Supplementary Figures

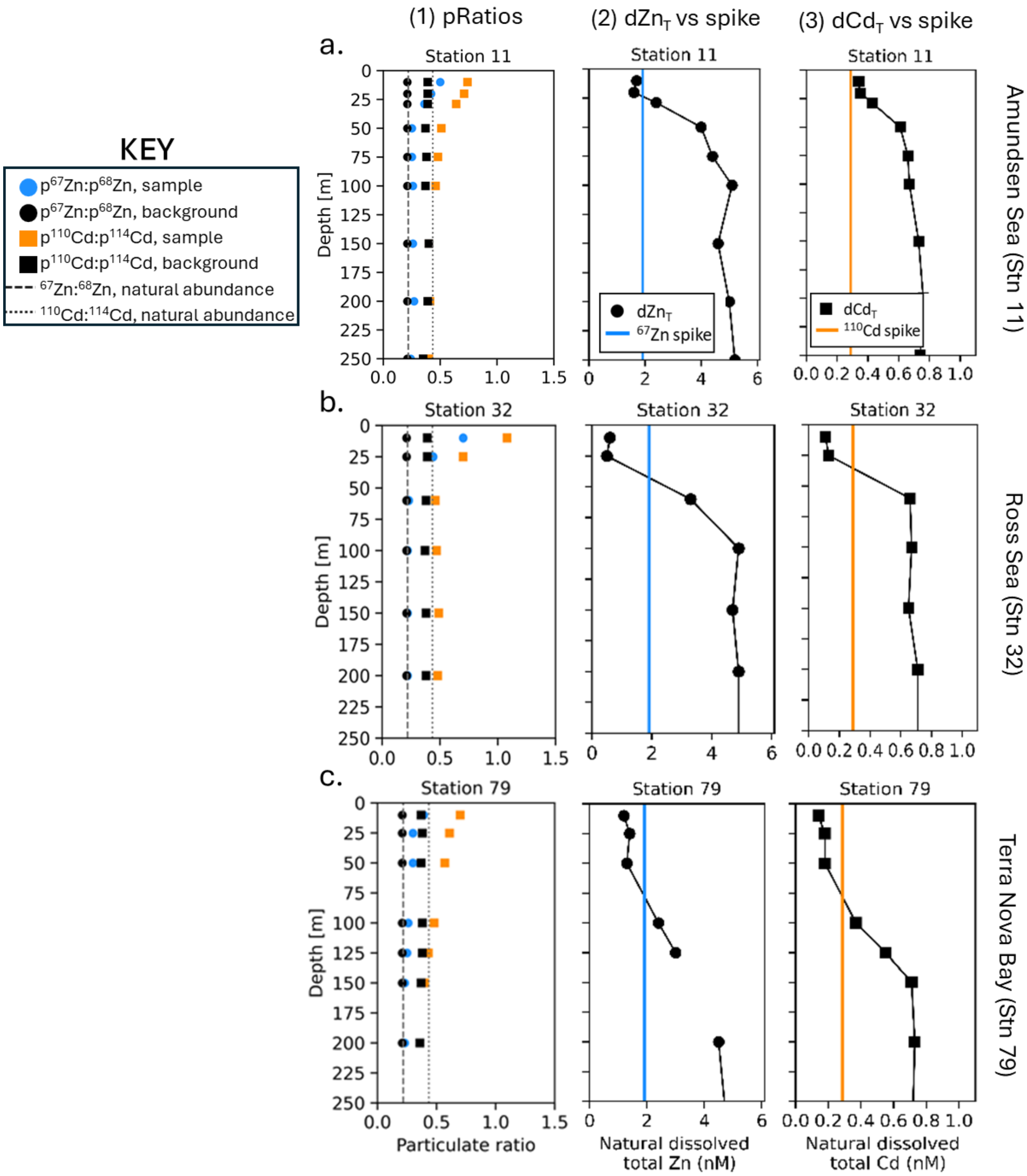

Figure S1. (1) Particulate ^{67}Zn:^{68}Zn and ^{110}Cd:^{114}Cd ratios measured in the ≥3 μm fraction showing deviations from natural abundance ratios, (2) natural total dissolved Zn (dZn_T) compared to the concentration of ^{67}Zn spike added, and (3) natural total dissolved Cd (dCd_T) compared to the concentration of ^{110}Cd spike at a representative station from each group (a., Amundsen Sea, b. Ross Sea, c., Terra Nova Bay (TNB)). Deviation of surface sample ratios from natural abundance represents enrichment of the spiked tracer isotopes ^{67}Zn and ^{110}Cd in the particulate fraction, indicative of uptake from the dissolved fraction. The background particulate ^{67}Zn:^{68}Zn was measured from the ^{110}Cd-spiked bottle. The background particulate ^{110}Cd:^{114}Cd was measured from the ^{67}Zn spiked bottle. Stn, station.

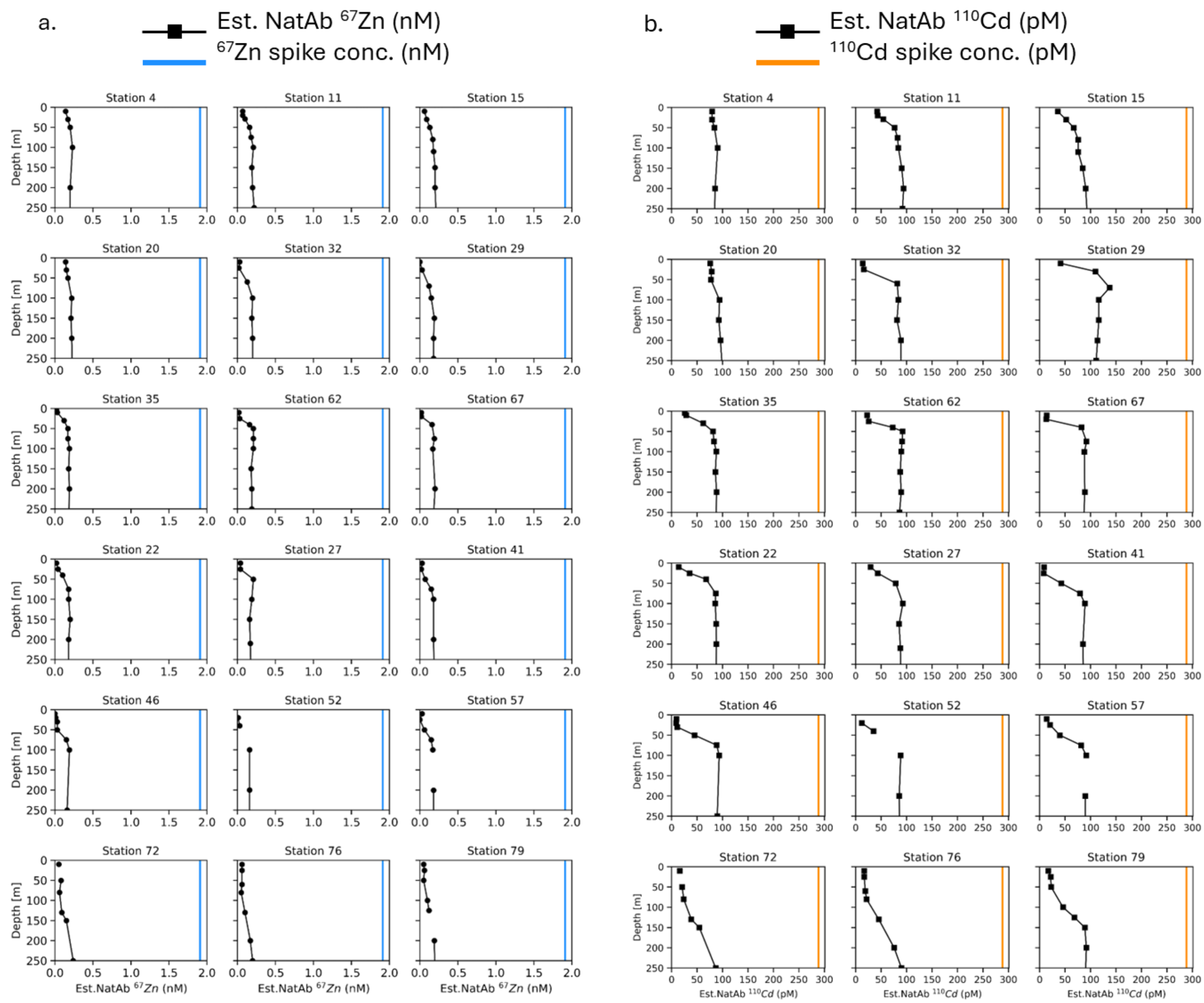

Figure S2. (a) The estimated natural abundance of ^{67}Zn and (b) the estimated natural abundance of ^{110}Cd in the upper 250m at each station calculated by multiplying total dissolved concentrations of Zn and Cd at each depth by the natural abundance of ^{67}Zn and ^{110}Cd (0.0410 and 0.1249, respectively; see Methods). Colored vertical lines denote the spiked concentration of ^{67}Zn (blue, 1.9 nM) and ^{110}Cd (orange, 288 pM). At each station, spikes were greater than the natural dissolved ^{67}Zn and ^{110}Cd at every depth.

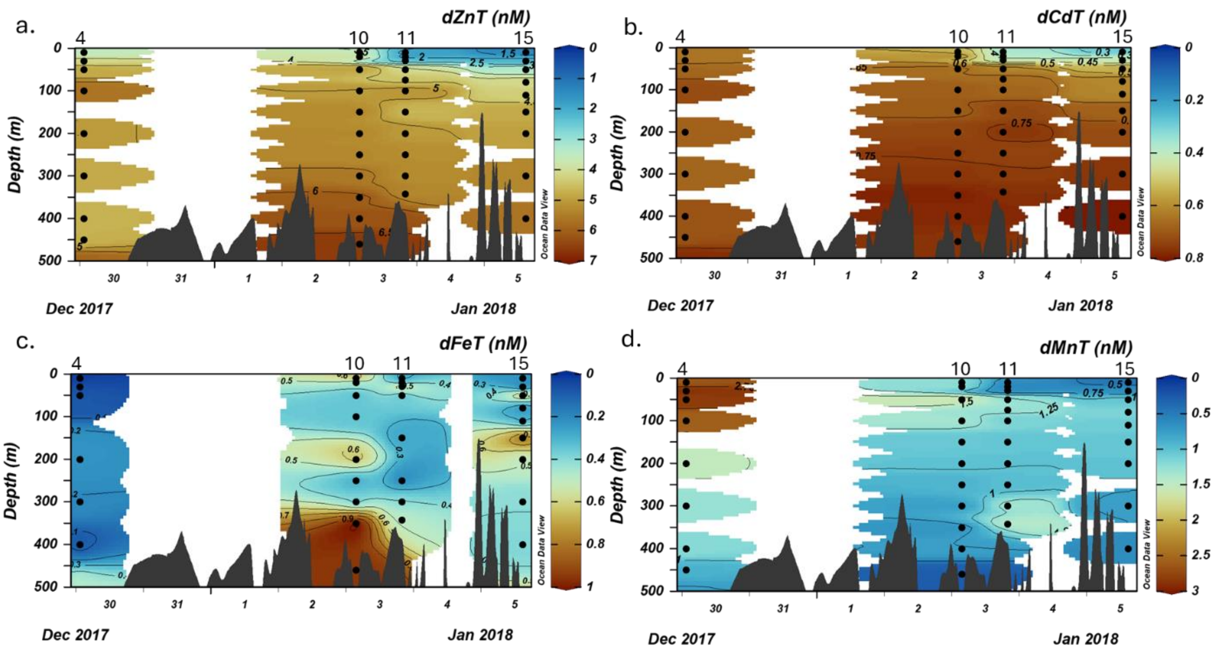

Figure S3. Total dissolved metal concentrations of (a) zinc, (b) cadmium, (c) iron, and (d) manganese measured in the upper 500 m in the Amundsen Sea represented in color scale.

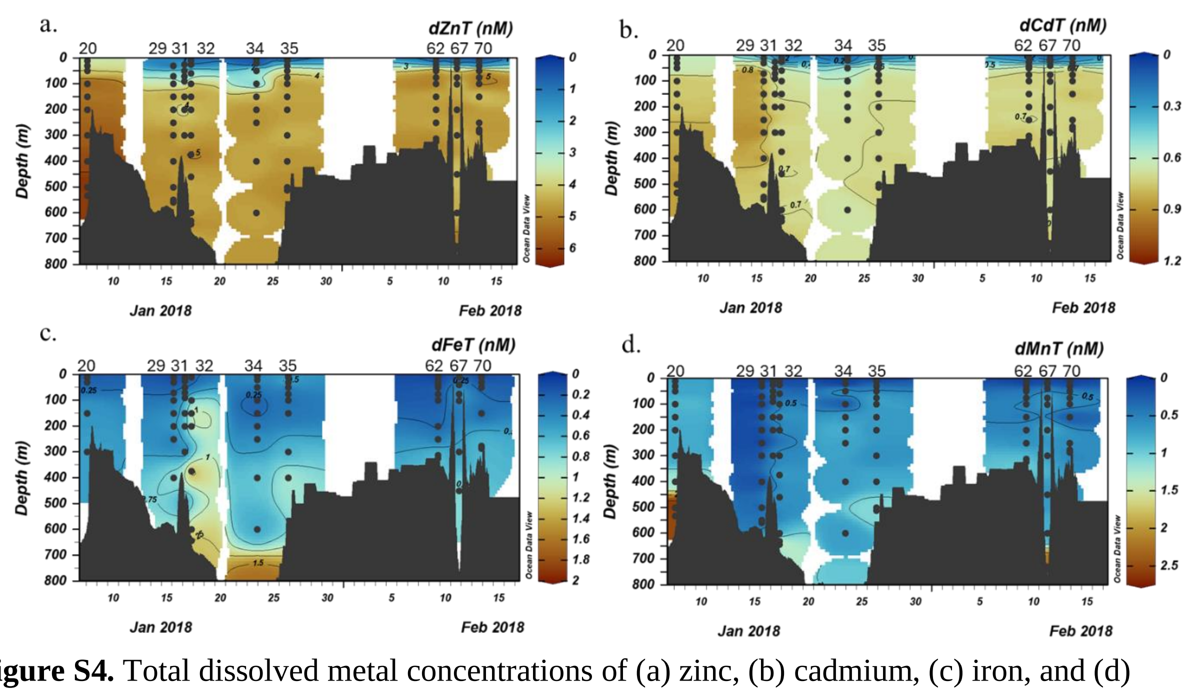

Figure S4. Total dissolved metal concentrations of (a) zinc, (b) cadmium, (c) iron, and (d) manganese measured in the upper 800 m in the Ross Sea represented in color scale. Data is plotted over time.

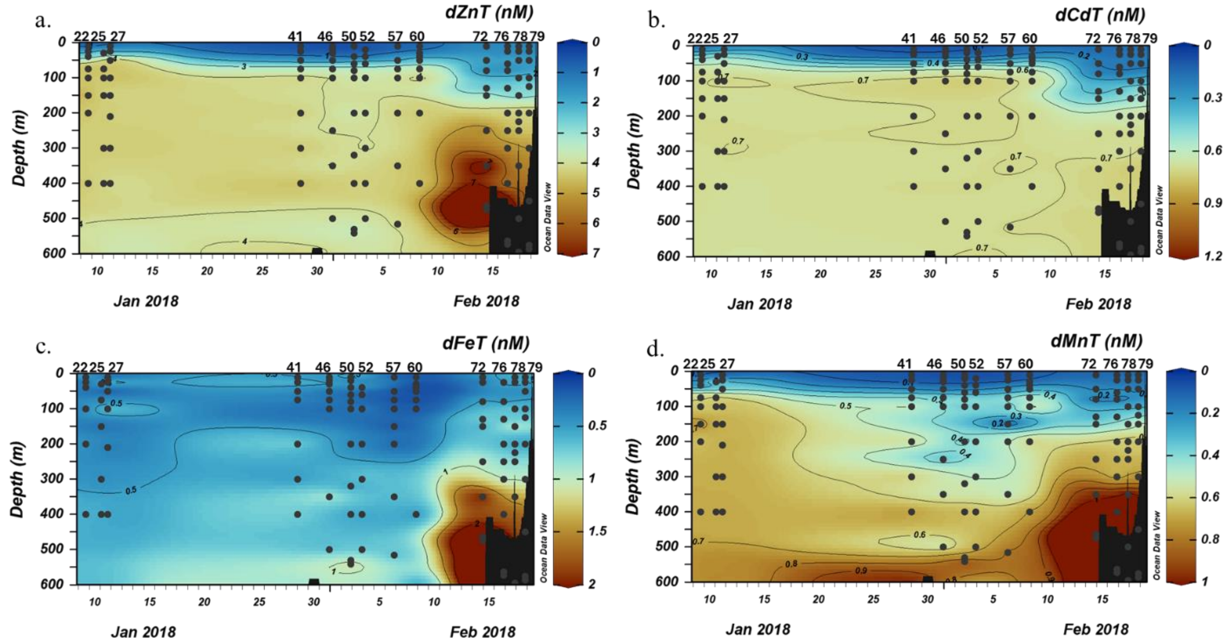

Figure S5. Total dissolved metal concentrations of (a) zinc, (b) cadmium, (c) iron, and (d) manganese measured in the upper 600 m in Terra Nova Bay represented in color scale. Note that samples collected at >500 m exist for stations 76, 78 and 79 but are obscured, demonstrating the limitations of gridded bathymetry file ETOPO_2min in representing bathymetry accurately at these coastal stations.

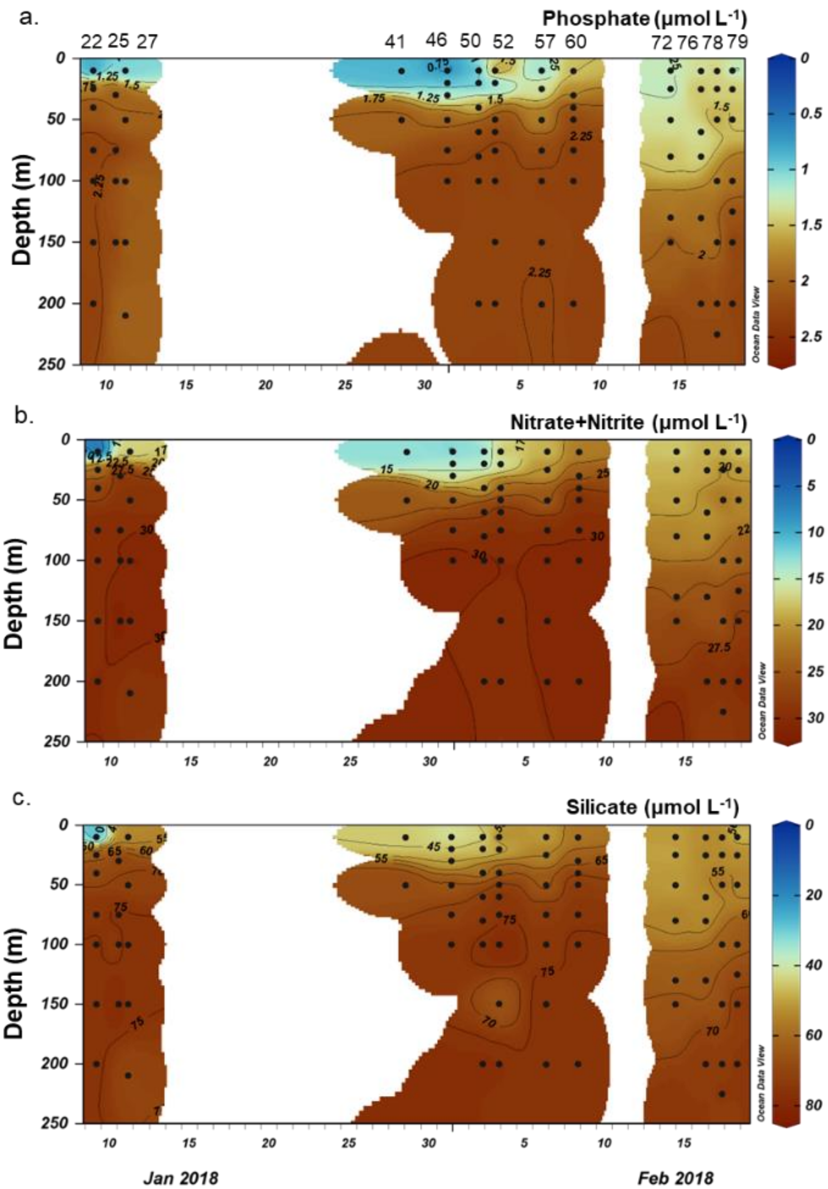

Figure S6. **Macronutrients measured within Terra Nova Bay.** (a) phosphate, (b), sum of nitrate and nitrite, and (c) silicate in the upper 250m measured at all 13 Terra Nova Bay stations represented in color scale. Station numbers are given at the top of (a) and (I). Station data is presented in order of sampling date, from the earliest (station 22, early January) to the latest (station 79, late February).

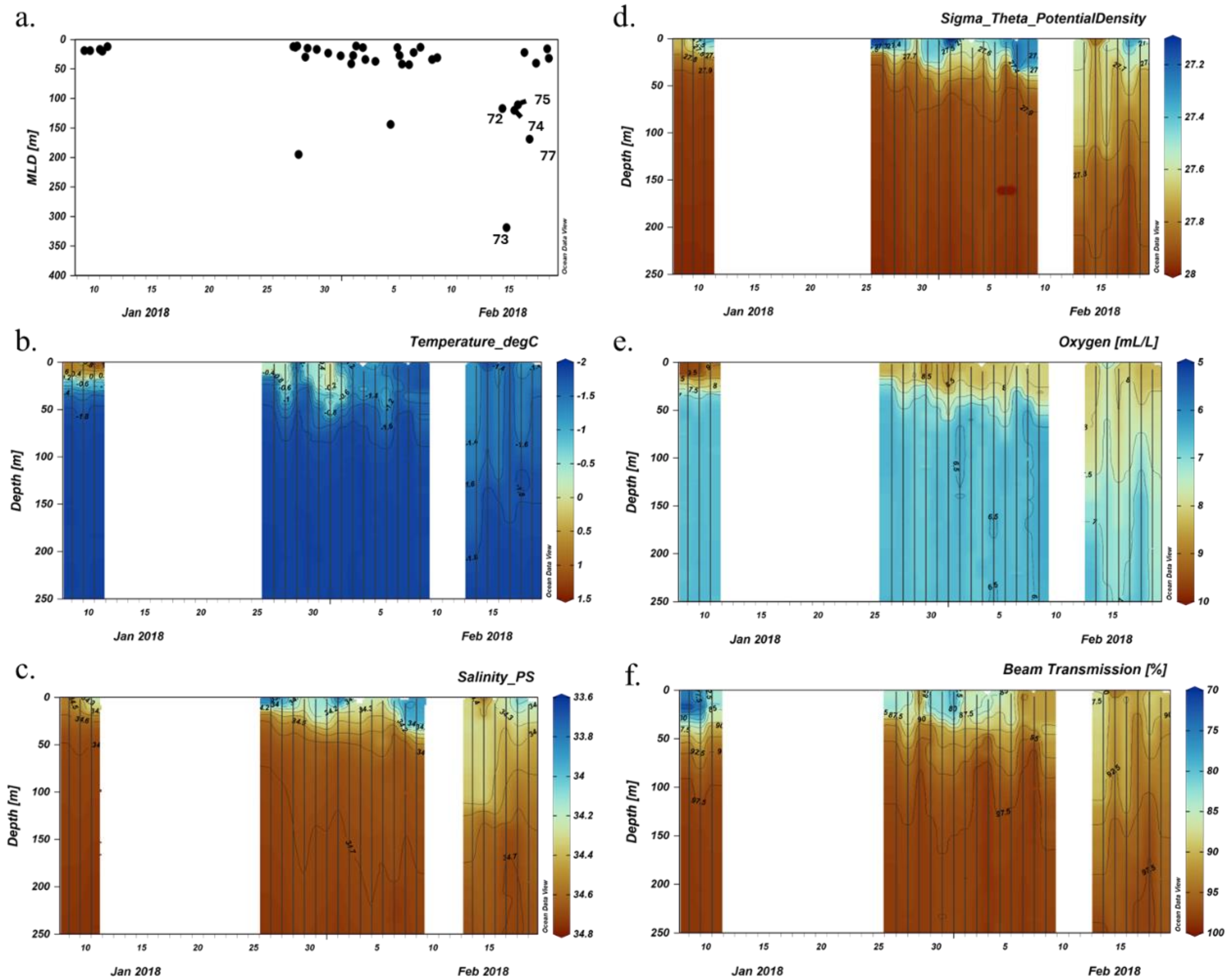

Figure S7. Evidence for deeper water column mixing at late Terra Nova Bay stations. (**a**) Mixed layer depths (MLDs) measured at Terra Nova Bay (TNB) stations. A group of late stations (station 72, 73, 74, 75, and 77) had MLDs < 100 m. The depth of the mixed layer was determined as the first depth at which the difference between the potential density (σ_θ) and reference density ($\sigma_{ref,}$ the potential density at 10m) was greater than or equal to 0.125 kg m^{-3} (see Methods). (**b**) Temperature, (**c**) salinity, (**d**) potential density (σ_θ), (**e**) oxygen, and (**f**) beam transmission measured at TNB stations within the upper 250m in color scale.

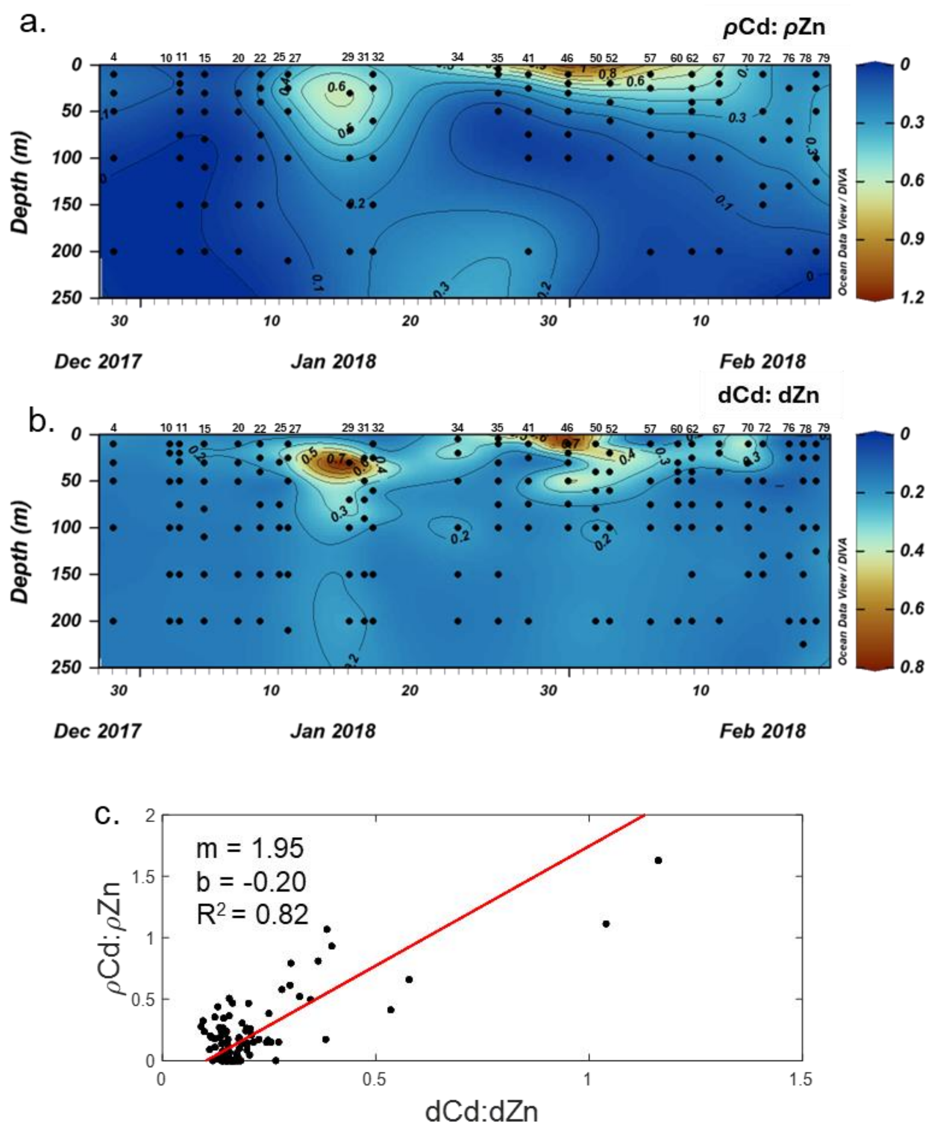

Figure S8. (a) Cd:Zn uptake ratios (ρCd:ρZn) and (b) total dissolved Cd:Zn ratios (dCd:dZn) for all stations during the CICLOPS expedition measured in the upper 250 m represented in color scale and over time of sampling. (c) Two-way linear regression showing the positive relationship between dCd:dZn and ρCd:ρZn inclusive of all stations and depth (n=111, R^2 = 0.82).

Supplementary Tables

Table S1. Station metadata for the CICLOPS cruise.

Station	Latitude (°N)	Longitude (°E)	Sampling Date (yyyy-mm-dd hh:mm)
4	-72.751	-116.001	2017-12-30 01:23
10	-73.054	-129.988	2018-01-03 03:39
11	-74.047	-133.764	2018-01-03 19:58
15	-75.864	-151.918	2018-01-05 14:51
20	-76.714	179.819	2018-01-08 02:00
22	-75.013	165.358	2018-01-09 15:56
25	-75.293	163.914	2018-01-11 01:26
27	-74.987	165.890	2018-01-11 16:05
29	-76.001	172.997	2018-01-16 03:00
31	-77.295	175.390	2018-01-17 04:39
32	-76.750	172.000	2018-01-17 19:19
34	-77.147	168.503	2018-01-23 22:59
35	-76.231	168.769	2018-01-26 20:17
41	-74.833	165.002	2018-01-29 00:41
46	-74.742	165.287	2018-01-31 21:32
50	-74.741	165.488	2018-02-02 21:17
52	-75.000	164.005	2018-02-03 21:43
57	-74.879	164.482	2018-02-06 20:12
60	-74.959	164.739	2018-02-08 20:06
62	-74.999	169.491	2018-02-09 19:27
67	-76.454	167.919	2018-02-11 19:19
70	-74.744	170.374	2018-02-13 21:25
72	-74.800	164.395	2018-02-14 22:28
76	-74.799	164.597	2018-02-16 20:15
78	-74.696	164.796	2018-02-17 20:34
79	-74.757	164.356	2018-02-18 19:29

Table S2. Reference seawater comparisons using the 2009 GEOTRACES coastal surface seawater (GSC) standard (https://www.geotraces.org/standards-and-reference-materials/) ± the standard deviation of technical replicates.

Metal	This study (n = 8) (nM)	GEOTRACES GSC consensus (nM)
Fe	1.58 ± 0.23	1.54 ± 0.12 (n=13)
Zn	1.39 ± 0.23	1.43 ± 0.10 (n=12)
Cd	0.36 ± 0.01	0.36 ± 0.02 (n=9)
Cu	1.30 ± 0.05	1.01 ± 0.15 (n=11)
Ni	4.21 ± 0.07	4.39 ± 0.21 (n=7)
Mn	2.06 ± 0.37	2.18 ± 0.08 (n=8)

Table S3. Natural abundances of Cd and Zn stable isotopes and ratios measured in this study based on IUPAC values. When added to filled incubation bottles, the added concentrations were 288 pM ^{110}Cd, 4.51 pM ^{111}Cd, and 1.69 pM ^{114}Cd for Cd spiked bottles and 1.91 nM ^{67}Zn, 0.045 nM ^{66}Zn, and 0.047 nM ^{68}Zn for Zn spiked bottles.

Isotope	Natural abundance (atom %)	Isotope ratio	Natural ratio	Spike ratio
^{106}Cd	1.25	$^{114}Cd/^{110}Cd$	2.30	0.01
^{108}Cd	0.89	$^{114}Cd/^{111}Cd$	2.24	0.37
^{110}Cd	12.49	$^{111}Cd/^{110}Cd$	1.02	0.02
^{111}Cd	12.80			
^{112}Cd	24.13			
^{113}Cd	12.22			
^{114}Cd	28.73			
^{116}Cd	7.49			
^{64}Zn	48.63	$^{68}Zn/^{66}Zn$	0.67	1.05
^{66}Zn	27.90	$^{68}Zn/^{67}Zn$	4.57	0.02
^{67}Zn	4.10	$^{67}Zn/^{66}Zn$	0.15	42.71
^{68}Zn	18.75			
^{70}Zn	0.62			

Table S4. dZn:Si, dZn:P, and dCd:P stoichiometric regressions showing relationships in both the surface and deep ocean of the Amundsen Sea, Ross Sea and Terra Nova Bay, as shown in Fig. 13. Although linear regression slopes with a $R^2 < 0.50$ should not be considered meaningful stoichiometric values, values are presented to demonstrate the range of slopes observed among station groups. Ross Sea and Terra Nova Bay dZn:P and dCd:dP data is reproduced from Chmiel et al. 2023 (Table 3) for ease of comparison with dZn:dSi data.

Region	dZn:dSi (mmol:mol)				$dZn:dPO_4^{3-}$ (mmol:mol)				$dCd:dPO_4^{3-}$ (mmol:mol)			
	Depths (m)	n	Slope	R^2	Depths (m)	n	Slope	R^2	Depths (m)	n	Slope	R^2
Amundsen Sea												
Surface	0-30	9	0.23 ± 0.05	0.72	0-30	9	4.6 ± 0.9	0.72	0-25	6	0.47 ± 0.08	0.86
Deep	> 30	35	0.08 ± 0.01	0.70	> 30	35	11 ± 2.5	0.37	> 25	38	0.59 ± 0.06	0.72
Ross Sea												
Surface	0-30	12	0.004 ± 0.006	0.04	0-30	11	0.18	0.07	0-25	11	0.19 ± 0.05	0.56
Deep	> 30	77	0.15 ± 0.02	0.35	> 30	77	9.8 ± 1.0	0.54	> 25	79	0.69 ± 0.13	0.26
Terra Nova Bay												
Surface	0-30	18	0.03 ± 0.01	0.30	0-50	24	1.9 ± 0.3	0.65	0-30	21	0.15 ± 0.03	0.59
Deep	> 30	102	0.15 ± 0.02	0.35	>50	95	13 ± 2.0	0.30	> 30	104	0.64 ± 0.03	0.80