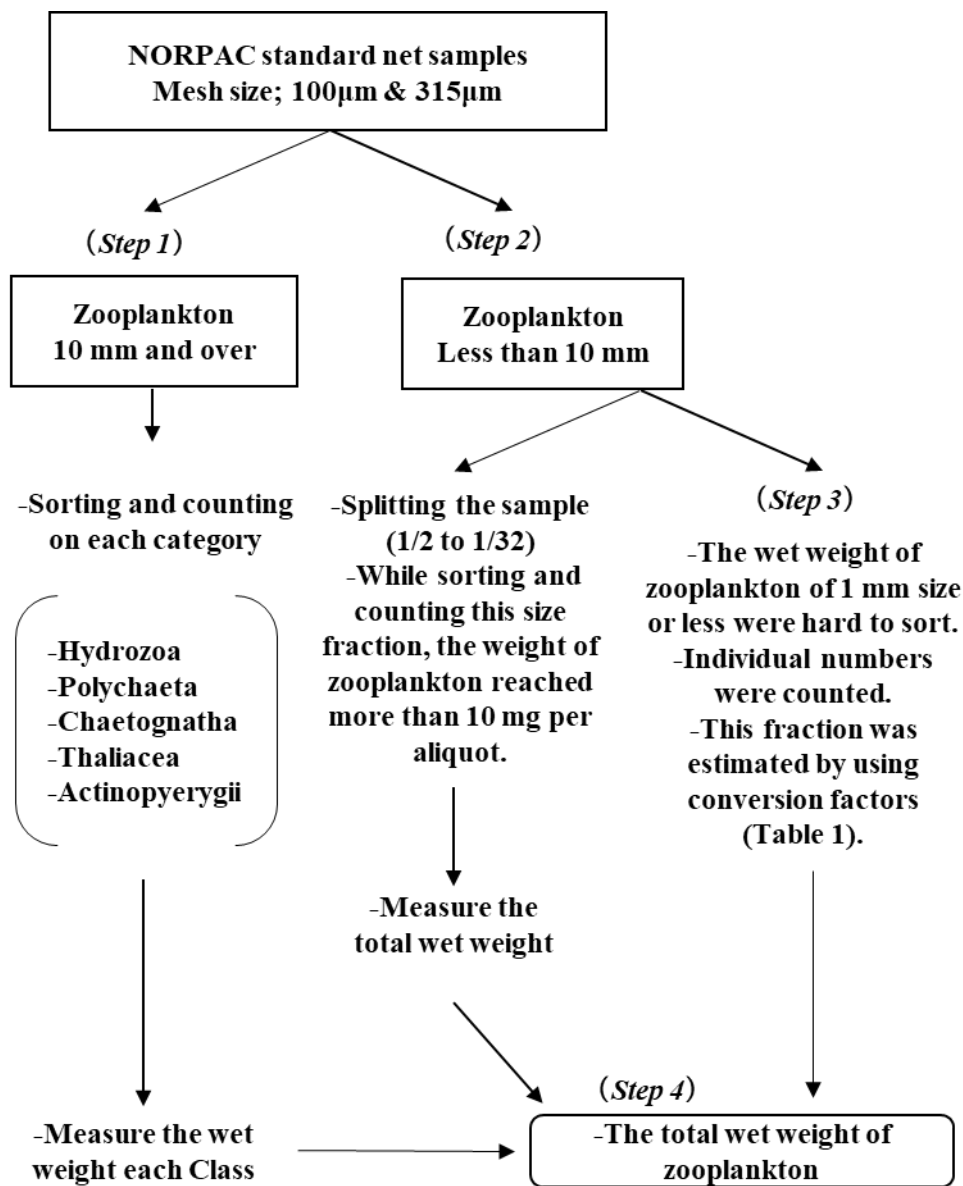


Fig. 3. Four-step procedure used to measure and to estimate the wet weight of NORPAC net samples.

7. Table

Table 1. Conversion factors between Carbon weight (CW), Dry weight (DW), Wet Weight (WW), Body length (L), Bell height (BH), Bell diameter (BD), Shell length (SL), Trunk length (TL) and Body width (BW) used in this study.

Category	Species/taxa and/or Form	Developmental stage	Conversion factors of wet weight	Conversion factors of dry weight	Conversion factors of carbon weight
Cnidaria	BH/BD ≥ 1		$WW(\mu\text{g})=DW(\mu\text{g})/0.040$	$\log DW(\text{mg})=-2.33+1.268\log BH(\text{mm})+1.125(\log BH(\text{mm}))^2$	[9]
	BH/BD < 1		$WW(\mu\text{g})=DW(\mu\text{g})/0.043$	$\log DW(\mu\text{g})=-7.67+2.75\log BD(\mu\text{m})$	[5]
Mollusca	Thecosomata, Gastropoda larvae		$WW(\mu\text{g})=DW(\mu\text{g})/0.256$	$\log DW(\mu\text{g})=-5.10+2.46\log SL(\mu\text{m})$	[5]
	Cavolinidae (Cone)		$WW(\mu\text{g})=(3.14*BW(\mu\text{m})^2*L(\mu\text{m}))/12*10^{-6}$ [2]		
	Bivalve	Larvae	$WW(\mu\text{g})=DW(\mu\text{g})/0.256$	$\log DW(\mu\text{g})=-2.70+1.47\log SL(\mu\text{m})$	[5]
	Polychaeta	Larvae	$WW(\mu\text{g})=DW(\mu\text{g})/0.097$	$\log DW(\mu\text{g})=-5.68+2.10\log L(\mu\text{m})$	[5]
Arthropoda	Ostracoda		$WW(\mu\text{g})=DW(\mu\text{g})/0.182$	$\log DW(\mu\text{g})=-13.77+4.99\log SL(\mu\text{m})$	[5]
	Copepoda; Calanoida	Adult, Copepodite	$WW(\mu\text{g})=DW(\mu\text{g})/0.135$	$\log DW(\mu\text{g})=-9.59+3.41\log L(\mu\text{m})$	[5]
	Copepoda; Cyclopoida	Adult, Copepodite	$WW(\mu\text{g})=DW(\mu\text{g})/0.135$	$\log DW(\mu\text{g})=-6.05+2.10\log L(\mu\text{m})$	[5]
	Copepoda; <i>Mircrossetella</i>	Adult, Copepodite	$WW(\mu\text{g})=DW(\mu\text{g})/0.135$	$\log DW(\mu\text{g})=-7.59+2.88\log L(\mu\text{m})$	[5]
	Copepoda; <i>Corycaeus</i>	Adult, Copepodite	$WW(\mu\text{g})=DW(\mu\text{g})/0.135$	$\log DW(\mu\text{g})=-6.45+2.43\log L(\mu\text{m})$	[5]
	Copepoda; <i>Oncaea</i>	Adult, Copepodite	$WW(\mu\text{g})=DW(\mu\text{g})/0.135$	$\log DW(\mu\text{g})=-5.59+2.25\log L(\mu\text{m})$	[5]
	Copepoda; Others	Adult, Copepodite	$WW(\mu\text{g})=DW(\mu\text{g})/0.135$	$\log DW(\mu\text{g})=-9.07+3.26\log L(\mu\text{m})$	[5]
	Copepoda; Eucalanoidae	Nauplius	$WW(\mu\text{g})=DW(\mu\text{g})/0.135$	$\log DW(\mu\text{g})=-9.59+3.41\log L(\mu\text{m})$	[5]
	Copepoda	Other nauplii	$WW(\mu\text{g})=DW(\mu\text{g})/0.135$	$DW(\mu\text{g})=CW(\mu\text{g})/0.457$	[5]
	Cirripedia	Cypris	$WW(\mu\text{g})=DW(\mu\text{g})/0.182$	$\log DW(\mu\text{g})=-13.77+4.99\log SL(\mu\text{m})$	[5]
		Nauplius	$WW(\mu\text{g})=DW(\mu\text{g})/0.182$	$\log DW(\mu\text{g})=-6.54+2.65\log L(\mu\text{m})$	[5]
	Amphipoda		$\log WW(\text{mg})=-1.517+2.832\log L(\text{mm})$ [8]		
	Euphausiacea		Calyptopis, Furcilia, Adult	$WW(\mu\text{g})=DW(\mu\text{g})/0.159$	$DW(\text{mg})=9.954*10^{-4}*L(\text{mm})^3/156$
		Nauplius	$WW(\mu\text{g})=DW(\mu\text{g})/0.159$	$DW(\mu\text{g})=CW(\mu\text{g})/0.407$	[5]
Chaetognatha			$WW(\mu\text{g})=DW(\mu\text{g})/0.068$	$\log DW(\mu\text{g})=-0.553+2.79\log L(\text{mm})$	[5]
Chordata	Doliolida, Salpida		$WW(\mu\text{g})=DW(\mu\text{g})/0.050$	$\log DW(\mu\text{g})=-6.94+2.54\log L(\mu\text{m})$	[5]
	Appendiculata		$WW(\mu\text{g})=DW(\mu\text{g})/0.050$	$DW(\mu\text{g})=CW(\mu\text{g})/0.442$	[5]
Others Larvae		including eggs	$WW(\mu\text{g})=(3.14*BW(\mu\text{m})^2*L(\mu\text{m}))/6*10^{-6}$ [1]		

[1]: Wet weight was calculated from the volume of the ellipsoid body (Specific gravity = 1). [2]: Wet weight was calculated from the volume of the cone (Specific gravity = 1). [3]: Beers (1966)²⁰. [4]: Ikeda (1970)²¹. [5]: The Oceanographic Society of Japan (1986)²². [6]: Uye et al. (1996)²³. [7]: Sato et al. (2001)²⁴. [8]: Ikeda (1990)²⁵. [9]: Ikeda and Imanura (1996)²⁶. [10]: Iguchi et al. (1999)²⁷.

Author contributions

K. T. Takahashi performed the processing of samples and writing of the manuscript and directed the JARE-63 monitoring program.

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