

1 Distribution, habitat and trophic ecology of Antarctic 2 cephalopods: inferences from predators and stable isotopes

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15 **Abstract:**

16 Cephalopods play a key role in the marine environment but knowledge of their
17 feeding habits is limited by a lack of observations and this is particularly true for
18 Antarctic species. Toothfish species are key predators of cephalopods and may be
19 viewed as ideal biological samplers of these species. A total of 256 cephalopod lower
20 beaks were identified from the stomachs of Patagonian (*Dissostichus eleginoides*) and
21 Antarctic toothfish (*D. mawsoni*), captured in fisheries of South Georgia and the
22 South Sandwich Islands in the South Atlantic. Long-armed octopus squid
23 (*Kondakovia longimana*) and smooth-hooked squid (*Moroteuthis knipovitchi*) were
24 the main cephalopod prey and both were predated upon wherever toothfish were
25 captured, though inhabit deeper waters at the South Sandwich Islands than at South
26 Georgia. Measurements of $\delta^{13}\text{C}$ from beak material indicated a clear segregation of
27 habitat use comparing adult and sub-adult sized *K. longimana*. Variation in $\delta^{15}\text{N}$ with
28 size indicated an ontogenetic shift in the diet of cephalopods and also suggested
29 trophic plasticity, with variation in diet in response to prey availability. This study
30 provides new insights in to private life of elusive Antarctic cephalopods in a largely
31 unexplored region of the South Atlantic.

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1 **Introduction**

2 Cephalopods play an important role in the Antarctic marine ecosystem both as
3 predators and prey of top predators (Clarke 1996), though there is still a general lack
4 of knowledge about their ecology and distribution, particularly of deep sea species
5 (Cherel et al. 2004; Clarke 1983; Southward et al. 2006; Xavier et al. 1999). This is
6 largely because of the small amount of dedicated survey cruises targeting oceanic
7 squid species allied with the fact that several species (particularly myopsid Antarctic
8 species) are extremely difficult to catch using scientific nets (Clarke 1977; Rodhouse
9 1990; Xavier et al. 2002). One solution is to use observations from the diet of squid
10 predators such as toothed whales (e.g. Mikhalev et al., 1981;), seals (e.g. Slip et al.
11 1995), seabirds (Xavier et al. 2003) and fish (Xavier et al. 2002).

12 The identification of cephalopod species from beak (keratinous mandibles)
13 morphology is now possible for a large number of commonly occurring Antarctic
14 species (Xavier and Cherel 2009). We can also use information from the ratio of
15 stable isotopes ($\delta^{15}\text{N}$ and $\delta^{13}\text{C}$) of keratin from cephalopod beaks to complement the
16 spatial distribution of presence in the diet of predators (Cherel et al. 2011; Cherel and
17 Hobson 2005). Heavy nitrogen is enriched in beak material with increasing trophic
18 level ($>\delta^{15}\text{N}$), consequently $\delta^{15}\text{N}$ measurements serve as indicator of individual
19 trophic position (Hobson & Welch 1992). Carbon ($\delta^{13}\text{C}$) is mainly used to determine
20 primary sources in a trophic network, indicating the lower versus higher-latitude
21 plankton and inshore versus offshore, or pelagic versus benthic, contribution to food
22 intake (Cherel and Hobson 2005; Hobson et al. 1994).

23 In this study, squid beaks were obtained from the stomachs of toothfish
24 species captured in demersal longline fisheries of South Georgia and the South
25 Sandwich Islands: Patagonian toothfish (*Dissostichus eleginoides*) which are found
26 mainly around sub-Antarctic Islands and Patagonian region and Antarctic toothfish
27 (*Dissostichus mawsoni*), which has several adaptations to very cold water
28 temperatures and is endemic to the austral seasonal pack-ice zone (De Witt et al.
29 1990). *Dissostichus* spp. are opportunistic predators feeding on a wide range of taxa,
30 including fish, crustaceans and cephalopods (Collins et al. 2010; Collins et al. 2007;
31 Fenaughty et al. 2003; Garcia de la Rosa et al. 1997; Pilling et al. 2001; Roberts et al.
32 2011; Stevens et al. 2012). This generalist feeding behaviour and generally low rates
33 of dispersal (Williams et al. 2002) make *Dissostichus* spp. ideal biological samplers
34 of deep water cephalopods and other prey taxa.

1 The distributions of the two toothfish congeners overlap in only a few places
2 including at the South Sandwich Islands, an island arc along the Scotia Ridge
3 (Roberts et al. 2011). The South Sandwich Islands are bisected by the Weddell Front,
4 which separates the marine habitat of this region in to two separate water bodies with
5 distinct hydrographical characteristics: the eastward-flowing Weddell–Scotia
6 Confluence (WSC) to the north and Weddell Gyre to the south (Orsi et al. 1995). The
7 segregation between these two water mass is evident from a north to south gradient in
8 water temperature and habitat type that causes the observed distributions of toothfish
9 species along the island chain (Roberts et al. 2011).

10 Commercial interest in Southern Ocean cephalopods has increased over the
11 past few decades. Cephalopod species including *Martialia hyadesi*, *Kondakovia*
12 *longimana*, *Moroteuthis knipovitchi* and *Gonatus antarcticus* are potential candidates
13 for commercial exploration (Xavier et al. 2007). However, the poor understanding of
14 ecology and distribution will hamper the estimation of stock size and the effective
15 management of any future cephalopod fisheries that may develop in the Southern
16 Ocean. In addition, these cephalopod species have been recorded regularly in the diet
17 of numerous predators and are likely to perform a relevant ecosystem function, at
18 least in particular areas of the Southern Ocean. As such it is desirable to improve our
19 knowledge on the ecology of the populations of cephalopod species of this region.
20 The main goals of this study were: (1) to describe the cephalopod fauna in the diet of
21 *Dissostichus* spp., in terms of diversity and quantity; (2) to characterise the vertical
22 and horizontal distribution of cephalopods; and (3) to assess the trophic level and the
23 habitat of the cephalopods fauna, using stable isotopes analysis.

24 25 **Materials and Methods**

26 Whole stomachs from *D. mawsoni* and *D. eleginoides* were collected on board
27 the demersal longline fishing vessel *San Aspiring* at the South Sandwich Islands
28 (from 55.7–59.9° S and 25–29° W) at depths ranging from 917 to 1720 m during
29 March and April 2009 (See Roberts *et al.* 2011 for a more detailed description). The
30 southern arrow squid (*Nototodarus sloanii*) were used as bait and do not naturally
31 occur at the study site. As such they were omitted from this analysis where found in
32 stomachs.

33 The stomach contents from both toothfish species were analysed following the
34 method of Roberts *et al.* (2011). The cephalopods beaks were preserved in 90%

1 ethanol prior to identification. Lower beaks were counted and identified to species
2 level using Xavier & Cherel (2009) while upper beaks were only counted. The lower
3 rostral length (LRL) was measured to the nearest 0.1 mm using Vernier callipers and
4 used to estimate reconstituted mass and mantle length for each individual using
5 allometric equations for each species given by Xavier & Cherel (2009). The
6 frequency of occurrence (% *O*) of cephalopods in the diet (count of sampled in which
7 a species was present divided by the total number of stomach sampled), the
8 proportion (% *N*) of lower beak beaks (count of lower beak of a species divided by
9 the total count of lower beaks) and the contribution to the estimated total prey mass
10 (% *M*) (estimated mass, *M*, of a species divided by the total estimated mass of all
11 cephalopod individuals) were calculated.

12 Lower beaks were selected for isotopic analyses (C and N) for the three
13 species that comprised the greatest proportion of reconstituted mass (% *M*;
14 *Kondakovia longimana*, *Moroteuthis knipovitchi* and *Psychroteuthis glacialis*) from
15 stomach sampled collected from *D. mawsoni* (beaks from stomachs of *D. eleginoides*
16 were not used because the sample size was small). For *K. longimana* sampled subsets
17 were taken based on beak LRL that were assumed to have belonged to sub-adults
18 (LRL ≤ 10mm) or adults (>10mm). Cleaned whole beaks were dried and reduced to a
19 fine powder. Stable isotope ratios of nitrogen (δ¹⁵N) and carbon (δ¹³C) were measured
20 using a Continuous Flow Isotope Ratio Mass Spectrometer (CFIRMS) at IMAR-
21 CMA following Ceia et al. (2012) (Ceia et al. 2012). The results are presented in δ
22 notation as deviations from the standard references in parts per thousand (‰)
23 according to the following equation:

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$$25 \quad \delta X = [(R_{\text{sample}} / R_{\text{standard}}) - 1] \times 1000$$

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27 where X represents ¹³C or ¹⁵N and *R*_{sample} the ratios ¹³C/¹²C or ¹⁵N/¹⁴N. *R*_{standard}
28 represents the international reference standard V-PDB ("Vienna" - PeeDee formation)
29 and atmospheric N₂ (AIR) is the standard for δ¹³C and δ¹⁵N, respectively. Data were
30 statistically analysed using R for Macintosh (R Core Team 2013).

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32 **Results**

33 **The cephalopod diet of Antarctic toothfish *Dissostichus mawsoni***

1 A total of 269 stomachs were collected, of which 205 (76.2%) contained prey.
2 The main prey was fish (62% *M* of *D. mawsoni*), followed by cephalopods (35% *M*).
3 Seven species of cephalopods were identified from a total of 205 stomachs, of which
4 76.2% of stomachs containing prey. A total of 311 beaks (71 uppers and 240 lowers)
5 were collected. *Kondakovia longimana* was (122 fresh lower beaks; 65.2% of total
6 fresh lower beaks) followed by *Moroteuthis knipovitchi* (48 beaks; 25.7%), these two
7 species (both Onychoteuthids) represented 90.9% of the total number of fresh lower
8 beaks found (Table 1). The estimated mass of cephalopods consumed by *D. mawsoni*
9 was 999.7 Kg (average of 4.9 kg for each *D. mawsoni* that had consumed squid). *K.*
10 *longimana* was also the most important cephalopod species in terms of estimated
11 mass (96.4% of the total estimated mass for all cephalopods) followed by *M.*
12 *knipovitchi* (2.9%) (Table 1).

13 Lower rostral lengths of beaks in the stomachs of *D. mawsoni* ranged from
14 5.3-19.8 mm (mean: 12.3 ±0.37 mm [SE]), slightly below that of the dominant
15 species *K. longimana* (mean: 15.6 ± 0.26mm [SE]). The smallest beak was identified
16 as a single *Slosarczykovia circumantarctica* (3.2 mm).

17 There were no significant effect of predator size on beak LRL (ANOVA: $F_{5, 175} = 1.2$; $p = 0.31$), or of predator sex (Mann-Whitney; $U = 3395$; $p = 0.22$).

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21 **The cephalopod diet of Patagonian toothfish *Dissostichus eleginoides***

22 A total of 775 stomachs were collected, of which only 56 contained prey
23 (7.2% *O*). The main prey was fish (73.6% *M*), followed by cephalopods (18% *M*).

24 Only three species were identified. A total of 21 beaks (5 uppers and 16
25 lowers) were collected. *K. longimana* and *M. knipovitchi* were, again, the most
26 important species by number (each species: 5 fresh lower beaks and 45.5% of total
27 fresh lower beaks; Table 2).

28 The estimated mass of cephalopods consumed by *D. eleginoides* was 34.5 kg
29 (average of 0.62 kg for each individual that had consumed squid). *K. longimana* was
30 also the most important cephalopod species by estimated mass (89.3% of the total
31 estimated mass for all cephalopods) followed by *M. knipovitchi* (10.2%; Table 2)

1 Lower rostral lengths of beaks in the stomachs of *D. mawsoni* ranged from
2 18.2 to 5.7mm (mean = 9.65 ±1.31mm [SE]). The smaller beak found was from a
3 specimen of *M. knipovitchi* (3.2 mm).

4 There were no significant effect of predator size on beak LRL (ANOVA: $F_{6,5}$
5 = 1.56; $p= 0.32$), or of predator sex (Mann- Whitney; $U = 8$; $p=0.23$).

6 7 8 **Vertical and horizontal distribution of toothfish species in relation to** 9 **cephalopods consumed**

10 Cephalopod beaks were found in fish caught from 1000 to 1800m depth. The
11 majority of beaks came from the range depth 1300 to 1600 m (60% of total fresh
12 lower beaks found on the diet of *Dissostichus* spp.; Figure 1; Figure 2).

13 The most important cephalopod species, *K. longimana* and *M. knipovitchi*,
14 were distributed across the depth range over which fish were captured, though no *M.*
15 *knipovitchi* were found at depths >1700m. Both cephalopod species were most
16 common at intermediate depths (1300-1600m). The sizes of *Dissostichus* spp. that
17 feed on cephalopod was not significantly comparing depth ranges (Kruskal-Wallis;
18 $H=27.07$; $p < 0.01$), neither was beak LRL (Kruskal-Wallis; $H= 8.16$; $p= 0.03$).
19 Cephalopods beaks were found in all locations where fish were captured and may
20 have greatest frequency of occurrence in south-eastern areas of the South Sandwich
21 Islands (Figure 1b from Roberts et al. 2011). There was no evidence for a location of
22 capture effect on the frequency of occurrence of the main cephalopod prey.

23 24 **Habitat and trophic level of Antarctic cephalopods according to stable isotope** 25 **signatures**

26 There was a clear delineation of adults and sub-adult from *K. longimana*
27 based on $\delta^{15}N$ (a proxy for their trophic level): $\delta^{15}N$ of sub-adult beaks ranged from
28 6.77-5.88, compared with 6.11-8.33 for adults (ANOVA; $F_{3,28}= 8.55$; $p < 0,01$;
29 Figure 3), indicating that they are at a greater trophic level. The value of $\delta^{13}C$ (a proxy
30 for their habitat) indicates that *K. longimana* (adult) and *Psychroteuthis glacialis*
31 occupy similar habitat types and are spatially segregated from *M. knipovitchi* and *K.*
32 *longimana* (sub-adult) (ANOVA; $F_{3,28} = 20.22$; $p < 0.01$; Figure 3).

1 Discussion

2 Regional variation in cephalopod prey of *Dissostichus* spp.

3 To our knowledge, this is the first detailed study to analyse the distribution,
4 habitat and trophic levels of cephalopods around South Sandwich Islands. The
5 cephalopod component of diet of *D. mawsoni* and *D. eleginoides* is typically quite
6 different though was quite similar at the South Sandwich Islands. All cephalopod
7 species found in this study had been previously recorded in the diet of at least one
8 toothfish species (Cherel et al. 2004; Stevens et al. 2012; Xavier et al. 2002; Xavier
9 and Cherel 2009). *D. eleginoides* from the Argentinian shelf prey on *Semirossia*
10 *tenera*, *Illex argentinus*, *Loligo gahi* and *Octopus tehuelchus* (Garcia de la Rosa et al.
11 1997). None of these species were observed in our study and may not be present at the
12 South Sandwich Islands, though *I. argentinus* may also occur in colder waters (Xavier
13 et al. 2006). Around the sub-Antarctic islands of Kerguelen and Crozet, *K. longimana*,
14 *Moroteuthis ingens* and *Gonatus antarcticus* were the most important cephalopods in
15 terms of estimated mass (Cherel et al. 2004) – the latter two species did not occur in
16 our study, probably due to a slightly warmer water distribution (Anderson and
17 Rodhouse 2002; Nesis 1987; Rodhouse 1989; Xavier and Cherel 2009). However, *G.*
18 *antarcticus* was reported in the diet of *D. eleginoides* around South Georgia (Xavier
19 et al. 2002) indicating that the distribution of this species is limited to the northern
20 islands of the Scotia Arc (Ward et al. 2012). Even so, despite the hydrographical
21 segregation of the Scotia Sea, the cephalopod component in the diet of *D. eleginoides*
22 found in South Georgia is relatively similar to the component of cephalopods found in
23 the present study, where *K. longimana* and *M. knipovitchi* were also the most
24 important species by estimated mass (76.1% *M* and 10.7% *M*, respectively; Xavier et
25 al. 2002).

26 In the Ross Sea just two cephalopod species – *K. longimana* and
27 *Psychroteuthis glacialis* – were found in *D. mawsoni* stomachs, the latter having the
28 greatest estimated mass (29.6% *M*; Stevens 2012). The dominance of *P. glacialis*
29 could be due increased latitude and proximity to the mainland as this cephalopod
30 species is considered to have a Antarctic distribution (Xavier et al. 1999). Comparing
31 our study with those of toothfish species in other regions we see that these species
32 have a high degree of trophic plasticity with respect to cephalopod prey and are likely
33 to predate on the species that are locally abundant.

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1 **Vertical/Horizontal distribution of Antarctic cephalopods**

2 There is considerable potential in using top predators to better describe the
3 spatial distributions of cephalopod species that are not yet commercially exploited
4 (Rodhouse et al. 1996). Cephalopod beaks were found in the diets of toothfish at all
5 depths sampled (100 m to 1800 m) with most present in fish caught between 1300 and
6 1600 m. This conforms with present assumption that most Antarctic cephalopod
7 species are confined to continental slope habitat, the mesopelagic/bathypelagic zones
8 (Croxall and Prince 1994; Kock 1987). *K. longimana* and *M. knipovitchi* – the most
9 important cephalopod prey in this study, were mainly found between 1300 at 1600m,
10 contrary to a previous study conducted at South Georgia where they were only found
11 between depths of 300 to 900m (Xavier et al. 2002). Therefore, we can say that the
12 vertical distributions of *K.longimana* and *M. knipovitchi* vary between bathyal and
13 mesopelagic zones in the Scotia Sea, depending on the oceanographic regime.
14 *Galiteuthis glacialis* and *P. glacialis* were also found in deeper water when compared
15 to the South Georgia study (600-900m and 300-1200 in Xavier *et al.* (2002),
16 respectively). These results show that the South Sandwich Islands cephalopod
17 community inhabits at greater depths than the population from South Georgia. A
18 recent study found that hydrographic differences effectively split the Scotia Sea in to
19 North and South groupings where the structure of the food web is different (Ward et
20 al. 2012), which can explain why there is an different observed vertical distribution of
21 cephalopods.

22 One of the more interesting characteristics of the South Sandwich Islands Arc
23 is the clear spatial segregation of the two *Dissostichus* spp. (Roberts et al. 2011) and
24 also of other fish species and benthic invertebrate communities (Roberts 2012). The
25 north to south gradient in temperature at bathyal depths is likely to be a key driver of
26 this bio-regionalisation (Roberts 2012), though does not appear to be a barrier to the
27 dispersal of key cephalopod prey of toothfish species in this study. In this study we
28 found the main cephalopod prey species in the diet of toothfish species both to the
29 north and south of the Weddell front. The relatively broad niche of these species has
30 been observed before by Xavier et al. (1999).

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33 **Habitat assessment from cephalopod beaks**

1 Based on the ratio of ^{13}C isotopic signatures of cephalopod beaks found in the
2 stomachs of *D. mawsoni* and comparing with reference values, all three species
3 analysed (*K. longimana*, *M. knipovitchi* e *P. glacialis*) have mainly inhabited
4 Antarctic waters (Stowasser et al. 2012). However, our results show differences
5 between species, indicating that they may feed in different areas of the ocean. There is
6 a clear segregation between sub-adults and adults of *K. longimana*, suggesting that
7 younger individuals of the South Sandwich Islands population inhabit more northerly
8 regions with a southward redistribution likely to occur as they increase in size.
9 In previous studies, $\delta^{13}\text{C}$ values of *K. longimana* and *M. knipovitchi* were relatively
10 high ($[\delta^{13}\text{C}$ of *K. longimana* and *M. knipovitchi* caught by Black-browed albatrosses
11 were -21.85 ± 1.53 and -21.24 ± 1.04 , respectively (Alvito , Rosa, Phillips, Ceia, Seco
12 and Xavier (unpublished data)]; (Anderson et al. 2009)) at South Georgia). The South
13 Sandwich Islands are at higher latitude that can explain the difference on the $\delta^{13}\text{C}$.
14

15 **Trophic assessment of cephalopods beaks**

16 We found a clear segregation between the ^{15}N signatures of sub-adults and
17 adults of *K. longimana*, suggesting an ontogenetic dietary shift in this species. The
18 trophic ecology of *K. longimana* is poorly understood, though through comparing
19 with the results of another study (Cherel and Hobson 2005) we can infer an
20 ontogenetic shift in *K. longimana* from a crustacean to a mesopelagic fish diet at
21 South Sandwich Islands.

22 The values of $\delta^{13}\text{C}$ from sub-adults of *K. longimana* and adults of *M.*
23 *knipovitchi* are very similar, though the $\delta^{15}\text{N}$ values for these two species are
24 significantly different, from which we can infer that they occupy similar habitat,
25 though have a different trophic ecology.

26 Comparing with other studies in the Scotia Sea region, $\delta^{15}\text{N}$ values found in
27 this study were relatively low ($[\delta^{15}\text{N}$ of *K. longimana* and *M. knipovitchi* caught by
28 Black-browed albatrosses were $8,00 \pm 0.82$ and 8.82 ± 0.76 , respectively (Alvito ,
29 Rosa, Phillips, Ceia, Seco and Xavier (unpublished data)]; (Anderson et al. 2009)). –
30 especially when compared with the study of Anderson et al (2009) ($\delta^{15}\text{N}$ of
31 *K.longimana* = 7.5; *M. knipovitchi* = 10.8, *P. glacialis* = 10.5). The large difference
32 between studies may indicate strong location or year effects on foodweb structure
33 beneath these cephalopod species. Antarctic Krill (*Euphasia superba*) perform a key
34 central role in the marine foodweb of the Scotia Sea region and in years of low krill

1 biomass in the Subantarctic region (as in 2009 – the year of this study) (Hill et al.
2 2009; Waluda et al. 2012). Intermediates species in the foodweb may switch to
3 feeding on species at a lower trophic level such as copepods, which will affect a
4 decrease in the value of $\delta^{15}\text{N}$ in cephalopods further up the foodweb (Tarling et al.
5 2012). The study of cephalopods present in the diet of albatrosses in 2009 around the
6 South Georgia confirms this inference (Alvito *et al.* (unpublished data)).
7 Nevertheless, cephalopods from the Scotia Sea had a greater $\delta^{15}\text{N}$ than those of the
8 Kerguelen Plateau (Cherel et al. 2011) indicating that the former are feeding prey at a
9 higher trophic level.

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11 **Final remarks**

12 This study once again confirms the importance that cephalopods have the
13 Antarctic food web, though we still know very little about their ecology and
14 distribution. Due to their high degree of trophic plasticity and generally low rates of
15 dispersal, *D. eleginoides* and *D. mawsoni* are two species that show great potential as
16 biological samplers of bathyal cephalopod species across the South Ocean. The
17 isotopic analysis indicated that habitat types of different cephalopod species vary
18 along the Scotia Arc, maybe due to variation in hydrographic conditions. Stable
19 isotopes also indicate ontogenetic shifts in diet of cephalopods and that they may be
20 generalist predators, with diet varying in response to the availability of prey.

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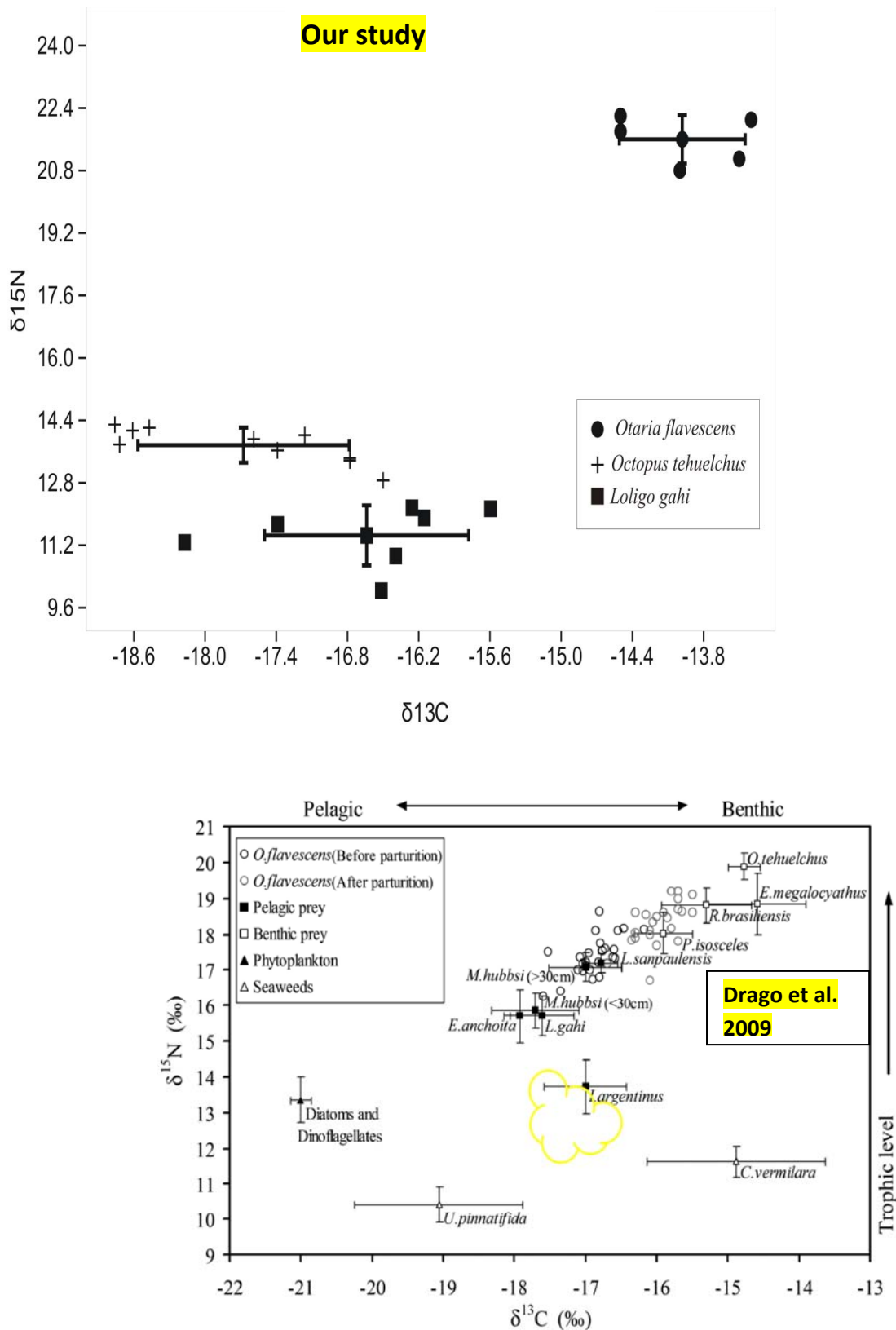


FIG. 2. – Bivariate isotopic signals of South American sea lion pups before and after parturition, once corrected in accordance with the expected total diet-to-pup isotopic enrichment for blood cells (before parturition) and serum (after parturition). Bivariate isotopic signals of the main potential prey of sea lion females and the primary producers shown as mean \pm SD. Sample size $n = 5$ for all the species, except for *O. flavescens* ($n = 26$ for each tissue), *L. gahi* ($n = 4$) and phytoplankton ($n = 2$; collective samples of diatoms and dinoflagellates).

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Table 1. Frequency of occurrence, number and mass of cephalopods identified from *Dissostichus mawsoni* diet.

Taxa	Frequency		Number lower beaks		Estimated mass (g)	
		%		%		%
<i>Kondakovia longimana</i>	60	22.30	122	65.2	963660.4	96.40
<i>Moroteuthis knipovitchi</i>	35	13.01	148	25.7	29391.4	2.94
<i>Psychroteuthis glacialis</i>	6	2.22	6	3.2	3168.0	0.32
<i>Alluroteuthis antarcticus</i>	1	0.37	3	1.6	1865.6	0.19
<i>Mesonychoteuthis hamiltoni</i>	1	0.37	1	0.5	846.9	0.08
<i>Galiteuthis glacialis</i>	5	1.86	5	2.7	559.8	0.06
<i>Taonius</i> sp. (Voss)	1	0.37	1	0.5	186.4	0.02
<i>Slosarczykovia circumantarctica</i>	1	0.37	1	0.5	8.9	0.00
Total lower beaks			240			
Total fresh lower beaks			187			
Total upper beaks			71			
Number of stomachs analysed			269			
Number of stomachs with material			205			
Number of stomachs with cephalopods present			158			

Table 2. Frequency of occurrence, number and mass of cephalopods identified from *Dissostichus eleginoides* diet

Taxa	Frequency		Number lower beaks		Estimated Mass (g)	
		%		%		%
<i>Kondakovia longimana</i>	4	52	5	45,5	30788,4	89,29
<i>Moroteuthis knipovitchi</i>	4	52	5	45,5	3505,2	10,27
<i>Taonius</i> sp. (Voss)	1	13	1	9	186,4	0,54
Total lower beaks				16		
Total fresh lower beaks				11		
Total upper beaks				5		
Number of stomachs analysed				775		
Number of stomachs with material				56		
Number of stomachs with cephalopods present				13		

Figure 1. Number of cephalopods beaks found according to the depth where *Dissotichus mawsoni* were found.

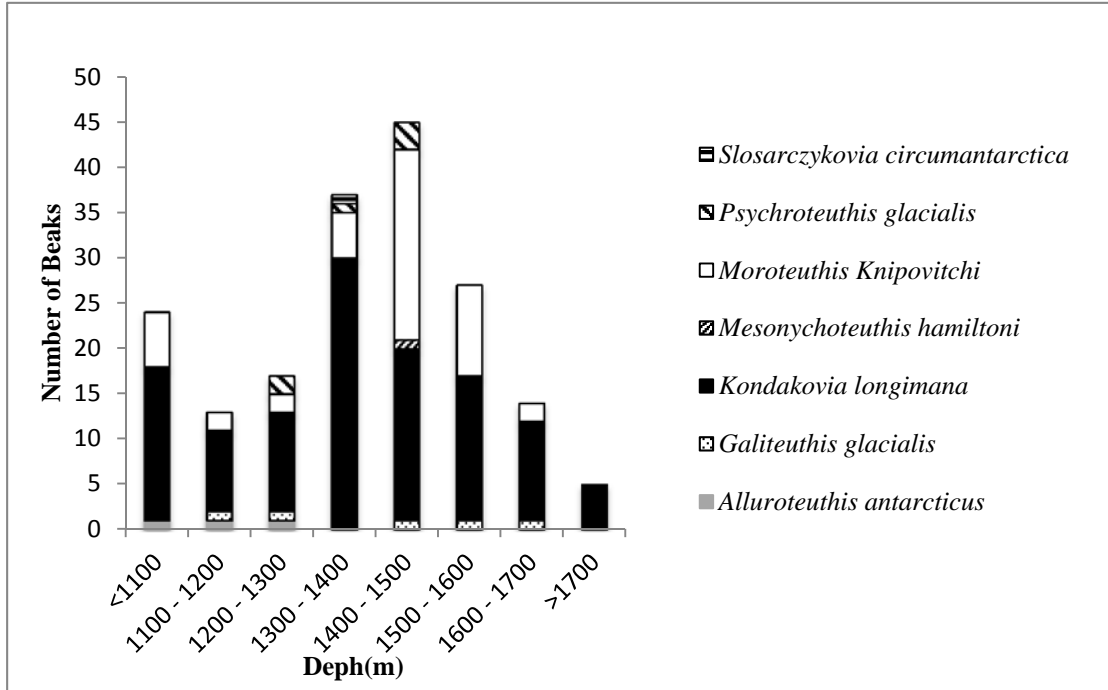


Figure 2. Number of cephalopods beaks found according to the depth where *Dissotichus eleginoides* were found.

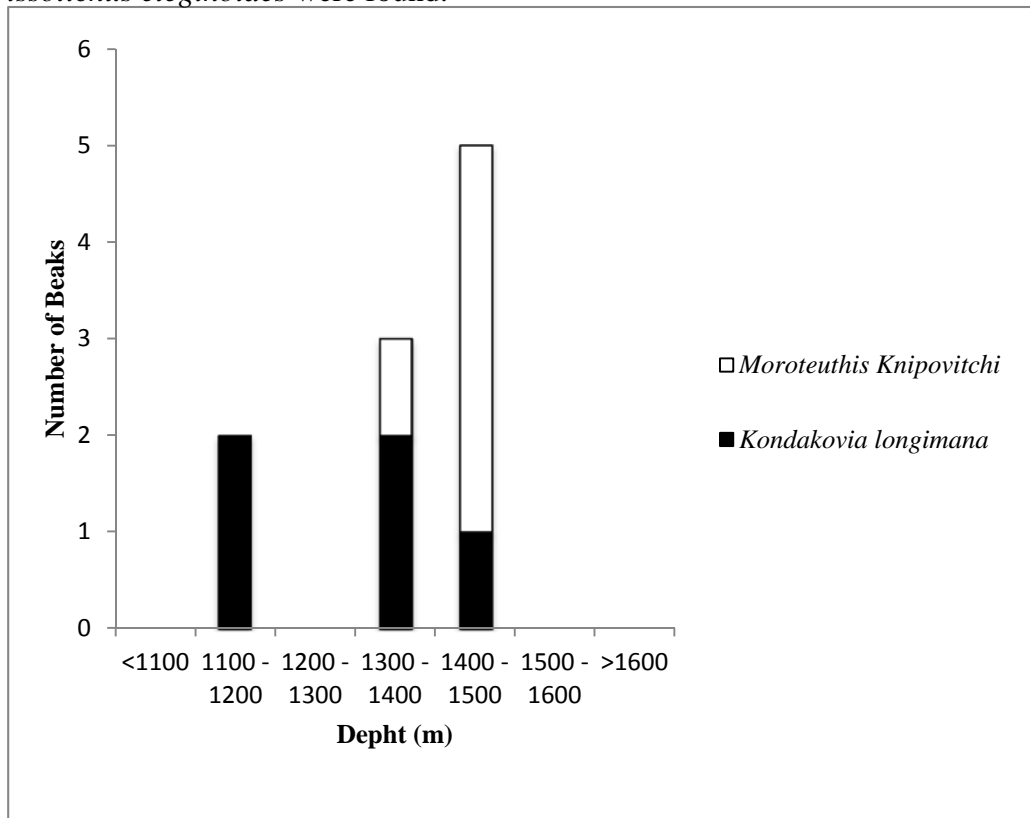


Figure 3. Signatures of stable isotopes of carbon and nitrogen for main cephalopod species found in the diet of *Dissostichus mawsoni* (Mean \pm SE). Abbreviations: AZ, Antarctic Zone; PF, Polar Front; SAZ, Sub-Antarctic Zone. Standard value for Carbon signature on the Polar Front given by Stowasser et al. (2012).

