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Diet of long-beaked common dolphin (*Delphinus capensis*) in the East Sea, Korea

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The long-beaked common dolphin is one of the most abundant cetaceans in Korean waters, and their population has been estimated to comprise of more than 35,000 individuals. *Delphinus capensis* generally appear close to the coast and primarily feed on epipelagic small fishes and cephalopods. Thirty long-beaked common dolphins were collected from the East Sea from February to September in 2012. For stomach content analysis (SCA), the fresh prey items were identified to their lowest taxonomic level, and unidentified preys due to digestion were identified using remnants such as fish otoliths and cephalopod beaks. Fatty acid (FA) patterns of 20 dolphins from the inner layer of blubber were compared with those in samples of prey items. *Enoploteuthis chunii* was the dominant prey in SCA, representing 55.8% by number and 75.9% by occurrence. Common squid (*Todarodes pacificus*) and Pacific herring (*Clupea pallasii*) were the next major preys at more than 80% occurrence. Even though a distinctive difference was not observed between genders, there was a significant diet variation related to maturity. Immature dolphins consumed a higher diversity of prey, and consumed more equally than the sexually mature group, who showed a high dominance of cephalopods. Furthermore, this result fairly corresponded to FAs composition of mature dolphins with the raised percent of 20:6*n*–3, which is relatively abundant in *T. pacificus*.

Keywords: long-beaked common dolphin; *Delphinus capensis*; diet; fatty acid; stomach contents analysis

Introduction

The long-beaked common dolphin, *Delphinus capensis*, is the member of the Delphinidae family of cetaceans. This species is distributed across world oceans, mostly in the tropical and temperate seas of the continental shelves in the Atlantic and the Pacific oceans (Perrin 2002). *D. capensis* generally appears within approximately 150 km of the coastline (Heyning & Perrin 1994) and exhibits long-term local residency compared to the short-beaked common dolphin (Bernal et al. 2003). Young and Cockcroft (1994) elucidated that the distribution of common dolphins (*Delphinus* sp.) correlates with the distribution of their preferred prey species. Osnes-Erie (1999) also demonstrated that *D. capensis* primarily feeds on epipelagic small fishes and cephalopods from by-caught data. In Korea, *D. capensis* is encountered mostly in the south-western part of the East Sea in all seasons and migrates in the form of a small subunit composed of about 20–30 or schools of 2000–3000 (Sohn et al. 2012). The by-catch of *D. capensis* frequently occurred around south region of the East Sea (An et al. 2004) and average of 220 common dolphins have been by-caught annually for the last 10 years (Unpublished data, the Cetacean Research Institute). Despite the high rate of annual by-catch in Korean waters, limited information was available because by-caught dolphins were generally used as food in Korea.

As one of the top predators, assessing the diet of dolphins is important to build our understanding of the ecological significance of both predator and prey in the marine food webs. Furthermore, knowledge of the diet of marine mammals gives us a better understanding of the potential interactions with fisheries. The traditional method of performing a diet study is a stomach content analysis (SCA), which allows a direct observation of prey. However, this method has provided limited information that only shows a representative of recent meals, owing to the inherent delay between feeding and a by-catch event (Hooker et al. 2001). Otoliths and beaks can be used to identify prey items in the case of severely digested stomach contents, because these tissues are relatively resistant to digestion and the morphological features of these are species-specific (Harkonen 1986).

Recently, the analysis of fatty acids (FAs) as a dietary tracer has increased in cetacean diet studies (Hooker et al. 2001). FA analysis for dietary study is based on the principle that the FA composition of prey will match that of the predator (Iverson 1993; Budge et al. 2006). Budge et al. (2006) claimed that *de novo* synthesis, biosynthesis-like elongation or desaturation of FAs, is restricted to mammals foraging for a high-fat diets or fasting feeding. The FAs consumed by these predators are directly deposited into adipose tissues with little

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modification, so can ultimately provide an integrated record of diet (Iverson 1993; Budge et al. 2006). The essential FAs such as 20:5*n*–3 and 22:6*n*–3 are especially important dietary FAs, as marine mammals must obtain essential FAs from their diet, much like humans. Moreover, this method complements the disadvantages of SCA, because a long-term indication of diets taken over periods of up to months can be derived from FA analysis (Kirsch et al. 1998).

The overall aim of this study was to describe the diet of the long-beaked common dolphin in the East Sea, Korea. More specifically, the first objective was to document stomach contents, including the identification of otoliths and beaks. The secondary objective of this work was to determine whether the FAs obtained from blubber can be used as a diet indicator and to detect intra-specific variations in diet. Additionally, this study examined the difference in diet composition between the genders, ages, and reproductive states of *D. capensis*.

Material and methods

Sample collection

Thirty long-beaked common dolphins (16 males and 14 females) were collected from the Ganggu, Jukbyeon, Hupo, and Samcheock of the East Sea (Figure 1). The sampled *D. capensis* were by-caught in gillnet, set net, and bladderwort from February to September in 2012. After a necropsy, SCA was conducted immediately. Stomach contents were collected and frozen at −19°C in a polyethylene bag. In case of otoliths and beaks, samples were stored in 70% ethanol for further identification. Teeth were sampled from the left mandibular ramus and were kept in 70% ethanol until age estimation. Blubber was taken at the mid-lateral region of the dorsal fin and approximately 5 cm × 5 cm in size was stored at −19°C in a polyethylene bag. The reproductive condition of *D. capensis* was determined by examining its gonads. Females were considered sexually mature if corpus luteum or corpus albicans was present in the

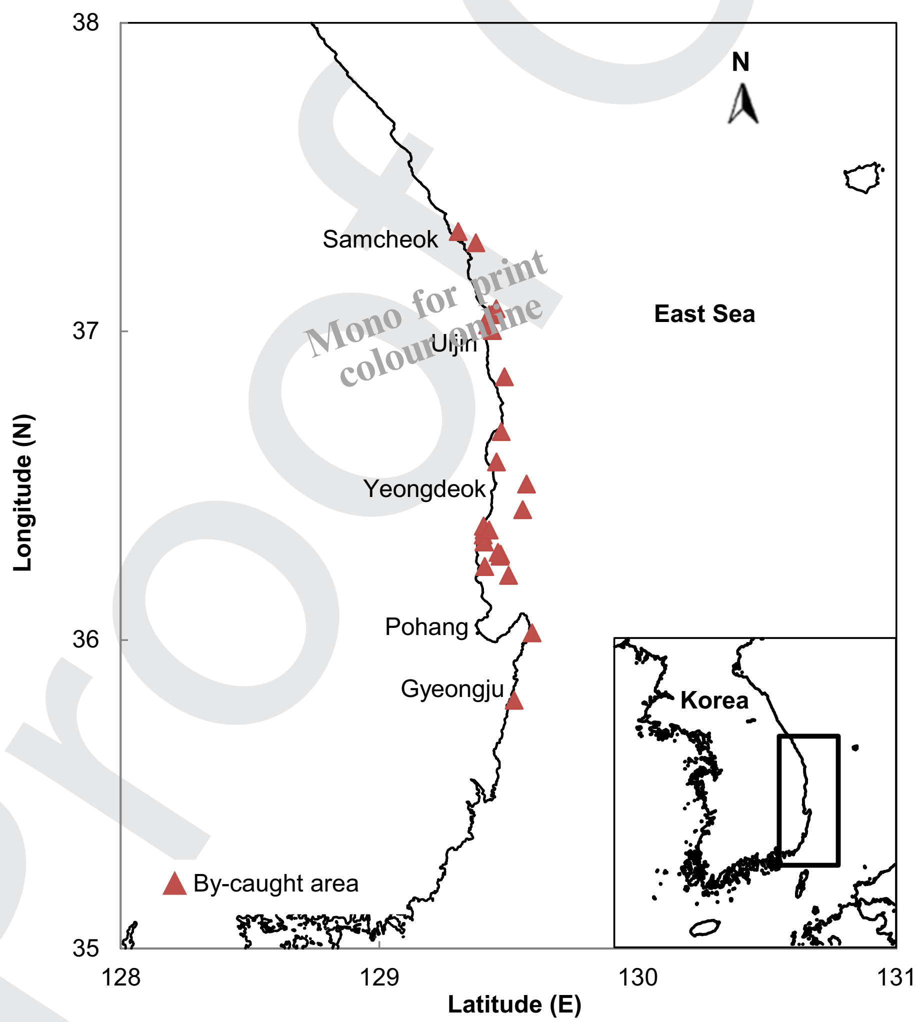


Figure 1. By-catch location of *D. capensis* (n = 30) from February to September in 2012.

ovaries (Lee 2011). Male specimens whose right testis weighed less than 150 g were classified as immature (Perrin et al. 1977).

Stomach content analysis

Stomach contents were placed in a large tray and then were separated into identifiable components. The residuals were washed gently through a sieve with a 1.0 mm mesh size in order to recover all fish otoliths and cephalopod beaks. The standard length of fishes and the mantle length of cephalopods were measured only for undigested items that were whole or nearly whole. Fresh prey items were identified to the lowest taxonomic level using published guides (Nakabo 2002; Youn 2002). Additional prey species were identified from the diagnostic hard parts such as fish otoliths and cephalopod beaks. The identification of fish otoliths was confirmed by the National Fisheries Research and Development Institute (NFRDI)'s otolith collection and specimens bought in the local market. To raise the reliability of otolith identification by direct comparison, DNA analysis was also conducted on uncontaminated muscle tissue of the fishes in stomach. The number of fishes in stomach was determined as a greater number of right or left otoliths (Pierce & Boyle 1991; Wang 2003). In the case of eroded but specifically identifiable otoliths, they were counted as half an otolith each. To prevent any bias, badly eroded and broken otoliths were not counted. Cephalopod beaks were identified following the manual and keys presented in National Museum of Natural Science (http://research.kahaku.go.jp/zoology/Beak-/index.htm). This was checked twice in the case of existence of the collected specimens. The higher number of upper or lower beaks was used to estimate the number of cephalopods (Pierce & Boyle 1991). The lower rostral length and lower hood length of the cephalopods were measured to the nearest 0.01 mm with digimatic calipers following the standards (Clarke 1986; Xavier & Cherel 2009) for identification.

Data analysis on prey importance

The percentage frequency of occurrence (%FO) and the percentage number (%*N*) were calculated. Additionally, the diet indices for prey diversity and evenness were analyzed using a mean *N*% of prey items (Krebs 1989). Percentage by number (%*N*), which is a measure of the numerical abundance of each prey species (%N_i) in the diet, was calculated as:

$$\%N_i = \frac{N_{ij}}{N_j} \times 100\%$$

where N_{ij} is the number of prey species *i* in stomach *j*, and N_j is the total number of prey in stomach *j*. The percentage frequency of occurrence (%FO), which is a measure of the frequency of occurrence of each prey species (% FO_i), was calculated as:

$$\%FO_i = \frac{F_{ij}}{F_j} \times 100$$

where F_{ij} is the number of stomachs *j* containing prey *i* and F_i is the total number of stomachs containing prey remains.

The Shannon–Wiener diversity index (H') was calculated as:

$$H' = \frac{n \log n - \sum_{i=0}^{k} f_i \log f_i}{n}$$

where *n* is the total number of prey in a stomach and it means sample size. f_i is the number of species *i* in the category of prey species, and thus, *k* is the number of prey species.

Evenness (J') was calculated as:

$$H'_{\max} = \log k$$

$$J' = \frac{H'}{H'_{\max}}$$

FA analysis

The 20 samples collected prior to August were used for FA analysis (Table 1). Lipids from the inner layer of blubber were extracted according to Folch et al. (1957). FA methyl esters were prepared directly from 100 mg of the pure extracted lipid using 5 mL 14% boron trifluoride in methanol and 10 mL hexane. Analyses of FA methyl esters were performed using temperature-programmed gas liquid chromatography fitted with a Supelco 2560 column (100 m × 0.25 mm). The injection and detector temperatures were held at 250°C and 280°C, respectively. The FA composition of the three prey species that were abundant in the stomach and stand for each distribution zone and class (*Clupea pallasii* for pelagic fishes, *Todarodes pacificus* for cephalopods and *Arctoscopus japonicus* for mesopelagic fishes) was obtained from the reference of the NFRDI (Unpublished data, NFRDI). FAs that occurred at less than 1% were not included in the statistical analysis, because their determination was uncertain (Walton & Pomeroy 2003). The selected FAs were arcsin transformed prior to analysis for the requirements of multivariate analysis of variance (MANOVA). The SPSS program was used to identify the distinct difference among the groups based on the FA profiles.

Results

Stomach content analysis

The stomach contents were collected from 14 female and 16 male long-beaked common dolphins. Most prey items were fairly well digested; therefore, hard parts (cephalopods beaks and fish otoliths) accounted for 90.3% of the total prey number. A total of 2954 prey items comprising eight species of fish and six species of cephalopods were

Table 1. Biological data of by-caught *D. capensis*, East Sea, Korea.

No.	Reg. no.	By-catch date	By-catch area	Body length (cm)	Sex	Age	Maturity	Comments	FA analysis
1	CRI0015	4 February 2012	Yeongdeok	242	F	20	Mature	Lactating	*v*
2	CRI0017	12 February 2012	Yeongdeok	211	F	7	Immature		*v*
3	CRI0018	14 February 2012	Pohang	229	F	23	Mature	Lactating	*v*
4	CRI0019	14 February 2012	Pohang	195	M	3	Immature		*v*
5	CRI0020	14 March 2012	Uljin	243	M	15	Mature		*v*
6	CRI0021	25 March 2012	Uljin	241	M	11	Mature		*v*
7	CRI0022	25 March 2012	Uljin	210	M	8	Mature		*v*
8	CRI0023	28 March 2012	Uljin	216	F	7	Immature	Empty stomach	*v*
9	CRI0024	25 April 2012	Yeongdeok	220	F	10	Mature	Lactating	*v*
10	CRI0025	5 May 2012	Yeongdeok	264	M	23	Mature		*v*
11	CRI0026	14 May 2012	Yeongdeok	243	M	14	Mature		*v*
12	CRI0027	15 May 2012	Yeongdeok	175	F	2	Immature		*v*
13	CRI0028	19 May 2012	Yeongdeok	232	F	9	Mature	Pregnant	*v*
14	CRI0029	19 May 2012	Yeongdeok	208	M	3	Immature		*v*
15	CRI0030	24 May 2012	Uljin	233	M	16	Mature		*v*
16	CRI0031	14 June 2012	Yeongdeok	233	M	14	Mature		*v*
17	CRI0032	29 June 2012	Uljin	233	F	25	Mature	Lactating	*v*
18	CRI0033	24 July 2012	Pohang	230	F	15	Mature	Pregnant	*v*
19	CRI0034	30 July 2012	Yeongdeok	218	M	7	Immature		*v*
20	CRI0035	31 July 2012	Gyeongju	167	F	2	Immature		*v*
21	CRI0038	4 August 2012	Uljin	242	M	14	Mature		
22	CRI0039	4 September 2012	Pohang	183	M	2	Immature		
23	CRI0040	27 August 2012	Samcheok	221	F	6	Mature		
24	CRI0041	9 September 2012	Pohang	220	F	8	Mature	Lactating	
25	CRI0042	25 August 2012	Samcheok	195	F	3	Immature		
26	CRI0043	7 September 2012	Yeongdeok	220	M	4	Immature		
27	CRI0044	5 September 2012	Yeongdeok	187	M	1	Immature		
28	CRI0045	6 September 2012	Pohang	232	F	10	Mature	Lactating	
29	CRI0046	7 September 2012	Uljin	231	M	6	Immature		
30	CRI0047	14 September 2012	Pohang	203	M	4	Immature		

identified by fish otoliths, squid beaks, and fresh fractions (Table 2). Cephalopods represented the most abundant prey group, accounting for 71.8% of the total number of prey items with a 96.6% occurrence. Fishes comprised 28.2% by number of the prey consumed and were found in 26 (82.8%) of the 29 stomachs. *Enoploteuthis chunii* was the dominant prey, representing 55.8% by number and 75.9% by occurrence. Common squid (*T. pacificus*) was the next major cephalopod prey, comprising 14.7% by number and occurred in 86.2% of the stomachs. Pacific herring (*C. pallasii*) was found predominantly among the fishes consumed, accounting for 18.8% by number and 82.8% by occurrence (Table 2). Only eight species were identified from fresh prey items. Six fish species' fresh remains comprised 10%*N* of the total number of fishes, and only two species of cephalopods were found in stomachs in an undigested condition (9%*N*). Otherwise, six species were identified by hard remains from fish otoliths and cephalopods beaks: Konoshiro gizzard shad (*Konosirus punctatus*), Sailfin sand fish (*Arctoscopus japonicus*), Mitra squid (*Uroteuthis chinensis*), Swordtip squid (*Uroteuthis edulis*), Big fin reef squid (*Sepioteuthis lessoniana*), and Schoolmaster gonate squid (*Berryteuthis magister*).

Nine species among 12 DNA samples corresponded to species identified by otoliths. Two samples failed in the amplification process, and one was expressed as pacific herring that was Konoshiro gizzard shad by otolith identification.

The scatter plot divided the different prey species into three groups (Figure 2). Eleven species were rarely found in the stomachs (occurrence < 40%) and occupied relatively small portions of the total prey number (%*N*). *T. pacificus* and *C. pallasii* were categorized as common preys as they were observed more than 80% stomachs. A single prominent prey species, *E. chunii*, was found. Although the occurrence percentage was slightly lower than *T. pacificus* and *C. pallasii*, more than half the number of total prey items were *E. chunii* (55.8%*N*).

The factors "sex," "maturity," and "age" were tested to investigate dietary variation among the individuals. The prey composition for males was more diversified (14 taxa)

Table 2. Composition of stomach contents for *D. capensis* (n = 30).

	Total composition (n = 2954)				Otoliths and beaks (n = 2667)				Fresh fraction (n = 287)						
	Occurrence		Number		Occurrence		Number		Occurrence		Number		Length		
	No.	Frequency (%)	No.	Percent of total	No.	Frequency (%)	No.	Percent of total	No.	Frequency (%)	No.	Percent of total	*n*	Mean	Range (cm)
Fishes	24	82.8	832	28.2	24	82.8	752	28.2	13	44.8	80	26.1			
Clupeidae															
Clupea pallasii	24	82.8	556	18.8	20	69.0	492	18.4	15	51.7	64	22.4	43	18.1	11.8–23.2
Konosirus punctatus	4	13.8	8	0.3	4	13.8	8	0.3	–	–	–	–	–	–	–
Engraulidae															
Engraulis japonicus	11	37.9	109	3.7	11	37.9	108	4.0	1	3.4	1	0.3	1	11.3	11.3
Exocoetidae															
Cypselurus agoo agoo	1	3.4	7	0.2					1	3.4	7	2.4	6	18.7	17.4–23.5
Trichodontidae															
Arctoscopus japonicas	7	24.1	89	3.0	7	24.1	89	3.3	–	–	–	–	–	–	–
Ammodytidae															
Ammodytes personatus	6	20.7	7	0.2	6	20.7	6	0.2	1	3.4	1	0.3	–	–	–
Centrolophidae															
Psenopsis anomala	6	20.7	10	0.3	5	17.2	6	0.2	1	3.4	4	1.4	4	10.9	10.1–12.1
Scombridae															
Scomberomorus niphonius	2	6.9	5	0.2	1	3.4	3	0.1	1	3.4	2	0.7	1	21.9	21.9
Unidentified species	10	34.5	41	1.4	9	31	40	104	1	3.4	1	0.3	–	–	–
Squids	28	96.6	2122	71.8	27	93.1	1915	71.8	17	58.6	207	73.9			
Ommastrephidae															
Todarodes pacificus	25	86.2	434	14.7	23	79.3	368	13.8	15	51.7	66	23.1	45	14.4	9.5–21.8
Enoploteuthidae															
Enoploteuthis chunii	22	75.9	1650	55.8	22	75.9	1509	56.6	3	10.3	141	49.3	13	5.06	2.3–7.2
Loliginidae															
Loligo chinensis	2	6.9	2	0.1	2	6.9	2	0.1	–	–	–	–	–	–	–
Loligo edulis	2	6.7	2	0.1	2	6.9	2	0.1	–	–	–	–	–	–	–
Sepioteuthis lessoniana	1	3.4	7	0.2	1	3.4	7	0.3	–	–	–	–	–	–	–
Gonatidae															
Berryteuthis magister	6	20.7	21	0.7	6	20.7	21	0.8	–	–	–	–	–	–	–
Unidentified species	3	10.3	6	0.2	3	10.3	6	0.2	–	–	–	–			

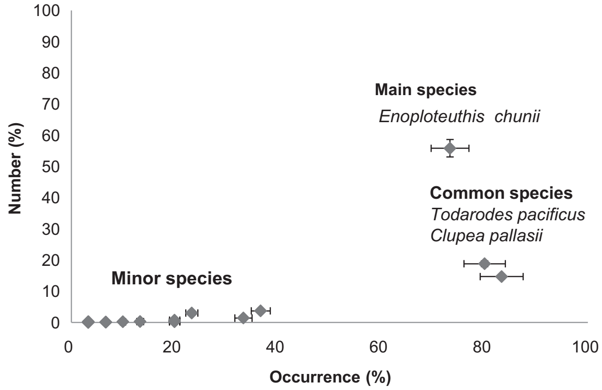


Figure 2. A scatterplot of all prey species according to occurrence (%) and number (%).

than the females (11 taxa). Immature dolphins consumed 13 taxa of prey species, which were 4 more taxa than the mature dolphins (i.e. 9 taxa), and the diet composition of the mature groups showed a high dominance of *E. chunii* (Figure 3). The prey diversity (H') of the long-beaked common dolphin was 0.5632, while evenness (J') was calculated to be 0.468. No significant difference was found between the males and females (t-test, p = 0.274). In the case of sexually maturity, immature common dolphins (H' = 0.616) had higher prey diversity than mature individuals (H' = 0.509), although small sample sizes prohibited the statistical difference (t-test, p = 0.254). Prey diversity was weakly correlated with age (r = −0.400, p = 0.041, n = 26). The significant difference

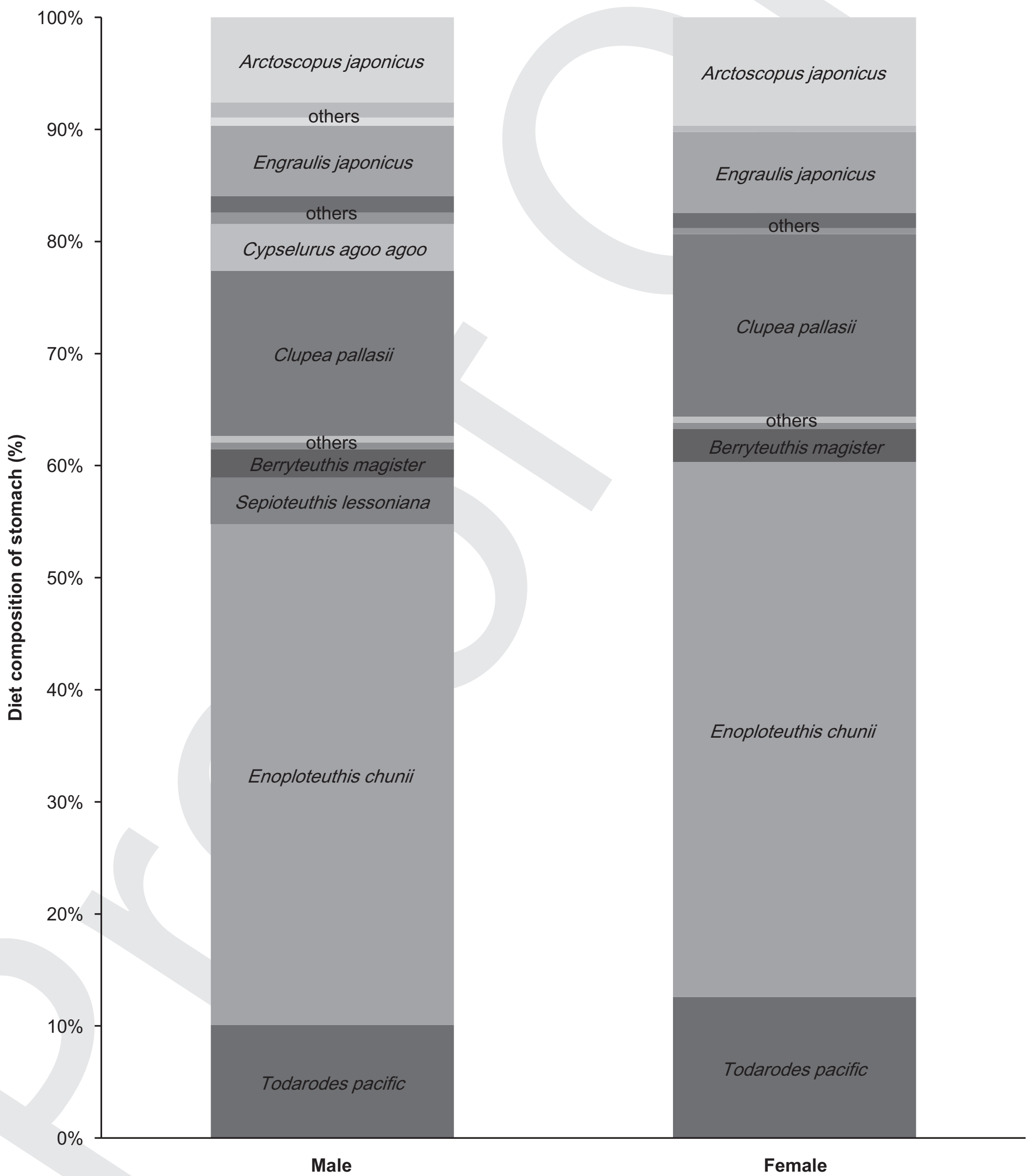


Figure 3. Diet composition (number of prey species and number of individuals) of stomach in groups related to sex and maturity.

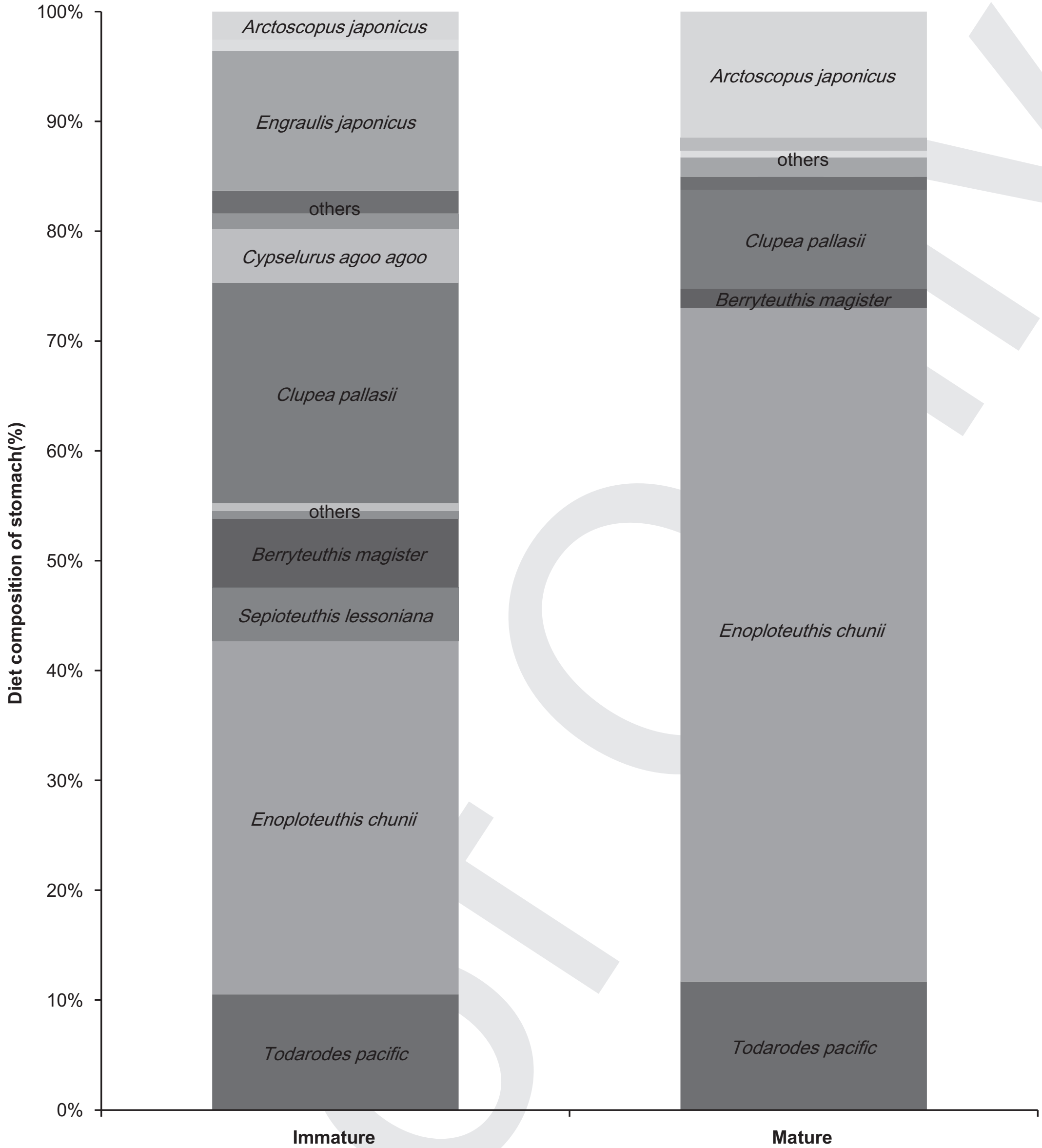


Figure 3. (*Continued*)

of evenness (J') was not found to be related to sex (t-test, p = 0.356). Likewise, the evenness difference between mature and immature, male for 0.4643 and female for 0.5311, was not significantly different (t-test, p = 0.7553). However, there was a significant correlation between age and evenness ($r = -0.488$, $p = 0.011$, $n = 26$).

FA analysis

Thirty-six individual FAs were identified in the inner layer of the blubber samples. The major FAs were classified as present in amounts ≥1% by mass and only 12 major FAs were present: 14:0, 14:1n−5, 16:0, 16:1n−7, 18:0, 18:1n−9, 18:2n−6, 18:3n−3, 20:1n−9, 20:4n−6, 22:6n−3, and 24:0. ΣMUFA (monounsaturated unsaturated fatty acids) accounted for the greatest proportion of all FA examined, 44.36 ± 1.29% by mass. ΣSFA (saturated fatty acids), Σ(n−3)PUFA (polyunsaturated fatty acids), and Σ(n−6)PUFA each accounted for 27.67 ± 0.71, 20.01 ± 0.61, and 3.49 ± 0.12%, respectively, by mass of all the FAs. Σ(n−3)PUFA/(n−6)PUFA ratios were 5.74 ± 0.11 in the inner layer (Table 3).

No significant difference was observed in the proportions of the major FAs between the male and female the long-beaked common dolphins (MANOVA, p = 0.114; Figure 4). However, immature groups notably differed in FA composition and could be readily separated from mature groups using MANOVA analyses (p = 0.006).

Table 3. FAs commonly found in quantities ≥0.5% by mass.

Fatty acids	
Saturated fatty acids	
12:0	0.51 ± 0.02
14:0	7.44 ± 0.13
15:0	0.75 ± 0.01
16:0	11.18 ± 0.52
17:0	0.45 ± 0.02
18:0	1.96 ± 0.15
24:0	5.38 ± 0.15
ΣSFA	27.67 ± 0.71
Monounsaturated fatty acids	
14:1*n*–5	1.57 ± 0.14
16:1*n*–7	16.88 ± 0.95
18:1*n*–9	22.59 ± 0.41
20:1*n*–9	2.94 ± 0.12
22:1*n*–9	0.37 ± 0.03
ΣMUFA	44.36 ± 1.29
Polyunsaturated fatty acids	
18:2*n*–6	2.32 ± 0.04
18:3*n*–3	1.34 ± 0.03
20:4*n*–6	1.17 ± 0.08
22:6*n*–3	18.67 ± 0.60
ΣPUFA	23.50 ± 0.61
Σ(*n*–3) PUFA	20.01 ± 0.61
Σ(*n*–6) PUFA	3.49 ± 0.12
Σ(*n*–3)/(*n*–6) PUFA	5.74 ± 0.11

Note: Mean with ± SD presents the ratio of each FA to total in the inner blubber layers of *D. capensis* (n = 20).

At the prey items, three species showed a large difference in FA composition, especially in 16:1*n*–7, 18:1*n*–9, and 22:6*n*–3 (Figure 4). 22:6*n*–3 was predominately higher in *T. pacificus* than the other preys. *Arctoscopus japonicus* contained high levels of the FAs 16:1*n*–7 and 18:1*n*–9, while *T. pacificus* contained low levels of these FAs but high levels of 22:6*n*–3.

Discussion

The prey composition of the SCA agreed with the findings of previous studies that the long-beaked common dolphin feeds on the scrolling epipelagic fishes and neritic cephalopods (Osnes-Erie 1999). Cephalopods mainly accounted for diet composition, and *E. chunii*, a neritic-oceanic mesopelagic squid, was a prevalent prey to *D. capensis*. It is known that this prey is distributed in the western Pacific Ocean at approximately 20°N to 40°N, 120°E to 150°E (Jereb & Roper 2010) and migrates vertically, ascending to the surface shallower than 300 m at night. Unfortunately, *E. chunii* is not a target species for commercial fishing in Korea; therefore, its habitat and biomass are uncertain. Only six *E. chunii* were recorded in Korean waters by Son and Hong (1992), and these specimens were collected by a mid-water trawler working at 200 m depth. In Japanese waters, *E. chunii* was known to be abundant in the mesopelagic zone, especially at depths of 15–200 m, and found as the prey of pollock (Okiyama, 1993). In addition, this cephalopod was reported as the prey of the spotted dolphin, Cuvier's beaked whale, and dwarf sperm whales in Taiwanese waters (Wang 2003). The luminescent organs of the family Enoploteuthidae may facilitate the feeding of dolphins and the large size of schools would be advantageous to dolphins by minimizing their energy-cost for increased foraging efficiency.

The composition of the diet mostly corresponds to the abundance of prey species in the environment. Even though there are no catch statistics for *E. chunii*, common squid and Pacific herring were reported as the most abundant species in the East Sea, based on their catch statistics (MIFAFF, 2012). The small sample size (n = 30) means that there is a limit to the usefulness of what we can infer about diet variation between the genders, ages, and maturity stages. Between the sex groups, there was no statistical difference in the prey diversity index (H') or the FAs composition (MANOVA, p = 0.114). However, Cockcroft and Ross (1990) suggested that cephalopods are consumed in greater number by lactating bottlenose dolphins, and presumably the high energetic demands of pregnancy or lactation should mean that reproductive dolphins require preys that are more specific. Compared to the sample sizes of previous researches (Osnes-Erie 1999, p. 94; Wang 2003, p. 45; ~~Pusineri 2007, p. 63~~), AQ1 20 samples are small in number to determine the effect of gender on diet. Therefore, sufficient sampling that takes into account the reproductive status of both males and females is needed to detect any diet difference between genders.

Immature dolphins revealed a higher diversity of prey than sexually mature groups, and the statistical correlation between age and diversity index (H') suggests that there is a meaningful diet change related to maturity. The decline in evenness and diversity can be interpreted as a concentration on specific preys. For example, the prey diversity of mature dolphins reduces as they get older, and the percentage composition of *E. chunii* increased. This trend was also stated by Meynier et al. (2008); they found that mature short-beaked common dolphins exhibited less diversity in their prey composition, and that they focused on sardine feeding. The preference for cephalopods was distinctly revealed by SCA that estimated that the ratio of cephalopods to fishes in the diet was 55:45 for immature groups and 74:26 for mature groups (Figure 3). Furthermore, this result fairly corresponded to the FAs composition of the mature dolphins, with the raised percentage of 20:6*n*–3. The FA patterns in the mature long-beaked common dolphins exhibited similar characteristics to those of *T. pacificus*, which also contained a relatively high value of 20:6*n*–3, and these were particularly different

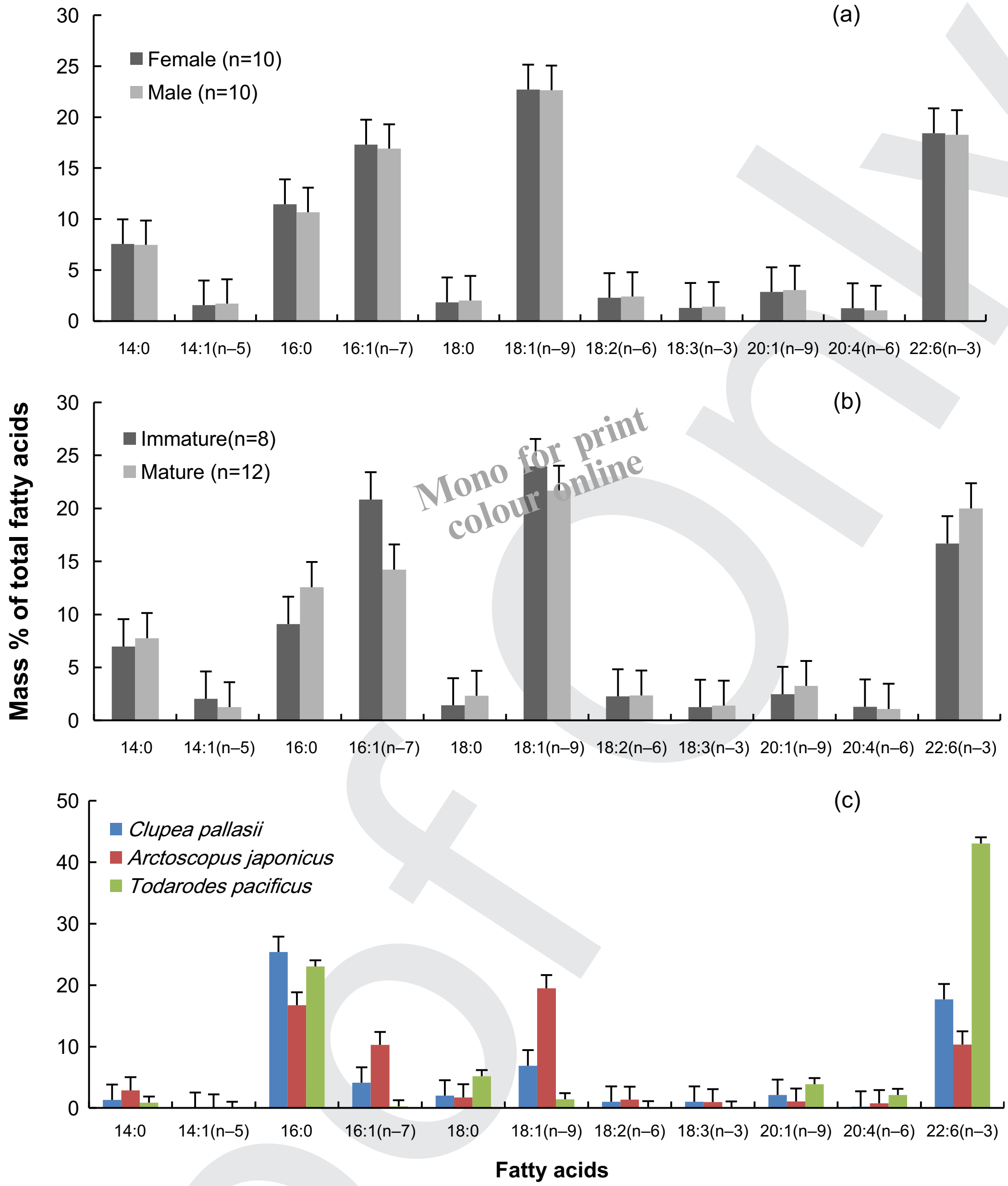
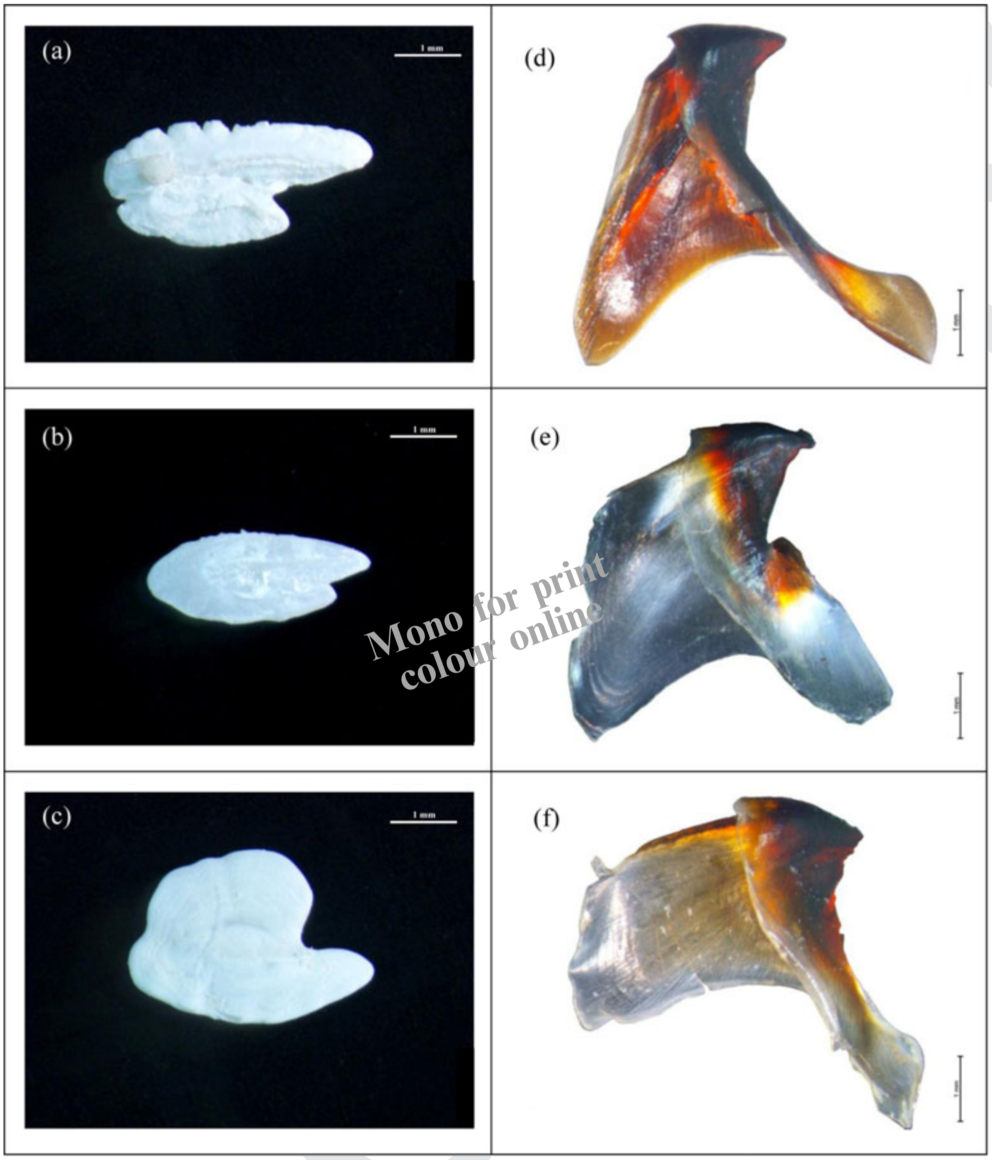


Figure 4. The selected FA (1% ≥ by mass) in the inner layer of *D. capensis* according to (a) sex and (b) maturity. (c) FAs of three prey species were indicated to *C. pallasii*, *Arctoscopus japonicas*, and *T. pacificus*.

from the immature dolphins and *Arctoscopus japonicus*, which contained a high level of 16:7*n*–1 and 18:1*n*–9 (Figure 4). Consequently, there was a distinct inference that the mature long-beaked common dolphins preferentially consumed cephalopods. This result also implies that the FA analysis can be used as a sufficiently reliable method to detect the inter-specific difference of diet.

The varied FA composition of *D. capensis* related to maturity (Figure 4) indicates that the diets of the long-beaked common dolphin change with growth. This difference was thought to result from the change of their energy needs and the development of their foraging skills depending on growth stage (Pusineri et al. 2007). Adult common dolphins feed cooperatively within large groups, but the calves of common dolphins were generally separated from the group during feeding (Burgess 2006). The increased composition of cephalopods with growth could be derived from the ability to dive deeper and the development of cooperative feeding skills as they grow.

There are possible biases in the estimation of a diet. A wrong estimate can be derived due to the variation in digestive rates between preys and the degree of acidity of stomach. Hence, only the forestomach was observed in this study to mitigate the effect of chemical digestion,



~~Figure 5. Photomicrographs of fish sagittal otolith and cephalopod beaks in stomach contents. Left column indicates fish sagittal otolith: (a) *C. pallasii*; (b) *Engraulis japonicas*; (c) *Arctoscopus japonicas*. Right column indicates cephalopod beaks: (d) *E. chunii*; (e) *T. pacificus*; (f) *B. magister*.~~

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because the digestive fluid was not secreted in the forestomach. Because otoliths are composed of calcium carbonate, they are easily broken, leading to the possibility of underestimation, owing to exclusion of the eroded and broken otoliths from the estimation. It is also likely that the secondary introduction of prey can also effect the diet estimation. Walker et al. (2002) claimed that some otoliths that exhibited sharp angular chips and severe erosion were considered as having been secondarily introduced by cephalopods and larger fish. In this work, one isopoda and crustacean found in CRI 0015 were presumed to have been eaten by fishes or cephalopods, and then these specimens were ignored in diet estimation.

In conclusion, one of the marked results presented this study was the obvious dominance of *E. chunii* in the diet of the long-beaked common dolphin. However, the evaluated prey importance in the present work should not be considered a mass of preys (*M*%). Although *E. chunii* occupied 55.8% of the diet by number, their contribution to the total mass may be diminished due to their very small individual size. While the quantitative information about consumption was not suggested in this study, it is obvious that *E. chunii, T. pacificus*, and *C. pallasii* are important prey in the long-beaked common dolphin's diet. The energetic needs of *D. capensis* and the caloric value of prey items would require investigation in future study.

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