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Plankton sampling by the training vessel *Umitaka-maru* in the Indian sector of the Southern Ocean in the austral summer of 2010/2011

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1. Introduction

The training vessel (T/V) *Umitaka-maru* II of the Tokyo University of Fisheries (currently Tokyo University of Marine Science and Technology [TUMSAT]) participated in the first Japanese Antarctic Research Expedition (JARE-1) as the ship associated with the icebreaker *Soya*. Research voyages for marine science in the Southern Ocean have been intermittently taken over by T/V *Umitaka-maru* III and IV (the present ship). After many years of a collaborative relationship, the National Institute of Polar Research (NIPR) and TUMSAT signed a comprehensive cooperation agreement on 9 February 2009.

With the start of the six-year plan for JARE phase VIII by NIPR (2010–2015) came the three-year (2010–2012) TUMSAT-NIPR joint program on "Studies on plankton community structure and environment parameters in the Southern Ocean." This program focused on the spatio-temporal variation in plankton distribution in the Southern Ocean ecosystem as one of the JARE projects (Project no. AP-25; Prof. Takashi Ishimaru, TUMSAT, principal investigator).

The present report describes the data from the first year research cruise conducted by T/V *Umitaka-maru* IV under the mission of the AP-25 project. This report contains information about the samples collected using three kinds of plankton nets—the Intelligent Operative Net Sampling System (IONESS), Rectangular Midwater Trawl (RMT), and twin North Pacific (NORPAC) standard net—along longitudes 110°E and 140°E off Wilkes Land, Antarctica, during the cruise period between 24 December 2010 and 22 January 2011.

2. Cruise number

Data covered in this report were obtained from the 14th *Kaiyodai* (abbreviated Japanese name for TUMSAT) Antarctic Research Expedition (*K*ARE-14) cruise by T/V *Umitaka-maru*, which was conducted as part of the 52nd Japanese Antarctic Research Expedition (JARE-52) program. This cruise also served as a leg of the long-distance voyage for the Advanced Course of Marine Science and Technology of TUMSAT (voyage number UM-10-04).

3. Sampling protocol

(1) IONESS

The IONESS is a multiple-net opening and closing zooplankton sampler (Kitamura *et al*., 2001). IONESS was equipped with nine nets with 335-μm mesh for catching meso- to macro-zooplankton.

IONESS was deployed from the stern of vessel and towed obliquely over predetermined depth intervals. Each of the nets was opened and closed sequentially by commands transmitted from an onboard deck unit through an armored cable to an underwater unit. A deployment consisted of the oblique down-cast from the surface to the maximum depth; the opening and closing sequences through specific depth strata occurred during the up-cast.

Although there was a flow-meter (Tsurumi-Seiki Kosakusho Co., Ltd., Yokohama, Japan) mounted outside the net-mouth opening to estimate towing distance, it was not used during this cruise because of a problem with the reliability of the flow-meter rotation due to rough sea conditions. In the present report, therefore, the volumes of water filtered (V, m^3) by each net were estimated with the following equation, assuming filtration efficiencies of 100%:

$$V = D \times A, \tag{1}$$

where D and A are towing distance (m) and mean working filtration area (m^2), respectively. D was calculated as:

$$D = \sqrt{D_{\mathrm{h}}^2 + D_{\mathrm{v}}^2}\,, \tag{2}$$

where D_{h} (m) and D_{v} (m) are the horizontal distance (towing time [s] multiplied by the ship speed [1.0 m s^{-1}]) and vertical distance, respectively. A was calculated as:

$$A = a \times \sin(\pi \times R/180), \tag{3}$$

where a is the mouth area of the net (1.44 m^2 [1.44 m high × 1.0 m wide]) and R is the mean frame angle during each net tow, calculated using the frame angle recorded every 2 s. Depth, temperature and salinity were also measured by a conductivity-temperature-depth (CTD) probe (ICTD, Falmouth Scientific, Inc., Cataumet, MA, USA) mounted on the net frame. CTD data were recorded in real-time by an onboard computer.

Four stations were occupied along 140°E for IONESS samplings (Fig. 1). A total of 13 tows were made during this cruise. However three of these tows (#4, #7, and # 8) failed to sample because of gear trouble. Detailed sampling information for the 10 successful IONESS tows is given in Table 1.

(2) RMT 1+8

The RMT 1+8 is a multiple-net opening and closing zooplankton sampler (Baker *et al*., 1973). An RMT 1+8 consists of two rectangular net systems that open and close simultaneously: an RMT-8 (mouth area, 8 m^2; mesh size, 4.5 mm) and an RMT-1 (mouth area, 1 m^2; mesh size, 335 µm).

The RMT 1+8 was operated in a manner similar to the IONESS; it was deployed from the stern of the vessel and towed obliquely with the nets sampling over predetermined depth intervals. The nets were opened and closed sequentially by commands transmitted from the surface deck unit through a single conducting cable to the underwater unit.

Generally, two series of oblique samplings were conducted at each station: a shallow cast down to 200-m depth and a deep cast below 200 m. A full set of samples could usually be collected within 6 h.

The RMT 1+8 was equipped with a calibrated flow-meter (Tsurumi-Seiki Kosakusho Co., Ltd.). The volume of water filtered was calculated according to the formula in the RMT 1+8 instruction manual as a function of the mouth area of the net perpendicular to the axis of flow and the towing distance indicated by the flow-meter. The average trawling speed was approximately 1.0 m s^{-1}. Depth, temperature and salinity were also measured by a conductivity-temperature-depth (CTD) probe (MicroCAT, Sea-Bird Electronics, Inc., Bellevue, WA, USA), which was mounted on the release gear immediately above the net. CTD data were recorded in real-time by an onboard computer.

Three stations were occupied along 140°E for RMT 1+8 samplings (Fig. 2). Detailed sampling information is given in Table 2.

(3) NORPAC net

A twin NORPAC standard net, with one net made of nylon bolting cloth with a 335-µm mesh and the other with 100-µm mesh, was used for catching micro- to meso-zooplankton (Motoda, 1957). The net was hauled vertically at a speed of about 1 m s^{-1} from an approximate depth of 150 m. The maximum depth reached was estimated from the wire angle and length of wire paid out. The volume of water filtered through each net was estimated using a calibrated flow-meter (RIGO Co., Ltd., Tokyo, Japan) mounted at the center of the mouth ring of each net.

NORPAC net samplings were conducted at five stations along the 110°E transect and 11 along 140°E (Fig. 3). Sampling information is given in Table 3.

(4) Zooplankton sample processing

All zooplankton samples were immediately preserved in 5% borate-buffered formalin seawater on board and stored in a cool, dark place on the ship.

4. Data policy

The purpose of this data report is to provide information about the collection of zooplankton samples for scientists and students researching Antarctic ecosystems and zooplankton. This report should also make interested researchers aware of the opportunity to use these samples to quantitatively describe zooplankton distribution and biomass in the Southern Ocean. All underlying physical data collected with the CTD and the samples are available for scientific use. We expect the information in this report, in combination with the available samples and environmental data set, to be utilized in various future studies.

Permission to use the data and the preserved samples for publication or presentation should be obtained in writing. Inquiries about details of the data record should be addressed to one of the following:

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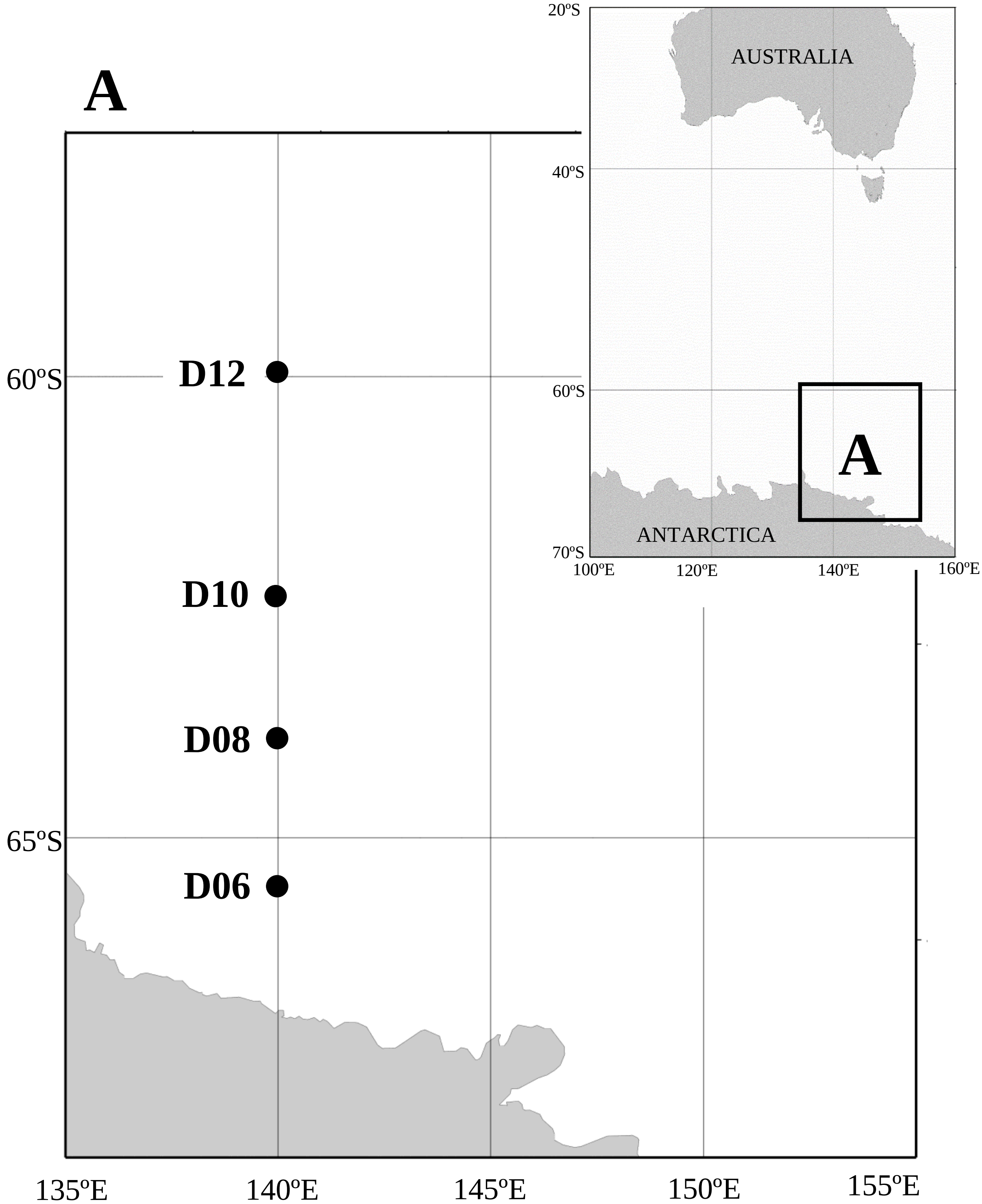

Fig. 1. Stations sampled with IONESS opening/closing multiple-net systems on board the training vessel *Umitaka-maru* in the Indian sector of the Southern Ocean, January 2011.

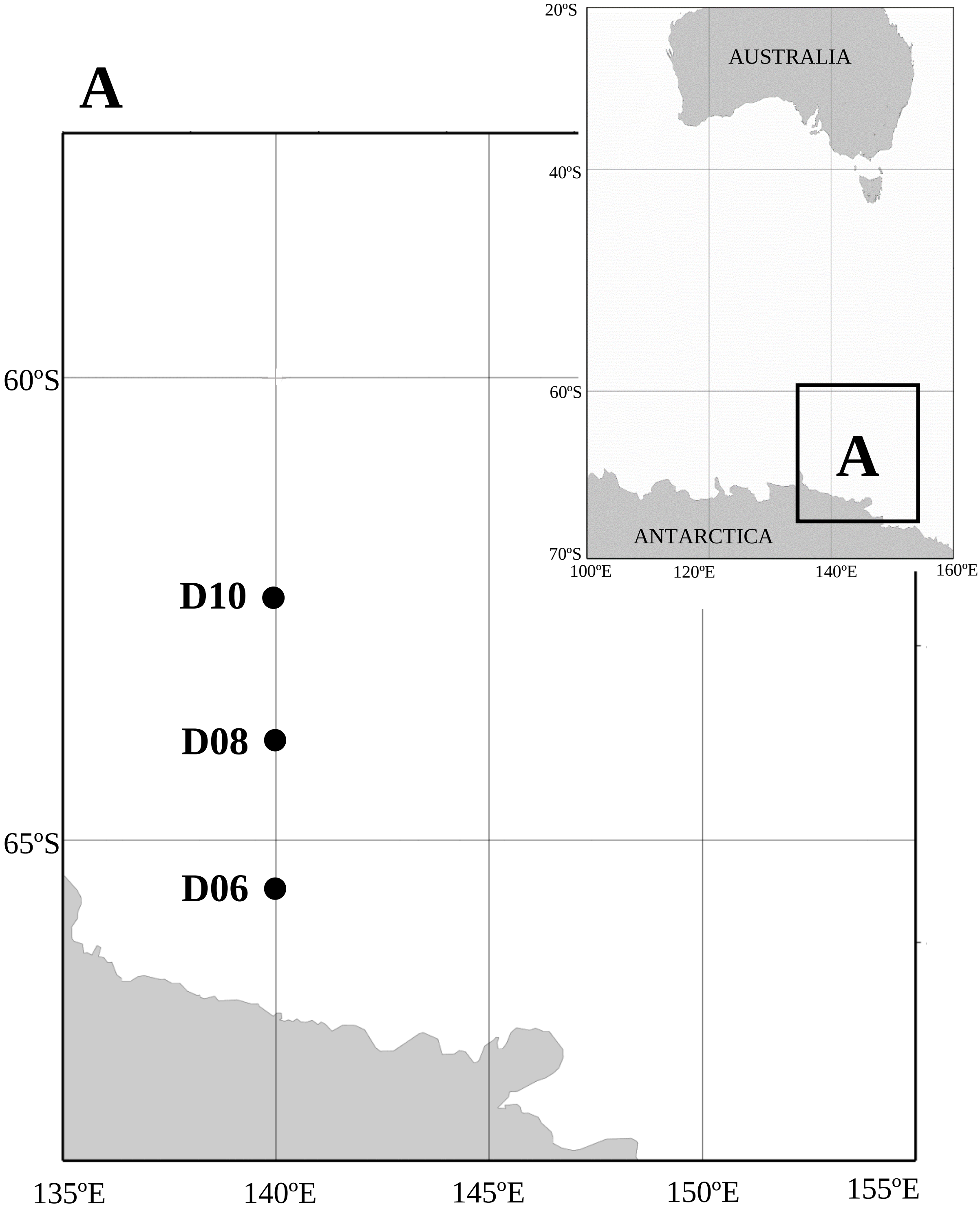

Fig. 2. Stations sampled with RMT 1+8 opening/closing multiple-net systems on board the training vessel *Umitaka-maru* in the Indian sector of the Southern Ocean, January 2011.

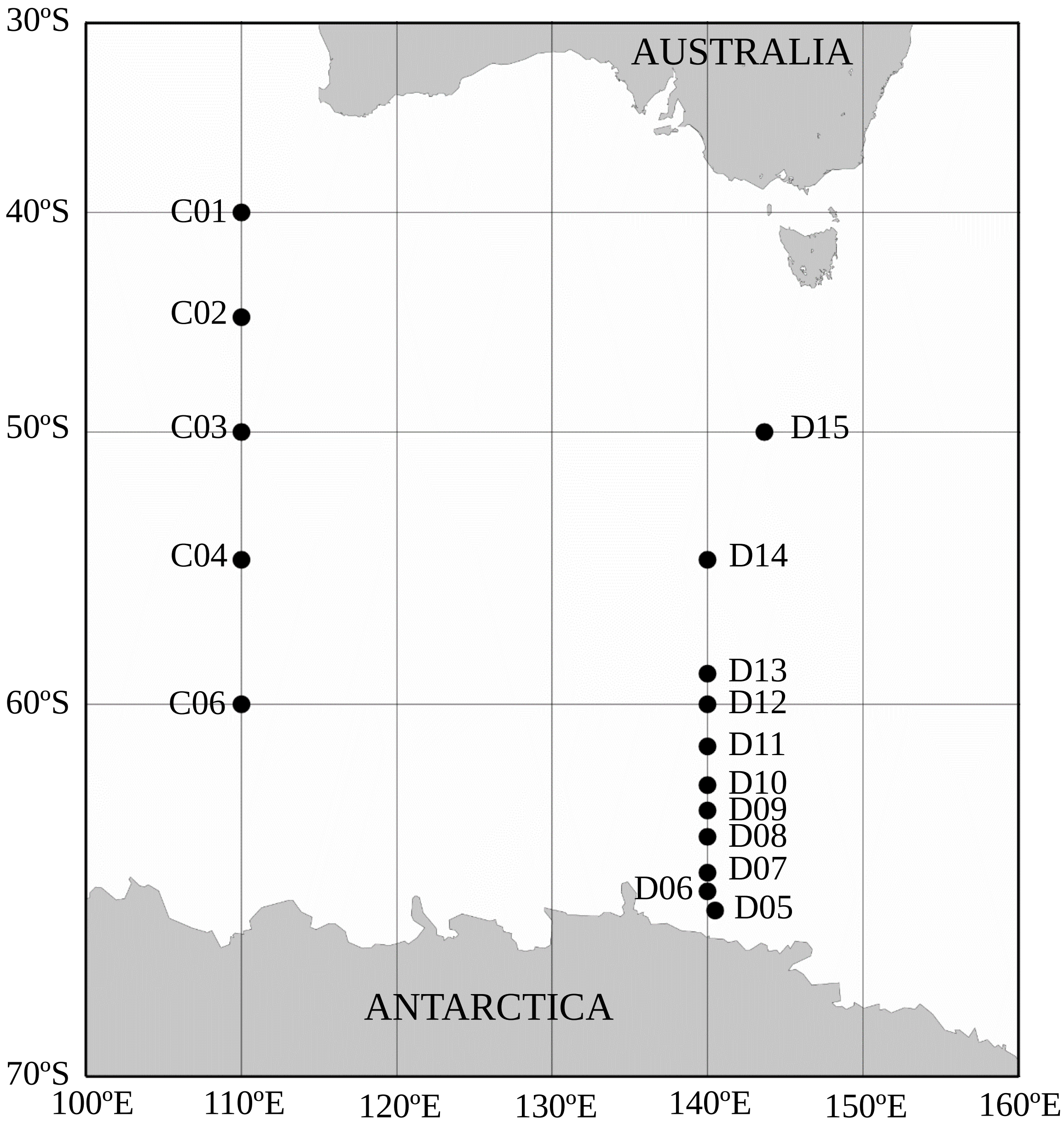

Fig. 3. Stations sampled with a twin NORPAC standard net on board the training vessel *Umitaka-maru* in the Indian sector of the Southern Ocean, January 2011.

Table 1. Sampling data of an IONESS along the 140^{o}E transect in the Southern Ocean in January 2011. (1 of 2)

Stn.	Tow	Position Start	Position Finish	Date (yyyy/mm/dd) & Time (UTC)[a] Start	Date (yyyy/mm/dd) & Time (UTC)[a] Finish	Bottom depth (m)	Net no.[b]	Sampling depth interval (m)	Volume filtered (m^3)
D06	1	65° 30.50´ S	65° 29.53´ S	2011/01/09 19:48	2011/01/09 21:34	1450	1	40-80	583
		140° 4.84´ E	139° 55.52´ E				2	80-120	538
							3	120-160	525
							4	160-200	606
							5	200-250	556
							6	250-300	583
							7	300-400	794
							D	0-400	
	2	65° 30.51´ S	65° 29.77´ S	2011/01/10 05:19	2011/01/10 07:41	1667	1	0-40	730
		140° 4.25´ E	139° 57.79´ E				2	40-80	467
							3	80-120	667
							4	120-160	644
							5	160-200	479
							6	200-250	514
							7	250-300	580
							8	300-400	702
							D	0-400	
	3	65° 30.50´ S	65° 29.56´ S	2011/01/10 11:28	2011/01/10 13:09	1738	1	0-40	342
		140° 5.23´ E	139° 56.54´ E				2	40-80	485
							3	80-120	603
							4	120-160	685
							5	160-200	639
							6	200-250	642
							7	250-300	634
							8	300-400	771
							D	0-400	
D08	5	64° 1.43´ S	64° 0.14´ S	2011/01/11 11:10	2011/01/11 13:32	3697	1	0-40	453
		140° 6.11´ E	140° 0.64´ E				2	40-80	401
							3	80-120	644
							4	120-160	674
							5	160-200	577
							6	200-300	1086
							7	300-400	606
							D	0-400	
	6	63° 59.18´ S	64° 1.87´ S	2011/01/11 14:18	2011/01/11 16:35	3702	1	40-0	382
		139° 57.55´ E	140° 7.30´ E				2	40-80	663
							3	80-120	579
							4	120-160	476
							5	160-200	466
							6	200-300	647
							7	300-400	588
							D	0-400	
D10	9	62° 29.63´ S	62° 30.84´ S	2011/01/13 13:56	2011/01/13 15:57	3943	1	0-40	564
		140° 2.73´ E	139° 53.71´ E				2	40-80	500
							3	80-120	496
							4	120-160	496
							5	160-200	640
							6	200-250	568
							7	250-300	1257
							8	300-400	722
							D	0-400	
	10	62° 29.37´ S	62° 31.38´ S	2011/01/13 19:45	2011/01/13 21:56	3946	1	0-40	226
		140° 3.61´ E	139° 53.31´ E				2	40-80	655
							3	80-120	670
							4	120-160	611
							5	160-200	582
							6	200-250	667
							7	250-300	597
							8	300-400	728
							D	0-400	
	11	62° 29.45´ S	62° 30.64´ S	2011/01/14 05:26	2011/01/14 07:05	3951	1	0-40	404
		140° 2.95´ E	139° 56.26´ E				2	40-80	625
							3	80-120	612
							4	120-160	737
							5	160-200	612
							6	200-250	685
							7	250-300	533
							8	300-400	818
							D	0-400	

[a]Ship mean time = UTC + 10 h

[b]Mesh size, 335 µm; D, down-tow

Table 1. Continued. (2 of 2)

Stn.	Tow	Position		Date (yyyy/mm/dd) & Time (UTC)[a]		Bottom depth (m)	Net no.[b]	Sampling depth interval (m)	Volume filtered (m^3)
		Start	Finish	Start	Finish				
D12	12	59 ° 58.87 ′ S	60 ° 1.03 ′ S	2011/01/15 02:54	2011/01/15 04:31	4483	1	0-40	531
		140 ° 2.84 ′ E	139 ° 57.38 ′ E				2	40-80	549
							3	80-120	540
							4	120-160	609
							5	160-200	771
							6	200-250	685
							7	250-300	628
							8	300-400	750
							D	0-400	
	13	59 ° 57.87 ′ S	60 ° 1.39 ′ S	2011/01/15 13:00	2011/01/15 14:57	4483	1	0-40	626
		140 ° 3.19 ′ E	139 ° 58.60 ′ E				2	40-80	539
							3	80-120	676
							4	120-160	828
							5	160-200	710
							6	200-250	763
							7	250-300	718
							8	300-400	841
							D	0-400	

[a]Ship mean time = UTC + 10 h

[b]Mesh size, 335 µm; D, down-tow

Table 2. Sampling data of a RMT 1+8 along the 140°E transect in the Southern Ocean in January 2011.

Stn.	Position		Date(yyyy/mm/dd) & Time (UTC)[a]		Bottom depth (m)	Net No.[b]	Sampling depth interval (m)	Volume filtered (m^3)
	Start	Finish	Start	Finish				
D06	65° 29.50′ S	65° 29.92′ S	2011/01/09 22:53	2011/01/10 04:32	1380-1983	1-1	0-50	500
	139° 55.21′ E	139° 59.07′ E				8-1	0-50	6273
						1-2	50-100	591
						8-2	50-100	7413
						1-3	100-200	636
						8-3	100-200	7984
						1-4	200-500	1000
						8-4	200-500	12546
						1-5	500-1000	1364
						8-5	500-1000	17108
						1-6	1000-1400	1046
						8-6	1000-1400	13116
D08	64° 0.92′ S	63° 57.50′ S	2011/01/11 23:33	2011/01/12 05:31	3663-3697	1-1	0-50	818
	140° 3.65′ E	139° 52.52′ E				8-1	0-50	10265
						1-2	50-100	773
						8-2	50-100	9694
						1-3	100-200	955
						8-3	100-200	11975
						1-4	200-500	1000
						8-4	200-500	12546
						1-5	500-1000	1000
						8-5	500-1000	12546
						1-6	1000-2000	2409
						8-6	1000-2000	30224
D10	62° 29.22′ S	62° 30.07′ S	2011/01/13 23:01	2011/01/14 04:32	3946-3956	1-1	0-50	955
	140° 5.02′ E	139° 59.21′ E				8-1	0-50	11975
						1-2	50-100	818
						8-2	50-100	10265
						1-3	100-200	409
						8-3	100-200	5132
						1-4	200-500	1091
						8-4	200-500	13686
						1-5	500-1000	1364
						8-5	500-1000	17108
						1-6	1000-2000	1455
						8-6	1000-2000	18248

[a]Ship mean time = UTC + 10 h

[b]Mesh size for 1-m^2 net, 335 μm; mesh size for 8-m^2 net, 4.5 mm

Table 3. Sampling data of a twin NORPAC standard net along the 110°E and 140°E transect in the Southern Ocean in December 2010-January 2011. (1 of 2)

No.	Stn.	Position Start	Position Finish	Date (yyyy/mm/dd) & Time (UTC) Start	Date (yyyy/mm/dd) & Time (UTC) Finish	Wire length (m)	Wire angle (°)	Estimated depth of haul (m)	Flow meter ID. no.	Flow meter Revolutions	Volume filtered (m^3)	Mesh size (μm)	Remarks
1	C01	40 ° 0.01 ′ S	40 ° 0.01 ′ S	2010/12/25 23:02	2010/12/25 23:15	164	25	150	3616	2550	37.66	100	
		109 ° 59.68 ′ E	109 ° 59.54 ′ E						3231	2633	33.18	335	
2	C02	44 ° 59.84 ′ S	44 ° 59.78 ′ S	2010/12/26 22:02	2010/12/26 22:15	153	12	150	3616	2322	34.29	100	
		110 ° 0.10 ′ E	110 ° 0.13 ′ E						3231	2640	33.27	335	
3	C03	49 ° 59.95 ′ S	50 ° 0.09 ′ S	2010/12/28 05:13	2010/12/28 05:28	166	25	150	3616	3200	47.26	100	
		110 ° 0.33 ′ E	110 ° 0.31 ′ E						3231	3739	47.12	335	
4	C04	55 ° 0.32 ′ S	55 ° 0.35 ′ S	2010/12/29 07:25	2010/12/29 07:34	177	32	150	3616	2151	31.76	100	
		109 ° 59.89 ′ E	109 ° 59.88 ′ E						3231	2645	33.33	335	
5	C06	60 ° 0.00 ′ S	60 ° 0.01 ′ S	2010/12/31 13:19	2010/12/31 13:29	151	7	150	3616	1535	22.67	100	
		110 ° 0.04 ′ E	110 ° 0.04 ′ E						3231	2283	28.77	335	
6	D05	65 ° 59.98 ′ S	65 ° 59.99 ′ S	2011/01/09 12:40	2011/01/09 12:49	151	8	150	3616	1592	23.51	100	
		140 ° 28.79 ′ E	140 ° 28.67 ′ E						3231	1126	14.19	335	
7	D06	65 ° 30.13 ′ S	65 ° 24.65 ′ S	2011/01/09 17:55	2011/01/08 18:05	151	5	150	3616	1619	23.91	100	
		139 ° 59.96 ′ E	139 ° 37.90 ′ E						3231	2009	25.32	335	
8	D07	64 ° 59.89 ′ S	64 ° 59.84 ′ S	2011/01/10 21:01	2011/01/10 21:14	150	4	150	3616	2510	37.07	100	Strong wind caused flowmeter to rotate when out of water.
		140 ° 0.17 ′ E	140 ° 0.20 ′ E						3231	3578	45.09	335	
9	D07	64 ° 59.86 ′ S	64 ° 59.87 ′ S	2011/01/10 22:23	2011/01/10 22:39	154	13	150	3616	2231	32.95	100	Strong wind caused flowmeter to rotate when out of water.
		140 ° 0.35 ′ E	140 ° 0.44 ′ E						3231	4186	52.75	335	
10	D08	64 ° 0.03 ′ S	64 ° 0.05 ′ S	2011/01/11 05:54	2011/01/11 06:03	151	5	150	3616	1928	28.47	100	
		140 ° 0.13 ′ E	140 ° 0.24 ′ E						3231	2403	30.28	335	

Ship mean time = UTC + 8 h for C01-C06 and UTC + 10 h for D05-D15.

Table 3. Continued. (2 of 2)

No.	Stn.	Position		Date (yyyy/mm/dd) & Time (UTC)		Wire length (m)	Wire angle (°)	Estimated depth of haul (m)	Flow meter		Volume filtered (m^3)	Mesh size (μm)	Remarks
		Start	Finish	Start	Finish				ID. no.	Revolutions			
11	D09	63 ° 15.07 ′ S	63 ° 15.12 ′ S	2011/01/12 23:10	2011/01/12 23:22	158	18	150	3616	2108	31.13	100	
		140 ° 0.01 ′ E	139 ° 59.93 ′ E						3231	2284	28.78	335	
12	D10	62 ° 29.94 ′ S	62 ° 29.94 ′ S	2011/01/13 09:32	2011/01/13 09:46	151	6	150	3616	2051	30.29	100	
		139 ° 59.93 ′ E	139 ° 59.88 ′ E						3231	2880	36.30	335	
13	D10	62 ° 29.96 ′ S	62 ° 30.00 ′ S	2011/01/13 10:05	2011/01/13 10:17	152	9	150	3616	2560	37.80	100	
		139 ° 59.89 ′ E	139 ° 59.92 ′ E						3231	2710	34.15	335	
14	D11	61 ° 19.97 ′ S	61 ° 19.97 ′ S	2011/01/14 18:04	2011/01/14 18:13	150	3	150	3616	1641	24.23	100	
		140 ° 0.07 ′ E	140 ° 0.08 ′ E						3231	1936	24.40	335	
15	D12	59 ° 59.86 ′ S	59 ° 59.82 ′ S	2011/01/15 05:15	2011/01/15 05:24	160	20	150	3616	1811	26.74	100	
		140 ° 0.37 ′ E	140 ° 0.58 ′ E						3231	2031	25.60	335	
16	D12	59 ° 59.96 ′ S	59 ° 59.98 ′ S	2011/01/15 06:30	2011/01/15 06:38	150	1	150	3294	1770	25.87	100	
		140 ° 1.61 ′ E	140 ° 1.64 ′ E						3296	1753	25.21	335	
17	D13	58 ° 59.98 ′ S	58 ° 59.98 ′ S	2011/01/15 23:02	2011/01/15 23:11	150	2	150	3616	1449	21.40	100	
		140 ° 0.19 ′ E	140 ° 0.27 ′ E						3231	1841	23.20	335	
18	D14	54 ° 59.94 ′ S	54 ° 59.92 ′ S	2011/01/17 00:25	2011/01/17 00:37	158	18	150	3616	-	-	100	Flow meter broken.
		139 ° 59.47 ′ E	139 ° 59.53 ′ E						3231	3080	38.82	335	
19	D14	54 ° 59.85 ′ S	54 ° 59.84 ′ S	2011/01/17 02:10	2011/01/17 02:21	155	15	150	3294	1760	25.73	100	
		139 ° 59.80 ′ E	139 ° 59.78 ′ E						3296	1975	28.40	335	
20	D15	49 ° 59.81 ′ S	49 ° 59.72 ′ S	2011/01/18 08:40	2011/01/18 08:50	154	13	150	3309	2303	29.40	100	
		143 ° 40.00 ′ E	143 ° 40.04 ′ E						3231	2115	26.65	335	

Ship mean time = UTC + 8 h for C01-C06 and UTC + 10 h for D05-D15.