2019

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This is a pre-publication author manuscript of the final, published article.

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TROPHIC POSITION AND FORAGING ECOLOGY OF ROSS, WEDDELL, AND CRABEATER SEALS REVEALED BY COMPOUND-SPECIFIC ISOTOPE ANALYSIS

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ABSTRACT

Ross seals (*Ommatophoca rossii*) are one of the least studied marine mammals, with little known about their foraging ecology. Research to date using bulk stable isotope analysis suggests that Ross seals have a trophic position intermediate between that of the Weddell (*Leptonychotes weddellii*) and crabeater (*Lobodon carcinophaga*) seals. However, consumer bulk isotope values not only reflect trophic dynamics, but also variations in baseline isotope values, which can be substantial. Here, we use a compound specific isotope analysis of amino acids (CSI-AA) to separate isotopic effects of a shifting baseline versus trophic structure on the foraging ecology of these ecologically important, but poorly understood Antarctic pinnipeds. We find that all three seals use different foraging habitats; Ross seals forage in a pelagic food web distinct from that of crabeater and Weddell seals. Crabeater and Weddell seals are foraging within similar food webs closer to shore. However, isotopic evidence suggests that crabeater seals are likely following sea ice, while Weddell seals target productive areas of the continental shelf of Western Antarctica. In addition, our CSI-AA data indicate that Ross seals have a high trophic position equivalent to that of Weddell seals, contrary to prior conclusions from nitrogen isotope results on bulk tissues. CSI-AA indicates that crabeater seals are at a trophic position lower than that of Ross and Weddell seals, consistent with a krill-dominated diet. Our results redefine the view of the Ross seal trophic dynamics and foraging ecology, while also highlighting the importance of quantifying baseline isotope variations in foraging studies.

KEYWORDS

Ross seal, Weddell seal, Crabeater seal, Compound specific isotopes, amino acids, Antarctica, Foraging ecology, Trophic dynamics

INTRODUCTION

The Ross seal (*Ommatophoca rossii*) is one of the least studied marine mammals (Reeves et al. 2008, Bengtson et al. 2011). The total population estimate for this species is around 200,000, considerably less than the estimates for other Antarctic true seals, which are 10 to 15 million individuals for crabeater seals (*Lobodon carcinophaga*) and approximately one million individuals for Weddell seals (*Leptonychotes weddellii*) (Laws 1977, Reeves et al. 2008, Bengtson et al. 2011). With individuals likely spending most of their time at sea and in habitats that are logistically challenging to access, the Ross seal is not commonly observed. Several keys aspects of their biology remain poorly understood, including their preferred prey, foraging habitat, and behavior. In contrast, many studies have been conducted on crabeater and Weddell seals and, thus, more information is available on their ecology.

Conventional techniques for studying an animal’s diet, such as scat and stomach content analysis, have significant limitations when applied to Antarctic pinnipeds. These methods capture only a snapshot of a predator’s diet, perhaps one to two days (Dellinger and Trillmich 1988, Burns et al. 1998). In addition, since soft tissues are more completely digested than hard tissues, resulting in biases towards prey with indigestible hard parts (Burns et al. 1998, Staniland

2002, Arim and Naya 2003, Yonezaki et al. 2003). Given these drawbacks, recent research on Antarctic seal ecology has often used bulk isotope values.

Measurements of bulk tissue carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope values (i.e., the weighted average of all components within in a tissue) have been used to indicate a predator's foraging region and trophic position (Boecklen et al. 2011). This approach has the advantage of providing an integrated view of an animal's diet over longer time scales (weeks to years depending on the tissue) than the traditional procedures (Vander Zanden et al. 2015). Carbon isotope values show little ^{13}C-enrichment with trophic transfer. Thus, consumer $\delta^{13}C$ values are often thought to closely reflect values at the base of marine food webs, making them useful for studying the foraging areas of a predator. Spatial changes in the $\delta^{13}C$ of phytoplankton (often referred to as "baseline" $\delta^{13}C$ values) reflect variations in dissolved inorganic carbon $\delta^{13}C$ values, dissolved CO_2 concentrations, temperature, cell size and geometry, internal biological parameters (e.g., growth rate), and CO_2 drawdown (reviewed in McMahon et al. 2013). Provided the primary processes driving variation are known, bulk $\delta^{13}C$ values of an animal can give valuable information on its foraging habitat. The Southern Ocean is known to have considerable spatial variation in baseline $\delta^{13}C$ ($\delta^{13}C_{baseline}$) values (Rau et al. 1982, Quillfeldt et al. 2010, Brault et al. 2018). Several studies have observed decreasing $\delta^{13}C$ values with increasing latitude, with offsets between about 55 °S and 79 °S of approximately 3 ‰, largely reflecting variations in sea surface temperature (Rau et al. 1982, Graham et al. 2010, Quillfeldt et al. 2010, Magozzi et al. 2017, Brault et al. 2018).

In contrast to carbon isotopes, trophic transfers considerably affect an animal's $\delta^{15}N$ values. Since a consumer's tissues become enriched in ^{15}N by ~ 2-5 ‰ with each trophic step (e.g., primary producers to herbivores to carnivores) due to the preferential loss of ^{14}N during amino acid metabolism (Minagawa and Wada, 1984), $\delta^{15}N$ values are often used to indicate an animal's trophic position. However, variations in baseline $\delta^{15}N$ values ($\delta^{15}N_{baseline}$) also occur and are passed on, with additional change due to trophic transfers, to upper trophic level predators (McMahon et al. 2013). Nutrient source (e.g., nitrate, ammonium, or N_2 fixation), microbial transformations (e.g., denitrification), and extent of nitrogen pool drawdown in a given environment can all strongly impact primary producer $\delta^{15}N$ values (reviewed in McMahon et al. 2013). If variations in these factors are well understood, then the bulk $\delta^{15}N$ values of a consumer provide insights into its foraging region and trophic position (Post 2002). As with carbon, substantial spatial variations in $\delta^{15}N_{baseline}$ values occur in the Southern Ocean (DiFiore et al. 2006, DiFiore et al. 2009, Somes et al. 2010, Jaeger et al. 2010, Brault et al. 2018). Low $\delta^{15}N_{baseline}$ values have been found for much of the Southern Ocean except in areas near the continent with extensive coastal open water polynya "hot spots" (Arrigo and Van Dijken 2003), where the baseline is up to ~ 3 ‰ higher than in pelagic regions (DiFiore et al. 2006, DiFiore et al. 2009, Brault et al. 2018). This pattern likely derives from changes in the extent of nutrient drawdown due to enhanced primary productivity, the main process influencing $\delta^{15}N_{baseline}$ in the Southern Ocean since it is a high nutrient-low chlorophyll (HNLC) region (Brault et al. 2018).

Although much remains unknown, especially regarding the behaviors and movements of the Ross seal, recent studies have furthered our understanding of Antarctic seal ecology. Isotopic measurements, coupled with traditional ecological methods, have indicated that Weddell seals forage near the top of the Antarctic food web, consuming diverse diets of fish, cephalopods, and invertebrates (Burns et al. 1998, Plötz 2001, Lake et al. 2003, Goetz et al. 2017). Researchers have debated the contribution of the upper trophic level prey species, in particular the Antarctic toothfish (*Dissotichus mawsoni*), to Weddell seal diets with some studies suggesting a substantial contribution of *D. mawsoni* (Ponganis and Stockard 2007, Ainley and Siniff 2009, Goetz et al. 2017). Hard parts of *D. mawsoni* are not consumed and, thus, not detected via scat and stomach content analyses, which have been used for much of the prior research on Weddell seal foraging ecology. Recently, Goetz et al. (2017) assessed Weddell seal foraging ecology with bulk $\delta^{13}C$ and $\delta^{15}N$ measurements of vibrissae and red blood cells from Ross Sea specimens. They reported considerable individual variability in diet and that Antarctic silverfish (*Pleuragamma antarcticum*) and cod icefishes (*Trematomus* species) were the primary prey consumed by Weddell seals. Overall, *D. mawsoni* contribute less than 2 % to the Weddell seal diet. However, *D. mawsoni* may become increasingly important with age and at certain times in the life cycle, such as during reproduction and molting, since this fish has a high fat content and energy density (Goetz et al. 2017). Additionally, Goetz et al. (2017) noted temporal diet shifts – likely in response to sea ice dynamics affecting prey abundances.

Crabeater seals occupy a much lower trophic level than Weddell seals, with diets dominated by Antarctic krill (*Euphausiia superba*), as evidenced by the results of both scat and stomach content analyses as well as bulk isotopic analysis (Laws 1977, Rau et al. 1992, Burns et al. 2004, Zhao et al. 2004, Burns et al. 2008, Aubail et al. 2011). Recent work by Hückstädt et al. (2012a) has revealed temporal variability in crabeater seal diet composition via bulk $\delta^{13}C$ and $\delta^{15}N$ measurements of vibrissae. The *E. superba* contribution ranged from 81 % to 95 %, likely in response to climate shifts affecting krill abundances. The authors also reported significant variation in $\delta^{13}C$ values with body mass (increasing $\delta^{13}C$ values with increasing body mass) and season (highest $\delta^{13}C$ values in the austral winter) that they suggested might result from changes in $\delta^{13}C_{baseline}$ values associated with temporal and/or spatial shifts between pelagic phytoplankton and sea ice phytoplankton communities (Hückstädt et al. 2012a).

Only a small number of studies have examined Ross seal foraging ecology. Dive records suggest that these animals typically dive from 100 to 300 m (maximum depth of 792 m) in search of mesopelagic squid and fish (Bengtson and Stewart 1997, Blix and Nordøy 2007). Analysis of Ross seal stomach contents showed that Antarctic silverfish (*Pleurogramma antarcticum*) and glacial squid (*Psychroteuthis glacialis*) were found in varying proportions (Skinner and Klages, 1994). Arcalís-Planas et al. (2015) suggested little use of sea ice by Ross seals, based on telemetry and remote sensing data. Seals tracked in this study generally remained in pelagic regions except for haul outs on ice to molt (from December to January) and breed (from late October to mid-November). During their extended pelagic period (February to mid-October), Ross seals remained an average ~ 840 km (range 587 to 1,282 km) seaward from the ice edge (Arcalís-Planas et al. 2015). Bulk $\delta^{13}C$ and $\delta^{15}N$ isotope measurements place the Ross seal a trophic level intermediate between Weddell seals and crabeater seals (Rau et al. 1992, Zhao et al. 2004, Aubail et al. 2011). Thus, bulk isotope results to date suggest that Ross seals consume mostly squid and fish, but with a contribution from lower trophic level prey like *E. superba* (Rau et al. 1992, Zhao et al. 2004, Aubail et al. 2011).

While these bulk isotope approaches have shed new light on the foraging ecology of these Antarctic pinnipeds, it is critical to remember that the Southern Ocean exhibits strong spatial gradients in both $\delta^{13}C_{baseline}$ and $\delta^{15}N_{baseline}$ values (DiFiore et al. 2006, DiFiore et al. 2009, Jaeger et al. 2010, Somes et al. 2010, Brault et al. 2018), suggesting that we likely need to explicitly tease apart the relative influences of trophic dynamics and baseline variation on seal isotope values. For instance, Ross seals may spend more time in pelagic regions than other true Antarctic seals (Arcalís-Planas et al. 2015), and thus forage in areas with lower $\delta^{15}N_{baseline}$ values than the nearshore regions of Weddell and crabeater seals (DiFiore et al. 2006, DiFiore et al.

2009, Brault et al. 2018). If so, not accounting for spatial variation in the $\delta^{15}N_{baseline}$ would result in Ross seals being assigned a lower trophic position than species foraging nearer the continent.

Compound-specific isotopic analysis of amino acids (CSI-AA) has opened new doors to studying the foraging ecology and trophic dynamics of marine predators (e.g., Graham et al. 2010). Since only certain amino acids become enriched in ^{15}N with increasing trophic level ("trophic" amino acids), while others ("source" amino acids) do not, impacts of $\delta^{15}N_{baseline}$ variation and trophic position on consumer $\delta^{15}N$ values can be disentangled using this technique (Ohkouchi et al. 2017). Glutamic acid/glutamine (Glu) and phenylalanine (Phe) are widely considered the most representative trophic and source amino acids, respectively, with Phe $\delta^{15}N$ values typically used a proxy for baseline isotope values, and Phe and Glu $\delta^{15}N$ values ($\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glu}$, correspondingly) used together to estimate an organism's trophic position (TP) internally indexed to the baseline (Ohkouchi et al. 2017). Proline (Pro) has also been shown to be a reliable trophic amino acid, however, with less variability than Glu for trophic ^{15}N-enrichment factors between organisms (McMahon et al. 2015). As a consequence, Pro and Phe may represent a new CSI-AA combination that provides more ecologically realistic TP estimates for higher trophic level consumers (McMahon and McCarthy 2016).

Here, we report the first CSI-AA data for modern Ross, Weddell, and crabeater seals to refine our understanding of the trophic dynamics and foraging ecology of these important Antarctic predators. In particular, CSI-AA allows us to directly examine changes in baseline $\delta^{15}N$ values linked to these seals' diets, and so to gain information on their foraging regions in conjunction with their trophic dynamics. Comparison of amino acid isotope data across these three Antarctic seals will also further our understanding of present Antarctic food web structures, which will provide valuable ecosystem baselines in light of ongoing climate change (Atkinson et al. 2004, Ducklow et al. 2007, Ducklow et al. 2012, Montes-Hugo et al. 2009).

MATERIALS AND METHODS

Sample collection

Tissue samples from Ross (n = 15), Weddell (n = 38), and crabeater seals (n = 41) were collected along western Antarctica from the West Antarctic Peninsula (WAP) to the Ross Sea during multiple field seasons in the austral summers of 2008/09 and 2010/11 aboard the *RV Oden.* These animal captures were conducted in accordance with the regulations of the Swedish Polar Research Secretariat (Registration No. 2010-112). All other samples were obtained from animal captures conducted under National Marine Fisheries Service permit No. 87-1851-00. In most cases, body mass, age class (juvenile, subadult, and adult), gender, and location were recorded for each sampled seal (Table S1). Additionally, the Institutional Animal Care and Use Committee (IACUC) at the University of Santa Cruz (UC Santa Cruz) approved all protocols for these samples.

Whole blood samples were obtained from most seals, and in some cases, clot (blood with serum removed), red blood cells (RBCs, whole blood exposed to an anticoagulant, heparin, before having plasma removed), and hair samples were also collected. The sampling protocols are described in Aubail et al. (2011) and Goetz et al. (2017). Whiskers were taken from crabeater seals during multiple cruises on the *RV Lawrence M. Gould* along the WAP, during fall 2001 (n = 7), winter 2001 (n = 7), fall 2002 (n = 15), winter 2002 (n = 14), and fall 2007 (n = 9). Plasma was also obtained from a few of the fall 2007 individuals (G105, G110, and G112) (Hückstädt et al. 2012a). In addition, serum or plasma was obtained from two Weddell seals during the fall

2007 sampling in this region, and whiskers were taken from two WAP Weddell seals in the austral summer of 2009/10. Whisker samples were also collected from Weddell seals during the summer 2009/10 (*n*=11), summer 2010/11 (*n*=10), summer 2011/12 (*n*=18) (Goetz et al. 2017). Hückstädt et al. (2012a) describe the procedure for sampling the whiskers, and Goetz et al. (2017) describe the protocol used for collecting seal blood.

Several blood samples were obtained from Weddell seals in the McMurdo Sound region, Ross Sea, Antarctica over multiple field seasons. Twelve whole blood samples were taken from juvenile Weddell seals near Inexpressible Island (74.9 °S, 163.7 °E) during the austral summer of 2010/11. Whole blood samples were taken from Weddell seals in the austral summer of 2010/11 (*n*=5) and austral spring of 2012 (*n*=5). RBCs were sampled in the austral summer of 2009/10 (*n*=5), austral summer of 2011/12 (*n*=5), and austral spring of 2012 (*n*=5). Whole blood, plasma, and serum were obtained from five Weddell seals sampled in the austral spring of 2015, and whole blood from an additional seven Weddell seals was also acquired during this time. Goetz et al. (2017) describe the sampling protocol for these Weddell seals.

Lastly, a few samples were obtained from crabeater seals in McMurdo Sound. Hair samples were taken from three recently deceased juvenile crabeater seals that were found on the seasonal pack ice around Cape Royds in the austral summer of 2009/10. Whole blood was sampled, using the protocol of Goetz et al. (2017), from a male adult crabeater seal found in Erebus Bay during the austral summer of 2010/11.

Sample preparation

After sample collection, all samples were kept frozen at -20 °C. Blood samples were freeze-dried with a Labconco Freeze Dry System (Lyph Lock 4.5) and homogenized manually prior to isotope analysis. Lipid extraction was not performed on the blood samples, as blood has a relatively low lipid content. A test set of blood samples with and without lipid extraction revealed no significant effect of lipid extraction on blood $\delta^{13}C$ values (Table S2), though lipid extraction did have an undesired impact on $\delta^{15}N$ values (Table S2).

Hair and whisker samples are known to have high enough lipid contents to affect $\delta^{13}C$ values so these samples were lipid extracted a la Hückstädt et al. (2012a). These samples were washed with Milli-Q water (Thermo Fisher Scientific, Inc.) and then rinsed three times in an ultrasonic bath with petroleum ether for 15 minutes.

Bulk stable isotope analysis

For all blood and hair samples, ~ 1 mg was weighed into tin cups (Costech, 3x5 mm) for bulk stable carbon and nitrogen isotope analysis. For hair, the follicle was removed since prior work has shown it to have a different biochemical and isotopic composition than the rest of the hair (Hückstädt et al. 2012b). This analysis was performed at the Stable Isotope Lab (SIL) of University of California - Santa Cruz (UCSC) on a Carlo Erba EA 1108 elemental analyzer coupled to a Thermo-Finnigan Delta^{Plus} XP isotope ratio mass spectrometer. The $\delta^{13}C$ values were referenced to the V-PDB standard, and $\delta^{15}N$ values were referenced to AIR. PUGel and Acetanilide standards were analyzed in each instrument session in order to correct for variations in mass across samples and instrument drift. Across 10 analytical sessions, the standard deviations were 0.1 ‰ (n = 139) for $\delta^{13}C$, 0.1 ‰ (n = 139) for $\delta^{15}N$, and 0.1 (n = 139) for C/N (atomic) for PUGel and 0.2 ‰ (n = 38) for $\delta^{13}C$, 0.2‰ (n = 38) for $\delta^{15}N$, and 0.4 (n = 38) for C/N (atomic) for Acetanilide.

Compound-specific isotope analysis

CSI-AA was performed at UCSC via gas chromatography-combustion-isotope ratio mass spectrometry (GC-C-IRMS). All samples were prepared for GC-C-IRMS analysis using the methods described in McCarthy et al. (2007) and McCarthy et al. (2013). In brief, samples were hydrolyzed (6 N HCl for 20 hr at 110 °C) and converted to trifluoro-acetylated isopropyl amino acid derivatives. Samples were stored at -20 °C in a 1:3 TFAA:DCM (dichloromethene) solution until analysis. Immediately before the analysis, the TFAA/DCM mixture was evaporated under N_2 and samples were diluted in ethyl acetate.

Amino acid $\delta^{15}N$ values were measured on a Thermo Trace GC coupled to a Thermo-Finnigan Delta^{Plus} XP isotope-ratio-monitoring mass spectrometer (oxidation furnace at 980 ºC and reduction furnace at 650 ºC) using an SGE Analytical Science BPX5 column (60 m by 0.32 mm with a 1 μm film thickness). The injector temperature was 250 ºC with a split He flow of 2 mL/min. The GC temperature program was: initial temp = 70 ºC hold for 1 min; ramp 1 = 10 ºC /min to 185 ºC, hold for 2 min; ramp 2 = 2 ºC/min to 200 ºC, hold for 10 min; ramp 3 = 30 ºC/min to 300 ºC, hold for 6 min. Directly measured amino acid $\delta^{15}N$ values were corrected based on bracketed external standards of amino acids with known isotopic composition, as described in McCarthy et al. (2013). The $\delta^{15}N$ values of 11 amino acids were quantified: alanine (Ala), glycine (Gly), threonine (Thr), serine (Ser), valine (Val), leucine (Leu), Pro, aspartic acid + asparagine (Asp), Glu, Phe, and lysine (Lys).

Data analysis

Most samples were whole blood. Since bulk isotope values can vary across different tissues, species-specific corrections were applied to account for isotopic offsets between different types of samples (see methods in *Supplementary Material* and resulting correction factors in Tables S3-S6). These corrections were applied to all bulk isotope data from tissues other than whole blood that had significant isotopic offsets from whole blood. An isotopic offset > 0.2 ‰ was considered significant, since the instrument error is ≤ 0.2 ‰.

All data analyses were performed in R statistical software (R Core Team, 2014). Tests of normality and equal variance were conducted to assure test assumptions were met. In a few cases, an assumption was violated and a data transformation was applied, as noted in *Results.* Bulk isotope values of the three different seal species were compared with a one-way analysis of variance (ANOVA) and post-hoc Bonferroni pairwise comparisons. Data were Box-Cox transformed (Box and Cox, 1964). A four-way ANOVA with post-hoc Bonferroni pairwise comparisons was used to test for significant effects of gender, sampling period, age class, and region (WAP, Amundsen Sea, and Ross Sea) on the bulk isotopic values of Ross, Weddell, and crabeater seals. Both Weddell and crabeater seal data were Box-Cox transformed. Linear regression analyses were used to test for significant relationships between bulk δ^{13}C and δ^{15}N values and body mass for each species.

A one-way ANOVA with post-hoc Bonferroni pairwise comparisons was used to test for significant differences in the δ^{15}N values of each amino acid among the three seal species. This same procedure was conducted to compare the δ^{15}N values for each category of amino acid (i.e., source or trophic) among the different seal species. For both Weddell and crabeater seals, a two-tailed student's *t*-test was used to compare the δ^{15}N values of Pro, Glu and Phe for the WAP to those of a combined Amundsen and Ross Sea region ("Amundsen/Ross Sea" in the subsequent text). Amino acid δ^{15}N values for seals from the Amundsen/Ross Seas were combined by species (crabeater or Weddell) since both species had bulk δ^{15}N values that were similar between these two regions. This analysis was not done for Ross seals since this species was almost exclusively sampled in the Amundsen Sea. A two-tailed student's *t*-test was used to compare the $\delta^{15}N_{Phe}$ values of Weddell seals to those of crabeater seals for the WAP, and a one-way ANOVA with post-hoc Bonferroni pairwise comparisons was conducted to assess variation between the $\delta^{15}N_{Phe}$ values of Ross, Weddell, and crabeater seals from the Amundsen/Ross Sea region.

CSI-AA based trophic positions ($TP_{CSI\text{-}AA}$) were calculated using a modified version of the equation originally proposed by Chikaraishi et al. (2009). Here, we substituted Pro for Glu as the trophic amino acid, as suggested by the comparative synthesis of $TP_{CSI\text{-}AA}$ methods in McMahon and McCarthy (2016), because Pro trophic discrimination appears to be less variable across variations in diet. McMahon and McCarthy (2016) suggest that this new equation will likely produce more ecologically realistic TP estimates for marine mammals. $TP_{CSI\text{-}AA}$ was, therefore, calculated as follows:

$$TP_{CSI-AA} = 1 + [(\delta^{15}N_{Pro} - \delta^{15}N_{Phe} - \beta_{Pro/Phe})/TDF_{Pro}]$$

where $\delta^{15}N_{Pro}$ is the seal Pro $\delta^{15}N$ value, $\beta_{Pro/Phe}$ is the isotopic difference between Pro and Phe in marine phytoplankton (3.1 ‰; Chikaraishi et al. 2009), and TDF_{Pro} is the trophic discrimination between diet and consumer for Pro minus the same for Phe ($\Delta^{15}N_{pro}$ - $\Delta^{15}N_{Phe}$ = 4.5 ‰; McMahon and McCarthy 2016). Differences in $TP_{CSI\text{-}AA}$ among the three seal species were determined with a one-way ANOVA with post-hoc Bonferroni pairwise comparisons using data for individuals only from the Ross and Amundsen Seas to reduce the effect of location on our findings. Differences in $TP_{CSI\text{-}AA}$ between the WAP versus Amundsen and Ross Seas were determined with a two-tailed students *t*-test for Weddell and crabeater seals. For all statistical analyses, a result was considered significant if $p < 0.05$.

Lastly, maps were produced in Ocean Data View (ODV) version (4.7.4) (Schlitzer 2015) to show spatial patterns in bulk $\delta^{13}C$ and $\delta^{15}N$ values, as well as $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Pro}$.

RESULTS

Bulk $\delta^{13}C$ and $\delta^{15}N$ values of Ross, Weddell, and crabeater seals

Bulk $\delta^{13}C$ and $\delta^{15}N$ values varied significantly among the three species (Fig. 1, Table S7). Ross seals had significantly higher $\delta^{13}C$ values (-23.8 ± 0.3 ‰ for the mean ± standard deviation, n = 15) than both Weddell seals (-25.0 ± 0.6 ‰, n = 125) and crabeater seals (-25.0 ± 1.4 ‰, n = 97) ($p < 0.001$ for post-hoc Bonferroni pairwise comparisons). All seals had $\delta^{15}N$ values significantly different from each other: crabeater seal (7.2 ± 0.8 ‰, n = 97) < Ross seal (9.1 ± 0.4 ‰, n = 15) < Weddell seal (12.3 ± 0.6 ‰, n = 125) ($p < 0.001$ for all Bonferroni post-hoc comparisons). We found no consistent relationships between bulk stable isotope values of seals and measures of sampling period, gender, age class, or body mass (see the *Supplementary Material*).

Spatial patterns of bulk $\delta^{13}C$ and $\delta^{15}N$ values for Antarctic seals

Both Weddell and crabeater seals showed significant spatial variation in their $\delta^{13}C$ values. Weddell seal $\delta^{13}C$ values were significantly greater in the Ross Sea (-25.1 ± 0.5 ‰, n = 100) and the Amundsen Sea (-24.7 ± 0.4 ‰, n = 21) than in the WAP (-22.9 ± 0.9 ‰, n = 4) ($p \leq 0.002$ in all cases from Bonferroni post-hoc comparisons; Fig. 2a, Table S7). Likewise, the $\delta^{13}C$ values of crabeater seals along the WAP were significantly higher (-24.0 ± 1.1 ‰, n = 52) than those in the Amundsen Sea (-26.1 ± 0.4 ‰, $n = 35$) and Ross Sea (-26.1 ± 0.5 ‰, $n = 10$) ($p < 0.001$ in both cases for Bonferroni post-hoc comparisons; Fig. 3a, Table S7).

Unlike their bulk $\delta^{13}C$ values, Weddell seals showed no significant differences in bulk $\delta^{15}N$ values across the three regions (Fig. 2b, Table S7). In contrast, crabeater seals from the WAP had significantly lower $\delta^{15}N$ values (6.8 ± 0.6 ‰, $n = 52$) than those from the Amundsen Sea (7.6 ± 0.6 ‰, $n = 35$) and Ross Sea (8.0 ± 1.4 ‰, $n = 10$) ($p < 0.001$ in both cases from Bonferroni post-hoc comparisons, Fig. 3b, Table S7). Note, spatial variation in bulk $\delta^{13}C$ and $\delta^{15}N$ values of Ross seals across West Antarctica could not be examined because all but one of the individuals were from the Amundsen Sea (Fig. S1).

Compound-specific $\delta^{15}N$ values of Ross, Weddell, and crabeater seals

Nitrogen isotope values were significantly different among at least two of the three seal species for all amino acids, except Gly (Figs. 4 and S2, Tables S8 and S9). For most trophic amino acids (Glu, Ala, Ile, Leu, Pro, and Val), $\delta^{15}N$ values differed significantly among all three species (Table S9), with Weddell > Ross > crabeater. For example, Pro $\delta^{15}N$ values of Weddell seals (20.0 ± 1.4 ‰, $n = 6$) are significantly greater than those of Ross (17.2 ± 0.5 ‰, $n = 6$) and crabeater (15.6 ± 0.6 ‰, $n = 6$) seals ($p < 0.001$ in both cases from Bonferroni post-hoc comparisons). Pro $\delta^{15}N$ values of Ross seals (17.2 ± 0.5 ‰, $n = 6$) are significantly greater than those of crabeater seals (15.6 ± 0.6 ‰, $n = 6$) with a p-value of 0.03 from Bonferroni post-hoc comparisons. For the trophic amino acid, Asp, crabeater seals had significantly lower $\delta^{15}N$ values (10.1 ± 0.6 ‰, $n = 6$) than Weddell (16.2 ± 2.2 ‰, $n = 6$) and Ross seals (14.1 ± 1.0 ‰, $n = 6$) ($p < 0.001$ in both cases from Bonferroni post-hoc comparisons). Additionally, $\delta^{15}N$ values among all trophic amino acids were significantly different among all three seal species ($p <$

0.001 in all cases from Bonferroni post-hoc comparisons) with these values decreasing in the manner: Weddell seals (21.1 ± 2.7 ‰, *n* = 42) > Ross seals (17.7 ± 1.9 ‰, *n* = 41) > crabeater seals (13.5 ± 1.9 ‰, *n* = 42).

δ^{15}N values were significantly different between at least two seal species for both commonly defined source amino acids (Phe and Lys). For Lys, Ross seals had significantly lower δ^{15}N values (2.8 ± 0.7 ‰, *n* = 6) than Weddell (5.2 ± 1.5 ‰, *n* = 6) and crabeater seals (5.0 ± 0.4 ‰, *n* = 6) (*p*-values of 0.005 and 0.009, correspondingly, from Bonferroni post-hoc comparisons). Likewise, Ross seals had significantly lower $\delta^{15}N_{Phe}$ values (2.7 ± 0.7 ‰, *n* = 6) than Weddell (5.7 ± 0.5 ‰, *n* = 6) and crabeater seals (5.2 ± 1.0 ‰, *n* = 6) ($p < 0.001$ in both cases from Bonferroni post-hoc comparisons). Combined, the δ^{15}N values of these source amino acids (Phe and Lys) for Ross seals (2.7 ± 0.7 ‰, *n* = 11) are less than those of crabeater (5.1 ± 0.7 ‰, *n* = 12) and Weddell seals (5.5 ± 1.1 ‰, *n* = 12) with $p < 0.001$ in all cases from from Bonferroni post-hoc comparisons.

While Gly and Ser are challenging to accurately categorize in terms of conventional trophic and source groupings (McMahon and McCarthy 2016), we do note that Ser δ^{15}N values of Weddell seals (8.7 ± 1.4 ‰, *n* = 6) were significantly higher than those of both crabeater (4.2 ± 1.9 ‰, *n* = 6) and Ross seals (5.3 ± 0.6 ‰, *n* = 6) (*p*-values of < 0.001 and 0.002, respectively, from Bonferroni post-hoc comparisons). No significant differences among the three seal species occur for Gly δ^{15}N values. Ross, Weddell, and crabeater seals have Gly δ^{15}N values of 4.9 ± 1.1 ‰ (*n* = 6), 5.4 ± 2.9 ‰ (*n* = 6), and 3.8 ± 2.8 ‰ (*n* = 6), correspondingly.

Spatial patterns of Phe, Pro, and Glu δ^{15}N values for Antarctic seals

For Weddell seals, Phe, Pro, and Glu values did not differ significantly between the Amundsen/Ross Sea and the WAP (Fig. S4). In contrast, crabeater seals had significantly lower $\delta^{15}N_{Phe}$ values in the WAP (4.3 ± 0.4 ‰, *n* = 3) relative to those from the Amundsen/Ross Sea region (6.0 ± 0.7 ‰, *n* = 3) (*p* = 0.04, two-tailed student's *t*-test) (Figs. 5 and 6, Table S8). Crabeater $\delta^{15}N_{Pro}$ and $\delta^{15}N_{Glu}$ were not significantly different between the WAP (15.9 ± 0.5 ‰ and 15.0 ± 0.2 ‰, respectively, *n*=3 for both) and the Amundsen/Ross Sea region (15.4 ± 0.6 ‰ and 14.8 ± 0.4 ‰, correspondingly, *n* = 3 for both, Table S8). As with bulk isotope values, spatial variation in $\delta^{15}N$ values of source amino acids for Ross seals could not be examined since all but one individual were from the Amundsen Sea (Fig. S3).

Both crabeater and Weddell seals had similar $\delta^{15}N_{Phe}$ for the Amundsen/Ross Sea region, 6.0 ± 0.7 ‰ (*n* = 3) and 5.7 ± 0.7‰ (*n* = 3), respectively, that were significantly higher than the $\delta^{15}N_{Phe}$ for Ross seals (2.7 ± 0.7 ‰, *n* = 6) (*p*-values < 0.001 in all cases from Bonferroni post-hoc comparisons). However, crabeater seals had significantly lower $\delta^{15}N_{Phe}$ (4.3 ± 0.4 ‰, *n* = 3) than Weddell seals (5.7 ± 0.4 ‰, *n* = 3) for the WAP (*p* = 0.01 from a two-tailed student's *t*-test).

Trophic positions of Ross, Weddell, and crabeater seals

Among species, both Ross seals (3.5 ± 0.2, *n* = 6) and Weddell seals (3.7 ± 0.1, *n* = 3) were over a full trophic level higher than crabeater seals (2.4 ± 0.2, *n* = 3) (*p* < 0.001 from Bonferroni post-hoc comparisons in both cases, restricted to Amudsen/Ross Seas where all species were collected) (Fig. 7). Within species, Weddell seals had similar $TP_{CSI\text{-}AA}$ values for the WAP (3.3 ± 0.4, *n* = 3) and Amundsen/Ross Sea region (3.7 ± 0.1, *n* = 3). However, crabeater seals had significantly higher $TP_{CSI\text{-}AA}$ values in the WAP (2.9 ± 0.1, *n* = 3) than the Amundsen/Ross Sea region (2.4 ± 0.2, *n* = 3) (*p* = 0.03 from a two-tailed student's *t*-test). For crabeater seals, note that one subadult was included along with five adult seals in the CSI-AA sample set. Although some significant variation in bulk δ^{15}N values was observed across different age classes for this species (see *Supplementary Material*), the $TP_{CSI\text{-}AA}$ value of the subadult from the Amundsen/Ross sea region (2.3) was indistinguishable from those of the adults from this region (2.4 ± 0.2, $n = 2$). Finally, we note that there were some significant differences in the bulk δ^{15}N values of Weddell seal age classes (discussed in the *Supplementary Material*), but only samples from adults are used in our CSI-AA subset.

DISCUSSION

Ross, Weddell, and crabeater seal bulk isotope values in our study were similar to those reported in earlier work on these species for our study region (Burns et al. 1998, Zhao et al. 2004, Aubail et al. 2011, Goetz et al. 2017, Botta et al. 2018), after correction for isotopic offsets for different tissue types (Table S10). These new bulk isotope results are especially valuable for Ross seals since very little isotopic measurements exist to date. Our bulk δ^{15}N values, like those of prior studies (Rau et al. 1992, Burns et al. 1998, Zhao et al. 2004, Aubail et al. 2011, Cipro et al. 2012, and Hückstädt et al. 2012a), all point to Ross seals being at an intermediate trophic position between those of Weddell and crabeater seals. In the following discussion we explore the trophic positions, diets, and foraging habitats of these three seal species using novel CSI-AA data to help interpret our bulk isotope data.

Spatial patterns in seal bulk and amino acid isotope values

Both Weddell and crabeater seals showed spatial patterns in their bulk $\delta^{13}C$ values. Weddell and crabeater seals had significantly higher $\delta^{13}C$ values in the WAP than the Amundsen and Ross Seas. As this carbon isotope gradient occurs in Weddell and crabeater seals at different trophic levels, it is likely driven by changes in baseline $\delta^{13}C$ values. Prior research has shown that $\delta^{13}C$ values decrease with increasing latitude in the West Antarctic as a result of increasing CO_2 solubility with decreasing sea surface temperatures (Cherel and Hobson 2007, Quillfeldt et al. 2010, Brault et al. 2018). Thus, the spatial variation in the bulk $\delta^{13}C$ values of these two species likely predominantly reflects the sea surface temperature gradient in the West Antarctic, with colder temperatures in the higher latitude Amundsen and Ross Sea compared to the warmer, lower latitude WAP. The difference in sea surface temperatures of the WAP and Ross Sea (Ducklow et al. 2007, Ducklow et al. 2012, Smith et al. 2014) has been shown to contribute to an ~ 2 ‰ decrease in the $\delta^{13}C_{baseline}$ between these regions (Brault et al. 2018), similar to the offset between the WAP and Ross Sea bulk $\delta^{13}C$ values that we observe for Weddell and crabeater seals (2.0 ‰ and 2.1‰, respectively).

Weddell and crabeater seals showed different spatial patterns in their bulk $\delta^{15}N$ values across West Antarctica. Weddell seals showed no spatial patterns in bulk $\delta^{15}N$ values across the study region, Crabeater seals had significantly lower bulk $\delta^{15}N$ values in the WAP than the Amundsen and Ross Seas. A spatial gradient in $\delta^{15}N_{baseline}$ in the Southern Ocean has been detected by previous research, and likely reflects changes in nutrient utilization and primary productivity (DiFiore et al. 2006, DiFiore et al. 2009, Brault et al. 2018). A lower $\delta^{15}N_{baseline}$ (~ 2 ‰) in the WAP compared to the Amundsen and Ross Seas was found in a study of zooplankton (Brault et al. 2018); this is similar to the difference observed here between WAP and Amundsen/Ross Sea crabeater seal $\delta^{15}N_{Phe}$ values (1.7 ‰). This difference in $\delta^{15}N_{baseline}$ values appears to reflect the relative proportion of oceanic versus coastal production across the West Antarctic (DiFiore et al. 2006, DiFiore et al. 2009, Brault et al. 2018). Baseline $\delta^{15}N$ values likely increase from oceanic to coastal areas due to increasing productivity and nutrient drawdown towards the continent in the summer (DiFiore et al. 2006, DiFiore et al. 2009, Brault et al. 2018). The WAP, with its narrow shelf, likely has a greater influence from oceanic waters beyond the continental margin, whereas the Amundsen Sea and Ross Sea have wider, more productive shelf systems consistent with higher $\delta^{15}N_{baseline}$ values (Arrigo et al. 1998, 2008, DiFiore et al. 2006, Smith & Comiso 2008, DiFiore et al. 2009, Alderkamp et al. 2012, Brault et al. 2018).

Continental shelves in Antarctica are especially productive areas compared to offshore waters since both light and iron become available for phytoplankton blooms at times of coastal polynya formation and increased iron inputs from various sources (e.g., melting glaciers) (Gordon et al. 2000, Alderkamp et al. 2012, Arrigo et al. 2015). Although annual production in the Amundsen and Ross Seas exceeds that of the WAP (Arrigo et al. 1998, 2008, Smith and Comiso 2008, Alderkamp et al. 2012), localized regions in the WAP may experience high rates of primary productivity comparable to those within the Amundsen and Ross Seas. For example, Schmidt et al. (2003) found that Marguerite Bay in the WAP can be a “hot spot” of productivity, as revealed by high phytoplankton and zooplankton $\delta^{15}N$ values. To date, examinations of $\delta^{15}N_{baseline}$ variation in West Antarctica have suggested that it increases from oceanic to coastal waters, tracking a gradient in productivity and nutrient drawdown (Brault et al. 2018).

While it is likely that the observed spatial differences in Weddell and crabeater seal bulk $\delta^{15}N$ values reflect these $\delta^{15}N_{baseline}$ gradients, spatial patterns in seal bulk $\delta^{15}N$ values could be related to shifts in diet, $\delta^{15}N_{baseline}$ values, or both. The $\delta^{15}N_{Phe}$ values of Ross, Weddell, and crabeater seals, on the other hand, reflect $\delta^{15}N_{baseline}$, driven by spatial gradients in nutrient utilization and primary productivity, without the confounding factor of trophic fractionation. As such, the spatial changes in $\delta^{15}N_{baseline}$ in West Antarctica are useful for deducing the relative foraging habitats of Weddell and crabeater seals. Weddell seals from the WAP to the Ross Sea consistently have the highest $\delta^{15}N_{Phe}$ values (5.7 ± 0.4 ‰ for the WAP and 5.7 ± 0.7 ‰ for the Amundsen/Ross Sea region, $n = 3$ in both cases) within the overall range of $\delta^{15}N_{Phe}$ for all Antarctic seal (1.90 ‰ to 6.81 ‰). This suggests that Weddell seals throughout West Antarctica follow a similar foraging behavior in which they predominantly target the most productive environments within an area (i.e., highest $\delta^{15}N_{baseline}$; Brault et al. 2018). These are likely to be coastal regions, given our understanding of the West Antarctic $\delta^{15}N_{baseline}$ gradients. Satellite tracking data of different seal species in this region support this hypothesis. Costa et al. (2010) used satellite data to show that in the WAP, Weddell seals (unlike crabeater seals) moved minimally, foraging almost exclusively in likely highly productive coastal fjords (Schmidt et al. 2003, DiFiore et al. 2006, 2009). Goetz (2015), likewise, found that Weddell seal movements do not extend beyond the Ross Sea continental shelf.

In contrast to Weddell seals, crabeater $\delta^{15}N_{Phe}$ values vary significantly across West Antarctica, with higher values in the Amundsen and Ross Seas versus the WAP. These data indicate that crabeater seals have greater foraging habitat flexibility than Weddell seals, and thus make use of a wider range of productivity regimes. Weddell and crabeater seals also have significantly different $\delta^{15}N_{baseline}$ for the WAP, which is not observed for the Amundsen/Ross Sea region, pointing to environmental heterogeneity in the WAP. Our current knowledge of crabeater seals indicates that this seal heavily consumes *E. superba* (Laws 1977, Rau et al. 1992, Burns et al. 2004, Zhao et al. 2004, Burns et al. 2008, Aubail et al. 2011, Hückstädt et al. 2012a), a krill species with a distribution linked to that of sea ice. As a consequence, crabeater seals move on and off the continental shelf, depending on the krill life cycle stage and seasonal ice cover (Nicol 2006). We hypothesize that crabeater seals move across the heterogeneous environments of the WAP, at times of the year incorporating the lower off-shelf $\delta^{15}N_{baseline}$ values, in contrast with Weddell seals. Such a movement pattern by crabeater seals is supported by the tracking results of Costa et al. (2010). Since crabeater seals in the Amundsen/Ross Sea region have $\delta^{15}N_{Phe}$ values more similar to those of Weddell seals from this area, the same interpretation would suggest that crabeater seals in this region stay within the wider and more productive continental shelf areas of the Amundsen and Ross Seas. Overall, our results indicate that Weddell seals have a strong preference for productive coastal sites, whereas crabeater seals use more diverse habitats in West Antarctica, but that their foraging patterns vary by region.

Ross seals sampled in the Amundsen/Ross Seas had significantly lower $\delta^{15}N_{Phe}$ values than both Weddell and crabeater seals from this region (Fig. 4). This result suggests that Ross seals are foraging in a different region from the other two species. These low $\delta^{15}N_{baseline}$ values coupled with our current understanding of the West Antarctic $\delta^{15}N_{baseline}$ gradient (Brault et al. 2018) strongly suggest that Ross seals are likely feeding much further offshore than Weddell and crabeater seals, largely in the oceanic region of the Southern Ocean that experiences low nutrient drawdown and low productivity relative to coastal areas (DiFiore et al. 2006, DiFiore et al. 2009, Jaeger et al. 2010, Somes et al. 2010).

Prior research supports our hypothesis that Ross seals are largely oceanic feeders. For example, Blix and Nordøy (2007) examined the foraging behavior of Ross seals via satellite-linked dive recorders. The tags tracked the movements of 10 adult Ross seals captured off Queen Maud Land (East Antarctica) just after their molt in February 2001. The animals migrated 2,000 km north to pelagic waters south of the Antarctic Polar Front. These Ross seals stayed in that area until October when they traveled south into the pack ice (Blix and Nordøy 2007). Similarly, Arcalís-Planas et al. (2015) showed that Ross seals minimally use sea ice, hauling out for only short periods each year to molt (December to January) and breed (late October to mid-November). They report that Ross seals are moving from 587 to 1,282 km off the ice edge during much of the year (Arcalís-Planas et al. 2015). The low $\delta^{15}N_{baseline}$ value measured in our study represents independent evidence that Ross seals are indeed are spending the majority of each year foraging in less productive, oceanic waters, separate from the more coastal food webs of the crabeater and Weddell seals.

Reevaluating trophic dynamics of Antarctic Seals

Differences in regional foraging habitat utilization among seals, indicated by $\delta^{15}N_{phe}$ between Ross seals versus crabeater and Weddell seals (~ 3 ‰), suggest the need for a reevaluation of the TP and associated food web ecology for Ross seals. Our compound-specific approach allowed us to calculate trophic positions of these Antarctic seals that were internally indexed to $\delta^{15}N_{baseline}$. We found that Ross seals had $TP_{CSI\text{-}AA}$ values similar to those of Weddell seals, both of which were significantly higher than crabeater seals. This result differed from previous conclusions based on bulk $\delta^{15}N$ values, which suggested that Ross seals were at an intermediate trophic position between crabeater and Weddell seals (Rau et al. 1992, Zhao et al. 2004, Aubail et al. 2011). Our results suggest that, like Weddell seals, Ross seals are predominantly feeding on high trophic level prey, such as mid-to-deep water fish and squid, and that lower trophic level prey (e.g., *E. superba*) are not a major part of their diets. This conclusion is supported by dive records, which indicate that Ross seals forage at depths associated with capturing mesopelagic squid and fish (Bengtson and Stewart 1997, Blix and Nordøy 2007), and corroborate limited stomach content analyses that have reported Antarctic silverfish and glacial squid comprising their diets in varying proportions (Skinner and Klages, 1994).

Our compound-specific isotope approach to trophic dynamics also revealed significant spatial variation in the trophic dynamics of crabeater seals across West Antarctica. The $TP_{CSI\text{-}AA}$ value of crabeater seals decreases by approximately 0.5 from the WAP to the Amundsen/Ross Sea region, which is substantial for a low trophic level consumer like the crabeater seal that is thought to specialize on krill. Variations of this range have been shown to be significant in many past studies (e.g., McCarthy et al. 2007; Batista et al. 2014), with recent ecological work showing that $TP_{CSI\text{-}AA}$ variation as small as 0.2 to 0.3 indicates real ecological change (Ostrom et al. 2017). This pattern is not likely driven by differences in age class across regions as all but one crabeater seal from both regions were adults. The WAP has been experiencing increased krill fishing pressure, a resurgence in baleen whales (competitors for krill), and dramatic reductions in sea ice extent as a function of rapid regional warming, all of which have negative effects on *E. superba* abundance (Ducklow et al. 2007, Trivelpiece et al. 2011, Ducklow et al. 2012, Nicol et al. 2012). Perhaps these environmental changes have decreased the availability of krill for crabeater seals in this area, causing crabeater seals to supplement their diet with fish in the WAP relative to the Amundsen/Ross Sea region.

Alternatively, the regional differences in crabeater seal $TP_{CSI\text{-}AA}$ values could be the result of bottom-up effects. Prior research has shown omnivorous behaviors by *E. superba* in the WAP and Drake Passage regions, possibly contributing to a higher euphausiid TP in this region than other areas of the Antarctic (Schmidt et al. 2006). However, euphausiid omnivory in the Ross Sea has also been suggested (Hopkins 1987, Pinkerton et al. 2010), and it is possible that omnivory by this taxon varies in time and space (Schmidt et al. 2006). Given these uncertainties, it is not possible to definitively assess the relative roles of shifts in diet versus krill omnivory to our observed spatial gradient of crabeater seal TP_{CSI-AA}.

CONCLUSIONS

Our work using bulk and amino acid isotope analyses revealed significant variability in the foraging habitats and trophic dynamics of three important Antarctic seal species in the West Antarctic. Ross seals are foraging in a low productivity, oceanic food web far offshore from that of crabeater and Weddell seals. Crabeater and Weddell seals are foraging within similar food webs closer to shore, but isotopic data suggest that crabeater seals are likely following sea ice to capture *E. superba*, while Weddell seals target the most productive, near-shore areas within the western Antarctic to take prey. In addition, our CSI-AA data revealed that Ross seals occupy a higher trophic position than originally thought, equivalent to Weddell seals and greater than that of crabeater seals. Additionally, since bulk isotope-based TP estimates are unable to account for varying baseline $\delta^{15}N$ values, we hypothesize that the strong baseline changes across the environments inhabited by these species are responsible for this underestimate of TP. This study will begin to reshape our understanding of Ross seal foraging ecology while also highlighting the challenges and potential solutions to accounting for variability in baseline and trophic dynamics when interpreting consumer isotope data in studies of foraging ecology.

ACKNOWLEDGEMENTS

Dyke Andreasen, Colin Carney, Elizabeth Gier, Stephanie Christensen, Jonathan Nye, and Aaron Rosenfield provided considerable assistance with method development and the laboratory analyses entailed in this study. The crew of *RV Oden* was extremely accommodating and helpful in completing our sampling protocols. The support staffs of McMurdo and Palmer Stations, similarly, gave us considerable assistance in performing our sample collections. The National Science Foundation (NSF) granted our funding for this study (NSF ANT-1142108). Drs. Elizabeth Canuel, Rebecca Dickhut, and Andrew Wozniak helped with the importation of samples (Permit No. 17178 from the National Marine Fisheries Service).

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FIGURES

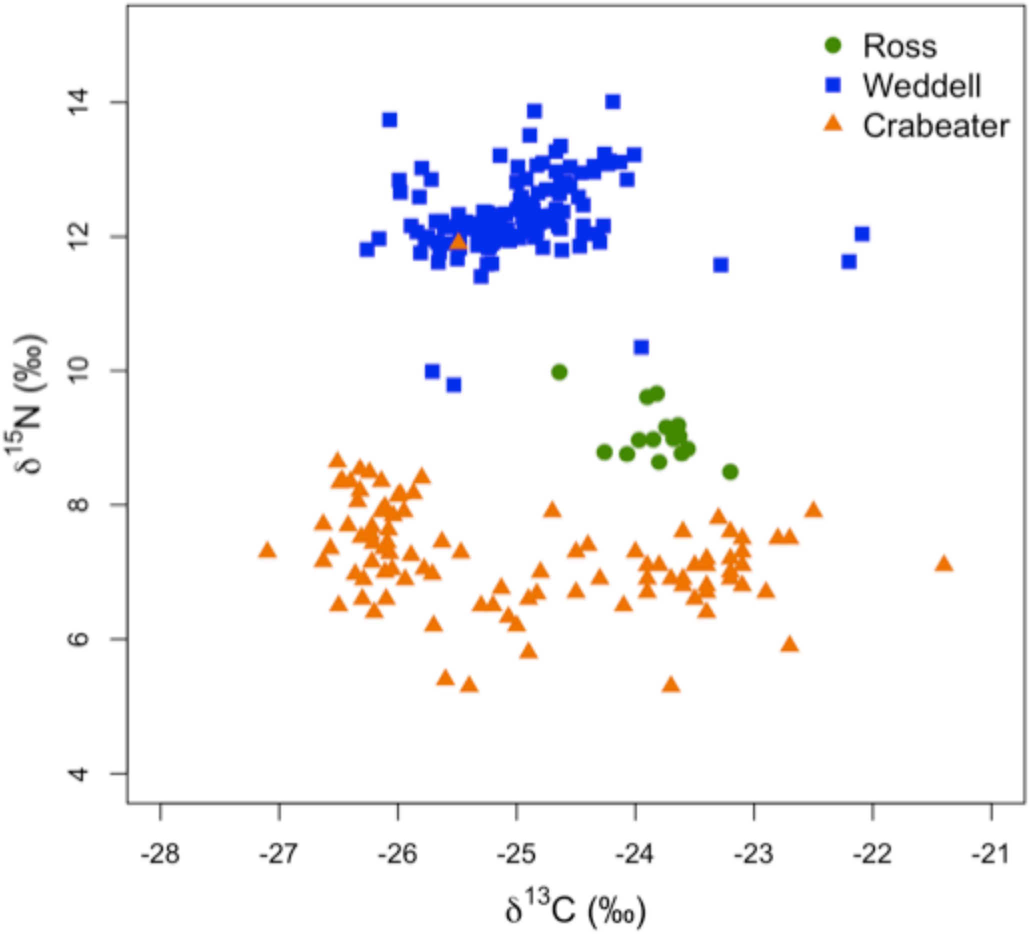

Fig. 1. Bulk $\delta^{15}N$ values versus $\delta^{13}C$ values for Ross seals (green circles), Weddell (blue squares), and crabeater (orange triangles) in the West Antarctic.

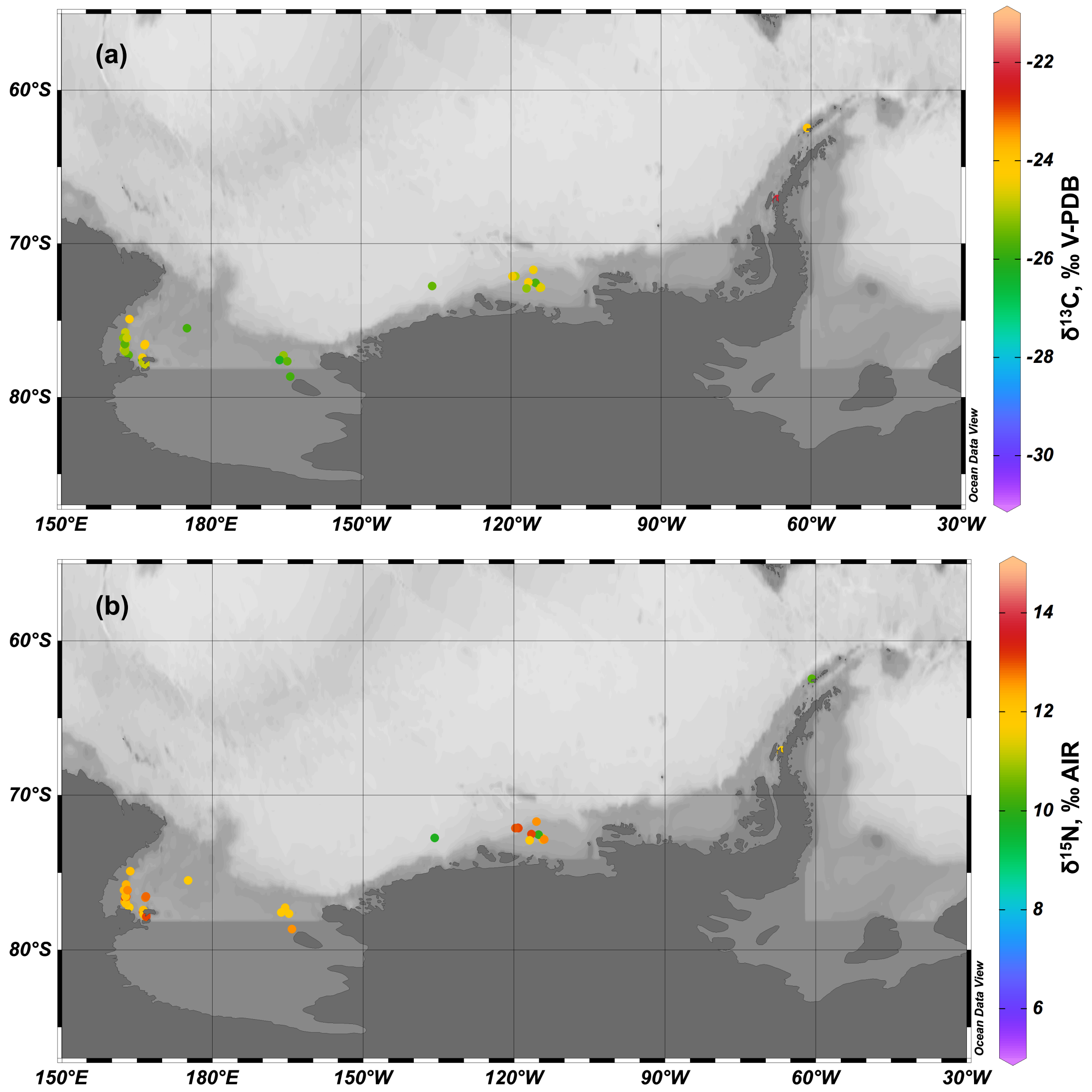

Fig. 2. Spatial variation in $\delta^{13}C$ (a) and $\delta^{15}N$ (b) values of Weddell seals. Figures were produced in Ocean Data View 4.7.4 (Schlitzer 2015).

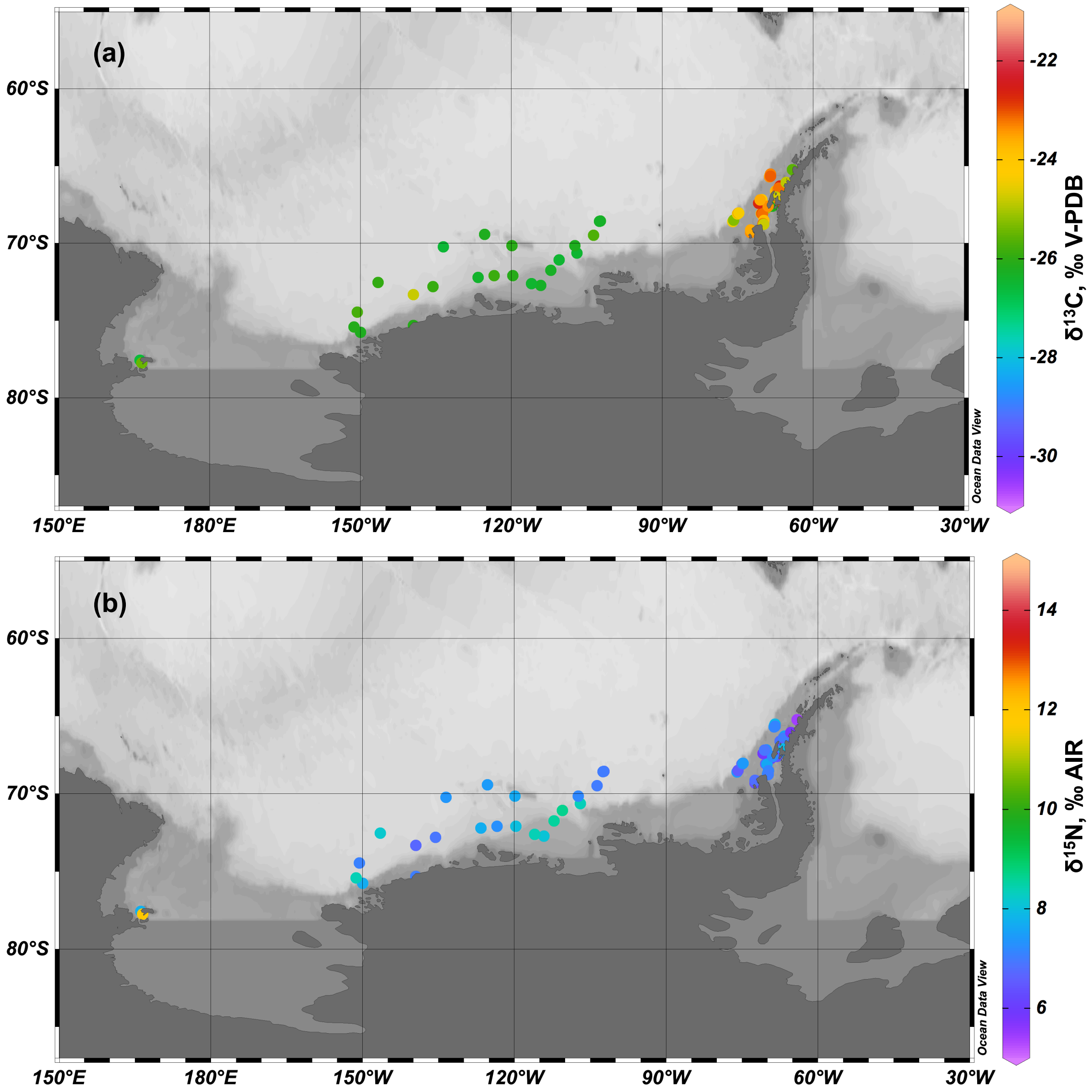

Fig. 3. Spatial variation in $\delta^{13}C$ (a) and $\delta^{15}N$ (b) values of crabeater seals. Figures were produced in Ocean Data View 4.7.4 (Schlitzer 2015).

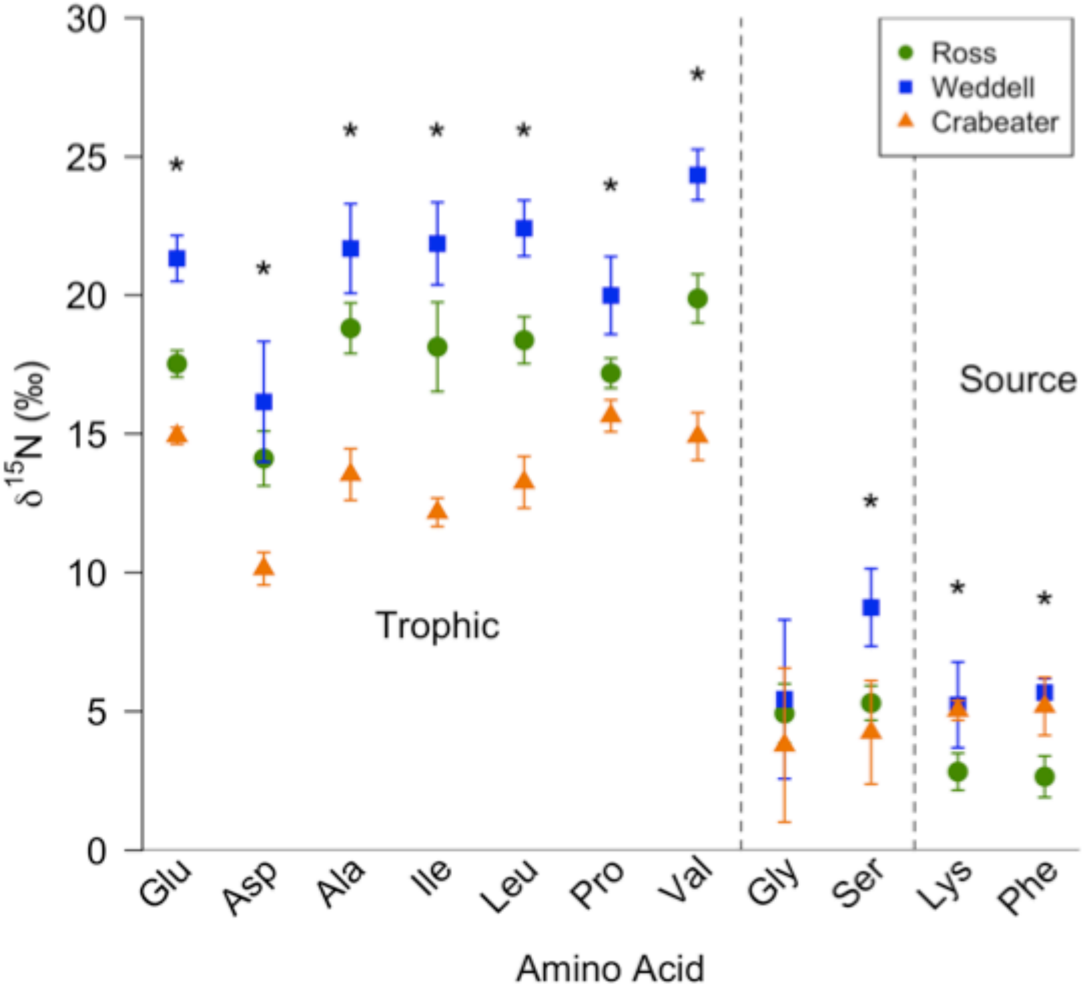

Fig. 4. Mean $\delta^{15}N$ values (± 1 SD) of amino acids for Ross (green circles), Weddell (blue squares), and crabeater (orange triangles) seals. Significant differences ($p < 0.05$) among species for an amino acid are indicated with asterisks. Amino acids are divided into trophic and source amino acids, with Gly and Ser separate given uncertainty in their classification for marine mammals (McMahon and McCarthy 2016).

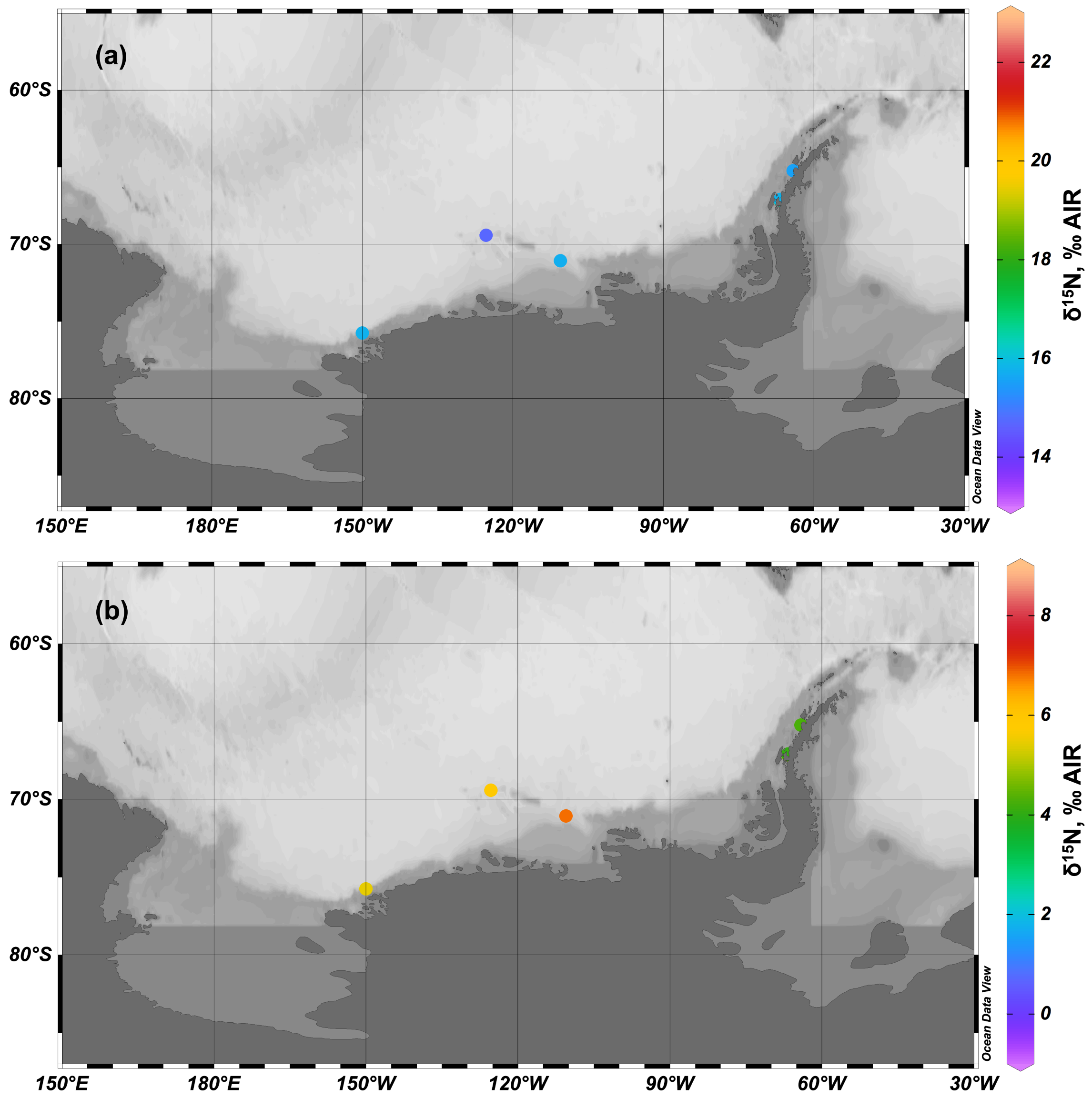

Fig. 5. Spatial variation in $\delta^{15}N$ values of Pro (a) and Phe (b) values for crabeater seals. Figures were produced in Ocean Data View 4.7.4 (Schlitzer 2015).

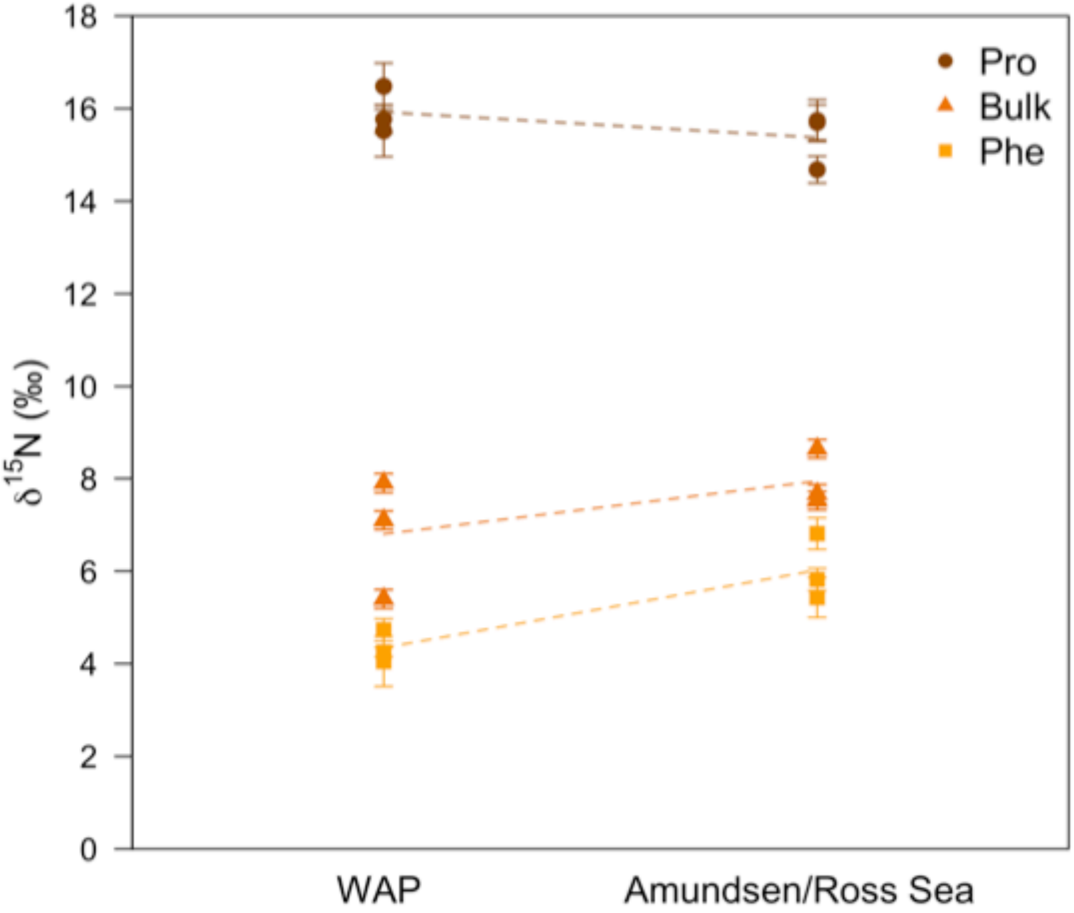

Fig. 6. Comparison of $\delta^{15}N$ values (mean ± 1 SD) of Pro, bulk material, and Phe for crabeater seals. Dark orange circles, medium orange triangles, light orange squares represent Pro, bulk, and Phe $\delta^{15}N$ values, respectively. Bulk $\delta^{15}N$ values represent whole blood, with corrections applied if the given sample type analyzed was not whole blood.

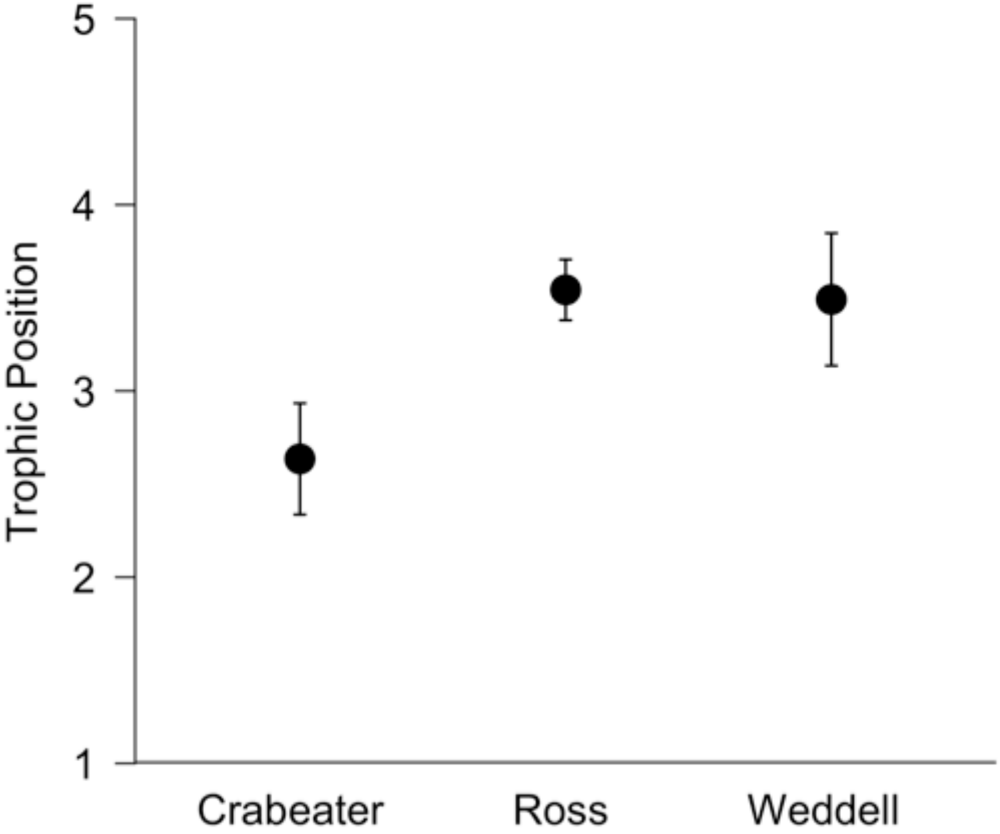

Fig. 7. Trophic position estimates (mean ± 1 SD) for crabeater, Ross, and Weddell seals from the Amundsen and Ross Seas. Trophic positions were calculated based on Pro and Phe $\delta^{15}N$ values.

SUPPLEMENTAL MATERIAL

Relationships of bulk $\delta^{13}C$ and $\delta^{15}N$ values with gender, sampling period, age class, and body mass of the Antarctic seals

Sampling period, gender, and age class have no significant effects on the bulk $\delta^{13}C$ values of Ross Seals (Figs. S5 and S6). However, there is a significant, but weak negative relationship between body mass and $\delta^{13}C$ values (R^2 value of 0.3 from a linear regression analysis, Fig. S6). Sampling period, gender, age class, and body mass all have no significant effects on the bulk $\delta^{15}N$ values of Ross seals (Figs. S5 and S6).

For Weddell seals, sampling period, gender, and body mass have no significant effects on bulk $\delta^{13}C$ values (Figs. S7 and S8). Adult Weddell seals have significantly higher bulk $\delta^{13}C$ values (-24.9 ± 0.6 ‰, n=93) than juveniles (-25.2 ± 0.6 ‰, n=17) and subadults (-25.4 ± 0.5 ‰, n=15) (p = 0.002 in both cases). Sampling period, gender, and body mass have no significant effects on bulk $\delta^{15}N$ values (Figs. S7, and S8). However, Weddell bulk $\delta^{15}N$ values are significantly lower in subadults (11.9 ± 0.7 ‰, n=15) than juveniles (12.6 ± 0.6 ‰, n=17) and adults (12.3 ± 0.6 ‰, n=93) (p-values of 0.02 and 0.004, correspondingly, from Bonferroni post-hoc comparisons) (Fig. S7).

Crabeater seal $\delta^{13}C$ values are not affected significantly by sampling period or gender (Fig. S9). Adult crabeater seals have significantly higher $\delta^{13}C$ values (-24.6 ± 1.3 ‰, n=76) than subadults (-26.3 ± 0.2 ‰, n=10) and juveniles (-26.2 ± 0.4 ‰, n=11) from Bonferroni post-hoc comparisons (p<0.001 in both cases) (Fig. S9). Additionally, crabeater seal $\delta^{13}C$ values increase significantly with increasing body mass (R^2 value of 0.4 from a linear regression analysis) (Fig.

S10). The $\delta^{15}N$ values of crabeater seals do not vary significantly with gender (Fig. S9). One significant difference occurs across sampling periods: Amundsen Sea $\delta^{15}N$ values are significantly higher for the austral summer 2007/08 sampling (8.1 ± 0.4 ‰, $n = 14$) than the austral summer 2010/11 sampling (7.3 ± 0.6 ‰, $n = 21$) ($p<0.001$ from Bonferroni post-hoc comparisons). Adult crabeater seals have significantly lower $\delta^{15}N$ values (7.0 ± 0.8 ‰, $n = 76$) than subadult animals (8.3 ± 0.4 ‰, $n = 10$, $p<0.0001$ for the Bonferroni post-hoc comparison) and juvenile seals (7.8 ± 0.3 ‰, $n = 11$, $p = 0.01$ for the Bonferroni post-hoc comparison) (Fig. S9). The $\delta^{15}N$ values significantly increase with decreasing body mass (Fig. S10, R^2 value of 0.4 from a linear regression analysis).

Discussion of relationships of bulk isotope values with gender, sampling period, age class, and body mass of the Antarctic seals

Our Ross seal bulk $\delta^{13}C$ and $\delta^{15}N$ results suggest a similar diet and foraging region across different genders and age classes. In contrast, the significant relationship between body mass and $\delta^{13}C$ (increasing $\delta^{13}C$ values with decreasing body mass) suggests that Ross seals of different sizes are foraging in slightly different areas. However, no significant relationship exists between body mass and phenylalanine (Phe) $\delta^{15}N$ value for Ross seals, which varies across different environments as described in the main text. Zhao et al. (2004) found no significant effects of age or sex on Ross seal $\delta^{13}C$ and $\delta^{15}N$ values.

Our Weddell and crabeater seal results show no significant effects of gender on $\delta^{13}C$ and $\delta^{15}N$ values, indicating that foraging area and diet do not differ across genders for these species. This finding is consistent with the results of Zhao et al. (2004) and Burns et al. (1998) for crabeater and Weddell seals, respectively. However, Zhao et al. (2004) reported that male Weddell seals have significantly higher $\delta^{13}C$ and $\delta^{15}N$ values than females.

Weddell seal bulk $\delta^{13}C$ values of adults are significantly higher than those of juveniles and subadults, suggesting that these animals vary their foraging region with age. In contrast, Zhao et al. (2004) and Aubail et al. (2011) found no significant variation in bulk $\delta^{13}C$ values across Weddell seal age classes. However, Goetz et al. (2017) found increasing $\delta^{13}C$ values with age for Weddell seals from analysis of red blood cells (RBC), consistent with our finding. Our results point to adult crabeater seals foraging in a different area than subadults and juveniles, perhaps further offshore given their higher $\delta^{13}C$ values, as well as the positive relationship between body mass and $\delta^{13}C$ value for this species. Likewise, Aubail et al. (2011) found significantly higher $\delta^{13}C$ values in crabeater adults than juveniles, and Hückstädt et al. (2012) found $\delta^{13}C$ values significantly increasing with increasing crabeater seal body mass. In contrast, Zhao et al. (2004) found no significant variability in $\delta^{13}C$ values across age groups.

In this study, both Weddell and crabeater seals have significant variability in $\delta^{15}N$ values across age classes. For crabeater seals, our finding of significantly lower $\delta^{15}N$ values in adults than juveniles is supported by the results of Aubail et al. (2011). The observed bulk isotope variation for Weddell and crabeater seals in this study could have resulted from differences in foraging regions, diet, or both between the various age classes. We did not attempt to explore the drivers of $\delta^{15}N$ variations across age classes of Weddell and crabeater seals further in our compound-specific isotope analysis of amino acids (CSI-AA) since limitations entailed in this analysis (i.e., expense and extensive laboratory processing) did not allow for aminio acid $\delta^{15}N$ measurements from a sufficient number of samples for such an investigation. For Weddell seals, we only conducted CSI-AA on tissues from adults. We performed CSI-AA on one subadult and five adults for crabeater seals. The subadult had a higher Phe $\delta^{15}N$ value (6.8 ‰) relative to that of the adults (5.6 ± 0.3 ‰) for the Amundsen/Ross sea region. The nitrogen isotope values of Pro and Glu for the subadult (15.7 ‰ and 15.1 ‰, respectively) were slightly higher than Pro and Glu δ^{15}N values of adults (15.2 ± 0.8 ‰ and 14.7 ± 0.5 ‰) for the Amundsen and Ross Seas. This result indicates the higher bulk δ^{15}N values of subadult than adult crabeater seals may be driven by the former using a habitat with moderately higher baseline δ^{15}N values and, perhaps, nitrogen drawdown than the latter. However, CSI-AA must be conducted on considerably more crabeater seal samples before δ^{15}N variation across age classes can be clearly established and the possible causes can be identified.

The results of other studies measuring bulk δ^{15}N values of Weddell and crabeater seals differed from our findings. Goetz et al. (2017) found increasing δ^{15}N values with increasing Weddell seal age. Zhao et al. (2004) compared δ^{15}N values of Weddell seal pups, juveniles, subadults, and adults, and found only one significant result: adults have higher δ^{15}N values than subadults. Aubail et al. (2011) reported no significant difference across Weddell seal age groups, which included juveniles and adults. For crabeater seals, Zhao et al. (2004) found no significant variability in δ^{15}N values of pups, juveniles, subadults, and adults. Overall, the effects of age, as well as gender, on the isotopic values of crabeater and Weddell seals vary across the research to date. Furthermore, isotope baseline variability may contribute to the differences in bulk isotope values across age groups or genders, as mentioned above and discussed in detail in the main text.

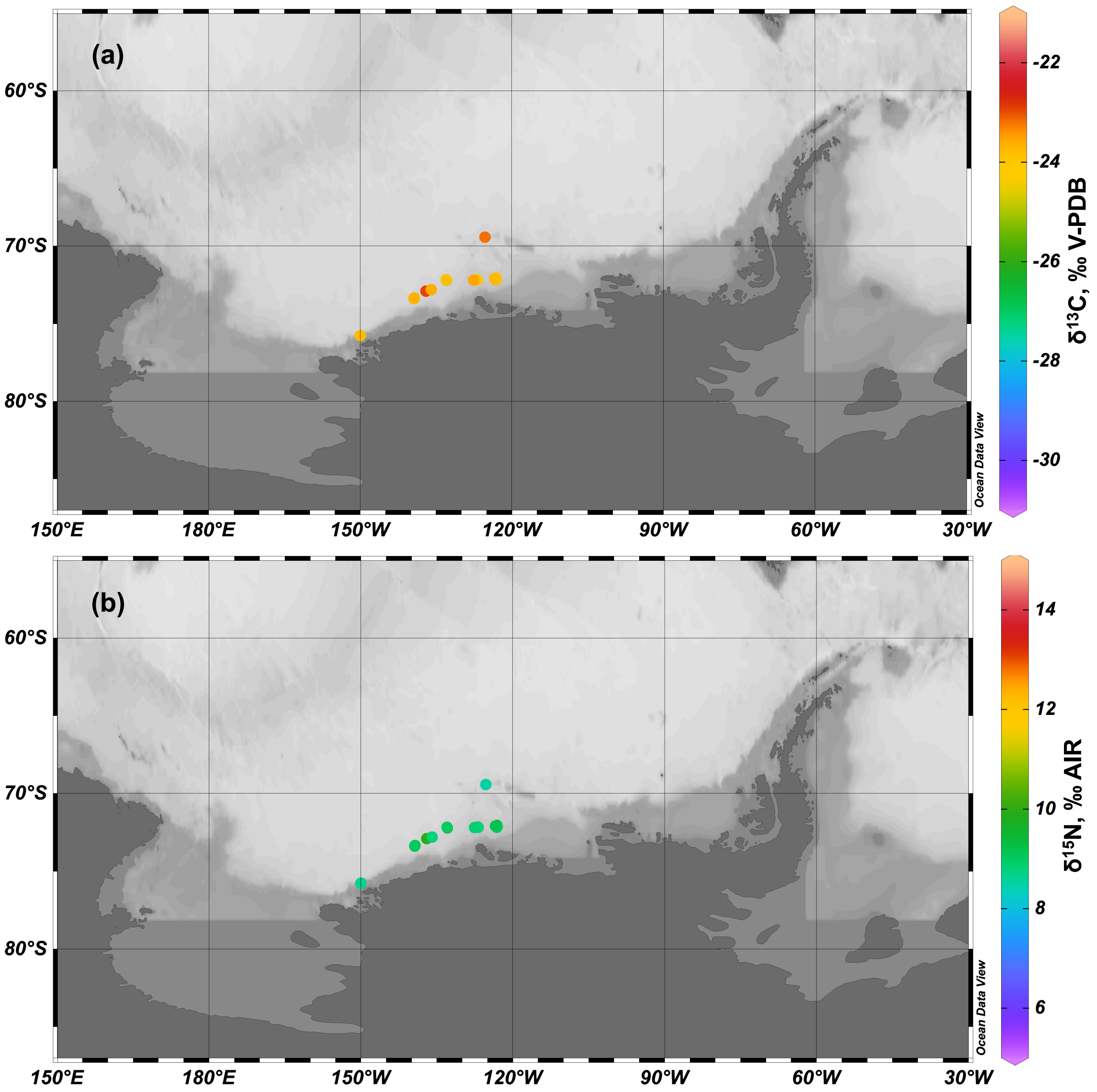

Fig. S1. Spatial variation in bulk $\delta^{13}C$ (a) and $\delta^{15}N$ (b) values of Ross seals. Figures were produced in Ocean Data View 4.7.4 (Schlitzer 2015).

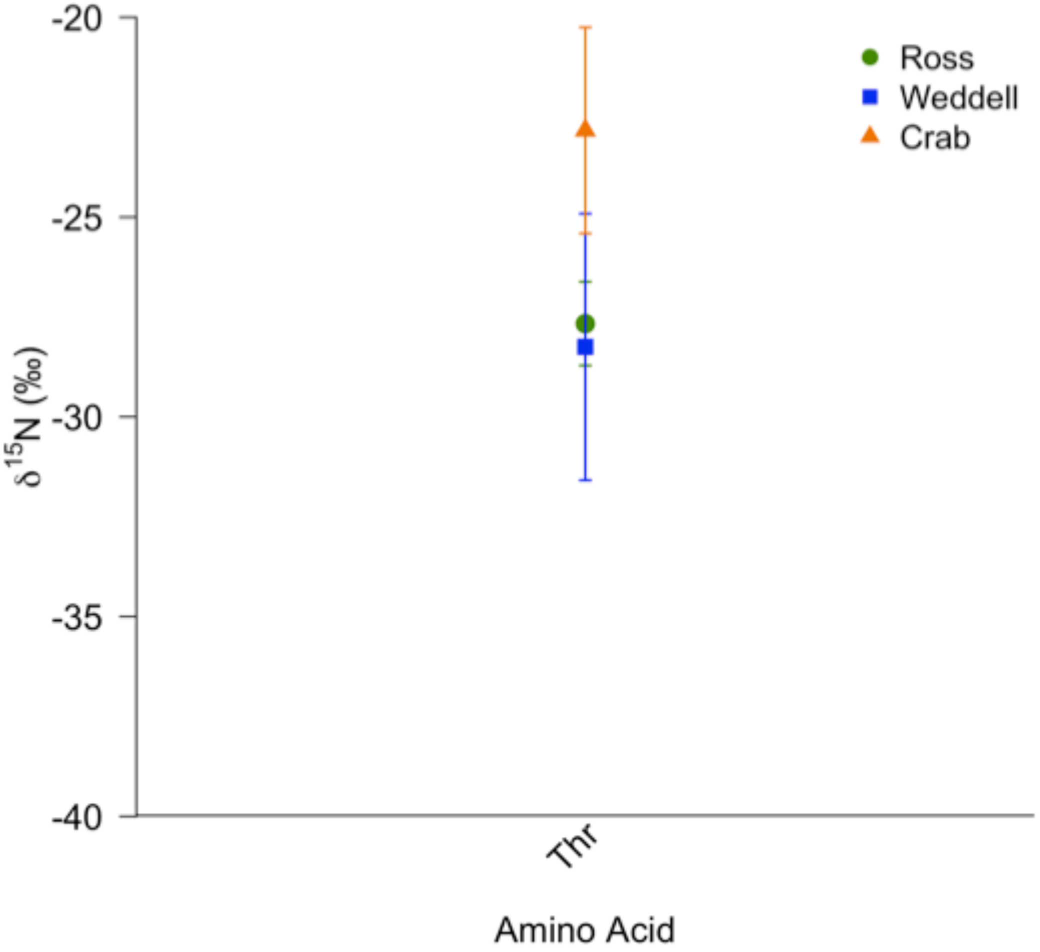

Fig. S2. δ^{15}N values (mean ± 1 standard deviation) of threonine for Ross, Weddell, and crabeater seals. Species are shown with colors: blue squares for Weddell seals, orange triangles for crabeater seals, and green circles for Ross seals.

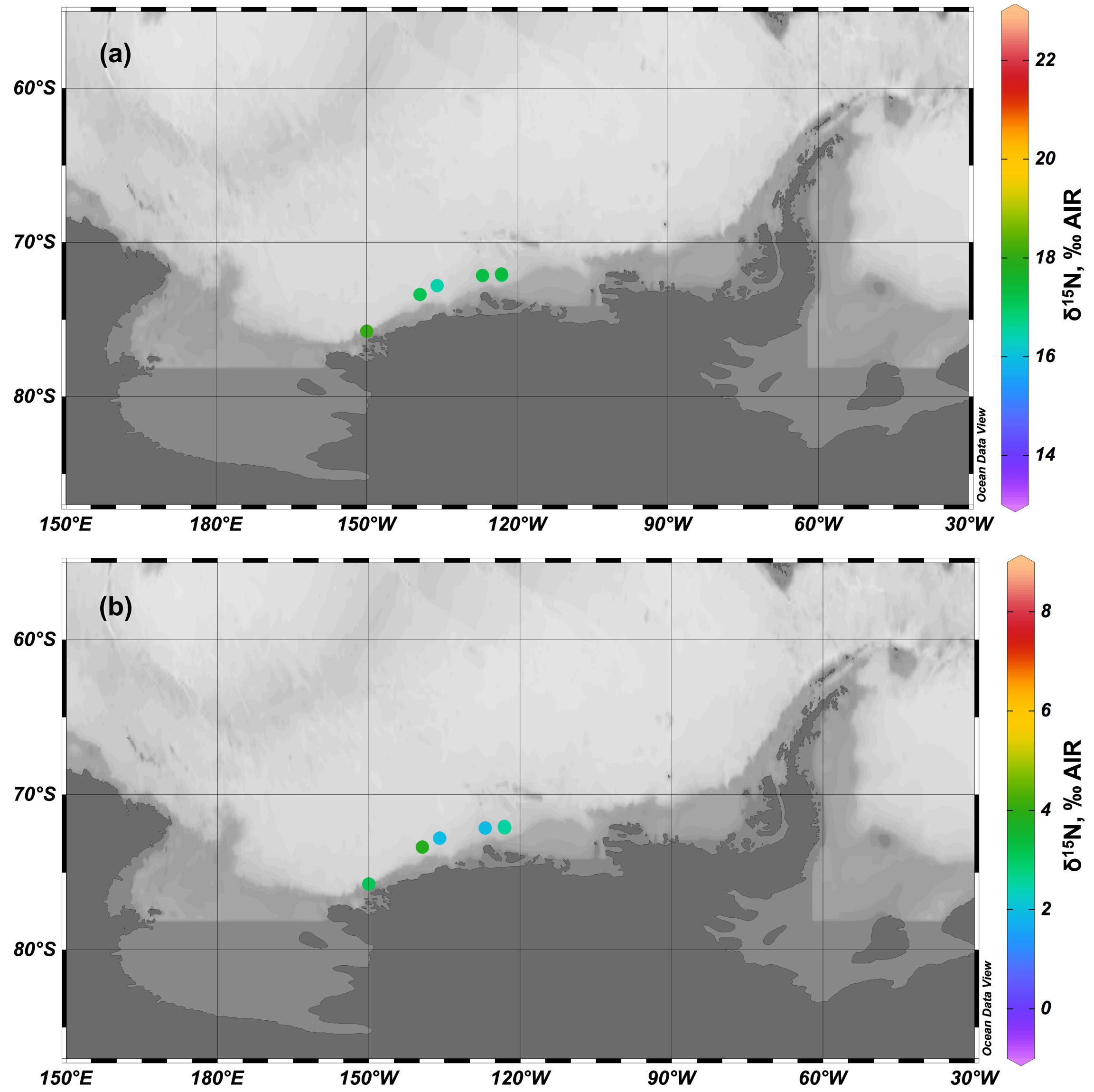

Fig. S3. Spatial variation in δ^{15}N values of Pro (a) and Phe (b) values for Ross seals. Figures were produced in Ocean Data View 4.7.4 (Schlitzer 2015).

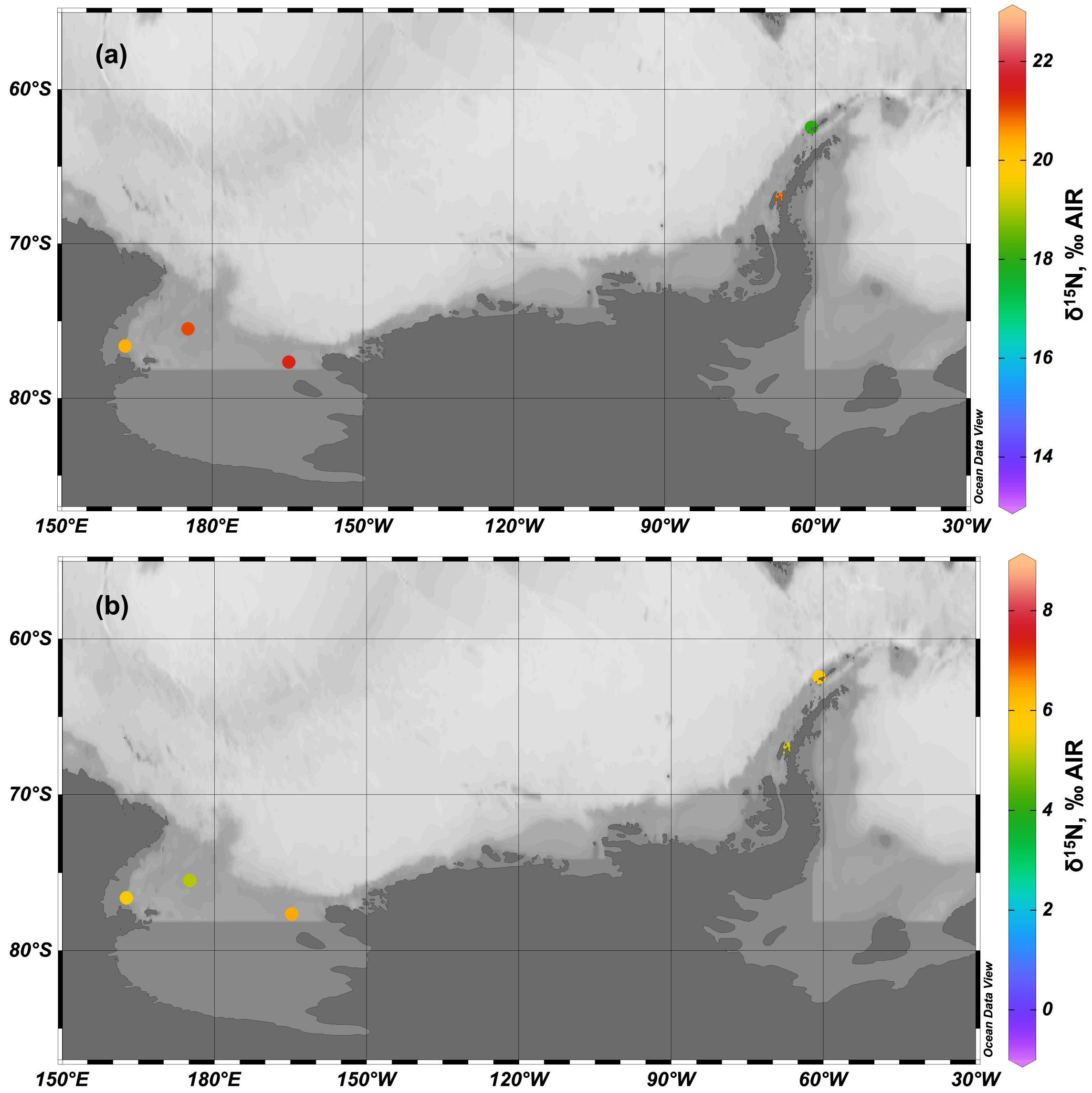

Fig. S4. Spatial variation in δ^{15}N values of Pro (a) and Phe (b) values for Weddell seals. Figures were produced in Ocean Data View 4.7.4 (Schlitzer 2015).

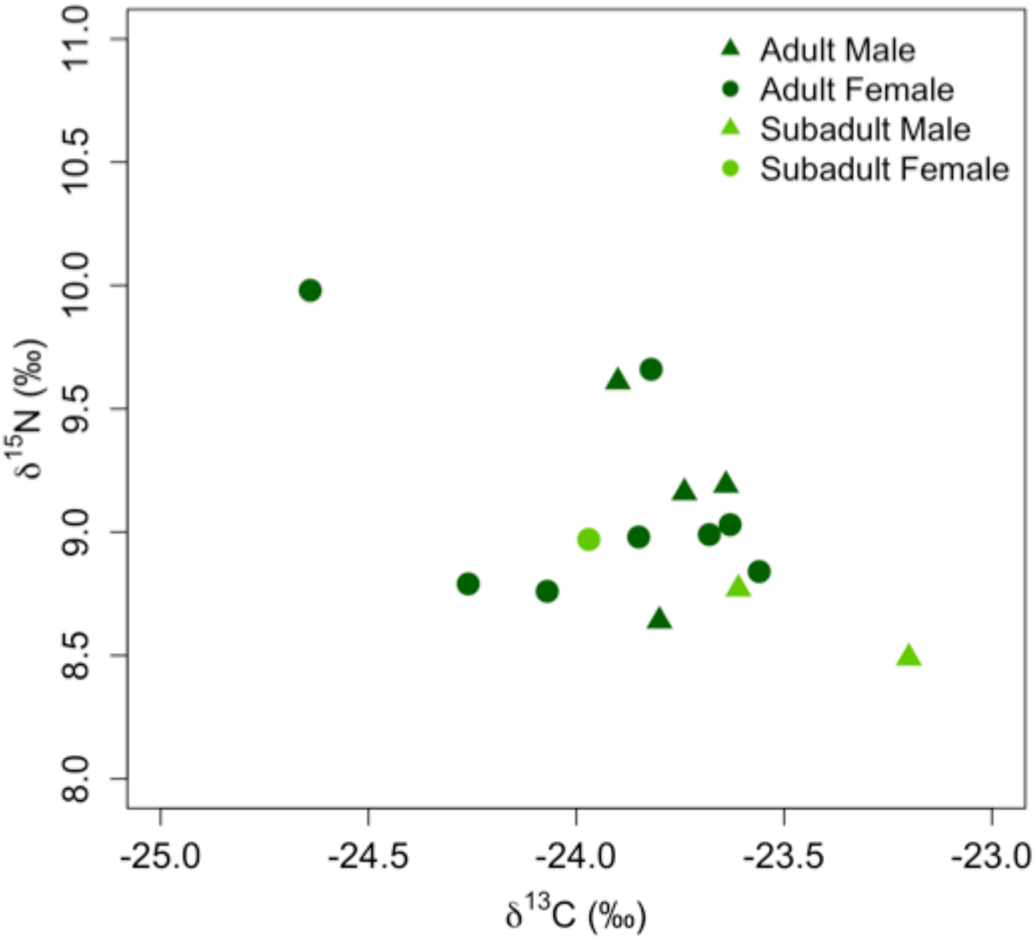

Fig. S5. Bulk $\delta^{13}C$ and $\delta^{15}N$ for Ross Seals. Age class and gender are indicated with colors (light green for subadults and dark green for adults) and shapes (triangles and circles for males and females, correspondingly).

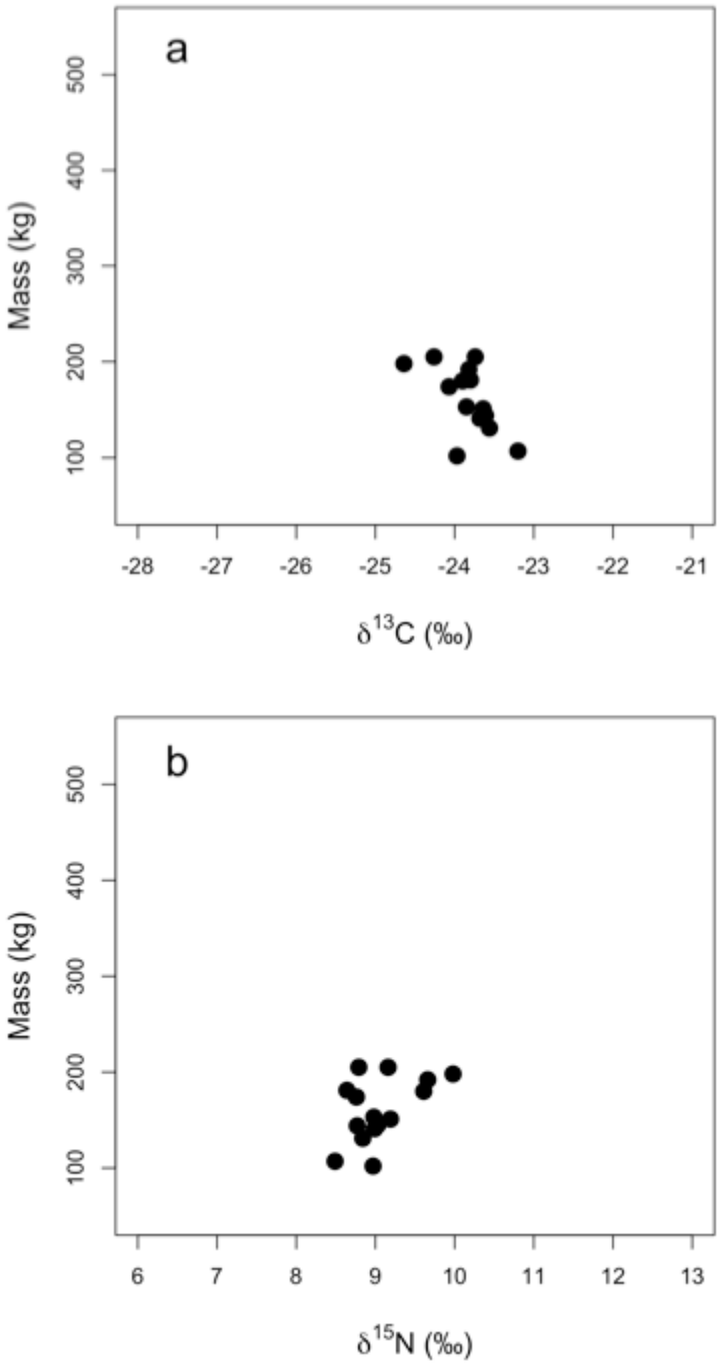

Fig. S6. Mass (kg) versus bulk $\delta^{13}C$ (a) and $\delta^{15}N$ (b) values for Ross Seals.

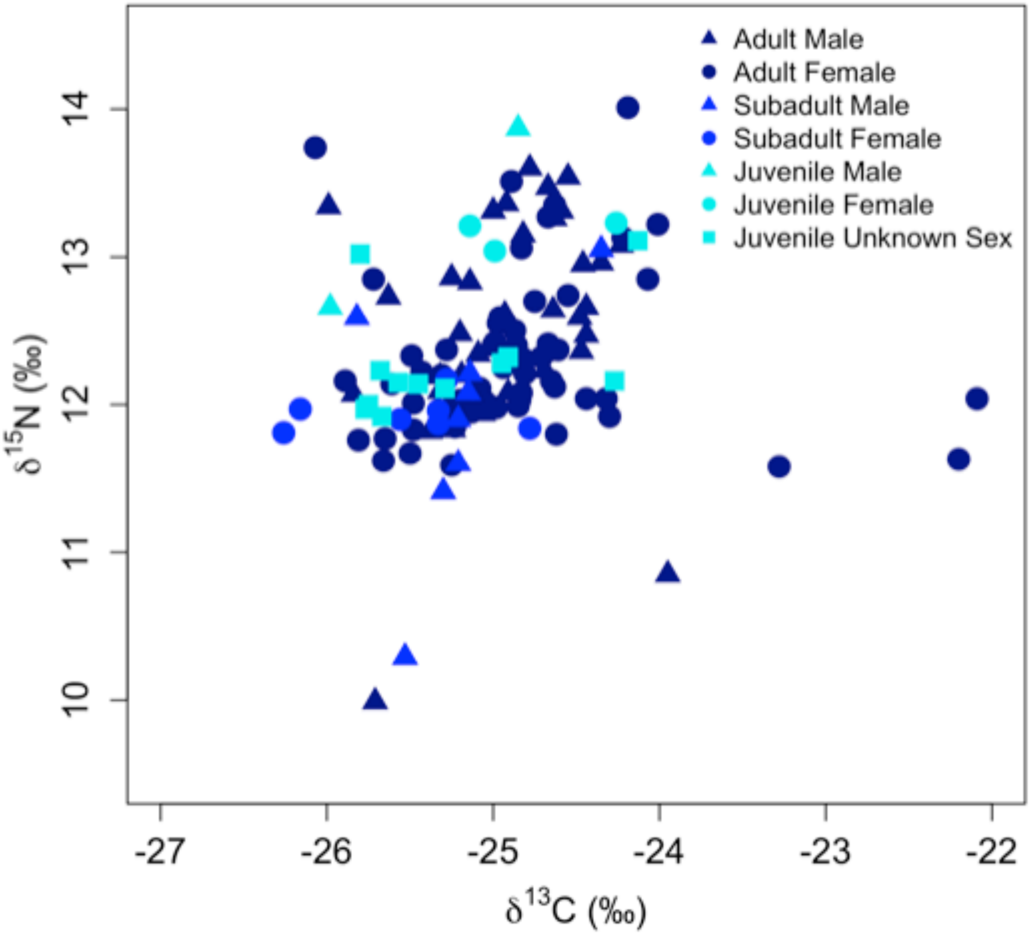

Fig. S7. Bulk $\delta^{13}C$ and $\delta^{15}N$ for Weddell Seals. Age class and gender are indicated with colors (light blue for juveniles, medium blue for subadults, and dark blue for adults) and shapes (triangles, circles, and squares for males, females, and unknown sex, correspondingly).

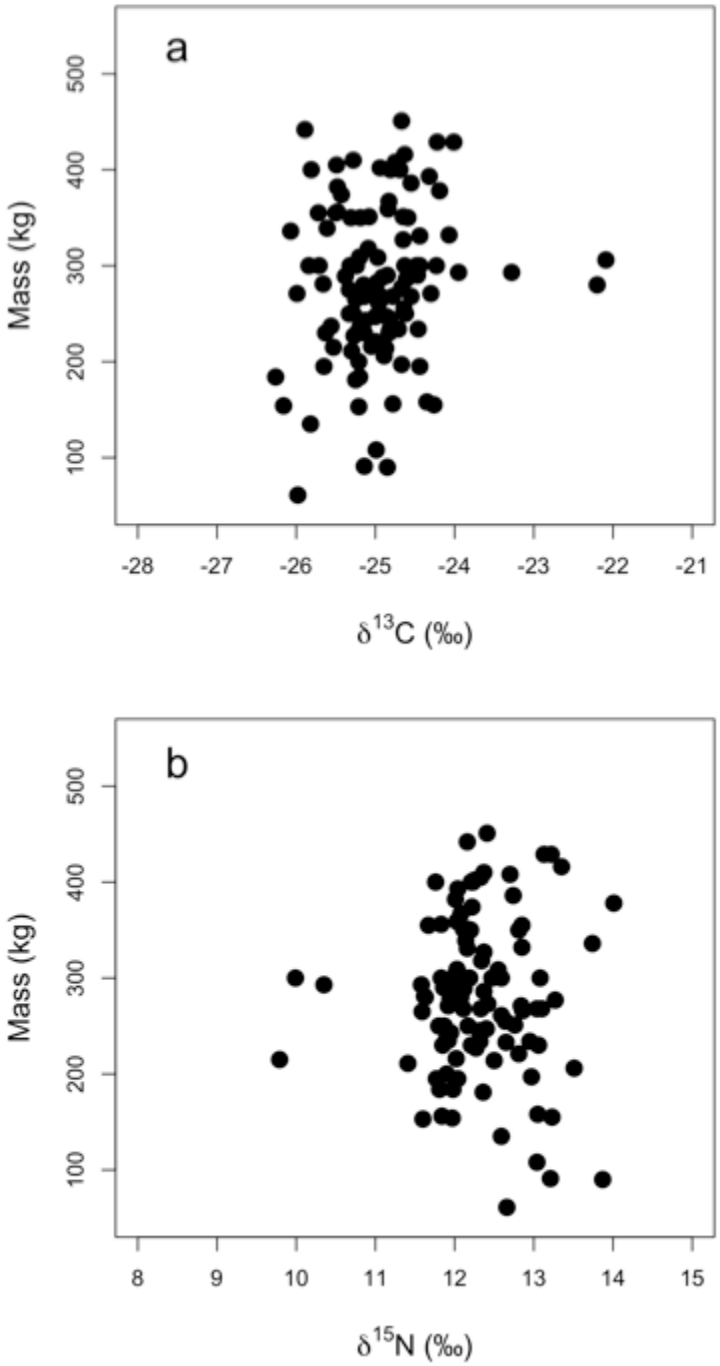

Fig. S8. Mass (kg) versus bulk $\delta^{13}C$ (a) and $\delta^{15}N$ (b) values of Weddell Seals.

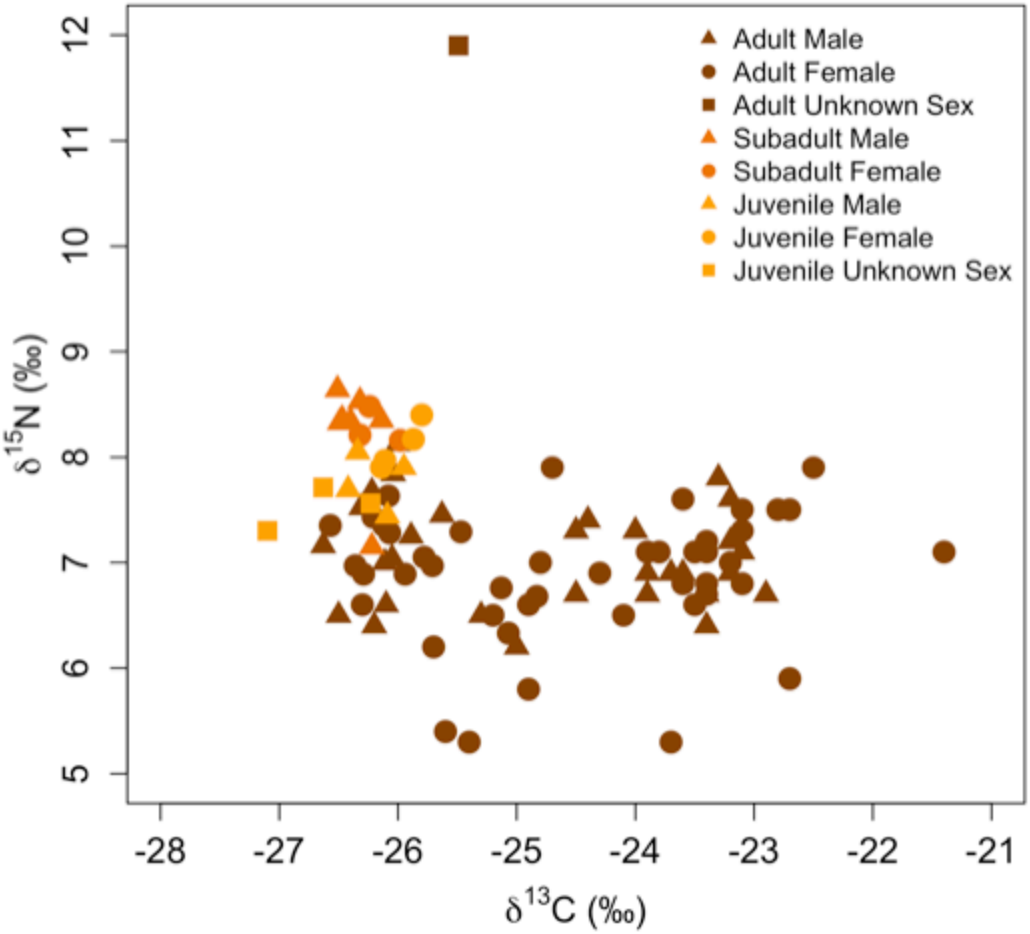

Fig. S9. Bulk $\delta^{13}C$ and $\delta^{15}N$ for Crabeater Seals. Age class and gender are indicated with colors (light orange for juveniles, medium orange for subadults, and dark orange for adults) and shapes (triangles, circles, and squares for males, females, and unknown sex, correspondingly).

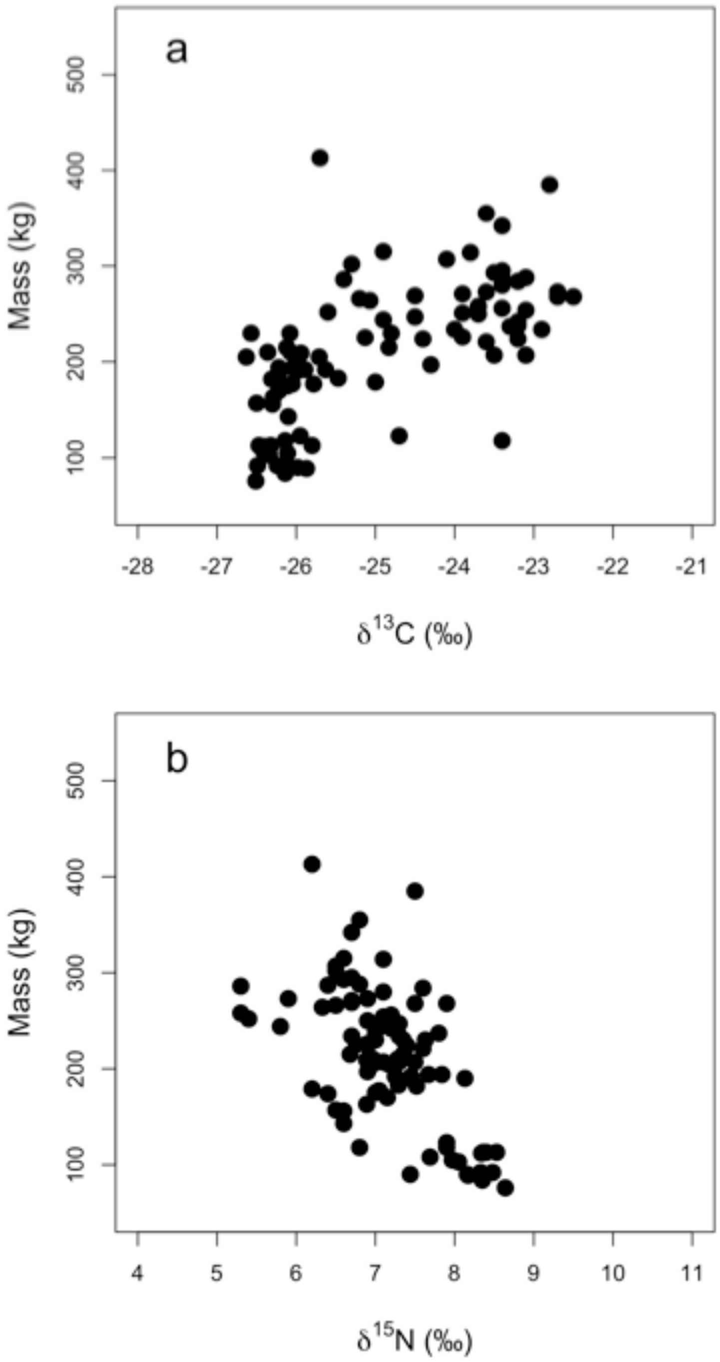

Fig. S10. Mass (kg) versus bulk δ^{13}C (a) and δ^{15}N (b) values of crabeater Seals.

Table S1. Sample information for Antarctic Seals. In cases where multiple sample types were obtained from a seal, we indicate the tissue from which isotopic values were used in figures and statistical analyses. Negative latitude and longitude indicate degrees south and west, respectively. Abbreviations: DD, decimal degrees; WB, whole blood; RBCs, red blood cells; F, female; M, male; na, information not available; Su, summer; Sp, spring; F, fall; W, winter; Oden, *RV Oden* cruises; MCM, McMurdo Station region; WAP, West Antarctic Peninsula area; Ad, adult; Sub, subadult; Juv, juvenile; Lat, latitude; Long, longitude.

Species	**Sample ID**	**Source**	**Season**	**Sample Type**	**Age Class**	**Sex**	**Weight (kg)**	**Lat (DD)**	**Long (DD)**
Crabeater	C02	*Oden*	Su 2010/11	Clot	Ad	F	163	-68.6	-102.3
	C03	*Oden*	Su 2008/09	WB	Sub	F	na	-70.6	-107.0
	C03	*Oden*	Su 2010/11	Clot	Ad	F	210	-68.6	-102.5
	C04	*Oden*	Su 2008/09	WB	Sub	M	92	-70.6	-107.0
	C06	*Oden*	Su 2008/09	WB	Sub	M	76	-71.1	-110.5
	C07	*Oden*	Su 2008/09	WB	Sub	F	92	-71.1	-110.5
	C07	*Oden*	Su 2010/11	Hair	Ad	F	205	-69.5	-103.7
	C10	*Oden*	Su 2010/11	Hair	Ad	F	225.4	-69.5	-103.7
	C11	*Oden*	Su 2010/11	Hair	Ad	F	264	-69.5	-103.7
	C14	*Oden*	Su 2010/11	Clot	Ad	F	215	-70.1	-107.4
	C15	*Oden*	Su 2010/11	WB	Sub	M	170	-70.1	-107.4
	C20	*Oden*	Su 2008/09	WB	Ad	M	190	-72.6	-116.0
	C20	*Oden*	Su 2010/11	RBCs	Juv	M	90	-72.7	-114.2
	C21	*Oden*	Su 2008/09	Clot	Sub	M	112	-72.6	-116.0
	C21	*Oden*	Su 2010/11	RBCs	Juv	M	103	-72.7	-114.2
	C22	*Oden*	Su 2008/09	Clot	Sub	M	113	-72.6	-116.0
	C32	*Oden*	Su 2008/09	WB	Ad	F	230	-70.2	-119.9
	C33	*Oden*	Su 2008/09	WB	Ad	M	194	-70.2	-119.9
	C43	*Oden*	Su 2008/09	WB	Ad	F	190	-69.4	-125.3
	C44	*Oden*	Su 2008/09	WB	Ad	M	182	-69.4	-125.3
	C45	*Oden*	Su 2008/09	WB	Ad	F	230	-70.2	-133.5
	C46	*Oden*	Su 2008/09	WB	Sub	F	90	-72.5	-146.5
	C47	*Oden*	Su 2008/09	WB	Ad	M	192	-74.4	-150.7
	C48	*Oden*	Su 2008/09	WB	Ad	F	177	-74.4	-150.7
	C50	*Oden*	Su 2008/09	WB	Sub	M	84	-75.4	-151.3

	C51	*Oden*	Su 2008/09	WB	Ad	F	210	-75.4	-151.3
	C52	*Oden*	Su 2008/09	WB	Ad	F	183	-75.4	-151.3
	C143	*Oden*	Su 2010/11	WB	Juv	F	105	-72.1	-119.7
	C144	*Oden*	Su 2010/11	WB	Juv	F	118	-72.1	-119.7
	C153	*Oden*	Su 2010/11	WB	Ad	M	192	-72.1	-123.5
	C154	*Oden*	Su 2010/11	WB	Ad	M	177	-72.1	-123.5
	C155	*Oden*	Su 2010/11	Hair	Juv	M	108	-72.2	-126.7
	C156	*Oden*	Su 2010/11	WB	Juv	M	123	-72.2	-126.7
	C157	*Oden*	Su 2010/11	WB	Juv	F	113	-72.2	-126.7
	C158	*Oden*	Su 2010/11	WB	Juv	F	89	-72.2	-126.7
	C173	*Oden*	Su 2010/11	WB	Ad	F	209	-72.8	-135.6
	C174	*Oden*	Su 2010/11	WB	Ad	M	175	-75.3	-139.5
	C175	*Oden*	Su 2010/11	Hair	Ad	F	215	-73.3	-139.5
	C176	*Oden*	Su 2010/11	WB	Ad	M	205	-73.3	-139.5
	C177	*Oden*	Su 2010/11	WB	Ad	M	194	-75.8	-150.0
	Cr 1	MCM	Su 2009/10	Hair	Juv	na	na	-77.6	166.2
	Cr Royds	MCM	Su 2009/10	Hair	Juv	na	na	-77.6	166.2
	Cr 2	MCM	Su 2009/10	Hair	Juv	na	na	-77.6	166.2
	CS11-01	MCM	Su 2010/11	WB	Ad	na	na	-77.7	166.5
	G001	Hückstädt et al. (2012a)	F 2001	Whisker	Ad	F	na	-67.3	-67.6
	G003	Hückstädt et al. (2012a)	F 2001	Whisker	Ad	F	258	-67.3	-67.6
	G004	Hückstädt et al. (2012a)	F 2001	Whisker	Ad	M	342	-69.2	-72.3
	G005	Hückstädt et al. (2012a)	F 2001	Whisker	Ad	F	293	-69.3	-72.4
	G006	Hückstädt et al. (2012a)	F 2001	Whisker	Ad	F	413	-69.3	-72.5
	G007	Hückstädt et al. (2012a)	F 2001	Whisker	Ad	M	287	-69.3	-72.5

	G008	Hückstädt et al. (2012a)	F 2001	Whisker	Ad	F	355	-69.1	-72.4
	G009	Hückstädt et al. (2012a)	W 2001	Whisker	Ad	M	179	-67.7	-69.3
	G010	Hückstädt et al. (2012a)	W 2001	Whisker	Ad	F	307	-68.1	-70.4
	G012	Hückstädt et al. (2012a)	W 2001	Whisker	Ad	F	288	-68.1	-70.2
	G013	Hückstädt et al. (2012a)	W 2001	Whisker	Ad	M	234	-68.1	-70.2
	G014	Hückstädt et al. (2012a)	W 2001	Whisker	Ad	M	284	-68.1	-70.1
	G015	Hückstädt et al. (2012a)	W 2001	Whisker	Ad	M	234	-67.2	-70.2
	G016	Hückstädt et al. (2012a)	W 2001	Whisker	Ad	F	273	-67.4	-70.9
	G017	Hückstädt et al. (2012a)	F 2002	Whisker	Ad	F	118	-66.4	-66.8
	G018	Hückstädt et al. (2012a)	F 2002	Whisker	Ad	M	157	-66.8	-66.8
	G019	Hückstädt et al. (2012a)	F 2002	Whisker	Ad	F	156	-66.8	-66.8
	G020	Hückstädt et al. (2012a)	F 2002	Whisker	Ad	M	143	-66.6	-67.5
	G021	Hückstädt et al. (2012a)	F 2002	Whisker	Ad	M	271	-66.6	-67.5
	G022	Hückstädt et al. (2012a)	F 2002	Whisker	Ad	F	268	-67.4	-67.7
	G023	Hückstädt et al. (2012a)	F 2002	Whisker	Ad	M	174	-67.6	-68.2
	G024	Hückstädt et al. (2012a)	F 2002	Whisker	Ad	F	256	-67.6	-69.0
	G026	Hückstädt et al. (2012a)	F 2002	Whisker	Ad	F	266	-67.6	-69.0
	G027	Hückstädt et al. (2012a)	F 2002	Whisker	Ad	M	226	-66.6	-67.5

	G028	Hückstädt et al. (2012a)	F 2002	Whisker	Ad	F	314	-68.5	-69.8
	G029	Hückstädt et al. (2012a)	F 2002	Whisker	Ad	M	242	-68.7	-70.0
	G030	Hückstädt et al. (2012a)	F 2002	Whisker	Ad	M	250	-66.6	-67.5
	G031	Hückstädt et al. (2012a)	F 2002	Whisker	Ad	F	385	-66.3	-66.6
	G032	Hückstädt et al. (2012a)	F 2002	Whisker	Ad	F	230	-68.8	-69.9
	G033	Hückstädt et al. (2012a)	W 2002	Whisker	Ad	F	268	-66.3	-66.7
	G034	Hückstädt et al. (2012a)	W 2002	Whisker	Ad	F	295	-66.5	-67.1
	G035	Hückstädt et al. (2012a)	W 2002	Whisker	Ad	F	238	-66.4	-66.9
	G036	Hückstädt et al. (2012a)	W 2002	Whisker	Ad	F	207	-66.4	-66.9
	G038	Hückstädt et al. (2012a)	W 2002	Whisker	Ad	M	273	-67.2	-70.6
	G039	Hückstädt et al. (2012a)	W 2002	Whisker	Ad	M	247	-68.6	-76.0
	G040	Hückstädt et al. (2012a)	W 2002	Whisker	Ad	M	302	-68.5	-75.8
	G041	Hückstädt et al. (2012a)	W 2002	Whisker	Ad	M	269	-68.1	-75.0
	G042	Hückstädt et al. (2012a)	W 2002	Whisker	Ad	M	224	-68.0	-74.9
	G043	Hückstädt et al. (2012a)	W 2002	Whisker	Ad	M	224	-68.0	-74.8
	G044	Hückstädt et al. (2012a)	W 2002	Whisker	Ad	F	280	-65.7	-68.7
	G045	Hückstädt et al. (2012a)	W 2002	Whisker	Ad	F	221	-65.6	-68.6
	G046	Hückstädt et al. (2012a)	W 2002	Whisker	Ad	M	237	-65.5	-68.5

	G047	Hückstädt et al. (2012a)	W 2002	Whisker	Ad	M	254	-65.7	-68.5
	G102	Hückstädt et al. (2012a)	F 2007	Whisker	Ad	F	286	-67.2	-66.9
	G104	Hückstädt et al. (2012a)	F 2007	Whisker	Ad	F	197	-67.2	-66.9
	G105	Hückstädt et al. (2012a)	F 2007	Whisker	Ad	F	251	-67.2	-66.8
	G106	Hückstädt et al. (2012a)	F 2007	Whisker	Ad	F	207	-67.2	-66.8
	G107	Hückstädt et al. (2012a)	F 2007	Whisker	Ad	F	315	-67.0	-67.4
	G108	Hückstädt et al. (2012a)	F 2007	Whisker	Ad	F	207	-67.2	-66.8
	G110	Hückstädt et al. (2012a)	F 2007	Whisker	Ad	F	123	-67.1	-66.8
	G112	Hückstädt et al. (2012a)	F 2007	Whisker	Ad	F	252	-65.2	-64.2
	G113	Hückstädt et al. (2012a)	F 2007	Whisker	Ad	F	244	-66.1	-65.4
	W02	*Oden*	Su 2008/09	WB	Sub	M	113	-71.7	-112.2
Weddell	W01	*Oden*	Su 2010/11	Hair	Ad	M	251	-72.6	-115.1
	W02	*Oden*	Su 2010/11	Hair	Ad	F	300	-72.6	-115.1
	W04	*Oden*	Su 2010/11	Clot	Ad	F	400	-72.8	-114.4
	W06	*Oden*	Su 2010/11	Clot	Ad	M	400	-72.9	-114.2
	W10	*Oden*	Su 2008/09	WB	Sub	F	156	-77.3	-165.5
	W11	*Oden*	Su 2008/09	WB	Sub	M	153	-77.3	-165.5
	W12	*Oden*	Su 2008/09	WB	Ad	M	318	-77.3	-165.5
	W14	*Oden*	Su 2008/09	WB	Ad	M	288	-77.3	-165.5
	W15	*Oden*	Su 2008/09	WB	Sub	M	211	-77.3	-165.5
	W17	*Oden*	Su 2008/09	WB	Ad	M	278	-77.3	-165.5
	W19	*Oden*	Su 2008/09	WB	Ad	F	309	-77.3	-165.5
	W103	*Oden*	Su 2010/11	WB	Ad	M	300	-72.6	-115.1

	W112	*Oden*	Su 2010/11	Hair	Ad	M	350	-72.9	-114.0
	W113	*Oden*	Su 2010/11	WB	Ad	M	255	-72.9	-114.0
	W116	*Oden*	Su 2010/11	WB	Ad	M	300	-71.7	-115.5
	W117	*Oden*	Su 2010/11	WB	Ad	F	290	-71.7	-115.5
	W118	*Oden*	Su 2010/11	WB	Ad	F	216	-71.7	-115.5
	W130	*Oden*	Su 2010/11	WB	Sub	M	158	-72.5	-116.6
	W133	*Oden*	Su 2010/11	WB	Ad	M	300	-72.5	-116.6
	W136	*Oden*	Su 2010/11	WB	Ad	F	235	-72.9	-116.9
	W137	*Oden*	Su 2010/11	WB	Ad	F	243	-72.9	-116.9
	W155	*Oden*	Su 2010/11	WB	Juv	F	155	-72.1	-119.2
	W157	*Oden*	Su 2010/11	WB	Juv	F	108	-72.1	-119.2
	W174	*Oden*	Su 2010/11	WB	Ad	F	250	-72.1	-119.7
	W175	*Oden*	Su 2010/11	WB	Ad	M	300	-72.1	-119.7
	W176	*Oden*	Su 2010/11	WB	Ad	M	na	-72.1	-119.7
	W177	*Oden*	Su 2010/11	WB	Ad	M	234	-72.1	-119.7
	W182	*Oden*	Su 2010/11	Hair	Sub	M	215	-72.8	-135.8
	W185	*Oden*	Su 2010/11	WB	Ad	F	400	-75.5	-184.9
	W186	*Oden*	Su 2010/11	WB	Sub	F	154	-75.5	-184.9
	W208	*Oden*	Su 2010/11	WB	Sub	M	135	-78.7	-164.2
	W209	*Oden*	Su 2010/11	WB	Juv	M	61	-78.7	-164.2
	W214	*Oden*	Su 2010/11	WB	Sub	F	184	-77.6	-166.3
	W216	*Oden*	Su 2010/11	WB	Juv	F	91	-77.6	-166.3
	W219	*Oden*	Su 2010/11	WB	Sub	F	237	-77.7	-164.7
	W220	*Oden*	Su 2010/11	WB	Ad	F	261	-77.7	-164.7
	W222	*Oden*	Su 2010/11	WB	Ad	M	350	-77.7	-164.7
	W223	*Oden*	Su 2010/11	WB	Juv	M	90	-77.7	-164.7
	WS10-11	MCM	Su 2009/10	RBCs	Ad	F	308.5	-75.8	162.8
	WS10-12	MCM	Su 2009/10	RBCs	Ad	F	282.5	-75.8	162.8
	WS10-13	MCM	Su 2009/10	RBCs	Ad	F	245	-75.8	162.8

	WS10-17	MCM	Su 2009/10	RBCs	Ad	F	356	-76.5	162.8
	WS10-18	MCM	Su 2009/10	RBCs	Ad	F	265	-76.5	162.8
	WS11-11	MCM	Su 2010/11	WB	Ad	F	281	-76.6	162.7
	WS11-12	MCM	Su 2010/11	WB	Ad	F	355	-77.9	166.8
	WS11-13	MCM	Su 2010/11	WB	Ad	F	247	-76.9	162.5
	WS11-14	MCM	Su 2010/11	WB	Ad	F	286	-76.6	162.7
	WS11-15	MCM	Su 2010/11	WB	Ad	F	195	-77.2	163.5
	WS12-11	MCM	Su 2011/12	RBCs	Ad	F	273	-76.9	162.8
	WS12-12	MCM	Su 2011/12	RBCs	Ad	F	374	-77.9	166.8
	WS12-13	MCM	Su 2011/12	RBCs	Ad	F	410	-77.9	166.8
	WS12-14	MCM	Su 2011/12	RBCs	Ad	M	227	-76.1	162.4
	WS12-15	MCM	Su 2011/12	RBCs	Ad	M	289	-76.5	162.7
	WS12-22	MCM	Sp 2012	WB	Ad	F	451	-77.7	166.5
	WS12-23	MCM	Sp 2012	WB	Ad	F	442	-77.7	166.9
	WS12-24	MCM	Sp 2012	WB	Ad	F	339	-77.7	166.8
	WS12-25	MCM	Sp 2012	WB	Ad	F	355	-77.7	166.9
	WS12-26	MCM	Sp 2012	WB	Ad	F	408	-77.7	166.7
	G103	WAP	F 2007	Serum	Ad	F	306	-67.2	-66.9
	G111	WAP	F 2007	Plasma	Ad	F	280	-67.1	-66.8
	LW11-03	MCM	Su 2010/11	WB	Juv	na	na	-74.9	163.7
	LW11-05	MCM	Su 2010/11	WB	Juv	na	na	-74.9	163.7
	LW11-06	MCM	Su 2010/11	WB	Juv	na	na	-74.9	163.7
	LW11-07	MCM	Su 2010/11	WB	Juv	na	na	-74.9	163.7
	LW11-08	MCM	Su 2010/11	WB	Juv	na	na	-74.9	163.7
	LW11-09	MCM	Su 2010/11	WB	Juv	na	na	-74.9	163.7
	LW11-10	MCM	Su 2010/11	WB	Juv	na	na	-74.9	163.7
	LW11-11	MCM	Su 2010/11	WB	Juv	na	na	-74.9	163.7
	LW11-12	MCM	Su 2010/11	WB	Juv	na	na	-74.9	163.7
	LW11-13	MCM	Su 2010/11	WB	Juv	na	na	-74.9	163.7

	LW11-14	MCM	Su 2010/11	WB	Juv	na	na	-74.9	163.7
	LW11-15	MCM	Su 2010/11	WB	Juv	na	na	-74.9	163.7
	LW15-01	MCM	Sp 2015	WB	Ad	M	300	-77.8	166.8
	LW15-02	MCM	Sp 2015	WB	Sub	M	280	-77.8	166.8
	LW15-03	MCM	Sp 2015	WB	Ad	M	300	-77.8	166.8
	LW15-04	MCM	Sp 2015	WB	Ad	M	300	-77.8	166.8
	LW15-05	MCM	Sp 2015	WB	Ad	M	300	-77.8	166.8
	LW15-06	MCM	Sp 2015	WB	Ad	M	300	-77.7	166.4
	LW15-07	MCM	Sp 2015	WB	Ad	F	350	-77.7	166.4
	LW15-08	MCM	Sp 2015	WB	Sub	F	250	-77.8	166.8
	LW15-09	MCM	Sp 2015	WB	Sub	F	275	-77.7	166.3
	LW15-10	MCM	Sp 2015	WB	Sub	M	230	-77.7	166.4
	LW15-11	MCM	Sp 2015	WB	Sub	F	250	-77.7	166.4
	LW15-12	MCM	Sp 2015	WB	Sub	M	200	-77.7	166.4
	W006	WAP	Su 2009/10	Whisker	Ad	M	293	-62.5	-60.8
	W013	WAP	Su 2009/10	Whisker	Ad	F	293	-62.5	-60.8
	WS10-01	Goetz et al. (2017)	Su 2009/10	Whisker	Ad	F	327	-77.8	166.8
	WS10-02	Goetz et al. (2017)	Su 2009/10	Whisker	Ad	F	378	-77.7	166.8
	WS10-03	Goetz et al. (2017)	Su 2009/10	Whisker	Ad	F	214	-77.7	166.7
	WS10-04	Goetz et al. (2017)	Su 2009/10	Whisker	Ad	F	195	-77.7	166.7
	WS10-05	Goetz et al. (2017)	Su 2009/10	Whisker	Ad	F	271	-77.7	166.7
	WS10-06	Goetz et al. (2017)	Su 2009/10	Whisker	Ad	M	271	-77.6	166.2
	WS10-07	Goetz et al. (2017)	Su 2009/10	Whisker	Ad	F	234	-77.7	166.7
	WS10-19	Goetz et al. (2017)	Su 2009/10	Whisker	Ad	M	184	-76.6	162.7
	WS10-20	Goetz et al. (2017)	Su 2009/10	Whisker	Ad	M	181	-76.6	162.7
	WS10-21	Goetz et al. (2017)	Su 2009/10	Whisker	Ad	F	393	-77.8	166.8
	WS10-22	Goetz et al. (2017)	Su 2009/10	Whisker	Ad	M	290	-77.8	166.8

	WS11-03	Goetz et al. (2017)	Su 2010/11	Whisker	Ad	F	367	-77.9	166.8
	WS11-04	Goetz et al. (2017)	Su 2010/11	Whisker	Ad	F	402	-77.9	166.8
	WS11-05	Goetz et al. (2017)	Su 2010/11	Whisker	Ad	M	197	-76.6	162.7
	WS11-06	Goetz et al. (2017)	Su 2010/11	Whisker	Ad	F	206	-76.6	162.7
	WS11-08	Goetz et al. (2017)	Su 2010/11	Whisker	Ad	F	277	-76.6	162.7
	WS11-09	Goetz et al. (2017)	Su 2010/11	Whisker	Ad	F	336	-77.9	166.8
	WS11-17	Goetz et al. (2017)	Su 2010/11	Whisker	Ad	F	359	-77.9	166.7
	WS11-18	Goetz et al. (2017)	Su 2010/11	Whisker	Ad	F	247	-77.9	166.7
	WS11-19	Goetz et al. (2017)	Su 2010/11	Whisker	Ad	M	266	-77.7	166.7
	WS11-21	Goetz et al. (2017)	Su 2010/11	Whisker	Ad	F	382	-77.9	166.8
	WS11-37	Goetz et al. (2017)	Su 2011/12	Whisker	Ad	M	331	-77.4	166.3
	WS11-38	Goetz et al. (2017)	Su 2011/12	Whisker	Ad	M	268	-77.4	166.3
	WS11-39	Goetz et al. (2017)	Su 2011/12	Whisker	Ad	M	268	-77.7	166.3
	WS11-40	Goetz et al. (2017)	Su 2011/12	Whisker	Ad	M	268	-77.7	166.3
	WS11-41	Goetz et al. (2017)	Su 2011/12	Whisker	Ad	M	268	-77.7	166.3
	WS12-01	Goetz et al. (2017)	Su 2011/12	Whisker	Ad	F	405	-77.9	166.8
	WS12-02	Goetz et al. (2017)	Su 2011/12	Whisker	Ad	F	351	-77.0	162.8
	WS12-04	Goetz et al. (2017)	Su 2011/12	Whisker	Ad	F	351	-77.9	166.8
	WS12-05	Goetz et al. (2017)	Su 2011/12	Whisker	Ad	F	386	-76.6	166.7
	WS12-06	Goetz et al. (2017)	Su 2011/12	Whisker	Ad	F	332	-76.5	166.8
	WS12-07	Goetz et al. (2017)	Su 2011/12	Whisker	Ad	F	416	-77.8	166.8
	WS12-08	Goetz et al. (2017)	Su 2011/12	Whisker	Ad	F	429	-77.8	166.8
	WS12-09	Goetz et al. (2017)	Su 2011/12	Whisker	Ad	F	429	-77.8	166.8
	WS12-10	Goetz et al. (2017)	Su 2011/12	Whisker	Ad	M	221	-76.6	162.9
	WS12-16	Goetz et al. (2017)	Su 2011/12	Whisker	Ad	M	230	-76.5	162.7
	WS12-17	Goetz et al. (2017)	Su 2011/12	Whisker	Ad	F	230	-77.8	166.8
	WS12-19	Goetz et al. (2017)	Su 2011/12	Whisker	Ad	F	230	-77.9	166.8

	WS12-20	Goetz et al. (2017)	Su 2011/12	Whisker	Ad	M	233	-76.1	163.1
Ross	R01	*Oden*	Su 2008/09	WB	Sub	M	107	-69.4	-125.3
	R101	*Oden*	Su 2010/11	WB	Ad	M	180	-72.1	-123.2
	R102	*Oden*	Su 2010/11	WB	Ad	F	145	-72.2	-123.2
	R103	*Oden*	Su 2010/11	WB	Sub	F	102	-72.1	-123.1
	R104	*Oden*	Su 2010/11	WB	Ad	M	205	-72.1	-123.5
	R105	*Oden*	Su 2010/11	WB	Ad	M	151	-72.2	-126.9
	R106	*Oden*	Su 2010/11	WB	Ad	F	174	-72.1	-127.0
	R107	*Oden*	Su 2010/11	WB	Ad	F	131	-72.2	-127.6
	R108	*Oden*	Su 2010/11	WB	Ad	F	198	-72.2	-132.9
	R109	*Oden*	Su 2010/11	WB	Ad	F	153	-72.2	-133.0
	R110	*Oden*	Su 2010/11	Hair	Ad	F	205	-72.9	-137.1
	R111	*Oden*	Su 2010/11	WB	Sub	M	144	-72.8	-136.0
	R112	*Oden*	Su 2010/11	WB	Ad	F	192	-73.4	-139.4
	R113	*Oden*	Su 2010/11	WB	Ad	F	141	-73.3	-139.4
	R114	*Oden*	Su 2010/11	WB	Ad	M	181	-75.8	-150.0

Table S2. Effect of lipid extraction on isotopic values of crabeater, Weddell, and Ross seals. Sample ID as in Table S1. Abbreviations: WB, whole blood without lipid extraction; LE, whole blood with lipid extraction. The difference in isotopic value between whole blood samples with and without lipid extraction is reported. The average difference is 0.0 ± 0.1 ‰ and 0.2 ± 0.1 ‰ for δ^{13}C and δ^{15}N, respectively. The average difference between the isotopic values with and without lipid extraction do not exceed the instrument error of 0.2 ‰ for either δ^{13}C and δ^{15}N values.

Species	**Sample ID**	**Year**	**Sample Type**	**δ^{13}C (‰)**	**LE δ^{13}C (‰)**	**δ^{15}N (‰)**	**LE δ^{15}N (‰)**	**δ^{13}C – LE δ^{13}C (‰)**	**δ^{15}N – LE δ^{15}N (‰)**
Crabeater	C03	2008	WB	-26.3	-26.5	8.2	8.0	0.2	0.2
	C06	2008	WB	-26.5	-26.6	8.6	8.5	0.1	0.1
	C07	2008	WB	-26.2	-26.3	8.5	8.3	0.1	0.2
	C20	2008	WB	-26.0	-26.0	8.1	7.9	0.0	0.2
	C46	2008	WB	-26.0	-26.0	8.2	8.1	0.0	0.1
	C52	2008	WB	-25.5	-25.7	7.3	7.1	0.2	0.2
	C153	2010	WB	-25.9	-25.9	7.3	7.2	0.0	0.1
	C154	2010	WB	-26.1	-26.1	7.0	6.9	0.0	0.1
	C176	2010	WB	-26.6	-26.7	7.2	7.0	0.1	0.2
Weddell	W12	2008	WB	-25.1	-25.1	12.3	12.1	0.0	0.2
	W15	2008	WB	-25.3	-25.3	11.4	11.2	0.0	0.2
	W117	2010	WB	-24.9	-24.9	12.0	11.8	0.0	0.2
	W216	2010	WB	-25.1	-25.2	13.2	13.1	0.1	0.1
	W223	2010	WB	-24.9	-24.9	13.9	13.8	0.0	0.1
Ross	R01	2008	WB	-23.2	-23.2	8.5	8.4	0.0	0.1
	R101	2010	WB	-23.9	-23.9	9.6	9.4	0.0	0.2
	R102	2010	WB	-23.6	-23.7	9.0	8.8	0.1	0.2
	R103	2010	WB	-24.0	-24.0	9.0	8.8	0.0	0.2
	R108	2010	WB	-24.6	-24.7	10.0	9.8	0.1	0.2
	R112	2010	WB	-23.8	-23.8	9.7	9.6	0.0	0.1
	R114	2010	WB	-23.7	-23.7	8.6	8.5	0.0	0.1

Table S3. Bulk $\delta^{13}C$ and $\delta^{15}N$ values of crabeater, Weddell, and Ross seals for multiple tissue types. These isotopic values are used to calculate the isotopic offsets between different tissue types, see Table S4 below. Abbreviations are as in Tables S1.

Species	ID	Year	WB		Clot		RBCs		Hair	
			$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Crabeater	C14	Su 2010/11			-26.1	7.3			-23.7	6.4
	C143	Su 2010/11	-26.1	8.0					-24.5	7.5
	C157	Su 2010/11	-25.8	8.4					-24.6	8.7
	C158	Su 2010/11	-25.9	8.2					-24.4	8.0
	C173	Su 2010/11	-25.9	6.9					-24.2	6.6
	C174	Su 2010/11	-26.1	7.0	-26.1	6.8			-24.4	7.5
	C176	Su 2010/11	-26.6	7.2			-26.8	6.9		
	C02	Su 2010/11			-26.3	6.9			-24.7	7.1
	C20	Su 2010/11					-26.1	7.4	-25.0	7.0
	C21	Su 2010/11					-26.3	8.1	-24.9	7.3
	C03	Su 2010/11			-26.4	7.0			-24.2	7.0
Weddell	WS12-22	Sp 2012	-24.7	12.4			-24.4	12.1		
	WS12-23	Sp 2012	-25.9	12.2			-25.3	11.7		
	WS12-24	Sp 2012	-25.6	12.1			-25.5	12.1		
	WS12-25	Sp 2012	-25.7	12.9			-25.0	12.0		
	WS12-26	Sp 2012	-24.8	12.7			-24.7	12.5		
	W116	Su 2010/11	-24.5	12.6					-23.2	12.9
	W117	Su 2010/11	-24.9	12.0					-23.3	12.7
	W118	Su 2010/11	-25.1	12.0	-24.9	11.9				
	W130	Su 2010/11	-24.4	13.1			-24.4	13.0		
	W133	Su 2010/11	-24.4	12.5					-23.0	13.1
	W136	Su 2010/11	-25.2	11.9	-25.3	12.0				
	W137	Su 2010/11	-25.1	12.0			-25.1	11.9	-23.6	12.8
	W176	Su 2010/11	-24.3	13.0					-22.9	13.0
	W208	Su 2010/11	-25.8	12.6			-25.9	12.4		

	W216	Su 2010/11	-25.1	13.2	-25.0	13.2				
	W219	Su 2010/11	-25.6	11.9	-25.4	11.9				
	W220	Su 2010/11	-25.0	12.6	-25.0	12.4				
	W04	Su 2010/11			-24.8	12.2			-23.5	12.6
	W06	Su 2010/11			-24.7	12.2			-23.5	12.2
Ross	R101	Su 2010/11	-23.9	9.6					-22.6	10.3
	R103	Su 2010/11	-24.0	9.0					-22.8	11.0
	R105	Su 2010/11	-23.6	9.2					-22.4	10.1
	R107	Su 2010/11	-23.6	8.8					-22.4	10.5
	R108	Su 2010/11	-24.6	10.0					-23.0	10.8

Table S4. Calculated isotopic offsets between different tissue types for crabeater, Weddell, and Ross seals. Abbreviations are as in Tables S1. If a calculated mean offset is ≤ 0.2 ‰, then the offset between the two tissue types is considered insignificant (less than instrumental error as indicated by the quality control standard).

Species	**Offset Type**	**Sample ID**	**δ^{13}C Offset (‰)**	**δ^{15}N Offset (‰)**	**Mean δ^{13}C Offset (‰)**	**Mean δ^{15}N Offset (‰)**
Crabeater	WB – Clot	C174	0.0	0.2	0.0	0.2
	WB – RBCs	C176	0.2	0.2	0.2	0.2
	WB – Hair	C143	-1.6	0.4	-1.6	0.0
		C157	-1.2	-0.3		
		C158	-1.5	0.2		
		C173	-1.7	0.3		
		C174	-1.7	-0.5		
	Clot – Hair	C14	-2.4	0.9	-2.0	0.0
		C174	-1.7	-0.7		
		C2	-1.5	-0.2		
		C3	-2.1	0.0		
	RBCs – Hair	C20	-1.1	0.4	-1.3	0.6
		C21	-1.5	0.8		
Weddell	WB – Clot	W118	-0.2	0.1	-0.1	0.1
		W136	0.1	-0.1		
		W216	-0.1	0.0		
		W219	-0.2	0.0		
		W220	0.0	0.2		
	WB – RBCs	WS12-22	-0.2	0.3	-0.2	0.3
		WS12-23	-0.6	0.4		
		WS12-24	-0.2	0.1		
		WS12-25	-0.7	0.9		
		WS12-26	-0.1	0.2		
		W130	0.1	0.1		
		W137	0.0	0.0		
		W208	0.0	0.2		
	WB – Hair	W116	-1.3	-0.3	-1.4	-0.5
		W117	-1.5	-0.7		
		W133	-1.4	-0.6		
		W137	-1.5	-0.9		
		W176	-1.4	0.0		
	Clot – Hair	W4	-1.3	-0.4	-1.2	-0.2
		W6	-1.2	0.0		
	RBCs – Hair	W137	-1.5	-0.9	-1.5	-0.9

Ross	WB – Hair	R101	-1.3	-0.7	-1.3	-1.2
		R103	-1.2	-2.0		
		R105	-1.2	-0.9		
		R107	-1.2	-1.6		
		R108	-1.6	-0.8		

Table S5. Bulk $\delta^{13}C$ and $\delta^{15}N$ values of Weddell seals for multiple blood sample types. These isotopic values are used to calculate the isotopic offsets between these different sample types, see Table S6 below. Abbreviations are as in Tables S1.

ID	**Year**	**WB**		**Plasma**		**Serum**		**RBCs**	
		$\delta^{13}C$ (‰)	**$\delta^{15}N$ (‰)**	**$\delta^{13}C$ (‰)**	**$\delta^{15}N$ (‰)**	**$\delta^{13}C$ (‰)**	**$\delta^{15}N$ (‰)**	**$\delta^{13}C$ (‰)**	**$\delta^{15}N$ (‰)**
LW15-01	Sp 2015	-25.8	12.1	-26.4	12.3	-26.2	12.7		
LW15-02	Sp 2015	-25.2	12.1	-25.6	13.0	-25.3	13.4		
LW15-03	Sp 2015	-25.3	12.1	-25.7	12.7	-25.5	13.1		
LW15-11	Sp 2015	-25.3	12.2	-26.2	12.8	-25.8	13.3		
LW15-12	Sp 2015	-25.2	11.9	-25.8	12.8	-25.5	13.3		
WS12-22	Sp 2012	-24.7	12.4					-24.4	12.1
WS12-23	Sp 2012	-25.9	12.2					-25.3	11.7
WS12-24	Sp 2012	-25.6	12.1					-25.5	12.1
WS12-25	Sp 2012	-25.7	12.9					-25.0	12.0
WS12-26	Sp 2012	-24.8	12.7					-24.7	12.5
W130	Su 2010/11	-24.4	13.1					-24.4	13.0
W137	Su 2010/11	-25.1	12.0					-25.1	11.9
W208	Su 2010/11	-25.8	12.6					-25.9	12.4

Table S6. Calculated isotopic offsets between different blood sample types for Weddell seals. Abbreviations are as in Tables S1. If a calculated mean offset is ≤ 0.2 ‰, then the offset between the two sample types is considered insignificant (less than instrumental error as indicated by the quality control standard).

Offset Type	**Sample ID**	**$\delta^{13}C$ Offset (‰)**	**$\delta^{15}N$ Offset (‰)**	**Mean $\delta^{13}C$ Offset (‰)**	**Mean $\delta^{15}N$ Offset (‰)**
Plasma – Serum	LW15-01	-0.2	-0.4	-0.3	-0.4
	LW15-02	-0.3	-0.4		
	LW15-03	-0.2	-0.4		
	LW15-11	-0.3	-0.5		
	LW15-12	-0.3	-0.5		
WB – Serum	LW15-01	0.4	-0.6	0.3	-1.1
	LW15-02	0.2	-1.3		
	LW15-03	0.1	-1.0		
	LW15-11	0.5	-1.2		
	LW15-12	0.3	-1.4		
WB – Plasma	LW15-01	0.5	-0.2	0.6	-0.7
	LW15-02	0.4	-0.9		
	LW15-03	0.4	-0.6		
	LW15-11	0.9	-0.7		
	LW15-12	0.6	-0.9		
WB – RBCs	WS12-22	-0.3	0.3	-0.2	0.3
	WS12-23	-0.6	0.5		
	WS12-24	-0.1	0.0		
	WS12-25	-0.7	0.9		
	WS12-26	-0.1	0.2		
	W130	0.1	0.1		
	W137	0.0	0.0		
	W208	0.0	0.2		

Table S7. Bulk $\delta^{13}C$ and $\delta^{15}N$ values of crabeater, Weddell, and Ross seals. Note, bulk $\delta^{13}C$ and $\delta^{15}N$ values are reported for the original measurement (Orig.) and with a correction to whole blood (Corr.) if the sample is a tissue type with a significant isotopic offset from whole blood. Isotopic offset between whole blood and the given sample type are reported in Tables S4 and S6, above. Atomic C:N ratios are from the original measurements. Samples with an asterisk and two asterisks are from Hückstädt et al. (2012a) and Goetz et al. (2017), correspondingly; all other data are from this study. Whisker data are from the segment representing the most recent time period, which best overlaps with the collection location and integrated time of blood tissues, except data from Hückstädt et al. (2012a) are an average for all segments. Abbreviations are as in Table S1. Additionally, "WAP," "RS," and "AM" abbreviate "West Antarctic Peninsula," "Ross Sea," and "Amundsen Sea," respectively.

Species	Sample ID	Season	Region	Sample Type	Orig. $\delta^{13}C$ (‰)	Orig. $\delta^{15}N$ (‰)	Corr. $\delta^{13}C$ (‰)	Corr. $\delta^{15}N$ (‰)	Atomic C:N
Crabeater	C02	Su 2010/11	AM	Clot	-26.3	6.9	–	–	3.8
	C03	Su 2008/09	AM	WB	-26.3	8.2	–	–	3.9
	C03	Su 2010/11	AM	Clot	-26.4	7.0	–	–	3.8
	C04	Su 2008/09	AM	WB	-26.5	8.3	–	–	4.0
	C06	Su 2008/09	AM	WB	-26.5	8.6	–	–	3.9
	C07	Su 2008/09	AM	WB	-26.2	8.5	–	–	3.9
	C07	Su 2010/11	AM	Hair	-24.1	7.0	-25.7	–	3.4
	C10	Su 2010/11	AM	Hair	-23.5	6.8	-25.1	–	3.4
	C11	Su 2010/11	AM	Hair	-23.5	6.3	-25.1	–	3.4
	C14	Su 2010/11	AM	Clot	-26.1	7.4	–	–	3.9
	C15	Su 2010/11	AM	WB	-26.2	7.2	–	–	3.9
	C20	Su 2008/09	AM	WB	-26.0	8.1	–	–	3.9
	C20	Su 2010/11	AM	RBCs	-26.1	7.4	–	–	3.8
	C21	Su 2008/09	AM	Clot	-26.4	8.3	–	–	3.9
	C21	Su 2010/11	AM	RBCs	-26.3	8.1	–	–	3.9
	C22	Su 2008/09	AM	Clot	-26.5	8.4	–	–	3.9
	C32	Su 2008/09	AM	WB	-26.1	7.6	–	–	3.9
	C33	Su 2008/09	AM	WB	-26.0	7.8	–	–	3.8
	C43	Su 2008/09	AM	WB	-26.2	7.4	–	–	3.9
	C44	Su 2008/09	AM	WB	-26.3	7.5	–	–	3.9
	C45	Su 2008/09	AM	WB	-26.6	7.4	–	–	3.9
	C46	Su 2008/09	AM	WB	-26.0	8.2	–	–	3.8
	C47	Su 2008/09	RS	WB	-25.6	7.5	–	–	3.9
	C48	Su 2008/09	RS	WB	-25.8	7.1	–	–	4.0
	C50	Su 2008/09	RS	WB	-26.1	8.4	–	–	4.0
	C51	Su 2008/09	RS	WB	-26.1	7.3	–	–	3.8
	C52	Su 2008/09	RS	WB	-25.5	7.3	–	–	3.8
	C143	Su 2010/11	AM	WB	-26.1	8.0	–	–	3.9
	C144	Su 2010/11	AM	WB	-26.1	7.9	–	–	3.9
	C153	Su 2010/11	AM	WB	-25.9	7.3	–	–	3.9
	C154	Su 2010/11	AM	WB	-26.1	7.0	–	–	3.9
	C155	Su 2010/11	AM	Hair	-24.8	7.7	-26.4	–	3.4
	C156	Su 2010/11	AM	WB	-26.0	7.9	–	–	3.9
	C157	Su 2010/11	AM	WB	-25.8	8.4	–	–	4.0
	C158	Su 2010/11	AM	WB	-25.9	8.2	–	–	4.0
	C173	Su 2010/11	AM	WB	-25.9	6.9	–	–	3.9
	C174	Su 2010/11	AM	WB	-26.1	7.0	–	–	3.9
	C175	Su 2010/11	AM	Hair	-23.2	6.7	-24.8	–	3.4
	C176	Su 2010/11	AM	WB	-26.6	7.2	–	–	3.9
	C177	Su 2010/11	RS	WB	-26.2	7.7	–	–	3.9
	Cr-1	Su 2009/10	RS	Hair	-25.0	7.7	-26.6	–	3.4
	Cr-CR	Su 2009/10	RS	Hair	-24.6	7.6	-26.2	–	3.4
	Cr-2	Su 2009/10	RS	Hair	-25.5	7.3	-27.1	–	3.4
	CS11-01	Su 2010/11	RS	WB	-25.5	11.9	–	–	4.0

	G001*	F 2001	WAP	Whisker	-19.8	7.1	-21.4	–	3.4
	G003*	F 2001	WAP	Whisker	-22.1	5.3	-23.7	–	3.5
	G004*	F 2001	WAP	Whisker	-21.8	6.7	-23.4	–	3.5
	G005*	F 2001	WAP	Whisker	-21.9	6.6	-23.5	–	3.5
	G006*	F 2001	WAP	Whisker	-24.1	6.2	-25.7	–	3.5
	G007*	F 2001	WAP	Whisker	-21.8	6.4	-23.4	–	3.4
	G008*	F 2001	WAP	Whisker	-22.0	6.8	-23.6	–	3.4
	G009*	W 2001	WAP	Whisker	-23.4	6.2	-25.0	–	3.4
	G010*	W 2001	WAP	Whisker	-22.5	6.5	-24.1	–	3.4
	G012*	W 2001	WAP	Whisker	-21.5	6.8	-23.1	–	3.5
	G013*	W 2001	WAP	Whisker	-21.3	6.7	-22.9	–	3.5
	G014*	W 2001	WAP	Whisker	-21.6	7.6	-23.2	–	3.4
	G015*	W 2001	WAP	Whisker	-22.4	7.3	-24.0	–	3.5
	G016*	W 2001	WAP	Whisker	-21.1	5.9	-22.7	–	3.5
	G017*	F 2002	WAP	Whisker	-21.8	6.8	-23.4	–	3.3
	G018*	F 2002	WAP	Whisker	-24.9	6.5	-26.5	–	3.3
	G019*	F 2002	WAP	Whisker	-24.7	6.6	-26.3	–	3.3
	G020*	F 2002	WAP	Whisker	-24.5	6.6	-26.1	–	3.3
	G021*	F 2002	WAP	Whisker	-22.3	6.7	-23.9	–	3.4
	G022*	F 2002	WAP	Whisker	-20.9	7.9	-22.5	–	3.4
	G023*	F 2002	WAP	Whisker	-24.6	6.4	-26.2	–	3.3
	G024*	F 2002	WAP	Whisker	-21.8	7.2	-23.4	–	3.3
	G026*	F 2002	WAP	Whisker	-23.6	6.5	-25.2	–	3.3
	G027*	F 2002	WAP	Whisker	-22.3	6.9	-23.9	–	3.3
	G028*	F 2002	WAP	Whisker	-22.2	7.1	-23.8	–	3.3
	G029*	F 2002	WAP	Whisker	-21.6	7.2	-23.2	–	3.3
	G030*	F 2002	WAP	Whisker	-22.1	6.9	-23.7	–	3.3
	G031*	F 2002	WAP	Whisker	-21.2	7.5	-22.8	–	3.3
	G032*	F 2002	WAP	Whisker	-23.2	7.0	-24.8	–	3.3
	G033*	W 2002	WAP	Whisker	-21.1	7.5	-22.7	–	3.3
	G034*	W 2002	WAP	Whisker	-21.8	6.7	-23.4	–	3.3
	G035*	W 2002	WAP	Whisker	-21.6	7.0	-23.2	–	3.3
	G036*	W 2002	WAP	Whisker	-21.5	7.3	-23.1	–	3.4
	G038*	W 2002	WAP	Whisker	-22.0	6.9	-23.6	–	3.4
	G039*	W 2002	WAP	Whisker	-22.9	7.3	-24.5	–	3.4
	G040*	W 2002	WAP	Whisker	-23.7	6.5	-25.3	–	3.4
	G041*	W 2002	WAP	Whisker	-22.9	6.7	-24.5	–	3.4
	G042*	W 2002	WAP	Whisker	-21.6	6.9	-23.2	–	3.5
	G043*	W 2002	WAP	Whisker	-22.8	7.4	-24.4	–	3.4
	G044*	W 2002	WAP	Whisker	-21.8	7.1	-23.4	–	3.5
	G045*	W 2002	WAP	Whisker	-22.0	7.6	-23.6	–	3.4
	G046*	W 2002	WAP	Whisker	-21.7	7.8	-23.3	–	3.4
	G047*	W 2002	WAP	Whisker	-21.5	7.1	-23.1	–	3.5
	G102*	F 2007	WAP	Whisker	-23.8	5.3	-25.4	–	na
	G104*	F 2007	WAP	Whisker	-22.7	6.9	-24.3	–	3.4
	G105*	F 2007	WAP	Whisker	-22.3	7.1	-23.9	–	na
	G106*	F 2007	WAP	Whisker	-21.9	7.1	-23.5	–	3.5
	G107*	F 2007	WAP	Whisker	-23.3	6.6	-24.9	–	na
	G108*	F 2007	WAP	Whisker	-21.5	7.5	-23.1	–	3.4
	G110*	F 2007	WAP	Whisker	-23.1	7.9	-24.7	–	na
	G112*	F 2007	WAP	Whisker	-24.0	5.4	-25.6	–	3.4
	G113*	F 2007	WAP	Whisker	-23.3	5.8	-24.9	–	3.5
	W02	Su 2008/09	AM	WB	-26.3	8.5	–	–	4.0
Weddell	W01	Su 2010/11	AM	Hair	-23.2	13.3	-24.6	12.8	3.5
	W02	Su 2010/11	AM	Hair	-23.2	12.6	-24.6	12.1	3.5
	W04	Su 2010/11	AM	Clot	-24.8	12.2	–	–	3.9

	W06	Su 2010/11	AM	Clot	-24.7	12.2	–	–	3.9
	W10	Su 2008/09	RS	WB	-24.8	11.8	–	–	3.9
	W11	Su 2008/09	RS	WB	-25.2	11.6	–	–	4.0
	W12	Su 2008/09	RS	WB	-25.1	12.3	–	–	3.9
	W14	Su 2008/09	RS	WB	-24.9	12.1	–	–	3.9
	W15	Su 2008/09	RS	WB	-25.3	11.4	–	–	3.9
	W17	Su 2008/09	RS	WB	-25.1	11.9	–	–	4.0
	W19	Su 2008/09	RS	WB	-25.2	12.0	–	–	3.9
	W103	Su 2010/11	AM	WB	-25.7	10.0	–	–	3.9
	W112	Su 2010/11	AM	Hair	-23.2	13.3	-24.6	12.8	3.5
	W113	Su 2010/11	AM	WB	-24.6	12.6	–	–	4.0
	W116	Su 2010/11	AM	WB	-24.5	12.6	–	–	3.9
	W117	Su 2010/11	AM	WB	-24.9	12.0	–	–	4.0
	W118	Su 2010/11	AM	WB	-25.1	12.0	–	–	4.0
	W130	Su 2010/11	AM	WB	-24.4	13.1	–	–	3.9
	W133	Su 2010/11	AM	WB	-24.4	12.5	–	–	3.9
	W136	Su 2010/11	AM	WB	-25.2	11.9	–	–	4.0
	W137	Su 2010/11	AM	WB	-25.1	12.0	–	–	3.9
	W155	Su 2010/11	AM	WB	-24.3	13.2	–	–	4.0
	W157	Su 2010/11	AM	WB	-25.0	13.0	–	–	4.0
	W174	Su 2010/11	AM	WB	-24.6	11.8	–	–	3.9
	W175	Su 2010/11	AM	WB	-24.2	13.1	–	–	4.0
	W176	Su 2010/11	AM	WB	-24.4	13.0	–	–	3.9
	W177	Su 2010/11	AM	WB	-24.5	13.0	–	–	3.9
	W182	Su 2010/11	AM	Hair	-24.1	10.3	-25.5	9.8	3.5
	W185	Su 2010/11	RS	WB	-25.8	11.8	–	–	3.9
	W186	Su 2010/11	RS	WB	-26.2	12.0	–	–	3.9
	W208	Su 2010/11	RS	WB	-25.8	12.6	–	–	3.9
	W209	Su 2010/11	RS	WB	-26.0	12.7	–	–	3.9
	W214	Su 2010/11	RS	WB	-26.3	11.8	–	–	4.0
	W216	Su 2010/11	RS	WB	-25.1	13.2	–	–	4.0
	W219	Su 2010/11	RS	WB	-25.6	11.9	–	–	4.0
	W220	Su 2010/11	RS	WB	-25.0	12.6	–	–	4.0
	W222	Su 2010/11	RS	WB	-25.2	12.2	–	–	3.9
	W223	Su 2010/11	RS	WB	-24.9	13.9	–	–	4.1
	WS10-11	Su 2009/10	RS	RBC	-25.0	12.3	–	12.6	3.9
	WS10-12	Su 2009/10	RS	RBC	-25.0	11.7	–	12.0	3.8
	WS10-13	Su 2009/10	RS	RBC	-24.8	12.0	–	12.3	3.9
	WS10-17	Su 2009/10	RS	RBC	-25.5	11.5	–	11.8	4.0
	WS10-18	Su 2009/10	RS	RBC	-25.3	11.3	–	11.6	3.8
	WS11-11	Su 2010/11	RS	WB	-25.7	11.6	–	–	4.0
	WS11-12	Su 2010/11	RS	WB	-25.5	11.7	–	–	3.9
	WS11-13	Su 2010/11	RS	WB	-24.9	12.4	–	–	3.9
	WS11-14	Su 2010/11	RS	WB	-24.6	12.4	–	–	3.9
	WS11-15	Su 2010/11	RS	WB	-25.7	11.8	–	–	4.0
	WS12-11	Su 2011/12	RS	RBC	-25.0	12.1	–	12.4	3.9
	WS12-12	Su 2011/12	RS	RBC	-25.4	11.9	–	12.2	3.9
	WS12-13	Su 2011/12	RS	RBC	-25.3	12.1	–	12.4	3.9
	WS12-14	Su 2011/12	RS	RBC	-25.3	12.0	–	12.3	3.8
	WS12-15	Su 2011/12	RS	RBC	-25.4	11.8	–	12.1	3.9
	WS12-22	Sp 2012	RS	WB	-24.7	12.4	–	–	4.1
	WS12-23	Sp 2012	RS	WB	-25.9	12.2	–	–	4.3
	WS12-24	Sp 2012	RS	WB	-25.6	12.1	–	–	4.1
	WS12-25	Sp 2012	RS	WB	-25.7	12.9	–	–	4.4
	WS12-26	Sp 2012	RS	WB	-24.8	12.7	–	–	4.0
	G103	F 2007	WAP	Serum	-22.4	13.1	-22.1	12.0	4.3

	G111	F 2007	WAP	Plasma	-22.8	12.3	-22.2	11.6	4.2
	LW11-03	Su 2010/11	RS	WB	-24.3	12.2	–	–	3.9
	LW11-05	Su 2010/11	RS	WB	-25.7	12.2	–	–	3.9
	LW11-06	Su 2010/11	RS	WB	-25.8	12.0	–	–	3.9
	LW11-07	Su 2010/11	RS	WB	-25.6	12.2	–	–	3.9
	LW11-08	Su 2010/11	RS	WB	-24.9	12.3	–	–	3.9
	LW11-09	Su 2010/11	RS	WB	-25.0	12.3	–	–	3.9
	LW11-10	Su 2010/11	RS	WB	-25.7	11.9	–	–	3.9
	LW11-11	Su 2010/11	RS	WB	-24.1	13.1	–	–	3.9
	LW11-12	Su 2010/11	RS	WB	-25.8	12.0	–	–	3.9
	LW11-13	Su 2010/11	RS	WB	-25.3	12.1	–	–	3.9
	LW11-14	Su 2010/11	RS	WB	-25.5	12.1	–	–	3.9
	LW11-15	Su 2010/11	RS	WB	-25.8	13.0	–	–	4.1
	LW15-01	Sp 2015	RS	WB	-25.8	12.1	–	–	4.2
	LW15-02	Sp 2015	RS	WB	-25.2	12.1	–	–	3.9
	LW15-03	Sp 2015	RS	WB	-25.3	12.1	–	–	3.9
	LW15-04	Sp 2015	RS	WB	-25.3	12.0	–	–	3.9
	LW15-05	Sp 2015	RS	WB	-25.3	12.2	–	–	3.9
	LW15-06	Sp 2015	RS	WB	-25.2	11.8	–	–	4.0
	LW15-07	Sp 2015	RS	WB	-25.3	12.2	–	–	4.0
	LW15-08	Sp 2015	RS	WB	-25.3	11.9	–	–	3.9
	LW15-09	Sp 2015	RS	WB	-25.3	12.0	–	–	3.9
	LW15-10	Sp 2015	RS	WB	-25.1	12.2	–	–	3.9
	LW15-11	Sp 2015	RS	WB	-25.3	12.2	–	–	3.9
	LW15-12	Sp 2015	RS	WB	-25.2	11.9	–	–	4.0
	W006	Su 2009/10	WAP	Whisker	-22.6	10.9	-24.0	10.4	3.4
	W013	Su 2009/10	WAP	Whisker	-21.9	12.1	-23.3	11.6	3.4
	WS10-01**	Su 2009/10	RS	Whisker	-23.3	12.9	-24.7	12.4	na
	WS10-02**	Su 2009/10	RS	Whisker	-22.8	14.5	-24.2	14.0	na
	WS10-03**	Su 2009/10	RS	Whisker	-23.5	13.0	-24.9	12.5	na
	WS10-04**	Su 2009/10	RS	Whisker	-23.0	12.5	-24.4	12.0	na
	WS10-05**	Su 2009/10	RS	Whisker	-22.9	12.4	-24.3	11.9	na
	WS10-06**	Su 2009/10	RS	Whisker	-24.6	13.3	-26.0	12.8	na
	WS10-07**	Su 2009/10	RS	Whisker	-23.3	12.8	-24.7	12.3	na
	WS10-19**	Su 2009/10	RS	Whisker	-23.8	12.5	-25.2	12.0	na
	WS10-20**	Su 2009/10	RS	Whisker	-23.8	12.9	-25.2	12.4	na
	WS10-21**	Su 2009/10	RS	Whisker	-22.9	12.5	-24.3	12.0	na
	WS10-22**	Su 2009/10	RS	Whisker	-23.1	12.4	-24.5	11.9	na
	WS11-03**	Su 2010/11	RS	Whisker	-23.4	12.6	-24.8	12.1	na
	WS11-04**	Su 2010/11	RS	Whisker	-23.5	12.8	-24.9	12.3	na
	WS11-05**	Su 2010/11	RS	Whisker	-23.3	13.5	-24.7	13.0	na
	WS11-06**	Su 2010/11	RS	Whisker	-23.5	14.0	-24.9	13.5	na
	WS11-08**	Su 2010/11	RS	Whisker	-23.3	13.8	-24.7	13.3	na
	WS11-09**	Su 2010/11	RS	Whisker	-24.7	14.2	-26.1	13.7	na
	WS11-17**	Su 2010/11	RS	Whisker	-23.4	12.5	-24.8	12.0	na
	WS11-18**	Su 2010/11	RS	Whisker	-23.6	12.9	-25.0	12.4	na
	WS11-19**	Su 2010/11	RS	Whisker	-23.5	13.4	-24.9	12.9	na
	WS11-21**	Su 2010/11	RS	Whisker	-24.1	12.5	-25.5	12.0	na
	WS11-37**	Su 2011/12	RS	Whisker	-23.0	12.7	-24.4	12.2	na
	WS11-38**	Su 2011/12	RS	Whisker	-23.1	13.5	-24.5	13.0	na
	WS11-39**	Su 2011/12	RS	Whisker	-23.5	12.6	-24.9	12.1	na
	WS11-40**	Su 2011/12	RS	Whisker	-23.7	12.8	-25.1	12.3	na
	WS11-41**	Su 2011/12	RS	Whisker	-23.4	13.6	-24.8	13.1	na

	WS12-01**	Su 2011/12	RS	Whisker	-24.1	12.8	-25.5	12.3	na
	WS12-02**	Su 2011/12	RS	Whisker	-23.7	12.6	-25.1	12.1	na
	WS12-04**	Su 2011/12	RS	Whisker	-23.3	12.7	-24.7	12.2	na
	WS12-05**	Su 2011/12	RS	Whisker	-23.2	13.2	-24.6	12.7	na
	WS12-06**	Su 2011/12	RS	Whisker	-22.7	13.4	-24.1	12.9	na
	WS12-07**	Su 2011/12	RS	Whisker	-23.2	13.8	-24.6	13.3	na
	WS12-08**	Su 2011/12	RS	Whisker	-22.6	13.7	-24.0	13.2	na
	WS12-09**	Su 2011/12	RS	Whisker	-22.8	13.6	-24.2	13.1	na
	WS12-10**	Su 2011/12	RS	Whisker	-23.6	13.3	-25.0	12.8	na
	WS12-16**	Su 2011/12	RS	Whisker	-24.2	12.7	-25.6	12.2	na
	WS12-17**	Su 2011/12	RS	Whisker	-23.8	12.4	-25.2	11.9	na
	WS12-19**	Su 2011/12	RS	Whisker	-23.4	13.6	-24.8	13.1	na
	WS12-20**	Su 2011/12	RS	Whisker	-23.4	13.2	-24.8	12.7	na
Ross	R01	Su 2008/09	AM	WB	-23.2	8.5	–	–	3.9
	R101	Su 2010/11	AM	WB	-23.9	9.6	–	–	3.9
	R102	Su 2010/11	AM	WB	-23.6	9.0	–	–	4.0
	R103	Su 2010/11	AM	WB	-24.0	9.0	–	–	4.0
	R104	Su 2010/11	AM	WB	-23.7	9.2	–	–	4.0
	R105	Su 2010/11	AM	WB	-23.6	9.2	–	–	4.0
	R106	Su 2010/11	AM	WB	-24.1	8.8	–	–	3.9
	R107	Su 2010/11	AM	WB	-23.6	8.8	–	–	3.9
	R108	Su 2010/11	AM	WB	-24.6	10.0	–	–	4.0
	R109	Su 2010/11	AM	WB	-23.9	9.0	–	–	4.0
	R110	Su 2010/11	AM	Hair	-23.0	10.0	-24.3	8.8	3.5
	R111	Su 2010/11	AM	WB	-23.6	8.8	–	–	4.0
	R112	Su 2010/11	AM	WB	-23.8	9.7	–	–	3.9
	R113	Su 2010/11	AM	WB	-23.7	9.0	–	–	4.0
	R114	Su 2010/11	RS	WB	-23.8	8.6	–	–	4.0

Table S8. Amino acid $\delta^{15}N$ values for crabeater, Ross, and Weddell seals. Values are reported as the mean ± one standard deviation for the injections on the GC/C/IRMS. For crabeater seals, whole blood (C06, C44, C177) and plasma (G112, G105, and G110) samples were analyzed. All Ross seal samples analyzed for amino acid $\delta^{15}N$ values were whole blood. For Weddell seals, whole blood (W185, W220, and WS11-11), plasma (G111), and sample from the first segment nearest the whisker base, 0.0-0.5 cm, (W006 and W013) were used for CSI-AA. Abbreviation: na, not available.

Species	**Sample ID**	**Region**	**Amino Acid**	**Injections**	**$\delta^{15}N$ (‰)**
Crabeater	C06	AM	Alanine	3	13.7 ± 0.3
	C06	AM	Glycine	3	8.5 ± 0.1
	C06	AM	Threonine	3	-21.9 ± 0.6
	C06	AM	Serine	3	7.0 ± 0.5
	C06	AM	Valine	3	14.9 ± 0.3
	C06	AM	Leucine	3	13.9 ± 0.2
	C06	AM	Isoleucine	3	12.8 ± 0.2
	C06	AM	Proline	3	15.7 ± 0.4
	C06	AM	Aspartic	3	11.0 ± 0.3
	C06	AM	Glutamic acid	3	15.1 ± 0.4
	C06	AM	Phenylalanine	3	6.8 ± 0.3
	C06	AM	Lysine	3	5.5 ± 0.6
	G112	WAP	Alanine	3	12.0 ± 0.7
	G112	WAP	Glycine	3	0.6 ± 0.1
	G112	WAP	Threonine	3	-20.7 ± 0.1
	G112	WAP	Serine	3	1.9 ± 0.2
	G112	WAP	Valine	3	13.5 ± 0.2
	G112	WAP	Leucine	3	11.8 ± 0.6
	G112	WAP	Isoleucine	3	11.6 ± 1.0
	G112	WAP	Proline	3	15.5 ± 0.6
	G112	WAP	Aspartic	3	9.9 ± 0.2
	G112	WAP	Glutamic acid	3	15.0 ± 0.4
	G112	WAP	Phenylalanine	3	4.3 ± 0.1
	G112	WAP	Lysine	2	4.5 ± 0.2
	C44	AM	Alanine	3	14.3 ± 0.4
	C44	AM	Glycine	3	4.7 ± 0.4
	C44	AM	Threonine	3	-25.4 ± 0.4
	C44	AM	Serine	3	4.2 ± 0.2
	C44	AM	Valine	3	15.1 ± 0.5
	C44	AM	Leucine	3	13.4 ± 0.5
	C44	AM	Isoleucine	3	12.2 ± 0.1
	C44	AM	Proline	3	14.7 ± 0.3
	C44	AM	Aspartic	3	9.3 ± 0.2
	C44	AM	Glutamic acid	3	15.0 ± 0.2
	C44	AM	Phenylalanine	3	5.8 ± 0.2
	C44	AM	Lysine	3	4.9 ± 0.3
	G105	WAP	Alanine	3	13.3 ± 0.4
	G105	WAP	Glycine	3	1.6 ± 0.3
	G105	WAP	Threonine	3	-19.6 ± 0.4
	G105	WAP	Serine	3	2.5 ± 0.3
	G105	WAP	Valine	3	14.4 ± 0.5
	G105	WAP	Leucine	3	12.7 ± 0.1
	G105	WAP	Isoleucine	3	11.5 ± 0.6
	G105	WAP	Proline	3	16.5 ± 0.5
	G105	WAP	Aspartic	3	10.4 ± 0.0
	G105	WAP	Glutamic acid	3	15.2 ± 0.3
	G105	WAP	Phenylalanine	3	4.7 ± 0.2
	G105	WAP	Lysine	3	5.3 ± 0.5
	C177	RS	Alanine	4	14.6 ± 0.4

	C177	RS	Glycine	4	3.9 ± 0.4
	C177	RS	Threonine	4	-26.1 ± 0.8
	C177	RS	Serine	4	5.2 ± 0.6
	C177	RS	Valine	4	15.7 ± 0.8
	C177	RS	Leucine	4	14.4 ± 0.5
	C177	RS	Isoleucine	4	12.6 ± 0.7
	C177	RS	Proline	4	15.7 ± 0.5
	C177	RS	Aspartic	4	9.8 ± 0.1
	C177	RS	Glutamic acid	4	14.4 ± 0.3
	C177	RS	Phenylalanine	4	5.4 ± 0.4
	C177	RS	Lysine	4	5.1 ± 0.5
	G110	WAP	Alanine	3	13.4 ± 0.1
	G110	WAP	Glycine	3	3.4 ± 0.1
	G110	WAP	Threonine	3	-23.4 ± 0.3
	G110	WAP	Serine	3	4.7 ± 0.5
	G110	WAP	Valine	3	15.8 ± 0.3
	G110	WAP	Leucine	3	13.5 ± 0.2
	G110	WAP	Isoleucine	3	12.3 ± 0.4
	G110	WAP	Proline	3	15.8 ± 0.3
	G110	WAP	Aspartic	3	10.4 ± 0.4
	G110	WAP	Glutamic acid	3	14.8 ± 0.4
	G110	WAP	Phenylalanine	3	4.1 ± 0.5
	G110	WAP	Lysine	3	5.0 ± 0.2
Weddell	G111	WAP	Alanine	3	18.9 ± 0.4
	G111	WAP	Glycine	3	5.0 ± 0.4
	G111	WAP	Threonine	3	-22.1 ± 0.6
	G111	WAP	Serine	3	8.6 ± 0.1
	G111	WAP	Valine	3	22.9 ± 0.5
	G111	WAP	Leucine	3	20.8 ± 0.4
	G111	WAP	Isoleucine	3	19.6 ± 0.6
	G111	WAP	Proline	3	20.8 ± 0.9
	G111	WAP	Aspartic	3	16.7 ± 0.5
	G111	WAP	Glutamic acid	3	20.4 ± 0.5
	G111	WAP	Phenylalanine	3	5.3 ± 0.4
	G111	WAP	Lysine	3	6.7 ± 0.4
	W006	WAP	Alanine	3	20.7 ± 0.2
	W006	WAP	Glycine	3	2.1 ± 0.1
	W006	WAP	Threonine	3	-29.4 ± 0.3
	W006	WAP	Serine	3	6.7 ± 0.2
	W006	WAP	Valine	3	24.0 ± 0.5
	W006	WAP	Leucine	3	21.7 ± 0.4
	W006	WAP	Isoleucine	3	21.4 ± 0.9
	W006	WAP	Proline	3	18.0 ± 0.1
	W006	WAP	Aspartic	3	12.8 ± 0.1
	W006	WAP	Glutamic acid	3	20.8 ± 0.2
	W006	WAP	Phenylalanine	3	5.9 ± 0.5
	W006	WAP	Lysine	1	3.1
	W013	WAP	Alanine	3	22.1 ± 0.1
	W013	WAP	Glycine	3	2.3 ± 0.1
	W013	WAP	Threonine	3	-31.9 ± 0.3
	W013	WAP	Serine	3	8.0 ± 0.2
	W013	WAP	Valine	3	25.5 ± 0.5
	W013	WAP	Leucine	3	23.5 ± 0.1
	W013	WAP	Isoleucine	3	24.0 ± 0.2
	W013	WAP	Proline	3	18.5 ± 0.2
	W013	WAP	Aspartic	3	14.2 ± 0.1

	W013	WAP	Glutamic acid	3	22.2 ± 0.2
	W013	WAP	Phenylalanine	3	5.9 ± 0.1
	W013	WAP	Lysine	2	3.6 ± 0.8
	W185	RS	Alanine	3	22.8 ± 0.1
	W185	RS	Glycine	3	6.9 ± 0.9
	W185	RS	Threonine	3	-29.9 ± 0.4
	W185	RS	Serine	3	9.0 ± 0.5
	W185	RS	Valine	3	24.2 ± 0.4
	W185	RS	Leucine	3	22.6 ± 0.4
	W185	RS	Isoleucine	3	21.7 ± 0.6
	W185	RS	Proline	3	21.0 ± 0.1
	W185	RS	Aspartic	3	17.2 ± 0.2
	W185	RS	Glutamic acid	3	20.7 ± 0.4
	W185	RS	Phenylalanine	3	5.0 ± 0.0
	W185	RS	Lysine	3	5.4 ± 0.4
	W220	RS	Alanine	3	23.1 ± 0.1
	W220	RS	Glycine	3	9.4 ± 0.3
	W220	RS	Threonine	3	-27.9 ± 0.3
	W220	RS	Serine	3	10.9 ± 0.3
	W220	RS	Valine	3	25.0 ± 0.6
	W220	RS	Leucine	3	23.3 ± 0.2
	W220	RS	Isoleucine	3	22.8 ± 1.0
	W220	RS	Proline	3	21.3 ± 0.7
	W220	RS	Aspartic	3	18.6 ± 0.1
	W220	RS	Glutamic acid	3	22.3 ± 0.2
	W220	RS	Phenylalanine	3	6.4 ± 0.1
	W220	RS	Lysine	3	6.8 ± 0.8
	WS11-11	RS	Alanine	3	22.5 ± 0.1
	WS11-11	RS	Glycine	3	7.0 ± 0.9
	WS11-11	RS	Threonine	3	-28.3 ± 0.3
	WS11-11	RS	Serine	3	9.2 ± 0.5
	WS11-11	RS	Valine	3	24.6 ± 0.3
	WS11-11	RS	Leucine	3	22.6 ± 0.3
	WS11-11	RS	Isoleucine	3	21.7 ± 0.9
	WS11-11	RS	Proline	3	20.4 ± 0.9
	WS11-11	RS	Aspartic	3	17.5 ± 0.5
	WS11-11	RS	Glutamic acid	3	21.5 ± 0.3
	WS11-11	RS	Phenylalanine	3	5.6 ± 0.2
	WS11-11	RS	Lysine	3	5.8 ± 0.5
Ross	R101	AM	Alanine	3	20.3 ± 0.3
	R101	AM	Glycine	3	2.9 ± 0.2
	R101	AM	Threonine	3	-29.2 ± 0.2
	R101	AM	Serine	3	4.4 ± 0.7
	R101	AM	Valine	3	21.5 ± 0.1
	R101	AM	Leucine	3	19.9 ± 0.3
	R101	AM	Isoleucine	3	20.1 ± 1.0
	R101	AM	Proline	3	17.3 ± 0.3
	R101	AM	Aspartic	3	15.9 ± 0.1
	R101	AM	Glutamic acid	3	18.3 ± 0.7
	R101	AM	Phenylalanine	3	2.5 ± 0.2
	R101	AM	Lysine	na	Na
	R103	AM	Alanine	3	18.5 ± 0.3
	R103	AM	Glycine	3	5.1 ± 0.4
	R103	AM	Threonine	3	-27.4 ± 0.7
	R103	AM	Serine	3	5.4 ± 0.8
	R103	AM	Valine	3	20.0 ± 0.4

	R103	AM	Leucine	3	18.6 ± 0.3
	R103	AM	Isoleucine	3	15.7 ± 0.6
	R103	AM	Proline	3	16.9 ± 0.6
	R103	AM	Aspartic	3	13.9 ± 0.2
	R103	AM	Glutamic acid	3	17.2 ± 0.6
	R103	AM	Phenylalanine	3	2.6 ± 0.4
	R103	AM	Lysine	3	1.8 ± 0.4
	R106	AM	Alanine	3	18.8 ± 0.1
	R106	AM	Glycine	3	5.7 ± 0.3
	R106	AM	Threonine	3	-27.5 ± 0.3
	R106	AM	Serine	3	5.8 ± 0.4
	R106	AM	Valine	3	19.3 ± 0.4
	R106	AM	Leucine	3	17.9 ± 0.3
	R106	AM	Isoleucine	3	18.8 ± 0.7
	R106	AM	Proline	3	17.3 ± 0.2
	R106	AM	Aspartic	3	14.0 ± 0.2
	R106	AM	Glutamic acid	3	16.9 ± 0.3
	R106	AM	Phenylalanine	3	1.9 ± 0.2
	R106	AM	Lysine	3	2.5 ± 0.4
	R111	AM	Alanine	3	18. 6 ± 0.3
	R111	AM	Glycine	3	5.2 ± 0.1
	R111	AM	Threonine	3	-28.0 ± 0.1
	R111	AM	Serine	3	5.7 ± 0.3
	R111	AM	Valine	3	19.7 ± 0.3
	R111	AM	Leucine	3	18.2 ± 0.3
	R111	AM	Isoleucine	3	18.4 ± 0.7
	R111	AM	Proline	3	16.4 ± 0.9
	R111	AM	Aspartic	3	13.6 ± 0.2
	R111	AM	Glutamic acid	3	17.6 ± 0.3
	R111	AM	Phenylalanine	3	1.9 ± 0.1
	R111	AM	Lysine	3	3.4 ± 0.2
	R112	AM	Alanine	3	19.2 ± 0.5
	R112	AM	Glycine	3	4.8 ± 0.5
	R112	AM	Threonine	3	-28.0 ± 0.7
	R112	AM	Serine	3	4.7 ± 0.4
	R112	AM	Valine	3	19.7 ± 0.1
	R112	AM	Leucine	3	18.2 ± 0.1
	R112	AM	Isoleucine	2	17.7 ± 0.6
	R112	AM	Proline	3	17.1 ± 0.6
	R112	AM	Aspartic	3	14.3 ± 0.4
	R112	AM	Glutamic acid	3	17.6 ± 0.5
	R112	AM	Phenylalanine	3	3.9 ± 0.2
	R112	AM	Lysine	3	3.1 ± 0.4
	R114	RS	Alanine	3	17.6 ± 0.4
	R114	RS	Glycine	3	5.9 ± 0.3
	R114	RS	Threonine	3	-25.9 ± 0.2
	R114	RS	Serine	3	5.9 ± 0.8
	R114	RS	Valine	3	19.0 ± 0.4
	R114	RS	Leucine	3	17.5 ± 0.4
	R114	RS	Isoleucine	na	Na
	R114	RS	Proline	3	18.1 ± 0.8
	R114	RS	Aspartic	3	12.9 ± 0.2
	R114	RS	Glutamic acid	3	17.5 ± 0.8
	R114	RS	Phenylalanine	3	3.1 ± 0.3
	R114	RS	Lysine	2	3.3 ± 0.1

Table S9. Results of one-way ANOVA Bonferroni post-hoc comparisons for amino acid δ^{15}N data for the three seal species. Significant *p*-values are < 0.05.

Amino Acid	**ANOVA Post-hoc *p*-values**	**Comparison**
Ala	<0.001	Crabeater vs. Ross
	<0.001	Crabeater vs. Weddell
	0.003	Ross vs. Weddell
Gly	–	Crabeater vs. Ross
	–	Crabeater vs. Weddell
	–	Ross vs. Weddell
Thr	0.01	Crabeater vs. Ross
	0.006	Crabeater vs. Weddell
	–	Ross vs. Weddell
Ser	–	Crabeater vs. Ross
	<0.001	Crabeater vs. Weddell
	0.002	Ross vs. Weddell
Val	<0.001	Crabeater vs. Ross
	<0.001	Crabeater vs. Weddell
	<0.001	Ross vs. Weddell
Leu	<0.001	Crabeater vs. Ross
	<0.001	Crabeater vs. Weddell
	<0.001	Ross vs. Weddell
Ile	<0.001	Crabeater vs. Ross
	<0.001	Crabeater vs. Weddell
	<0.001	Ross vs. Weddell
Pro	0.03	Crabeater vs. Ross
	<0.001	Crabeater vs. Weddell
	<0.001	Ross vs. Weddell
Asp	<0.001	Crabeater vs. Ross
	<0.001	Crabeater vs. Weddell
	–	Ross vs. Weddell
Glu	<0.001	Crabeater vs. Ross
	<0.001	Crabeater vs. Weddell
	<0.001	Ross vs. Weddell
Phe	<0.001	Crabeater vs. Ross
	–	Crabeater vs. Weddell
	<0.001	Ross vs. Weddell
Lys	0.009	Crabeater vs. Ross
	–	Crabeater vs. Weddell
	0.005	Ross vs. Weddell

Table S10. Bulk δ^{13}C and δ^{15}N values of crabeater, Weddell, and Ross seals from the literature. Note, bulk δ^{13}C and δ^{15}N values are reported for the original measurement (Orig.) and with a correction to whole blood (Corr.) if the sample is a tissue type with a significant isotopic offset from whole blood. Isotopic offset between whole blood and the given sample type are reported in Tables S4 and S6, above. Abbreviations: RBCs, red blood cells; F, female; M, male; na, information not available; NDR, no dive records; RS, Ross Sea; AS, Amundsen Sea; WAP, West Antarctic Peninsula; *n*, sample size.

Species	**Sample Type**	***n***	**Sex**	**Age Class**	**Area**	**Orig. δ^{13}C (‰)**	**Orig. δ^{15}N (‰)**	**Corr. δ^{13}C (‰)**	**Corr. δ^{15}N (‰)**	**Source**
Ross	Serum	21	M	na	RS/AS	24.3 ± 0.4	10.6 ± 0.6	-24.0 ± 0.4	9.5 ± 0.4	Zhao et al. (2004)
	Serum	12	F	na	RS/AS	-24.0 ± 0.4	10.0 ± 0.5	-23.7 ± 0.4	8.9 ± 0.5	Zhao et al. (2004)
	Hair	1	M	na	RS	-22.3	10.4	-23.6	9.2	Aubail et al. (2011)
Weddell	Serum	17	M	na	RS/AS	-24.6 ± 0.6	13.3 ± 0.8	-24.3 ± 0.6	12.2 ± 0.8	Zhao et al. (2004)
	Serum	16	F	na	RS/AS	-25.3 ± 0.9	12.5 ± 1.1	-25.0 ± 0.9	11.4 ± 1.1	Zhao et al. (2004)
	Serum	22	na	Adult	RS/AS	-24.9 ± 0.8	13.0 ± 0.9	-24.6 ± 0.8	11.9 ± 0.9	Zhao et al. (2004)
	Serum	4	na	Subadult	RS/AS	-25.5 ± 0.9	11.5 ± 1.1	-25.2 ± 0.9	10.4 ± 1.1	Zhao et al. (2004)
	Serum	6	na	Juvenile	RS/AS	-24.8 ± 1.0	13.1 ± 1.0	-24.5 ± 1.0	12.0 ± 1.0	Zhao et al. (2004)
	Serum	1	na	Pup	RS/AS	-25.2	13.4	-24.9	12.3	Zhao et al. (2004)
	Plasma	12	na	Adult	RS	-25.5 ± 0.1	13.1 ± 0.2	-24.9 ± 0.1	12.4 ± 0.2	Burns et al. (1998)
	Plasma	6	na	Deep-diving yearling	RS	-25.4 ± 0.2	12.6 ± 0.2	-24.8 ± 0.2	11.9 ± 0.2	Burns et al. (1998)
	Plasma	4	na	NDR yearling	RS	-25.1 ± 0.2	12.9 ± 0.1	-24.5 ± 0.2	12.2 ± 0.1	Burns et al. (1998)
	Plasma	4	na	Shallow-diving yearling	RS	-23.5 ± 0.1	13.3 ± 0.1	-22.9 ± 0.1	12.6 ± 0.1	Burns et al. (1998)
	Plasma	16	na	Pup	RS	-26.0 ± 0.2	13.8 ± 0.1	-25.4 ± 0.2	13.1 ± 0.1	Burns et al. (1998)
	Hair	12	na	na	RS	-23.2 ± 0.1	13.5 ± 0.2	-24.6 ± 0.1	13.0 ± 0.2	Aubail et al. (2011)
	Whisker	14	na	na	WAP	-21.6 ± 0.6	12.7 ± 0.7	-23.0 ± 0.6	12.2 ± 0.7	Botta et al.

										(2018)
	RBCs	116	na	na	RS	-25.2 ± 0.3	12.0± 0.3	-25.2 ± 0.3	12.3 ± 0.3	Goetz et al. (2017)
Crabeater	Serum	26	M	na	RS/AS	-26.7 ± 0.9	8.2 ± 0.5	-26.4 ± 0.9	7.1 ± 0.5	Zhao et al. (2004)
	Serum	15	F	na	RS/AS	-26.5 ± 1.2	8.4 ± 0.4	-26.2 ± 1.2	7.3 ± 0.4	Zhao et al. (2004)
	Serum	30	na	Adult	RS/AS	-26.5 ± 1.0	8.4 ± 0.6	-26.2 ± 1.0	7.3 ± 0.6	Zhao et al. (2004)
	Serum	4	na	Subadult	RS/AS	-26.1 ± 1.2	8.4 ± 0.3	-25.8 ± 1.2	7.3 ± 0.3	Zhao et al. (2004)
	Serum	3	na	Juvenile	RS/AS	-27.2 ± 1.2	8.0 ± 0.1	-26.9 ± 1.2	7.9 ± 0.1	Zhao et al. (2004)
	Serum	4	na	Pup	RS/AS	-27.4 ± 0.4	7.7 ± 0.1	-27.1 ± 0.4	6.6 ± 0.1	Zhao et al. (2004)
	Hair	33	na	na	RS	-24.3 ± 0.1	7.7 ± 0.1	-25.9 ± 0.1	7.7 ± 0.1	Aubail et al. (2011)
	Whisker	13	na	na	WAP	-23.0 ± 0.6	7.0 ± 0.8	-24.6 ± 0.6	7.0 ± 0.8	Botta et al. (2018)

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