

SHORT COMMUNICATION

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Diet composition and feeding strategy of John Dory, *Zeus faber*, in the coastal waters of Korea

Han Ju Kim¹, Hyeong-Gi Kim² and Chul-Woong Oh^{1*}

Abstract

Background: Most fish undergo prey switch from juvenile to adult. It is thought that slightly different feeding habits occur among adult fishes due to growth, spawning, habitat change, and so on. Therefore, the diet of the John Dory *Zeus faber* (≥ 24 cm TL) was studied in the coastal waters of Korea by analysis of stomach contents, with comparison by season and size class of diet composition and prey diversity. Monthly samples were taken from February 2017 to January 2018.

Results: The results showed that the John Dory was a piscivorous predator, and pisces had occupied 82.3% of IRI%. *Trichiurus lepturus* and *Trachurus japonicus* were important preys in all size classes and seasons. Diet composition differed among the size classes and seasons (Chi-square test, $P < 0.05$). As body size of *Z. faber* increased, the occurrence of benthic fish (*Glyptocephalus stelleri*) tended to increase. The seasonal prey composition also changed depending on the abundant species of each season.

Conclusions: *Z. faber* is a piscivorous predator. The consumption habits of *Z. faber* appear to different results by their size and seasons. This study suggests that *Z. faber* could be considered an opportunistic predator.

Keywords: John Dory, *Zeus faber*, Diet composition, Feeding habits, Feeding ecology

Background

John Dory (*Zeus faber* Linnaeus, 1758) is widely distributed in the Atlantic, Pacific, and Indian oceans, as well as along the entire West African coast (Janssen 1979; Akyol 2001; Yoneda et al. 2002). In Korea, they are distributed on the South Sea and East Sea of Korea (Choi et al. 2011). This species is a demersal fish, inhabiting depths of 50–140 m (Vrgoč et al. 2006; Kim et al. 2013). In Korea, the commercial value of *Z. faber* has recently increased but is treated as bycatch. It is thought that research on their basic ecology is necessary.

Previous studies on feeding habits of *Z. faber* were conducted in eastern Mediterranean Sea (Stergiou and Fourtouni 1991), Portuguese coast (Silva 1999), North

Aegean Sea (Ismen et al. 2013), and South Sea in Korea (Choi et al. 2011; An et al. 2012). All results of them shown that *Z. faber* is a piscivorous predator. However, these studies lack the ecological study on feeding habits because there is only descriptive information about the prey composition of *Z. faber*. To understand the overall dynamics of community feeding ecology, it is necessary to investigate higher predators within marine trophic food webs.

Most fish undergo prey switch. Diet shifts in fish can be influenced by season, environmental factors, interspecific composition, ontogeny, and body size (Gerking 1994; Preciado et al. 2006; Cusa et al. 2019). The prey composition of *Z. faber* also vary with ontogeny. Stergiou and Fourtouni (1991) suggested that changes in feeding can occur based on 14 cm TL. When > 14 cm TL, *Z. faber* consumes benthic and demersal fish exclusively (Stergiou and Fourtouni 1991). On the other hand,

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diets of *Z. faber* from along the Portuguese coastline do not show distinct changes (Silva 1999). These studies focused on the dietary changes from juvenile to adult. However, this study thought that the diet of adult *Z. faber* varies with body size, season, and feeding strategy. The objectives of this study were to reveal the overall diet composition and feeding strategy for specimens of ≥ 24 cm TL in the coastal waters of Korea.

Materials and methods

Sample collection

A total of 711 samples were monthly collected between February 2017 and January 2018 by commercial bottom trawl net in the coastal waters of Korea (35°58'N 129°50'E). Bottom trawl mesh size was 54 mm, and net length was about 40.8 m. The samplings were conducted around 2 h at a time. All samples were brought in thermos cool boxes to the laboratory. Fish specimens were collected in the range from 24 to 47 cm (mean \pm SD: 34.10 \pm 4.21) in total length (TL) and from 221.01 to 2458.35 g (mean \pm SD: 679.42 \pm 278.17) in total weight (TW) (Table 1).

Analysis of stomach contents

Stomachs of 711 individuals were dissected, and prey items in the stomachs were classified to the lowest taxonomic level by the naked eye and under microscope. Biomass and length of all prey items were measured with an electronic balance to the nearest 0.01 g and the nearest millimeter. A regression analysis was performed using excel to observe the changes in lengths of prey items according to the sizes of *Z. faber*.

Feeding habits were determined by using the index (Hyslop 1980): (1) the frequency of occurrence (%F), (2) the numerical percentage (%N), (3) the weight percentage (%W), and (4) the index of relative importance (IRI). Indices were calculated for each stomach as follows:

$$\%F = \frac{A_i}{N} \times 100$$

$$\%N = \frac{N_i}{N_{total}} \times 100$$

$$\%W = \frac{W_i}{W_{total}} \times 100$$

$$IRI = (\%N + \%W) \times \%F$$

A_i is the number of fish with prey i (th) in their stomach, N is the total number of fish with stomach contents, N_i is the number of prey i (th), N_{total} is the total number of prey items, W_i is the mass of prey i (th), and W_{total} is the total mass of prey items. IRI was converted into a percentage and expressed as %IRI.

Data analysis

To investigate variation of diet according to size group, *Z. faber* was divided into four size classes: 24–30 cm ($n = 143$), 31–35 cm ($n = 168$), 36–40 cm ($n = 210$), and 41–47 cm ($n = 190$). These size groups were divided into four classes based on size at sexual maturity, age, and growth. The first class (24–30 cm TL) was sub-adult before maturity (size at first maturity = 30 cm) (Kim 2019). The other classes were divided according to size at age by Yoneda et al. (2002): 31–35 cm at 6–8 years, 35–40 cm at 8–10 years, and 41–47 cm at 10–14 years.

Seasonal variation of diet was investigated for four seasons: spring (March–May, $n = 150$), summer (June–August, $n = 161$), autumn (September–November, $n = 210$), and winter (December–February, $n = 190$). Statistical differences in diet composition among size classes and seasons were employed by a chi-square test of the frequencies of a given prey categories (Sokal and Rohlf 1995).

Table 1 Monthly number of samples and range of total length (TL) for *Zeus faber* in the coastal waters of Korea

Month	Number of samples	Range of TL (cm)	Mean TL \pm SD (cm)	Range of TW (cm)	Mean TW \pm SD (cm)
Feb.	50	24.7–47.7	35.6 \pm 5.4	562.82–1430.02	846.19 \pm 194.48
Mar.	50	25.3–42.1	35.7 \pm 3.0	182.23–2438.35	818.87 \pm 465.68
Apr.	50	25.4–44.5	34.7 \pm 5.1	418.02–1093.88	722.23 \pm 164.36
May	50	25.4–47.6	35.3 \pm 4.4	292.78–1548.35	706.06 \pm 296.52
Jun.	50	26.6–44.3	32.1 \pm 4.4	355.87–1460.91	733.52 \pm 334.84
Jul.	51	25.2–42.0	32.4 \pm 4.9	295.48–1460.91	539.63 \pm 249.08
Aug.	60	24.7–47.4	32.9 \pm 4.3	259.74–1381.22	585.17 \pm 304.20
Sep.	70	26.6–44.8	32.4 \pm 4.1	247.24–1739.52	616.6 \pm 259.14
Oct.	70	28.2–41.3	33.1 \pm 2.7	314.39–1367.95	585.70 \pm 226.11
Nov.	70	25.8–43.4	33.4 \pm 3.3	384.78–1219.33	611.25 \pm 167.91
Dec.	70	26.0–40.6	34.3 \pm 3.4	354.71–1584.81	658.41 \pm 230.80
Jan.	70	33.5–43.4	37.1 \pm 2.3	356.53–1208.96	730.01 \pm 205.37

Niche breadth analysis was conducted using the Shannon-Wiener diversity index (H') (Colwell and Futuyama 1971),

$$H' = -\sum_{i=1}^S P_i \ln P_i$$

where P_i is the proportion of individuals belonging to i th species. s is the total number of different prey categories consumed by predator. The value of H' increases with species diversity.

Results

Diet compositions

Of the 711 stomachs examined, a total of 24 prey species were found. Percentage of empty was 47.3%. Prey items were divided into three categories: pisces, crustacean, and Cephalopoda. The index of relative importance (IRI) analysis recovered pisces as the most important prey category (82.3%), followed by crustaceans (17.5%) and Cephalopoda (0.3%) (Table 2). *Z. faber* were shown to be piscivorous that consume fishes as principal prey items.

Difference of diet by size class

For each of the four size classes, *Trichiurus japonicus* and *Trachurus japonicus* were the most common prey by biomass (Fig. 1). *Engraulis japonicus* was an important prey in the 24–30 cm and 31–35 cm size classes, but the occurrence of *E. japonicus* from the 36–40 cm group was greatly reduced. In the large fish (> 38 cm), the proportion of *Glyptocephalus stelleri* increased markedly. There is no significant difference in the size of the prey items (*Trichiurus japonicus*, *E. japonicus*, *Trachurus japonicus*, and *G. stelleri*) according to the TL ($P > 0.05$). There was a significant difference in the proportions of prey categories consumed by the four size classes ($\chi^2 = 318.24$, $df = 24$, $P < 0.001$).

Difference of diet by season class

In all seasons, *Trichiurus japonicus* and *Trachurus japonicus* were consumed (Fig. 2). *Trichiurus japonicus* was the most common prey item by %IRI in spring (34.9%) and summer (31.3%). Overall crustacean prey biomass increased during summer and autumn. In autumn, *E. japonicus* dominated the prey mass, making up 37.4% of the total diet, respectively. %IRI of *Trachurus japonicus* and *G. stelleri* increased in winter to 16.8% and 11.9%, respectively. We found a significant difference in diet compositions among seasons ($\chi^2 = 499.41$, $df = 24$, $P < 0.001$).

Difference of diet by size and season

There were variation of diet in size group by season, as shown in the percentage of IRI (Fig. 3). Dominant preys of 24–30 cm group consisted of pelagic fishes in all the seasons; *Trichiurus japonicus* in spring (93.5%) and summer

Table 2 Diet composition in the stomach contents

Prey items	%F	%N	%W	%IRI
Pisces				82.3
<i>Acropoma japonicum</i>	4.0	1.7	3.6	1.0
<i>Argentina kagoshimae</i>	1.0	0.3	0.3	0.0
<i>Coelorinchus multispinulosus</i>	0.5	0.2	0.3	0.0
<i>Chelidoperca hirundinacea</i>	0.5	0.2	0.5	0.0
<i>Cleisthenes pinetorum</i>	1.0	0.3	2.9	0.2
<i>Cololabis saira</i>	1.0	2.8	1.7	0.2
<i>Decapterus muroadsi</i>	0.5	0.3	0.9	0.0
<i>Doederleinia berycoides</i>	2.0	0.6	1.6	0.2
<i>Engraulis japonicus</i>	10.9	7.6	6.0	7.2
<i>Glyptocephalus stelleri</i>	5.0	3.0	14.5	4.2
<i>Larimichthys polyactis</i>	2.5	0.9	4.7	0.7
<i>Lepidotrigla guentheri</i>	0.5	0.2	0.2	0.0
<i>Malakichthys wakiyae</i>	1.0	0.3	0.2	0.0
<i>Pagrus major</i>	1.0	0.5	1.0	0.1
<i>Pennahia argentata</i>	1.5	0.5	2.5	0.2
<i>Psenopsis anomala</i>	1.5	0.5	3.5	0.3
<i>Scomber japonicus</i>	0.5	0.2	1.6	0.0
<i>Trachurus japonicus</i>	8.5	2.8	10.4	5.4
<i>Trichiurus japonicus</i>	18.9	7.3	23.9	28.6
Unidentified fish	28.4	9.5	15.0	33.8
Crustacean				17.5
<i>Plesionika izumiae</i>	0.5	2.0	0.1	0.1
<i>Pandalus eous</i>	6.0	57.5	2.4	17.4
Unidentified shrimp	0.5	0.2	0.0	0.0
Cephalopoda				0.3
<i>Todarodes pacificus</i>	2.0	0.6	2.2	0.3
<i>Sepiolo birostrata</i>	0.5	0.2	0.0	0.0

%F frequency of occurrence, %N numerical percentage, %W percentage weight, %IRI percentage index of relative importance

(29.3%), *E. japonicus* (63.4%) in autumn, and *Trachurus japonicus* (50.0%) in winter (Fig. 3). In 31–35 cm group, *Trichiurus japonicus* (35.5%) was consumed as dominant preys in spring, and crustacean was mainly prey items in summer (45.9%) and autumn (59.8%). In winter, *Acropoma japonicum* and *Trachurus japonicus* were dominant, making up 46.0% and 31.5%, respectively. In 36–40 cm group, *Trichiurus japonicus* was the most important prey item in all the seasons. In 41–47 cm group, *G. stelleri* was consumed as a main prey item in all the seasons expect autumn in which *Psenopsis anomala* (58.4%) and *Larimichthys crocea* (29.4%) were consumed.

Trophic diversity

Trophic diversity of *Z. faber* was generally low. Among the size classes, trophic diversity was highest in the 31–

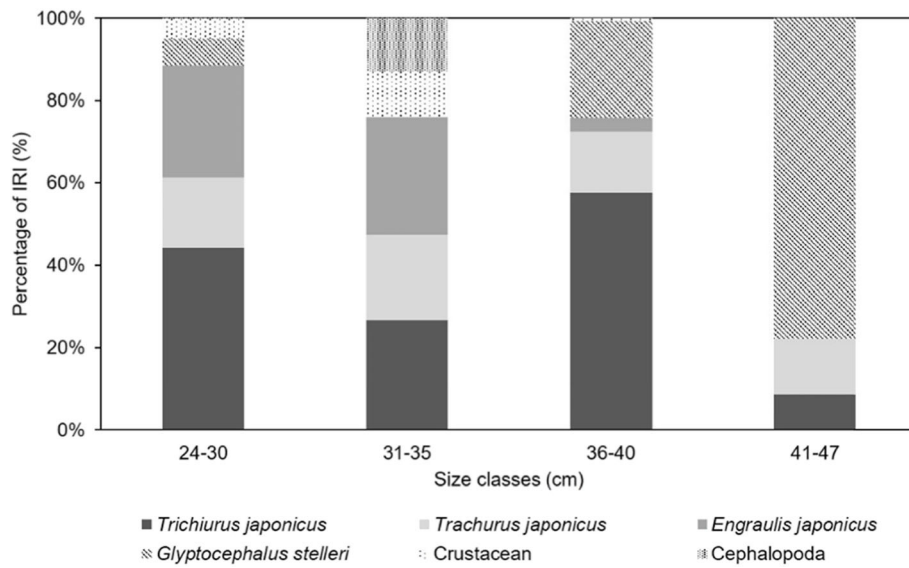


Fig. 1 Variation of the diet composition by the percentage IRI by size classes

35 cm group and lowest in the 24–30 cm group (Fig. 4a). This confirmed that as body size increased, dietary variability also increased. In terms of season, autumn and summer obtained the highest trophic diversity (Fig. 4b), indicating that more prey items were consumed during this time period than in other seasons.

Discussion

The diet of *Z. faber* consisted of a limited range of prey items from cephalopods to pisces. It was a total of 24 prey species. Despite the fact that *Z. faber* fed on a range

of prey items, fish dominated the diet in all seasons. In particular, *Trichiurus japonicus*, *Trachurus japonicus*, and *E. japonicus* were consumed in all seasons, which was similar to all the previous studies performed in Korea (Huh et al. 2006; Choi et al. 2011; An et al. 2012). *Z. faber* has narrow dietary niche width (15–24 prey items) in all previous studies (Huh et al. 2006; Choi et al. 2011; An et al. 2012), which is one of the characteristics of piscivorous fish. This feeding behavior could be attributed to a large mouth, suction capabilities, and extensive swimming maneuverability (Stergiou and Fourtouni 1991; An et al. 2012).

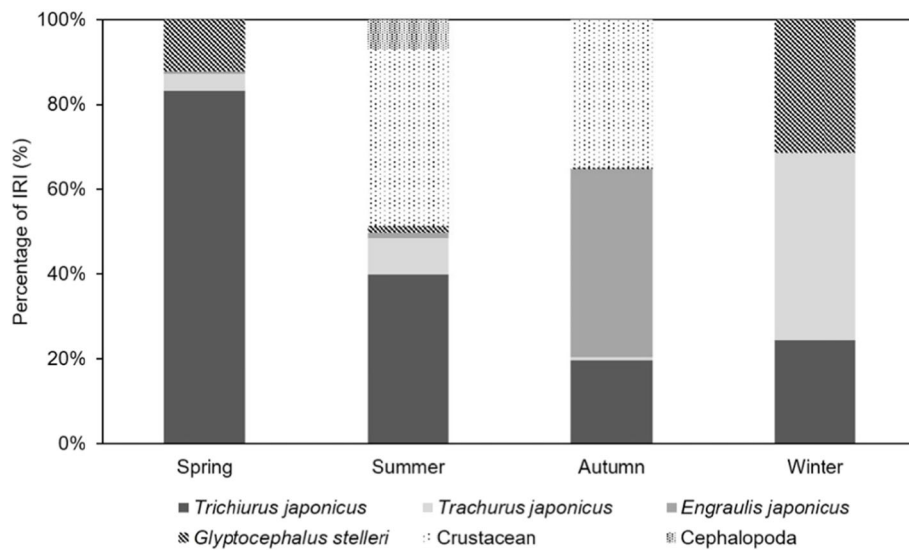


Fig. 2 Seasonal variation in the diet composition by the percentage of IRI

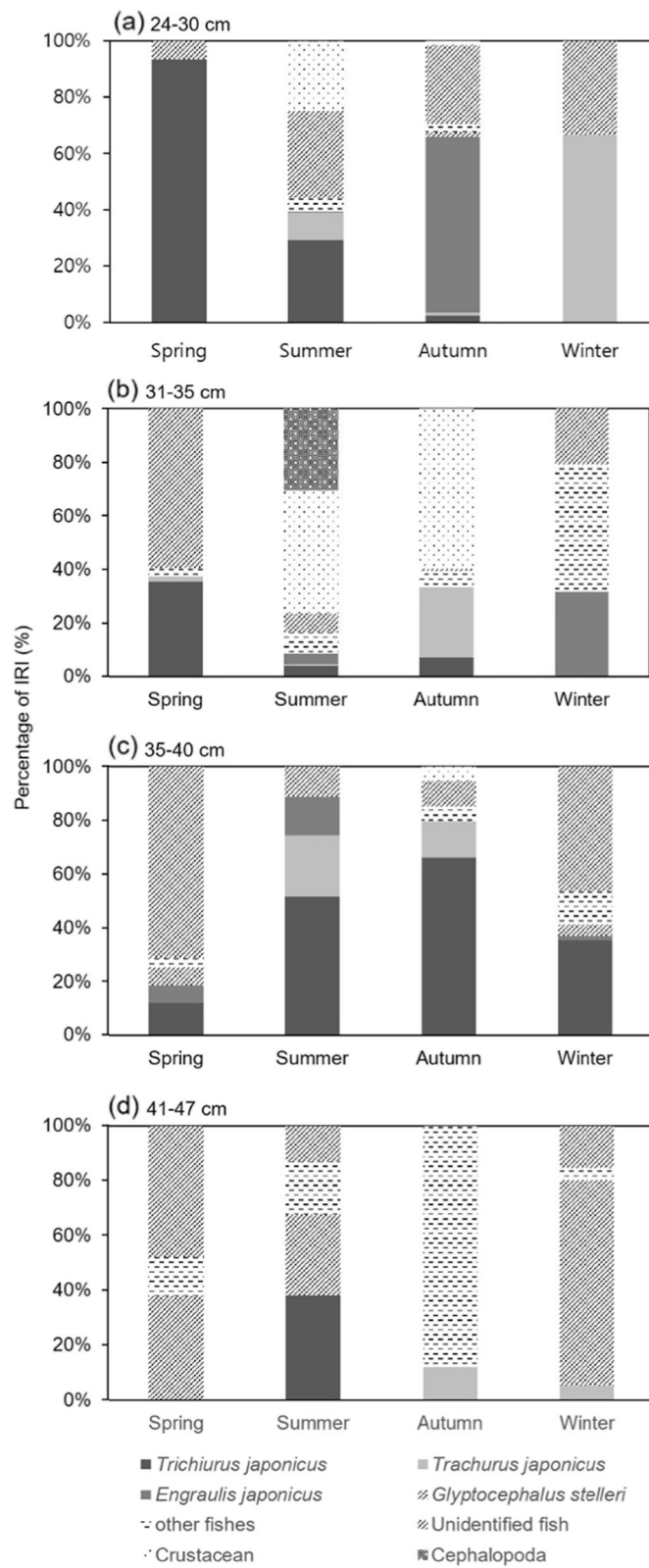


Fig. 3 Variation of diet composition between size classes and seasons by the percentage of IRI

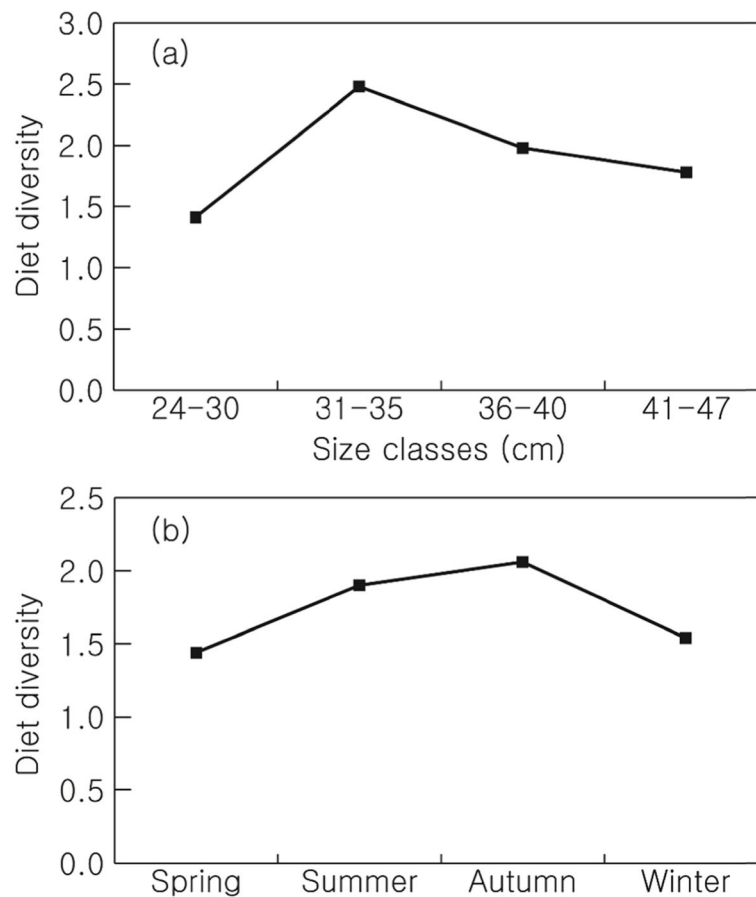


Fig. 4 Trophic diversity of prey items; **a** size classes and **b** seasons

In the Gori study, however, the main preys included *Psenopsis anomala*, *Conger myriaster*, and *Glossando semifasciata* (Huh et al. 2006). In Geomun-island, dominant preys consisted of *Scomber japonicus* and *Callanthias japonicus* (An et al. 2012). These results indicated that the prey items varied with habitats. *Z. faber* are opportunistic species which consume mainly abundant and diverse species according to habitat. Similar results are observed in other fishes, *Lophius litulon* (Choi et al. 2011; Park et al. 2014), *Coryphaena hippurus* (Jeong et al. 2017), and *Muraenesox cinereus* (An et al. 2011).

In the present study, *Trichiurus japonicus* was the most commonly consumed species, as reported previously (Huh et al. 2006; Choi et al. 2011; An et al. 2012). *T. japonicus* inhabits at depths of 40 to 120 m (Martins and Haimovici 1997), which overlaps the habitat of *Z. faber* (50 to 140 m) (Vrgoč et al. 2006; Kim et al. 2013). Fishes with a long body swim in a head-up state with limited swimming capabilities (Wilson 1958). In addition, the body of *T. japonicus* is thin, long, and reflective. Therefore, *Z. faber* can efficiently detect *T. japonicus* at any depth (Stergiou and Fourtouni 1991). In the eastern

Mediterranean, long body fishes such as *Cepola macrophthalma* are most commonly consumed by *Z. faber* (Stergiou and Fourtouni 1991).

Z. faber consumed *Trichiurus japonicus* and *E. japonicus*, which is schooling fish. *Z. faber* has a stalking ability to consume prey fish selected in a school or group (Ressell 1983). Two species inhabit the wild layer of the ocean, indicating that *Z. faber* moves to the surface layer to feed. Previous studies have found Jack Mackerel (*Trachurus symmetricus*) in the eastern Mediterranean and along the Portuguese coastline (Stergiou and Fourtouni 1991; Silva 1999). *Trichiurus japonicus* and *E. japonicus* were the most abundant species in the coastal waters of Korea (Cha 2010), which indicates that *Z. faber* is an opportunistic feeder by energy effectivity.

In the present study, predation by *Z. faber* was not significantly dependent on prey size. As there are no distinct morphological changes related to feeding ability with growth (Stergiou and Fourtouni 1991), large specimens of *Z. faber* expand their prey options by altering feeding behavior. In this study, individuals less than 30 cm preferred surface fish as *E. japonicus* and *Trachurus japonicus*, while specimens of *Z. faber* up to 38 cm were

found to feed on the benthic species *G. stelleri*. In other words, as body size increased, *Z. faber* preferred fish lived deep water such as *Conger myriaster* (Huh et al. 2006) and *Micromesistius poutassou* (Silva 1999). This indicates that *Z. faber* can exploit the entire water column when feeding. This partial dietary change can reduce intraspecific competition by resource partitioning (Gerking 1994). After consuming a diet of small fish and zooplankton during the juvenile stage, adult *Z. faber* (> 24 cm) undergo a transformation in prey selection to reduce intraspecific competition.

Z. faber consumed more prey items during summer and autumn than in other seasons. Some fishes that inhabited Korea tend to spend the winter in near Jeju Island and East China Sea. In the spring, as temperature rise, they come back to the coastal waters of Korea due to spawning ground (Noh et al. 2013). Therefore, species abundance in summer becomes higher, compared with winter. We found that crustaceans were the dominant species in summer and autumn in this study because of the behavior and life history of crustacean prey (Xue et al. 2005; Blasina et al. 2010). *P. eous* used as prey mainly migrate to inshore (< 50 m) for the larval hatch during late winter and early spring (Park et al. 2012; Richards 2012). The density of crustaceans increases as the hatched crustaceans recruit in summer. Also, *P. eous* can be captured more than other invertebrates because *P. eous* inhabit in various water depths up to 600 m deep (Park et al. 2012). Therefore, larger individuals of *Z. faber* inhabit in deeper depths and can consume crustaceans abundantly. Stergiou and Fourtouni (1991) found that only individuals up to 14 cm consumed tiny crustaceans, but this study obtained different results, as crustaceans were consumed by specimens of *Z. faber* up to 38 cm, and up to 168 crustaceans were consumed at a time. Along the Portuguese coastline, crustaceans are also an important food source for specimens up to 25 cm (Silva 1999). The short period of research in the Mediterranean has showed different results to this study and a previous study of *Z. faber*.

Conclusion

The present study was performed by commercial trawl and collected adult *Z. faber* (> 24 cm, TL). A total of 24 prey items were found and tropic diversity was low because *Z. faber* consumes mainly fishes. As *Z. faber* grew, they consumed the demersal fish species that live near their habitat. We found that prey items of *Z. faber* also changed depending on the abundant species of each season. As this results, *Z. faber* could be considered a piscivorous fish and opportunistic predator which consume mainly fish prey items from various depth of waters.

Abbreviation

SD: Standard deviation

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Authors' contributions

HanJu Kim carried out the field study and performed the analysis, and wrote the manuscript. Hyeong-Gi Kim participated in the design of the study, conducted field study, and reviewed the manuscript. Chul-Woong Oh conceived the study and reviewed/edited the manuscript. HanJu Kim and Chul-Woong Oh made equal contributions to this study. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

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