FATTY ACID AND STABLE ISOTOPE ANALYSES TO INFER DIET OF ANTARCTIC TOOTHFISH CAUGHT IN THE SOUTHERN ROSS SEA

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Abstract

To infer important prey resources for Antarctic toothfish (*Dissostichus mawsoni*) in the southern Ross Sea, their lipid composition was determined and compared to lipid profiles of fish and invertebrate species taken as by-catch in the fishery or collected from the stomachs of toothfish. Stable carbon and nitrogen isotope ratios were also determined to further identify feeding relationships between these species. The aim of this study was to establish the feasibility of tracking the main dietary items of Antarctic toothfish by comparing results of biomarker analysis and conventional diet analysis. Samples were collected during a longline survey of pre-recruit toothfish in February 2012. Results of fatty acid (FA) and stable isotope analyses from this study provide evidence that a combination of these two techniques can delineate the main prey items of Antarctic toothfish and trophic structure of the toothfish-related fish food web in the southern Ross Sea ecosystem. Similarities in total FA compositions and the FA profiles in muscle tissue of Antarctic toothfish, and *Pleuragramma antarcticum*, *Pogonophryne barsukovi*, *Dacodraco hunteri* and *Trematomus loennbergii* indicated a trophic connection between toothfish and these fish species. Mean $\delta^{15}N$ values of Antarctic toothfish were higher than those of *P. antarcticum*, *P. barsukovi* and *T. loennbergii*, indicating a higher trophic position of the toothfish. In contrast, similar $\delta^{15}N$ values between Antarctic toothfish and icefish (*D. hunteri*) suggested that they occupy the same trophic position. Overall results of this survey are consistent with the frequency and percentage occurrence of prey in Antarctic toothfish stomachs. Further sample collection and biomarker analyses for more pelagic and benthic biota are needed to better understand the entire food-web structure in the southern Ross Sea.

Introduction

Antarctic toothfish (*Dissostichus mawsoni*) is a key component of the Ross Sea ecosystem, feeding on a wide range of prey but being primarily fish-eating piscivorous (Fenaughty et al., 2003; Pinkerton et al., 2010). Changes to the predation of toothfish on fish prey species may have either trophic-cascade or keystone-predator effects on other fish species, leading to changes in abundances of some prey species and competitors of their prey sources. Antarctic toothfish is also considered to be a prey of Weddell seals (*Leptonychotes weddellii*) and killer whales (*Orcinus orca*), and a competitor with the Weddell seals and emperor (*Aptenodytes forsteri*) and Adélie penguins (*Pygoscelis adeliae*) for Antarctic silverfish (*Pleuragramma antarcticum*) (Ponganis and Stockard, 2007; Smith et al., 2007; Pinkerton et al., 2010). Because of the ecological importance of Antarctic toothfish, CCAMLR has set precautionary catch levels to manage this species in the Ross Sea region. Robust stock assessments are needed to manage this fishery effectively. In this respect, better understanding of its life cycle, ecosystem role and recruitment variability of Antarctic toothfish is crucial in assessing stock variability (Hanchet et al., 2010).

Trophic studies of deep-sea fish populations are critical for understanding how fishing activity will affect deep-sea ecosystems. Pinkerton et al. (2010) modelled food and feeding relationships in the Ross Sea based on research and fisheries-based sampling. Although the diet of Antarctic toothfish has been typically examined using its stomach contents, they are often empty and the contents are unidentifiable (e.g. Fenaughty et al., 2003; Hanchet et al., 2012). In addition, the stomach contents may represent only a snapshot of the dietary items consumed at a particular point in time and space, usually during the brief summer season when samples can be collected.

As an alternative to conventional stomach sampling, lipid biomarkers have been proven useful in inferring the diet of top trophic level organisms (Drazen et al., 2009). Biomarker profiles can be compared to potential prey and the level of similarity between profiles can be used to infer a trophic connection. However, the existence of similar fatty acid (FA) profiles between fish species may not necessarily reflect a prey–predator relationship between the species. Understanding these relationships can be further informed using the stable carbon and nitrogen isotope ratios in consumer tissue as these reflect those of diets actually assimilated by consumers during their entire feeding history (Fry and Sherr, 1984; Peterson and Fry, 1987; Michener and Schell, 1994). In particular, the nitrogen isotope ratio has been used extensively to delineate the trophic position of an animal (DeNiro and Epstein, 1981; Minagawa and Wada, 1984; Vander Zanden and Rasmussen, 2001; Post, 2002). Therefore, using a combination of FA profiles (diet composition) and stable isotope ratios (trophic levels) has proved to be a powerful method in the study of complex food webs. Previous studies have already described diet and trophic niche of *P. antarcticum* in the Ross Sea and off Dumont d'Urville Sea, based on the combination of gut content and stable isotope analyses (Giraldo et al., 2011; Pinkerton et al., 2012).

The goals of the present investigation were to:

(i) infer important prey resources for pre-recruit Antarctic toothfish in the southern Ross Sea by determining their lipid composition and comparing their lipid profiles to those of potential prey species

(ii) identify feeding relationships between fish species by determining their stable carbon and nitrogen isotope ratios

(iii) establish the feasibility of tracking the main dietary items of Antarctic toothfish by comparing results of biomarker analysis and conventional diet (gut content) analysis.

Materials and methods

Sample collection, treatment and fatty acid analysis

The survey area was in the south of the small-scale research units (SSRUs) 881J and L (Figure 1). The survey area, strata, and planned and completed station locations are shown in Figure 2. A total of 29 stations were planned for SSRU 881L and 16 stations for SSRU 881J. The numbers of planned stations, and catchment details, are summarised by stratum in Table 1. Field sampling was carried out in February 2012. Commercial fishing gear on the *San Aotea II* was used for the research lines (Hanchet et al., 2012).

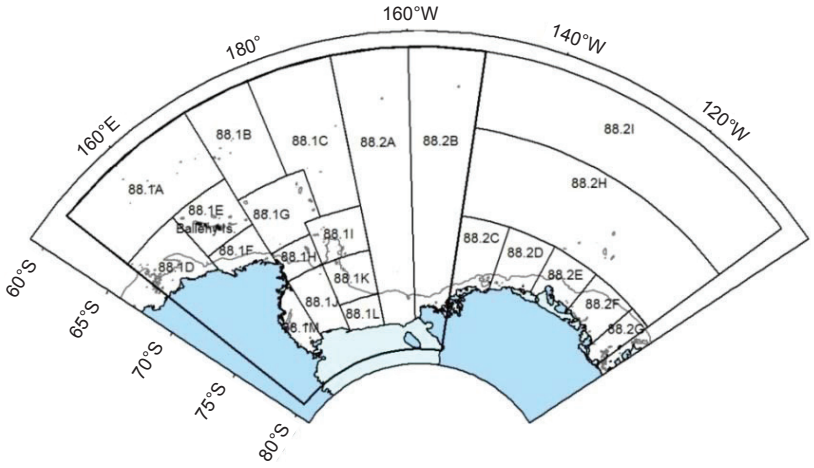

Figure 1: The Ross Sea region – CCAMLR Subareas 88.1 and 88.2 showing the small-scale research units (SSRUs) used for management, with depth contours plotted at 1 000 m. Survey area was in the south of SSRUs 881J and L (after Hanchet et al., 2012).

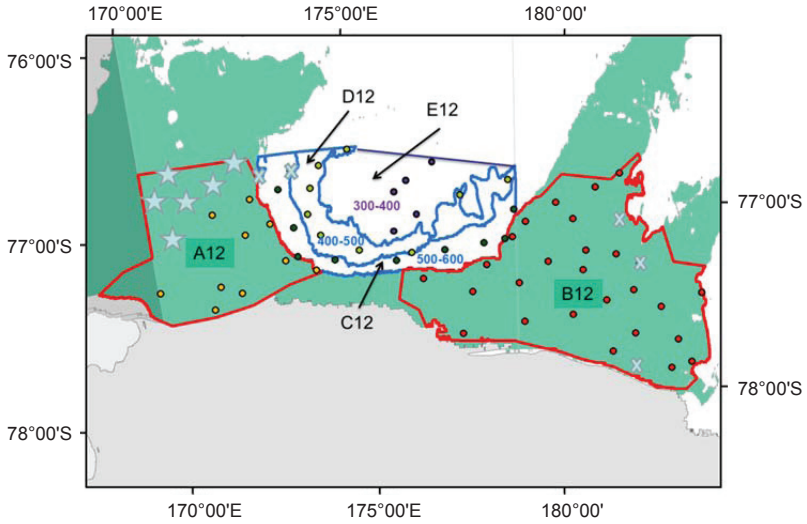

Figure 2: Stratum boundaries and station positions for the 2012 survey. Depths greater than 600 m are shaded in green. The stars indicate the six stations which could not be completed due to bad weather and time constraints at the end of the survey (after Hanchet et al., 2012).

Muscle tissue samples were collected from Antarctic toothfish and individual fish specimens which were taken as by-catch. In addition, muscle tissue samples were taken from specimens in good condition collected from toothfish stomachs. FA and stable isotope compositions of a total of 57 specimens of Antarctic toothfish (33 from SSRU 881J and 23 from SSRU 881L) were analysed in this study. Fish caught as by-catch and prey collected from toothfish stomachs were pooled or divided into two to three subsamples, and their FA and stable isotope compositions were analysed. The stomach contents and liver tissues were also collected from Antarctic toothfish, but the composition analysis is not presented in this paper.

Only the fleshy tissue of animals was prepared for FA and stable isotope analyses. Lipid extraction from muscle tissues for isotope analysis was carried out in a mixed solution of methanol, chloroform and water (2:1:0.8) according to the method of Bligh and Dyer (1959). The procedure was applied to avoid variation in $\delta^{13}C$ values arising from difference in the concentration of ^{13}C-depleted lipids

in different tissues/organs of the fish (Focken and Becker, 1998). All the samples were freeze-dried and ground with a mortar and a pestle.

Fish and invertebrates sampled in sufficient quantities were used to identify the FA profiles. Lipids were extracted for freeze-dried organic matter sources and animal tissues with a solution of methanol and chloroform (2:1, v/v) according to the procedure of Bligh and Dyer (1959). To obtain FA methyl esters (FAMEs), the extracted lipids were subjected to methylation as described by the American Oil Chemists' Society (AOCS, 1998). The extracted lipids were saponified at 100°C for 7 min with 1.5 ml of 0.5 N NaOH-methanol. FAMEs were prepared by transesterification with a 2 ml solution of BF_3-methanol (14%). The mixture was shaken, closed under nitrogen, and then heated on a hot block at 100°C for 5 min. After cooling, 5 ml of saturated sodium sulfate was added and voltexed under nitrogen. Then, 1 ml of isooctane was added to the mixture. Enough voltexing was undertaken after capping under nitrogen, and then the upper isooctane phases containing FAMEs were isolated using a Pasteur pipette. The isooctane phases were filtered with a 0.45 µm filter and transferred into a vial for analysis using a gas chromatograph (GC) (Varian CP-3800, USA) equipped with a flame ionisation detector (FID). A flexible fused silica capillary column (bonded omega wax, 30 m × 0.25 mm internal diameter and 0.25 µm film thickness) was used to separate the FAME classes. Helium was used as a carrier gas. The GC temperature was programmed at 180°C for 5 min, raised from 180°C to 230°C at 3°C min^{-1}, and then finally maintained at 230°C for 15 min. The injector and detector temperatures were 250°C and 260°C respectively. The FAMEs were identified by comparing the retention times with standard mixtures (Supelco Co., Bellefonte, PA).

Stable isotope analysis

Carbon and nitrogen stable isotope ratios were determined using continuous flow isotope ratio-mass spectrometry (CF-IRMS, Isoprime, GV instruments, UK) coupled with an elemental analyser (Eurovector 3000 Series, Italy). Powdered samples were weighed according to sample types (1.5–2.5 mg for animals, 6.0 mg for plants and 30.0 mg for sediments), wrapped in tin capsules and put into the elemental analyser to oxidise at high temperature (1 030°C). The resultant gases of CO_2 and N_2 were introduced into the CF-IRMS using a He carrier. Data for isotopic composition are expressed as the relative difference between isotopic ratios of the sample and conventional standard gases of Pee Dee Belemnite (PDB) for carbon and atmospheric N_2 for nitrogen. The delta (δ) notation is used to express these relative differences, according to the following equation:

$$\delta X\ (‰) = [(R_{sample}/R_{standard}) - 1] \times 10^3 \qquad (1)$$

where X is ^{13}C or ^{15}N and R is the $^{13}C/^{12}C$ or $^{15}N/^{14}N$. A secondary standard of known relation to the international standard was used as reference material. The analytical precision for 20 replicates of urea was approximately 0.1‰ and 0.3‰ for $\delta^{13}C$ and $\delta^{15}N$ respectively. $\delta^{15}N$ was used to identify the trophic position of animals.

Data analysis

To examine ontogenetic diet change, Antarctic toothfish were divided into four size groups: 60–80 cm length, 80–99 cm, 100–119 cm, and 120–135 cm. FA profiles of Antarctic toothfish were compared to fish caught as by-catch and prey collected from toothfish stomachs using principal component analysis (PCA). PCA reduces the number of dimensions produced by the large number of variables and uses linear correlations (components) to identify those FAs that contribute most to the separation between observed groups. FAs that contributed a mean of less than 1.0% (of total FAs) to the profile were omitted from statistical analyses. All analyses were performed on percentage composition data. The first two principal components were plotted on the x- and y-axes with FAs contributing most to the separation on each axis. A hierarchical cluster analysis was also performed on a Bray-Curtis similarity matrix of specimen FA profiles. Clusters were overlaid on the PCA plots to assist in the interpretation of similarity and grouping between samples. All statistical analyses were performed using Primer 6 software (Primer-E). Normality was tested using the Shapiro-Wilk normality test. Homogeneity of variances was tested using Levene's test. Two-way ANOVA was used to test differences in isotope data ($\delta^{13}C$ and $\delta^{15}N$) among size groups of Antarctic toothfish collected at different sites. A Tukey HSD post-hoc test was subsequently used to determine where the significant differences occurred among variables. SPSS software (version 12.0) was used for the statistics.

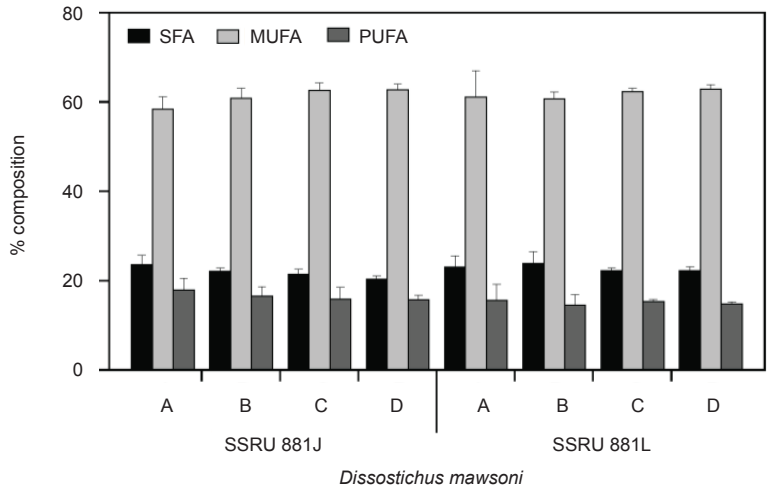

Figure 3: Saturated, monounsaturated and polyunsaturated fatty acid (SFA, MUFA and PUFA respectively) percentage composition for each size group of Antarctic toothfish: 60–80 cm length (A), 80–99 cm (B), 100–119 cm (C) and 120–135 cm (D). Values are mean ± SD.

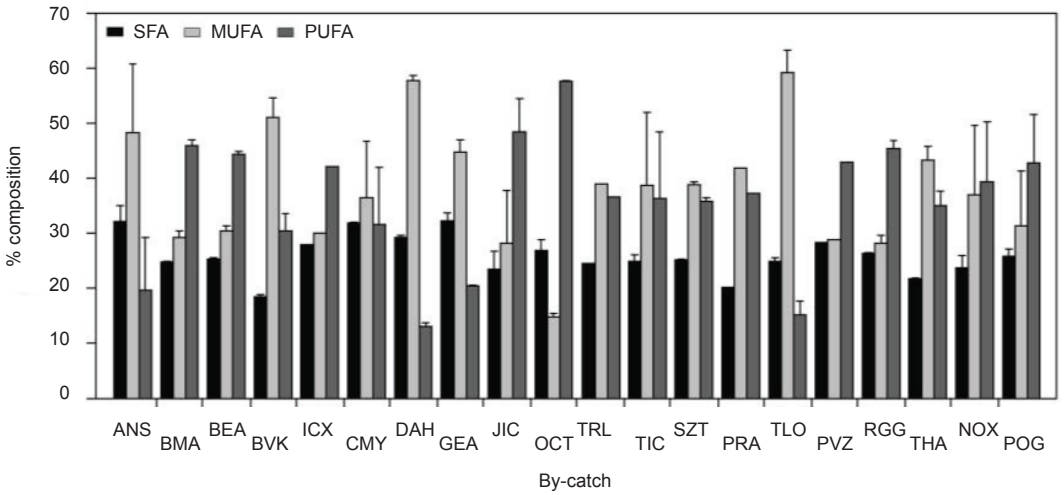

Figure 4: Saturated, monounsaturated and polyunsaturated fatty acid (SFA, MUFA, and PUFA, respectively) percentage composition for species taken as by-catch and in good condition collected from toothfish stomachs. Values are mean ± SD.

Results

All the specimens collected during the 2012 survey are listed in Table 2. Total FA compositions of Antarctic toothfish and species taken as by-catch and in good condition collected from toothfish stomachs are presented in Figures 3 and 4. Monounsaturated FAs (MUFAs) comprised >50% of the FAs in muscle tissue of Antarctic toothfish and by-catch species *P. antarcticum*, *Pogonophryne barsukovi*, *Dacodraco hunteri* and *Trematomus loennbergii*. While total polyunsaturated FAs (PUFAs) were lowest in muscle tissues of most of these species, total saturated FAs (SFAs) were lowest in muscle tissues of most other by-catch species.

The FA profiles of Antarctic toothfish, *P. antarcticum*, *P. barsukovi*, *D. hunteri*, and *T. loennbergii* were similar (Tables 3 and 4). The MUFA C18:1n9c was the most abundant FA (23.4 to 31.7%) in muscle tissues of these species. In contrast, the PUFA decosahexaenoic acid (DHA, C22:6n3) and eicosapentaenoic acid (EPA, C20:5n3) were more abundant in other species.

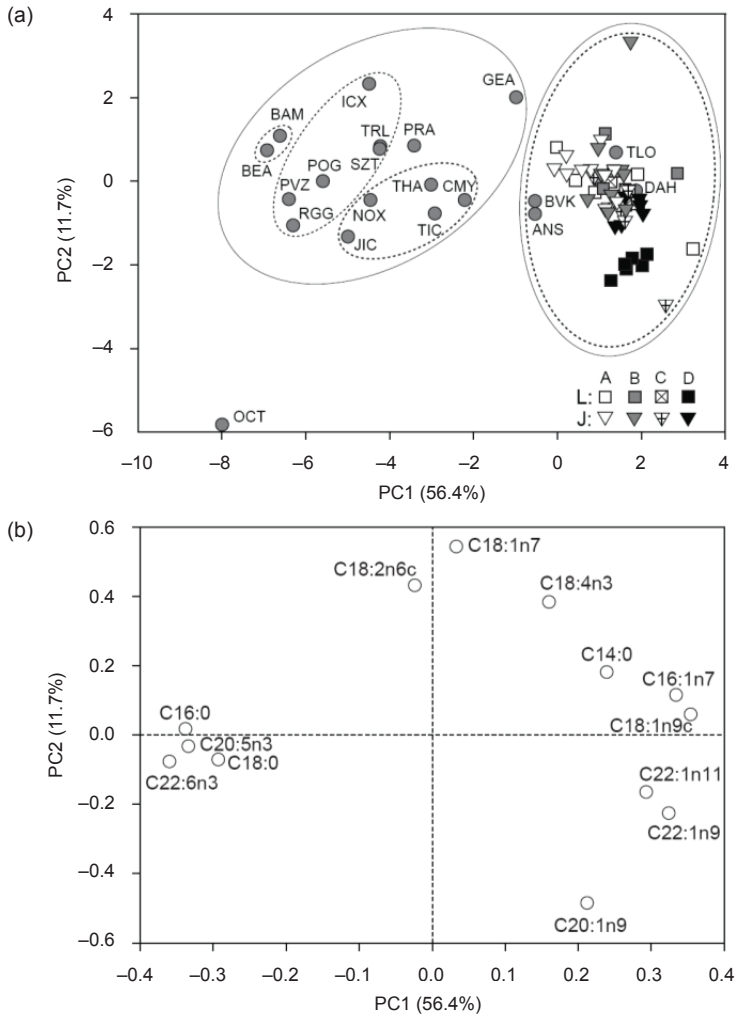

Figure 5: Biplot of the first and second principal components (PC) derived from fatty acid composition of Antarctic toothfish and species collected (from stomachs and by-catch). Antarctic toothfish include four size groups of 60–80 cm length (A), 80–99 cm (B), 100–119 cm (C) and 120–135 cm (D). Ellipses around samples represent hierarchical clustering using Bray-Curtis similarity matrix (—, > 80% similarity; ·····, > 95%).

Antarctic toothfish FA profiles were compared to those of species collected from the stomachs of toothfish or caught as by-catch using PCA (Figure 5). PC1 explained most of the variance (56.4%) and separated Antarctic toothfish, *P. antarcticum*, *P. barsukovi*, *D. hunteri* and *T. loennbergii* from the other species. The former group of five fish species displayed higher proportions in C18:1n9c, C16:1n7 and C14:0 than the other samples which recorded higher proportions in C16:0, C20:5n3, C18:0 and C22:6n3. PC2 explained 11.7% of the variance in FA profiles. Although C18:1n7, C18:2n6c, C18:4n3 and C20:1n9 contributed as the major FAs to separations along this axis, groupings of species by this axis were not distinct.

Mean $\delta^{13}C$ values of all the species collected in this survey fell within a very narrow range between –26.1 ± 0.1‰ (the crocodile icefish (*Neopagetopsis ionah*)) and –22.7 ± 0.5‰ (octopus unidentified, OCT) (Table 5). $\delta^{13}C$ values (–24.0 ± 0.5‰ to –23.3 ± 0.6‰) of Antarctic toothfish did not differ between size groups, and were within the range of by-catch species. Although two-way ANOVA revealed a significant difference in $\delta^{13}C$ of Antarctic toothfish between SSRUs 881J and L, the difference was only 0.3‰ (Table 6).

Mean $\delta^{15}N$ values of all the species were in the range from 6.6 ± 0.1‰ (Prawns (*Pasiphaea* sp.)) to 14.2 ± 0.1‰ (*Trematomus* sp.) (Table 5). $\delta^{15}N$ values (12.7 ± 0.9‰ to 14.6 ± 0.2‰) of Antarctic

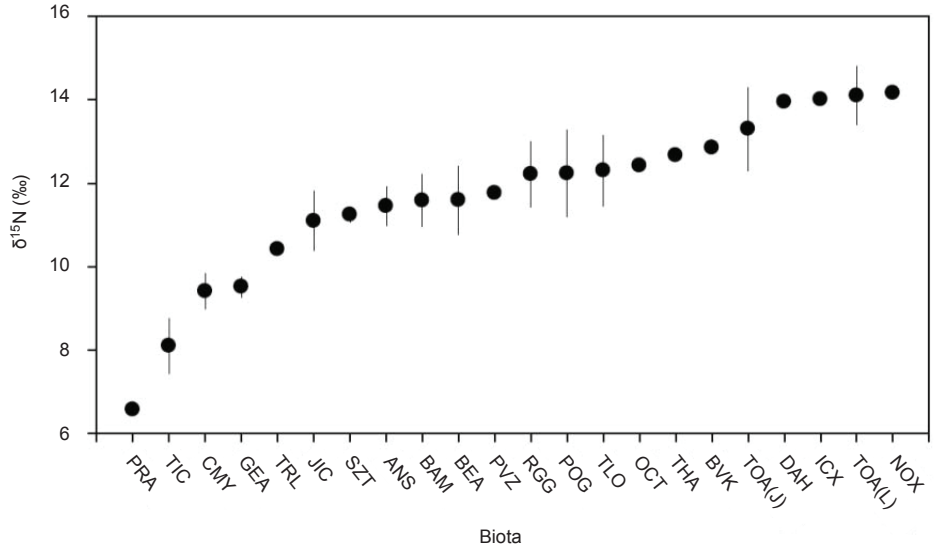

Figure 6: $\delta^{15}N$ values of Antarctic toothfish and species collected (from stomachs and by-catch). Species codes are given in Table 2.

toothfish were located at the highest level (Figure 6). Two-way ANOVA also revealed a between-area difference of 0.8‰ in $\delta^{15}N$ of Antarctic toothfish but not among size groups (Table 6).

Discussion

Results of FA and stable isotope analyses from this survey provide the feasibility that a combination of these two techniques can delineate the main prey items of Antarctic toothfish and trophic structure of toothfish-related fish food web in the southern Ross Sea ecosystem. Similarities in total FA compositions and the FA profiles in muscle tissue of Antarctic toothfish and by-catch species *P. antarcticum*, *P. barsukovi*, *D. hunteri* and *T. loennbergii* indicated a trophic connection between toothfish and these fish species. Similarity in their $\delta^{13}C$ values also confirmed their dependence on the same prey resources. On the other hand, $\delta^{15}N$ values of Antarctic toothfish were higher than those of *P. antarcticum*, *P. barsukovi* and *T. loennbergii*, indicating higher trophic position of the toothfish. In contrast, similar $\delta^{15}N$ values between Antarctic toothfish and *D. hunteri*) suggested that they occupy the same trophic position.

The results of this study showed reasonable consistency with the frequency and percentage occurrence of prey recorded from Antarctic toothfish stomachs collected during the survey. Hanchet et al. (2012) found that fish occurred in about 85% of stomachs, whilst invertebrates (prawns and octopus) occurred in only about 10% of stomachs. Over 50% of the fish could not be identified to family level. Of the fish which were identified, the majority were rock cods (mainly *T. loennbergii*), which occurred in 17.6% of stomachs, and icefishes (mainly *N. ionah*, *Chionodraco hamatus* and *C. myersi*), which occurred in 10.4% of stomachs. Dragonfish were found in 3.2% of stomachs whilst *P. antarcticum* were only found in 1.4% of stomachs. It is interesting to note the very strong similarity in levels of the three main FAs between toothfish of all sizes and *T. loenbergii*, supporting the idea that this is one of their main prey species in the southern Ross Sea.

Previous studies based on stomach contents have demonstrated that fish constitute the main dietary components of Antarctic toothfish in the Ross Sea (Yukhov, 1971; Eastman, 1985; Fenaughty et al., 2003; Stevens, 2004, 2006). *Pleuragramma antarcticum* were reported to dominate (over 70% of occurrence) the diet of Antarctic toothfish on the Ross Sea continental shelf (La Mesa et al., 2004; references therein). Fenaughty et al. (2003) also found that fish are the most important prey items, which accounted for 77–86% of the Antarctic toothfish stomach contents in the continental slope region and near oceanic seamounts, where icefish (Channichthyidae) and Whitson's rattail (*Macrourus whitsoni*) dominated the fish prey items. Stevens (2004) and Stevens et al. (2010) found that while Whitson's grenadier (*M. whitsoni*), icefish (*Chionobathyscus dewitti*), eel cods (*Muraenolepis*

spp.), and cephalopods predominated in the diet of Antarctic toothfish in the Ross Sea continental slope waters, *M. whitsoni*, violet (deep-sea) cods (*Antimora rostrata*) and cephalopods were important on oceanic seamounts. Stevens et al. (2012) concluded that the diet of sub-adult toothfish was similar to that of adults, but the sub-adult toothfish preyed on a greater variety of smaller prey than adults, including smaller fishes (such as *Trematomus* sp., dragonfish, mainly *Bathydraco* spp.), and large decapod prawns (*Nematocarcinus*). It is not surprising that *T. loennbergii* is one of the main prey species of Antarctic toothfish, as it is one of the deepest notothenid on the Ross Sea continental shelf, inhabiting the same waters where toothfish occur (Eastman and Hubold, 1999). According to Near et al. (2003), there was an evident ontogenetic shift in buoyancy and habitat in the Antarctic toothfish, which was also reflected in the different diet composition of juveniles and adults of this species. In particular, juveniles (i.e. individuals less than 80 cm SL) were not buoyant, whereas adults were neutrally buoyant and were found in deeper waters. It was expected to detect some differences between size group A (60–80 cm) and the other size groups. Although statistically insignificant, there was a light trend of increasing MUFA and decreasing SFA and PUFA with fish size. However, this investigation failed to highlight shifts in FA and stable isotope compositions with four size groups of toothfish. As a result, the diversity of the main prey items of Antarctic toothfish may reflect variation in their diet with size, depth and season in the Ross Sea, depending on several factors, including prey availability, as shown for Patagonian toothfish (*D. eleginoides*) by Arkhipkin et al. (2003).

For opportunistic predator species like toothfish that experience spatial and temporal variation in prey availability, a snapshot indication of diet from stomach contents may lead to a biased result in identifying feeding relationship. These biases may be compounded by factors such as the high proportion of empty stomachs and difference in digestibility of prey items. For example, *P. antarcticum* is believed to be the main prey item of Antarctic toothfish in the McMurdo Sound area (Calhaem and Christoffel, 1969; Eastman, 1985; La Mesa et al., 2004) and also a key prey species in the southern Ross Sea (Pinkerton et al., 2010). The similarity in FA signatures between the two species in the present study is consistent with these earlier studies. The relatively small numbers of *P. antarcticum* recorded in the stomach contents of toothfish during this survey could be due to the difficulty in identifying digested fish remains in many of the stomachs to species level (see above discussion), or could reflect the fishing method since toothfish were caught by a bottom longline and are therefore more likely to be feeding on benthic or demersal fish species (Stevens et al., 2012). Overall, the results presented here suggest that the use of biomarker analyses can complement conventional stomach content dietary analysis, providing longer time-scale information on the feeding relationship of Antarctic toothfish within the Ross Sea ecosystem. Further collection and subsequent biomarker analyses for more pelagic and benthic biota are needed to better understand the entire food-web structure in the southern Ross Sea.

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References

AOCS. 1998. AOCS official method Ce 1b-89. In: Firestone, D. (Ed.). *Official Methods and Recommended Practice of the AOCS* (5th Edition). AOCS, Champaign, USA.

Arkhipkin, A., P. Brickle and V. Laptikhovsky. 2003. Variation in the diet of the Patagonian toothfish with size, depth and season around the Falkland Islands. *J. Fish. Biol*., 63 (2): 428–441.

Bligh, E.G. and W.J. Dyer. 1959. A rapid method of total lipid extraction and purification. *Can. J. Biochem. Phys*., 37 (8): 911–917.

Calhaem, I. and D.A. Christoffel. 1969. Some observations of the feeding habit of a Weddell seal, and measurements of its prey, *Dissostichus mawsoni*, at McMurdo Sound, Antarctica. *New Zeal. J. Mar. Fresh.*, 3: 181–190.

DeNiro, M.J. and S. Epstein. 1981. Influence of diet on the distribution of nitrogen isotopes in animals. *Geochim. Cosmochim. Acta*, 45 (3): 341–351.

Drazen, J.C., C.F. Phleger, M.A. Guest and P.D. Nichols. 2009. Lipid composition and diet inferences in abyssal macrourids of the eastern North Pacific. *Mar. Ecol. Prog. Ser.*, 387: 1–14.

Eastman, J.T. 1985. *Pleuragramma antarcticum* (Pisces, Nototheniidae) as food for other fishes in McMurdo Sound, Antarctica. *Polar Biol.*, 4 (3): 155–160.

Eastman, J.T. and G. Hubold. 1999. The fish fauna of the Ross Sea, Antarctica. *Antarctic Sci.*, 11 (3): 293–304.

Fenaughty, J.M., D.W. Stevens and S.M. Hanchet. 2003. Diet of the Antarctic toothfish (*Dissostichus mawsoni*) from the Ross Sea, Antarctica (Subarea 88.1). *CCAMLR Science*, 10: 113–123.

Focken, U. and K. Becker. 1998. Metabolic fractionation of stable carbon isotopes: implications of different proximate compositions for studies of the aquatic food webs using $\delta^{13}C$ data. *Oecologia*, 115: 337–343.

Fry, B. and E.B. Sherr. 1984. $\delta^{13}C$ measurements as indicators of carbon flow in marine and freshwater systems. *Contrib. Mar. Sci.*, 27: 13–47.

Giraldo, C., Y. Cherel, C. Vallet, P. Mayzaud, E. Tavernier, M. Moteki, G. Hosie and P. Koubbi. 2011. Ontogenic changes in the feeding ecology of the early life stages of the Antarctic silverfish (*Pleuragramma antarcticum*) documented by stable isotopes and diet analysis in the Dumont d'Urville Sea (East Antarctica). *Polar Sci.*, 5 (2): 252–263.

Hanchet, S.M., S. Mormede and A. Dunn. 2010. Distribution and relative abundance of Antarctic toothfish (*Dissostichus mawsoni*) on the Ross Sea shelf. *CCAMLR Science*, 17: 33–51.

Hanchet, S.M., S. Mormede, A. Dunn and H.-S. Jo. 2012. Results of a research survey to monitor abundance of pre-recruit Antarctic toothfish in the southern Ross Sea, February 2012. Document *WG-SAM-12/29*. CCAMLR, Hobart, Australia.

La Mesa, M., J.T. Eastman and M. Vacchi. 2004. The role of notothenioid fish in the food web of the Ross Sea shelf waters: a review. *Polar Biol.*, 27 (6): 321–338.

Michener, R.H. and D.M. Schell. 1994. Stable isotope ratios as tracers in marine aquatic food webs. In: Lajtha, K. and R.H. Michener (Eds). *Stable Isotopes in Ecology and Environmental Science*. Blackwell Scientific Publications, Oxford: 138–157.

Minagawa, M. and E. Wada. 1984. Stepwise enrichment of ^{15}N along food chains: Further evidence and the relation between $\delta^{15}N$ and animal age. *Geochim. Cosmochim. Acta*, 48 (5): 1135–1140.

Near, T.J., S.E. Russo, C.D. Jones and A.L. DeVries. 2003. Ontogenetic shift in buoyancy and habitat in the Antarctic toothfish, *Dissostichus mawsoni* (Perciformes: Nototheniidae). *Polar Biol.*, 26 (2): 124–128.

Peterson, B.J. and B. Fry. 1987. Stable isotopes in ecosystem studies. *Ann. Rev. Ecol. Syst.*, 18: 293–320.

Pinkerton, M.H., J.M. Bradford-Grieve and S.M. Hanchet. 2010. A balanced model of the food web of the Ross Sea, Antarctica. *CCAMLR Science*, 17: 1–31.

Pinkerton, M.H., J. Forman, D.W. Stevens, S.J. Bury and J. Brown. 2012. Diet and trophic niche of *Macrourus* spp. (Gadiformes, Macrouridae) in the Ross Sea region of the Southern Ocean. *J. Ichthyol.*, 52 (10): 787–799.

Ponganis, P.J. and T.K. Stockard. 2007. The Antarctic toothfish: how common a prey for Weddell seals? *Antarct. Sci.*,19 (4): 441–442.

Post, D.M. 2002. Using stable isotopes to estimate trophic position: models, methods, and assumptions. *Ecology*, 83 (3): 703–718.

Smith, W.O. Jr., D.G. Ainley and R. Cattaneo-Vietti. 2007. Trophic interactions within the Ross Sea continental shelf ecosystem. *Phil. Trans. R. Soc. B*, 362: 95–111.

Stevens, D.W. 2004. Stomach contents of the Antarctic toothfish (*Dissostichus mawsoni*) from the western Ross Sea, Antarctica. Document *WG-FSA-04/31*. CCAMLR, Hobart, Australia.

Stevens, D.W. 2006. Stomach contents of sub-adult Antarctic toothfish (*Dissostichus mawsoni*) from the western Ross Sea, Antarctica. Document *WG-FSA-06/27*. CCAMLR, Hobart, Australia.

Stevens, D.W., J. Forman and S. Hanchet. 2010. Stomach contents of Antarctic toothfish (*Dissostichus mawsoni*) from the Ross Sea region in 2010 and a comparison with 2003. Document *WG-FSA-10/22*. CCAMLR, Hobart, Australia.

Stevens, D.W., M.R. Dunn, M.H. Pinkerton and J.S. Forman. 2012. Diet of Antarctic toothfish (*Dissostichus mawsoni*) from the Ross Sea region, Antarctica. Document *WG-FSA-12/52*. CCAMLR, Hobart, Australia.

Vander Zanden, M.J and J.B. Rasmussen. 2001. Variation in $\delta^{15}N$ and $\delta^{13}C$ trophic fractionation: implications for aquatic food web studies. *Limnol. Oceanogr*., 46: 2061–2066.

Yukhov, V.L. 1971. The range of *Dissostichus mawsoni* Norman and some features of its biology. *J. Ichthyol*., 11: 8–18.

Table 1: Number of stations, depth, soak times, fish weight, mean catch rate (CPUE) and CV (kg 1 000 hooks^{-1}), and total catch by stratum (after Hanchet et al., 2012).

Stratum	Stations planned	Stations completed	Depth (m)	Mean soak time (hours)	Mean fish weight (kg)	CPUE	CV
A12	16	10	616–877	16.8	11.6	147	0.47
B12	29	26[1]	607–778	17.3	11.1	122	0.58
C12	10	9	514–597	19.0	11.0	173	0.51
D12	10	9	407–492	16.6	11.1	55	1.02
E12	0	5	321–378	18.6	15.1	15	0.67
Total	65	59					

[1] Includes station 138 where only 2 750 hooks were set instead of 4 600 hooks.

Table 2: List of specimens collected during the 2012 survey. List of species codes used in study.

Species codes	Species	Common name	Muscle tissue (A)[1]	Liver tissue	Muscle tissue (B)[2]	Gut content	Total
ANS	*Pleuragramma antarcticum*	Antarctic silverfish	0	0	20	0	20
BAM	*Bathyraja maccaini*	McCain's skate	25	0	0	3	28
BEA	*Bathyraja eatonii*	Eaton's skate	9	0	0	3	12
BVK	*Pogonophryne barsukovi*	Plunderfish	4	0	0	2	6
ICX	Unidentified icefish	Icefish	0	0	1	0	1
CMY	*Chionodraco myersi*	Myers icefish	1	0	7	0	8
DAH	*Dacodraco hunteri*	Icefish	0	0	2	0	2
GEA	*Gerlachea australis*	Dragonfish	6	0	0	2	8
JIC	*Neopagetopsis ionah*	Crocodile icefish	0	0	25	3	28
OCT	*Octopodidae*	Octopus	10	0	20	0	30
SZT	*Pogonophryne scotti*	Plunderfish	25	0	0	3	28
PRA	*Pasiphaea* sp.	Prawns	0	0	25	0	25
TIC	*Chionodraco hamatus*	Icefish	0	0	13	3	16
TLO	*Trematomus loennbergii*	Scaly rockcod	31	0	0	3	34
TOA	*Dissostichus mawsoni*	Antarctic toothfish	207	207	0	0	414
THA	*Pagothenia hansoni*	Striped rockcod	5	0	0	3	8
TRL	*Trematomus eulepidotus*	Antarctic rockcod	3	0	0	1	4
NOX	*Trematomus* sp.	Trematomus	2	0	0	0	2
PVZ	*Paraliparis* sp.	Snailfish	0	0	1	0	1
RGG	*Racovitzia glacialis*	Dragonfish	0	0	3	0	3
POG	*Pogonophryne* spp.	Plunderfish	2	0	0	0	2
	Total		328	207	117	26	678

[1] Muscle tissue samples (A) were collected from individual specimens which were taken as by-catch.
[2] Muscle tissue samples (B) were taken from specimens in good condition collected from toothfish stomachs.

Table 3: Fatty acid (FA) composition (% of total FAs) of different size classes of Antarctic toothfish (*Dissostichus mawsoni*) from SSRUs 881J and 881L in the southern Ross Sea: 60–80 cm length (A), 80–99 cm (B), 100–119 cm (C) and 120–135 cm (D). Values are mean ± SD. Replicates (n) are presented in parenthesis. AA – arachidonic acid; DHA – decosahexaenoic acid; DMA – dimethylacetal; DPA – decosapentaenoic acid; EPA – eicosapentaenoic acid; NMD – nonmethylene-interrupted diene.

FA	SSRU 881J				SSRU 881L			
	A (10)	B (10)	C (8)	D (6)	A (5)	B (6)	C (6)	D (6)
C14:0	9.4 ± 2.1	8.6 ± 0.9	8.1 ± 0.8	8.0 ± 0.4	9.1 ± 1.0	9.9 ± 1.7	9.2 ± 0.5	9.0 ± 0.5
C14:1	0.3 ± 0.3	-	0.3 ± 0.2	0.3 ± 0.0	0.4 ± 0.1	0.3 ± 0.2	0.4 ± 0.0	0.4 ± 0.0
C15:0	0.1 ± 0.1	0.1 ± 0.1	0.2 ± 0.2	0.3 ± 0.0	0.3 ± 0.0	0.2 ± 0.2	0.4 ± 0.0	0.4 ± 0.0
C16:0 DMA	-	-	-	-	0.0 ± 0.1	0.2 ± 0.1	0.1 ± 0.2	0.1 ± 0.2
C16:0	12.1 ± 1.0	11.2 ± 0.4	11.1 ± 0.6	10.2 ± 0.5	11.9 ± 1.5	11.7 ± 1.4	10.8 ± 0.5	10.8 ± 0.6
C16:1n9	0.4 ± 0.5	0.2 ± 0.2	0.4 ± 0.3	0.3 ± 0.2	0.4 ± 0.2	0.4 ± 0.4	0.3 ± 0.3	0.1 ± 0.2
C16:1n7	12.9 ± 1.3	13.0 ± 0.9	13.1 ± 0.8	12.6 ± 0.5	12.0 ± 1.0	13.5 ± 1.7	13.2 ± 0.4	12.8 ± 0.6
C16:1n5	0.0 ± 0.1	0.7 ± 0.1	0.2 ± 0.2	0.3 ± 0.1	0.3 ± 0.0	0.2 ± 0.2	0.2 ± 0.2	0.2 ± 0.2
C16:2n7	-	-	-	-	0.1 ± 0.1	0.0 ± 0.1	0.1 ± 0.1	1.9 ± 0.0
C16:2n4	0.5 ± 0.3	-	0.8 ± 0.1	0.5 ± 0.1	0.6 ± 0.4	0.5 ± 0.3	0.8 ± 0.1	-
C17:0	-	0.3 ± 0.2	-	0.0 ± 0.1	0.0 ± 0.1	-	-	-
C17:1	0.1 ± 0.2	0.3 ± 0.2	0.3 ± 0.2	0.4 ± 0.0	0.5 ± 0.2	0.2 ± 0.2	0.3 ± 0.2	0.4 ± 0.1
C18:0 DMA	0.1 ± 0.2	0.2 ± 0.2	0.2 ± 0.2	0.1 ± 0.1	0.3 ± 0.0	0.2 ± 0.2	0.2 ± 0.2	0.2 ± 0.2
C18:0	1.8 ± 0.2	1.6 ± 0.2	1.9 ± 0.2	1.6 ± 0.2	1.4 ± 0.8	1.6 ± 0.1	1.6 ± 0.1	1.7 ± 0.1
C18:1n9c	29.7 ± 2.0	30.7 ± 1.3	31.7 ± 2.2	31.7 ± 0.9	31.0 ± 3.5	30.4 ± 1.3	31.4 ± 0.4	32.1 ± 0.6
C18:1n7	7.6 ± 0.3	7.6 ± 0.4	6.8 ± 6.8	7.1 ± 0.4	7.6 ± 0.2	7.4 ± 0.2	7.3 ± 0.1	7.3 ± 0.1
C18:1n5	0.3 ± 0.2	0.4 ± 0.2	0.4 ± 0.4	0.5 ± 0.0	0.4 ± 0.1	0.4 ± 0.4	0.5 ± 0.0	0.5 ± 0.0
C18:2n6c	2.0 ± 0.1	1.9 ± 0.1	2.1 ± 0.1	2.0 ± 0.1	1.8 ± 0.0	1.9 ± 0.1	2.0 ± 0.1	0.0 ± 0.1
C18:3n6	0.0 ± 0.1	0.1 ± 0.1	0.0 ± 0.1	-	0.1 ± 0.1	0.0 ± 0.1	0.1 ± 0.1	0.5 ± 0.0
C18:3n3	0.5 ± 0.3	0.6 ± 0.2	0.5 ± 0.1	0.5 ± 0.0	0.5 ± 0.1	0.5 ± 0.2	0.5 ± 0.0	0.1 ± 0.2
C18:4n3	1.3 ± 0.1	1.6 ± 1.2	1.1 ± 0.3	1.0 ± 0.1	1.1 ± 0.3	1.2 ± 0.1	1.1 ± 0.1	0.7 ± 0.3
C22:1n11	-	-	-	-	-	-	-	-
C20:1n9	4.1 ± 0.5	3.9 ± 1.6	5.2 ± 0.6	5.0 ± 0.2	4.1 ± 1.1	3.4 ± 1.8	4.8 ± 0.3	4.9 ± 0.2
C20:1n7	0.4 ± 0.2	0.5 ± 0.2	0.5 ± 0.2	0.6 ± 0.1	0.6 ± 0.1	0.9 ± 1.3	0.6 ± 0.1	0.6 ± 0.1
C20:2 NMD	-	-	-	0.1 ± 0.1	-	-	-	-
C20:2n6	0.0 ± 0.1	0.1 ± 0.1	0.0 ± 0.1	-	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1
C20:3n6	-	-	-	-	-	-	-	-
C20:3n3	0.2 ± 0.3	0.2 ± 0.3	0.2 ± 0.3	-	-	-	-	-
C20:4n6 AA	0.3 ± 0.3	0.2 ± 0.3	0.3 ± 0.4	0.5 ± 0.0	0.5 ± 0.1	0.5 ± 0.2	0.6 ± 0.1	0.6 ± 0.1
C20:4n3	0.2 ± 0.3	0.2 ± 0.2	0.1 ± 0.2	0.3 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.1 ± 0.2	0.3 ± 0.3
C20:5n3 EPA	6.8 ± 0.9	6.1 ± 0.5	5.6 ± 1.3	5.4 ± 0.1	5.4 ± 1.8	4.7 ± 2.1	5.3 ± 0.4	4.8 ± 0.4
C22:1n11	1.4 ± 0.4	1.8 ± 0.2	2.1 ± 0.4	2.2 ± 0.2	1.8 ± 0.9	2.1 ± 1.5	2.0 ± 0.2	2.1 ± 0.1
C22:1n9	1.1 ± 0.2	1.3 ± 0.1	1.5 ± 0.4	1.5 ± 0.1	1.4 ± 0.6	1.1 ± 0.2	1.3 ± 0.1	1.4 ± 0.1
C22:4n6	0.2 ± 0.6	0.1 ± 0.1	0.0 ± 0.1	0.2 ± 0.4	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1
C22:5n3DPA	0.1 ± 0.2	0.3 ± 0.2	0.2 ± 0.2	0.4 ± 0.2	0.3 ± 0.0	1.4 ± 3.0	0.2 ± 0.2	0.2 ± 0.2
C22:6n3DHA	5.9 ± 1.3	5.0 ± 0.5	5.0 ± 1.0	4.4 ± 0.5	4.7 ± 1.2	3.5 ± 1.7	4.3 ± 0.3	4.4 ± 0.6
Other	1.1 ± 1.1	1.1 ± 0.6	0.8 ± 0.8	1.2 ± 0.9	0.2 ± 0.2	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.2

Table 4: Fatty acid (FA) composition (% of total fatty acids) of by-catch species during the collection of Antarctic toothfish in the southern Ross Sea. Values are mean ± SD. AA – arachidonic acid; DHA – decosahexaenoic acid; DPA – decosapentaenoic acid; EPA – eicosapentaenoic acid. See Table 2 for a list of species codes.

FA	ANS	BAM	BEA	BVK	ICX	CMY	DAH	GEA	JIC	OCT
C14:0	12.5 ± 0.9	0.8 ± 0.1	0.7 ± 0.1	6.2 ± 0.3	9.2	11.2 ± 3.4	15.2 ± 0.0	17.9 ± 1.6	3.6 ± 1.5	2.4 ± 0.4
C14:1	-	-	-	-	-	0.6 ± 0.8	-	0.7 ± 0.9	-	-
C15:0	0.5 ± 0.7	-	-	-	-	0.5 ± 0.8	-	-	-	-
C16:0	17.6 ± 2.4	18.8 ± 0.1	18.8 ± 0.1	10.3 ± 0.5	16.6	16.3 ± 0.7	13.5 ± 0.3	14.3 ± 0.1	17.5 ± 4.3	19.4 ± 0.9
C16:1n9	-	-	-	-	-	-	-	-	-	-
C16:1n7	12.0 ± 1.1	2.5 ± 0.1	2.6 ± 0.0	12.8 ± 1.2	6.0	7.6 ± 3.8	11.7 ± 0.2	9.1 ± 0.8	3.0 ± 0.6	-
C16:1n5	0.2 ± 0.3	-	-	-	-	-	-	-	0.2 ± 0.3	0.4 ± 0.5
C16:2n7	-	-	-	-	-	-	-	-	-	-
C16:2n4	0.7 ± 0.2	-	-	0.8 ± 0.1	-	-	-	-	0.6 ± 0.8	-
C17:0	-	-	-	-	-	0.5 ± 0.7	-	-	-	0.5 ± 0.8
C17:1	0.2 ± 0.3	-	-	0.3 ± 0.5	-	0.4 ± 0.6	-	-	-	-
C18:0 DMA	0.2 ± 0.3	0.8 ± 0.1	0.9 ± 0.1	-	-	-	-	-	-	-
C18:0	1.4 ± 0.4	4.3 ± 0.1	4.9 ± 0.4	2.0 ± 0.1	2.1	2.5 ± 1.2	0.5 ± 0.7	-	2.4 ± 0.5	3.7 ± 1.1
C18:1n9c	23.5 ± 4.6	12.6 ± 0.6	12.5 ± 0.6	23.4 ± 1.6	15.9	17.7 ± 6.7	30.3 ± 0.0	26.7 ± 0.2	12.8 ± 5.4	1.2 ± 1.7
C18:1n7	5.5 ± 0.5	9.0 ± 0.0	9.4 ± 0.6	7.0 ± 0.1	8.1	5.7 ± 1.2	7.5 ± 0.0	8.4 ± 0.3	6.3 ± 0.4	2.9 ± 1.6
C18:1n5	0.3 ± 0.4	-	0.3 ± 0.4	0.6 ± 0.1	-	-	-	-	-	2.6 ± 3.6
C18:2n6c	1.7 ± 0.2	3.1 ± 0.2	2.8 ± 2.8	1.6 ± 0.0	2.5	2.7 ± 0.7	1.9 ± 0.1	1.6 ± 0.2	3.2 ± 0.6	-
C18:3n6	-	-	-	-	-	-	-	-	-	-
C18:3n3	0.2 ± 0.4	0.4 ± 0.6	-	-	-	1.0 ± 0.3	-	-	0.2 ± 0.3	-
C18:4n3	1.1 ± 0.4	0.6 ± 0.8	-	1.5 ± 0.3	1.7	0.7 ± 0.9	0.5 ± 0.7	-	0.3 ± 0.4	-
C20:1n11	-	-	-	-	-	-	-	-	-	-
C20:1n9	3.6 ± 2.3	2.1 ± 0.1	2.1 ± 0.1	3.7 ± 0.1	-	2.1 ± 0.8	4.7 ± 0.5	-	3.7 ± 1.6	7.2 ± 1.1
C20:1n7	0.3 ± 0.5	-	0.2 ± 0.3	1.0 ± 0.1	-	-	-	-	-	0.7 ± 0.9
C20:2 NMD	-	-	-	-	-	-	-	-	-	-
C20:2n6	-	-	-	-	-	0.5 ± 0.7	-	-	-	0.4 ± 0.5
C20:3n6	-	-	-	-	-	0.9 ± 1.3	-	-	-	-
C20:3n3	-	-	-	-	-	0.4 ± 0.6	-	-	-	1.9 ± 0.3
C20:4n6 AA	0.7 ± 0.5	4.9 ± 0.0	5.1 ± 0.4	1.5 ± 0.3	1.4	1.4 ± 0.8	-	-	2.5 ± 0.4	2.1 ± 1.1
C20:4n3	-	-	-	-	-	-	-	-	-	-
C20:5n3 EPA	8.5 ± 6.0	9.9 ± 0.0	9.1 ± 0.8	11.6 ± 1.2	17.1	10.0 ± 2.1	5.7 ± 0.3	10.5 ± 0.1	20.2 ± 2.7	21.4 ± 1.8
C22:1n11	-	-	-	1.0 ± 0.2	-	1.4 ± 0.7	2.1 ± 0.3	-	1.4 ± 1.1	-

(continued)

Table 4 (continued)

FA	TRL	TIC	SZT	PRA	TLO	PVZ	RGG	THA	NOX	POG
C22:1n9	1.4 ± 2.0	-	-	1.2 ± 0.1	-	1.0 ± 0.1	1.3 ± 0.1	-	0.9 ± 0.7	-
C22:4n6	-	1.6 ± 2.2	-	-	-	-	-	-	-	-
C22:5n3 DPA	-	1.1 ± 0.1	1.4 ± 0.3	1.3 ± 0.3	-	0.9 ± 1.3	-	-	0.2 ± 0.3	0.7 ± 0.9
C22:6n3 DHA	6.6 ± 2.7	24.4 ± 0.1	25.9 ± 0.2	12.1 ± 1.6	19.3	12.2 ± 2.0	4.8 ± 0.3	8.4 ± 0.5	21.1 ± 3.2	31.2 ± 1.4
Other	1.1 ± 1.6	3.1 ± 0.3	3.3 ± 0.4	-	-	-	-	2.5 ± 3.5	0.2 ± 0.3	1.6 ± 0.1
C14:0	5.4	6.6 ± 3.1	7.2 ± 0.7	3.4	11.5 ± 0.7	3.9	4.2 ± 0.1	4.6 ± 2.0	3.6 ± 2.1	5.2 ± 3.1
C14:1	-	-	-	-	0.4 ± 0.0	-	-	-	-	-
C15:0	-	-	-	-	0.5 ± 0.0	-	-	-	0.3 ± 0.0	-
C16:0	16.2	16.4 ± 3.7	15.2 ± 0.2	12.6	11.3 ± 0.5	21.4	19.2 ± 0.2	14.5 ± 1.5	16.5 ± 4.2	17.6 ± 3.7
C16:1n9	-	-	-	-	-	-	-	0.2 ± 0.3	0.2	-
C16:1n7	7.7	6.8 ± 3.6	6.9 ± 0.4	11.5	14.1 ± 0.0	4.8	5.6 ± 0.2	10.9 ± 0.6	9.4 ± 4.9	5.2 ± 1.9
C16:1n5	-	-	-	-	0.4 ± 0.0	-	-	0.2 ± 0.2	0.2 ± 0.3	-
C16:2n7	-	-	-	1.0	0.2 ± 0.2	-	-	-	-	-
C16:2n4	0.8	-	0.4 ± 0.5	1.2	1.0 ± 0.2	-	-	0.7 ± 0.1	0.4 ± 0.5	0.5 ± 0.6
C17:0	-	-	-	1.3	0.2 ± 0.2	-	-	-	0.2 ± 0.4	-
C17:1	-	-	-	1.0	0.2 ± 0.3	-	0.3 ± 0.5	-	0.2 ± 0.3	-
C18:0 I	-	-	-	1.1	0.2 ± 0.3	-	-	0.2 ± 0.3	0.2 ± 0.3	-
C18:0	3.0	1.9 ± 0.6	2.9 ± 0.4	1.8	1.4 ± 0.3	3.0	3.0 ± 0.3	2.4 ± 0.6	2.8 ± 0.8	3.0 ± 0.7
C18:1n9c	20.2	19.5 ± 6.4	21.7 ± 0.3	14.1	30.1 ± 2.8	15.2	14.5 ± 0.5	20.8 ± 1.2	17.5 ± 6.0	17.1 ± 7.0
C18:1n7	7.5	6.8 ± 1.1	7.6 ± 0.1	9.6	6.2 ± 2.1	8.7	5.6 ± 0.6	6.7 ± 0.2	6.0 ± 1.3	6.8 ± 1.1
C18:1n5	-	-	-	1.2	-	-	-	0.2 ± 0.3	0.2 ± 0.3	-
C18:2n6c	1.9	2.0 ± 0.4	1.9 ± 0.1	1.3	2.1 ± 0.0	-	1.8 ± 1.1	1.7 ± 0.1	1.9 ± 0.1	1.8 ± 0.4
C18:3n6	-	-	-	-	-	-	-	-	-	-
C18:3n3	-	0.3 ± 0.4	-	-	0.6 ± 0.1	-	-	0.2 ± 0.3	0.2 ± 0.3	-
C18:4n3	0.8	0.8 ± 0.2	0.4 ± 0.4	-	1.5 ± 0.2	-	-	0.9 ± 0.5	0.5 ± 0.7	0.3
C20:1n11	2.7	-	2.8 ± 0.3	1.6	3.7 ± 0.3	-	2.1 ± 0.3	2.5 ± 0.4	2.2 ± 0.5	2.2 ± 0.1
C20:1n9	-	3.4 ± 0.8	-	1.6	0.8 ± 0.0	-	-	0.7 ± 0.4	0.4 ± 0.5	-
C20:1n7	-	0.2 ± 0.3	-	1.2	0.5 ± 0.0	-	-	-	-	-
C20:2 NMD	-	-	-	-	-	-	-	-	-	-
C20:2n6	-	-	-	1.3	0.2 ± 0.2	-	-	-	-	-
C20:3n6	-	-	-	1.4	0.3 ± 0.4	-	-	-	-	-
C20:3n3	-	-	-	-	0.2 ± 0.3	-	-	-	-	-
C20:4n6 AA	2.8	1.4 ± 0.3	2.8 ± 0.1	2.7	0.8 ± 0.4	3.6	3.7 ± 0.6	1.5 ± 0.5	2.9 ± 1.8	4.6 ± 2.8

(continued)

Table 4 (continued)

FA	TRL	TIC	SZT	PRA	TLO	PVZ	RGG	THA	NOX	POG
C20:4n3	-	-	-	-	-	-	-	-	-	-
C20:5n3 EPA	15.6	13.5 ± 5.1	13.5 ± 0.8	14.8	5.5 ± 0.0	14.5	15.5 ± 1.1	12.4 ± 0.4	17.7 ± 6.4	15.8 ± 1.9
C22:1n11	0.9	1.2 ± 0.5	-	-	1.6 ± 0.1	-	-	0.4 ± 0.5	0.2 ± 0.3	-
C22:1n9	-	0.8 ± 0.4	-	-	1.2 ± 0.2	-	-	0.6 ± 0.2	0.3 ± 0.5	-
C22:4n6	-	-	-	-	-	-	-	-	-	-
C22:5n3 DPA	-	0.3 ± 0.4	-	1.3	-	-	-	1.1 ± 0.8	0.8 ± 1.1	-
C22:6n3 DHA	14.6	18.1 ± 7.3	16.9 ± 0.6	12.4	2.7 ± 0.6	24.8	24.4 ± 0.3	16.5 ± 3.4	15.0 ± 5.3	19.8 ± 5.6
Other	-	-	-	0.8	0.5 ± 0.6	-	-	0.2 ± 0.2	-	-

Table 5: Isotope ($\delta^{13}C$ and $\delta^{15}N$) values (mean ± SD) for individual fish specimens which were taken as by-catch and from toothfish stomachs, and Antarctic toothfish (*Dissostichus mawsoni*).

Species codes	Species	Common name	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	n
ANS	*Pleuragramma antarcticum*	Antarctic silverfish	−24.3 ± 0.1	11.4 ± 0.5	2
BAM	*Bathyraja maccaini*	McCain's skate	−23.6 ± 0.0	11.6 ± 0.6	2
BEA	*Bathyraja eatonii*	Eaton's skate	−25.5 ± 0.6	11.6 ± 0.8	2
BVK	*Pogonophryne barsukovi*	Plunderfish	−24.3 ± 0.7	12.8 ± 0.1	2
ICX	Unidentified icefish	Icefish	−23.9	14.0	1
CMY	*Chionodraco myersi*	Myers icefish	−23.7 ± 0.9	9.4 ± 0.4	2
DAH	*Dacodraco hunterii*	Icefish	−25.4 ± 0.6	13.9 ± 0.0	2
GEA	*Gerlachea australis*	Dragonfish	−26.8 ± 0.5	9.5 ± 0.2	2
JIC	*Neopagetopsis ionah*	Crocodile icefishes	−26.1 ± 0.1	11.1 ± 0.7	2
OCT	Octopodidae	Octopus	−22.7 ± 0.5	12.4 ± 0.0	2
SZT	*Pogonophryne scotti*	Plunderfish	−24.0 ± 0.1	11.2 ± 0.2	2
PRA	*Pasiphaea* sp.	Prawns	−23.8 ± 0.5	6.6 ± 0.1	2
TIC	*Chionodraco hamatus*	Icefish	−25.1 ± 0.0	8.1 ± 0.7	2
TLO	*Trematomus loennbergii*	Scaly rockcod	−23.8 ± 0.4	12.3 ± 0.8	2
THA	*Pagothenia hansoni*	Striped rockcod	−24.0 ± 0.3	12.7 ± 0.1	2
TRL	*Trematomus eulepidotus*	Antarctic rockcod	−23.3	10.4	1
NOX	*Trematomus* sp.	Trematomus	−23.6 ± 0.1	14.2 ± 0.1	2
PVZ	*Paraliparis* sp.	Snailfish	−24.6	11.8	1
RGG	*Racovitzia glacialis*	Dragonfish	−23.7 ± 0.3	12.2 ± 0.8	2
POG	*Pogonophryne* spp.	Plunderfish	−23.9 ± 0.0	12.2 ± 1.0	2
TOA	*Dissostichus mawsoni*	Antarctic toothfish			
	SSRU	Size group	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	n
	881J	A	−23.6 ± 0.5	12.7 ± 0.9	10
		B	−23.8 ± 0.5	13.3 ± 0.9	9
		C	−24.0 ± 0.5	13.8 ± 1.0	8
		D	−23.8 ± 0.2	13.2 ± 0.8	6
	881L	A	−23.3 ± 0.6	13.5 ± 1.0	5
		B	−23.8 ± 0.3	14.1 ± 0.7	6
		C	−23.5 ± 0.3	14.1 ± 0.6	6
		D	−23.4 ± 0.7	14.6 ± 0.2	6

Table 6: Two-way ANOVA and means for $\delta^{13}C$ and $\delta^{15}N$ values of Antarctic toothfish (*Dissostichus mawsoni*). Main factors were SSRU (881J and L) and length group.

ANOVA	$\delta^{13}C$			$\delta^{15}N$		
	df	MS	F	df	MS	F
Area	1	1.1	4.8[1]	1	8.5	13.3[2]
Length	3	0.4	1.5	3	1.6	2.5
Area × length	3	0.2	0.9	3	0.8	1.3
Residual	48	0.2		48	0.6	
Mean values	n	mean	SD	n	mean	SD
SSRU 881J	33	–23.8	0.5	33	13.3	1.0
SSRU 881L	23	–23.5	0.5	23	14.1	0.7

[1] $0.01 < p < 0.05$
[2] $0.001 < p < 0.01$